REPORT OF REVIEW THE STONE STRONG SYSTEMS® PRECAST MODULAR RETAINING WALL SYSTEM

January 2021

HIGHWAY INNOVATIONS, DEVELOPMENTS, ENHANCEMENTS AND ADVANCEMENTS (IDEA)

The Stone Strong Systems® Precast Modular Retaining Wall System has been evaluated in accordance with the IDEA protocol. Stone Strong's original HITEC evaluation published in 2010 consisted of gravity wall applications only. This update evaluation consists of review of a system re-evaluation with respect to gravity wall applications and evaluation of the system for MSE applications. Key Information regarding this system is presented in this final report of review. Comprehensive and important details of the system's components, design, construction and quality control measures are presented in the "Summary Table of MSEW Program Input Parameters for Stone Strong Systems® Precast Modular Retaining Wall System" located at the end of this report and the Stone Strong Submittal.

Applicant Information

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Review Summary

Following its initial review of the Stone Strong Systems® Precast Modular Retaining Wall System submittal, the review team provided the applicant with three series of comments, requests for clarification and additional testing and analysis. **The applicant has been thorough in its responses and the review team finds that there are no outstanding issues that should be brought to the attention of the transportation agencies. Rather, the agencies are encouraged to rely upon the final Stone Strong Systems® Precast Modular Retaining Wall System submittal for projects where the Stone Strong Systems® Retaining Wall System is proposed.**

Submittal Checklist

The checklists used from the IDEA protocol for this evaluation are C1 – Initial Technical Evaluation Checklist for Concrete Modular Block Paired with Extensible Reinforcement and C7 – Initial Technical Evaluation Checklist for Concrete Modular Gravity Wall System. This is the first update of the previous HITEC evaluation for the Stone Strong Gravity Wall System and this is the first evaluation of the Stone Strong System paired with extensible reinforcement evaluated by IDEA.

Confidential Information

The applicant has the option to omit information from the version of its submittal that is attached to the final report if it believes that such information is confidential. In such instances, the applicant will notify the review team. However, for Stone Strong Systems® Precast Modular Retaining Wall System no information has been designated by the applicant as confidential.

System Description

Components

Stone Strong Systems® Precast Modular Retaining Wall System is comprised of wet cast concrete large modular block facing units and Paraweb polyester strap soil reinforcements. Other components include gravel core fill, geotextile filter, and traffic barriers. The standard facing unit is 96 inches long, 36 inches high, and 44 inches wide (i.e., deep). The connection of Paraweb strap geosynthetic reinforcement to the Stone Strong unit is made using Macbox inserts in the back of the Stone Strong units. After the Stone Strong modular units are set in the wall, the Paraweb straps are run through the Macbox connector, wrapped around the shielded #5 rebar and laid out in a V-shape in the reinforced fill. There are multiple grades (i.e., strength) of Paraweb straps, however, the Stone Strong System only uses the 2D-50 strap.

System History

Stone Strong precast modular retaining wall units were originally developed in 2002 and 2003. The product was first licensed to a dealer in 2003, and the first commercial retaining walls were completed in early 2004. At that time, only the standard 44-inch width units were available, along with the Corner/End unit.

The original market for Stone Strong precast modular retaining walls was private development and commercial projects. The system has also gained widespread acceptance with public clients, including state transportation departments, provincial transport ministries, and local county/municipal entities across the US and Canada. Over the past 18 years, millions of square feet of Stone Strong facing have been installed. A large percentage of the walls have been gravity retaining structures, but over the last 5 years many MSE walls have also been erected using the Paraweb reinforcement.

The oldest Stone Strong gravity wall was installed in 2004, in Milford Massachusetts. The oldest MSE wall with Paraweb reinforcement located in the US was installed in 2018 in Nebraska. The tallest gravity wall is 36 feet in height and is located in Maryland. The tallest Paraweb reinforced Stone Strong MSE wall in the US is 30 feet and the tallest located outside of the US is 39 feet.

System Properties

The following properties are reported by the applicant for Stone Strong Systems® Precast Modular Retaining Wall System.

> **Soil reinforcement ultimate tensile strengths**. The ultimate tensile strengths for the Paraweb polyester strap soil reinforcement are the minimum average roll values (MARV) as published by the reinforcement manufacturer, Linear Composites/Maccaferri. The AASHTO NTPEP independently measured ultimate strength values (NTPEP, 2018) indicate that the sampled products have a tensile strength that exceeds the manufacturer's MARVs.
> **Soil reinforcement nominal tensile strengths**. The nominal tensile strengths (T_{al}) for the Paraweb 2D-50 polyester strap soil reinforcement is computed as the ultimate strength ($T_{ult\text{-}MARV}$) divided by

reduction factors for creep (RF_{CR}), degradation (RF_D), and installation damage (RF_{ID}). The equation for this calculation is:

$$T_{al} = \frac{T_{ult-MARV}}{RF_{CR} x RF_D x RF_{ID}} \qquad \text{Eq. 1}$$

The AASHTO NTPEP independently measured creep reduction value (NTPEP, 2018) of 1.36 is used for both a 75- and 100-year design life. The durability reduction factor is a function of wall fill specifications, particularly pH limits. A durability reduction value of 1.15 or 1.3 is typical. The installation damage reduction factor is a function of the wall fill properties (gradation, D_{50}, angularity, etc.) and placement techniques. Recommended values or value ranges are presented for three wall fills with maximum gradation sizes 2-inch, 3/4-inch and No. 4 sieve.

Soil reinforcement-facing unit connection capacity. The connection capacities of the Paraweb strap and Stone Strong Modular units has been evaluated by short-term connection strength testing. The long-term Paraweb strap creep reduction factor was used to evaluate the long-term connection strength.

Reinforcement Pullout and Interface Shear. Independent pullout test results are as presented in Appendix Tab 1.2.7. Testing was performed on Paraweb straps in general accordance with ASTM D 6706. The tests were performed on a range of soils (i.e., silty sand, concrete sand and graded aggregate base). Based on these results, an F* equal to 1.0 tanφ to a depth of 7 feet, 0.8 tanφ below a depth of 7 feet, and α value equal to 0.8 may be used for reinforced backfill consisting of sand and in the absence of project-specific pullout testing.

The interface shear friction angle was determined from direct shear tests in general accordance with ASTM D 5321. A copy of the interface direct shear test report is provided in Appendix Tab 1.1.10. Based on the test results the interface friction coefficient (ρ) is equal to 0.7 for well-graded sand (SW) and gravel (GW) and equal to 0.7 for fine to medium sands and poorly-graded sands (SP).

System Innovations

This IDEA evaluation concurs with Stone Strong that their system provides the following innovations:

- The majority of wet cast modular retaining wall systems are solid concrete blocks. Stone Strong is a structural shape, typically consisting of two webs connecting the face shell and back wall. The thickness of the webs and shells were established to provide sufficient strength in a plain concrete (unreinforced) section to perform in most gravity wall applications and reinforced in typical MSE applications.
- The other innovation is the use of an inherently stable facing unit with a geosynthetic strap reinforcement for MSE wall applications. Most MSE wall systems with geosynthetic strap reinforcements utilize a thin facing panel that must be plumbed and braced when set. By using a robust, block-style facing, the process to set the facing is simplified.

References

HITEC (2010). *Technical Evaluation Report, Evaluation of the Stone Strong Gravity Wall System by Stone Strong,* Highway Innovation Technology Evaluation Center, American Society of Civil Engineers, Washington, D.C.

NTPEP (2018). Laboratory Evaluation of Geosynthetic Reinforcement, Final Product Qualification Report for Linear Composites Paraweb Product Lines, Submitting Manufacturer: Linear Composites, National Transportation Product Evaluation Program (NTPEP) Report REGEO-2016-01- [Linear Composites-Paraweb-Paralink], American Association of State Highway and Transportation Officials (AASHTO), Washington, D.C.

Summary Table of MSEW Program Input Parameters for Stone Strong Systems® **Precast Modular Retaining Wall System**				
Paraweb Soil Reinforcement				
Data / Paraweb		Paraweb 2D-50 0-7 ft depth 48-in spacing	Paraweb 2D-50 >7 ft depth 48-in spacing	Paraweb 2D-50 > 12 ft depth 32-in spacing
T_{ult} (lb/ft)		38,101	38,101	38,101
Durability Reduction Factor, RF_D	5<pH<8	1.15	1.15	1.15
	4.5≤pH≤5	1.3	1.3	1.3
	8≤pH≤9	1.3	1.3	1.3
Installation Damage Reduction Factor, RF_{ID}	100% passing 2-in.	1.20	1.20	1.20
	100% passing ¾-in.	1.10	1.10	1.10
	100% passing No. 4	1.10	1.10	1.10
Creep Reduction Factor, RF_{cr}	75 years	1.36	1.36	1.36
	100 years	1.36	1.36	1.36
Coverage Ratio		0.147	0.147	0.221
Friction Coefficient along geogrid-soil Interface, ρ	Sands[a]	0.7	0.7	0.7
	Gravel[a]	0.7	0.7	0.7
Pullout Resistance factor, F*	Sands[a]	1.0 tan φ	0.8 tan φ	0.8 tan φ
	Gravels[a]	1.0 tan φ	0.8 tan φ	0.8 tan φ
Scale-effect correction factor, α	Sands[a]	0.8	0.8	0.8
	Gravels[a]	0.8	0.8	0.8
Facia Geometry and Unit Weight:		Depth/height = 3.67 ft / 3.0 ft		
		Horizontal distance to center of gravity = 1.90 ft		
		Average unit weight of block = 122.2 lb/ft^3		
Connection Strengths:		$CRcr^c$ x (T_{LOT}/T_{MARV})		
	σ'[b] (lb/ft^2)	Paraweb 2D-50 0-7 ft depth 48-in spacing	Paraweb 2D-50 >7 ft depth 48-in spacing	Paraweb 2D-50 > 12 ft depth 32-in spacing
	0	0.63	0.63	0.63
	10,000	0.63	0.63	0.63
Connection strength reduction factor, Rf_d[d]		1.00	1.00	1.00
Creep Reduction Factor, Rf_c[d]		1.00	1.00	1.00

Notes: [a] Predominate material; [b] Normal pressure (lbf/ft^2); [c] MSEW program term (T_{cre}/T_{ult});

[d] The value for CR_{cr}[c] includes reduction factors for durability and creep.

Product Submittal

Innovations, Developments, Enhancement and Advancements (IDEA) Program

Stone Strong
Precast Modular Retaining Wall System

January 8, 2021

The information in this submittal is solely for use in assessing the retaining wall system and its components and is not intended for construction of any specific retaining wall. Site specific design should be performed by a licensed Professional Engineer based on actual site conditions, materials, and local practices or requirements.

Product Submittal
Innovations, Developments, Enhancement and Advancements (IDEA) Program

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APPENDIX

Supporting information in the Appendix is presented following the same numbering system in the text of the submittal and the IDEA C1 checklist. Checklist C7 information for gravity wall applications is also incorporated into this submittal in the corresponding section numbers from the C1 checklist or in additional subsections added at the end of a main section.

INTRODUCTION

This submittal presents information on the Stone Strong precast modular retaining wall system. The system was developed by Stone Strong Systems, Omaha, Nebraska, and is licensed to producer/dealers across North America and the South Pacific region.

Stone Strong is a large-format, wet-cast concrete product (see Figure 1). The wall units are machine set to construct earth retaining systems on public and private infrastructure and development projects. The units conform to ASTM C1776, Standard Specification for Wet-Cast Precast Modular Retaining Wall Units.

Figure 1 – Stone Strong 24SF Unit

Unlike most precast modular block systems, Stone Strong is not a solid mass of concrete. Rather, Stone Strong units follow structural shapes, typically with two webs connecting the face shell and back wall, creating a center void and half voids on both sides of the block. When installed in a wall, the half voids meet, and the voids align in either a running bond or stack bond to create continuous vertical column voids through the wall (see Figure 2). These voids are normally filled with drainage aggregate, but can also be utilized as a stay-in-place form to incorporate structures or other rigid elements into a retaining wall.

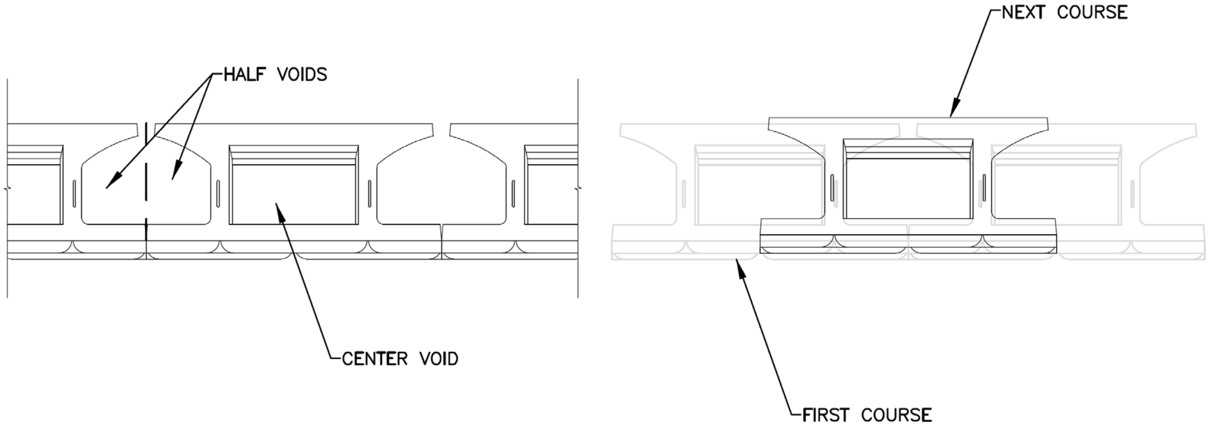

Figure 2 – Alignment of Block Voids in Running Bond Layup

Stone Strong Systems was originally reviewed by the Highway Innovative Technology Evaluation Center (HITEC). The final evaluation report was issued by HITEC in February 2010. This report only covered gravity applications, and was conducted under the 2002 AASHTO standard. Additional components have been added to the system since that report, but the design principles are comparable to the original submittal. Although the calculation of forces and resistance has not changed, the design procedures have been updated to the current AASHTO LRFD standard.

In addition to gravity configurations, Stone Strong has developed an MSE system using Paraweb reinforcing straps manufactured by Linear Composites/Maccaferri (see Figure 3). The MSE application is configured similarly to traditional steel strap MSE systems, but with a more robust facing system to simplify installation and improve system productivity. The MSE and gravity applications are intended to be installed together seamlessly, both along a wall alignment and within a vertical section to accommodate later construction near the crest of a wall.

Figure 3 – Paraweb 2D-50 Reinforcing Strap

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The following sections of this report follow the Innovations, Developments, Enhancement and Advancements (IDEA) Program checklist C1. The C7 checklist information is also incorporated into this submittal for gravity wall applications, but is generally addressed in the corresponding section numbers from the C1 checklist or in additional subsections added at the end of a main section.

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SECTION 1: ERS COMPONENTS

1.1 FACING UNIT

1.1.1 Facing Innovations

Stone Strong incorporates several unique features and innovations that advance the state of practice for retaining wall delivery. The fundamental principle is that a large size enhances productivity, stability, and economy. The large size also creates a simpler, more robust retaining wall.

The majority of precast modular retaining wall systems are solid concrete blocks. Stone Strong is a structural shape, typically consisting of two webs connecting the face shell and back wall. The thickness of the webs and shells were carefully established to provide sufficient strength in a plain concrete (unreinforced) section to perform in most gravity wall applications. However, all extended units (greater than 44 inches wide, measured face to tail) are reinforced, and most units are reinforced in an MSE application.

The other important innovation is the use of an inherently stable facing unit in a strap-style MSE wall application. Most current strap-style MSE systems utilize a thin facing panel that must be carefully plumbed and braced when set. By using a robust, block-style facing, the process to set the block is simplified.

Ultimately, the most important innovation is the combination of the gravity wall capabilities and MSE wall capabilities into a single, coherent wall system that brings efficiency to a wide array of project types and applications.

1.1.2 Facing Components

Stone Strong is a complete system, including a variety of precast modular block units and accessories that adapt to most configurations and applications. The following is a list of standard Stone Strong components:

24SF unit	24SF Top unit	24-86 unit	24-62 unit
24-ME unit	6SF unit	6SF Top unit	3SF unit
3SF Top unit	6-28 unit	6-28 Top unit	3-28 unit
3-28 Top unit	Dual Face unit	Dual Face Half unit	3-Sided End unit
End unit	Corner unit	90 Deg Corner unit	45 Deg Corner unit
Inside Corner unit	Outside Corner unit	Cap unit	Custom Top unit

The 24SF unit is the primary block that the system is based around. This block is 36 inches tall and 96 inches long (length is measured along the face of the wall), covering 24 square feet of wall face for each unit. The 24SF unit is 44 inches wide (width is measured perpendicular to the face), and weighs approximately 6,000 pounds. When filled with drainage aggregate, this unit weighs approximately

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10,000 pounds. The block has two webs connecting the face shell and back wall, creating a center void and half voids on both sides of the block. The webs are centered on the quarter points, 2 feet from each edge (spaced 4 feet apart), so the webs and voids align vertically when stacked either on running bond or stack bond. In gravity wall applications, this block is unreinforced. The 24SF-P version used in MSE retaining walls is reinforced in the face, webs, and rear shell. The 24SF-P unit also includes 4 Macbox inserts for connecting Paraweb straps.

Several extended versions of the 24SF unit are available, and can be used to build taller gravity walls. The 24-86 unit has the same face dimensions as the 24SF unit, but the webs have been extended to provide a unit width of 86 inches. Similarly, the 24-62 unit has been extended to a width of 62 inches. The 24-ME unit has a width of 56 inches, but this is accomplished by increasing the thickness of the rear shell. These units are typically only used in gravity applications, and are not normally produced with Macbox inserts for use in an MSE application.

The 6SF unit is one-fourth of the size of the 24SF unit. With a height of 18 inches and length of 48 inches, this block covers 6 square feet of wall face. The unit has a similar shape as the 24SF unit, with 2 webs located at the quarter points. The block is unreinforced in gravity applications, and is provided with a single Macbox insert for MSE applications. The 6SF unit can be used at either the top or bottom of a wall to make steps in 18 inch increments, or can be used for the entire wall section where necessary to achieve a tighter radius or in cases where access is limited to small equipment that cannot carry the heavier 24SF units.

The 6-28 unit is a lighter version of the 6SF unit. The 6-28 unit has a height of 18 inches and length of 48 inches, but has a reduced width of 28 inches. This unit weighs approximately 950 pounds, and can be used at the top of the wall or as an MSE facing unit. The 6-28 unit can also be used in landscape application for wall heights of 3 to 4.5 feet, typically.

There are numerous accessory units available, including several corner block options (End/Corner, 90 Degree Corner, 45 Degree Corner, Outside Corner, and Inside Corner), Dual Face units (architectural finish on both the front and rear faces of the unit), End units, Cap units, 3SF, 3-28, and top block versions of the 24SF, 6SF, 6-28, 3SF, and 3-28 units.

Note that cap units are not commonly used on retaining walls that are backfilled to the top of the wall, but are available for use on above grade parapets or special applications. Instead, top units are normally used where the webs and rear shell are coped down to allow for backfill to be brought to the back of the block face, as shown Figure 4. Top units are available for 24SF, 6SF, and 6-28 units. An End unit is used to provide a finished transition at steps in the top of the wall, as shown. Other top treatments can be used and are discussed in section 1.3.4. Fences, railings, vehicle guardrails, and highway barriers with moment slabs can be accommodated above the wall as well.

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Figure 4 – Top Unit and Landscaping Around End Unit

1.1.3 Component Specifications

Design weights and dimensions for standard Stone Strong units are provided in the following table. Note that top units are not included as they are typically analyzed as the parent unit.

Unit Type	Description	Conc. Wt. (lbs)	Void Vol (ft3)	Length (ft)	Height (ft)	Unit Width (in)
Standard units (verify availability - not all units available from every producer)						
24	24SF unit (24 square feet)	6,000	43.21	8.00	3.00	44.0
24-ME	24SF Mass Extender unit	10,000	44.94	8.00	3.00	56.0
24-62	24-62 unit (extended 24SF)	6,800	76.05	8.00	3.00	62.0
24-86	24-86 unit (extended 24SF)	7,600	117.90	8.00	3.00	86.0
6	6SF unit (6 square feet)	1,500	10.95	4.00	1.50	44.0
3	3SF unit (3 square feet)	750	5.48	2.00	1.50	44.0
6-28	6-28 Unit (mini 6SF)	950	6.65	4.00	1.50	28.0
3-28	3-28 Unit (mini 3SF)	475	3.33	2.00	1.50	28.0
Alternate top units						
Cap	Cap unit	1,600	0.00	8.00	0.58	32.0
DF	Dual Face unit	3,500	0.00	8.00	1.50	28.0
Vertical stack units (modified recess and face to permit construction of a vertical face)						
V24	Vertical 24SF unit (24 square feet)	6,000	43.21	8.00	3.00	43.0
V24-ME	Vertical 24SF Mass Extender unit	10,000	44.94	8.00	3.00	55.0
V24-62	Vertical 24-62 unit (extended 24SF)	6,800	76.05	8.00	3.00	61.0
V24-86	Vertical 24-86 unit (extended 24SF)	7,600	117.90	8.00	3.00	85.0
V6	Vertical 6SF unit (6 square feet)	1,500	10.95	4.00	1.50	44.0
V3	Vertical 3SF unit (3 square feet)	750	5.48	2.00	1.50	44.0
V6-28	Vertical 6-28 Unit (mini 6SF)	950	6.65	4.00	1.50	28.0
V3-28	Vertical 3-28 Unit (mini 3SF)	475	3.33	2.00	1.50	28.0

Components are manufactured under license from Stone Strong, LLC by producer/dealers. The blocks are cast in forms provided through Stone Strong. Concrete must meet a minimum compressive strength of 4,000 psi, although much higher strength mixes are typically used in order to attain sufficient early strength to remove the product from the form. All units meet or exceed the requirements of ASTM C1776.

For gravity wall applications, most units are unreinforced. The exception would be the extended 24SF units, including the 24-86, 24-62, and 24-ME units, which are always reinforced.

In MSE wall applications, the majority of the units are reinforced. For taller walls, heavier reinforcement is required for units in the lower sections.

Appendix section 1.1.3 includes Technical Memorandum TM-2018-01 that details what type of reinforcement is required based on the application. Reinforcing details and structural calculations for reinforcing are also included in this Appendix section (refer also to IDEA checklist C7, item 1.1.4).

1.1.4 Reinforcement Connection

In MSE applications, Paraweb reinforcement is attached using Macbox inserts in the back of the Stone Strong block unit. A Macbox assembled with a rebar and a Paraweb strap is shown in Figure 5.

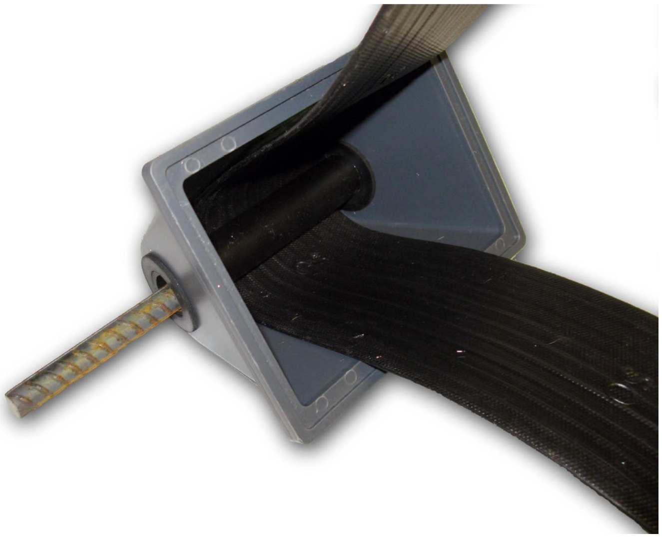

Figure 5 – Maccaferri Macbox Insert with Paraweb

The Macbox connection is manufactured exclusively by Maccaferri, and consists of an HDPE box to create a cavity in the back of the block unit. A polymeric sleeve runs through the cavity and is sealed to the box with rubber bushings. A #5 bar is inserted through the Macbox in the back wall of the block unit (see Paraweb insert details in Appendix section 1.1.4). After the block is set in a wall, Paraweb straps are run through the cavity and wrapped around the shielded #5 bar. The straps are laid out in a V-shape in the reinforced fill zone (see typical Paraweb layout in this Appendix section). This creates a positive mechanical connection of the Paraweb to the facing unit.

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1.1.5 Unit Dimensions and Tolerances

A library of standard units with dimensions, weights, and infill volume is included in the Appendix under section 1.1.5.

Stone Strong requires producers to maintain relatively tight tolerances. The height and length of the units are held to ±1/8 inch from design dimensions, and the width is held to between -1/4 inch to +1/2 inch from design. Note that these tolerances are significantly tighter than the tolerances in ASTM C1776 for comparable products.

1.1.6 Unit Fabrication

Stone Strong precast modular units are produced in a wet-cast process. The units are typically produced in climate controlled precast plants.

Most units are cast in a face-down orientation in heavy steel forms. Architectural face patterns are achieved with interchangeable synthetic liners attached in the form. The forms have either hinged or rollback doors to speed and simplify stripping and setup.

1.1.7 Concrete Compressive Strength

All Stone Strong products have a minimum compressive strength of 4,000 psi. Units are required to achieve this strength prior to shipping.

A compressive strength of approximately 1,200 psi is required to safely lift a block unit from the form. Each form may be poured once, twice, or even 3 times per 24-hour period. In order to turn the form in 8 to 20 hours, a design mix strength of 5,000 to 6,500 psi is used by the majority of the licensed producers.

1.1.8 Facing Unit Absorption

Not applicable

1.1.9 Concrete Air Content

Precast mixes for most producers use a nominal maximum aggregate size of 3/4 to 1 inch. For normal exposures, Stone Strong recommends an entrained air content of 5% to 7%. However, precast modular units cast for extreme exposure conditions, such as shorelines or saltwater exposures, the guidance from PCA Manual on Control of Air Content in Concrete (EB116) should be followed.

1.1.10 Interface Shear Properties

Shear tests were performed in 2004 and 2005 on 24SF units and 6SF units. These tests were originally included in geogrid interaction reports. The data has been excerpted and supplemented with design shear capacity envelopes, and are included in Appendix section 1.1.10. Note that the steel lift/alignment loops were removed for this testing, and interface shear was obtained through aggregate interlock through the large voids filled with coarse drainage aggregate. The peak and deflection limited shear resistance was slightly higher for the 6SF units, so the values from the 24SF unit tests are used for design, as follows:

$$V_u = N \tan 35.2° + 362 \text{ lb/ft}$$

where N is the normal force (weight of overlying block/infill) and V_u is the ultimate shear capacity between units (both values in lb/ft of wall)

The complete original interaction reports are also included in the Appendix for reference. Note that these reports include geogrid connection tests, but that the use of geogrid reinforcement in MSE walls is not included in this submittal. These reports are only provided as supporting information for the interface shear tests referenced above.

1.1.11 Alignment Details

Stone Strong utilizes a lifting and alignment loop on the 24 square foot and 6 square foot units. The loop is positioned at the block center of gravity so that the 44 inch wide blocks lift level and can be easily set into place in a wall. A corresponding alignment recess is provided in the bottom of these units that fits over the lift/alignment loop to set the batter, as shown in Figure 6.

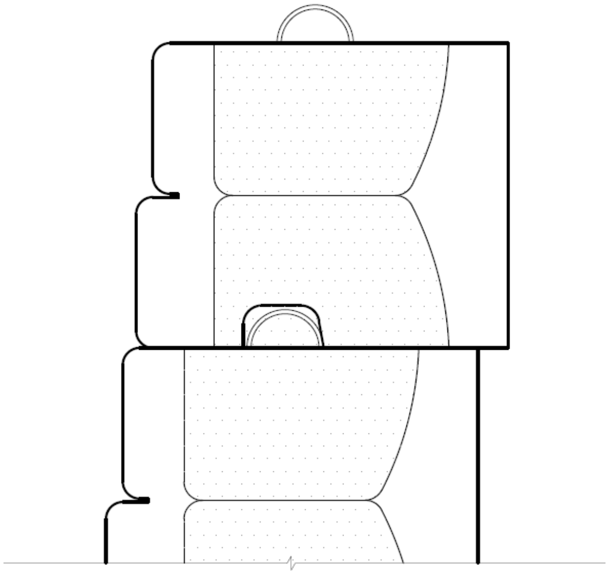

Figure 6 – Lift/Alignment Mechanism, 4-inch Setback

The standard Stone Strong units are set up for a 6.3 degree face batter. This is achieved with a setback of 4 inches for 24SF units (36 inch height) and 2 inches for 6SF units (18 inch height). The alignment can be changed by adjusting the alignment recess, however. The recess former is held in the form by bolts or magnets, and can be reconfigured to extend the recess toward the rear of the block by 4 inches or 2 inches, respectively, resulting in a vertical face alignment. Note that some of the architectural finishes have batter built into the face of the unit, but all of the standard patterns are available without any batter in the liner for vertical applications.

The lift/alignment loops are available off-the-shelf from several precast industry suppliers. These are galvanized smooth bars, either 5/8 inch for 24SF units or 1/2 inch for 6SF units. The lift loops can also be fabricated using conventional rebar benders using smooth 5/8 inch or 1/2 inch bar stock that is then hot-dip galvanized.

Note that the alignment mechanism is provided purely for simplicity and productivity during installation. The design values for interface shear do not rely on any connection force from this alignment mechanism. The interface shear tests used for design were performed with the lifting loops removed.

1.1.12 Filtration

The block voids are filled after placement with coarse drainage aggregate. The unit fill serves several functions: 1) internal drainage, 2) interface shear between block units, and 3) retention at the facing joints.

Unit fill should generally consist of a screened crushed aggregate. To achieve the required inter-unit shear resistance, Stone Strong recommends that a minimum of 75% of coarse material should have 2 or more fractured faces. The following gradation is suggested for the unit fill:

US Standard Sieve Size	Percent Passing
1-1/2"	100
3/4"	50-90
#4	0-10
#8	0-5

Stone Strong allows this gradation to be adjusted for locally available aggregates. For alternate gradations, the nominal maximum size should be between 3/4 inch and 2 1/2 inches. The percent passing the #4 sieve should also be limited to roughly 10 percent, both for drainage and joint retention functions. The normal joint installation tolerance is for gaps no wider than ¼ inch, and the coarse unit fill material will bridge the joints and minimize any loss of unit fill aggregate through the joints.

The large size of the Stone Strong units results in a 3 feet wide zone of drainage aggregate between the backfill and the face of the wall. Any seepage from the retained backfill is collected in one or more drain tiles installed inside or behind the facing units. Free moisture can also weep through the face joints. A drainage column can also be provided behind the facing units, especially in applications subject to rapid drawdown such as a channel wall. In an MSE application, it is best to capture any ground water seepage at the back of the reinforced soil zone.

To provide filtration between the unit fill drainage zone and the backfill or reinforced fill zone, a geotextile filter is recommended for DOT applications. In this case, a non-woven geotextile filter can

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be placed on the back of the units or behind any drainage column behind the units. The geotextile can be placed in a solid piece covering the entire back of the precast units, or can be installed in discrete strips covering the gaps in the back of the units, as shown in Figure 7.

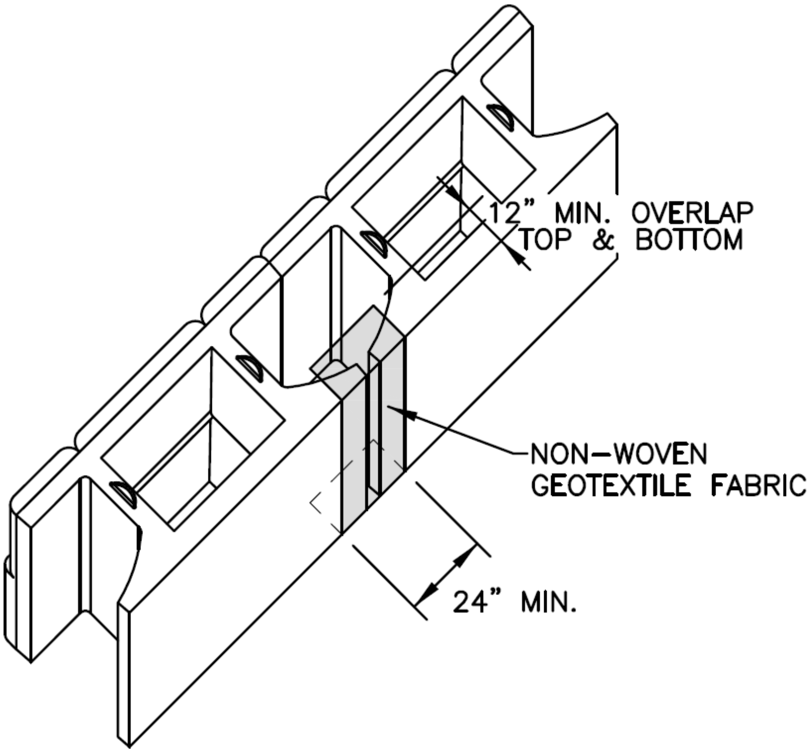

Figure 7 – Optional Geotextile on Back of Facing

1.1.13 Face Patterns

Architectural finishes are cast into the face of the units using a synthetic liner mounted in the forms. The liners are interchangeable, and virtually any pattern can be cast into the units.

Sample face patterns are shown in Figure 8. These patterns are generally produced in plain concrete. Color can be added by applying concrete stain after erection or by casting the units with integral color. The Fractured Ledge pattern lends itself to stain-hardeners applied in the form. In this process, powdered stain-hardener can be shaken into the liner and multiple colors can be layered in. The color then impregnates into the plastic concrete when the block is cast.

An anti-graffiti coating can also be applied to the precast units after erection.

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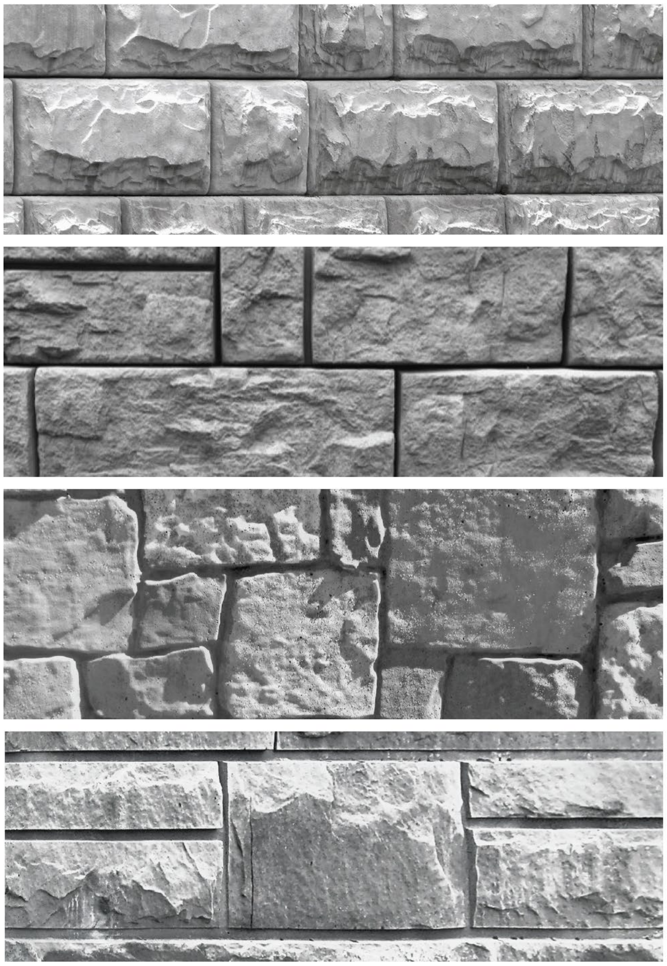

CHISELED GRANITE
Derived from blocks hand-chiseled by artisans, the pattern is intended to match the classic look of natural, chiseled stone.

FRACTURED LEDGE
Created from actual fractured ledge stone, the highly defined pattern offers the most natural look to match most any application.

POTOMAC
Smooth and broken up, this pattern was produced to replicate actual original cobblestone from the East Coast cities.

TENNESSEE FOOTHILLS
Sharp and well defined, the pattern was developed by laser-mapping actual retaining walls in the Smoky Mountains.

Figure 8 –Face Patterns

In addition to these face patterns, custom liners can produced to match nearly any environment. Several architectural finishes have been created by laser scanning existing surfaces and producing matching liners through computer aided machining. In addition, units can be produced with smooth finish or with exposed aggregate.

1.1.14 Curves and Corners

All of the precast modular units have tapered sides to accommodate curved alignments.

The 24SF unit is 96 inches long on the face, but only 90 inches long at the rear shell (see Figure 9). This results in a taper of 4.5° on each side. Thus, a deflection of 9 degrees may be made at any joint. On a convex curve, the minimum radius is controlled by this taper. The tails come into contact at the minimum radius, and a tighter radius would result in a gap at the face. For 24SF units, the theoretical minimum radius in a convex curve is 51.67 feet (see Figure 10). Note that the minimum convex radius occurs at the top of the wall when the facing is battered, and the minimum layout radius must be adjusted

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for the setback between courses. On a concave radius, the minimum radius is controlled by overhang at the joints when the units are installed on running bond. The recommended minimum concave radius is 46 feet (see Figure 10). On a concave radius, the minimum radius occurs on the bottom course when the facing is battered.

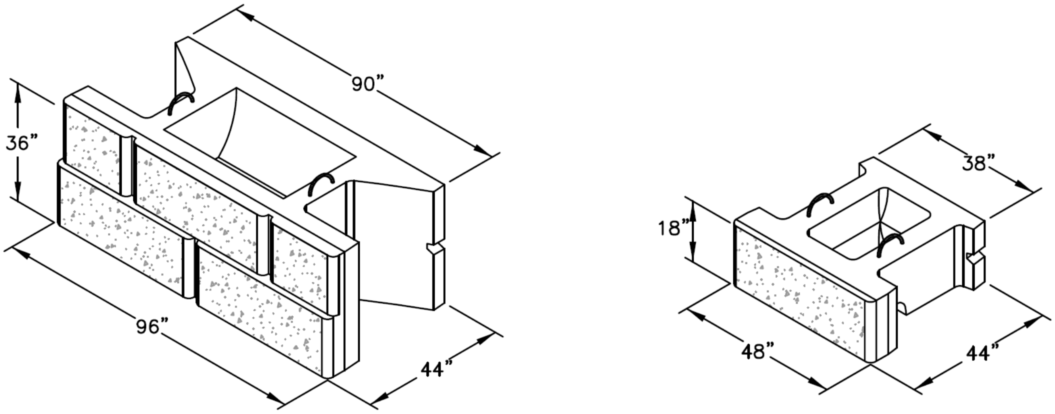
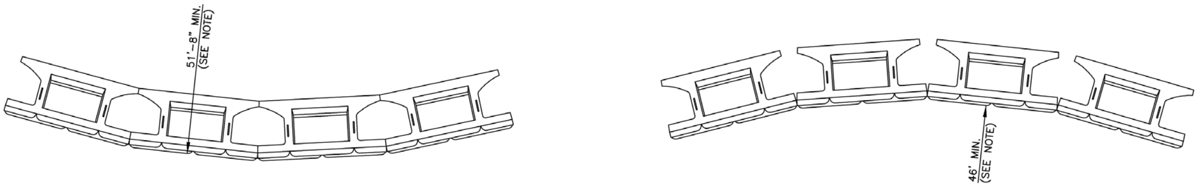


Figure 9 – 24SF & 6SF Unit Dimension & Taper

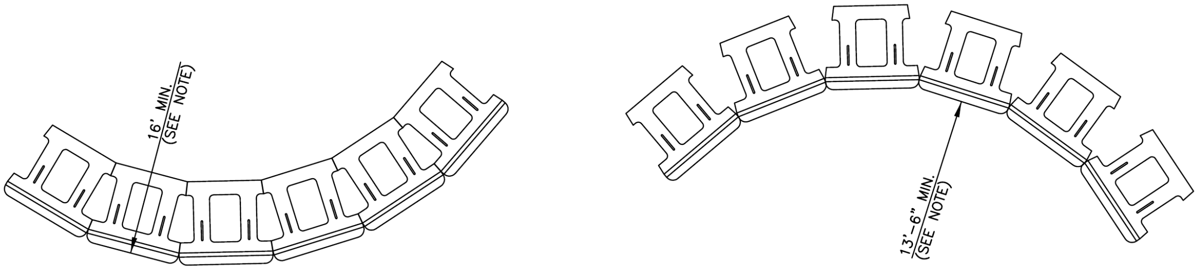


Minimum Convex Radius, 24SF Units		
Wall Height (ft)	Total # of Courses	Min. Radius at First Course
6	2	52' 0"
9	3	52' 4"
12	4	52' 8"
15	5	53' 0"
18	6	53' 4"
21	7	53' 8"
24	8	54' 0"

Minimum Concave Radius, 24SF Units		
Wall Height (ft)	Total # of Courses	Min. Radius at Top Course
6	2	46' 4"
9	3	46' 8"
12	4	47' 0"
15	5	47' 4"
18	6	47' 8"
21	7	48' 0"
24	8	48' 4"

Figure 10 – Minimum Radius for 24SF Units (Battered)

The 6SF unit is 48 inches long on the face and 38 inches long at the back (see Figure 9), resulting in a 7.5° degree taper. Similarly, the minimum radius is controlled by the tail taper or by overhang. For the 6SF units, the theoretical minimum radius in a convex curve is 16 feet (see Figure 11). Note that the minimum convex radius occurs at the top of the wall when the facing is battered, and the minimum layout radius must be adjusted for the setback between courses. On a concave radius, the minimum radius is controlled by overhang at the joints when the units are installed on running bond. The recommended minimum concave radius is 13.5 feet (see Figure 11). On a concave radius, the minimum radius occurs on the bottom course when the facing is battered.



Minimum Convex Radius, 6SF Units		
Wall Height (ft)	Total # of Courses	Min. Radius at First Course
3	2	16' 2"
4 1/2	3	16' 4"
6	4	16' 6"
7 1/2	5	16' 8"
9	6	16' 10"
10 1/2	7	17' 0"
12	8	17' 2"

Minimum Concave Radius, 6SF Units		
Wall Height (ft)	Total # of Courses	Min. Radius at Top Course
3	2	13' 8"
4 1/2	3	13' 10"
6	4	14' 0"
7 1/2	5	14' 2"
9	6	14"4"
10 1/2	7	14' 6"
12	8	14' 8"

Figure 11 – Minimum Radius for 6SF Units (Battered)

The 24SF units and 6SF units are intended to be used together. Where a tight radius is required, the blocks can be transitioned from 24SF units to 6SF units, and switched back for the next straight section of the wall.

Several different styles of corner units are available. For 90° corners, there are 3 different corner blocks that can be utilized, depending are the particular requirements of the project. A 45° corner block is also available. When taking advantage of the block side taper on both sides of the corner unit, the actual corner angle can vary as much as 15° from either 90° or 45°.

1.2 EXTENSIBLE REINFORCEMENT

1.2.1 Reinforcement Innovations

Stone Strong MSE wall applications use an innovative combination of robust precast modular facing units with Paraweb reinforcing straps. Paraweb geosynthetic strap reinforcement is manufactured

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exclusively by Maccaferri, and is exclusively used with Stone Strong in the precast modular block retaining wall market. This combination is simpler, speeds installation, and allows for a wider range of backfill materials. In addition to the economics associated with MSE applications, the facing can transition seamlessly into a gravity wall configuration at reduced heights, further improving the speed of installation and reducing the overall cost of the combined retaining wall.

1.2.2 Reinforcement Type

Stone Strong utilizes Paraweb geosynthetic reinforcement strips manufactured exclusively by Maccaferri. Paraweb straps are manufactured of high-tenacity, multifilament polyester yarns aligned and coextruded with a polyethylene (LLDPE) sheath.

Most Stone Strong MSE applications utilize 2D-50 straps, but other weights and grades may be used. A Paraweb 2D-50 strap is shown in Figure 3.

1.2.3 Reinforcement Properties

The Paraweb 2D-50 strap has an ultimate tensile strength of 11,240 pounds, and a long-term design strength (coarse gravel soil) of 6,812 pounds. The strap is 3.54 inches wide and 0.10 inch thick. The strap has a weight of 0.13 pound per foot. Standard rolls are 328 feet long. A Technical Data Sheet with MARV values is included in Appendix section 1.2.3.

1.2.4 NTPEP Report

An NTPEP evaluation of Paraweb was completed in August, 2018 for Linear Composites Limited, a Maccaferri subsidiary. The Laboratory Evaluation of Geosynthetic Reinforcement report, REGEO-2016-01, is attached in Appendix section 1.2.4.

1.2.5 Reinforcement Connection Details

A positive mechanical connection of the Paraweb to the facing unit is achieved using a Macbox, manufactured exclusively by Maccaferri. This consists of an HDPE box to create a cavity in the back of the block unit. A polymeric sleeve runs through the cavity and is sealed to the box with rubber bushings. A #5 bar is inserted through the Macbox in the back wall of the block unit (see Paraweb insert details in Appendix section 1.1.4). Paraweb straps are then run through the cavity from the back of the block and wrapped around the shielded #5 bar. A Macbox with rebar insert and a Paraweb strap is shown in Figure 5.

Additional information on the Macbox system is attached in Appendix section 1.2.5.

1.2.6 Connection Properties

Pullout tests on the Macbox insert were performed by TRI/Environmental, Inc. The tests were run with #5 Grade 60 rebar through the Macbox set in a 5-1/2 inch thick test block. The average tensile strength of 4 trials was 13,870 pounds. While this is a short-term ultimate strength, there are no load-bearing

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polymeric components. A creep reduction factor of 1.00 is used for the Macbox connector. Similarly, the steel bar is encased in concrete and shielded by the watertight connection box. The steel bar is not prone to corrosion, and a durability reduction factor of 1.00 is used for the Macbox connector.

The connection pullout test report is included in Appendix section 1.2.6. Note that the test report includes tests using polymeric reinforcing bars. Stone Strong only uses steel connection bars, and polymeric bars are not used with any Stone Strong products in the United States.

In addition to the pullout tests, calculations on the theoretical pullout capacity were run by Delta Engineers. Their calculation report is also attached in Appendix section 1.2.6. Their calculations determined slightly higher pullout loads for a lightly reinforced unit, and significantly higher loads for a more heavily reinforced block. Based on these calculations, the actual pullout tests were adopted as the controlling connection load. The pullout test values were adjusted for the actual concrete strength at the time of testing, compared to the design concrete strength for Stone Strong units.

The Paraweb strap is wrapped around the shielded bar inside of the Macbox connector. The bar diameter is nominally 1 inch. To evaluate possible strength reduction of the Paraweb in this tight bend, tension tests were performed by TRI/Environmental, Inc. These tests included ultimate tension tests to determine the average lot strength, and additional tests with the strap wrapped around a 1 inch diameter pin. This testing determined a reduction factor of 1.02 for the Paraweb strap in a 1-inch bend. The bend test results are attached in Appendix section 1.2.6.

The connection and strap strengths are summarized below:

	Nominal Value	Resistance Factor	Factored Value
Connection Strength - Paraweb 2D-50 Strap			
MARV ultimate strength (lb)	11,240	0.55	6,182
Creep reduced strength (lb)	8,264		
Durability reduction factor RF_D	1.15		
Reduction factor for 1" bend (T_{lot}/T_b)	1.02		
T_{crc}	7,045	0.55	3,875
Connection Strength - Macbox Pullout (2 strap legs)			
Pullout test (lb) (from TRI report)	13,870		
adjust test value for f'_c (4,000/4,105 = 97.4%)	13,515		
Calculated pullout (lb) (from Delta report)	14,000		
T_{crc} (min value, divided by 2 for single strap)	6,758	0.60	4,055
CR_{CR}			
Factored Paraweb strength controls			
T_{crc}/T_{ult}			0.63

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The factored strength of the Paraweb strap controls the design connection strength. The connection strength includes reductions for creep and durability as shown above. Therefore, creep and durability reduction factors of 1.00 are used for design.

1.2.7 Reinforcement Pullout Properties

Paraweb is treated as an extensible reinforcement. Since it is a solid strap without any cross fibers, the passive resistance term of the generalized pullout equation is neglected. The frictional resistance using the interaction coefficient, C_i, defined as follows:

$$F^* = C_i \tan \phi$$

Paraweb pullout tests were run for Maccaferri by SGI Testing Services. Test reports for these pullout tests are attached in Appendix section 1.2.7. A summary plot of the pullout test data is shown in Figure 12.

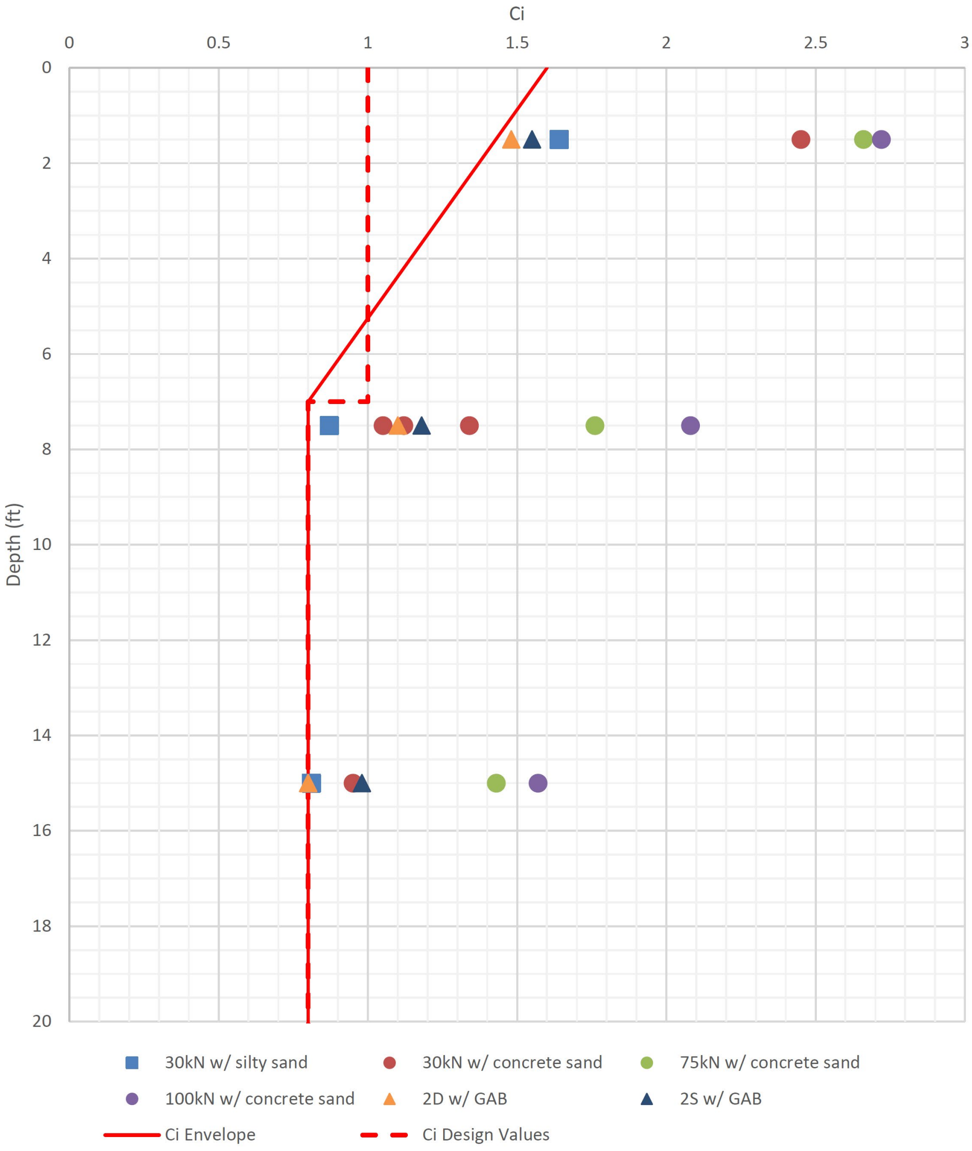

Figure 12 – Coefficient of Interaction with Depth (Pullout Tests)

Based on the test data, we recommend the following values for determining pullout resistance:

Backfill Type	Coefficient of Interaction		α
	Max Value at Zero Depth	Min Value at/below Critical Depth	
Silty Sand	1.0	0.8 Critical Depth = 7 ft.	0.8 (default)
Concrete Sand	1.0	0.8 Critical Depth = 7 ft.	0.8 (default)
Graded Aggregate Base	1.0	0.8 Critical Depth = 7 ft.	0.8 (default)

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Since the commonly used MSEW software does not accommodate a variable C_i for pullout resistance, we recommend stepped values for C_i based on depth, as shown in Figure 12. A C_i value of 1.0 is recommended for the top 7 feet of the wall, and a C_i value of 0.8 is recommended below the top 7 feet.

Stone Strong recommends a shape effect factor, α, of 0.80 for Paraweb straps based on the default value from NHI-10-024/025.

1.2.8 Direct Sliding Properties

Direct sliding tests were run for Maccaferri by SGI Testing Services. Test reports for these tests are attached in Appendix section 1.2.8. Based on these tests, we recommend a C_{ds} value of 0.7 to determine the direct sliding resistance at the soil/strap interface. The direct sliding coefficient, C_{ds}, is defined as follows:

$$\tan \rho = Cds \tan \phi$$

Based on this value, the following values of ρ are recommended:

ϕ	ρ
30°	22.0°
32°	23.6°
34°	25.3°

1.3 OTHER COMPONENTS

1.3.1 Other Innovations

The other system components provide for a complete, flexible, and adaptable system, but do not include specific innovations in this context.

1.3.2 Reinforced Soil

For MSE walls, select fill is generally required within the reinforced soil zone. They may consist of free-draining sands, well graded sand-gravel mixtures, or even crushed aggregate in some applications. Select fill would generally have less than 5 percent passing a #200 sieve, and would have a maximum size in the ¾ inch to 1½ inch range. An internal friction angle for the reinforced fill would typically be in the range of 30 to 35 degrees. Electrochemical properties of the backfill are not as critical as with steel reinforcement, but a pH range between 4.5 and 9 is recommended. The recommended range of select fill generally conforms to the AASHTO LRFD standard.

Random backfill behind the reinforced soil zone would typically consist of on-site soils.

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For gravity wall applications, random backfill materials may be used behind the facing units. This may consist of on-site sands, silts, or low-plasticity lean clays. Moderate to high-plasticity clays or organic soils are generally avoided as backfill in gravity wall applications. In some applications, a select backfill similar to a reinforced fill may be used within a 1H:1V influence zone behind a gravity wall. In some states/regions, crusher run or screened crushed aggregates are commonly used for backfill behind gravity retaining walls.

1.3.3 Drainage

Unsatisfactory behavior of any geotechnical feature is almost always accompanied by the presence of water. This is less likely to be caused by hydrostatic loading than by a change in soil strength or volume, revealing some deficiency in the original design (including failure to plan for moisture intrusion or the improper selection of shear strength parameters for design). It is critical to plan for change in soil moisture levels over the life of the retaining system, and to incorporate drainage provisions into the installation to avoid buildup of hydrostatic loads on the retaining wall. This is important for both MSE and gravity applications.

Stone Strong units are normally filled with drainage aggregate, providing for drainage at the facing in all applications. The alignment recess in the bottom of the units can accommodate placement of a perforated drain pipe within the facing zone, and this is a common approach for gravity wall applications. It is not required to place the drain tile within this recess, however, and drains may also be placed behind the facing units or at the back of the leveling pad. Drainage provisions may also include a chimney drain behind the units for channels and waterfront applications or a blanket drain in MSE applications.

In gravity wall applications with a cast in place tail extension, the tail extension can disrupt drainage and lead to weeping through the face of the wall above the tail extension. While this effectively prevents buildup of hydrostatic load on the wall system, it may be an aesthetic concern. When cast in place tail extensions taller than 3 feet are used, an additional drain tile is recommended immediately above the extension, typically placed behind the facing units.

1.3.4 Coping

Cast in place copings are not commonly used on Stone Strong walls, either in gravity or MSE applications. Top units are typically used when there is some flexibility in the grade above the wall, as shown in section 1.1.2.

Where the grade above the wall is less flexible, such as with a swale or walkway above the wall, Dual Face units can be used to create a short curb or a parapet. Alternate top treatments with a Dual Face units are shown in Figure 13.

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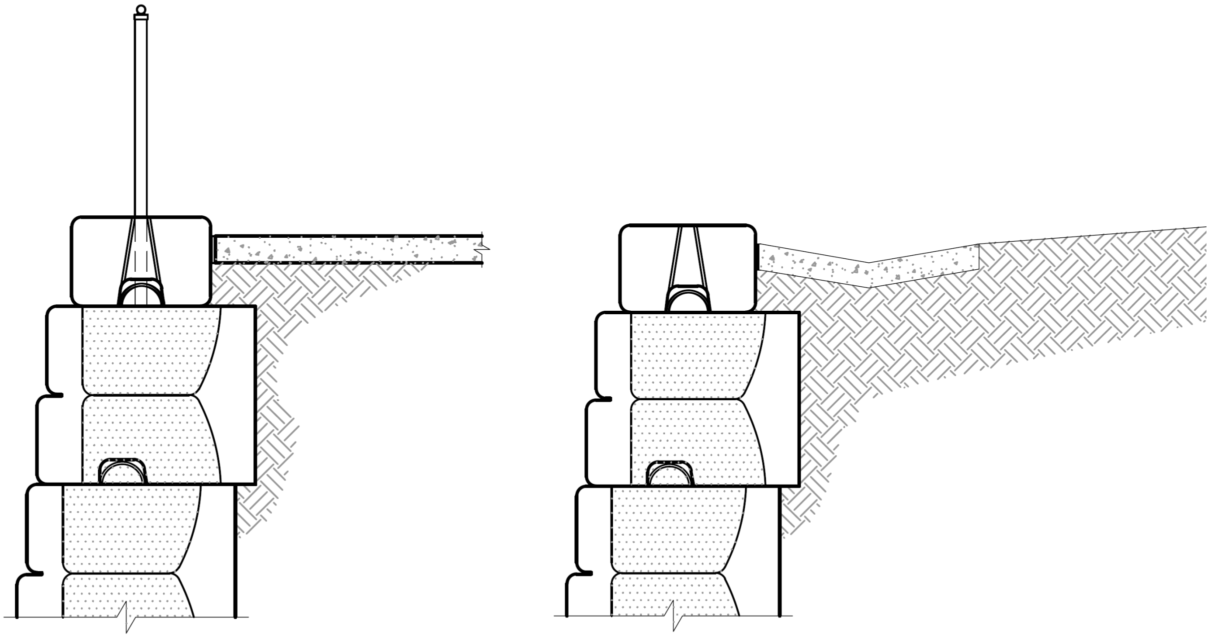

Figure 13 – Alternate Top Treatments with Dual Face Unit

The Custom Top Unit can also be used to function as coping at the top of either a gravity wall or MSE wall as shown in Figure 14. The CT Unit can be cast with a variable stem height, ranging from 6 inches to 30 inches above the base (24 inches to 48 inches total unit height), and the top can slope across the length of the unit. This allows the top the CT unit to follow the grade of a swale, walkway, or pavement located above the wall.

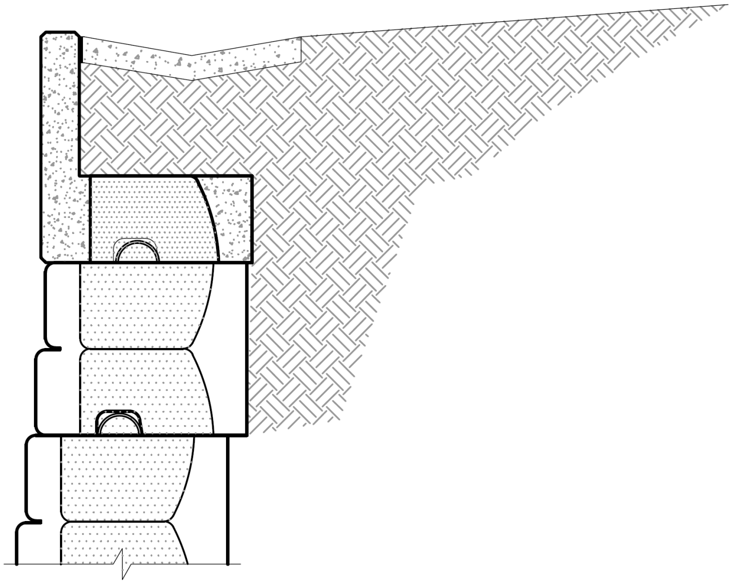

Figure 14 – Custom Top Unit with Concrete Swale

1.3.5 Traffic Barriers

Traffic barriers are often required atop both gravity and MSE retaining walls. These include post and W-beam guardrails as well as concrete barriers with moment slabs. If the barrier system is installed within the influence zone of the retaining system, collision loads should be applied at the ground surface based on the AASHTO LRFD standard. Appendix section 1.3.5 includes typical moment slab and barrier details. The configuration and dimensions of the moment slab and barrier may be adjusted to match typical standard details for the specifying agency.

Post and beam guardrail systems are flexible systems that are expected to deflect significantly on impact. The posts will shear or deflect, and the W-beam transfers load along the system to additional posts while absorbing energy. The guardrail posts would typically be set behind the facing units, but in some cases, the guardrail posts may actually be installed within the voids of the block units. The face of the guardrail should be set a minimum of 3 feet from the face of the wall to allow for deflection, which may require larger offset blocks if the posts are installed within the block voids.

Concrete barrier and moment slabs are more rigid, self-supporting systems. The internal design of these systems is typically established outside of the scope of the retaining wall design. To allow for movement of the moment slab/barrier, and to avoid directly applying load to the wall facing, the moment slab and barrier should be isolated from the precast units. Isolation is usually provided by placing a 1 to 2 inch thick layer of polystyrene over the top of the precast wall units.

Examples of barriers with a moment slab are shown in Figure 15. Note that the coping configuration and dimensions may be adjusted to match typical standard details for the specifying agency. For a sloping pavement grade, the thickness of the concrete placed under the moment slab to the top of the wall units will potentially vary by 18 inches to accommodate steps in the top of the wall. This varying thickness can be exposed above the top of the precast wall units as shown in the first example, or a uniform thickness coping may be extended as a skirt over the facing units as shown in the second example.

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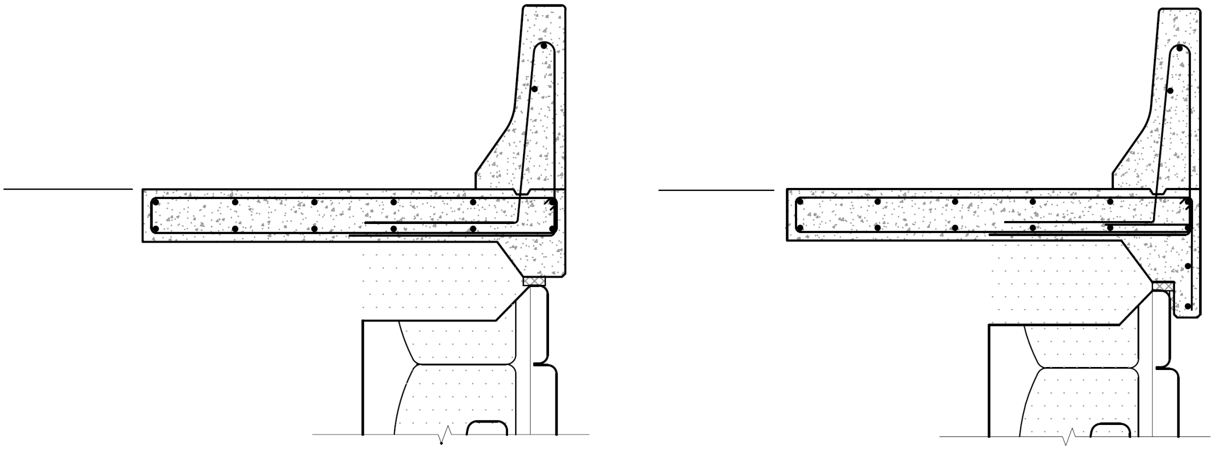

Figure 15 – Cast in Place Coping

Custom Top units can also be used in pavement applications. These units are custom produced with a sloping variable stem height that can follow the overlying pavement grade. This allows for a uniform thickness of moment slab above the wall. A moment slab can be placed flush to the face of the CT unit, or a skirt can be extended over the face of the CT unit to cover the separation joint as shown in Figure 16.

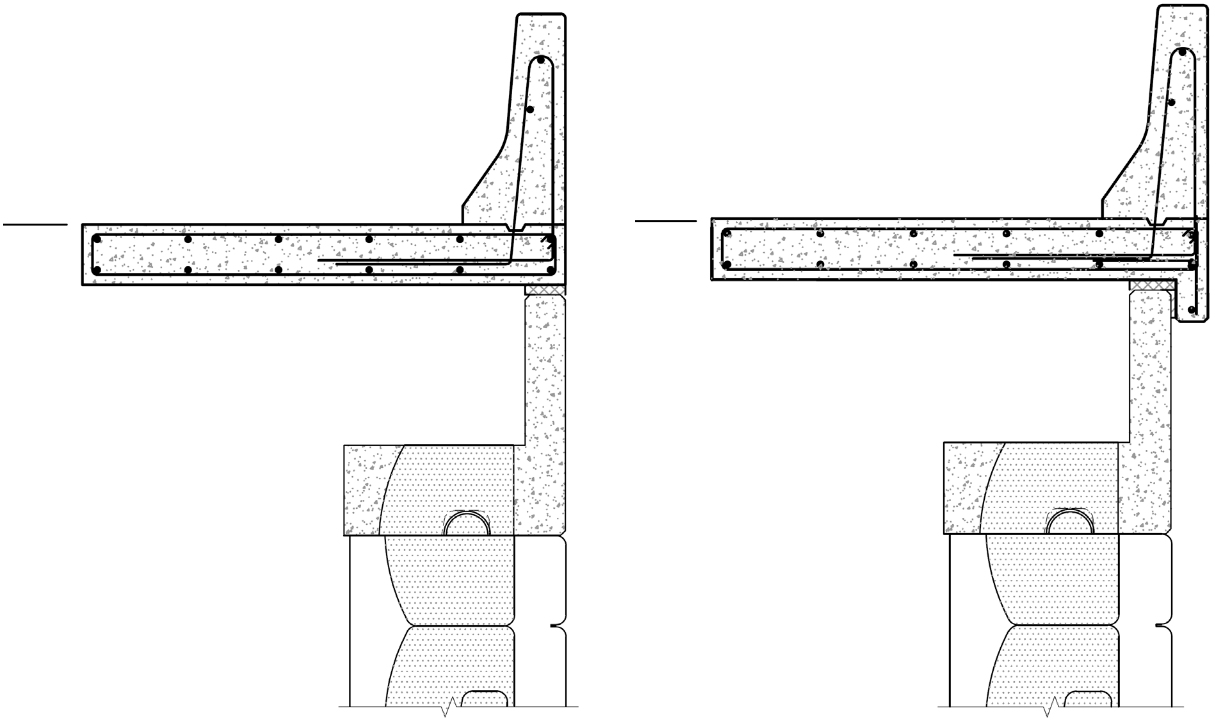

Figure 16 – Coping with Custom Top Unit

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1.3.6 Slip Joints

Slip joints can be provided as necessary within a wall elevation by using 6SF units to create an uninterrupted vertical joint as shown in Figure 17. A separate facing piece is not normally provided to cover the joint. Since some differential movement is expected across these joints, gaps greater than the normal tolerance of ¼ inch may develop within this vertical joint. Although the unit voids behind the joint are filled course drainage fill aggregate, a non-woven geotextile fabric is provided behind these joints to ensure that the course unit fill is retained in the event that larger gaps occur. See Appendix section 1.3.6 for additional details.

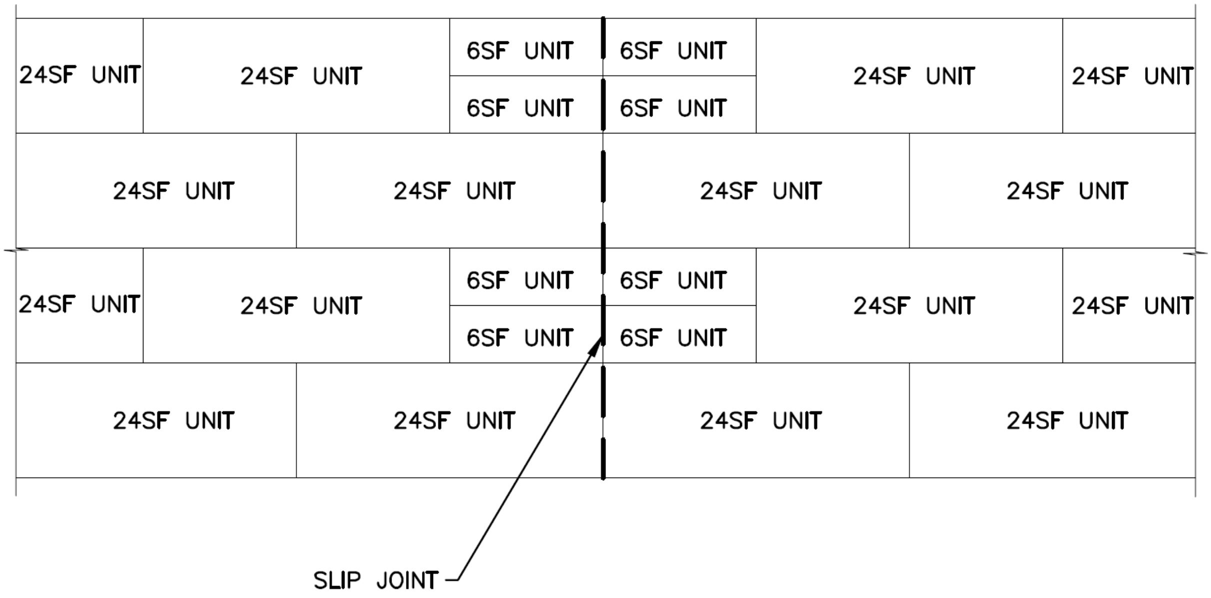

Figure 17 – Partial Wall Elevation View with Slip Joint

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SECTION 2: ERS DESIGN

2.1 DESIGN METHODOLOGY

2.1.1 Design Innovations

The analytical methods for design of gravity and MSE walls are intended to conform to the AASHTO LRFD standard. MSE analysis is done using MSEW software from ADAMA Engineering. Gravity wall analysis follows customary geotechnical concepts and practice.

A gravity wall analysis spreadsheet based on the Microsoft Excel platform is distributed by Stone Strong to perform gravity wall stability calculations. The spreadsheet includes an LRFD version that incorporates the methodology in the following section of this submittal. This spreadsheet can be downloaded through the Stone Strong website (http://www.stonestrong.com/form/gated_asset), but requires user registration for tracking and to allow for notification of periodic updates to the spreadsheet.

The gravity analysis spreadsheet utilizes a Coulomb trial wedge method for resolving complex boundary and surcharge condition above the wall. The wedge trials are iterated separately for gravity and seismic load cases. Separate individual trial wedge analysis is performed for internal stability at each unit interface.

2.1.2 Design Methodologies

MSE analysis is done using MSEW software from ADAMA Engineering. The software adheres to the AASHTO LRFD standard. The methodology is documented in the User Manual and is not replicated here.

When selecting modular facing with geosynthetic reinforcement, MSEW assumes that the reinforcement extends to the front of the facing element. To account for the typical 44 inch facing width, the calculated effective reinforcing lengths are adjusted. The connection point is roughly 3 inches inside of the back surface of the facing unit. In addition, the angled layout of the Paraweb strap results in a length measured perpendicular to the wall face that is 1 to 3 inches less than the angled strap length. Therefore, the effective reinforcing lengths from the MSEW calculations are reduced by 3.0 feet to determine the required strap lengths for installation. This value should be adjusted for different width facing units, if used.

Documents describing gravity wall analysis are attached in Appendix section 2.1.2. The LRFD Gravity Wall Design Methodology provides detailed description of the calculation of forces and the evaluation of load cases. The methodology includes citations to the AASHTO standard and NHI-10-024/025. Example calculations are also provided to demonstrate the methodology. Finally, spreadsheet output is included for verification and for demonstration. Note that the engineering approach presented here has not materially changed from that presented in the 2010 HITEC review. The techniques have been updated follow the LRFD standard, but the calculation of driving/resisting forces and other engineering principles remain as previously reviewed.

2.1.3 Reinforcement Obstructions

While it is a good design practice to avoid obstructions within the reinforced soil zone of an MSE wall, some exceptions are unavoidable. These would include pile or pier foundations for bridge abutments located shortly behind the face of an MSE wall.

The first design approach for handling obstructions is to construct the section affected by conflicts as a gravity wall. While this may require a fairly large tail extension or a significant number of larger precast units, it is often a simpler and more robust approach.

Where a gravity wall is not practical due to height or other considerations, the Paraweb reinforcement is very flexible and can be splayed around small to moderately sized obstructions. Further, since Paraweb is a polymeric material, there is minimal concern over electrochemical deterioration if the reinforcement is in contact with metal obstructions such as piling or protective sleeves. Although the Paraweb straps are capable of severe distortions around obstacles, a maximum deviation of 15 degrees is suggested to keep the reinforcement relatively perpendicular to the direction of load.

Typical obstruction details are provided in Appendix section 2.1.3.

2.2 DESIGN EXAMPLE

2.2.1 MSE Design Problem 1 (C1 Checklist)

MSEW output is provided in Appendix section 2.2.1 for Problem 1 from checklist C1, as shown in Figure 18. The wall was analyzed as 31 feet tall, to include a 12 inch thick coping/moment slab. A barrier load was also analyzed using NHI-10-024/25 option.

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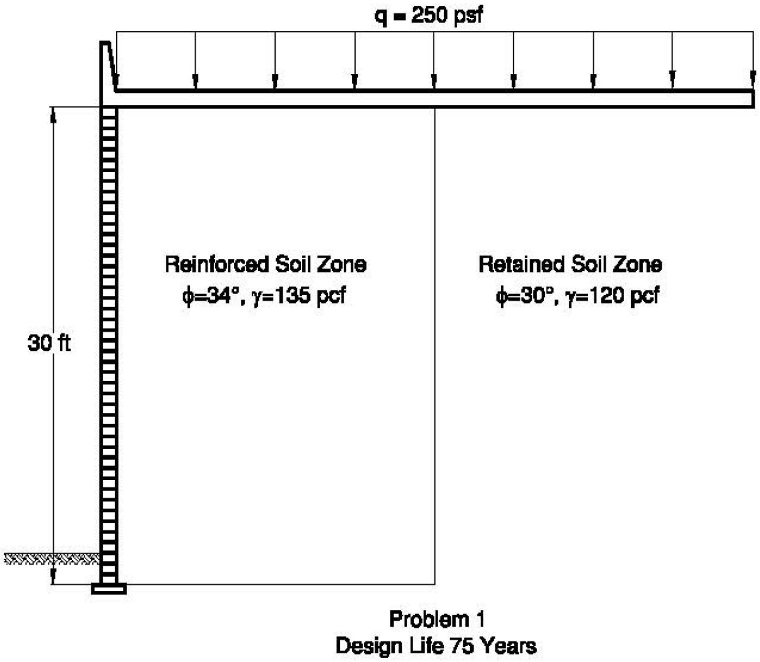

Figure 18 – Problem 1 (C1 Checklist)

2.2.2 MSE Design Problem 2 (C1 Checklist)

MSEW output is provided in Appendix section 2.2.2 for Problem 2 from checklist C1, as shown in Figure 19. The 30 feet tall wall was analyzed with a 2H:1V backslope from the back of the top unit.

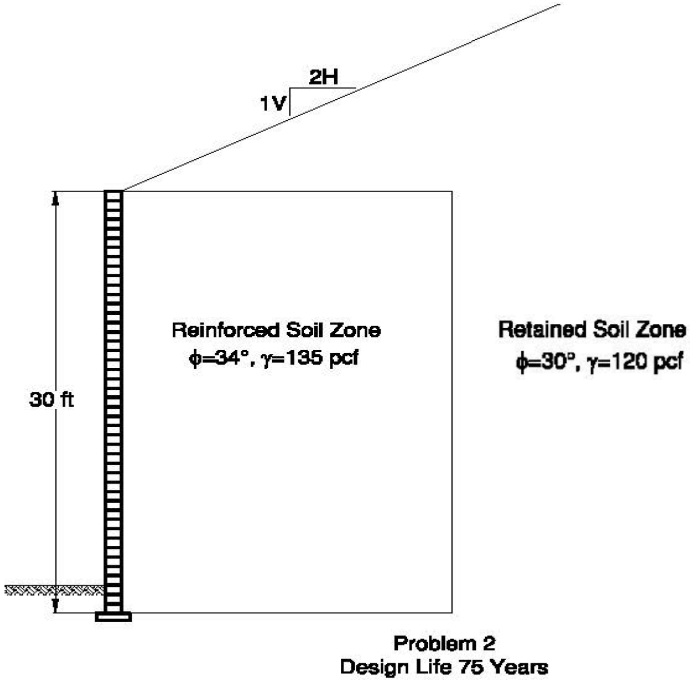

Figure 19 – Problem 2 (C1 Checklist)

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2.2.3 Gravity Design Problem 1 (C7 Checklist)

Spreadsheet output is provided in Appendix section 2.2.3 for example Problem 1 from checklist C7, as shown in Figure 20. The wall was analyzed as 13 feet tall, to include a 12 inch thick coping/moment slab. A barrier load was also analyzed in Extreme II load case (CT). External stability analysis is provided, which includes a check of internal stability at each block joint. Separate internal stability analysis is included to provide complete output at each unit interface, 9 feet, 6 feet, and 3 feet below the coping/moment slab.

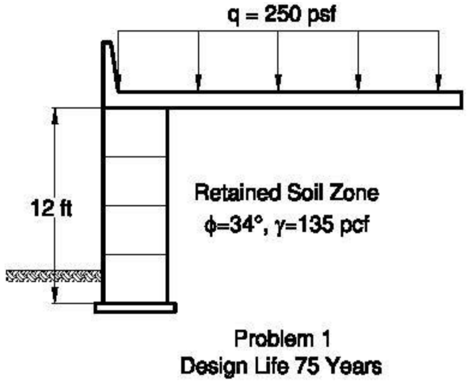

Figure 20 – Problem 1 (C7 Checklist)

2.2.4 Gravity Design Problem 2 (C7 Checklist)

Spreadsheet output is provided in Appendix section 2.2.4 for example Problem 2 from checklist C7, as shown in Figure 21. The 12 feet tall wall was analyzed with a 2H:1V backslope from the back of the top unit. A slope break was set beyond the influence based on trial wedge analysis. External stability analysis is provided, which includes a check of internal stability at each block joint. Separate internal stability analysis is included to provide complete internal analysis output at each unit interface, 9 feet, 6 feet, and 3 feet below the top of wall.

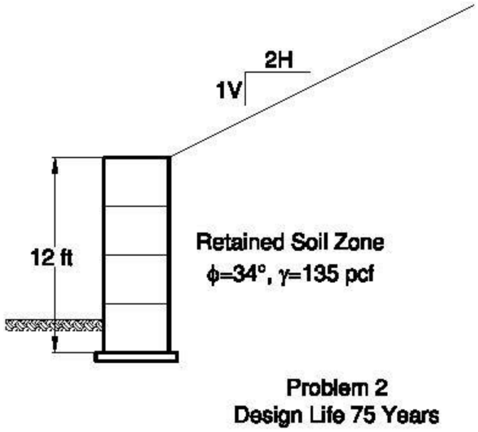

Figure 21 – Problem 2 (C7 Checklist)

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SECTION 3: CONSTRUCTION

3.1 CONSTRUCTION PROCEDURES

3.1.1 Construction Innovations

The wall system is configured for high-productivity installation, but does not include specific innovations in this context.

3.1.2 Installation Manual

The Stone Strong Field Construction Manual is included in Appendix section 3.1.2.

3.1.3 Facing Unit Installation

Precast modular facing units for either a gravity wall or MSE wall are typically installed on running bond, where each unit is approximately centered over the joint between units in the preceding course. However, the units may be installed on stack bond where required for aesthetic (e.g. complex face pattern) or technical (e.g. differential settlement) reasons. Note that a stack bond, where units are placed directly above the units in the preceding course, is not recommended for battered units on a curved alignment. The units may also be installed on partial or odd bond patterns to accommodate specific applications.

The recess in the bottom of the unit fits over the lift/alignment loop in the preceding course. This mechanism sets the facing setback, typically either vertical or battered at 6.3 degrees. For battered facing on curves, the arc length of each course will vary as the setback between units changes the radius by 2 to 4 inches per course. Over a curve of approximately 40 degrees, the length will vary by roughly 3 inches per course and the recess will no longer engage the alignment loop. This is only a minor concern, as the unit shear only relies on aggregate interlock through the block voids. In this occurrence, the block batter can be manually set by measuring or aligning the back of the units. In the case of any vertical intersections, such as a corner, slip joint, or abutting structure, the units may be trimmed with a concrete saw.

3.1.4 Facing Installation on Curved Sections & Corners

Stone Strong precast modular facing units have tapered sides to accommodate installation on curves. The 24SF units (including 24-86, 24-62, and 24-ME units) can be installed on convex or concave radius of approximately 60 feet. The facing units can be transitioned to 6SF units for installation on convex or concave radius of approximately 20 feet. See section 1.1.14 and details in Appendix section 3.1.4. No modifications are required to the facing units except the occasional requirement to trim a unit to length on a battered wall with a vertical intersection adjacent to a curve.

There are several different options for constructing corners, depending partly on whether the wall has a battered or vertical face. For vertical faces, the 90° Corner Unit works well for inside and outside

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corners. Similarly, the 45° Corner Unit is well suited to vertical face configurations. These corner units work well with battered walls of modest heights, typically 12 feet or less. For taller battered walls, the Inside Corner and Outside Corner units are cast in differing sizes for each course of the wall to accommodate batter of both faces. Other options include laced inside corners and outside corners using the End/Corner Unit. Corner facing details are provided in Appendix section 3.1.4.

3.1.5 Reinforcement Installation on Curved Sections & Corners

On a straight alignment, Paraweb reinforcing straps are laid out in V-shapes spaced 4 feet on center, with the ends overlapping on the same spacing. In a curved alignment, the ends of the straps are spaced closer or further apart. On very tight convex curves, it becomes impractical to maintain a uniform spacing, and the straps are laid in an overlapping fashion. Layout details for Paraweb straps on straight alignments, curved alignments, and on corners are provided in Appendix section 3.1.5.

3.1.6 Facing Alignment

Once the first course of units is aligned and leveled, very little effort is required to maintain the design horizontal and vertical alignment of the face. Stone Strong units are produced to very tight tolerances (±1/8 inch for height and length dimensions). Because of these close tolerances, the units set neatly and shimming is not required or recommended during installation. The alignment loops and recess provide rapid alignment to similar tolerances. In addition, the units are very robust and are not prone to defection or displacement during placement and compaction of backfill.

It is good practice to periodically check that the block units are level during installation and check that the alignment and batter are maintained. The alignment and batter can be adjusted by pulling units back rather than pushing them forward after setting over the alignment loops and prior to filling with unit fill. For larger adjustments, the lifting loops can be cut off or bent to allow changes to the alignment or batter.

3.1.7 Backfill Placement

Fill within the reinforced zone and the retained zone (for both MSE walls and gravity walls) should be placed and compacted in a controlled manner. Select fill should be used within the reinforced zone limits and within the influence zone, typically 1H:1V, when specified for a gravity retaining wall. Lift thicknesses should be limited based on the compaction equipment and the type of material, but reinforced fill should generally be placed in lifts not exceeding 8 inches thick. All fill, both select and retained/random, should be compacted to a minimum of 95 percent of the maximum dry density (ASTM D698, Standard Proctor). Moisture sensitive materials should have the moisture content controlled near optimum based on the specific material, but generally within -2 to +3 percent of optimum moisture content. Project or agency specific requirements that are more stringent than these general guidelines should be followed.

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Compaction equipment may operate directly behind the precast modular units. No zone of reduced compaction should be permitted behind the facing.

3.1.8 Erosion During Construction

The contractor should provide temporary grading including swales and ditches to prevent runoff from entering the excavation and to direct surface water within the excavation away from the wall face.

3.1.9 Installer Qualifications

Stone Strong does not establish minimum qualifications for wall installers. On-site installation support is available through the local dealer/producers, and technical support can also be provided through Stone Strong LLC.

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SECTION 4: QUALITY CONTROL

4.1 MANUFACTURING

4.1.1 Facing Production Quality Control

The Stone Strong QA/QC Manual is attached in Appendix section 4.1.1.

4.1.2 Reinforcement Manufacture Quality Control

The Manufacturers Quality Control for Paraweb Reinforcement is attached in Appendix section 4.1.2.

4.1.3 Connection Manufacture Quality Control

The reinforcing bar through the Macbox connector is the critical component of the connection system. Placement and positioning of internal reinforcement is covered in the Stone Strong QA/QC Manual.

4.2 CONSTRUCTION

4.2.1 Construction Quality Control

Quality control during construction is addressed in the QA/QC Manual (see Appendix section 4.1.1) and in the Field Construction Manual (see Appendix section 3.1.2). In addition, construction quality control should be addressed in the project specification. The Stone Strong guide specification is included in Appendix section 4.2.1.

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SECTION 5: PERFORMANCE

5.1 PERFORMANCE HISTORY

5.1.1 System Development and Usage

Stone Strong precast modular retaining wall units were originally developed in 2002 and 2003. The product was first licensed to a dealer in 2003, and the first commercial retaining walls were completed in early 2004. At that time, only the standard 44 inch width 24SF and 6SF units were available, along with the Corner/End unit.

Over the ensuing years, additional dealers have been added and additional products have been developed. The Dual Face unit debuted in 2005. The 90 Degree Corner and 45 Degree Corner followed in 2006. The extended width units, 24-86 and 24-62, were released in 2010, expanding the limits of gravity wall installations using only precast elements. The reduced width 6-28 unit was added in 2014, rounding out the suite of variable width precast units.

There are currently 38 licensed dealers located primarily in North America, but extending to the south Pacific region. These licensees produce and stock wall units in 40 or more fixed precast plants plus temporary satellite locations.

The original market for Stone Strong precast modular retaining walls was private development and commercial projects. The system has also gained widespread acceptance with public clients, including state transportation departments, provincial transport ministries, and local county/municipal entities across the US and Canada.

Over the past 18 years, millions of square feet of Stone Strong facing have been installed. A large percentage of the walls have been gravity retaining structures, but a significant percentage of MSE walls have also been erected. Historically, the majority of the MSE walls have used geogrid reinforcement. The first Paraweb reinforced MSE wall was constructed in New Zealand in 2015. The first Paraweb reinforced MSE wall in the US was built in 2018.

5.1.2 Oldest 3 Structures

The oldest 3 Stone Strong gravity wall installations, excluding minor or demonstration installations, are listed as follows, including facing area and year of original construction:

- Quarry Place, Milford, Massachusetts, 11,370 square feet, installed in 2004
- Westfield Shopping Center, Lincoln, Nebraska, 2,160 square feet, installed in 2004
- Harrison Street Reconstruction, Omaha, Nebraska, 17,430 square feet, installed in 2004-2005

The oldest 3 MSE wall installations are listed as follows, including facing area and year of original construction (these wall utilized geogrid reinforcement):

- Thayer Academy, Braintree, Massachusetts, 9,580 square feet, installed in 2004
- Oak Point Phase 6, Middleboro, Massachusetts, 27,040 square feet, installed in 2004
- Central Catholic High School, Lawrence, Massachusetts, 2,850 square feet, installed in 2005

The oldest 3 MSE walls using Paraweb reinforcement are listed as follows, including facing area and year of original construction (only US projects included):

- West Dodge Off-Ramp, Omaha, Nebraska, 5,000 square feet, installed in 2018
- Southern Connector Road, Douglas County, Colorado, 1,750 square feet, installed in 2019
- Ridgefield Main Avenue, Clark County, Washington, 2,840 square feet, installed in 2019

5.1.3 Tallest 3 Structures

The tallest 3 gravity wall installations are as follows, including peak height and type of extended block units:

- Office Building, Shelton, Connecticut, 28.5 feet tall, cast in place tail extensions, installed in 2007
- Eagle Ridge Apartments, Colorado Springs, Colorado, 19.5 feet tall, precast 24-86 units, installed in 2016
- Confidential government installation, Maryland, 36 feet tall, cast in place tail extensions behind 24-86 units, installed in 2017

The tallest 3 MSE wall installations are as follows, including maximum height and configuration:

- Route 15, Steuben County, New York, 54 feet tall, geogrid reinforced, single tier
- Foothills Parkway, Great Smokey Mountain National Park, Tennessee, 70 feet tall, geogrid reinforced, 2 tiers
- Rutland Airport, Rutland, Vermont, 63 feet tall, geogrid reinforced, 2 tiers

5.1.4 Agency/Owner Approvals

Stone Strong is currently approved by 17 state DOTs. In addition, Stone Strong is accepted by numerous county and municipal agencies that do not have formal approval processes. The following is a listing of state DOT approvals:

State	DOT Approved	DOT Approved Date	Product Group
Alabama	Yes	7/11/2011	Gravity Wall Systems II-28
Georgia	Yes	10/7/2008	QPL-4 Misc. Precast Products
Florida	Yes	2009 & 5/27/2020	548 - Retaining Wall Systems
Illinois	Yes	11/24/2008	Structural Systems/Precast Modular Retaining Walls
Kansas	Yes	2/3/2006	40.5 - Landscape Retaining Wall Systems
Maine	Yes	11/1/2010	Wet Cast Small Landscape Block Wall
Maryland	Yes	6/2009 & 5/2020	450 - Retaining Walls
Massachusetts	Yes	6/2009	Precast Concrete Producers
Nebraska	Yes	2008	MSE Walls/Modular Bock Facing Units - 715
New Jersey	Yes	4/7/2006	Precast Concrete Retaining Walls, Modular (904.02)
New York	Yes	3/23/2006	Precast Concrete Wall Units - 704-06
Pennsylvania	Yes	11/2010	MISC Precast Concrete Products
South Dakota	Yes	3/2010	Earth Retaining Structures and Systems
Tennessee	Yes	6/2009	38 - Retaining Walls
Texas	Yes	4/2010	Concrete Block Retaining Wall Systems
Virginia	Yes	11/19/2009	Concrete Precast Producers
West Virginia	Yes	2019	MSE Modular Block Wall Systems - 626.002.003

Stone Strong is widely accepted by private commercial users and institutional users. Stone Strong has been successfully used in land development, retail, education, and infrastructure projects across North America.

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SECTION 6: OTHER INFORMATION

6.1 OTHER INFORMATION

No other information is presented at this time.

Appendix

Innovations, Developments, Enhancement and Advancements (IDEA) Program

Stone Strong
Precast Modular Retaining Wall System

January 8, 2021

Appendix Contents

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1.1.1 FACING INNOVATIONS

No attachments

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1.1.2 FACING COMPONENTS

No attachments

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1.1.3 COMPONENT SPECIFICATIONS

Technical Memorandum TM-2018-01
Block Reinforcement Details
Structural Modeling and Design Calculations

TM-2018-01 **Date: 3/30/18**
(supersedes TM-2013-01 and TM-2013-02) Total Pages: 2

Technical Memorandum

Subject: Steel reinforcement in Stone Strong precast modular wall units

Technical Information:

Stone Strong 24SF and 6SF units are designed to be unreinforced in typical gravity wall applications. The thickness of the webs and flanges provide structural integrity for normal gravity wall applications with these units. All extended units (24-86, 24-62, and 24-ME) are required to be reinforced in all applications, and reinforcement is required in many MSE applications as shown in the accompanying tables.

Stone Strong Systems has investigated MSE retaining walls using 24SF units and have found some instances of cracking in the lower portion of tall walls. Our evaluation has determined that minor yielding in the foundation results in differential movement of the units in the lower course. This causes cracks to develop in one or more courses above the bottom course. This typically does not affect the structural integrity of the 24SF unit or the wall system, but can have an aesthetic impact. In taller walls, reinforcement is necessary to ensure the structural integrity of the units.

For MSE walls using Paraweb reinforcement, all units should be reinforced and heavy duty (HD) reinforcement should be used below prescribed heights based on the type of unit. Rebar is necessary in the back face of 24SF, 6SF, and 6-28 units as part of the Paraweb connector. Standard reinforcement in 24SF-Paraweb units will also include a steel mesh or rebar cage in the face and webs. For 24SF-HDParaweb units between 36 and 51 feet (11.0 to 15.5 m) below the top of wall, HD reinforcement should also include a steel mesh or rebar cage within the back face. For 6SF-HDParweb or 6-28-HDParaweb units between 12 and 51 feet (3.7 to 15.5 m) below the top of wall, HD reinforcement should include a mesh or rebar cage in the face and webs.

For MSE walls using geogrid reinforcement over 12 feet (3.7 m) in height and less than 30 feet (9.1 m) in height, internal reinforcement shall be utilized in all 24SF units below the top 12 feet (3.7 m) of the wall. A reinforcement cage consisting of steel mesh or rebar should be placed in the face and webs of 24SF-Reinforced units. Stone Strong recommends that project specific guidance be provided for geogrid reinforced MSE walls over approximately 30 feet (9.1 m).

Reinforcing details are provided in the Production Manual for 24SF-Reinforced, 24SF-Paraweb, 24SF-HDParaweb, 6SF-Paraweb, 6SF-HDParaweb, 6-28-Paraweb, 6-28-HDParaweb, 24-86, 24-62, and 24-ME units. Options are provided for both steel mesh and rebar options, where applicable. Stone Strong Systems recommends that designers indicate types of reinforced or HD reinforced blocks where required on shop drawings or installation drawings for MSE walls.

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Gravity Wall Applications

Unit Type	All Heights
24SF	24SF
6SF	6SF
6-28	6-28
24-62	**24-62**
24-86	**24-86**
24-ME	**24-ME**

Paraweb MSE Applications

Unit Type	Depth Below Top of Wall		
	0-12 feet (0-3.7 m)	12-36 feet (3.7-11.0 m)	36-51 feet (11.0-15.5 m)
24SF	**24SF-P**	**24SF-P**	**24SF-HDP**
6SF	**6SF-P**	**6SF-HDP**	**6SF-HDP**
6-28	**6-28-P**	**6-28-HDP**	**6-28-HDP**

Note: If a gravity section is included at the top of the wall (hybrid applications), gravity units may follow the gravity application table

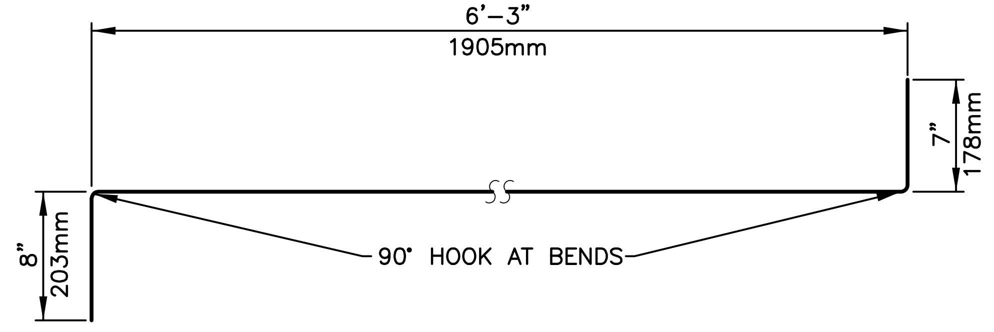
Geogrid MSE Applications

Unit Type	Depth Below Top of Wall	
	0-12 feet (0-3.7 m)	12-30 feet (3.7-9.1 m) **
24SF	24SF	**24SF-R**
6SF	6SF	6SF
6-28	6-28	6-28

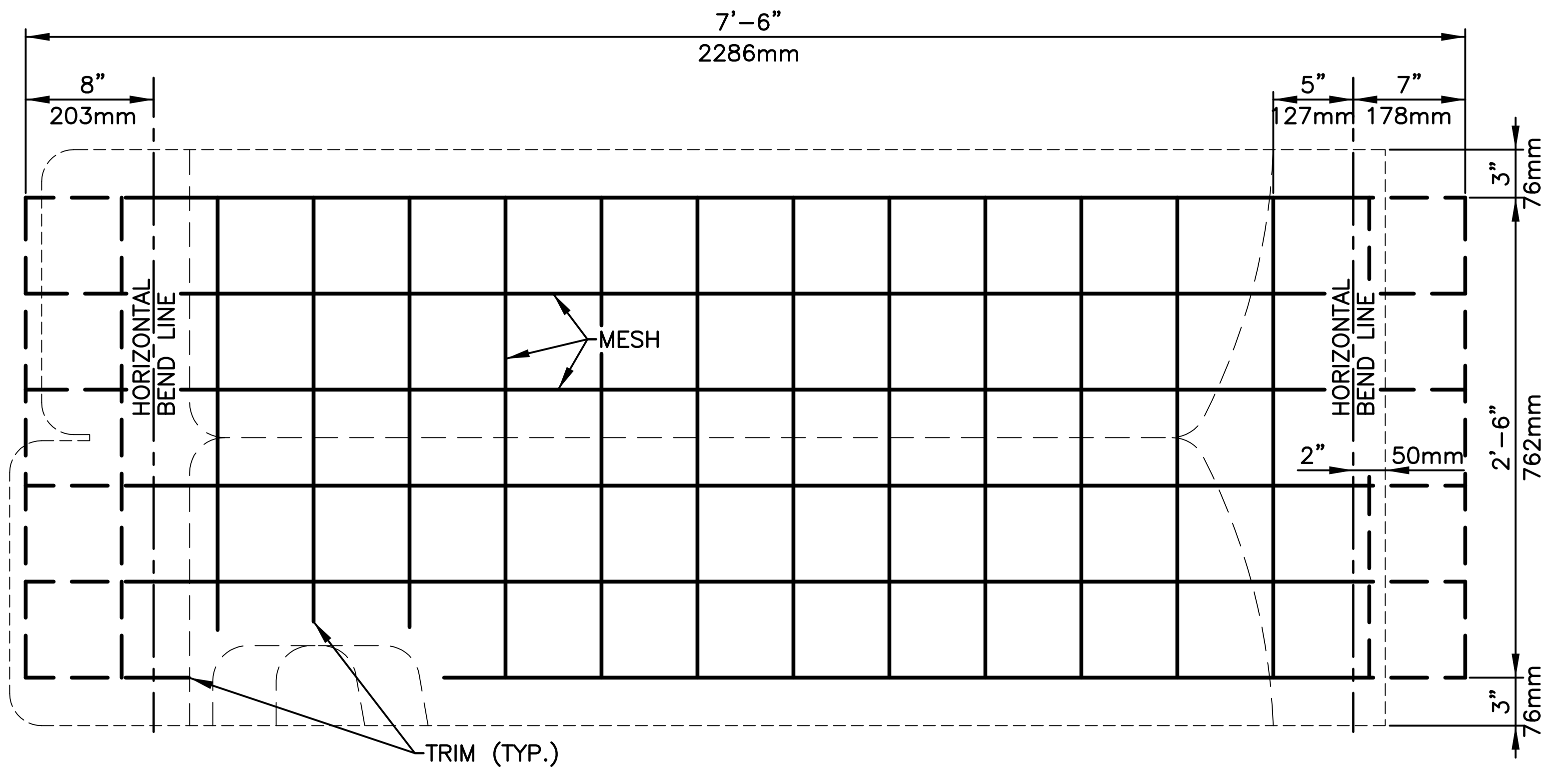
** Project specific guidance is recommended for geogrid reinforced MSE walls over 30 feet tall

(In all tables, light shading indicates reinforced units, dark shading indicates HD reinforced units)

NOTES:
1. ALL MESH SHALL BE W8xW8–6x6 WWF PER ASTM A185/A497/A1064, GRADE 65 U.N.O.
2. USE IN ALL 24–86 UNITS.



BENT WEB MESH – PLAN VIEW



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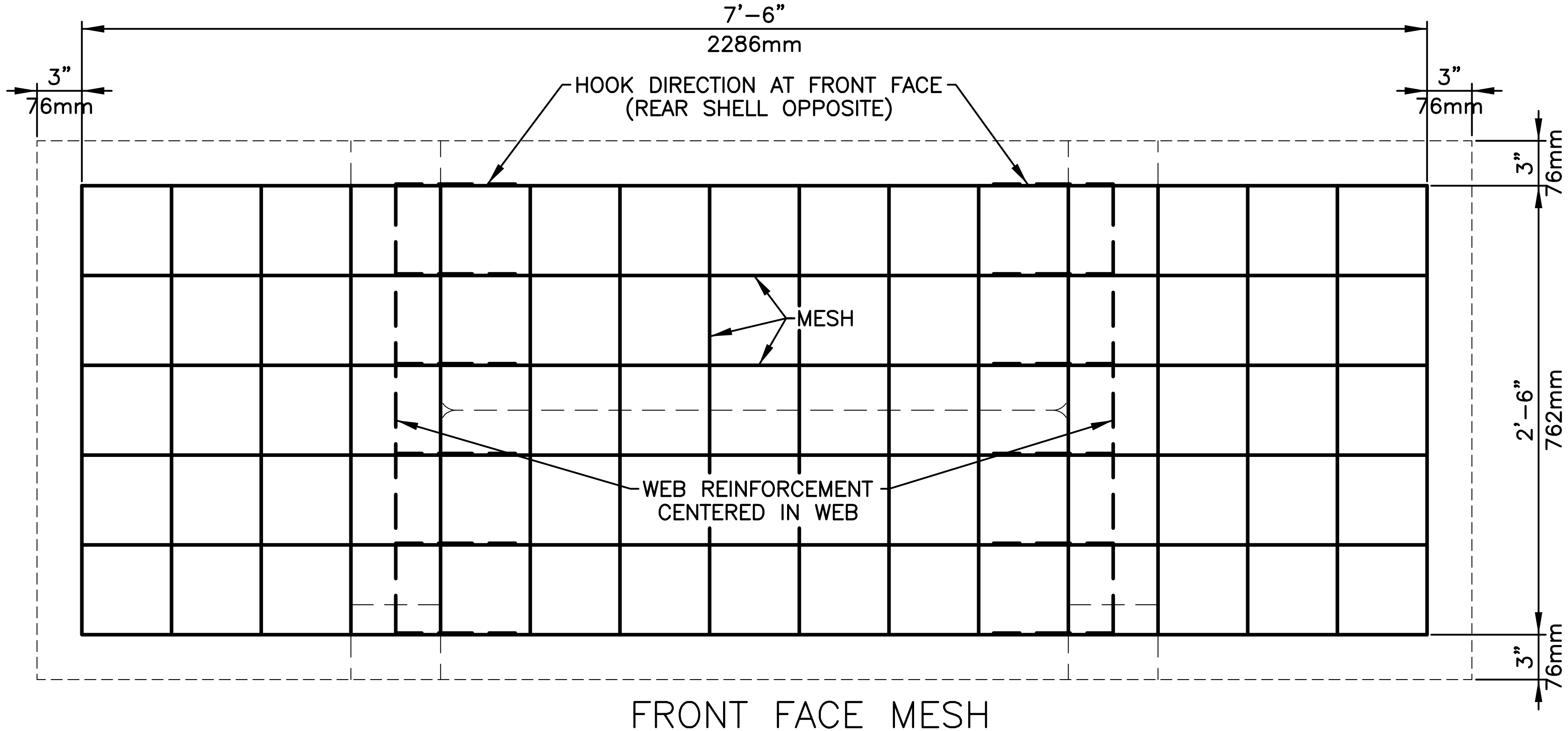

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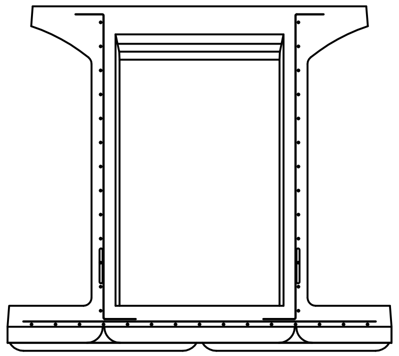

24–86 UNIT (24–86) – MESH OPTION

NOT TO SCALE

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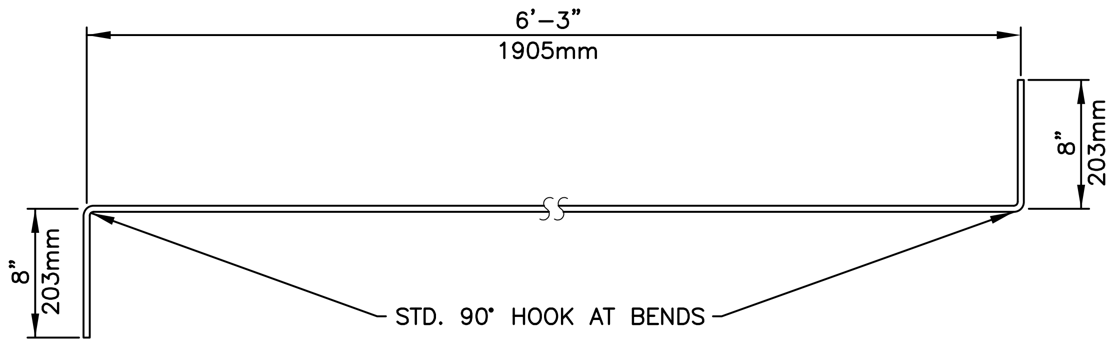
PROJECT
REINFORCING DETAILS
STONE STRONG SYSTEMS

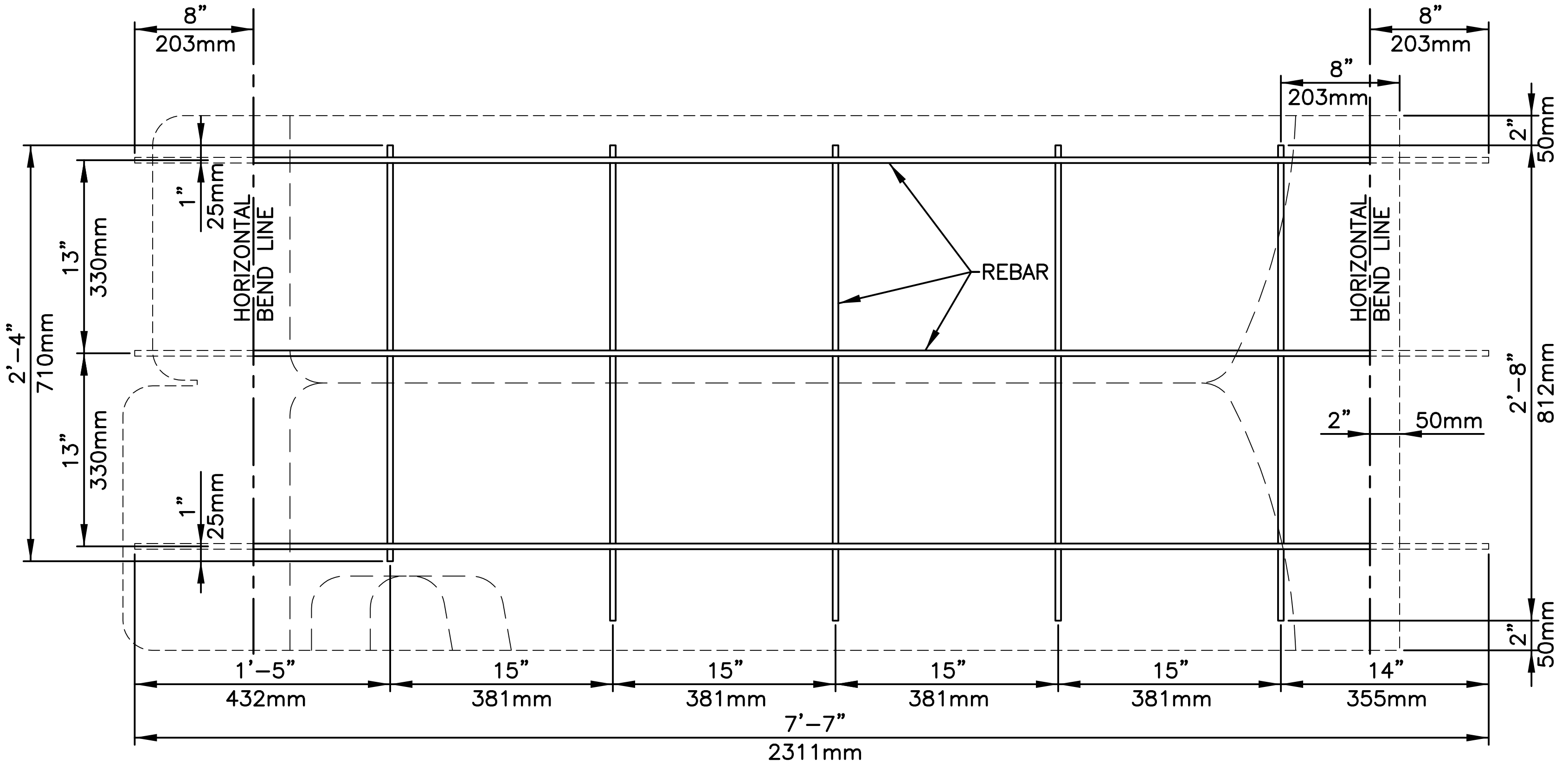
DATE: 6/29/18
FILE: 01_24–86 Mesh

NOTES:

1. ALL STEEL SHALL BE #4 BARS, GRADE 60, U.N.O.
2. USE IN ALL 24–86 UNITS.



BENT WEB REBAR – PLAN VIEW



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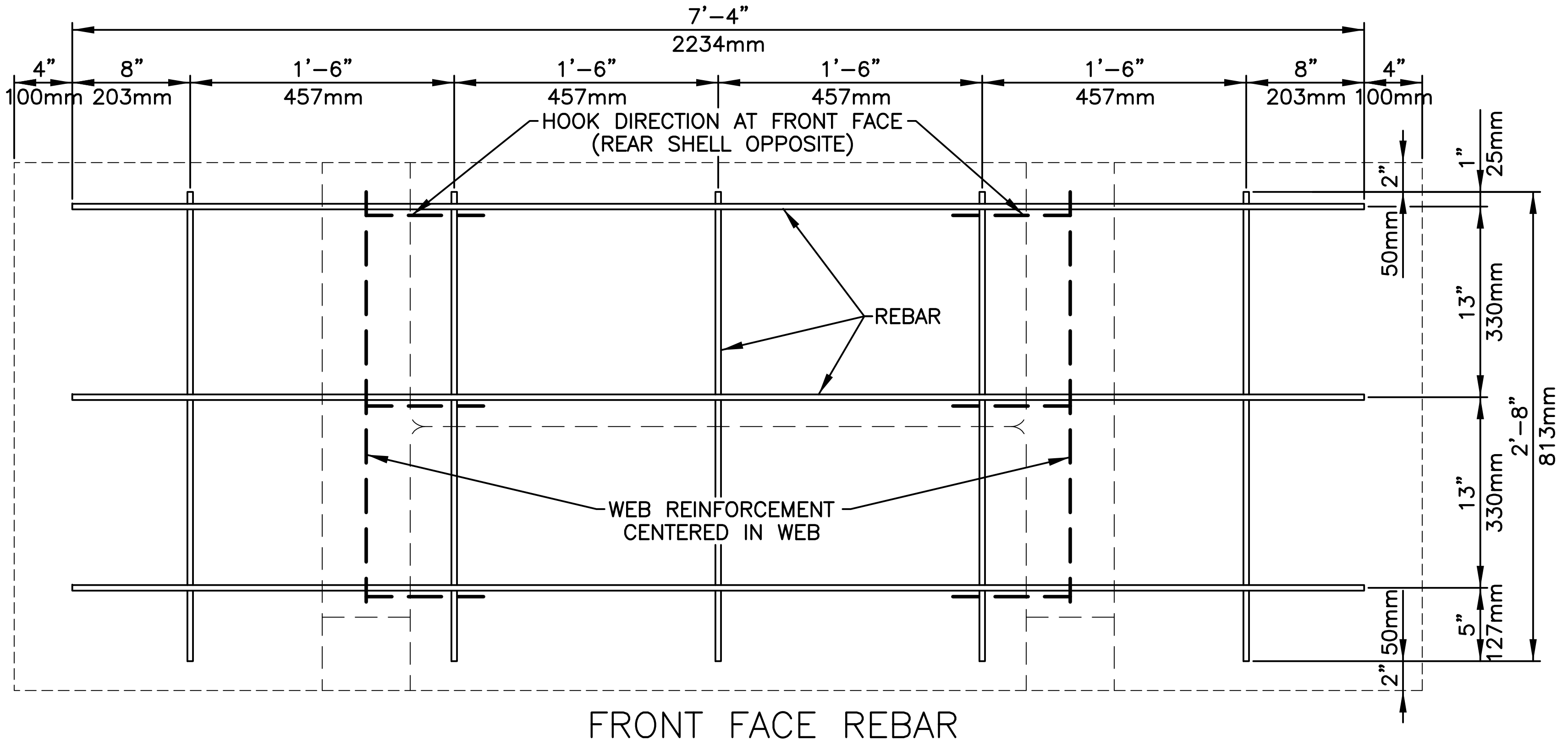

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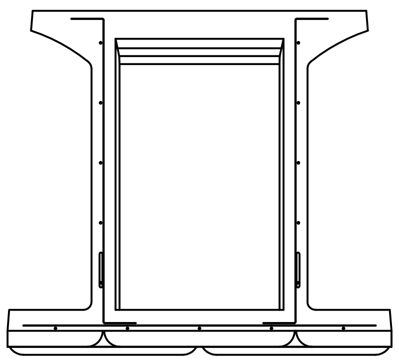

24–86 UNIT (24–86) – REBAR OPTION

NOT TO SCALE

DISCLAIMER:

These typical details are preliminary and conceptual in nature. They are provided for general information purposes only. Anyone making use of these details and related information does so at their own risk and assumes all liability for such use. Site specific design should be performed by a licensed Professional Engineer who is familiar with the actual site conditions, materials, and local practices.

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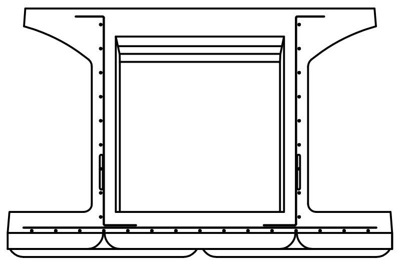
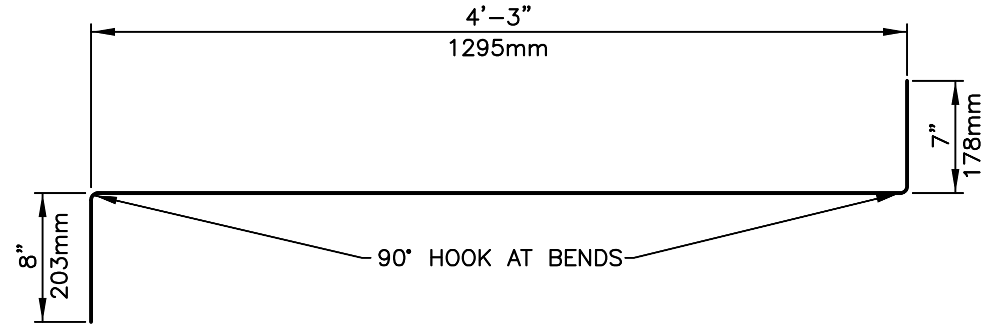
REINFORCING DETAILS
STONE STRONG SYSTEMS

DATE: 6/29/18 | FILE: 02_24-86 Rebar

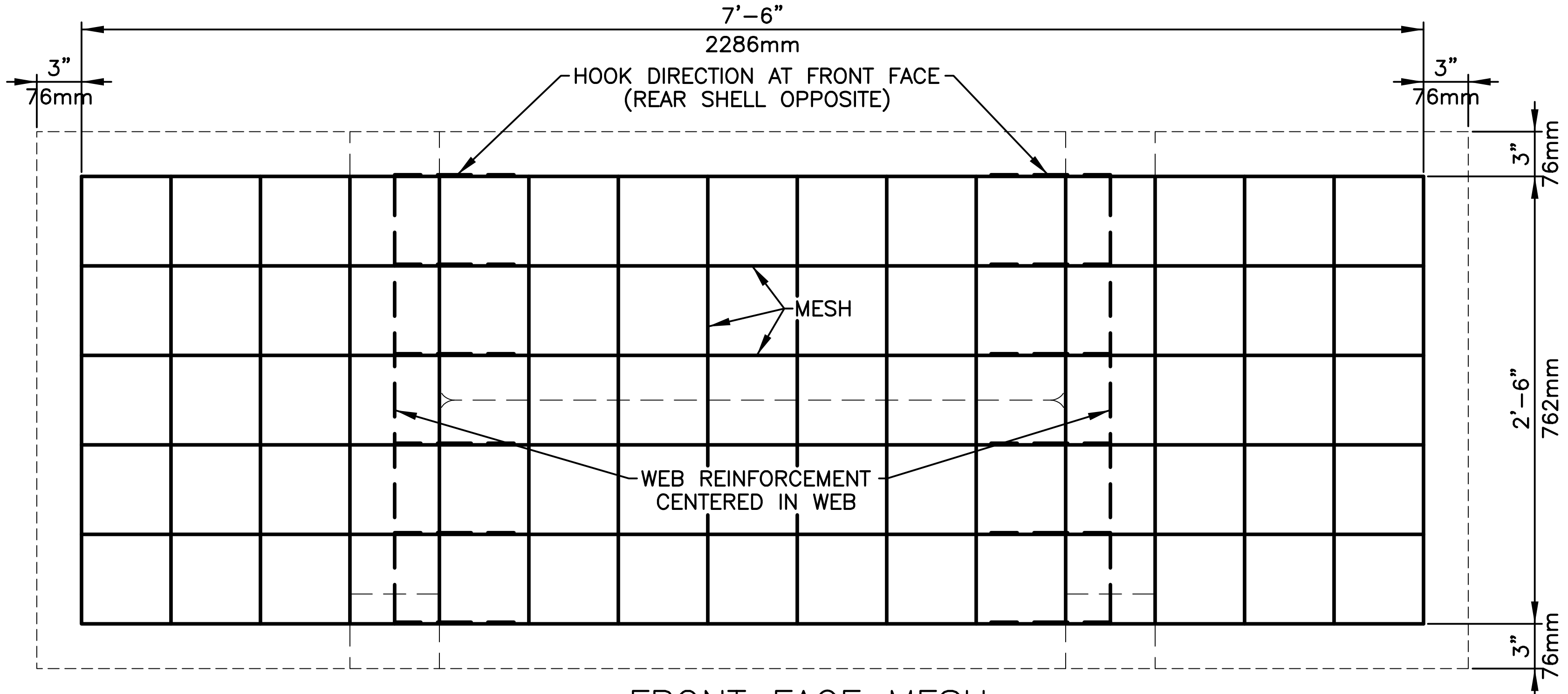
NOTES:

1. ALL MESH SHALL BE W8xW8-6x6 WWF PER ASTM A185/A497/A1064, GRADE 65 U.N.O.
2. USE IN ALL 24-62 UNITS.





BENT WEB MESH – PLAN VIEW



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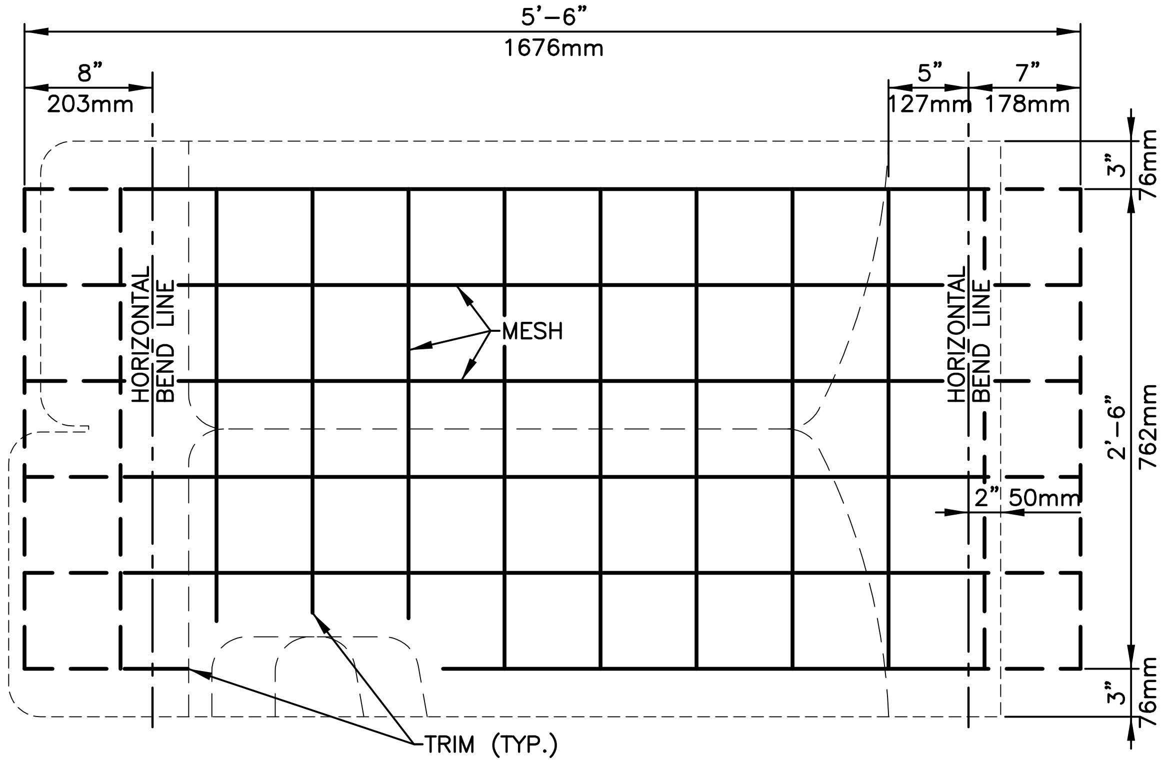

BENT WEB MESH (2 REQUIRED)

24-62 UNIT (24-62) – MESH OPTION

NOT TO SCALE

DISCLAIMER:

These typical details are preliminary and conceptual in nature. They are provided for general information purposes only. Anyone making use of these details and related information does so at their own risk and assumes all liability for such use. Site specific design should be performed by a licensed Professional Engineer who is familiar with the actual site conditions, materials, and local practices.

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REINFORCING DETAILS
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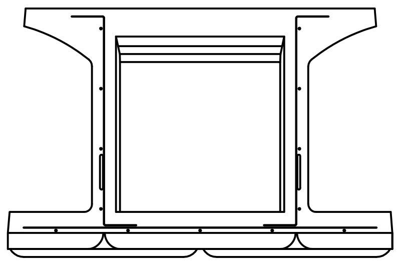
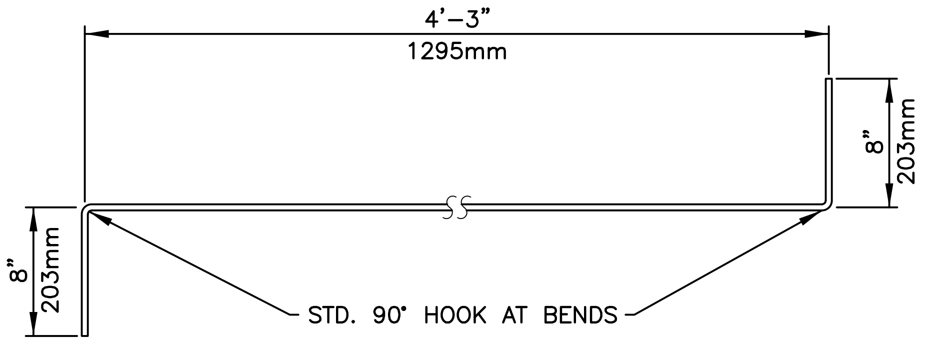
DATE: 6/29/18 | FILE: 03_24-62 Mesh

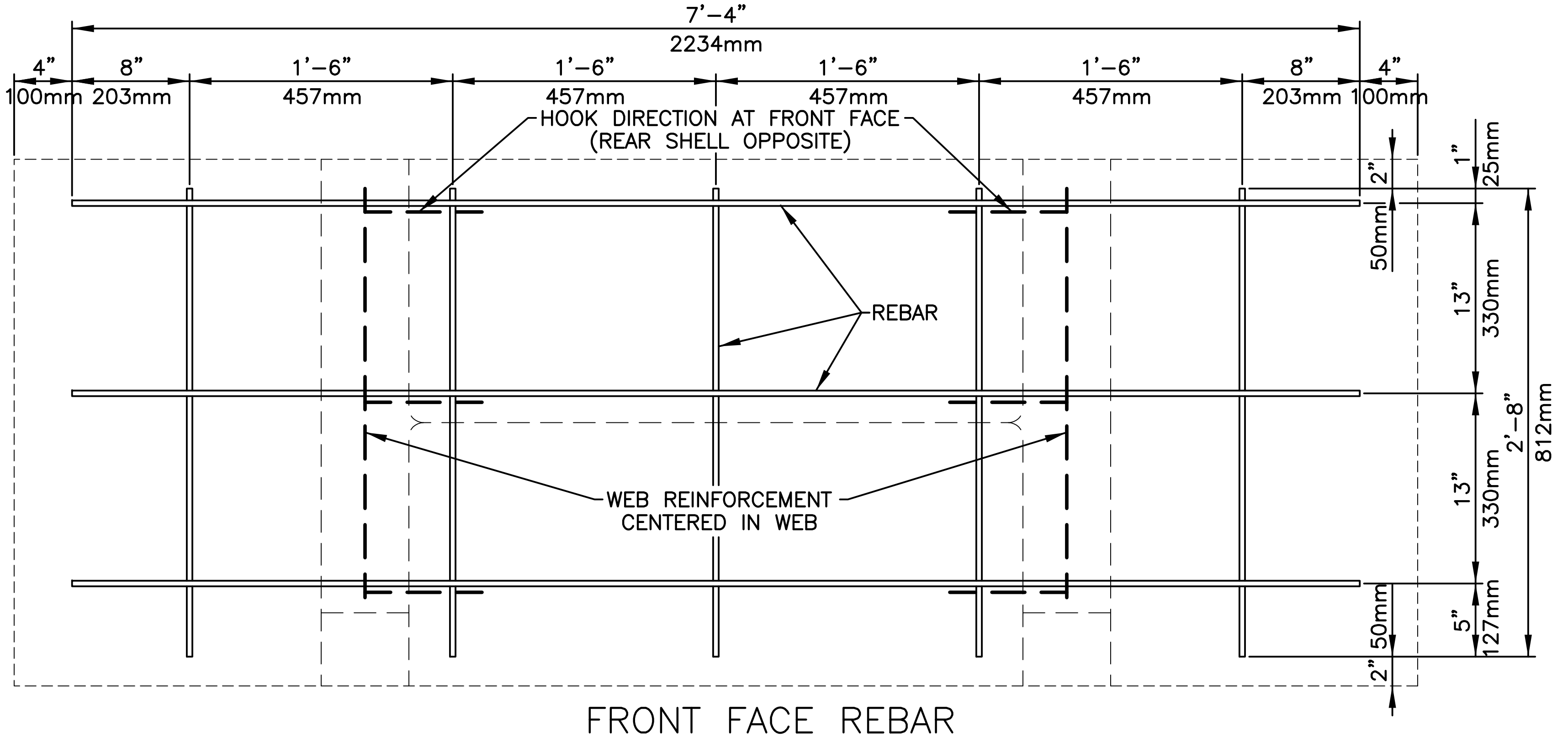
NOTES:

1. ALL STEEL SHALL BE #4 BARS, GRADE 60, U.N.O.
2. USE IN ALL 24–62 UNITS.





BENT WEB REBAR – PLAN VIEW



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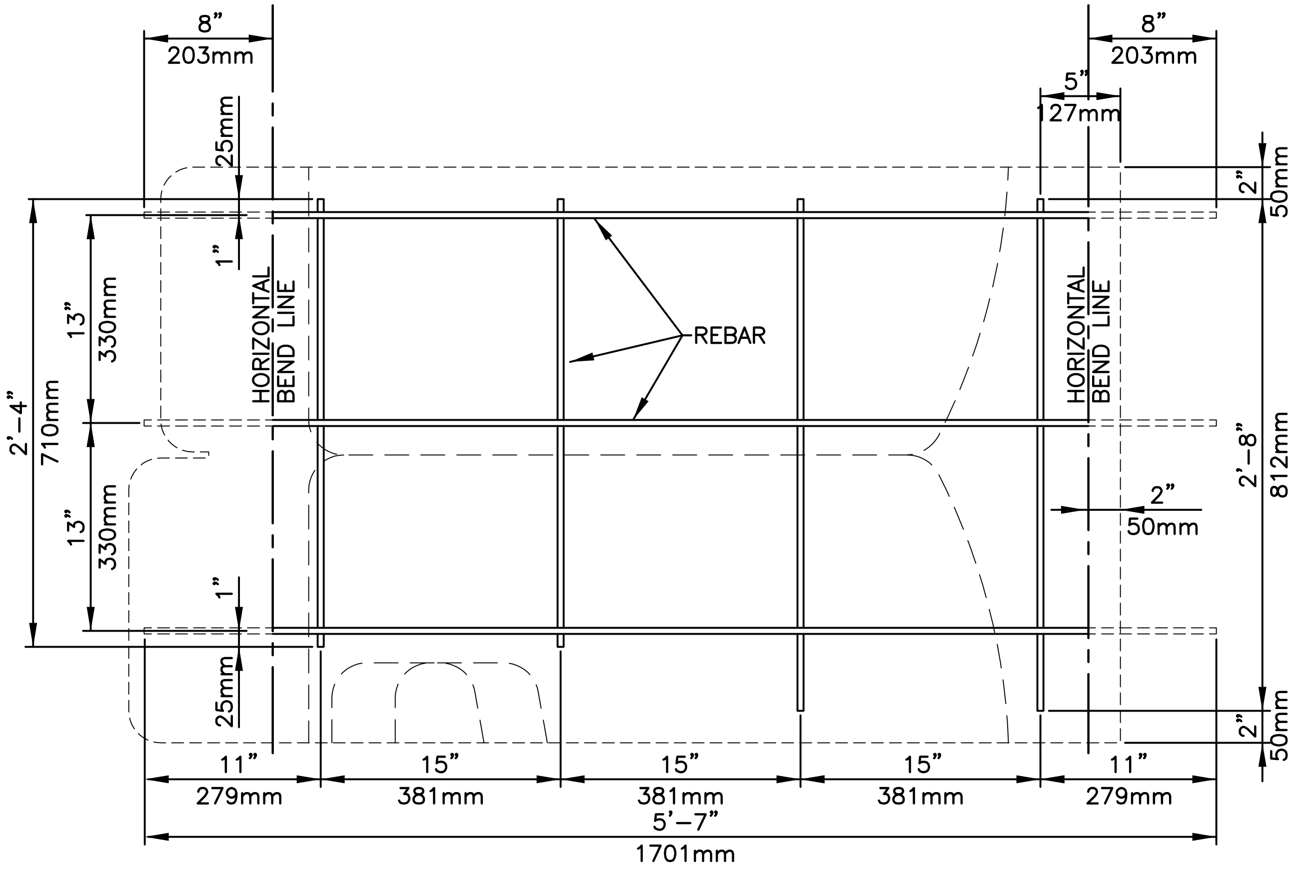

BENT WEB REBAR (2 REQUIRED)

24–62 UNIT (24–62) – REBAR OPTION

NOT TO SCALE

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PROJECT
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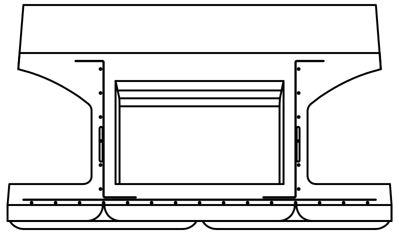
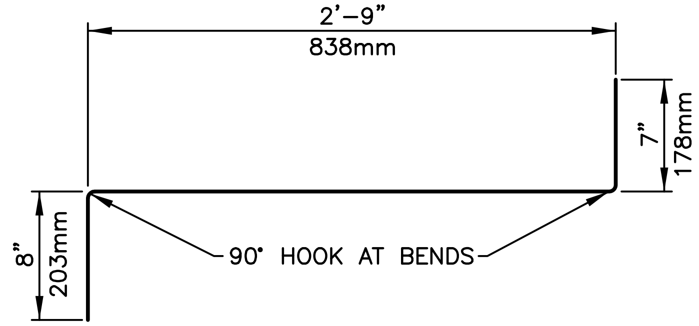
DATE: 6/29/18
FILE: 04_24–62 Rebar

NOTES:

1. ALL MESH SHALL BE W8xW8–6x6 WWF PER ASTM A185/A497/A1064, GRADE 65 U.N.O.
2. USE IN ALL 24–ME UNITS.





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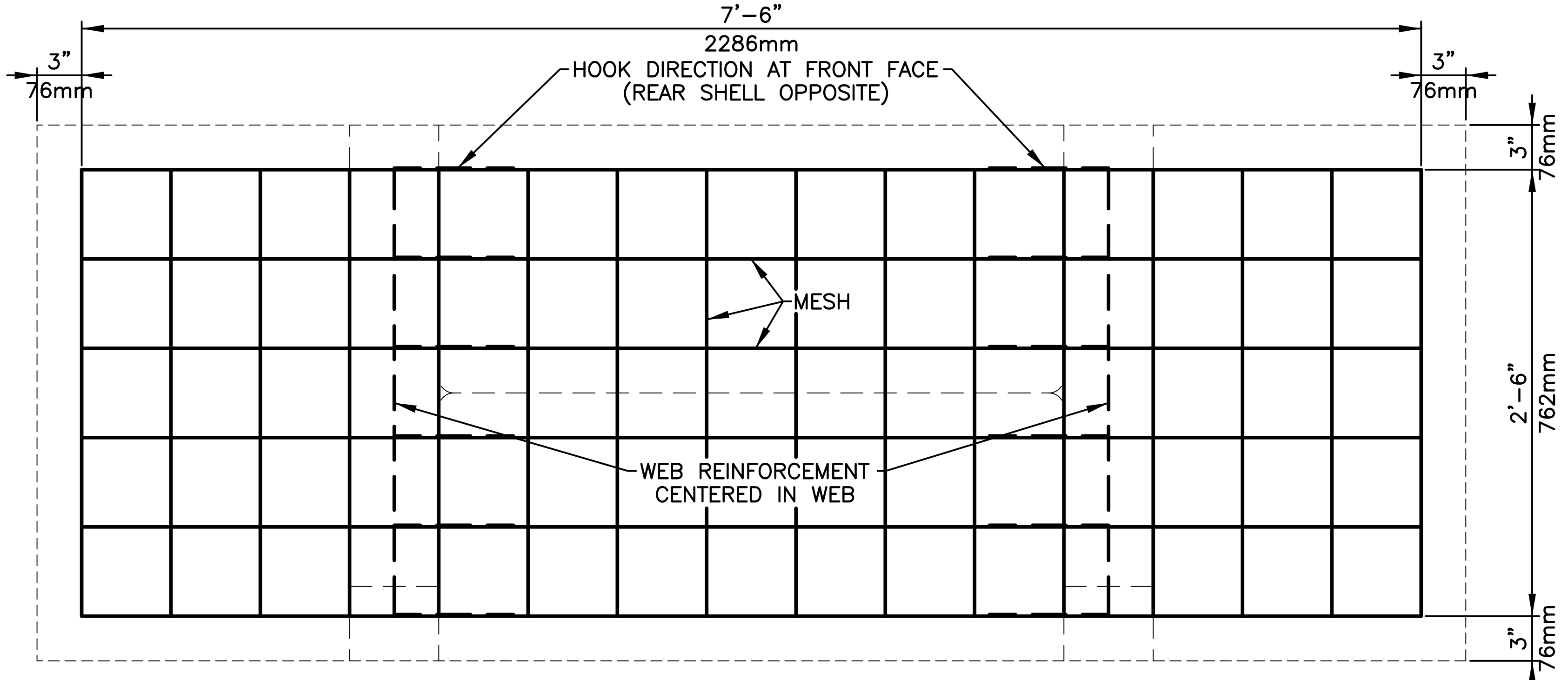

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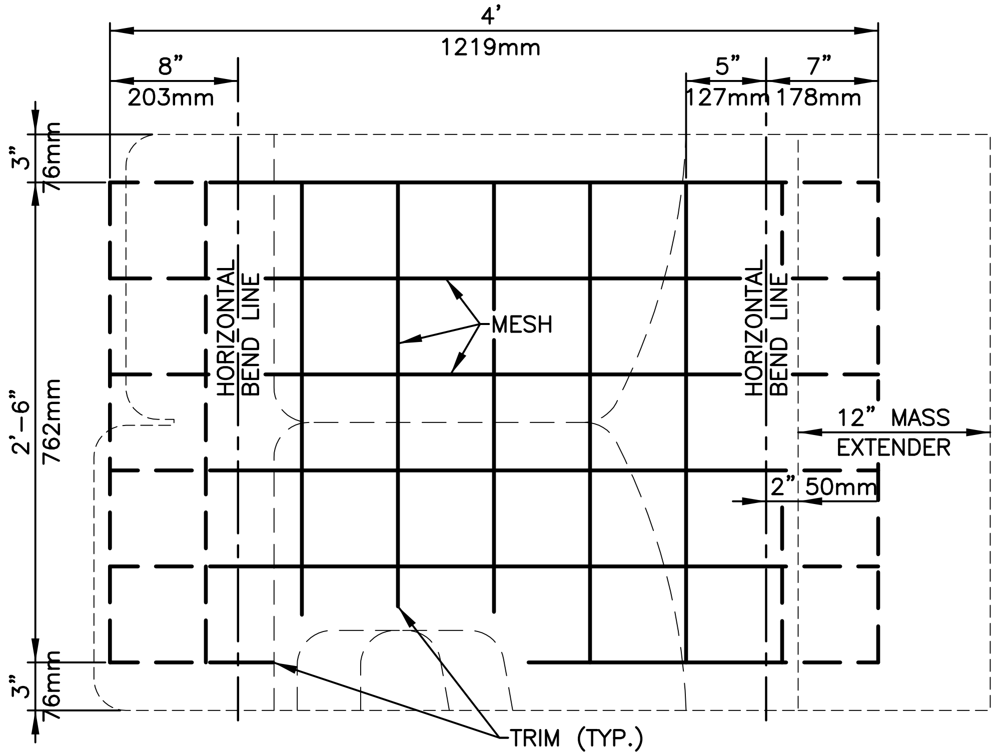

BENT WEB MESH (2 REQUIRED)

24SF MASS EXTENDER UNIT (24–ME) – MESH OPTION

NOT TO SCALE

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REINFORCING DETAILS
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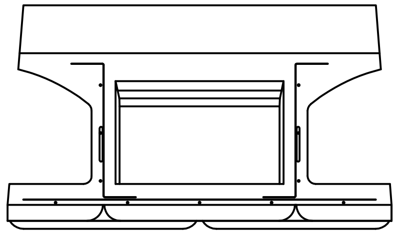
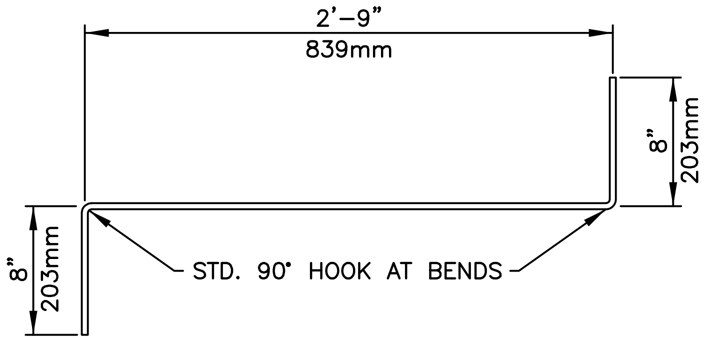
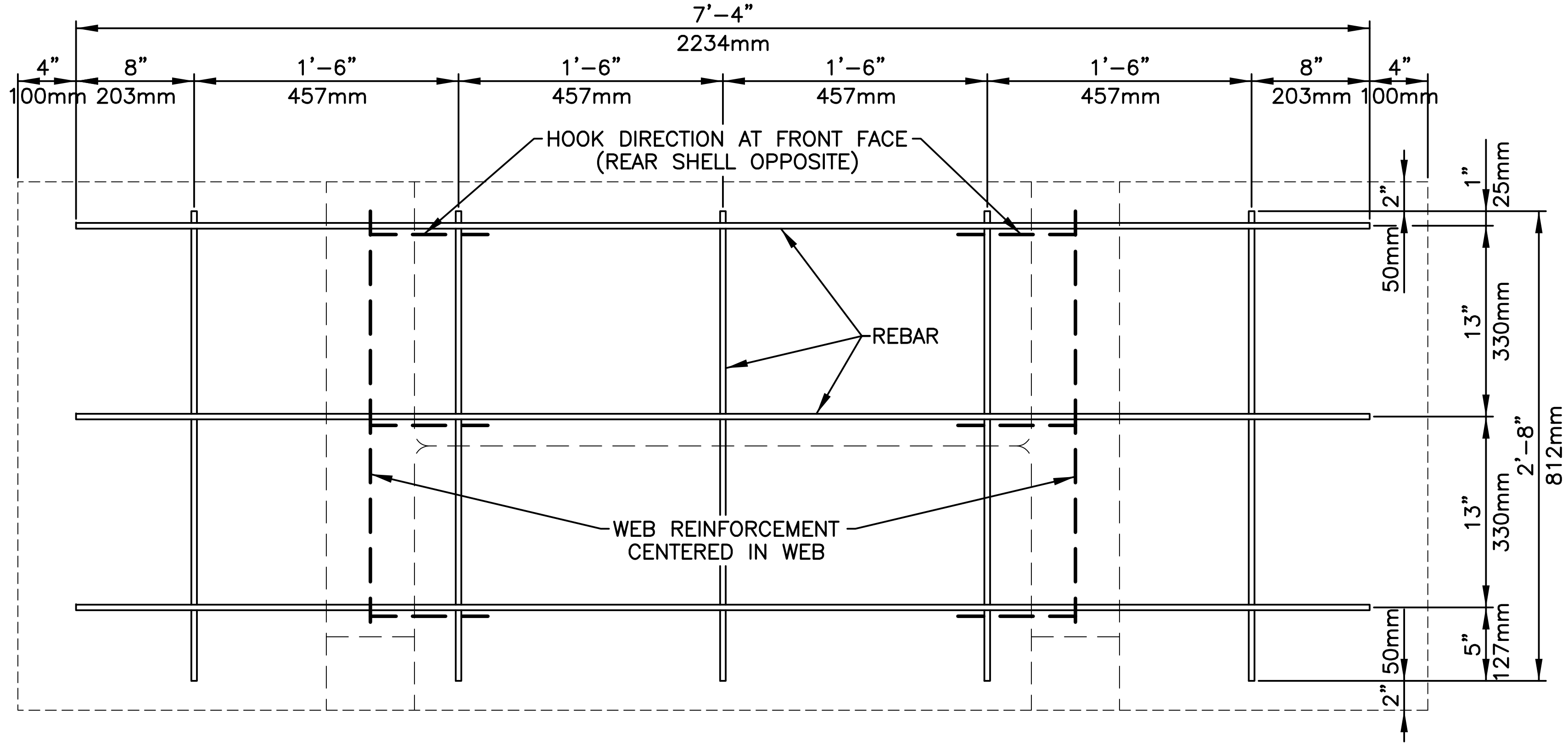
DATE: 6/29/18 | FILE: 05_24–ME Mesh

NOTES:
1. ALL STEEL SHALL BE #4 BARS, GRADE 60, U.N.O.
2. USE IN ALL 24-ME UNITS.





BENT WEB REBAR – PLAN VIEW



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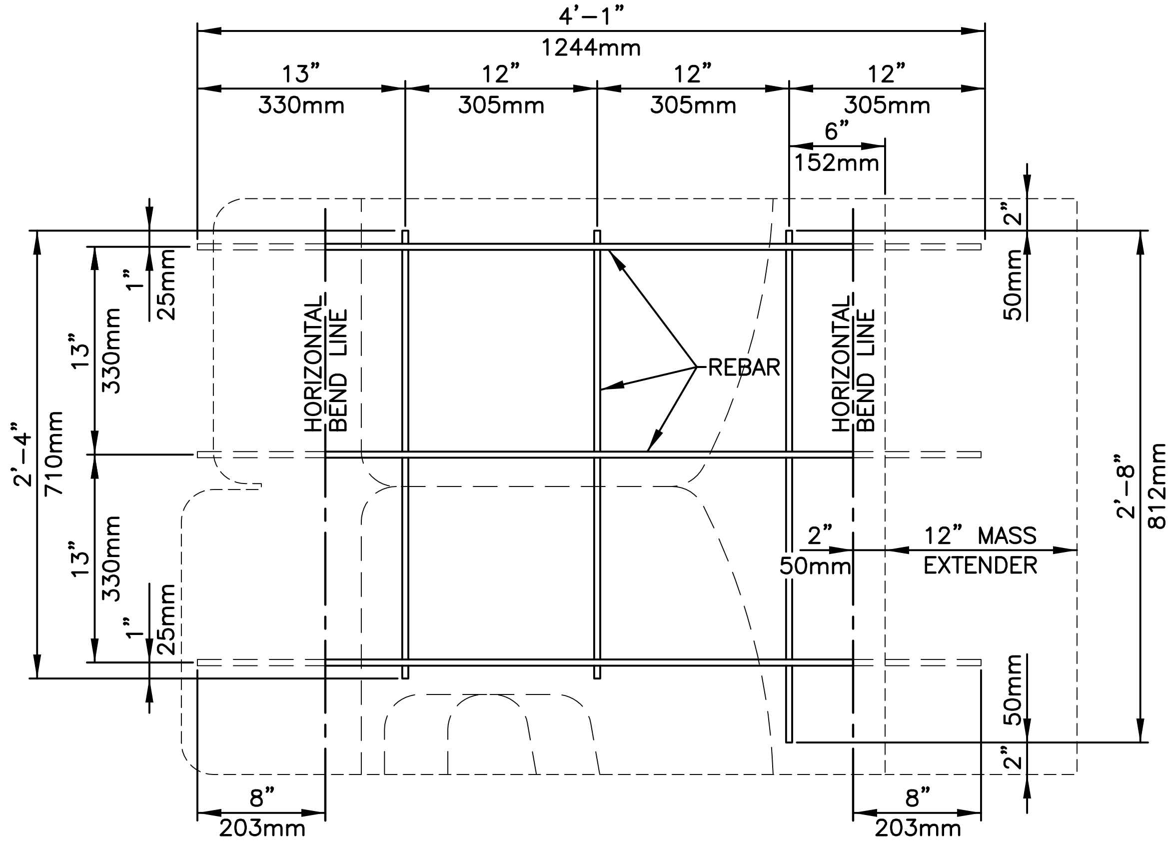

BENT WEB REBAR (2 REQUIRED)

24SF MASS EXTENDER UNIT (24-ME) – REBAR OPTION

NOT TO SCALE

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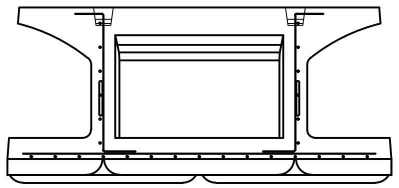
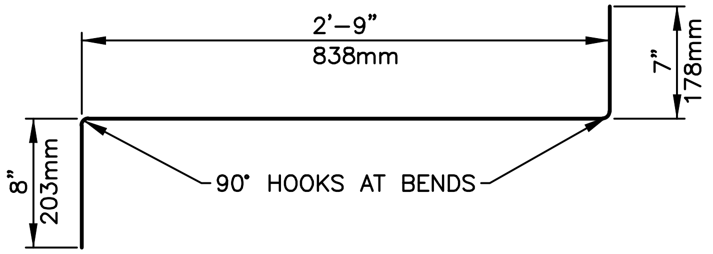
PROJECT
REINFORCING DETAILS
STONE STRONG SYSTEMS

DATE: 6/29/18 | FILE: 06_24-ME Rebar

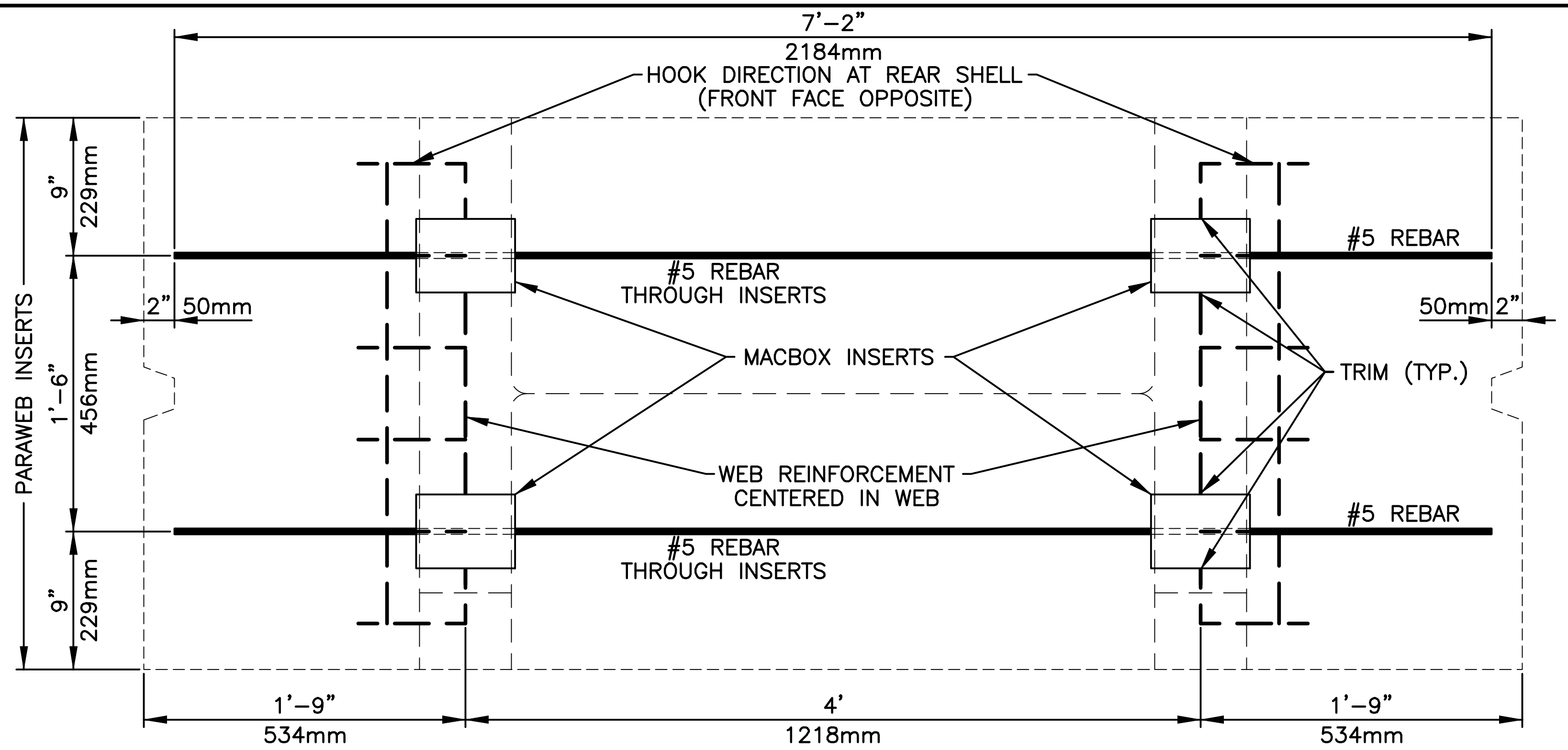
NOTES:

1. ALL MESH SHALL BE W8xW8-6x6 WWF PER ASTM A185/A497/A1064, GRADE 65 U.N.O.
2. ALL #5 BARS SHALL BE GRADE 60.
3. USE FOR PARAWEB MSE WALL IN TOP 36 FEET.

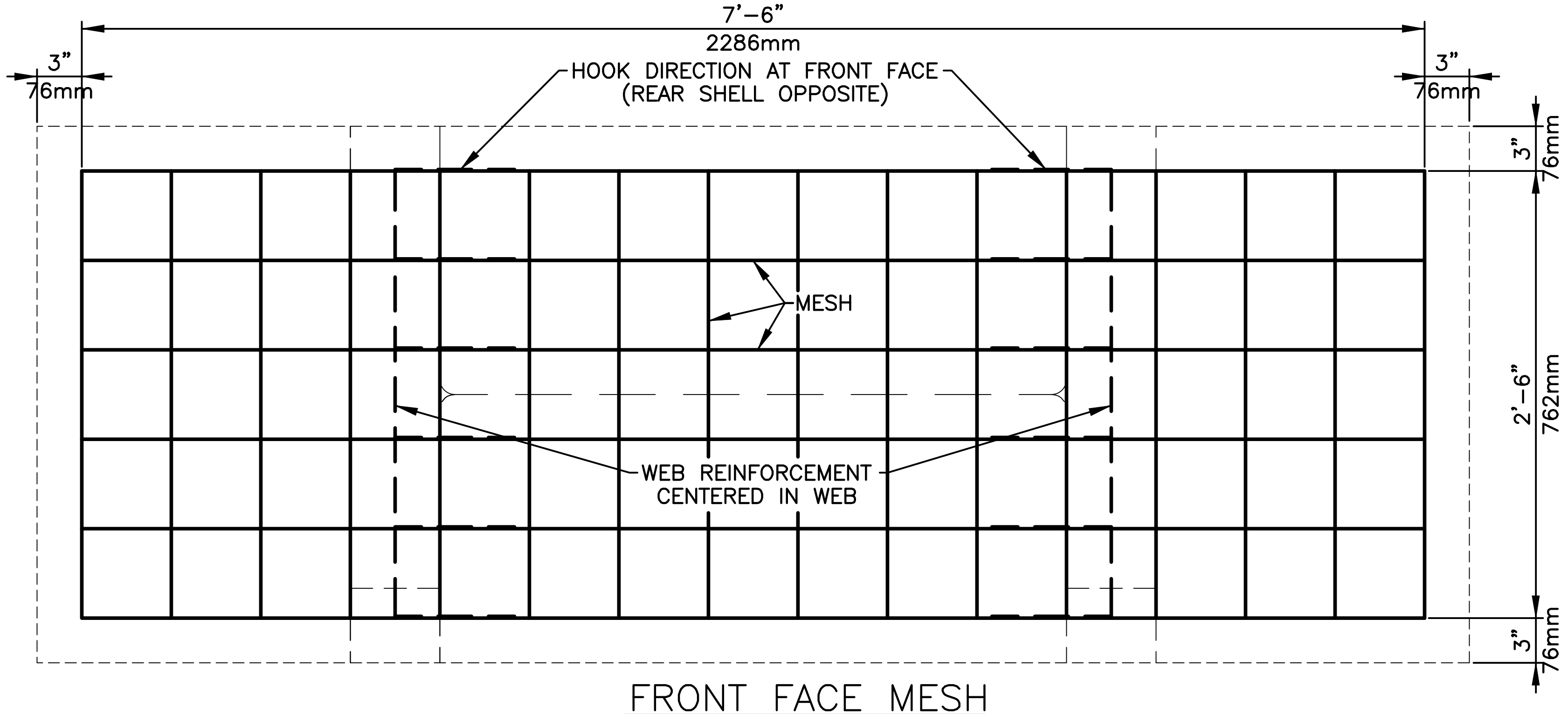




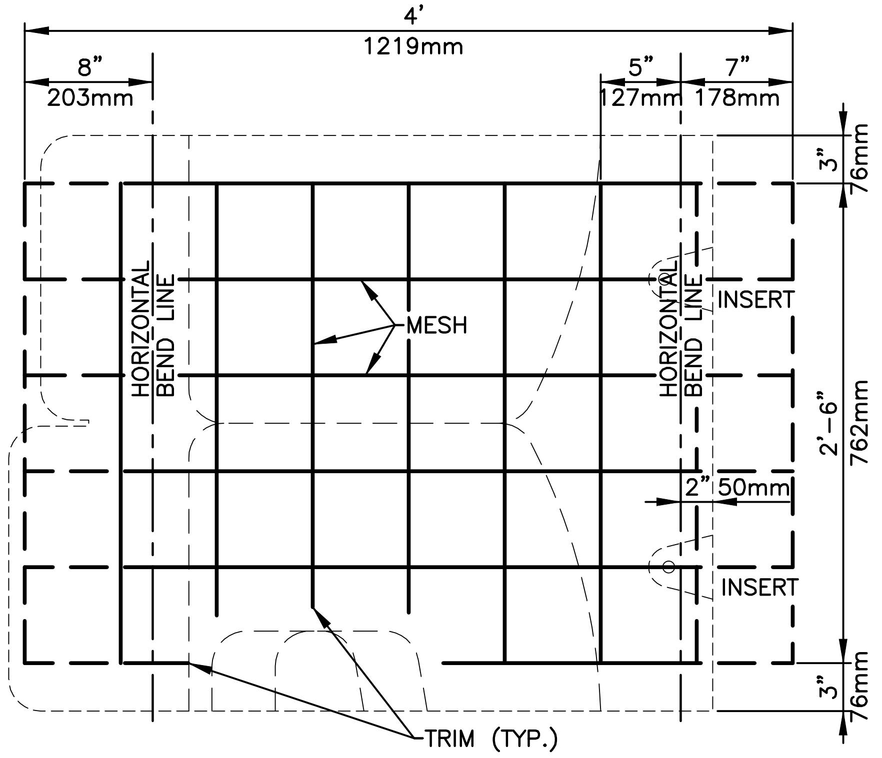
BENT WEB MESH – PLAN VIEW



REAR SHELL MESH w/PARAWEB INSERTS



FRONT FACE MESH



BENT WEB MESH (2 REQUIRED)

24SF PARAWEB UNIT (24SF–P) – MESH OPTION

NOT TO SCALE

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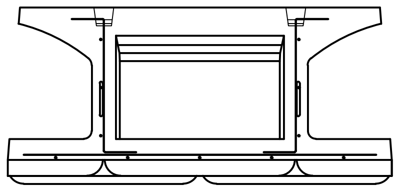
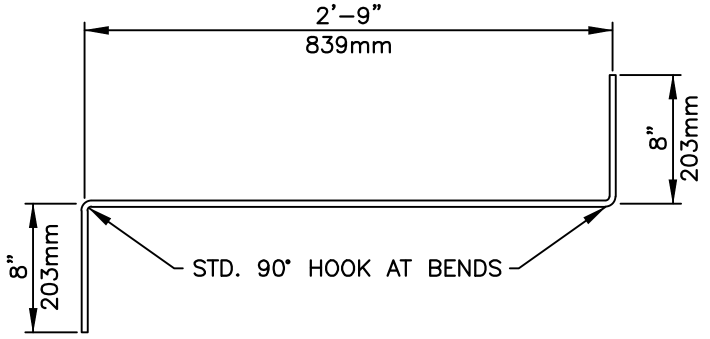
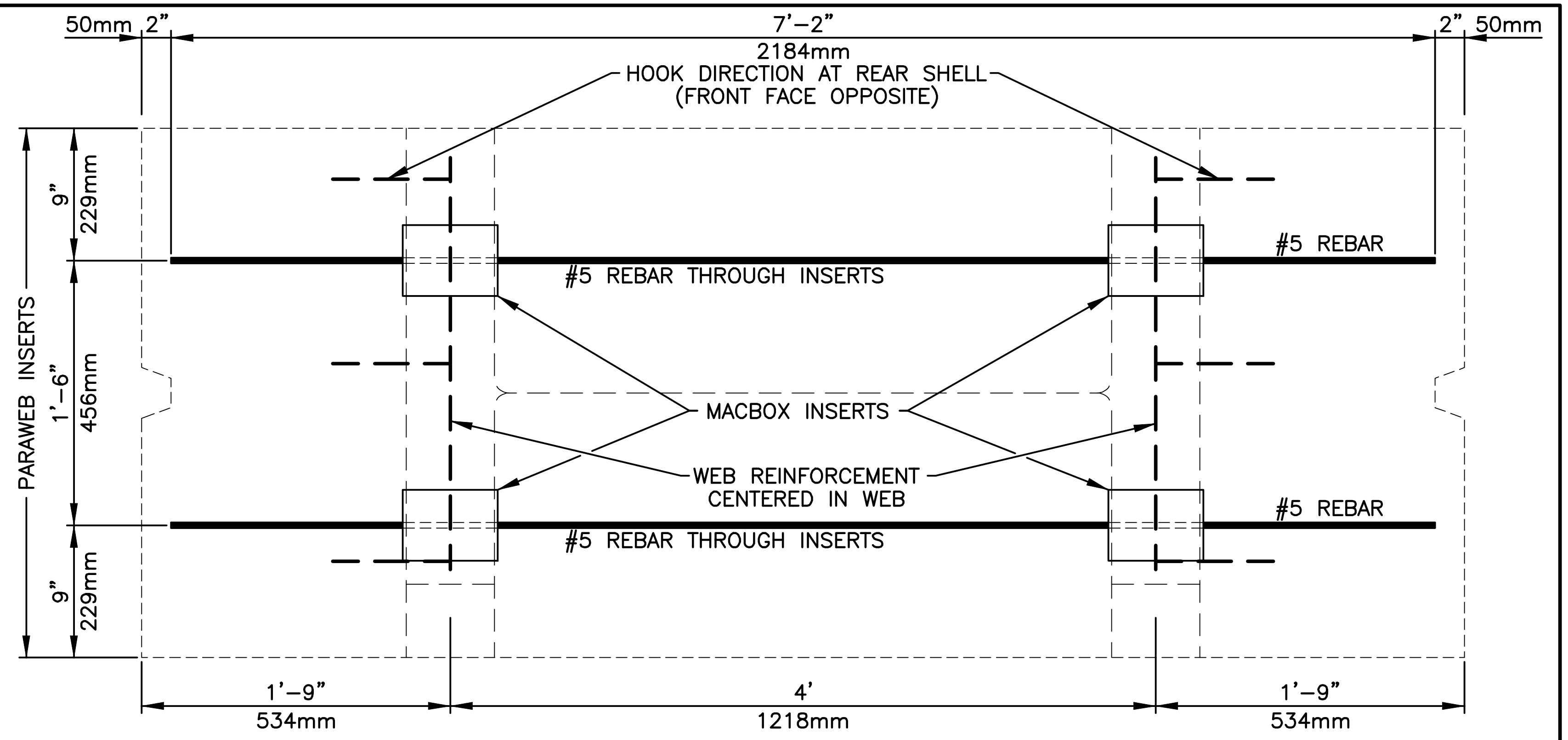
DATE: 12/16/19 | FILE: 07_24SF–P Mesh

NOTES:
1. ALL STEEL SHALL BE #4 BARS, GRADE 60, U.N.O.
2. ALL #5 BARS SHALL BE GRADE 60.
3. USE FOR PARAWEB MSE WALL IN TOP 36 FEET.

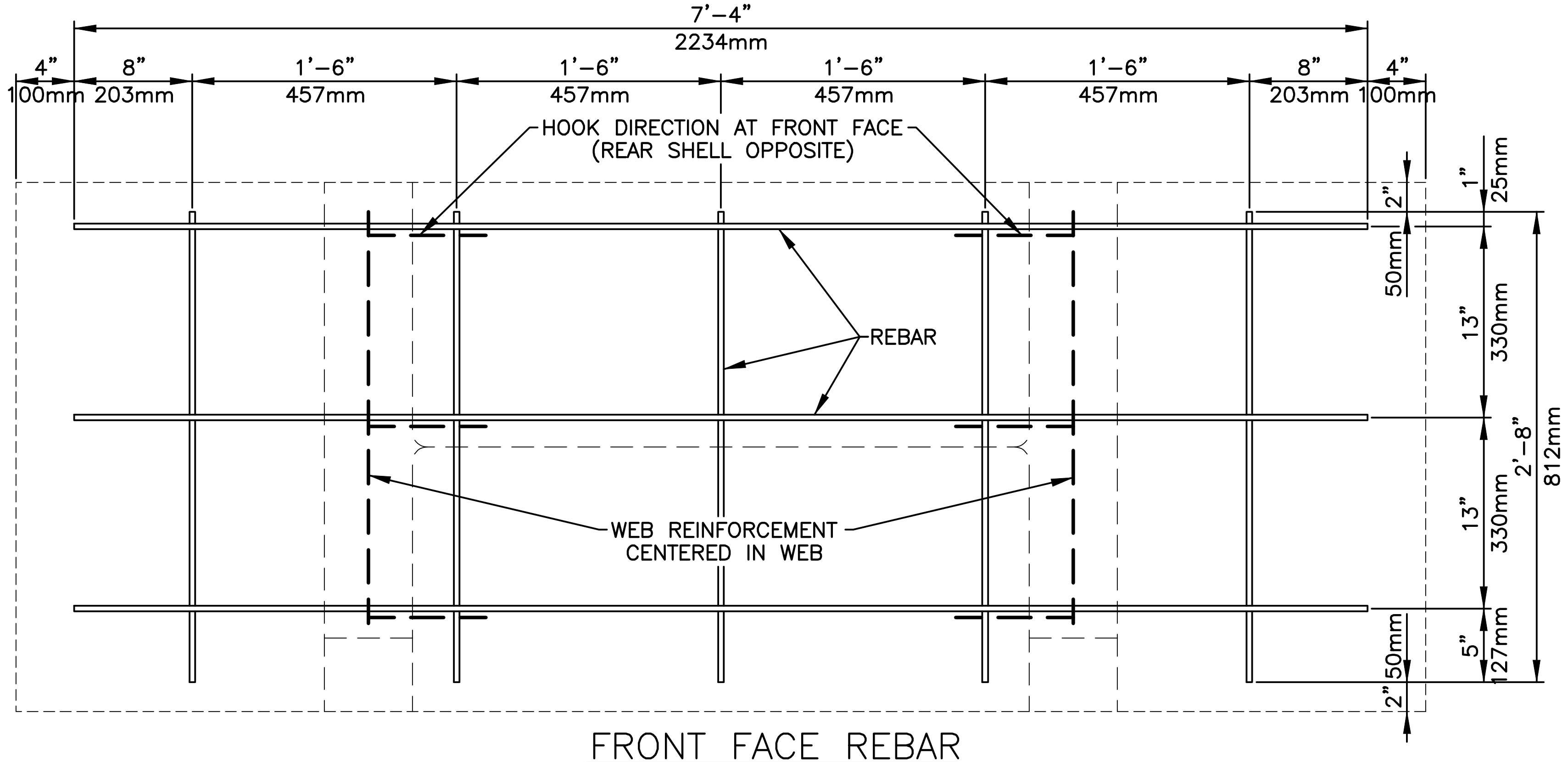




BENT WEB REBAR – PLAN VIEW



REAR SHELL REBAR



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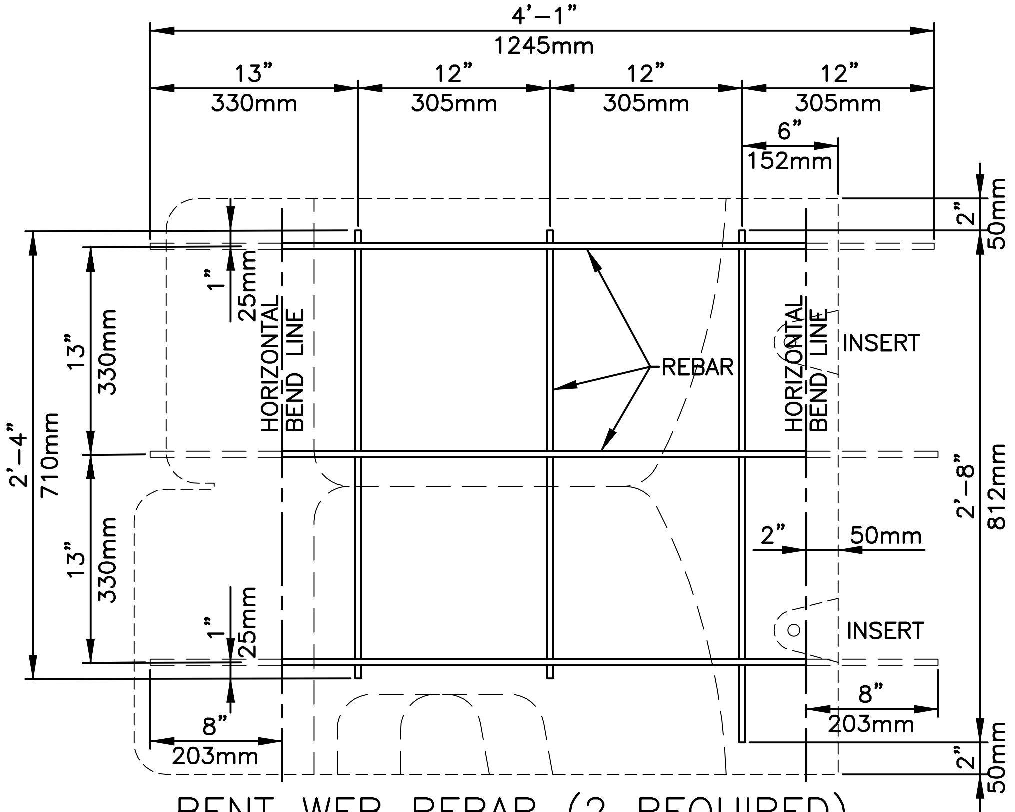

BENT WEB REBAR (2 REQUIRED)

24SF PARAWEB UNIT (24SF-P) – REBAR OPTION

NOT TO SCALE

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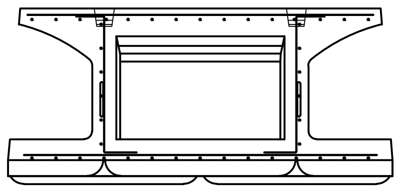
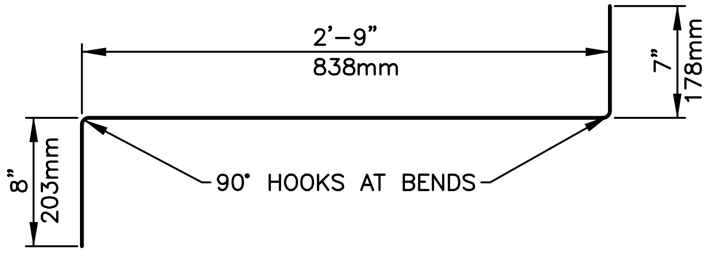
DATE: 12/16/19 | FILE: 08_24SF-P Rebar

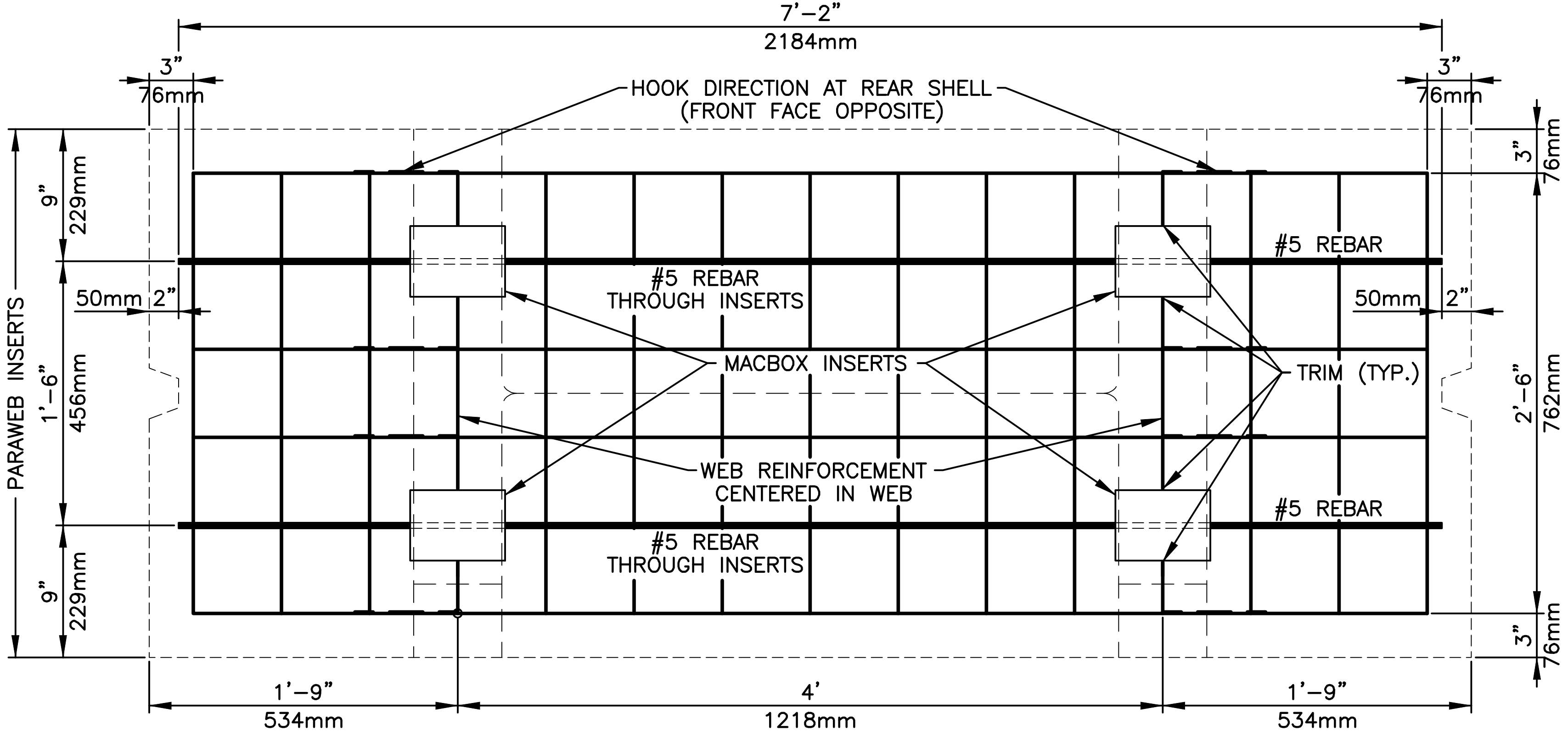
NOTES:

1. ALL MESH SHALL BE W8xW8-6x6 WWF PER ASTM A185/A497/A1064, GRADE 65 U.N.O.
2. ALL #5 BARS SHALL BE GRADE 60.
3. USE IN PARAWEB MSE WALL BETWEEN 36 AND 51 FEET BELOW TOP OF WALL.

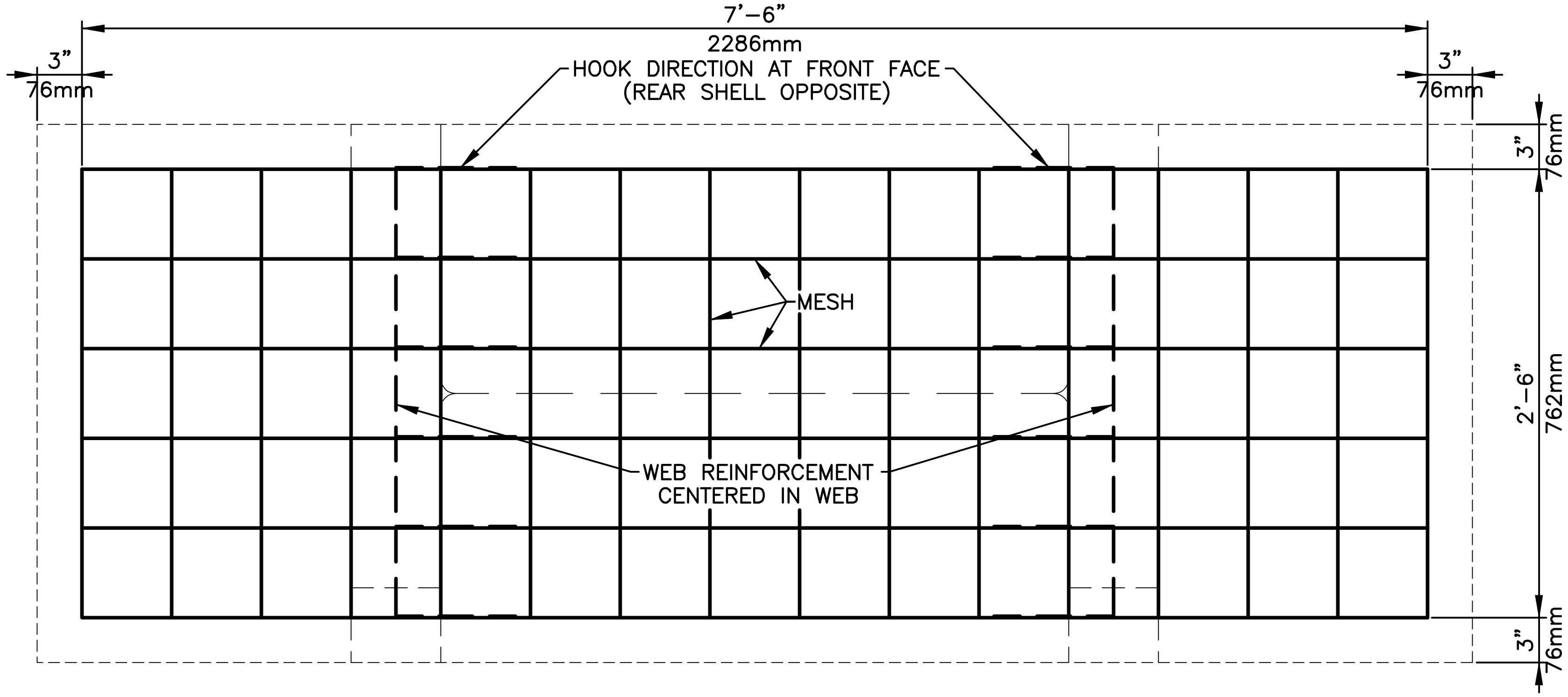




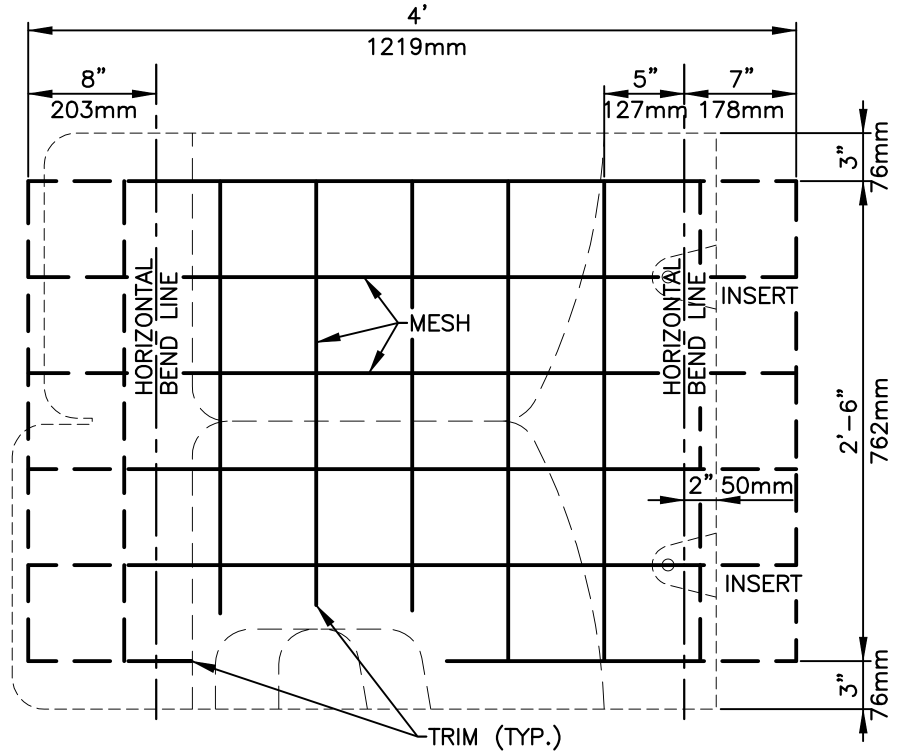
BENT WEB MESH – PLAN VIEW



REAR SHELL MESH w/PARAWEB INSERTS



FRONT FACE MESH



BENT WEB MESH (2 REQUIRED)

24SF HEAVY DUTY PARAWEB UNIT (24SF-HDP) – MESH OPTION

NOT TO SCALE

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REINFORCING DETAILS
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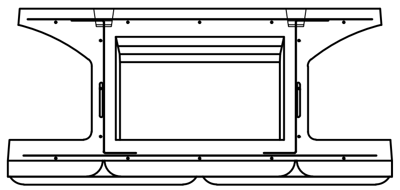
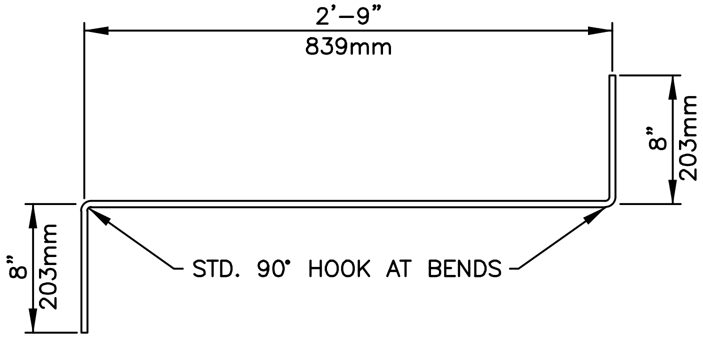
DATE: 12/16/19 FILE: 09_24SF-HDP Mesh

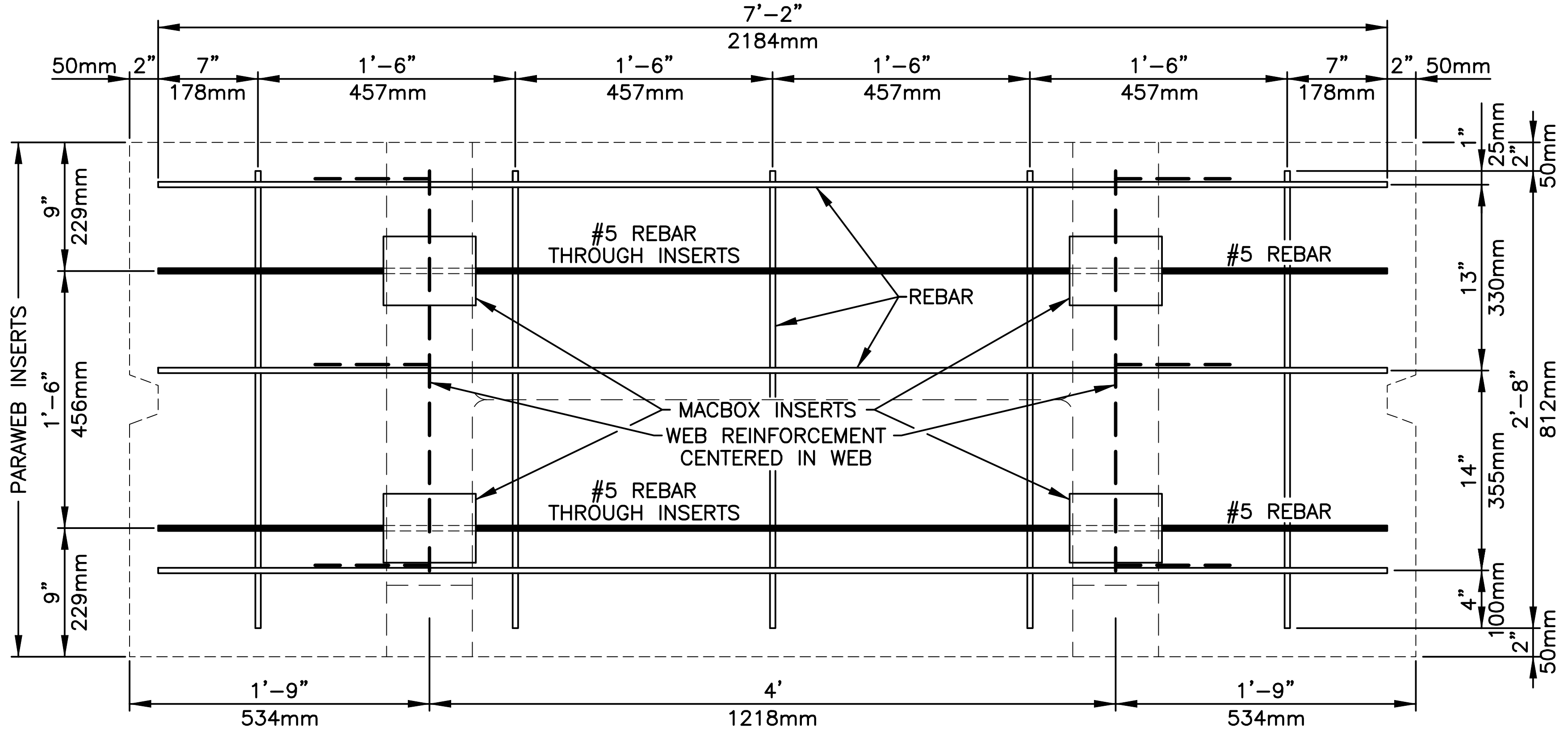
NOTES:

1. ALL STEEL SHALL BE #4 BARS, GRADE 60, U.N.O.
2. ALL #5 BARS SHALL BE GRADE 60.
3. USE IN PARAWEB MSE WALL BETWEEN 36 AND 51 FEET BELOW TOP OF WALL.

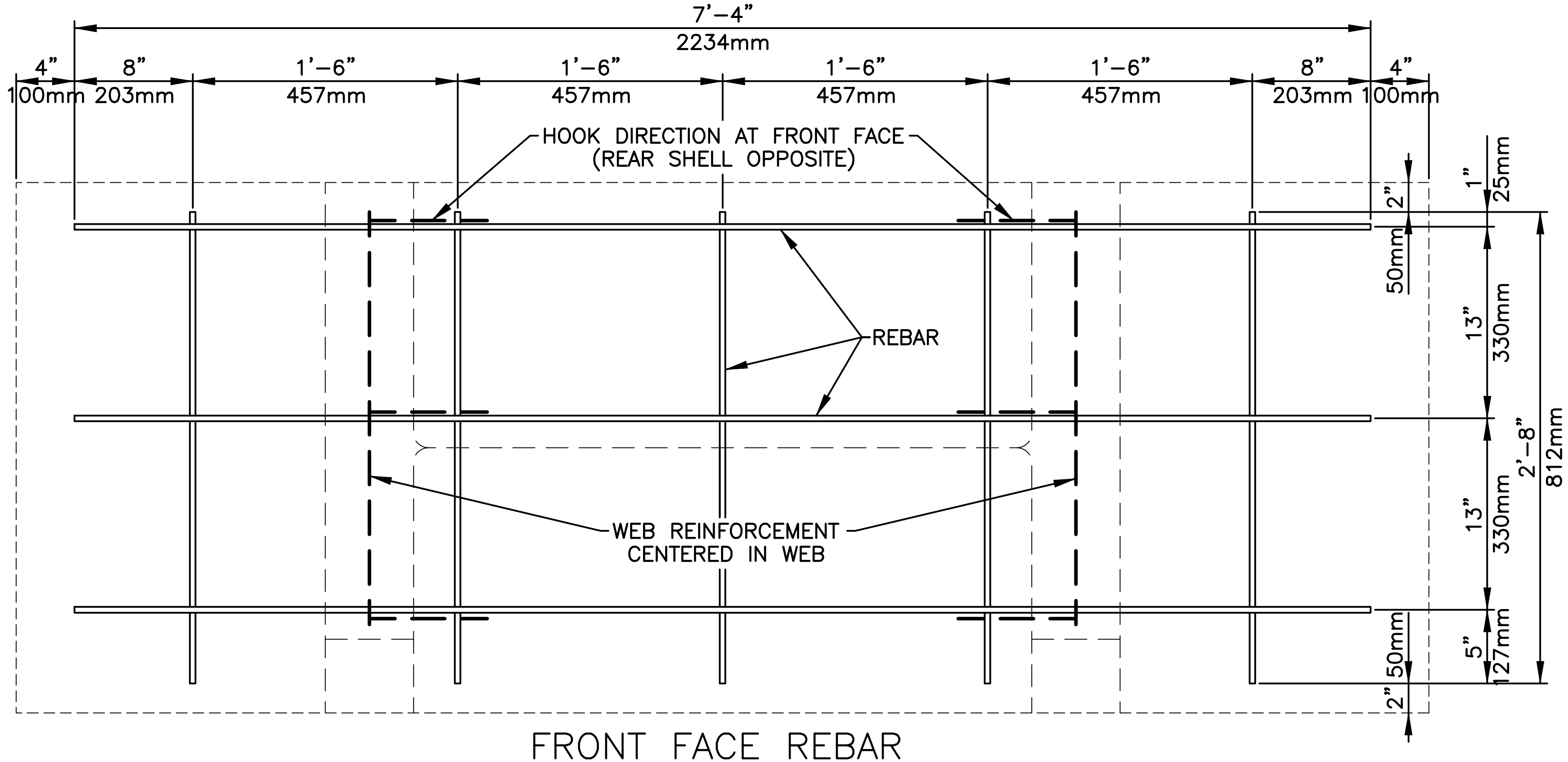




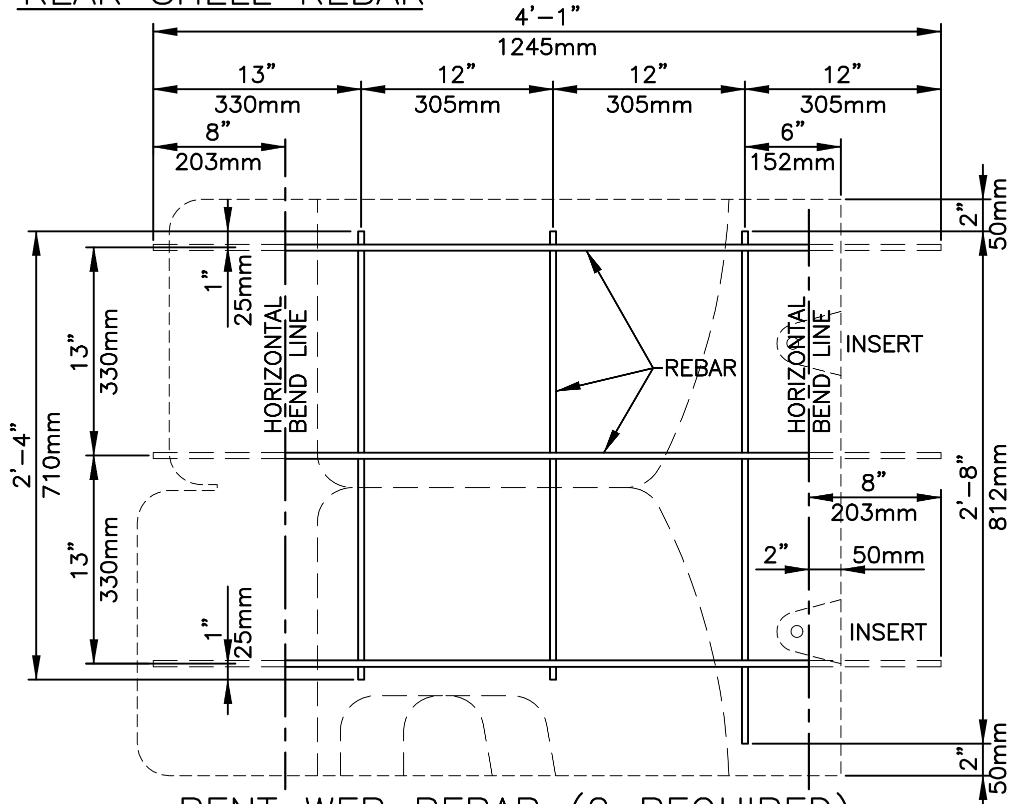
BENT WEB REBAR – PLAN VIEW



REAR SHELL REBAR



FRONT FACE REBAR



BENT WEB REBAR (2 REQUIRED)

24SF HEAVY DUTY PARAWEB UNIT (24SF–HDP) – REBAR OPTION

NOT TO SCALE

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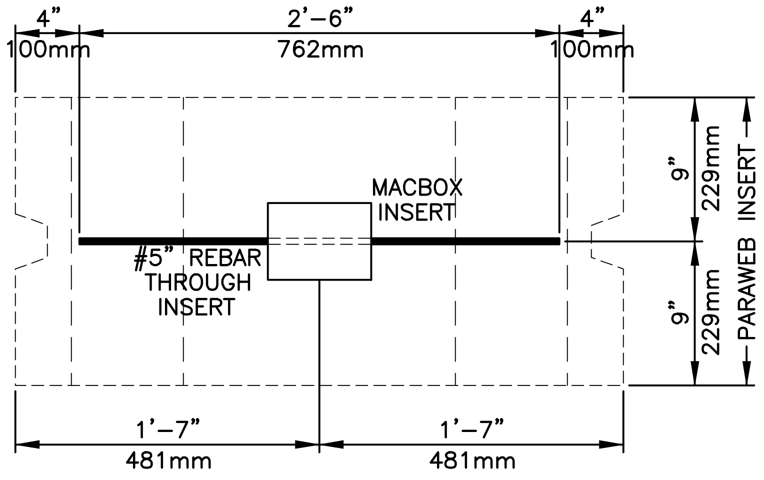
REINFORCING DETAILS
STONE STRONG SYSTEMS

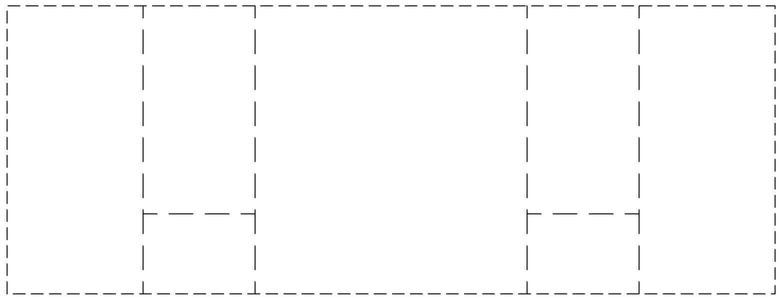
DATE: 12/16/19 | FILE: 10_24SF–HDP Rebar

NOTES:

1. ALL #5 BARS SHALL BE GRADE 60.
2. USE IN PARAWEB MSE WALL IN TOP 12 FEET.
3. MAY ALSO BE USED IN BOTTOM COURSE ONLY OF PARAWEB MSE WALL USING 24SF UNITS ABOVE.



REAR SHELL



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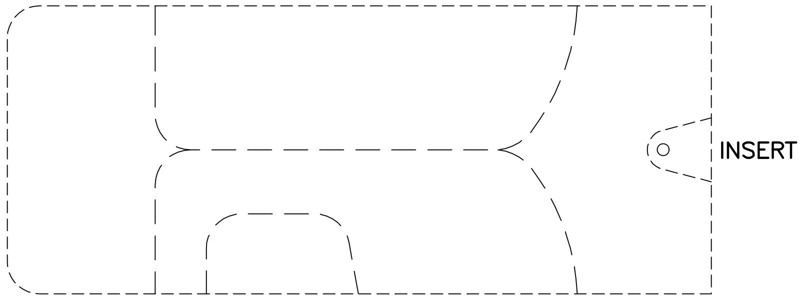

SIDE ELEVATION

6SF PARAWEB UNIT (6SF–P)

NOT TO SCALE

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REINFORCING DETAILS
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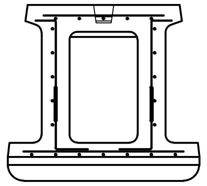
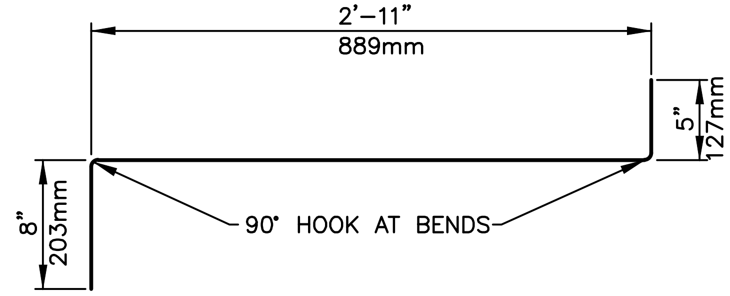
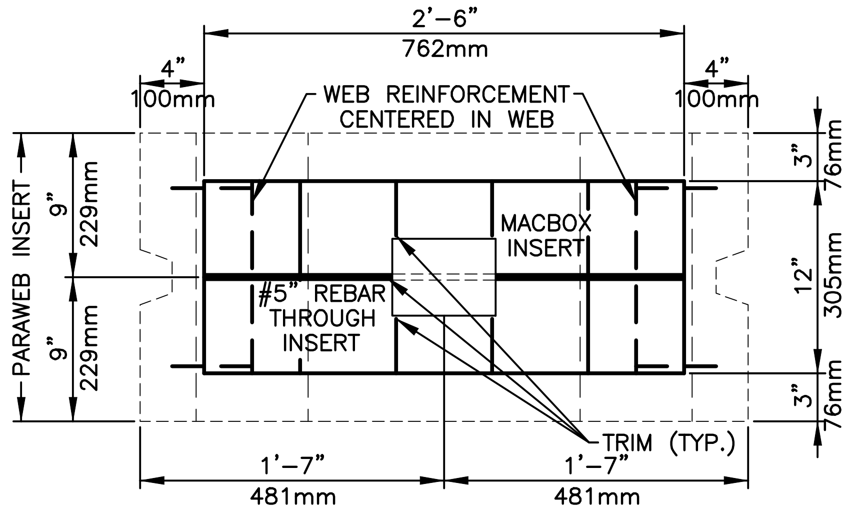
DATE: 12/16/19 FILE: 11_6SF–P

NOTES:
1. ALL MESH SHALL BE W8xW8-6x6 WWF PER ASTM A185/A497/A1064, GRADE 65 U.N.O.
2. ALL #5 BARS SHALL BE GRADE 60.
3. USE IN PARAWEB MSE WALL BETWEEN 12 AND 51 FEET BELOW TOP OF WALL.

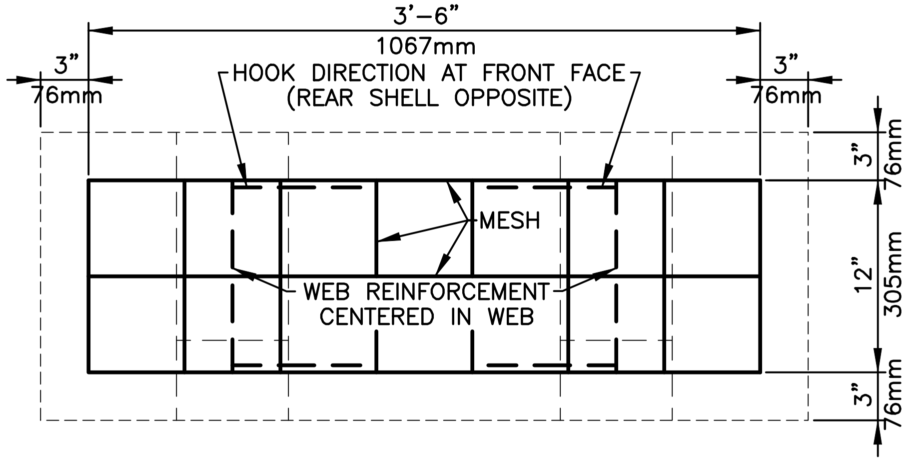




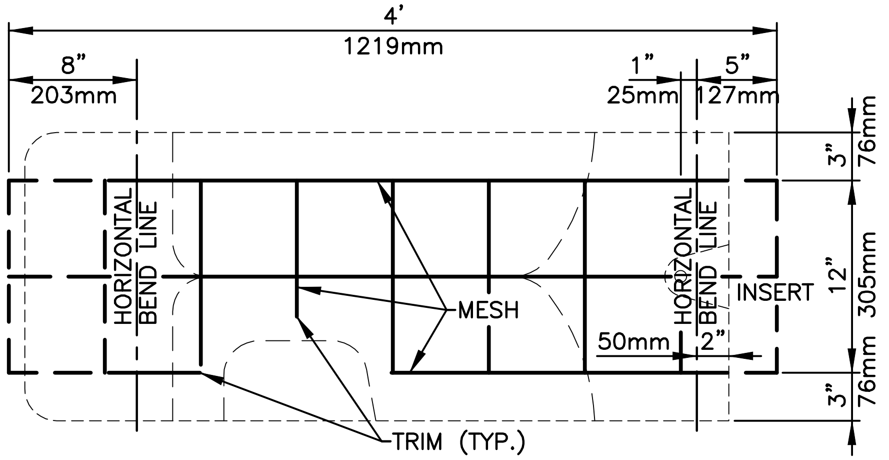
BENT WEB MESH – PLAN VIEW



REAR SHELL MESH



FRONT FACE MESH



BENT WEB MESH (2 REQUIRED)

6 SF HEAVY DUTY PARAWEB UNIT (6SF–HDP) – MESH OPTION

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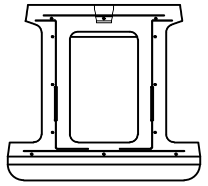
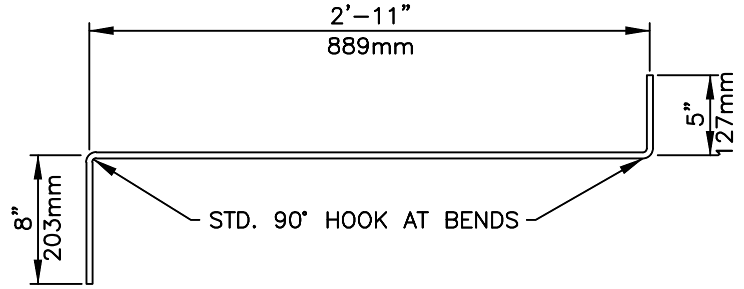
DATE: 12/16/19 | FILE: 12_6SF–HDP Mesh

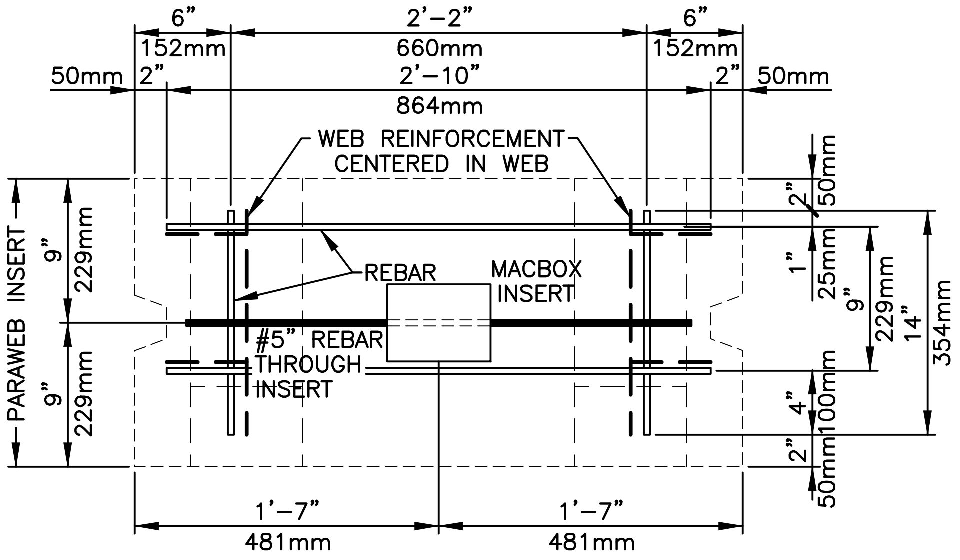
NOTES:

1. ALL STEEL SHALL BE #4 BARS, GRADE 60, U.N.O.
2. ALL #5 BARS SHALL BE GRADE 60.
3. USE IN PARAWEB MSE WALL BETWEEN 12 AND 51 FEET BELOW TOP OF WALL.

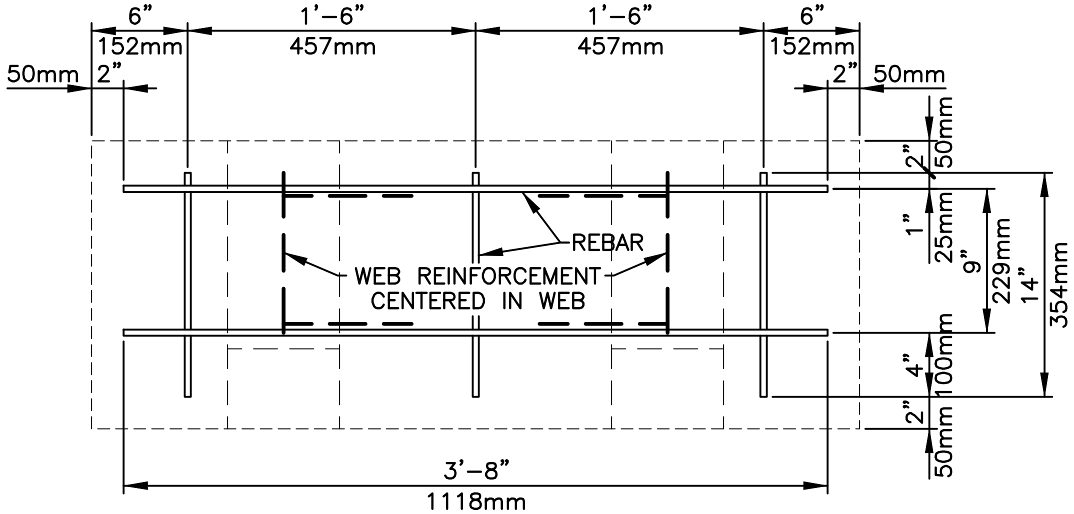




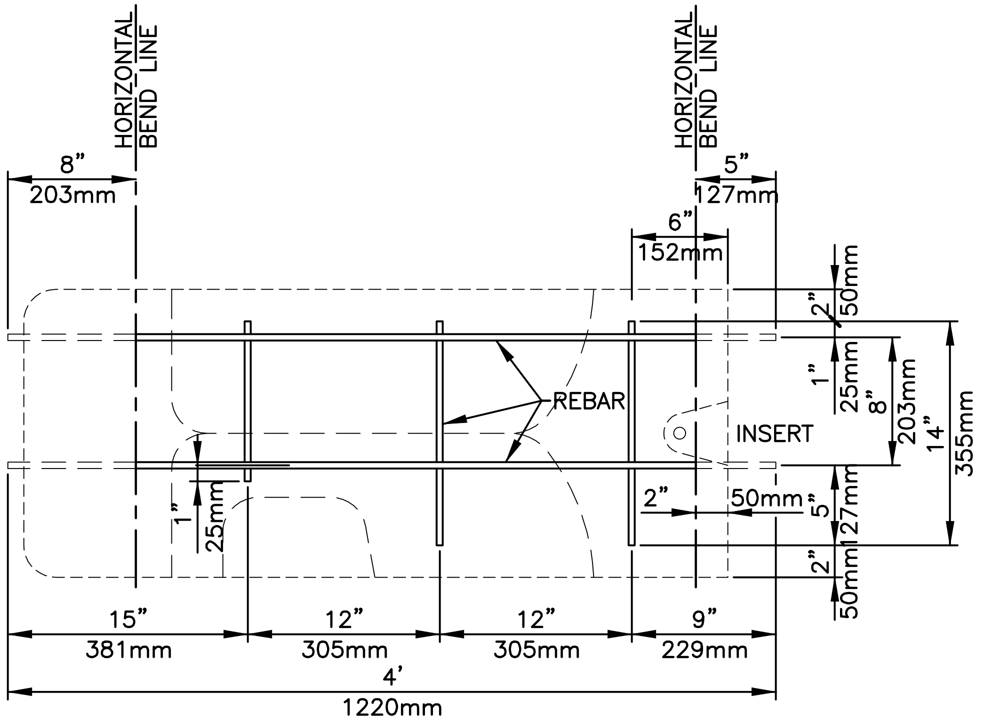
BENT WEB REBAR – PLAN VIEW



REAR SHELL REBAR



FRONT FACE REBAR



BENT WEB REBAR (2 REQUIRED)

6 SF HEAVY DUTY PARAWEB UNIT (6SF–HDP) – REBAR OPTION

NOT TO SCALE

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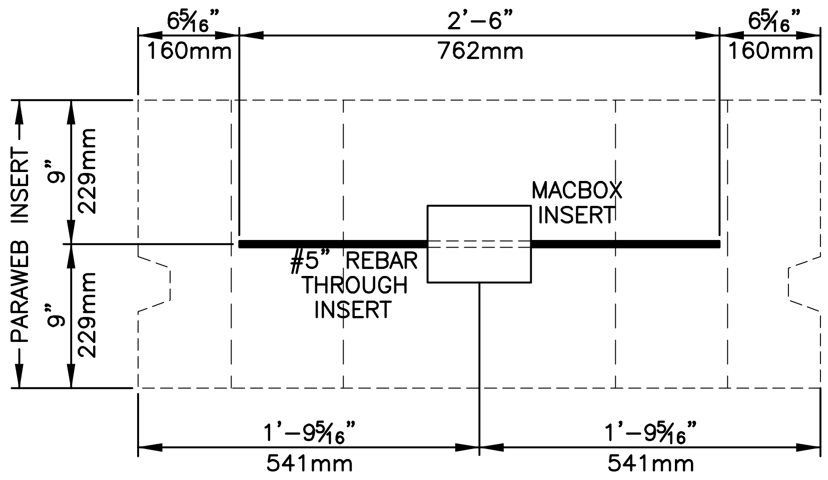
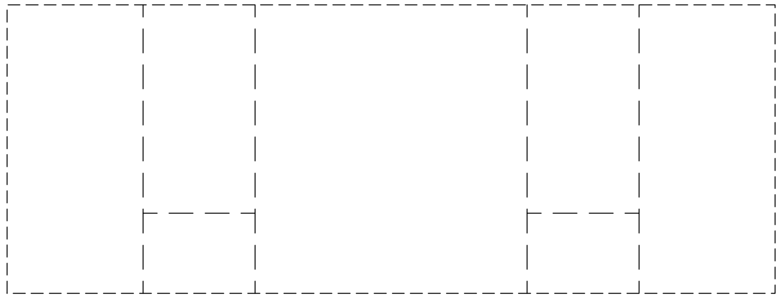
DATE: 7/22/19 | FILE: 13_6SF–HDP Rebar

NOTES:

1. ALL #5 BARS SHALL BE GRADE 60.
2. USE IN PARAWEB MSE WALL IN TOP 12 FEET ONLY.



REAR SHELL



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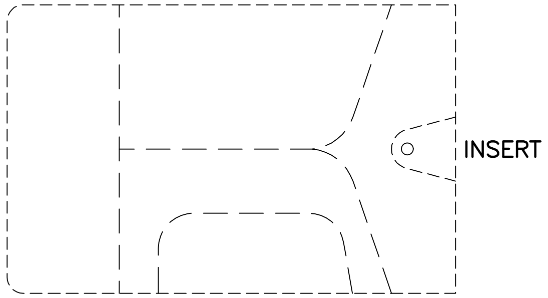

SIDE ELEVATION

6–28 PARAWEB UNIT (6–28–P)

NOT TO SCALE

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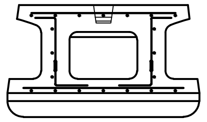
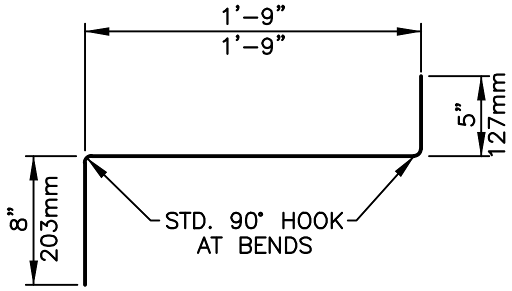
STONE STRONG SYSTEMS

DATE: 12/16/19 | FILE: 14_6–28–P

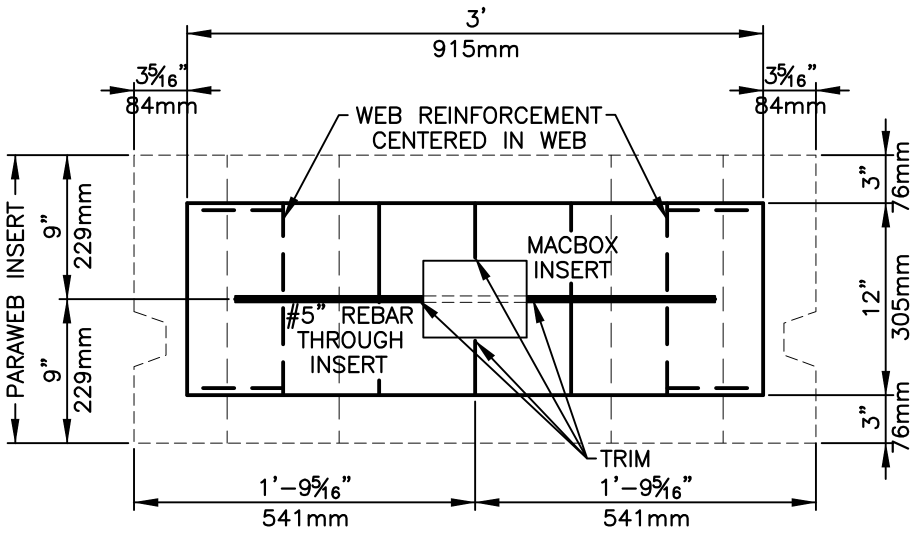
NOTES:

1. ALL MESH SHALL BE W8xW8–6x6 WWF PER ASTM A185/A497/A1064, GRADE 65 U.N.O.
2. ALL #5 BARS SHALL BE GRADE 60.
3. USE IN PARAWEB MSE WALL BETWEEN 12 AND 51 FEET BELOW TOP OF WALL.

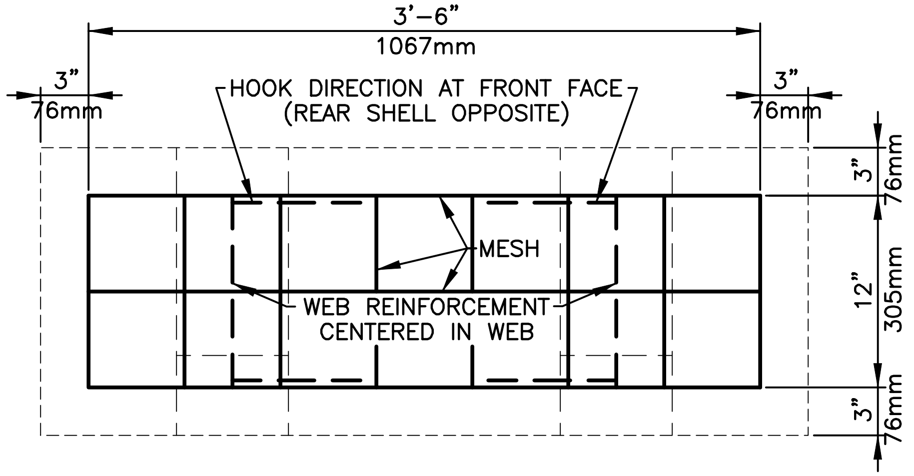




BENT WEB MESH – PLAN VIEW



REAR SHELL MESH



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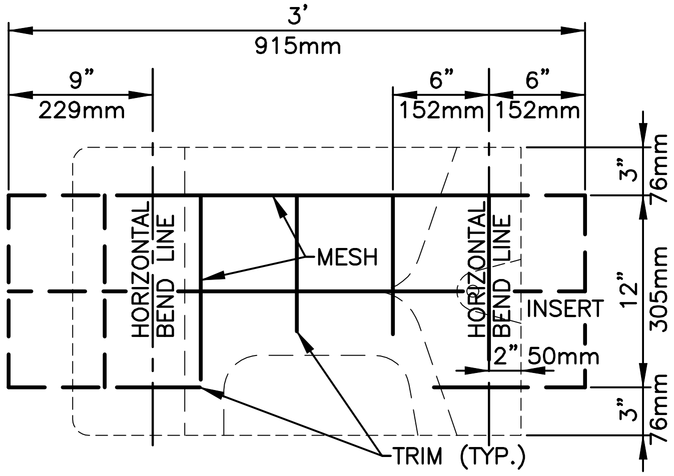

BENT WEB MESH (2 REQUIRED)

6–28 HEAVY DUTY PARAWEB UNIT (6–28–HDP) – MESH OPTION

NOT TO SCALE

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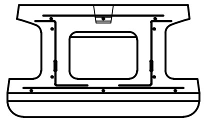
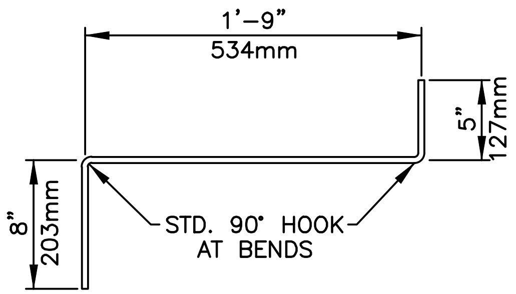
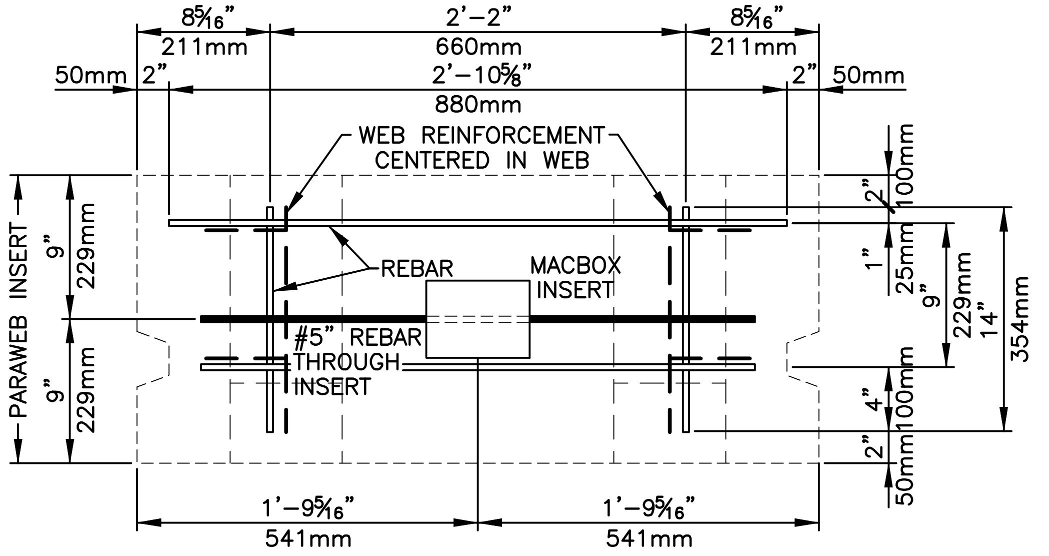
DATE: 12/16/19 | FILE: 15_6–28–HDP Mesh

NOTES:
1. ALL STEEL SHALL BE #4 BARS, GRADE 60, U.N.O.
2. ALL #5 BARS SHALL BE GRADE 60.
3. USE IN PARAWEB MSE WALL BETWEEN 12 AND 51 FEET BELOW TOP OF WALL.





BENT WEB REBAR – PLAN VIEW



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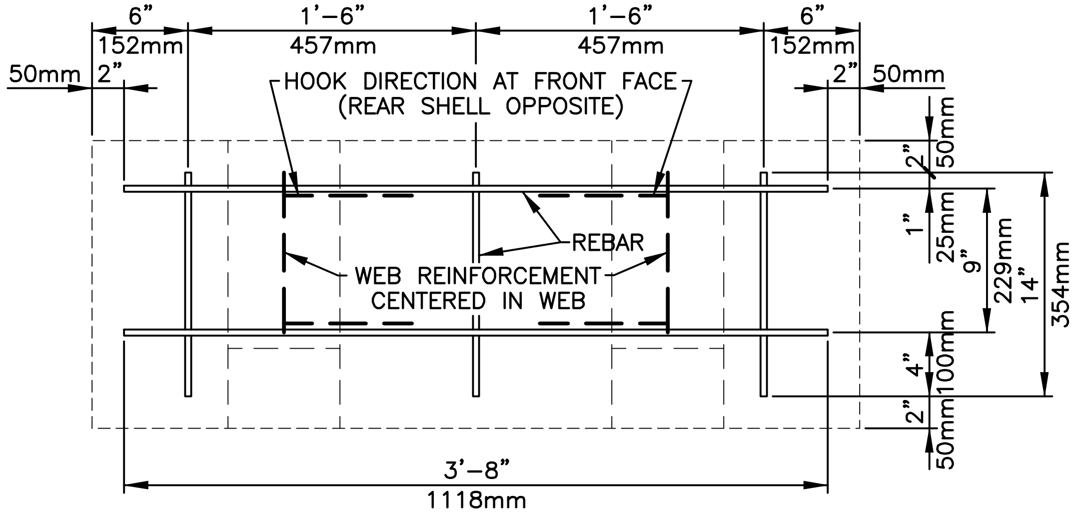

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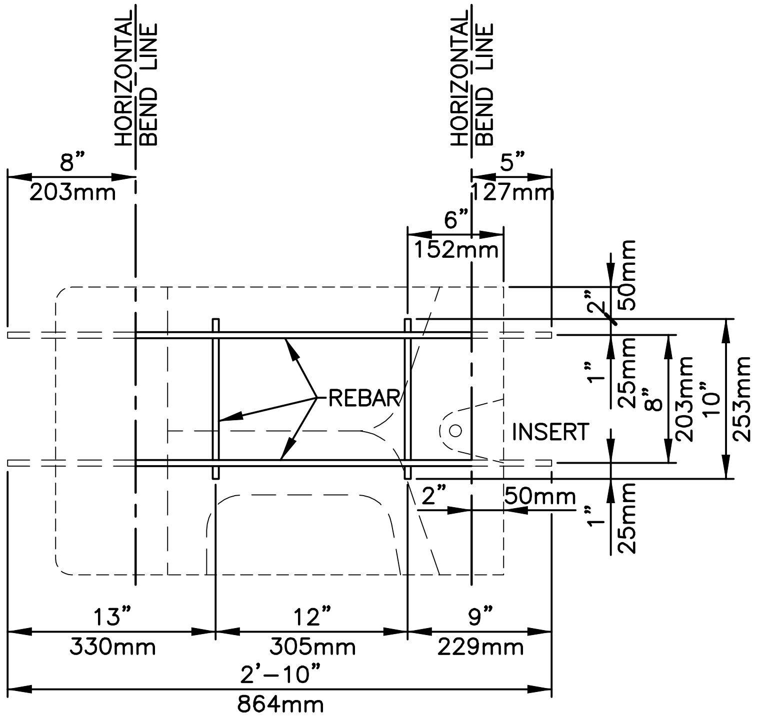

BENT WEB REBAR (2 REQUIRED)

6-28 HEAVY DUTY PARAWEB UNIT (6-28-HDP) – REBAR OPTION

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STONE STRONG SYSTEMS

DATE: 12/16/19 | FILE: 16_6-28-HDP Rebar

Project Number: 2017.478.001
Page 1 of __

DESIGN COMPUTATIONS FOR

Stone Strong Standard Block Analysis

12/1/2017

PREPARED FOR:

Stone Strong Systems
13460 Chandler Road
Suite 100
Omaha, Nebraska 68138

PREPARED BY:

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SPECIALTY PRECAST CONCRETE ENGINEERS

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SPECIALTY PRECAST CONCRETE ENGINEERS
860 Hooper Road, Endwell, NY 13760
www.delta-eas.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB 2017.478.001
DESCRIPTION Stonestrong Retaining Wall
SHEET NO. OF SCALE
CALCULATED BY YL DATE 12/1/2017
CHECKED BY DATE

Table of Contents

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DESCRIPTION Stonestrong Retaining Wall
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Summary

Analysis performed:

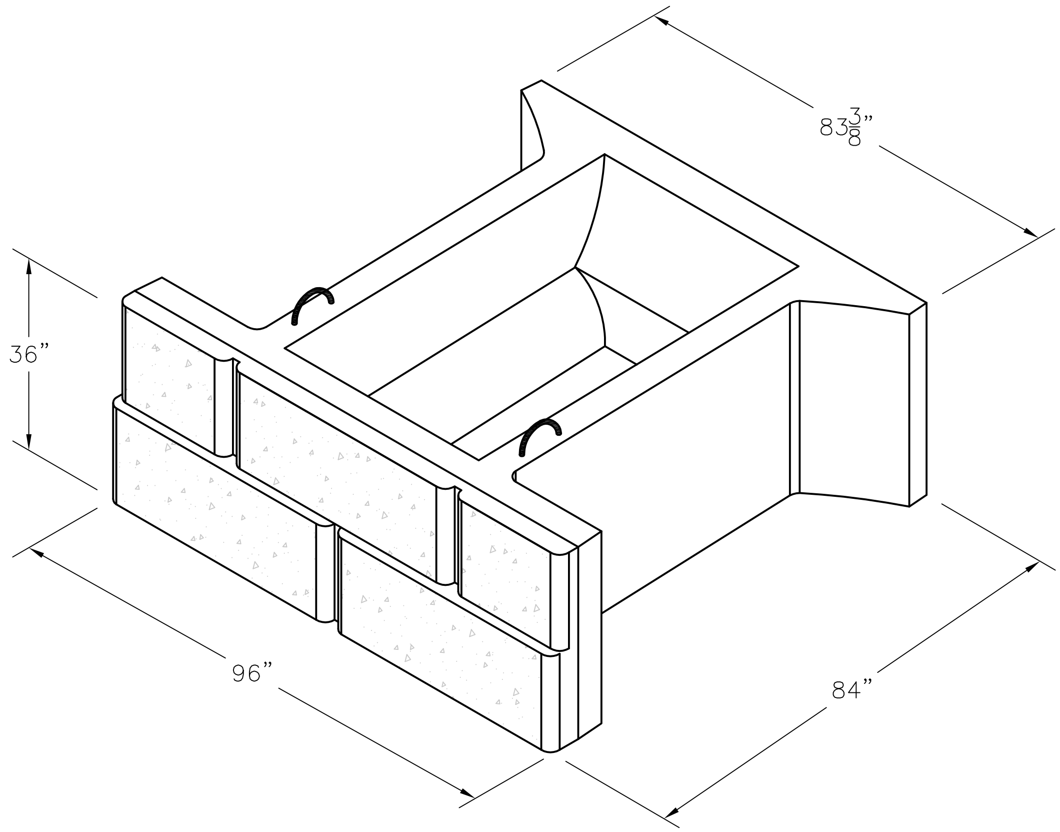
1. 24-86 block is analyzed using a maximum gravity wall height of 15ft.
2. 24SF block is analyzed using maximum reinforced wall height of 36.5ft and 50ft.
3. 6-28 block is analyzed using a maximum gravity wall height of 6ft and reinforced wall height of 50ft.
4. All blocks are analyzed for the internal at rest pressure from the infill and active pressure from the retained soil. A unit weight of 100pcf and ko=0.5 are used for the infill and 120pcf and ka=0.33 are used for the retained soil.
5. Risa-3D program is used to performed the analyses.
6. Handling analysis is perfomed using the controlling 24-86 blocks.
7. The analyses are performed per AASHTO LRFD and ACI 318-11.

Conclusions

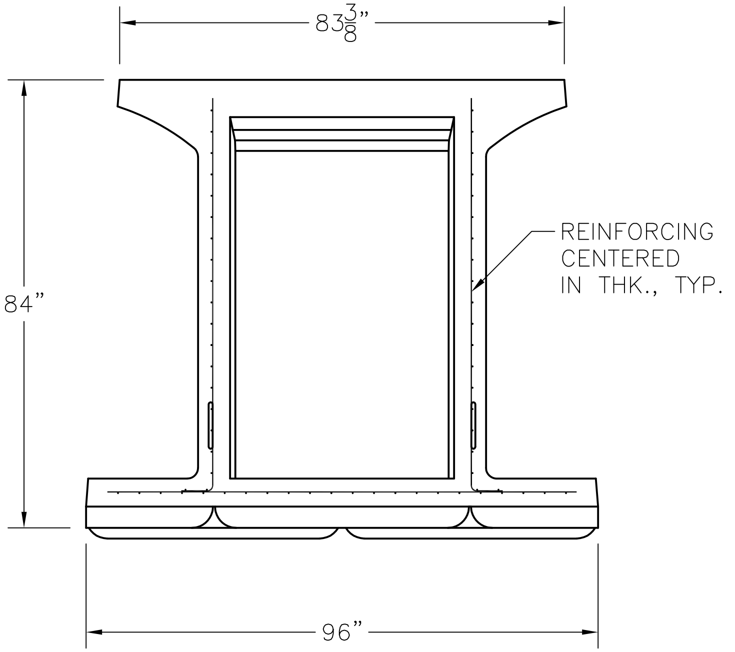
1. Analysis results of 24-86 and 24 SF indicate that for a maximum wall height of 36.5ft, both 24-86 and 24 SF blocks require shrinkage and temperature reinforcing only.
2. For 24SF block with a maximum wall height of 50ft, rear face reinforcing is required for bending moment.
3. For 6-28 block with a maximum wall height of 6ft, only shrinkage and temperature reinforcing is required.
4. For 6-28 block with a maximum wall height of 50ft, web reinforcing is required for tension.

Required shrinkage and temperature reinforcing area is 0.11 in^2/ft or W4XW4 - 4X4 mesh.

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017



STONE STRONG 24–86 UNIT



24–86 UNIT
PLAN VIEW

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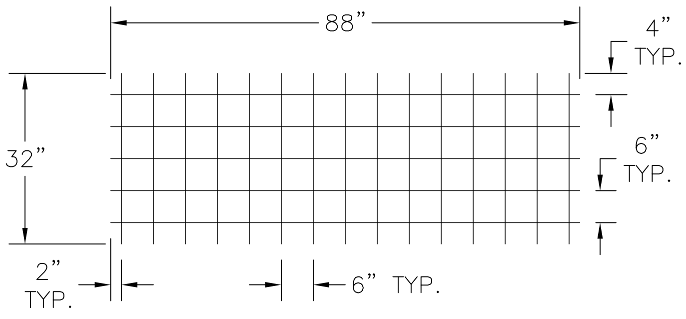
TEL: (607) 231–6600 FAX: (607) 231–6650

DATE: 11/22/17
SCALE: N.T.S.
SHEET TITLE: BLOCK GEOMETRY
DRWN BY: YL
CKD BY:
PROJECT: STONE STRONG
24–86 UNITS
15FT MAX. WALL HEIGHT
CONTRACTOR:
DWG. I.D.
DELTA PROJ. NO.: 2017.478.001
SHT. NO.



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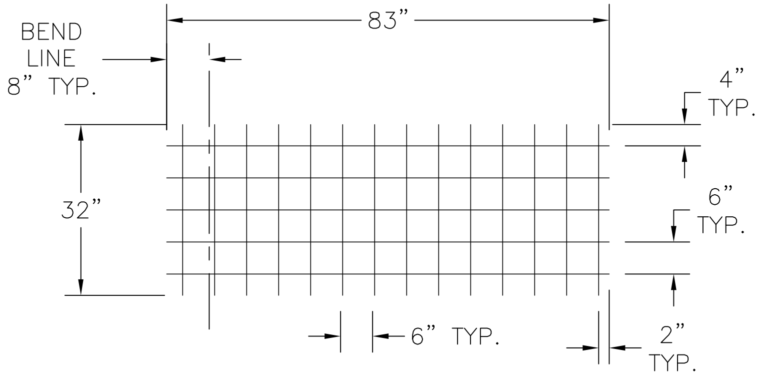
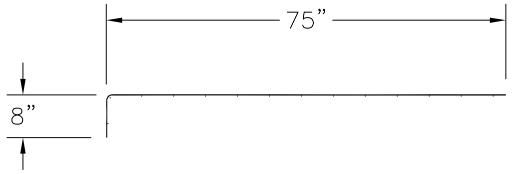


24–86 UNIT – WEB MATS – 2 REQ'D



24–86 UNIT – WEB MATS – PLAN VIEW

NOTES

1. ALL REINFORCING = W8xW8 – 6x6 WWF
2. REINFORCEMENT = WWF PER ASTM A185/A497/A1064 GRADE 65

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SHEET TITLE: WWF – REINFORCING DETAILS
DRWN BY: YL
CKD BY:
PROJECT: STONE STRONG
24–86 UNITS
15FT MAX. WALL HEIGHT
CONTRACTOR:
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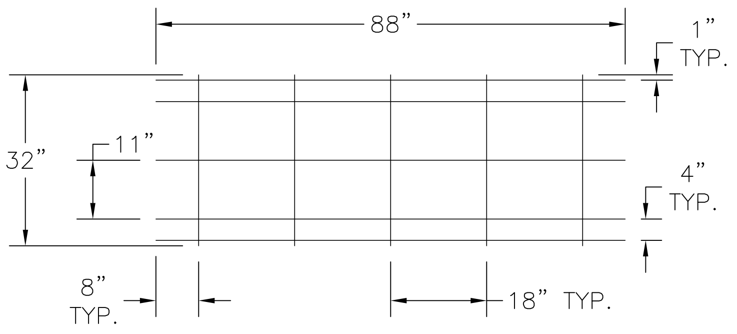

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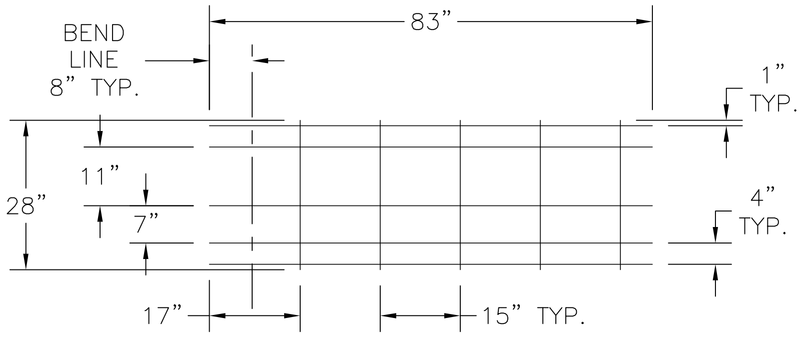

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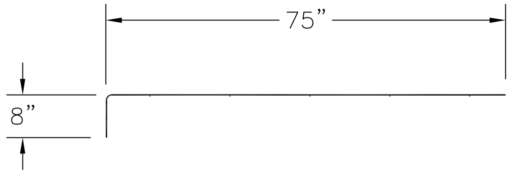

24–86 UNIT – WEB REBAR – PLAN VIEW

NOTES

1. ALL REINFORCING = #4 BARS (SPACED AS SHOWN)
2. REINFORCEMENT = BAR PER ASTM A615, GRADE 60

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DRWN BY: YL
CKD BY:
PROJECT: STONE STRONG
24–86 UNITS
15FT MAX. WALL HEIGHT
CONTRACTOR:
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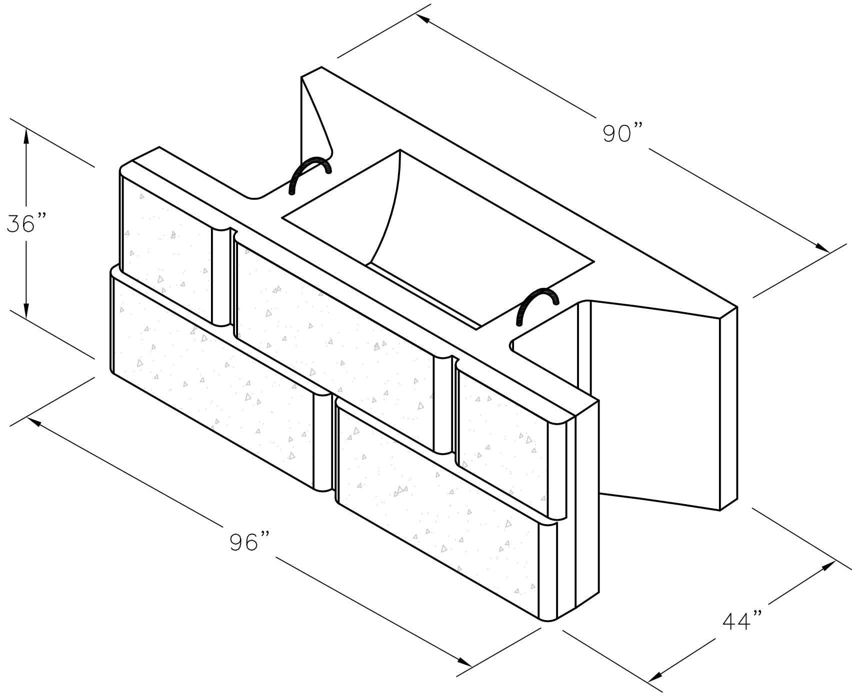
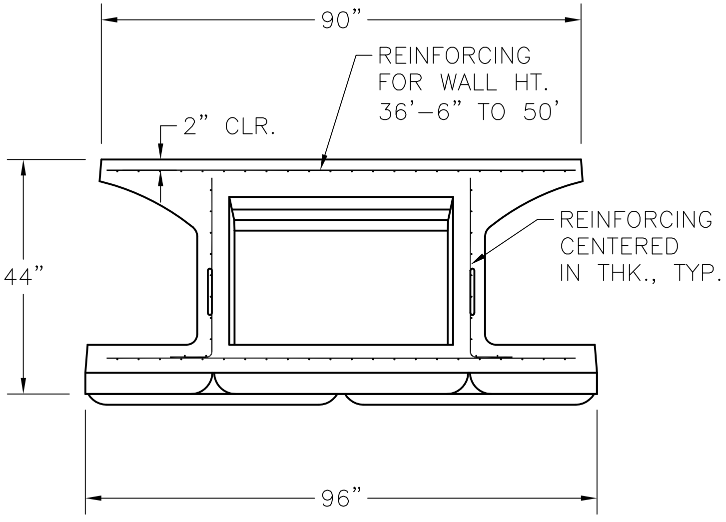


STONE STRONG 24SF UNIT



24SF UNIT
PLAN VIEW

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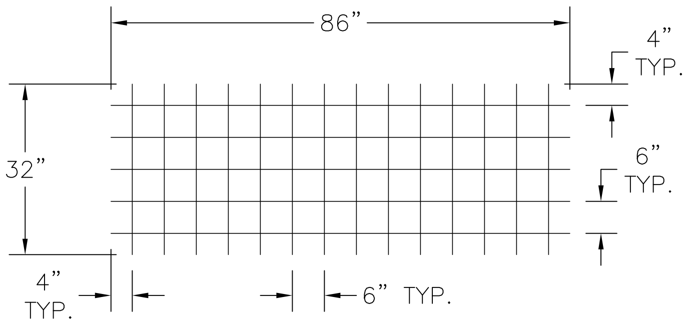
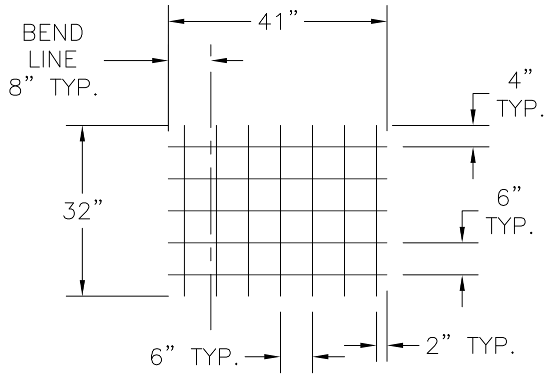
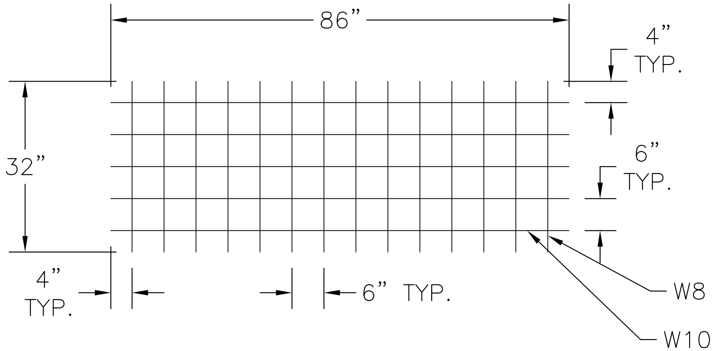
SCALE: N.T.S.
SHEET TITLE: BLOCK GEOMETRY
DRWN BY: YL
CKD BY:
PROJECT: STONE STRONG 24SF UNITS 50FT MAX. WALL HEIGHT
CONTRACTOR:
DWG. I.D.
DELTA PROJ. NO.: 2017.478.001
SHT. NO.



24SF UNIT – FRONT FACE MAT

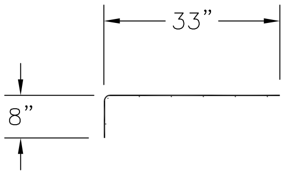


24SF UNIT – WEB MATS – 2 REQ'D



24SF UNIT – REAR FACE MAT

FOR WALL HEIGHT 36'-6" TO 50'-0"



24SF UNIT – WEB MATS – PLAN VIEW

NOTES

1. ALL REINFORCING = W8xW8 – 6x6 WWF UNO
2. REINFORCEMENT = WWF PER ASTM A185/A497/A1064 GRADE 65

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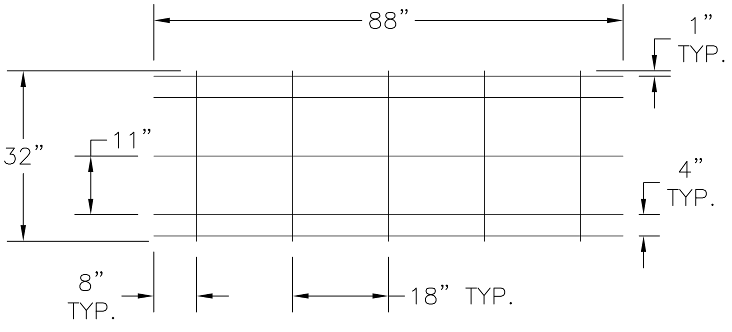
SHEET TITLE: WWF – REINFORCING DETAILS
DRWN BY: YL
CKD BY:
PROJECT: STONE STRONG 24SF UNITS 50FT MAX. WALL HEIGHT
CONTRACTOR:
DWG. I.D.
DELTA PROJ. NO.: 2017.478.001
SHT. NO.

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017



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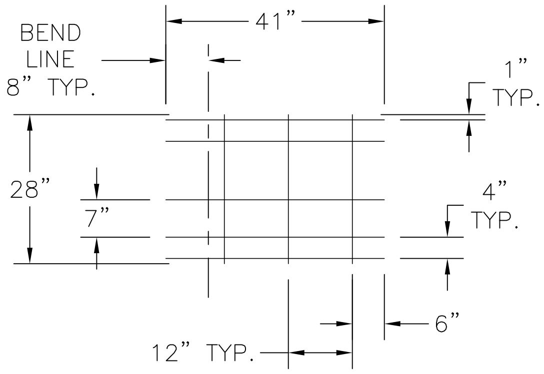

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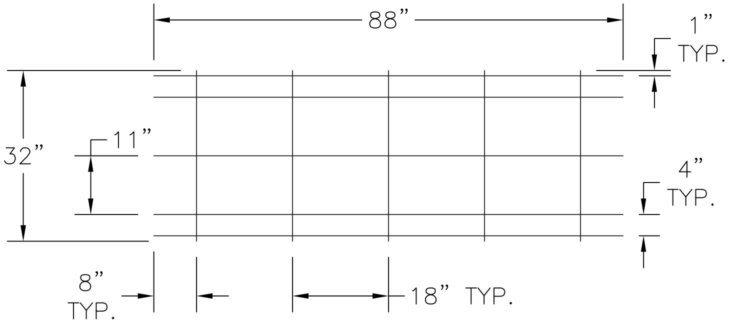

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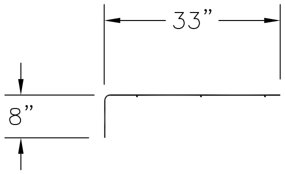

24SF UNIT – WEB REBAR – PLAN VIEW

NOTES

1. ALL REINFORCING = #4 BARS (SPACED AS SHOWN)
2. REINFORCEMENT = BAR PER ASTM A615, GRADE 60

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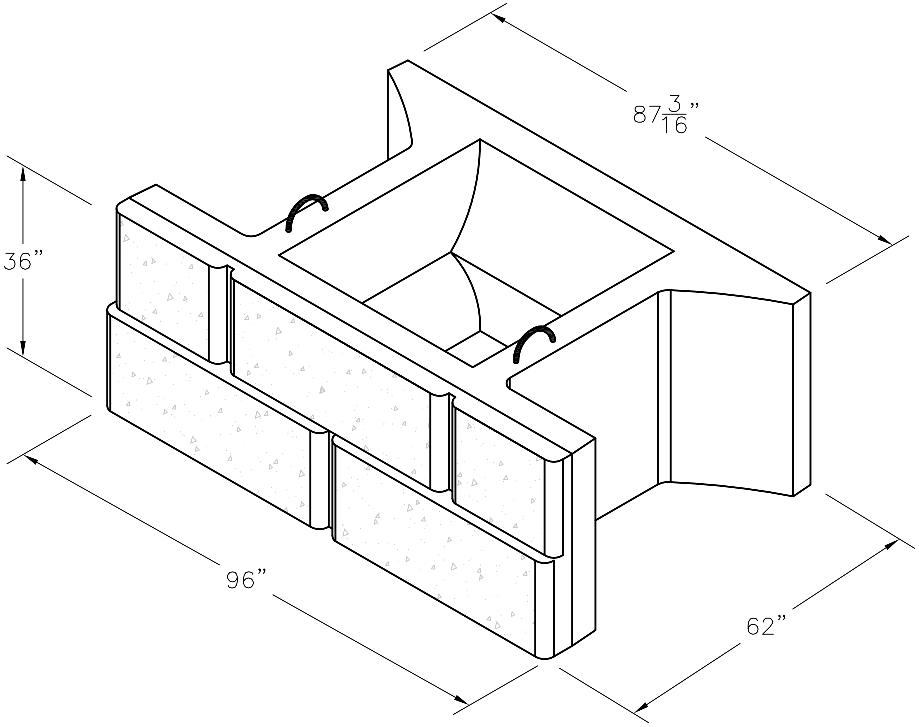
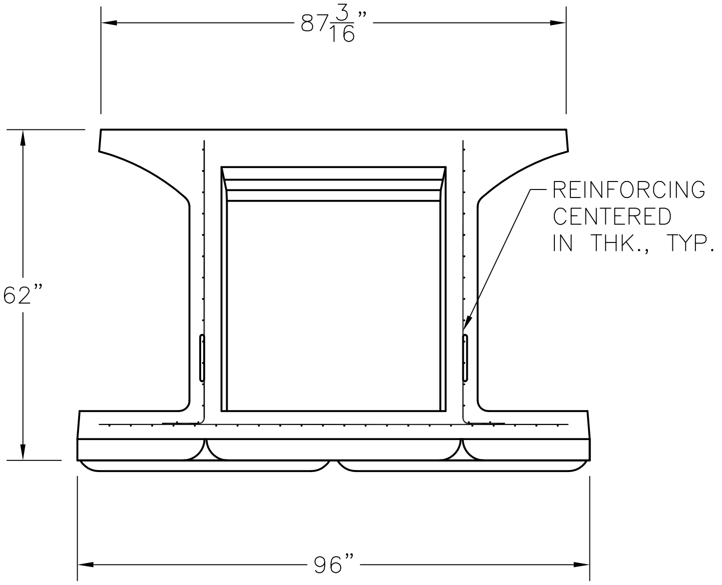


STONE STRONG 24–62 UNIT



24–62 UNIT
PLAN VIEW

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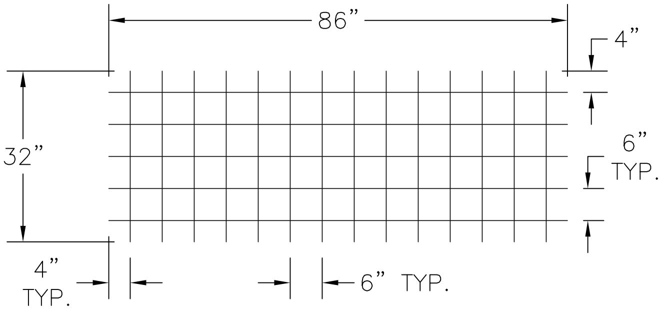
DATE: 11/22/17
SCALE: N.T.S.
SHEET TITLE: BLOCK GEOMETRY
DRWN BY: YL
CKD BY:
PROJECT: STONE STRONG 24–62 UNITS 15FT MAX. WALL HEIGHT
CONTRACTOR:
DWG. I.D.
DELTA PROJ. NO.: 2017.478.001
SHT. NO.



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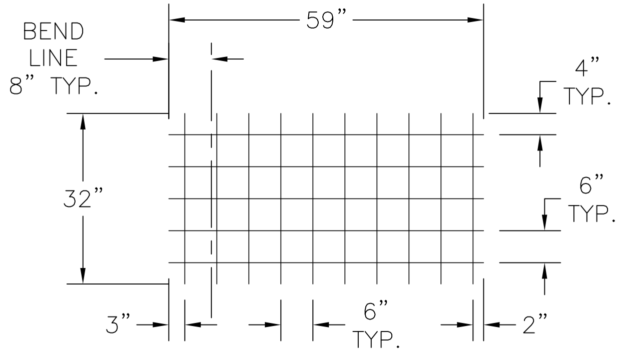
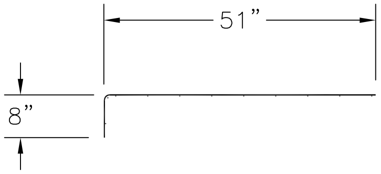


24–62 UNIT – WEB MATS – 2 REQ'D



24–62 UNIT – WEB MATS – PLAN VIEW

NOTES

1. ALL REINFORCING = W8xW8 – 6x6 WWF
2. REINFORCEMENT = WWF PER ASTM A185/A497/A1064 GRADE 65

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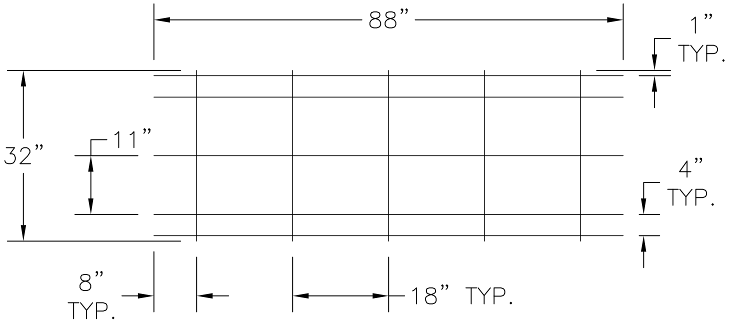
DATE: 11/22/17
SHEET TITLE: WWF – REINFORCING DETAILS
DRWN BY: YL
SCALE: N.T.S.
CKD BY:
PROJECT: STONE STRONG
24–62 UNITS
15FT MAX. WALL HEIGHT
CONTRACTOR:
DWG. I.D.
DELTA PROJ. NO.: 2017.478.001
SHT. NO.

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017



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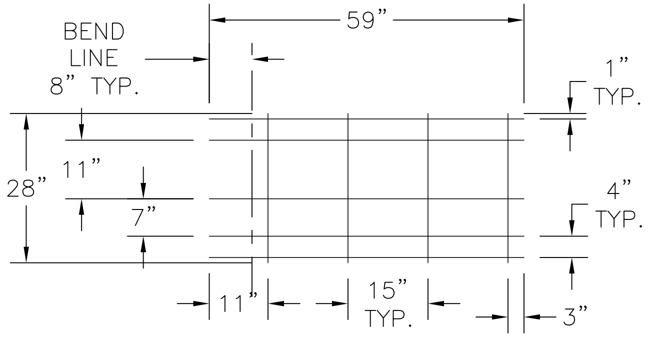
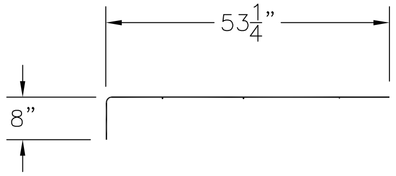


24–62 UNIT – WEB REBAR – 2 REQ'D



24–62 UNIT – WEB REBAR – PLAN VIEW

NOTES

1. ALL REINFORCING = #4 BARS (SPACED AS SHOWN)
2. REINFORCEMENT = BAR PER ASTM A615, GRADE 60

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SHEET TITLE: REBAR – REINFORCING DETAILS
DRWN BY: YL
CKD BY:
PROJECT: STONE STRONG
24–62 UNITS
15FT MAX. WALL HEIGHT
CONTRACTOR:
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DELTA PROJ. NO.: 2017.478.001
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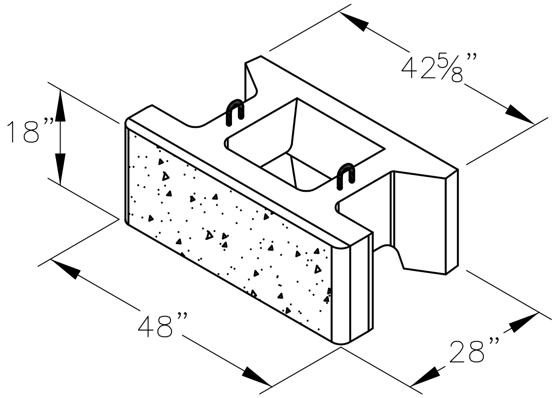
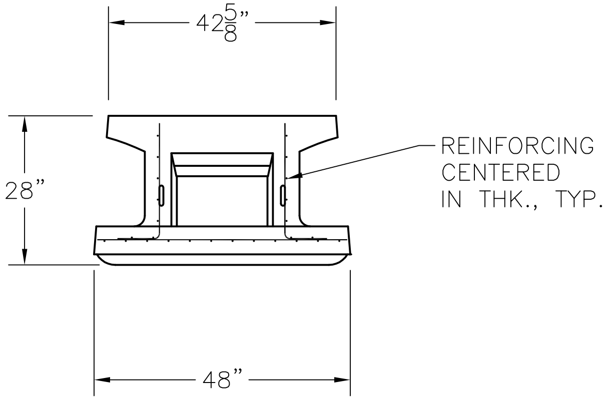


STONE STRONG 6–28 UNIT



6–28 UNIT
PLAN VIEW

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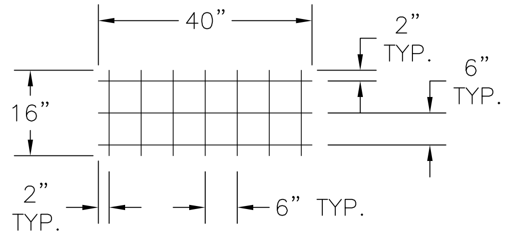
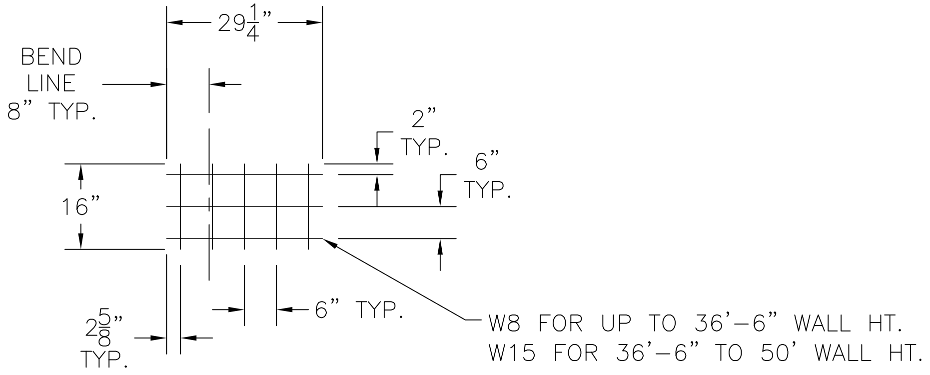
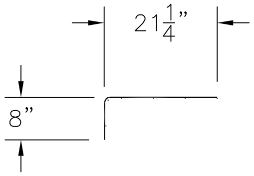
DATE: 11/22/17
SHEET TITLE: BLOCK GEOMETRY
DRWN BY: YL
SCALE: N.T.S.
CKD BY:
PROJECT: STONE STRONG
6–28 UNITS
50FT MAX. WALL HEIGHT
CONTRACTOR:
DWG. I.D.
DELTA PROJ. NO.: 2017.478.001
SHT. NO.



6–28 UNIT – FRONT FACE MAT



6–28 UNIT – WEB MATS – 2 REQ'D



6–28 UNIT – WEB MATS – PLAN VIEW

NOTES

1. ALL REINFORCING = W8xW8 – 6x6 WWF UNO
2. REINFORCEMENT = WWF PER ASTM A185/A497/A1064 GRADE 65

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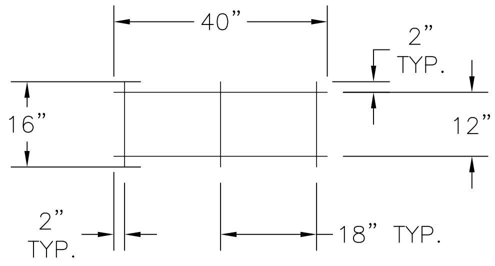
SCALE: N.T.S.
SHEET TITLE: WWF – REINFORCING DETAILS
DRWN BY: YL
CKD BY:
PROJECT: STONE STRONG 6–28 UNITS 50FT MAX. WALL HEIGHT
CONTRACTOR:
DWG. I.D.
DELTA PROJ. NO.: 2017.478.001
SHT. NO.



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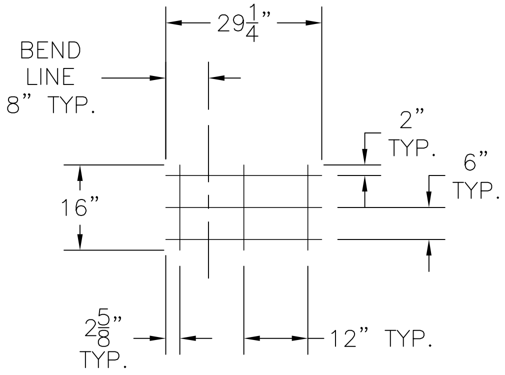
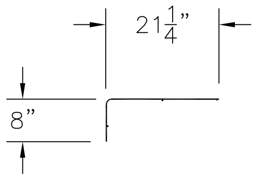


6–28 UNIT – WEB REBAR – 2 REQ'D



6–28 UNIT – WEB REBAR – PLAN VIEW

NOTES

1. ALL REINFORCING = #4 BARS (SPACED AS SHOWN)
2. REINFORCEMENT = BAR PER ASTM A615, GRADE 60

REV.NO.	DATE	REVISION

PREPARED FOR:
STONE STRONG SYSTEMS®
www.stonestrong.com

PREPARED BY:
DELTA
SPECIALTY PRECAST CONCRETE ENGINEERS
860 HOOPER ROAD, ENDWELL, NY 13760–1564
TEL: (607) 231–6600 FAX: (607) 231–6650

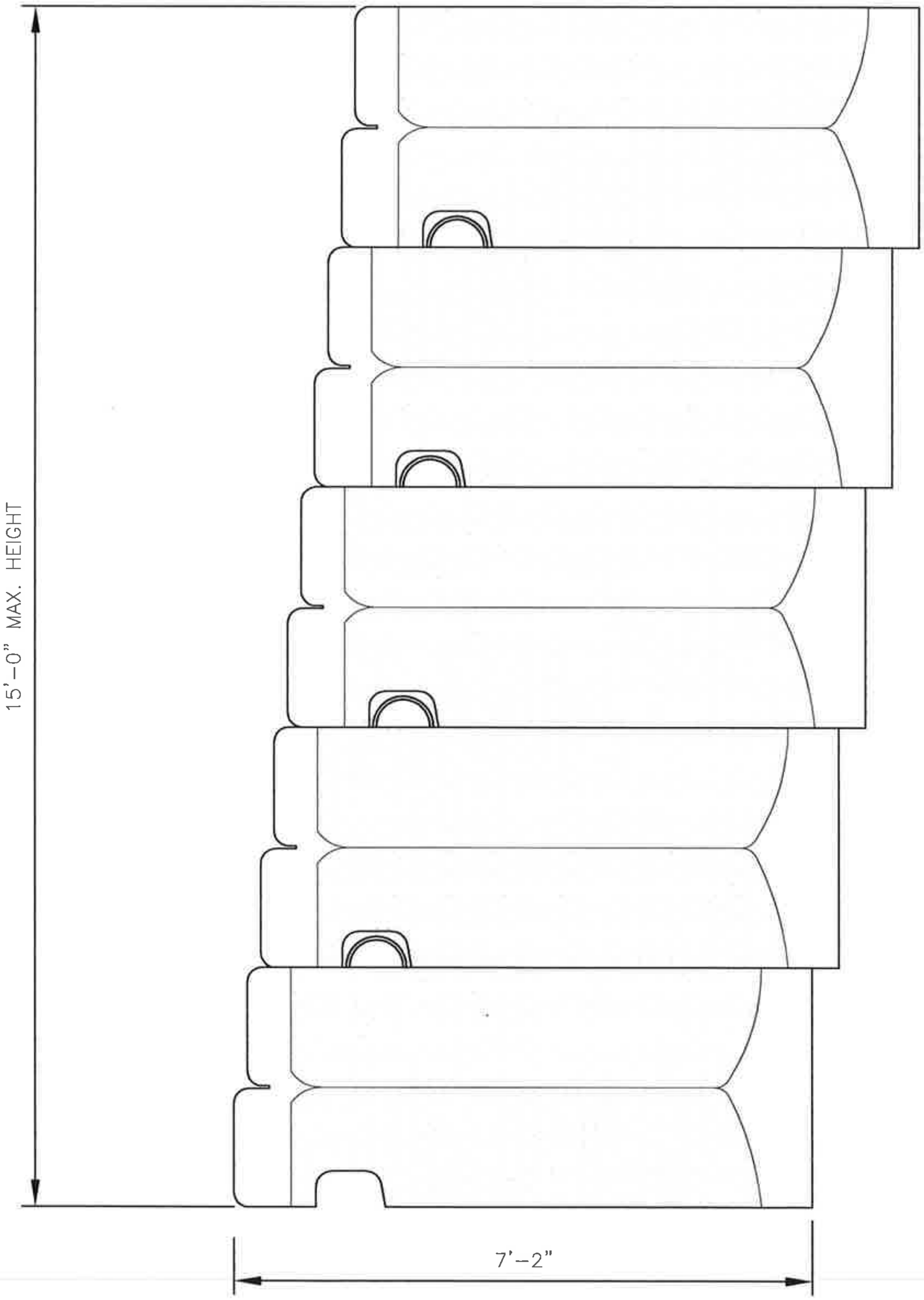
DATE: 11/22/17
SCALE: N.T.S.
SHEET TITLE: REBAR – REINFORCING DETAILS
DRWN BY: YL
CKD BY:
PROJECT: STONE STRONG 6–28 UNITS 50FT MAX. WALL HEIGHT
CONTRACTOR:
DWG. I.D.
DELTA PROJ. NO.: 2017.478.001
SHT. NO.

DELTA
SPECIALTY PRECAST CONCRETE ENGINEERS
860 Hooper Road, Endwell, NY 13760
www.delta-eas.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB 2017.478.001
DESCRIPTION Gravity Wall - 24-86 Blocks
SHEET NO. OF SCALE
CALCULATED BY YL DATE 6/8/2017
CHECKED BY DATE

Gravity Wall - Maximum 15ft Wall Height
24-86 Blocks

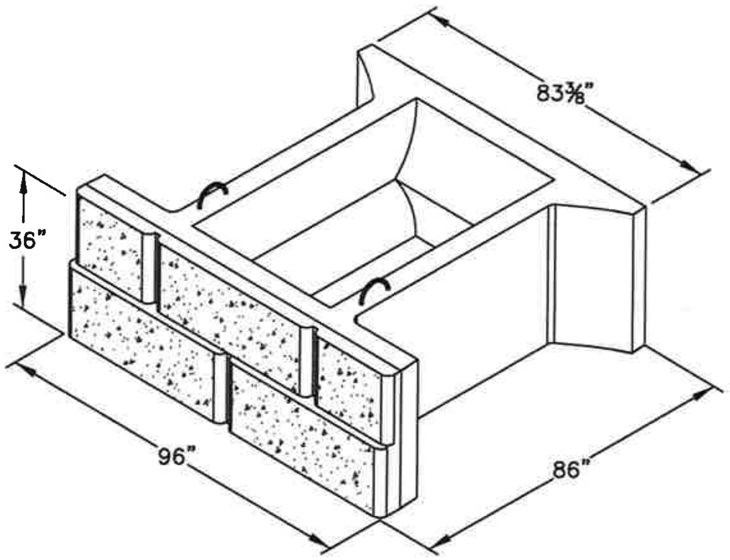
Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017



GRAVITY WALL
24-86 UNIT

NOTES:

1. SEE FACE AND WEB MESH DETAILS FOR REINFORCEMENT GRID.
2. CHISELLED GRANITE STYLE HAS 4 DIFFERENT FACE PATTERNS ON 24-86 BLOCKS. INSTALL A, B, C, & D PATTERNS AT RANDOM IN WALL.



STONE STRONG 24-86 UNIT

NOT TO SCALE

CHECK ON AVAILABILITY OF ALL UNITS w/ LOCAL PRODUCER/
DEALER. SOME UNITS MAY HAVE LIMITED AVAILABILITY.

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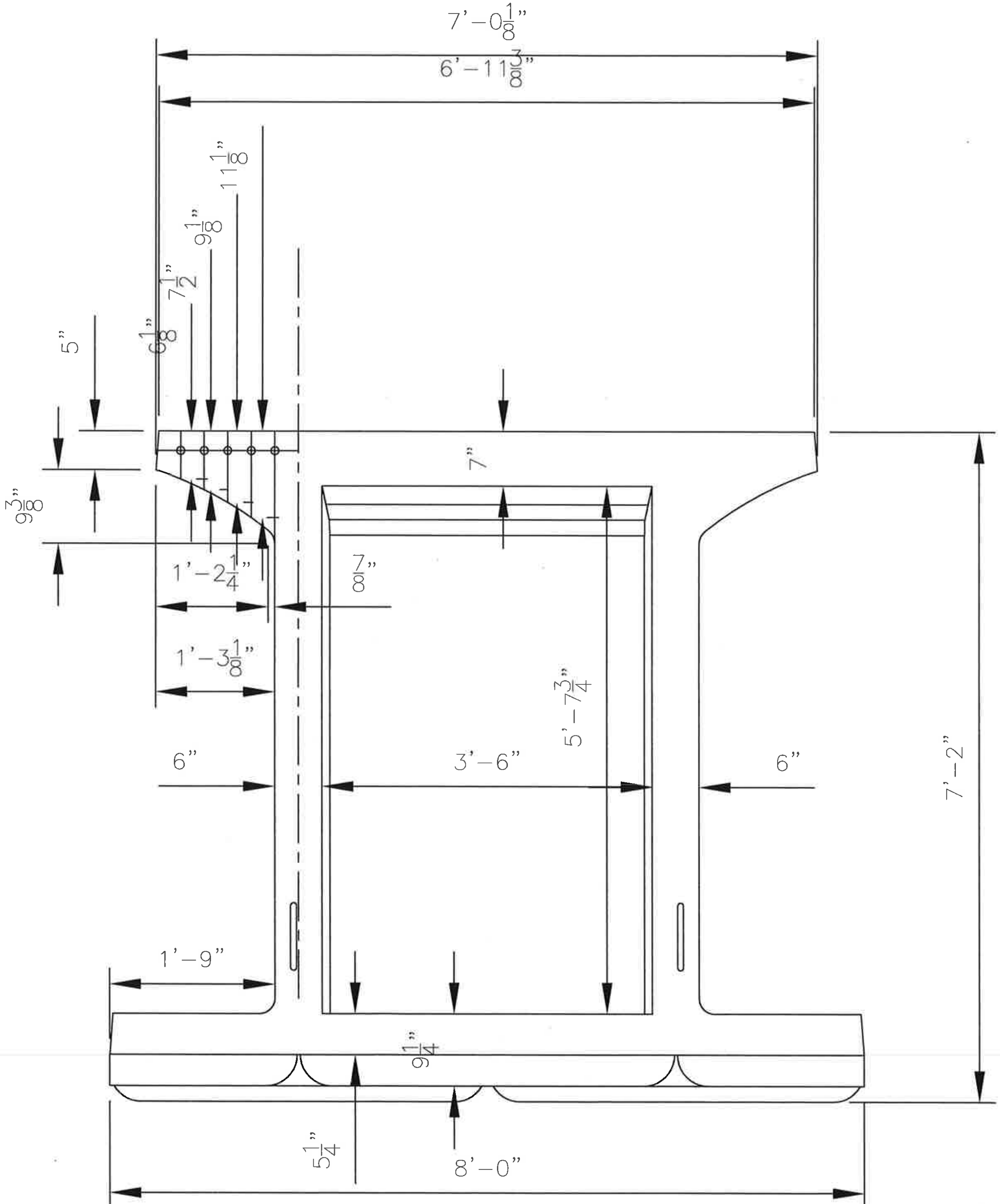
PROJECT

COMPONENTS
STONE STRONG SYSTEMS

DATE: 2/10/16
FILE: 09_Block.24-86

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017



24-86 UNIT

STONE STRONG SYSTEMS®

STONE STRONG GRAVITY CALCULATIONS - ver 5.7

Project Name: 24-86 Gravity Retaining Wall
Location:
Job#: 2017.478.001
Section:
Calc by: YL

6/15/17 13:34

Notes

Wall Configuration

			setback (in)		modular units		unit fill		soil wedge		CIP Extension		Internal Stability FS		Seismic Internal FS		
unit	w (in)	h (ft)	face	tail	Wb (lb)	xb (in)	Wa (lb)	xa (in)	Ws (lb)	xs (in)	we (in)	h_t	Topple	Shear	Topple	Shear	
24-86	86.0	3.00	16.0	16.0	962	54.0	1,438	59.1					16.29	5.79			OK!
24-86	86.0	3.00	12.0	12.0	962	50.0	1,438	55.1					7.09	4.16			OK!
24-86	86.0	3.00	8.0	8.0	962	46.0	1,438	51.1					4.03	3.13			OK!
24-86	86.0	3.00	4.0	4.0	962	42.0	1,438	47.1					2.67	2.52			OK!
24-86	86.0	3.00	0.0	0.0	962	38.0	1,438	43.1					**External Stability OK!**				
	86.0	15.00	16.0	16.0	4,808	46.0	7,192	51.1	0	0.0	12,000						

backfill height 15.00 feet

exposed height 14.25 feet

ω= 6.34 deg

ω'= 6.34 deg

interface friction angle

δ 15.0 deg

Retained Soil

γ 120 pcf
ϕ 30 deg

Foundation Soil

γ 120 pcf
c' psf
ϕ 30 deg

(if specified)
allowable bearing pressure n/a psf
(net)

base embedment 9 in
base thickness 9 in
base material agg
toe slope H:1V slope

composite friction coefficient μ_b 0.69

Aggregate Unit Fill

γ 100 pcf

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017

STONE STRONG GRAVITY CALCULATIONS - ver 5.7

Project Name: 24-86 Gravity Retaining Wall
Location:
Job#: 2017.478.001
Section:
Calc by: YL

Seismic Load

Ss 0.00 G site class (A to E or 1) D Fa 1.60 k_h 0.00

Backfill Slope & Surcharge

			rise in grade		LL surcharge		tier height	
length 1	30	feet (horizontal)		ft	240	psf		ft
length 2		feet (horizontal)		ft		psf		ft
length 3		feet (horizontal)		ft		psf		ft
length 4		feet (horizontal)		ft		psf		

effective slope H:1V slope β 0.0 deg avg q 232 psf

failure plane α 54.29 deg zone of influence 17.95 ft

Analysis

		Q_{lh} =	924 lb	ΔK_{AE} =	0.000	e=	1.14 ft
K_a =	0.260	Q_{lv} =	141 lb	P_{IR} =	0 lb	B_f' =	5.47 ft
P_h =	3465 lb	R_s =	7233 lb	ΔP_{AEh} =	0 lb	e_{eq}=	0.65 ft
P_v =	528 lb	q_{ult} =	10,664 psf	ΔP_{AEv} =	0 lb	$B_f'{}_{eq}$ =	6.45 ft

Results

Overturning:	Desired FS =	1.5	**Actual FS =**	**1.98**	***OK!***
Sliding:	Desired FS =	1.5	**Actual FS =**	**1.65**	***OK!***
Bearing Capacity:	Desired FS =	2	**Actual FS =**	**4.42**	***OK!***
	q_{all} =	5,332 psf	q_c =	2,410 psf	

Internal Safety Factors

Desired FS = 1.5
Desired FS = 1.5

Desired FS =
Desired FS =

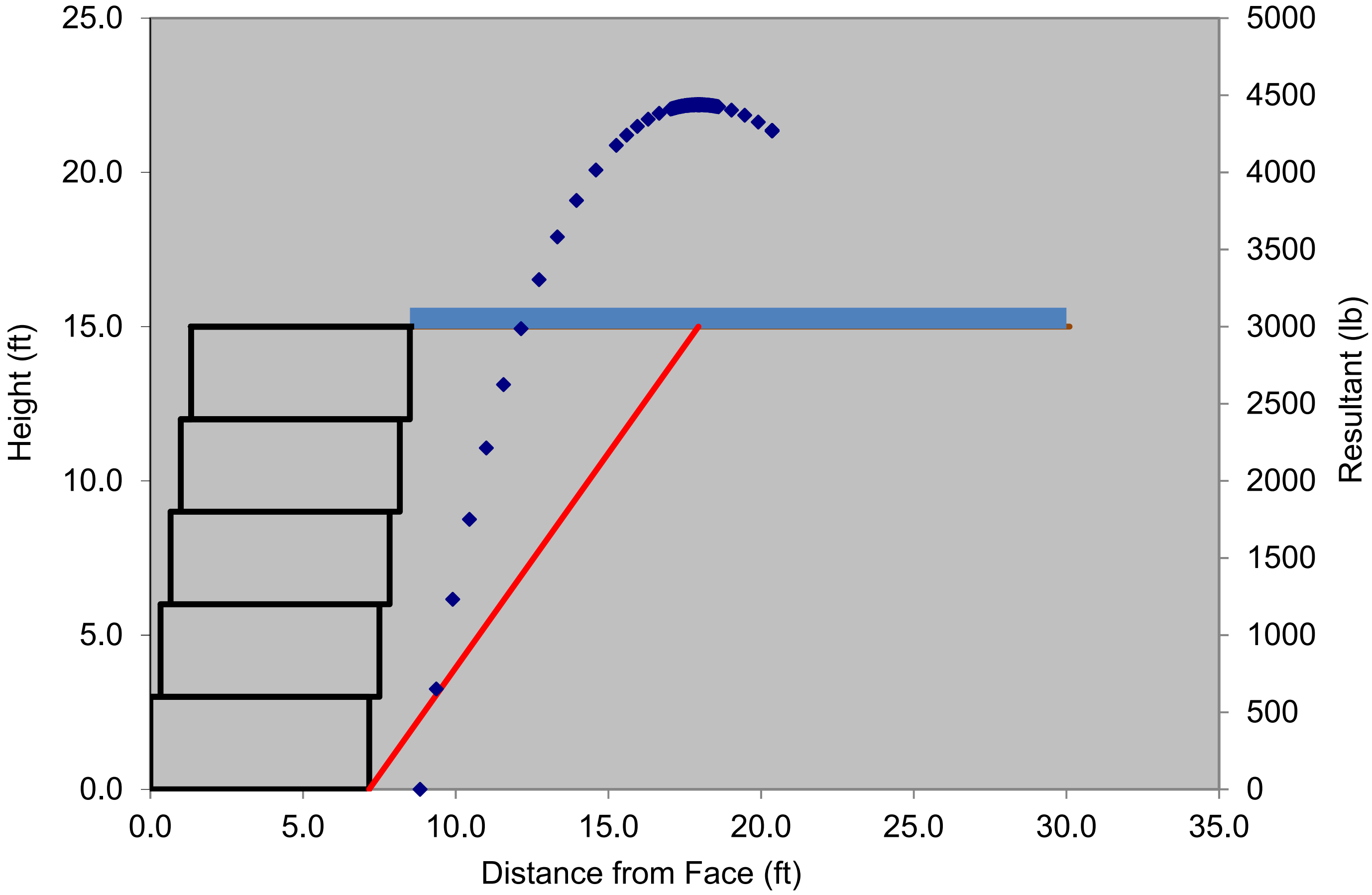
Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017

STONE STRONG GRAVITY CALCULATIONS - ver 5.7

Project Name: 24-86 Gravity Retaining Wall
Location:
Job#: 2017.478.001
Section:
Calc by: YL

6/15/17 13:34

Ground Surface & Trial Wedge Plot



Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017

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STONE STRONG GRAVITY CALCULATIONS - ver 5.7

Project Name: 24-86 Gravity Retaining Wall
Location:
Job#: 2017.478.001
Section:
Calc by: YL

(AASHTO 6th Edition, 2012)

6/15/17 13:36

Notes

Wall Configuration

			setback (in)		modular units		unit fill		soil wedge		CIP Extension		
unit	w (in)	h (ft)	face	tail	Wb (lb)	xb (in)	Wa (lb)	xa (in)	Ws (lb)	xs (in)	we (in)	h_t	Internal
6	44.0	1.50	16.0	-26.0	400	37.0	269	39.5	238	72.7			Internal Stability OK!
24-86	86.0	3.00	12.0	12.0	962	52.0	1,438	57.1	0	0.0			Internal Stability OK!
24-86	86.0	3.00	8.0	8.0	962	48.0	1,438	53.1	0	0.0			Internal Stability OK!
24-86	86.0	3.00	4.0	4.0	962	44.0	1,438	49.1	0	0.0			Internal Stability OK!
24-86	86.0	3.00	0.0	0.0	962	40.0	1,438	45.1	0	0.0			**External Stability OK!**
	86.0	13.50	16.0	-26.0	4,247	45.2	6,022	50.6	238	72.7			

backfill height	13.50	feet	ω=	6.34 deg	interface friction angle	
exposed height	12.75	feet	ω'=	-9.12 deg	δ	22.5 deg

Retained Soil

γ 120 pcf
ϕ 30 deg

Aggregate Unit Fill

γ 100 pcf

Foundation Soil

γ 120 pcf
c' psf
ϕ 30 deg

(if specified)
bearing pressure n/a psf
(net)

base embedment 9 in
base thickness 9 in
base material agg
toe slope H:1V slope

composite friction coefficient μ_b 0.69

STONE STRONG GRAVITY CALCULATIONS - ver 5.7

Project Name: 24-86 Gravity Retaining Wall
Location:
Job#: 2017.478.001
Section:
Calc by: YL

Seismic Load

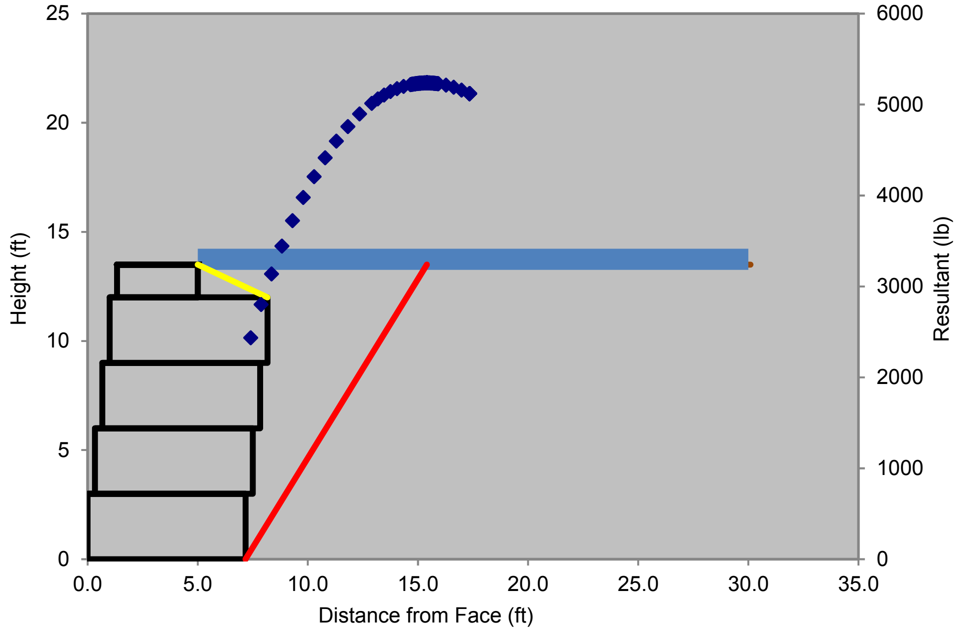
PGA 0.00 G site class (A to E or 1) D Fpga 1.60 k_h 0.00

Backfill Slope & Surcharge

			rise in grade		LL surcharge		tier height	
length 1	30	feet (horizontal)		ft	240	psf		ft
length 2		feet (horizontal)		ft		psf		ft
length 3		feet (horizontal)		ft		psf		ft
length 4		feet (horizontal)		ft		psf		

effective slope H:1V slope β 0.0 deg avg q 240 psf

failure plane α 58.61 deg zone of influence 15.40 ft



Ground Surface & Trial Wedge Plot

Unfactored Loads

K_a =	0.370	K_{AE} =	0.370
P_h =	3,441 lb	ΔK_{AE} =	0.000
P_v =	2,118 lb	P_{IR} =	0 lb
Q_{lh} =	1,020 lb	ΔP_{AEh} =	0 lb
Q_{lv} =	628 lb	ΔP_{AEv} =	0 lb

STONE STRONG GRAVITY CALCULATIONS - ver 5.7

Project Name: 24-86 Gravity Retaining Wall
Location:
Job#: 2017.478.001
Section:
Calc by: YL

Load Cases:		Strngth I-a	Strngth I-b	Strngth IV	Extrme I-a (EQ)	Extrme I-b (EQ)	Extrme II (CT)	Service I	
Factored Loading	*Overturning (lb-ft):*	35,271	35,271	23,227	15,485	15,485	18,926	22,367	**OK!**
	Sliding (lb):	6,946	6,946	5,162	3,441	3,441	3,951	4,461	**OK!**
	Bearing (psf):	2,819	3,318	2,664	1,837	1,837	1,984	2,265	**OK!**
	e (ft):	1.47	1.03	0.51	0.45	0.45	0.67	0.84	**OK!**
	Bf' (ft):	5.36	6.16	7.13	7.24	7.24	6.85	6.51	
Factored Resistance	*Overturning (lb-ft):*	62,999	80,979	73,414	51,089	51,089	52,998	57,694	
	Sliding (lb):	7,460	10,171	9,352	7,289	7,289	7,470	8,159	
	Bearing (psf):	4,732	5,216	5,804	13,044	13,044	12,514	12,061	
	(@ top of base) Max e (ft):	2.39	2.39	2.39	2.87	2.87	2.87	2.39	
Load & Resistance Factors	LL	1.75	1.75	0.00	0.00	0.00	0.50	1.00	
	EH	1.50	1.50	1.50	1.00	1.00	1.00	1.00	
	EQ	0.00	0.00	0.00	1.00	1.00	0.00	0.00	
	CT	0.00	0.00	0.00	0.00	0.00	1.00	0.00	
	LL Surcharge over Wall	0.00	1.75	0.00	0.00	0.00	0.00	1.00	
	DC	0.90	1.25	1.50	1.00	1.00	1.00	1.00	
	EV	1.00	1.35	1.35	1.00	1.00	1.00	1.00	
	BC	0.45	0.45	0.45	1.00	1.00	1.00	1.00	
	ϕt precast to agg	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	ϕt CIP to agg/soil	0.80	0.80	0.80	1.00	1.00	1.00	1.00	
	ϕt soil to soil	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	ϕt precast to precast	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	concrete interface - eccentricity limit	0.45	0.45	0.45	0.40	0.40	0.45	0.45	
	bearing on soil - eccentricity limit	0.33	0.33	0.33	0.40	0.40	0.40	0.33	

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www.delta-eas.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB 2017.478.001

DESCRIPTION Gravity Wall - 24-86 Blocks

SHEET NO OF SCALE

CALCULATED BY YL DATE 6/8/2017

CHECKED BY DATE

Load Calculations - 24-86 Blocks - 15' Wall Height

Internal Pressure from Infill

Infill Density = 100 pcf
ko = 0.5
Height to Middle of Bottom Block = 13.5 ft
Internal Pressure (at rest) = 675 psf

External Pressure from Retained Soil

Soil Density = 120 pcf
ka = 0.33
Height to Middle of Bottom Block = 13.5 ft
External Pressure (at rest) = 535 psf

Live Load Surcharge = 80 psf

JOB 2017.478.001
DESCRIPTION Gravity Wall - 24-86 Blocks
SHEET NO. OF SCALE
CALCULATED BY YL DATE 6/8/2017
CHECKED BY DATE

Risa Results - 24-86 Blocks - 15' Wall Height

fc' = 5000 psi
5*√f'c = 354 psi

Front Face:

-Mu = 1.17 k-ft/ft
Thickness t = 8 in
$S = 12\ t^2/6 =$ 128 in^3
ϕMn =0.6* 5*√f'c S = 2.26 k-ft/ft OK

+Mu = 0.63 k-ft/ft
Thickness t = 6 in
$S = 12\ t^2/6 =$ 72 in^3
ϕMn =0.6* 5*√f'c S = 1.27 k-ft/ft OK

Vu = 3.15 k/ft
Thickness t = 8 in
ϕVn =0.6* 4/3*√f'c *12 t = 5.43 k-ft/ft OK

Front Face Reinforcing required for temperature and shrinkage only.

Rear Face:

Bending moment and shear are negaligle due to balancing of infill pressure and retained soil pressure.

Rear Face Reinforcing required for temperature and shrinkage only.

Web

Tu = 8.10 k/ft
Thickness t = 6 in
ϕTn =0.6*5*√f'c *12 t = 15.27 k-ft/ft OK

Web Reinforcing required for temperature and shrinkage only.

JOB 2017.478.001
DESCRIPTION Stonestrong Retaining Wall
SHEET NO OF SCALE
CALCULATED BY YL DATE 6/8/2017
CHECKED BY DATE

Temperature and Shrinkage Reinforcing (AASHTO LRFD 5.10.8)

fy = 60 ksi

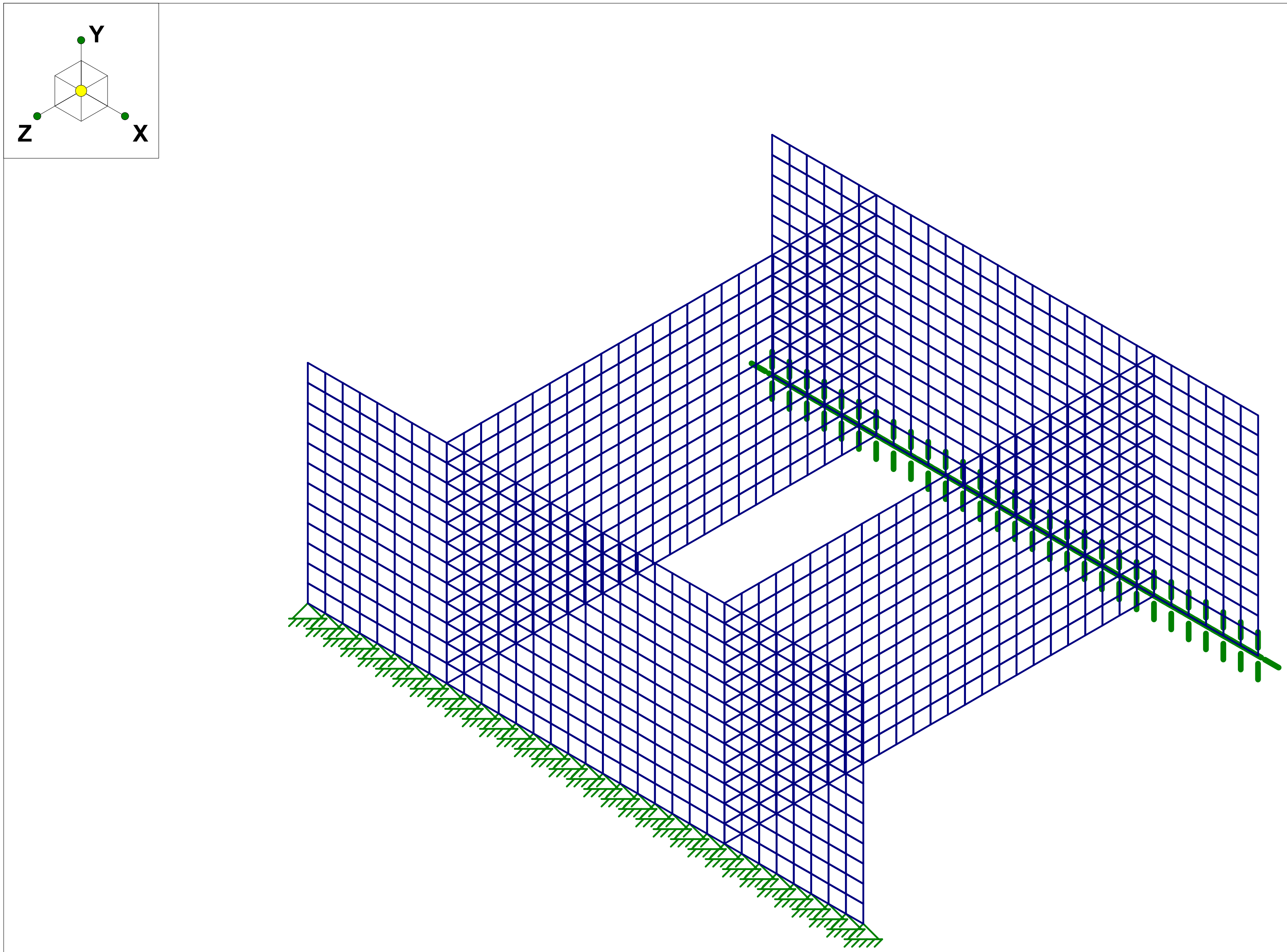
$$As = \frac{1.30\,bh}{2(b+h)Fy}$$

0.11<= As <= 0.6

b = 36 in Least Width of Component Section
h = 6 in Least Thickness of Component Section

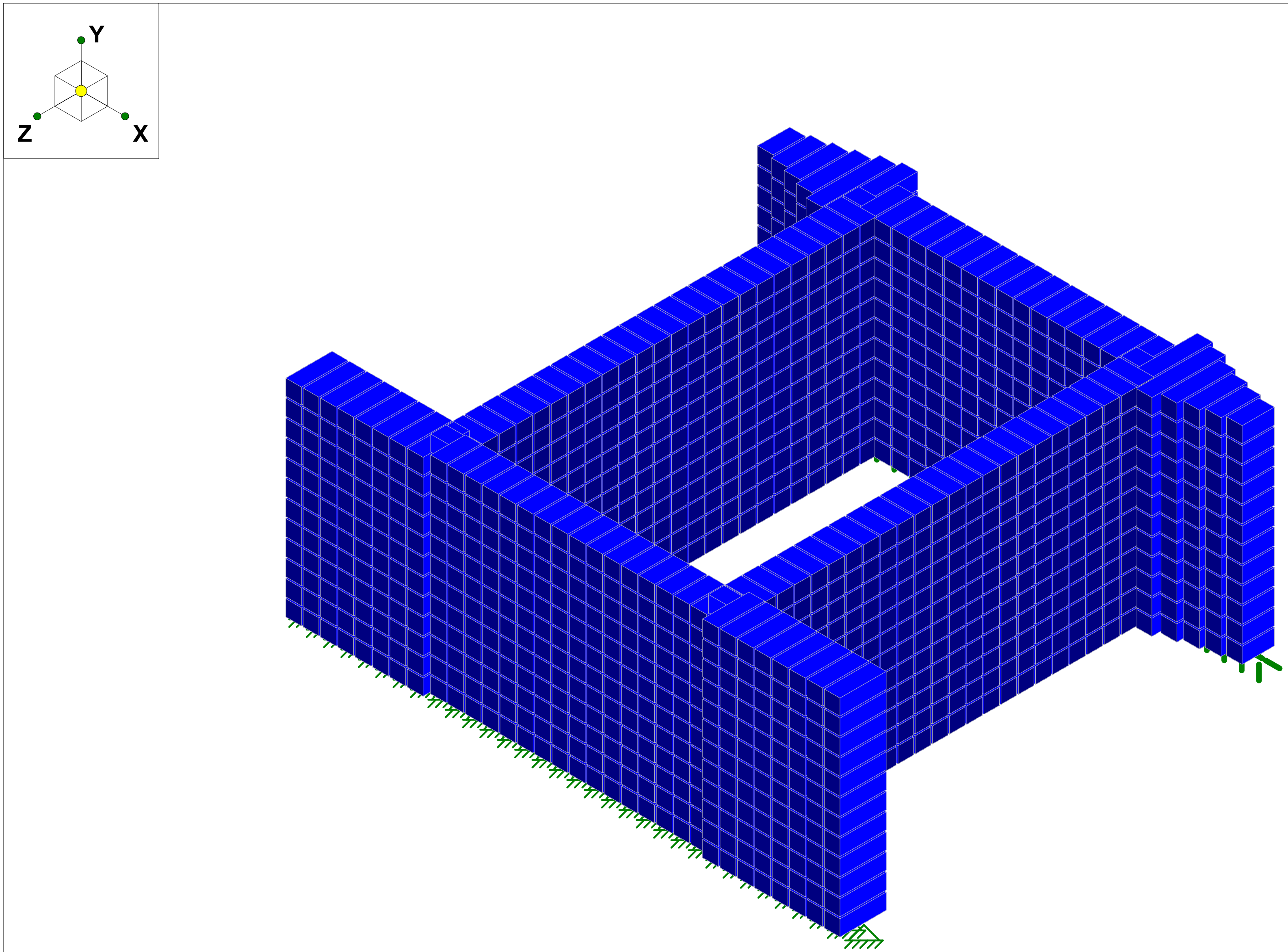
As = 0.11 in^2/ft

Provide W8xW8 - 6x6 Wire Mesh in Front Face & Webs. Bend Web Mesh into Front Face to Form a Standard Hook.



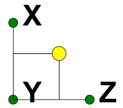
Delta Engineers,Inc	Gravity Wall - 24-86 Blocks	SK - 1
YL		June 15, 2017 at 2:25 PM
2017.478.001		24-86 Block.r3d

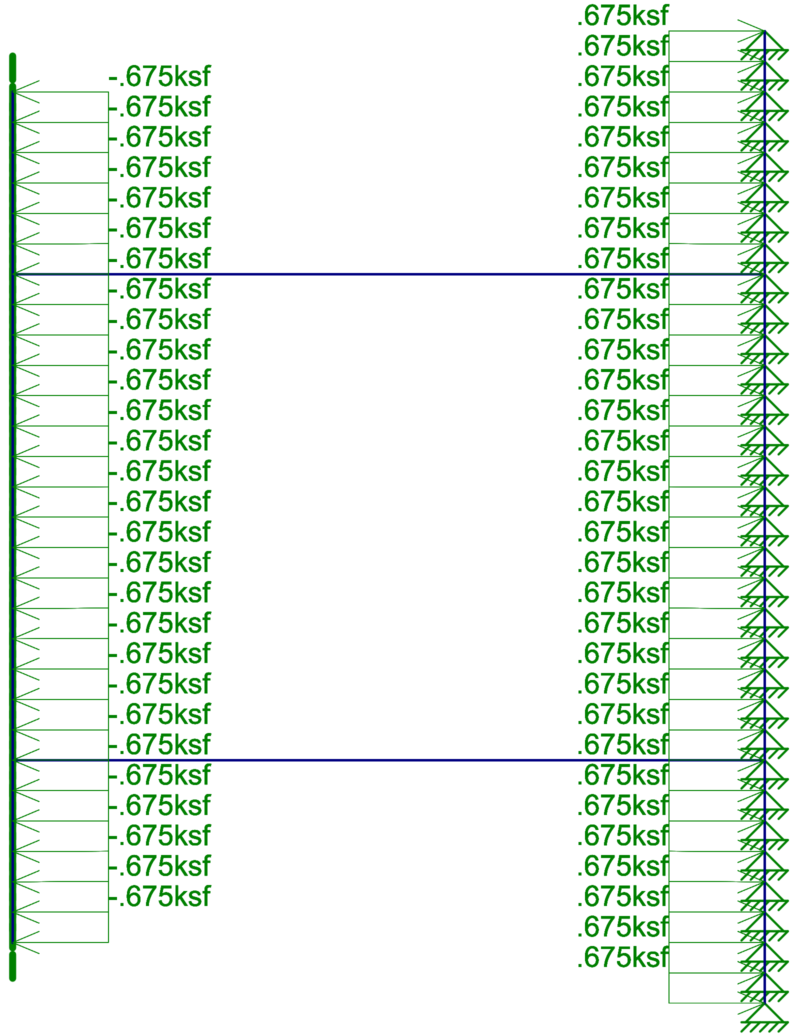
Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017



Delta Engineers,Inc	Gravity Wall - 24-86 Blocks	SK - 2
YL		June 15, 2017 at 2:26 PM
2017.478.001		24-86 Block.r3d

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017





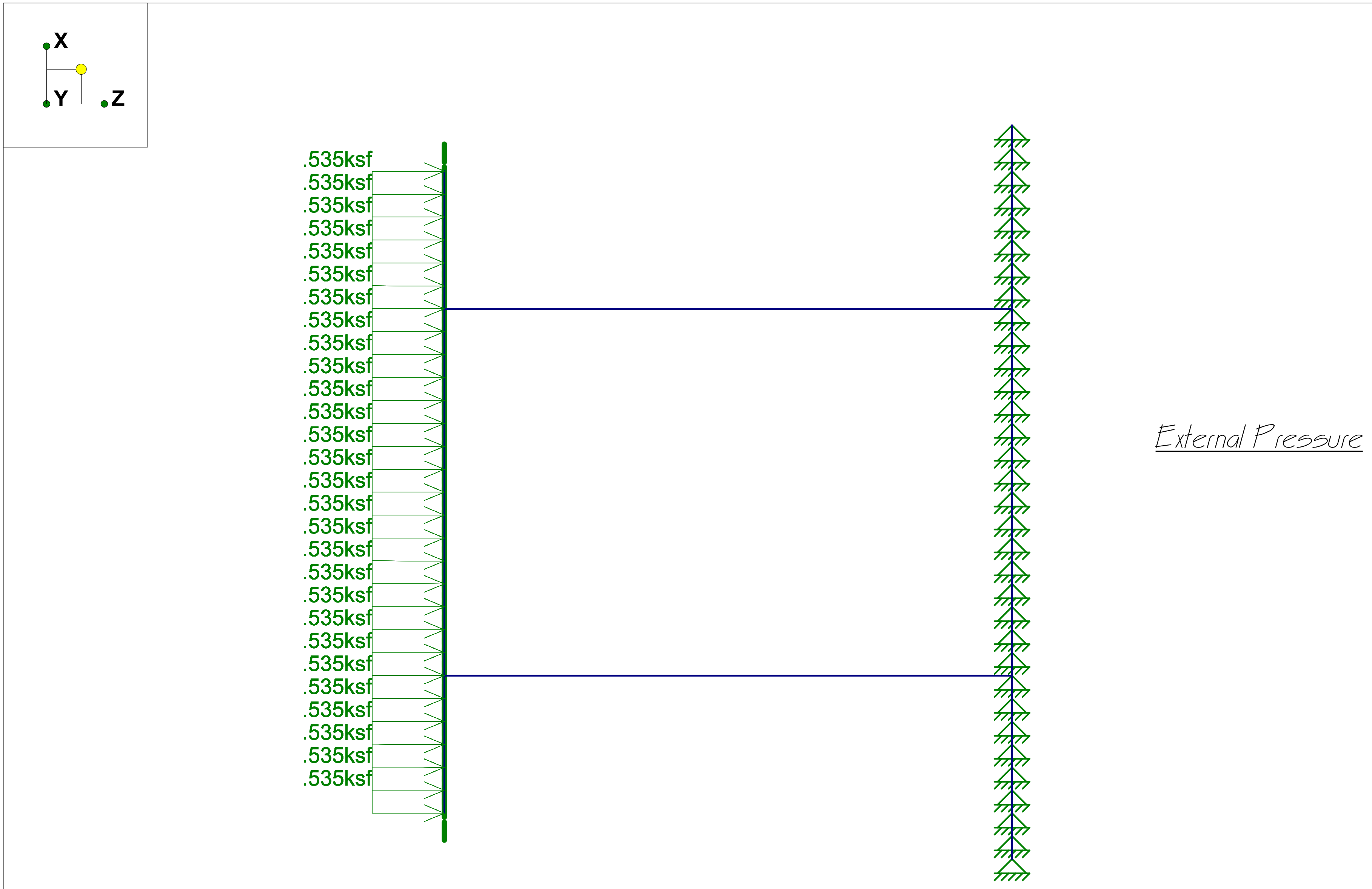
Internal pressure

Loads: BLC 1, EH-rest

Delta Engineers,Inc
YL
2017.478.001

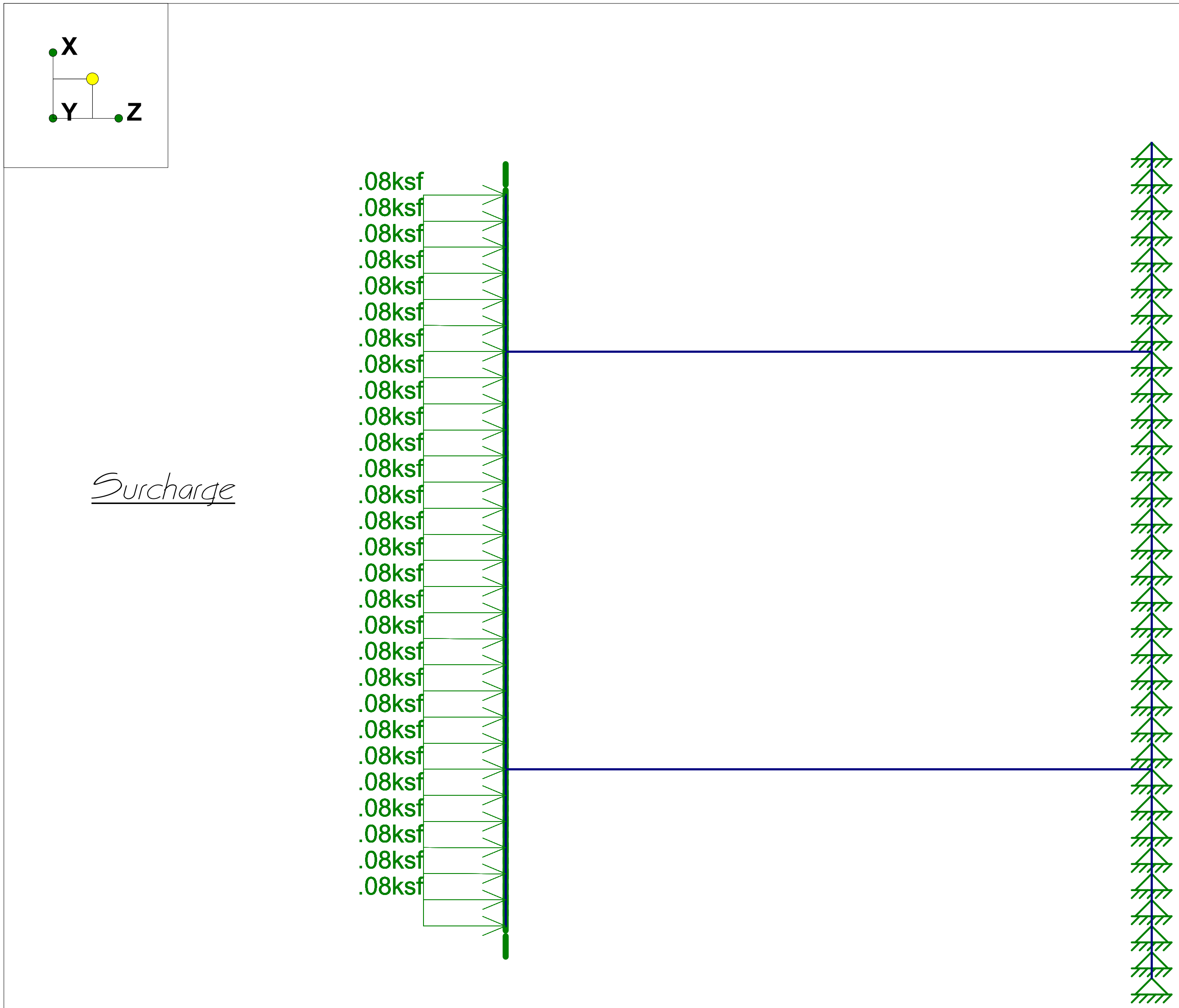
Gravity Wall - 24-86 Blocks

SK - 3
June 15, 2017 at 2:26 PM
24-86 Block.r3d



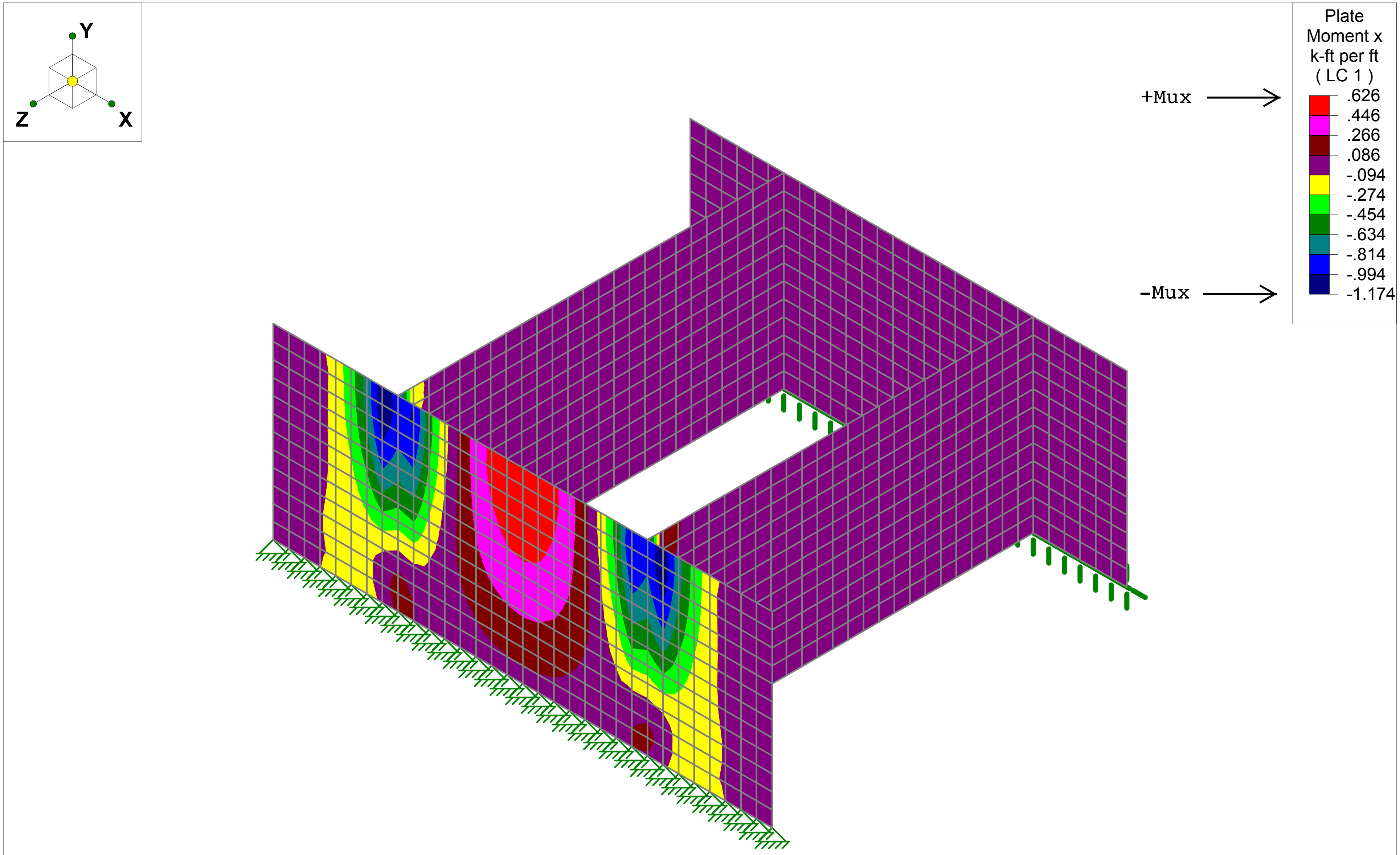
Loads: BLC 2, EH-active

Delta Engineers,Inc	Gravity Wall - 24-86 Blocks	SK - 4
YL		June 15, 2017 at 2:27 PM
2017.478.001		24-86 Block.r3d



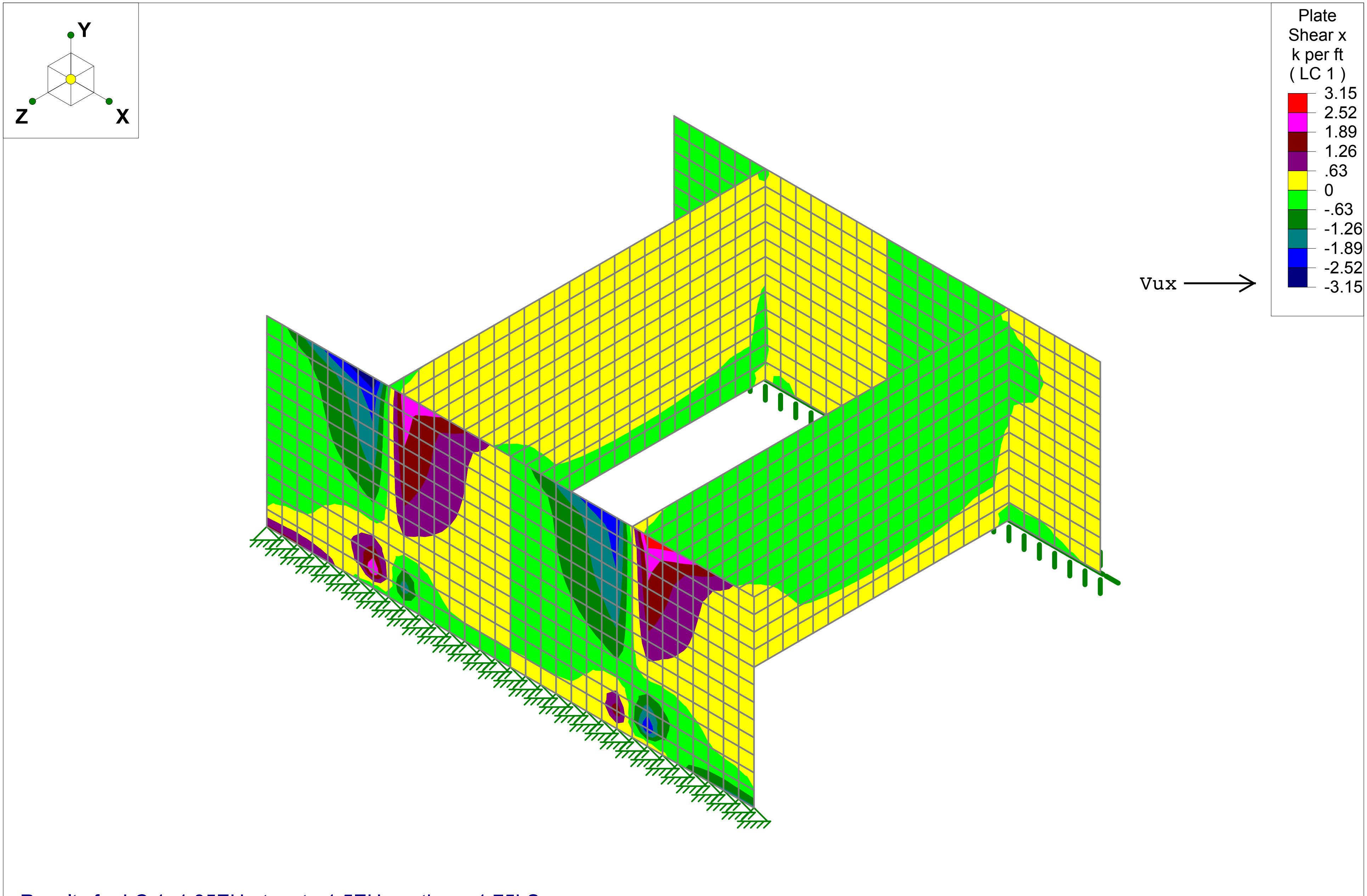
Loads: BLC 3, LS

Delta Engineers,Inc	Gravity Wall - 24-86 Blocks	SK - 5
YL		June 15, 2017 at 2:27 PM
2017.478.001		24-86 Block.r3d



Results for LC 1, 1.35EH-at rest +1.5EH - active + 1.75LS

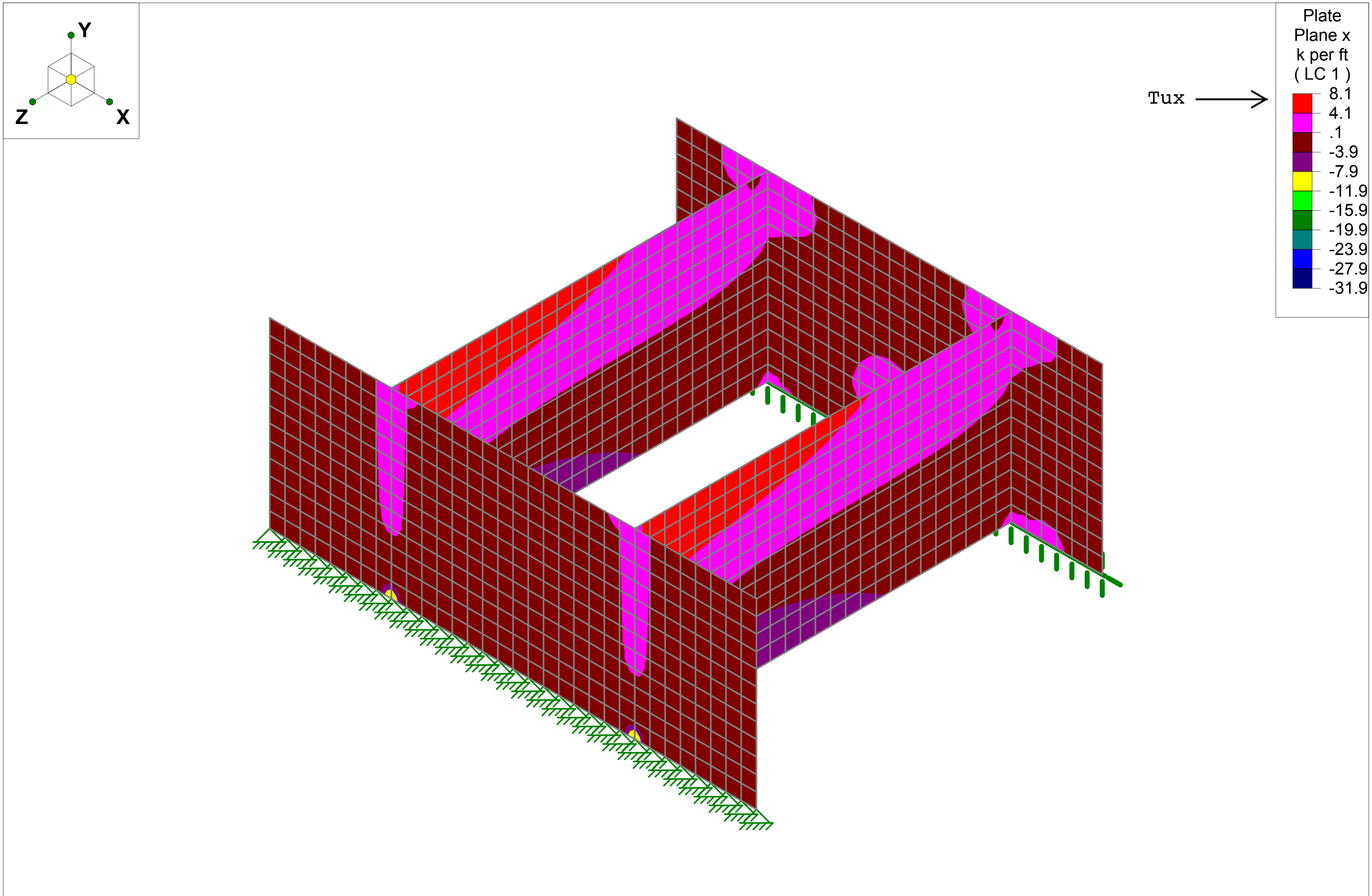
Delta Engineers,Inc		SK - 6
YL	Gravity Wall - 24-86 Blocks	June 15, 2017 at 2:28 PM
2017.478.001		24-86 Block.r3d



Results for LC 1, 1.35EH-at rest +1.5EH - active + 1.75LS

Delta Engineers,Inc	Gravity Wall - 24-86 Blocks	SK - 8
YL		June 15, 2017 at 2:29 PM
2017.478.001		24-86 Block.r3d

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017



Results for LC 1, 1.35EH-at rest +1.5EH - active + 1.75LS

Delta Engineers,Inc	Gravity Wall - 24-86 Blocks	SK - 9
YL		June 15, 2017 at 2:33 PM
2017.478.001		24-86 Block.r3d

Basic Load Cases

	BLC Description	Category	X Gravity	Y Gravity	Z Gravity	Joint	Point	Distributed	Area(Me...	Surface(...
1	EH-rest	None								720
2	EH-active	None								336
3	LS	None								336

Load Combinations

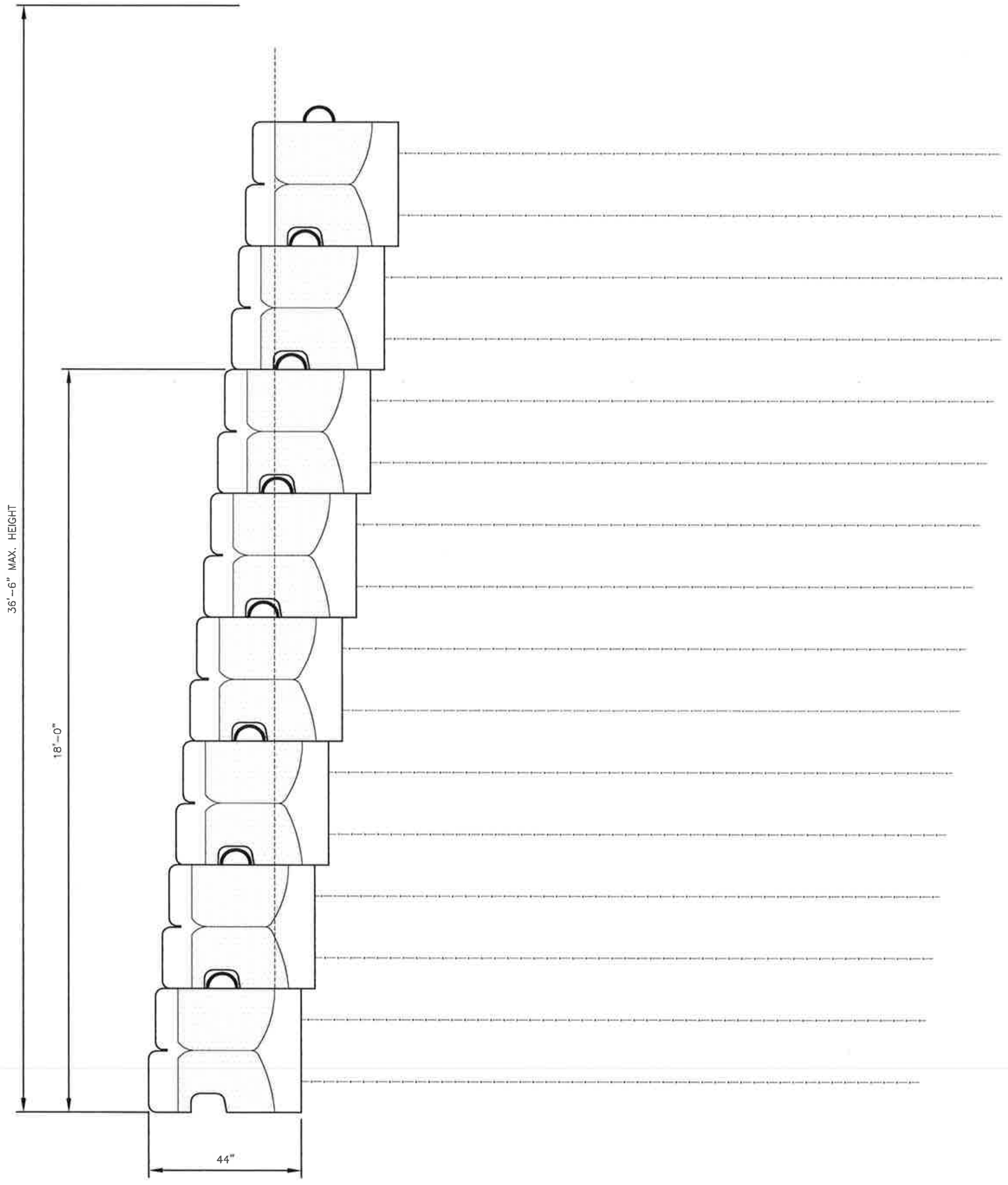
	Description	S...	P...	S...	B...	Factor	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...
1	1.35EH-at rest +1.5EH - active + ..	Yes			1	1.35	2	1.5	3	1.75														
2	EH-at rest +EH - active +LS	Yes			1	1	2	1	3	1														

DELTA
SPECIALTY PRECAST CONCRETE ENGINEERS
860 Hooper Road, Endwell, NY 13760
www.delta-eas.com
Phone: (607) 231-6600
Fax: (607) 231-6650

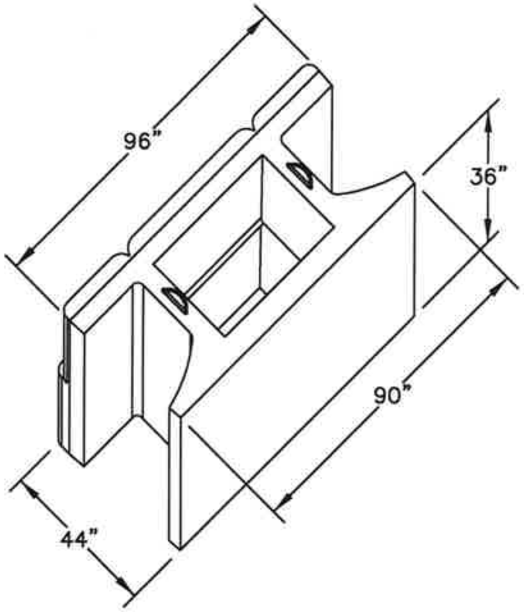
JOB 2017.478.001
DESCRIPTION Reinforced Wall - 24SF
SHEET NO ____ OF ____ SCALE ____
CALCULATED BY YL DATE 6/8/2017
CHECKED BY ____ DATE ____

Reinforce Wall - Maximum 36.5ft Wall Height
24SF Blocks

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017



REINFORCED WALL
24 SF UNIT



REAR VIEW
STONE STRONG 24SF UNIT

NOT TO SCALE

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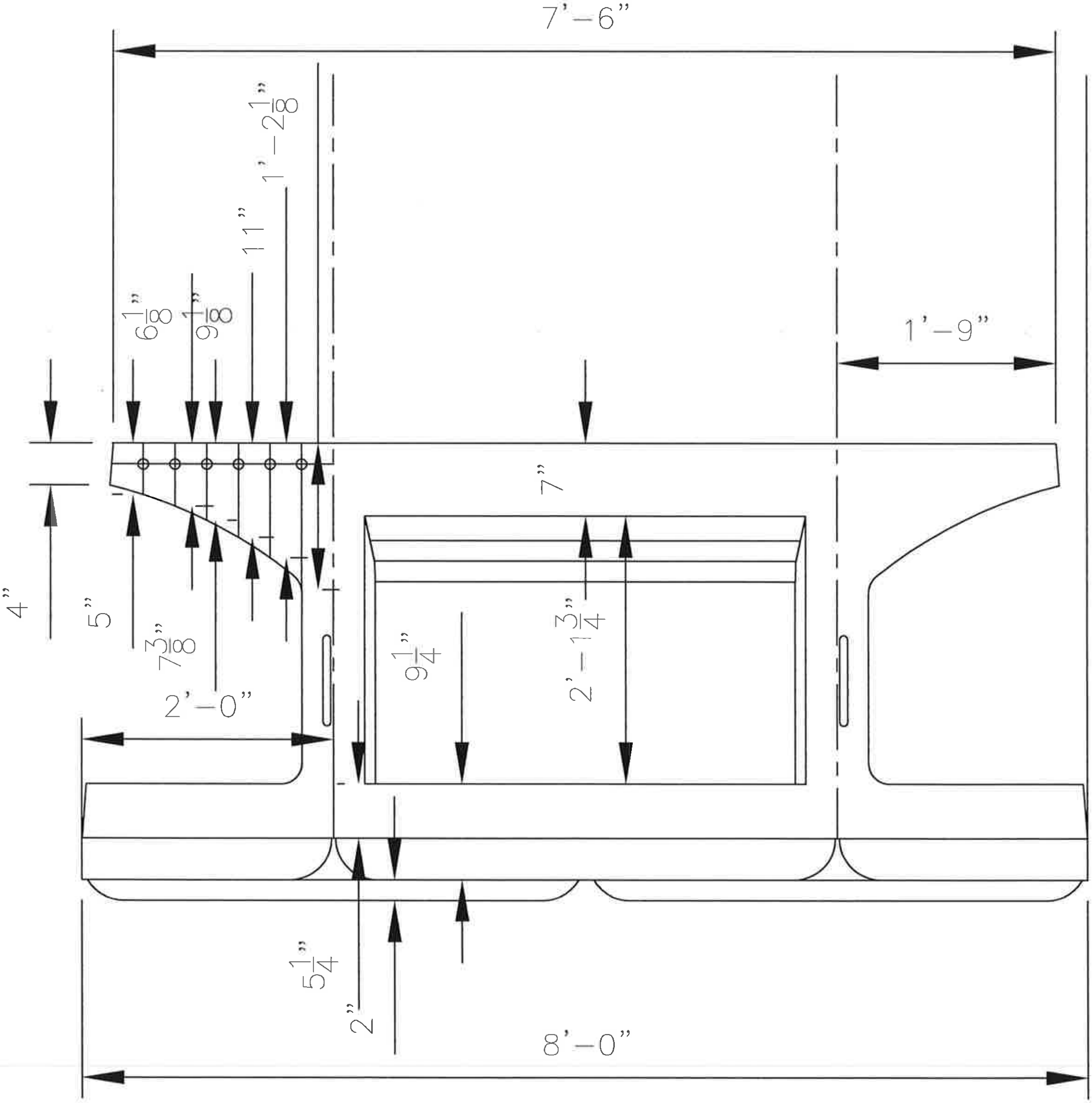
PROJECT

COMPONENTS
STONE STRONG SYSTEMS

DATE: 2/10/16 FILE: 05_Block.24sf.Rear

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017



24 SF UNIT

DELTA
SPECIALTY PRECAST CONCRETE ENGINEERS
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Fax: (607) 231-6650

JOB 2017.478.001
DESCRIPTION Reinforced Wall - 24SF
SHEET NO. OF SCALE
CALCULATED BY YL DATE 6/8/2017
CHECKED BY DATE

Load Calculations - 24 SF Blocks - 36.5' Wall Height

Internal Pressure from Infill

Infill Density = 100 pcf
ko = 0.5
Height to Middle of Bottom Block = 16.5 ft
Internal Pressure (at rest) = 825 psf

External Pressure from Retained Soil

Soil Density = 120 pcf
ka = 0.33
Height to Middle of Bottom Block = 35 ft
External Pressure (at rest) = 1386 psf

Live Load Surcharge = 0 psf

DELTA
SPECIALTY PRECAST CONCRETE ENGINEERS
860 Hooper Road, Endwell, NY 13760
www.delta-eas.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB 2017.478.001
DESCRIPTION Reinforced Wall - 24SF
SHEET NO OF SCALE
CALCULATED BY YL DATE 6/8/2017
CHECKED BY DATE

Risa Results - 24SF - 36.5' Wall Height

fc' = 5000 psi
5*√f'c = 354 psi

Front Face:

-Mu = 1.99 k-ft/ft
Thickness t = 8 in
S = 12 t^2/6= 128 in^3
ϕMn =0.6* 5*√f'c S = 2.26 k-ft/ft OK

+Mu = 0.53 k-ft/ft
Thickness t = 6 in
S = 12 t^2/6= 72 in^3
ϕMn =0.6* 5*√f'c S = 1.27 k-ft/ft OK

Vu = 2.20 k/ft
Thickness t = 8 in
ϕVn =0.6* 4/3*√f'c *12 t = 5.43 k-ft/ft OK

Front Face Reinforcing required for temperature and shrinkage only.

Rear Face:

-Mu = 1.55 k-ft/ft
Thickness t = 8 in
S = 12 t^2/6= 128 in^3
ϕMn =0.6* 5*√f'c S = 2.26 k-ft/ft OK

+Mu = 0.66 k-ft/ft
Thickness t = 7 in
S = 12 t^2/6= 98 in^3
ϕMn =0.6* 5*√f'c S = 1.73 k-ft/ft OK

Vu = 6.52 k/ft
Thickness t = 14.13 in
ϕVn =0.6* 4/3*√f'c *12 t = 9.59 k-ft/ft OK

Rear Face Reinforcing required for temperature and shrinkage only.

JOB 2017.478.001
DESCRIPTION Reinforced Wall - 24SF
SHEET NO OF SCALE
CALCULATED BY YL DATE 6/8/2017
CHECKED BY DATE

Risa Results - 24SF - 36.5' Wall Height

Web

fc' = 5000 psi
5*√f'c = 354 psi

Tu = 9.81 k/ft
Thickness t = 6 in
ϕTn =0.6*5*√f'c *12 t = 15.27 k-ft/ft OK

Web Reinforcing required for temperature and shrinkage only.

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Phone: (607) 231-6600
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JOB 2017.478.001
DESCRIPTION Stonestrong Retaining Wall
SHEET NO OF SCALE
CALCULATED BY YL DATE 6/8/2017
CHECKED BY DATE

Temperature and Shrinkage Reinforcing (AASHTO LRFD 5.10.8)

fy = 60 ksi

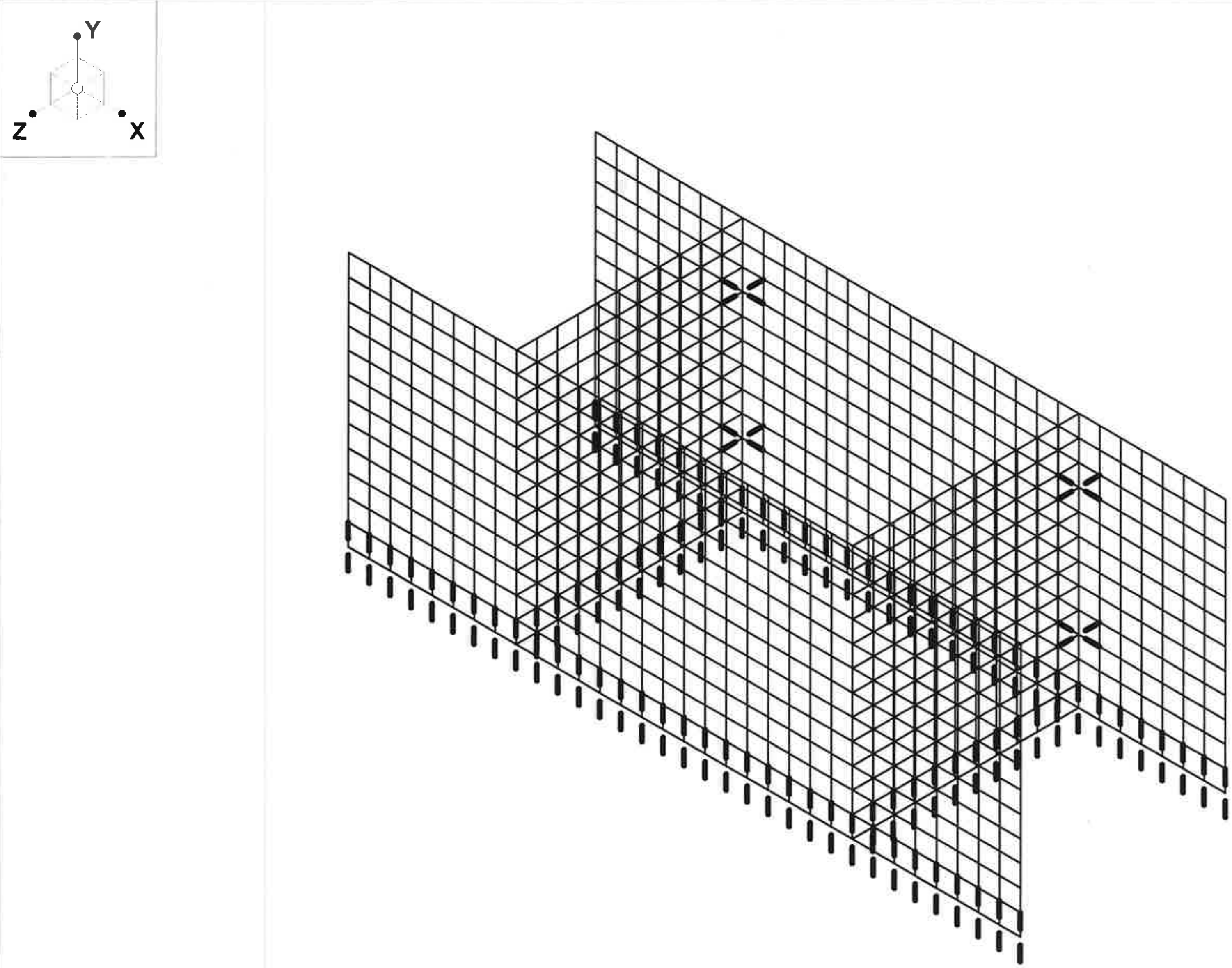
$$As = \frac{1.30\,bh}{2(b+h)Fy}$$

0.11<= As <= 0.6

b = 36 in Least Width of Component Section
h = 6 in Least Thickness of Component Section

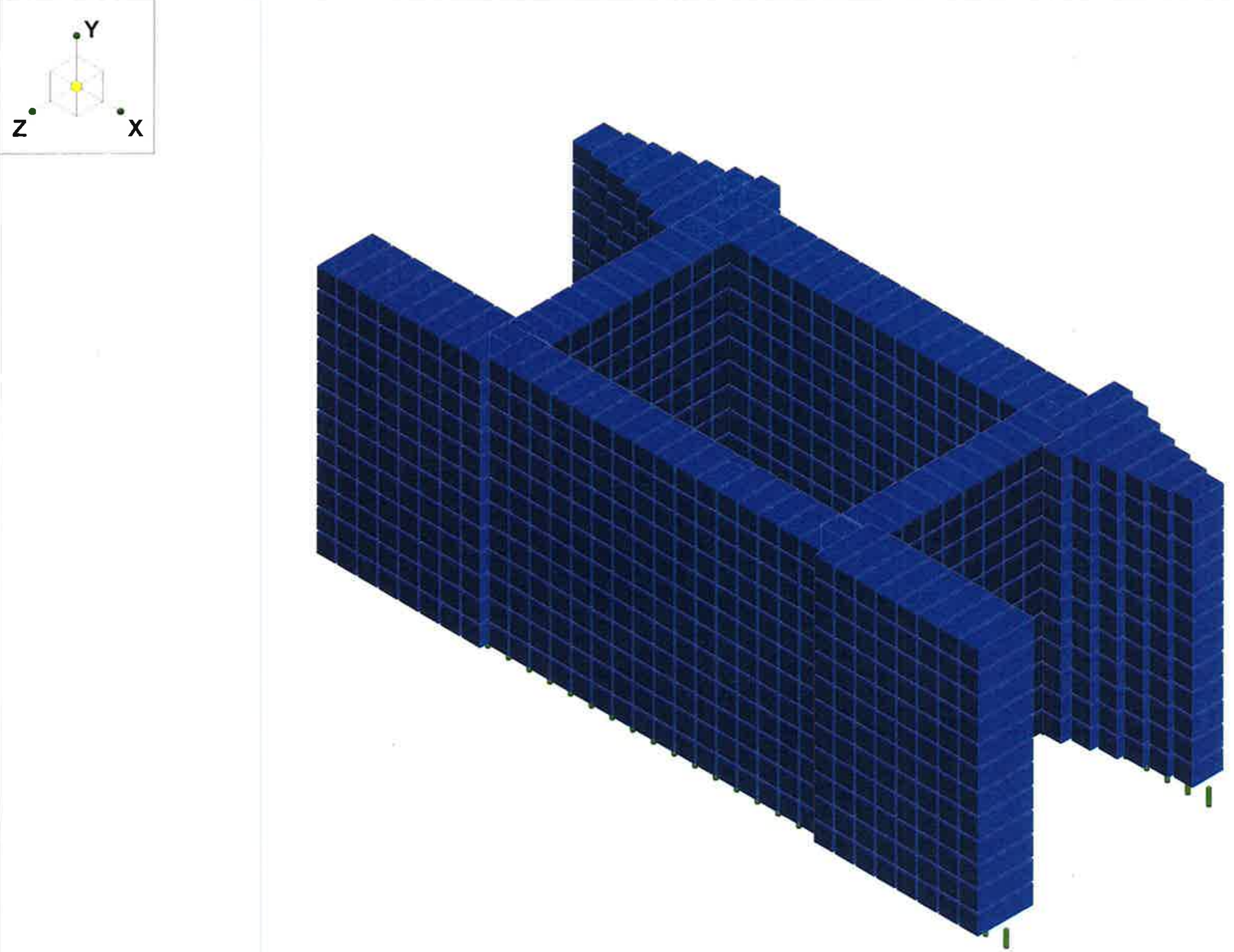
As = 0.11 in^2/ft

Provide W8xW8 - 6x6 Wire Mesh in Front Face & Webs. Bend Web Mesh into Front Face to Form a Standard Hook.



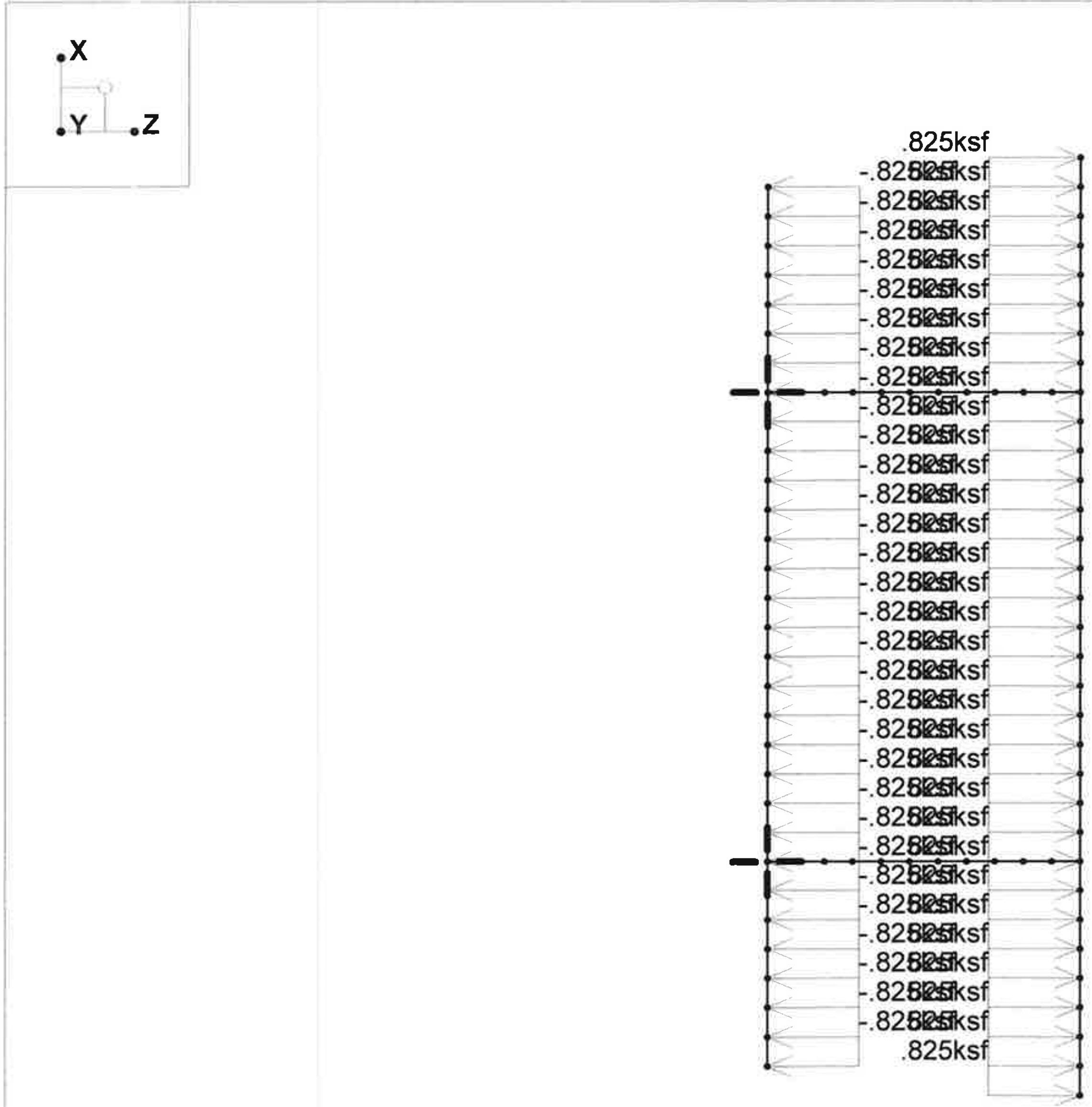
Delta Engineers,Inc	Reinforced Wall - 24 SF Blocks	SK - 1
YL		June 8, 2017 at 4:02 PM
2017.478.001		24 SF Block.r3d

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017



Delta Engineers,Inc	Reinforced Wall - 24 SF Blocks	SK - 2
YL		June 8, 2017 at 4:17 PM
2017.478.001		24 SF Block.r3d

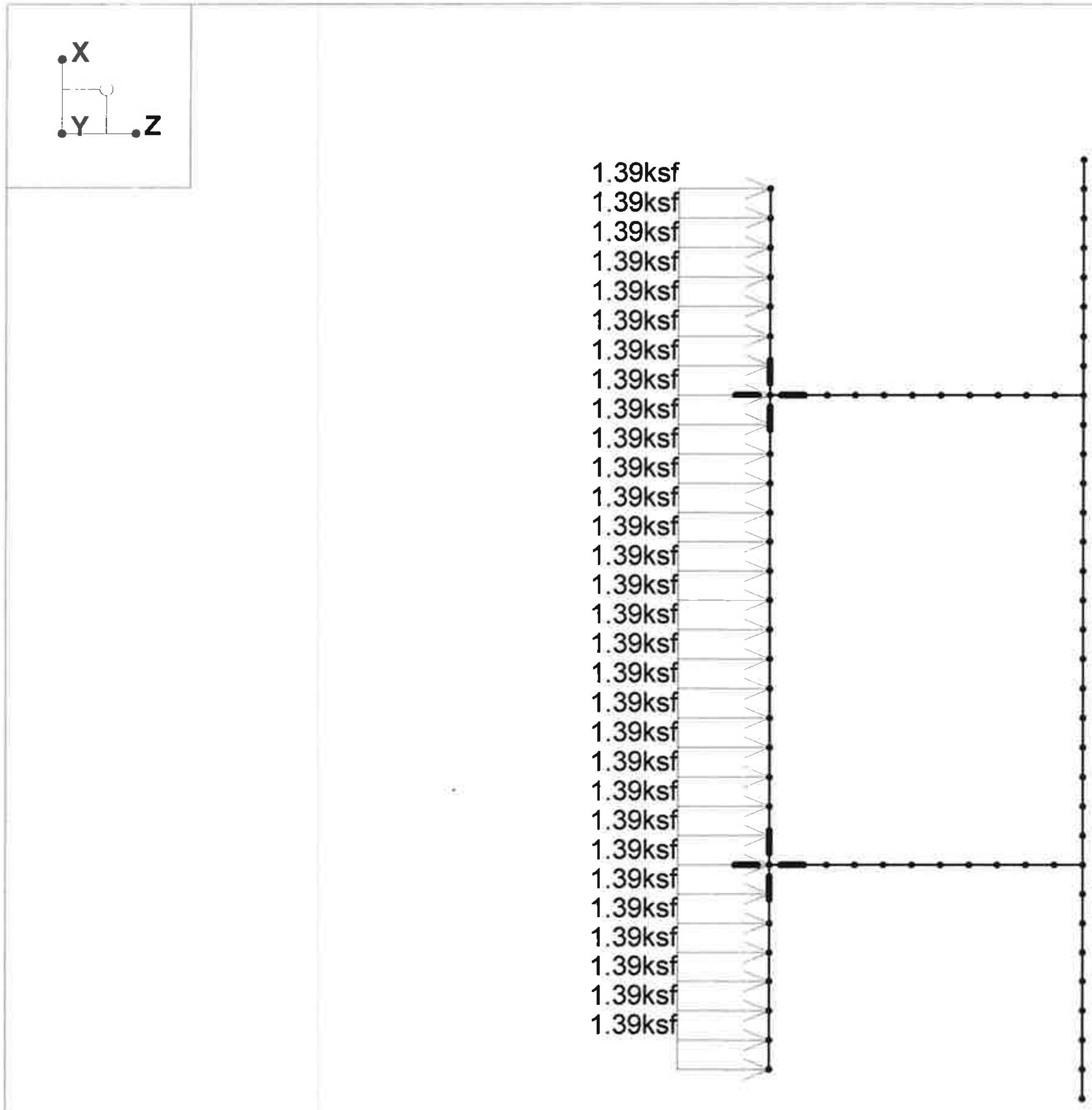
Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017



Internal Pressure

Loads: BLC 1, EH-rest

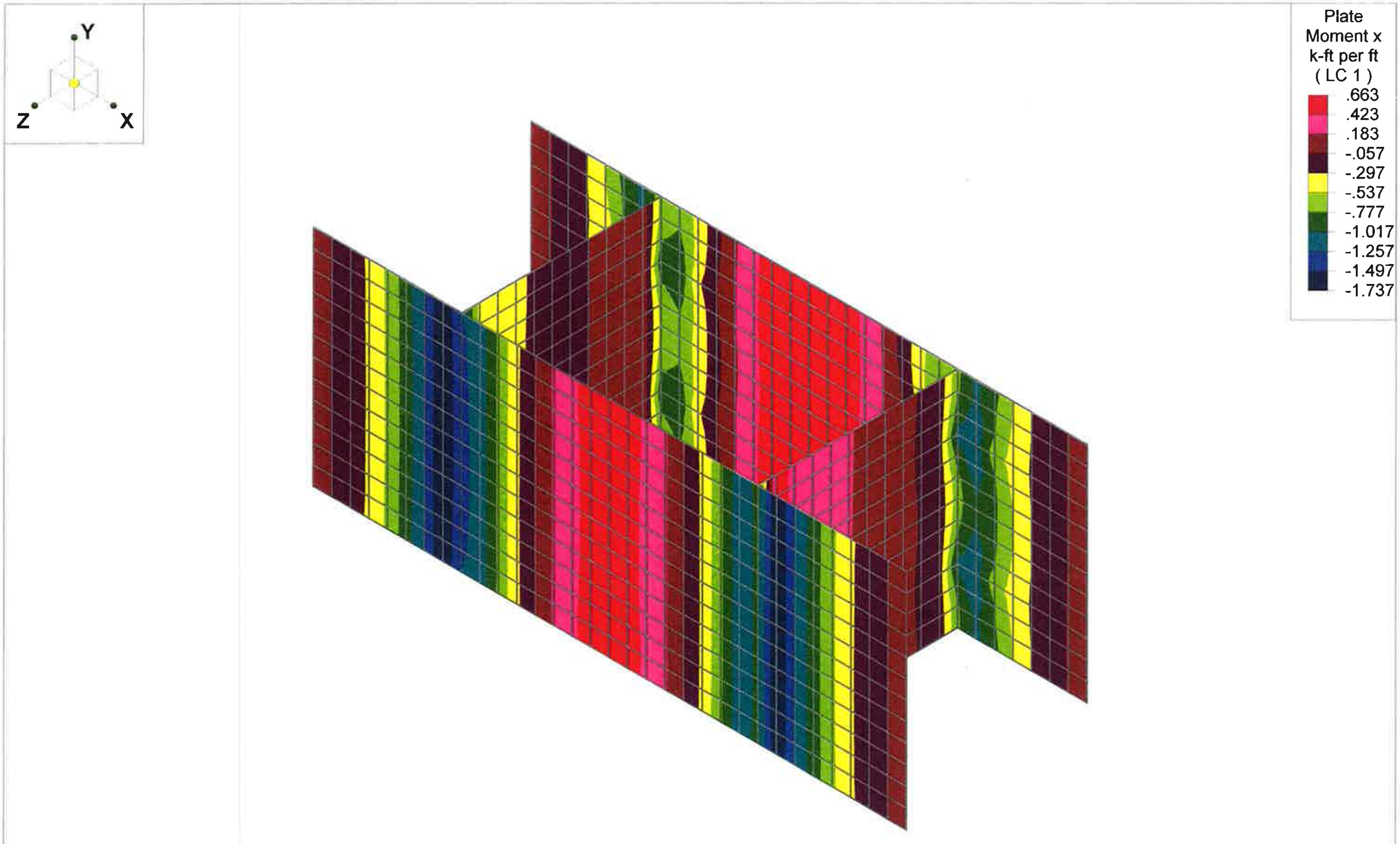
Delta Engineers,Inc	Reinforced Wall - 24 SF Blocks	SK - 3
YL		June 8, 2017 at 4:19 PM
2017.478.001		24 SF Block.r3d



External Pressure

Loads: BLC 2, EH-active

Delta Engineers,Inc	Reinforced Wall - 24 SF Blocks	SK - 4
YL		June 8, 2017 at 4:20 PM
2017.478.001		24 SF Block.r3d



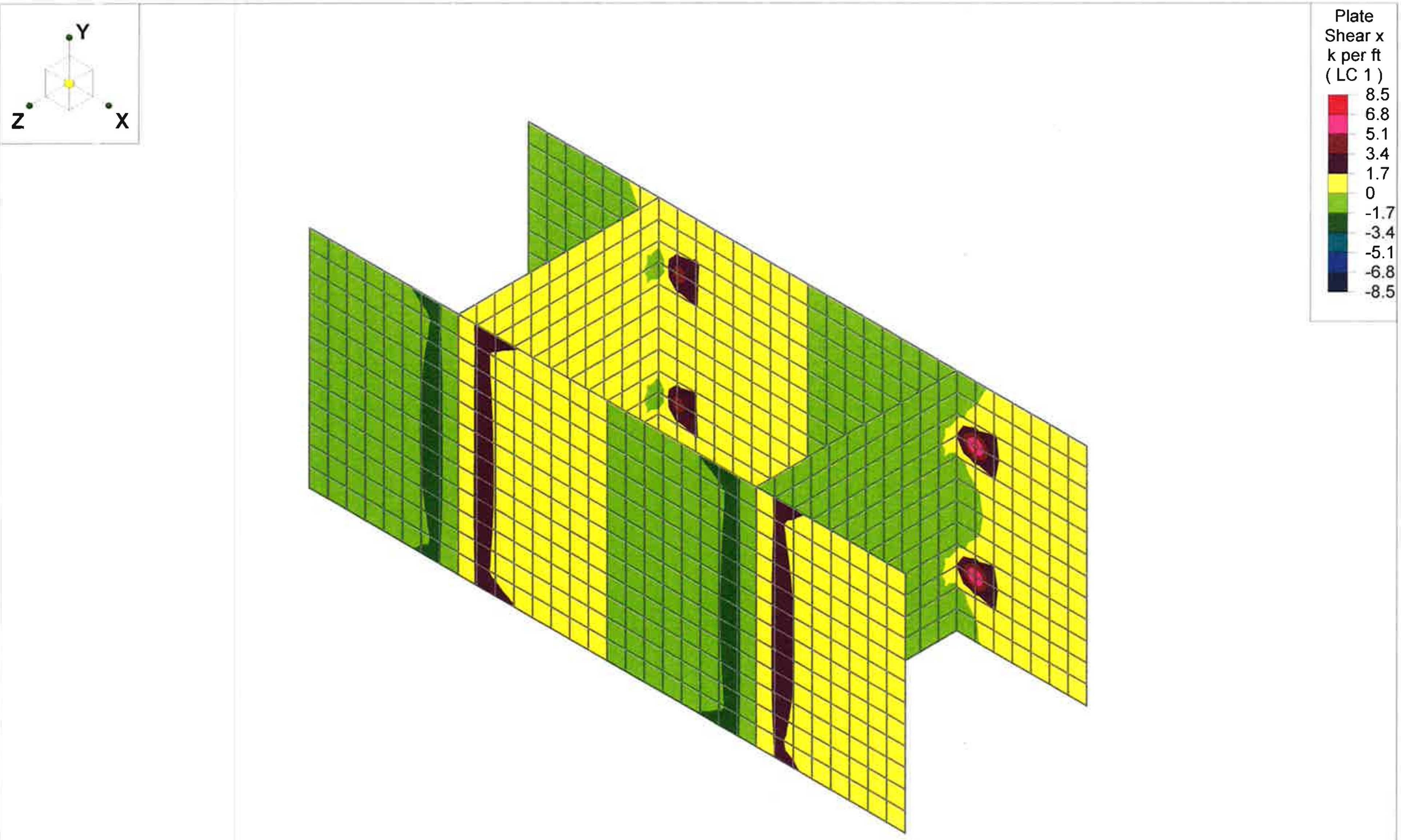
Results for LC 1, 1.35EH-at rest +1.5EH - active + 1.75LS

Delta Engineers,Inc
YL
2017.478.001

Reinforced Wall - 24 SF Blocks

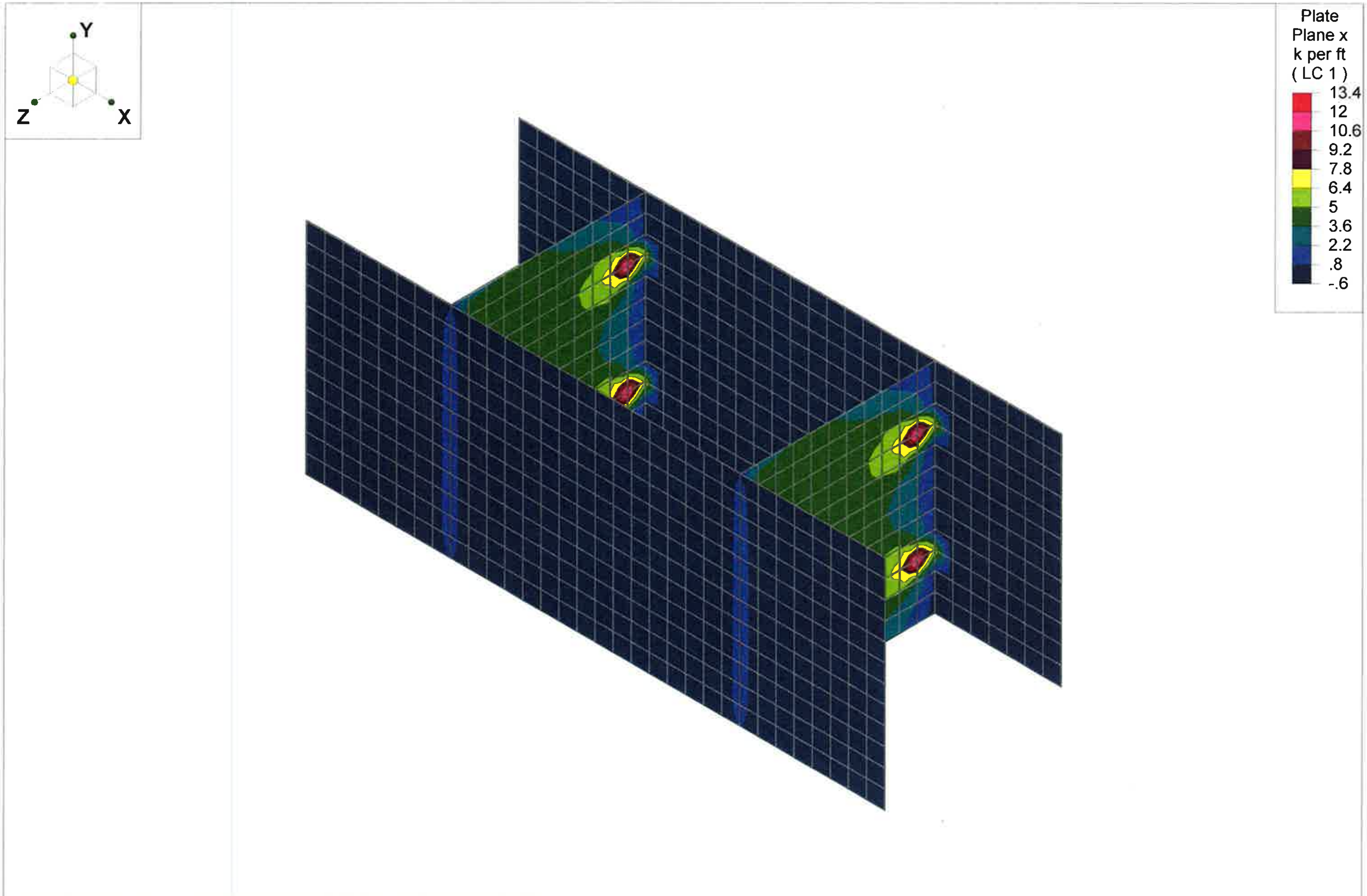
SK - 5
June 8, 2017 at 4:21 PM
24 SF Block.r3d

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017



Results for LC 1, 1.35EH-at rest +1.5EH - active + 1.75LS

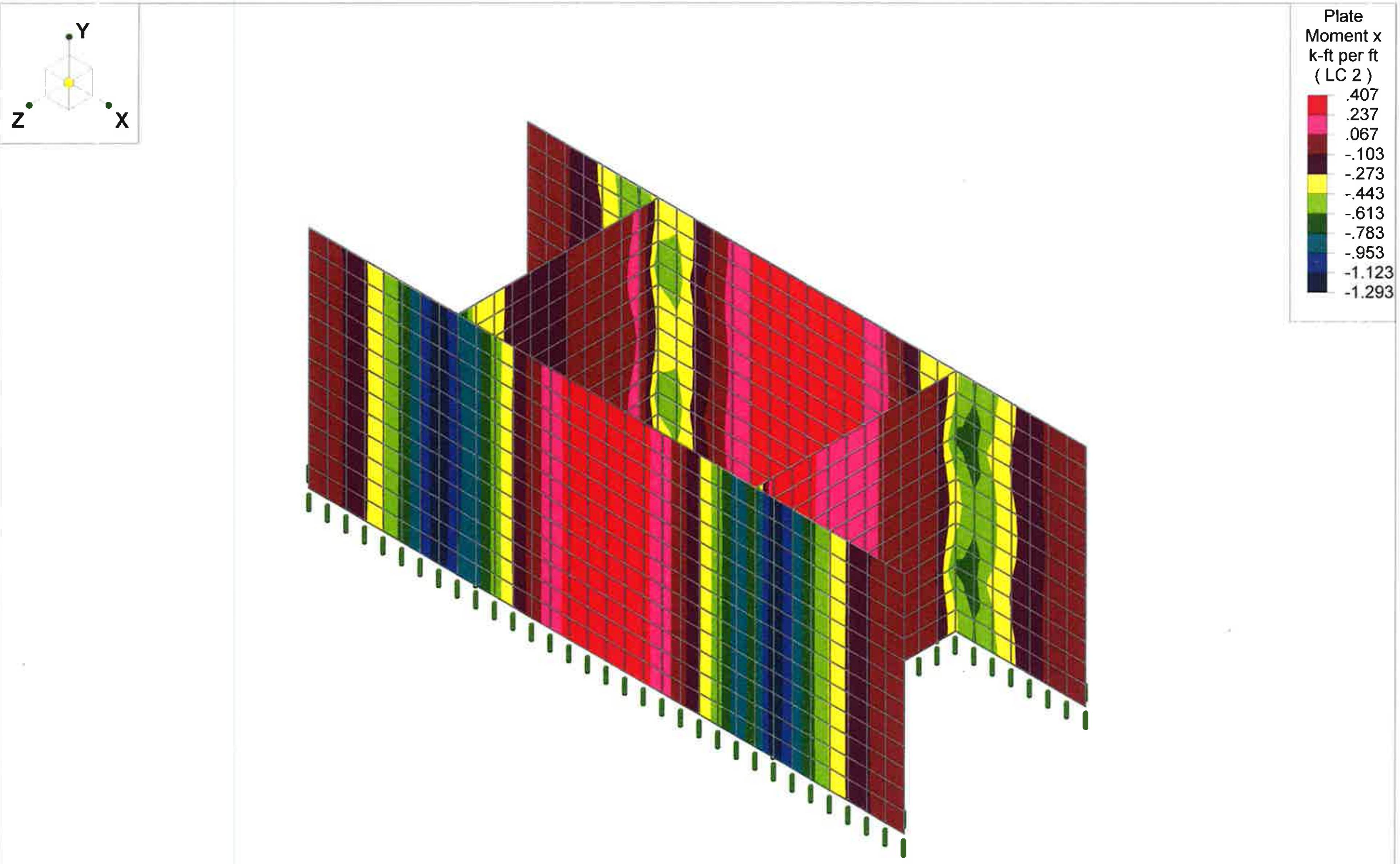
Delta Engineers,Inc	Reinforced Wall - 24 SF Blocks	SK - 6
YL		June 8, 2017 at 4:21 PM
2017.478.001		24 SF Block.r3d



Results for LC 1, 1.35EH-at rest +1.5EH - active + 1.75LS

Delta Engineers,Inc	Reinforced Wall - 24 SF Blocks	SK - 7
YL		June 8, 2017 at 4:22 PM
2017.478.001		24 SF Block.r3d

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017



Results for LC 2, EH-at rest +EH - active +LS

Delta Engineers,Inc	Reinforced Wall - 24 SF Blocks	SK - 8
YL		June 8, 2017 at 4:51 PM
2017.478.001		24 SF Block.r3d

RISA

Company : Delta Engineers,Inc
Designer : YL
Job Number : 2017.478.001
Model Name : Reinforced Wall - 24 SF Blocks

June 9, 2017
11:45 AM
Checked By:_____

Basic Load Cases

	BLC Description	Category	X Gravity	Y Gravity	Z Gravity	Joint	Point	Distributed	Area(Me...	Surface(...
1	EH-rest	None								744
2	EH-active	None								360
3	LS	None								

Load Combinations

	Description	S...	P...	S...	B...	Factor	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...
1	1.35EH-at rest +1.5EH - active + ...	Yes			1	1.35	2	1.5	3	1.75														
2	EH-at rest +EH - active +LS	Yes			1	1	2	1	3	1														

Plate Forces (per ft) (By Combination) FRONT FACE MAX. +Mux

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P372	.168	-.038	.533	.011	-.004	-.206	0	0
2	1	P373	-.168	-.038	.533	.011	.004	-.206	0	0
3	1	P548	.168	.038	.533	.01	.004	-.3	-.09	0
4	1	P549	-.168	.038	.533	.01	-.004	-.3	-.09	0
5	1	P532	.135	.053	.533	.032	.006	-.3	-.087	0
6	1	P533	-.135	.053	.533	.032	-.006	-.3	-.087	0
7	1	P389	-.135	-.054	.533	.032	.006	-.237	0	0
8	1	P388	.135	-.054	.533	.032	-.006	-.237	0	0
9	1	P517	-.132	.04	.526	.052	-.004	-.301	-.081	0
10	1	P516	.132	.04	.526	.052	.004	-.301	-.081	0

Plate Forces (per ft) (By Combination)

FRONT FACE. MAX. – Mux

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P64	-2.197	-.003	-1.988	-.256	0	.054	-.153	-.076
2	1	P152	2.197	-.003	-1.988	-.256	0	.054	-.153	.076
3	1	P72	-2.2	-.052	-1.988	-.248	.005	.062	-.165	-.067
4	1	P160	2.2	-.052	-1.988	-.248	-.005	.062	-.165	.067
5	1	P56	-2.189	.041	-1.986	-.252	-.004	.047	-.137	-.086
6	1	P144	2.189	.041	-1.986	-.252	.004	.047	-.137	.086
7	1	P80	-2.191	-.116	-1.984	-.226	.01	.069	-.176	-.06
8	1	P168	2.191	-.116	-1.984	-.226	-.01	.069	-.176	.06
9	1	P48	-2.176	.085	-1.983	-.237	-.008	.039	-.116	-.095
10	1	P136	2.176	.085	-1.983	-.237	.008	.039	-.116	.095

Plate Forces (per ft) (By Combination)

FRONT FACE MAX Qux

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P72	-2.2	-.052	-1.988	-.248	.005	.062	-.165	-.067
2	1	P160	2.2	-.052	-1.988	-.248	-.005	.062	-.165	.067
3	1	P64	-2.197	-.003	-1.988	-.256	0	.054	-.153	-.076
4	1	P152	2.197	-.003	-1.988	-.256	0	.054	-.153	.076
5	1	P80	-2.191	-.116	-1.984	-.226	.01	.069	-.176	-.06
6	1	P168	2.191	-.116	-1.984	-.226	-.01	.069	-.176	.06
7	1	P56	-2.189	.041	-1.986	-.252	-.004	.047	-.137	-.086
8	1	P144	2.189	.041	-1.986	-.252	.004	.047	-.137	.086
9	1	P48	-2.176	.085	-1.983	-.237	-.008	.039	-.116	-.095
10	1	P136	2.176	.085	-1.983	-.237	.008	.039	-.116	.095

Plate Forces (per ft) (By Combination)

REAR FACE. MAX. +Mux

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P723	.119	.028	$\boxed{.659}$	.017	.003	.045	-.043	0
2	1	P724	-.119	.028	.659	.017	-.003	.045	-.043	0
3	1	P579	.119	-.027	.659	.016	-.003	.087	0	0
4	1	P580	-.119	-.027	.659	.016	.003	.087	0	0
5	1	P740	-.137	.02	.657	.006	-.002	.044	-.044	0
6	1	P739	.137	.02	.657	.006	.002	.044	-.044	0
7	1	P563	.136	-.019	.657	.006	-.002	.097	0	0
8	1	P564	-.136	-.019	.657	.006	.002	.097	0	0
9	1	P595	.118	-.021	.656	.027	-.002	.08	-.009	0
10	1	P596	-.118	-.021	.656	.027	.002	.08	-.009	0

Plate Forces (per ft) (By Combination) REBAR FACE . MAX . - Mux

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P296	6.522	8.127	$\boxed{-1.55}$	-1.686	.401	.102	1.28	.048
2	1	P219	-6.522	8.127	-1.55	-1.686	-.401	.102	1.28	-.048
3	1	P303	6.456	-8.508	-1.542	-1.619	-.392	.13	1.157	.271
4	1	P226	-6.456	-8.508	-1.542	-1.619	.392	.13	1.157	-.271
5	1	P345	6.335	-8.006	-1.535	-1.579	-.39	.246	.823	.155
6	1	P268	-6.335	-8.006	-1.535	-1.579	.39	.246	.823	-.155
7	1	P338	6.297	8.337	-1.525	-1.525	.383	.244	.867	.024
8	1	P261	-6.297	8.337	-1.525	-1.525	-.383	.244	.867	-.024
9	1	P603	-4.217	4.016	-1.291	-.432	-.019	-.162	.657	.185
10	1	P588	4.217	4.016	-1.291	-.432	.019	-.162	.657	-.185

Plate Forces (per ft) (By Combination)

REAR FACE. MAX. Qux

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P219	-6.522	8.127	-1.55	-1.686	-.401	.102	1.28	-.048
2	1	P296	6.522	8.127	-1.55	-1.686	.401	.102	1.28	.048
3	1	P226	-6.456	-8.508	-1.542	-1.619	.392	.13	1.157	-.271
4	1	P303	6.456	-8.508	-1.542	-1.619	-.392	.13	1.157	.271
5	1	P268	-6.335	-8.006	-1.535	-1.579	.39	.246	.823	-.155
6	1	P345	6.335	-8.006	-1.535	-1.579	-.39	.246	.823	.155
7	1	P261	-6.297	8.337	-1.525	-1.525	-.383	.244	.867	-.024
8	1	P338	6.297	8.337	-1.525	-1.525	.383	.244	.867	.024
9	1	P588	4.217	4.016	-1.291	-.432	.019	-.162	.657	-.185
10	1	P603	-4.217	4.016	-1.291	-.432	-.019	-.162	.657	.185

Plate Primary Data

PLATE THICKNESS

	Label	A Joint	B Joint	C Joint	D Joint	Material	Thickness[in]
208	P214	N258	N259	N267	N266	gen_Conc3NW	5.56
209	P215	N259	N260	N268	N267	gen_Conc3NW	6.75
210	P216	N260	N261	N269	N268	gen_Conc3NW	8.25
211	P217	N261	N262	N270	N269	gen_Conc3NW	10.06
212	P218	N262	N263	N271	N270	gen_Conc3NW	12.56
213	P219	N263	N264	N272	N271	gen_Conc3NW	14.125
214	P220	N265	N266	N274	N273	gen_Conc3NW	4.5
215	P221	N266	N267	N275	N274	gen_Conc3NW	5.56
216	P222	N267	N268	N276	N275	gen_Conc3NW	6.75
217	P223	N268	N269	N277	N276	gen_Conc3NW	8.25
218	P224	N269	N270	N278	N277	gen_Conc3NW	10.06

Plate Forces (per ft) (By Combination)

WEB. MAX. Fux

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P790	.387	.081	.212	.044	.006	9.812	.818	5.036
2	1	P921	-.387	-.081	-.212	-.044	-.006	9.812	.818	5.036
3	1	P845	.389	-.092	.21	.044	-.006	9.799	.813	-4.417
4	1	P976	-.389	.092	-.21	-.044	.006	9.799	.813	-4.417
5	1	P856	.398	.078	.213	.043	.009	9.726	.793	4.83
6	1	P987	-.398	-.078	-.213	-.043	-.009	9.726	.793	4.83
7	1	P779	.396	-.066	.215	.043	-.009	9.69	.802	-4.288
8	1	P910	-.396	.066	-.215	-.043	.009	9.69	.802	-4.288
9	1	P789	.322	.033	.12	.023	-.001	6.913	-.872	1.739
10	1	P920	-.322	-.033	-.12	-.023	.001	6.913	-.872	1.739

DELTA
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860 Hooper Road, Endwell, NY 13760
www.delta-eas.com
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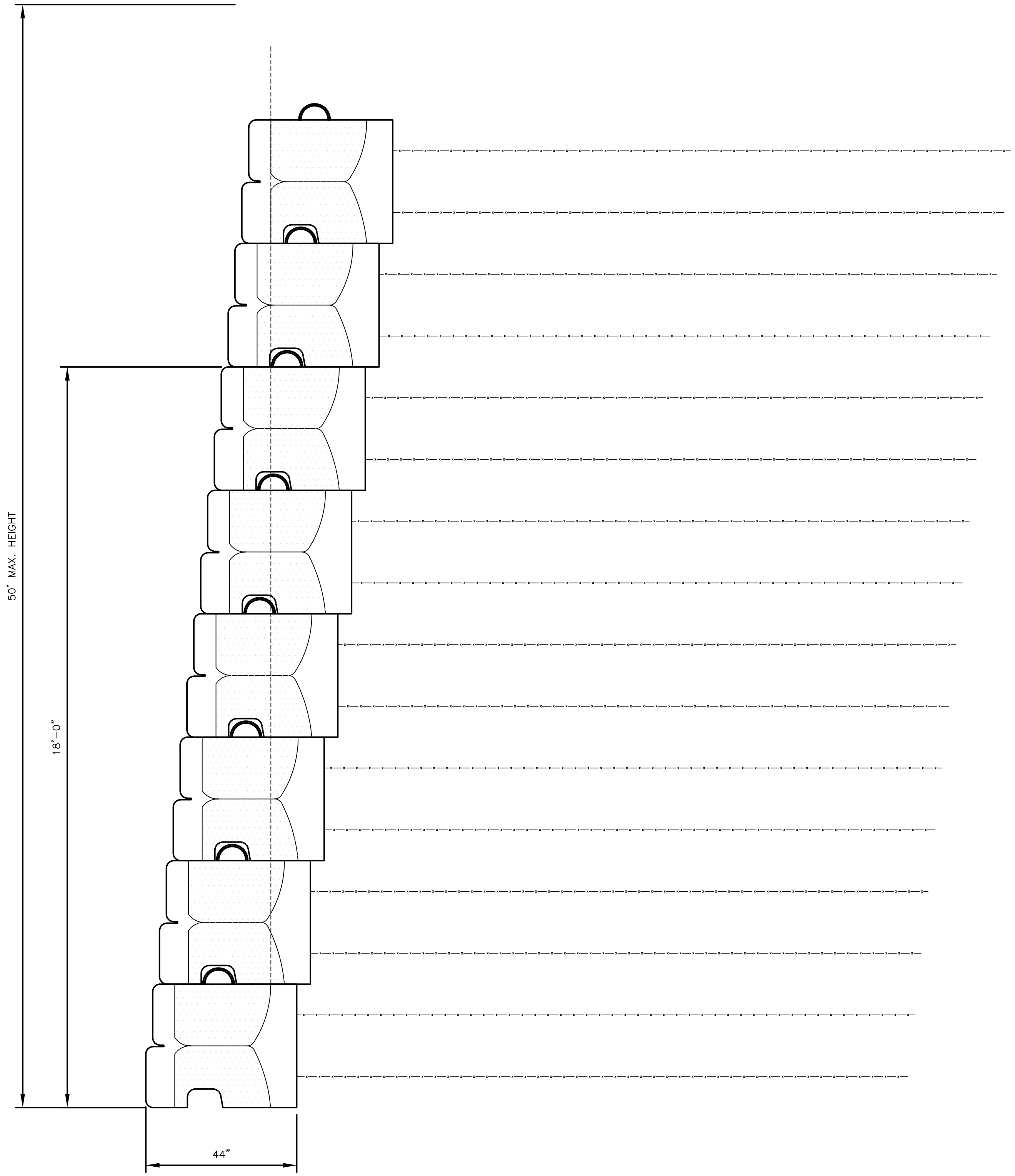
Fax: (607) 231-6650

JOB 2017.478.001
DESCRIPTION Reinforced Wall - 24SF - 50ft
SHEET NO. OF SCALE
CALCULATED BY YL DATE 6/8/2017
CHECKED BY DATE

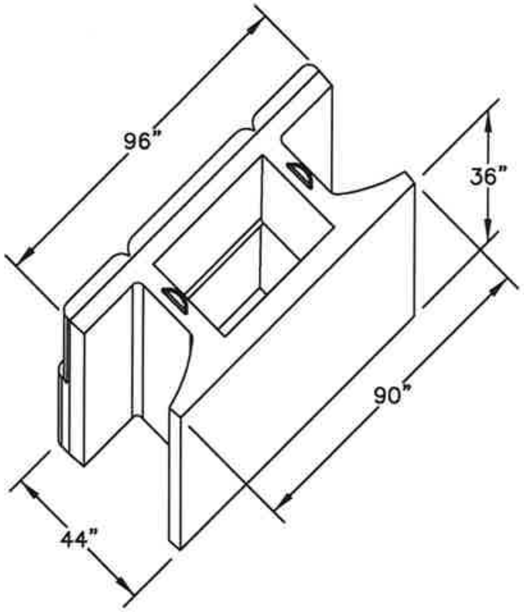
Reinforce Wall - Maximum 50ft Wall Height
24SF Blocks

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017



REINFORCED WALL – 50' MAX. HEIGHT
24 SF UNIT

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017



REAR VIEW
STONE STRONG 24SF UNIT

NOT TO SCALE

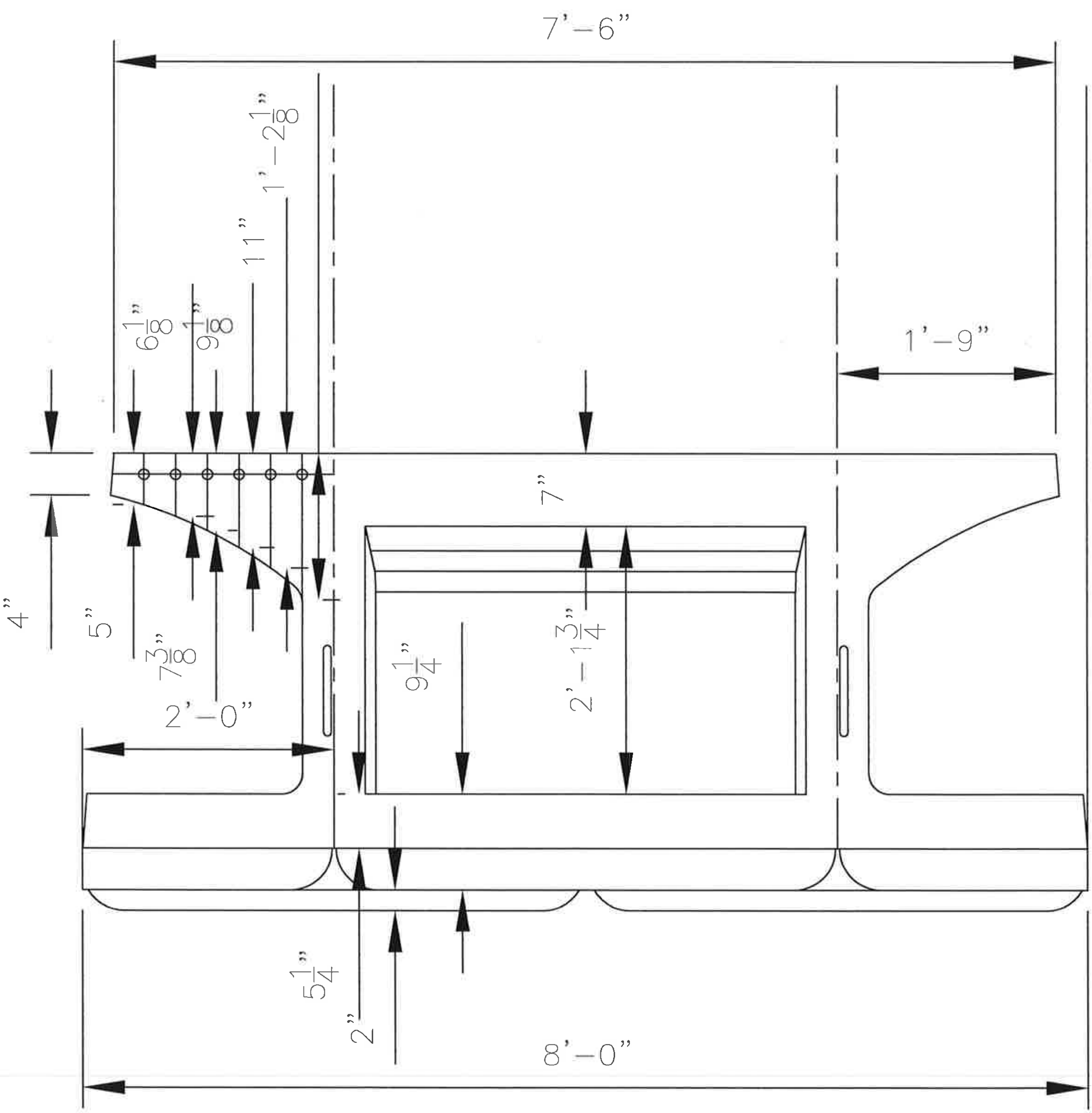
STONE STRONG SYSTEMS®
www.stonestrong.com

PROJECT

COMPONENTS
STONE STRONG SYSTEMS

DATE: 2/10/16 FILE: 05_Block.24sf.Rear

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017



24 SF UNIT

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Phone: (607) 231-6600
Fax: (607) 231-6650

JOB 2017.478.001
DESCRIPTION Reinforced Wall - 24SF - 50ft
SHEET NO. OF SCALE
CALCULATED BY YL DATE 11/16/2017
CHECKED BY DATE

Load Calculations - 24 SF Blocks - 50' Wall Height

Internal Pressure from Infill

Infill Density =	100	pcf
ko =	0.5	
Height to Middle of Bottom Block =	16.5	ft
Internal Pressure (at rest) =	825	psf

External Pressure from Retained Soil

Soil Density =	120	pcf
ka =	0.33	
Height to Middle of Bottom Block =	48.5	ft
External Pressure (active) =	1921	psf

Live Load Surcharge = 0 psf

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017

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JOB 2017.478.001
DESCRIPTION Reinforced Wall - 24SF - 50ft
SHEET NO. ____ OF ____ SCALE ____
CALCULATED BY YL DATE 6/8/2017
CHECKED BY ____ DATE ____

Risa Results - 24SF - 50' Wall Height

fc' = 5000 psi
5*√f'c = 354 psi

Front Face:

-Mu = 1.99 k-ft/ft
Thickness t = 8 in
$S = 12\ t^2/6=$ 128 in^3
ϕMn =0.6* 5*√f'c S = 2.26 k-ft/ft OK

+Mu = 0.55 k-ft/ft
Thickness t = 6 in
$S = 12\ t^2/6=$ 72 in^3
ϕMn =0.6* 5*√f'c S = 1.27 k-ft/ft OK

Vu = 2.20 k/ft
Thickness t = 8 in
ϕVn =0.6* 4/3*√f'c *12 t = 5.43 k-ft/ft OK

Front Face Reinforcing required for temperature and shrinkage only.

Rear Face:

-Mu = 2.70 k-ft/ft
Thickness t = 7 in
$S = 12\ t^2/6=$ 98 in^3
ϕMn =0.6* 5*√f'c S = 1.73 k-ft/ft NG PROVIDE REINFORCING SEE ATTACHED.

+Mu = 1.12 k-ft/ft
Thickness t = 7 in
$S = 12\ t^2/6=$ 98 in^3
ϕMn =0.6* 5*√f'c S = 1.73 k-ft/ft OK

Vu = 9.60 k/ft
Thickness t = 14.13 in
ϕVn =0.6* 4/3*√f'c *12 t = 9.59 k-ft/ft ~~NG~~ SAY OK

Rear Face Reinforcing required for strength.

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017

JOB 2017.478.001
DESCRIPTION Reinforced Wall - 24SF - 50ft
SHEET NO. OF SCALE
CALCULATED BY YL DATE 6/8/2017
CHECKED BY DATE

Risa Results - 24SF - 50' Wall Height

Web

fc' = 5000 psi
5*√f'c = 354 psi

Tu = 11.75 k/ft
Thickness t = 6 in
ϕTn =0.6*5*√f'c *12 t = 15.27 k-ft/ft OK

Web Reinforcing required for temperature and shrinkage only.

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017

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JOB 2017.478.001
DESCIPTION Stonestrong Retaining Wall
SHEET NO ______ OF ______ SCALE ______
CALCULATED BY YL DATE 11/20/2017
CHECKED BY ______ DATE ______

24SF Block Rear Face Reinforcing

AASHTO LRFD - 7th Edition

Limit State: Strength 1

MATERIAL PROPERTIES:

1	Concrete Strength, F'c	5	ksi
2	Reinforcing Steel Yield, Fy	60	ksi
3	Concrete Unit Weight	150	pcf
4	Soil Unit Weight	120	pcf

Member Design Width b = 12.00 in
Member Thickness Ts = 7.00 in
Bar Cover = 2.00 in
Bar Size = 4
de=Ts-Cov-Bar Size/2 = 4.75 in

$E_c = 120{,}000\ K_1\ wc^{2.0}\ f'c^{0.33} =$ 4.59E+03 ksi
Es = 29000 ksi
n = Es / Ec = 6.32
0.65 < β1 < 0.85 = 0.80

$$\rho_b = \frac{0.85\beta_1 \bullet f'c}{f_y} \bullet \left[\frac{87{,}000}{87{,}000 + f_y}\right] = \quad 0.0335$$

fr = .24 * λ * √f'c = 0.54 ksi AASHTO 5.7.3.3

Capacity Reduction Factors
($\phi M = 0.75 + 0.15[(\varepsilon_t - \varepsilon_{cl})/(\varepsilon_{tl} - \varepsilon_{cl})]$, 0.75min, 0.9max, Fig. C5.5.4.2.1-1)

Unfactored Moment, Ma = 1.07 kip-ft
Design Ultimate Moment, Mu = 2.70 kip-ft
Ultimate Shear, Vu = kips

Moment, ΦM = 0.9
Shear, ΦV = 0.9
β = 2.0

dv = Greater of .72h or 0.9 de = 5.04 in
Vc=ϕ(0.0316)β√f'c*b*dv= 7.69 kips/ft **> Vu OK**

$$\rho = \left[1 - \left(\sqrt{1 - \frac{2 \bullet M_u}{\phi b d^2 \bullet .85 f'c}}\right)\right] \bullet \frac{.85 f'c}{f_y} = 0.00225$$

Steel Area Req'd; As =ρ * b * d = 0.128 in^2/ft
#4 Bar @ 12.00 in oc
As Prov = 0.20 in^2/ft
Use #4 Prov = 0.00344 **OK**

Check c/d Ratio: (Art. 5.7.2.1)
c=As*Fy/.85*f'c*β1*b = 0.289 in
c/de ≤ 0.003/(0.003+ε_{cl}); c/de = 0.061 **OK, Use Fy**
$a = \beta_1 c =$ 0.231 in
$S_c = bt^2/6 =$ 98 in³
Flexural cracking var. fac. (Other Con. Strs.) 1.60 γ_1
A615, Gr. 60 Reinforcement (Carbon steel) 0.67 $\gamma 3$
AASHTO 5.7.3.3.2-1 $Mcr = \gamma_3 * [(\gamma_1 * fr) * S_c] =$ 4.70 kip-ft

φMn = φAsfy(de-a/2)/12 = 4.095 kip-ft **OK**
AASHTO 5.7.3.2.2-1

Mr = ϕMn > (lesser of Mcr or 1.33 Mu)
Mcr = 4.70 kip-ft
1.33 * Mu = 3.59 kip-ft <= Controls
Mr = ϕMn = 4.09 kip-ft **OK**

CHECK CRACKING AASHTO 5.7.3.4

$$k = \sqrt{2\rho n + (\rho n)^2} - \rho n = 0.188$$

j = 1 - (k/3) = 0.937
fs = Ma/(As*j*d) = 14.69 ksi
max spa ≤ [(700γe) / (βsfs)] - 2dc = 17 in **OK**
dc= 2.25 in
Bs=1+dc/(0.7*(h-dc))= 1.677
γe= 0.75

JOB 2017.478.001
DESCRIPTION Stonestrong Retaining Wall -24 SF Blocks
SHEET NO. OF SCALE
CALCULATED BY YL DATE 6/8/2017
CHECKED BY DATE

Temperature and Shrinkage Reinforcing (AASHTO LRFD 5.10.8)

fy = 60 ksi

$$As = \frac{1.30\,bh}{2(b+h)Fy}$$

0.11<= As <= 0.6

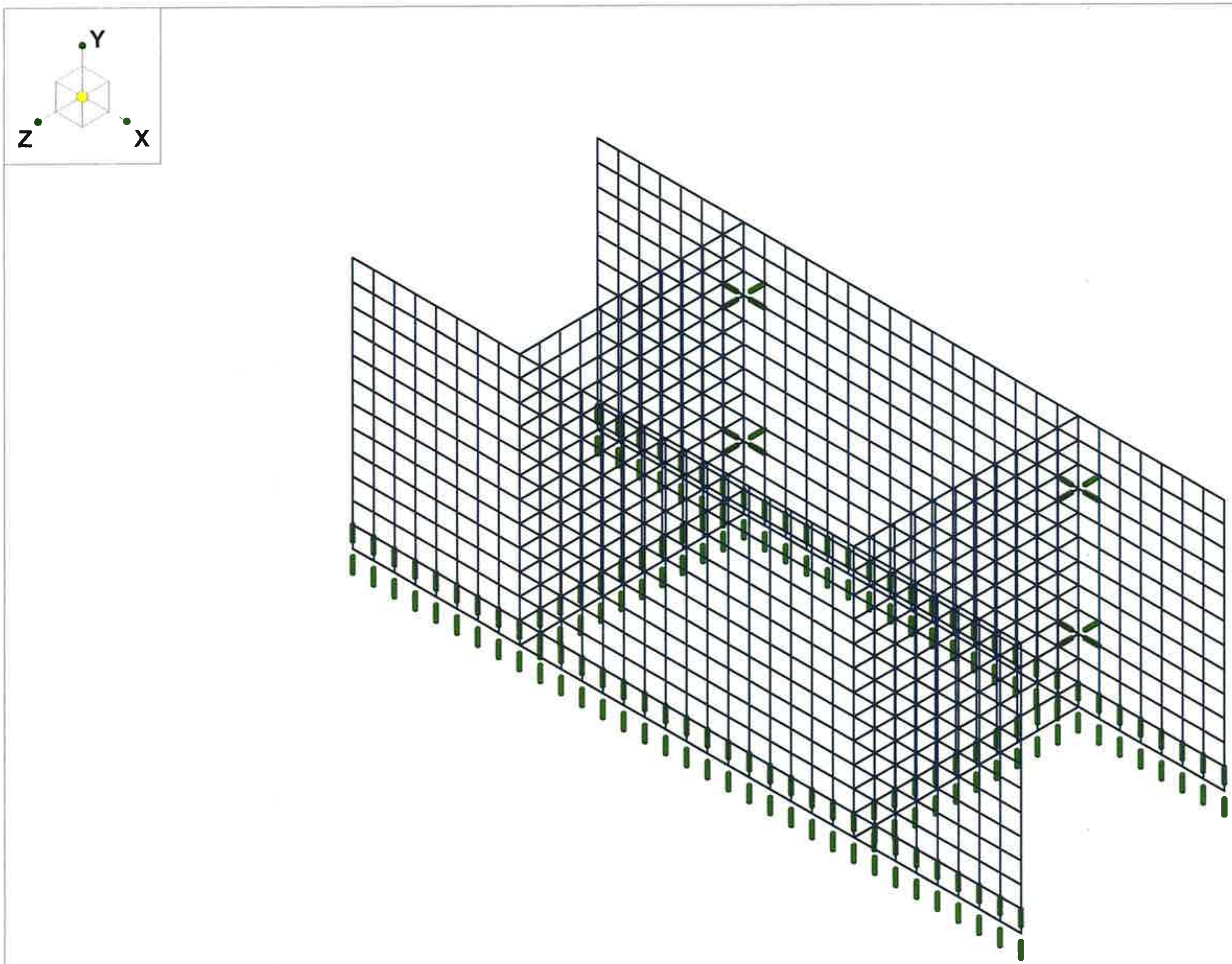
b =	36	in	Least Width of Component Section
h =	6	in	Least Thickness of Component Section

As = 0.11 in^2/ft

Provide W4xW4 - 4x4 Wire Mesh in front face, webs and rear face.

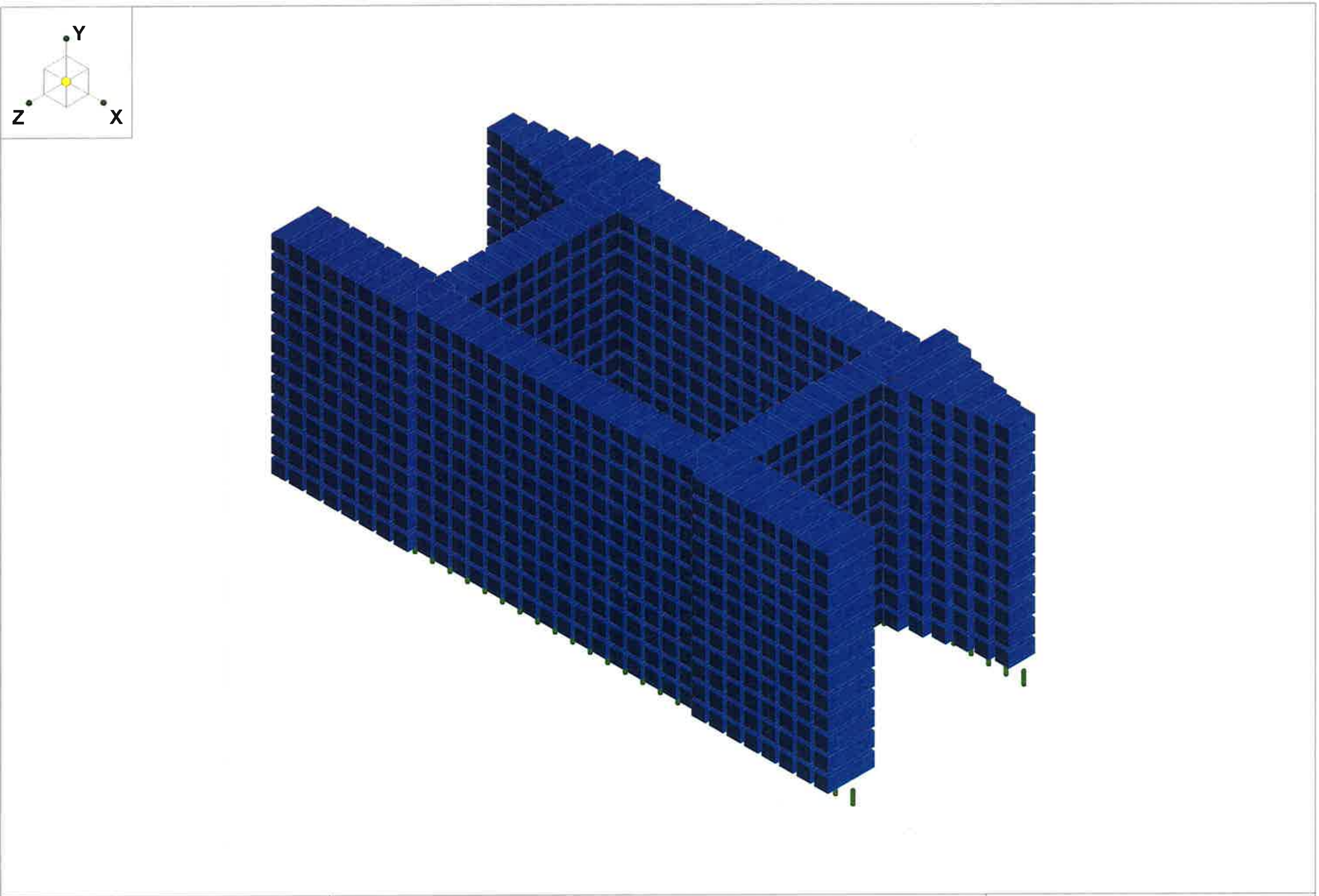
Bend web mesh into front face to form a standard hook.

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017

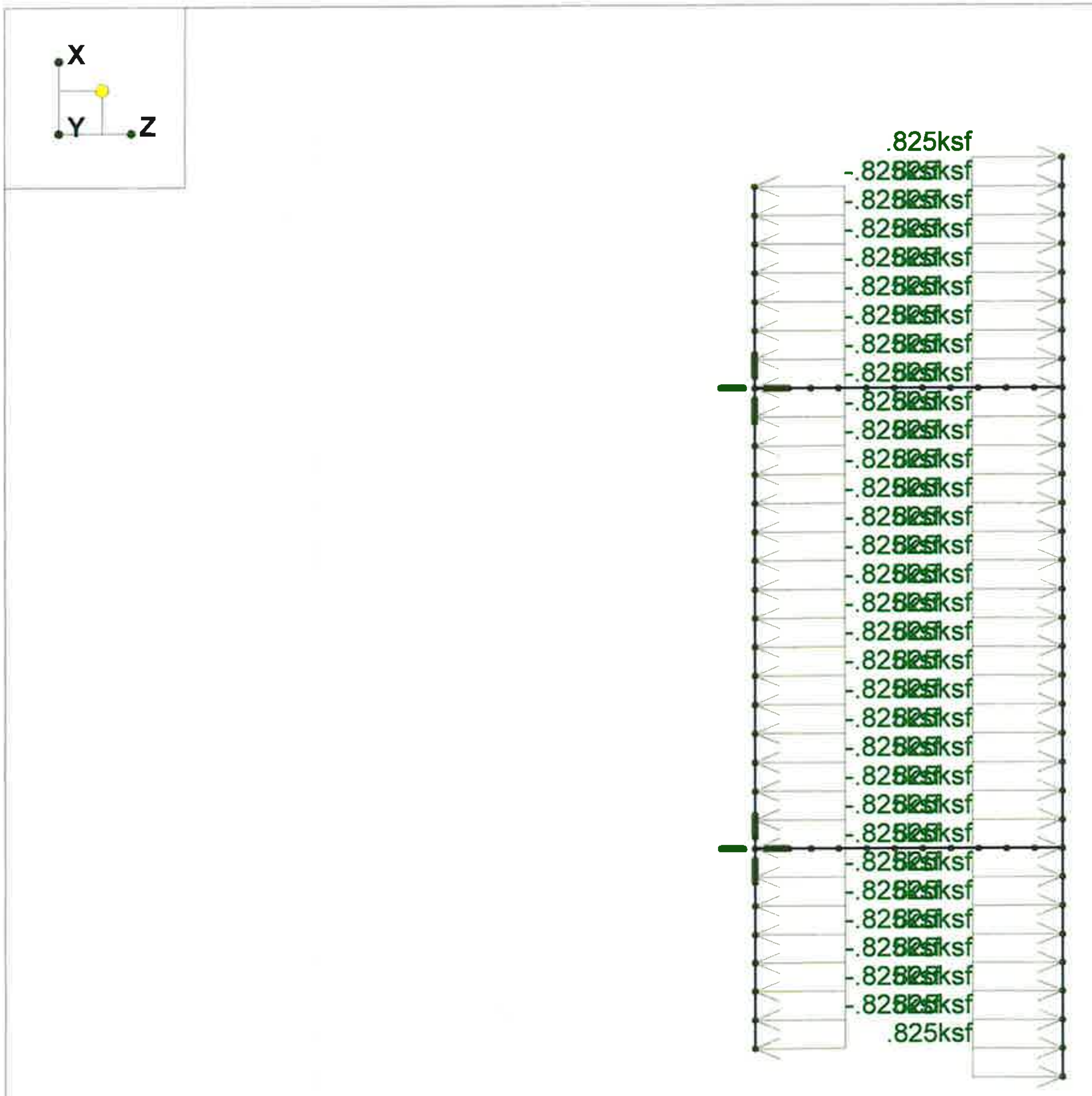


Delta Engineers,Inc	Reinforced Wall 50ft - 24 SF Blocks	SK - 1
YL		Nov 16, 2017 at 10:38 AM
2017.478.001		24 SF Block_50ft Wall.r3d

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017



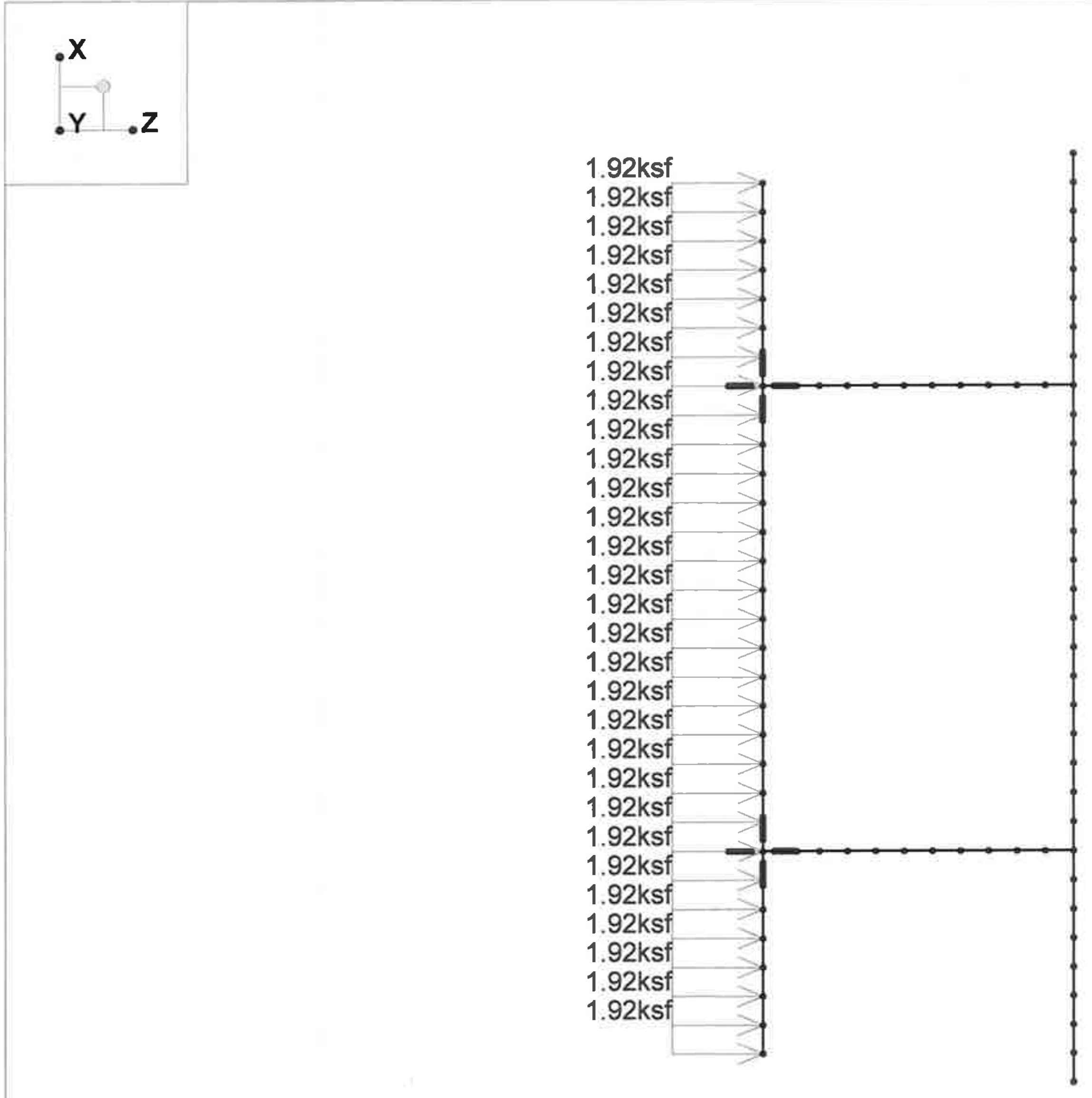
Delta Engineers,Inc	Reinforced Wall 50ft - 24 SF Blocks	SK - 2
YL		Nov 16, 2017 at 10:38 AM
2017.478.001		24 SF Block_50ft Wall.r3d



Internal Pressure

Loads: BLC 1, EH-rest

Delta Engineers,Inc	Reinforced Wall 50ft - 24 SF Blocks	SK - 3
YL		Nov 16, 2017 at 10:39 AM
2017.478.001		24 SF Block_50ft Wall.r3d

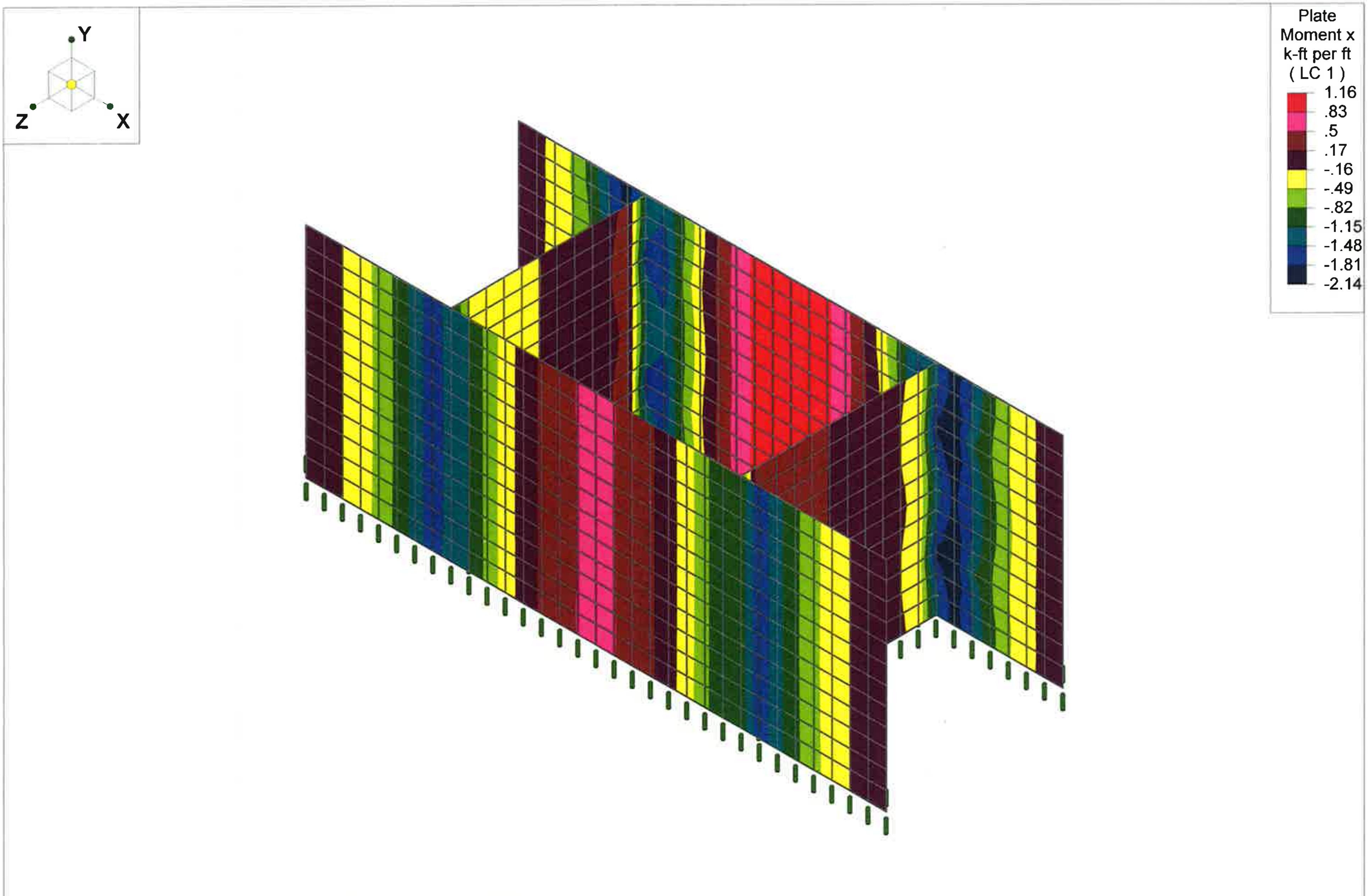


External Pressure

Loads: BLC 2, EH-active

Delta Engineers,Inc	Reinforced Wall 50ft - 24 SF Blocks	SK - 4
YL		Nov 16, 2017 at 10:39 AM
2017.478.001		24 SF Block_50ft Wall.r3d

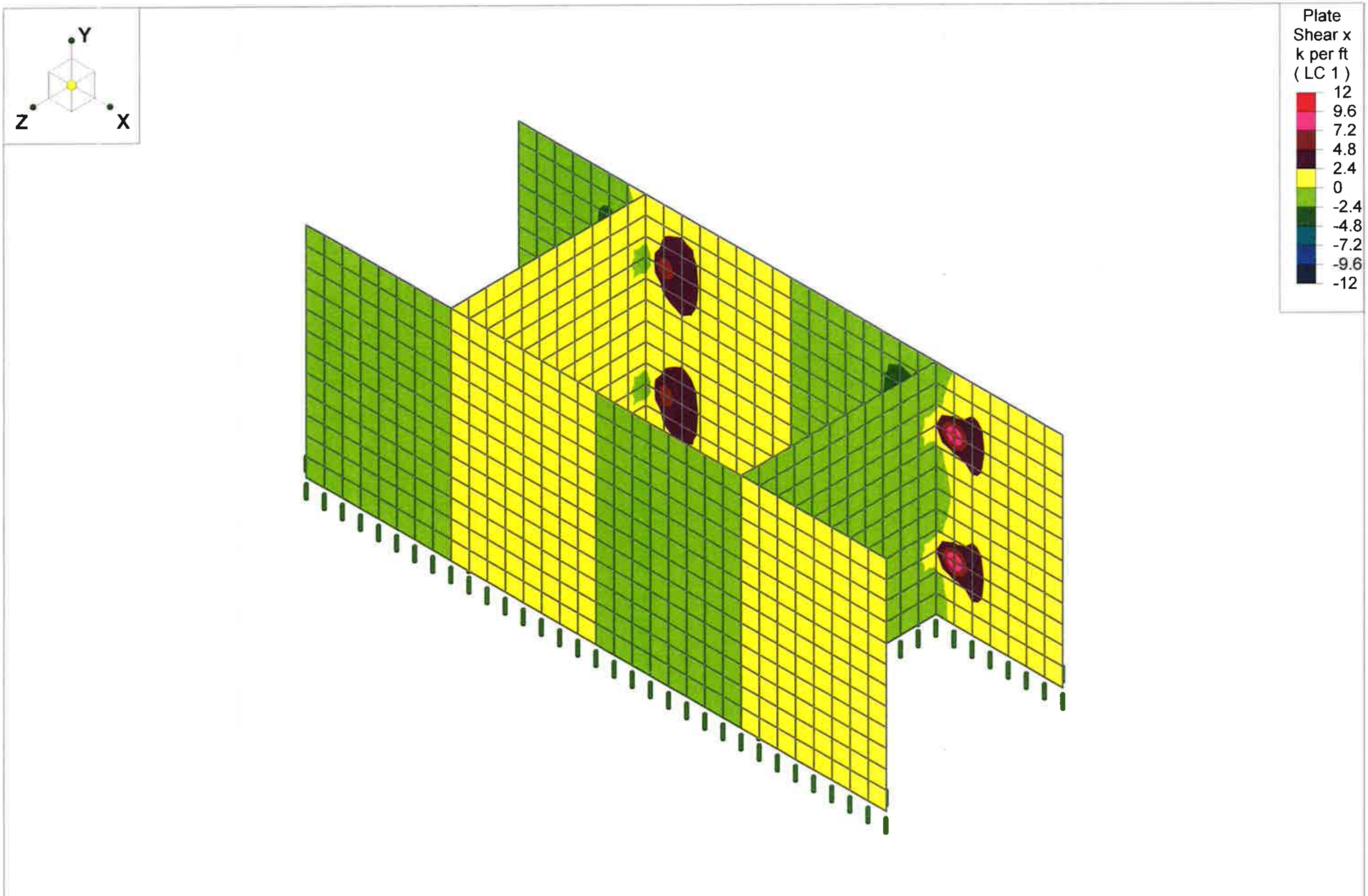
Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017



Results for LC 1, 1.35EH-at rest +1.5EH - active + 1.75LS

Delta Engineers,Inc	Reinforced Wall 50ft - 24 SF Blocks	SK - 5
YL		Nov 16, 2017 at 10:39 AM
2017.478.001		24 SF Block_50ft Wall.r3d

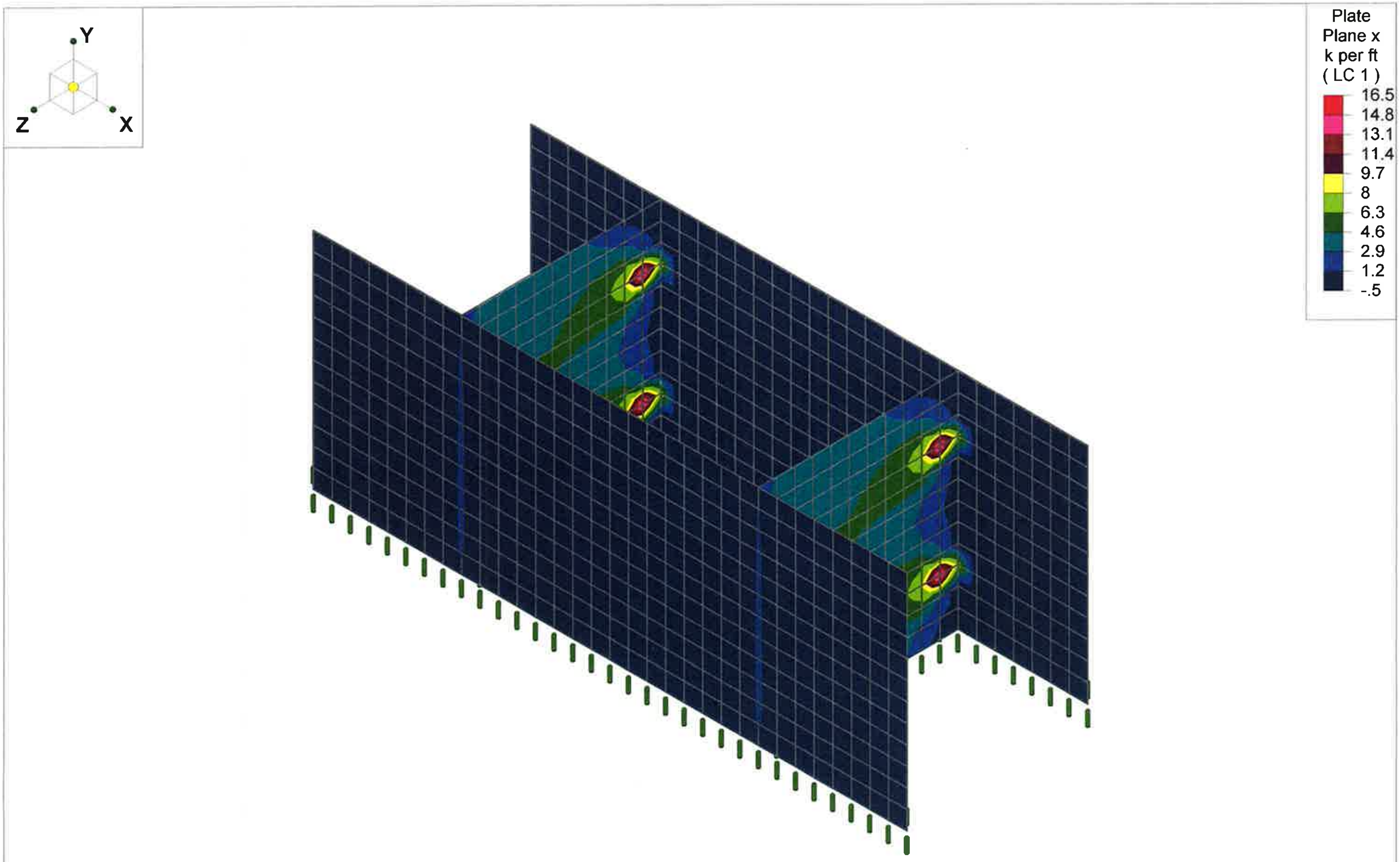
Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017



Results for LC 1, 1.35EH-at rest +1.5EH - active + 1.75LS

Delta Engineers,Inc	Reinforced Wall 50ft - 24 SF Blocks	SK - 6
YL		Nov 16, 2017 at 10:40 AM
2017.478.001		24 SF Block_50ft Wall.r3d

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017



Results for LC 1, 1.35EH-at rest +1.5EH - active + 1.75LS

Delta Engineers,Inc

YL

2017.478.001

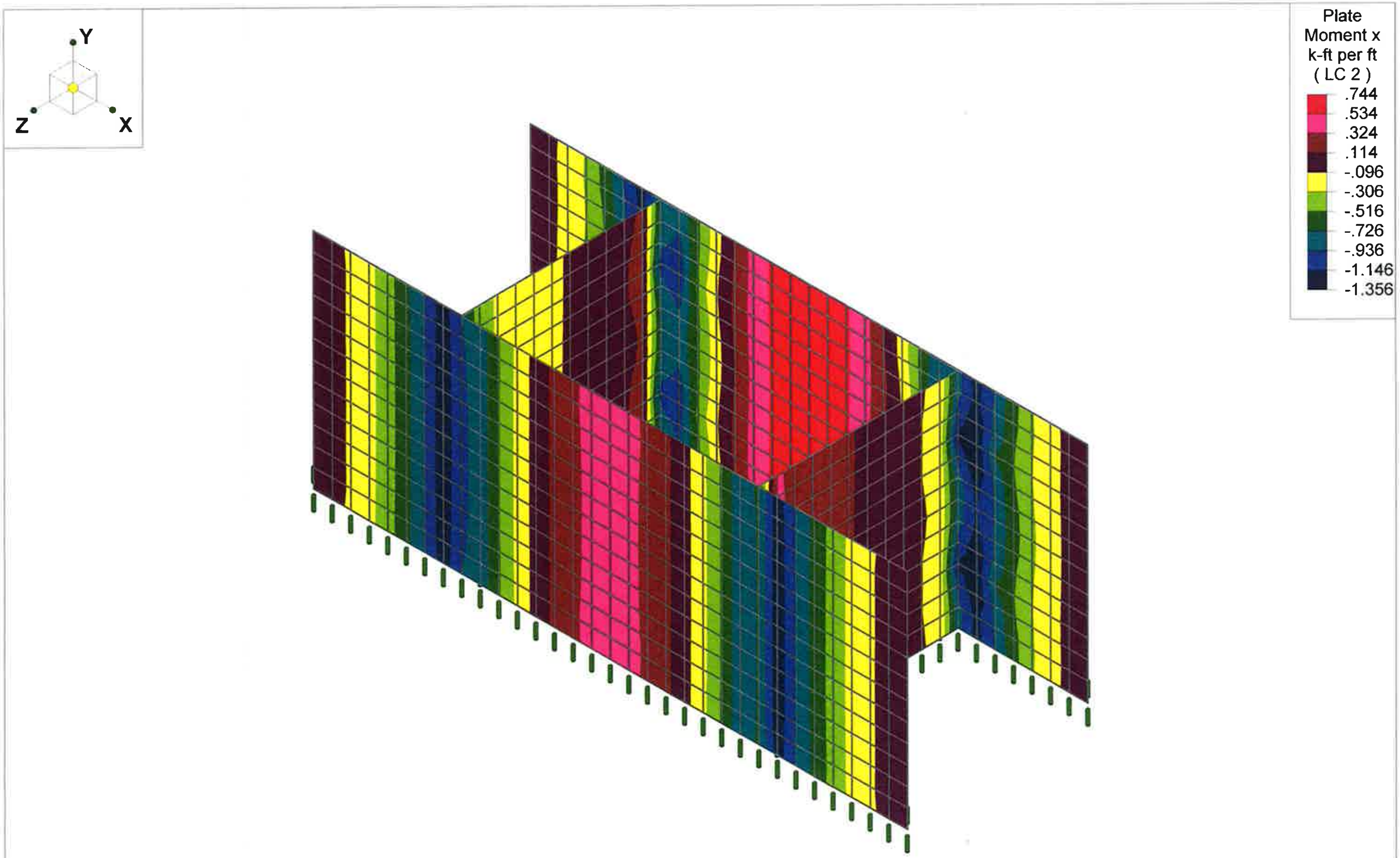
Reinforced Wall 50ft - 24 SF Blocks

SK - 7

Nov 16, 2017 at 10:41 AM

24 SF Block_50ft Wall.r3d

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017



Results for LC 2, EH-at rest +EH - active +LS

Delta Engineers,Inc
YL
2017.478.001

Reinforced Wall 50ft - 24 SF Blocks

SK - 8
Nov 16, 2017 at 10:41 AM
24 SF Block_50ft Wall.r3d

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017

Basic Load Cases

	BLC Description	Category	X Gravity	Y Gravity	Z Gravity	Joint	Point	Distributed	Area(Me...	Surface(...
1	EH-rest	None								744
2	EH-active	None								360
3	LS	None								

Load Combinations

	Description	S...	P...	S...	B...	Factor	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...
1	1.35EH-at rest +1.5EH - active + ..	Yes			1	1.35	2	1.5	3	1.75														
2	EH-at rest +EH - active +LS	Yes			1	1	2	1	3	1														

Plate Forces (per ft) (By Combination) FRONT FACE MAX +Mux

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P372	.168	-.039	.546	.011	-.005	-.242	0	0
2	1	P373	-.168	-.039	.546	.011	.005	-.242	0	0
3	1	P549	-.168	.038	.546	.01	-.004	-.341	-.094	0
4	1	P548	.168	.038	.546	.01	.004	-.341	-.094	0
5	1	P533	-.135	.054	.546	.032	-.006	-.342	-.091	0
6	1	P532	.135	.054	.546	.032	.006	-.342	-.091	0
7	1	P389	-.135	-.054	.546	.032	.006	-.274	0	0
8	1	P388	.135	-.054	.546	.032	-.006	-.274	0	0
9	1	P517	-.132	.041	.54	.053	-.004	-.343	-.085	0
10	1	P516	.132	.041	.54	.053	.004	-.343	-.085	0

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017

Plate Forces (per ft) (By Combination) FRONT FACE MAX. −Mux

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P64	-2.195	-.002	$\boxed{-1.987}$	-.256	0	.054	-.158	-.08
2	1	P152	2.195	-.002	-1.987	-.256	0	.054	-.158	.08
3	1	P72	-2.199	-.051	-1.987	-.248	.006	.061	-.171	-.071
4	1	P160	2.199	-.051	-1.987	-.248	-.006	.061	-.171	.071
5	1	P56	-2.187	.041	-1.985	-.252	-.004	.046	-.14	-.09
6	1	P144	2.187	.041	-1.985	-.252	.004	.046	-.14	.09
7	1	P80	-2.191	-.114	-1.983	-.226	.01	.069	-.183	-.063
8	1	P168	2.191	-.114	-1.983	-.226	-.01	.069	-.183	.063
9	1	P48	-2.174	.085	-1.982	-.237	-.008	.037	-.118	-.098
10	1	P136	2.174	.085	-1.982	-.237	.008	.037	-.118	.098

Plate Forces (per ft) (By Combination) FRONT FACE MAX Qux

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P72	$\boxed{-2.199}$	-.051	-1.987	-.248	.006	.061	-.171	-.071
2	1	P160	2.199	-.051	-1.987	-.248	-.006	.061	-.171	.071
3	1	P64	-2.195	-.002	-1.987	-.256	0	.054	-.158	-.08
4	1	P152	2.195	-.002	-1.987	-.256	0	.054	-.158	.08
5	1	P80	-2.191	-.114	-1.983	-.226	.01	.069	-.183	-.063
6	1	P168	2.191	-.114	-1.983	-.226	-.01	.069	-.183	.063
7	1	P56	-2.187	.041	-1.985	-.252	-.004	.046	-.14	-.09
8	1	P144	2.187	.041	-1.985	-.252	.004	.046	-.14	.09
9	1	P48	-2.174	.085	-1.982	-.237	-.008	.037	-.118	-.098
10	1	P136	2.174	.085	-1.982	-.237	.008	.037	-.118	.098

Plate Forces (per ft) (By Combination)

REAR FACE. MAX. +Mux

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P723	.217	.059	$\boxed{1.117}$	.035	.006	.058	-.032	0
2	1	P724	-.217	.059	1.117	.035	-.006	.058	-.032	0
3	1	P579	.217	-.057	1.117	.034	-.006	.094	0	0
4	1	P580	-.217	-.057	1.117	.034	.006	.094	0	0
5	1	P739	.252	.041	1.114	.012	.005	.056	-.033	0
6	1	P740	-.252	.041	1.114	.012	-.005	.056	-.033	0
7	1	P563	.251	-.04	1.114	.012	-.005	.099	0	0
8	1	P564	-.251	-.04	1.114	.012	.005	.099	0	0
9	1	P595	.213	-.044	1.111	.057	-.004	.092	-.01	0
10	1	P596	-.213	-.044	1.111	.057	.004	.092	-.01	0

Plate Forces (per ft) (By Combination)

REAR FACE MAX. -Mux

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P296	9.607	11.156	-2.7	-2.282	.549	.094	1.821	-.032
2	1	P219	-9.607	11.156	-2.7	-2.282	-.549	.094	1.821	.032
3	1	P303	9.539	-11.579	-2.691	-2.207	-.532	.123	1.662	.372
4	1	P226	-9.539	-11.579	-2.691	-2.207	.532	.123	1.662	-.372
5	1	P345	9.393	-11.02	-2.682	-2.159	-.536	.254	1.256	.255
6	1	P268	-9.393	-11.02	-2.682	-2.159	.536	.254	1.256	-.255
7	1	P338	9.358	11.383	-2.672	-2.099	.522	.251	1.306	-.05
8	1	P261	-9.358	11.383	-2.672	-2.099	-.522	.251	1.306	.05
9	1	P603	-6.592	5.518	-2.318	-.657	-.023	-.201	.929	.264
10	1	P588	6.592	5.518	-2.318	-.657	.023	-.201	.929	-.264

Plate Forces (per ft) (By Combination)

REAR FACE. MAX. Qux

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P219	$\boxed{\underline{-9.607}}$	11.156	-2.7	-2.282	-.549	.094	1.821	.032
2	1	P226	-9.539	-11.579	-2.691	-2.207	.532	.123	1.662	-.372
3	1	P268	-9.393	-11.02	-2.682	-2.159	.536	.254	1.256	-.255
4	1	P261	-9.358	11.383	-2.672	-2.099	-.522	.251	1.306	.05
5	1	P603	-6.592	5.518	-2.318	-.657	-.023	-.201	.929	.264
6	1	P619	-6.535	-5.691	-2.305	-.649	.031	-.182	.85	-.494
7	1	P715	-6.49	-5.451	-2.3	-.637	.022	-.146	.654	-.47
8	1	P699	-6.444	5.599	-2.286	-.63	-.034	-.158	.678	.316
9	1	P218	-3.793	.593	-1.578	-1.193	-.304	.222	.238	-.16
10	1	P225	-3.754	-.845	-1.582	-1.157	.259	.226	.156	.07

Plate Primary Data

PLATE THICKNESS

	Label	A Joint	B Joint	C Joint	D Joint	Material	Thickness[in]
210	P216	N260	N261	N269	N268	gen_Conc3NW	8.25
211	P217	N261	N262	N270	N269	gen_Conc3NW	10.06
212	P218	N262	N263	N271	N270	gen_Conc3NW	12.56
213	P219	N263	N264	N272	N271	gen_Conc3NW	14.125
214	P220	N265	N266	N274	N273	gen_Conc3NW	4.5
215	P221	N266	N267	N275	N274	gen_Conc3NW	5.56
216	P222	N267	N268	N276	N275	gen_Conc3NW	6.75
217	P223	N268	N269	N277	N276	gen_Conc3NW	8.25
218	P224	N269	N270	N278	N277	gen_Conc3NW	10.06
219	P225	N270	N271	N279	N278	gen_Conc3NW	12.56
220	P226	N271	N272	N280	N279	gen_Conc3NW	14.125

Plate Forces (per ft) (By Combination)

WEB MAX. Fux

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P790	.469	.089	.315	.061	.01	$\boxed{11.75}$	.944	6.797
2	1	P921	-.469	-.089	-.315	-.061	-.01	11.75	.944	6.797
3	1	P845	.471	-.1	.312	.061	-.009	11.732	.931	-6.104
4	1	P976	-.471	.1	-.312	-.061	.009	11.732	.931	-6.104
5	1	P856	.478	.102	.314	.059	.011	11.647	.909	6.564
6	1	P987	-.478	-.102	-.314	-.059	-.011	11.647	.909	6.564
7	1	P779	.477	-.09	.316	.059	-.012	11.607	.931	-5.95
8	1	P910	-.477	.09	-.316	-.059	.012	11.607	.931	-5.95
9	1	P789	.383	.037	.203	.034	0	7.785	-1.294	2.303
10	1	P920	-.383	-.037	-.203	-.034	0	7.785	-1.294	2.303

DELTA
SPECIALTY PRECAST CONCRETE ENGINEERS
860 Hooper Road, Endwell, NY 13760
www.delta-eas.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB 2017.478.001

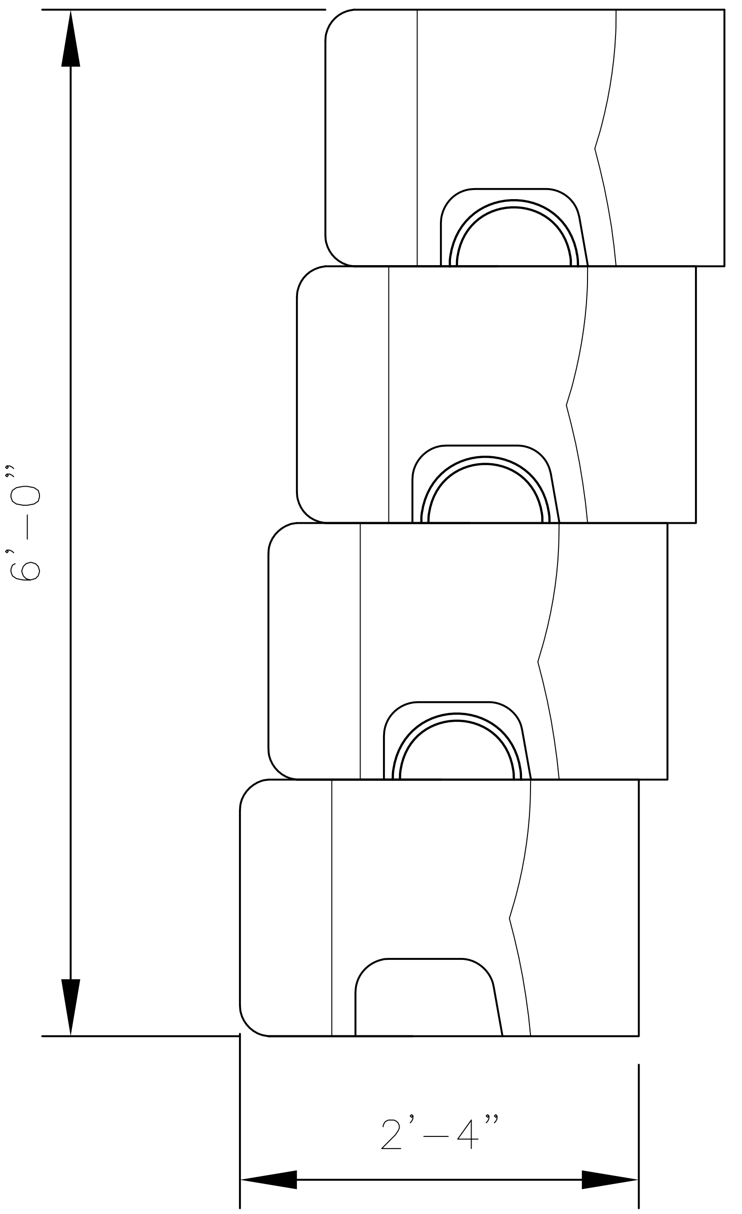
DESCRIPTION Gravity Wall - 6-28 Blocks - 6ft

SHEET NO OF SCALE

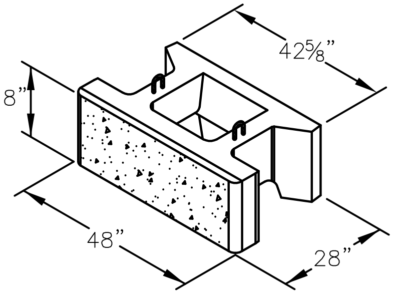
CALCULATED BY YL DATE 6/8/2017

CHECKED BY DATE

Gravity Wall - Maximum 6ft Wall Height
6-28 Blocks

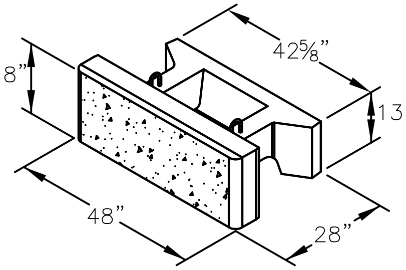


GRAVITY WALL
6–28 UNIT



STONE STRONG 6–28 UNIT

NOT TO SCALE



STONE STRONG 6–28 TOP UNIT

NOT TO SCALE

CHECK ON AVAILABILITY OF ALL UNITS w/ LOCAL PRODUCER/ DEALER. SOME UNITS MAY HAVE LIMITED AVAILABILITY.

DISCLAIMER:

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Z:\Title Sheets\LOGOS\StoneStrong_Stacked_CMYK.jpg

www.stonestrong.com

PROJECT

COMPONENTS
STONE STRONG SYSTEMS

DATE: 3/15/16 **FILE:** 16_Block.6–28

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017

DELTA
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JOB 2017.478.001
DESCRIPTION Gravity Wall - 6-28 Blocks - 6ft
SHEET NO. OF SCALE
CALCULATED BY YL DATE 6/8/2017
CHECKED BY DATE

Load Calculations - 6-28 Blocks - 6' Wall Height

Internal Pressure from Infill

Infill Density = 100 pcf
ko = 0.5
Height to Middle of Bottom Block = 5.25 ft
Internal Pressure (at rest) = 262.5 psf

External Pressure from Retained Soil

Soil Density = 120 pcf
ka = 0.33
Height to Middle of Bottom Block = 5.25 ft
External Pressure (at rest) = 208 psf

Live Load Surcharge = 80 psf

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Fax: (607) 231-6650

JOB 2017.478.001
DESCRIPTION Gravity Wall - 6-28 Blocks - 6ft
SHEET NO. OF SCALE
CALCULATED BY YL DATE 6/8/2017
CHECKED BY DATE

Risa Results - 6-28 Blocks - 6' Wall Height

fc' = 5000 psi
5*√f'c = 354 psi

Front Face:

-Mu = 0.06 k-ft/ft
Thickness t = 6 in
S = 12 t^2/6= 72 in^3
ϕMn =0.6* 5*√f'c S = 1.27 k-ft/ft OK

+Mu = 0.08 k-ft/ft
Thickness t = 7.01 in
S = 12 t^2/6= 98 in^3
ϕMn =0.6* 5*√f'c S = 1.74 k-ft/ft OK

Vu = 0.60 k/ft
Thickness t = 6 in
ϕVn =0.6* 4/3*√f'c *12 t = 4.07 k-ft/ft OK

Front Face Reinforcing required for temperature and shrinkage only.

Rear Face:

Bending moment and shear are negaligle due to balancing of infill pressure and retained soil pressure.

Rear Face Reinforcing required for temperature and shrinkage only.

Web

Tu = 1.39 k/ft
Thickness t = 5 in
ϕTn =0.6*5*√f'c *12 t = 12.73 k/ft OK

Web Reinforcing required for temperature and shrinkage only.

JOB	2017.478.001		
DESCRIPTION	Stonestrong Retaining Wall 6-28 Blocks		
SHEET NO		OF	
SCALE			
CALCULATED BY	YL	DATE	6/8/2017
CHECKED BY		DATE	

Temperature and Shrinkage Reinforcing (AASHTO LRFD 5.10.8)

fy = 60 ksi

$$As = \frac{1.30\,bh}{2(b+h)Fy}$$

0.11<= As <= 0.6

b = 18 in Least Width of Component Section

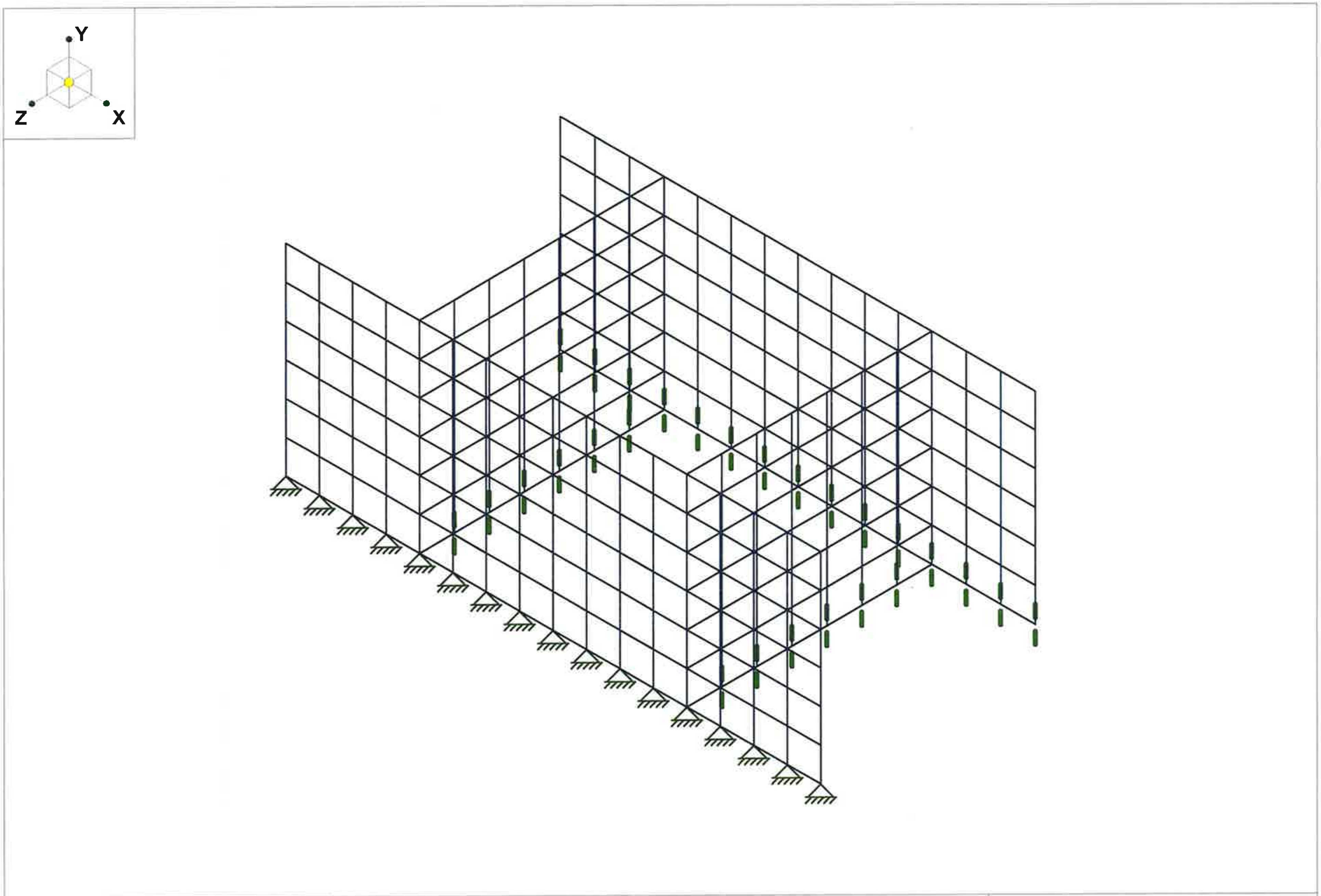
h = 6 in Least Thickness of Component Section

As = 0.11 in^2/ft

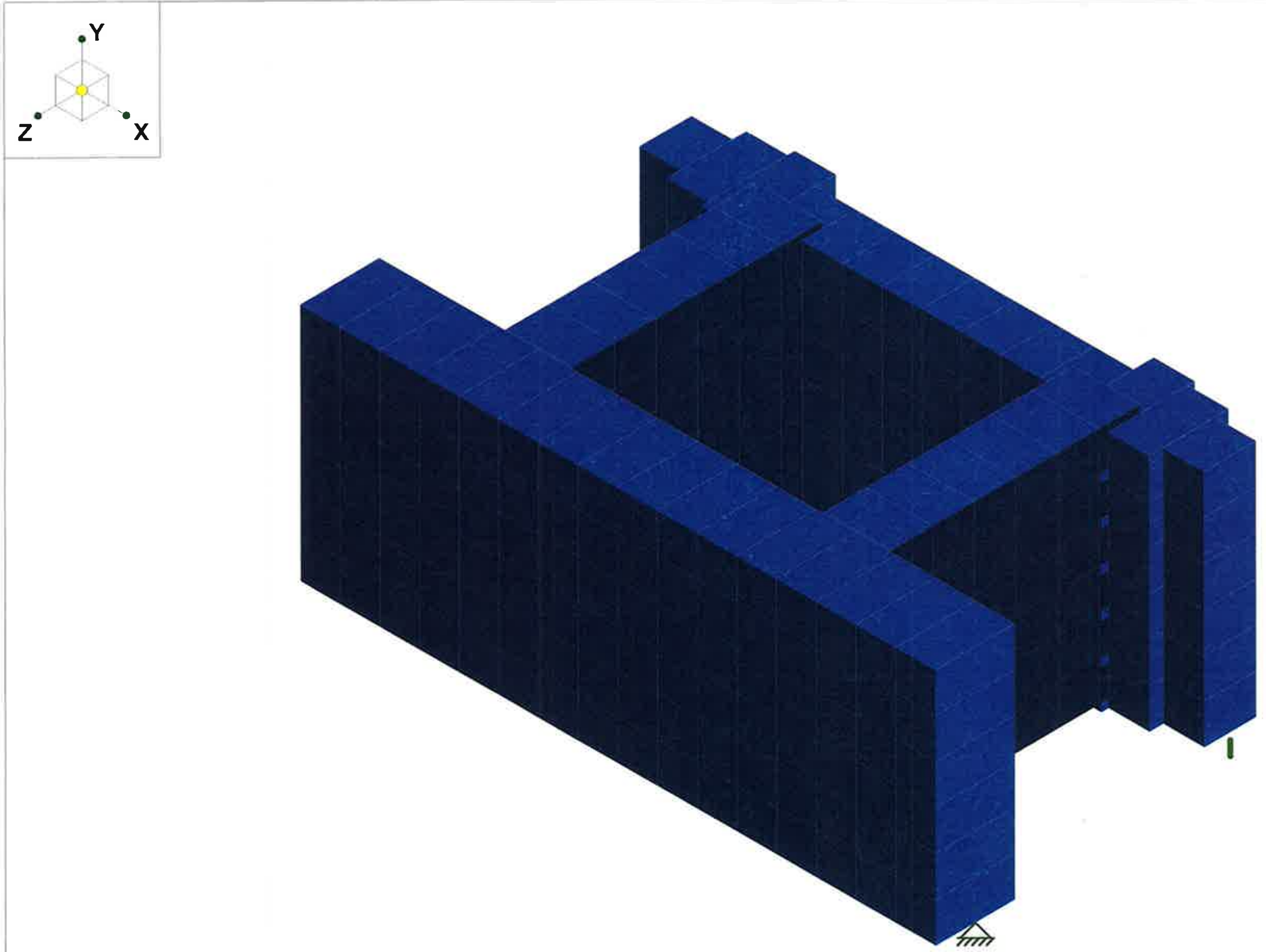
Provide W4xW4 - 4x4 Wire Mesh in front face, webs and rear face.

Bend web mesh into front face to form a standard hook.

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017

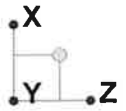


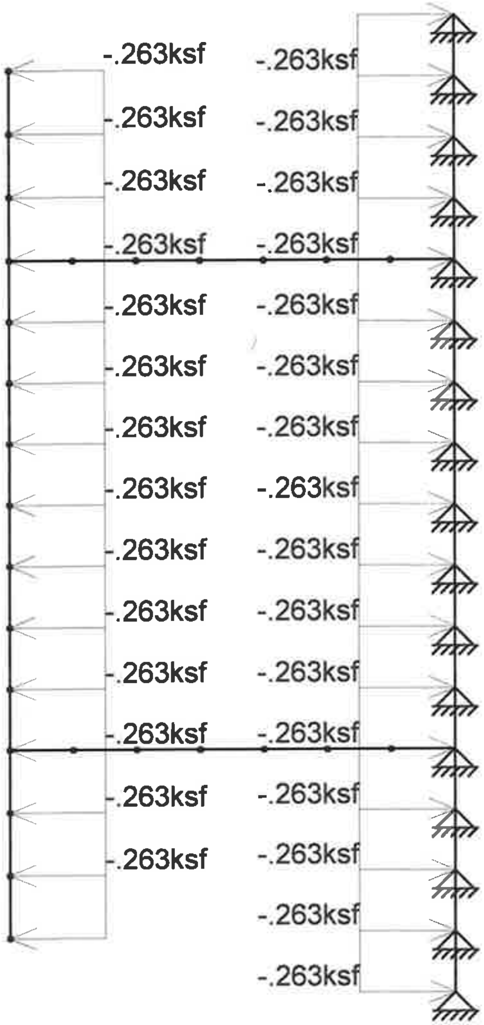
Delta Engineers,Inc	Gravity Wall 6ft 6-28 Blocks	SK - 1
YL		Nov 20, 2017 at 1:55 PM
2017.478.001		6-28 Block_6ft Wall.r3d



Delta Engineers,Inc	Gravity Wall 6ft 6-28 Blocks	SK - 2
YL		Nov 20, 2017 at 1:55 PM
2017.478.001		6-28 Block_6ft Wall.r3d

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017





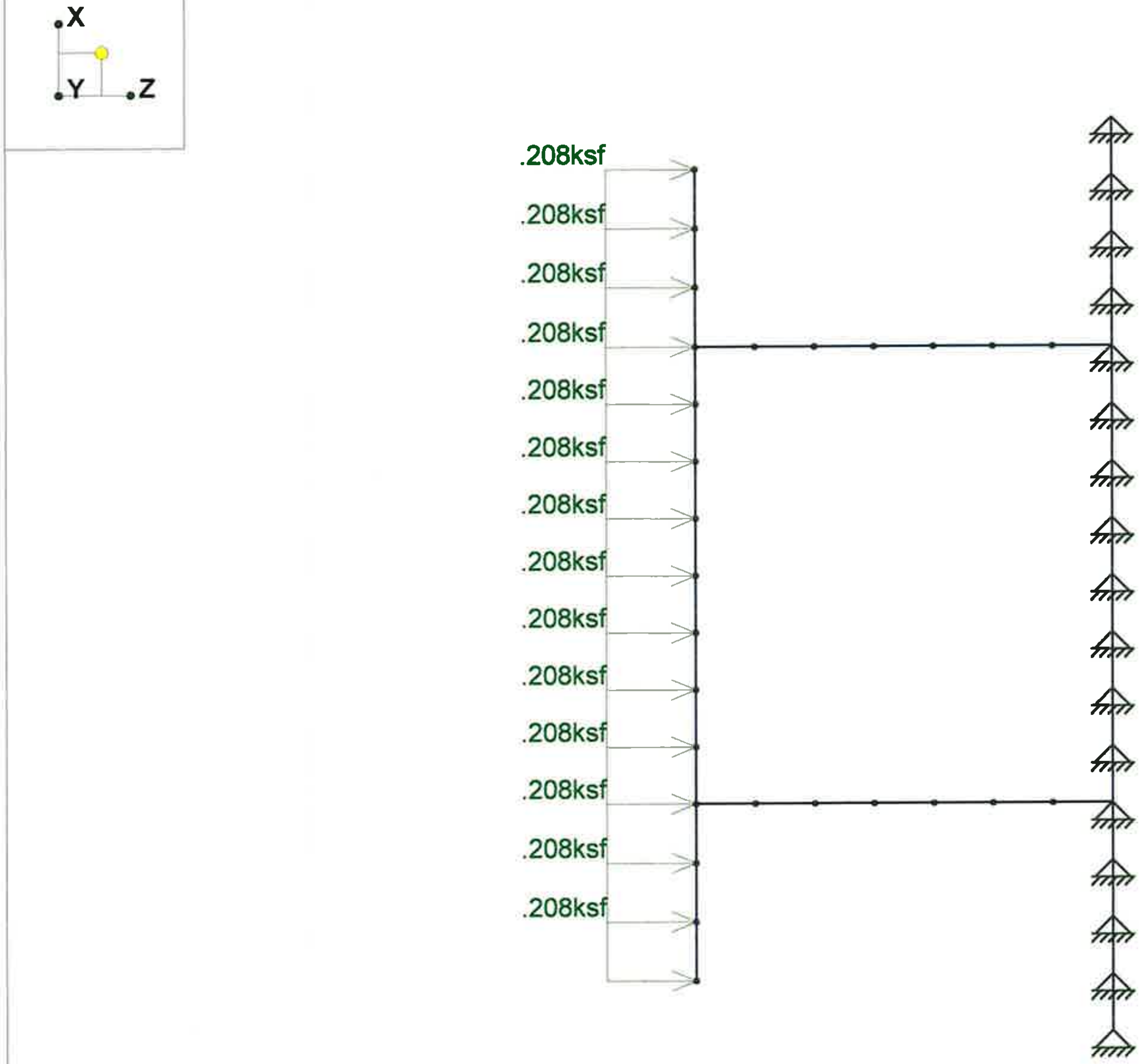
INTERNAL PRESSURE

Loads: BLC 1, EH-rest

Delta Engineers,Inc
YL
2017.478.001

Gravity Wall 6ft 6-28 Blocks

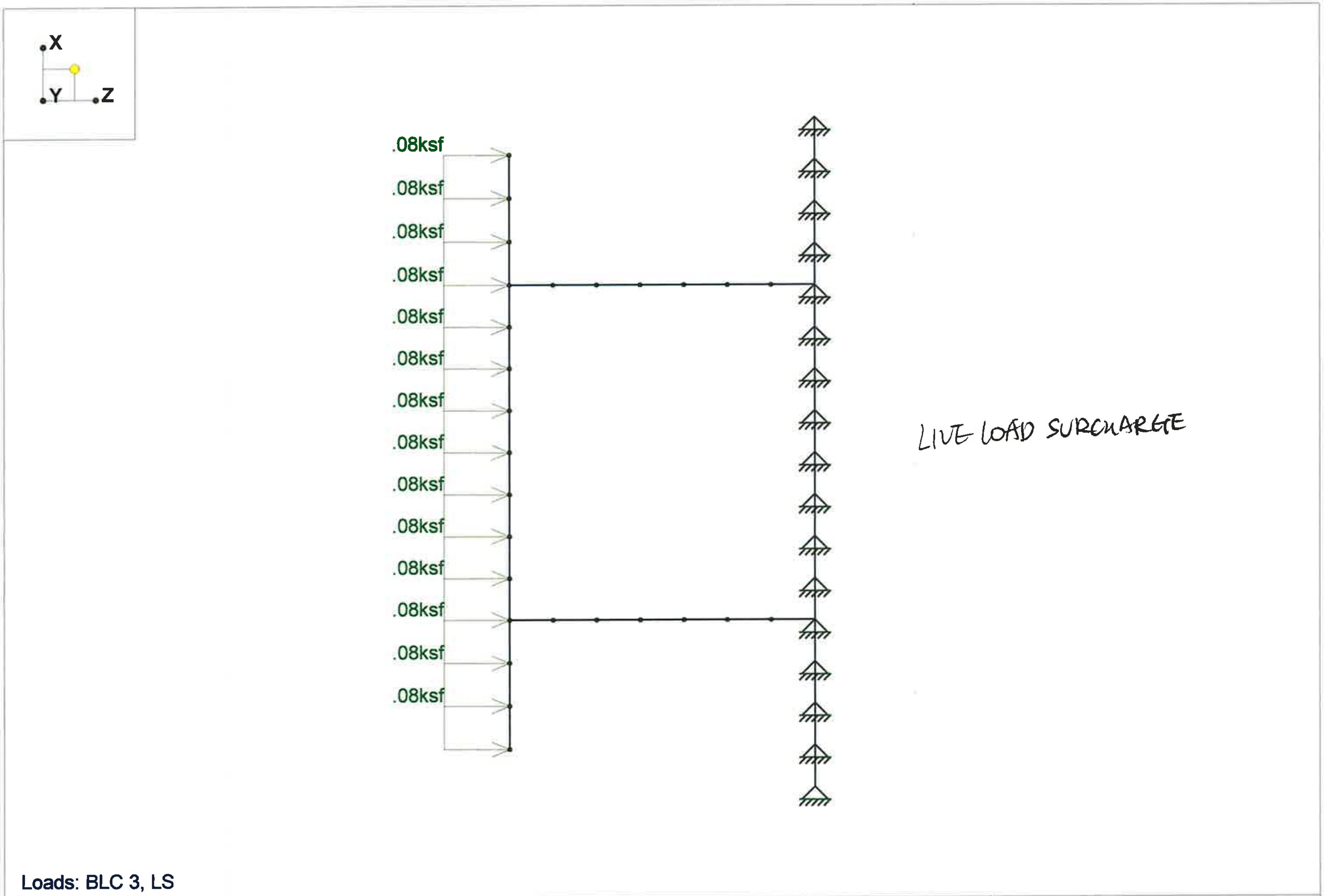
SK - 3
Nov 20, 2017 at 1:56 PM
6-28 Block_6ft Wall.r3d



EXTERNAL PRESSURE

Loads: BLC 2, EH-active

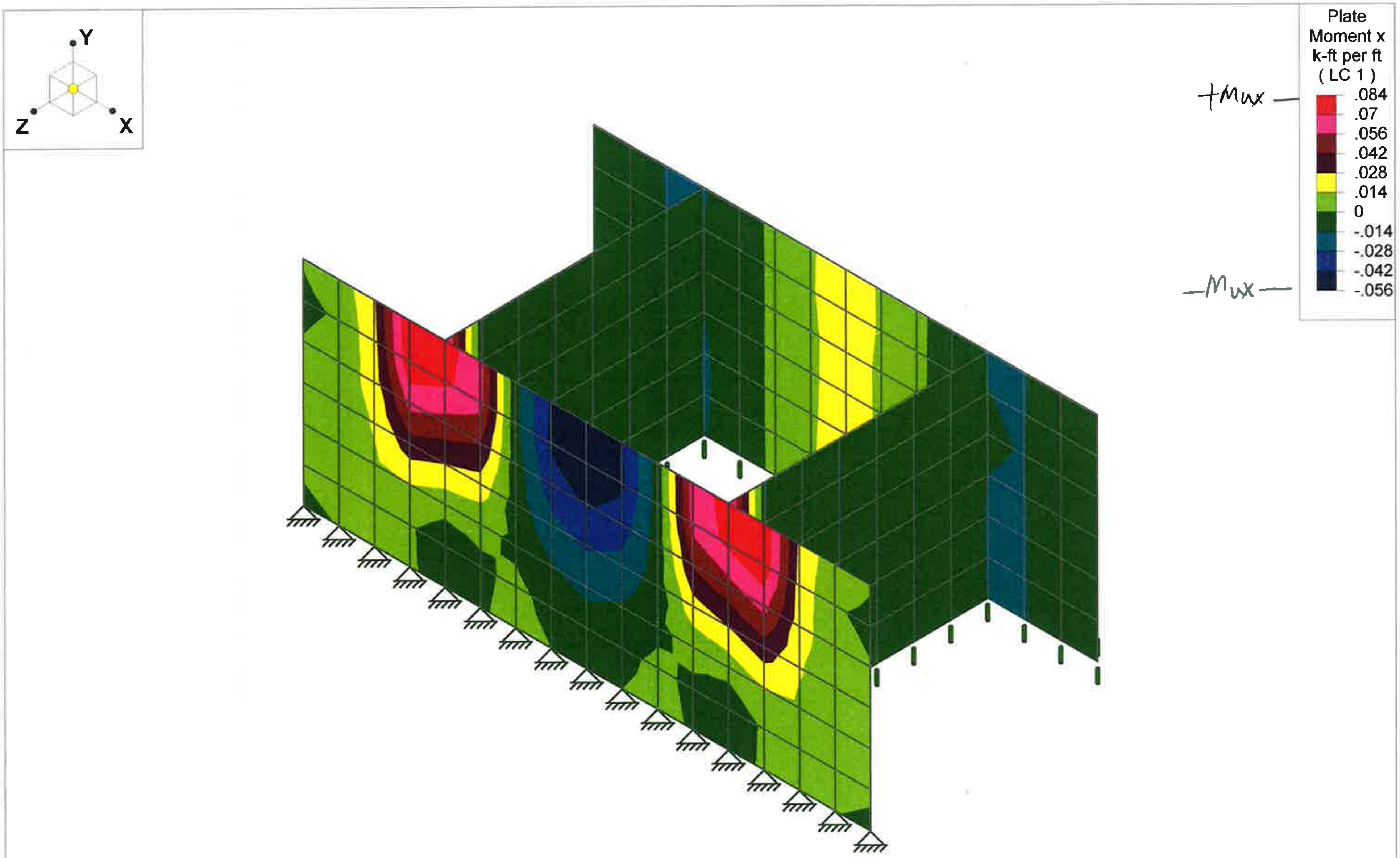
Delta Engineers,Inc	Gravity Wall 6ft 6-28 Blocks	SK - 4
YL		Nov 20, 2017 at 1:56 PM
2017.478.001		6-28 Block_6ft Wall.r3d



LIVE LOAD SURCHARGE

Loads: BLC 3, LS

Delta Engineers,Inc	Gravity Wall 6ft 6-28 Blocks	SK - 5
YL		Nov 20, 2017 at 1:57 PM
2017.478.001		6-28 Block_6ft Wall.r3d



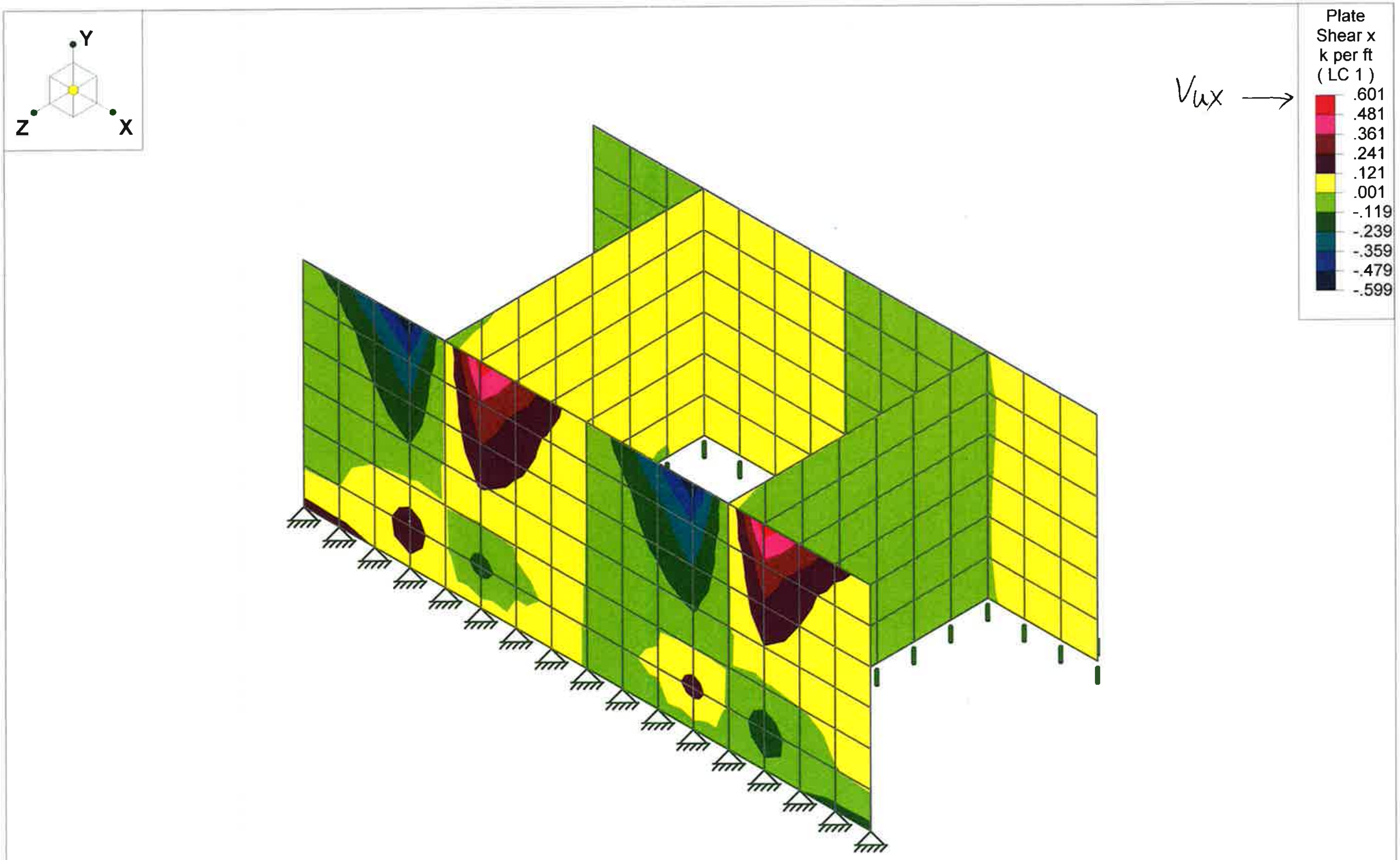
+Mux

-Mux

Results for LC 1, 1.35EH-at rest +1.5EH - active + 1.75LS

Delta Engineers,Inc	Gravity Wall 6ft 6-28 Blocks	SK - 6
YL		Nov 20, 2017 at 1:58 PM
2017.478.001		6-28 Block_6ft Wall.r3d

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017



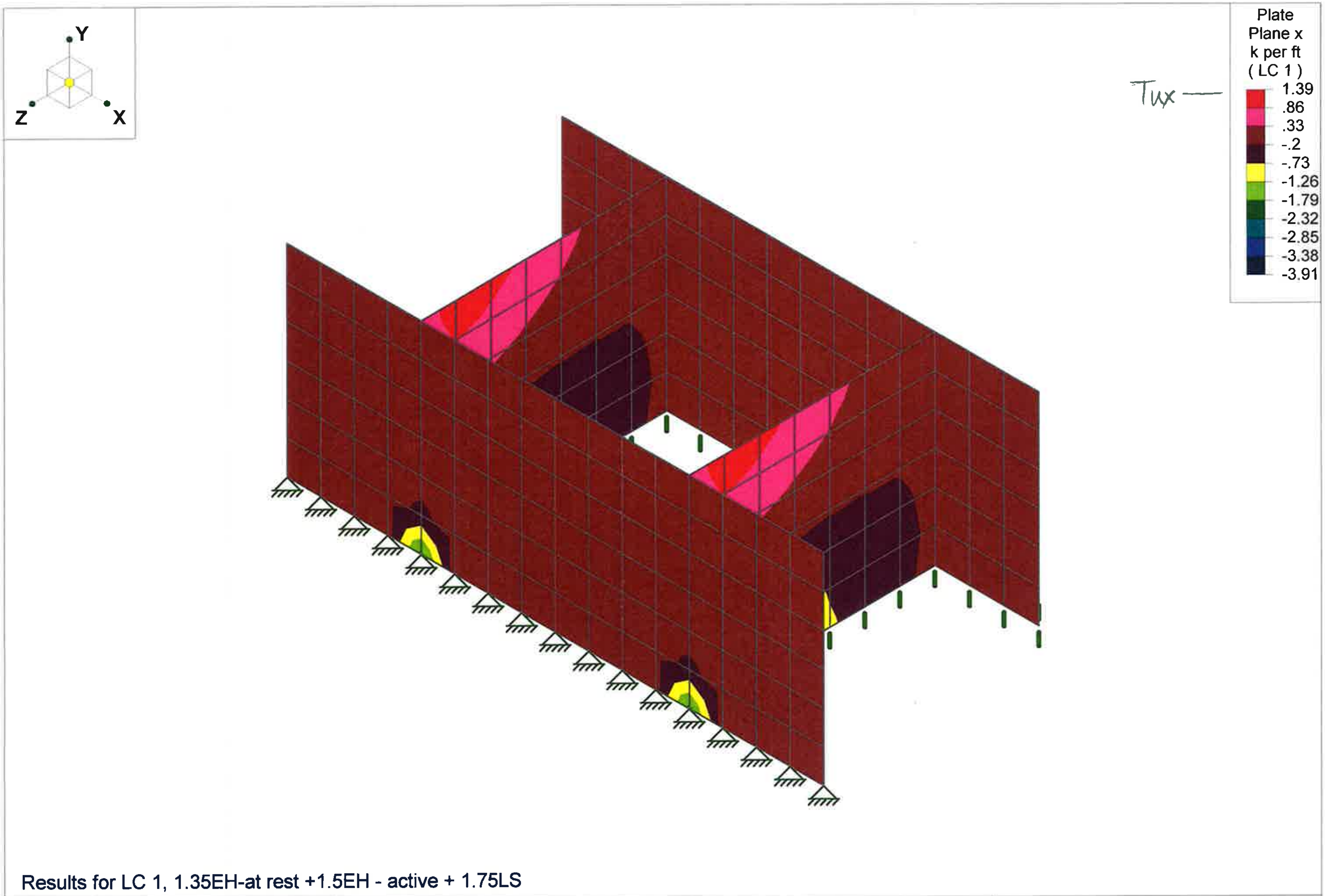
Results for LC 1, 1.35EH-at rest +1.5EH - active + 1.75LS

Delta Engineers,Inc
YL
2017.478.001

Gravity Wall 6ft 6-28 Blocks

SK - 7
Nov 20, 2017 at 1:58 PM
6-28 Block_6ft Wall.r3d

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017



Results for LC 1, 1.35EH-at rest +1.5EH - active + 1.75LS

Delta Engineers,Inc	Gravity Wall 6ft 6-28 Blocks	SK - 8
YL		Nov 20, 2017 at 1:59 PM
2017.478.001		6-28 Block_6ft Wall.r3d

Basic Load Cases

	BLC Description	Category	X Gravity	Y Gravity	Z Gravity	Joint	Point	Distributed	Area(Me...	Surface(...
1	EH-rest	None								180
2	EH-active	None								84
3	LS	None								84

Load Combinations

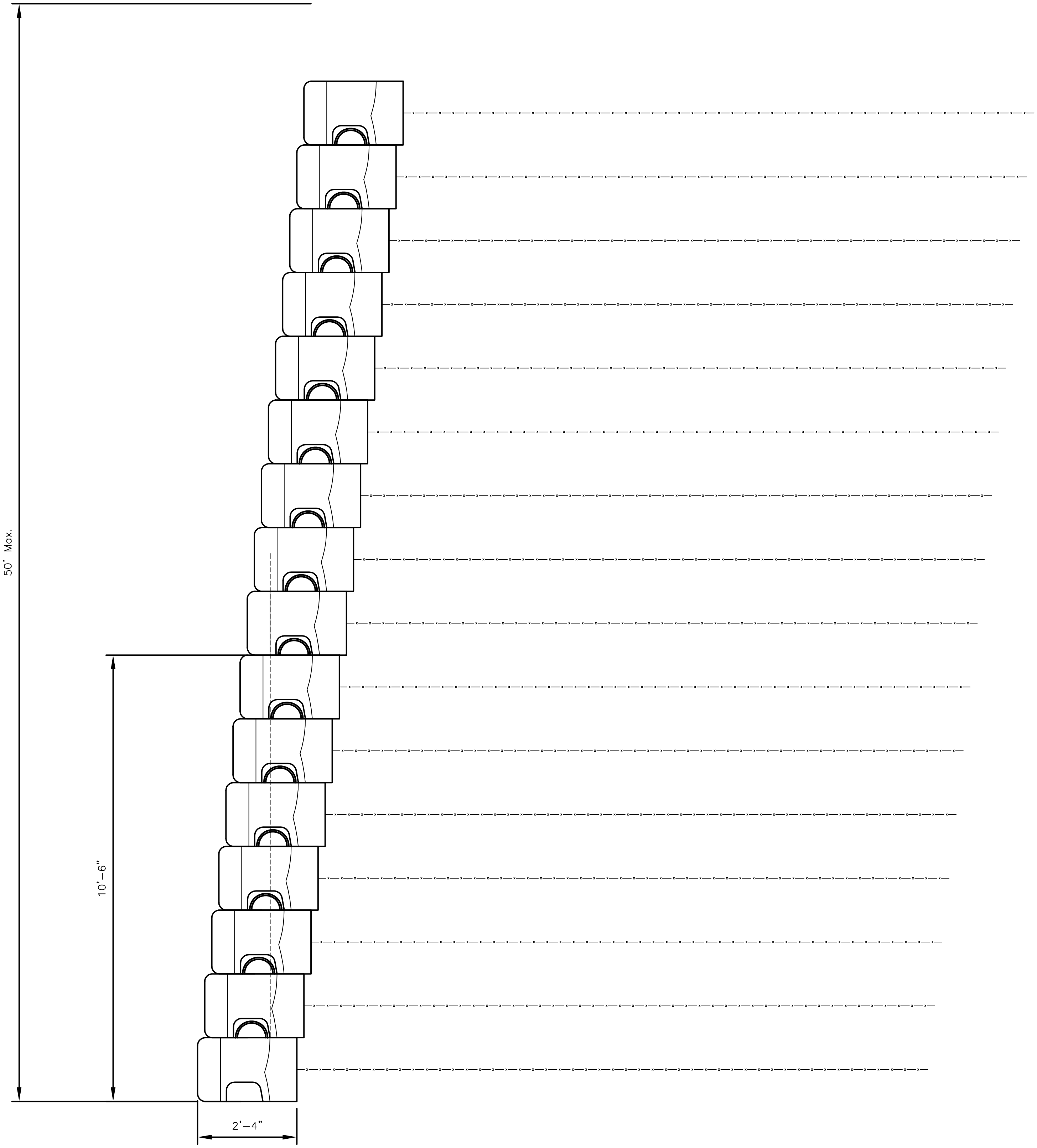
	Description	S...	P...	S...	B...	Factor	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...
1	1.35EH-at rest +1.5EH - active + ..	Yes			1	1.35	2	1.5	3	1.75														
2	EH-at rest +EH - active +LS	Yes			1	1	2	1	3	1														

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017

DELTA
SPECIALTY PRECAST CONCRETE ENGINEERS
860 Hooper Road, Endwell, NY 13760
www.delta-eas.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2017.478.001		
DESCRIPTION	Reinforced Wall - 6-28 Blocks -50ft		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	6/8/2017
CHECKED BY		DATE	

Reinforce Wall - Maximum 50ft Wall Height
6-28 Blocks



REINFORCED WALL – 50' MAX.
6–28 UNIT

JOB 2017.478.001
DESCRIPTION Reinforced Wall - 6-28 Blocks -50ft
SHEET NO. OF SCALE
CALCULATED BY YL DATE 12/1/2017
CHECKED BY DATE

Load Calculations - 6-28 Blocks - 50' Wall Height

Internal Pressure from Infill

Infill Density = 100 pcf
ko = 0.5
Height to Middle of Bottom Block = 9.75 ft
Internal Pressure (at rest) = 487.5 psf

External Pressure from Retained Soil

Soil Density = 120 pcf
ka = 0.33
Height to Middle of Bottom Block = 49.25 ft
External Pressure (at rest) = 1950 psf

Live Load Surcharge = 0 psf

JOB 2017.478.001
DESCRIPTION Reinforced Wall - 6-28 Blocks -50ft
SHEET NO. OF SCALE
CALCULATED BY YL DATE 12/1/2017
CHECKED BY DATE

Risa Results - 6-28 Blocks - 50' Wall Height

fc' = 5000 psi
5*√f'c = 354 psi

Front Face:

-Mu = 0.26 k-ft/ft
Thickness t = 6 in
S = 12 t^2/6= 72 in^3
ϕMn =0.6* 5*√f'c S = 1.27 k-ft/ft OK

+Mu = 0.03 k-ft/ft
Thickness t = 7.01 in
S = 12 t^2/6= 98 in^3
ϕMn =0.6* 5*√f'c S = 1.74 k-ft/ft OK

Vu = 0.59 k/ft
Thickness t = 6 in
ϕVn =0.6* 4/3*√f'c *12 t = 4.07 k-ft/ft OK

Front Face Reinforcing required for temperature and shrinkage only.

Rear Face:

-Mu = 0.63 k-ft/ft
Thickness t = 6.97 in
S = 12 t^2/6= 97 in^3
ϕMn =0.6* 5*√f'c S = 1.72 k-ft/ft OK

+Mu = 0.38 k-ft/ft
Thickness t = 4 in
S = 12 t^2/6= 32 in^3
ϕMn =0.6* 5*√f'c S = 0.57 k-ft/ft OK

Vu = 3.51 k/ft
Thickness t = 6.97 in
ϕVn =0.6* 4/3*√f'c *12 t = 4.73 k-ft/ft OK

Rear Face Reinforcing required for temperature and shrinkage only.

DELTA
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860 Hooper Road, Endwell, NY 13760
www.delta-eas.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB 2017.478.001

DESCRIPTION Reinforced Wall - 6-28 Blocks -50ft

SHEET NO. OF SCALE

CALCULATED BY YL DATE 12/1/2017

CHECKED BY DATE

Risa Results - 6-28 Blocks - 50' Wall Height

Web

fc' = 5000 psi

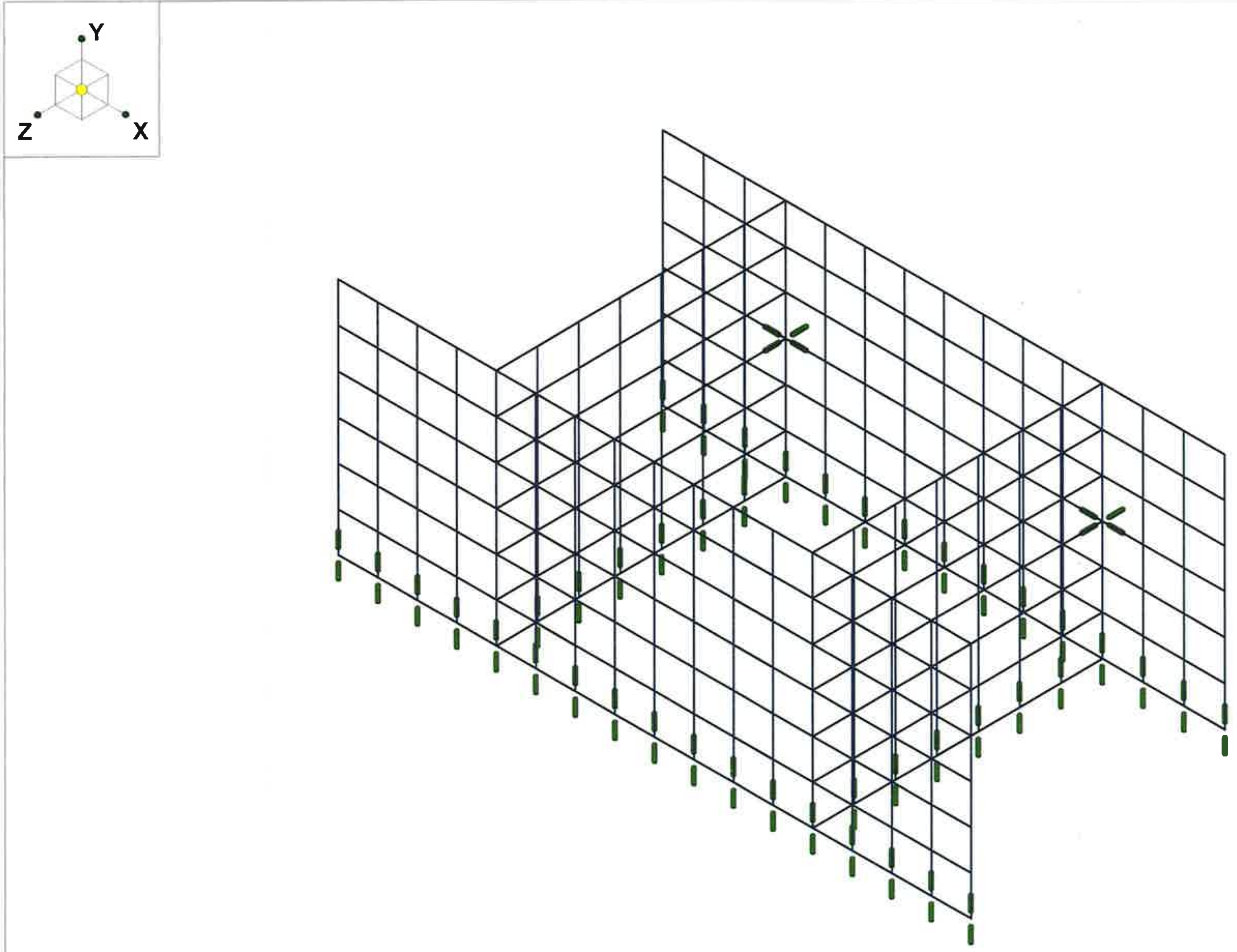
5*√f'c = 354 psi

Tu = 9.47 k/ft

Thickness t = 5 in

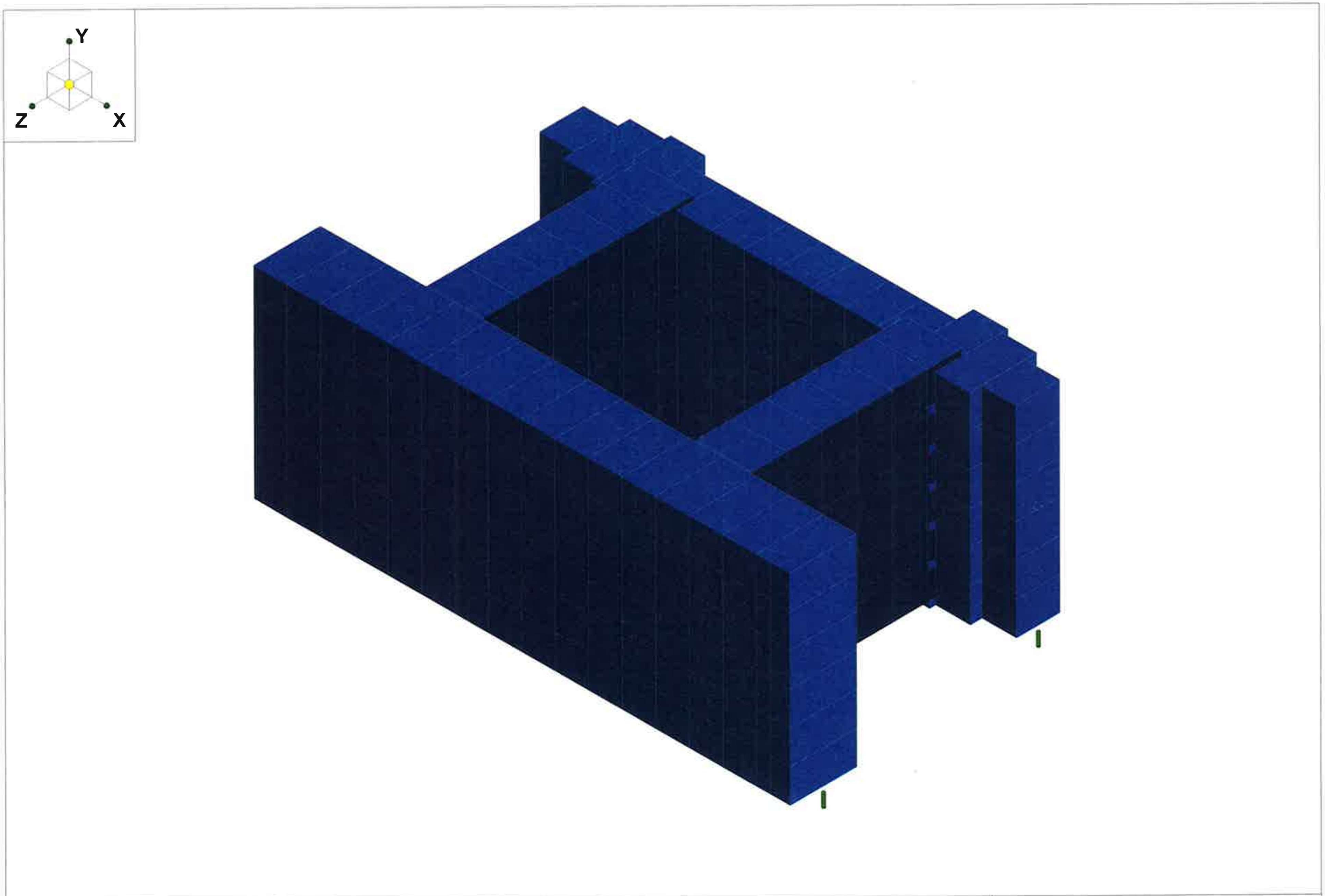
ϕTn =0.6*5*√f'c *12 t = 12.73 k/ft OK

Web Reinforcing required for temperature and shrinkage only.

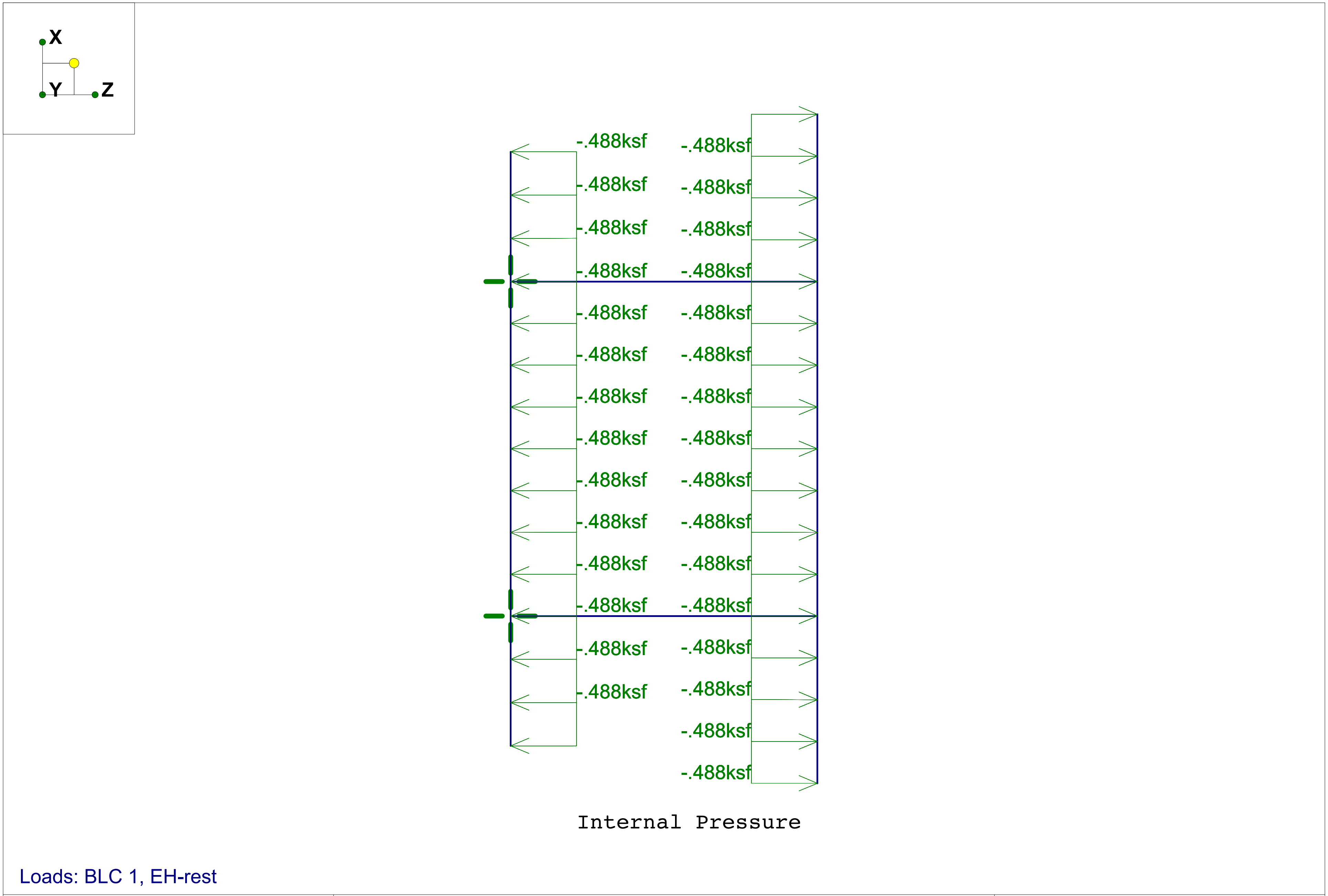


Delta Engineers,Inc	Reinforced Wall 50ft 6-28 Blocks	SK - 1
YL		Nov 20, 2017 at 2:45 PM
2017.478.001		6-28 Block_50ft Wall.r3d

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017

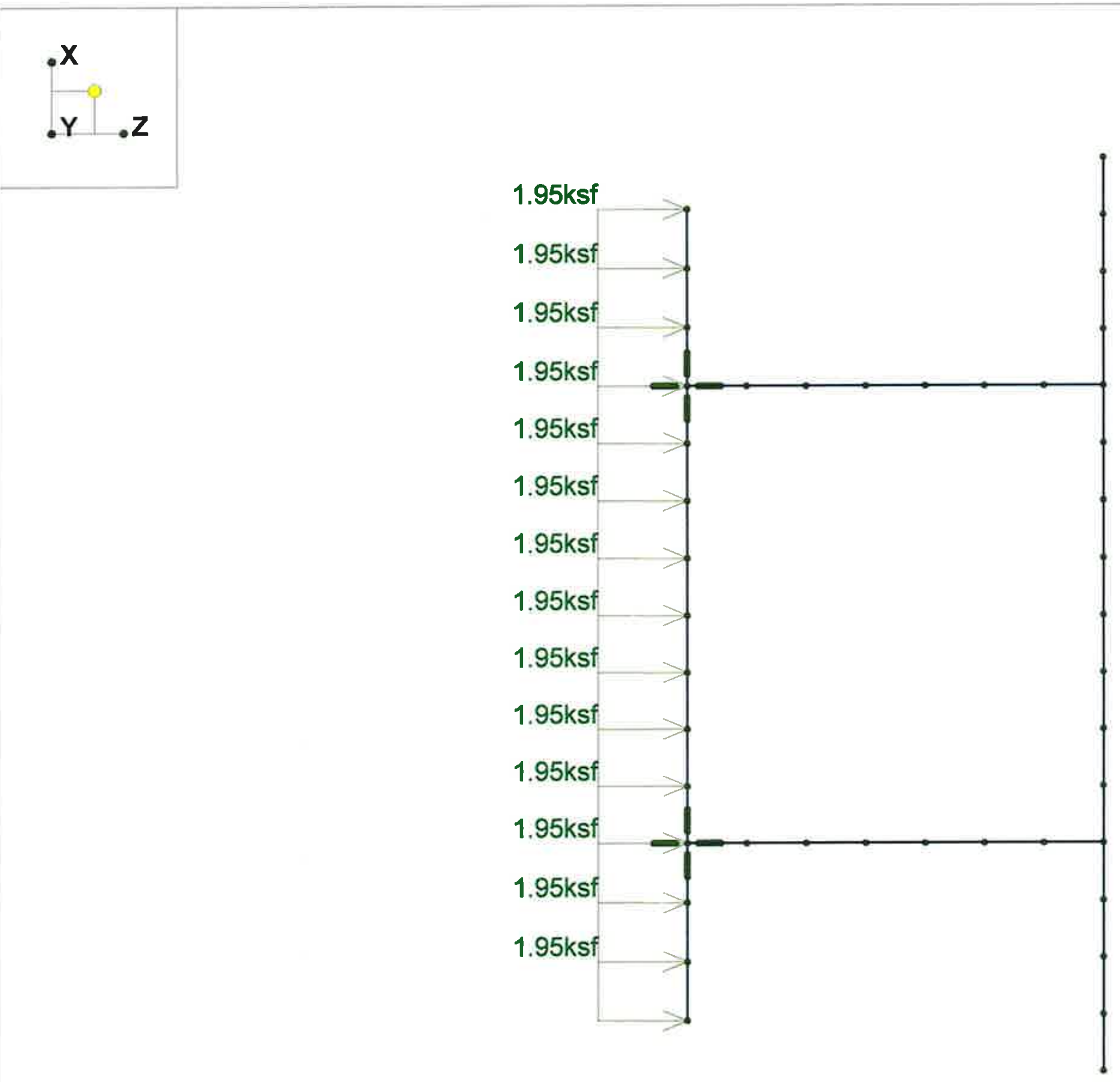


Delta Engineers,Inc	Reinforced Wall 50ft 6-28 Blocks	SK - 2
YL		Nov 20, 2017 at 2:45 PM
2017.478.001		6-28 Block_50ft Wall.r3d



Loads: BLC 1, EH-rest

Delta Engineers,Inc	Reinforced Wall 50ft 6-28 Blocks	SK - 3
YL		Dec 1, 2017 at 8:59 AM
2017.478.001		6-28 Block_50ft Wall.r3d

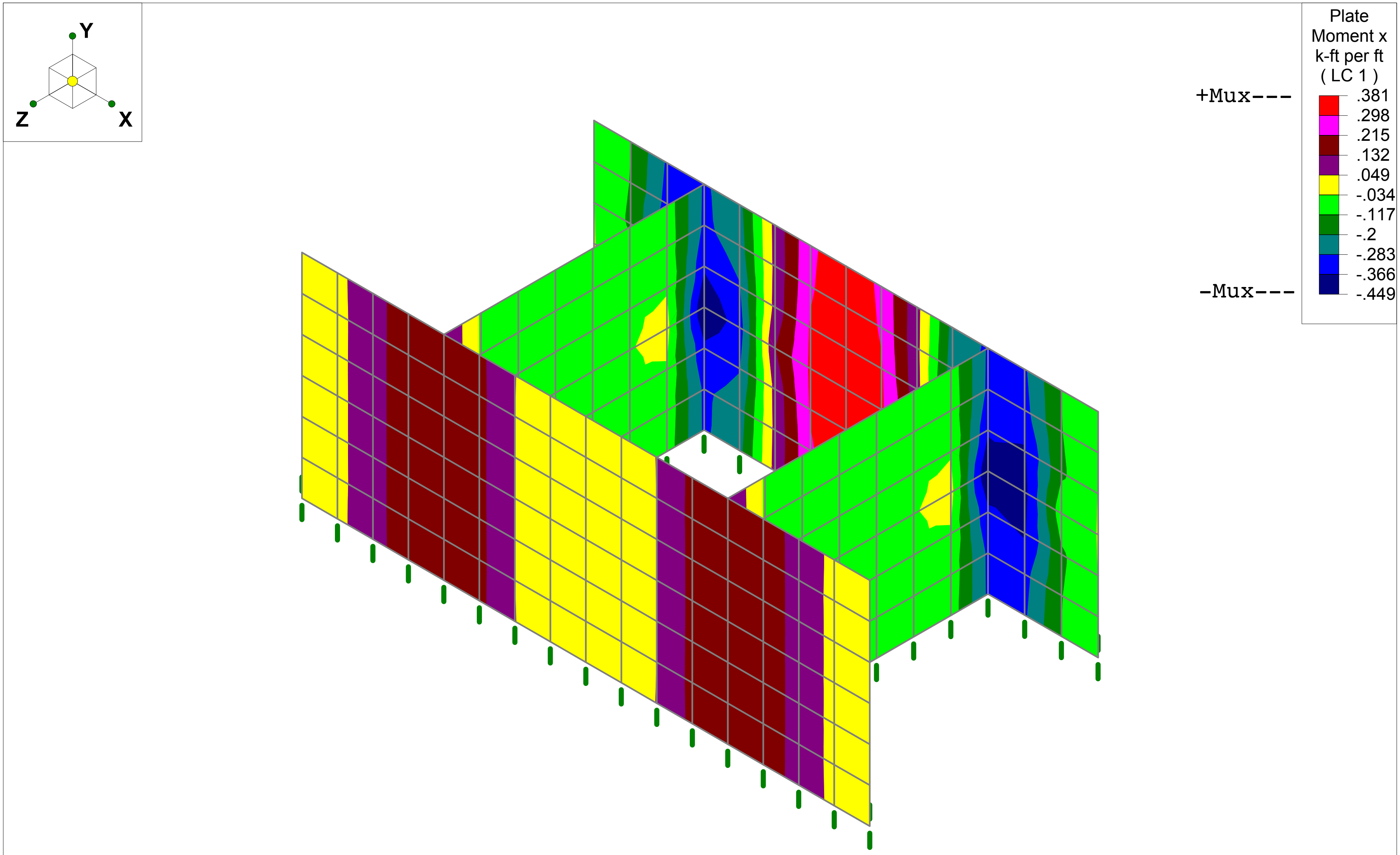


External Pressure

Loads: BLC 2, EH-active

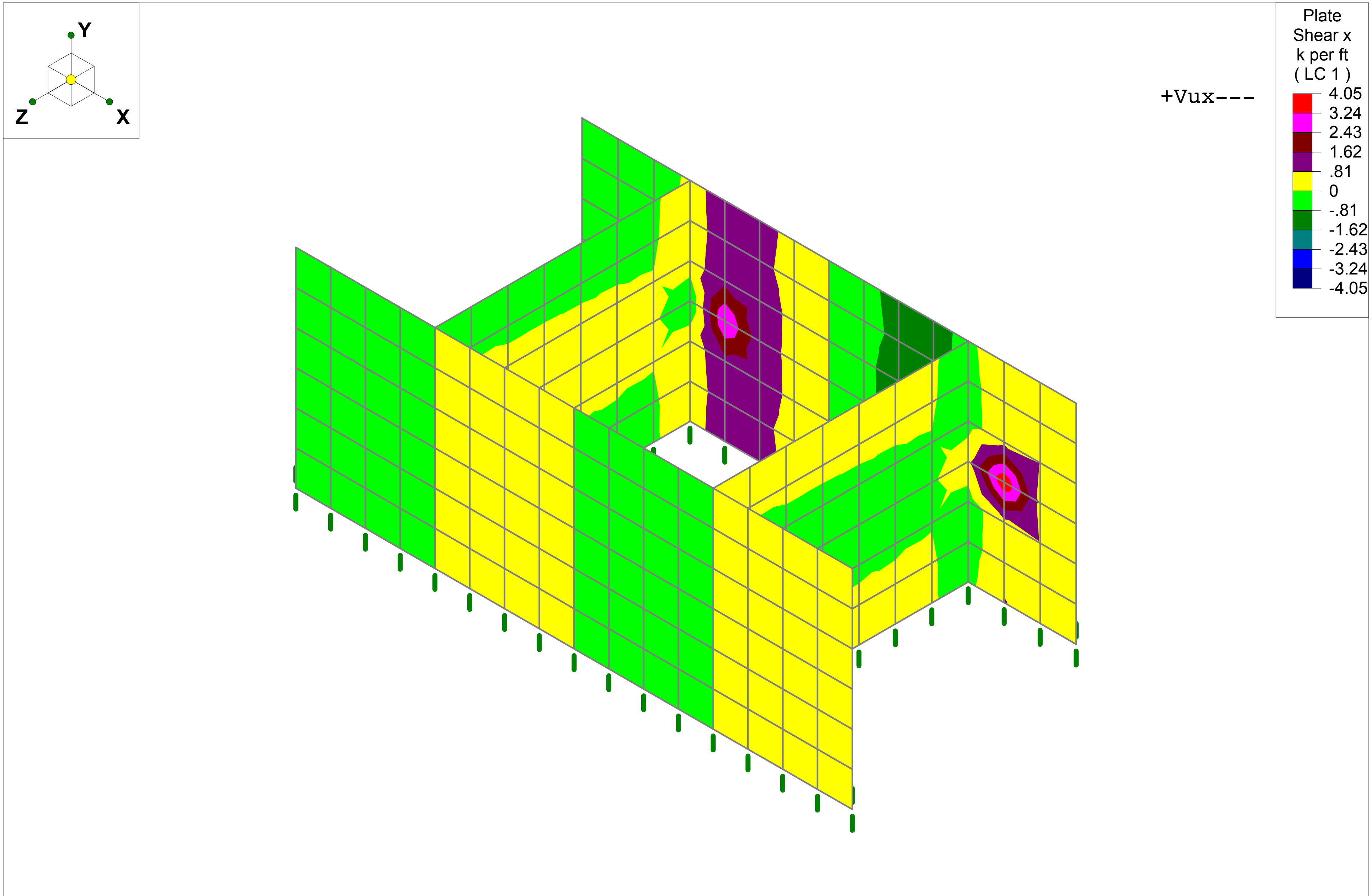
Delta Engineers,Inc	Reinforced Wall 50ft 6-28 Blocks	SK - 4
YL		Nov 20, 2017 at 2:45 PM
2017.478.001		6-28 Block_50ft Wall.r3d

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017



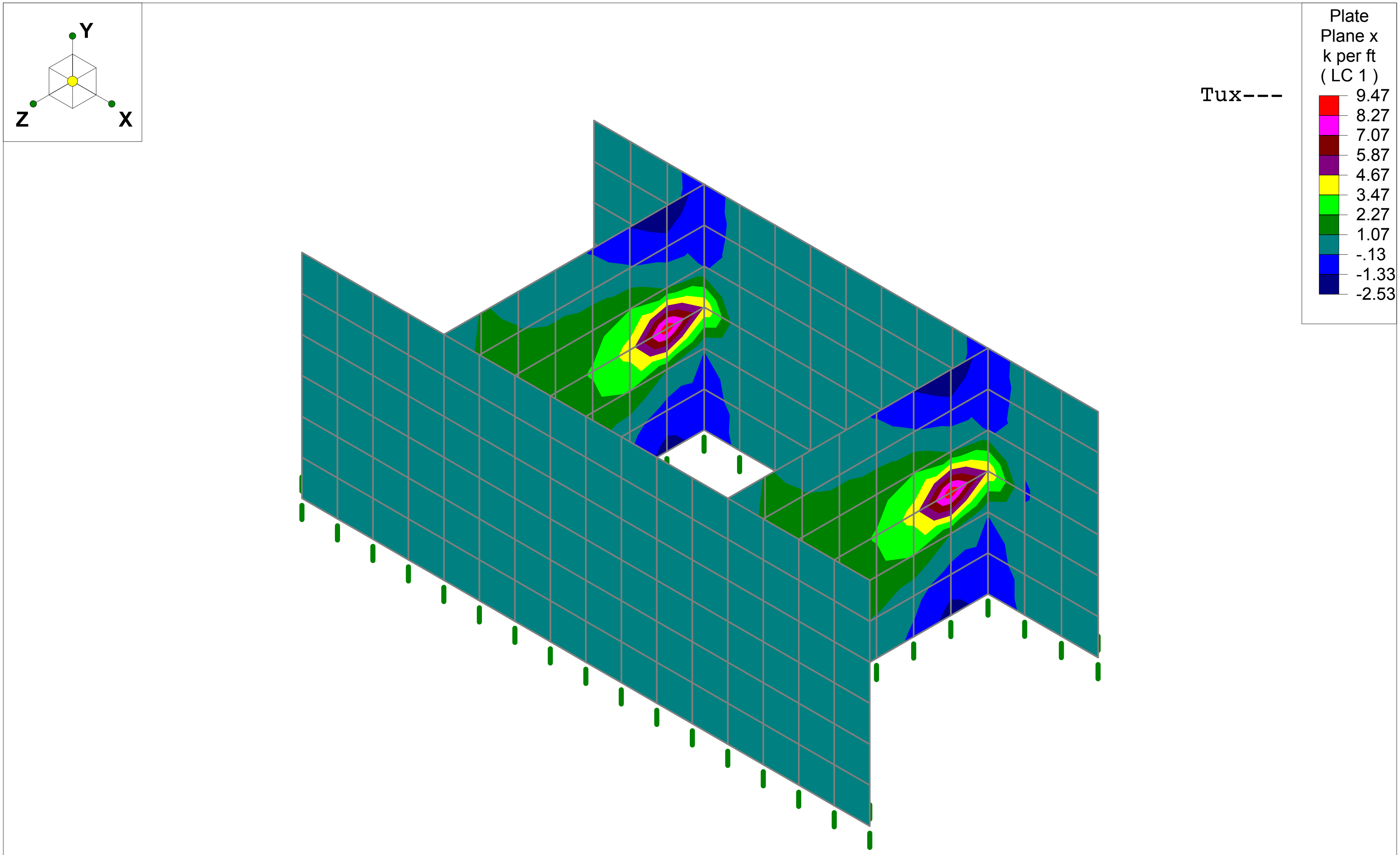
Results for LC 1, 1.35EH-at rest +1.5EH - active + 1.75LS

Delta Engineers,Inc	Reinforced Wall 50ft 6-28 Blocks	SK - 5
YL		Dec 1, 2017 at 9:01 AM
2017.478.001		6-28 Block_50ft Wall.r3d



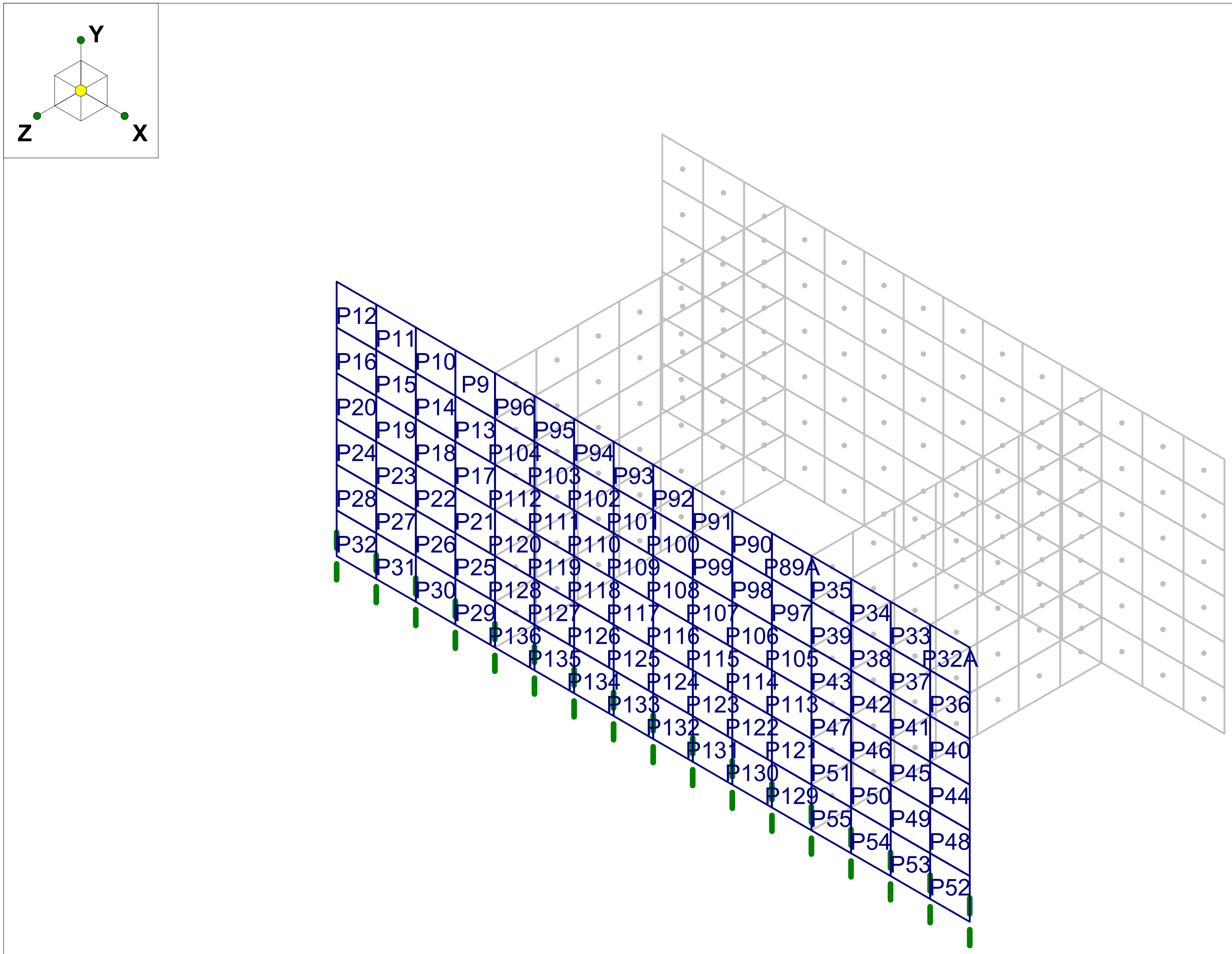
Results for LC 1, 1.35EH-at rest +1.5EH - active + 1.75LS

Delta Engineers,Inc	Reinforced Wall 50ft 6-28 Blocks	SK - 6
YL		Dec 1, 2017 at 9:03 AM
2017.478.001		6-28 Block_50ft Wall.r3d



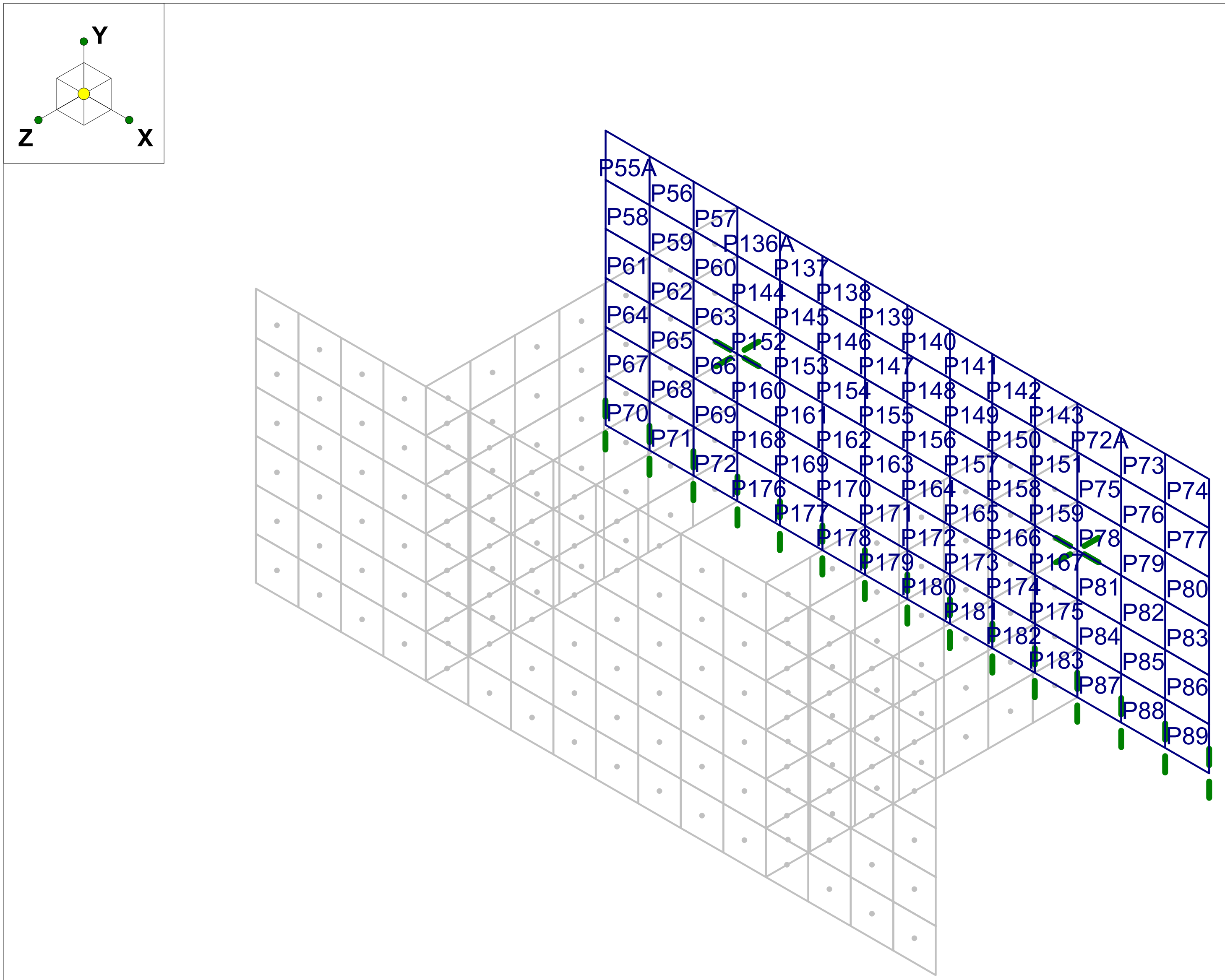
Results for LC 1, 1.35EH-at rest +1.5EH - active + 1.75LS

Delta Engineers,Inc	Reinforced Wall 50ft 6-28 Blocks	SK - 7
YL		Dec 1, 2017 at 9:06 AM
2017.478.001		6-28 Block_50ft Wall.r3d



Front Face Plates

Delta Engineers,Inc	Reinforced Wall 50ft 6-28 Blocks	SK - 8
YL		Dec 1, 2017 at 9:35 AM
2017.478.001		6-28 Block_50ft Wall.r3d



Rear Face Plates

Delta Engineers,Inc	Reinforced Wall 50ft 6-28 Blocks	SK - 9
YL		Dec 1, 2017 at 9:51 AM
2017.478.001		6-28 Block_50ft Wall.r3d

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017

Company : Delta Engineers,Inc
Designer : YL
Job Number : 2017.478.001
Model Name : Reinforced Wall 50ft 6-28 Blocks

Nov 20, 2017
3:09 PM
Checked By:_____

Basic Load Cases

	BLC Description	Category	X Gravity	Y Gravity	Z Gravity	Joint	Point	Distributed	Area(Me...	Surface(...
1	EH-rest	None								180
2	EH-active	None								84
3	LS	None								

Load Combinations

	Description	S...	P...	S...	B...	Factor	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...
1	1.35EH-at rest +1.5EH - active + ..	Yes			1	1.35	2	1.5	3	1.75																
2	EH-at rest +EH - active +LS	Yes			1	1	2	1	3	1																

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017

Plate Forces (per ft) (By Combination)

Front Face Max. +Mux

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P47	.591	0	$\boxed{.259}$	.026	0	.023	-.086	-.033
2	1	P21	-.591	0	.259	.026	0	.023	-.086	.033
3	1	P51	.587	.024	.259	.021	0	.025	-.1	-.018
4	1	P25	-.587	.024	.259	.021	0	.025	-.1	.018
5	1	P43	.583	-.016	.259	.024	0	.015	-.067	-.044
6	1	P17	-.583	-.016	.259	.024	0	.015	-.067	.044
7	1	P39	.57	-.026	.258	.018	0	0	-.047	-.051
8	1	P13	-.57	-.026	.258	.018	0	0	-.047	.051
9	1	P55	.56	.042	.255	.011	0	.012	-.113	0
10	1	P29	-.56	.042	.255	.011	0	.012	-.113	0

Designed By: YL 12/18/2017
Checked By: GAS 12/18/2017

Plate Forces (per ft) (By Combination)

Front Face Max. -Mux

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P125	.079	-.011	-.033	-.008	.001	-.008	-.045	0
2	1	P124	-.079	-.011	-.033	-.008	-.001	-.008	-.045	0
3	1	P101	.079	.011	-.033	-.008	-.001	.008	-.009	0
4	1	P100	-.079	.011	-.033	-.008	.001	.008	-.009	0
5	1	P117	.078	-.004	-.033	-.012	0	-.008	-.034	0
6	1	P116	-.078	-.004	-.033	-.012	0	-.008	-.034	0
7	1	P133	.09	-.01	-.032	-.003	.001	0	-.05	0
8	1	P132	-.09	-.01	-.032	-.003	-.001	0	-.05	0
9	1	P109	.078	.003	-.032	-.012	0	0	-.022	0
10	1	P108	-.078	.003	-.032	-.012	0	0	-.022	0

Plate Forces (per ft) (By Combination)

`Front Face Max. Vux`

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P47	.591	0	.259	.026	0	.023	-.086	-.033
2	1	P21	-.591	0	.259	.026	0	.023	-.086	.033
3	1	P51	.587	.024	.259	.021	0	.025	-.1	-.018
4	1	P25	-.587	.024	.259	.021	0	.025	-.1	.018
5	1	P89A	-.585	-.016	.213	.005	.004	-.04	-.032	.045
6	1	P96	.585	-.016	.213	.005	-.004	-.04	-.032	-.045
7	1	P43	.583	-.016	.259	.024	0	.015	-.067	-.044
8	1	P17	-.583	-.016	.259	.024	0	.015	-.067	.044
9	1	P121	-.581	.021	.216	.016	-.002	.017	-.1	.035
10	1	P128	.581	.021	.216	.016	.002	.017	-.1	-.035

Plate Forces (per ft) (By Combination)

Rear Face Max. +Mux

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P155	.288	.008	$\boxed{.375}$	-.016	.002	.079	.031	-.012
2	1	P156	-.288	.008	.375	-.016	-.002	.079	.031	.012
3	1	P163	.288	-.009	.375	-.016	-.002	.069	.056	-.015
4	1	P164	-.288	-.009	.375	-.016	.002	.069	.056	.015
5	1	P148	-.278	.007	.368	-.007	-.004	.039	.01	.007
6	1	P147	.278	.007	.368	-.007	.004	.039	.01	-.007
7	1	P171	.277	-.007	.368	-.006	-.004	.031	.083	-.013
8	1	P172	-.277	-.007	.368	-.006	.004	.031	.083	.013
9	1	P140	-.285	-.004	.361	.001	-.002	-.057	0	0
10	1	P139	.285	-.004	.361	.001	.002	-.057	0	0

Plate Forces (per ft) (By Combination)

Rear Face Max. -Mux

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P63	-3.505	4.03	-.628	-.798	-.156	-.15	1.306	.247
2	1	P78	3.505	4.03	-.628	-.798	.156	-.15	1.306	-.247
3	1	P66	-3.478	-4.098	-.625	-.789	.16	-.129	1.195	-.332
4	1	P81	3.478	-4.098	-.625	-.789	-.16	-.129	1.195	.332
5	1	P152	3.083	2.271	-.58	-.238	.016	-.077	.744	-.142
6	1	P159	-3.083	2.271	-.58	-.238	-.016	-.077	.744	.142
7	1	P160	3.069	-2.306	-.579	-.236	-.016	-.06	.68	.19
8	1	P167	-3.069	-2.306	-.579	-.236	.016	-.06	.68	-.19
9	1	P151	-1.287	.551	-.454	-.072	.006	-.041	.149	.301
10	1	P144	1.287	.551	-.454	-.072	-.006	-.041	.149	-.301

Plate Forces (per ft) (By Combination)

Rear Face Max. Vux

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P63	-3.505	4.03	-.628	-.798	-.156	-.15	1.306	.247
2	1	P78	3.505	4.03	-.628	-.798	.156	-.15	1.306	-.247
3	1	P66	-3.478	-4.098	-.625	-.789	.16	-.129	1.195	-.332
4	1	P81	3.478	-4.098	-.625	-.789	-.16	-.129	1.195	.332
5	1	P152	3.083	2.271	-.58	-.238	.016	-.077	.744	-.142
6	1	P159	-3.083	2.271	-.58	-.238	-.016	-.077	.744	.142
7	1	P160	3.069	-2.306	-.579	-.236	-.016	-.06	.68	.19
8	1	P167	-3.069	-2.306	-.579	-.236	.016	-.06	.68	-.19
9	1	P176	1.613	-.023	-.413	-.032	.013	.111	-.335	.128
10	1	P183	-1.613	-.023	-.413	-.032	-.013	.111	-.335	-.128

DELTA
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860 Hooper Road, Endwell, NY 13760
www.delta-eas.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB 2017.478.001

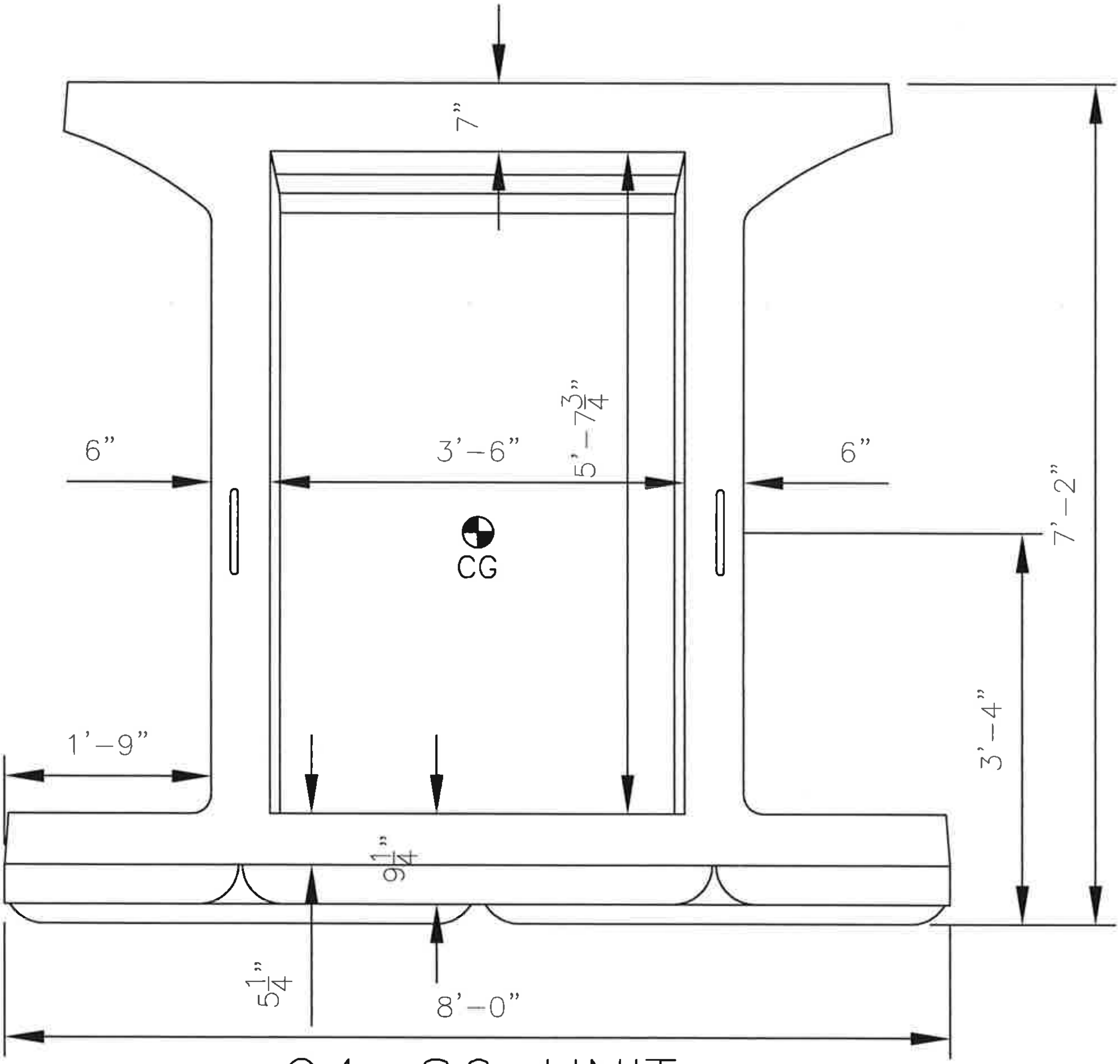
DESCRIPTION Stonestrong Retaining Wall

SHEET NO OF SCALE

CALCULATED BY YL DATE 6/8/2017

CHECKED BY DATE

Handling Analysis



24-86 UNIT

Block Library

10/31/2013

Unit Type	Unit Description (check unit availability - see Note)	Conc. Wt. (lbs)	Void Vol (ft^3)	Length (ft)	Height (ft)	Unit Width (in)	Lift (in)	Align (in)	x_c (in)	x_v (in)	Special Top
6	6SF unit (6 square feet)	1,600	10.75	4	1.50	44	19.0	17.0	21.0	23.5	
24	24SF unit (24 square feet)	6,000	43.74	8	3.00	44	21.0	17.0	21.2	24.8	
24-ME	24SF Mass Extender unit	10,000	45.45	8	3.00	56	21.0	17.0	32.7	25.8	
24-M6	24SF w/ 6" Mass Extender	8,000	44.35	8	3.00	50	21.0	17.0	38.5	25.3	
24-M18	24SF w/ 18" Mass Extender	12,000	45.56	8	3.00	62	21.0	17.0	50.0	26.5	
24-M24	24SF w/ 24" Mass Extender	14,000	46.16	8	3.00	68	21.0	17.0	44.2	26.1	
24-62	24-62 unit (24 square feet)	6,855	75.87	8	3.00	62	21.0	17.0	29.1	33.0	
24-86	24-86 unit (24 square feet)	7,693	115.07	8	3.00	86	21.0	17.0	40.0	45.1	
Alternate top units (not typically used - regular 24SF top unit is used in most applications, analyzed as regular 24 SF unit)											
Cap	Cap unit	1,600	0.00	8	0.58	32.0		16.0	16.0	16.0	Yes
DF	Dual Face unit	3,500	0.00	8	1.50	28.0	14.0	14.0	14.0	14.0	Yes
Cast-in-place coping (overhang would be 19 inches less than the Alignment dimension entered - custom coping may be entered below)											
12" cp	cast-in-place concrete coping	604		1	1.00	**50.0**		**27.0**	25.0		Yes
18" cp	cast-in-place concrete coping	906		1	1.50	**50.0**		**27.0**	25.0		Yes
24" cp	cast-in-place concrete coping	1,208		1	2.00	**50.0**		**27.0**	25.0		Yes
30" cp	cast-in-place concrete coping	1,510		1	2.50	**50.0**		**27.0**	25.0		Yes
coping	custom cast-in-place concrete coping	755		1	**1.25**	**50.0**		**27.0**	25.0		Yes
Vertical stack units (modified recess and face to permit construction of a vertical face)											
V6	6SF unit (6 square feet)	1,600	10.75	4	1.50	44	21.0	21.0	21.0	23.5	
V24	24SF unit (24 square feet)	6,000	43.74	8	3.00	44	21.0	21.0	21.2	24.8	
V24-ME	24SF Mass Extender unit	10,000	45.45	8	3.00	56	21.0	21.0	32.7	25.8	
V24-M6	24SF w/ 6" Mass Extender	8,000	44.35	8	3.00	50	21.0	21.0	38.5	25.3	
V24-M18	24SF w/ 18" Mass Extender	12,000	45.56	8	3.00	62	21.0	21.0	50.0	26.5	
V24-M24	24SF w/ 24" Mass Extender	14,000	46.16	8	3.00	68	21.0	21.0	44.2	26.1	
V24-62	24-62 unit (24 square feet)	6,855	75.87	8	3.00	62	21.0	21.0	29.1	33.0	
V24-86	24-86 unit (24 square feet)	7,693	115.07	8	3.00	86	21.0	21.0	40.0	45.1	
Green Wall units (increased setback - use for green wall or as isolated planter block)											
G6	6SF unit set behind loops (6 square feet)	1,600	10.75	4	1.50	44	19.0	**-4.5**	21.0	23.5	
G24	24SF unit set behind loops (24 square feet)	6,000	43.74	8	3.00	44	21.0	**-4.5**	21.2	24.8	
Custom user entered elements below (use for any dealer specific variances from above default dimensions/weights)											

Note: Check on availability of all units w/ local Producer/Dealer. Some units may have limited availabilty.

JOB 2017.478.001
DESCRIPTION Stonestrong Retaining Wall
SHEET NO OF SCALE
CALCULATED BY YL DATE 6/8/2017
CHECKED BY DATE

Handling Analysis

24-86 Blocks control.

Stripping fc' = 2500 psi
5*√f'c = 250 psi

Load Factor = 1.3

Casting Position - Face Down

Assume a single strap a midpoint of rear face

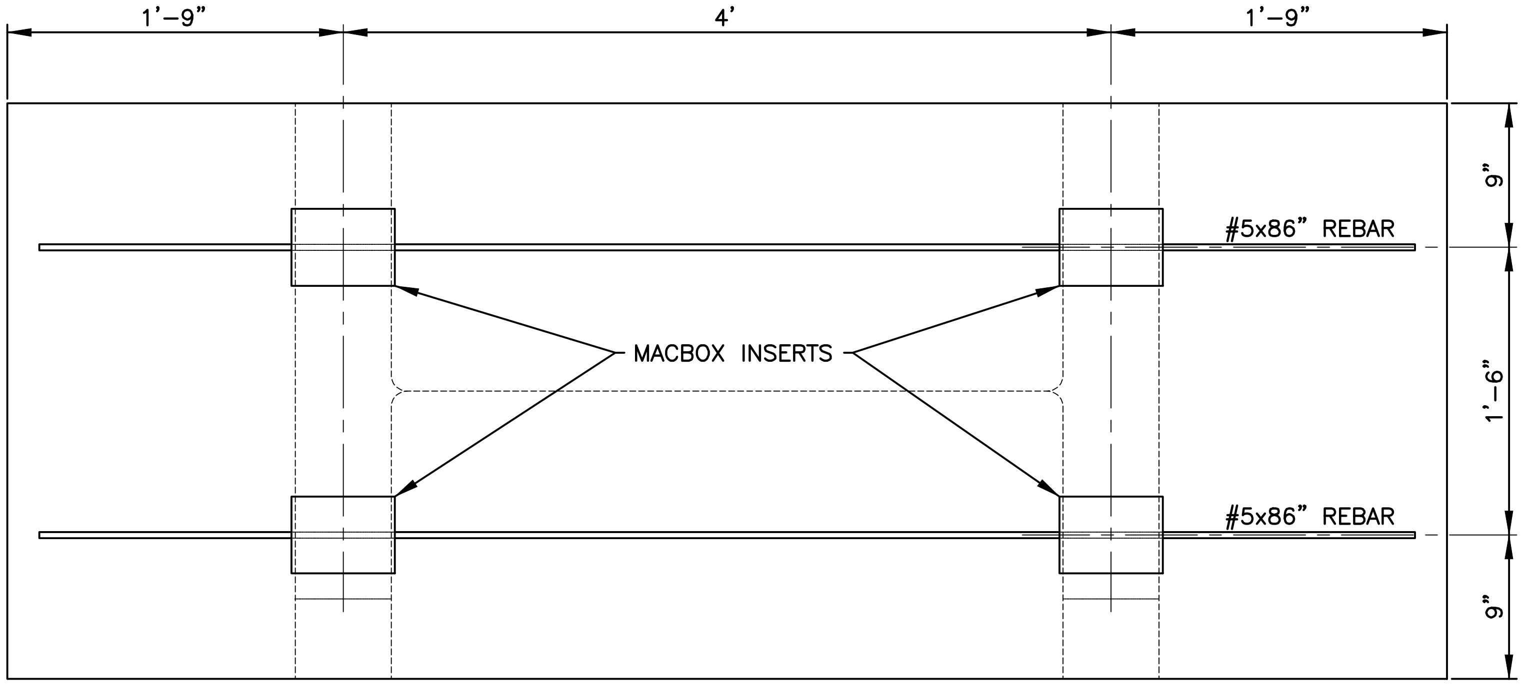
Weight of Block = 7693 lb
Web Tension Tu = 5000 lb
Web Height h = 36 in
Web Thickness t = 6 in
5*√f'c h t = 54000 lb OK

Upright Position

CG of Block from Front Face = 40 in
CG of Block from Rear Face = 46 in
Half of Block Weight = 3847 lb
Web Bending Mu = 9584 lb-ft
$S = t\,h^2/6 =$ 1296 in^3
5*√f'c S = 27000 lb-ft OK

1.1.4 REINFORCEMENT CONNECTION

Paraweb Connection Insert Details
Typical Paraweb Layout



24 SF UNIT w/PARAWEB INSERTS

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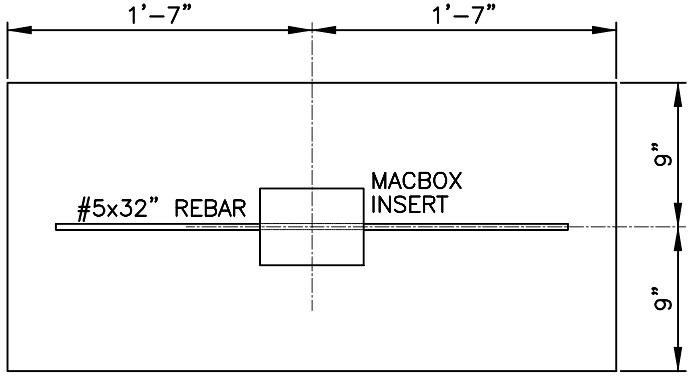
PROJECT

TYPICAL DETAILS
STONE STRONG SYSTEMS

DATE: 12/16/19 | FILE: 26_24sf–Rear Shell–Inserts



6 SF UNIT w/PARAWEB INSERT

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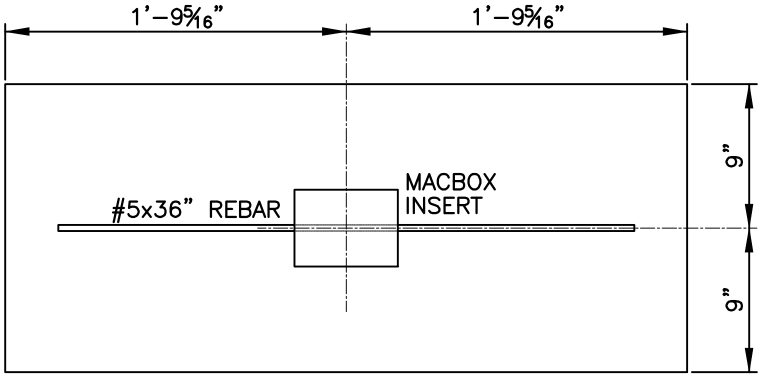
PROJECT
TYPICAL DETAILS
STONE STRONG SYSTEMS

DATE: 12/16/19 FILE: 27_6sf–Rear Shell–Insert



6–28 UNIT w/PARAWEB INSERT

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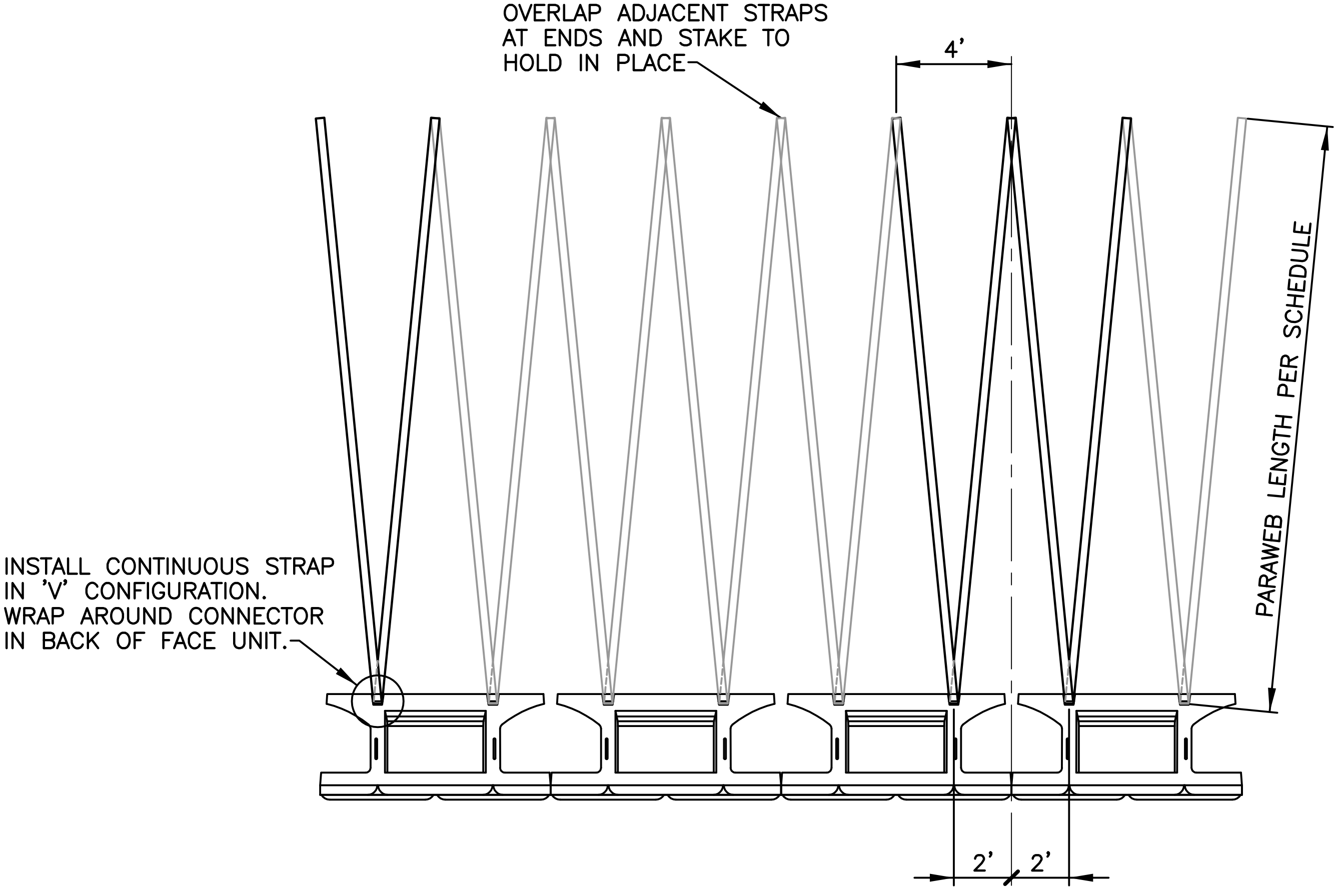
PROJECT

TYPICAL DETAILS
STONE STRONG SYSTEMS

DATE: 12/16/19 | FILE: 28_6–28 Rear Shell–Insert



TYPICAL PARAWEB LAYOUT

NOT TO SCALE

DISCLAIMER:

These typical details are preliminary and conceptual in nature. They are provided for general information purposes only. Anyone making use of these details and related information does so at their own risk and assumes all liability for such use. Site specific design should be performed by a licensed Professional Engineer based on actual site conditions, materials, and local practices.

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PROJECT

TYPICAL DETAILS
STONE STRONG SYSTEMS

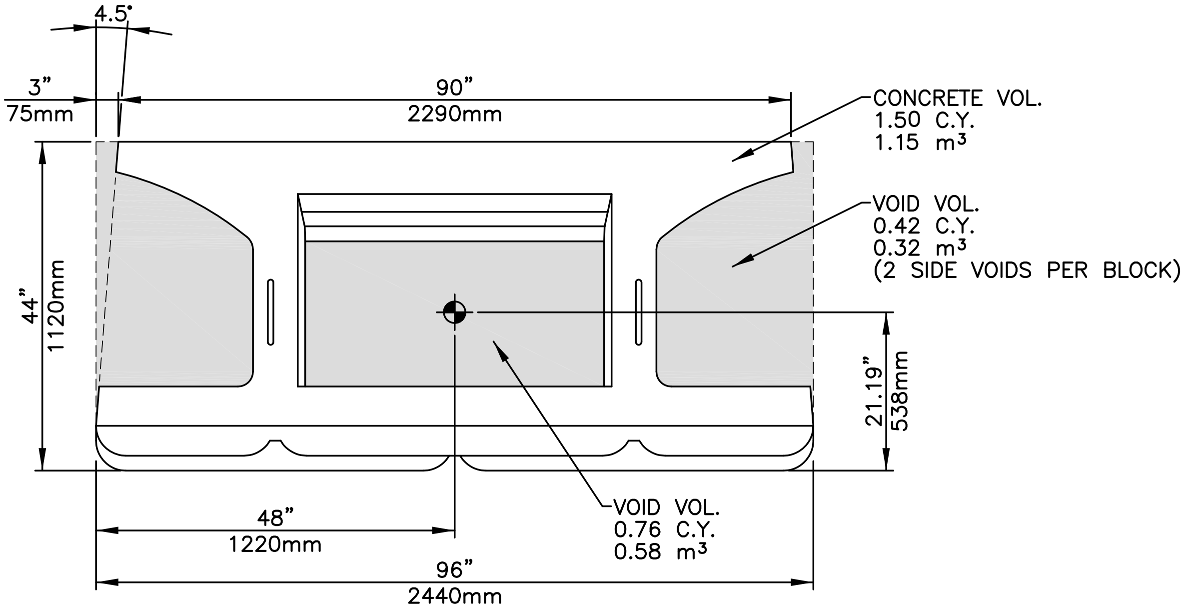
DATE: 6/29/18
FILE: 18_Typical Paraweb Layout

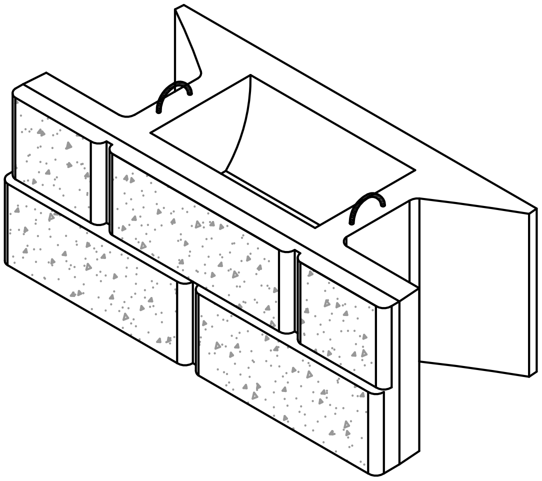
1.1.5 UNIT DIMENSIONS AND TOLERANCES

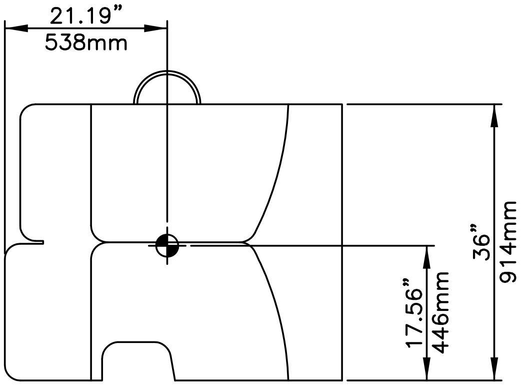
System Components

SYSTEM COMPONENTS

24 SF BLOCK



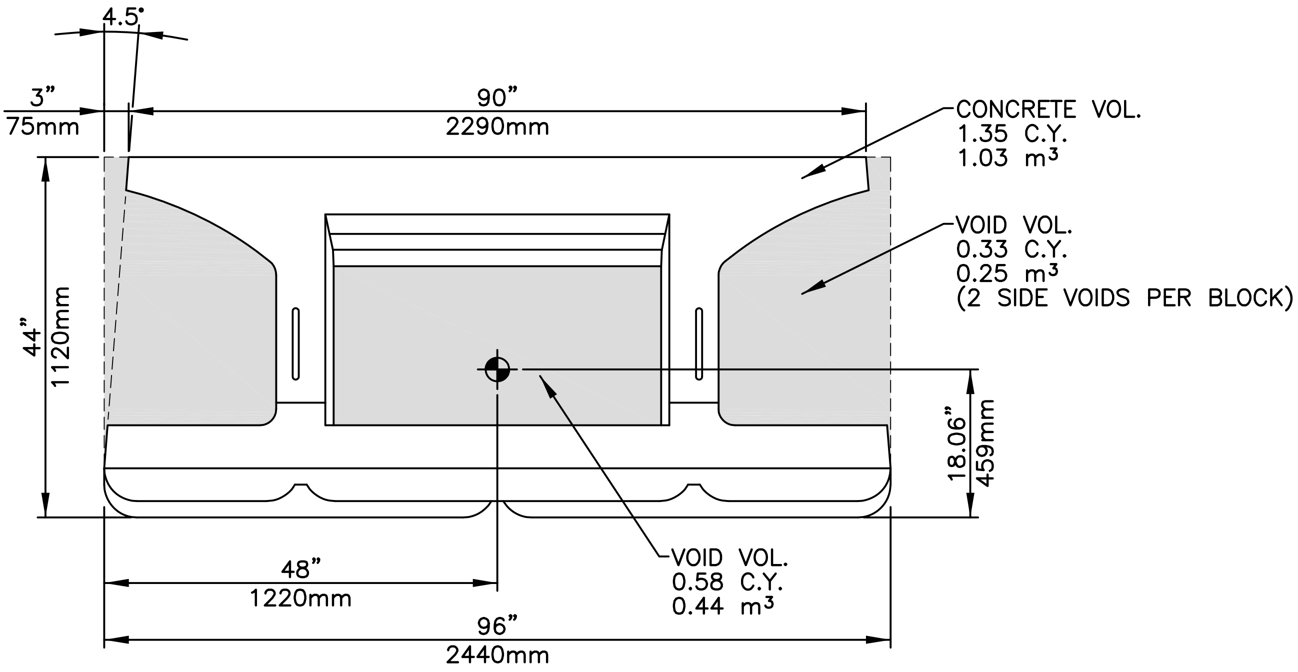


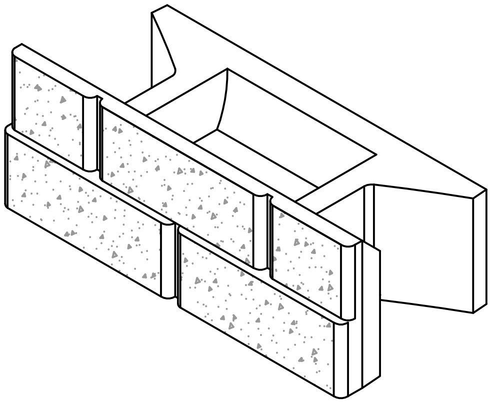


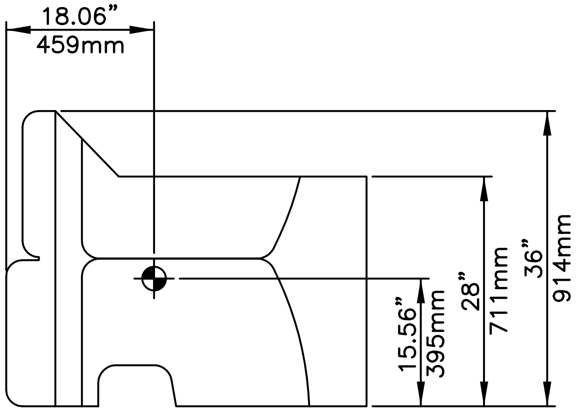
Block Wt.	6,000 lbs	2,720 kg
Form Wt.	4,600 lbs	2,090 kg
Concrete Volume	1.50 CY	1.15 m³
Aggregate Infill	1.60 CY	1.22 m³
(per face area)	0.1 tons/sf	1,000 kg/m²

SYSTEM COMPONENTS

24 SF TOP BLOCK







Block Wt.	5,400 lbs	2,445 kg
Form Wt.	4,930 lbs	2,235 kg
Concrete Volume	1.35 CY	1.03 m³
Aggregate Infill	1.24 CY	0.94 m³
(per face area)	0.1 tons/sf	1,000 kg/m²

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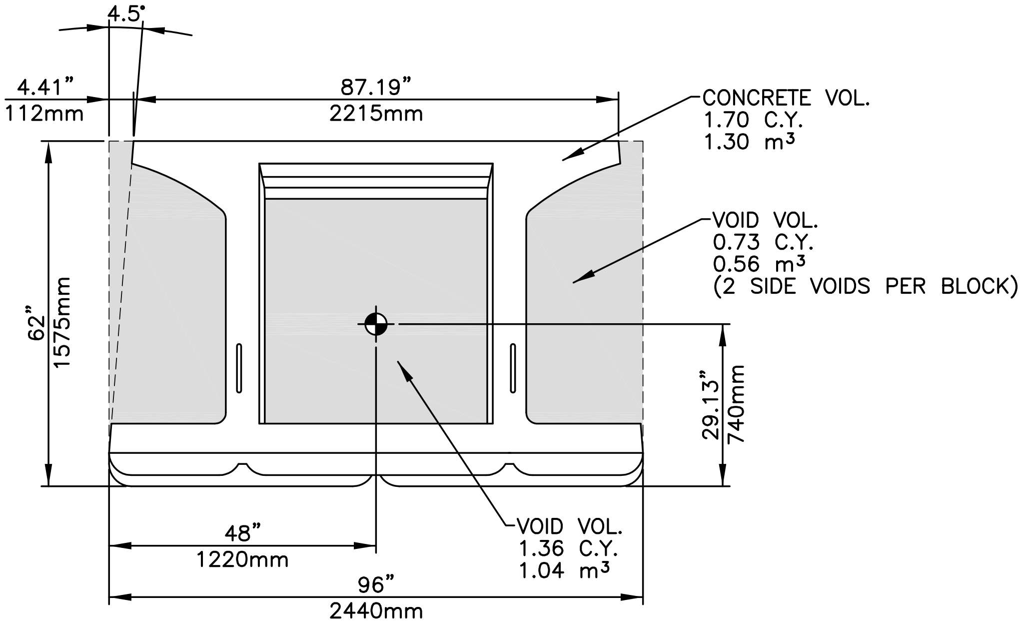
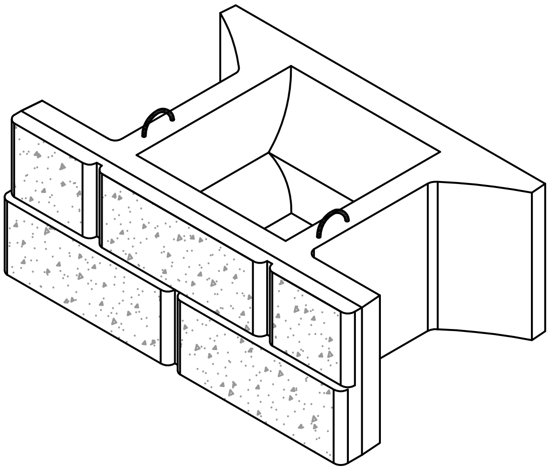
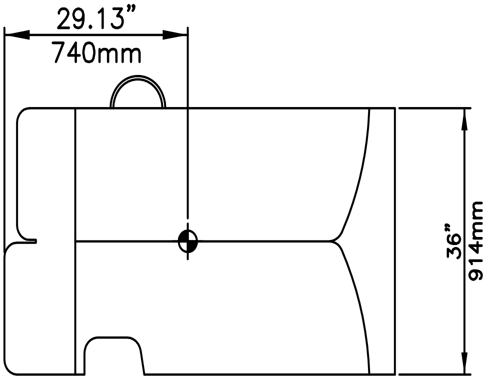
SYSTEM COMPONENTS

24 – 62 BLOCK



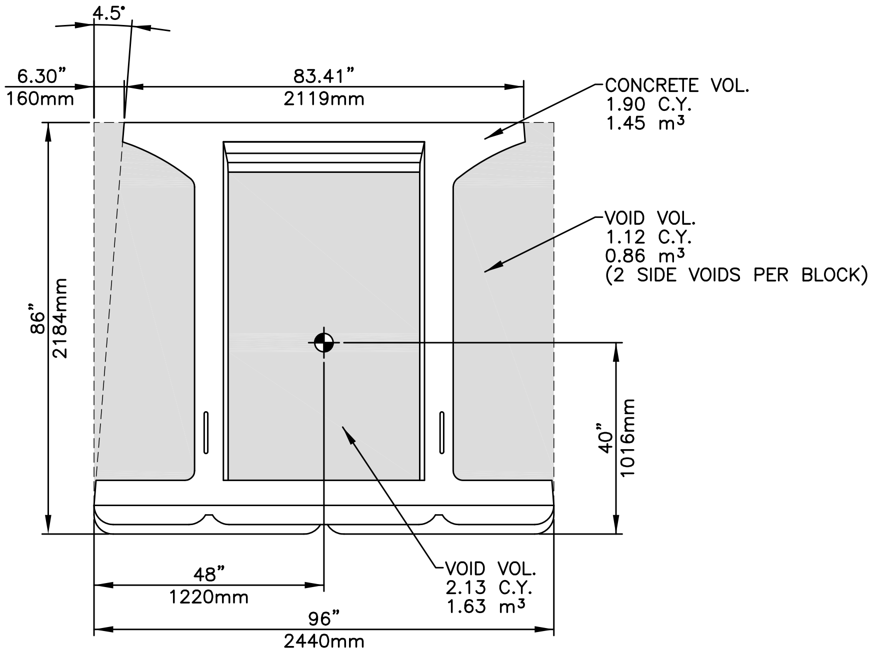


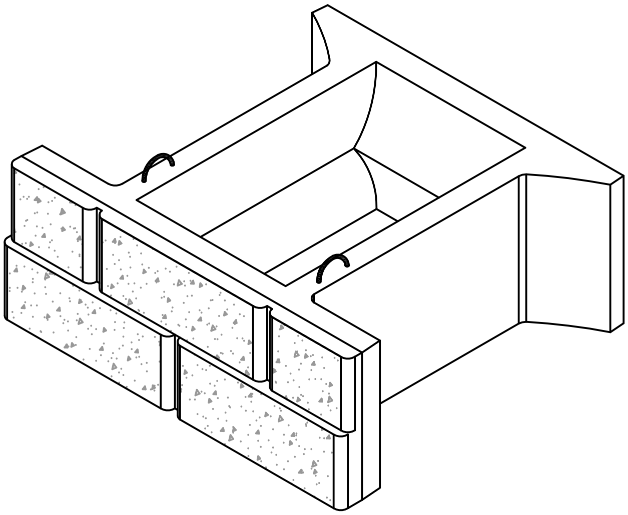


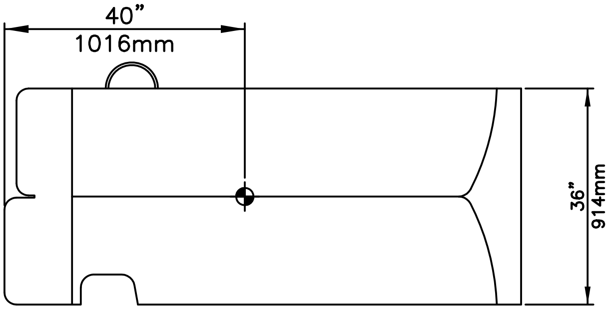
Block Wt.	6,800 lbs	3,080 kg
Form Wt.	6,580 lbs	2,990 kg
Concrete Volume	1.70 CY	1.30 m^3
Aggregate Infill	2.82 CY	2.16 m^3
(per face area)	0.2 tons/sf	2,000 kg/m^2

SYSTEM COMPONENTS

24 – 86 BLOCK







Block Wt.	7,600 lbs	3,445 kg
Form Wt.	7,695 lbs	3,490 kg
Concrete Volume	1.90 CY	1.45 m³
Aggregate Infill	4.37 CY	3.35 m³
(per face area)	0.3 tons/sf	3,000 kg/m²

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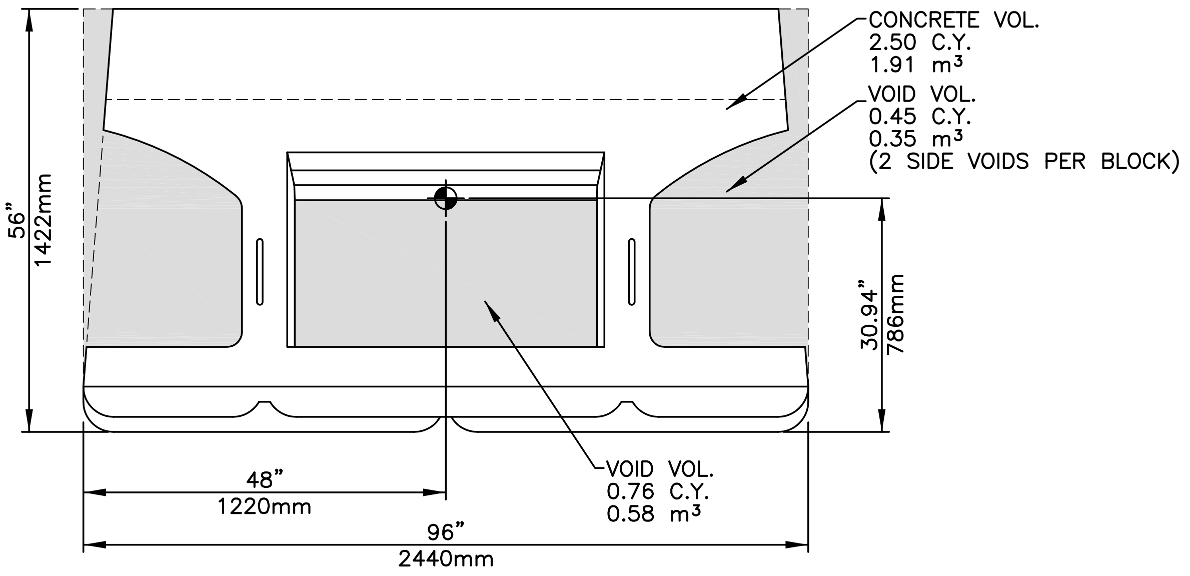
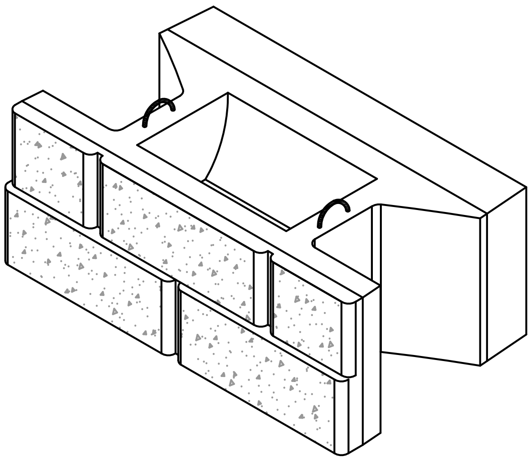
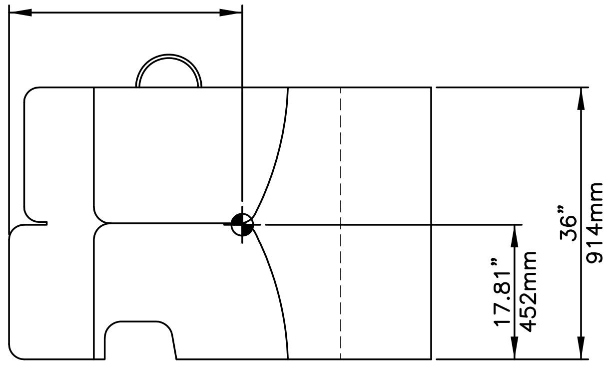
SYSTEM COMPONENTS

24 SF MASS EXTENDER BLOCK



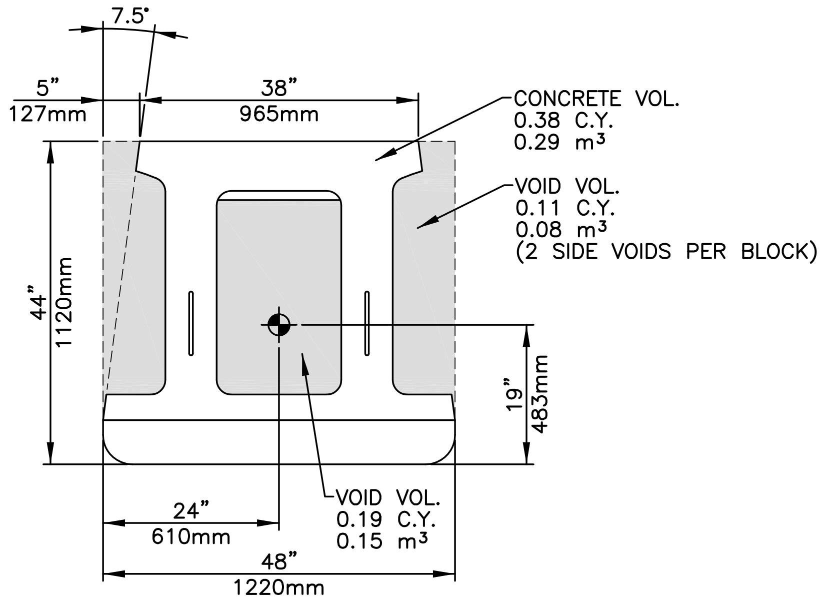


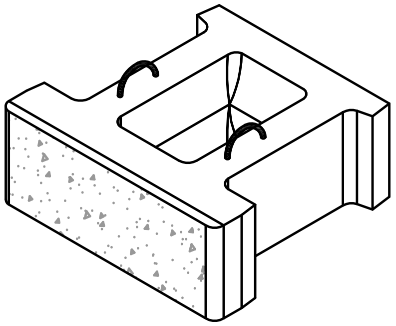


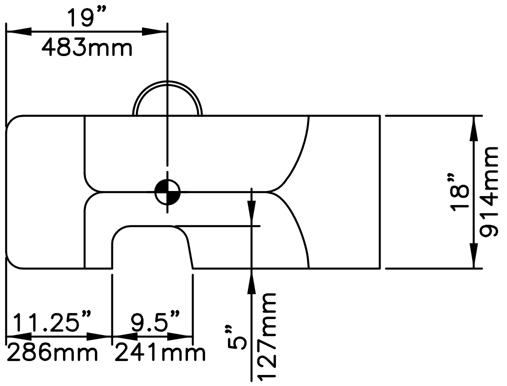
Block Wt.	10,000 lbs	4,585 kg
Form Wt.	5,120 lbs	2,320 kg
Concrete Volume	2.50 CY	1.91 m³
Aggregate Infill	1.66 CY	1.28 m³
(per face area)	0.1 tons/sf	1,000 kg/m²

SYSTEM COMPONENTS

6 SF BLOCK



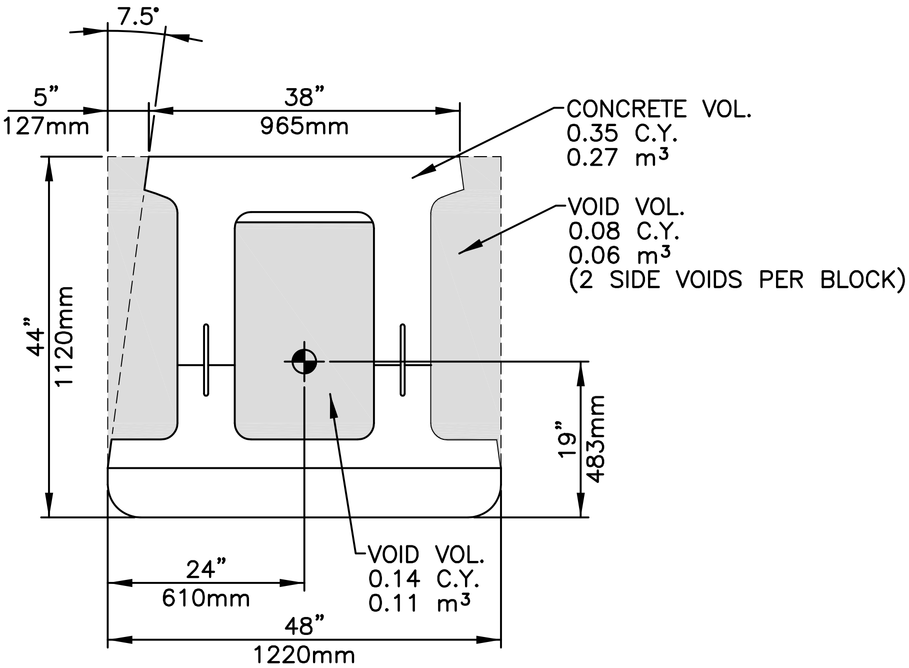


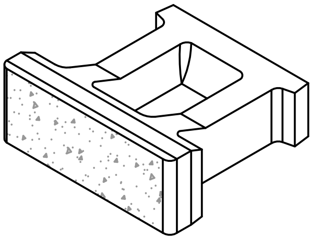


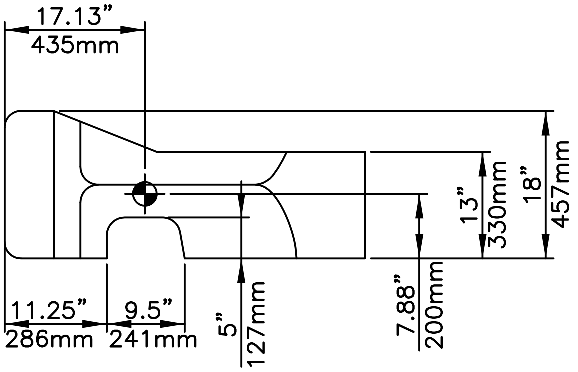
Block Wt.	1,500 lbs	680 kg
Form Wt.	1,800 lbs	815 kg
Concrete Volume	0.38 CY	0.29 m^3
Aggregate Infill	0.41 CY	0.31 m^3
(per face area)	0.1 tons/sf	1,000 kg/m^2

SYSTEM COMPONENTS

6SF TOP BLOCK







Block Wt.	**1,400 lbs**	**635 kg**
Form Wt.	**1,955 lbs**	**885 kg**
Concrete Volume	**0.5 CY**	**0.27 m³**
Aggregate Infill	**0.30 CY**	**0.23 m³**
(per face area)	**0.1 ton/sf**	**1,000 kg/ m²**

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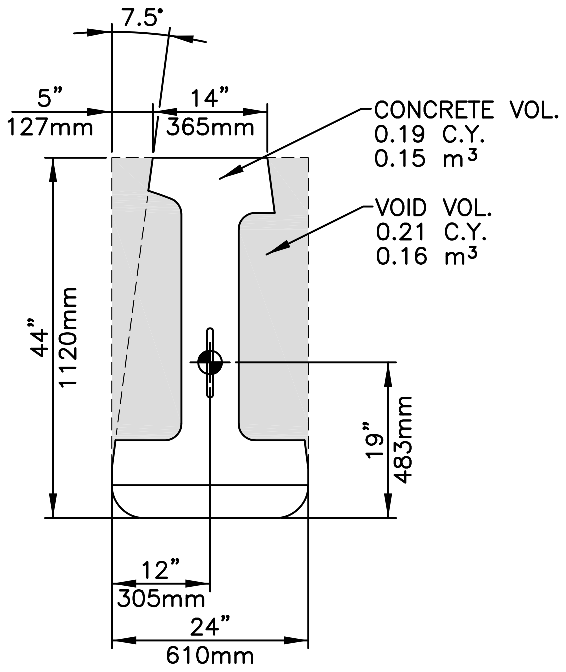
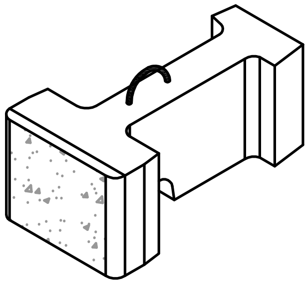
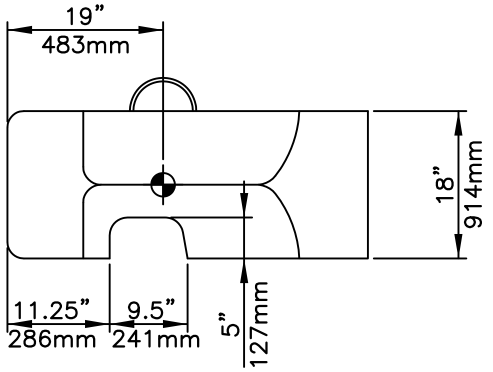
SYSTEM COMPONENTS

3SF BLOCK



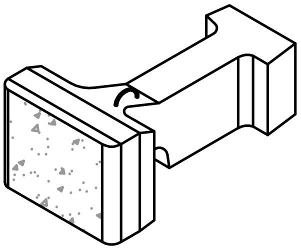


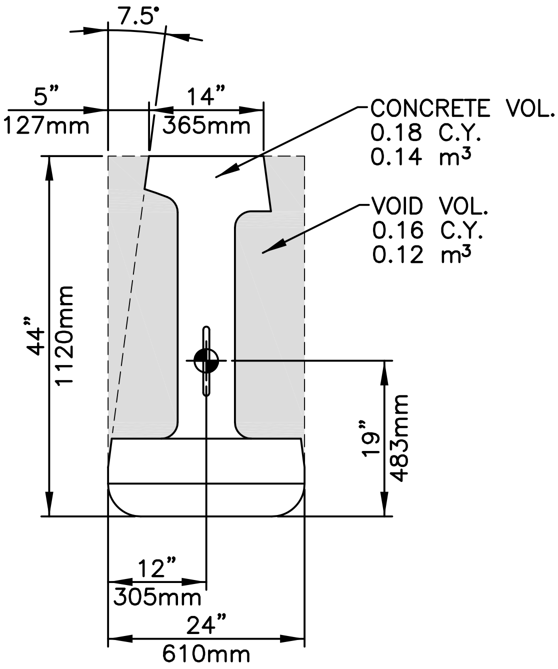


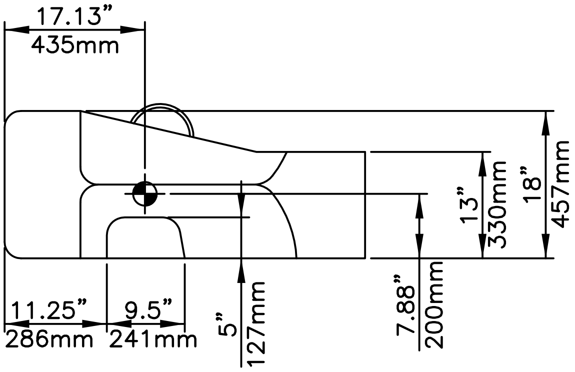
Block Wt.	**740 lbs**	**355 kg**
Form Wt.	**1,820 lbs**	**825 kg**
Concrete Volume	**0.19 CY**	**0.15 m^3**
Aggregate Infill	**0.21 CY**	**0.16 m^3**
(per face area)	**.01 ton/sf**	**1,000 kg/ m^2**

SYSTEM COMPONENTS

3SF TOP BLOCK



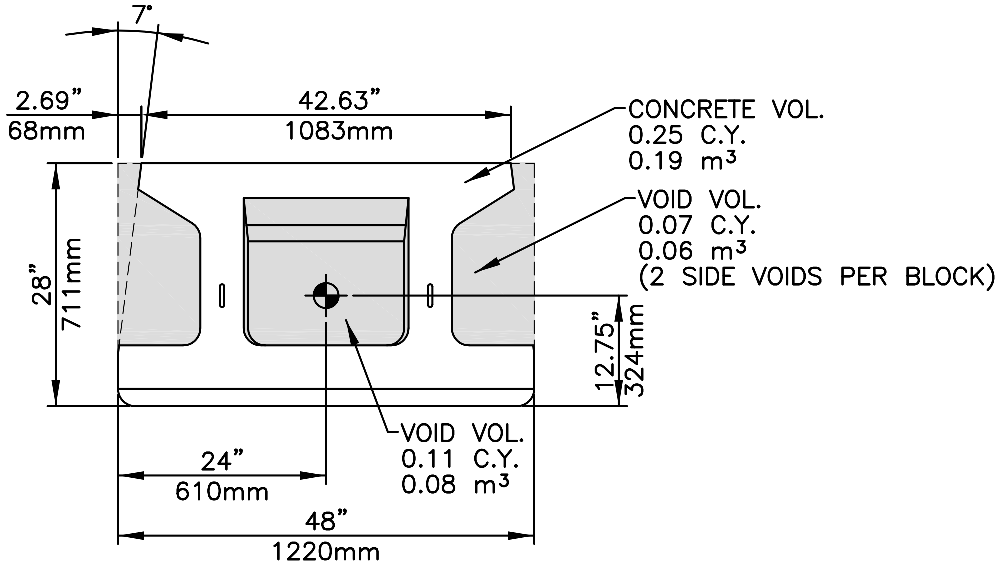


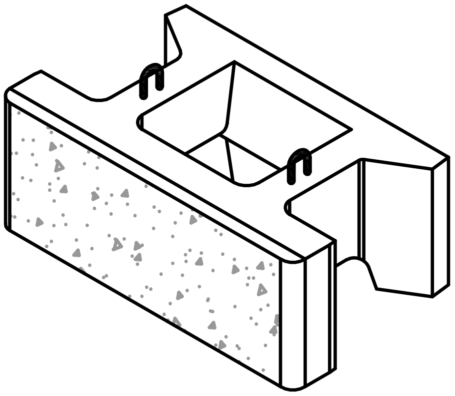


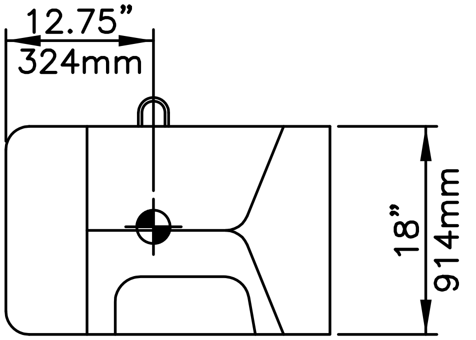
Block Wt.	690 lbs	310 kg
Form Wt.	1,975 lbs	895 kg
Concrete Volume	0.18 CY	0.14 m³
Aggregate Infill	0.16 CY	0.12 m³
(per face area)	.01 ton/sf	1,000 kg/ m²

SYSTEM COMPONENTS

6 – 28 BLOCK



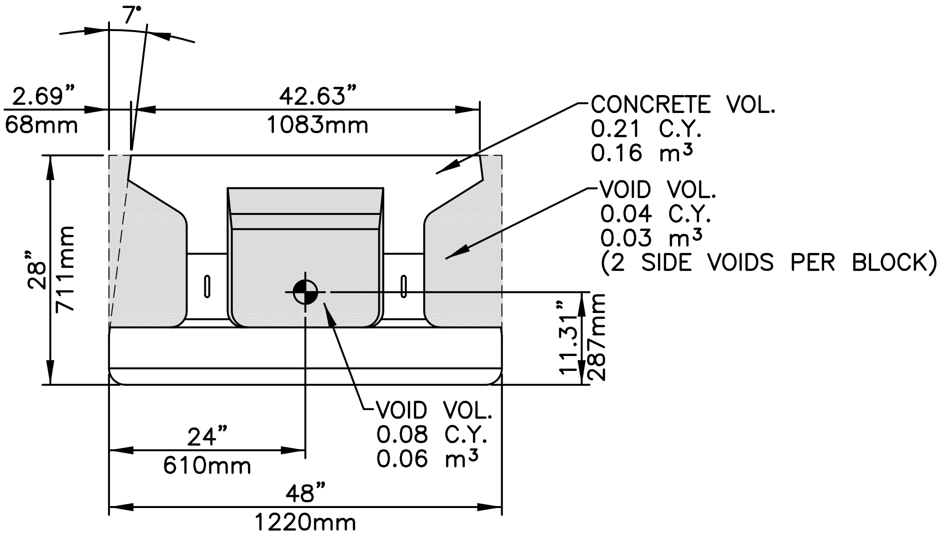


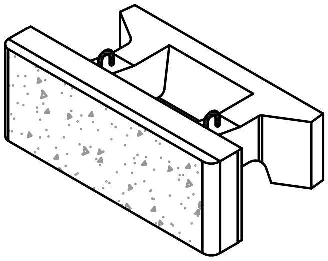


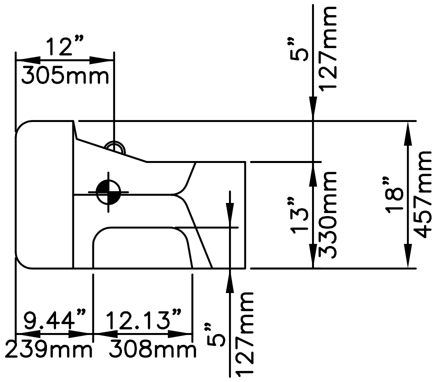
Block Wt.	**950 lbs**	**430 kg**
Form Wt.	**1,500 lbs**	**680 kg**
Concrete Volume	**0.25 CY**	**0.19 m³**
Aggregate Infill	**0.25 CY**	**0.19 m³**
(per face area)	**0.07 tons/sf**	**700 kg/m²**

SYSTEM COMPONENTS

6 – 28 TOP BLOCK



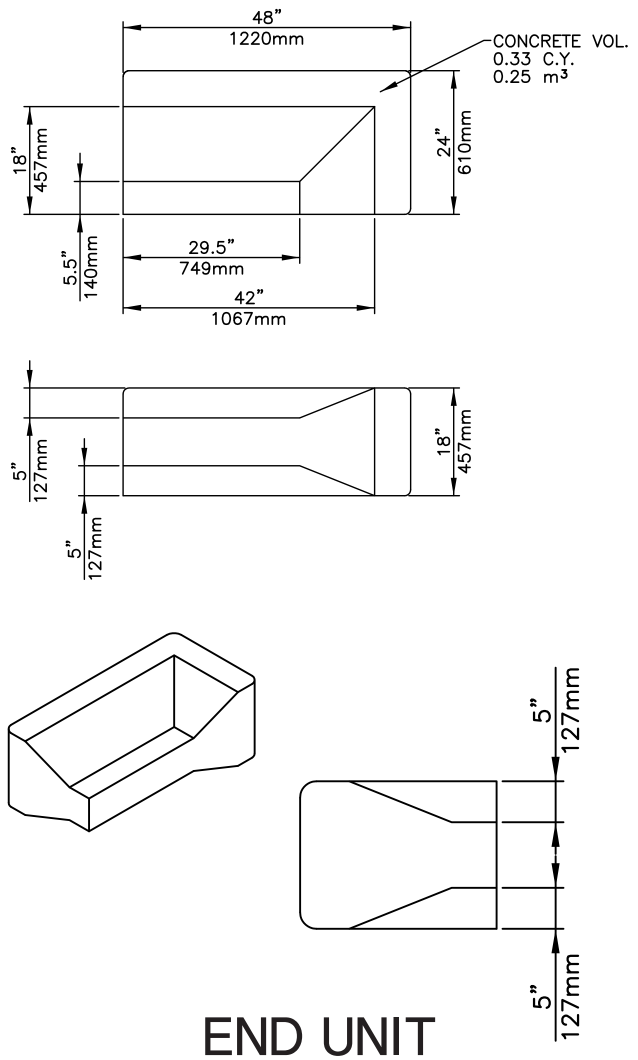




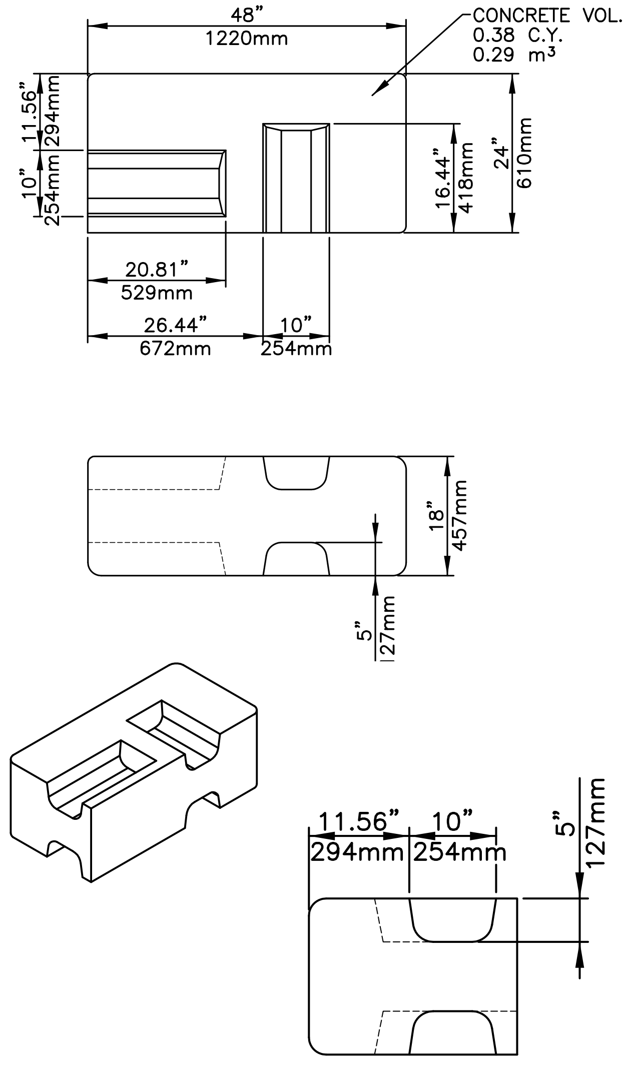
Block Wt.	**840 lbs**	**380 kg**
Form Wt.	**1,580 lbs**	**715 kg**
Concrete Volume	**0.21 CY**	**0.16 m^3**
Aggregate Infill **(per face area)**	**0.16 CY** **0.07 ton/sf**	**0.12 m^3** **700 kg/ m^2**

SYSTEM COMPONENTS

END – CORNER BLOCK



END UNIT



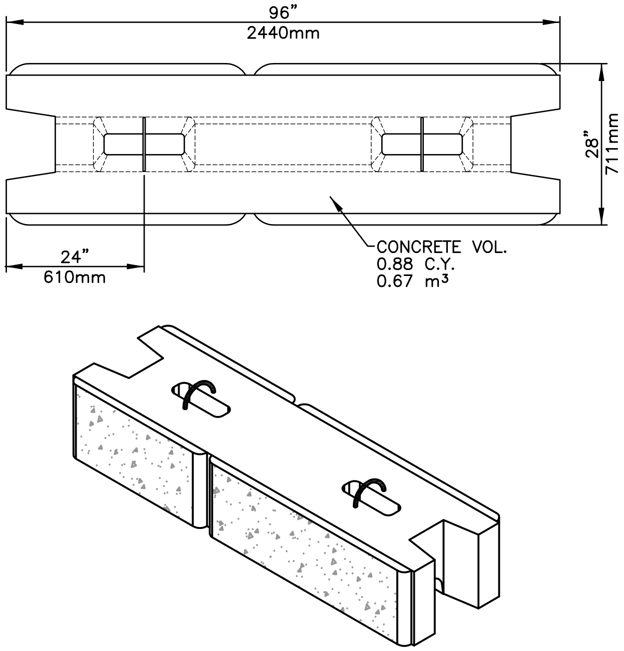
CORNER UNIT

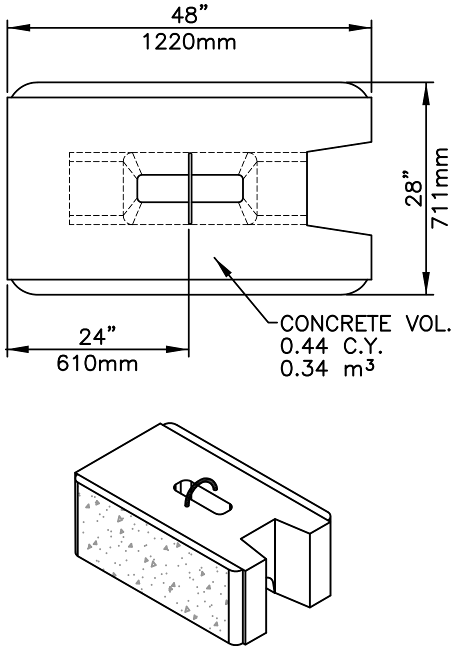
Block Wt.	1,300 lbs	590 kg
Form Wt.	1,650 lbs	750 kg
Concrete Volume	0.33 CY	0.25 m³

Block Wt.	1,500 lbs	680 kg
Form Wt.	1,490 lbs	675 kg
Concrete Volume	0.38 CY	0.29 m³

SYSTEM COMPONENTS

DUAL FACE BLOCK



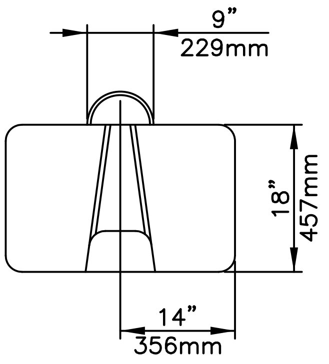


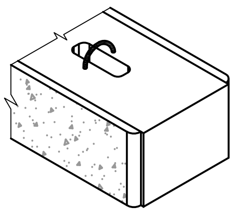
DUAL FACE UNIT

Block Wt.	**3,520 lbs**	**1,595 kg**
Form Wt.	**2,430 lbs**	**1,100 kg**
Concrete Volume	**0.88 CY**	**0.67 m³**

DUAL FACE HALF UNIT

Block Wt.	**1,760 lbs**	**800 kg**
Form Wt.	**2,430 lbs**	**1,100 kg**
Concrete Volume	**0.44 CY**	**0.34 m³**





ALTERNATE FINISHED END

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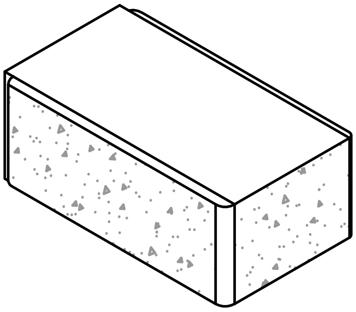
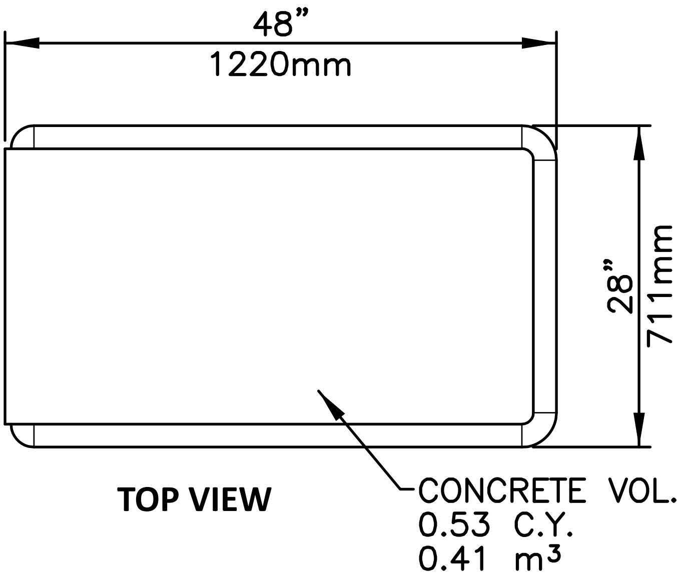
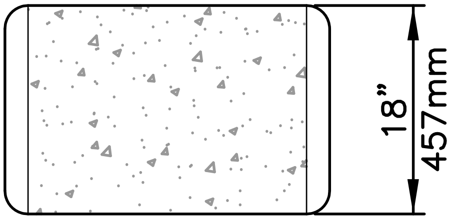
SYSTEM COMPONENTS

DUAL FACE END BLOCK





TOP VIEW

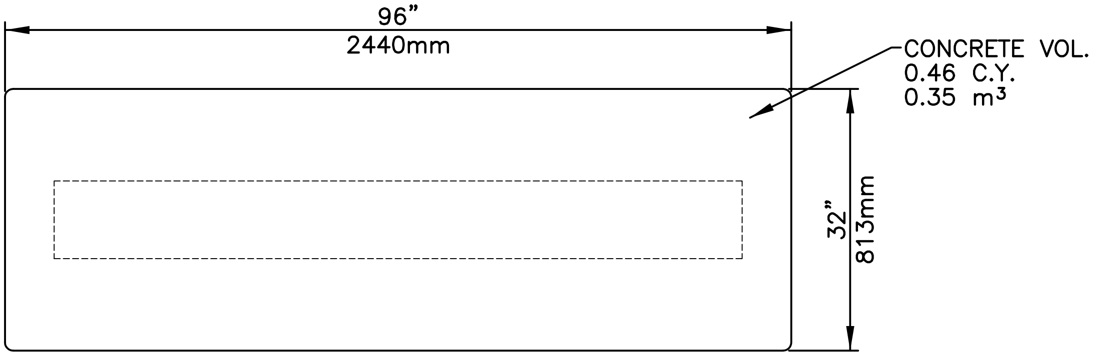


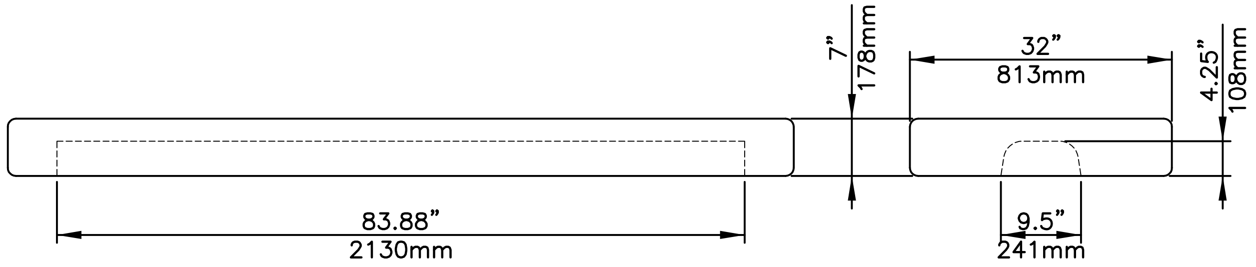
END VIEW

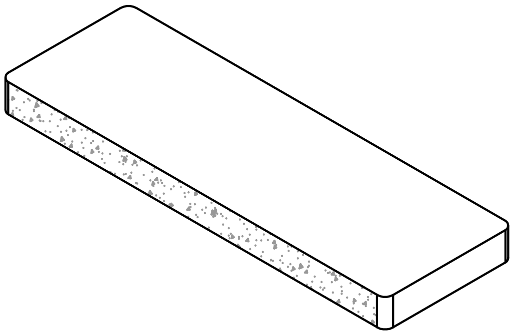
Block Wt.	2,150 lbs	975 kg
Form Wt.	1,889 lbs	857 kg
Concrete Volume	0.53 CY	0.41 m³

SYSTEM COMPONENTS

CAP BLOCK



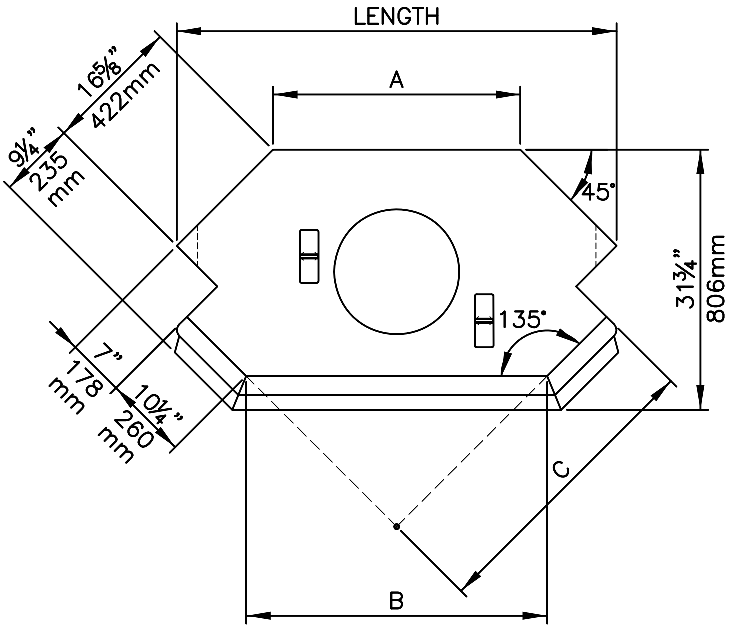


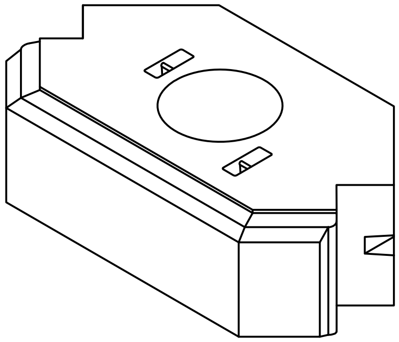


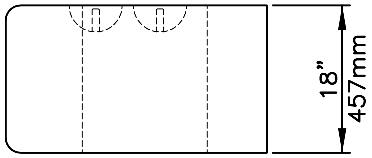
Block Wt.	**1,800 lbs**	**815 kg**
Form Wt.	**1,425 lbs**	**645 kg**
Concrete Volume	**0.46 CY**	**0.35 m^3**

SYSTEM COMPONETS

OUTSIDE CORNER BLOCK



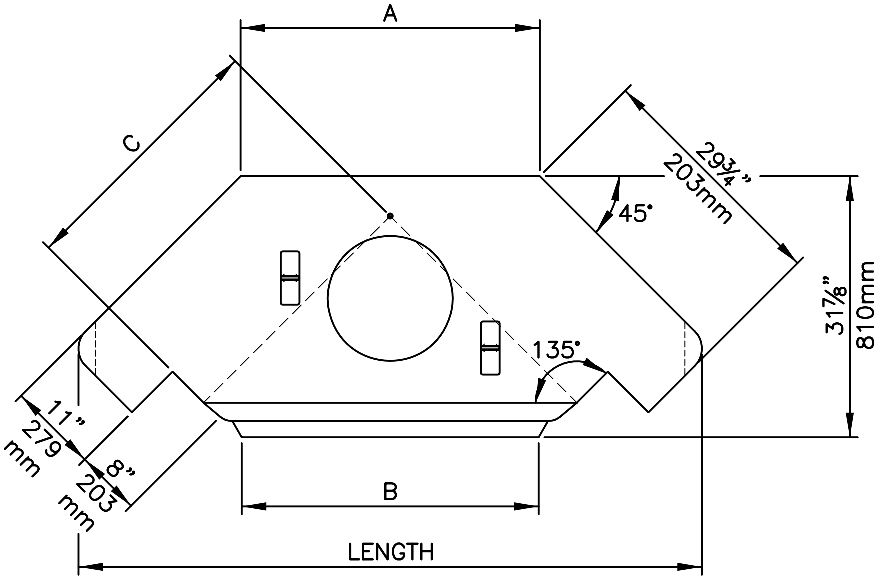


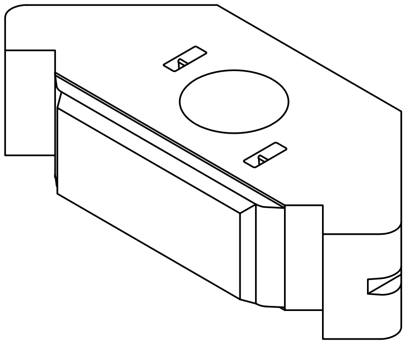


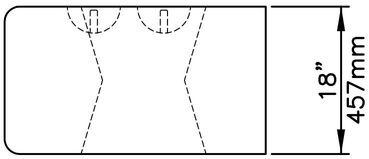
Block #	Length	A	B	C	Block Weight
1	65 in 1652 mm	42 in 1054 mm	48 in 1221 mm	44 in 1124 mm	2600 lbs 1180 kg
2	59 in 1508 mm	36 in 910 mm	42 in 1077 mm	40 in 1022 mm	2330 lbs 1055 kg
3	56 in 1415 mm	30 in 767 mm	37 in 933 mm	36 in 920 mm	2050 lbs 930 kg
4	48 in 1221 mm	25 in 623 mm	31 in 790 mm	32 in 819 mm	1770 lbs 805 kg
5	42 in 1077 mm	19 in 479 mm	25 in 646 mm	28 in 717 mm	1500 lbs 680 kg
6	37 in 933 mm	13 in 336 mm	20 in 502 mm	24 in 616 mm	1220 lbs 555 kg

SYSTEM COMPONETS

INSIDE CORNER BLOCK



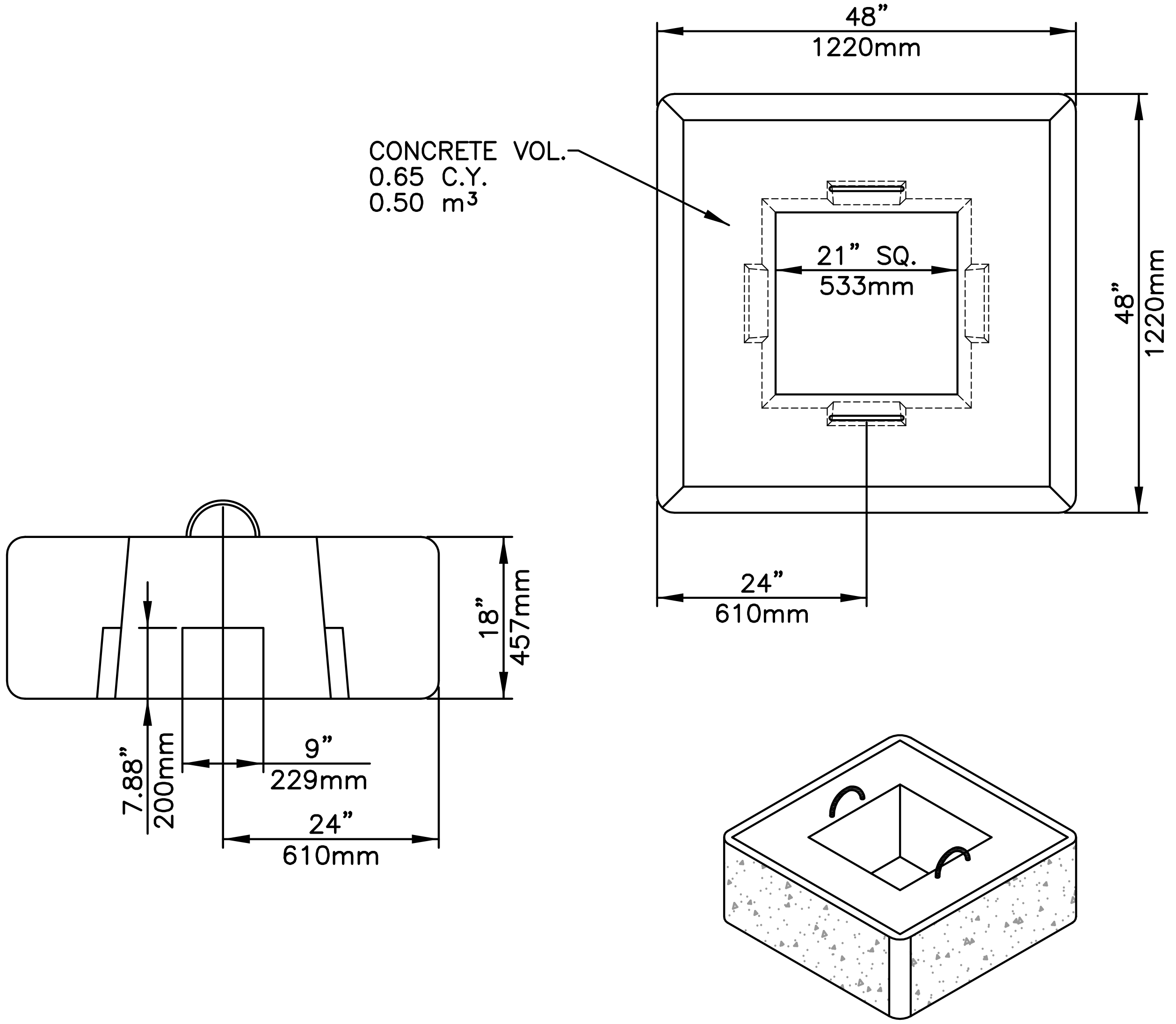




Block #	Length	A	B	C	Block Weight
1	65 in 1646 mm	25 in 641 mm	25 in 633 mm	19 in 485 mm	2070 lbs 940 kg
2	70 in 1790 mm	31 in 784 mm	31 in 777 mm	23 in 593 mm	2350 lbs 1065 kg
3	76 in 1934 mm	37 in 928 mm	36 in 921 mm	27 in 694 mm	2630 lbs 1195 kg
4	82 in 2077 mm	42 in 1072 mm	42 in 1064 mm	31 in 796 mm	2900 lbs 1315 kg
5	87 in 2221 mm	48 in 1215 mm	48 in 1208 mm	35 in 896 mm	3180 lbs 1445 kg
6	93 in 2365 mm	54 in 1359 mm	53 in 1352 mm	39 in 997 mm	3460 lbs 1570 kg

SYSTEM COMPONENTS

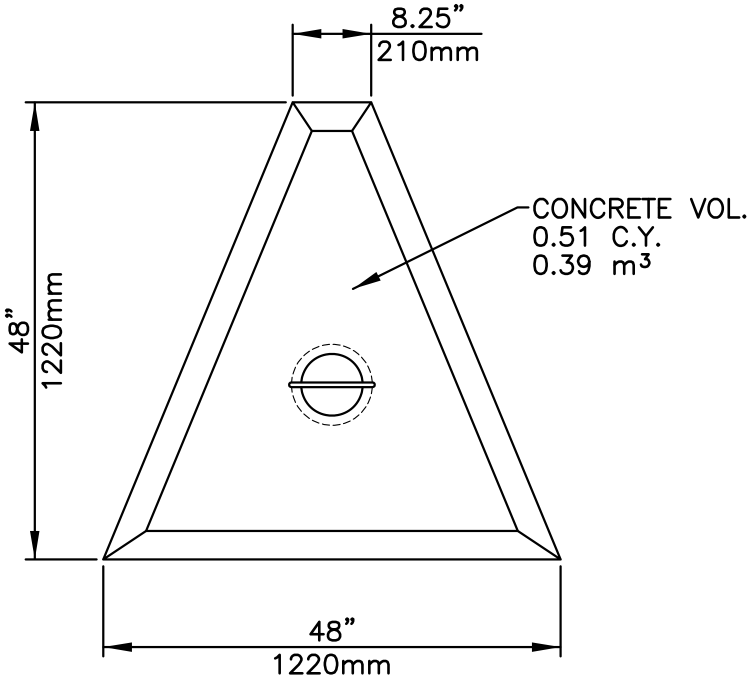
90° CORNER BLOCK

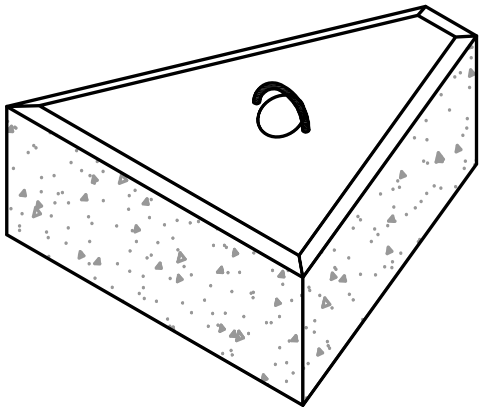


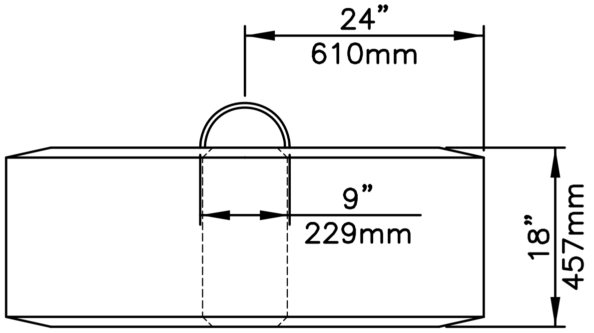
Block Wt.	**2,600 lbs**	**1,180 kg**
Form Wt.	**2,455 lbs**	**1,115 kg**
Concrete Volume	**0.65 CY**	**0.50 m³**

SYSTEM COMPONENTS

45° CORNER BLOCK



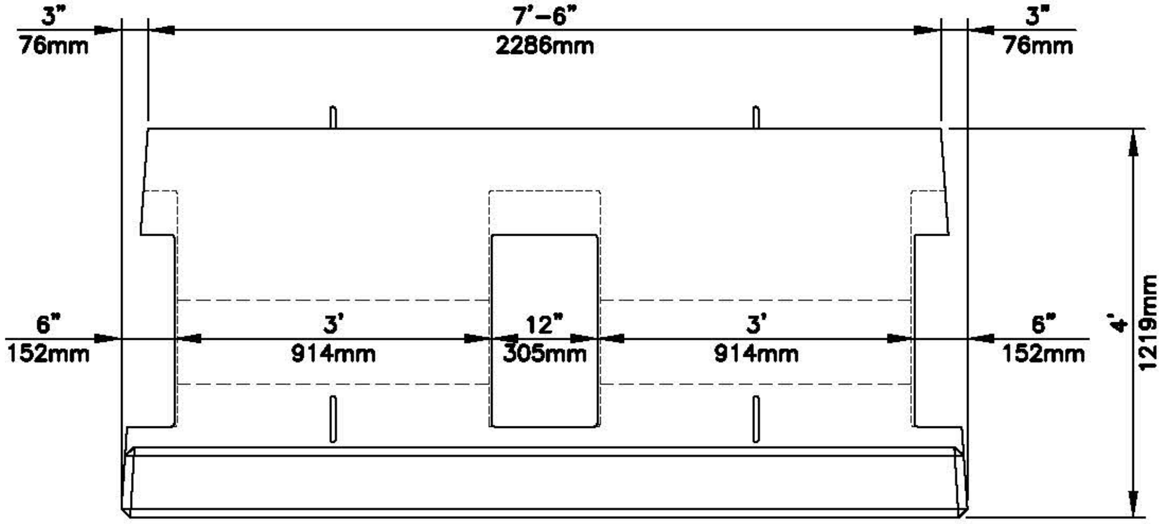


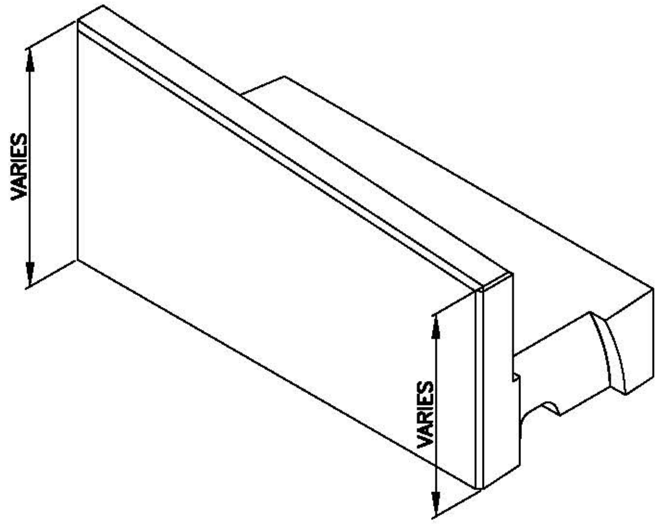


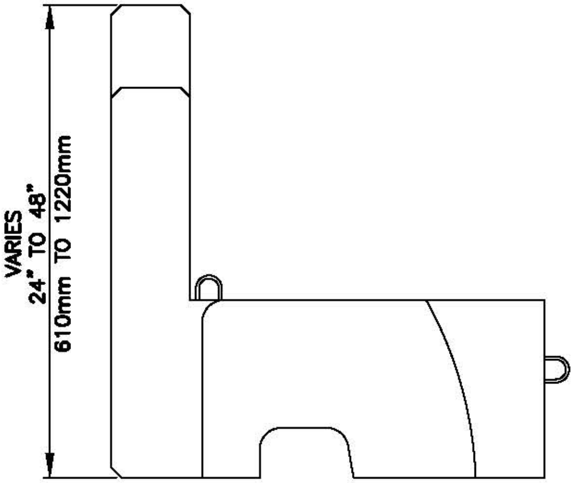
Block Wt.	**2,040 lbs**	**925 kg**
Form Wt.	**3,325 lbs**	**1,510 kg**
Concrete Volume	**0.51 CY**	**0.39 m^3**

SYSTEM COMPONENTS

CUSTOM TOP BLOCK







Block Wt.	varies	varies
Form Wt.	4,500 lbs	2,040 kg
Concrete Volume	varies	varies

jump to TOC

jump to Appendix TOC

1.1.6 UNIT FABRICATION

No attachments

1.1.7 CONCRETE COMPRESSIVE STRENGTH

No attachments

jump to TOC

jump to Appendix TOC

1.1.8 FACING UNIT ABSORPTION

No attachments

jump to TOC

jump to Appendix TOC

1.1.9 CONCRETE AIR CONTENT

No attachments

jump to TOC

jump to Appendix TOC

1.1.10 INTERFACE SHEAR PROPERTIES

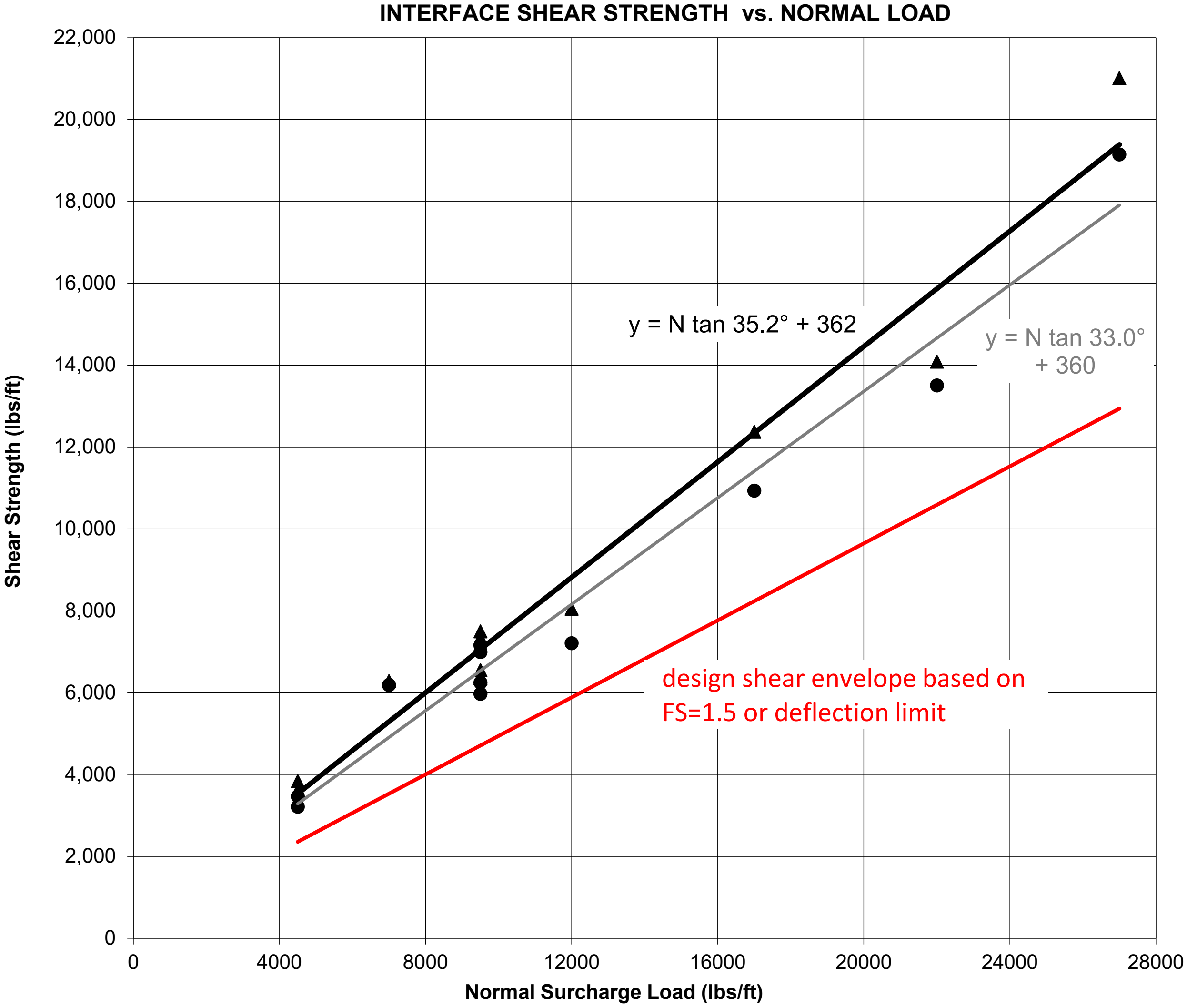
Interface Shear Plot – 24SF Units
Interface Shear Plot – 6SF Units
Interaction Testing Report, 24SF Units with Synteen Geogrid
Interaction Testing Report, 6SF Units with Synteen Geogrid

Note: The interaction test reports are provided only as the source references for the excerpted interface shear plots. These reports are not intended for review of geogrid reinforced MSE systems on DOT projects.

INTERFACE SHEAR TESTS

24 SF UNITS

Trial #	Normal (lbs/ft)	Approx Wall Height (ft)	Approx # of Units	Shear @ 3/4" displacement (lbs/ft)	Peak Shear (lbs/ft)
1	4,500	9.6	3.2	3,212	3,616
2	4,500	9.6	3.2	3,464	3,842
3	7,000	14.9	5.0	6,185	6,286
4	9,500	20.2	6.7	6,992	7,344
5	9,500	20.2	6.7	7,155	7,496
6	9,500	20.2	6.7	6,249	6,349
7	9,500	20.2	6.7	5,971	6,551
8	12,000	25.5	8.5	7,206	8,050
9	17,000	36.2	12.1	10,935	12,371
10	22,000	46.8	15.6	13,505	14,084
11	27,000	57.4	19.1	19,149	21,013

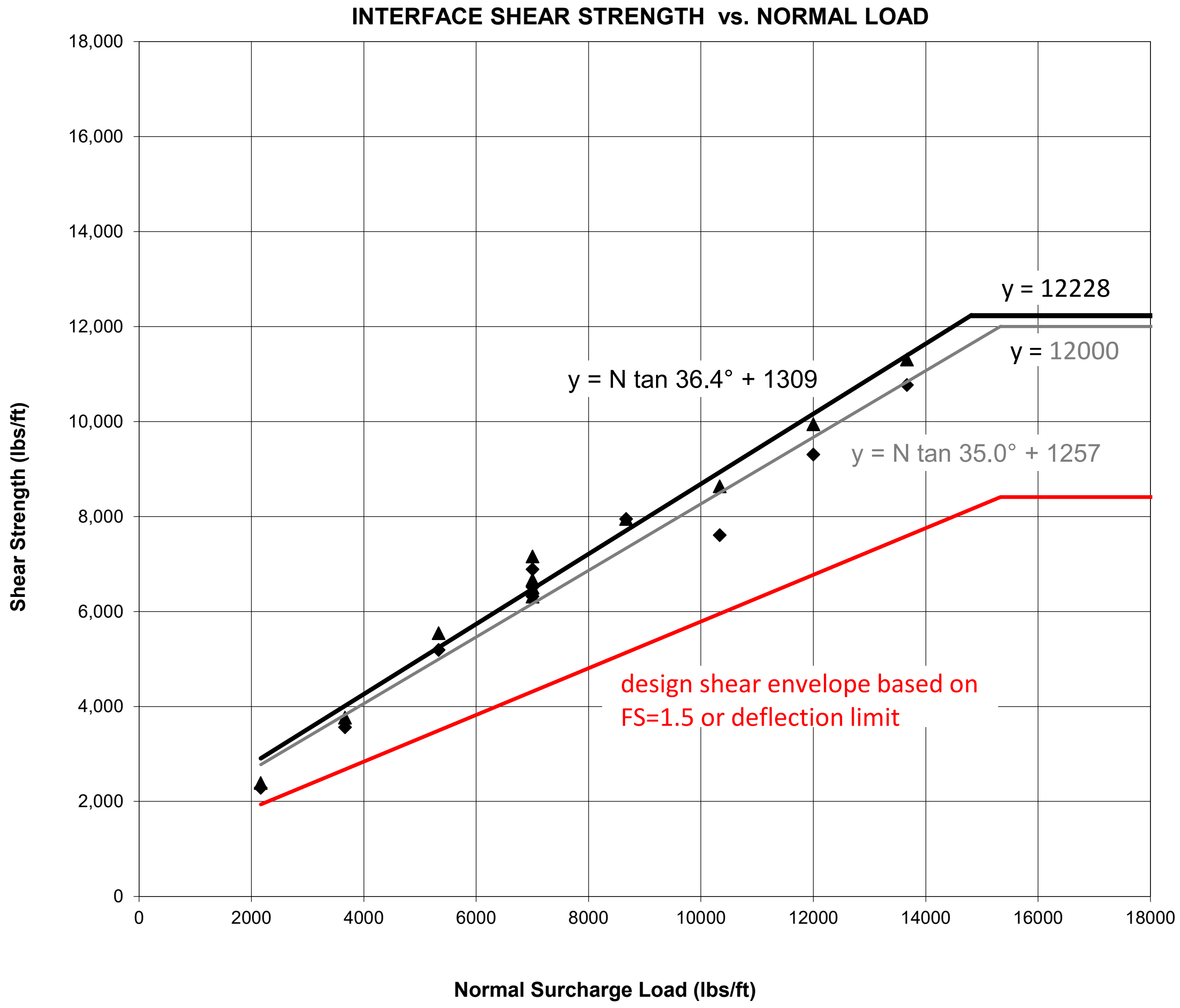


Data is excerpted from Interaction Testing Report, 24SF Units with Synteen Geogrids
September 17, 2004 by Thiele Geotech, Inc. in association with Tadros Associates, LLC

INTERFACE SHEAR TESTS

6 SF UNITS

Trial #	Normal (lbs/ft)	Approx Wall Height (ft)	Approx # of Units	Shear @ 3/4" displacement (lbs/ft)	Peak Shear (lbs/ft)
1	2,167	4.6	1.5	2,284	2,385
2	3,667	7.8	2.6	3,561	3,763
3	5,333	11.3	3.8	5,190	5,543
4	7,000	14.9	5.0	6,316	6,316
5	7,000	14.9	5.0	6,383	6,500
6	7,000	14.9	5.0	6,517	6,668
7	7,000	14.9	5.0	6,887	7,156
8	8,667	18.4	6.1	7,945	7,945
9	10,333	22.0	7.3	7,609	8,634
10	12,000	25.5	8.5	9,306	9,944
11	13,667	29.1	9.7	10,767	11,304
12	15,333	32.6	10.9	12,000	12,228



Data is excerpted from Interaction Testing Report, 6SF Units with Synteen Geogrids
May 27, 2005 by Thiele Geotech, Inc. in association with Tadros Associates, LLC

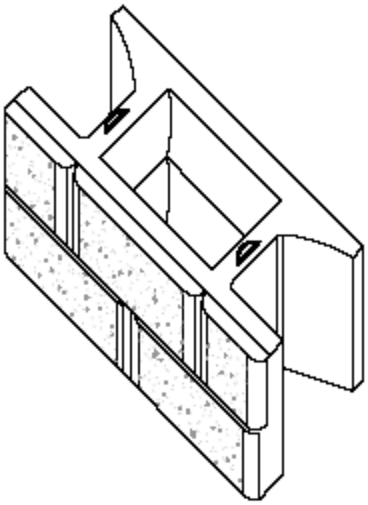
Tadros Associates, LLC
Structural Engineering Consultants

thiele geotech inc

Interaction Testing Report

24 SF Units with Synteen Geogrids

Stone Strong Systems
Lincoln, Nebraska



Prepared for:
Stone Strong Systems
1620 South 70th Street, Suite 105
Lincoln, Nebraska 68506

September 17, 2004
TG Project No. 02546.2

THIELE GEOTECH, INC
13478 Chandler Road
Omaha, Nebraska 68138-3716
402/556-2171 Fax 402/556-7831
www.thielegeotech.com

In association with:
TADROS ASSOCIATES, LLC
6910 Pacific Street, Suite 204
Omaha, Nebraska 68106-1045

Interaction Testing Report
24 SF Units with Synteen Geogrids

Table of Contents

INTRODUCTION

Thiele Geotech, Inc., in association with Tadros Associates, LLC, has completed an interaction testing program to evaluate the interface shear capacity and the connection strength between Stone Strong Systems 24 SF precast concrete segmental retaining wall blocks and Synteen SF55 and SF110 geogrids used in the construction of segmental retaining walls. The results of the testing program were used to define relationships for surcharge load representing stacked Stone Strong units with facing/geogrid connection strength and with interface shear strength both with and without geogrid inclusions.

Due to the large size of the Stone Strong blocks, a custom testing frame was designed by Tadros Associates, LLC. This large test frame accommodates full scale tests under conditions that reproduced field shear and connection conditions. Testing was performed by personnel from Tadros Associates and Thiele Geotech.

MATERIALS

Stone Strong Systems 24 SF blocks are precast concrete blocks used for construction of segmental retaining walls.

The 24 SF unit has nominal face dimensions of 96 inches long and 36 inches tall for a total face area of 24 square feet. The unit has a depth (measured horizontally from the face to the tail) of approximately 44 inches. The units have a center void between twin webs, and the face and tail flanges extend beyond the webs. The rear flange is tapered to allow the blocks to be laid on a curve. Each unit weighs approximately 5,800 to 6,200 pounds empty, depending on the aggregate used to manufature the block. When installed in a retaining wall, the block voids are filled with aggregate. The infilled weight is approximately 10,200 to 11,000 pounds, depending on the unit weights of the concrete and aggregate fill.

Synteen SF55 and SF110 geogrids are uni-directional grids composed of high strength polyester yarns coated with a PVC material. The SF55 and SF110 Geogrids have average ultimate tensile strengths of 3,774 pounds per foot and 10,212 pounds per foot, respectively, based on published test data.

TEST PROCEDURES

TEST FRAME

The apparatus used to conduct the tests consisted of a steel frame anchored to a rigid concrete mat foundation. The frame is capable of resisting 150,000 pounds of surcharge load and 100,000 pounds of shear/pullout force simultaneously. Rollers were mounted between the test frame and the loading beam to allow for block movement during shear testing. Photographs and schematics of the test frame are included in the Appendix of this report.

Surcharge and shear/pullout loads were placed on the blocks using two (2) Enerpac PEJ-1301 submerged hydraulic pumps capable of delivering 20 in^3 per minute at 10,000 psi each. Loads were measured by the use of Omega PX303 pressure transducers with 0 to 10,000 psig range and an accuracy of 0.25 percent FS. Mounted on each pump is a manifold to distribute hydraulic fluid to the two (2) 25 ton, 6 inch stroke (Enerpac RC256) surcharge actuators and the two (2) 25 ton, 6 inch stroke (Enerpac RC256) shear/pullout actuators and to the pressure transducers. The flow of fluid to the shear/pullout actuators is adjustable by an Enerpac V-8F needle valve.

Displacements were measured by the use of two (2) 3 inch stroke and one (1) 6 inch stroke linear potentiometers with 0.15 percent maximum linearity (0.07 percent typical) and less than 0.01 mm hysteresis.

Loads and displacements were continuously measured and recorded during the test by a Data Translation DT9802 date acquisition module connected to a loptop computer via USB interface. Sensor excitation was provided by an Omega 5v regulated power supply. Loads and displacements were recorded a minimum of once per second using DT Measure Foundry software.

INTERFACE SHEAR TESTS

The NCMA SRWU-2 and ASTM D6638 methods of test were used to determine the shear strength between Stone Strong Systems 24 SF concrete block units. The tests were carried out with and without a layer of geosynthetic reinforcement between layers of Stone Strong units. The bottom block was installed and braced against the front of the load frame. Portions of the top of the block were recessed with a bush hammer to control the dimension of the loaded area. Crushed limestone infill was placed in the void of the bottom block. When a geogrid layer was included, the geosynthetic reinforcement was centered over the bottom block. The top Stone Strong unit layer was centered over the bottom block. Crushed limestone infill was placed in the void of the top block.

The top unit was loaded with a constant vertical surcharge load applied to the concrete webs, simulating an equivalent height of stacked blocks. The shear force was applied at a constant rate of displacement until large shear displacements were achieved. The load and displacements were continuously measured and recorded during the test by a microcomputer/data acquisition system. The tests were continued until failure of the interface components occurred, causing a sustained loss of shearing resistance, or to a displacement of 1½ inches.

CONNECTION STRENGTH PULLOUT TESTS

The NCMA SRWU-1 and ASTM D6638 methods of test were used to determine the connection strength between geosynthetic reinforcement and Stone Strong Systems 24 SF concrete block units. The tests were carried out with a layer of geosynthetic reinforcement between layers of Stone Strong units. The bottom block was installed and braced against the back of the load frame. Crushed limestone infill was placed in the voids of the bottom block. The geosynthetic reinforcement was centered over the bottom block and attached to a clamping device. Sacrificial pieces of geogrid were placed over the extended flanges to maintain even load distribution across the block unit. The top Stone Strong unit layer was placed over the geogrid and centered over the bottom block. Crushed limestone infill was placed in the voids of the top block, and the block was braced against the back of the frame.

The top unit was loaded with a constant vertical surcharge load applied to the concrete webs, simulating an equivalent height of stacked blocks. A tensile force was placed on the geosynthetic reinforcement under constant rate of displacement until failure of the connection system occurred. The load and displacements were continuously measured and recorded during the test by a microcomputer/data acquisition system. Tests were continued until failure occurred as excessive deformation or slippage of the geogrid in the connection or failure of the blocks occurred, causing a sustained loss of tensile resistance recorded.

TEST RESULTS

INTERFACE SHEAR TESTS

Results of the interface shear tests are attached in tables and graphs recorded in the Appendix of this report. The peak interface shear capacity and shear capacity at the displacement criterion of ¾ inch were plotted versus the normal load. The minimum peak shear capacity recorded was 2,822 pounds per foot. The peak interface shear strength between Stone Strong Systems 24 SF units and Synteen SF55 and SF110 Geogrid for equivalent wall heights between 9.6 and 57.4 feet high ranged between 8,667 and 12,371 pounds per foot. Tests repeated using the same normal load had peak shear capacity values within 10 percent of the mean peak shear capacity of the identical tests; therefore, they are within the NCMA recommended limits for demonstrating test repeatability. The service state criterion is defined as the load at ¾ inch deflection.

Lines were best fit to the test data for the individual tests series. Interface shear properties were interpolated from the data, and are summarized in Table 1.

Table 1, Interface Shear Properties

Case	**Ultimate**			**Service State Criterion**		
	Minimum (lbs/ft)	**Friction Angle (degrees)**	**Maximum (lbs/ft)**	**Minimum (lbs/ft)**	**Friction Angle (degrees)**	**Maximum (lbs/ft)**
Block shear (no geogrid)	362	35.2	19,000	360	33.0	18,000
Shear w/ SF 55 inclusion	2,018	22.5	10,115	1,901	20.5	9,450
Shear w/ SF 110 inclusion	1,640	19.2	10,835	1,640	16.6	9,500

CONNECTION STRENGTH PULLOUT TESTS

Results of the connection strength tests are summarized in tables and graphs recorded in the Appendix of this report. The peak connection capacity and connection capacity at the displacement criterion of ¾ inch were plotted versus the normal load. The minimum peak connection capacity recorded was 2,268 pounds per foot. The recorded peak connection strengths between Stone Strong Systems 24 SF units and Synteen SF55 and SF110 Geogrid were 2,847 and 6,198 pounds per foot, respectively, for equivalent wall heights between 4.8 and 28.7 feet high. Tests repeated using the same normal load had peak shear capacity values within 10 percent of the mean peak shear capacity of the identical tests; therefore, they are within the NCMA recommended limits for demonstrating test repeatability.

Lines were best fit to the test data for the individual tests series. Interface shear properties were interpolated from the data, and are summarized in Table 2.

Table 2, Connection Strength Properties

Case	Ultimate			Service State Criterion		
	Minimum (lbs/ft)	Friction Angle (degrees)	Maximum (lbs/ft)	Minimum (lbs/ft)	Friction Angle (degrees)	Maximum (lbs/ft)
Connection Strength w/ SF 55 inclusion	1,555	16.6	3,090	806	15.0	2,822
Connection Strength w/ SF 110 inclusion	2,233	24.3	6,126	1,624	22.4	4,065

CONCLUSIONS

The design curves illustrated on the graphs in the appendix are based on interpretation of the test data, based on the NCMA Segmental Retaining Wall Design Manual. The design curves are controlled by the ¾ inch displacement criterion. The design values taken from the graphs should be used with caution, as shear and connection strengths may vary based on actual site conditions and construction quality.

Respectfully submitted,
Thiele Geotech, Inc.

Daniel J. Thiele, P.E.

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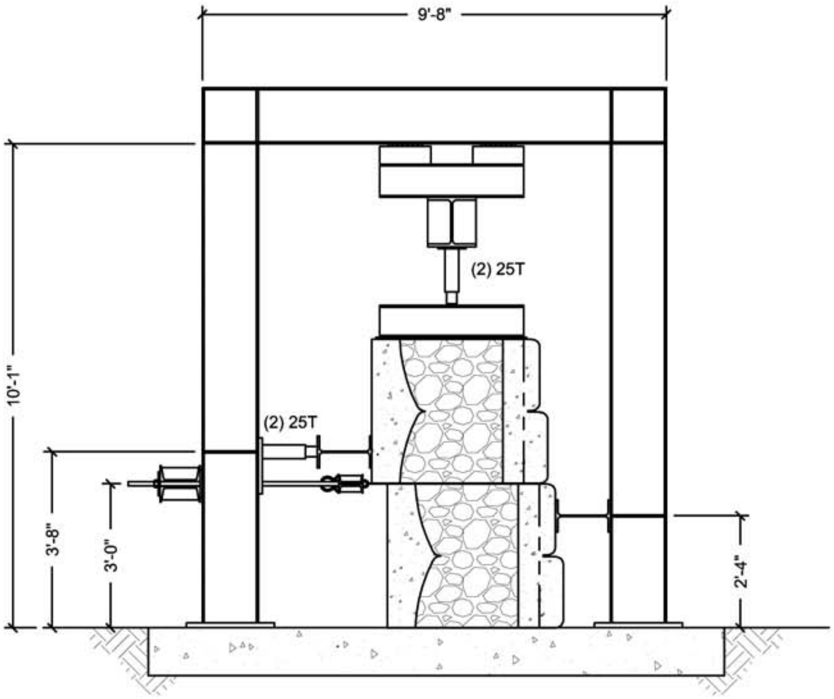
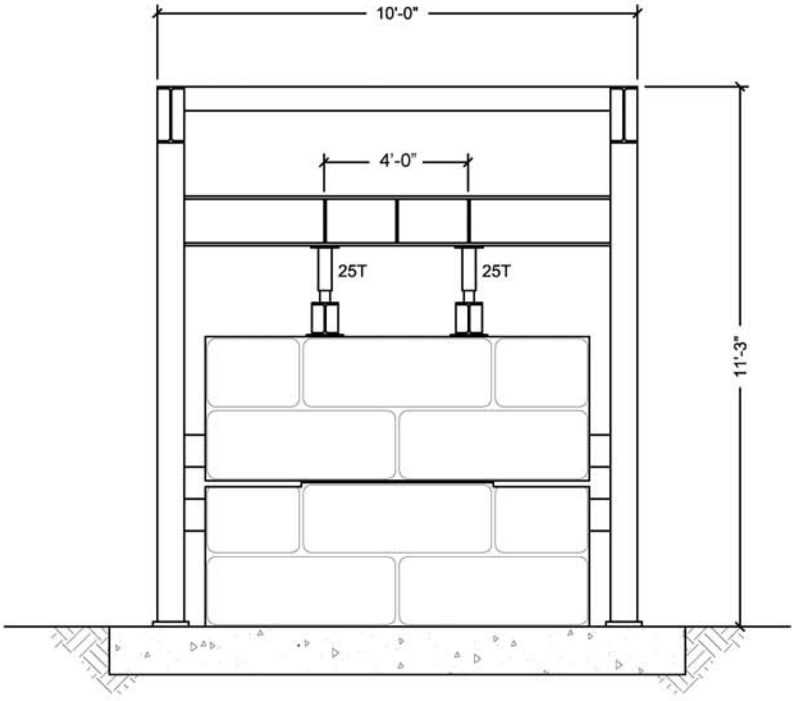
APPENDIX





Tadros Associates, LLC
6910 Pacific Street, Suite 204, Omaha, NE 68106
Phone: (402) 553-0234 Fax: (402) 553-0201

Project
SSS Grid Testing

Title
Shear Frame Setup

Project No.
NE058-04P01

Date
9/15/04

Scale
None

Designed By

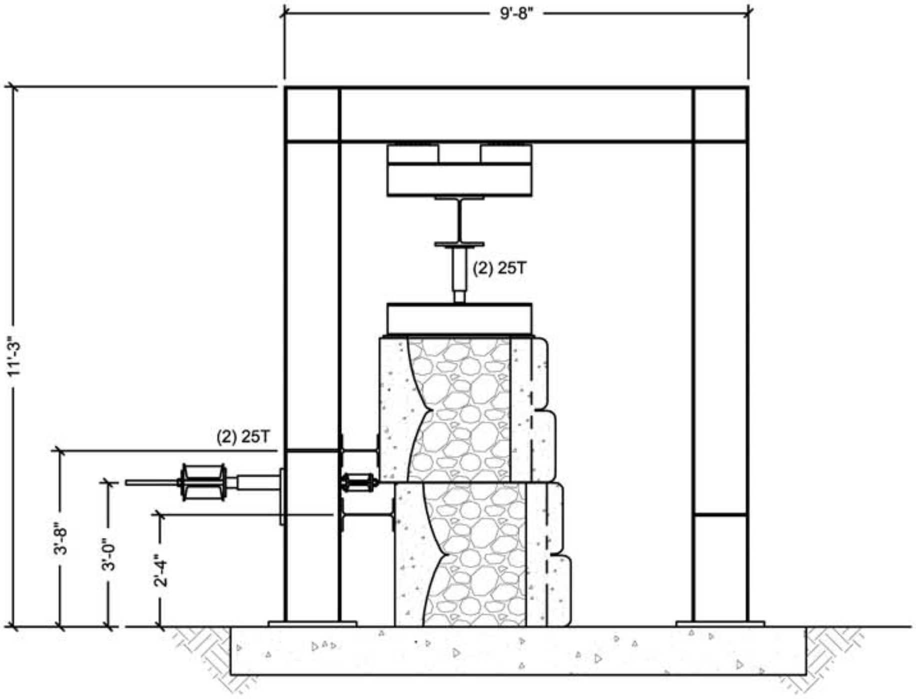
Checked By

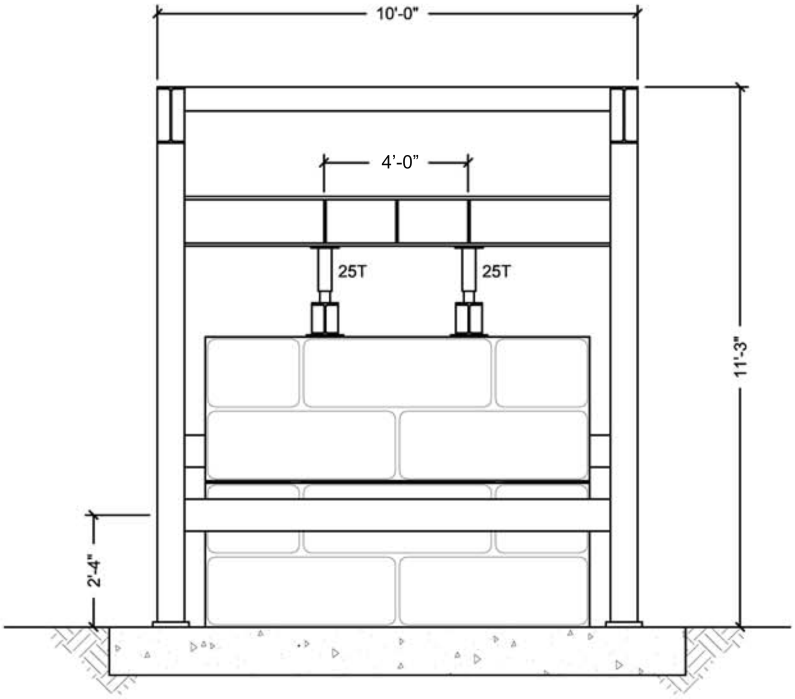
Detailed By
NAM

Rev.

Rev. Date

Page of





Tadros Associates, LLC
6910 Pacific Street, Suite 204, Omaha, NE 68106
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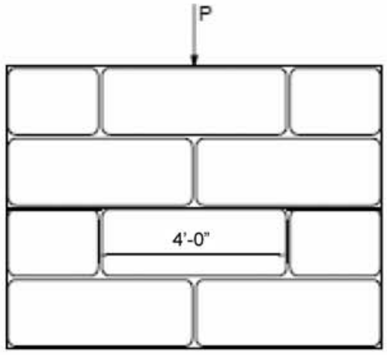
Project SSS Grid Testing	Project No. NE058-04P01	Designed By	Rev.
Title Grid Pullout Frame Setup	Date 9/15/04	Checked By	Rev. Date
	Scale None	Detailed By NAM	Page of

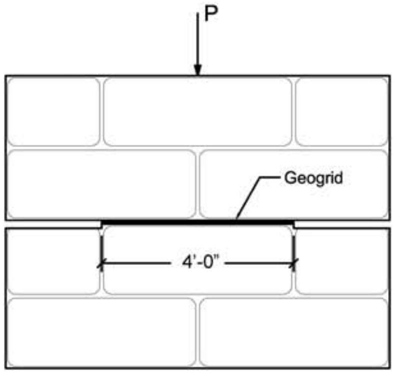
24SF Block Shear



Normal Force $\left(\frac{\text{kips}}{\text{ft}}\right) = \frac{\text{P kips}}{\text{4 ft}}$

Shear Force $\left(\frac{\text{kips}}{\text{ft}}\right) = \frac{\text{V kips}}{\text{4 ft}}$

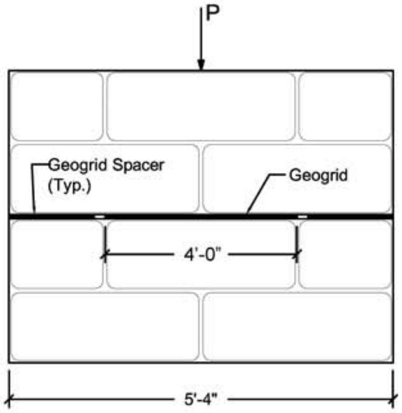
24SF Grid Shear



Normal Force $\left(\frac{\text{kips}}{\text{ft}}\right) = \frac{\text{P kips}}{\text{4 ft}}$

Shear Force $\left(\frac{\text{kips}}{\text{ft}}\right) = \frac{\text{V kips}}{\text{4 ft}}$

24SF Grid Pullout



Normal Force $\left(\frac{\text{kips}}{\text{ft}}\right) = \frac{\text{P kips}}{\text{8 ft}}$

Grid Pullout $\left(\frac{\text{kips}}{\text{ft}}\right) = \frac{\text{T kips}}{\text{4 ft}}$

Tadros Associates, LLC
6910 Pacific Street, Suite 204, Omaha, NE 68106
Phone: (402) 553-0234 Fax: (402) 553-0201

Project SSS Grid Testing	Project No. NE058-04P01	Designed By	Rev.
	Date 9/15/04	Checked By	Rev. Date
Title Test Setup	Scale None	Detailed By NAM	Page of

PHOTO NUMBER 1
Test Frame Setup

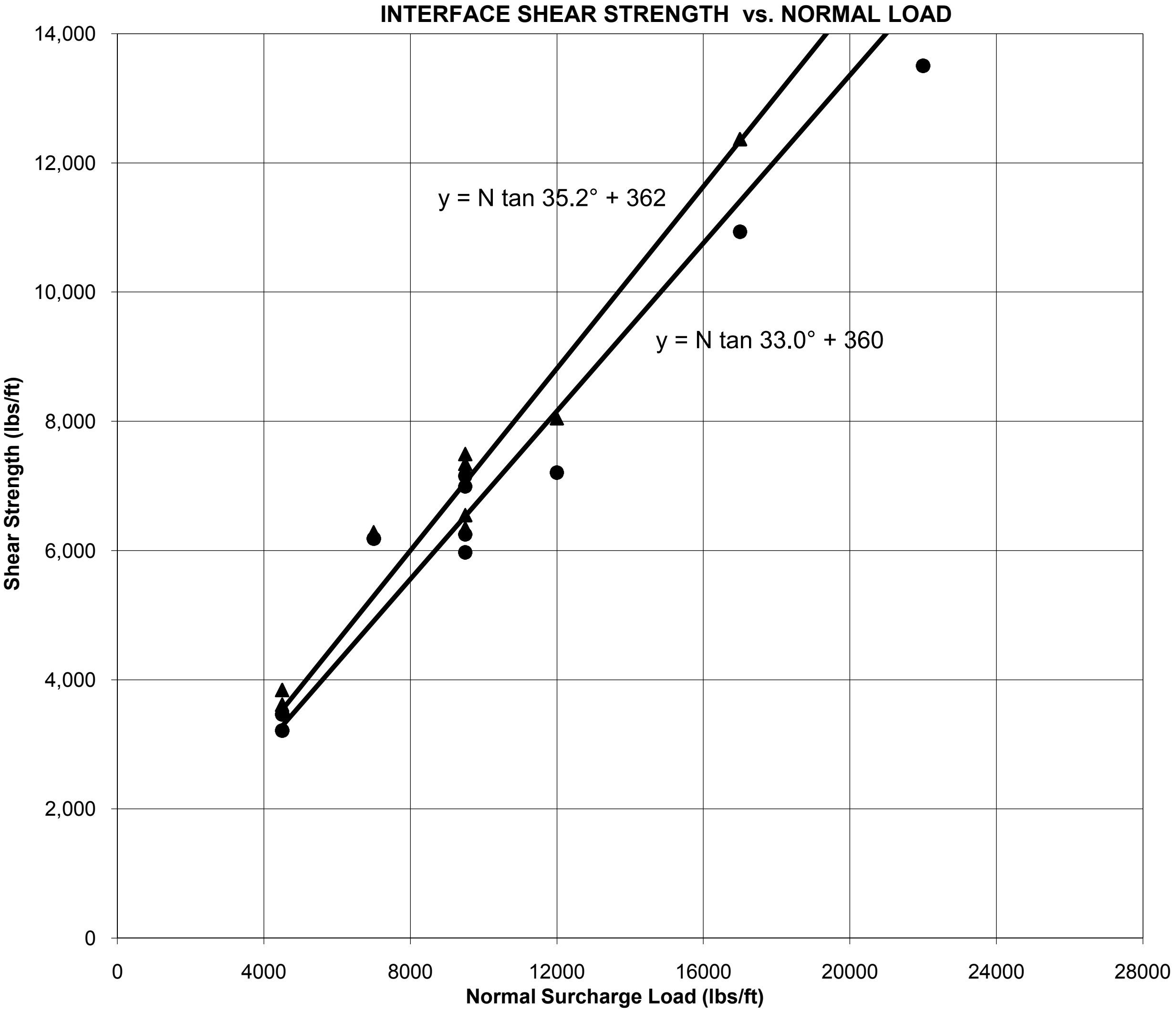
PHOTO NUMBER 2
Geogrid Pullout System

PHOTO NUMBER 3
Pullout Test Setup

INTERFACE SHEAR TESTS

24 SF UNITS

Trial #	Normal (lbs/ft)	Approx Wall Height (ft)	Approx # of Units	Shear @ 3/4" displacement (lbs/ft)	Peak Shear (lbs/ft)
1	4,500	9.6	3.2	3,212	3,616
2	4,500	9.6	3.2	3,464	3,842
3	7,000	14.9	5.0	6,185	6,286
4	9,500	20.2	6.7	6,992	7,344
5	9,500	20.2	6.7	7,155	7,496
6	9,500	20.2	6.7	6,249	6,349
7	9,500	20.2	6.7	5,971	6,551
8	12,000	25.5	8.5	7,206	8,050
9	17,000	36.2	12.1	10,935	12,371
10	22,000	46.8	15.6	13,505	14,084
11	27,000	57.4	19.1	19,149	21,013

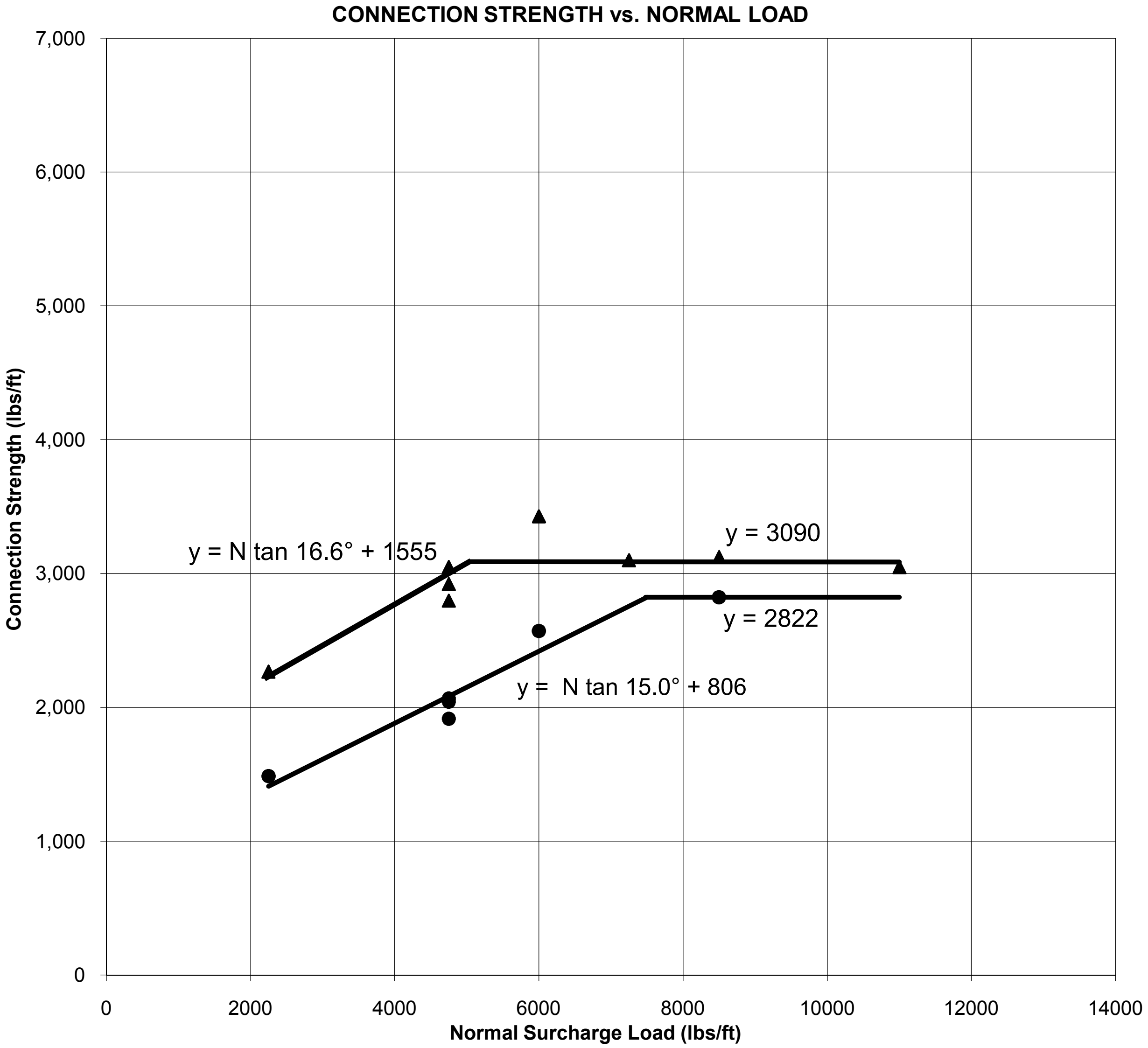


GEOGRID PULLOUT TESTS

24 SF UNITS w/ SYNTEEN SF55 GEOGRID

Trial #	Normal (lbs/ft)	Approx Wall Height (ft)	Approx # of Units	Tension @ 3/4" displ (lbs/ft)	Peak Tension (lbs/ft)
1	2,250	4.8	1.6	1,487	2,268
2	4,750	10.1	3.4	2,041	3,049
3	4,750	10.1	3.4	1,915	2,797
4	4,750	10.1	3.4	2,066	2,923
5	6,000	12.8	4.3	2,570	3,427
6	7,250	15.4	5.1	2,771	3,099
7	8,500	18.1	6.0	2,822	3,124
8	11,000	23.4	7.8	0*	3,049
9	13,500	28.7	9.6	0*	2,847

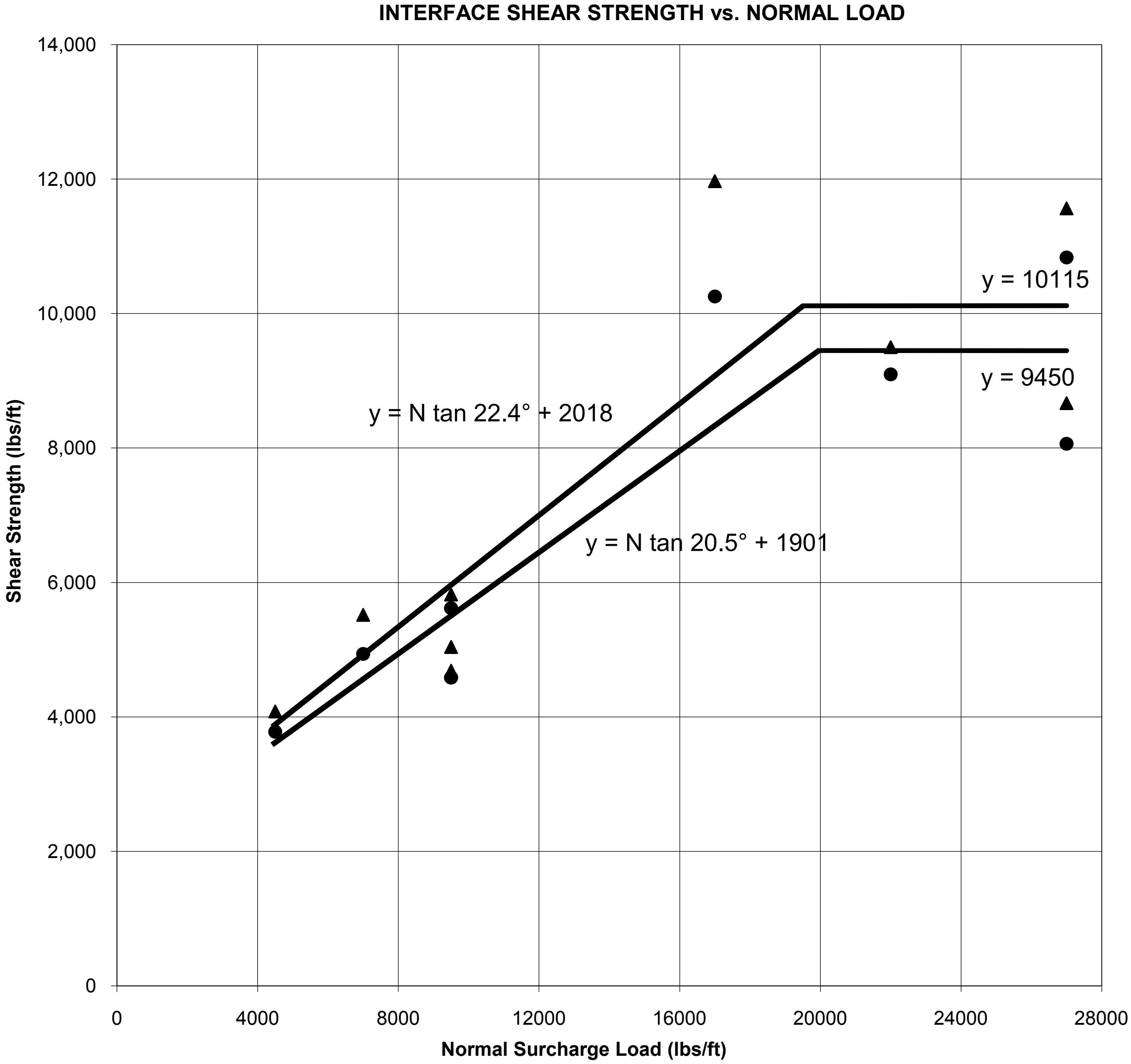
* - geogrid ruptured before reaching 3/4" displacement



INTERFACE SHEAR TESTS

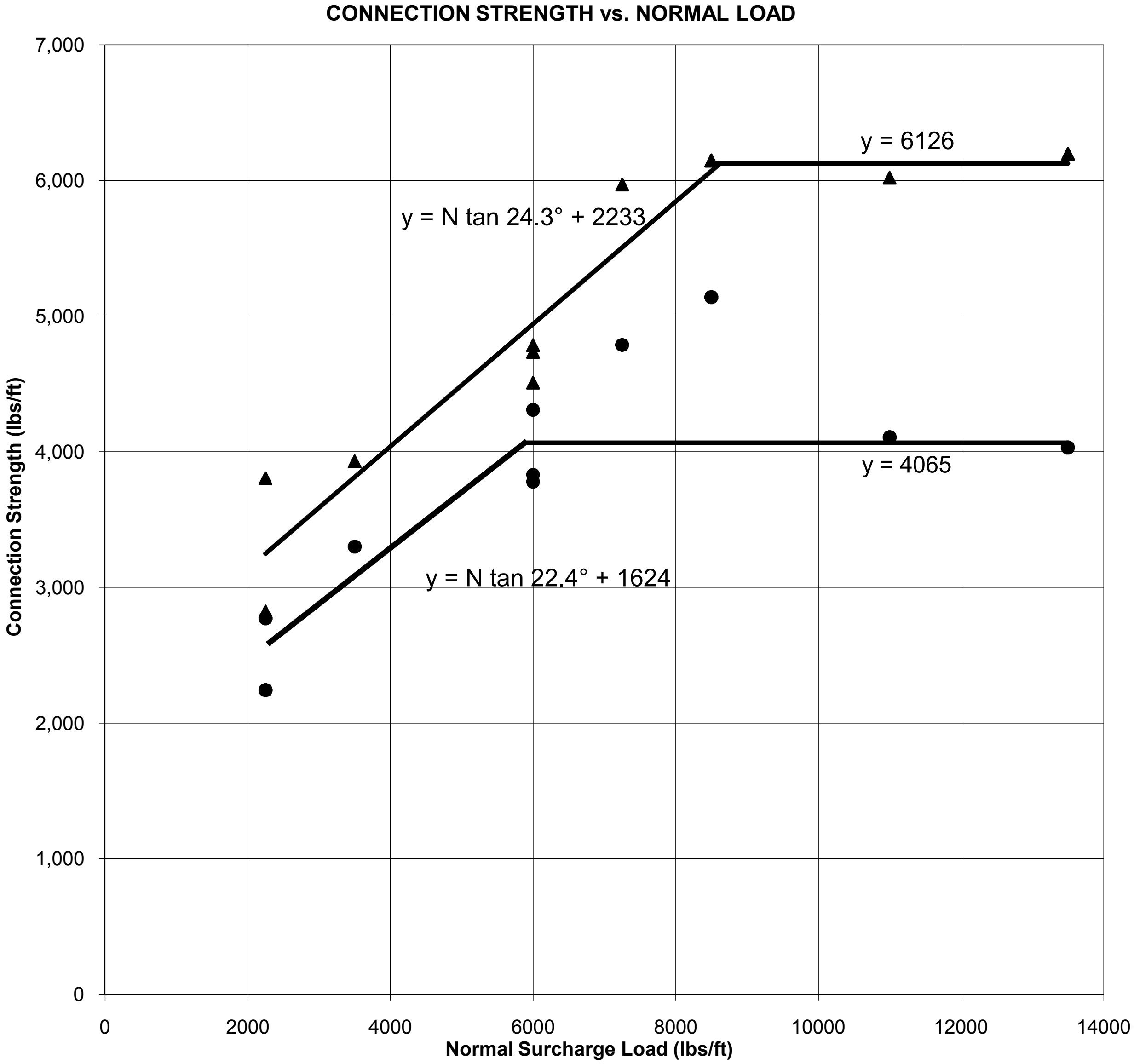
24 SF UNITS w/ SYNTEEN SF55 INCLUSION

Trial #	Normal (lbs/ft)	Approx Wall Height (ft)	Approx # of Units	Shear @ 3/4" displacement (lbs/ft)	Peak Shear (lbs/ft)
1	4,500	9.6	3.2	3,779	4,082
2	7,000	14.9	5.0	4,938	5,518
3	9,500	20.2	6.7	4,586	4,686
4	9,500	20.2	6.7	5,619	5,820
5	9,500	20.2	6.7	4,586	5,039
6	17,000	36.2	12.1	10,255	11,968
7	22,000	46.8	15.6	9,096	9,499
8	27,000	57.4	19.1	8,063	8,667
9	27,000	57.4	19.1	10,834	11,565



GEOGRID PULLOUT TESTS
24 SF UNITS w/ SYNTEEN SF110 GEOGRID

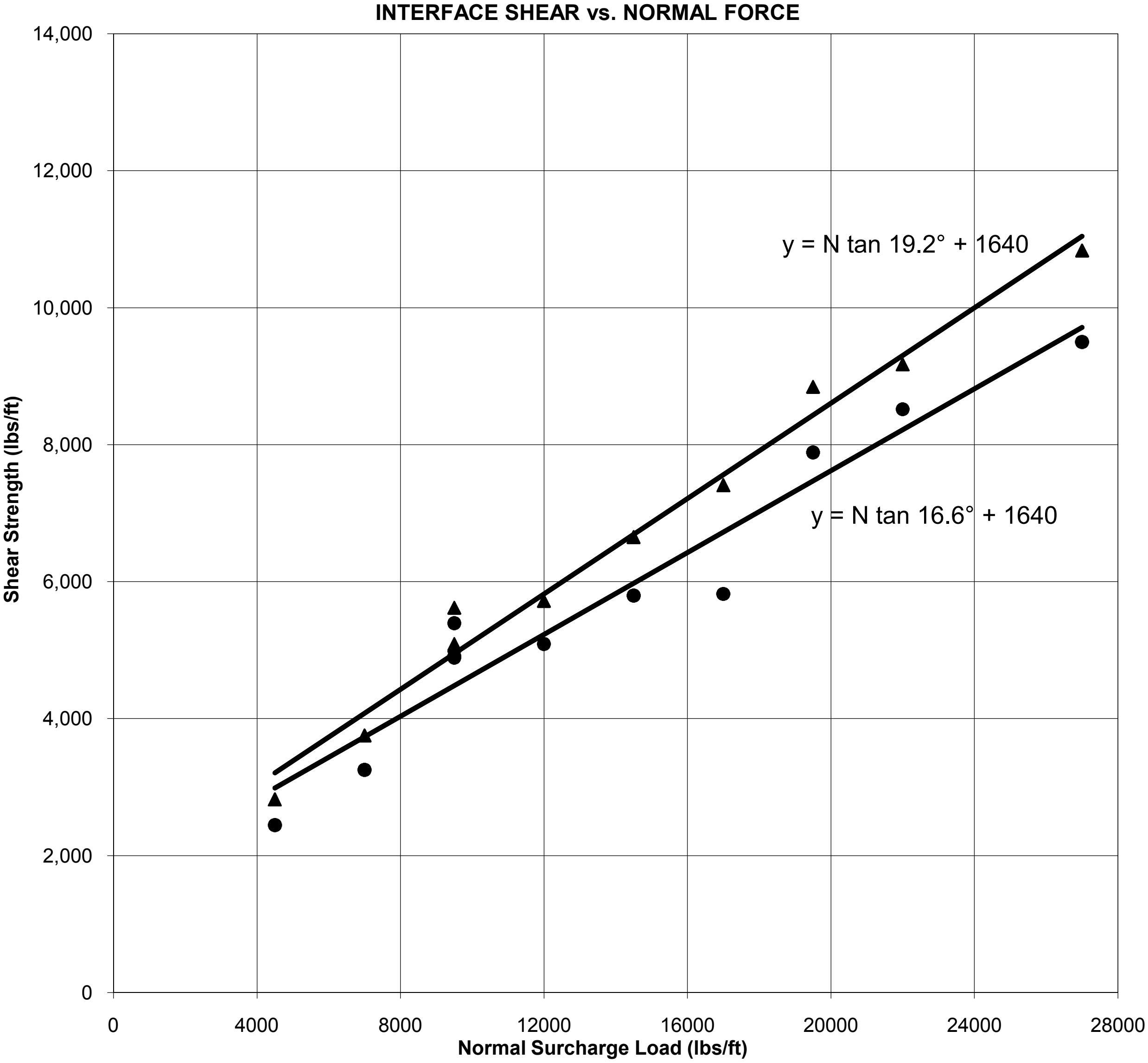
Trial #	Normal (lbs/ft)	Approx Wall Height (ft)	Approx # of Units	Tension @ 3/4" displ (lbs/ft)	Peak Tension (lbs/ft)
1	2,250	4.8	1.6	2,242	2,822
2	2,250	4.8	1.6	2,771	3,805
3	3,500	7.4	2.5	3,301	3,930
4	6,000	12.8	4.3	4,308	4,787
5	6,000	12.8	4.3	3,830	4,737
6	6,000	12.8	4.3	3,779	4,510
7	7,250	15.4	5.1	4,787	5,971
8	8,500	18.1	6.0	5,140	6,148
9	11,000	23.4	7.8	4,107	6,022
10	13,500	28.7	9.6	4,031	6,198



INTERFACE SHEAR TESTS

24 SF UNITS w/ SF110 INCLUSION

Trial #	Normal (lbs/ft)	Approx Wall Height (ft)	Approx # of Units	Shear @ 3/4" displacement (lbs/ft)	Peak Shear (lbs/ft)
1	4,500	9.6	3.2	2,444	2,822
2	7,000	14.9	5.0	3,250	3,754
3	9,500	20.2	6.7	5,392	5,619
4	9,500	20.2	6.7	4,913	5,089
5	9,500	20.2	6.7	4,888	5,064
6	12,000	25.5	8.5	5,089	5,719
7	14,500	30.9	10.3	5,795	6,652
8	17,000	36.2	12.1	5,820	7,407
9	19,500	41.5	13.8	7,886	8,844
10	22,000	46.8	15.6	8,516	9,171
11	27,000	57.4	19.1	9,499	10,834



TG **THIELE GEOTECH, INC**

AGGREGATE REPORT

Project
Stone Strong Systems

Job No.
02546.0

Location
Lincoln, NE

Date
7/31/03

US Standard Sieve No.	Cumulative Percent		Specification Percent	
	Retained	Passing	Retained	Passing
1 1/2"	0.3	99.7		
3/4"	39.4	60.6	0 to 40	60 to 100
3/8"	96.3	3.7		
# 4	96.9	3.1	60 to 100	0 to 40
# 10	97.1	2.9		
# 20	97.3	2.7		
# 40	97.5	2.5		
# 100	97.9	2.1		
# 200	98.2	1.8	95 to 100	0 to 5

Sample of: Limestone Unit Fill

Sampled at: Workman Precast from stockpile

Source:

Date Received: 7/22/03

Remarks: Dry Unit Weight by Rodding ASTM C29 90.5 pcf

Lab No.______

TG **THIELE GEOTECH, INC**

AGGREGATE REPORT

Project
Stone Strong Systems

Job No.
02546.0

Location
Lincoln, NE

Date
8/6/03

US Standard	Cumulative Percent		Specification Percent	
Sieve No.	Retained	Passing	Retained	Passing
1 1/2"	0.0	100.0		
3/4"	33.9	66.1	0 to 40	60 to 100
3/8"	95.5	4.5		
# 4	96.4	3.6	60 to 100	0 to 40
# 10	96.6	3.4		
# 20	96.8	3.2		
# 40	96.9	3.1		
# 100	97.3	2.7		
# 200	97.5	2.5	95 to 100	0 to 5

Sample of Limestone Unit Fill

Sampled at Workman Precast from stockpile

Source

Date Received

Remarks Sample #2

Lab No.______

TG **THIELE GEOTECH, INC**

AGGREGATE REPORT

Project Stone Strong Systems	Job No. 02546.0
Location Lincoln, NE	Date 3/11/04

US Standard Sieve No.	Cumulative Percent		Specification Percent	
	Retained	Passing	Retained	Passing
1 1/2"	0.0	100.0		
3/4"	33.9	66.1	0 to 40	60 to 100
3/8"	95.5	4.5		
# 4	96.4	3.6	60 to 100	0 to 40
# 10	96.6	3.4		
# 20	96.8	3.2		
# 40	96.9	3.1		
# 100	97.3	2.7		
# 200	97.5	2.5	95 to 100	0 to 5

Sample of Limestone Unit Fill

Sampled at Workman Precast from stockpile

Source

Date Received

Remarks Sample #3

Lab No.______

THIELE GEOTECH, INC

AGGREGATE REPORT

Project: Stone Strong Systems

Job No.: 02546.0

Location: Lincoln, NE

Date: 6/1/04

US Standard Sieve No.	Cumulative Percent		Specification Percent	
	Retained	Passing	Retained	Passing
1 1/2"	0.0	100.0		
3/4"	5.4	94.6	0 to 40	60 to 100
3/8"	44.9	55.1		
# 4	81.3	18.7	60 to 100	0 to 40
# 10	89.4	10.6		
# 20	92.1	7.9		
# 40	93.3	6.7		
# 100	94.4	5.6		
# 200	94.9	5.1	95 to 100	0 to 5

Sample of: Limestone Unit Fill

Sampled at: Workman Precast from stockpile

Source:

Date Received: 5/25/04

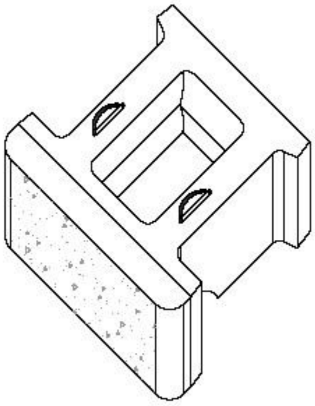
Remarks: Sample #4

Lab No. G825

Interaction Testing Report

6 SF Units with Synteen Geogrids

Stone Strong Systems
Lincoln, Nebraska



Prepared for:
Stone Strong Systems
3801 Union Drive, Suite 102
Lincoln, Nebraska 68516

May 27, 2005
TG Project No. 02546.2

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Omaha, Nebraska 68138-3716
402/556-2171   Fax 402/556-7831
www.thielegeotech.com

In association with:
TADROS ASSOCIATES, LLC
6910 Pacific Street, Suite 204
Omaha, Nebraska 68106-1045

Interaction Testing Report
6 SF Units with Synteen Geogrids

Table of Contents

INTRODUCTION

Thiele Geotech, Inc., in association with Tadros Associates, LLC, has completed an interaction testing program to evaluate the interface shear capacity and the connection strength between Stone Strong Systems 6 SF precast concrete segmental retaining wall blocks and Synteen SF55 and SF110 geogrids used in the construction of segmental retaining walls. The results of the testing program were used to define relationships for surcharge load representing stacked Stone Strong units with facing/geogrid connection strength and with interface shear strength both with and without geogrid inclusions.

Due to the large size of the Stone Strong blocks, a custom testing frame was designed by Tadros Associates, LLC. This large test frame accommodates full scale tests under conditions that reproduced field shear and connection conditions. Testing was performed by personnel from Tadros Associates and Thiele Geotech.

MATERIALS

Stone Strong Systems 6 SF blocks are precast concrete blocks used for construction of segmental retaining walls. These units are typically used as accessories with the 24 SF blocks to make elevation transitions, but they are sometimes used as a stand-alone product to construct tight radius curves or for other special applications.

The 6 SF unit has nominal face dimensions of 48 inches long and 18 inches tall for a total face area of 6 square feet. The unit has a depth (measured horizontally from the face to the tail) of approximately 44 inches. The units have dual center webs, and the face and tail flanges extend beyond the webs. The rear flange is tapered to allow the blocks to be laid on a curve. Each unit weighs approximately 1,450 to 1,550 pounds empty, depending on the aggregate used to manufacture the block. When installed in a retaining wall, the block voids are filled with aggregate. The infilled weight is approximately 2,550 to 2,850 pounds, depending on the unit weights of the concrete and aggregate fill.

Synteen SF55 and SF110 geogrids are uni-directional grids composed of high strength polyester yarns coated with a PVC material. The SF55 and SF110 Geogrids have average ultimate tensile strengths of 3,774 pounds per foot and 10,212 pounds per foot, respectively, based on published test data.

TEST PROCEDURES

TEST FRAME

The apparatus used to conduct the tests consisted of a steel frame anchored to a rigid concrete mat foundation. The frame is capable of applying 150,000 pounds of surcharge load and 100,000 pounds of shear/pullout force simultaneously. Rollers were mounted between the test frame and the loading beam to allow for block movement during shear testing. Photographs and schematics of the test frame are included in the Appendix of this report.

Surcharge and shear/pullout loads were placed on the blocks using two (2) Enerpac PEJ-1301 submerged hydraulic pumps capable of delivering 20 in^3 per minute at 10,000 psi each. Loads were measured by the use of Omega PX303 pressure transducers with 0 to 10,000 psig range and an accuracy of 0.25 percent FS. Mounted on each pump is a manifold to distribute hydraulic fluid to the two (2) 25 ton, 6 inch stroke (Enerpac RC256) surcharge actuators and the two (2) 25 ton, 6 inch stroke (Enerpac RC256) shear/pullout actuators and to the pressure transducers. The flow of fluid to the shear/pullout actuators is adjustable by an Enerpac V-8F needle valve.

Displacements were measured by the use of two (2) 3 inch stroke and one (1) 6 inch stroke linear potentiometers with 0.15 percent maximum linearity (0.07 percent typical) and less than 0.01 mm hysteresis.

Loads and displacements were continuously measured and recorded during the test by a Data Translation DT9802 date acquisition module connected to a laptop computer via USB interface. Sensor excitation was provided by an Omega 5v regulated power supply. Loads and displacements were recorded a minimum of once per second using DT Measure Foundry software.

INTERFACE SHEAR TESTS

The NCMA SRWU-2 and ASTM D6638 methods of test were used to determine the shear strength between Stone Strong Systems 6 SF concrete block units. The tests were carried out with and without a layer of geosynthetic reinforcement between layers of Stone Strong units. Six bottom blocks were installed and braced against the front of the load frame. Crushed limestone infill was placed in the voids between the bottom blocks. When a geogrid layer was included, the geosynthetic reinforcement was centered over the bottom blocks. Three Stone Strong units were stacked in a running bond and centered over the bottom blocks. Crushed limestone infill was placed in the voids between the top blocks.

The top unit was loaded with a constant vertical surcharge load applied to the concrete webs, simulating an equivalent height of stacked blocks. The shear force was applied at a constant rate of displacement until large shear displacements were achieved. The load and displacements were continuously measured and recorded during the test by a microcomputer/data acquisition system. The tests were continued until failure of the interface components occurred, causing a sustained loss of shearing resistance, or to a displacement of 1½ inches.

CONNECTION STRENGTH PULLOUT TESTS

The NCMA SRWU-1 and ASTM D6638 methods of test were used to determine the connection strength between geosynthetic reinforcement and Stone Strong Systems 6 SF concrete block units. The tests were carried out with a layer of geosynthetic reinforcement between layers of Stone Strong units. Four bottom blocks were installed and braced against the back of the load frame. Crushed limestone infill was placed in the voids between the bottom blocks. The geosynthetic reinforcement was centered over the bottom blocks and attached to a clamping device. The top layer of Stone Strong units was placed over the geogrid and centered over the bottom block layer. Crushed limestone infill was placed in the voids between the top blocks, and the blocks were braced against the back of the frame.

The top units were loaded with a constant vertical surcharge load applied to the concrete webs, simulating an equivalent height of stacked blocks. A tensile force was placed on the geosynthetic reinforcement under constant rate of displacement until failure of the connection system occurred. The load and displacements were continuously measured and recorded during the test by a microcomputer/data acquisition system. Tests were continued until failure occurred as excessive deformation or slippage of the geogrid in the connection or failure of the blocks occurred, causing a sustained loss of tensile resistance recorded.

TEST RESULTS

INTERFACE SHEAR TESTS

Results of the interface shear tests are attached in tables and graphs recorded in the Appendix of this report. The peak interface shear capacity and shear capacity at the displacement criterion of ¾ inch were plotted versus the normal load. The peak interface shear strength between Stone Strong Systems 6 SF units and Synteen SF110 Geogrid for equivalent wall heights between 4.3 and 32.6 feet high ranged between 2,100 and 12,228 pounds per foot. Tests repeated using the same normal load had peak shear capacity values within 10 percent of the mean peak shear capacity of the identical tests; therefore, they are within the NCMA recommended limits for demonstrating test repeatability. The service state criterion is defined as the load at ¾ inch deflection.

Lines were best fit to the test data for the individual tests series. Interface shear properties were interpolated from the data, and are summarized in Table 1.

Table 1, Interface Shear Properties

Case	Ultimate			Service State Criterion		
	Minimum (lbs/ft)	**Friction Angle (degrees)**	**Maximum (lbs/ft)**	**Minimum (lbs/ft)**	**Friction Angle (degrees)**	**Maximum (lbs/ft)**
Block shear (no geogrid)	1,309	36.4	12,228	1,257	35.0	12,000
Shear w/ SF110 inclusion	1,271	20.2	7,038	1,036	17.0	6,198

The peak interface shear strength between Stone Strong Systems 6 SF units and Synteen SF55 Geogrid was not tested. During testing of the Stone Strong Systems 24 SF units, it was found that interface shear strengths were generally better with the Synteen SF55 Geogrid than with the Synteen SF110 Geogrid. Therefore, when using the 6 SF units with Synteen SF55 Geogrid, the interface shear test data for 6 SF units with Synteen SF110 Geogrid should be used for analysis.

CONNECTION STRENGTH PULLOUT TESTS

Results of the connection strength tests are summarized in tables and graphs recorded in the Appendix of this report. The peak connection capacity and connection capacity at the displacement criterion of ¾ inch were plotted versus the normal load. The recorded peak connection strengths between Stone Strong Systems 6 SF units and Synteen SF55 and SF110 Geogrid were 2,428 and 4,690 pounds per foot, respectively, for equivalent wall heights between 4.3 and 36.2 feet high. Tests repeated using the same normal load had peak shear capacity values within 10 percent of the mean peak shear capacity of the identical tests; therefore, they are within the NCMA recommended limits for demonstrating test repeatability.

Lines were best fit to the test data for the individual tests series. Interface shear properties were interpolated from the data, and are summarized in Table 2.

Table 2, Connection Strength Properties

Case	Ultimate			Service State Criterion		
	Minimum (lbs/ft)	**Friction Angle (degrees)**	**Maximum (lbs/ft)**	**Minimum (lbs/ft)**	**Friction Angle (degrees)**	**Maximum (lbs/ft)**
Connection Strength w/ SF55 Geogrid	1,743	9.5	2,210	993	9.4	1,390
Connection Strength w/ SF110 Geogrid	1,765	12.1	4,690	1,238	9.5	3,614

CONCLUSIONS

The design curves illustrated on the graphs in the appendix are based on interpretation of the test data, based on the NCMA Segmental Retaining Wall Design Manual. The design curves are controlled by the ¾ inch displacement criterion. The design values taken from the graphs should be used with caution, as shear and connection strengths may vary based on actual site conditions and construction quality.

Respectfully submitted,
Thiele Geotech, Inc.

Daniel J. Thiele, P.E.

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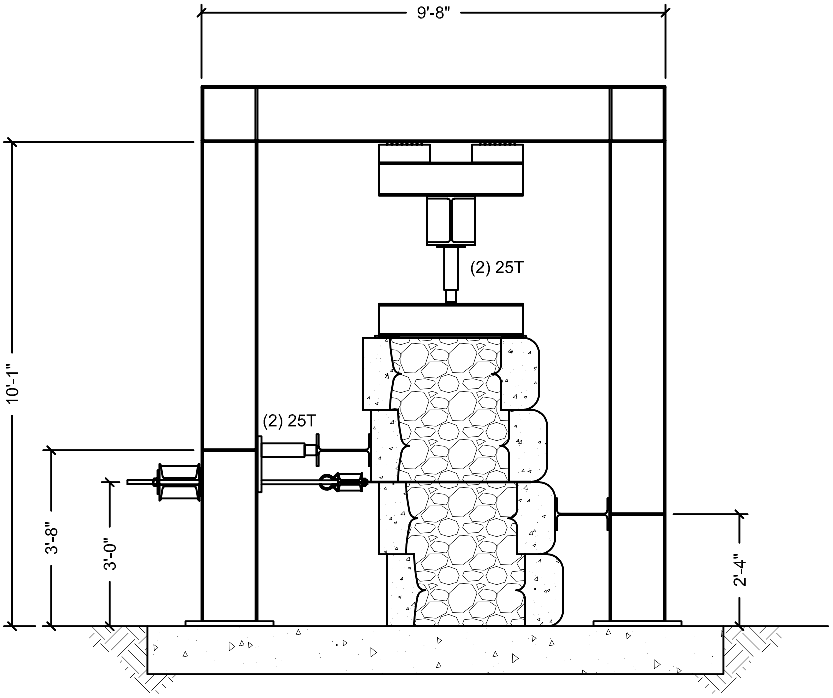
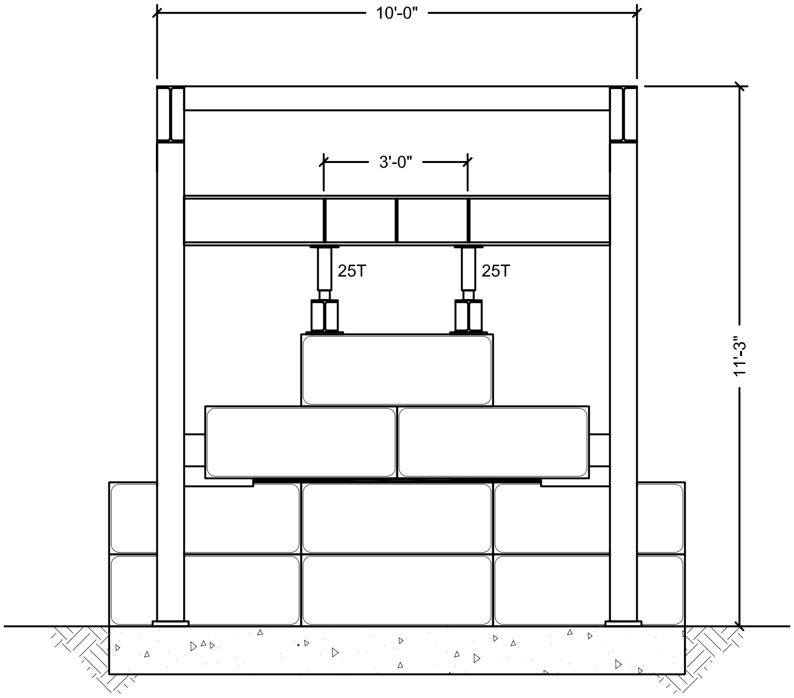
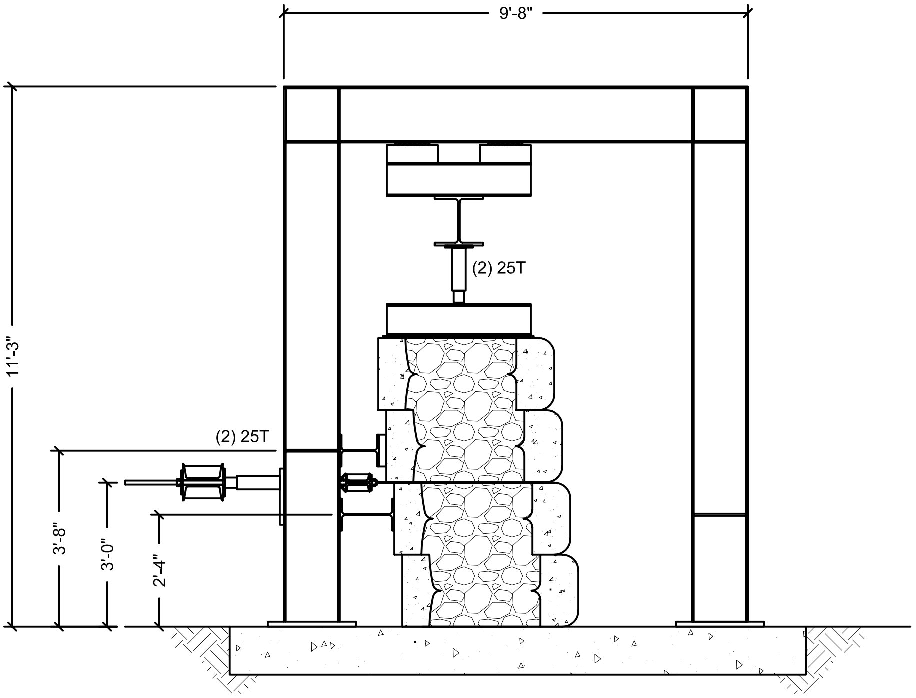
APPENDIX

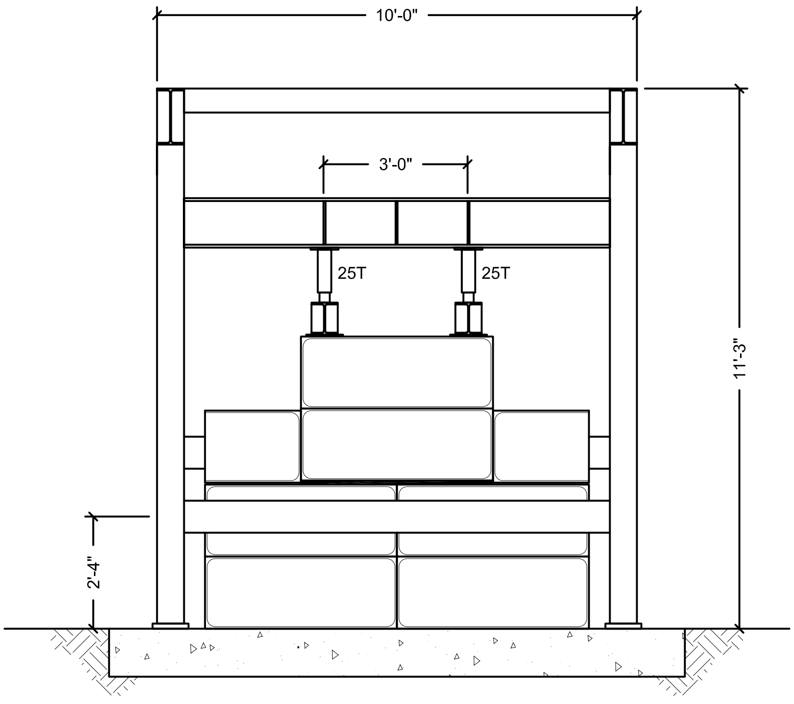




Tadros Associates, LLC
6910 Pacific Street, Suite 204, Omaha, NE 68106
Phone: (402) 553-0234 Fax: (402) 553-0201

Project: SSS Grid Testing
Title: Shear Frame Setup
Project No.: NE058-04P01
Date: 11/03/04
Scale: None
Designed By:
Checked By:
Detailed By: NAM
Rev.:
Rev. Date:
Page of

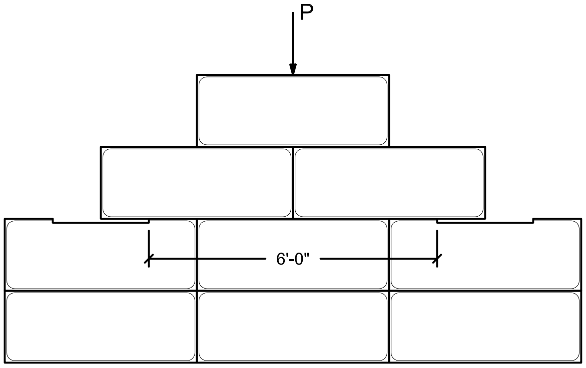




Tadros Associates, LLC
6910 Pacific Street, Suite 204, Omaha, NE 68106
Phone: (402) 553-0234 Fax: (402) 553-0201

Project: SSS Grid Testing
Title: Grid Pullout Frame Setup
Project No.: NE058-04P01
Date: 11/03/04
Scale: None
Designed By:
Checked By:
Detailed By: NAM
Rev.:
Rev. Date:
Page of

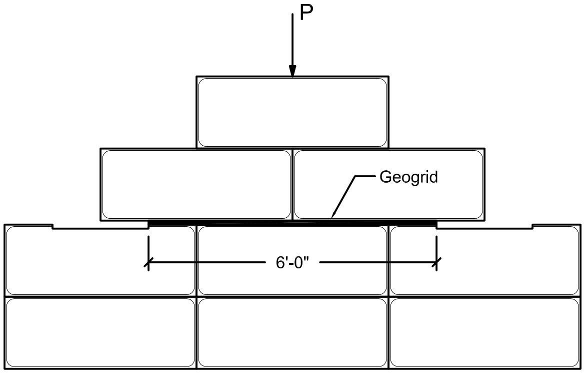
6SF Block Shear



$$\text{Normal Force}\left(\frac{\text{kips}}{\text{ft}}\right) = \frac{\text{P kips}}{\text{6 ft}}$$

$$\text{Shear Force}\left(\frac{\text{kips}}{\text{ft}}\right) = \frac{\text{V kips}}{\text{6 ft}}$$

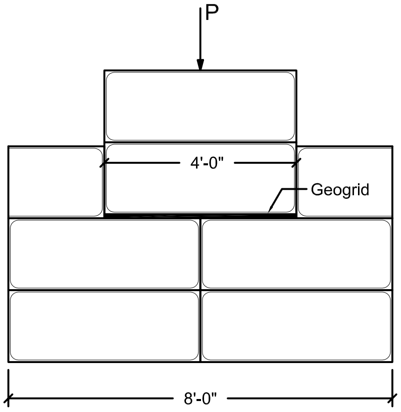
6SF Grid Shear



$$\text{Normal Force}\left(\frac{\text{kips}}{\text{ft}}\right) = \frac{\text{P kips}}{\text{6 ft}}$$

$$\text{Shear Force}\left(\frac{\text{kips}}{\text{ft}}\right) = \frac{\text{V kips}}{\text{6 ft}}$$

6SF Grid Pullout



$$\text{Normal Force}\left(\frac{\text{kips}}{\text{ft}}\right) = \frac{\text{P kips}}{\text{4 ft}}$$

$$\text{Grid Pullout}\left(\frac{\text{kips}}{\text{ft}}\right) = \frac{\text{T kips}}{\text{4 ft}}$$

Tadros Associates, LLC
6910 Pacific Street, Suite 204, Omaha, NE 68106
Phone: (402) 553-0234 Fax: (402) 553-0201

Project SSS Grid Testing	Project No. NE058-04P01	Designed By	Rev.
	Date 11/03/04	Checked By	Rev. Date
Title Test Setup	Scale None	Detailed By NAM	Page of

PHOTO NUMBER 1
Front View of Test Setup

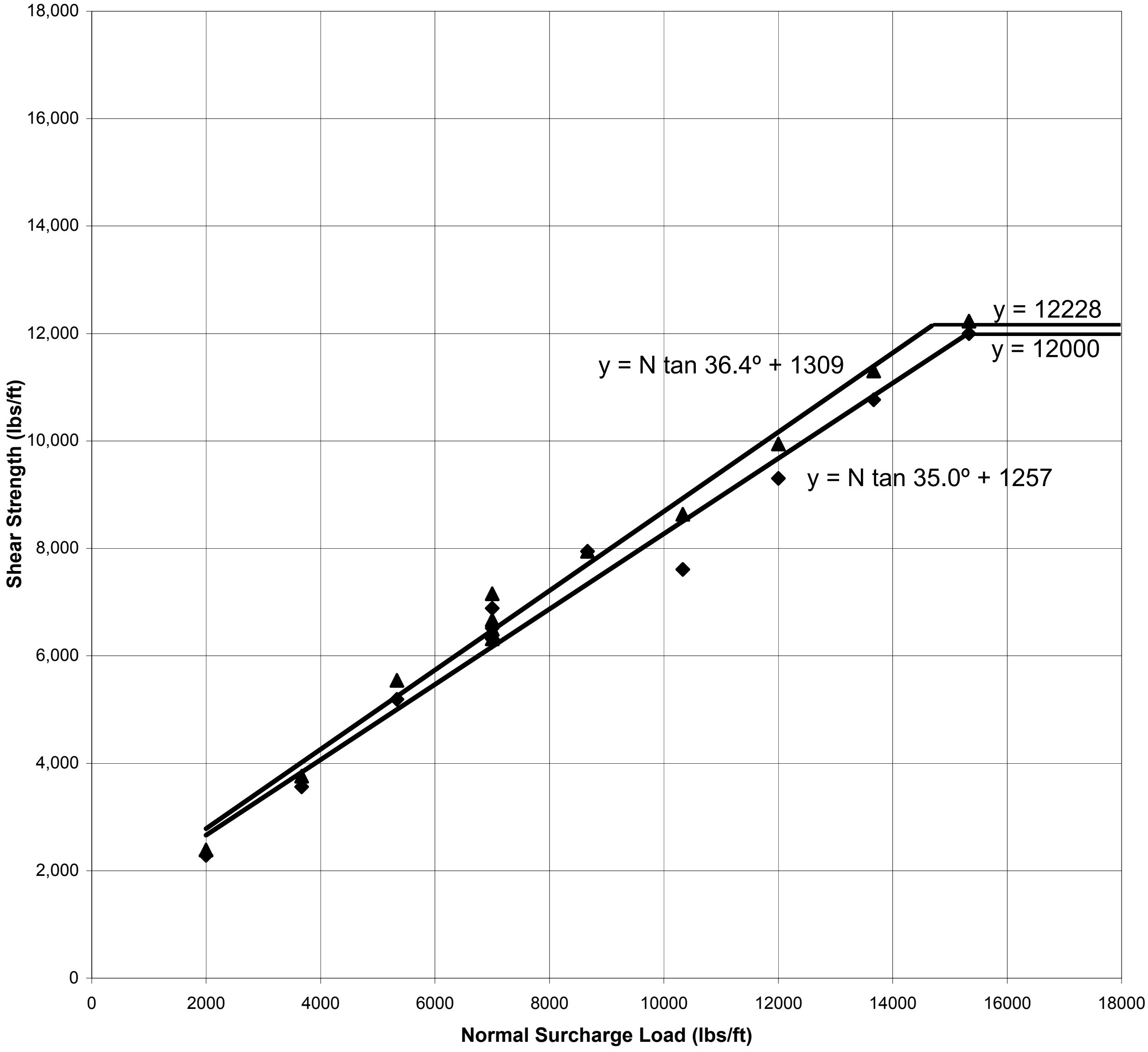
PHOTO NUMBER 2
Side View of Test Setup

INTERFACE SHEAR TESTS

6 SF UNITS

Trial #	Normal (lbs/ft)	Approx Wall Height (ft)	Approx # of Units	Shear @ 3/4" displacement (lbs/ft)	Peak Shear (lbs/ft)
1	2,000	4.3	1.4	2,284	2,385
2	3,667	7.8	2.6	3,561	3,763
3	5,333	11.3	3.8	5,190	5,543
4	7,000	14.9	5.0	6,316	6,316
5	7,000	14.9	5.0	6,383	6,500
6	7,000	14.9	5.0	6,517	6,668
7	7,000	14.9	5.0	6,887	7,156
8	8,667	18.4	6.1	7,945	7,945
9	10,333	22.0	7.3	7,609	8,634
10	12,000	25.5	8.5	9,306	9,944
11	13,667	29.1	9.7	10,767	11,304
12	15,333	32.6	10.9	12,000	12,228

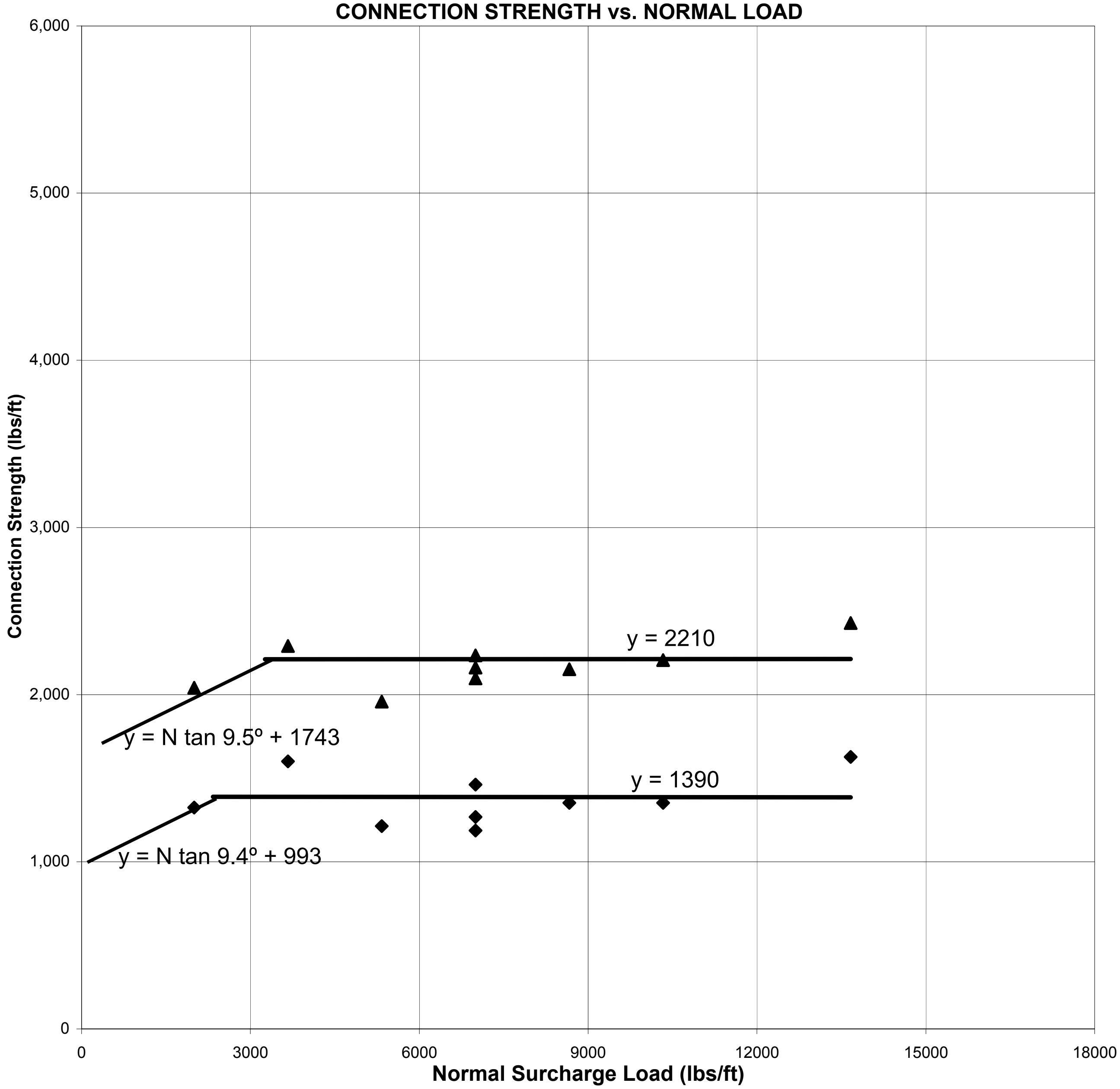
INTERFACE SHEAR STRENGTH vs. NORMAL LOAD



GEOGRID PULLOUT TESTS

6 SF UNITS w/ SYNTEEN SF55 GEOGRID

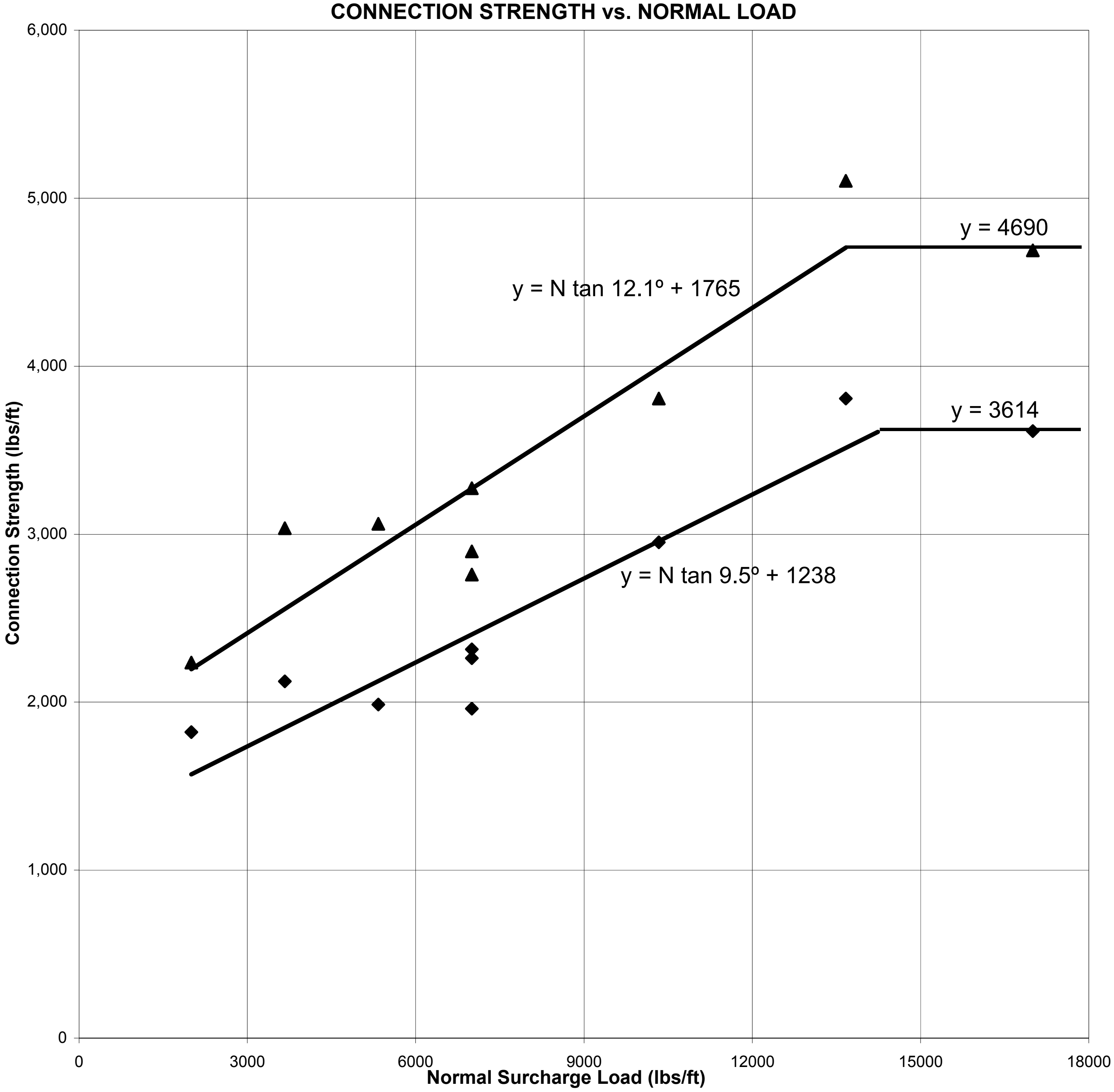
Trial #	Normal (lbs/ft)	Approx Wall Height (ft)	Approx # of Units	Tension @ 3/4" displ (lbs/ft)	Peak Tension (lbs/ft)
1	2,000	4.3	1.4	1,324	2,042
2	3,667	7.8	2.6	1,600	2,290
3	5,333	11.3	3.8	1,214	1,959
4	7,000	14.9	5.0	1,186	2,097
5	7,000	14.9	5.0	1,268	2,162
6	7,000	14.9	5.0	1,462	2,235
7	8,667	18.4	6.1	1,352	2,152
8	10,333	22.0	7.3	1,352	2,207
9	13,667	29.1	9.7	1,628	2,428



GEOGRID PULLOUT TESTS

6 SF UNITS w/ SYNTEEN SF110 GEOGRID

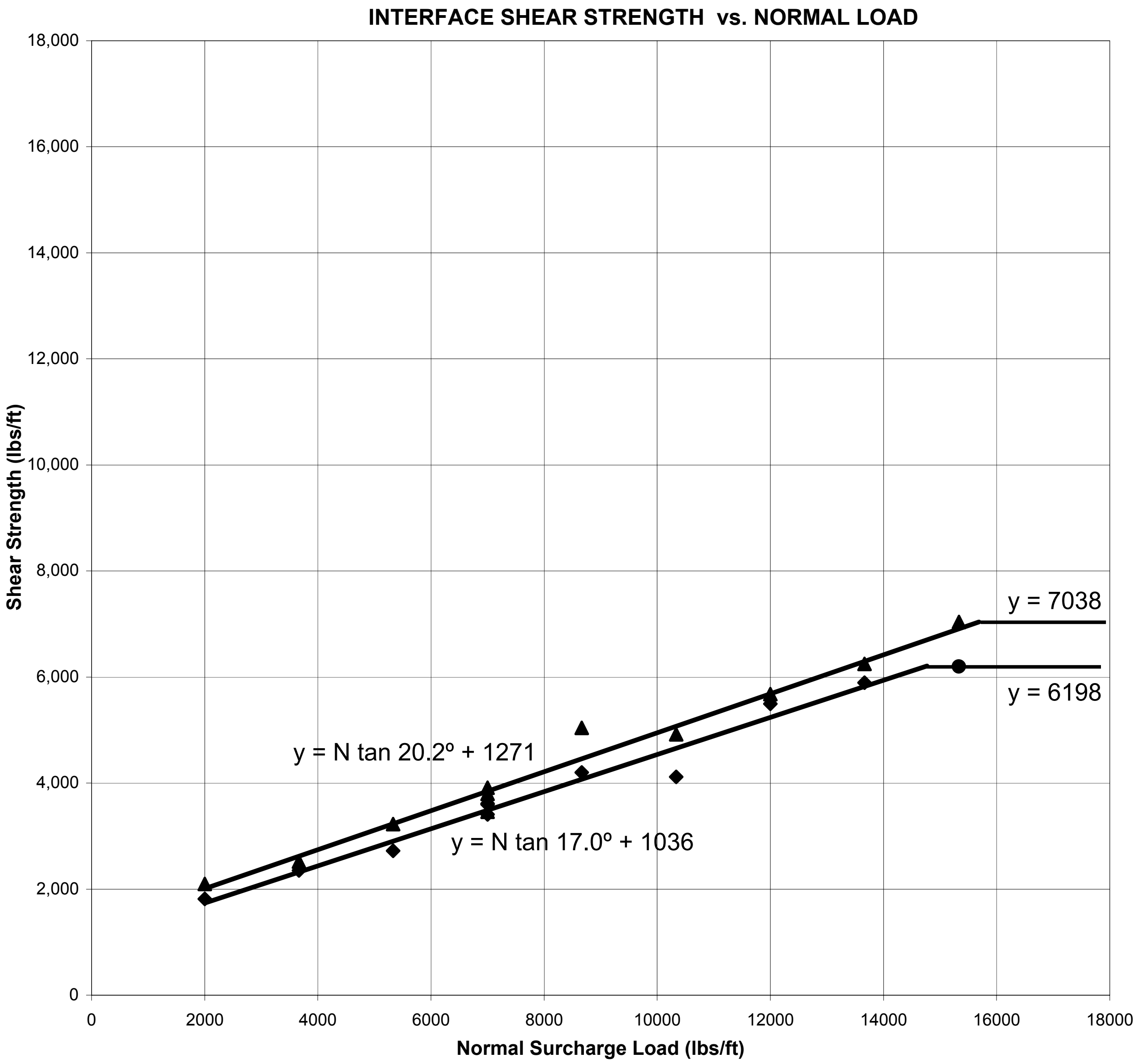
Trial #	Normal (lbs/ft)	Approx Wall Height (ft)	Approx # of Units	Tension @ 3/4" displ (lbs/ft)	Peak Tension (lbs/ft)
1	2,000	4.3	1.4	1,821	2,235
2	3,667	7.8	2.6	2,124	3,035
3	5,333	11.3	3.8	1,987	3,062
4	7,000	14.9	5.0	1,961	2,759
5	7,000	14.9	5.0	2,314	3,274
6	7,000	14.9	5.0	2,262	2,897
7	10,333	22.0	7.3	2,952	3,807
8	13,667	29.1	9.7	3,807	5,104
9	17,000	36.2	12.1	3,614	4,690



INTERFACE SHEAR TESTS

6 SF UNITS w/ SF110 INCLUSION

Trial #	Normal (lbs/ft)	Approx Wall Height (ft)	Approx # of Units	Shear @ 3/4" displacement (lbs/ft)	Peak Shear (lbs/ft)
1	2,000	4.3	1.4	1,814	2,100
2	3,667	7.8	2.6	2,352	2,520
3	5,333	11.3	3.8	2,721	3,225
4	7,000	14.9	5.0	3,611	3,796
5	7,000	14.9	5.0	3,595	3,914
6	7,000	14.9	5.0	3,410	3,460
7	8,667	18.4	6.1	4,199	5,039
8	10,333	22.0	7.3	4,115	4,922
9	12,000	25.5	8.5	5,493	5,677
10	13,667	29.1	9.7	5,896	6,249
11	15,333	32.6	10.9	6,198	7,038



TG **THIELE GEOTECH, INC**

AGGREGATE REPORT

Project Stone Strong Systems	Job No. 02546.0
Location Lincoln, NE	Date 6/1/04

US Standard Sieve No.	Cumulative Percent		Specification Percent	
	Retained	Passing	Retained	Passing
1 1/2"	0.0	100.0		
3/4"	5.4	94.6	0 to 40	60 to 100
3/8"	44.9	55.1		
# 4	81.3	18.7	60 to 100	0 to 40
# 10	89.4	10.6		
# 20	92.1	7.9		
# 40	93.3	6.7		
# 100	94.4	5.6		
# 200	94.9	5.1	95 to 100	0 to 5

Sample of	Limestone Unit Fill
Sampled at	Workman Precast from stockpile
Source	
Date Received	5/25/04
Remarks	Sample #4

Lab No. G825

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jump to Appendix TOC

1.1.11 ALIGNMENT DETAILS

No attachments

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[jump to Appendix TOC]

1.1.12 FILTRATION

No attachments

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1.1.13 FACE PATTERNS

No attachments

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jump to Appendix TOC

1.1.14 CURVES AND CORNERS

No attachments

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1.2.1 REINFORCEMENT INNOVATIONS

No attachments

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jump to Appendix TOC

1.2.2 REINFORCEMENT TYPE

No attachments

jump to TOC

jump to Appendix TOC

1.2.3 REINFORCEMENT PROPERTIES

Technical Data Sheet – Paraweb 2, 11/2/15

Note: The letter designations (E, D, & S) on the data sheet designate the sheath thickness over the yarn bundles. In most applications, Stone Strong utilizes 2D-50 reinforcement straps.

MACCAFERRI

TECHNICAL DATA SHEET
Rev: 03, Issue Date 11.12.2015

PARAWEB™2
GEOSYNTHETICS REINFORCEMENT STRIP

ParaWeb™ 2 range is manufactured from high tenacity, mutifilament polyester yarns aligned and co-extruded with polyethylene (LLDPE) to form polymeric strips. ParaWeb™ strips are planar structures consisting of a core of high tenacity polyester yarn tendons encased in a polyethylene (LLDPE) sheath; it enables **ParaWeb™ 2** range to be used as reinforcement of contaminated or high aggressive materials for use in environmental applications. The strips are suitable for reinforcement applications in combination with concrete wall facing panels. The **ParaWeb™ 2** range has been tested internally and independently (NTPEP) in accordance to published standards and will conform to the property values listed below.

PARAWEB 2E		**30**	**40**	**50**	**75**	**100**	
MECHANICAL PROPERTIES							
Ultimate Tensile Strength (ASTM 6637)	lb	**6744**	**8992**	**11240**	**16861**	**22481**	1
Creep Reduced Strength @100y, 20°C	lb	**4958**	**6611**	**8264**	**12397**	**16530**	1
Long term Design Strength (AASHTO LRFD)	lb	**4087**	**5449**	**6812**	**10218**	**13624**	1, 2
PHYSICAL PROPERTIES (nominal values)							
Strip width & thickness	in	3.27 / 0.06	3.27 / 0.07	3.43 / 0.08	3.54 / 0.10	3.54 / 0.12	4
Strip weight	lb/328ft	19.18	24.03	27.34	39.46	53.13	4

PARAWEB 2D		**30**	**40**	**50**	**75**	**100**	
MECHANICAL PROPERTIES							
Ultimate Tensile Strength (ASTM 6637)	lb	**6744**	**8992**	**11240**	**16861**	**22481**	1
Creep Reduced Strength @100y, 20°C	lb	**4958**	**6611**	**8264**	**12397**	**16530**	1
Long term Design Strength (AASHTO LRFD)	lb	**4087**	**5449**	**6812**	**10218**	**13624**	1, 2
PHYSICAL PROPERTIES (nominal values)							
Strip width & thickness	in	3.27 / 0.07	3.31 / 0.09	3.54 / 0.10	3.54 / 0.12	3.54 / 0.15	4
Strip weight	lb/328ft	28.00	36.82	42.99	56.44	68.56	4

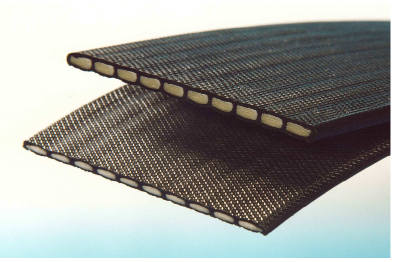
PARAWEB 2S		**30**	**40**	**50**	**75**	**100**	
MECHANICAL PROPERTIES							
Ultimate Tensile Strength (ASTM 6637)	lb	**7550**	**10067**	**13584**	**18876**	**25168**	1
Creep Reduced Strength @100y, 20°C	lb	**5551**	**7402**	**9988**	**13879**	**18505**	1
Long term Design Strength (AASHTO LRFD)	lb	**4575**	**6101**	**8232**	**11440**	**15253**	1, 3
PHYSICAL PROPERTIES (nominal values)							
Strip width & thickness	in	3.35 / 0.09	3.35 / 0.10	3.54 / 0.14	3.54 / 0.16	3.54 / 0.24	4
Strip weight	lb/328ft	32.63	40.79	50.71	66.14	83.11	4

1. Minimum average roll values (MARV) are calculated as typical minus two standard deviations. Statistically, it yields a 97.7% degree of confidence that any samples taken from quality assurance testing will exceed the value reported;
2. LTDS calculated for a standard temperature of 20°C, 4≤ph≤9 in coarse gravel soil; on request more data available;
3. As above but for 9<ph≤11; product for lime-soil mix applications and aggressive environments.
4. Width, thickness and weight values per roll are nominal a tolerance of 5% on the reported value is admitted.

Maccaferri can engineer specific solutions in any of our products; please contact us for specific solution targeted to your project.

NTPEP CERTIFIED MATERIAL

AASHTO NATIONAL TRANSPORTATION PRODUCT EVALUATION PROGRAM



Disclaimer: The short term and long term mechanical properties listed in this TDS are in compliance with the Paraweb™ NTPEP certifications and AASHTO LRFD regulation; it means that different values can be reported in other TDS not because not accurate but simply because listed following different testing method or different standards.

Maccaferri reserves the right to amend product specifications without notice and specifiers are requested to check as to the validity of the pecifications they are using.

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Phoenix, Arizona
Sacramento, California
Miami, Florida
St. Louis, Missouri
Trenton, New Jersey
Albuquerque, New Mexico
Caguas, Puerto Rico
Dallas/Ft. Worth, Texas

1.2.4 NTPEP REPORT

NTPEP Report REGEO-2016-01, Laboratory Evaluation of Geosynthetic Reinforcement, August 2018

2018 NTPEP Report Series

NTPEP Report REGEO-2016-01-[Linear Composites-ParaWeb-ParaLink]

Laboratory Evaluation of Geosynthetic Reinforcement

Final Product Qualification Report for Linear Composites ParaWeb and Product Lines

Report Issued: August 2018
Report Expiration Date: August 2024
Next Quality Assurance Update Report: 2021

American Association of State Highway and Transportation Officials (AASHTO)

Executive Office: 444 North Capitol Street, NW, Suite 249 • Washington, DC • 20001
(t) 202.624.5800 • (f) 202.624.5469 • www.NTPEP.ORG

2018 NTPEP Report Series

National Transportation Product Evaluation Program (NTPEP)

NTPEP Report REGEO-2016-01-[Linear Composites-ParaWeb-ParaLink]

LABORATORY EVALUATION OF GEOSYNTHETIC REINFORCEMENT

2016 PRODUCT SUBMISSIONS
SAMPLED JANUARY 2017

Laboratory Evaluation by:

TRI/Environmental, Inc.
9063 Bee Caves Road
Austin, TX 78733-6201

Product Line Manufactured by:

Linear Composites Limited
Vale Mills, Oakworth, Keighley
West Yorkshire, UK BD22 0EB

PROLOGUE

General Facts about NTPEP Reports:

- NTPEP Reports contain data collected according to laboratory testing and field evaluation protocols developed through consensus-based decision by the AASHTO's NTPEP Oversight Committee. These test and evaluation protocols are described in the *Project Work Plan* (see NTPEP website).
- Products are voluntarily submitted by manufacturers for testing by NTPEP. Testing fees are assessed from manufacturers to reimburse AASHTO member departments for conducting testing and to report results. AASHTO member departments provide a voluntary yearly contribution to support the administrative functions of NTPEP.
- AASHTO/NTPEP does not endorse any manufacturer's product over another. Use of certain proprietary products as "primary products" does not constitute endorsement of those products.
- AASHTO/NTPEP does not issue product approval or disapproval; rather, test data are furnished for the User to make judgment for product prequalification or approval for their transportation agency.

Guidelines for Proper Use of NTPEP Results:

- The User is urged to carefully read any introductory notes at the beginning of this Report, and also to consider any special clauses, footnotes or conditions which may apply to any test reported herein. Any of these notes may be relevant to the proper use of NTPEP test data.
- The User of this Report must be sufficiently familiar with the product performance requirements and/or (standard) specification of their agency in order to determine which test data are relevant to meeting those qualifying factors.
- NTPEP test data is intended to be predictive of actual product performance. Where a transportation agency has successful historical experience with a given product, it is suggested to factor that precedence in granting or withholding product approval or prequalification.

NTPEP Report Special Advisory for Geosynthetic Reinforcement (REGEO):

- This report contains product data that are intended to be applied to a product line, based on the test results obtained for specific products that are used to represent the product line for the purposes of NTPEP testing. It is expected that the User will estimate the properties of specific products in the line not specifically tested through interpolation or a lower or upper bound approach.
- It is intended that this data be used by the User to add products to their Qualified Products or Approved Products List, and/or to develop geosynthetic reinforcement strength design parameters in accordance with AASHTO, FHWA, or other widely accepted design specifications/guidelines. It is also intended that the User will conduct further, but limited, evaluation and testing of the products identified in this report for product acceptance purposes to verify product quality.
- Products included in this report must be resubmitted to NTPEP every three (3) years for a quality assurance evaluation and every six (6) years for a full qualification evaluation in accordance with the work plan. Hence, all product test results included in this Report supersede data provided in previous Editions of this report.
- The User is guided to read the document entitled "Use and Application of NTPEP Geosynthetic Reinforcement Test Results" (see NTPEP website) for instructions and background on how to apply the results of the data contained in this report.

John Schuler **(Virginia DOT)**
Chairman, Geosynthetics
Technical Committee

Rodrigo Herrera **(Florida DOT)**
Vice Chairman, Geosynthetics
Technical Committee

Table of Contents

Tables

Note: Appendix tables not included.

Figures

Executive Summary

This test report provides data that can be used to characterize the short-term and long-term tensile strength the Linear Composites Limited polyester, Linear Low Density Polyethylene (LLDPE) coated geogrid reinforcement product lines using testing conducted on representative products within the product line. The purpose of this report is to provide data for product qualification purposes.

The test results contained herein were obtained in accordance with AASHTO R69-15 and the NTPEP work plan (see www.NTPEP.org) and can be used to determine the long-term strength of the geosynthetic reinforcement, including the long-term strength reduction factors RF_{ID}, RF_{CR}, and RF_D, and also used to determine low strain creep stiffness values.

All testing reported herein was performed on the materials tested in the direction of manufacture, i.e., the machine direction.

Product Line Description: The product line evaluated includes the following specific polyester, Linear Low Density Polyethylene (LLDPE) coated polymeric strips and geogrid reinforcement products:

Linear Composites ParaWeb 2S/2D/2E 30, ParaWeb 2S/2D/2E 40, ParaWeb 2S/2D/2E 50, ParaWeb 2S/2D/2E 75, ParaWeb 2S/2D/2E 100, ParaWeb 2S/2D/2E 135, ParaWeb MS/MD/ME 45, ParaWeb MS/MD/ME 54, ParaWeb MS/MD/ME 63, ParaLink 300, ParaLink 400, ParaLink 500, ParaLink 600, ParaLink 700, ParaLink 800, ParaLink 1000, ParaLink 1200 & ParaLink 1500.

This product line was evaluated through detailed testing of five representative products in the ParaWeb/ParaLink product line, and very limited testing of the other remaining products in the product line. ParaWeb 2E 50 was used as the primary product for product line characterization purposes (i.e., the baseline to which the other products were compared), and ParaWeb 2E 30, ParaWeb 2E 135, ParaLink 300 and ParaLink 1000 were used as secondary products to evaluate the properties of the range of products in the ParaWeb/ParaLink product line.

ParaWeb 2S/2D/2E & ParaWeb MS/MD/ME products are six styles of polymer straps which differ only in dimensional tolerances specific to strap width and coating thickness. The “2” and “M” designations refer to the width of the strap. ParaWeb “2” products are approximately 3.5 inches wide while ParaWeb “M” products are approximately two inches wide. The “S”, “D” and “E” designations refer to the thickness of the LLDPE coating with “S” having the thickest coating and “E” having the thinnest coating. Still, the production process itself remains the same for all types and it is this aspect of same production parameters that enables all styles to be considered one type of product.

Samples of the primary and secondary products were taken by an independent sampler on behalf of NTPEP on January 6, 2017, at the Linear Composites manufacturing plant located in West Yorkshire, UK. The remaining intermediate samples were sent by the manufacturer January 29, 2018.

Statistical Validation of Use of SIM and Validation of Product Line: The creep rupture test results obtained were statistically evaluated in accordance with R69-15 to assess the validity of using SIM to extend the creep rupture data and to assess the validity of treating the products submitted as a single product line. The following was verified:

i. Validation of the use of SIM to extend the creep rupture data was conducted previously as reported in the 2010 NTPEP report for this product line (NTPEP Report 8508.1). The results of that validation from this previous testing are summarized in Figure F-29 in Appendix F. Revalidation of the use of SIM for this product line was considered unnecessary in accordance with the NTPEP work plan and R69-15, since it was determined that the product line has not significantly changed in its formulation and processing relative to the product line as previously tested and reported in the 2010 NTPEP report.

ii. Based on the available creep data for all the products tested, the product line submitted by the manufacturer statistically qualifies to be a product line and can therefore be represented using test results from representative products in the product line (see Figures F-30 through F-33 in Appendix F for details). Recommendations on application of the representative product data to the rest of the product line for installation damage, durability and creep stiffness are provided in their respective report sections and summarized below in this executive summary.

Test Results for T_{ult}: All wide width test results (ASTM D6637) obtained for this product line through the NTPEP testing were greater than the minimum average roll values (MARV's) provided by the manufacturer (see Table 3-1).

Test Results for RF_{ID}: Installation damage testing on this product line resulted in values of RF_{ID} that ranged as follows:

$$RF_{ID} = 1.00 \text{ to } 1.46$$

In general, as the test material gradation becomes more coarse, the value of RF_{ID} increased. Therefore, interpolation of this data to intermediate gradations appears to be feasible especially between the larger gradations since the finer gradations resulted in minimal damage. See Table 4-3 and Figures 4-5 through 4-8 for details. Laboratory installation damage test data in accordance with ISO/EN 10722 are also provided for future use in comparison to quality assurance testing (see Table 4-6).

It should be noted that the installation damage testing conducted represents an increase in compaction and spreading equipment size (i.e., a 15,000 lb wheeled front end loader – Caterpillar 416F, and a 23,000-26,000 lb single drum vibratory roller) and a reduced aggregate lift thickness over the sample of 6 inches relative to the installation damage testing reported in some previous NTPEP test reports. Actual RF_{ID} values could be lower if installation conditions are less severe (e.g., greater initial lift thickness over the geosynthetic, use of lighter weight equipment, etc.). Actual RF_{ID} values could be higher if the spreading or compacting equipment tires or tracks are allowed to be in direct contact with the geosynthetic before or during fill placement and compaction, if the thickness of the fill material between the equipment tires or tracks is inadequate (especially for high tire pressure equipment such as dump trucks), or if excessive rutting of the first lift of soil over the geosynthetic (e.g., due to soft subgrade soil) is allowed to occur.

Test Results for RF_{CR}: The creep rupture testing conducted indicates that the following value of RF_{CR} may be used:

$$RF_{CR} = 1.36$$

This value of RF_{CR} is applicable to a 75 year life at 68^o F (20^o C), and may be used to characterize the full product line as defined herein. See Figure 5-1 for detailed creep rupture envelope or to obtain values for other design lives.

Test Results for RF_D: The chemical durability index testing results meet the requirements in AASHTO R69-15 to allow use of a default reduction factor for RF_D. See Table 6-2 for specific test results, and see AASHTO R69-15 or the document entitled "Use and Application of NTPEP Geosynthetic Reinforcement Test Results" (www.NTPEP.org) for recommended default reduction factors for RF_D. The UV test results (ASTM D4355) for this product line, as represented by the lightest weight product from each manufacturing plant, indicate strength retained at 500 hours in the weatherometer of 93%. These values of UV strength retained should be considered to be a lower bound value for the product line.

Test Results for Creep Stiffness: The 1000 hr, 2% strain secant stiffness ($J_{2\%,1000hr}$) test results ranged from 39,993 lb/rib for the lowest strength style to 151,878 lb/rib for the highest strength style. There exists a strong linear relationship between creep stiffness and the short-term tensile strength (T_{lot}), therefore the 1000 hr, 2% strain secant stiffness can be reasonably expressed for any product in the product line as:

$$J_{2\%,1000\,hr} = 3.8033(T_{lot}) +16{,}498$$

Where, T_{lot} is the roll/lot specific single rib tensile strength per ASTM D6637. See Table 7-2 and Figure 7-1 for details. Note that once the stiffness is determined from this equation, an equivalent MARV for this property can be determined by multiplying the stiffness by the ratio of T_{MARV}/T_{lot}.

1.0 Product Line Description and Testing Strategy

1.1 Product Description

The **Linear Composites** family of straps are high-strength, Linear Low Density Polyethylene (LLDPE) coated straps. The ParaLink products connect ParaWeb straps into a geogrid product. The product line evaluated consists of the products as manufactured by Linear Composites listed in Table 1-1.

Table 1-1. Product designations included in product line.

Linear Composites Reinforcement Product Designations (i.e., Styles)		
ParaWeb		ParaLink
ParaWeb 2S/2D/2E 30		ParaLink 300
ParaWeb 2S/2D/2E 40		ParaLink 400
ParaWeb 2S/2D/2E 50		ParaLink 500
ParaWeb 2S/2D/2E 75		ParaLink 600
ParaWeb 2S/2D/2E 100		ParaLink 700
ParaWeb 2S/2D/2E 135		ParaLink 800
ParaWeb MS/MD/ME 45		ParaLink 1000
ParaWeb MS/MD/ME 54		ParaLink 1200
ParaWeb MS/MD/ME 63		ParaLink 1500

ParaWeb 2S/2D/2E & ParaWeb MS/MD/ME products are six styles of polymer straps which differ only in dimensional tolerances specific to strap width and coating thickness. The “2” and “M” designations refer to the width of the strap. ParaWeb “2” products are approximately 3.5 inches wide while ParaWeb “M” products are approximately two inches wide. The “S”, “D” and “E” designations refer to the thickness of the LLDPE coating with “S” having the thickest coating and “E” having the thinnest coating. Still, the production process itself remains the same for all types and it is this aspect of same production parameters that enables all styles to be considered one type of product.

The scope of the evaluation is limited to the strength in the machine direction (MD). The cross-machine direction (XD) was not specifically evaluated.

1.2 Product Line Testing Approach

This product line was evaluated through detailed testing of five representative products in the ParaWeb/ParaLink product line, and very limited testing of the other remaining products in the product line. ParaWeb 2E 50 was used as the primary product for product line characterization purposes (i.e., the baseline to which the other products were compared), and ParaWeb 2E 30, ParaWeb 2E 135, ParaLink 300 and ParaLink 1000 were used as secondary products to evaluate the properties of the range of products in the ParaWeb/ParaLink product line. For the ParaWeb products, the "E" designation products were selected for testing because they had the thinnest coating and would be most susceptible to installation damage and UV damage. Therefore use of the "E" products would provide the most conservative assessment for the product line.

Photographs of all the products tested are provided in Figures 1-1 through 1-6.

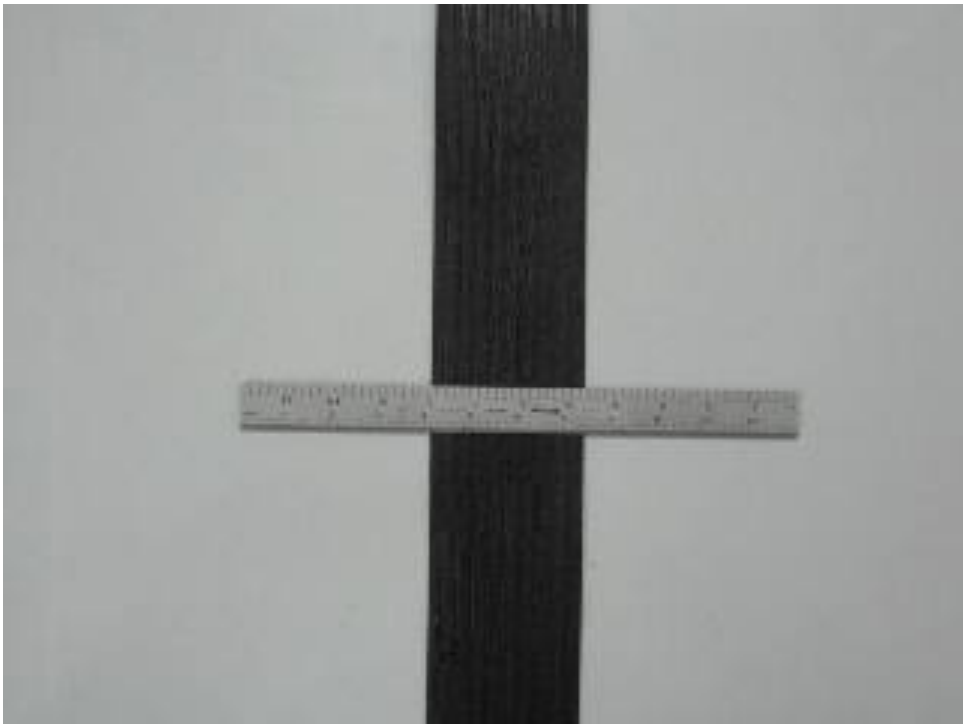

Figure 1-1. Photo of ParaWeb 30 machine direction is perpendicular to ruler shown).

Figure 1-2. Photo of ParaWeb 50 (machine direction is perpendicular to ruler shown).

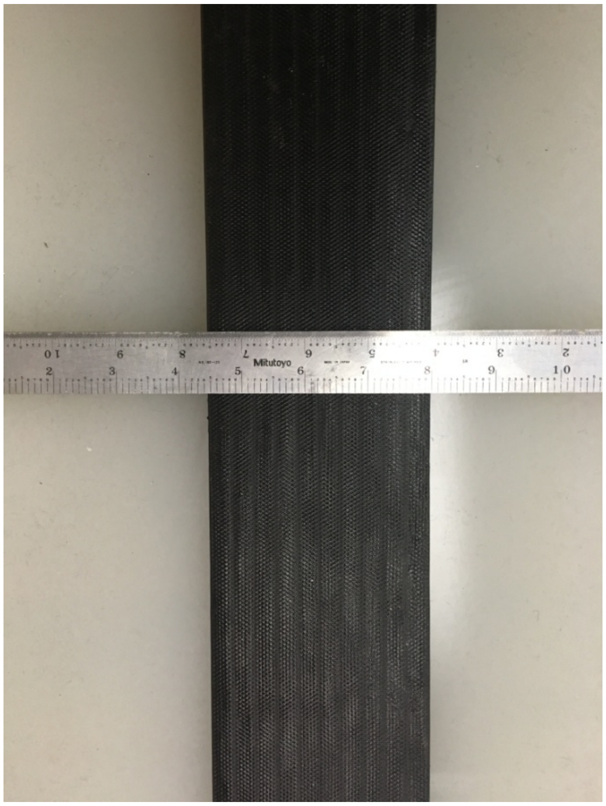

Figure 1-3. Photo of ParaWeb 135 (machine direction is perpendicular to ruler shown).

Figure 1-4. Photo of ParaLink 300 (machine direction is perpendicular to ruler shown).

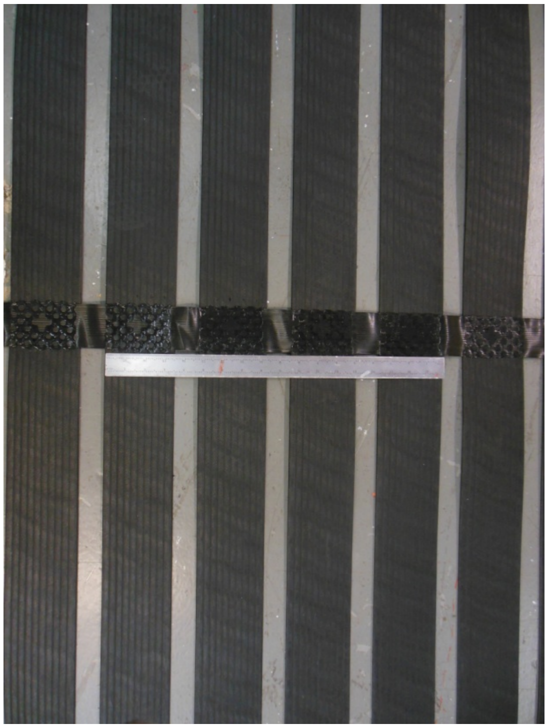

Figure 1-5. Photo of ParaLink 1000 (machine direction is perpendicular to ruler shown).

2.0 Product Polymer, Geometry, and Manufacturing Information

2.1 Product/Polymer Descriptors

Yarn used in the **ParaWeb and ParaLink** products are high molecular weight, low CEG, high tenacity polyester (PET). The source of the yarns is proprietary. Coating used in all **ParaWeb and ParaLink** products is a Linear Low Density Polyethylene (LLDPE)-based coating with no post-consumer recycled materials. The source of coating is confidential.

For the PET yarns, key descriptors include minimum production number average molecular weight (GRI-GG7 and ASTM D 4603) and maximum carboxyl end group content (GRI-GG8 and ASTM D 7409):

- Minimum Molecular Weight > 25,000 (Measured value is 34,456)
- Maximum CEG < 30 (Measured value is 15.9)
- % of regrind used in product: 0%.
- % of post-consumer recycled material by weight: 0%

2.2 Geometric Properties of Straps

Rib width, thickness, and product weight/unit length vary depending on strap style. While such data are generally not used for design, it can be useful for identification purposes, and to be able to detect any changes in the product. Measurements of geogrid rib spacing (ParaLink only) are also used to convert tensile test results (i.e., load at peak strength, T_{ult}), to a load per unit width value (i.e., lbs/ft or kN/m). Detailed measurement results, as well as the typical values supplied by the manufacturer for each product, are provided in Appendix B, Section B.1.

2.3 Product Production Data and Manufacturing Quality Control

Product roll sizes and weights, lot sizes, and a summary of the manufacturer's quality control program are provided in Appendix B, Sections B.2 and B.3. Such information can be useful in working with the manufacturer if product quality issues occur.

3.0 Wide Width Tensile Strength Data

Minimum average roll values supplied by the manufacturer and test results obtained on all the products in the product line for this NTPEP testing program are provided in Tables 3-1 and 3-2. Wide width tensile tests were conducted in accordance with ASTM D6637. The measured strap dimensions discussed in Section 2 and provided in Appendix B, Section B.1, were used to convert test loads to load per unit width values. Note that the independently measured T_{ult} values only indicate that the sampled products have a tensile strength that exceeds the Manufacturer's minimum average roll values (MARV's). As such, these independently measured T_{ult} values should not be used directly for design purposes. However, these independently measured T_{ult} test results have been used as roll specific tensile strengths used for developing installation damage and creep reduction factors. Detailed test results are provided in Appendix C.

Table 3-1. Wide width tensile strength, T_{ult}, for the Linear Composites ParaWeb products.

Product Style/Type	**Test Method**	**MARV for T_{ult}, in MD (lbs)**	**T_{ult}, Independently Measured in MD (lbs)***
ParaWeb 2D/2E 30	ASTM D 6637	6,744	7,029
ParaWeb 2S 30	ASTM D 6637	7,550	
ParaWeb 2D/2E 40	ASTM D 6637	8,992	
ParaWeb 2S 40	ASTM D 6637	10,067	
ParaWeb MS/MD/ME 45	ASTM D 6637	10,116	
ParaWeb 2D/2E 50	ASTM D 6637	11,240	11,807
ParaWeb 2S 50	ASTM D 6637	12,584	
ParaWeb MS/MD/ME 54	ASTM D 6637	12,140	
ParaWeb MS/MD/ME 63	ASTM D 6637	14,163	
ParaWeb 2D/2E 75	ASTM D 6637	16,861	
ParaWeb 2S 75	ASTM D 6637	18,876	
ParaWeb 2D/2E 100	ASTM D 6637	22,481	
ParaWeb 2S 100	ASTM D 6637	25,168	
ParaWeb 2D/2E 135	ASTM D 6637	30,349	35,130
ParaWeb 2S 135	ASTM D 6637	NP	

(Conversion: 1 lbs = 0.00445 kN)

MD = machine direction, NP = Not Provided.

*Average of 5 readings obtained during NTPEP testing.

Note: The reported strengths are per strap.

Table 3-2. Wide width tensile strength, T_{ult}, for the Linear Composites ParaLink products.

Product Style/Type	**Test Method**	**MARV for T_{ult}, in MD (lb/ft)**	**T_{ult}, Independently Measured in MD (lb/ft)***
ParaLink 300	ASTM D 6637	20,548	21,166
ParaLink 400	ASTM D 6637	27,397	
ParaLink 500	ASTM D 6637	34,247	
ParaLink 600	ASTM D 6637	41,096	
ParaLink 700	ASTM D 6637	47,945	
ParaLink 800	ASTM D 6637	54,795	
ParaLink 1000	ASTM D 6637	68,493	73,224
ParaLink 1200	ASTM D 6637	82,192	
ParaLink 1500	ASTM D 6637	102,780	

(Conversion: 1 lb/ft = 0.0146 kN/m)

MD = machine direction

*Average of 5 readings obtained during NTPEP testing.

4.0 Installation Damage Data (RF_{ID})

4.1 Installation Damage Test Program

Installation damage testing and interpretation was conducted in accordance with AASHTO R69-15, except as noted herein. Samples were exposed to three "standard" soils: a coarse gravel, a sandy gravel, and a sand. Additional laboratory installation damage testing in accordance with ISO/EN 10722 was also conducted. The specific installation damage test program is summarized in Table 4-1.

Table 4-1. Independent installation damage testing required for NTPEP qualification.

Manufacturer: Linear Composites Limited **PRODUCT Line:** ParaWeb 30 to ParaWeb 135 ParaLink 300 to ParaLink 1500			
Tests Conducted	**Qualification (every 6 yrs) / Verification (every 3 yrs)**		
	Products Tested		**# of Tests (see Note 1)**
	Qualification	**Verification**	
Index tensile tests on undamaged material (ASTM D 6637)	ParaWeb 30, ParaWeb 50, ParaWeb 135, ParaLink 300 and ParaLink 1000	NA	5
Three field exposures, including soil characterization and compaction measurements (ASTM D5818)	ParaWeb 30, ParaWeb 50, ParaWeb 135, ParaLink 300 and ParaLink 1000 in Types 1, 2 and 3 soils	NA	15
Tensile tests on damaged specimens (ASTM D 6637)	ParaWeb 30, ParaWeb 50, ParaWeb 135, ParaLink 300 and ParaLink 1000 in Types 1, 2 and 3 soils	NA	15
Laboratory installation damage testing –as basis for future verification and to help interpolate test results to products not tested (ISO/EN 10722)	ParaWeb 30, 40, 45, 50, 54, 63, 75, 100 & 135 and ParaLink 300, 400, 500, 600, 700, 800, 1000, 1200 & 1500	NA	18
Note 1 Each test is performed using the number of specimens required by the test standard. For example, for index tensile testing, a test is defined 5 to 6 specimens. See the specific test procedures for details on this.			

4.2 Installation Damage Full Scale Field Exposure Procedures and Materials Used

Three "standard" soils were used for the field exposure of the strap samples to installation damage. Soil gradation curves for each soil are provided in Figure 4-1. Photographs of each soil illustrating particle angularity are provided in Figures 4-2 through 4-4. LA Abrasion tests conducted to characterize the backfill materials indicted a maximum loss of 20%, which is well within the requirements stated in R69-15.

The approach specifically used for applying installation damage to the geosynthetic samples that allows for exhumation of the test samples while avoiding unintended damage was initially developed by Watts and Brady[1] of the Transport Research Laboratory (TRL) in the United Kingdom. The procedure generally conforms to R69-15 and ASTM D 5818 requirements.

Since compaction typically occurs parallel to the face of retaining walls and the contour lines of slopes, the machine direction was placed perpendicular to the running direction of the compaction equipment. To initiate the exposure procedure, four steel plates each measuring 42-inches x 52-inches (1.07 m x 1.32 m), equipped with lifting chains, were placed on a flat clean surface of hardened limestone rock. The longer side of the plates is parallel to the running direction of the compaction equipment. A layer of soil/aggregate was then placed over the adjacent plates to an approximate compacted thickness of 6 inches (0.15 m). Next, each of four coupons of the tested geosynthetic sample was placed on the compacted soil over an area corresponding to an underlying steel plate. To complete the installation, the second layer of soil was placed over the coupons using spreading equipment and compacted to a thickness of 6 inches (0.15 m) using a vibratory compactor. The spreading equipment used included a wheeled front end loader and a 23,000 -26,000 lb single drum vibratory roller with pneumatic rear wheels. The front end loader was allowed to spread the aggregate by driving over the geosynthetic with a 6 inch aggregate lift between the wheels and the geosynthetic.

The following construction quality control measures were followed during exposure:

- Proctor and sieve analyses were performed on each soil/aggregate, when possible. (Proctors could not be performed on Gradations 1 and 2.)
- Lift thickness measurements were made after soil/aggregate compaction.
- When possible, moisture and density measurements were made on each lift using a nuclear density gage to confirm that densities >90% of modified Proctor (per ASTM D 1557) were being achieved.

To exhume the geosynthetic, railroad ties were removed and one end of each plate was raised with lifting chains. After raising the plate to about 45°, soil located near the bottom of the leaning plate was removed and, if necessary, the plate was struck with a sledgehammer to loosen the fill. The covering soil/aggregate was then carefully removed from the surface while "rolling" the geosynthetic away from the underlying soil/aggregate. This procedure assured a minimum of exhumation stress. Photographs of the installation damage field exposures are provided in Appendix D. A detailed tabulation of each soil gradation is provided in Appendix D, Table D-10.

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[1] G.R.A. Watts and K.C. Brady (1990), *Site Damage trials on geogrids*, Geogrids, Geomembranes and Related Produts, Balkema Rotterdam.

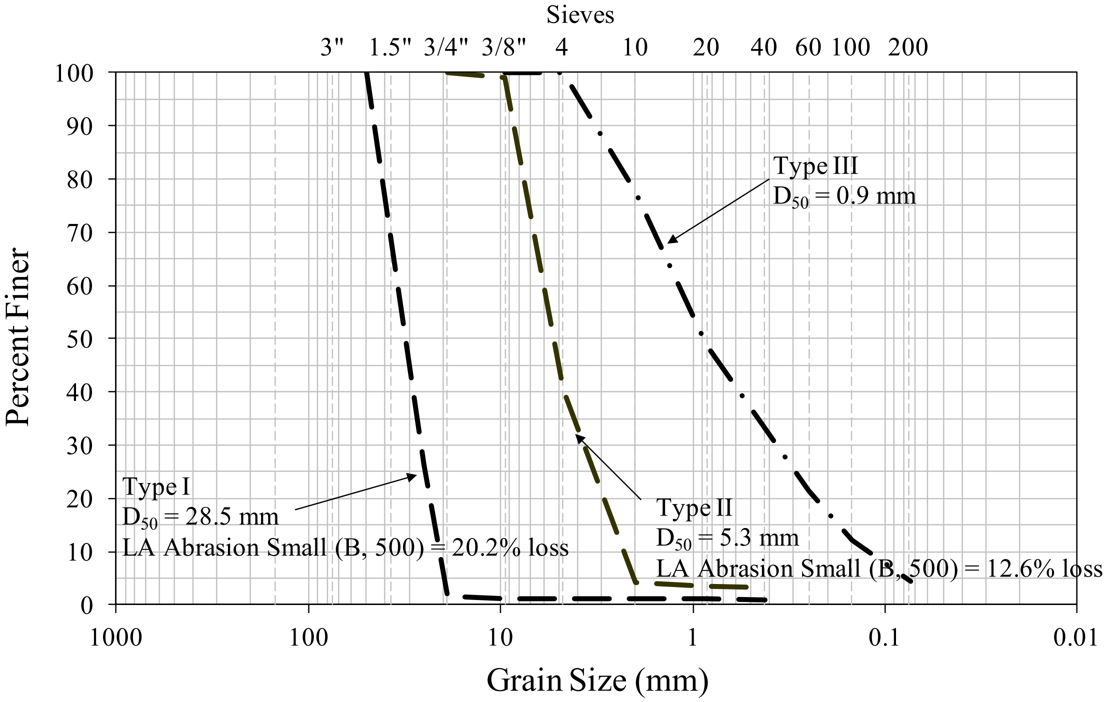


Figure 4-1. Test soil grain size distribution.

Figure 4-2. Installation damage Type 1 test aggregate.

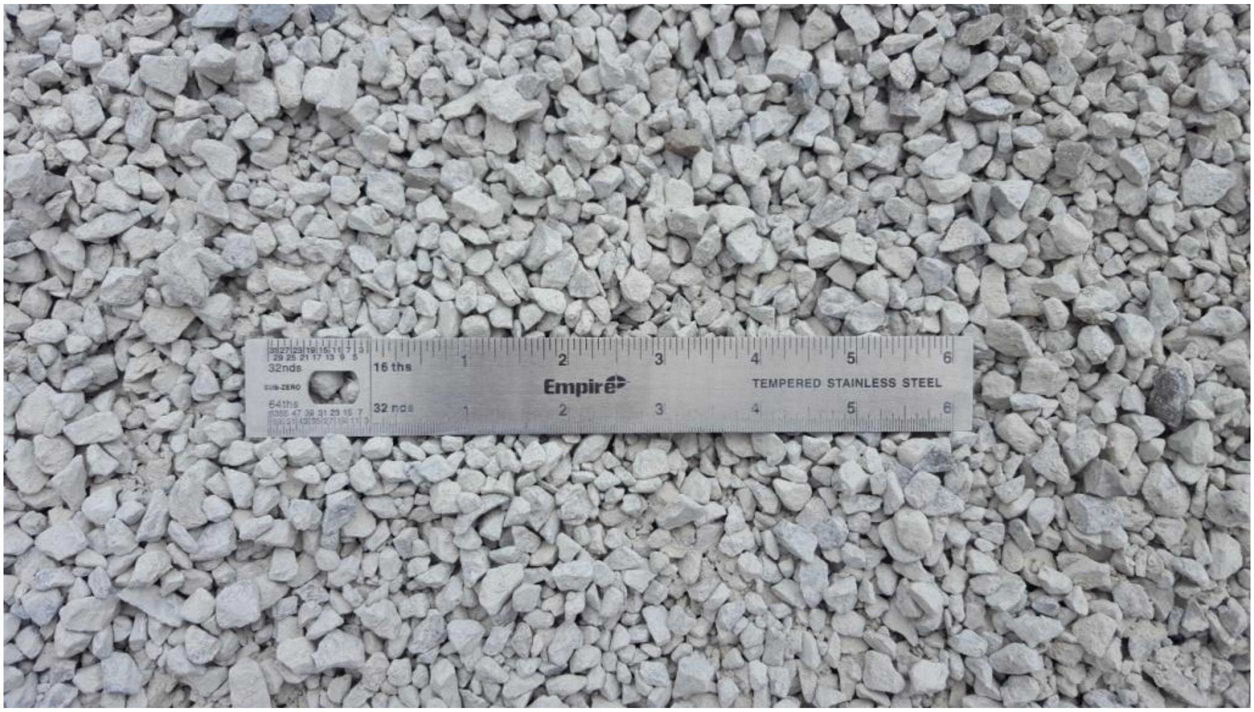


Figure 4-3. Installation damage Type 2 test aggregate.

Figure 4-4. Installation damage Type 3 test aggregate.

4.3 Summary of Installation Damage Full Scale Field Exposure Test Results

The roll specific ultimate tensile strength (ASTM D6637) test results for the baseline, T_{lot} (i.e., undamaged tensile strength tested prior to sample installation in the ground) and the ultimate tensile strength of the installation damaged strap samples, T_{dam}, are provided in Table 4-2. RF_{ID}, calculated using the results shown in Table 4-2, are summarized in Table 4-3. Strength retained is calculated as the ratio of the average exhumed strength T_{dam} divided by the average baseline strength T_{lot} for the product sample. RF_{ID} is the inverse of the retained strength (i.e. 1 / 0.779 = 1.28). Detailed test results for each specimen tested are provided in Appendix D, Tables D-1 through D-15.

Table 4-2. Summary of installation damage tensile test results.

Backfill Type	Product Style	Baseline		Exhumed	
		[1]T_{lot} (lb/rib)	COV (%)	[2]T_{dam} (lb/rib)	COV (%)
Type 1 Coarse Gravel (GP)	ParaWeb 30	7,029	0.3	4,825	12.0
	ParaWeb 50	11,807	0.5	9,848	6.2
	ParaWeb 135	35,130	0.1	34,979	0.4
	ParaLink 300	12,316	1.3	11,662	5.7
	ParaLink 1000	29,168	0.5	29,178	0.8
Type 2 Sandy Gravel (GP)	ParaWeb 30	7,029	0.3	6,902	2.3
	ParaWeb 50	11,807	0.5	11,644	0.6
	ParaWeb 135	35,130	0.1	35,031	0.5
	ParaLink 300	12,316	1.3	12,432	0.8
	ParaLink 1000	29,168	0.5	29,168	0.6
Type 3 Silty Sand (SM)	ParaWeb 30	7,029	0.3	7,015	0.4
	ParaWeb 50	11,807	0.5	11,831	0.5
	ParaWeb 135	35,130	0.1	34,987	0.4
	ParaLink 300	12,316	1.3	12,398	1.4
	ParaLink 1000	29,168	0.5	29,043	0.6

[1] Average of 5 specimens.
[2] Average of 10 specimens.
(Conversion: 1 lbs = 0.00445 kN)

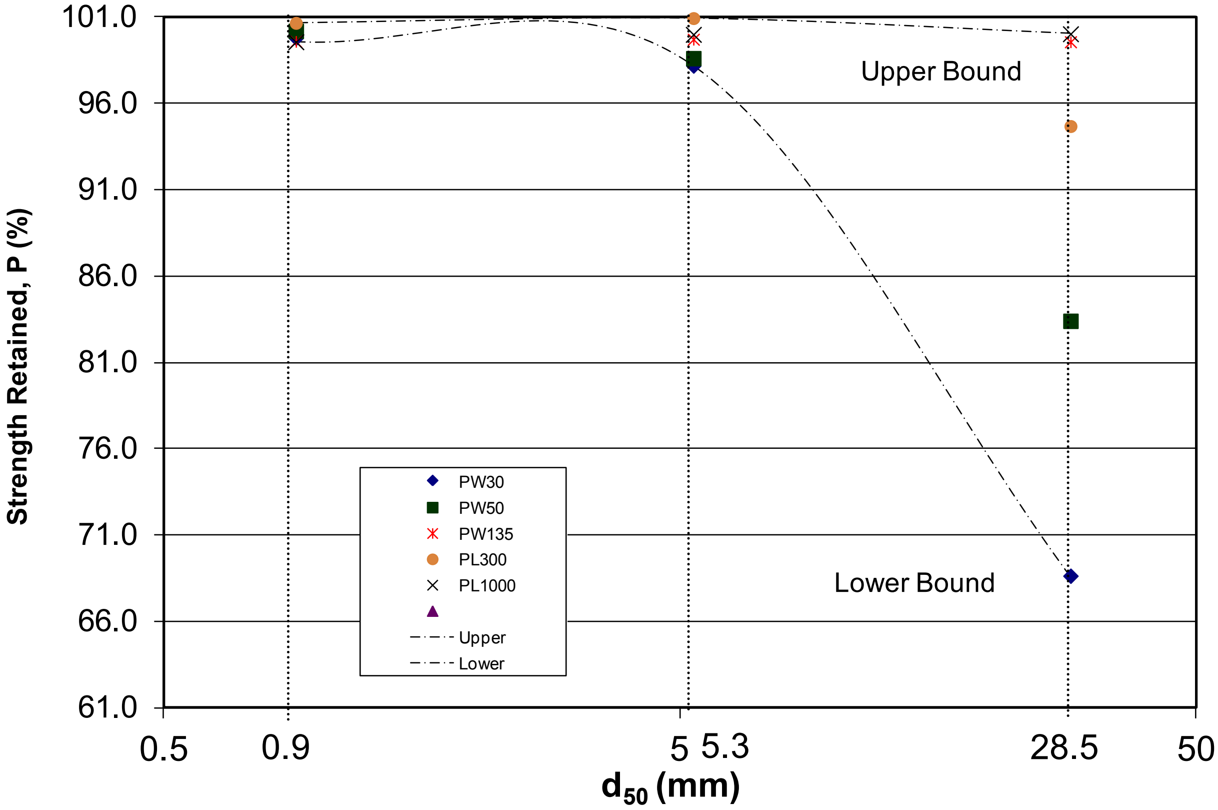
Table 4-3. Measured RF_{ID}.

Product Style	Type 1 Coarse Gravel		Type 2 Sandy Gravel		Type 3 Silty Sand	
	% Retained	RF_{ID}	% Retained	RF_{ID}	% Retained	RF_{ID}
ParaWeb 30	68.6	1.46	98.2	1.02	99.8	1.00
ParaWeb 50	83.4	1.20	98.6	1.01	100.2	1.00
ParaWeb 135	99.6	1.00	99.7	1.00	99.6	1.00
ParaLink 300	94.7	1.06	100.9	1.00	100.7	1.00
ParaLink 1000	100.0	1.00	100.0	1.00	99.6	1.00

4.4 Estimating RF_{ID} for Specific Soils or Products

In general, as the test material gradation becomes more coarse, the value of strength retained decreased (i.e., RF_{ID} increased). Trend lines plotted in Figure 4-5 for the upper bound and lower bound for all the installation damage data obtained for the product line illustrate the general trend of the installation damage data with regard to soil d_{50} size. Interpolation of this data to intermediate gradations appears to be feasible based on these test results, especially between the larger gradations since the finer gradations resulted in minimal damage, though the scatter in that trend should be recognized when estimating values of RF_{ID} for specific soils. All products in the product line were installation damage tested for the full range of soil gradations (Gradations 1 through 3).

Only representative products in the product line were installation damage tested for the full range of soil gradations (Gradations 1 through 3). However, bench scale installation damage tests (ISO/EN 10722) were conducted for the remaining products in the line to verify whether or not interpolation of the installation damage test results was feasible for the remaining products in the line not fully evaluated for installation damage resistance. The ParaWeb/ParaLink product line generally exhibited moderately strong relationships between the weight or the tensile strength of the product and the strength retained after installation damage for gradation 1 but showed no consistent relationship with product weight or tensile strength for gradations 2 and 3. See figures 4-6 through 4-8 for illustrations of those relationships. Therefore, interpolation of these test results to products in the line not tested based on product weight or strength may be only feasible for gradation 1, though caution should be exercised and appropriate judgment applied to insure a safe estimate of RF_{ID} each product. For products in the product line not tested in the full scale installation damage tests, for gradations 2 and 3, use of a lower bound value of strength retained for the products not tested in the full scale installation damage tests (i.e., (P_{dmin} in figure 4-7) appears to be appropriate for design.



Note: $RF_{ID} = 1/P$; d_{50} = sieve size at which 50% of soil passes by weight

Figure 4-5. ParaWeb/ParaLink product line installation damage as a function of soil d_{50} size.

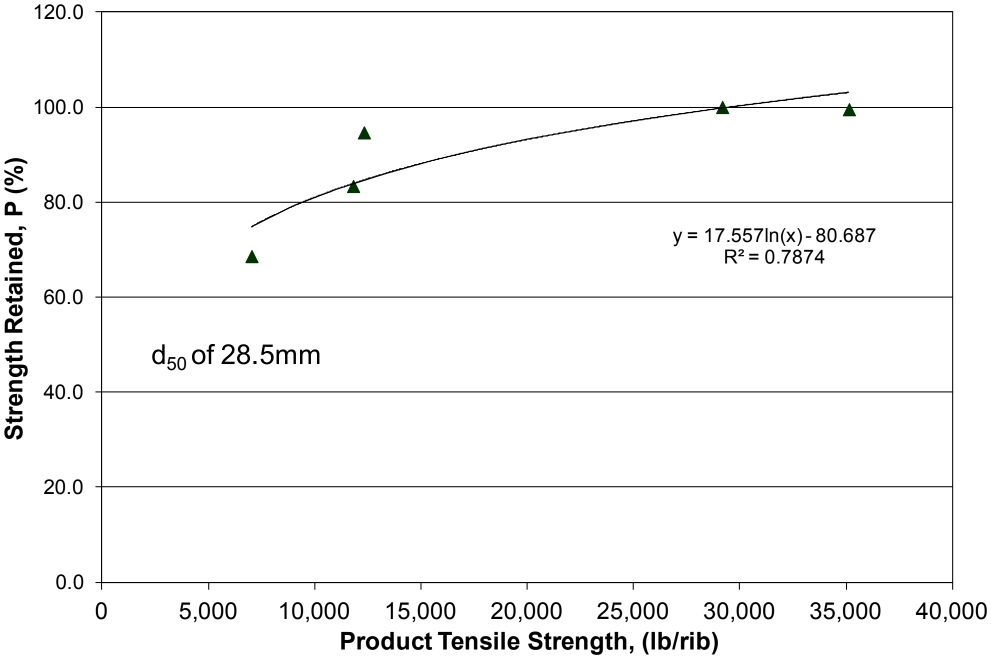


Figure 4-6. ParaWeb/ParaLink product line installation damage as a function of product unit weight for type 1 soil (coarse gravel - GP).

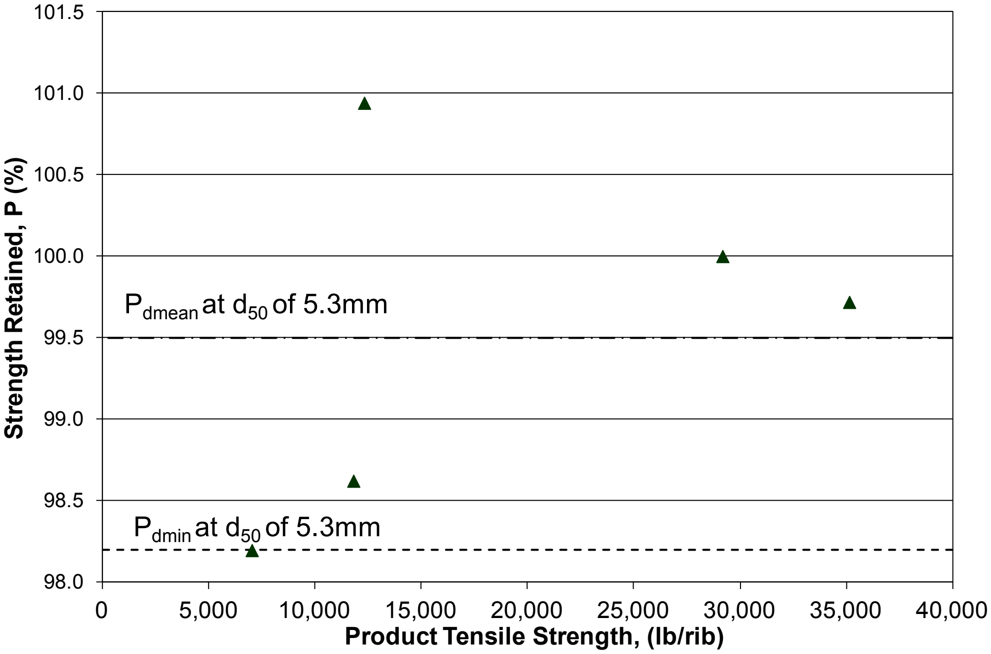


Figure 4-7. ParaWeb/ParaLink product line installation damage as a function of product unit weight for type 2 soil (sandy gravel - GP).

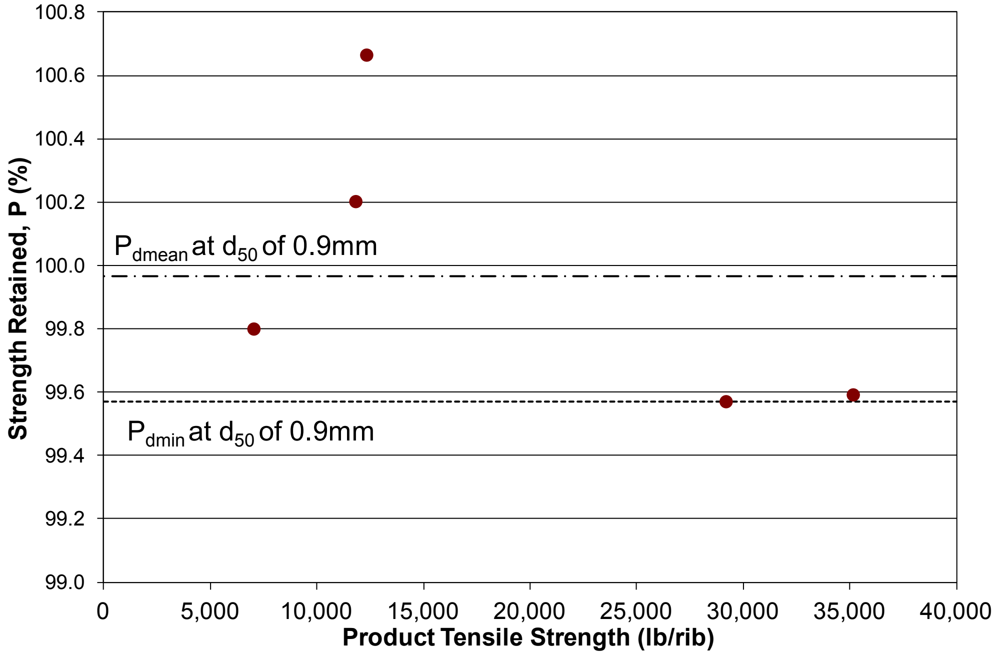


Figure 4-8. ParaWeb/ParaLink product line installation damage as a function of product unit weight for type 3 soil (silty sand – SM).

It should be noted that the installation damage testing conducted represents an increase in compaction and spreading equipment size (i.e., a 15,000 lb wheeled front end loader – Caterpillar 416F, and a 23,000-26,000 lb single drum vibratory roller – a 10,000 lb roller was used in past testing) and a reduced aggregate lift thickness over the geosynthetic of 6 inches (an 8 inch lift thickness was used in past testing) relative to the installation damage testing reported in some previous NTPEP test reports. Actual RF_{ID} values could be lower if installation conditions are less severe (e.g., greater initial lift thickness over the geosynthetic, use of lighter weight equipment, etc.). Actual RF_{ID} values could be higher if the spreading or compacting equipment tires or tracks are allowed to be in direct contact with the geosynthetic before or during fill placement and compaction, if the thickness of the fill material between the equipment tires or tracks is inadequate (especially for high tire pressure equipment such as dump trucks), or if excessive rutting of the first lift of soil over the geosynthetic (e.g., due to soft subgrade soil) is allowed to occur.

4.5 Laboratory Installation Damage Test Results per ISO/EN 10722

Laboratory installation damage testing and interpretation was conducted in accordance with ISO/EN 10722. In this procedure, geosynthetic specimens are exposed to simulated installation stresses and abrasion using a standard "backfill" material in a bench scale device. Once exposed, they are tested for tensile strength to determine the retained strength after damage. Five baseline and five exposed specimens from each product were tested. The test results are summarized in Table 4-4. Detailed test results are provided in Appendix E, as well as a photograph of the test set-up and a close up of the standard backfill material used.

This procedure is intended to be a reproducible index test to assess relative susceptibility of the geosynthetic to damage. In this NTPEP testing program, the results from this test are primarily intended to be used for future quality assurance to assess the consistency in the product's susceptibility to installation damage. It is not intended to be used directly in the determination of RF_{ID} for a given soil backfill gradation.

Table 4-4. Summary of laboratory (ISO procedure) installation damage test results.

Product Style	Mean Baseline Tensile Strength (lb/rib)	Coefficient of Variation (%)	Mean Exposed Tensile Strength (lb/rib)	Coefficient of Variation (%)	Strength Retained (%)
ParaWeb 30	7,121	1	5,802	3	81
ParaWeb 40	10,129	1	9,380	2	93
ParaWeb 45	10,130	0.2	9,855	2	97
ParaWeb 50	11,895	1	10,971	2	92
ParaWeb 54	12,599	0.3	12,458	1	99
ParaWeb 63	14,529	0.5	14,407	1	99
ParaWeb 75	19,377	0.2	19,008	1	98
ParaWeb 100	24,647	1	24,653	0.4	100
ParaWeb 135	35,334	0.5	35,325	0.3	100
ParaLink 300	12,601	1	12,239	2	97
ParaLink 400	17,031	0.3	16,387	1	96
ParaLink 500	22,020	1	21,919	0.4	100
ParaLink 600	26,180	1	26,258	1	100
ParaLink 700	31,577	1	31,552	1	100
ParaLink 800	29,768	0.2	29,781	0.4	100
ParaLink 1000	29,044	1	28,374	2	98
ParaLink 1200	29,729	0.2	29,749	0.3	100
ParaLink 1500	35,762	1	35,674	0.4	100

(Conversion: 1 lbs = 0.00445 kN)

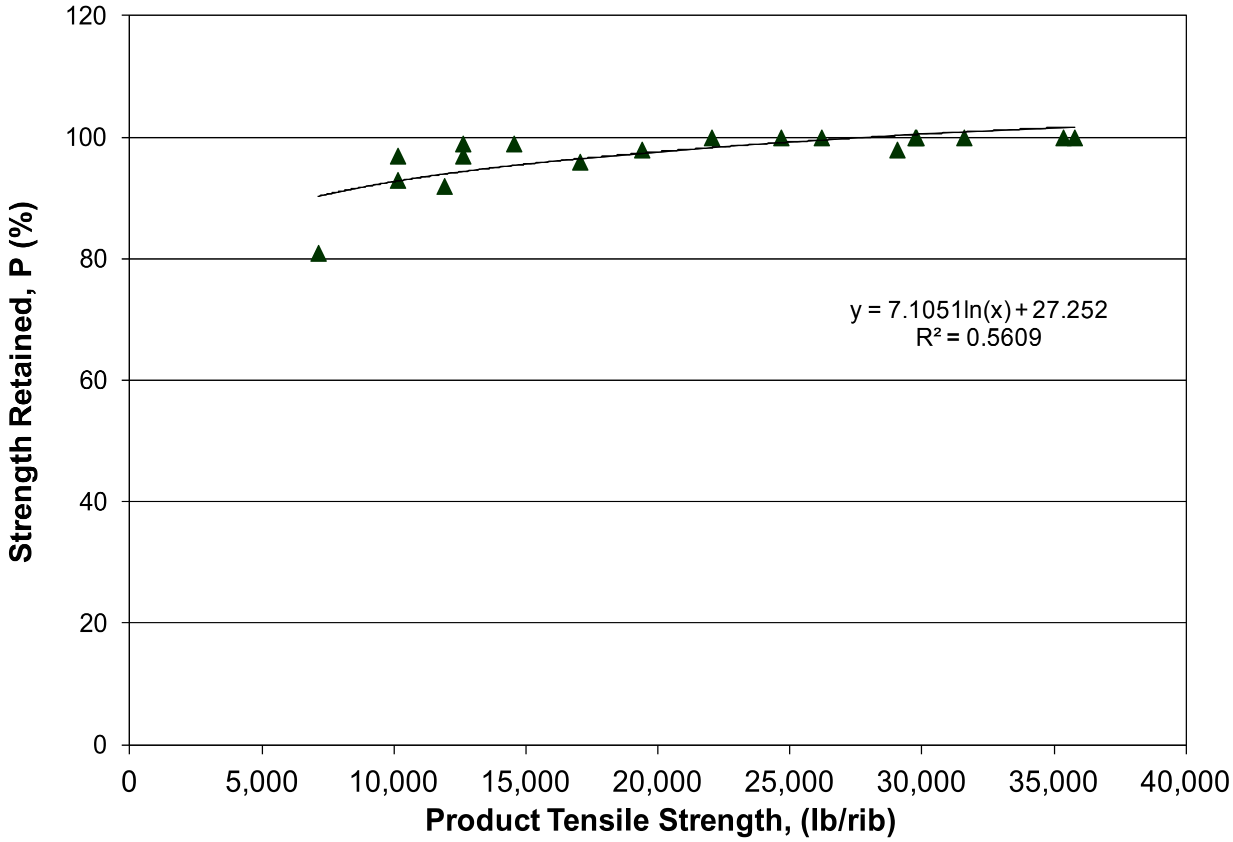


Figure 4-9. ParaWeb/ParaLink product line installation damage as a function of product unit weight for ISO/EN 10722.

5.0 Creep Rupture Data (RF_{CR})

5.1 Creep Rupture Test Program

Creep testing and interpretation has been conducted in accordance with AASHTO R69-15. A baseline (i.e., reference) temperature of 68° F (20° C) was used. ParaWeb 50 was used as the primary product to establish the creep rupture envelope, with limited creep testing of ParaWeb 30, ParaWeb 135, ParaLink 300 and ParaLink 1000 to verify the ability to interpolate creep rupture behavior to the products not specifically tested (i.e., to treat all the products submitted for evaluation as a product line per R69-15 and the NTPEP work plan).

The creep rupture testing program is summarized in Figure 5-1. Since validation of the use of SIM to extend the creep rupture data was conducted previously as reported in the 2010 NTPEP report for this product line (NTPEP Report 8508.1), creep testing was conducted using only ASTM D6992 (i.e., the Stepped Isothermal Method - SIM).

Table 5-1. Independent creep rupture testing required for NTPEP qualification.

<table>
<tr><td colspan="4">Manufacturer: Linear Composites Limited PRODUCT Line: ParaWeb 30 to ParaWeb 135
ParaLink 300 to ParaLink 1500</td></tr>
<tr><th rowspan="3">Tests Conducted</th><th colspan="3">Qualification (every 6 yrs) / Verification (every 3 yrs)</th></tr>
<tr><th colspan="2">Products Tested</th><th rowspan="2"># of Tests (see Note 1)</th></tr>
<tr><th>Qualification</th><th>Verification</th></tr>
<tr><td>Index single rib tensile tests on lot specific material (ASTM D 6637)</td><td>None</td><td>NA</td><td>0</td></tr>
<tr><td>Index wide width tensile tests on lot specific material (ASTM D 6637)</td><td>ParaWeb 30, ParaWeb 50, ParaWeb 135, ParaLink 300 and ParaLink 1000</td><td>NA</td><td>5</td></tr>
<tr><td>PRIMARY PRODUCT 6 Rupture Points – Conventional Creep testing up to 1000 hrs (ASTM D5262)</td><td>NA</td><td>NA</td><td>0</td></tr>
<tr><td>PRIMARY PRODUCT 6 Rupture Points – Accelerated Creep rupture testing (SIM). (ASTM D6992)</td><td>ParaWeb 50 @ 12 load levels</td><td>NA</td><td>12</td></tr>
<tr><td>SECONDARY PRODUCT(S) Conventional Creep Testing (ASTM D5262)</td><td>None</td><td>NA</td><td>0</td></tr>
<tr><td>SECONDARY PRODUCT(S) Accelerated Creep rupture testing (SIM). (ASTM D6992)</td><td>ParaWeb 30, ParaWeb 135, ParaLink 300 and ParaLink 1000@ 4 load levels</td><td>NA</td><td>16</td></tr>
<tr><td colspan="4">Note 1: Each test is performed using the number of specimens required by the test standard. For example, for index tensile testing, a test is defined 5 to 6 specimens. See the specific test procedures for details on this.</td></tr>
</table>

5.2 Baseline Tensile Strength Test Results

The width, spacing and strength of the individual sample ribs prohibited creep rupture testing from being performed on multi-rib specimens. Therefore, all accelerated creep testing via SIM (ASTM D6992) were performed on single rib specimens. Sample specific geogrid dimensions were used to convert tensile test loads to load per unit width values for ParaLink products only. The tensile test specimens tested were taken from the same rolls of material that were used for the creep testing. The measured geogrid dimensions discussed in Section 2 and provided in Appendix B, Section B.1, were used to convert tensile test loads to load per unit width values.

Table 5-2. Ultimate tensile strength (UTS) and associated strain.

Product	**Single Rib UTS per ASTM D6637, T_{lot} (lb/rib @ % Strain)**	**Single Rib UTS per ASTM D6637, T_{lot} (lb/ft @ % Strain)**
ParaWeb 30	7,029 @ 11.6%	NA
ParaWeb 50	11,807 @ 10.7%	NA
ParaWeb 135	35,130 @ 11.8%	NA
ParaLink 300	12,316 @ 10.8%	21,166 @ 10.8%
ParaLink 1000	29,168 @ 12.4%	73,224 @ 12.4%

(Conversion: 1 lbs = 0.00445 kN, 1 lb/ft = 0.0146 kN/m)

5.3 Creep Rupture Test Results

A total of 28 Stepped Isothermal Method (SIM) tests were run to fulfill the qualification requirements. Table 5-3 summarize the tests performed and their outcomes. Detailed test results, including creep curves for each specimen tested, are provided in Appendix F, Figures F-1 through F-28.

Table 5-3. Creep rupture test results for all tests conducted.

Style & Test Type	Creep Load (% of T_{lot})	Time to Rupture (log hrs)
ParaWeb 30 - SIM	70.00	6.9671
ParaWeb 30 - SIM	75.00	5.7666
ParaWeb 30 - SIM	80.00	3.6362
ParaWeb 30 - SIM	85.00	2.1750
ParaWeb 50 - SIM	70.00	7.0453
ParaWeb 50 – SIM	70.00	6.3200
ParaWeb 50 – SIM	73.00	6.4199
ParaWeb 50 – SIM	73.00	6.1543
ParaWeb 50 – SIM	76.00	5.2937
ParaWeb 50 – SIM	76.00	4.8878
ParaWeb 50 – SIM	79.00	4.0613
ParaWeb 50 – SIM	79.00	4.4808
ParaWeb 50 – SIM	82.00	3.1278
ParaWeb 50 – SIM	82.00	3.3442
ParaWeb 50 – SIM	85.00	2.3120
ParaWeb 50 – SIM	85.00	1.6706
ParaWeb 135 – SIM	71.00	6.7252
ParaWeb 135 – SIM	75.00	5.5371
ParaWeb 135 – SIM	79.00	4.0846
ParaWeb 135 – SIM	83.00	2.6451
ParaLink 300 – SIM	72.00	6.6291
ParaLink 300 – SIM	76.00	5.2294
ParaLink 300 – SIM	80.00	3.7831
ParaLink 300 – SIM	84.00	2.3855
ParaLink 1000 – SIM	70.00	6.8905
ParaLink 1000 – SIM	74.00	5.7714
ParaLink 1000 – SIM	78.00	4.4481
ParaLink 1000 – SIM	82.00	3.0249

*finished without rupture

5.3.1 Statistical Validation to Allow the Use of SIM Data to Establish Rupture Envelope

Validation of the use of SIM to extend the creep rupture data was conducted previously as reported in the 2010 NTPEP report for this product line (NTPEP Report 8508.1). For convenience, the results of that validation from this previous testing are summarized in Figure F-29 in Appendix F. Revalidation of the use of SIM for this product line was considered unnecessary in accordance with the NTPEP work plan and R69-15, since it was determined that the product line has not significantly changed in its formulation and processing relative to the product line as previously tested and reported in the 2010 NTPEP report..

5.3.2 Statistical Validation to Allow the Use of Composite Rupture Envelope for Product Line

Details of the confidence limits evaluation for the product line conducted in accordance with R69-15 are contained in Appendix F. Figures F-30-33 provides plots of the creep rupture envelope with the confidence limits and the rupture envelopes for the primary product and the other tested products (i.e., ParaWeb 30, ParaWeb 135, ParaLink 300 and ParaLink 1000), illustrating this statistical test. Detailed calculation results for this statistical analysis are provided in Tables F-3 through F-5, and summarized in Table F-8. The results indicate that the rupture envelopes for the ParaWeb 30, ParaWeb 135, ParaLink 300 and ParaLink 1000 products are within the specified 90% confidence limits of the primary product (i.e., ParaWeb 50) creep rupture data, meeting R69-15 requirements. Thus, all the ParaWeb and ParaLink products tested can be used to construct a composite creep rupture envelope representing the entire product line. The calculation results for the statistical analysis and regression to create the full composite creep curve are provided in Table F-6.

5.4 Creep Rupture Envelope Development and Determination of RF_{CR}

In consideration of the statistical validation described in Section 5.3 of this report, a composite creep rupture envelope, using log-linear regression, was constructed as shown in Figure 5-1. The mix of conventional and accelerated (SIM) creep rupture test data points meets R69-15 requirements. Based on this plot of all data, the regression of the data shows that the r^2 value is 0.98 (see Table F-6 in Appendix F for details). Per R69-15, this degree of scatter in the data is acceptable for a composite rupture envelope.

The creep rupture envelope in Figure 5-1 should be considered valid for the entire The Linear Composites ParaWeb/ParaLink product line evaluated in this report. Since the temperature accelerated creep results produced through the SIM testing allowed time shifting of the creep rupture data points to over 1,000,000 hours (i.e., 114 years), no extrapolation uncertainty factor in accordance with R69-15 need be applied. Table 5-4 provides the estimated value of RF_{CR} for The Linear Composites ParaWeb/ParaLink product line based on the reported testing for a period of long-term loading of up to 100 years. This rupture envelope can be used to determine RF_{CR} for times other than 3, 75 and 100 years, if desired.

Table 5-4. RF_{CR} value for ParaWeb/ParaLink series for 3, 75 and 100 yr periods of loading/use.

Period of Use (in years)	RF_{CR} for Rupture – All ParaWeb/ParaLink Styles
3	1.28
75	1.36
100	1.36

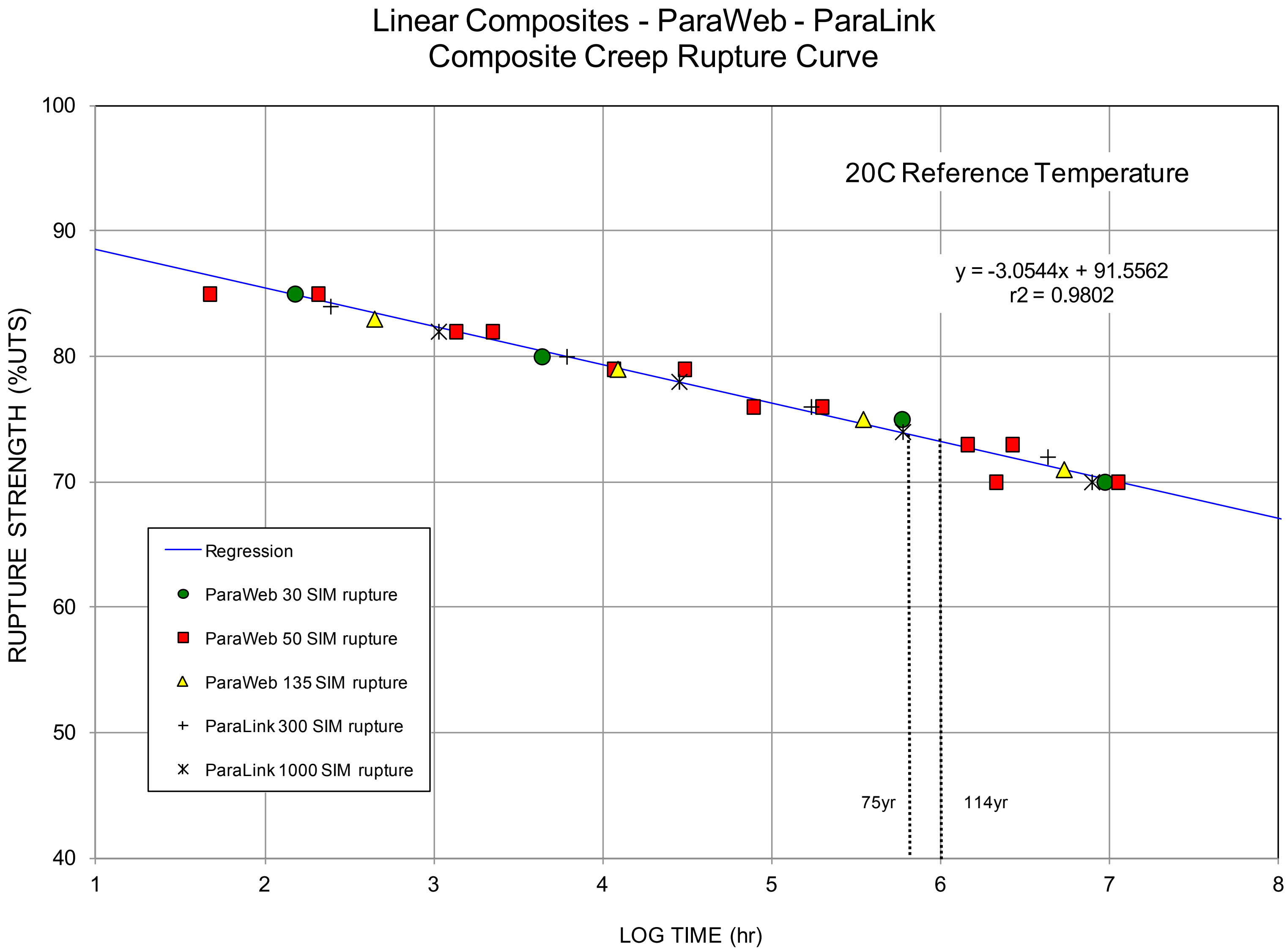


Figure 5-1. Composite creep rupture data/envelope for the ParaWeb/ParaLink product line.

6.0 Long-Term Durability Data (RF_D)

6.1 Durability Test Program

Basic molecular properties relating to durability were evaluated, allowing a "default" RF_D to be used in accordance with AASHTO R69-15, provided that the long-term environment in which the geosynthetic is to be used is considered to be non-aggressive in accordance with the AASHTO LRFD Bridge Design Specifications and R69-15. A non-aggressive long-term environment is described in these documents as follows:

- A soil ph of 4.5 to 9.0,
- A maximum particle size of 0.75 inches or less unless installation damage effects are specifically evaluated using full scale installation damage testing in accordance with ASTM D 5818,
- A soil organic content of 1% or less, and
- An effective design temperature at the site of 86°F (30°C) or less.

It should be noted that installation damage testing was conducted in accordance to ASTM D 5818 on an aggregate with a D50 = 1.12 inches (28.5 mm).

Other specific soil/environmental conditions that could be of concern to consider the site environment to be aggressive are discussed in Elias[2].

The index properties/test results obtained can be related to long-term performance of the polymer through correlation to longer-term laboratory durability performance tests and long-term experience. Note that long-term durability performance testing in accordance with R69-15 and the NTPEP work plan to allow direct calculation of RF_D was not available from the manufacturer, nor evaluated as part of the testing program for this product line.

For polyester (PET) geosynthetics, key durability issues to address include hydrolysis and ultraviolet (UV) oxidative degradation. To assess the potential for these types of degradation, index property tests to assess molecular weight, carboxyl end group content, and ultraviolet (UV) oxidative degradation are conducted. Criteria for test results obtained from each of these tests are provided in R69-15 as well as the AASHTO LRFD Bridge Design Specifications.

The UV degradation tests were conducted on the lightest weight product in the product line (35T) as recommended in R69-15. Since UV degradation attacks from the surface of the geosynthetic, the heavier the product, the more resistant it will be to UV degradation. Therefore, UV testing the lightest weight product should produce the most conservative result.

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[2] Elias, V., 2000, *Corrosion/Degradation of Soil Reinforcements for Mechanically Stabilized Earth Walls and Reinforced Soil Slopes,* FHWA-NHI-00-0044, Federal Highway Administration, Washington, D.C.

The molecular weight and carboxyl end group content tests are conducted on the base yarn for the product series. Since for a product line the base yarn used must be the same for all products in the line, these tests on the base yarn will be applicable to all products in the product line.

Table 6-1. Independent durability testing required for NTPEP qualification.

Manufacturer: Linear Composites Limited **PRODUCT Line:** ParaWeb 30 to ParaWeb 135 ParaLink 300 to ParaLink 1500			
Tests Conducted	**Qualification (every 6 yrs) / Verification (every 3 yrs)**		
	Products Tested		**# of Tests (see Note 1)**
	Qualification	**Verification**	
All polymers, resistance to weathering @ 500 hrs (ASTM D4355), including before/after tensile strength	ParaWeb 30	NA	1
For polyesters, molecular weight determination (ASTM D4603 and GRI-GG8) – **on yarn/strip**	ParaWeb/ParaLink yarns	NA	1
For polyesters, carboxyl end group content determination (ASTM D 7409 and GRI-GG7) – **on yarn/strip**	ParaWeb/ParaLink yarns	NA	1
CEG-MW Testing Coating Removal, if necessary	NA	NA	0
Brittleness (AASHTO R69-15)	NA	NA	0
For polyolefins, long-term evaluation via Oxidative degradation (ISO/EN 13438:1999)	NA	NA	0
For polyesters, long-term evaluation via Hydrolytic degradation (AASHTO R69-15)	None	None	0
For polyolefins, long-term evaluation via Oxidative degradation (AASHTO R69-15)	NA	NA	0
Note 1: Each test is performed using the number of specimens required by the test standard. For example, for index tensile testing, a test is defined by 5 to 6 specimens. See the specific test procedures for details on this.			

6.2 Durability Test Results

A summary of the test results is provided in Table 6-2. This table also includes the criteria to allow the use of a default reduction factor for RF_D provided in R69-15 and the AASHTO LRFD Bridge Design Specifications. Detailed durability test results are provided in Appendix G.

Table 6-2. NTPEP durability test results for the ParaWeb/ParaLink product line and criteria to allow use of a default value for RF_D.

Polymer Type	Property	Test Method	Criteria to Allow Use of Default RF*	Test Result Obtained as Part of NTPEP Program
PP and HDPE	UV Oxidation Resistance	ASTM D4355	Min. 70% strength retained after 500 hrs in weatherometer	NA
PET	UV Oxidation Resistance	ASTM D4355	Min. 50% strength retained after 500 hrs in weatherometer if geosynthetic will be buried within one week, 70% if left exposed for more than one week.	93% strength retained
PP and HDPE	Thermo-Oxidation Resistance	ENV ISO 13438:1999, Method A (PP) or B (HDPE)	Min. 50% strength retained after 28 days (PP) or 56 days (HDPE)	NA
PET	Hydrolysis Resistance	Inherent Viscosity Method (ASTM D4603 and GRI Test Method GG8)	Min. Number Average Molecular Weight of 25,000	34,456
PET	Hydrolysis Resistance	ASTM D 7409 and GRI Test Method GG7	Max. Carboxyl End Group Content of 30	15.9

Note: PP = polypropylene, HDPE = high density polyethylene, PET = polyester

Based on these test results, all products in the product line meet the minimum UV requirement shown in Table 6-2. Regarding hydrolysis resistance, these test results shown in Table 6-2 indicate that this product line has adequate long-term resistance to hydrolysis to justify the use of a default value for RF_D, meeting the requirements in AASHTO R69-15.

Note that while no specific tests, other than installation damage, were conducted to evaluate the durability of the coating, because the hydrolysis resistance characterization was determined based on the base polymer, any potential coating degradation should have very little effect on the long-term durability of the strap product and the default value of RF_D selected. Typically, a default value of 1.3 for RF_D is selected. See AASHTO R69-15, or the document entitled "Use and Application of NTPEP Geosynthetic Reinforcement Test Results" (www.NTPEP.org), for guidance on the selection of a default value for RF_D.

7.0 Low Strain Creep Stiffness Data

7.1 Low Strain Creep Stiffness Test Program

Creep stiffness testing was conducted in accordance with AASHTO R69-15 and the NTPEP work plan. The creep stiffness determination was targeted to 2% strain at 1,000 hours.

Some of the products selected to represent the ParaWeb/ParaLink product line (i.e., ParaWeb 30, ParaWeb 50, ParaWeb 135, ParaLink 300 and ParaLink 1000) were tested for creep stiffness. Roll specific single rib short-term rapid loading tensile strength tests (T_{lot}) were conducted for each product for correlation purposes and to calculate load levels. A total of nine Ramp and Hold (R&H), 1,000 second creep tests, were conducted on each product. Three specimens were R&H tested at each of the following stresses: 5, 10 and 20% of the ultimate tensile strength (UTS). A linear regression based on %UTS and % strain at 0.1 hour was used to normalize strain curves to reduce the variability of the elastic portion of the strain curve. The % UTS required to obtain 2% strain at 1,000 hours was then determined. Three R&H tests and two 1,000 hour conventional creep tests (ASTM D5262, but as modified for low strain in R69-15 and using a single rib specimen) were conducted at this load. All tests were conducted at 68^o F (20^o C).

7.2 Ultimate Tensile Test Results for Creep Stiffness Test Program

The values provided in Table 7-1 represent the baseline, roll specific, ultimate tensile strength used to normalize the load level for the creep stiffness testing.

Table 7-1. Ultimate tensile strength (UTS) & associated strain.

Product	Single Rib UTS per ASTM D6637, T_{lot} (lb/rib @ % Strain)	Single Rib UTS per ASTM D6637, T_{lot} (lb/ft @ % Strain)
ParaWeb 30	7,029 @ 11.6%	NA
ParaWeb 50	11,807 @ 10.7%	NA
ParaWeb 135	35,130 @ 11.8%	NA
ParaLink 300	12,316 @ 10.8%	21,166 @ 10.8%
ParaLink 1000	29,168 @ 12.4%	73,224 @ 12.4%

(Conversion: 1 lbs = 0.00445 kN, 1 lb/ft = 0.0146 kN/m)

7.3 Creep Stiffness Test Results

Detailed test results are provided in Appendix H. Table 7-2 provides a summary of the creep stiffness values obtained. Note that the creep stiffness values at 1,000 hours and 5%UTS, 10%UTS and 20%UTS represent stiffness values at strains other than 2% strain. See Appendix H for details. Figure 7-1 shows the relationship between the measured tensile strength and the creep stiffness. Considering the strong linear relationship between the creep stiffness and the product tensile strength, interpolation to other products in the product line not tested to determine creep stiffness values for those products is acceptable.

Table 7-2. Summary of creep stiffness test results.

Product Style	Average Creep Stiffness @ 1000 hours for 5% UTS Ramp & Hold (lb/rib)	Average Creep Stiffness @ 1000 hours for 10% UTS Ramp & Hold (lb/rib)	Average Creep Stiffness @ 1000 hours for 20% UTS Ramp & Hold (lb/rib)	Average Creep Stiffness for 2% strain @ 1000 hrs (lb/rib)
ParaWeb 30	50,615	37,857	36,686	**39,993**
ParaWeb 50	85,148	60,899	63,111	**66,896**
ParaWeb 135	162,859	141,312	147,200	**151,878**
ParaLink 300	65,247	54,065	69,419	**62,561**
ParaLink 1000	128,818	117,909	124,201	**124,185**

(Conversion: 1 lbs = 0.00445 kN)

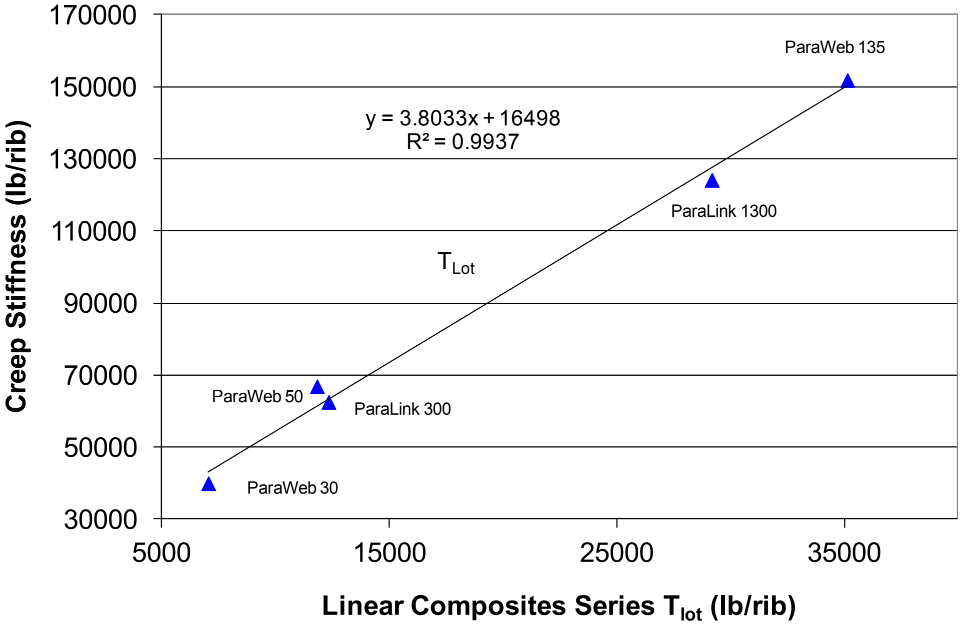

Figure 7-1. ParaWeb/ParaLink creep stiffness for 2 % strain @ 1000 hours.

To obtain the minimum likely stiffness value for each product in consideration of the MARV tensile strength, multiply the stiffness value from the plot by the ratio of T_{MARV}/T_{lot}. T_{MARV} is the minimum tensile strength, as provided by the manufacturer, for each product in the product line. T_{lot} is the actual roll specific tensile strength for the sample used in the creep stiffness testing.

APPENDICES

Appendix A: NTPEP Oversight Committee

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Appendix B: Product Geometric and Production Details

B.1 Product Geometric Information

Table B-1 (Part 1). Typical and measured MD geogrid geometry for the ParaWeb product line.

Machine Direction (MD) Ribs								
Style	Width (in)		Spacing (in)		Aperture Size (in)		Rib Thickness (in)	
	Typical Values	As Measured *	Typical Values	As Measured *	Typical Values	As Measured *	Typical Values	As Measured *
ParaWeb 2S 30	3.19 - 3.35		NA		NA		0.09	
ParaWeb 2D 30	3.19 - 3.35		NA		NA		0.07	
ParaWeb 2E 30	3.19 - 3.35	3.31	NA		NA		0.06	0.061
ParaWeb 2S 40	3.23 - 3.39		NA		NA		0.10	
ParaWeb 2D 40	3.23 - 3.39		NA		NA		0.09	
ParaWeb 2E 40	3.19 - 3.35	3.33	NA		NA		0.07	0.074
ParaWeb 2S 50	3.47 - 3.63		NA		NA		0.14	
ParaWeb 2D 50	3.47 - 3.63		NA		NA		0.10	
ParaWeb 2E 50	3.35 - 3.51	3.41	NA		NA		0.08	0.072
ParaWeb 2S 75	3.47 - 3.63		NA		NA		0.16	
ParaWeb 2D 75	3.47 - 3.63		NA		NA		0.12	
ParaWeb 2E 75	3.47 - 3.63	3.52	NA		NA		0.10	0.103
ParaWeb 2S 100	3.47 - 3.63		NA		NA		0.24	
ParaWeb 2D 100	3.47 - 3.63		NA		NA		0.15	
ParaWeb 2E 100	3.47 - 3.63	3.60	NA		NA		0.12	0.124
ParaWeb 2S 135			NA		NA			
ParaWeb 2D 135			NA		NA			
ParaWeb 2E 135		3.56	NA		NA			0.174

Table B-1 (Part 2). Typical and measured MD geogrid geometry for the ParaWeb product line.

Machine Direction (MD) Ribs								
Style	**Width (in)**		**Spacing (in)**		**Aperture Size (in)**		**Rib Thickness (in)**	
	Typical Values	**As Measured ***	**Typical Values**	**As Measured ***	**Typical Values**	**As Measured ***	**Typical Values**	**As Measured ***
ParaWeb MS 45	1.89 - 2.05		NA		NA		0.14	
ParaWeb MD 45	1.89 - 2.05		NA		NA		0.13	
ParaWeb ME 45	1.89 - 2.05	1.91	NA		NA		0.11	0.091
ParaWeb MS 54	2.45 - 2.6		NA		NA		0.14	
ParaWeb MD 54	2.45 - 2.6		NA		NA		0.13	
ParaWeb ME 54	2.41 - 2.56	2.45	NA		NA		0.10	0.092
ParaWeb MS 63	2.49 - 2.64		NA		NA		0.15	
ParaWeb MD 63	2.49 - 2.64		NA		NA		0.15	
ParaWeb ME 63	2.45 - 2.6	2.51	NA		NA		0.11	0.101

(Conversions: 1 in = 25.4 mm)

*Average of 5 readings obtained during NTPEP testing. Full test results in tables B-8 through B-25.

Table B-2. Typical and measured MD geogrid geometry for the ParaLink product line.

Machine Direction (MD) Ribs								
Style	**Width (in)**		**Spacing (in)**		**Aperture Size (in)**		**Rib Thickness (in)**	
	Typical Values	**As Measured***	**Typical Values**	**As Measured***	**Typical Values**	**As Measured***	**Typical Values**	**As Measured***
ParaLink 300	3.46	3.35	7.09	6.766	37.01	40.7	0.071	0.073
ParaLink 400	3.54	3.45	7.09	7.057	37.01	37.0	0.094	0.088
ParaLink 500	3.54	3.55	7.09	7.075	37.01	36.4	0.118	0.101
ParaLink 600	3.54	3.58	7.09	7.069	37.01	36.8	0.150	0.124
ParaLink 700	3.58	3.60	7.09	7.025	37.01	36.5	0.165	0.145
ParaLink 800	3.58	3.57	5.91	5.830	37.01	36.5	0.150	0.141
ParaLink 1000	3.58	3.54	4.93	4.817	37.01	36.7	0.165	0.153
ParaLink 1200	3.58	3.56	3.94	3.952	37.01	36.6	0.150	0.139
ParaLink 1500	3.58	3.63	3.94	3.943	37.01	36.7	0.150	0.166

(Conversions: 1 in = 25.4 mm)

Table B-3. Typical and measured XD geogrid geometry for the ParaLink product line.

Cross-Machine Direction (XD) Ribs								
Style	**Width (in)**		**Spacing (in)**		**Aperture Size (in)**		**Rib Thickness (in)**	
	Typical Values	**As Measured***	**Typical Values**	**As Measured***	**Typical Values**	**As Measured***	**Typical Values**	**As Measured***
ParaLink 300	2.33 - 2.41	2.47	39.37	43.179	3.70	3.41	0.043	0.031
ParaLink 400	2.33 - 2.41	2.30	39.37	39.275	3.62	3.61	0.043	0.036
ParaLink 500	2.33 - 2.41	2.39	39.37	38.809	3.54	3.52	0.043	0.033
ParaLink 600	2.33 - 2.41	2.31	39.37	39.068	3.50	3.49	0.043	0.035
ParaLink 700	2.33 - 2.41	2.31	39.37	38.832	3.50	3.42	0.043	0.037
ParaLink 800	2.33 - 2.41	2.31	39.37	38.764	2.36	2.26	0.043	0.034
ParaLink 1000	2.33 - 2.41	2.34	39.37	39.076	1.34	1.27	0.043	0.036
ParaLink 1200	2.33 - 2.41	2.31	39.37	38.887	0.35	0.39	0.043	0.034
ParaLink 1500	2.33 - 2.41	2.30	39.37	39.044	0.35	0.31	0.043	0.032

(Conversions: 1 in = 25.4 mm)

*Average of 5 readings obtained during NTPEP testing. Full test results in tables B-8 through B-25.

Table B-4. Typical and measured geogrid junction thickness for the ParaWeb product line.

Style	Junction Thickness (in)	
	Typical Values	As Measured*
ParaWeb 2S/2D/2E 30	NA	NA
ParaWeb 2S/2D/2E 40	NA	
ParaWeb 2S/2D/2E 50	NA	NA
ParaWeb 2S/2D/2E 75	NA	
ParaWeb 2S/2D/2E 100	NA	
ParaWeb 2S/2D/2E 135	NA	NA
ParaWeb MS/MD/ME 45	NA	
ParaWeb MS/MD/ME 54	NA	
ParaWeb MS/MD/ME 63	NA	

(Conversions: 1 in = 25.4 mm)

*Average of 5 readings obtained during NTPEP testing. Full test results in tables B-8 through B-25.

Table B-5. Typical and measured geogrid junction thickness for the ParaLink product line.

Style	Junction Thickness (in)	
	Typical Values	As Measured*
ParaLink 300	NA	0.105
ParaLink 400	NA	0.132
ParaLink 500	NA	0.137
ParaLink 600	NA	0.164
ParaLink 700	NA	0.185
ParaLink 800	NA	0.183
ParaLink 1000	NA	0.196
ParaLink 1200	NA	0.175
ParaLink 1500	NA	0.206

(Conversions: 1 in = 25.4 mm)

*Average of 5 readings obtained during NTPEP testing. Full test results in tables B-8 through B-25.

Table B-6. Typical and measured geogrid unit weight for the ParaWeb product line.

Geogrid Style/Type	Typical Weight (oz/yd^2)	Typical Weight (oz/yd)	Measured Weight, per ASTM D5261 (oz/yd)
ParaWeb 2S 30	51.41	4.67	
ParaWeb 2D 30	45.18	4.10	
ParaWeb 2E 30	30.95	2.81	2.67
ParaWeb 2S 40	64.26	5.91	
ParaWeb 2D 40	58.70	5.40	
ParaWeb 2E 40	38.78	3.57	3.52
ParaWeb 2S 50	75.46	7.44	
ParaWeb 2D 50	63.97	6.31	
ParaWeb 2E 50	42.08	4.01	3.78
ParaWeb 2S 75	98.42	9.71	
ParaWeb 2D 75	83.99	8.28	
ParaWeb 2E 75	58.72	5.79	5.94
ParaWeb 2S 100	123.68	12.20	
ParaWeb 2D 100	102.03	10.06	
ParaWeb 2E 100	79.06	7.80	7.73
ParaWeb 2S 135			
ParaWeb 2D 135			
ParaWeb 2E 135			11.66
ParaWeb MS 45	86.22	4.72	
ParaWeb MD 45	78.54	4.30	
ParaWeb ME 45	60.23	3.30	2.89
ParaWeb MS 54	91.81	6.44	
ParaWeb MD 54	82.58	5.79	
ParaWeb ME 54	61.86	4.34	4.03
ParaWeb MS 63	105.84	7.54	
ParaWeb MD 63	95.39	6.80	
ParaWeb ME 63	69.20	4.93	4.46

(Conversion: 1 oz/ yd = 31.01 g/m)

*Average of 5 readings obtained during NTPEP testing. Full test results in tables B-8 through B-25.

Table B-7. Typical and measured geogrid unit weight for the ParaLink product line.

Geogrid Style/Type	Typical Weight (oz/yd^2)	Measured Weight, per ASTM D5261 (oz/yd^2)
ParaLink 300	23.30	22.57
ParaLink 400	29.82	28.47
ParaLink 500	36.02	35.45
ParaLink 600	44.58	42.90
ParaLink 700	54.33	49.83
ParaLink 800	63.19	57.99
ParaLink 1000	79.72	75.40
ParaLink 1200	93.60	87.51
ParaLink 1500	118.00	109.25

(Conversion: 1 oz/ yd^2 = 33.9 g/m^2)

*Average of 5 readings obtained during NTPEP testing. Full test results in tables B-8 through B-25.

Table B-8. Geometric measurements for ParaWeb 30

PARAMETER		TEST REPLICATE NUMBER 1	2	3	4	5	MEAN	STD. DEV.
Mass/Unit Area (ASTM D 5261)								
Specimen Width (in)	3.31							
Specimen Length (in)	24							
Mass(g)		50.46	50.46	50.46	50.56	50.85		
Mass/unit length (oz/yd)		2.67	2.67	2.67	2.67	2.69	**2.67**	0.01
Mass/unit length (g/meter)		82.8	82.8	82.8	82.9	83.4	**82.9**	0.3
Aperature Size (Calipers)								
MD - Aperature Size (in)				Not Applicable				
MD - Aperature Size (mm)				Not Applicable				
TD - Aperature Size (in)				Not Applicable				
TD - Aperature Size (mm)				Not Applicable				
Rib Width (Calipers)								
MD - Width (in)		3.31	3.31	3.31	3.30	3.30	**3.31**	0.01
MD - Width (mm)		84.1	84.1	84.1	83.8	83.8	**84.0**	0.1
TD - Width (in)				Not Applicable				
TD - Width (mm)				Not Applicable				
Rib Thickness (Calipers)								
MD - Thickness (in)		0.062	0.061	0.061	0.061	0.061	**0.061**	0.000
MD - Thickness (mm)		1.56	1.54	1.54	1.55	1.55	**1.55**	0.01
TD - Thickness (in)				Not Applicable				
TD - Thickness (mm)				Not Applicable				
Node/Junction Thickness (Calipers)								
Thickness (in)				Not Applicable				
Thickness (mm)				Not Applicable				

MD - Machine Direction TD - Transverse/Cross Machine Direction NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table B-9. Geometric measurements for ParaWeb 40

PARAMETER		TEST REPLICATE NUMBER					MEAN	STD. DEV.
		1	2	3	4	5		
Mass/Unit Area (ASTM D 5261)								
Specimen Width (in)	3.25							
Specimen Length (in)	24							
Mass(g)		66.83	66.29	66.53	66.44	66.50		
Mass/unit length (oz/yd)		3.53	3.50	3.52	3.51	3.52	**3.52**	0.01
Mass/unit length (g/meter)		109.6	108.7	109.1	109.0	109.1	**109.1**	0.3
Aperature Size (Calipers)								
MD - Aperature Size (in)				Not Applicable				
MD - Aperature Size (mm)				Not Applicable				
TD - Aperature Size (in)				Not Applicable				
TD - Aperature Size (mm)				Not Applicable				
Rib Width (Calipers)								
MD - Width (in)		3.33	3.34	3.33	3.33	3.33	**3.33**	0.00
MD - Width (mm)		84.5	84.7	84.7	84.5	84.6	**84.6**	0.1
TD - Width (in)				Not Applicable				
TD - Width (mm)				Not Applicable				
Rib Thickness (Calipers)								
MD - Thickness (in)		0.068	0.076	0.075	0.076	0.076	**0.074**	0.004
MD - Thickness (mm)		1.71	1.93	1.91	1.93	1.93	**1.88**	0.09
TD - Thickness (in)				Not Applicable				
TD - Thickness (mm)				Not Applicable				
Node/Junction Thickness (Calipers)								
Thickness (in)				Not Applicable				
Thickness (mm)				Not Applicable				

MD - Machine Direction TD - Transverse/Cross Machine Direction NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table B-10. Geometric measurements for ParaWeb 45

PARAMETER		TEST REPLICATE NUMBER					MEAN	STD. DEV.
		1	2	3	4	5		
Mass/Unit Area (ASTM D 5261)								
Specimen Width (in)	2.00							
Specimen Length (in)	24							
Mass(g)		54.90	54.66	54.53	54.60	54.69		
Mass/unit length (oz/yd)		2.90	2.89	2.88	2.89	2.89	**2.89**	0.01
Mass/unit length (g/meter)		90.1	89.7	89.5	89.6	89.7	**89.7**	0.2
Aperature Size (Calipers)								
MD - Aperature Size (in)				Not Applicable				
MD - Aperature Size (mm)				Not Applicable				
TD - Aperature Size (in)				Not Applicable				
TD - Aperature Size (mm)				Not Applicable				
Rib Width (Calipers)								
MD - Width (in)		1.91	1.91	1.91	1.91	1.91	**1.91**	0.00
MD - Width (mm)		48.5	48.5	48.6	48.5	48.5	**48.5**	0.1
TD - Width (in)				Not Applicable				
TD - Width (mm)				Not Applicable				
Rib Thickness (Calipers)								
MD - Thickness (in)		0.092	0.089	0.091	0.092	0.091	**0.091**	0.001
MD - Thickness (mm)		2.34	2.26	2.30	2.34	2.30	**2.31**	0.03
TD - Thickness (in)				Not Applicable				
TD - Thickness (mm)				Not Applicable				
Node/Junction Thickness (Calipers)								
Thickness (in)				Not Applicable				
Thickness (mm)				Not Applicable				

MD - Machine Direction TD - Transverse/Cross Machine Direction NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table B-11. Geometric measurements for ParaWeb 50

PARAMETER		TEST REPLICATE NUMBER					MEAN	STD. DEV.
		1	2	3	4	5		
Mass/Unit Area (ASTM D 5261)								
Specimen Width (in)	3.41							
Specimen Length (in)	24							
Mass(g)		71.46	71.57	71.67	71.49	71.53		
Mass/unit length (oz/yd)		3.78	3.78	3.79	3.78	3.78	**3.78**	0.00
Mass/unit length (g/meter)		117	117	118	117	117	**117**	0
Aperature Size (Calipers)								
MD - Aperature Size (in)				Not Applicable				
MD - Aperature Size (mm)				Not Applicable				
TD - Aperature Size (in)				Not Applicable				
TD - Aperature Size (mm)				Not Applicable				
Rib Width (Calipers)								
MD - Width (in)		3.41	3.42	3.41	3.42	3.41	**3.41**	0.01
MD - Width (mm)		86.6	86.9	86.6	86.9	86.6	**86.7**	0.1
TD - Width (in)				Not Applicable				
TD - Width (mm)				Not Applicable				
Rib Thickness (Calipers)								
MD - Thickness (in)		0.072	0.071	0.071	0.073	0.072	**0.072**	0.001
MD - Thickness (mm)		1.82	1.79	1.80	1.84	1.83	**1.82**	0.02
TD - Thickness (in)				Not Applicable				
TD - Thickness (mm)				Not Applicable				
Node/Junction Thickness (Calipers)								
Thickness (in)				Not Applicable				
Thickness (mm)				Not Applicable				

MD - Machine Direction TD - Transverse/Cross Machine Direction NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table B-12. Geometric measurements for ParaWeb 54

PARAMETER		TEST REPLICATE NUMBER					MEAN	STD. DEV.
		1	2	3	4	5		
Mass/Unit Area (ASTM D 5261)								
Specimen Width (in)	2.50							
Specimen Length (in)	24							
Mass(g)		76.58	76.13	76.11	76.10	76.26		
Mass/unit length (oz/yd)		4.05	4.02	4.02	4.02	4.03	**4.03**	0.01
Mass/unit length (g/meter)		125.6	124.9	124.9	124.8	125.1	**125.1**	0.3
Aperature Size (Calipers)								
MD - Aperature Size (in)		Not Applicable						
MD - Aperature Size (mm)		Not Applicable						
TD - Aperature Size (in)		Not Applicable						
TD - Aperature Size (mm)		Not Applicable						
Rib Width (Calipers)								
MD - Width (in)		2.45	2.45	2.45	2.45	2.45	**2.45**	0.00
MD - Width (mm)		62.3	62.3	62.3	62.1	62.1	**62.2**	0.1
TD - Width (in)		Not Applicable						
TD - Width (mm)		Not Applicable						
Rib Thickness (Calipers)								
MD - Thickness (in)		0.090	0.092	0.092	0.093	0.093	**0.092**	0.001
MD - Thickness (mm)		2.29	2.34	2.34	2.35	2.35	**2.33**	0.03
TD - Thickness (in)		Not Applicable						
TD - Thickness (mm)		Not Applicable						
Node/Junction Thickness (Calipers)								
Thickness (in)		Not Applicable						
Thickness (mm)		Not Applicable						

MD - Machine Direction TD - Transverse/Cross Machine Direction NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table B-13. Geometric measurements for ParaWeb 63

PARAMETER		TEST REPLICATE NUMBER					MEAN	STD. DEV.
		1	2	3	4	5		
Mass/Unit Area (ASTM D 5261)								
Specimen Width (in)	2.50							
Specimen Length (in)	24							
Mass(g)		84.19	84.30	84.18	84.50	84.29		
Mass/unit length (oz/yd)		4.45	4.46	4.45	4.47	4.46	**4.46**	0.01
Mass/unit length (g/meter)		138.1	138.3	138.1	138.6	138.3	**138.3**	0.2
Aperature Size (Calipers)								
MD - Aperature Size (in)				Not Applicable				
MD - Aperature Size (mm)				Not Applicable				
TD - Aperature Size (in)				Not Applicable				
TD - Aperature Size (mm)				Not Applicable				
Rib Width (Calipers)								
MD - Width (in)		2.51	2.51	2.51	2.51	2.51	**2.51**	0.00
MD - Width (mm)		63.8	63.8	63.8	63.7	63.8	**63.8**	0.0
TD - Width (in)				Not Applicable				
TD - Width (mm)				Not Applicable				
Rib Thickness (Calipers)								
MD - Thickness (in)		0.105	0.100	0.100	0.100	0.103	**0.101**	0.002
MD - Thickness (mm)		2.65	2.54	2.53	2.54	2.62	**2.58**	0.06
TD - Thickness (in)				Not Applicable				
TD - Thickness (mm)				Not Applicable				
Node/Junction Thickness (Calipers)								
Thickness (in)				Not Applicable				
Thickness (mm)				Not Applicable				

MD - Machine Direction TD - Transverse/Cross Machine Direction NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table B-14. Geometric measurements for ParaWeb 75

PARAMETER		TEST REPLICATE NUMBER					MEAN	STD. DEV.
		1	2	3	4	5		
Mass/Unit Area (ASTM D 5261)								
Specimen Width (in)	3.50							
Specimen Length (in)	24							
Mass(g)		113.00	112.55	112.26	112.41	112.04		
Mass/unit length (oz/yd)		5.97	5.95	5.93	5.94	5.92	**5.94**	0.02
Mass/unit length (g/meter)		185.4	184.6	184.2	184.4	183.8	**184.5**	0.6
Aperature Size (Calipers)								
MD - Aperature Size (in)				Not Applicable				
MD - Aperature Size (mm)				Not Applicable				
TD - Aperature Size (in)				Not Applicable				
TD - Aperature Size (mm)				Not Applicable				
Rib Width (Calipers)								
MD - Width (in)		3.52	3.51	3.52	3.51	3.52	**3.52**	0.00
MD - Width (mm)		89.5	89.3	89.4	89.3	89.3	**89.3**	0.1
TD - Width (in)				Not Applicable				
TD - Width (mm)				Not Applicable				
Rib Thickness (Calipers)								
MD - Thickness (in)		0.106	0.103	0.104	0.103	0.101	**0.103**	0.002
MD - Thickness (mm)		2.69	2.60	2.64	2.60	2.57	**2.62**	0.05
TD - Thickness (in)				Not Applicable				
TD - Thickness (mm)				Not Applicable				
Node/Junction Thickness (Calipers)								
Thickness (in)				Not Applicable				
Thickness (mm)				Not Applicable				

MD - Machine Direction   TD - Transverse/Cross Machine Direction   NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table B-15. Geometric measurements for ParaWeb 100

PARAMETER		TEST REPLICATE NUMBER					MEAN	STD. DEV.
		1	2	3	4	5		
Mass/Unit Area (ASTM D 5261)								
Specimen Width (in)	3.50							
Specimen Length (in)	24							
Mass(g)		145.09	146.49	146.69	146.47	146.67		
Mass/unit length (oz/yd)		7.67	7.74	7.75	7.74	7.75	**7.73**	0.04
Mass/unit length (g/meter)		238.0	240.3	240.6	240.3	240.6	**240.0**	1.1
Aperature Size (Calipers)								
MD - Aperature Size (in)				Not Applicable				
MD - Aperature Size (mm)				Not Applicable				
TD - Aperature Size (in)				Not Applicable				
TD - Aperature Size (mm)				Not Applicable				
Rib Width (Calipers)								
MD - Width (in)		3.58	3.58	3.61	3.61	3.60	**3.60**	0.02
MD - Width (mm)		90.9	91.0	91.6	91.8	91.4	**91.3**	0.4
TD - Width (in)				Not Applicable				
TD - Width (mm)				Not Applicable				
Rib Thickness (Calipers)								
MD - Thickness (in)		0.124	0.121	0.121	0.127	0.127	**0.124**	0.003
MD - Thickness (mm)		3.14	3.07	3.06	3.23	3.23	**3.14**	0.08
TD - Thickness (in)				Not Applicable				
TD - Thickness (mm)				Not Applicable				
Node/Junction Thickness (Calipers)								
Thickness (in)				Not Applicable				
Thickness (mm)				Not Applicable				

MD - Machine Direction TD - Transverse/Cross Machine Direction NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table B-16. Geometric measurements for ParaWeb 135

PARAMETER		TEST REPLICATE NUMBER					MEAN	STD. DEV.
		1	2	3	4	5		
Mass/Unit Area (ASTM D 5261)								
Specimen Width (in)	3.56							
Specimen Length (in)	24							
Mass(g)		220.3	220.4	220.8	220.3	220.7		
Mass/unit length (oz/yd)		11.65	11.65	11.67	11.65	11.67	**11.66**	0.01
Mass/unit length (g/meter)		361	362	362	361	362	**362**	0
Aperature Size (Calipers)								
MD - Aperature Size (in)				Not Applicable				
MD - Aperature Size (mm)				Not Applicable				
TD - Aperature Size (in)				Not Applicable				
TD - Aperature Size (mm)				Not Applicable				
Rib Width (Calipers)								
MD - Width (in)		3.55	3.56	3.55	3.56	3.56	**3.56**	0.01
MD - Width (mm)		90.2	90.4	90.2	90.4	90.4	**90.3**	0.1
TD - Width (in)				Not Applicable				
TD - Width (mm)				Not Applicable				
Rib Thickness (Calipers)								
MD - Thickness (in)		0.174	0.177	0.176	0.173	0.172	**0.174**	0.002
MD - Thickness (mm)		4.42	4.50	4.47	4.39	4.37	**4.43**	0.05
TD - Thickness (in)				Not Applicable				
TD - Thickness (mm)				Not Applicable				
Node/Junction Thickness (Calipers)								
Thickness (in)				Not Applicable				
Thickness (mm)				Not Applicable				

MD - Machine Direction TD - Transverse/Cross Machine Direction NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table B-17. Geometric measurements for ParaLink 300

PARAMETER	TEST REPLICATE NUMBER						MEAN	STD. DEV.
		1	2	3	4	5		
Mass/Unit Area (ASTM D 5261)								
Specimen Width (in)	6.98							
Specimen Length (in)	24							
Mass(g)		82.71	82.65	82.79	83.03	82.76		
Mass/unit area (oz/sq.yd)		22.55	22.53	22.57	22.64	22.56	**22.57**	0.04
Mass/unit area (g/sq.meter)		764	764	765	767	765	**765**	1
Aperature Size (Calipers)								
MD - Aperature Size (in)		40.9	40.5	40.6	40.8	40.9	**40.7**	0.2
MD - Aperature Size (mm)		1038	1029	1030	1035	1038	**1034**	4
TD - Aperature Size (in)		3.36	3.32	3.54	3.22	3.62	**3.41**	0.16
TD - Aperature Size (mm)		85.3	84.3	89.9	81.8	91.9	**86.7**	4.2
Rib Width (Calipers)								
MD - Width (in)		3.35	3.38	3.34	3.34	3.36	**3.35**	0.02
MD - Width (mm)		85.1	85.9	84.8	84.8	85.3	**85.2**	0.4
TD - Width (in)		2.46	2.46	2.47	2.47	2.47	**2.47**	0.01
TD - Width (mm)		62.48	62.48	62.74	62.74	62.74	**62.64**	0.14
Rib Thickness (Calipers)								
MD - Thickness (in)		0.074	0.073	0.074	0.073	0.073	**0.073**	0.001
MD - Thickness (mm)		1.88	1.85	1.88	1.85	1.85	**1.86**	0.01
TD - Thickness (in)		0.031	0.03	0.03	0.031	0.032	**0.031**	0.001
TD - Thickness (mm)		0.79	0.76	0.76	0.79	0.81	**0.78**	0.02
Node/Junction Thickness (Calipers)								
Thickness (in)		0.105	0.108	0.102	0.104	0.106	**0.105**	0.002
Thickness (mm)		2.67	2.74	2.59	2.64	2.69	**2.67**	0.06

MD - Machine Direction TD - Transverse/Cross Machine Direction NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table B-18. Geometric measurements for ParaLink 400

PARAMETER		TEST REPLICATE NUMBER					MEAN	STD. DEV.
		1	2	3	4	5		
Mass/Unit Area (ASTM D 5261)								
Specimen Width (in)	14.0							
Specimen Length (in)	39.5							
Mass(g)		342.72	344.83	346.14	345.40	344.17		
Mass/unit area (oz/sq.yd)		28.31	28.48	28.59	28.53	28.43	**28.47**	0.11
Mass/unit area (g/sq.meter)		960	965	969	967	964	**965**	4
Aperature Size (Calipers)								
MD - Aperature Size (in)		37.0	36.9	37.0	37.0	37.0	**37.0**	0.1
MD - Aperature Size (mm)		940	936	939	940	941	**939**	2
TD - Aperature Size (in)		3.47	3.51	3.67	3.68	3.72	**3.61**	0.11
TD - Aperature Size (mm)		88.1	89.2	93.2	93.5	94.5	**91.7**	2.8
Rib Width (Calipers)								
MD - Width (in)		3.44	3.45	3.44	3.45	3.45	**3.45**	0.01
MD - Width (mm)		87.4	87.6	87.4	87.7	87.7	**87.5**	0.1
TD - Width (in)		2.30	2.30	2.31	2.29	2.29	**2.30**	0.01
TD - Width (mm)		58.33	58.36	58.61	58.23	58.15	**58.34**	0.17
Rib Thickness (Calipers)								
MD - Thickness (in)		0.088	0.087	0.088	0.090	0.091	**0.088**	0.002
MD - Thickness (mm)		2.22	2.21	2.22	2.27	2.30	**2.25**	0.04
TD - Thickness (in)		0.037	0.036	0.034	0.036	0.036	**0.036**	0.001
TD - Thickness (mm)		0.93	0.91	0.85	0.91	0.90	**0.90**	0.03
Node/Junction Thickness (Calipers)								
Thickness (in)		0.128	0.132	0.138	0.131	0.132	**0.132**	0.003
Thickness (mm)		3.25	3.34	3.49	3.31	3.34	**3.35**	0.09

MD - Machine Direction TD - Transverse/Cross Machine Direction NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table B-19. Geometric measurements for ParaLink 500

PARAMETER	TEST REPLICATE NUMBER					MEAN	STD. DEV.
	1	2	3	4	5		
Mass/Unit Area (ASTM D 5261)							
Specimen Width (in) 14.0							
Specimen Length (in) 39.5							
Mass(g)	424.54	427.27	430.18	430.67	433.28		
Mass/unit area (oz/sq.yd)	35.06	35.29	35.53	35.57	35.79	**35.45**	0.28
Mass/unit area (g/sq.meter)	1189	1196	1204	1206	1213	**1202**	9
Aperature Size (Calipers)							
MD - Aperature Size (in)	36.8	36.9	35.8	36.9	35.8	**36.4**	0.6
MD - Aperature Size (mm)	933	936	909	937	908	**925**	15
TD - Aperature Size (in)	3.67	3.33	3.51	3.59	3.51	**3.52**	0.13
TD - Aperature Size (mm)	93.2	84.6	89.2	91.2	89.2	**89.5**	3.2
Rib Width (Calipers)							
MD - Width (in)	3.56	3.58	3.51	3.56		**3.55**	0.03
MD - Width (mm)	90.4	90.8	89.2	90.5		**90.2**	0.7
TD - Width (in)	2.38	2.39	2.42	2.40	2.38	**2.39**	0.01
TD - Width (mm)	60.50	60.77	61.42	60.90	60.52	**60.82**	0.37
Rib Thickness (Calipers)							
MD - Thickness (in)	0.101	0.101	0.103	0.102		**0.101**	0.001
MD - Thickness (mm)	2.55	2.57	2.60	2.58		**2.57**	0.02
TD - Thickness (in)	0.039	0.037	0.029	0.029	0.031	**0.033**	0.005
TD - Thickness (mm)	0.99	0.93	0.72	0.74	0.79	**0.83**	0.12
Node/Junction Thickness (Calipers)							
Thickness (in)	0.165	0.151	0.059	0.160	0.151	**0.137**	0.044
Thickness (mm)	4.19	3.84	1.50	4.06	3.84	**3.48**	1.12

MD - Machine Direction TD - Transverse/Cross Machine Direction NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table B-20. Geometric measurements for ParaLink 600

PARAMETER		TEST REPLICATE NUMBER					MEAN	STD. DEV.
		1	2	3	4	5		
Mass/Unit Area (ASTM D 5261)								
Specimen Width (in)	14.2							
Specimen Length (in)	39.3							
Mass(g)		523.63	525.33	522.20	520.11	526.45		
Mass/unit area (oz/sq.yd)		42.91	43.05	42.79	42.62	43.14	**42.90**	0.21
Mass/unit area (g/sq.meter)		1455	1459	1451	1445	1463	**1454**	7
Aperature Size (Calipers)								
MD - Aperature Size (in)		36.5	36.5	37.0	37.0	36.9	**36.8**	0.3
MD - Aperature Size (mm)		927	926	939	939	937	**934**	7
TD - Aperature Size (in)		3.56	3.40	3.43	3.48	3.61	**3.49**	0.09
TD - Aperature Size (mm)		90.4	86.2	87.0	88.3	91.7	**88.7**	2.3
Rib Width (Calipers)								
MD - Width (in)		3.58	3.58	3.58	3.58	3.57	**3.58**	0.00
MD - Width (mm)		90.8	90.9	90.8	90.9	90.7	**90.8**	0.1
TD - Width (in)		2.33	2.34	2.30	2.28	2.29	**2.31**	0.03
TD - Width (mm)		59.27	59.50	58.47	57.96	58.17	**58.67**	0.68
Rib Thickness (Calipers)								
MD - Thickness (in)		0.122	0.123	0.132	0.121	0.123	**0.124**	0.004
MD - Thickness (mm)		3.09	3.12	3.34	3.06	3.11	**3.14**	0.11
TD - Thickness (in)		0.035	0.036	0.036	0.034	0.034	**0.035**	0.001
TD - Thickness (mm)		0.89	0.90	0.91	0.85	0.86	**0.88**	0.03
Node/Junction Thickness (Calipers)								
Thickness (in)		0.166	0.163	0.170	0.162	0.158	**0.164**	0.005
Thickness (mm)		4.20	4.13	4.32	4.11	4.00	**4.15**	0.12

MD - Machine Direction TD - Transverse/Cross Machine Direction NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table B-21. Geometric measurements for ParaLink 700

PARAMETER		TEST REPLICATE NUMBER					MEAN	STD. DEV.
		1	2	3	4	5		
Mass/Unit Area (ASTM D 5261)								
Specimen Width (in)	14.0							
Specimen Length (in)	39.5							
Mass(g)		598.90	609.77	594.81	604.72	608.41		
Mass/unit area (oz/sq.yd)		49.47	50.36	49.13	49.95	50.25	**49.83**	0.52
Mass/unit area (g/sq.meter)		1677	1707	1665	1693	1703	**1689**	18
Aperature Size (Calipers)								
MD - Aperature Size (in)		36.0	37.2	37.2	36.1	36.2	**36.5**	0.6
MD - Aperature Size (mm)		913	944	945	916	918	**928**	16
TD - Aperature Size (in)		3.36	3.50	3.46	3.39	3.39	**3.42**	0.06
TD - Aperature Size (mm)		85.3	88.9	87.9	86.1	86.1	**86.9**	1.5
Rib Width (Calipers)								
MD - Width (in)		3.60	3.61	3.59	3.60	3.62	**3.60**	0.01
MD - Width (mm)		91.5	91.6	91.3	91.6	91.9	**91.6**	0.2
TD - Width (in)		2.30	2.32	2.30	2.32	2.33	**2.31**	0.01
TD - Width (mm)		58.41	58.94	58.47	58.98	59.11	**58.78**	0.32
Rib Thickness (Calipers)								
MD - Thickness (in)		0.144	0.140	0.150	0.144	0.146	**0.145**	0.004
MD - Thickness (mm)		3.66	3.54	3.81	3.64	3.71	**3.67**	0.10
TD - Thickness (in)		0.036	0.035	0.038	0.035	0.040	**0.037**	0.002
TD - Thickness (mm)		0.91	0.88	0.97	0.88	1.02	**0.93**	0.06
Node/Junction Thickness (Calipers)								
Thickness (in)		0.185	0.184	0.188	0.180	0.191	**0.185**	0.004
Thickness (mm)		4.70	4.66	4.78	4.56	4.85	**4.71**	0.11

MD - Machine Direction   TD - Transverse/Cross Machine Direction   NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table B-22. Geometric measurements for ParaLink 800

PARAMETER		TEST REPLICATE NUMBER					MEAN	STD. DEV.
		1	2	3	4	5		
Mass/Unit Area (ASTM D 5261)								
Specimen Width (in)	11.8							
Specimen Length (in)	39.5							
Mass(g)		588.36	588.69	587.54	591.32	590.31		
Mass/unit area (oz/sq.yd)		57.90	57.93	57.82	58.19	58.09	**57.99**	0.15
Mass/unit area (g/sq.meter)		1963	1964	1960	1973	1969	**1966**	5
Aperature Size (Calipers)								
MD - Aperature Size (in)		36.8	36.0	36.8	36.0	36.7	**36.5**	0.4
MD - Aperature Size (mm)		935	915	933	913	932	**926**	11
TD - Aperature Size (in)		2.24	2.32	2.20	2.30	2.26	**2.26**	0.05
TD - Aperature Size (mm)		56.9	58.9	55.9	58.4	57.4	**57.5**	1.2
Rib Width (Calipers)								
MD - Width (in)		3.57	3.57	3.55	3.56	3.58	**3.57**	0.01
MD - Width (mm)		90.8	90.6	90.1	90.4	90.8	**90.6**	0.3
TD - Width (in)		2.31	2.33	2.33	2.33	2.27	**2.31**	0.03
TD - Width (mm)		58.69	59.30	59.14	59.26	57.54	**58.79**	0.74
Rib Thickness (Calipers)								
MD - Thickness (in)		0.140	0.142	0.150	0.138	0.134	**0.141**	0.006
MD - Thickness (mm)		3.56	3.59	3.80	3.51	3.40	**3.57**	0.15
TD - Thickness (in)		0.035	0.033	0.035	0.035	0.034	**0.034**	0.001
TD - Thickness (mm)		0.89	0.83	0.89	0.89	0.85	**0.87**	0.03
Node/Junction Thickness (Calipers)								
Thickness (in)		0.189	0.181	0.177	0.179	0.189	**0.183**	0.005
Thickness (mm)		4.79	4.58	4.50	4.54	4.79	**4.64**	0.14

MD - Machine Direction TD - Transverse/Cross Machine Direction NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table B-23. Geometric measurements for ParaLink 1000

PARAMETER		TEST REPLICATE NUMBER					MEAN	STD. DEV.
		1	2	3	4	5		
Mass/Unit Area (ASTM D 5261)								
Specimen Width (in)	4.78							
Specimen Length (in)	24							
Mass(g)		187.3	192.1	187.6	191.9	188.2		
Mass/unit area (oz/sq.yd)		74.55	76.47	74.67	76.38	74.94	**75.40**	0.94
Mass/unit area (g/sq.meter)		2527	2592	2531	2589	2540	**2556**	32
Aperature Size (Calipers)								
MD - Aperature Size (in)		36.8	36.8	36.7	36.8	36.8	**36.7**	0.0
MD - Aperature Size (mm)		933	933	932	933	933	**933**	1
TD - Aperature Size (in)		1.29	1.28	1.26	1.29	1.26	**1.27**	0.01
TD - Aperature Size (mm)		32.7	32.5	31.9	32.7	32.1	**32.4**	0.4
Rib Width (Calipers)								
MD - Width (in)		3.56	3.52	3.56	3.53	3.54	**3.54**	0.02
MD - Width (mm)		90.4	89.4	90.4	89.7	89.9	**90.0**	0.5
TD - Width (in)		2.37	2.34	2.33	2.33	2.32	**2.34**	0.02
TD - Width (mm)		60.20	59.44	59.18	59.18	58.93	**59.39**	0.49
Rib Thickness (Calipers)								
MD - Thickness (in)		0.151	0.153	0.153	0.151	0.155	**0.153**	0.002
MD - Thickness (mm)		3.84	3.89	3.89	3.84	3.94	**3.88**	0.04
TD - Thickness (in)		0.041	0.034	0.035	0.037	0.034	**0.036**	0.003
TD - Thickness (mm)		1.04	0.86	0.89	0.94	0.86	**0.92**	0.07
Node/Junction Thickness (Calipers)								
Thickness (in)		0.196	0.195	0.194	0.200	0.197	**0.196**	0.002
Thickness (mm)		4.97	4.95	4.91	5.07	4.99	**4.98**	0.06

MD - Machine Direction TD - Transverse/Cross Machine Direction NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table B-24. Geometric measurements for ParaLink 1200

PARAMETER		TEST REPLICATE NUMBER					MEAN	STD. DEV.
		1	2	3	4	5		
Mass/Unit Area (ASTM D 5261)								
Specimen Width (in)	7.8							
Specimen Length (in)	39.5							
Mass(g)		587.39	587.09	585.79	587.58	584.89		
Mass/unit area (oz/sq.yd)		87.64	87.59	87.40	87.67	87.27	**87.51**	0.17
Mass/unit area (g/sq.meter)		2971	2969	2963	2972	2958	**2967**	6
Aperature Size (Calipers)								
MD - Aperature Size (in)		36.4	36.4	36.3	36.4	37.3	**36.6**	0.4
MD - Aperature Size (mm)		925	925	923	925	947	**929**	10
TD - Aperature Size (in)		0.37	0.46	0.40	0.36	0.36	**0.39**	0.04
TD - Aperature Size (mm)		9.4	11.7	10.1	9.1	9.1	**9.9**	1.1
Rib Width (Calipers)								
MD - Width (in)		3.56	3.56	3.56	3.56	3.57	**3.56**	0.00
MD - Width (mm)		90.5	90.4	90.4	90.5	90.6	**90.5**	0.1
TD - Width (in)		2.32	2.31	2.32	2.30	2.33	**2.31**	0.01
TD - Width (mm)		58.81	58.66	58.80	58.45	59.06	**58.76**	0.22
Rib Thickness (Calipers)								
MD - Thickness (in)		0.139	0.141	0.138	0.136	0.142	**0.139**	0.002
MD - Thickness (mm)		3.53	3.58	3.51	3.45	3.59	**3.53**	0.06
TD - Thickness (in)		0.033	0.034	0.035	0.035	0.034	**0.034**	0.001
TD - Thickness (mm)		0.83	0.85	0.89	0.88	0.86	**0.86**	0.02
Node/Junction Thickness (Calipers)								
Thickness (in)		0.177	0.175	0.173	0.179	0.174	**0.175**	0.003
Thickness (mm)		4.50	4.43	4.38	4.55	4.42	**4.46**	0.07

MD - Machine Direction TD - Transverse/Cross Machine Direction NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table B-25. Geometric measurements for ParaLink 1500

PARAMETER		TEST REPLICATE NUMBER					MEAN	STD. DEV.
		1	2	3	4	5		
Mass/Unit Area (ASTM D 5261)								
Specimen Width (in)	7.8							
Specimen Length (in)	39.5							
Mass(g)		737.60	734.56	741.27	727.76	719.92		
Mass/unit area (oz/sq.yd)		110.05	109.60	110.60	108.58	107.41	**109.25**	1.26
Mass/unit area (g/sq.meter)		3731	3715	3749	3681	3641	**3704**	43
Aperature Size (Calipers)								
MD - Aperature Size (in)		37.3	37.3	36.1	36.0	37.1	**36.7**	0.6
MD - Aperature Size (mm)		946	947	916	915	943	**933**	16
TD - Aperature Size (in)		0.31	0.34	0.28	0.36	0.28	**0.31**	0.04
TD - Aperature Size (mm)		7.9	8.6	7.1	9.1	7.1	**8.0**	0.9
Rib Width (Calipers)								
MD - Width (in)		3.64	3.62	3.62	3.63	3.63	**3.63**	0.01
MD - Width (mm)		92.5	92.0	91.9	92.2	92.2	**92.2**	0.2
TD - Width (in)		2.28	2.30	2.29	2.32	2.29	**2.30**	0.01
TD - Width (mm)		58.03	58.33	58.18	58.81	58.18	**58.31**	0.30
Rib Thickness (Calipers)								
MD - Thickness (in)		0.169	0.175	0.163	0.167	0.157	**0.166**	0.007
MD - Thickness (mm)		4.28	4.45	4.14	4.23	3.99	**4.22**	0.17
TD - Thickness (in)		0.031	0.033	0.031	0.033	0.035	**0.032**	0.002
TD - Thickness (mm)		0.79	0.83	0.79	0.83	0.89	**0.82**	0.04
Node/Junction Thickness (Calipers)								
Thickness (in)		0.210	0.206	0.210	0.211	0.193	**0.206**	0.007
Thickness (mm)		5.32	5.22	5.32	5.35	4.90	**5.22**	0.19

MD - Machine Direction TD - Transverse/Cross Machine Direction NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

B.2 Product Production Information

Table B-26. Typical coil dimensions for the ParaWeb product line.

Style/Type	Width (ft)	Length (ft)	Area (yd²)	Coil Diameter (ft)	Gross weight (lbs)
ParaWeb 2S 30	0.28	328	11.11	1.79	32.63
ParaWeb 2D 30	0.27	328	10.84	1.58	28.00
ParaWeb 2E 30	0.27	328	10.84	1.47	19.18
ParaWeb 2S 40	0.28	328	11.11	1.88	40.79
ParaWeb 2D 40	0.28	328	10.97	1.79	36.82
ParaWeb 2E 40	0.27	328	10.84	1.58	24.03
ParaWeb 2S 50	0.30	328	11.76	2.22	50.71
ParaWeb 2D 50	0.30	328	11.76	1.88	42.99
ParaWeb 2E 50	0.29	328	11.37	1.69	27.34
ParaWeb 2S 75	0.30	328	11.76	2.37	66.14
ParaWeb 2D 75	0.30	328	11.76	2.06	56.44
ParaWeb 2E 75	0.30	328	11.76	1.88	39.46
ParaWeb 2S 100	0.30	328	11.76	2.90	83.11
ParaWeb 2D 100	0.30	328	11.76	2.30	68.56
ParaWeb 2E 100	0.30	328	11.76	2.06	53.13
ParaWeb 2S 135					
ParaWeb 2D 135					
ParaWeb 2E 135					
ParaWeb MS 45	0.16	328	6.53	2.22	32.19
ParaWeb MD 45	0.16	328	6.53	2.14	29.32
ParaWeb ME 45	0.16	328	11.11	1.97	22.49
ParaWeb MS 54	0.21	328	10.84	2.22	43.87
ParaWeb MD 54	0.21	328	10.84	2.14	39.46
ParaWeb ME 54	0.21	328	11.11	1.88	29.10
ParaWeb MS 63	0.21	328	10.97	2.30	51.37
ParaWeb MD 63	0.21	328	10.84	2.30	46.30
ParaWeb ME 63	0.21	328	11.76	1.97	33.07

(Conversions: 1 ft = 0.3048 m; 1 yd^2 = 0.836 m^2)

Table B-27. Typical geogrid roll dimensions for the ParaLink product line.

Style/Type	Width (ft)	Length (ft)	Area (yd²)	Roll Diameter (ft)	Gross weight (lbs)
ParaLink 300	14.8	656	1079	2.30	1808
ParaLink 400	14.8	492	809	2.46	1698
ParaLink 500	14.8	427	702	2.46	1808
ParaLink 600	14.8	328	539	2.30	1698
ParaLink 700	14.8	164	270	1.64	1036
ParaLink 800	14.8	164	270	1.64	1168
ParaLink 1000	14.8	164	270	1.64	1433
ParaLink 1200	14.8	164	270	1.64	1676
ParaLink 1500	14.8	164	270	1.64	2205

(Conversions: 1 ft = 0.3048 m; 1 yd^2 = 0.836 m^2)

B.3 Product Manufacturing Quality Control Program

Testing/sampling is done per the Linear Composites Quality Control Plan Document. A summary of the program is provided in Table B-10.

Table B-28. Typical summary of quality control testing conducted by the manufacturer for the ParaWeb/ParaLink product line.

Test Method	Property	Testing Frequency
ASTM D 5261	Mass / Unit Area	N/A
ASTM D6637	Single Rib Tensile	Twice every 8 hours during production run.
ASTM D6637	Multi-Rib Tensile	One test per run or weekly if period of run exceeds a week.
Hand measure	Aperture Size	N/A
Hand measure	Width	Once per hour during production run.
GRI-GG2	Junction Strength	N/A
GRI-GG7	CEG	Tested when polyester suppliers are changed.
GRI-GG8	MW	Tested by polyester supplier.

Table B-29. Typical production lot size for the ParaWeb product line.

Style/Type	Lot Size (yd^2)	# of rolls per Lot
ParaWeb 2S 30	6066	500
ParaWeb 2D 30	5923	500
ParaWeb 2E 30	5923	500
ParaWeb 2S 40	6066	500
ParaWeb 2D 40	5994	500
ParaWeb 2E 40	5923	500
ParaWeb 2S 50	6422	500
ParaWeb 2D 50	6422	500
ParaWeb 2E 50	6208	500
ParaWeb 2S 75	6422	500
ParaWeb 2D 75	6422	500
ParaWeb 2E 75	6422	500
ParaWeb 2S 100	6422	500
ParaWeb 2D 100	6422	500
ParaWeb 2E 100	6422	500
ParaWeb 2S 135		
ParaWeb 2D 135		
ParaWeb 2E 135		
ParaWeb MS 45	3568	500
ParaWeb MD 45	3568	500
ParaWeb ME 45	3568	500
ParaWeb MS 54	4567	500
ParaWeb MD 54	4567	500
ParaWeb ME 54	4496	500
ParaWeb MS 63	4638	500
ParaWeb MD 63	4638	500
ParaWeb ME 63	4567	500

Table B-30. Typical production lot size for the ParaLink product line.

Style/Type	Lot Size (yd^2)	# of rolls per Lot
ParaLink 300	23120	18
ParaLink 400	17340	18
ParaLink 500	15028	18
ParaLink 600	11560	18
ParaLink 700	5780	18
ParaLink 800	5780	18
ParaLink 1000	5780	18
ParaLink 1200	5780	18
ParaLink 1500	5780	18

Appendix C: Tensile Strength Detailed Test Results

Table C-1. Wide width tensile test results for ParaWeb 30.

PARAMETER	TEST REPLICATE NUMBER					MEAN	STD. DEV.	MARV
	1	**2**	**3**	**4**	**5**			
Wide Width Tensile Properties (ASTM D 6637, Method B modified for straps)								
MD Maximum Strength (lbs)	7014	7036	6998	7055	7044	**7029**	23	6,744 min
MD Maximum Strength (kN)	31.2	31.3	31.1	31.4	31.3	**31.3**	0.1	30 Min
MD Strength @ 2% Strain (lbs)	1313	1310	1310	1306	1310	**1310**	2	
MD Strength @ 2% Strain (kN)	5.84	5.83	5.83	5.81	5.83	**5.83**	0.01	
MD Strength @ 5% Strain (lbs)	3287	3274	3285	3249	3253	**3270**	18	
MD Strength @ 5% Strain (kN)	14.6	14.6	14.6	14.5	14.5	**14.5**	0.1	
MD Strength @ 10% Strain (lbs)	6698	6686	6700	6687	6720	**6698**	14	
MD Strength @ 10% Strain (kN)	29.8	29.8	29.8	29.8	29.9	**29.8**	0.1	
MD Break Elongation (%)	11.6	11.8	11.4	11.6	11.5	**11.6**	0.1	

MD - Machine Direction   TD - Transverse/Cross Machine Direction   NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table C-2. Wide width tensile test results for ParaWeb 50.

PARAMETER	TEST REPLICATE NUMBER 1	2	3	4	5	MEAN	STD. DEV.	MARV
Wide Width Tensile Properties (ASTM D 6637, Method B modified for straps)								
MD Maximum Strength (lbs)	11800	11876	11846	11814	11699	**11807**	67	11,240 min
MD Maximum Strength (kN)	52.5	52.8	52.7	52.6	52.1	**52.5**	0.3	50 Min
MD Strength @ 2% Strain (lbs)	2121	2094	2111	2211	2169	**2141**	48	
MD Strength @ 2% Strain (kN)	9.44	9.32	9.39	9.84	9.65	**9.53**	0.21	
MD Strength @ 5% Strain (lbs)	5696	5602	5637	5870	5801	**5721**	112	
MD Strength @ 5% Strain (kN)	25.3	24.9	25.1	26.1	25.8	**25.5**	0.5	
MD Strength @ 10% Strain (lbs)	11627	11532	11563	11616	11604	**11588**	40	
MD Strength @ 10% Strain (kN)	51.7	51.3	51.5	51.7	51.6	**51.6**	0.2	
MD Break Elongation (%)	10.5	11.1	10.9	10.7	10.5	**10.7**	0.3	

MD - Machine Direction TD - Transverse/Cross Machine Direction NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table C-3. Wide width tensile test results for ParaWeb 135.

PARAMETER	TEST REPLICATE NUMBER 1	2	3	4	5	MEAN	STD. DEV.	MARV
Wide Width Tensile Properties (ASTM D 6637, Method B modified for straps)								
MD Maximum Strength (lbs)	35178	35080	35148	35153	35090	**35130**	43	30,349 min
MD Maximum Strength (kN)	157	156	156	156	156	**156**	0	135 Min
MD Strength @ 2% Strain (lbs)	5534	5660	5625	5875	5876	**5714**	154	
MD Strength @ 2% Strain (kN)	24.6	25.2	25.0	26.1	26.1	**25.4**	0.7	
MD Strength @ 5% Strain (lbs)	13286	13342	13148	13966	13840	**13516**	363	
MD Strength @ 5% Strain (kN)	59.1	59.4	58.5	62.1	61.6	**60.1**	1.6	
MD Strength @ 10% Strain (lbs)	32810	32743	32667	33179	32960	**32872**	203	
MD Strength @ 10% Strain (kN)	146	146	145	148	147	**146**	1	
MD Break Elongation (%)	11.7	11.8	11.9	11.6	11.9	**11.8**	0.1	

MD - Machine Direction TD - Transverse/Cross Machine Direction NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table C-4. Wide width tensile test results for ParaLink 300.

PARAMETER	TEST REPLICATE NUMBER					MEAN	STD. DEV.	MARV
	1	**2**	**3**	**4**	**5**			
Wide Width Tensile Properties (ASTM D 6637, Method B)								
MD Number of Ribs per Specimen:	1							
MD Number of Ribs per foot:	1.72							
MD Ultimate Strength (lbs)	12450	12405	12241	12080	12402	**12316**	154	
MD Ultimate Strength (lbs/ft)	21397	21320	21038	20762	21315	**21166**	264	20,548 min
MD Ultimate Strength (kN/m)	312	311	307	303	311	**309**	4	300 min
MD Strength @ 2% Strain (lbs)	1744	1957	1868	2014	1756	**1868**	120	
MD Strength @ 2% Strain (lbs/ft)	2997	3363	3210	3461	3018	**3210**	205	
MD Strength @ 2% Strain (kN/m)	43.8	49.1	46.9	50.5	44.1	**46.9**	3.0	
MD Strength @ 5% Strain (lbs)	3633	4794	4283	4851	4176	**4347**	499	
MD Strength @ 5% Strain (lbs/ft)	6244	8239	7361	8337	7177	**7472**	858	
MD Strength @ 5% Strain (kN/m)	91.2	120	107	122	105	**109**	13	
MD Strength @ 10% Strain (lbs)	11161	12008	12010		11743	**11731**	400	
MD Strength @ 10% Strain (lbs/ft)	19182	20638	20641		20182	**20161**	687	
MD Strength @ 10% Strain (kN/m)	280.1	301.3	301.4		294.7	**294.3**	10.0	
MD Break Elongation (%)	12.1	10.9	10.3	9.68	11.3	**10.8**	0.9	

MD - Machine Direction   TD - Transverse/Cross Machine Direction   NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table C-5. Wide width tensile test results for ParaLink 1000.

PARAMETER	TEST REPLICATE NUMBER					MEAN	STD. DEV.	MARV
	1	2	3	4	5			
Wide Width Tensile Properties (ASTM D 6637, Method B)								
MD Number of Ribs per Specimen:	1							
MD Number of Ribs per foot:	2.51							
MD Ultimate Strength (lbs)	28980	29106	29218	29143	29391	**29168**	152	
MD Ultimate Strength (lbs/ft)	72753	73069	73351	73162	73785	**73224**	381	68,493 min
MD Ultimate Strength (kN/m)	1062	1067	1071	1068	1077	**1069**	6	1000 min
MD Strength @ 2% Strain (lbs)	3811	3886	3930	3140	3186	**3591**	393	
MD Strength @ 2% Strain (lbs/ft)	9567	9756	9866	7883	7998	**9014**	987	
MD Strength @ 2% Strain (kN/m)	140	142	144	115	117	**132**	14	
MD Strength @ 5% Strain (lbs)	10077	10161	10358	9356	9103	**9811**	548	
MD Strength @ 5% Strain (lbs/ft)	25298	25509	26003	23488	22853	**24630**	1375	
MD Strength @ 5% Strain (kN/m)	369	372	380	343	334	**360**	20	
MD Strength @ 10% Strain (lbs)	26393	25878	26368	26064	25283	**25997**	454	
MD Strength @ 10% Strain (lbs/ft)	66259	64966	66196	65433	63472	**65265**	1139	
MD Strength @ 10% Strain (kN/m)	967	948	966	955	927	**953**	17	
MD Break Elongation (%)	11.9	12.6	12.5	12.2	12.7	**12.4**	0.3	

MD - Machine Direction TD - Transverse/Cross Machine Direction NP - Not Provided

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

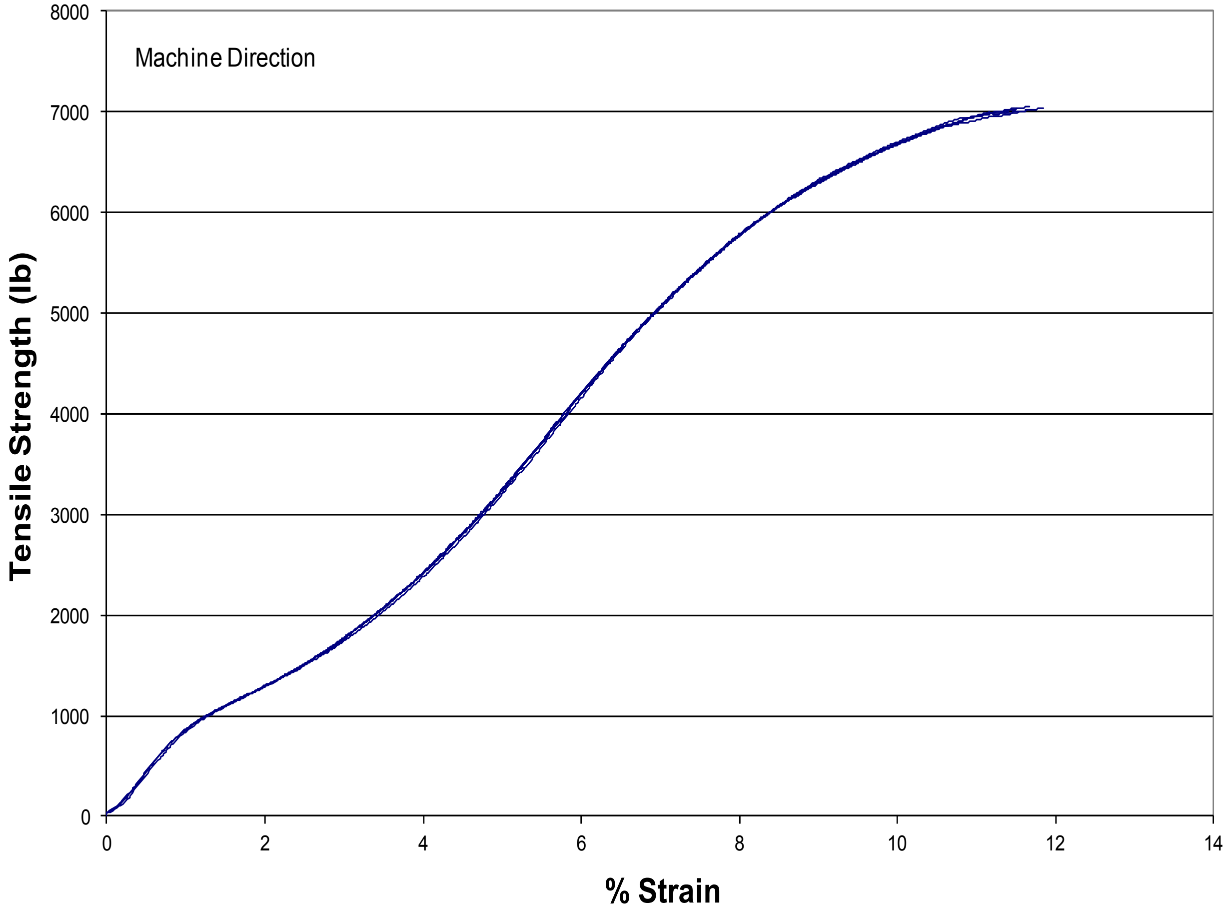

Figure C-1. Wide width tensile test load-strain curve for ParaWeb 30

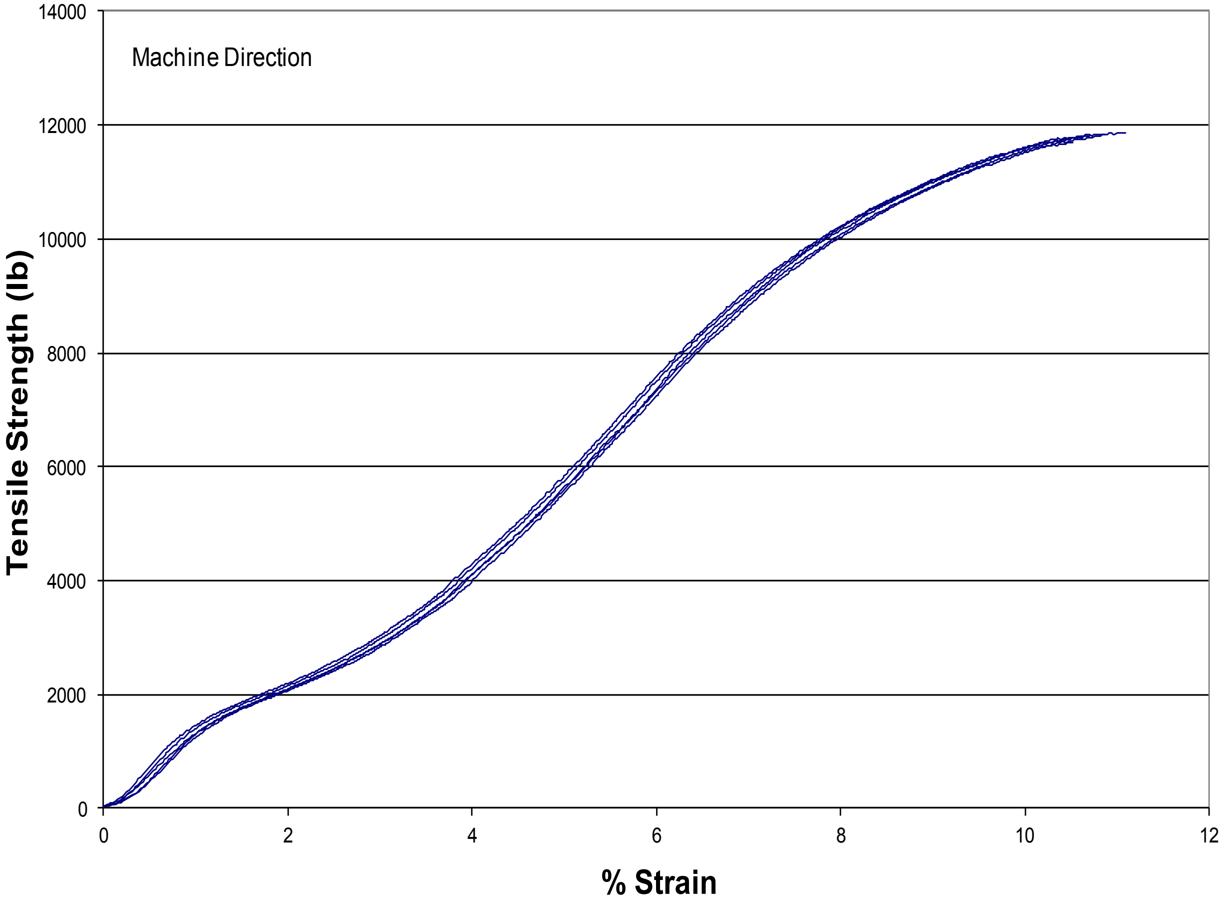

Figure C-2. Wide width tensile test load-strain curve for ParaWeb 50

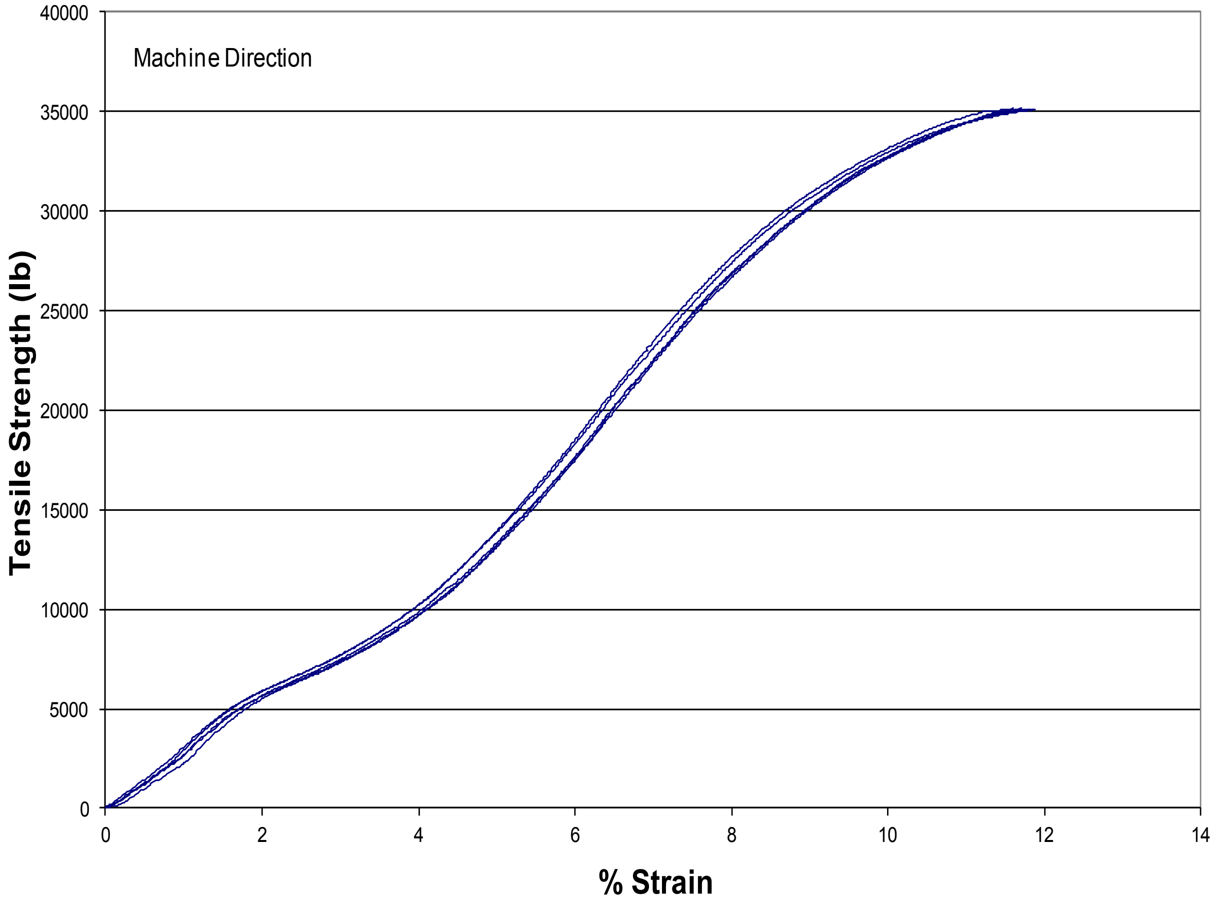

Figure C-3. Wide width tensile test load-strain curve for ParaWeb 135

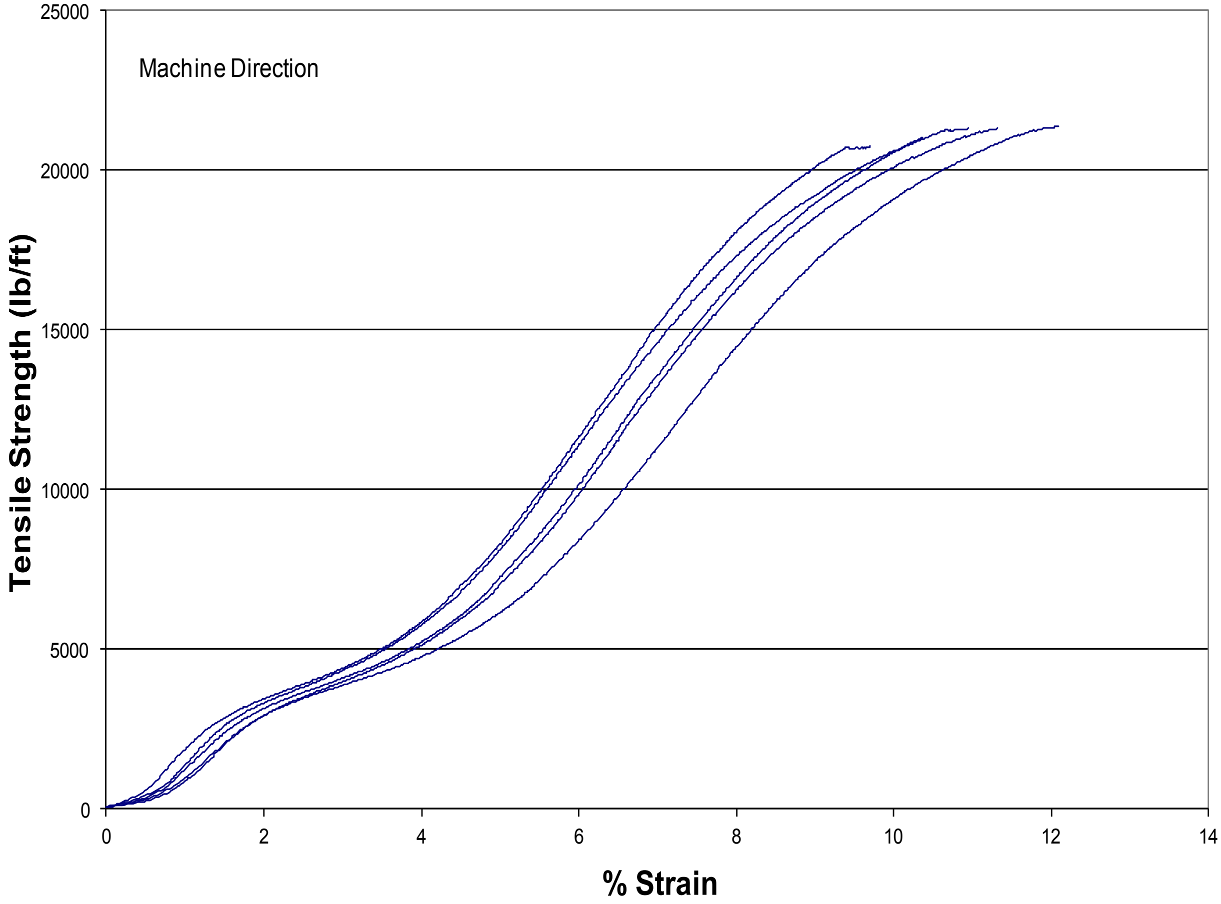

Figure C-4. Wide width tensile test load-strain curve for ParaLink 300

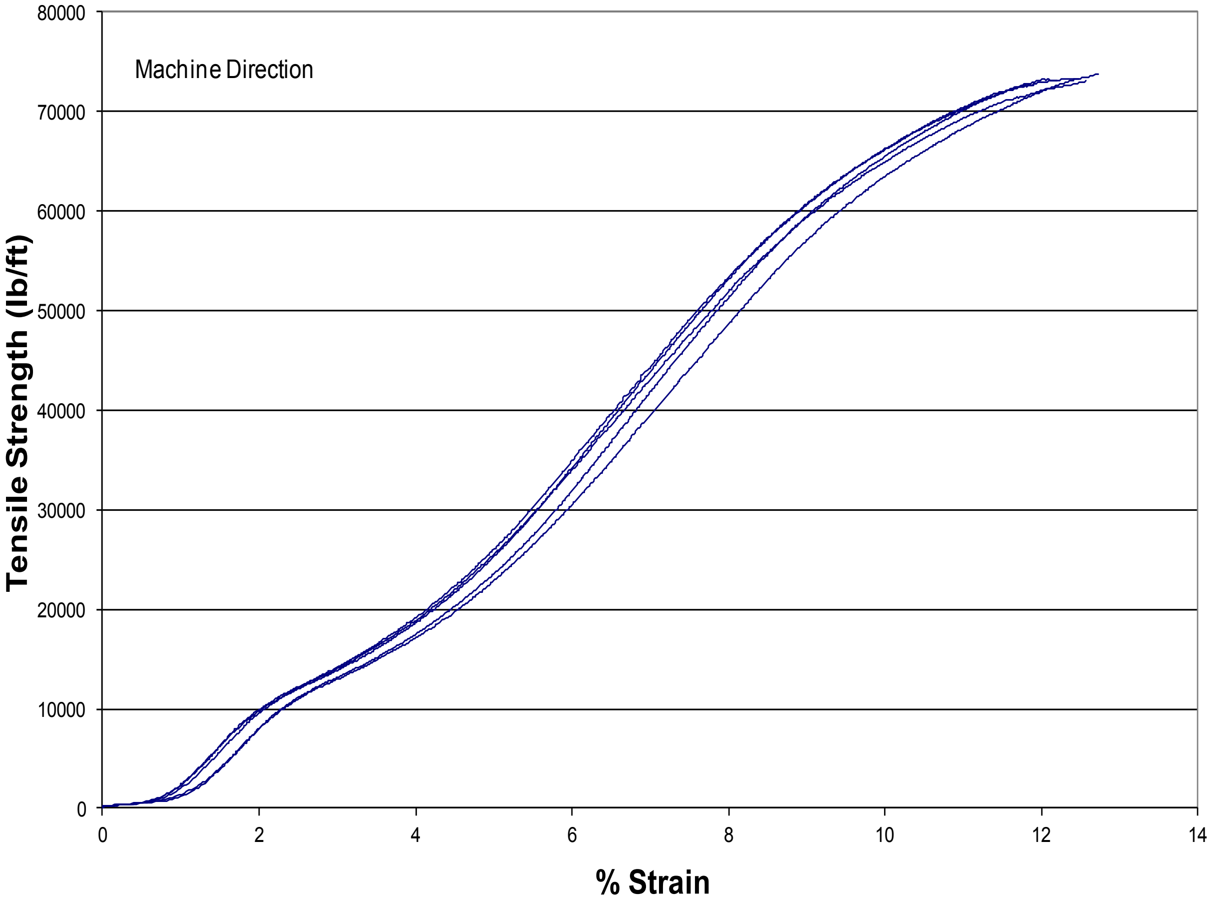

Figure C-5. Wide width tensile test load-strain curve for ParaLink 1000

Appendix D: Installation Damage Detailed Test Results

Table D-1. Installation damage wide width tensile test results for ParaWeb 30, soil gradation 1.
Installation damage testing (ASTM D 5818, as modified in AASHTO R69-15).
Wide wide tensile testing (ASTM D 6637, Method B, moddified for straps).

Machine Direction

Sample Identification	Specimen Number	Maximum Load (lbs)	Maximum Load (kN)	Elongation @ Break (%)	Load @ 2% (lbs)	Load @ 2% (kN)	Load @ 5% (lbs)	Load @ 5% (kN)	Load @ 10% (lbs)	Load @ 10% (kN)
ParaWeb 30 Baseline	1	7014	31.2	11.6	1313	5.84	3287	14.6	6698	29.8
	2	7036	31.3	11.8	1310	5.83	3274	14.6	6686	29.8
	3	6998	31.1	11.4	1310	5.83	3285	14.6	6700	29.8
	4	7055	31.4	11.6	1306	5.81	3249	14.5	6687	29.8
	5	7044	31.3	11.5	1310	5.83	3253	14.5	6720	29.9
Average		7029	31.3	11.6	1310	5.83	3270	14.5	6698	29.8
Standard Deviation		20.7	0.1	0.1	2.2	0.01	15.9	0.1	12.3	0.1
% COV		0.3	0.3	1.1	0.2	0.17	0.5	0.5	0.2	0.2

Machine Direction

Sample Identification	Specimen Number	Maximum Load (lbs)	Maximum Load (kN)	Elongation @ Break (%)	Load @ 2% (lbs)	Load @ 2% (kN)	Load @ 5% (lbs)	Load @ 5% (kN)	Load @ 10% (lbs)	Load @ 10% (kN)
ParaWeb 30 installed in Gradation 1 (Coarse Gravel)	1	5053	22.5	9.22	1146	5.10	2531	11.3		
	2	4906	21.8	8.80	1154	5.13	2529	11.3		
	3	5100	22.7	8.09	1245	5.54	3015	13.4		
	4	3618	16.1	9.36	738	3.28	1769	7.9		
	5	3968	17.7	7.71	1045	4.65	2461	10.9		
	6	4998	22.2	8.88	1170	5.21	2670	11.9		
	7	4696	20.9	8.52	1175	5.23	2594	11.5		
	8	5288	23.5	8.48	1239	5.51	2895	12.9		
	9	4927	21.9	8.67	1217	5.42	2780	12.4		
	10	5699	25.4	9.35	1240	5.52	2828	12.6		
Average		4825	21.5	8.71	1137	5.06	2607	11.6		
Standard Deviation		579.6	2.6	0.51	144.8	0.64	326.8	1.5		
% COV		12.0	12.0	5.9	12.7	12.74	12.5	12.5		

Percent Retained	68.6	68.6	75.2	86.8	86.8	79.7	79.7		
RFid	**1.46**	**1.46**							

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table D-2. Installation damage wide width tensile test results for ParaWeb 30, soil gradation 2.
Installation damage testing (ASTM D 5818, as modified in AASHTO R69-15).
Wide wide tensile testing (ASTM D 6637, Method B, moddified for straps).

Machine Direction

Sample Identification	Specimen Number	Maximum Load (lbs)	Maximum Load (kN)	Elongation @ Break (%)	Load @ 2% (lbs)	Load @ 2% (kN)	Load @ 5% (lbs)	Load @ 5% (kN)	Load @ 10% (lbs)	Load @ 10% (kN)
ParaWeb 30 Baseline	1	7014	31.2	11.6	1313	5.84	3287	14.6	6698	29.8
	2	7036	31.3	11.8	1310	5.83	3274	14.6	6686	29.8
	3	6998	31.1	11.4	1310	5.83	3285	14.6	6700	29.8
	4	7055	31.4	11.6	1306	5.81	3249	14.5	6687	29.8
	5	7044	31.3	11.5	1310	5.83	3253	14.5	6720	29.9
Average		7029	31.3	11.6	1310	5.83	3270	14.5	6698	29.8
Standard Deviation		20.7	0.1	0.1	2.2	0.01	15.9	0.1	12.3	0.1
% COV		0.3	0.3	1.1	0.2	0.17	0.5	0.5	0.2	0.2

Machine Direction

Sample Identification	Specimen Number	Maximum Load (lbs)	Maximum Load (kN)	Elongation @ Break (%)	Load @ 2% (lbs)	Load @ 2% (kN)	Load @ 5% (lbs)	Load @ 5% (kN)	Load @ 10% (lbs)	Load @ 10% (kN)
ParaWeb 30 installed in Gradation 2 (Sandy Gravel)	1	6975	31.0	12.5	1180	5.25	2352	10.5	6198	27.6
	2	6706	29.8	11.8	1191	5.30	2464	11.0	6213	27.6
	3	7022	31.2	12.4	1221	5.43	2620	11.7	6381	28.4
	4	7027	31.3	12.1	1231	5.48	2681	11.9	6420	28.6
	5	6927	30.8	11.8	1232	5.48	2728	12.1	6460	28.7
	6	7078	31.5	12.0	1251	5.57	2841	12.6	6542	29.1
	7	6965	31.0	11.8	1233	5.49	2809	12.5	6527	29.0
	8	6538	29.1	11.9	1124	5.00	2462	11.0	6203	27.6
	9	6832	30.4	11.8	1200	5.34	2726	12.1	6454	28.7
	10	6951	30.9	11.6	1229	5.47	2824	12.6	6522	29.0
Average		6902	30.7	12.0	1209	5.38	2651	11.8	6392	28.4
Standard Deviation		157.8	0.7	0.3	35.2	0.16	162.6	0.7	131.3	0.6
% COV		2.3	2.3	2.4	2.9	2.91	6.1	6.1	2.1	2.1

Percent Retained	98.2	98.2	103.3	92.3	92.3	81.1	81.1	95.4	95.4
RFid	**1.02**	**1.02**							

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table D-3. Installation damage wide width tensile test results for ParaWeb 30, soil gradation 3.
Installation damage testing (ASTM D 5818, as modified in AASHTO R69-15).
Wide wide tensile testing (ASTM D 6637, Method B, moddified for straps).

Machine Direction

Sample Identification	Specimen Number	Maximum Load (lbs)	Maximum Load (kN)	Elongation @ Break (%)	Load @ 2% (lbs)	Load @ 2% (kN)	Load @ 5% (lbs)	Load @ 5% (kN)	Load @ 10% (lbs)	Load @ 10% (kN)
ParaWeb 30 Baseline	1	7014	31.2	11.6	1313	5.84	3287	14.6	6698	29.8
	2	7036	31.3	11.8	1310	5.83	3274	14.6	6686	29.8
	3	6998	31.1	11.4	1310	5.83	3285	14.6	6700	29.8
	4	7055	31.4	11.6	1306	5.81	3249	14.5	6687	29.8
	5	7044	31.3	11.5	1310	5.83	3253	14.5	6720	29.9
Average		7029	31.3	11.6	1310	5.83	3270	14.5	6698	29.8
Standard Deviation		20.7	0.1	0.1	2.2	0.01	15.9	0.1	12.3	0.1
% COV		0.3	0.3	1.1	0.2	0.17	0.5	0.5	0.2	0.2

Machine Direction

Sample Identification	Specimen Number	Maximum Load (lbs)	Maximum Load (kN)	Elongation @ Break (%)	Load @ 2% (lbs)	Load @ 2% (kN)	Load @ 5% (lbs)	Load @ 5% (kN)	Load @ 10% (lbs)	Load @ 10% (kN)
ParaWeb 30 installed in Gradation 3 (Sand)	1	6936	30.9	11.9	1270	5.65	2985	13.3	6601	29.4
	2	6993	31.1	11.6	1278	5.69	3031	13.5	6633	29.5
	3	7026	31.3	11.7	1270	5.65	2988	13.3	6603	29.4
	4	7030	31.3	11.6	1267	5.64	3007	13.4	6614	29.4
	5	7016	31.2	11.7	1301	5.79	3114	13.9	6650	29.6
	6	7040	31.3	11.7	1278	5.69	3068	13.7	6631	29.5
	7	7029	31.3	11.6	1293	5.75	3087	13.7	6646	29.6
	8	7019	31.2	11.6	1287	5.73	3067	13.6	6628	29.5
	9	7005	31.2	11.9	1270	5.65	3028	13.5	6609	29.4
	10	7059	31.4	11.8	1266	5.64	3042	13.5	6617	29.4
Average		7015	31.2	11.7	1278	5.69	3042	13.5	6623	29.5
Standard Deviation		31.5	0.1	0.1	11.2	0.05	40.4	0.2	16.3	0.1
% COV		0.4	0.4	1.0	0.9	0.88	1.3	1.3	0.2	0.2

Percent Retained	99.8	99.8	101.1	97.6	97.6	93.0	93.0	98.9	98.9
RFid	**1.00**	**1.00**							

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

**Table D-4. Installation damage wide width tensile test results for ParaWeb 50, soil gradation 1.
Installation damage testing (ASTM D 5818, as modified in AASHTO R69-15).
Wide wide tensile testing (ASTM D 6637, Method B, moddified for straps).**

Machine Direction

Sample Identification	Specimen Number	Maximum Load (lbs)	Maximum Load (kN)	Elongation @ Break (%)	Load @ 2% (lbs)	Load @ 2% (kN)	Load @ 5% (lbs)	Load @ 5% (kN)	Load @ 10% (lbs)	Load @ 10% (kN)
ParaWeb 50 Baseline	1	11800	52.5	10.5	2121	9.44	5696	25.3	11627	51.7
	2	11876	52.8	11.1	2094	9.32	5602	24.9	11532	51.3
	3	11846	52.7	10.9	2111	9.39	5637	25.1	11563	51.5
	4	11814	52.6	10.7	2211	9.84	5870	26.1	11616	51.7
	5	11699	52.1	10.5	2169	9.65	5801	25.8	11604	51.6
Average		11807	52.5	10.7	2141	9.53	5721	25.5	11588	51.6
Standard Deviation		60.1	0.3	0.2	42.9	0.19	100.4	0.4	35.6	0.2
% COV		0.5	0.5	2.2	2.0	2.00	1.8	1.8	0.3	0.3

Machine Direction

Sample Identification	Specimen Number	Maximum Load (lbs)	Maximum Load (kN)	Elongation @ Break (%)	Load @ 2% (lbs)	Load @ 2% (kN)	Load @ 5% (lbs)	Load @ 5% (kN)	Load @ 10% (lbs)	Load @ 10% (kN)
ParaWeb 50 installed in Gradation 1 (Coarse Gravel)	1	10389	46.2	10.0	1993	8.87	4831	21.5		
	2	10513	46.8	9.60	2034	9.05	5057	22.5		
	3	10580	47.1	9.42	2095	9.32	5263	23.4		
	4	10137	45.1	9.19	2078	9.25	5295	23.6		
	5	9910	44.1	8.91	2050	9.12	5195	23.1		
	6	9539	42.4	9.06	2006	8.93	4907	21.8		
	7	8561	38.1	9.08	1995	8.88	5002	22.3		
	8	9088	40.4	9.68	1930	8.59	4655	20.7		
	9	9708	43.2	8.88	2056	9.15	5183	23.1		
	10	10054	44.7	9.02	2075	9.23	5209	23.2		
Average		9848	43.8	9.29	2031	9.04	5060	22.5		
Standard Deviation		612.4	2.7	0.36	47.8	0.21	198.9	0.9		
% COV		6.2	6.2	3.9	2.4	2.35	3.9	3.9		

Percent Retained	83.4	83.4	86.5	94.9	94.9	88.4	88.4		
RFid	**1.20**	**1.20**							

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table D-5. Installation damage wide width tensile test results for ParaWeb 50, soil gradation 2.
Installation damage testing (ASTM D 5818, as modified in AASHTO R69-15).
Wide wide tensile testing (ASTM D 6637, Method B, moddified for straps).

Machine Direction

Sample Identification	Specimen Number	Maximum Load (lbs)	Maximum Load (kN)	Elongation @ Break (%)	Load @ 2% (lbs)	Load @ 2% (kN)	Load @ 5% (lbs)	Load @ 5% (kN)	Load @ 10% (lbs)	Load @ 10% (kN)
ParaWeb 50 Baseline	1	11800	52.5	10.5	2121	9.44	5696	25.3	11627	51.7
	2	11876	52.8	11.1	2094	9.32	5602	24.9	11532	51.3
	3	11846	52.7	10.9	2111	9.39	5637	25.1	11563	51.5
	4	11814	52.6	10.7	2211	9.84	5870	26.1	11616	51.7
	5	11699	52.1	10.5	2169	9.65	5801	25.8	11604	51.6
Average		11807	52.5	10.7	2141	9.53	5721	25.5	11588	51.6
Standard Deviation		60.1	0.3	0.2	42.9	0.19	100.4	0.4	35.6	0.2
% COV		0.5	0.5	2.2	2.0	2.00	1.8	1.8	0.3	0.3

Machine Direction

Sample Identification	Specimen Number	Maximum Load (lbs)	Maximum Load (kN)	Elongation @ Break (%)	Load @ 2% (lbs)	Load @ 2% (kN)	Load @ 5% (lbs)	Load @ 5% (kN)	Load @ 10% (lbs)	Load @ 10% (kN)
ParaWeb 50 installed in Gradation 2 (Sandy Gravel)	1	11670	51.9	10.8	2112	9.40	5469	24.3	11463	51.0
	2	11660	51.9	10.8	2118	9.43	5341	23.8	11427	50.8
	3	11606	51.6	10.6	2150	9.57	5482	24.4	11439	50.9
	4	11544	51.4	10.8	2150	9.57	5410	24.1	11390	50.7
	5	11799	52.5	11.1	2098	9.33	5362	23.9	11437	50.9
	6	11587	51.6	10.6	2105	9.37	5306	23.6	11394	50.7
	7	11634	51.8	10.7	2160	9.61	5535	24.6	11426	50.8
	8	11683	52.0	10.7	2145	9.54	5414	24.1	11414	50.8
	9	11589	51.6	10.6	2137	9.51	5510	24.5	11449	50.9
	10	11670	51.9	10.3	2144	9.54	5500	24.5	11508	51.2
Average		11644	51.8	10.7	2132	9.49	5433	24.2	11434	50.9
Standard Deviation		67.0	0.3	0.2	20.7	0.09	74.1	0.3	32.6	0.1
% COV		0.6	0.6	1.9	1.0	0.97	1.4	1.4	0.3	0.3

Percent Retained	98.6	98.6	99.6	99.6	99.6	95.0	95.0	98.7	98.7
RFid	**1.01**	**1.01**							

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table D-6. Installation damage wide width tensile test results for ParaWeb 50, soil gradation 3.
Installation damage testing (ASTM D 5818, as modified in AASHTO R69-15).
Wide wide tensile testing (ASTM D 6637, Method B, moddified for straps).

Machine Direction

Sample Identification	Specimen Number	Maximum Load (lbs)	Maximum Load (kN)	Elongation @ Break (%)	Load @ 2% (lbs)	Load @ 2% (kN)	Load @ 5% (lbs)	Load @ 5% (kN)	Load @ 10% (lbs)	Load @ 10% (kN)
ParaWeb 50 Baseline	1	11800	52.5	10.5	2121	9.44	5696	25.3	11627	51.7
	2	11876	52.8	11.1	2094	9.32	5602	24.9	11532	51.3
	3	11846	52.7	10.9	2111	9.39	5637	25.1	11563	51.5
	4	11814	52.6	10.7	2211	9.84	5870	26.1	11616	51.7
	5	11699	52.1	10.5	2169	9.65	5801	25.8	11604	51.6
Average		11807	52.5	10.7	2141	9.53	5721	25.5	11588	51.6
Standard Deviation		60.1	0.3	0.2	42.9	0.19	100.4	0.4	35.6	0.2
% COV		0.5	0.5	2.2	2.0	2.00	1.8	1.8	0.3	0.3

Machine Direction

Sample Identification	Specimen Number	Maximum Load (lbs)	Maximum Load (kN)	Elongation @ Break (%)	Load @ 2% (lbs)	Load @ 2% (kN)	Load @ 5% (lbs)	Load @ 5% (kN)	Load @ 10% (lbs)	Load @ 10% (kN)
ParaWeb 50 installed in Gradation 3 (Sand)	1	11799	52.5	10.8	2110	9.39	5351	23.8	11513	51.2
	2	11904	53.0	11.2	2085	9.28	5334	23.7	11484	51.1
	3	11918	53.0	11.2	2091	9.31	5345	23.8	11506	51.2
	4	11808	52.5	10.9	2118	9.43	5441	24.2	11486	51.1
	5	11856	52.8	11.0	2113	9.40	5388	24.0	11453	51.0
	6	11710	52.1	10.6	2089	9.29	5395	24.0	11510	51.2
	7	11794	52.5	10.9	2111	9.39	5430	24.2	11509	51.2
	8	11866	52.8	11.2	2038	9.07	5220	23.2	11414	50.8
	9	11865	52.8	10.9	2116	9.42	5451	24.3	11504	51.2
	10	11787	52.5	10.9	2140	9.52	5567	24.8	11554	51.4
Average		11831	52.6	11.0	2101	9.35	5392	24.0	11493	51.1
Standard Deviation		59.5	0.3	0.2	26.2	0.12	86.5	0.4	36.0	0.2
% COV		0.5	0.5	1.8	1.2	1.25	1.6	1.6	0.3	0.3

Percent Retained	100.2	100.2	102.0	98.1	98.1	94.3	94.3	99.2	99.2
RFid	**1.00**	**1.00**							

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table D-7. Installation damage wide width tensile test results for ParaWeb 135, soil gradation 1.
Installation damage testing (ASTM D 5818, as modified in AASHTO R69-15).
Wide wide tensile testing (ASTM D 6637, Method B, moddified for straps).

Machine Direction

Sample Identification	Specimen Number	Maximum Load (lbs)	Maximum Load (kN)	Elongation @ Break (%)	Load @ 2% (lbs)	Load @ 2% (kN)	Load @ 5% (lbs)	Load @ 5% (kN)	Load @ 10% (lbs)	Load @ 10% (kN)
ParaWeb 135 Baseline	1	35178	156.5	11.7	5534	24.6	13286	59.1	32810	146.0
	2	35080	156.1	11.8	5660	25.2	13342	59.4	32743	145.7
	3	35148	156.4	11.9	5625	25.0	13148	58.5	32667	145.4
	4	35153	156.4	11.6	5875	26.1	13966	62.1	33179	147.6
	5	35090	156.2	11.9	5876	26.1	13840	61.6	32960	146.7
Average		35130	156.3	11.8	5714	25.4	13516	60.1	32872	146.3
Standard Deviation		38.1	0.2	0.1	138.1	0.6	324.4	1.4	181.4	0.8
% COV		0.1	0.1	1.0	2.4	2.4	2.4	2.4	0.6	0.6

Machine Direction

Sample Identification	Specimen Number	Maximum Load (lbs)	Maximum Load (kN)	Elongation @ Break (%)	Load @ 2% (lbs)	Load @ 2% (kN)	Load @ 5% (lbs)	Load @ 5% (kN)	Load @ 10% (lbs)	Load @ 10% (kN)
ParaWeb 135 installed in Gradation 1 (Coarse Gravel)	1	34865	155.1	11.2	6034	26.85	14956	66.6	33647	149.7
	2	35047	156.0	11.7	5585	24.85	13389	59.6	32824	146.1
	3	34918	155.4	11.9	5442	24.22	12755	56.8	32368	144.0
	4	34915	155.4	12.0	5188	23.09	12296	54.7	32174	143.2
	5	34897	155.3	11.5	5940	26.43	13902	61.9	32952	146.6
	6	35049	156.0	11.9	5423	24.13	12626	56.2	32424	144.3
	7	35341	157.3	11.6	5842	25.99	13923	62.0	33181	147.7
	8	34904	155.3	11.9	5332	23.73	12606	56.1	32292	143.7
	9	34756	154.7	11.8	5300	23.59	12409	55.2	32192	143.3
	10	35099	156.2	11.8	5781	25.73	13681	60.9	32952	146.6
Average		34979	155.7	11.7	5587	24.9	13254	59.0	32701	145.5
Standard Deviation		154.1	0.7	0.2	279.7	1.2	816.1	3.6	464.7	2.1
% COV		0.4	0.4	1.9	5.0	5.0	6.2	6.2	1.4	1.4

Percent Retained	99.6	99.6	99.5	97.8	97.8	98.1	98.1	99.5	99.5
RFid	**1.00**	**1.00**							

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table D-8. Installation damage wide width tensile test results for ParaWeb 135, soil gradation 2.
Installation damage testing (ASTM D 5818, as modified in AASHTO R69-15).
Wide wide tensile testing (ASTM D 6637, Method B, moddified for straps).

Machine Direction

Sample Identification	Specimen Number	Maximum Load (lbs)	Maximum Load (kN)	Elongation @ Break (%)	Load @ 2% (lbs)	Load @ 2% (kN)	Load @ 5% (lbs)	Load @ 5% (kN)	Load @ 10% (lbs)	Load @ 10% (kN)
ParaWeb 135 Baseline	1	35178	156.5	11.7	5534	24.6	13286	59.1	32810	146.0
	2	35080	156.1	11.8	5660	25.2	13342	59.4	32743	145.7
	3	35148	156.4	11.9	5625	25.0	13148	58.5	32667	145.4
	4	35153	156.4	11.6	5875	26.1	13966	62.1	33179	147.6
	5	35090	156.2	11.9	5876	26.1	13840	61.6	32960	146.7
Average		35130	156.3	11.8	5714	25.4	13516	60.1	32872	146.3
Standard Deviation		38.1	0.2	0.1	138.1	0.6	324.4	1.4	181.4	0.8
% COV		0.1	0.1	1.0	2.4	2.4	2.4	2.4	0.6	0.6

Machine Direction

Sample Identification	Specimen Number	Maximum Load (lbs)	Maximum Load (kN)	Elongation @ Break (%)	Load @ 2% (lbs)	Load @ 2% (kN)	Load @ 5% (lbs)	Load @ 5% (kN)	Load @ 10% (lbs)	Load @ 10% (kN)
ParaWeb 135 installed in Gradation 2 (Sandy Gravel)	1	35375	157.4	12.0	5402	24.04	12769	56.8	32394	144.2
	2	35086	156.1	12.0	5360	23.85	12671	56.4	32387	144.1
	3	35027	155.9	12.0	5476	24.37	13007	57.9	32469	144.5
	4	34909	155.3	11.6	5402	24.04	12904	57.4	32429	144.3
	5	34854	155.1	12.0	5207	23.17	12219	54.4	32107	142.9
	6	35097	156.2	11.7	5601	24.92	13340	59.4	32833	146.1
	7	34992	155.7	11.7	5502	24.48	13310	59.2	32810	146.0
	8	34725	154.5	11.6	5671	25.23	13403	59.6	32718	145.6
	9	35125	156.3	11.8	5603	24.94	13484	60.0	32880	146.3
	10	35122	156.3	12.1	5305	23.61	12575	56.0	32294	143.7
Average		35031	155.9	11.8	5453	24.3	12968	57.7	32532	144.8
Standard Deviation		168.5	0.7	0.2	138.1	0.6	395.0	1.8	248.2	1.1
% COV		0.5	0.5	1.5	2.5	2.5	3.0	3.0	0.8	0.8

Percent Retained	99.7	99.7	100.4	95.4	95.4	95.9	95.9	99.0	99.0
RFid	**1.00**	**1.00**							

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table D-9. Installation damage wide width tensile test results for ParaWeb 135, soil gradation 3.
Installation damage testing (ASTM D 5818, as modified in AASHTO R69-15).
Wide wide tensile testing (ASTM D 6637, Method B, moddified for straps).

Machine Direction

Sample Identification	Specimen Number	Maximum Load (lbs)	Maximum Load (kN)	Elongation @ Break (%)	Load @ 2% (lbs)	Load @ 2% (kN)	Load @ 5% (lbs)	Load @ 5% (kN)	Load @ 10% (lbs)	Load @ 10% (kN)
ParaWeb 135 Baseline	1	35178	156.5	11.7	5534	24.6	13286	59.1	32810	146.0
	2	35080	156.1	11.8	5660	25.2	13342	59.4	32743	145.7
	3	35148	156.4	11.9	5625	25.0	13148	58.5	32667	145.4
	4	35153	156.4	11.6	5875	26.1	13966	62.1	33179	147.6
	5	35090	156.2	11.9	5876	26.1	13840	61.6	32960	146.7
Average		35130	156.3	11.8	5714	25.4	13516	60.1	32872	146.3
Standard Deviation		38.1	0.2	0.1	138.1	0.6	324.4	1.4	181.4	0.8
% COV		0.1	0.1	1.0	2.4	2.4	2.4	2.4	0.6	0.6

Machine Direction

Sample Identification	Specimen Number	Maximum Load (lbs)	Maximum Load (kN)	Elongation @ Break (%)	Load @ 2% (lbs)	Load @ 2% (kN)	Load @ 5% (lbs)	Load @ 5% (kN)	Load @ 10% (lbs)	Load @ 10% (kN)
ParaWeb 135 installed in Gradation 3 (Sand)	1	35115	156.3	12.0	5270	23.45	12748	56.7	32452	144.4
	2	34860	155.1	11.9	4977	22.15	12049	53.6	31931	142.1
	3	35049	156.0	12.0	5181	23.06	12466	55.5	32338	143.9
	4	34874	155.2	12.0	4920	21.89	11831	52.6	31958	142.2
	5	34757	154.7	12.1	4815	21.43	11630	51.8	31630	140.8
	6	34922	155.4	12.2	4914	21.87	11666	51.9	31571	140.5
	7	35122	156.3	11.9	5506	24.50	13037	58.0	32576	145.0
	8	35172	156.5	12.2	5083	22.62	12178	54.2	31995	142.4
	9	35187	156.6	12.4	4878	21.71	11815	52.6	31610	140.7
	10	34815	154.9	12.0	5126	22.81	12277	54.6	32117	142.9
Average		34987	155.7	12.1	5067	22.5	12170	54.2	32018	142.5
Standard Deviation		151.1	0.7	0.1	201.0	0.9	445.7	2.0	337.7	1.5
% COV		0.4	0.4	1.2	4.0	4.0	3.7	3.7	1.1	1.1

Percent Retained	99.6	99.6	102.4	88.7	88.7	90.0	90.0	97.4	97.4
RFid	**1.00**	**1.00**							

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table D-10. Installation damage wide width tensile test results for Linear Composites ParaLink 300 geogrid, soil gradation 1.
Installation damage testing (ASTM D 5818, as modified in AASHTO R69-15).
Wide wide tensile testing (ASTM D 6637, Method B).

Machine Direction

Sample Identification	Specimen Number	Ribs per Foot Width	Number of Ribs Tested	Maximum Load (lbs)	Maximum Load (lbs/ft)	Maximum Load (kN/m)	Elongation @ Break (%)	Load @ 2% lbs	Load @ 2% (lbs/ft)	Load @ 2% (kN/m)	Load @ 5% lbs	Load @ 5% (lbs/ft)	Load @ 5% (kN/m)	Load @ 10% lbs	Load @ 10% (lbs/ft)	Load @ 10% (kN/m)
ParaLink 300 Baseline	1	1.72	1	12450	21397	312.4	12.1	1744	2997	43.76	3633	6244	91.2	11161	19182	280.1
	2	1.72	1	12405	21320	311.3	10.9	1957	3363	49.11	4794	8239	120.3	12008	20638	301.3
	3	1.72	1	12241	21038	307.2	10.3	1868	3210	46.87	4283	7361	107.5	12010	20641	301.4
	4	1.72	1	12080	20762	303.1	9.68	2014	3461	50.54	4851	8337	121.7			
	5	1.72	1	12402	21315	311.2	11.3	1756	3018	44.06	4176	7177	104.8	11743	20182	294.7
Average				12316	21166	309.0	10.8	1868	3210	46.87	4347	7472	109.1	11731	20161	294.3
Standard Deviation				153.8	264.3	3.86	0.92	119.5	205.4	3.00	499.2	858.0	12.53	399.8	687	10.03
% COV				1.25	1.25	1.25	8.50	6.40	6.40	6.40	11.48	11.48	11.48	3.41	3.41	3.41

Machine Direction

Sample Identification	Specimen Number	Ribs per Foot Width	Number of Ribs Tested	Maximum Load (lbs)	Maximum Load (lbs/ft)	Maximum Load (kN/m)	Elongation @ Break (%)	Load @ 2% lbs	Load @ 2% (lbs/ft)	Load @ 2% (kN/m)	Load @ 5% lbs	Load @ 5% (lbs/ft)	Load @ 5% (kN/m)	Load @ 10% lbs	Load @ 10% (lbs/ft)	Load @ 10% (kN/m)
ParaLink 300 installed in Gradation 1 (Coarse Gravel)	1	1.72	1	10196	17524	255.9	7.19	2271	3904	57.00	7513	12912	188.5			
	2	1.72	1	12123	20836	304.2	10.4	2200	3781	55.21	5875	10098	147.4	12054	20718	302.5
	3	1.72	1	12135	20856	304.5	9.92	2118	3640	53.15	5693	9785	142.9			
	4	1.72	1	12440	21381	312.2	11.3	2110	3627	52.96	5279	9073	132.5	11854	20374	297.5
	5	1.72	1	11517	19794	289.0	10.0	2244	3856	56.30	5849	10053	146.8	11475	19721	287.9
	6	1.72	1	11787	20258	295.8	10.2	2192	3767	54.99	5754	9890	144.4	11770	20228	295.3
	7	1.72	1	12111	20814	303.9	10.7	2147	3689	53.86	5362	9215	134.5	11797	20275	296.0
	8	1.72	1	11956	20548	300.0	10.4	2136	3671	53.59	5349	9193	134.2	11842	20352	297.1
	9	1.72	1	11310	19438	283.8	8.91	2153	3700	54.03	5841	10039	146.6			
	10	1.72	1	11040	18974	277.0	7.83	2265	3893	56.84	7042	12102	176.7			
Average				11662	20042	292.6	9.67	2184	3753	54.79	5956	10236	149.4	11799	20278	296.1
Standard Deviation				668.8	1149	16.78	1.30	60.14	103.36	1.51	739.6	1271.1	18.56	187.7	322.6	4.71
% COV				5.73	5.73	5.73	13.43	2.75	2.75	2.75	12.42	12.42	12.42	1.59	1.59	1.59

Percent Retained			94.7	94.7	94.7	89.1	116.9	116.9	116.9	137.0	137.0	137.0	100.6	100.6	100.6
RFid			**1.06**	**1.06**	**1.06**										

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

**Table D-11. Installation damage wide width tensile test results for Linear Composites ParaLink 300 geogrid, soil gradation 2.
Installation damage testing (ASTM D 5818, as modified in AASHTO R69-15).
Wide wide tensile testing (ASTM D 6637, Method B).**

Machine Direction

Sample Identification	Specimen Number	Ribs per Foot Width	Number of Ribs Tested	Maximum Load (lbs)	Maximum Load (lbs/ft)	Maximum Load (kN/m)	Elongation @ Break (%)	Load @ 2% lbs	Load @ 2% (lbs/ft)	Load @ 2% (kN/m)	Load @ 5% lbs	Load @ 5% (lbs/ft)	Load @ 5% (kN/m)	Load @ 10% lbs	Load @ 10% (lbs/ft)	Load @ 10% (kN/m)
ParaLink 300 Baseline	1	1.72	1	12450	21397	312.4	12.1	1744	2997	43.76	3633	6244	91.2	11161	19182	280.1
	2	1.72	1	12405	21320	311.3	10.9	1957	3363	49.11	4794	8239	120.3	12008	20638	301.3
	3	1.72	1	12241	21038	307.2	10.3	1868	3210	46.87	4283	7361	107.5	12010	20641	301.4
	4	1.72	1	12080	20762	303.1	9.7	2014	3461	50.54	4851	8337	121.7			
	5	1.72	1	12402	21315	311.2	11.3	1756	3018	44.06	4176	7177	104.8	11743	20182	294.7
Average				12316	21166	309.0	10.8	1868	3210	46.87	4347	7472	109.1	11731	20161	294.3
Standard Deviation				153.8	264.3	3.86	0.92	119.5	205.4	3.00	499.2	858.0	12.53	399.8	687	10.03
% COV				1.25	1.25	1.25	8.50	6.40	6.40	6.40	11.48	11.48	11.48	3.41	3.41	3.41

Machine Direction

Sample Identification	Specimen Number	Ribs per Foot Width	Number of Ribs Tested	Maximum Load (lbs)	Maximum Load (lbs/ft)	Maximum Load (kN/m)	Elongation @ Break (%)	Load @ 2% lbs	Load @ 2% (lbs/ft)	Load @ 2% (kN/m)	Load @ 5% lbs	Load @ 5% (lbs/ft)	Load @ 5% (kN/m)	Load @ 10% lbs	Load @ 10% (lbs/ft)	Load @ 10% (kN/m)
ParaLink 300 installed in Gradation 2 (Sandy Gravel)	1	1.72	1	12447	21392	312.3	11.9	1810	3110	45.41	3775	6488	94.7	11281	19388	283.1
	2	1.72	1	12415	21337	311.5	10.7	2013	3461	50.52	5150	8851	129.2	12175	20925	305.5
	3	1.72	1	12526	21528	314.3	10.5	1962	3371	49.22	4791	8234	120.2	12358	21239	310.1
	4	1.72	1	12389	21292	310.9	11.1	1978	3400	49.64	4642	7978	116.5	11810	20297	296.3
	5	1.72	1	12456	21408	312.6	12.1	1903	3271	47.76	4106	7057	103.0	11339	19488	284.5
	6	1.72	1	12200	20968	306.1	9.94	2341	4024	58.75	6461	11105	162.1			
	7	1.72	1	12426	21357	311.8	10.8	2100	3610	52.71	5603	9629	140.6	12194	20958	306.0
	8	1.72	1	12536	21546	314.6	9.91	2097	3603	52.61	5359	9211	134.5			
	9	1.72	1	12383	21282	310.7	10.6	1985	3411	49.80	4692	8063	117.7	12145	20874	304.8
	10	1.72	1	12540	21552	314.7	11.0	1952	3354	48.97	4423	7601	111.0	12000	20624	301.1
Average				12432	21366	311.9	10.9	2014	3462	50.54	4900	8422	123.0	11913	20474	298.9
Standard Deviation				100.2	172	2.51	0.71	143.02	245.80	3.59	778.2	1337.5	19.53	404.7	695.6	10.16
% COV				0.81	0.81	0.81	6.56	7.10	7.10	7.10	15.88	15.88	15.88	3.40	3.40	3.40

Percent Retained				100.9	100.9	100.9	100.1	107.8	107.8	107.8	112.7	112.7	112.7	101.6	101.6	101.6
RFid				**1.00**	**1.00**	**1.00**										

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table D-12. Installation damage wide width tensile test results for Linear Composites ParaLink 300 geogrid, soil gradation 3.
Installation damage testing (ASTM D 5818, as modified in AASHTO R69-15).
Wide wide tensile testing (ASTM D 6637, Method B).

Machine Direction

Sample Identification	Specimen Number	Ribs per Foot Width	Number of Ribs Tested	Maximum Load (lbs)	Maximum Load (lbs/ft)	Maximum Load (kN/m)	Elongation @ Break (%)	Load @ 2% lbs	Load @ 2% (lbs/ft)	Load @ 2% (kN/m)	Load @ 5% lbs	Load @ 5% (lbs/ft)	Load @ 5% (kN/m)	Load @ 10% lbs	Load @ 10% (lbs/ft)	Load @ 10% (kN/m)
ParaLink 300 Baseline	1	1.72	1	12450	21397	312.4	12.1	1744	2997	43.76	3633	6244	91.2	11161	19182	280.1
	2	1.72	1	12405	21320	311.3	10.9	1957	3363	49.11	4794	8239	120.3	12008	20638	301.3
	3	1.72	1	12241	21038	307.2	10.3	1868	3210	46.87	4283	7361	107.5	12010	20641	301.4
	4	1.72	1	12080	20762	303.1	9.7	2014	3461	50.54	4851	8337	121.7			
	5	1.72	1	12402	21315	311.2	11.3	1756	3018	44.06	4176	7177	104.8	11743	20182	294.7
Average				12316	21166	309.0	10.8	1868	3210	46.87	4347	7472	109.1	11731	20161	294.3
Standard Deviation				153.8	264.3	3.86	0.92	119.5	205.4	3.00	499.2	858.0	12.53	399.8	687	10.03
% COV				1.25	1.25	1.25	8.50	6.40	6.40	6.40	11.48	11.48	11.48	3.41	3.41	3.41

Machine Direction

Sample Identification	Specimen Number	Ribs per Foot Width	Number of Ribs Tested	Maximum Load (lbs)	Maximum Load (lbs/ft)	Maximum Load (kN/m)	Elongation @ Break (%)	Load @ 2% lbs	Load @ 2% (lbs/ft)	Load @ 2% (kN/m)	Load @ 5% lbs	Load @ 5% (lbs/ft)	Load @ 5% (kN/m)	Load @ 10% lbs	Load @ 10% (lbs/ft)	Load @ 10% (kN/m)
ParaLink 300 installed in Gradation 3 (Sand)	1	1.72	1	12155	20891	305.0	11.1	1979	3402	49.66	4815	8276	120.8	11775	20238	295.5
	2	1.72	1	12167	20910	305.3	10.2	2025	3480	50.80	5245	9015	131.6	12087	20774	303.3
	3	1.72	1	12640	21724	317.2	9.84	2104	3617	52.80	5890	10122	147.8			
	4	1.72	1	12398	21307	311.1	9.83	2045	3515	51.31	5660	9728	142.0			
	5	1.72	1	12306	21150	308.8	11.0	2001	3439	50.21	5061	8697	127.0	11946	20531	299.8
	6	1.72	1	12590	21639	315.9	11.0	2089	3590	52.41	5392	9267	135.3	12108	20809	303.8
	7	1.72	1	12311	21158	308.9	11.4	1931	3319	48.46	4588	7885	115.1	11578	19899	290.5
	8	1.72	1	12332	21195	309.5	10.7	1941	3337	48.71	4645	7983	116.5	12013	20647	301.4
	9	1.72	1	12571	21605	315.4	11.0	1974	3393	49.54	4636	7968	116.3	12046	20704	302.3
	10	1.72	1	12515	21508	314.0	11.1	1919	3298	48.15	4765	8190	119.6	11988	20603	300.8
Average				12398	21309	311.1	10.7	2001	3439	50.21	5070	8713	127.2	11943	20526	299.7
Standard Deviation				173.8	299	4.36	0.57	64.36	110.62	1.62	461.2	792.6	11.57	180.0	309.4	4.52
% COV				1.40	1.40	1.40	5.29	3.22	3.22	3.22	9.10	9.10	9.10	1.51	1.51	1.51

Percent Retained			100.7	100.7	100.7	98.7	107.1	107.1	107.1	116.6	116.6	116.6	101.8	101.8	101.8
RFid			**1.00**	**1.00**	**1.00**										

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table D-13. Installation damage wide width tensile test results for Linear Composites ParaLink 1000 geogrid, soil gradation 1.
Installation damage testing (ASTM D 5818, as modified in AASHTO R69-15).
Wide wide tensile testing (ASTM D 6637, Method B).

Machine Direction

Sample Identification	Specimen Number	Ribs per Foot Width	Number of Ribs Tested	Maximum Load (lbs)	Maximum Load (lbs/ft)	Maximum Load (kN/m)	Elongation @ Break (%)	Load @ 2% lbs	Load @ 2% (lbs/ft)	Load @ 2% (kN/m)	Load @ 5% lbs	Load @ 5% (lbs/ft)	Load @ 5% (kN/m)	Load @ 10% lbs	Load @ 10% (lbs/ft)	Load @ 10% (kN/m)
ParaLink 1000 Baseline	1	2.51	1	28980	72753	1062.2	11.9	3811	9567	139.68	10077	25298	369.3	26393	66259	967.4
	2	2.51	1	29106	73069	1066.8	12.6	3886	9756	142.43	10161	25509	372.4	25878	64966	948.5
	3	2.51	1	29218	73351	1070.9	12.5	3930	9866	144.05	10358	26003	379.6	26368	66196	966.5
	4	2.51	1	29143	73162	1068.2	12.2	3140	7883	115.09	9356	23488	342.9	26064	65433	955.3
	5	2.51	1	29391	73785	1077.3	12.7	3186	7998	116.78	9103	22853	333.6	25283	63472	926.7
Average				29168	73224	1069.1	12.4	3591	9014	131.61	9811	24630	359.6	25997	65265	952.9
Standard Deviation				151.7	380.8	5.56	0.33	393.0	986.6	14.40	547.9	1375.5	20.08	453.6	1139	16.62
% COV				0.52	0.52	0.52	2.64	10.95	10.95	10.95	5.58	5.58	5.58	1.74	1.74	1.74

Machine Direction

Sample Identification	Specimen Number	Ribs per Foot Width	Number of Ribs Tested	Maximum Load (lbs)	Maximum Load (lbs/ft)	Maximum Load (kN/m)	Elongation @ Break (%)	Load @ 2% lbs	Load @ 2% (lbs/ft)	Load @ 2% (kN/m)	Load @ 5% lbs	Load @ 5% (lbs/ft)	Load @ 5% (kN/m)	Load @ 10% lbs	Load @ 10% (lbs/ft)	Load @ 10% (kN/m)
ParaLink 1000 installed in Gradation 1 (Coarse Gravel)	1	2.51	1	28990	72778	1062.6	11.6	5044	12662	184.86	12222	30684	448.0	27323	68592	1001.4
	2	2.51	1	28763	72208	1054.2	11.3	4751	11926	174.12	11868	29795	435.0	27185	68247	996.4
	3	2.51	1	29629	74382	1086.0	12.0	4785	12013	175.39	11573	29053	424.2	27056	67924	991.7
	4	2.51	1	29224	73365	1071.1	11.8	4931	12380	180.75	12115	30415	444.1	27366	68700	1003.0
	5	2.51	1	29323	73614	1074.8	12.2	4619	11596	169.31	11250	28242	412.3	26853	67414	984.2
	6	2.51	1	29120	73106	1067.3	11.7	4734	11884	173.51	11354	28505	416.2	26959	67681	988.1
	7	2.51	1	29249	73428	1072.1	12.1	4533	11379	166.13	10949	27488	401.3	26512	66557	971.7
	8	2.51	1	29253	73437	1072.2	11.7	4804	12059	176.07	11707	29391	429.1	27304	68545	1000.8
	9	2.51	1	29046	72920	1064.6	11.8	4502	11301	165.00	10903	27372	399.6	26608	66799	975.3
	10	2.51	1	29183	73264	1069.6	12.0	4555	11436	166.97	11520	28919	422.2	26971	67709	988.5
Average				29178	73250	1069.5	11.8	4726	11864	173.21	11546	28986	423.2	27014	67817	990.1
Standard Deviation				227.4	571	8.34	0.27	176.84	443.94	6.48	448.1	1124.9	16.42	294.6	739.6	10.80
% COV				0.78	0.78	0.78	2.30	3.74	3.74	3.74	3.88	3.88	3.88	1.09	1.09	1.09

Percent Retained			100.0	100.0	100.0	95.6	131.6	131.6	131.6	117.7	117.7	117.7	103.9	103.9	103.9
RFid			**1.00**	**1.00**	**1.00**										

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table D-14. Installation damage wide width tensile test results for Linear Composites ParaLink 1000 geogrid, soil gradation 2.
Installation damage testing (ASTM D 5818, as modified in AASHTO R69-15).
Wide wide tensile testing (ASTM D 6637, Method B).

Machine Direction

Sample Identification	Specimen Number	Ribs per Foot Width	Number of Ribs Tested	Maximum Load (lbs)	Maximum Load (lbs/ft)	Maximum Load (kN/m)	Elongation @ Break (%)	Load @ 2% lbs	Load @ 2% (lbs/ft)	Load @ 2% (kN/m)	Load @ 5% lbs	Load @ 5% (lbs/ft)	Load @ 5% (kN/m)	Load @ 10% lbs	Load @ 10% (lbs/ft)	Load @ 10% (kN/m)
ParaLink 1000 Baseline	1	2.51	1	28980	72753	1062.2	11.9	3811	9567	139.68	10077	25298	369.3	26393	66259	967.4
	2	2.51	1	29106	73069	1066.8	12.6	3886	9756	142.43	10161	25509	372.4	25878	64966	948.5
	3	2.51	1	29218	73351	1070.9	12.5	3930	9866	144.05	10358	26003	379.6	26368	66196	966.5
	4	2.51	1	29143	73162	1068.2	12.2	3140	7883	115.09	9356	23488	342.9	26064	65433	955.3
	5	2.51	1	29391	73785	1077.3	12.7	3186	7998	116.78	9103	22853	333.6	25283	63472	926.7
Average				29168	73224	1069.1	12.4	3591	9014	131.61	9811	24630	359.6	25997	65265	952.9
Standard Deviation				151.7	380.8	5.56	0.33	393.0	986.6	14.40	547.9	1375.5	20.08	453.6	1139	16.62
% COV				0.52	0.52	0.52	2.64	10.95	10.95	10.95	5.58	5.58	5.58	1.74	1.74	1.74

Machine Direction

Sample Identification	Specimen Number	Ribs per Foot Width	Number of Ribs Tested	Maximum Load (lbs)	Maximum Load (lbs/ft)	Maximum Load (kN/m)	Elongation @ Break (%)	Load @ 2% lbs	Load @ 2% (lbs/ft)	Load @ 2% (kN/m)	Load @ 5% lbs	Load @ 5% (lbs/ft)	Load @ 5% (kN/m)	Load @ 10% lbs	Load @ 10% (lbs/ft)	Load @ 10% (kN/m)
ParaLink 1000 installed in Gradation 2 (Sandy Gravel)	1	2.51	1	29441	73911	1079.1	11.6	4897	12294	179.50	12172	30557	446.1	27533	69119	1009.1
	2	2.51	1	29206	73322	1070.5	12.2	4435	11135	162.57	11166	28031	409.3	26862	67437	984.6
	3	2.51	1	29059	72950	1065.1	11.9	4587	11515	168.12	11060	27767	405.4	26640	66879	976.4
	4	2.51	1	29291	73533	1073.6	12.2	4615	11585	169.14	11263	28276	412.8	26851	67408	984.2
	5	2.51	1	29077	72997	1065.8	12.1	4662	11704	170.88	11646	29236	426.8	26950	67658	987.8
	6	2.51	1	29294	73543	1073.7	12.3	4558	11442	167.05	11105	27879	407.0	26572	66709	973.9
	7	2.51	1	29270	73480	1072.8	12.2	4513	11330	165.41	10890	27338	399.1	26412	66307	968.1
	8	2.51	1	29128	73124	1067.6	11.8	4471	11224	163.88	11371	28545	416.8	26800	67279	982.3
	9	2.51	1	28901	72556	1059.3	11.7	4625	11611	169.52	11560	29021	423.7	27009	67806	990.0
	10	2.51	1	29009	72827	1063.3	12.1	4435	11133	162.54	10989	27589	402.8	26511	66554	971.7
Average				29168	73224	1069.1	12.0	4580	11497	167.86	11322	28424	415.0	26814	67316	982.8
Standard Deviation				161.8	406	5.93	0.25	137.27	344.61	5.03	384.0	963.9	14.07	319.5	802.2	11.71
% COV				0.55	0.55	0.55	2.10	3.00	3.00	3.00	3.39	3.39	3.39	1.19	1.19	1.19

Percent Retained			100.0	100.0	100.0	97.0	127.5	127.5	127.5	115.4	115.4	115.4	103.1	103.1	103.1
RFid			**1.00**	**1.00**	**1.00**										

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table D-15. Installation damage wide width tensile test results for Linear Composites ParaLink 1000 geogrid, soil gradation 3.
Installation damage testing (ASTM D 5818, as modified in AASHTO R69-15).
Wide wide tensile testing (ASTM D 6637, Method B).

Machine Direction

Sample Identification	Specimen Number	Ribs per Foot Width	Number of Ribs Tested	Maximum Load (lbs)	Maximum Load (lbs/ft)	Maximum Load (kN/m)	Elongation @ Break (%)	Load @ 2% lbs	Load @ 2% (lbs/ft)	Load @ 2% (kN/m)	Load @ 5% lbs	Load @ 5% (lbs/ft)	Load @ 5% (kN/m)	Load @ 10% lbs	Load @ 10% (lbs/ft)	Load @ 10% (kN/m)
ParaLink 1000 Baseline	1	2.51	1	28980	72753	1062.2	11.9	3811	9567	139.68	10077	25298	369.3	26393	66259	967.4
	2	2.51	1	29106	73069	1066.8	12.6	3886	9756	142.43	10161	25509	372.4	25878	64966	948.5
	3	2.51	1	29218	73351	1070.9	12.5	3930	9866	144.05	10358	26003	379.6	26368	66196	966.5
	4	2.51	1	29143	73162	1068.2	12.2	3140	7883	115.09	9356	23488	342.9	26064	65433	955.3
	5	2.51	1	29391	73785	1077.3	12.7	3186	7998	116.78	9103	22853	333.6	25283	63472	926.7
Average				29168	73224	1069.1	12.4	3591	9014	131.61	9811	24630	359.6	25997	65265	952.9
Standard Deviation				151.7	380.8	5.56	0.33	393.0	986.6	14.40	547.9	1375.5	20.08	453.6	1139	16.62
% COV				0.52	0.52	0.52	2.64	10.95	10.95	10.95	5.58	5.58	5.58	1.74	1.74	1.74

Machine Direction

Sample Identification	Specimen Number	Ribs per Foot Width	Number of Ribs Tested	Maximum Load (lbs)	Maximum Load (lbs/ft)	Maximum Load (kN/m)	Elongation @ Break (%)	Load @ 2% lbs	Load @ 2% (lbs/ft)	Load @ 2% (kN/m)	Load @ 5% lbs	Load @ 5% (lbs/ft)	Load @ 5% (kN/m)	Load @ 10% lbs	Load @ 10% (lbs/ft)	Load @ 10% (kN/m)
ParaLink 1000 installed in Gradation 3 (Sand)	1	2.51	1	29147	73172	1068.3	12.0	4361	10948	159.84	11214	28151	411.0	26930	67607	987.1
	2	2.51	1	29017	72845	1063.5	12.1	4111	10322	150.70	10388	26079	380.8	26248	65894	962.1
	3	2.51	1	28696	72041	1051.8	12.1	3799	9538	139.26	9928	24924	363.9	26000	65272	953.0
	4	2.51	1	29152	73184	1068.5	12.5	3592	9017	131.65	9692	24332	355.3	25664	64429	940.7
	5	2.51	1	29033	72886	1064.1	12.3	3694	9273	135.39	10072	25284	369.2	26080	65474	955.9
	6	2.51	1	29243	73413	1071.8	12.5	3547	8906	130.02	9850	24728	361.0	26033	65355	954.2
	7	2.51	1	29155	73192	1068.6	12.2	3951	9919	144.81	10362	26014	379.8	26477	66470	970.5
	8	2.51	1	29106	73070	1066.8	12.6	3709	9312	135.96	9583	24057	351.2	25518	64061	935.3
	9	2.51	1	29072	72985	1065.6	12.5	3861	9693	141.51	10198	25601	373.8	26132	65603	957.8
	10	2.51	1	28807	72320	1055.9	11.8	4416	11086	161.86	11079	27814	406.1	26446	66390	969.3
Average				29043	72911	1064.5	12.3	3904	9801	143.10	10237	25699	375.2	26153	65655	958.6
Standard Deviation				168.8	424	6.19	0.25	304.75	765.06	11.17	547.8	1375.1	20.08	406.8	1021.3	14.91
% COV				0.58	0.58	0.58	2.05	7.81	7.81	7.81	5.35	5.35	5.35	1.56	1.56	1.56

Percent Retained			99.6	99.6	99.6	99.1	108.7	108.7	108.7	104.3	104.3	104.3	100.6	100.6	100.6
RFid			**1.00**	**1.00**	**1.00**										

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table D-19. Standard test soil gradations (% passing).

Standard Installation Damage Soils Used for Field Exposures				
US Sieve No.	**Sieve Size (mm)**	**Percent Passing by Weight**		
		Type 1 (Coarse Gravel)	**Type2 (Sandy Gravel)**	**Type 3 (Silty Sand)**
6 - in	150	100.0	100.0	100.0
3 - in.	75	100.0	100.0	100.0
2 - in.	50	100.0	100.0	100.0
1.5 - in.	38	-	100.0	100.0
1 - in.	25	26.4	100.0	100.0
3/4 - in.	19	1.6	100.0	100.0
1/2 - in.	12.5	-	-	100.0
3/8 - in.	9.5	1.1	99.1	100.0
No. 4	4.75	1.1	40.5	100.0
No. 10	1.7	1.1	4.2	77.6
No. 20	0.85	1.1	3.4	48.8
No. 40	0.425	1.0	3.3	33.1
No. 60	0.25	-	-	21.5
No. 100	0.15	-	-	12.2
No. 200	0.075	-	-	4.4
D50, mm		28.5	5.3	0.9
LA Abrasion Small Drum Method B 500 Cycles		20.2% loss	12.6% loss	
Liquid Limit, %		-	-	-
Plasticity Index, %		-	-	-
Angularity (ASTM D 2488)		Angular to Subangular	Angular	Angular to Subangular
AASHTO Classification		No. 4 Aggregate	No. 89 Aggregate	A-1b Soil
Soil Classification		GP	GP	SM
		Poorly Graded Gravel	Poorly Graded Gravel with Sand	Well Graded Silty Sand

Figure D-1. Lifting Plates positioned between ties and covered with first lift of compacted soil/aggregate.

Figure D-2. Grid positioned over compacted base and covered. Cover soil/aggregate is uniformly spread and compacted using field-scale equipment and procedures.

Figure D-3. The density of the compacted soil is measured with a nuclear density gauge.

Figure D-4. The steel plates are tilted to facilitate exhumation.

Appendix E: ISO/EN Laboratory Installation Damage Detailed Test Results

E.1 ISO/EN Laboratory Installation Damage Test Program

Testing is done per the EN/ISO 10722. Five wide width tensile specimens are exposed to 200 cycles producing between 209 lb/ft^2 (10 kPa) minimum and 10,443 lb/ft^2 (500 kPa) maximum stress at a frequency of 1 Hz. The aggregate used is a sintered aluminum oxide with a grain size such that 100% shall pass a 10 mm sieve and 0% shall pass a 5 mm sieve. The exposed specimens and five baseline specimens are tested according to ISO/EN 10319.

Representative photos of test apparatus and aggregate are provided in Figures E-1 and E-2. Detailed test results are provided in Tables E-1 through E-3.

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Figure E-1. ISO/EN 10722, laboratory installation damage test apparatus.

Figure E-2. ISO/EN 10722, laboratory installation damage aggregate.

Table E-1: Laboratory installation damage (ISO/EN 10722) tensile test results for ParaWeb 30

PARAMETER	TEST REPLICATE NUMBER 1	2	3	4	5	MEAN	STD. DEV.	COEF. VARI.	PERCENT RETAINED
Laboratory Installation Damage (ISO/EN 10722)									
Strength Retained measured via wide width tensile (ISO/EN 10319)									
MD - Tensile Strength (lbs) - B	7169	7058	7073	7152	7154	**7121**	52	1	
MD Tensile Strength (kN) - B	31.9	31.4	31.5	31.8	31.8	**31.7**	0.2	0.7	
MD - Tensile Strength (lbs) - E	5778	5533	5787	5854	6058	**5802**	188	3	
MD Tensile Strength (kN) - E	25.7	24.6	25.8	26.1	27.0	**25.8**	0.8	3.2	**81**
MD - Elong. @ Max. Load (%) - B	11.5	10.6	10.7	11.3	11.2	**11.1**	0.4	3.5	
MD - Elong. @ Max. Load (%) - E	9.89	9.39	9.62	9.52	9.53	**9.59**	0.19	1.95	**87**

B - Baseline Unexposed
E - Exposed

MD - Machine Direction TD - Transverse/Cross Machine Direction

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table E-2: Laboratory installation damage (ISO/EN 10722) tensile test results for ParaWeb 40

PARAMETER	TEST REPLICATE NUMBER					MEAN	STD. DEV.	COEF. VARI.	PERCENT RETAINED
	1	2	3	4	5				
Laboratory Installation Damage (ISO/EN 10722)									
Strength Retained measured via wide width tensile (ISO/EN 10319)									
MD - Tensile Strength (lbs) - B	10031	10031	10180	10187	10217	**10129**	90	1	
MD Tensile Strength (kN) - B	44.6	44.6	45.3	45.3	45.5	**45.1**	0.4	0.9	
MD - Tensile Strength (lbs) - E	9254	9329	9378	9636	9304	**9380**	150	2	
MD Tensile Strength (kN) - E	41.2	41.5	41.7	42.9	41.4	**41.7**	0.7	1.6	**93**
MD - Elong. @ Max. Load (%) - B	9.49	10.11	9.88	9.95	10.12	**9.91**	0.26	2.59	
MD - Elong. @ Max. Load (%) - E	9.28	9.73	9.59	10.22	10.08	**9.78**	0.38	3.87	**99**
B - Baseline Unexposed									
E - Exposed									

MD - Machine Direction TD - Transverse/Cross Machine Direction

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table E-3: Laboratory installation damage (ISO/EN 10722) tensile test results for ParaWeb 45

PARAMETER	TEST REPLICATE NUMBER					MEAN	STD. DEV.	COEF. VARI.	PERCENT RETAINED
	1	2	3	4	5				
Laboratory Installation Damage (ISO/EN 10722)									
Strength Retained measured via wide width tensile (ISO/EN 10319)									
MD - Tensile Strength (lbs) - B	10153	10145	10100	10144	10107	**10130**	24	0	
MD Tensile Strength (kN) - B	45.2	45.1	44.9	45.1	45.0	**45.1**	0.1	0.2	
MD - Tensile Strength (lbs) - E	9726	10017	9618	9958	9958	**9855**	173	2	
MD Tensile Strength (kN) - E	43.3	44.6	42.8	44.3	44.3	**43.9**	0.8	1.8	**97**
MD - Elong. @ Max. Load (%) - B	10.94	11.05	10.95	10.72	11.04	**10.94**	0.13	1.21	
MD - Elong. @ Max. Load (%) - E	10.57	11.12	10.90	11.02	11.07	**10.94**	0.22	2.01	**100**

B - Baseline Unexposed
E - Exposed

MD - Machine Direction TD - Transverse/Cross Machine Direction

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table E-4: Laboratory installation damage (ISO/EN 10722) tensile test results for ParaWeb 50

PARAMETER	TEST REPLICATE NUMBER					MEAN	STD. DEV.	COEF. VARI.	PERCENT RETAINED
	1	2	3	4	5				
Laboratory Installation Damage (ISO/EN 10722)									
Strength Retained measured via wide width tensile (ISO/EN 10319)									
MD - Tensile Strength (lbs) - B	11843	11932	12002	11860	11838	**11895**	71	1	
MD Tensile Strength (kN) - B	52.7	53.1	53.4	52.8	52.7	**52.9**	0.3	0.6	
MD - Tensile Strength (lbs) - E	10992	10616	11045	11077	11124	**10971**	204	2	
MD Tensile Strength (kN) - E	48.9	47.2	49.2	49.3	49.5	**48.8**	0.9	1.9	**92**
MD - Elong. @ Max. Load (%) - B	10.5	10.6	10.8	10.4	10.5	**10.6**	0.2	1.4	
MD - Elong. @ Max. Load (%) - E	9.98	9.30	9.93	10.1	9.78	**9.82**	0.31	3.17	**93**

B - Baseline Unexposed
E - Exposed

MD - Machine Direction   TD - Transverse/Cross Machine Direction

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table E-5: Laboratory installation damage (ISO/EN 10722) tensile test results for ParaWeb 54

PARAMETER	TEST REPLICATE NUMBER					MEAN	STD. DEV.	COEF. VARI.	PERCENT RETAINED
	1	**2**	**3**	**4**	**5**				
Laboratory Installation Damage (ISO/EN 10722)									
Strength Retained measured via wide width tensile (ISO/EN 10319)									
MD - Tensile Strength (lbs) - B	12622	12588	12572	12553	12661	**12599**	43	0.3	
MD Tensile Strength (kN) - B	56.2	56.0	55.9	55.9	56.3	**56.1**	0.2	0.3	
MD - Tensile Strength (lbs) - E	12452	12170	12568	12504	12595	**12458**	170	1	
MD Tensile Strength (kN) - E	55.4	54.2	55.9	55.6	56.0	**55.4**	0.8	1.4	**99**
MD - Elong. @ Max. Load (%) - B	11.96	11.57	11.92	11.85	11.69	**11.80**	0.16	1.39	
MD - Elong. @ Max. Load (%) - E	11.53	11.04	11.51	11.62	11.54	**11.45**	0.23	2.03	**97**

B - Baseline Unexposed
E - Exposed

MD - Machine Direction   TD - Transverse/Cross Machine Direction

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table E-6: Laboratory installation damage (ISO/EN 10722) tensile test results for ParaWeb 63

PARAMETER	**TEST REPLICATE NUMBER**					**MEAN**	**STD. DEV.**	**COEF. VARI.**	**PERCENT RETAINED**
	1	**2**	**3**	**4**	**5**				
Laboratory Installation Damage (ISO/EN 10722)									
Strength Retained measured via wide width tensile (ISO/EN 10319)									
MD - Tensile Strength (lbs) - B	14534	14538	14453	14633	14485	**14529**	68	0.5	
MD Tensile Strength (kN) - B	64.7	64.7	64.3	65.1	64.5	**64.7**	0.3	0.5	
MD - Tensile Strength (lbs) - E	14493	14334	14326	14339	14541	**14407**	102	1	
MD Tensile Strength (kN) - E	64.5	63.8	63.8	63.8	64.7	**64.1**	0.5	0.7	**99**
MD - Elong. @ Max. Load (%) - B	10.62	10.81	10.36	10.75	10.67	**10.64**	0.17	1.63	
MD - Elong. @ Max. Load (%) - E	10.61	10.49	10.54	10.58	10.79	**10.60**	0.11	1.08	**100**
B - Baseline Unexposed									
E - Exposed									

MD - Machine Direction TD - Transverse/Cross Machine Direction

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table E-7: Laboratory installation damage (ISO/EN 10722) tensile test results for ParaWeb 75

PARAMETER	TEST REPLICATE NUMBER					MEAN	STD. DEV.	COEF. VARI.	PERCENT RETAINED
	1	2	3	4	5				
Laboratory Installation Damage (ISO/EN 10722)									
Strength Retained measured via wide width tensile (ISO/EN 10319)									
MD - Tensile Strength (lbs) - B	19325	19446	19351	19384	19381	**19377**	45	0.2	
MD Tensile Strength (kN) - B	86.0	86.5	86.1	86.3	86.2	**86.2**	0.2	0.2	
MD - Tensile Strength (lbs) - E	19281	18985	18950	18746	19078	**19008**	195	1	
MD Tensile Strength (kN) - E	85.8	84.5	84.3	83.4	84.9	**84.6**	0.9	1.0	**98**
MD - Elong. @ Max. Load (%) - B	9.91	10.01	9.96	10.01	10.02	**9.98**	0.05	0.47	
MD - Elong. @ Max. Load (%) - E	9.91	9.99	9.97	10.19	10.02	**10.02**	0.11	1.05	**100**
B - Baseline Unexposed									
E - Exposed									

MD - Machine Direction TD - Transverse/Cross Machine Direction

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table E-8: Laboratory installation damage (ISO/EN 10722) tensile test results for ParaWeb 100

PARAMETER	TEST REPLICATE NUMBER					MEAN	STD. DEV.	COEF. VARI.	PERCENT RETAINED
	1	**2**	**3**	**4**	**5**				
Laboratory Installation Damage (ISO/EN 10722)									
Strength Retained measured via wide width tensile (ISO/EN 10319)									
MD - Tensile Strength (lbs) - B	25031	24397	24678	24403	24726	**24647**	263	1	
MD Tensile Strength (kN) - B	111.4	108.6	109.8	108.6	110.0	**109.7**	1.2	1.1	
MD - Tensile Strength (lbs) - E	24700	24773	24521	24669	24602	**24653**	96	0.4	
MD Tensile Strength (kN) - E	109.9	110.2	109.1	109.8	109.5	**109.7**	0.4	0.4	**100**
MD - Elong. @ Max. Load (%) - B	10.44	10.11	10.09	9.96	10.03	**10.13**	0.19	1.83	
MD - Elong. @ Max. Load (%) - E	10.36	10.27	9.88	10.44	9.88	**10.17**	0.27	2.64	**100**
B - Baseline Unexposed									
E - Exposed									

MD - Machine Direction TD - Transverse/Cross Machine Direction

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table E-9: Laboratory installation damage (ISO/EN 10722) tensile test results for ParaWeb 135

PARAMETER	TEST REPLICATE NUMBER					MEAN	STD. DEV.	COEF. VARI.	PERCENT RETAINED
	1	2	3	4	5				
Laboratory Installation Damage (ISO/EN 10722)									
Strength Retained measured via wide width tensile (ISO/EN 10319)									
MD - Tensile Strength (lbs) - B	35254	35186	35519	35502	35208	**35334**	163	0.5	
MD Tensile Strength (kN) - B	157	157	158	158	157	**157**	1	0.5	
MD - Tensile Strength (lbs) - E	35429	35237	35367	35190	35401	**35325**	105	0.3	
MD Tensile Strength (kN) - E	158	157	157	157	158	**157**	0	0.3	**100**
MD - Elong. @ Max. Load (%) - B	11.8	11.7	11.5	11.8	11.4	**11.6**	0.2	1.6	
MD - Elong. @ Max. Load (%) - E	11.7	11.7	11.1	11.7	11.9	**11.6**	0.3	2.6	**100**

B - Baseline Unexposed
E - Exposed

MD - Machine Direction TD - Transverse/Cross Machine Direction

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table E-10: Laboratory installation damage (ISO/EN 10722) tensile test results for ParaLink 300

PARAMETER	TEST REPLICATE NUMBER					MEAN	STD. DEV.	COEF. VARI.	PERCENT RETAINED
	1	**2**	**3**	**4**	**5**				
Laboratory Installation Damage (ISO/EN 10722)									
Strength Retained measured via wide width tensile (ISO/EN 10319)									
MD Number of Ribs per Specimen:	1								
MD Number of Ribs per foot:	1.72								
MD - Tensile Strength (lbs) - B	12595	12516	12561	12599	12735	**12601**	82	1	
MD Tensile Strength (lbs/ft) - B	21647	21511	21588	21654	21887	**21657**	141	1	
MD Tensile Strength (kN/m) - B	316	314	315	316	320	**316**	2	1	
MD - Tensile Strength (lbs) - E	12234	11963	12004	12569	12425	**12239**	262	2	
MD Tensile Strength (lbs/ft) - E	21026	20560	20631	21602	21354	**21035**	451	2	**97**
MD Tensile Strength (kN/m) - E	307	300	301	315	312	**307**	7	2	
MD - Elong. @ Max. Load (%) - B	11.1	10.7	9.89	10.1	10.0	**10.4**	0.5	5.0	
MD - Elong. @ Max. Load (%) - E	9.43	9.45	8.81	11.2	11.2	**10.0**	1.1	11.1	**97**
B - Baseline Unexposed									
E - Exposed									

MD - Machine Direction TD - Transverse/Cross Machine Direction

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table E-11: Laboratory installation damage (ISO/EN 10722) tensile test results for ParaLink 400

PARAMETER	TEST REPLICATE NUMBER					MEAN	STD. DEV.	COEF. VARI.	PERCENT RETAINED
	1	2	3	4	5				
Laboratory Installation Damage (ISO/EN 10722)									
Strength Retained measured via wide width tensile (ISO/EN 10319)									
MD Number of Ribs per Specimen:	1								
MD Number of Ribs per foot:	1.70								
MD - Tensile Strength (lbs) - B	17072	17040	17036	17067	16942	**17031**	52	0.3	
MD Tensile Strength (lbs/ft) - B	29081	29026	29020	29072	28859	**29011**	89	0.3	
MD Tensile Strength (kN/m) - B	425	424	424	424	421	**424**	1	0.3	
MD - Tensile Strength (lbs) - E	16525	16146	16568	16476	16219	**16387**	191	1	
MD Tensile Strength (lbs/ft) - E	28149	27503	28223	28066	27627	**27914**	326	1	**96**
MD Tensile Strength (kN/m) - E	411	402	412	410	403	**408**	5	1	
MD - Elong. @ Max. Load (%) - B	9.96	9.19	9.24	10.85	10.48	**9.94**	0.74	7.41	
MD - Elong. @ Max. Load (%) - E	9.54	7.94	8.75	8.69	8.38	**8.66**	0.59	6.78	**87**

B - Baseline Unexposed
E - Exposed

MD - Machine Direction TD - Transverse/Cross Machine Direction

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table E-12: Laboratory installation damage (ISO/EN 10722) tensile test results for ParaLink 500

PARAMETER	TEST REPLICATE NUMBER					MEAN	STD. DEV.	COEF. VARI.	PERCENT RETAINED
	1	2	3	4	5				
Laboratory Installation Damage (ISO/EN 10722)									
Strength Retained measured via wide width tensile (ISO/EN 10319)									
MD Number of Ribs per Specimen:	1								
MD Number of Ribs per foot:	1.71								
MD - Tensile Strength (lbs) - B	22056	22226	21972	21878	21968	**22020**	131	1	
MD Tensile Strength (lbs/ft) - B	37810	38102	37666	37506	37659	**37749**	225	1	
MD Tensile Strength (kN/m) - B	552	556	550	548	550	**551**	3	1	
MD - Tensile Strength (lbs) - E	22011	21942	21972	21793	21878	**21919**	85	0.4	
MD Tensile Strength (lbs/ft) - E	37733	37615	37665	37360	37506	**37576**	146	0.4	**100**
MD Tensile Strength (kN/m) - E	551	549	550	545	548	**549**	2	0.4	
MD - Elong. @ Max. Load (%) - B	10.63	11.56	10.65	10.50	10.57	**10.78**	0.44	4.07	
MD - Elong. @ Max. Load (%) - E	10.14	9.95	10.34	10.58	10.33	**10.27**	0.24	2.30	**95**

B - Baseline Unexposed
E - Exposed

MD - Machine Direction   TD - Transverse/Cross Machine Direction

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table E-13: Laboratory installation damage (ISO/EN 10722) tensile test results for ParaLink 600

PARAMETER	TEST REPLICATE NUMBER					MEAN	STD. DEV.	COEF. VARI.	PERCENT RETAINED
	1	2	3	4	5				
Laboratory Installation Damage (ISO/EN 10722)									
Strength Retained measured via wide width tensile (ISO/EN 10319)									
MD Number of Ribs per Specimen:	1								
MD Number of Ribs per foot:	1.71								
MD - Tensile Strength (lbs) - B	26340	26060	26019	26152	26330	**26180**	150	1	
MD Tensile Strength (lbs/ft) - B	45155	44674	44603	44831	45137	**44880**	256	1	
MD Tensile Strength (kN/m) - B	659	652	651	655	659	**655**	4	1	
MD - Tensile Strength (lbs) - E	26479	26142	26119	26369	26180	**26258**	158	1	
MD Tensile Strength (lbs/ft) - E	45392	44814	44775	45203	44880	**45013**	271	1	**100**
MD Tensile Strength (kN/m) - E	663	654	654	660	655	**657**	4	1	
MD - Elong. @ Max. Load (%) - B	10.28	9.66	9.71	9.74	10.13	**9.90**	0.28	2.84	
MD - Elong. @ Max. Load (%) - E	9.92	9.43	9.95	10.28	9.62	**9.84**	0.33	3.33	**99**

B - Baseline Unexposed
E - Exposed

MD - Machine Direction   TD - Transverse/Cross Machine Direction

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table E-14: Laboratory installation damage (ISO/EN 10722) tensile test results for ParaLink 700

PARAMETER	TEST REPLICATE NUMBER					MEAN	STD. DEV.	COEF. VARI.	PERCENT RETAINED
	1	2	3	4	5				
Laboratory Installation Damage (ISO/EN 10722)									
Strength Retained measured via wide width tensile (ISO/EN 10319)									
MD Number of Ribs per Specimen:	1								
MD Number of Ribs per foot:	1.71								
MD - Tensile Strength (lbs) - B	31187	31563	31857	31520	31866	**31577**	256	1	
MD Tensile Strength (lbs/ft) - B	53464	54107	54612	54035	54628	**54169**	481	1	
MD Tensile Strength (kN/m) - B	781	790	797	789	798	**791**	7	1	
MD - Tensile Strength (lbs) - E	31167	31726	31647	31546	31674	**31552**	225	1	
MD Tensile Strength (lbs/ft) - E	53430	54387	54251	54079	54298	**54089**	385	1	**100**
MD Tensile Strength (kN/m) - E	780	794	792	790	793	**790**	6	1	
MD - Elong. @ Max. Load (%) - B	10.79	10.52	11.19	10.50	10.85	**10.77**	0.28	2.62	
MD - Elong. @ Max. Load (%) - E	10.79	10.84	11.02	10.82	10.53	**10.80**	0.18	1.63	**100**

B - Baseline Unexposed
E - Exposed

MD - Machine Direction TD - Transverse/Cross Machine Direction

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table E-15: Laboratory installation damage (ISO/EN 10722) tensile test results for ParaLink 800

PARAMETER	TEST REPLICATE NUMBER					MEAN	STD. DEV.	COEF. VARI.	PERCENT RETAINED
	1	2	3	4	5				
Laboratory Installation Damage (ISO/EN 10722)									
Strength Retained measured via wide width tensile (ISO/EN 10319)									
MD Number of Ribs per Specimen:	1								
MD Number of Ribs per foot:	2.07								
MD - Tensile Strength (lbs) - B	29727	29751	29721	29884	29756	**29768**	67	0.2	
MD Tensile Strength (lbs/ft) - B	61460	61510	61448	61785	61519	**61544**	138	0.2	
MD Tensile Strength (kN/m) - B	897	898	897	902	898	**899**	2	0.2	
MD - Tensile Strength (lbs) - E	29619	29856	29725	29897	29809	**29781**	111	0.4	
MD Tensile Strength (lbs/ft) - E	61237	61726	61456	61812	61629	**61572**	230	0.4	**100**
MD Tensile Strength (kN/m) - E	894	901	897	902	900	**899**	3	0.4	
MD - Elong. @ Max. Load (%) - B	10.84	11.68	11.16	11.71	11.55	**11.39**	0.38	3.31	
MD - Elong. @ Max. Load (%) - E	10.69	11.06	10.80	10.98	10.90	**10.89**	0.15	1.34	**96**
B - Baseline Unexposed									
E - Exposed									

MD - Machine Direction TD - Transverse/Cross Machine Direction

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table E-16: Laboratory installation damage (ISO/EN 10722) tensile test results for ParaLink 1000

PARAMETER	TEST REPLICATE NUMBER					MEAN	STD. DEV.	COEF. VARI.	PERCENT RETAINED
	1	2	3	4	5				
Laboratory Installation Damage (ISO/EN 10722)									
Strength Retained measured via wide width tensile (ISO/EN 10319)									
MD Number of Ribs per Specimen:	1								
MD Number of Ribs per foot:	2.51								
MD - Tensile Strength (lbs) - B	28726	28799	29034	29319	29341	**29044**	285	1	
MD Tensile Strength (lbs/ft) - B	72115	72299	72889	73604	73659	**72913**	716	1	
MD Tensile Strength (kN/m) - B	1053	1056	1064	1075	1075	**1065**	10	1	
MD - Tensile Strength (lbs) - E	28765	27778	28758	28934	27634	**28374**	616	2	
MD Tensile Strength (lbs/ft) - E	72213	69736	72196	72638	69374	**71231**	1546	2	**98**
MD Tensile Strength (kN/m) - E	1054	1018	1054	1061	1013	**1040**	23	2	
MD - Elong. @ Max. Load (%) - B	10.9	11.2	10.9	11.0	11.3	**11.1**	0.2	1.6	
MD - Elong. @ Max. Load (%) - E	10.6	10.6	10.6	11.1	10.6	**10.7**	0.2	2.1	**97**

B - Baseline Unexposed
E - Exposed

MD - Machine Direction TD - Transverse/Cross Machine Direction

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table E-17: Laboratory installation damage (ISO/EN 10722) tensile test results for ParaLink 1200

PARAMETER	TEST REPLICATE NUMBER					MEAN	STD. DEV.	COEF. VARI.	PERCENT RETAINED
	1	2	3	4	5				
Laboratory Installation Damage (ISO/EN 10722)									
Strength Retained measured via wide width tensile (ISO/EN 10319)									
MD Number of Ribs per Specimen:	1								
MD Number of Ribs per foot:	3.11								
MD - Tensile Strength (lbs) - B	29651	29829	29743	29743	29678	**29729**	69	0.2	
MD Tensile Strength (lbs/ft) - B	92093	92646	92380	92378	92175	**92334**	215	0.2	
MD Tensile Strength (kN/m) - B	1345	1353	1349	1349	1346	**1348**	3	0.2	
MD - Tensile Strength (lbs) - E	29800	29689	29660	29850	29747	**29749**	78	0.3	
MD Tensile Strength (lbs/ft) - E	92555	92212	92120	92711	92391	**92398**	242	0.3	**100**
MD Tensile Strength (kN/m) - E	1351	1346	1345	1354	1349	**1349**	4	0.3	
MD - Elong. @ Max. Load (%) - B	11.07	10.95	10.62	10.56	10.73	**10.79**	0.22	2.02	
MD - Elong. @ Max. Load (%) - E	10.50	10.80	10.63	10.34	10.57	**10.57**	0.17	1.60	**98**

B - Baseline Unexposed
E - Exposed

MD - Machine Direction TD - Transverse/Cross Machine Direction

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table E-18: Laboratory installation damage (ISO/EN 10722) tensile test results for ParaLink 1500

PARAMETER	TEST REPLICATE NUMBER					MEAN	STD. DEV.	COEF. VARI.	PERCENT RETAINED
	1	2	3	4	5				
Laboratory Installation Damage (ISO/EN 10722)									
Strength Retained measured via wide width tensile (ISO/EN 10319)									
MD Number of Ribs per Specimen:	1								
MD Number of Ribs per foot:	3.08								
MD - Tensile Strength (lbs) - B	35644	35878	35755	35998	35537	**35762**	183	1	
MD Tensile Strength (lbs/ft) - B	109875	110597	110216	110967	109545	**110240**	564	1	
MD Tensile Strength (kN/m) - B	1604	1615	1609	1620	1599	**1610**	8	1	
MD - Tensile Strength (lbs) - E	35618	35843	35595	35513	35801	**35674**	142	0.4	
MD Tensile Strength (lbs/ft) - E	109795	110490	109725	109471	110360	**109968**	437	0.4	**100**
MD Tensile Strength (kN/m) - E	1603	1613	1602	1598	1611	**1606**	6	0.4	
MD - Elong. @ Max. Load (%) - B	10.63	11.28	10.83	11.27	10.79	**10.96**	0.30	2.71	
MD - Elong. @ Max. Load (%) - E	10.50	10.69	10.47	10.54	10.95	**10.63**	0.20	1.86	**97**

B - Baseline Unexposed
E - Exposed

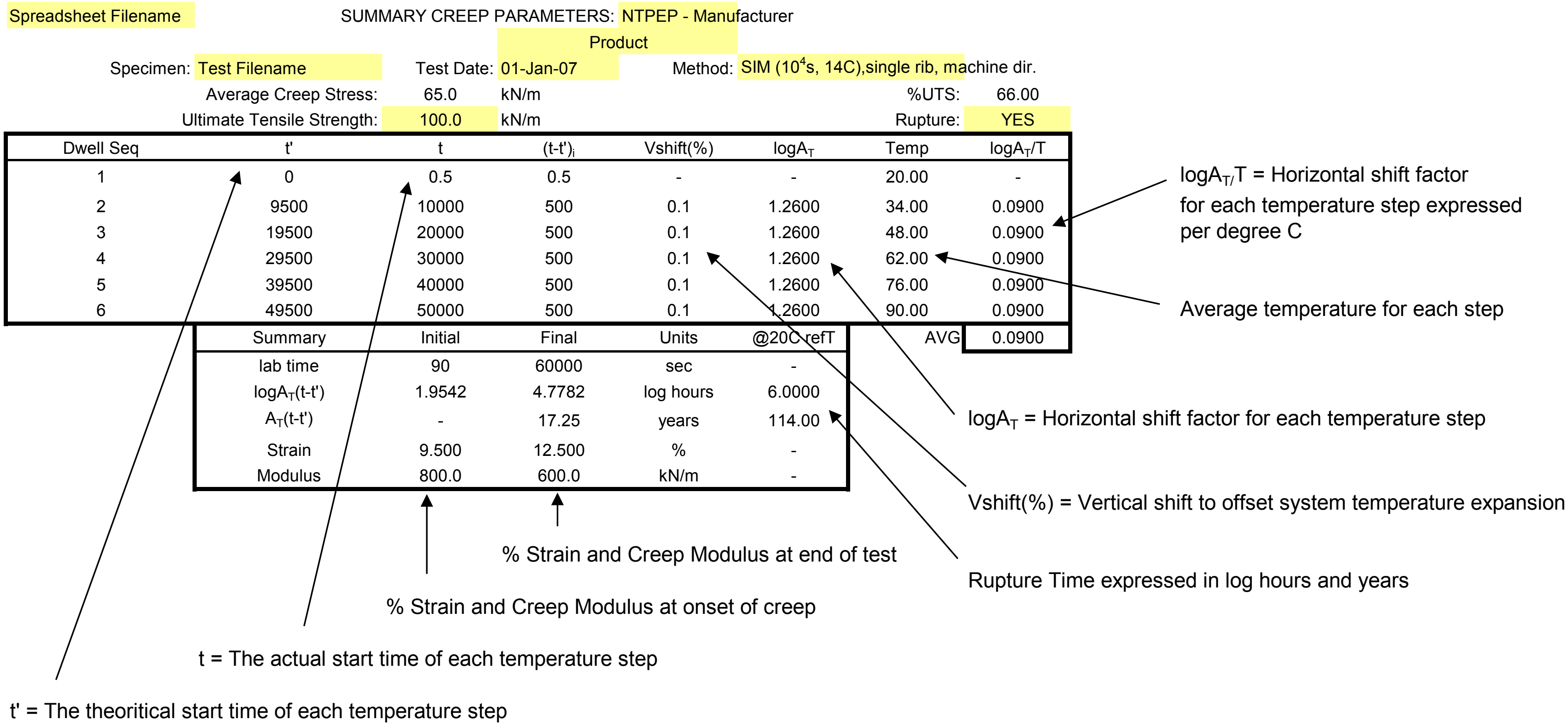
MD - Machine Direction TD - Transverse/Cross Machine Direction

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Appendix F: Creep Rupture Detailed Test Results

Table F-1: Explanation/Key for Individual Creep Test Data Tables/Figures

Accelerated Creep Rupture via SIM - ASTM D 6992



Spreadsheet Filename

SUMMARY CREEP PARAMETERS: NTPEP - Manufacturer
Product

Specimen: Test Filename Test Date: 01-Jan-07 Method: SIM (10^4s, 14C),single rib, machine dir.

Average Creep Stress: 65.0 kN/m %UTS: 66.00

Ultimate Tensile Strength: 100.0 kN/m Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
1	0	0.5	0.5	-	-	20.00	-
2	9500	10000	500	0.1	1.2600	34.00	0.0900
3	19500	20000	500	0.1	1.2600	48.00	0.0900
4	29500	30000	500	0.1	1.2600	62.00	0.0900
5	39500	40000	500	0.1	1.2600	76.00	0.0900
6	49500	50000	500	0.1	1.2600	90.00	0.0900

Summary	Initial	Final	Units	@20C refT	AVG	0.0900
lab time	90	60000	sec	-		
$\log A_T(t-t')$	1.9542	4.7782	log hours	6.0000		
$A_T(t-t')$	-	17.25	years	114.00		
Strain	9.500	12.500	%	-		
Modulus	800.0	600.0	kN/m	-		

$\log A_{T/}T$ = Horizontal shift factor for each temperature step expressed per degree C

Average temperature for each step

$\log A_T$ = Horizontal shift factor for each temperature step

Vshift(%) = Vertical shift to offset system temperature expansion

Rupture Time expressed in log hours and years

% Strain and Creep Modulus at end of test

% Strain and Creep Modulus at onset of creep

t = The actual start time of each temperature step

t' = The theoritical start time of each temperature step

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaWeb 30

Specimen: 27063n2l2-pw30-sim
Test Date: July 2017
Method: SIM (10^4s, 14C),strapping
Average Creep Stress: 4797.6 lb/rib
%UTS: 70.00
Ultimate Tensile Strength: 6853.7 lb/rib
Rupture: YES

Dwell Seq	t'	t	$(t\text{-}t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
1	0	0.5	0.5	-	-	19.9	-
2	9500	10019	519	0.1	1.2844	34.1	0.0908
3	19500	20009	509	0.11	1.3136	48.4	0.0917
4	29500	29999	499	0.12	1.3218	62.7	0.0925
5	39500	39989	489	0.15	1.3302	77.0	0.0928
6	49400	49979	579	0.1	1.2564	91.7	0.0858
						AVG	0.0907

Summary	Initial	Final	Units	@20C refT
lab time	47	59939	sec	-
$\log A_T(t\text{-}t')$	1.6721	10.5291	log hours	6.9671
$A_T(t\text{-}t')$	-	1071.60	years	1057.61
Strain	6.236	12.219	%	-
Modulus	66944.6	39263.1	lb/rib	-

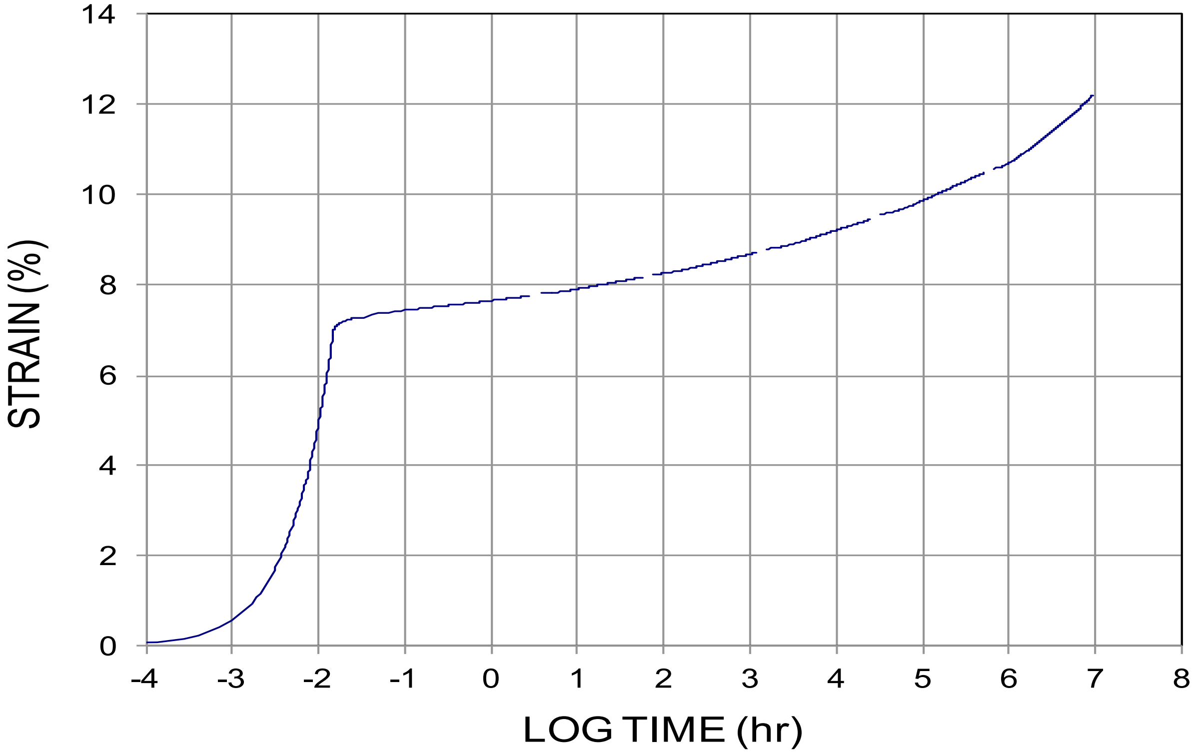


Figure F-1. SIM/Creep data/curve for ParaWeb 30 at load level of 70.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaWeb 30

Specimen: 27063n2l2-pw30-sim Test Date: July 2017 Method: SIM (10^4s, 14C),strapping

Average Creep Stress: 5140.2 lb/rib %UTS: 75.00

Ultimate Tensile Strength: 6853.7 lb/rib Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
1	0	0.5	0.5	-	-	19.9	-
2	9400	10019	619	0.1	1.2078	34.1	0.0854
3	19400	20009	609	0.11	1.2398	48.4	0.0865
4	29400	29999	599	0.12	1.2466	62.7	0.0872
5	39300	39989	689	0.15	1.1854	77.0	0.0827
6	49100	49979	879	0.15	1.0833	91.7	0.0738
						AVG	0.0831

Summary	Initial	Final	Units	@20C refT
lab time	51.5	51419	sec	-
$\log A_T(t-t')$	1.7118	9.3283	log hours	5.7666
$A_T(t-t')$	-	67.48	years	66.65
Strain	7.417	16.079	%	-
Modulus	70050.4	31985.1	lb/rib	-

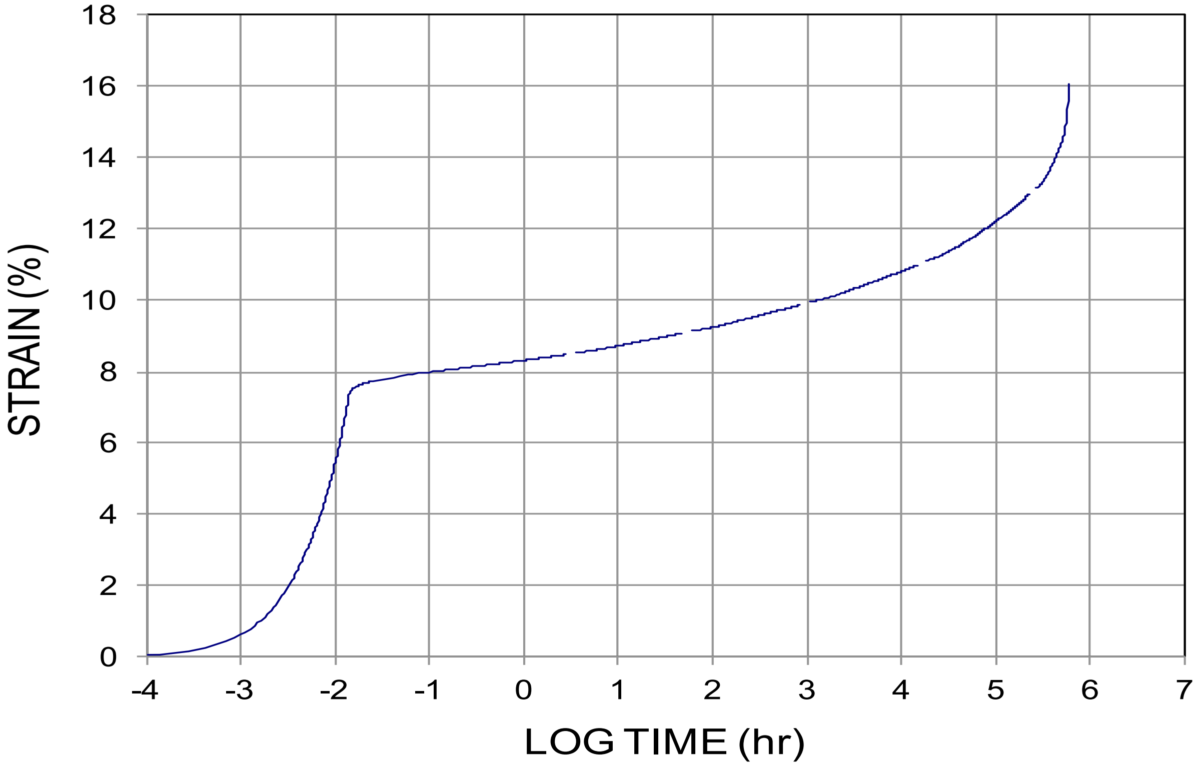


Figure F-2. SIM/Creep data/curve for ParaWeb 30 at load level of 75.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaWeb 30

Specimen: 27063n2l2-pw30-sim
Test Date: May 2017
Method: SIM (10^4s, 14C),strapping

Average Creep Stress: 5482.8 lb/rib
%UTS: 80.00

Ultimate Tensile Strength: 6853.7 lb/rib
Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
1	0	0.5	0.5	-	-	19.9	-
2	9500	10019	519	0.1	1.2844	34.1	0.0908
3	19500	20009	509	0.12	1.3136	48.4	0.0917
4	29400	29999	599	0.14	1.2425	62.6	0.0875
5							
6							

Summary	Initial	Final	Units	@20C refT
lab time	66	31679	sec	-
$\log A_T(t-t')$	1.8195	7.1982	log hours	3.6362
$A_T(t-t')$	-	0.50	years	0.49
Strain	8.05	14.57	%	-
Modulus	68519.5	37238.0	lb/rib	-

AVG 0.0900

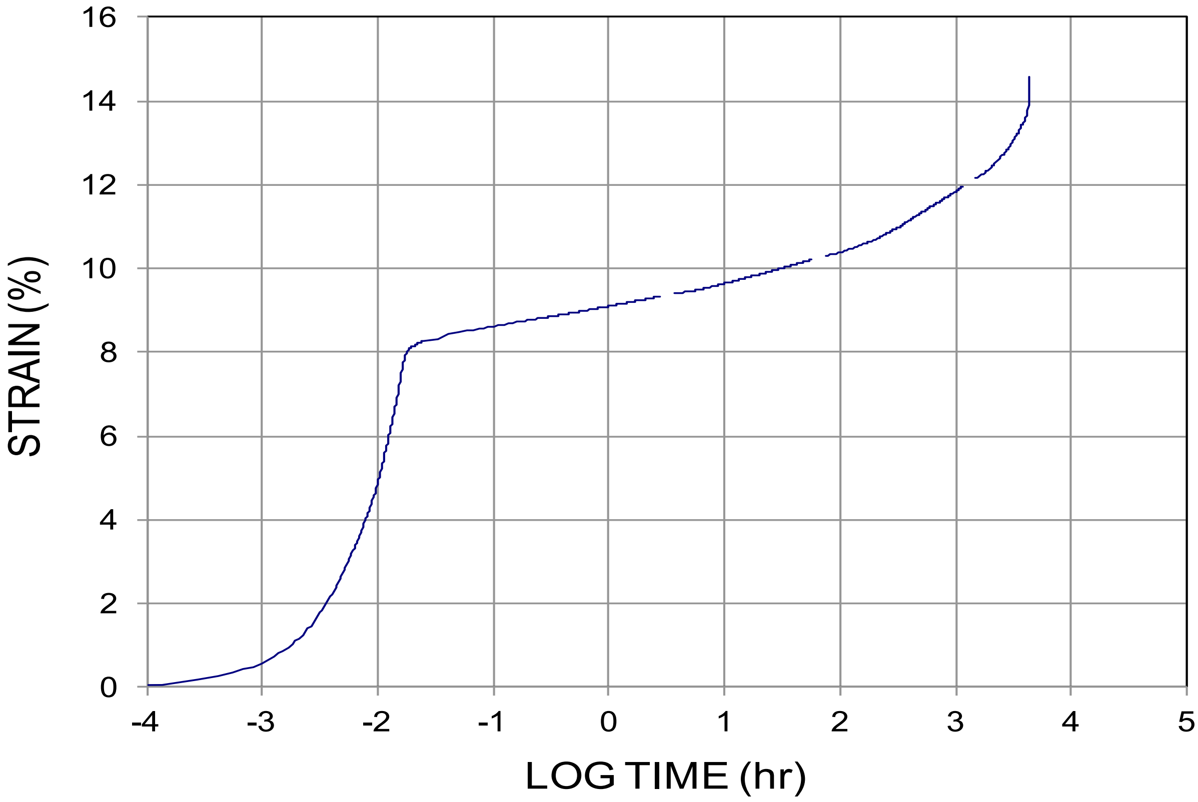


Figure F-3. SIM/Creep data/curve for ParaWeb 30 at load level of 80.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaWeb 30

Specimen: 27063n2l2-pw30-sim
Test Date: July 2017
Method: SIM (10^4s, 14C),strapping
Average Creep Stress: 5825.5 lb/rib
%UTS: 85.00
Ultimate Tensile Strength: 6853.7 lb/rib
Rupture: YES

Dwell Seq	t'	t	(t-t')$_i$	Vshift(%)	logA$_T$	Temp	logA$_T$/T
1	0	0.5	0.5	-	-	19.9	-
2	9500	10019	519	0.1	1.2844	34.1	0.0908
3	19200	20009	809	0.11	1.1124	48.7	0.0762
4							
5							
6							

Summary	Initial	Final	Units	@20C refT
lab time	66	21389	sec	-
logA$_T$(t-t')	1.8195	5.7370	log hours	2.1750
A$_T$(t-t')	-	0.02	years	0.02
Strain	8.38	13.651	%	-
Modulus	70041.1	42667.0	lb/rib	-

AVG 0.0834

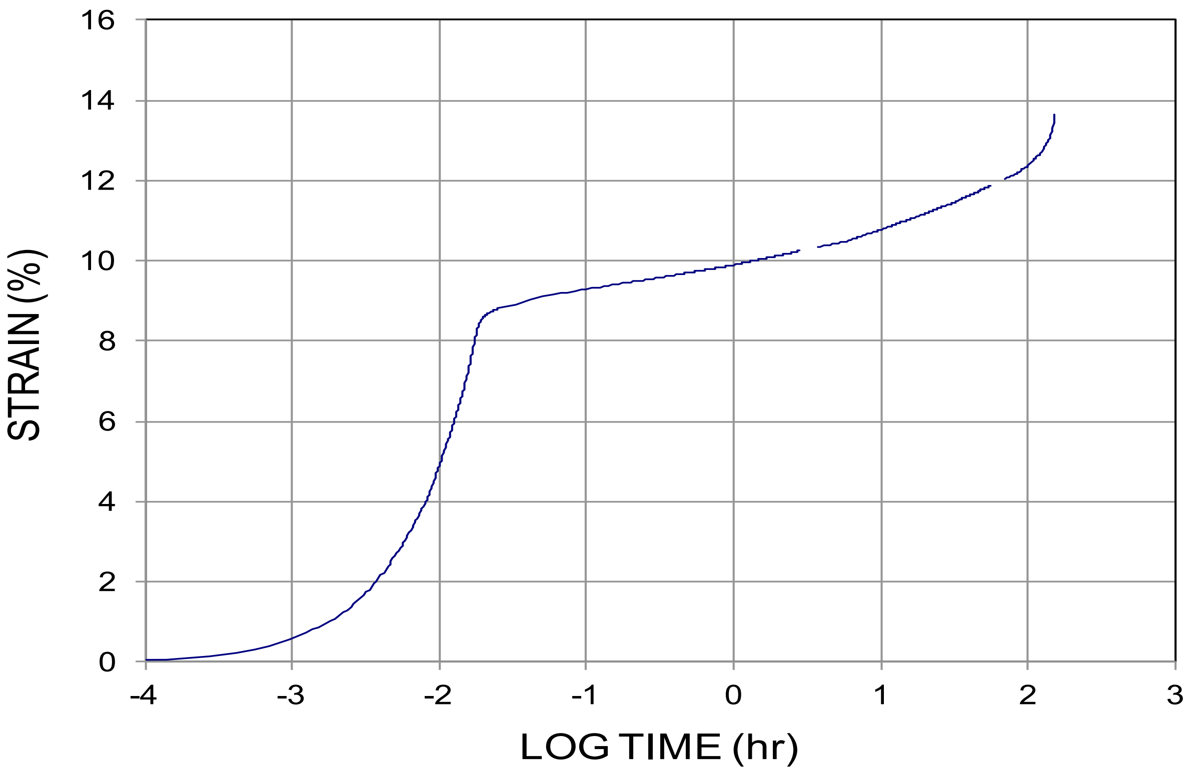


Figure F-4. SIM/Creep data/curve for ParaWeb 30 at load level of 85.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaWeb 50

Specimen: 27063n2l2-pw50-sim Test Date: April 2017 Method: SIM (10^4s, 14C),strapping
Average Creep Stress: 8132.2 lb/rib %UTS: 70.00
Ultimate Tensile Strength: 11617.5 lb/rib Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
1	0	0.5	0.5	-	-	19.9	-
2	9500	10019	519	0.1	1.2844	34.1	0.0908
3	19500	20009	509	0.12	1.3136	48.4	0.0917
4	29500	29999	499	0.14	1.3218	62.7	0.0925
5	39500	39989	489	0.15	1.3302	77.0	0.0928
6	49500	49979	479	0.17	1.3387	91.7	0.0914

AVG 0.0918

Summary	Initial	Final	Units	@20C refT
lab time	46.5	59939	sec	-
$\log A_T(t-t')$	1.6675	10.6073	log hours	7.0453
$A_T(t-t')$	-	1283.03	years	1266.27
Strain	7.131	14.217	%	-
Modulus	116648.8	57197.2	lb/rib	-

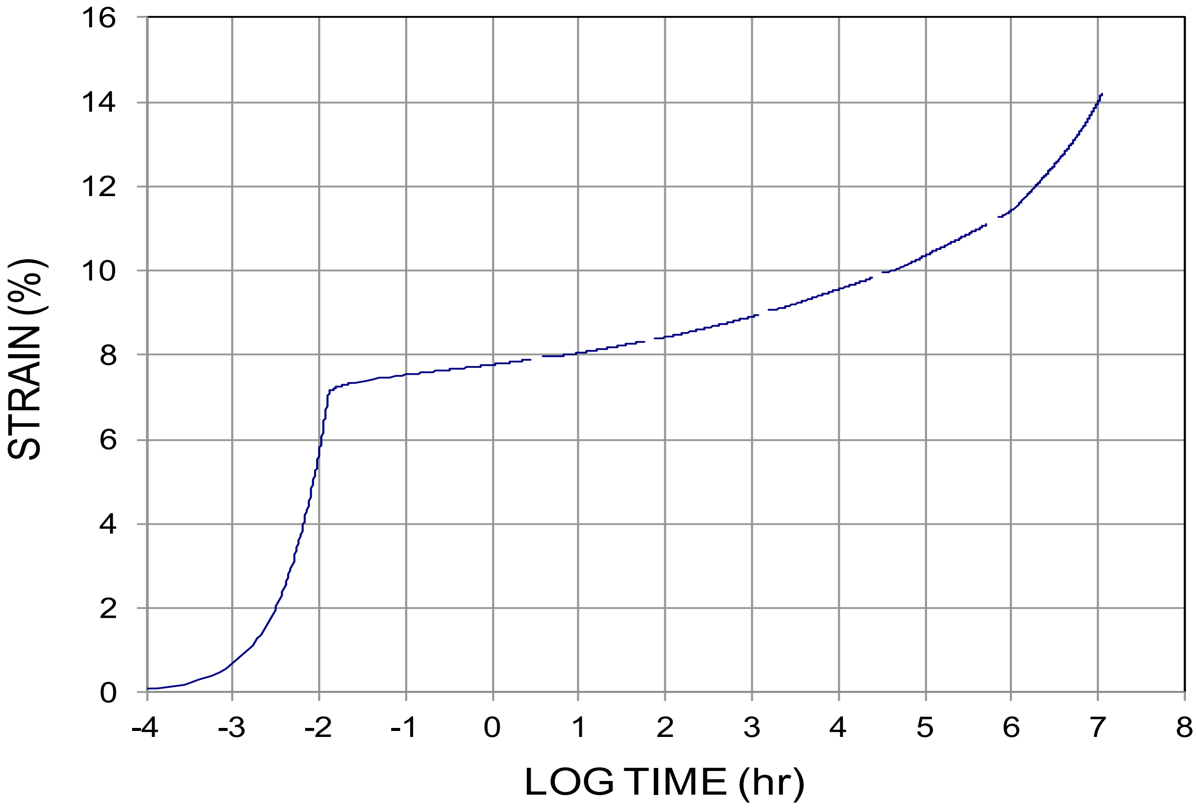


Figure F-5. SIM/Creep data/curve for ParaWeb 50 at load level of 70.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaWeb 50

Specimen: 27063n2l2-pw50-sim	Test Date:	April 2017	Method: SIM (10^4s, 14C),strapping		
Average Creep Stress:	8132.2	lb/rib		%UTS:	70.00
Ultimate Tensile Strength:	11617.5	lb/rib		Rupture:	YES

Dwell Seq	t'	t	$(t\text{-}t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
1	0	0.5	0.5	-	-	19.9	-
2	9500	10019	519	0.13	1.2844	34.1	0.0908
3	19500	20009	509	0.16	1.3136	48.4	0.0917
4	29500	29999	499	0.14	1.3218	62.7	0.0925
5	39500	39989	489	0.15	1.3302	77.0	0.0928
6	49500	49979	479	0.17	1.3387	91.8	0.0910

Summary	Initial	Final	Units	@20C refT		
					AVG	0.0917
lab time	45.5	51479	sec	-		
$\log A_T(t\text{-}t')$	1.6580	9.8851	log hours	6.3231		
$A_T(t\text{-}t')$	-	243.23	years	240.06		
Strain	7.022	11.107	%	-		
Modulus	118501.3	73211.5	lb/rib	-		

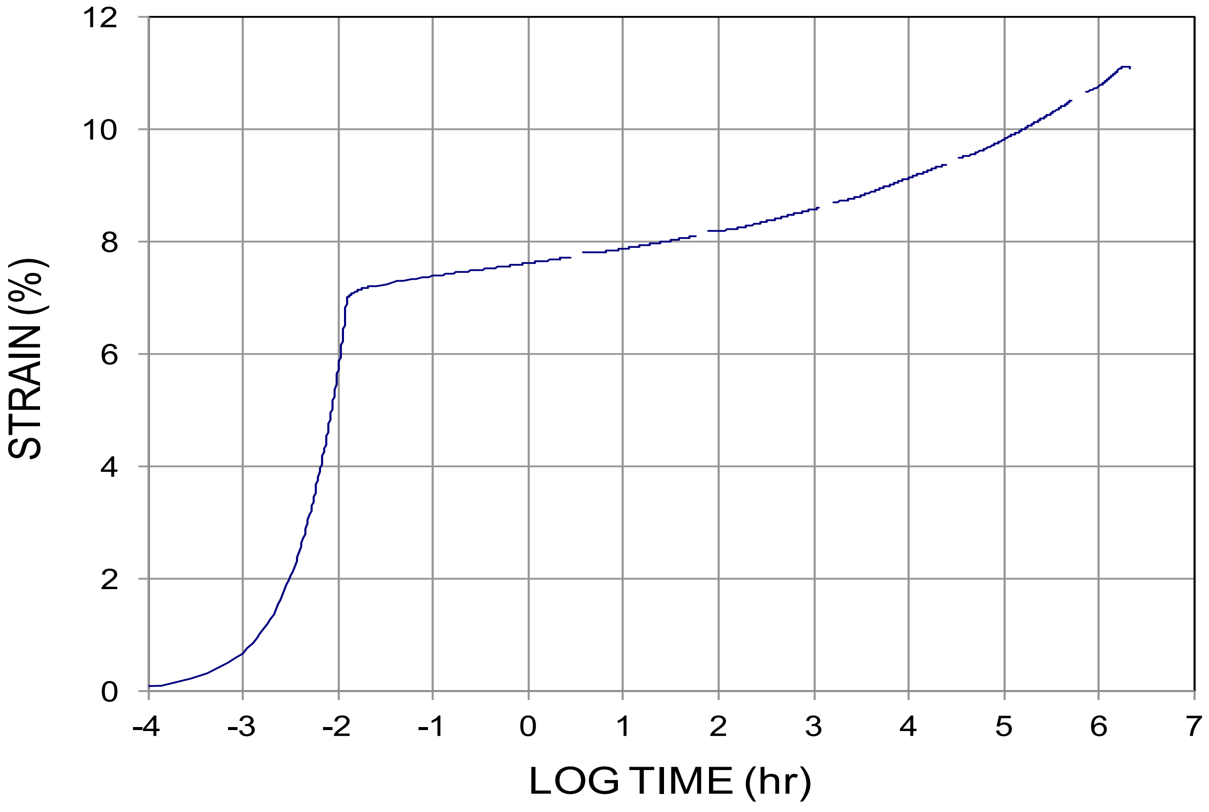


Figure F-6. SIM/Creep data/curve for ParaWeb 50 at load level of 70.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaWeb 50

Specimen: 27063n2l2-pw50-sim
Test Date: April 2017
Method: SIM (10^4s, 14C),strapping

Average Creep Stress: 8480.6 lb/rib
%UTS: 73.00

Ultimate Tensile Strength: 11617.5 lb/rib
Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
1	0	0.5	0.5	-	-	19.9	-
2	9500	10019	519	0.1	1.2844	34.1	0.0908
3	19500	20009	509	0.13	1.3136	48.4	0.0917
4	29500	29999	499	0.14	1.3218	62.7	0.0925
5	39400	39989	589	0.15	1.2494	77.0	0.0871
6	49200	49979	779	0.17	1.1317	91.7	0.0772

AVG 0.0878

Summary	Initial	Final	Units	@20C refT
lab time	51.5	53999	sec	-
$\log A_T(t-t')$	1.7118	9.9820	log hours	6.4199
$A_T(t-t')$	-	303.99	years	300.02
Strain	7.311	15.304	%	-
Modulus	118363.0	55412.7	lb/rib	-

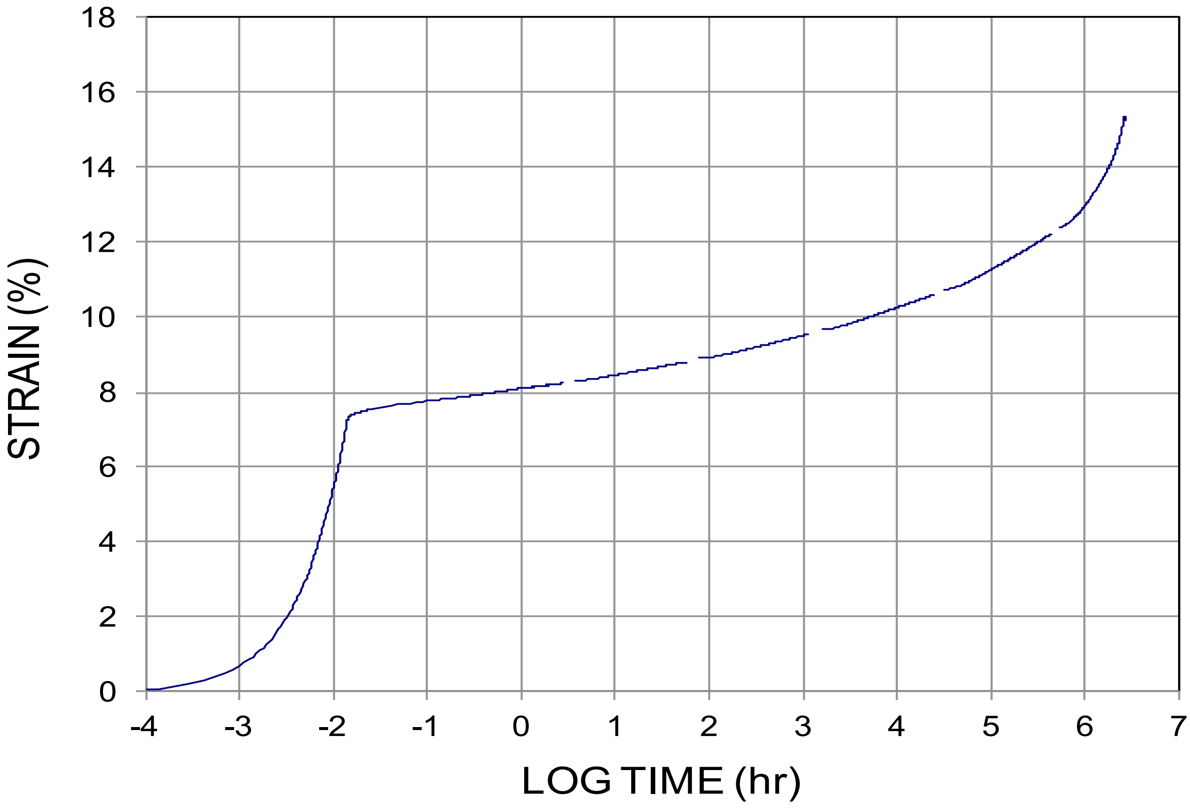


Figure F-7. SIM/Creep data/curve for ParaWeb 50 at load level of 73.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaWeb 50

Specimen: 27063n2l2-pw50-sim Test Date: April 2017 Method: SIM (10^4s, 14C),strapping
Average Creep Stress: 8480.7 lb/rib %UTS: 73.00
Ultimate Tensile Strength: 11617.5 lb/rib Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
1	0	0.5	0.5	-	-	19.9	-
2	9500	10019	519	0.1	1.2844	34.1	0.0908
3	19500	20009	509	0.12	1.3136	48.4	0.0917
4	29500	29999	499	0.14	1.3218	62.7	0.0925
5	39400	39989	589	0.13	1.2494	77.0	0.0871
6	49300	49979	679	0.17	1.1913	91.8	0.0808

AVG 0.0885

Summary	Initial	Final	Units	@20C refT
lab time	53.5	51569	sec	-
$\log A_T(t-t')$	1.7284	9.7163	log hours	6.1543
$A_T(t-t')$	-	164.90	years	162.74
Strain	7.506	15.413	%	-
Modulus	115297.5	55020.7	lb/rib	-

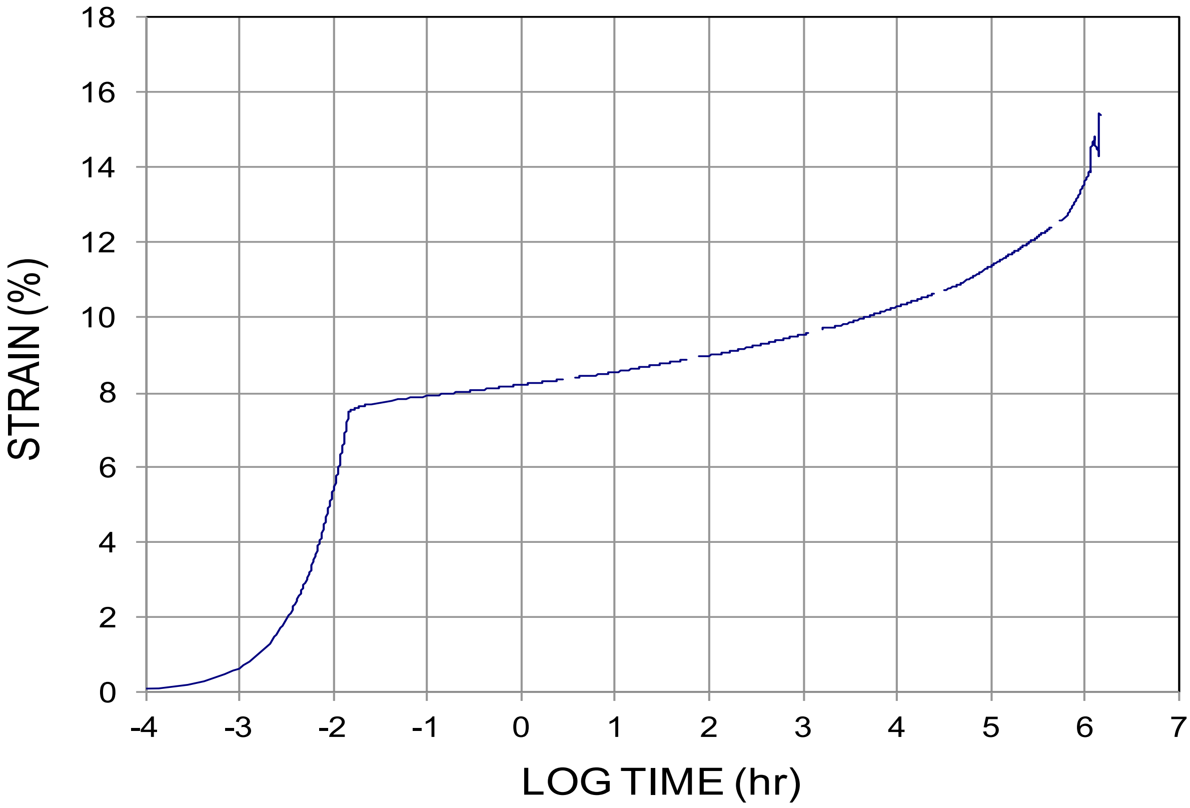


Figure F-8. SIM/Creep data/curve for ParaWeb 50 at load level of 73.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaWeb 50

Specimen: 27063n2l2-pw50-sim
Test Date: April 2017
Method: SIM (10^4s, 14C),strapping

Average Creep Stress:	8829.2	lb/rib	%UTS:	76.00
Ultimate Tensile Strength:	11617.5	lb/rib	Rupture:	YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$logA_T$	Temp	$logA_T/T$
1	0	0.5	0.5	-	-	19.9	-
2	9500	10019	519	0.11	1.2844	34.1	0.0908
3	19500	20009	509	0.12	1.3136	48.4	0.0917
4	29300	29999	699	0.14	1.1754	62.7	0.0822
5	39400	39989	589	0.13	1.2576	77.0	0.0878
6							

Summary	Initial	Final	Units	@20C refT
lab time	50.5	46079	sec	-
$logA_T(t-t')$	1.7033	8.8557	log hours	5.2937
$A_T(t-t')$	-	22.73	years	22.43
Strain	7.433	14.965	%	-
Modulus	121086.7	58999.6	lb/rib	-

AVG 0.0881

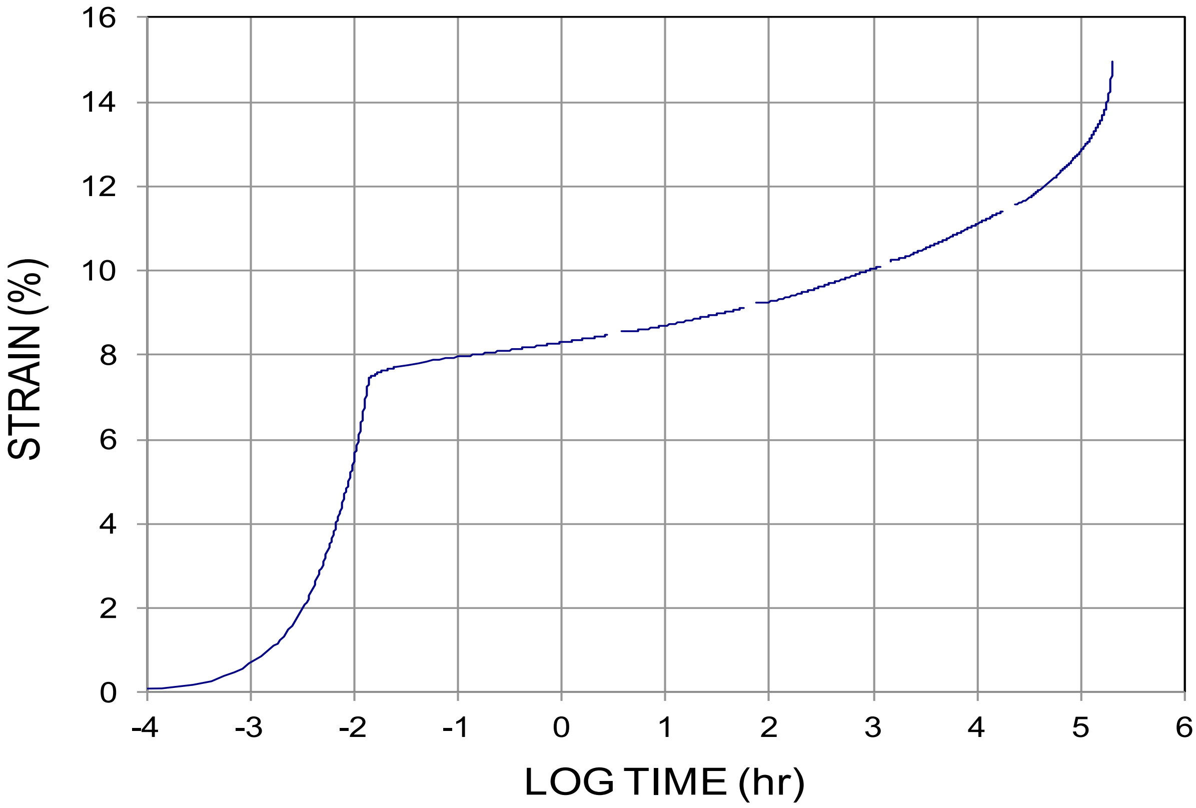


Figure F-9. SIM/Creep data/curve for ParaWeb 50 at load level of 76.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaWeb 50

Specimen: 27063n2l2-pw50-sim Test Date: April 2017 Method: SIM (10^4s, 14C),strapping
Average Creep Stress: 8829.2 lb/rib %UTS: 76.00
Ultimate Tensile Strength: 11617.5 lb/rib Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
1	0	0.5	0.5	-	-	19.9	-
2	9500	10019	519	0.12	1.2844	34.1	0.0908
3	19500	20009	509	0.14	1.3136	48.4	0.0917
4	29400	29999	599	0.13	1.2425	62.7	0.0869
5	39400	39989	589	0.13	1.2535	77.0	0.0878
6							

AVG 0.0893

Summary	Initial	Final	Units	@20C refT
lab time	53.5	41669	sec	-
$\log A_T(t-t')$	1.7284	8.4498	log hours	4.8878
$A_T(t-t')$	-	8.93	years	8.81
Strain	7.32	12.70	%	-
Modulus	122891.4	69528.9	lb/rib	-

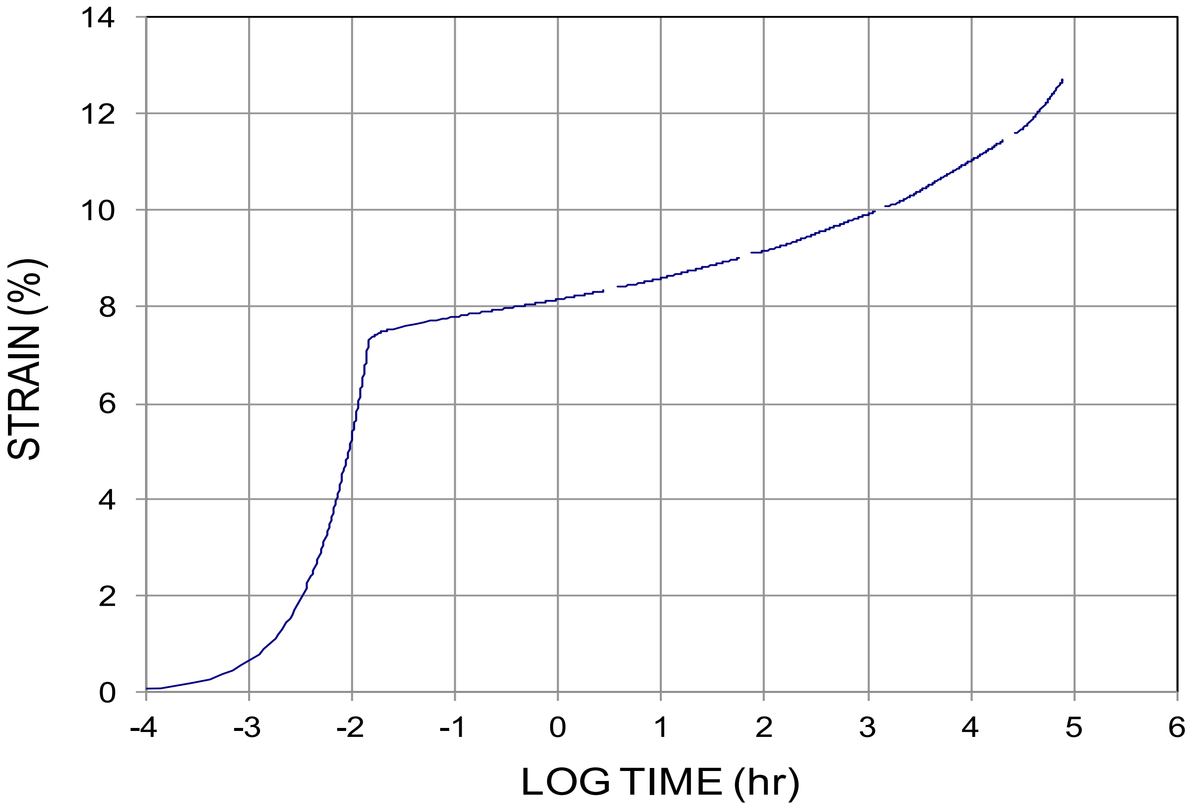


Figure F-10. SIM/Creep data/curve for ParaWeb 50 at load level of 76.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaWeb 50

Specimen: 27063n2l2-pw50-sim
Test Date: April 2017
Method: SIM (10^4s, 14C),strapping
Average Creep Stress: 9177.7 lb/rib
%UTS: 79.00
Ultimate Tensile Strength: 11617.5 lb/rib
Rupture: YES

Dwell Seq	t'	t	$(t\text{-}t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
1	0	0.5	0.5	-	-	19.9	-
2	9300	10019	719	0.03	1.1428	34.1	0.0808
3	19500	20009	509	0.14	1.3218	48.4	0.0923
4	29500	29999	499	0.11	1.3218	62.7	0.0925
5							
6							

Summary	Initial	Final	Units	@20C refT
lab time	53.5	36359	sec	-
$\log A_T(t\text{-}t')$	1.7284	7.6227	log hours	4.0613
$A_T(t\text{-}t')$	-	1.33	years	1.31
Strain	7.60	13.13	%	-
Modulus	122805.3	69891.3	lb/rib	-

AVG 0.0886

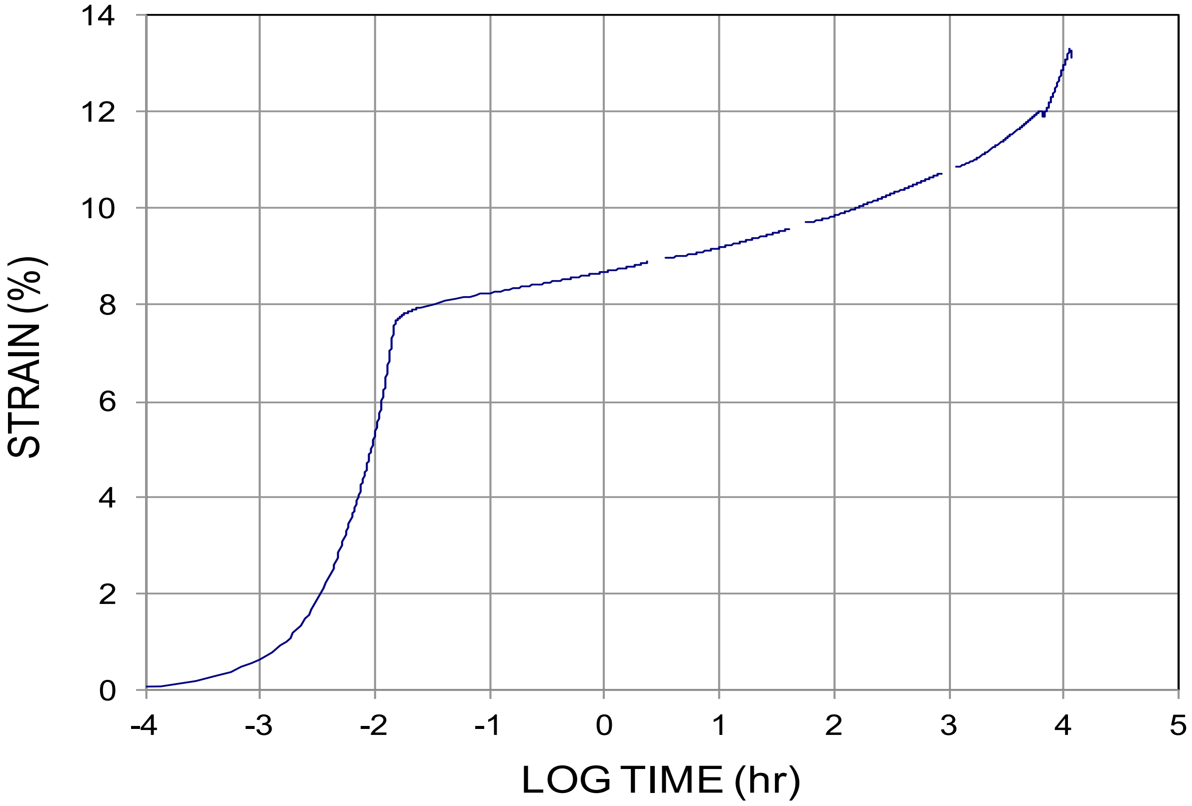


Figure F-11. SIM/Creep data/curve for ParaWeb 50 at load level of 79.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaWeb 50

Specimen: 27063n2l2-pw50-sim
Test Date: April 2017
Method: SIM (10^4s, 14C),strapping
Average Creep Stress: 9177.6 lb/rib
%UTS: 79.00
Ultimate Tensile Strength: 11617.5 lb/rib
Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$logA_T$	Temp	$logA_T/T$
1	0	0.5	0.5	-	-	19.9	-
2	9500	10019	519	0.12	1.2844	34.1	0.0908
3	19500	20009	509	0.14	1.3136	48.4	0.0917
4	29400	29999	599	0.13	1.2425	62.7	0.0869
5	39400	39989	589	0.13	1.2535	77.8	0.0828
6							
						AVG	0.0880

Summary	Initial	Final	Units	@20C refT
lab time	52.5	40289	sec	-
$logA_T(t-t')$	1.7202	8.0428	log hours	4.4808
$A_T(t-t')$	-	3.50	years	3.45
Strain	7.85	14.75	%	-
Modulus	119069.1	62108.9	lb/rib	-

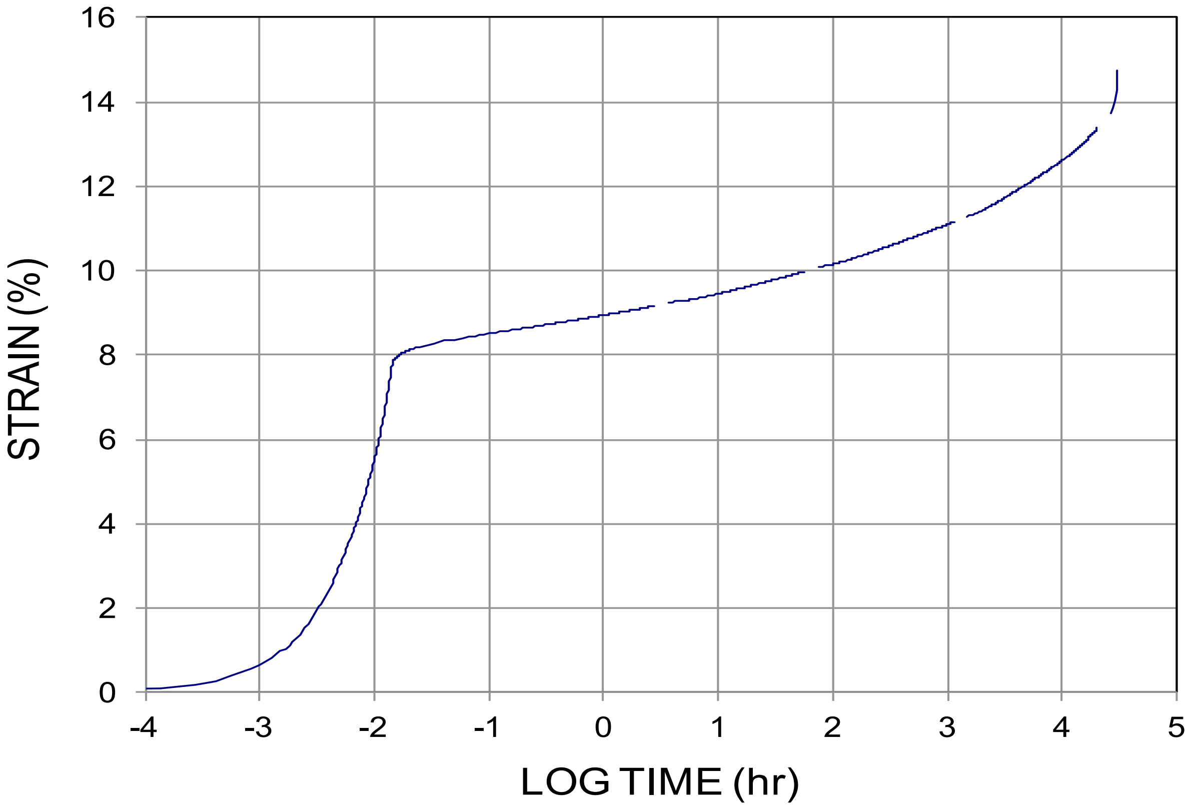


Figure F-12. SIM/Creep data/curve for ParaWeb 50 at load level of 79.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaWeb 50

Specimen: 27063n2l2-pw50-sim Test Date: April 2017 Method: SIM (10^4s, 14C),strapping

Average Creep Stress: 9526.2 lb/rib %UTS: 82.00

Ultimate Tensile Strength: 11617.5 lb/rib Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
1	0	0.5	0.5	-	-	19.9	-
2	9400	10019	619	0.14	1.2078	34.1	0.0854
3	19400	20009	609	0.14	1.2398	48.4	0.0865
4	29400	29999	599	0.16	1.2466	62.9	0.0858
5							
6							

AVG 0.0859

Summary	Initial	Final	Units	@20C refT
lab time	53	30389	sec	-
$\log A_T(t-t')$	1.7243	6.6895	log hours	3.1278
$A_T(t-t')$	-	0.16	years	0.15
Strain	7.89	12.04	%	-
Modulus	122606.6	79138.7	lb/rib	-

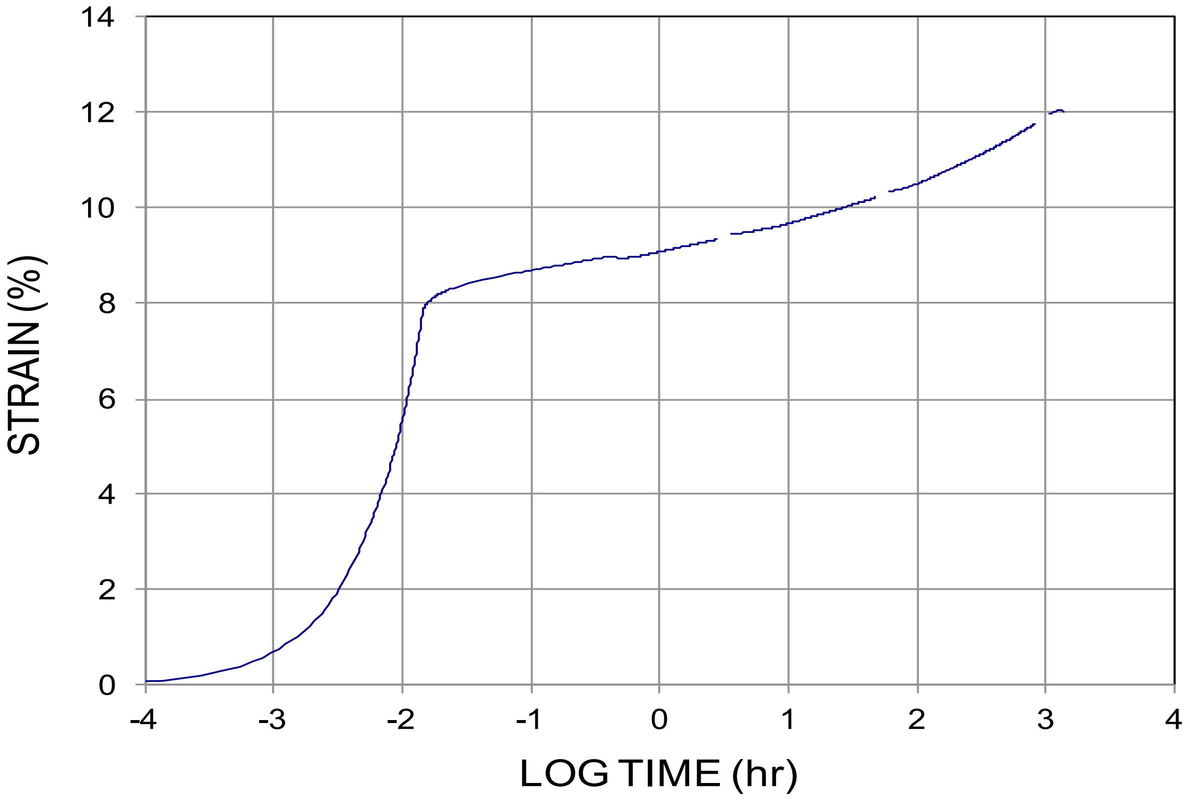


Figure F-13. SIM/Creep data/curve for ParaWeb 50 at load level of 82.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaWeb 50

Specimen: 27063n2l2-pw50-sim
Test Date: May 2017
Method: SIM (10^4s, 14C),strapping
Average Creep Stress: 9526.2 lb/rib
%UTS: 82.00
Ultimate Tensile Strength: 11617.5 lb/rib
Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
1	0	0.5	0.5	-	-	19.9	-
2	9500	10019	519	0.11	1.2844	34.1	0.0908
3	19400	20009	609	0.14	1.2357	48.4	0.0862
4	29400	29999	599	0.16	1.2466	62.6	0.0882
5							
6							

Summary	Initial	Final	Units	@20C refT
lab time	53	30779	sec	-
$\log A_T(t-t')$	1.7243	6.9062	log hours	3.3442
$A_T(t-t')$	-	0.26	years	0.25
Strain	8.14	14.60	%	-
Modulus	118457.8	65263.4	lb/rib	-

AVG 0.0884

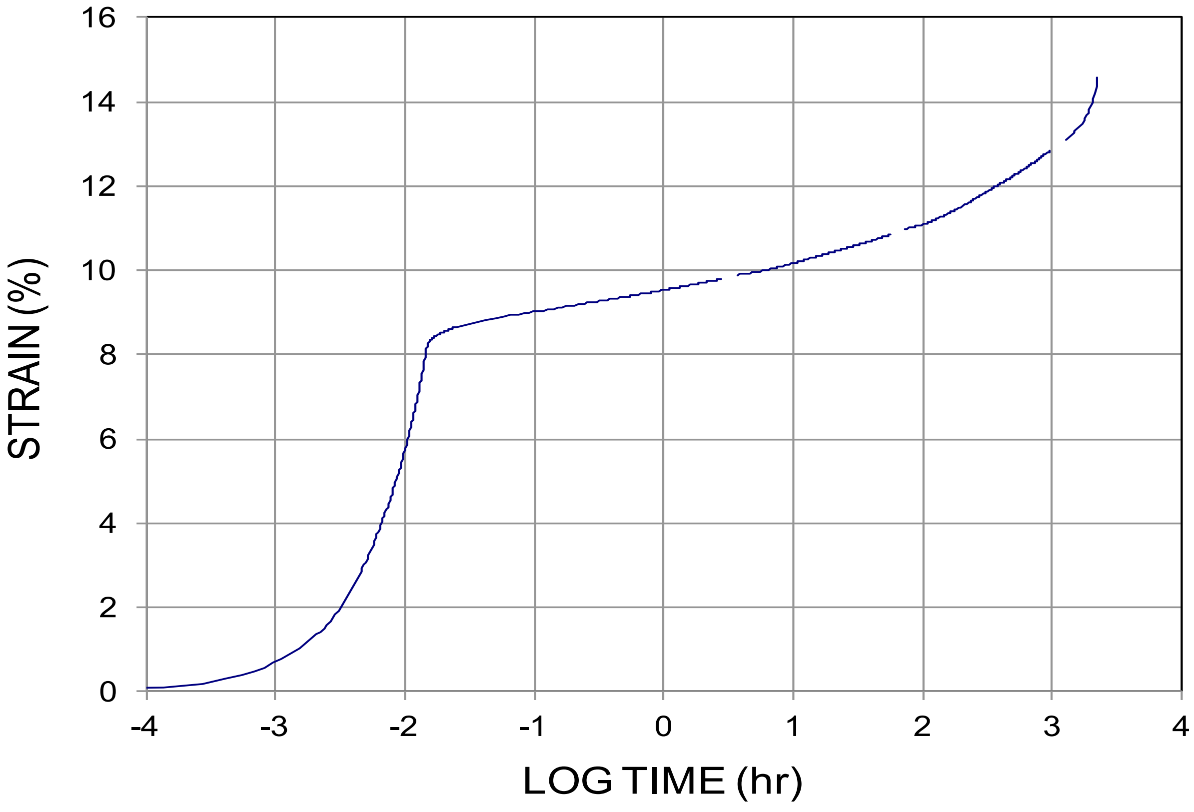


Figure F-14. SIM/Creep data/curve for ParaWeb 50 at load level of 82.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaWeb 50

Specimen: 27063n2l2-pw50-sim Test Date: April 2017 Method: SIM (10^{4}s, 14C),strapping
Average Creep Stress: 9874.6 lb/rib %UTS: 85.00
Ultimate Tensile Strength: 11617.5 lb/rib Rupture: YES

Dwell Seq	t'	t	(t-t')$_i$	Vshift(%)	logA$_T$	Temp	logA$_T$/T
1	0	0.5	0.5	-	-	19.9	-
2	9500	10019	519	0.13	1.2844	34.1	0.0908
3	19400	20009	609	0.16	1.2357	48.6	0.0849
4							
5							
6							

AVG 0.0878

Summary	Initial	Final	Units	@20C refT
lab time	55.5	21659	sec	-
logA$_T$(t-t')	1.7443	5.8740	log hours	2.3120
A$_T$(t-t')	-	0.02	years	0.02
Strain	8.19	13.57	%	-
Modulus	122207.0	72648.4	lb/rib	-

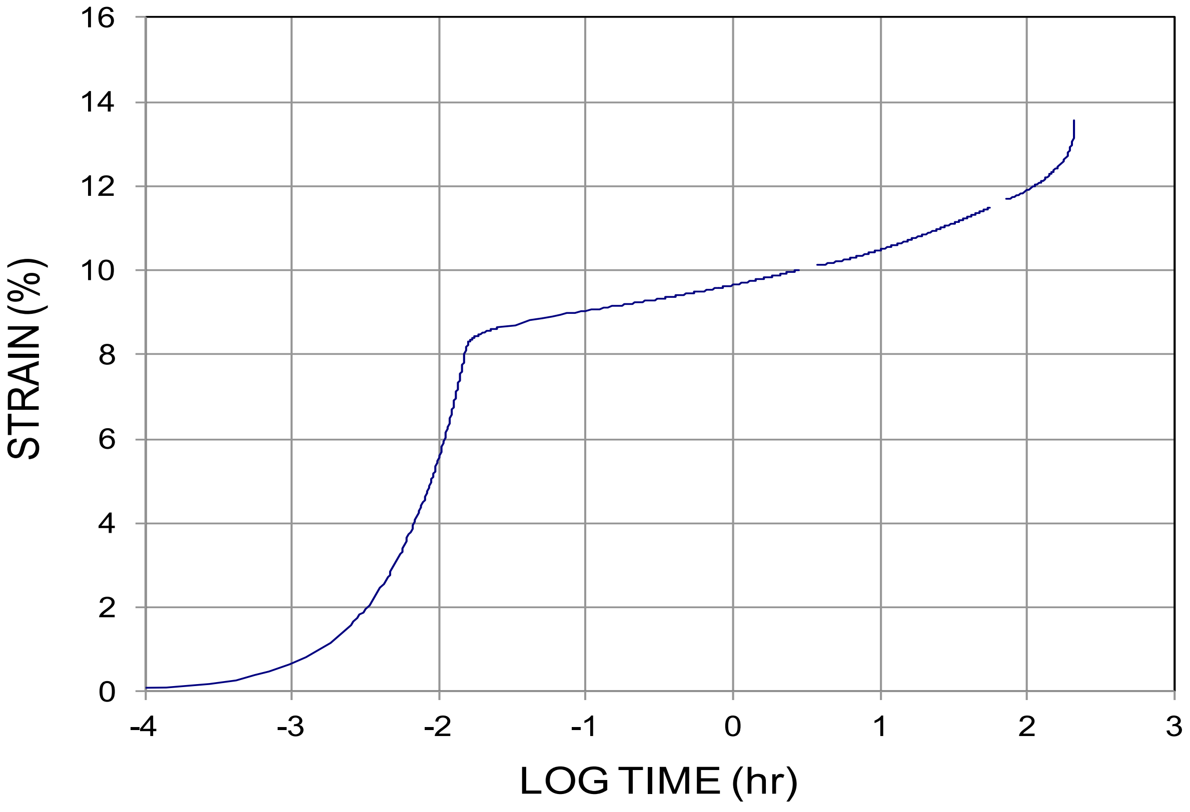


Figure F-15. SIM/Creep data/curve for ParaWeb 50 at load level of 85.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaWeb 50

Specimen: 27063n2l2-pw50-sim	Test Date:	May 2017	Method: SIM (10^4s, 14C),strapping		
Average Creep Stress:	9874.5	lb/rib		%UTS:	85.00
Ultimate Tensile Strength:	11617.5	lb/rib		Rupture:	YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
1	0	0.5	0.5	-	-	19.9	-
2	9400	10019	619	0.1	1.2078	34.1	0.0854
3							
4							
5							
6							

Summary	Initial	Final	Units	@20C refT
lab time	58	19979	sec	-
$\log A_T(t-t')$	1.7634	5.2323	log hours	1.6706
$A_T(t-t')$	-	0.01	years	0.01
Strain	8.41	12.58	%	-
Modulus	119003.0	78516.7	lb/rib	-

AVG	0.0854

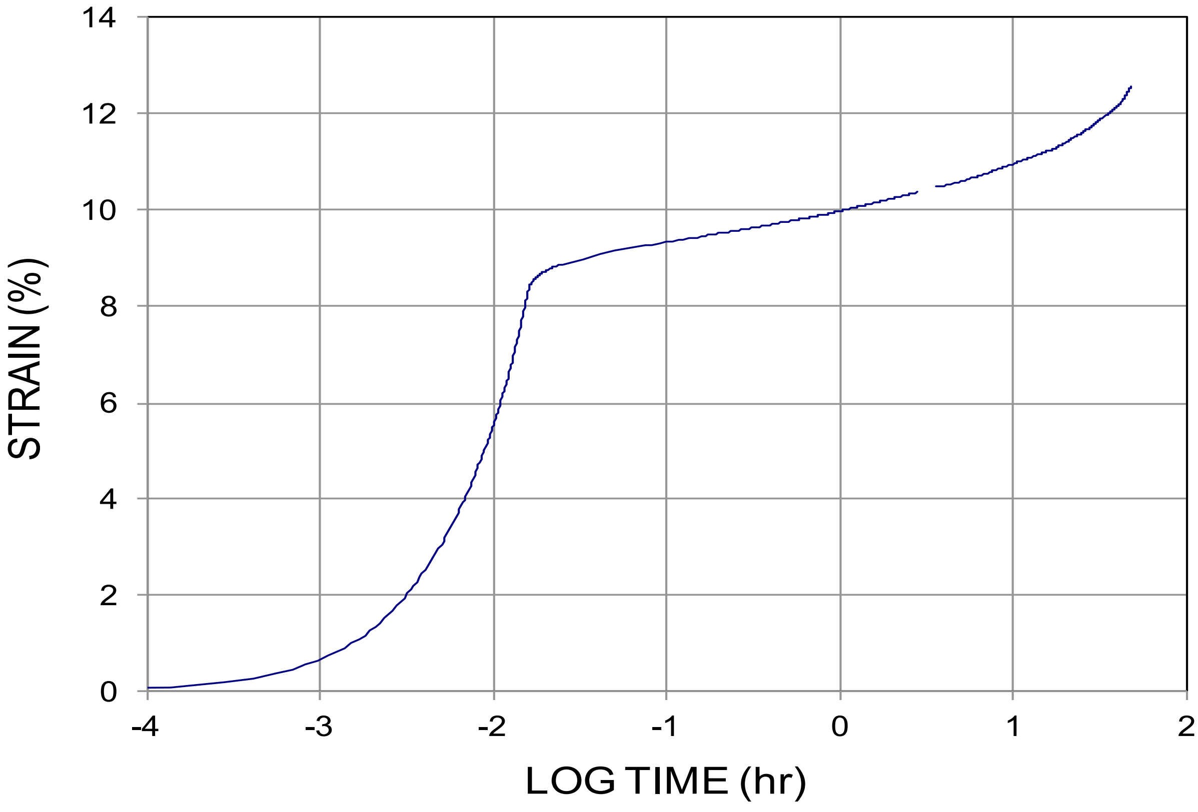


Figure F-16. SIM/Creep data/curve for ParaWeb 50 at load level of 85.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaWeb 135

Specimen: 27063n2l2-pw135-sin Test Date: July 2017 Method: SIM (10^4s, 14C),strapping
Average Creep Stress: 24942.1 lb/rib %UTS: 71.00
Ultimate Tensile Strength: 35130.0 lb/rib Rupture: YES

Dwell Seq	t'	t	(t-t')$_i$	Vshift(%)	logA$_T$	Temp	logA$_T$/T
1	0	0.5	0.5	-	-	19.9	-
2	9550	10019	469	0.14	1.3283	34.1	0.0939
3	19500	20009	509	0.15	1.3115	48.4	0.0915
4	29500	29999	499	0.2	1.3218	62.7	0.0925
5	39500	39989	489	0.24	1.3302	77.0	0.0928
6	49200	49979	779	0.2	1.1275	91.6	0.0775
						AVG	0.0896

Summary	Initial	Final	Units	@20C refT
lab time	69	56579	sec	-
logA$_T$(t-t')	1.8388	10.2874	log hours	6.7252
A$_T$(t-t')	-	614.17	years	605.88
Strain	8.490	17.034	%	-
Modulus	295858.7	146428.0	lb/rib	-

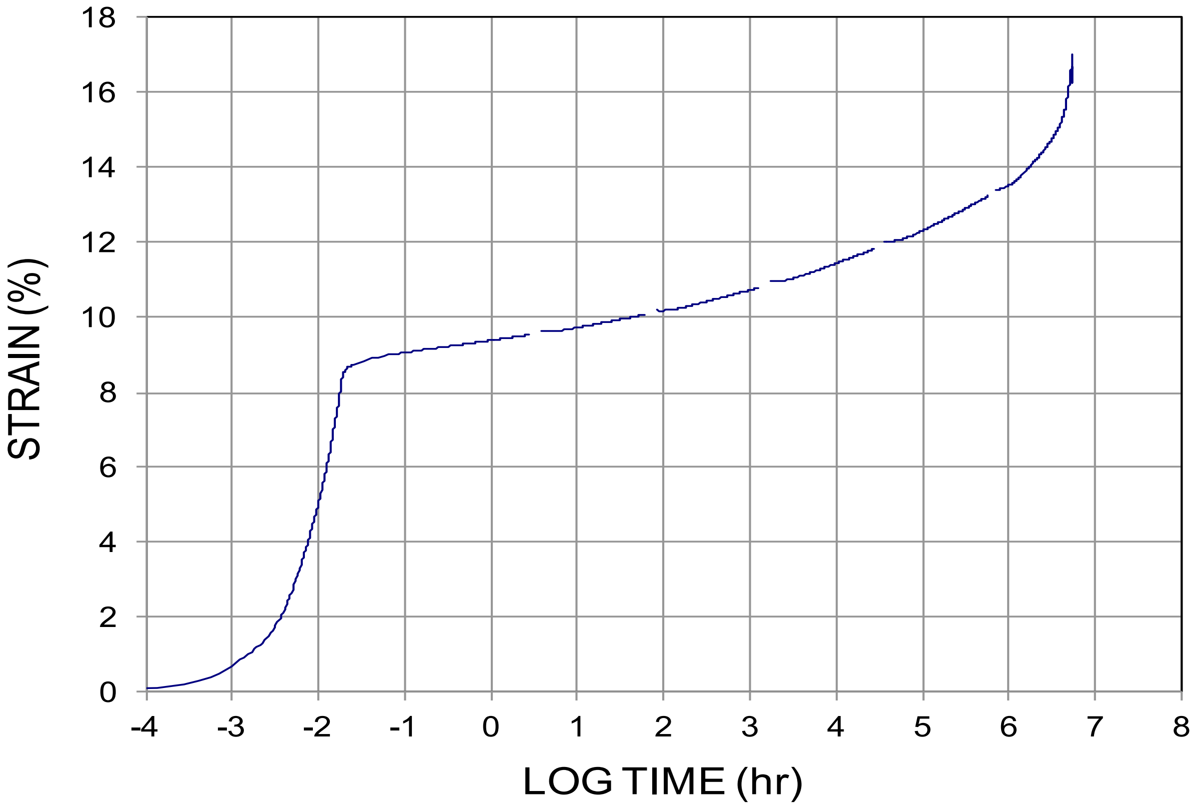


Figure F-17. SIM/Creep data/curve for ParaWeb 135 at load level of 71.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaWeb 135

Specimen: 27063n2l2-pw135-sin Test Date: July 2017 Method: SIM (10^4s, 14C),strapping

Average Creep Stress:	26347.1	lb/rib	%UTS:	75.00
Ultimate Tensile Strength:	35130.0	lb/rib	Rupture:	YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
1	0	0.5	0.5	-	-	19.9	-
2	9500	10019	519	0.15	1.2844	34.1	0.0908
3	19500	20009	509	0.18	1.3136	48.4	0.0917
4	29500	29999	499	0.22	1.3218	62.7	0.0925
5	39000	39989	989	0.12	1.0243	77.0	0.0714
6	48800	49979	1179	0.2	0.9679	92.0	0.0646
						AVG	0.0820

Summary	Initial	Final	Units	@20C refT
lab time	70	50339	sec	-
$\log A_T(t-t')$	1.8451	9.0992	log hours	5.5371
$A_T(t-t')$	-	39.82	years	39.30
Strain	8.053	14.677	%	-
Modulus	330609.8	179534.8	lb/rib	-

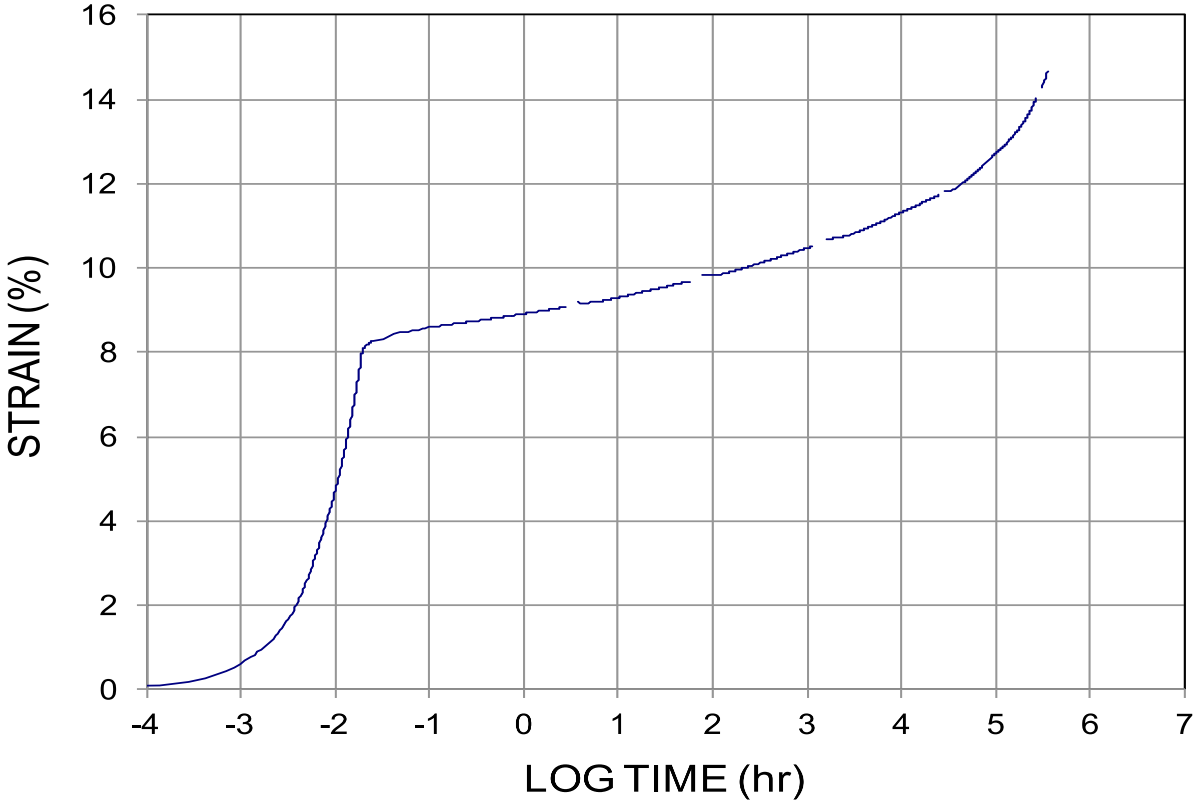


Figure F-18. SIM/Creep data/curve for ParaWeb 135 at load level of 75.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaWeb 135

Specimen: 27063n2l2-pw135-sin Test Date: July 2017 Method: SIM (10^4s, 14C),strapping

Average Creep Stress: 27752.2 lb/rib %UTS: 79.00

Ultimate Tensile Strength: 35130.0 lb/rib Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
1	0	0.5	0.5	-	-	19.9	-
2	9600	10019	419	0.18	1.3773	34.1	0.0973
3	19600	20009	409	0.2	1.4044	48.4	0.0980
4	29500	29999	499	0.2	1.3176	62.7	0.0924
5							
6							

Summary	Initial	Final	Units	@20C refT
lab time	74	33029	sec	-
$\log A_T(t-t')$	1.8692	7.6470	log hours	4.0846
$A_T(t-t')$	-	1.41	years	1.39
Strain	9.061	15.389	%	-
Modulus	307977.6	180376.0	lb/rib	-

AVG 0.0959

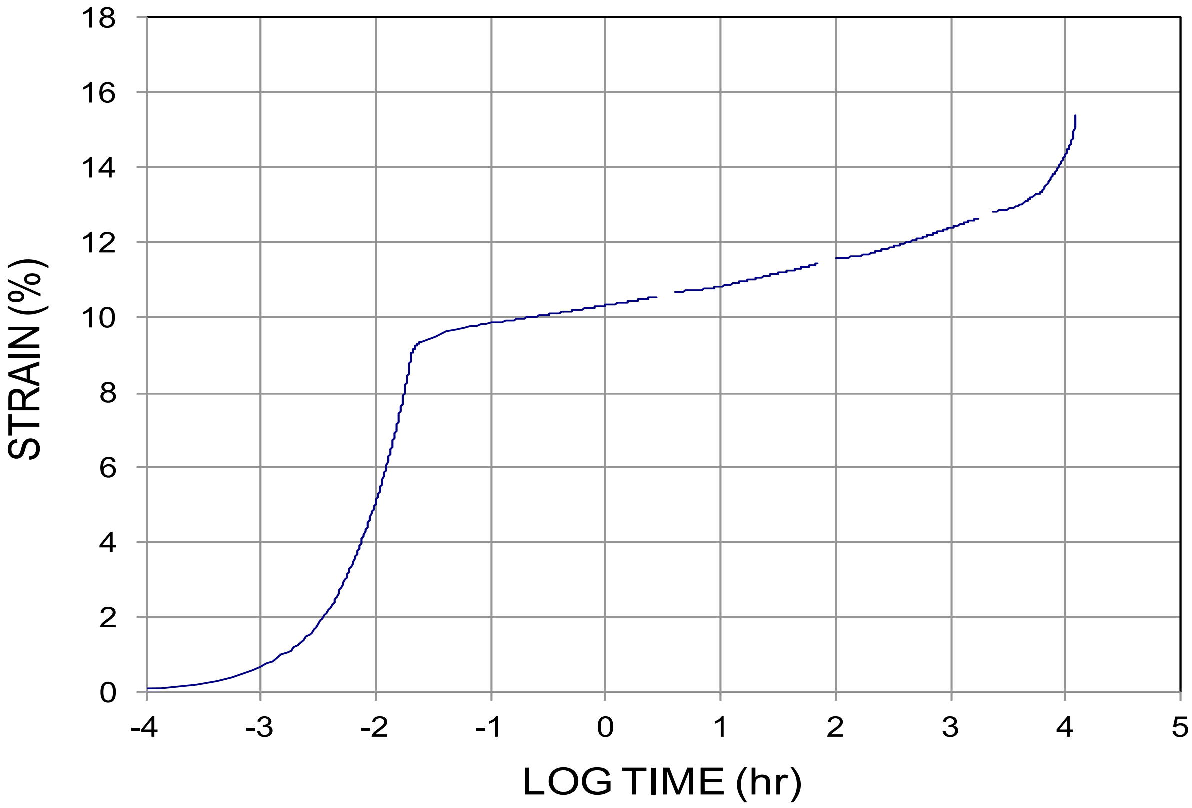


Figure F-19. SIM/Creep data/curve for ParaWeb 135 at load level of 79.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaWeb 135

Specimen: 27063n2l2-pw135-sin Test Date: July 2017 Method: SIM (10^4s, 14C),strapping

Average Creep Stress: 29157.2 lb/rib %UTS: 83.00

Ultimate Tensile Strength: 35130.0 lb/rib Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
1	0	0.5	0.5	-	-	19.9	-
2	9600	10019	419	0.22	1.3773	34.1	0.0973
3	19400	20009	609	0.18	1.2315	48.5	0.0854
4							
5							
6							

AVG 0.0913

Summary	Initial	Final	Units	@20C refT
lab time	77	23369	sec	-
$\log A_T(t-t')$	1.8865	6.2075	log hours	2.6451
$A_T(t-t')$	-	0.05	years	0.05
Strain	9.454	14.878	%	-
Modulus	309930.4	195978.6	lb/rib	-

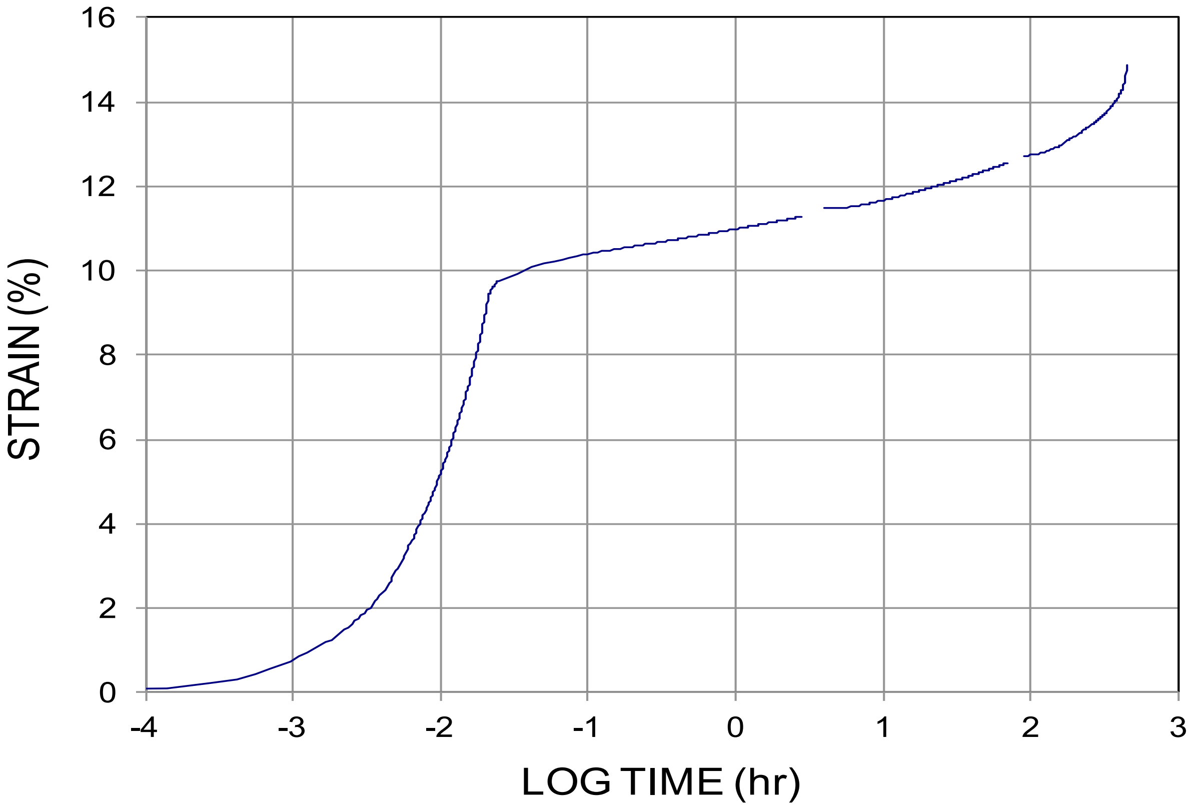


Figure F-20. SIM/Creep data/curve for ParaWeb 135 at load level of 83.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaLink 300

Specimen: 27063n2l2-pl300-sim Test Date: July 2017 Method: SIM (10^4s, 14C),strapping
Average Creep Stress: 1849.7 lb/rib %UTS: 72.00
Ultimate Tensile Strength: 2569.1 lb/rib Rupture: YES

Dwell Seq	t'	t	(t-t')$_i$	Vshift(%)	logA$_T$	Temp	logA$_T$/T
1	0	0.5	0.5	-	-	19.9	-
2	9500	10019	519	0.1	1.2844	34.1	0.0908
3	19500	20009	509	0.12	1.3136	48.4	0.0917
4	29500	29999	499	0.14	1.3218	62.7	0.0925
5	39500	39989	489	0.15	1.3302	77.0	0.0928
6	49400	49979	579	0.15	1.2564	91.8	0.0854

Summary	Initial	Final	Units	@20C refT
lab time	58	54239	sec	-
logA$_T$(t-t')	1.7634	10.1911	log hours	6.6291
A$_T$(t-t')	-	492.03	years	485.60
Strain	7.155	13.758	%	-
Modulus	26065.8	13442.1	lb/rib	-

AVG 0.0906

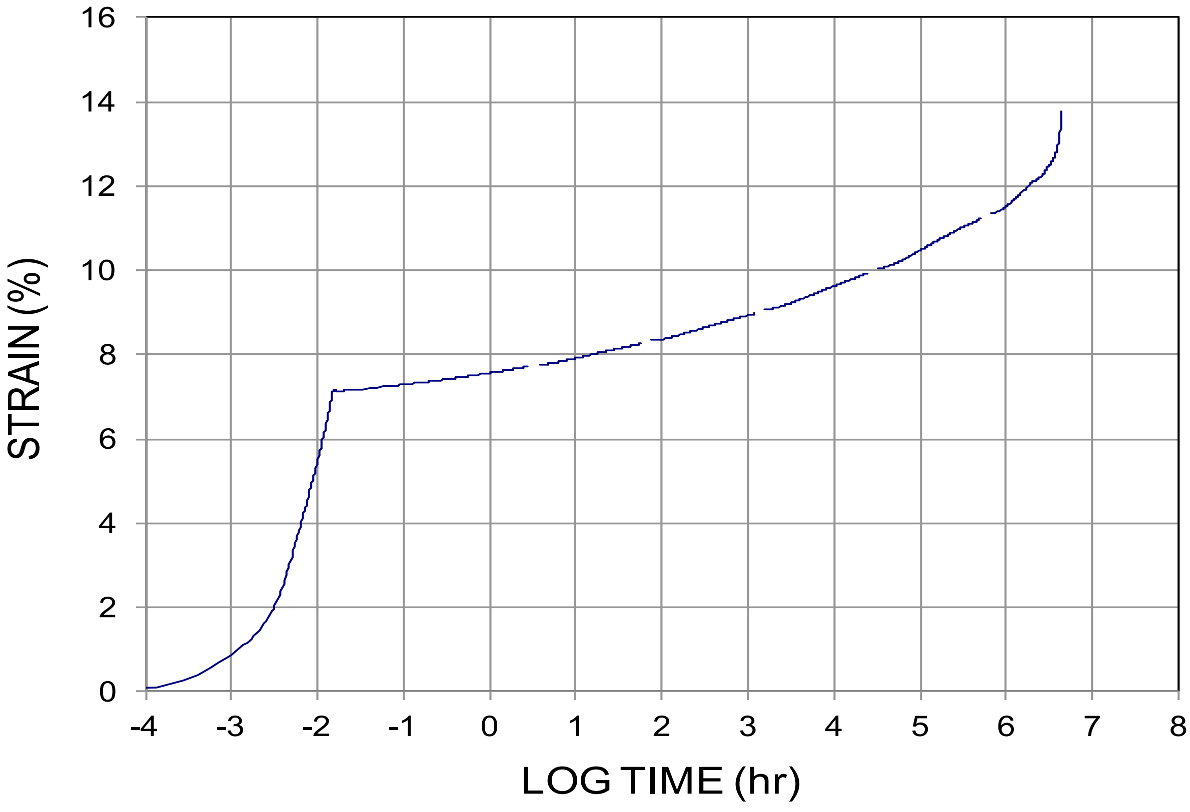


Figure F-21. SIM/Creep data/curve for ParaLink 300 at load level of 72.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaLink 300

Specimen:	27063n2l2-pl300-sim	Test Date:	July 2017	Method:	SIM (10^4s, 14C),strapping
Average Creep Stress:	23429.4	lb/ft		%UTS:	76.00
Ultimate Tensile Strength:	30828.7	lb/ft		Rupture:	YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
1	0	0.5	0.5	-	-	19.9	-
2	9300	10019	719	0.16	1.1428	34.1	0.0808
3	19500	20009	509	0.14	1.3218	48.4	0.0923
4	29500	29999	499	0.16	1.3218	62.7	0.0925
5	39400	39989	589	0.2	1.2494	77.1	0.0871
6							
						AVG	0.0882

Summary	Initial	Final	Units	@20C refT
lab time	52.5	45089	sec	-
$\log A_T(t-t')$	1.7202	8.7908	log hours	5.2294
$A_T(t-t')$	-	19.58	years	19.35
Strain	8.10	13.61	%	-
Modulus	293006.1	172183.1	lb/ft	-

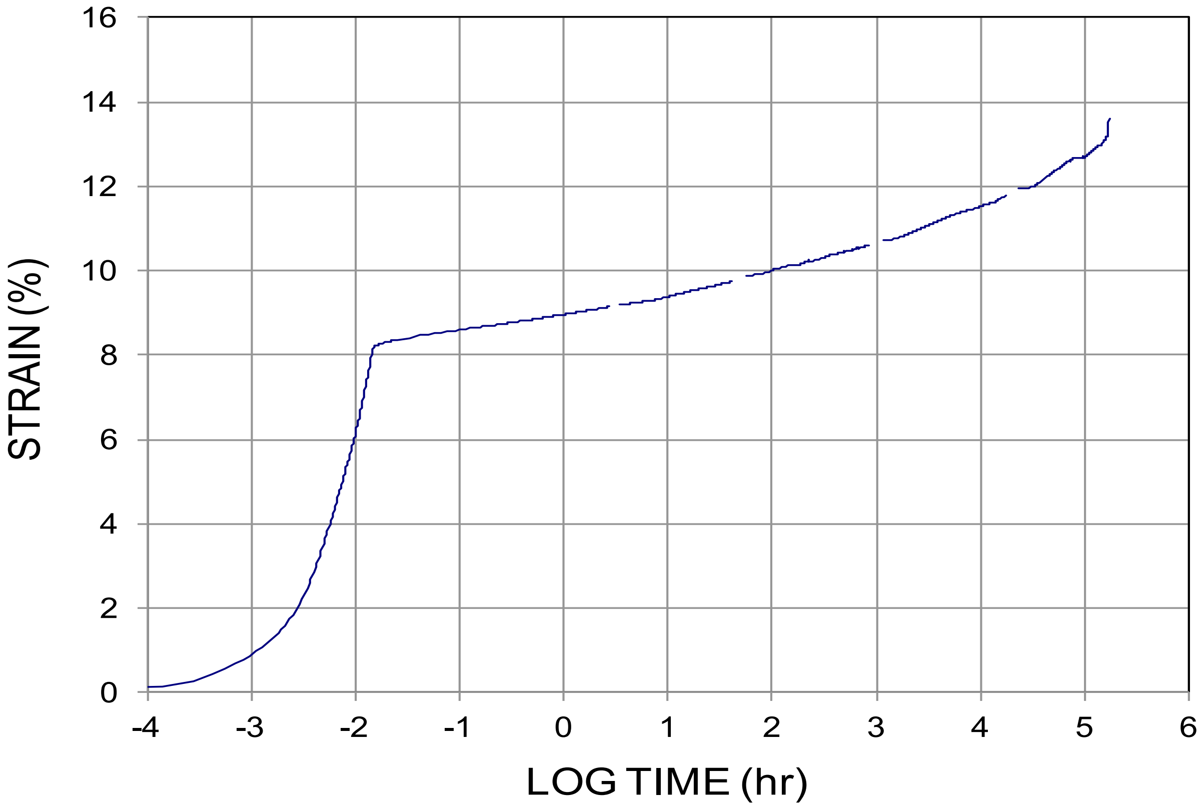


Figure F-22. SIM/Creep data/curve for ParaLink 300 at load level of 76.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaLink 300

Specimen: 27063n2l2-pl300-sim Test Date: July 2017 Method: SIM (10^4s, 14C),strapping

Average Creep Stress: 24662.0 lb/ft %UTS: 80.00

Ultimate Tensile Strength: 30828.7 lb/ft Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
1	0	0.5	0.5	-	-	19.9	-
2	9900	10019	119	0.2	1.9240	34.1	0.1360
3	19700	20009	309	0.2	1.5135	48.4	0.1055
4							
5							
6							

Summary	Initial	Final	Units	@20C refT
lab time	64.5	27839	sec	-
$\log A_T(t-t')$	1.8096	7.3480	log hours	3.7831
$A_T(t-t')$	-	0.71	years	0.69
Strain	8.67	12.10	%	-
Modulus	287829.1	203549.5	lb/ft	-

AVG 0.1206

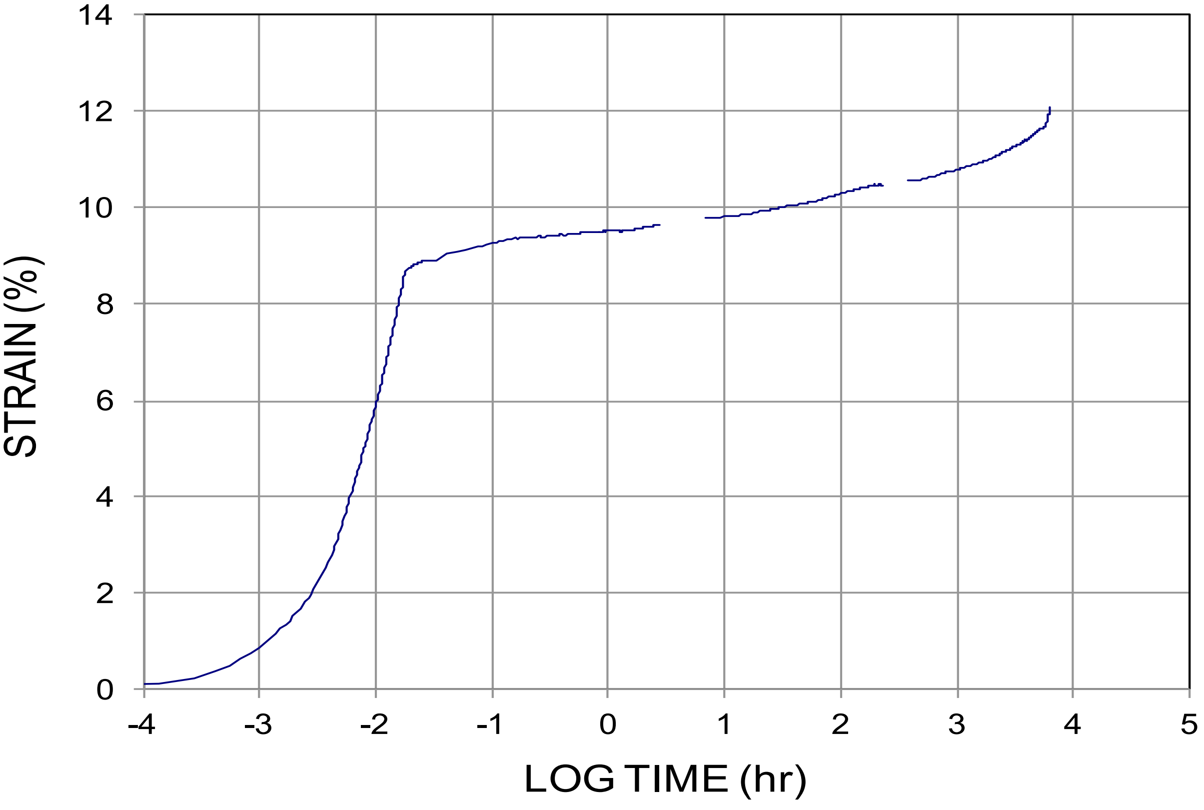


Figure F-23. SIM/Creep data/curve for ParaLink 300 at load level of 80.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaLink 300

Specimen: 27063n2l2-pl300-sim Test Date: July 2017 Method: SIM (10^4s, 14C),strapping

Average Creep Stress:	25895.4	lb/ft	%UTS:	84.00
Ultimate Tensile Strength:	30828.7	lb/ft	Rupture:	YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
1	0	0.5	0.5	-	-	19.9	-
2	9400	10019	619	0.1	1.2078	34.1	0.0854
3	19400	20009	609	0.15	1.2398	48.6	0.0856
4							
5							
6							

Summary	Initial	Final	Units	@20C refT
lab time	64	22559	sec	-
$\log A_T(t-t')$	1.8062	5.9472	log hours	2.3855
$A_T(t-t')$	-	0.03	years	0.03
Strain	10.60	15.40	%	-
Modulus	247426.0	167750.6	lb/ft	-

AVG 0.0855

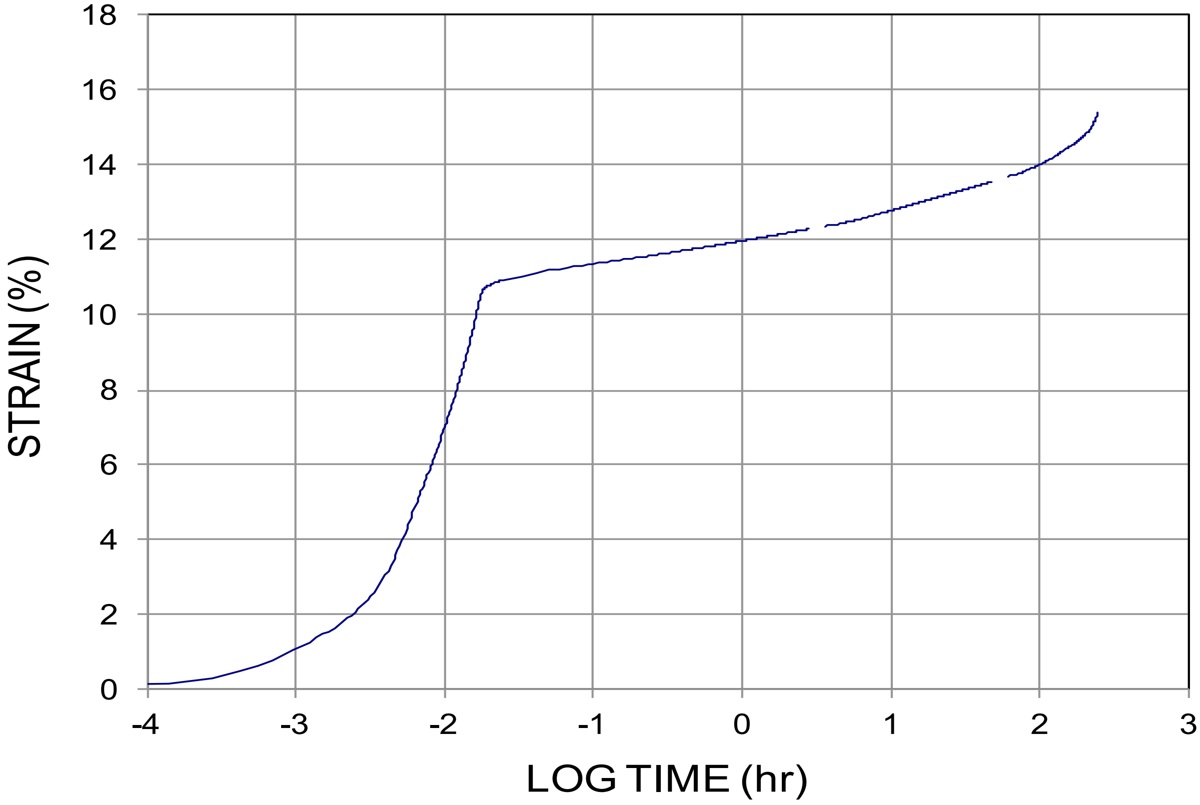


Figure F-24. SIM/Creep data/curve for ParaLink 300 at load level of 84.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaLink 1000

Specimen: 27063n2l2-pl1000-sir Test Date: May 2017 Method: SIM (10^4s, 14C),strapping
Average Creep Stress: 50359.9 lb/ft %UTS: 70.00
Ultimate Tensile Strength: 71943.7 lb/ft Rupture: YES

Dwell Seq	t'	t	$(t\text{-}t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
1	0	0.5	0.5	-	-	19.9	-
2	9500	10019	519	0.14	1.2844	34.1	0.0908
3	19500	20009	509	0.14	1.3136	48.4	0.0917
4	29500	29999	499	0.16	1.3218	62.7	0.0925
5	39400	39989	589	0.2	1.2494	77.0	0.0871
6	49400	49979	579	0.25	1.2605	91.7	0.0861

Summary	Initial	Final	Units	@20C refT
lab time	62	59939	sec	-
$\log A_T(t\text{-}t')$	1.7924	10.4525	log hours	6.8905
$A_T(t\text{-}t')$	-	898.18	years	886.45
Strain	7.58	13.83	%	-
Modulus	670640.4	364066.4	lb/ft	-

AVG 0.0896

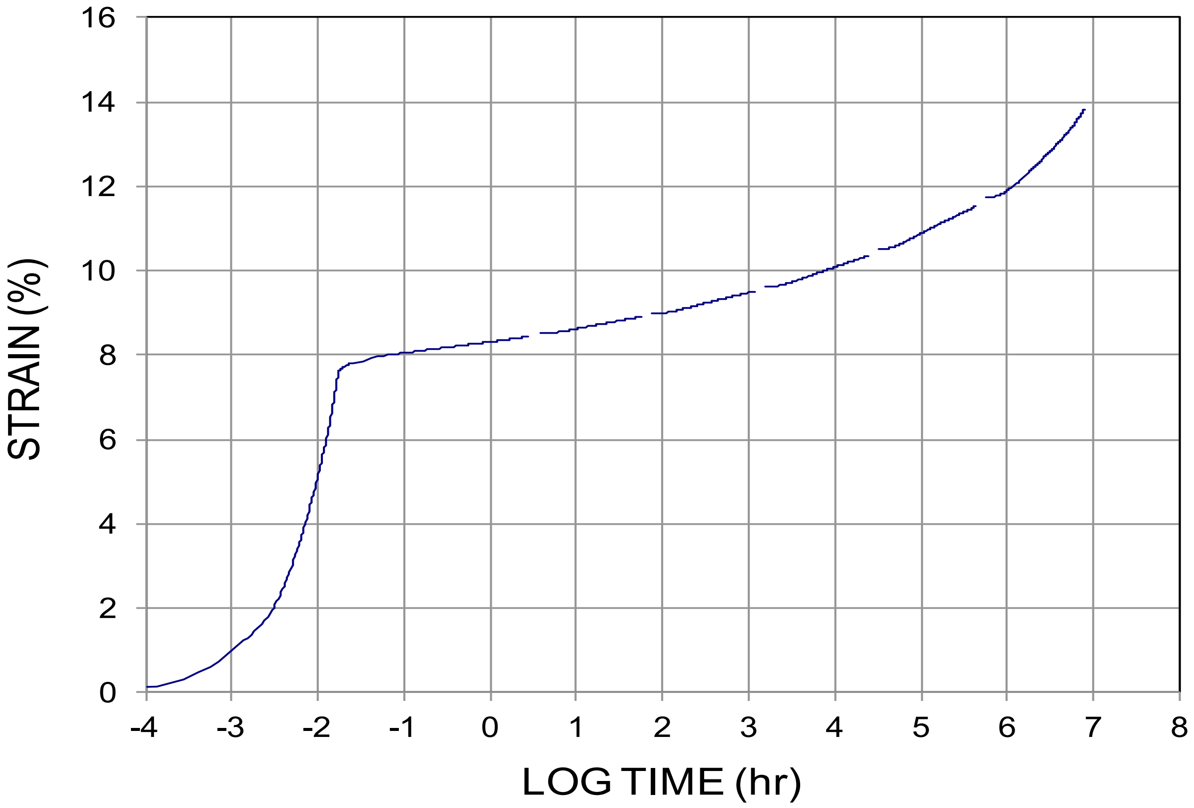


Figure F-25. SIM/Creep data/curve for ParaLink 1000 at load level of 70.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaLink 1000

Specimen: 27063n2l2-pl1000-sir   Test Date: July 2017   Method: SIM (10^4s, 14C),strapping

Average Creep Stress: 53237.2 lb/ft   %UTS: 74.00

Ultimate Tensile Strength: 71943.7 lb/ft   Rupture: YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
1	0	0.5	0.5	-	-	19.9	-
2	9500	10019	519	0.14	1.2844	34.1	0.0908
3	19400	20009	609	0.14	1.2357	48.4	0.0862
4	29400	29999	599	0.16	1.2466	62.7	0.0872
5	39400	39989	589	0.2	1.2535	77.0	0.0874
6	49000	49979	979	0.25	1.0324	92.1	0.0687

AVG 0.0839

Summary	Initial	Final	Units	@20C refT
lab time	69	50909	sec	-
$\log A_T(t-t')$	1.8388	9.3334	log hours	5.7714
$A_T(t-t')$	-	68.28	years	67.39
Strain	8.26	15.10	%	-
Modulus	649492.4	348246.5	lb/ft	-

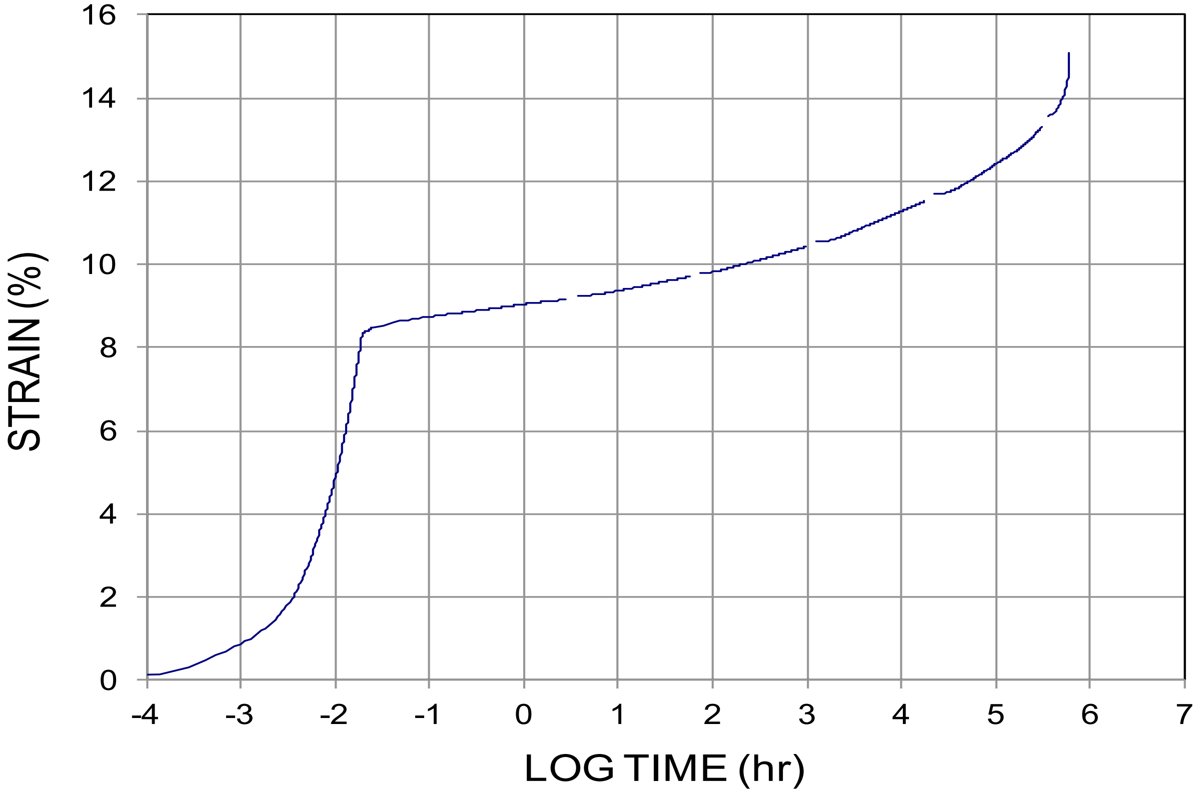


Figure F-26. SIM/Creep data/curve for ParaLink 1000 at load level of 74.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaLink 1000

Specimen: 27063n2l2-pl1000-sir Test Date: July 2017 Method: SIM (10^4s, 14C),strapping
Average Creep Stress: 56115.4 lb/ft %UTS: 78.00
Ultimate Tensile Strength: 71943.7 lb/ft Rupture: YES

Dwell Seq	t'	t	$(t\text{-}t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
1	0	0.5	0.5	-	-	19.9	-
2	9400	10019	619	0.12	1.2078	34.1	0.0854
3	19500	20009	509	0.14	1.3177	48.4	0.0920
4	29300	29999	699	0.16	1.1754	62.7	0.0822
5	39000	39989	989	0.2	1.0325	77.6	0.0694
6							

AVG 0.0821

Summary	Initial	Final	Units	@20C refT
lab time	72	40889	sec	-
$\log A_T(t\text{-}t')$	1.8573	8.0097	log hours	4.4481
$A_T(t\text{-}t')$	-	3.24	years	3.20
Strain	9.02	15.21	%	-
Modulus	626715.4	368686.6	lb/ft	-

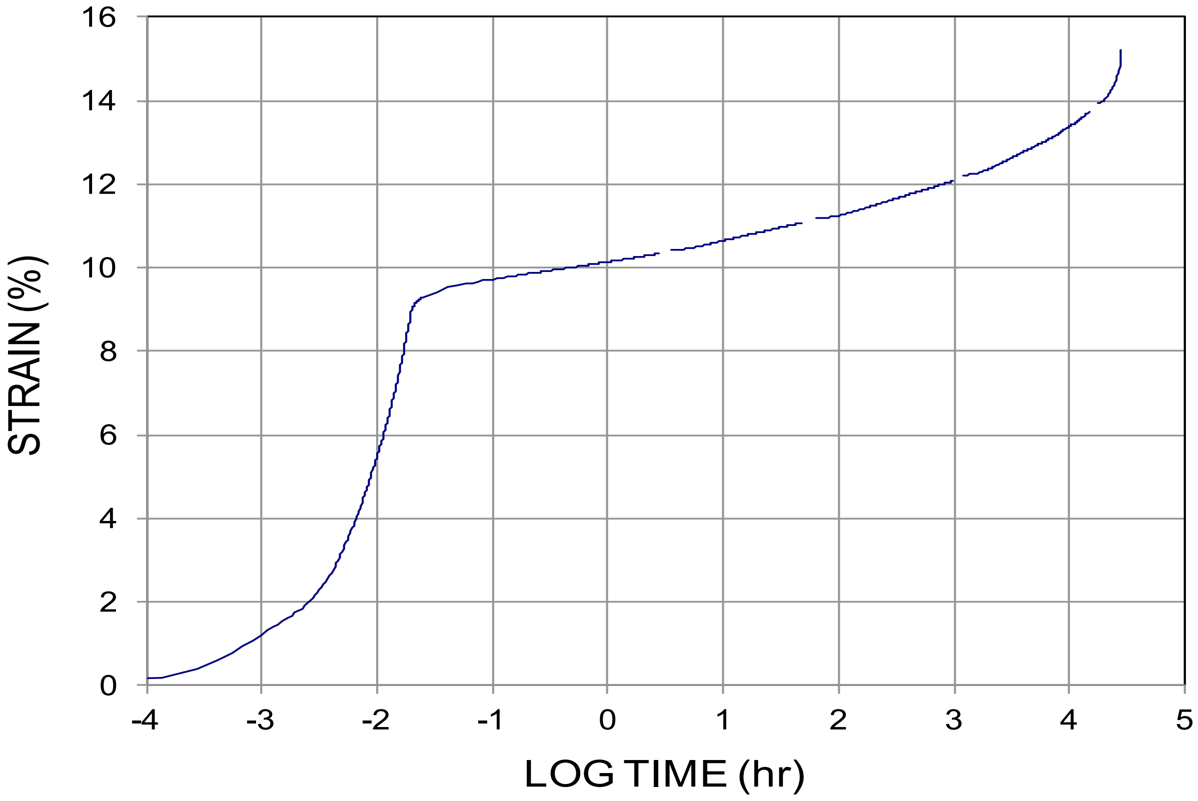


Figure F-27. SIM/Creep data/curve for ParaLink 1000 at load level of 78.00% UTS.

Accelerated Creep Rupture via SIM - ASTM D 6992

SUMMARY CREEP PARAMETERS: NTPEP - Linear Composites
ParaLink 1000

Specimen: 27063n2l2-pl1000-sir Test Date: July 2017 Method: SIM (10^4s, 14C),strapping

Average Creep Stress:	58992.7	lb/ft	%UTS:	82.00
Ultimate Tensile Strength:	71943.7	lb/ft	Rupture:	YES

Dwell Seq	t'	t	$(t-t')_i$	Vshift(%)	$\log A_T$	Temp	$\log A_T/T$
1	0	0.5	0.5	-	-	19.9	-
2	9500	10019	519	0.12	1.2844	34.1	0.0908
3	19500	20009	509	0.15	1.3136	48.4	0.0917
4							
5							
6							
						AVG	0.0912

Summary	Initial	Final	Units	@20C refT
lab time	75	29249	sec	-
$\log A_T(t-t')$	1.8751	6.5869	log hours	3.0249
$A_T(t-t')$	-	0.12	years	0.12
Strain	9.13	13.86	%	-
Modulus	649961.7	425981.2	lb/ft	-

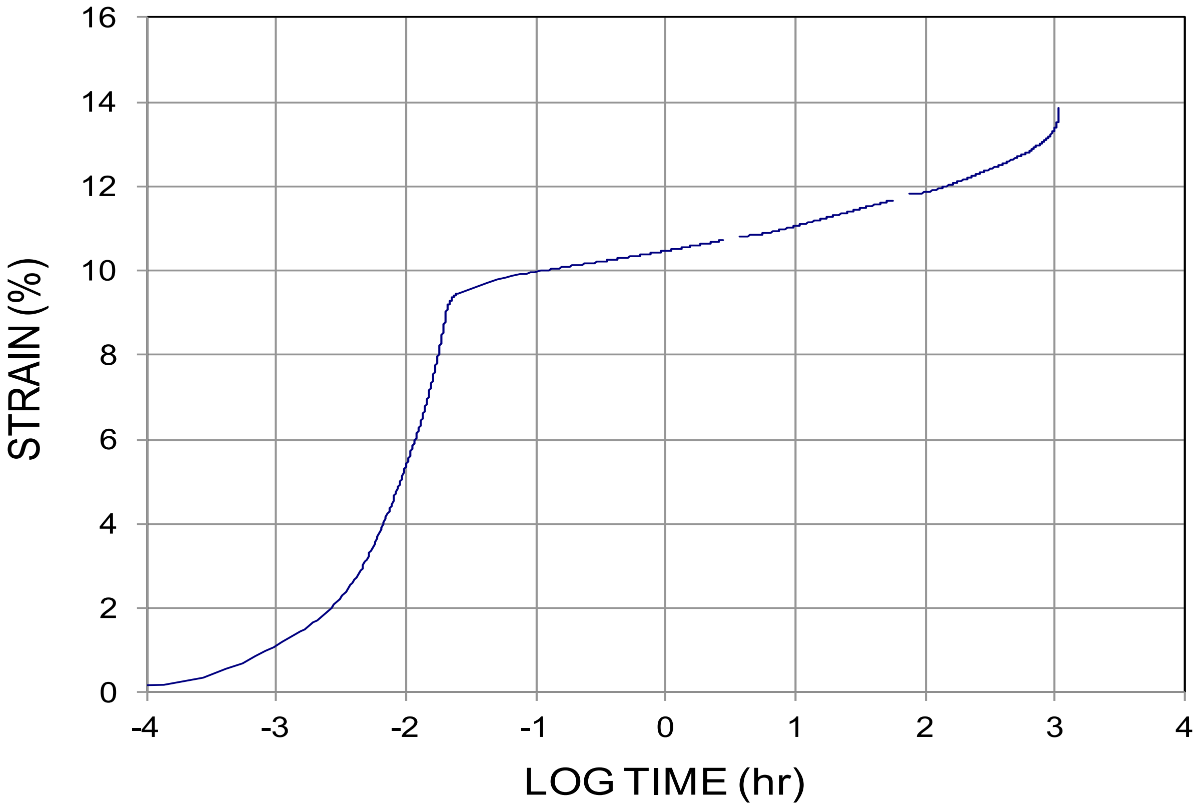


Figure F-28. SIM/Creep data/curve for ParaLink 1000 at load level of 82.00% UTS.

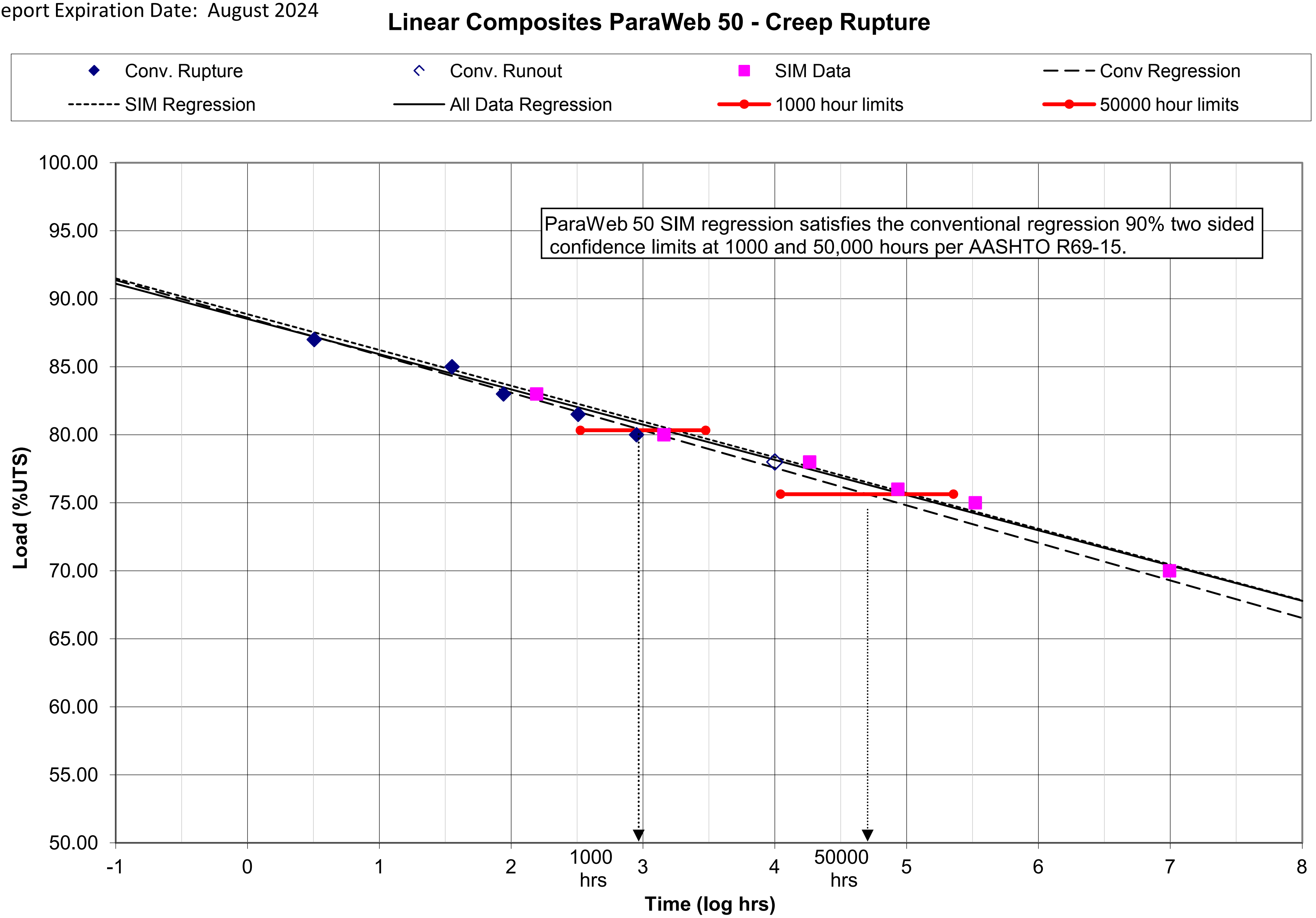


Figure F-29. Statistical evaluation results for determining validity of using SIM to extend ParaWeb conventional creep rupture data.

ParaWeb 50- ParaWeb 30- Creep Rupture

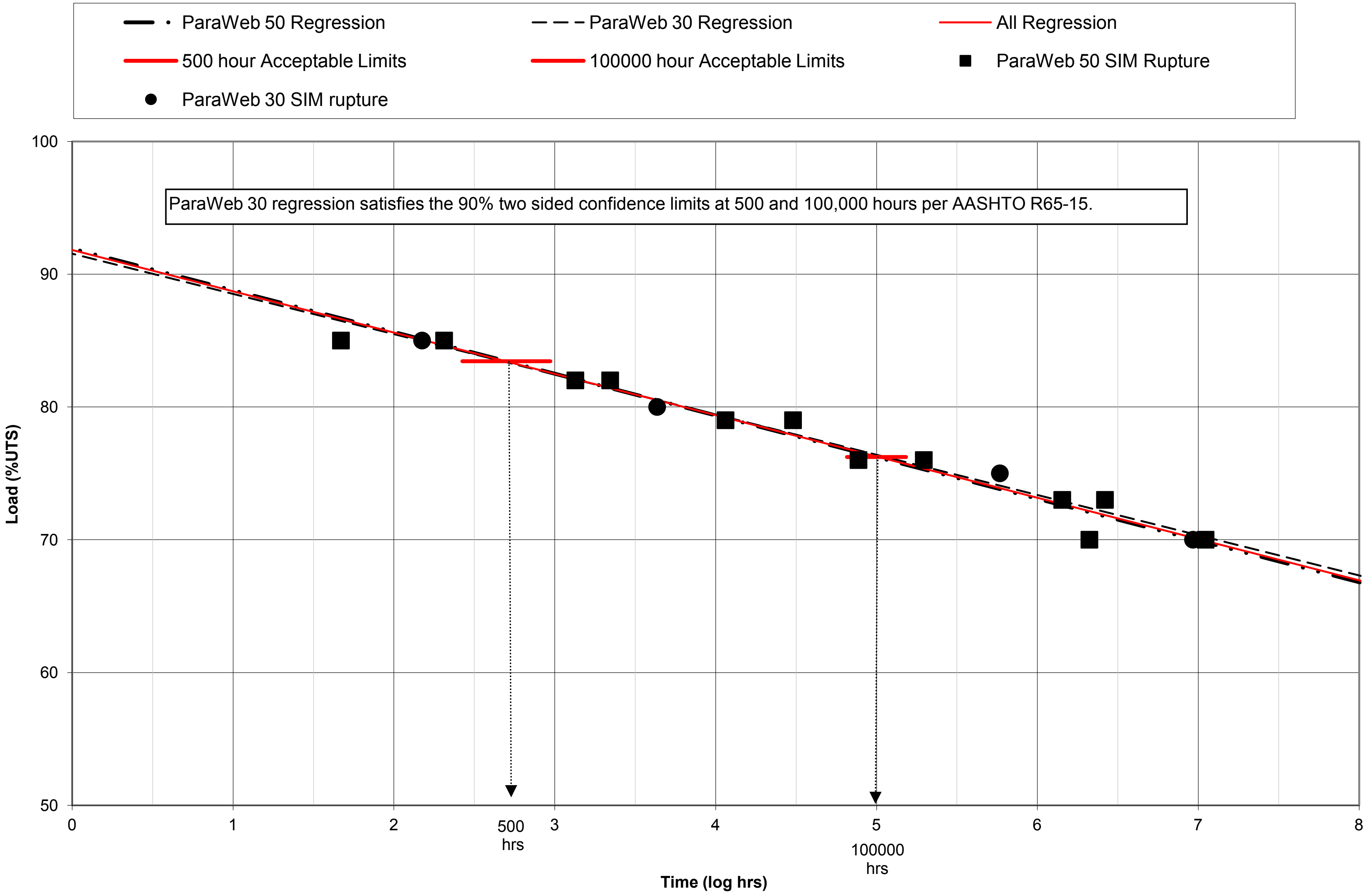


Figure F-30. Statistical evaluation results for determining validity of creating composite creep rupture envelope for the ParaWeb/ParaLink product line.

Table F-2. Computation table to determine statistical validity of creating composite creep rupture envelope for Linear Composites ParaWeb/ParaLink product line - ParaWeb 30 and ParaWeb 50 comparision.

SIM Tests on ParaWeb 30

Test Report	**Product**	**Expected time, log hrs**	**%UTS**	**Rupture**
	ParaWeb 30	6.9671	70.00	70.00
	ParaWeb 30	5.7666	75.00	75.00
	ParaWeb 30	3.6362	80.00	80.00
	ParaWeb 30	2.1750	85.00	85.00

student's t = 1.812 (90% 2-sided prediction limit)

n-ParaWeb 30 = 4

n-ParaWeb 50 = 12 d-o-f 10

treg = 2.699

treg = 5.000

P500 = 83.4488

P100000 = 76.2232

sigma squared = 0.1160

sigma = 0.3406

SIM & Conventional Tests on ParaWeb 50

Test Report	**Product**	**time, log hrs**	**%UTS**	**Rupture**	**Runout**	logti-logbar	(logti-logbar)2	Pi - Pbar	(Pi-Pbar)2	K * L	
	ParaWeb 50	7.0453	70.00	70.00		2.45	6.0118	-7.50	56.25	-18.3893	SIM
	ParaWeb 50	6.3231	70.00	70.00		1.73	2.9919	-7.50	56.25	-12.9728	SIM
	ParaWeb 50	6.4199	73.00	73.00		1.83	3.3361	-4.50	20.25	-8.21925	SIM
	ParaWeb 50	6.1543	73.00	73.00		1.56	2.4364	-4.50	20.25	-7.02405	SIM
	ParaWeb 50	5.2937	76.00	76.00		0.70	0.4904	-1.50	2.25	-1.05045	SIM
	ParaWeb 50	4.8878	76.00	76.00		0.29	0.0867	-1.50	2.25	-0.4416	SIM
	ParaWeb 50	4.0613	79.00	79.00		-0.53	0.2831	1.50	2.25	-0.79815	SIM
	ParaWeb 50	4.4808	79.00	79.00		-0.11	0.0127	1.50	2.25	-0.1689	SIM
	ParaWeb 50	3.1278	82.00	82.00		-1.47	2.1480	4.50	20.25	-6.5952	SIM
	ParaWeb 50	3.3442	82.00	82.00		-1.25	1.5605	4.50	20.25	-5.6214	SIM
	ParaWeb 50	2.3120	85.00	85.00		-2.28	5.2048	7.50	56.25	-17.1105	SIM
	ParaWeb 50	1.6706	85.00	85.00		-2.92	8.5428	7.50	56.25	-21.921	SIM
	ParaWeb 50										SIM
	ParaWeb 50										SIM
	ParaWeb 50										SIM
	ParaWeb 50										SIM
	ParaWeb 50										SIM
	ParaWeb 50										SIM
	Sum	55.1208	930.00		Sum	0.00	33.11	0.00	315.00	-100.31	
	Mean	4.5934	77.50								

* runout plotting below the regression line is not included in the regression

ParaWeb 50 - 500 hrs (log 2.699)			**ParaWeb 50 - 100000 hrs (log 5.000)**		
log tL - lower =	2.43	83.4488	log tL - lower =	4.82	76.2232
log tL - upper =	2.97	83.4488	log tL - upper =	5.18	76.2232
ParaWeb 30 - logtL @ Load =	2.67	**OK**	**ParaWeb 30 - logtL @ Load =**	5.06	**OK**

ParaWeb 30 - All Points

time is dependent variable:

	if time were the y axis	but time is the x axis
slope	-0.33013	-3.02907
intercept	30.22161	91.54346
R squared	0.98948	0.98948
	-2	97.60161
	10	61.25273
2.6990	83.368	= 500 hr intercept
5.0000	76.3981	= 100000 hr intercept

ParaWeb 50 - All Points

time is dependent variable:

	if time were the y axis	but time is the x axis
slope	-0.31845	-3.14019
intercept	29.27346	91.92413
R squared	0.964949	0.964949
	-2	98.20451
	10	60.52227
2.6990	83.44877	= 500 hr intercept
5.0000	76.2232	= 100000 hr intercept

All Creep Data ParaWeb 50 & ParaWeb 30 (conv & SIM)

time is dependent variable:

	if time were the y axis	but time is the x axis
slope	-0.32177	-3.1078
intercept	29.54136	91.80864
R squared	0.97178	0.97178
	-2	98.02424
	10	60.73064
5.8176	73.7287	= 75-yr intercept
5.9425	73.34054	= 100-yr intercept

90% 2-sided conf. limit	
df	student's t
2	2.92
3	2.353
4	2.132
5	2.015
6	1.943
7	1.895
8	1.86
9	1.833
10	1.812
11	1.796
12	1.782
13	1.771
14	1.761

ParaWeb 50- ParaWeb 135- Creep Rupture

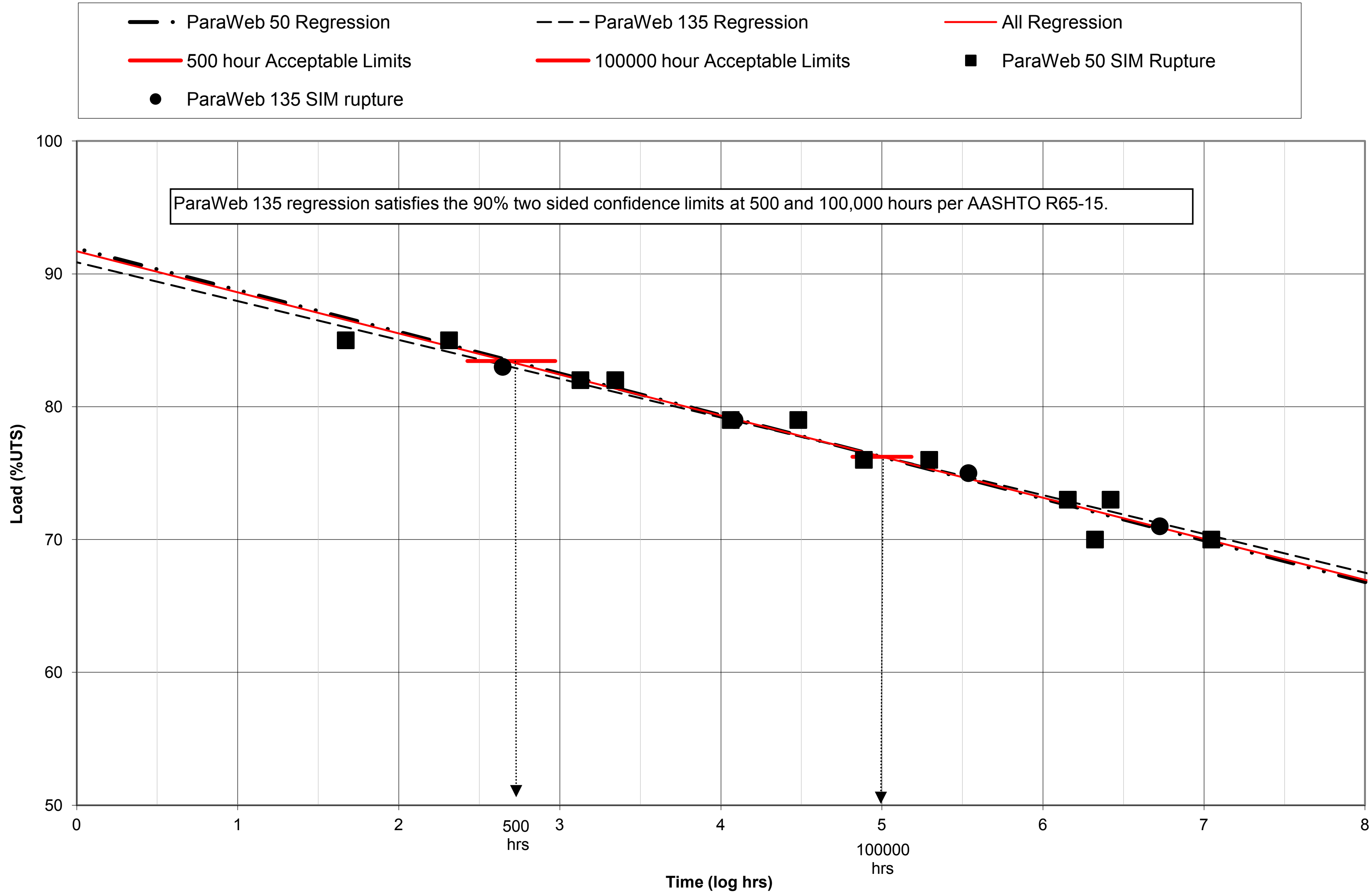


Figure F-31. Statistical evaluation results for determining validity of creating composite creep rupture envelope for the ParaWeb/ParaLink product line.

Table F-3. Computation table to determine statistical validity of creating composite creep rupture envelope for Linear Composites ParaWeb/ParaLink product line - ParaWeb 135 and ParaWeb 50 comparision.

SIM Tests on ParaWeb 135

Test Report	Product	Expected time, log hrs	%UTS	Rupture
	ParaWeb 135	6.7252	71.00	71.00
	ParaWeb 135	5.5371	75.00	75.00
	ParaWeb 135	4.0846	79.00	79.00
	ParaWeb 135	2.6451	83.00	83.00

student's t = 1.812 (90% 2-sided prediction limit)

n-ParaWeb 135 = 4

n-ParaWeb 50 = 12 d-o-f 10

treg = 2.699

treg = 5.000

P500 = 83.4488

P100000 = 76.2232

sigma squared = 0.1160

sigma = 0.3406

90% 2-sided conf. limit	
df	student's t
2	2.92
3	2.353
4	2.132
5	2.015
6	1.943
7	1.895
8	1.86
9	1.833
10	1.812
11	1.796
12	1.782
13	1.771
14	1.761

SIM & Conventional Tests on ParaWeb 50

Test Report	Product	time, log hrs	%UTS	Rupture	Runout	logti-logtbar	(logti-logtbar)2	Pi - Pbar	(Pi-Pbar)2	K * L	
	ParaWeb 50	7.0453	70.00	70.00		2.45	6.0118	-7.50	56.25	-18.3893	SIM
	ParaWeb 50	6.3231	70.00	70.00		1.73	2.9919	-7.50	56.25	-12.9728	SIM
	ParaWeb 50	6.4199	73.00	73.00		1.83	3.3361	-4.50	20.25	-8.21925	SIM
	ParaWeb 50	6.1543	73.00	73.00		1.56	2.4364	-4.50	20.25	-7.02405	SIM
	ParaWeb 50	5.2937	76.00	76.00		0.70	0.4904	-1.50	2.25	-1.05045	SIM
	ParaWeb 50	4.8878	76.00	76.00		0.29	0.0867	-1.50	2.25	-0.4416	SIM
	ParaWeb 50	4.0613	79.00	79.00		-0.53	0.2831	1.50	2.25	-0.79815	SIM
	ParaWeb 50	4.4808	79.00	79.00		-0.11	0.0127	1.50	2.25	-0.1689	SIM
	ParaWeb 50	3.1278	82.00	82.00		-1.47	2.1480	4.50	20.25	-6.5952	SIM
	ParaWeb 50	3.3442	82.00	82.00		-1.25	1.5605	4.50	20.25	-5.6214	SIM
	ParaWeb 50	2.3120	85.00	85.00		-2.28	5.2048	7.50	56.25	-17.1105	SIM
	ParaWeb 50	1.6706	85.00	85.00		-2.92	8.5428	7.50	56.25	-21.921	SIM
	ParaWeb 50										SIM
	ParaWeb 50										SIM
	ParaWeb 50										SIM
	ParaWeb 50										SIM
	ParaWeb 50										SIM
	ParaWeb 50										SIM
	Sum	55.1208	930.00		Sum	0.00	33.11	0.00	315.00	-100.31	
	Mean	4.5934	77.50								

* runout plotting below the regression line is not included in the regression

ParaWeb 50 - 500 hrs (log 2.699)			ParaWeb 50 - 100000 hrs (log 5.000)		
log tL - lower =	2.43	83.4488	log tL - lower =	4.82	76.2232
log tL - upper =	2.97	83.4488	log tL - upper =	5.18	76.2232

ParaWeb 135 - logtL @ Load = 2.54 **OK**

ParaWeb 135 - logtL @ Load = 5.01 **OK**

ParaWeb 135 - All Points

time is dependent variable:

	if time were the y axis	but time is the x axis
slope	-0.34232	-2.92124
intercept	31.10664	90.87006
R squared	0.997909	0.997909
	-2	96.71255
	10	61.65763
2.6990	82.98563	= 500 hr intercept
5.0000	76.26385	= 100000 hr intercept

ParaWeb 50 - All Points

time is dependent variable:

	if time were the y axis	but time is the x axis
slope	-0.31845	-3.14019
intercept	29.27346	91.92413
R squared	0.964949	0.964949
	-2	98.20451
	10	60.52227
2.6990	83.44877	= 500 hr intercept
5.0000	76.2232	= 100000 hr intercept

All Creep Data ParaWeb 50 & ParaWeb 135 (conv & SIM)

time is dependent variable:

	if time were the y axis	but time is the x axis
slope	-0.32326	-3.09349
intercept	29.64426	91.70419
R squared	0.971424	0.971424
	-2	97.89117
	10	60.76931
5.8176	73.70751	= 75-yr intercept
5.9425	73.32114	= 100-yr intercept

ParaWeb 50- ParaLink 300-Creep Rupture

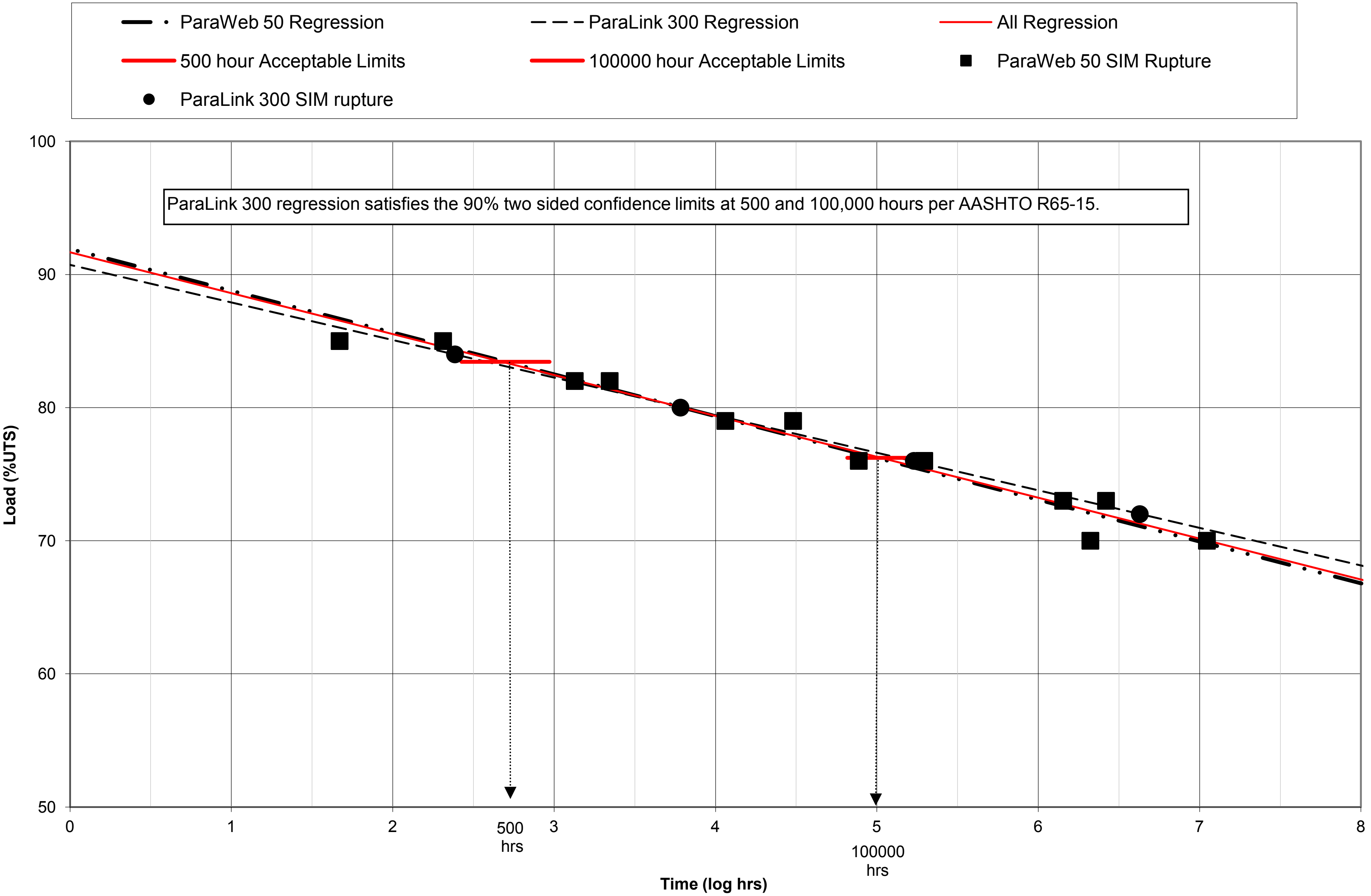


Figure F-32. Statistical evaluation results for determining validity of creating composite creep rupture envelope for the ParaWeb/ParaLink product line.

Table F-4. Computation table to determine statistical validity of creating composite creep rupture envelope for Linear Composites ParaWeb/ParaLink product line - ParaLink 300 and ParaWeb 50 comparision.

SIM Tests on ParaLink 300

Test Report	Product	Expected time, log hrs	%UTS	Rupture
	ParaLink 300	6.6291	72.00	72.00
	ParaLink 300	5.2294	76.00	76.00
	ParaLink 300	3.7831	80.00	80.00
	ParaLink 300	2.3855	84.00	84.00

student's t = 1.812 (90% 2-sided prediction limit)
n-ParaLink 300 = 4
n-ParaWeb 50 = 12 d-o-f 10
treg = 2.699
treg = 5.000
P500 = 83.4488
P100000 = 76.2232
sigma squared = 0.1160
sigma = 0.3406

90% 2-sided conf. limit	
df	student's t
2	2.92
3	2.353
4	2.132
5	2.015
6	1.943
7	1.895
8	1.86
9	1.833
10	1.812
11	1.796
12	1.782
13	1.771
14	1.761

SIM & Conventional Tests on ParaWeb 50

Test Report	Product	time, log hrs	%UTS	Rupture	Runout	logti-logtbar	(logti-logtbar)2	Pi - Pbar	(Pi-Pbar)2	K * L	
	ParaWeb 50	7.0453	70.00	70.00		2.45	6.0118	-7.50	56.25	-18.3893	SIM
	ParaWeb 50	6.3231	70.00	70.00		1.73	2.9919	-7.50	56.25	-12.9728	SIM
	ParaWeb 50	6.4199	73.00	73.00		1.83	3.3361	-4.50	20.25	-8.21925	SIM
	ParaWeb 50	6.1543	73.00	73.00		1.56	2.4364	-4.50	20.25	-7.02405	SIM
	ParaWeb 50	5.2937	76.00	76.00		0.70	0.4904	-1.50	2.25	-1.05045	SIM
	ParaWeb 50	4.8878	76.00	76.00		0.29	0.0867	-1.50	2.25	-0.4416	SIM
	ParaWeb 50	4.0613	79.00	79.00		-0.53	0.2831	1.50	2.25	-0.79815	SIM
	ParaWeb 50	4.4808	79.00	79.00		-0.11	0.0127	1.50	2.25	-0.1689	SIM
	ParaWeb 50	3.1278	82.00	82.00		-1.47	2.1480	4.50	20.25	-6.5952	SIM
	ParaWeb 50	3.3442	82.00	82.00		-1.25	1.5605	4.50	20.25	-5.6214	SIM
	ParaWeb 50	2.3120	85.00	85.00		-2.28	5.2048	7.50	56.25	-17.1105	SIM
	ParaWeb 50	1.6706	85.00	85.00		-2.92	8.5428	7.50	56.25	-21.921	SIM
	ParaWeb 50										SIM
	ParaWeb 50										SIM
	ParaWeb 50										SIM
	ParaWeb 50										SIM
	ParaWeb 50										SIM
	ParaWeb 50										SIM
	Sum	55.1208	930.00		Sum	0.00	33.11	0.00	315.00	-100.31	
	Mean	4.5934	77.50								

* runout plotting below the regression line is not included in the regression

ParaWeb 50 - 500 hrs (log 2.699)			ParaWeb 50 - 100000 hrs (log 5.000)		
log tL - lower =	2.43	83.4488	log tL - lower =	4.82	76.2232
log tL - upper =	2.97	83.4488	log tL - upper =	5.18	76.2232
ParaLink 300 - logtL @ Load =	2.58	**OK**	**ParaLink 300 - logtL @ Load =**	5.14	**OK**

ParaLink 300 - All Points

time is dependent variable:

	if time were the y axis	but time is the x axis
slope	-0.35443	-2.82145
intercept	32.15212	90.71565
R squared	0.999955	0.999955
	-2	96.35855
	10	62.50113
2.6990	83.10055	= 500 hr intercept
5.0000	76.60839	= 100000 hr intercept

ParaWeb 50 - All Points

time is dependent variable:

	if time were the y axis	but time is the x axis
slope	-0.31845	-3.14019
intercept	29.27346	91.92413
R squared	0.964949	0.964949
	-2	98.20451
	10	60.52227
2.6990	83.44877	= 500 hr intercept
5.0000	76.2232	= 100000 hr intercept

All Creep Data ParaWeb 50 & ParaLink 300 (conv & SIM)

time is dependent variable:

	if time were the y axis	but time is the x axis
slope	-0.32545	-3.07267
intercept	29.83476	91.67248
R squared	0.9708	0.9708
	-2	97.81782
	10	60.94574
5.8176	73.79689	= 75-yr intercept
5.9425	73.41311	= 100-yr intercept

ParaWeb 50- ParaLink 1000-Creep Rupture

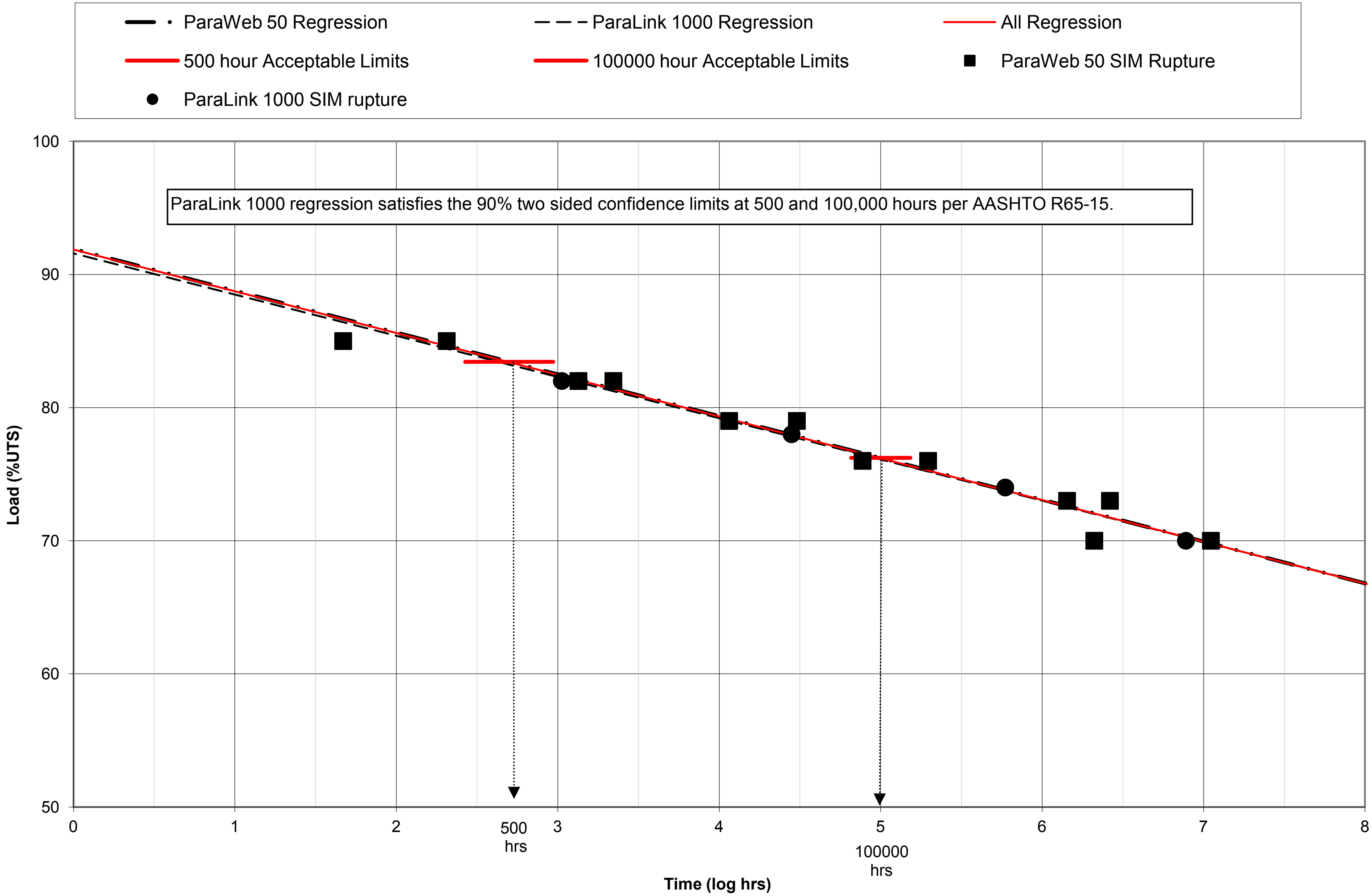


Figure F-33. Statistical evaluation results for determining validity of creating composite creep rupture envelope for the ParaWeb/ParaLink product line.

Table F-5. Computation table to determine statistical validity of creating composite creep rupture envelope for Linear Composites ParaWeb/ParaLink product line - ParaLink 300 and ParaWeb 50 comparision.

SIM Tests on ParaLink 300

Test Report	Product	Expected time, log hrs	%UTS	Rupture
	ParaLink 300	6.8905	70.00	70.00
	ParaLink 300	5.7714	74.00	74.00
	ParaLink 300	4.4481	78.00	78.00
	ParaLink 300	3.0249	82.00	82.00

student's t = 1.812 (90% 2-sided prediction limit)

n-ParaLink 300 = 4

n-ParaWeb 50 = 12 d-o-f 10

treg = 2.699

treg = 5.000

P500 = 83.4488

P100000 = 76.2232

sigma squared = 0.1160

sigma = 0.3406

90% 2-sided conf. limit	
df	student's t
2	2.92
3	2.353
4	2.132
5	2.015
6	1.943
7	1.895
8	1.86
9	1.833
10	1.812
11	1.796
12	1.782
13	1.771
14	1.761

SIM & Conventional Tests on ParaWeb 50

Test Report	Product	time, log hrs	%UTS	Rupture	Runout	logti-logtbar	(logti-logtbar)2	Pi - Pbar	(Pi-Pbar)2	K * L	
	ParaWeb 50	7.0453	70.00	70.00		2.45	6.0118	-7.50	56.25	-18.3893	SIM
	ParaWeb 50	6.3231	70.00	70.00		1.73	2.9919	-7.50	56.25	-12.9728	SIM
	ParaWeb 50	6.4199	73.00	73.00		1.83	3.3361	-4.50	20.25	-8.21925	SIM
	ParaWeb 50	6.1543	73.00	73.00		1.56	2.4364	-4.50	20.25	-7.02405	SIM
	ParaWeb 50	5.2937	76.00	76.00		0.70	0.4904	-1.50	2.25	-1.05045	SIM
	ParaWeb 50	4.8878	76.00	76.00		0.29	0.0867	-1.50	2.25	-0.4416	SIM
	ParaWeb 50	4.0613	79.00	79.00		-0.53	0.2831	1.50	2.25	-0.79815	SIM
	ParaWeb 50	4.4808	79.00	79.00		-0.11	0.0127	1.50	2.25	-0.1689	SIM
	ParaWeb 50	3.1278	82.00	82.00		-1.47	2.1480	4.50	20.25	-6.5952	SIM
	ParaWeb 50	3.3442	82.00	82.00		-1.25	1.5605	4.50	20.25	-5.6214	SIM
	ParaWeb 50	2.3120	85.00	85.00		-2.28	5.2048	7.50	56.25	-17.1105	SIM
	ParaWeb 50	1.6706	85.00	85.00		-2.92	8.5428	7.50	56.25	-21.921	SIM
	ParaWeb 50										SIM
	ParaWeb 50										SIM
	ParaWeb 50										SIM
	ParaWeb 50										SIM
	ParaWeb 50										SIM
	ParaWeb 50										SIM
	Sum	55.1208	930.00		Sum	0.00	33.11	0.00	315.00	-100.31	
	Mean	4.5934	77.50								

* runout plotting below the regression line is not included in the regression

ParaWeb 50 - 500 hrs (log 2.699)			ParaWeb 50 - 100000 hrs (log 5.000)		
log tL - lower =	2.43	83.4488	log tL - lower =	4.82	76.2232
log tL - upper =	2.97	83.4488	log tL - upper =	5.18	76.2232
ParaLink 300 - logtL @ Load =	2.63	**OK**	**ParaLink 300 - logtL @ Load =**	4.96	**OK**

ParaLink 300 - All Points

time is dependent variable:

	if time were the y axis	but time is the x axis
slope	-0.323	-3.09595
intercept	29.58192	91.58417
R squared	0.997173	0.997173
	-2	97.77607
	10	60.62465
2.6990	83.22819	= 500 hr intercept
5.0000	76.10441	= 100000 hr intercept

ParaWeb 50 - All Points

time is dependent variable:

	if time were the y axis	but time is the x axis
slope	-0.31845	-3.14019
intercept	29.27346	91.92413
R squared	0.964949	0.964949
	-2	98.20451
	10	60.52227
2.6990	83.44877	= 500 hr intercept
5.0000	76.2232	= 100000 hr intercept

All Creep Data ParaWeb 50 & ParaLink 300 (conv & SIM)

time is dependent variable:

	if time were the y axis	but time is the x axis
slope	-0.31894	-3.13539
intercept	29.30173	91.87223
R squared	0.97171	0.97171
	-2	98.143
	10	60.51837
5.8176	73.63181	= 75-yr intercept
5.9425	73.2402	= 100-yr intercept

Table F-6. Computation table for composite creep rupture envelope for the Linear Composites ParaWeb / ParaLink product line.

			Stress, % of UTS										
		data for regression calculation							sim	rlt	conv''l	sim	conv'l
product:		loghrs	all	ParaWeb 30	ParaWeb 135	ParaWeb 50	ParaLink 300	ParaLink 1000	rupture	rupture	rupture	runout*	runout*
SIM DATA:	ParaWeb 30	6.9671	70.00	70.00					70.00				
	ParaWeb 30	5.7666	75.00	75.00					75.00				
	ParaWeb 30	3.6362	80.00	80.00					80.00				
	ParaWeb 30	2.1750	85.00	85.00					85.00				
	ParaWeb 135	6.7252	71.00		71.00				71.00				
	ParaWeb 135	5.5371	75.00		75.00				75.00				
	ParaWeb 135	4.0846	79.00		79.00				79.00				
	ParaWeb 135	2.6451	83.00		83.00				83.00				
	ParaLink 300	6.6291	72.00				72.00		72.00				
	ParaLink 300	5.2294	76.00				76.00		76.00				
	ParaLink 300	3.7831	80.00				80.00		80.00				
	ParaLink 300	2.3855	84.00				84.00		84.00				
	ParaLink 1000	6.8905	70.00					70.00	70.00				
	ParaLink 1000	5.7714	74.00					74.00	74.00				
	ParaLink 1000	4.4481	78.00					78.00	78.00				
	ParaLink 1000	3.0249	82.00					82.00	82.00				
	ParaWeb 50	7.0453	70.00			70.00			70.00				
	ParaWeb 50	6.3231	70.00			70.00			70.00				
	ParaWeb 50	6.4199	73.00			73.00			73.00				
	ParaWeb 50	6.1543	73.00			73.00			73.00				
	ParaWeb 50	5.2937	76.00			76.00			76.00				
	ParaWeb 50	4.8878	76.00			76.00			76.00				
	ParaWeb 50	4.0613	79.00			79.00			79.00				
	ParaWeb 50	4.4808	79.00			79.00			79.00				
	ParaWeb 50	3.1278	82.00			82.00			82.00				
	ParaWeb 50	3.3442	82.00			82.00			82.00				
	ParaWeb 50	2.3120	85.00			85.00			85.00				
	ParaWeb 50	1.6706	85.00			85.00			85.00				

NOTE: Don't include runouts in the regression calculation unless the points lie above the line

SIM Only - ParaWeb 30
time is dependent variable:

	if time were the y axis	but time is the x axis	
slope	-0.330134	-3.029073	
intercept	30.22161	91.543464	
R squared	0.98948	0.9894797	
	-2	97.60161	
	10	61.252734	
	6	73.36903	= 114 Year intercept
	5.817863	73.92073	= 75 Year intercept

SIM Only - ParaWeb 135
time is dependent variable:

	if time were the y axis	but time is the x axis	
slope	-0.34232	-2.92124	
intercept	31.10664	90.87006	
R squared	0.997909	0.997909	
	-2	96.71255	
	10	61.65763	
	6	73.3426	= 114 Year intercept
	5.817863	73.87467	= 75 Year intercept

SIM Only - ParaWeb 50
time is dependent variable:

	if time were the y axis	but time is the x axis	
slope	-0.318452	-3.140187	
intercept	29.27346	91.924135	
R squared	0.964949	0.9649491	
	-2	98.204508	
	10	60.522265	
	5.999706	73.08394	= 114 Year intercept
	5.817863	73.65496	= 75 Year intercept

SIM Only - ParaLink 300
time is dependent variable:

	if time were the y axis	but time is the x axis	
slope	-0.35443	-2.82145	
intercept	32.15212	90.71565	
R squared	0.999955	0.999955	
	-2	96.35855	
	10	62.50113	
	6	73.78694	= 114 Year intercept
	5.817863	74.30083	= 75 Year intercept

SIM Only - All
time is dependent variable:

	if time were the y axis	but time is the x axis	
slope	-0.327398	-3.0544	
intercept	29.97534	91.5562	
R squared	0.98021	0.9802	
	-2	97.664968	
	10	61.01236	
	6.000	73.23	= 114 Year intercept
	5.943	73.40	= 100 Year intercept
	5.818	73.79	= 75 Year intercept
	4.420	78.06	= 3 Year intercept

SIM Only - ParaLink 1000
time is dependent variable:

	if time were the y axis	but time is the x axis	
slope	-0.323	-3.09595	
intercept	29.58192	91.58417	
R squared	0.997173	0.997173	
	-2	97.77607	
	10	60.62465	
	6	73.00846	= 114 Year intercept
	5.817863	73.57235	= 75 Year intercept

The regression for the all creep tests on the primary product (ParaWeb 50) produced log 2.699 hr (500 hrs) and log 5.000 hr (100,000 hrs) intercepts at 83.45% and 76.22% UTS, respectively. The regression for the creep tests on ParaWeb 30, ParaWeb 135, ParaLink 300 and ParaLink 1000 produced log time intercepts for the same %UTS within the 90% confidence limits of log 2.43 to log 2.97 and log 4.82 to log 5.18 associated with those %UTS. This evaluation is summarized in Table F-7. Thus, the primary, ParaWeb 50, and secondary products, ParaWeb 30, ParaWeb 135, ParaLink 300 and ParaLink 1000, data may be used together to construct the characteristic creep rupture curve of the family of products. Confidence limits satisfied per R69-15.

Table F-7. Summary of statistical comparison between rupture envelopes for all tested ParaWeb/ParaLink products, to test validity of composite creep rupture envelope for product line.

Product	Intercept at log 2.699 & 5.000 hrs, %UTS	Intercept at same % UTS, log hrs	90% Confidence Limits @ Higher %UTS, log hrs	90% Confidence Limits @ Lower %UTS, log hrs
ParaWeb 50	83.45 & 76.22	2.699 & 5.000	-	-
ParaWeb 30	-	2.67 & 5.06	2.43 to 2.97	4.82 to 5.18
ParaWeb 135	-	2.54 & 5.01	2.43 to 2.97	4.82 to 5.18
ParaLink 300	-	2.58 & 5.14	2.43 to 2.97	4.82 to 5.18
ParaLink 1000	-	2.63 & 4.96	2.43 to 2.97	4.82 to 5.18

Appendix G: Durability Detailed Test Results

Table G-1. Yarn test results to evaluate susceptibility to hydrolysis

Material: Polyester Yarn
Product Identification: ParaWeb 30

PARAMETER	TEST REPLICATE NUMBER			MEAN	STD. DEV.
	1	2	3		
Carboxyl End Group (CEG) Count (Test Method: GRI GG7)					
mmol/Kg	15.3	16.0	16.4	**15.9**	0.6
Molecular Weight (Test Method: GRI GG8)					
Mn (Number average molecular weight)	38,358	33,081	31,930	**34,456**	3,428

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table G-2. UV resistance test results of ParaWeb 30.

PARAMETER	TEST REPLICATE NUMBER					MEAN	STD. DEV.	PERCENT RETAINED
	1	2	3	4	5			
UV Resistance (ASTM D 4355) Strength Retained measured via single strip tensile (ASTM D 6637, Method A, mod.)								
MD - Tensile Strength (lbs) - B	6870	6694	6725	6758	6778	**6765**	67	
MD - Tensile Strength (kN) - B	30.6	29.8	29.9	30.1	30.2	**30.1**	0.3	
MD - Tensile Strength (lbs) - E	6326	6224	6288	6222	6310	**6274**	48	**93**
MD - Tensile Strength (kN) - E	28.2	27.7	28.0	27.7	28.1	**27.9**	0.2	
MD - Elong. @ Max. Load (%) - B	11.1	10.2	10.8	10.3	10.4	**10.6**	0.4	
MD - Elong. @ Max. Load (%) - E	12.0	11.3	11.5	12.3	12.2	**11.9**	0.4	**112**

B - Baseline Unexposed
E - Exposed for 500 hours of ASTM D 4355 Cycle

MD - Machine Direction TD - Transverse/Cross Machine Direction

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested.

Table G-3. Summary of UV resistance test results for ParaWeb/ParaLink.

Product Style	Mean Baseline Tensile Strength (lb/rib)	Standard Deviation (lb/rib)	Mean Exposed Tensile Strength (lb/rib)	Standard Deviation (lb/rib)	% Strength Retained
ParaWeb 30	6,765	67	6,274	48	93

(Conversion: 1 lb/ft = 0.0146 kN/m)

Appendix H: Creep Stiffness Detailed Test Results

Low Strain Ramp and Hold Test Results
Product: ParaWeb 30

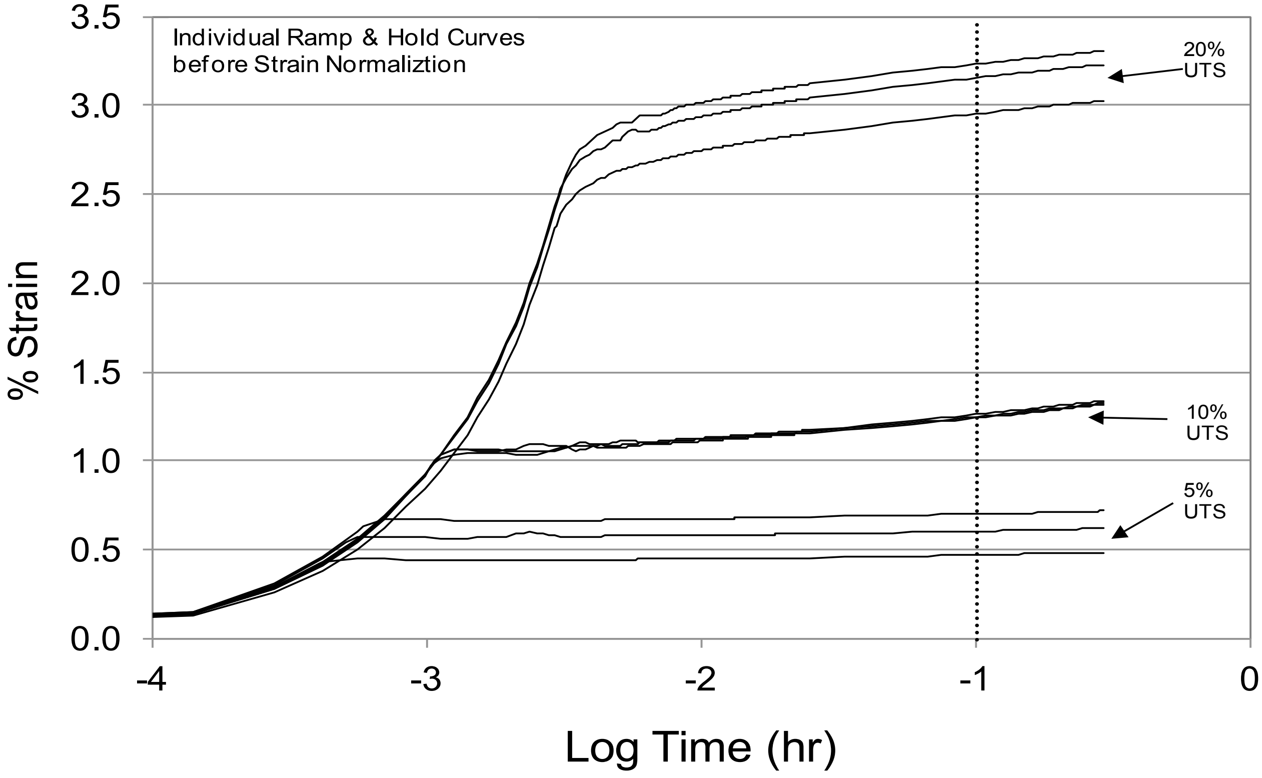


Figure H-1. Low strain ramp and hold tests for ParaWeb 30, before strain normalization.

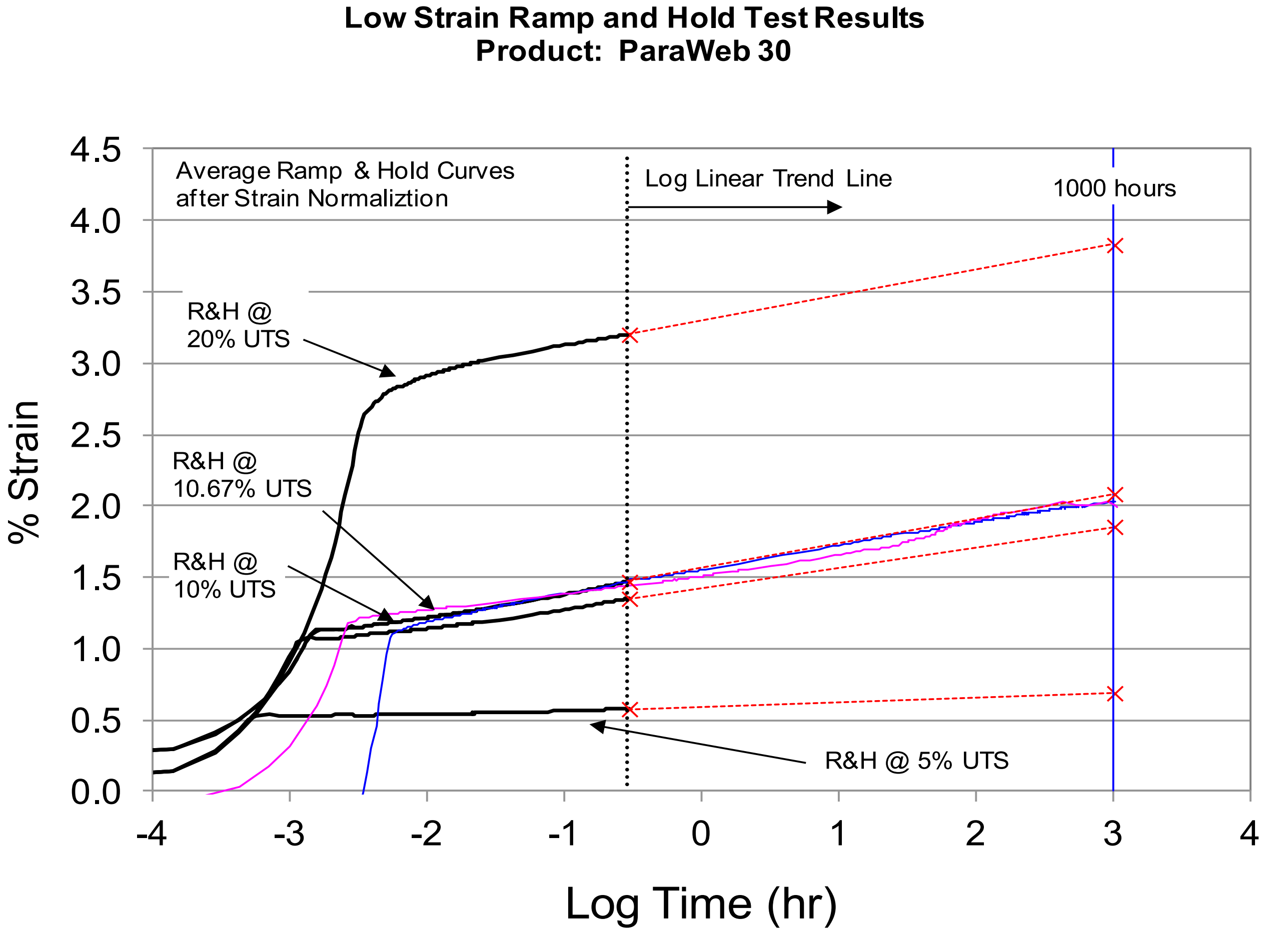


Figure H-2. Low strain ramp and hold tests for ParaWeb 30, after strain normalization, with 1000 hour low strain creep tests.

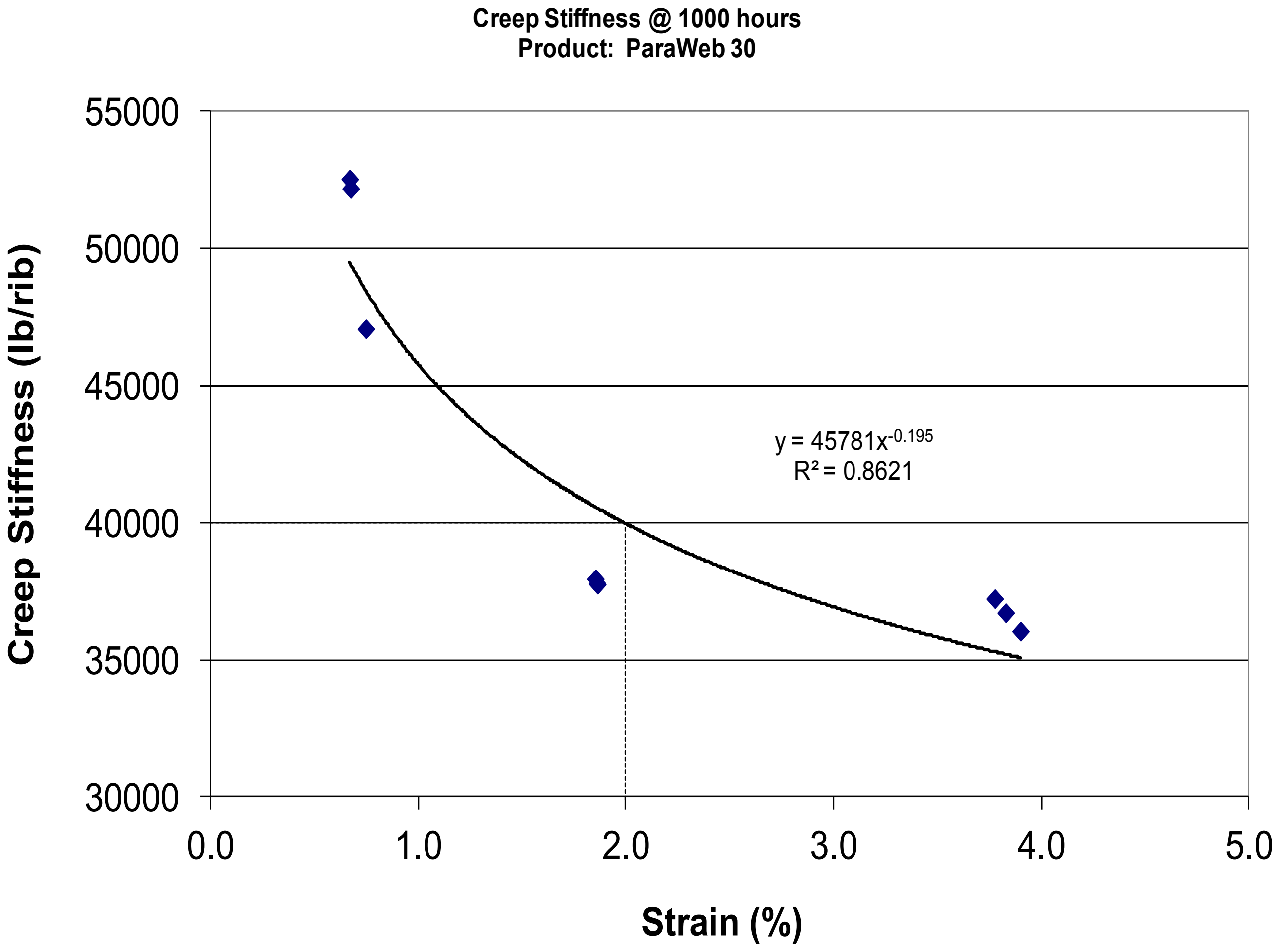


Figure H-3. Creep stiffness versus strain at 1,000 hours for ParaWeb 30.

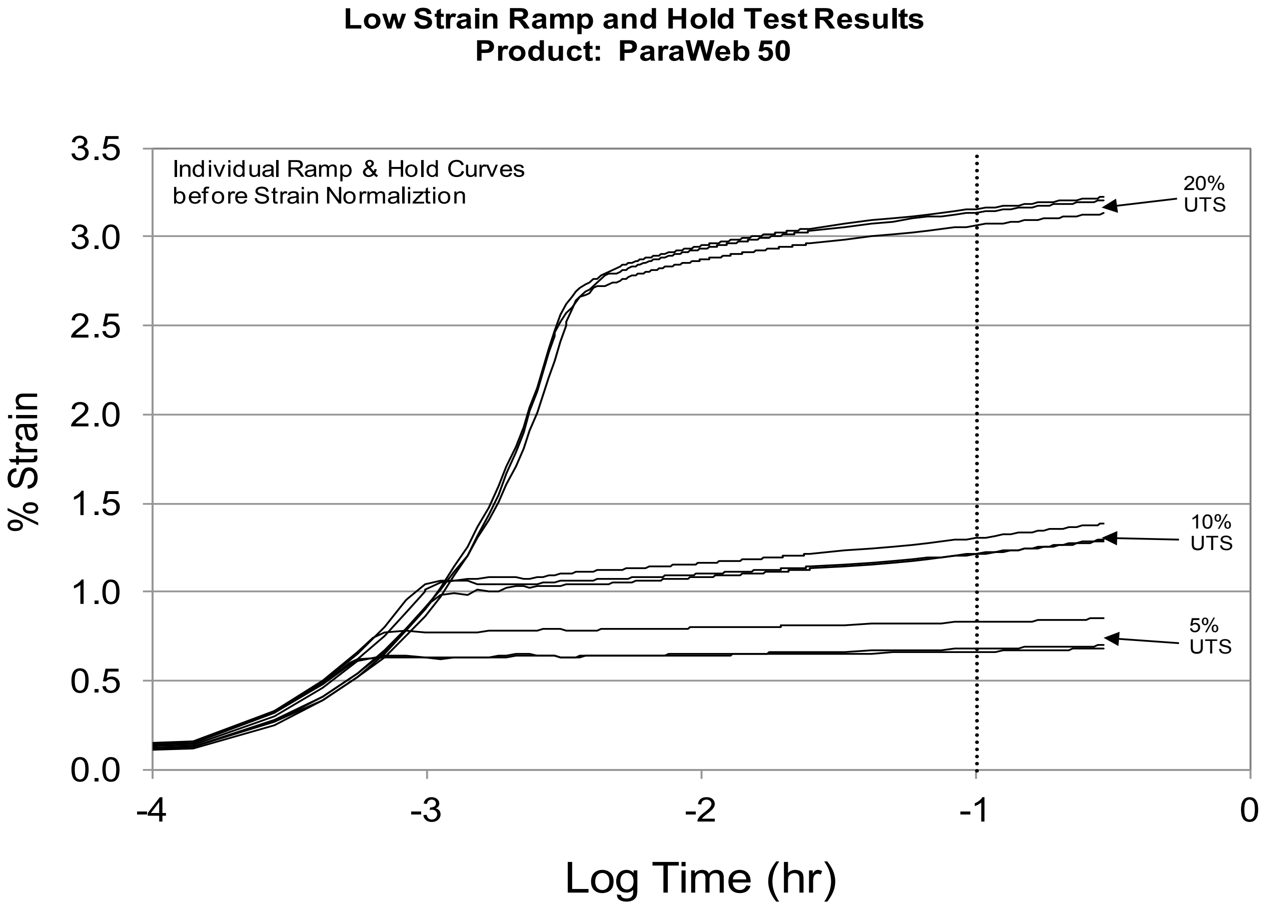


Figure H-4. Low strain ramp and hold tests for ParaWeb 50, before strain normalization.

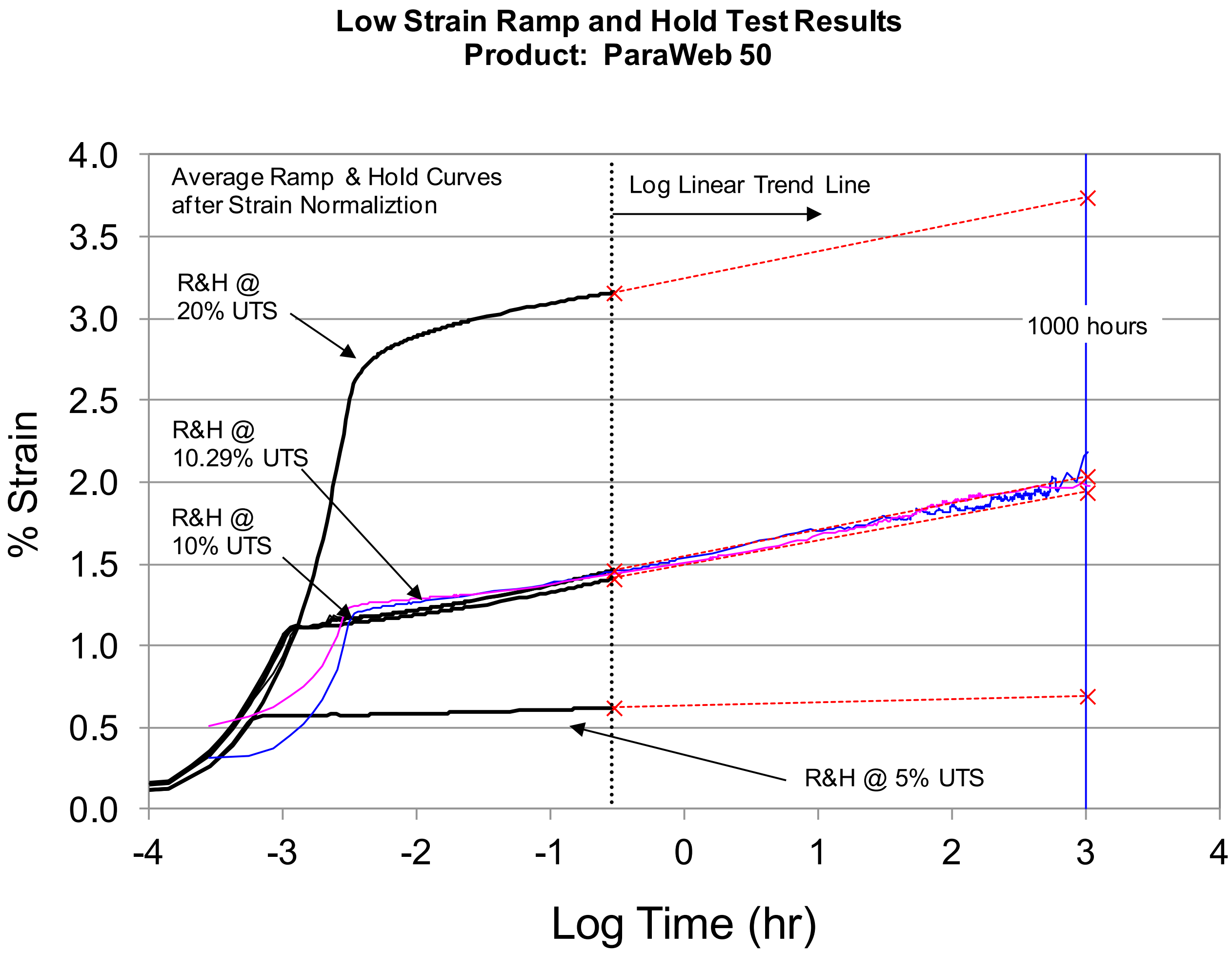


Figure H-5. Low strain ramp and hold tests for ParaWeb 50, after strain normalization, with 1000 hour low strain creep tests.

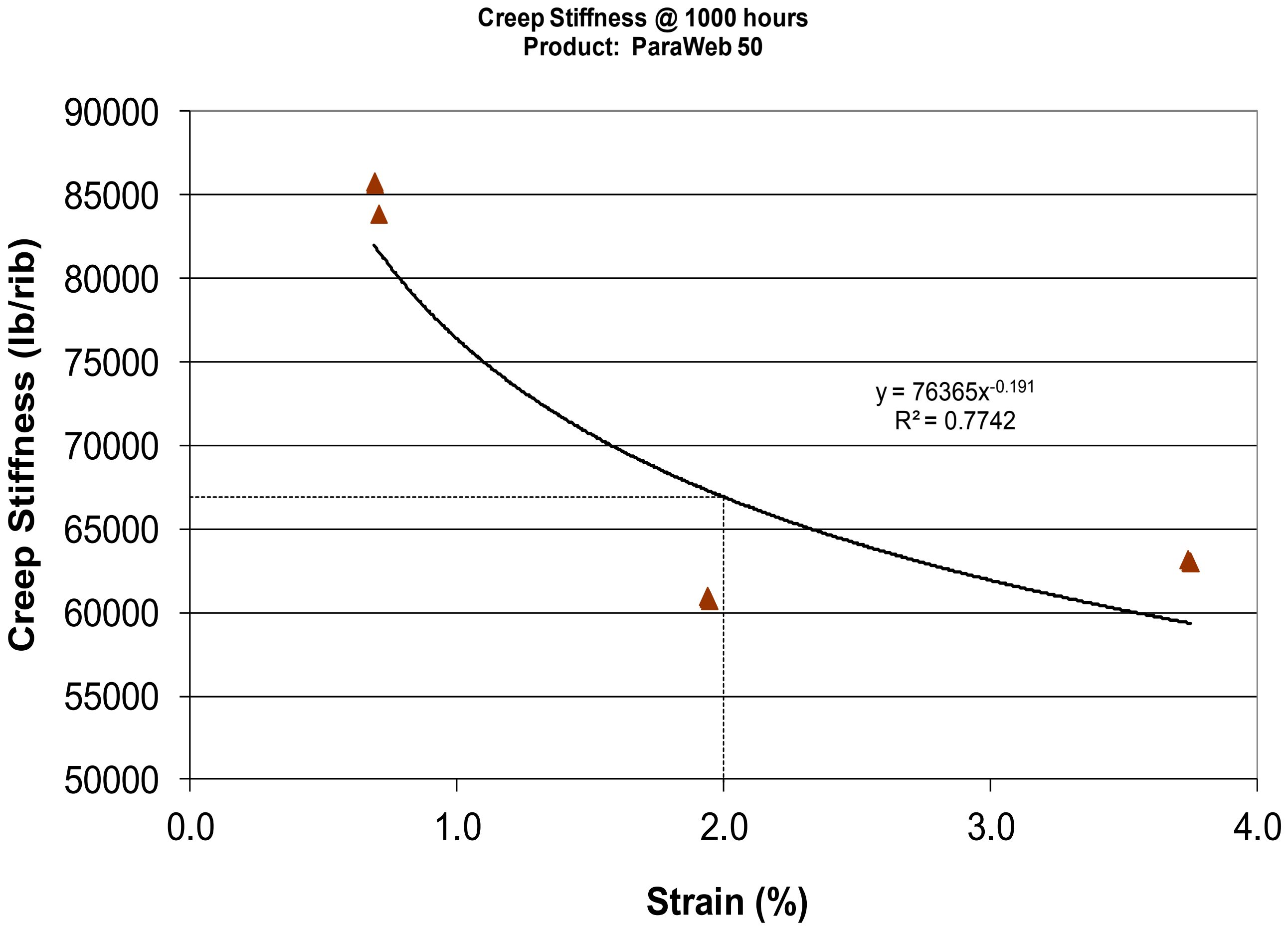


Figure H-6. Creep stiffness versus strain at 1,000 hours for ParaWeb 50.

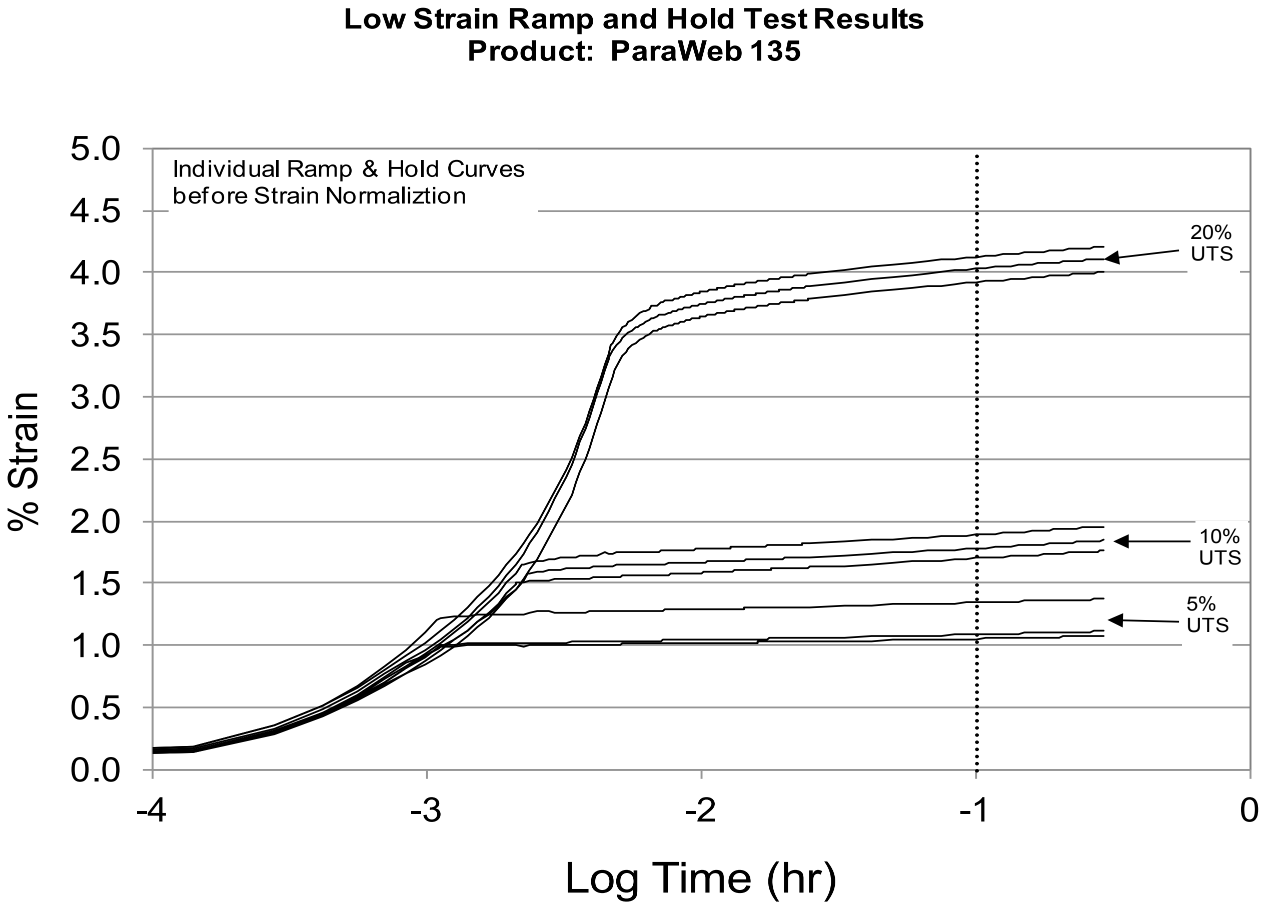


Figure H-7. Low strain ramp and hold tests for ParaWeb 135, before strain normalization.

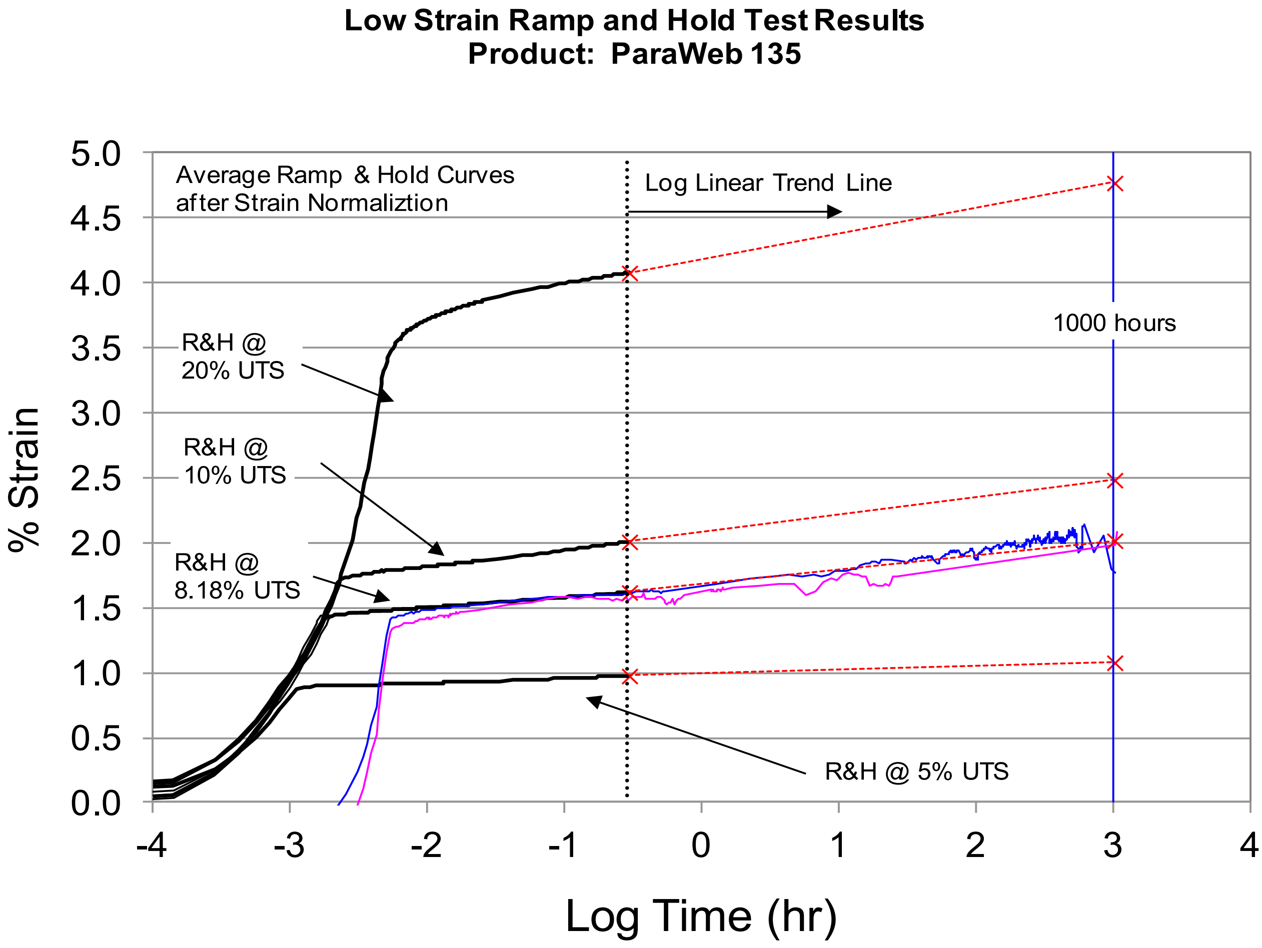


Figure H-8. Low strain ramp and hold tests for ParaWeb 135, after strain normalization, with 1000 hour low strain creep tests.

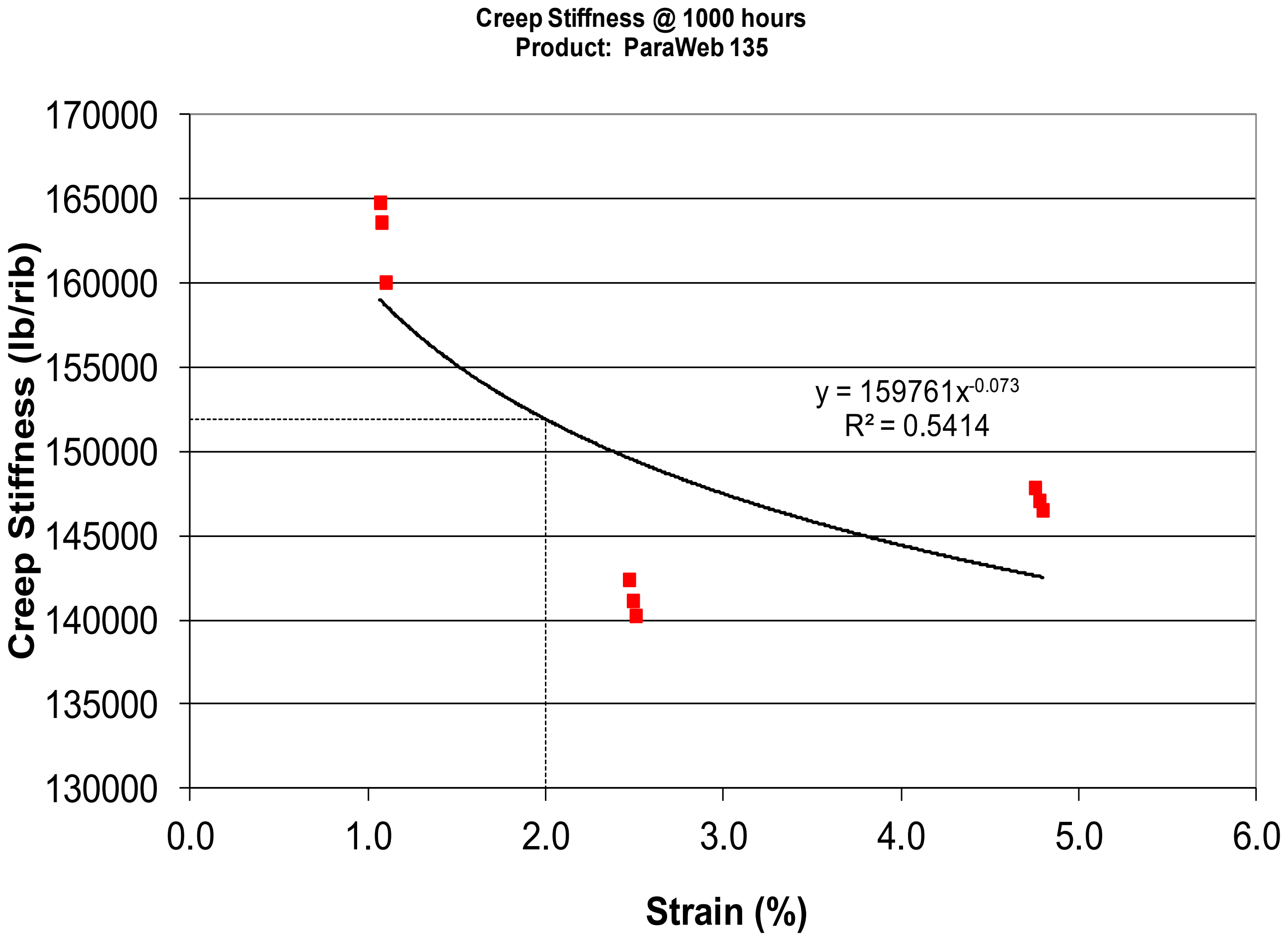


Figure H-9. Creep stiffness versus strain at 1,000 hours for ParaWeb 135.

Low Strain Ramp and Hold Test Results
Product: ParaLink 300

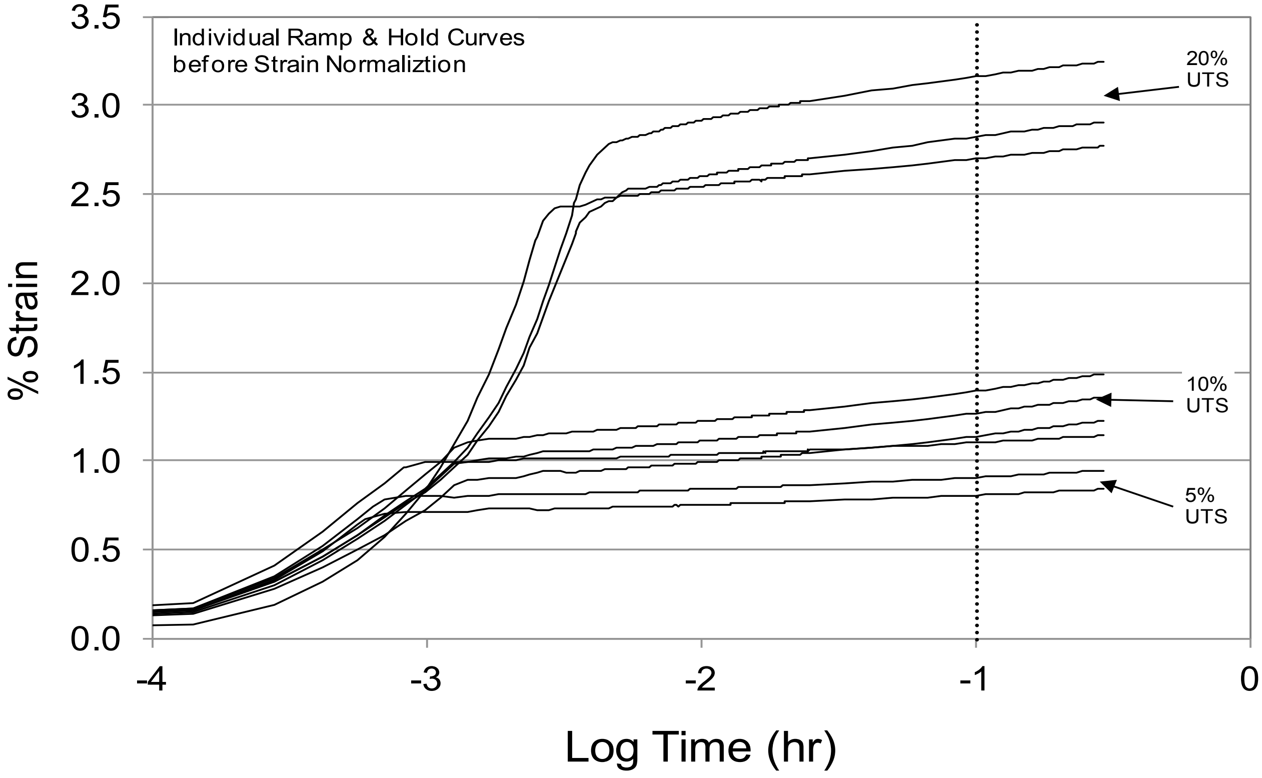


Figure H-10. Low strain ramp and hold tests for ParaLink 300, before strain normalization.

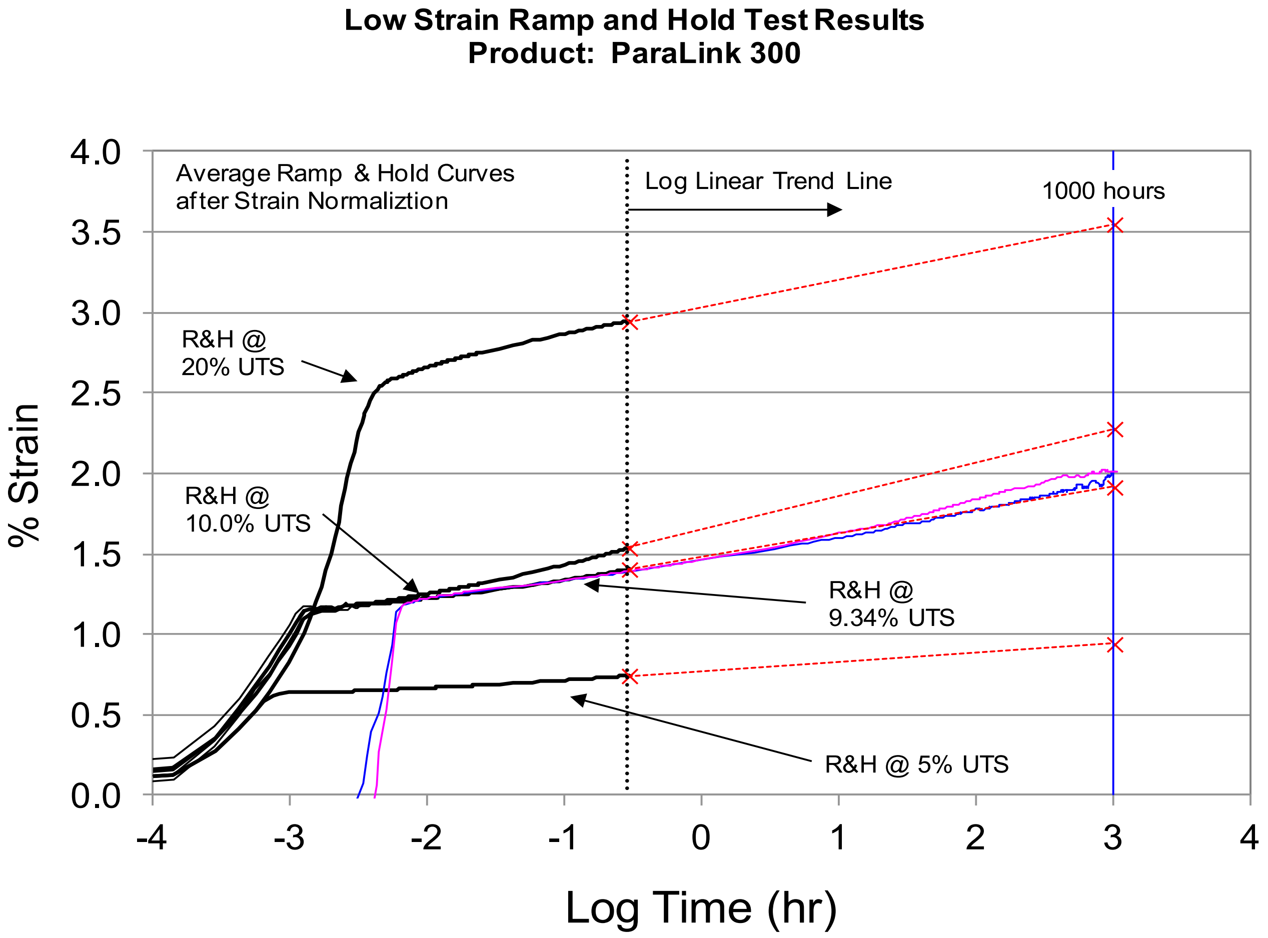


Figure H-11. Low strain ramp and hold tests for ParaLink 300, after strain normalization, with 1000 hour low strain creep tests.

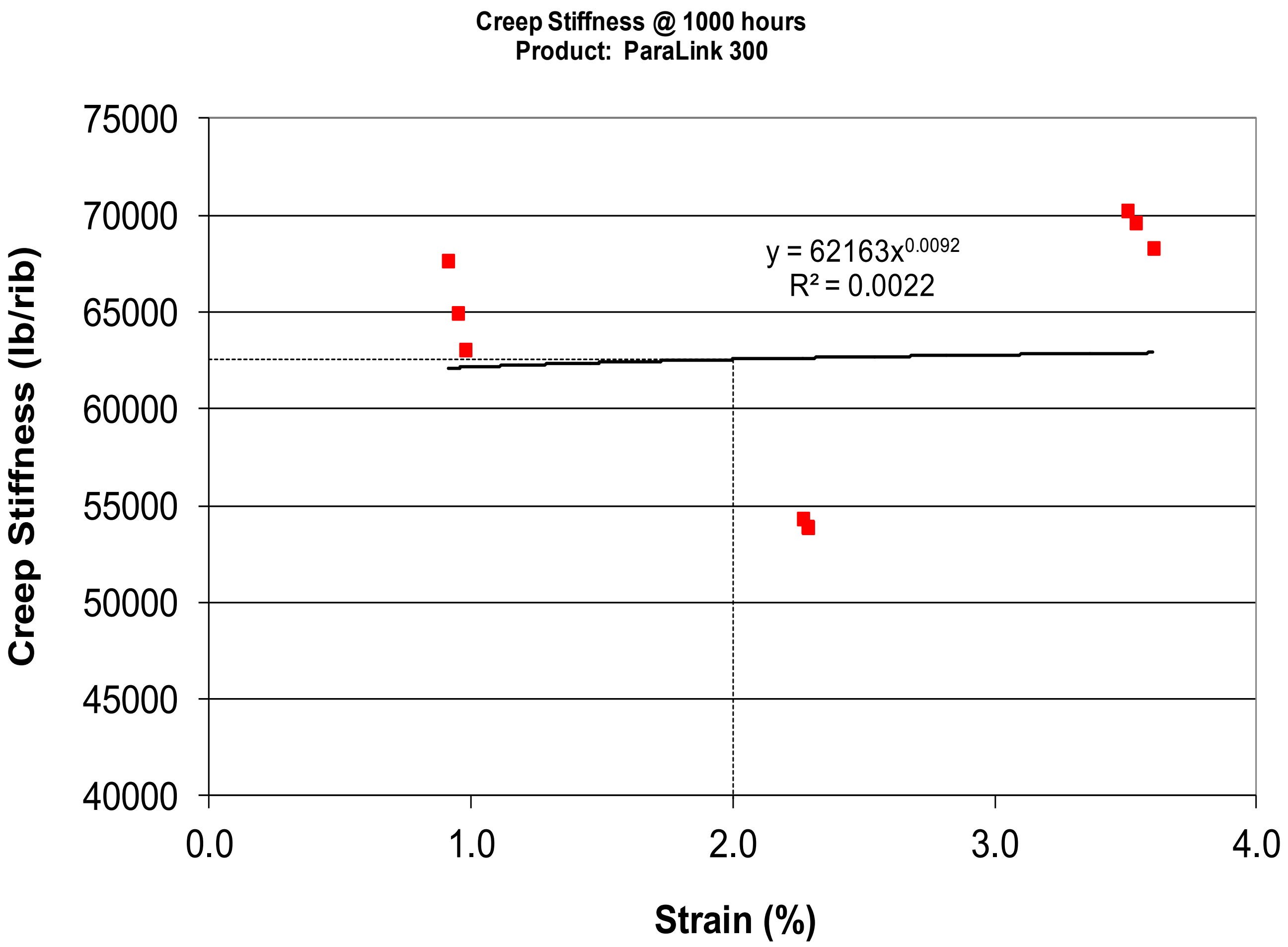


Figure H-12. Creep stiffness versus strain at 1,000 hours for ParaLink 300.

Low Strain Ramp and Hold Test Results
Product: ParaLink 1000

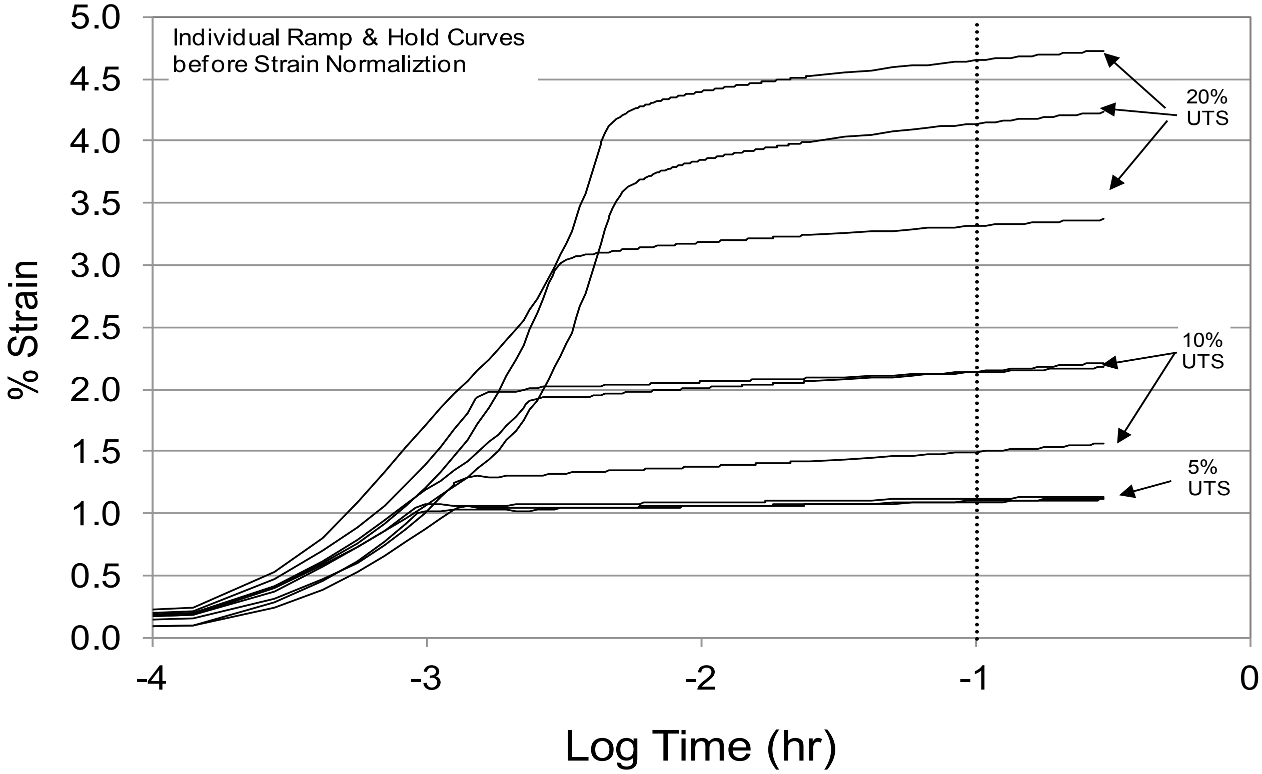


Figure H-13. Low strain ramp and hold tests for ParaLink 1000, before strain normalization.

Low Strain Ramp and Hold Test Results
Product: ParaLink 1000

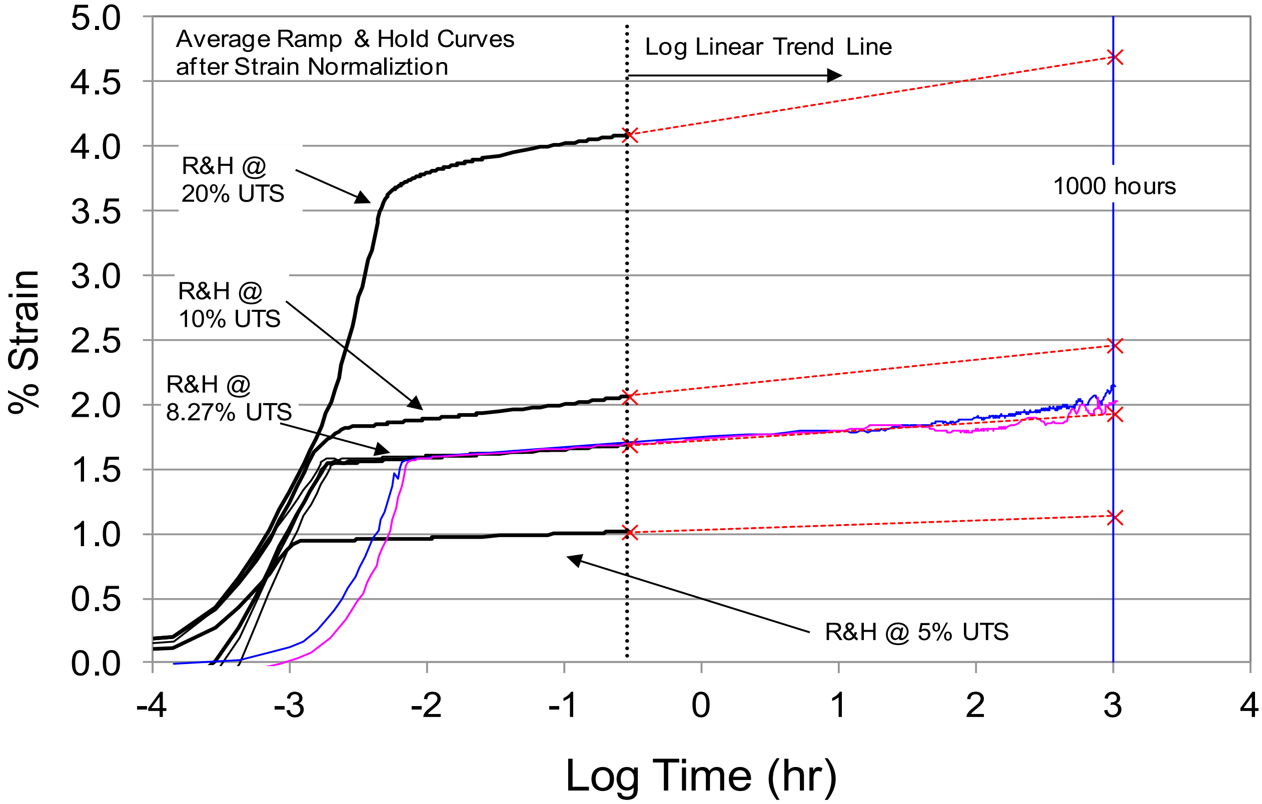


Figure H-14. Low strain ramp and hold tests for ParaLink 1000, after strain normalization, with 1000 hour low strain creep tests.

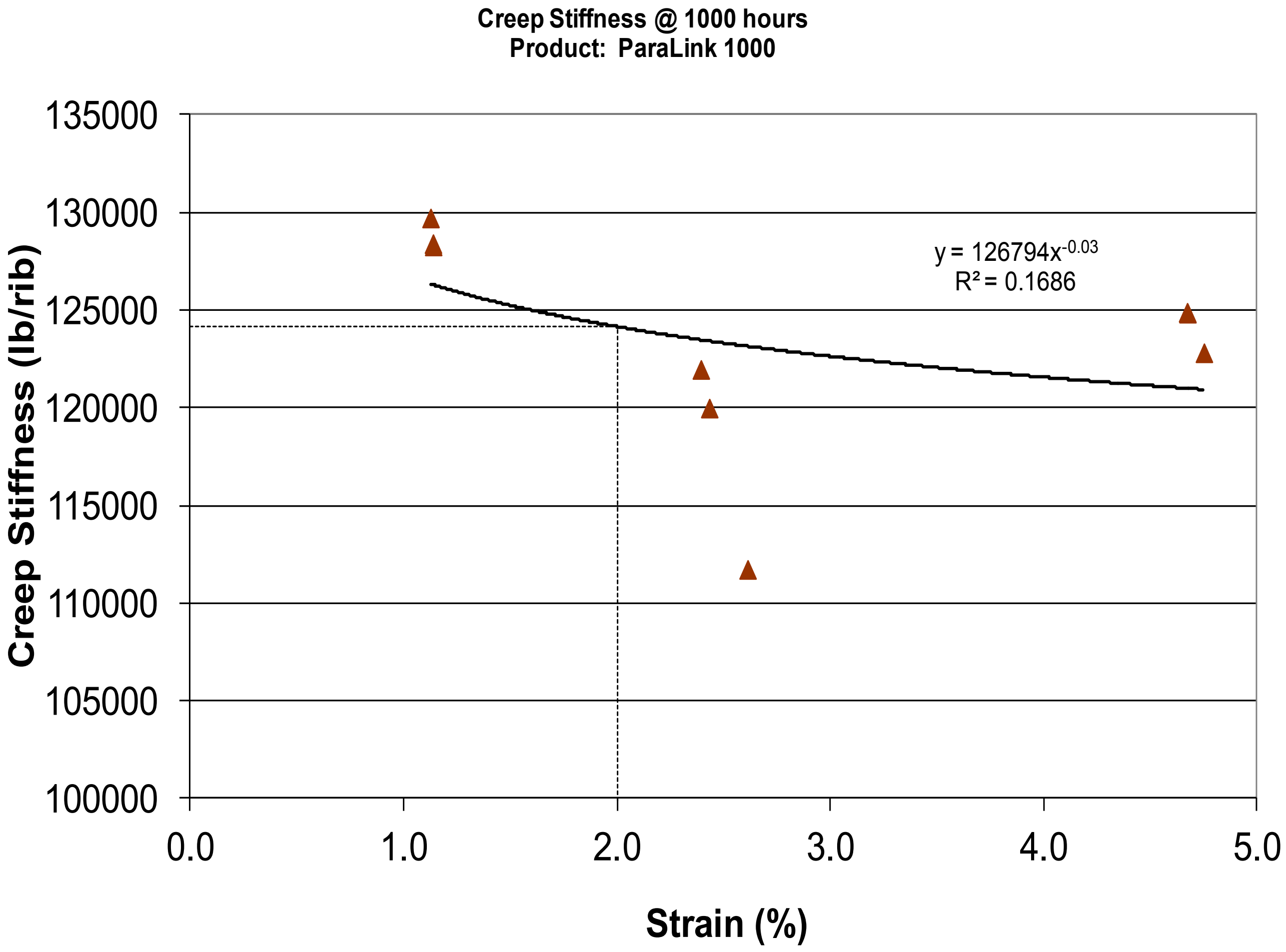


Figure H-15. Creep stiffness versus strain at 1,000 hours for ParaLink 1000.

> “The National Transportation Product Evaluation Program (NTPEP) was established by the American Association of State Highway and Transportation Officials (AASHTO) in early 1994. The program pools the professional and physical resources of the AASHTO member departments in order to test materials, products and devices of common interest. The primary goals of the program are to provide cost-effective evaluations for the states by eliminating duplication of routine testing by the states; and to reduce duplication of effort by the manufacturers who produce and market commonly used proprietary, engineered products.” ❧ **NTPEP** ☙
>
> **-- Rick Smutzer (IN), former NTPEP Chairman**

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call 1.202.624.5800
fax 1.800.525.5469
online www.NTPEP.ORG

ITEM: NTPEP Report REGEO-2016-01-[Linear Composites-ParaWeb-ParaLink]

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THE VOICE OF TRANSPORTATION

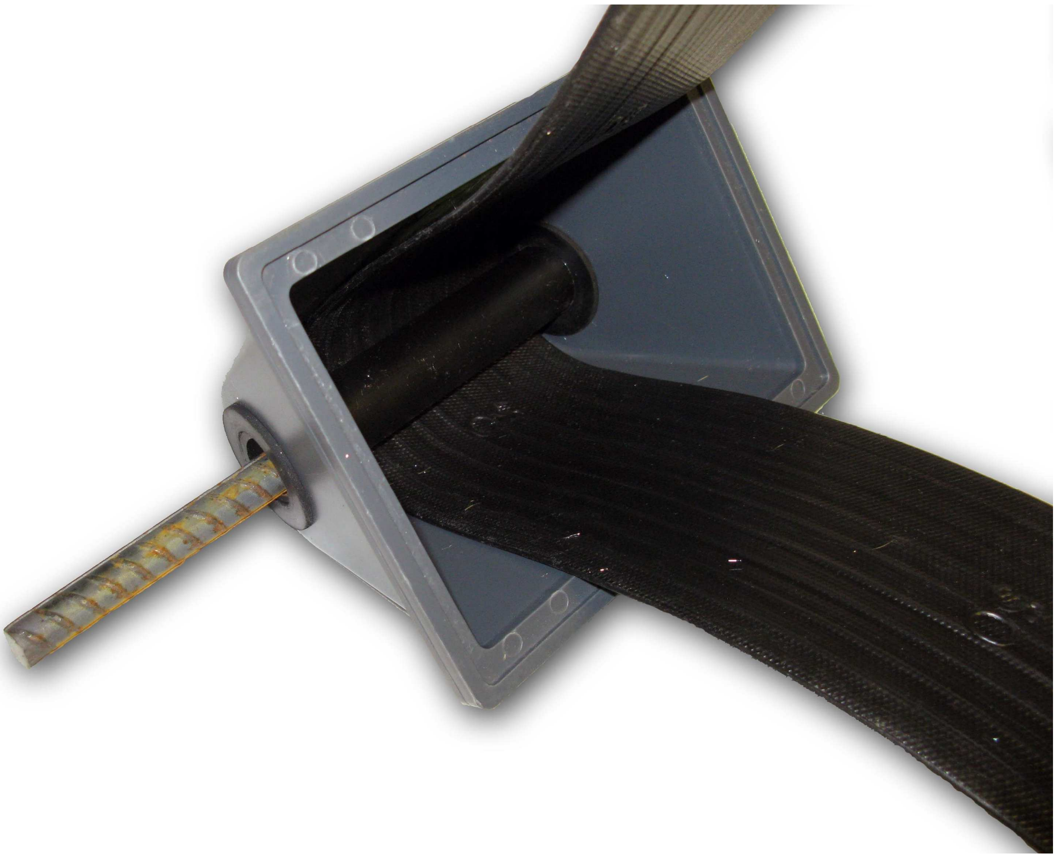
1.2.5 REINFORCEMENT CONNECTION DETAILS

Maccaferri Macbox Connection System (excerpt)

Note: This excerpt provides general information on the proprietary connector box. Detailed test data for the strength of the connector is presented in the following Appendix section. Therefore, the strength summary information in this original document is not included here.

Maccaferri MacBox

Connection System



MACCAFERRI

Table of Contents:

1.0 Maccaferri MacBox Connecting System

Polymeric Cavity Connection Assembly

The Maccaferri connection assembly is composed of a (High Density Polyethylene (HDPE) cavity insert box secured by a steel rebar (anchor bar) in the precast concrete element (Figure 1 and Figure 2). The steel embedded rebar is encased in a polymeric sleeve for corrosion protection. The sleeve prevents water and concrete for entering during the casting phase and prevents damage to the polymeric soil reinforcing strips in contact with the deformed rebar. An alternate polymeric anchor rod (in lieu of a steel rebar) may also be considered with this system (Figure 3).

The connection system is supplied with a HDPE lid, which is closed during the casting phase to prevent the wet concrete from entering the cavity insert box.

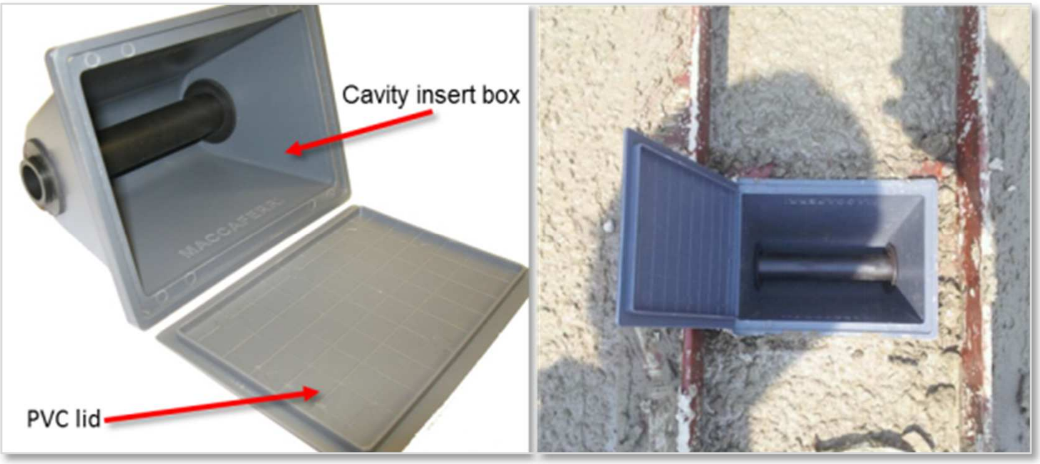


Figure 1 – Macres ® MSE Wall System's PVC Cavity Insert Box with a HDPE Lid.

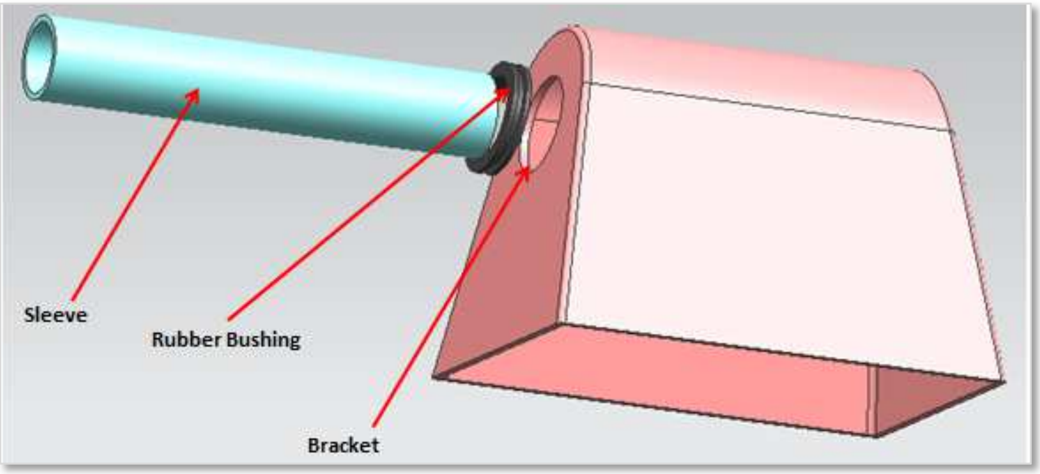


Figure 2 – MacRes® MSE Wall System's Connection Components.

Figure 3 – MacRes ® MSE Wall System's Connection Assembly with Polymeric Anchor Rod.

The strength of the connection has been determined through an independent connection/pullout testing program performed at TRI/Environmental Laboratories in Austin, TX. The test results are discussed in detail in Chapter 2 of this report.

Steel Rebar/Anchor Bar (for Securing the Connection Assembly)

The steel rebar/anchor bar that secures the MacRes® connection's cavity insert box consists of ASTM A615 Grade 60, deformed rebar (uncoated).

The alternate polymeric anchor bar that secures the MacRes® connection's cavity insert box consists of a salt resistant and non-corrosive GFRP reinforcement rod (Glass Fiber Reinforced

Polymer) manufactured of high performance composite materials including vinylester resin and ECR glass fibers.

1.2.6 CONNECTION PROPERTIES

Macbox Connector Pullout Test
Macbox Pullout Calculations
Paraweb Bend Tensile Test

Note: The connector pullout test report includes tests using polymeric anchor bars. Stone Strong only uses steel reinforcing bars for anchorage inside of the Macbox connectors. Polymeric anchor bars are not used.

TESTING, RESEARCH, CONSULTING AND FIELD SERVICES
AUSTIN, TX - USA | ANAHEIM, CA - USA | ANDERSON, SC - USA | GOLD COAST - AUSTRALIA | SUZHOU - CHINA

June 17, 2015

Mail To:	**Bill To:**
Ms. Giulia Lugli **Maccaferri, Inc.** 10303 Governor Lane Blvd. Williamsport, MD 21795	**<= Same**

email: glugli@maccaferri-usa.com

Dear Ms. Lugli:

Thank you for consulting TRI/Environmental, Inc. (TRI) for your laboratory testing needs. TRI is pleased to submit this final report for laboratory testing.

TRI Job Reference Number:	E2371-04-09
Material(s) Tested:	4 Concrete Panels with Polymeric Anchor Bars 4 Concrete Panels with Steel Anchor Bars
Test(s) Requested:	Tensile Testing

If you have any questions or require any additional information, please call us at 1-800-880-8378.

Sincerely,

Jarrett A. Nelson

Jarrett A. Nelson
Technical Director
Geosynthetic Services Division
www.GeosyntheticTesting.com

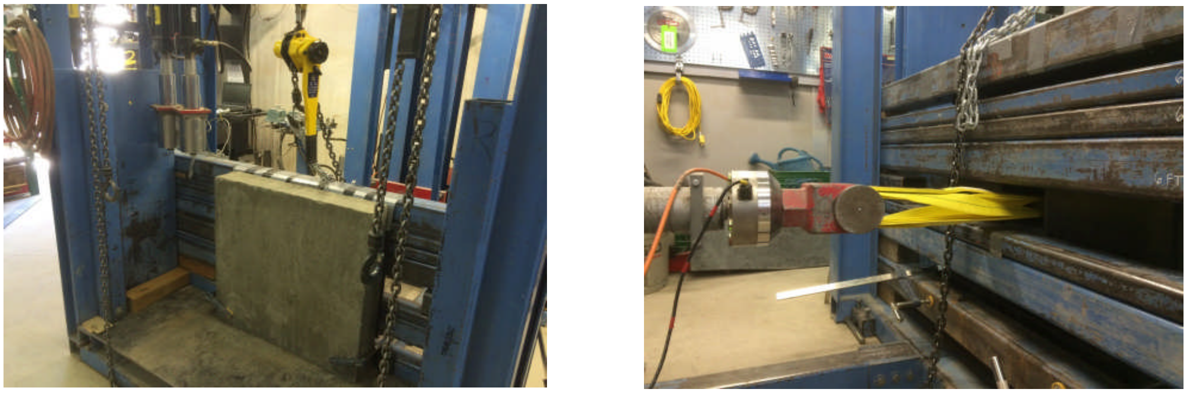
LABORATORY TEST RESULTS
TRI Client: Maccaferri, Inc.
Photographs

Concrete Blocks as Received (Plywood Lid Removed)

Concrete Blocks with Forms Removed

Concrete Block with Polymeric Bar

Concrete Block with Steel Bar



Test Set-Up

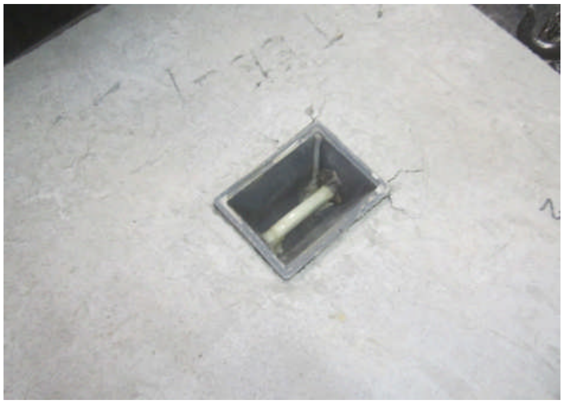
LABORATORY TEST RESULTS

TRI Client: Maccaferri, Inc.

Material: Concrete Panels
Sample Identification: Polymeric Anchor Bars
TRI Log #: E2371-04-09

PARAMETER	TEST REPLICATE NUMBER				RESULT	
	1	2	3	4		
Tensile Strength						
Test Date:	6/12	6/12	6/15	6/15		
Peak Load (lbs)	6386	6036	6513	5931	$\boxed{6217}$	277

Specimen 1 - Post-Test

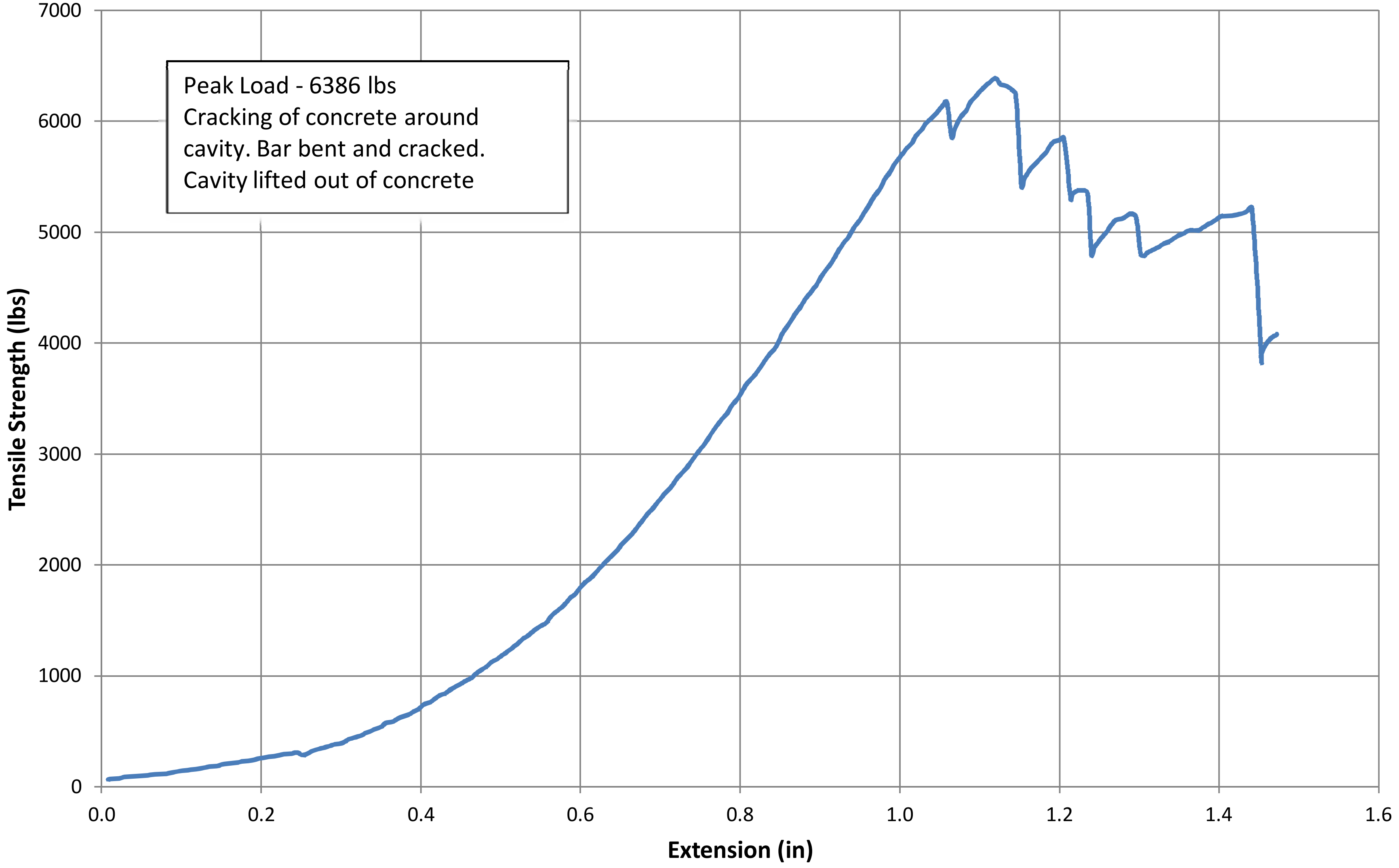


Specimen 2 - Post-Test

Specimen 3 - Post-Test

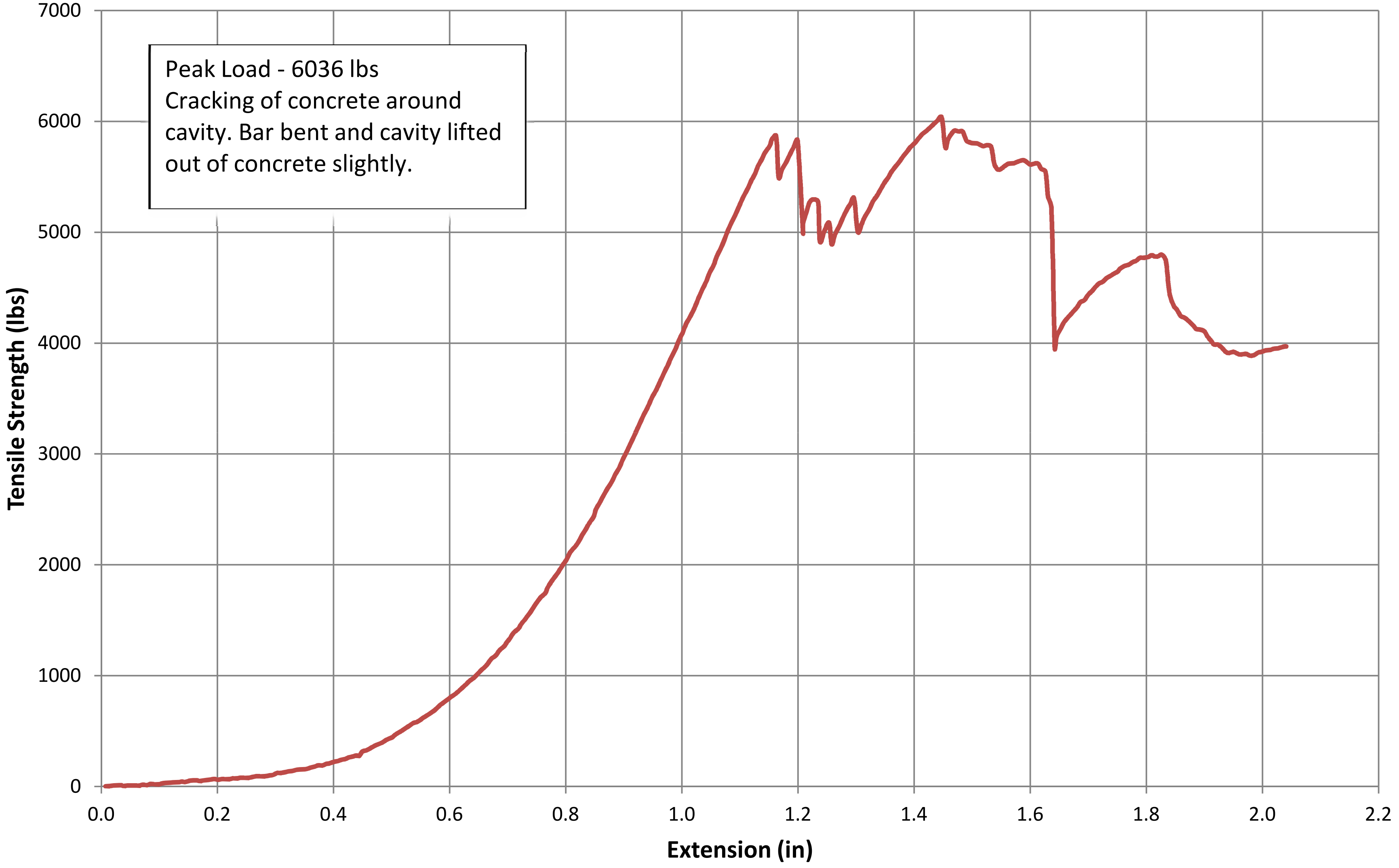
Specimen 4 - Post-Test

Tensile Test Results
TRI: Client: Maccaferri, Inc.
Product: Concrete Block with Polymeric Bar



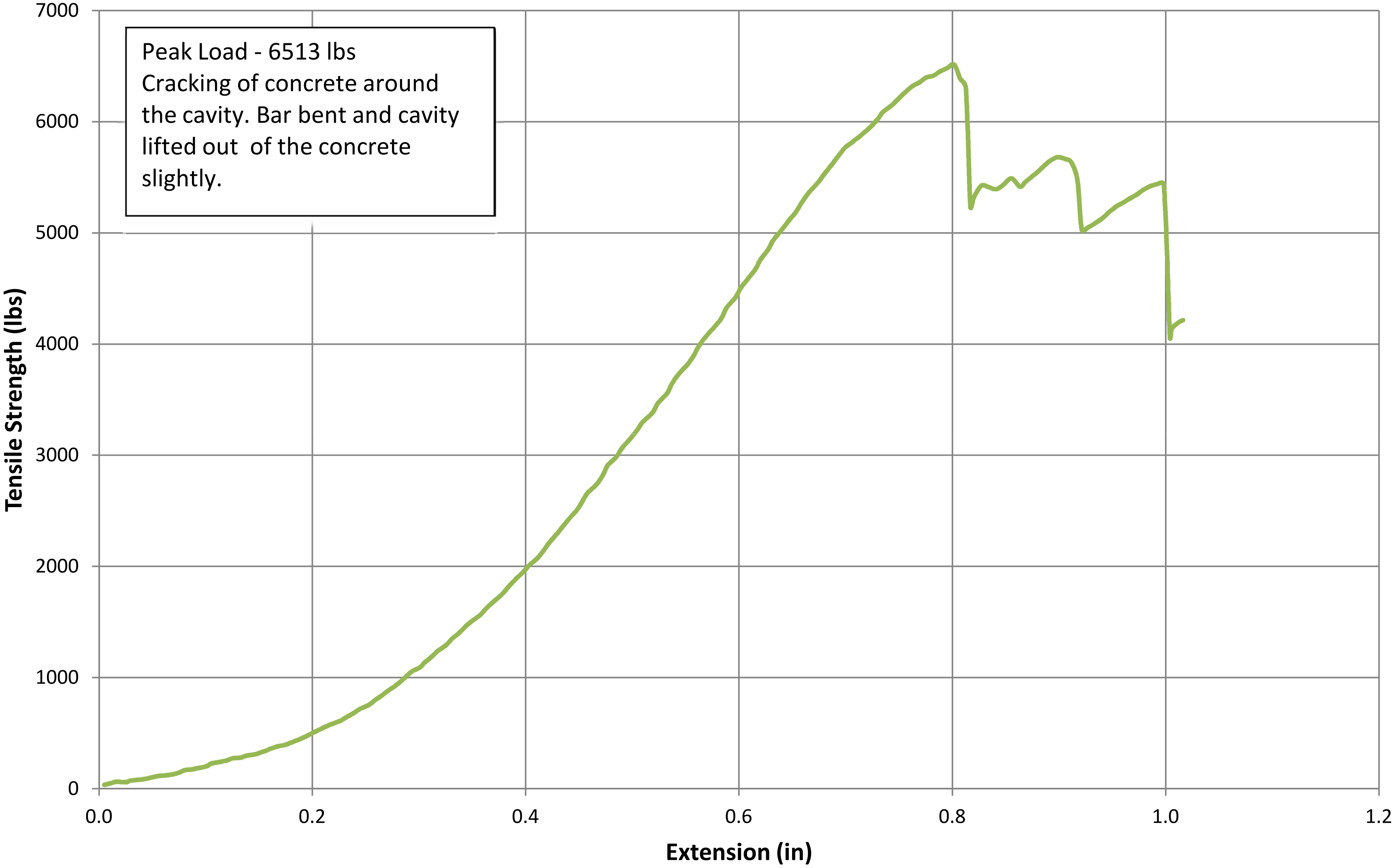
Peak Load - 6386 lbs
Cracking of concrete around cavity. Bar bent and cracked. Cavity lifted out of concrete

Tensile Test Results
TRI: Client: Maccaferri, Inc.
Product: Concrete Block with Polymeric Bar



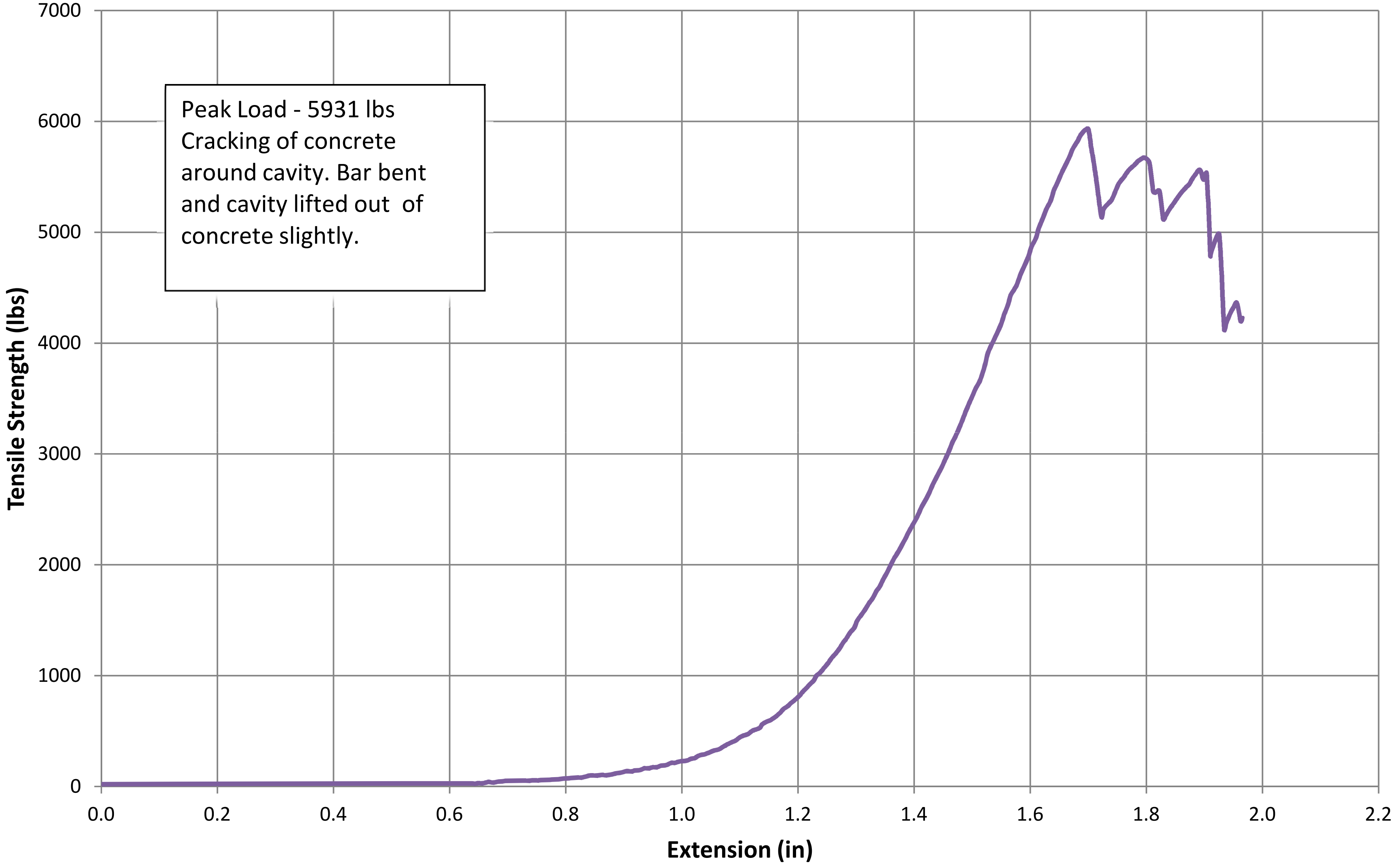
Peak Load - 6036 lbs
Cracking of concrete around cavity. Bar bent and cavity lifted out of concrete slightly.

Tensile Test Results
TRI: Client: Maccaferri, Inc.
Product: Concrete Block with Polymeric Bar



Peak Load - 6513 lbs
Cracking of concrete around the cavity. Bar bent and cavity lifted out of the concrete slightly.

Tensile Test Results
TRI: Client: Maccaferri, Inc.
Product: Concrete Block with Polymeric Bar

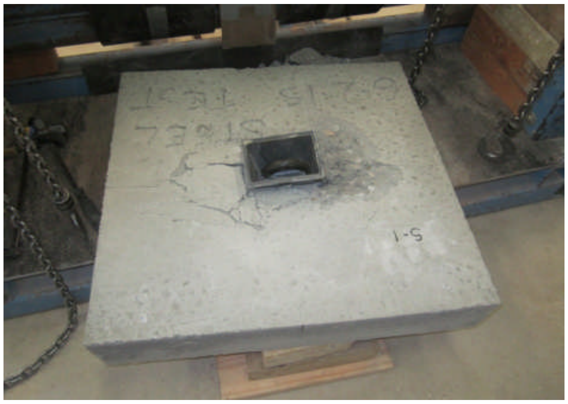


LABORATORY TEST RESULTS

TRI Client: Maccaferri, Inc.

Material: Concrete Panels
Sample Identification: Steel Anchor Bars
TRI Log #: E2371-04-09

PARAMETER	TEST REPLICATE NUMBER				RESULT	
	1	**2**	**3**	**4**		
Tensile Strength						
Test Date:	6/12	6/12	6/15	6/15		
Peak Load (lbs)	14731	14870	12978	12899	**13870**	1077



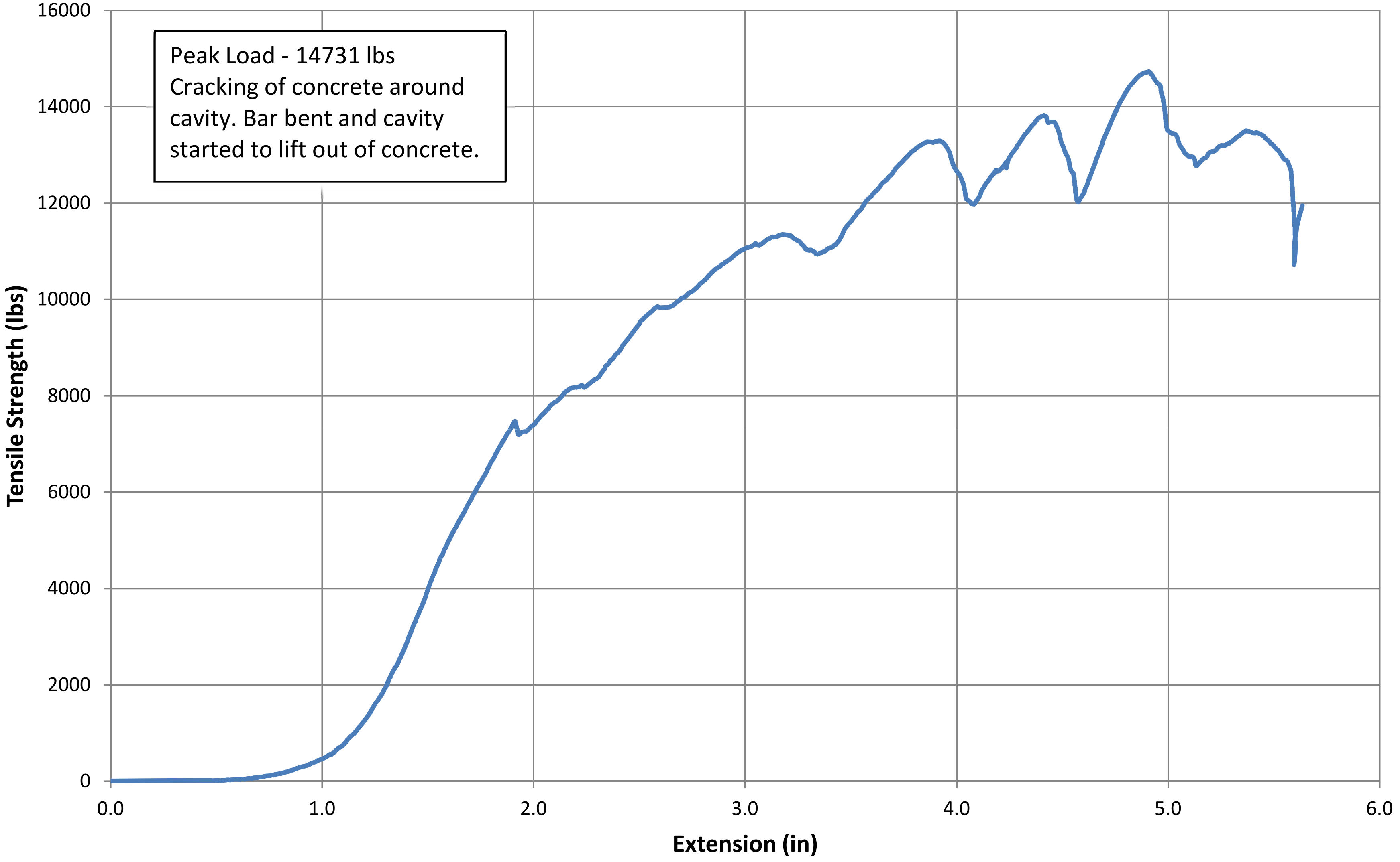
Specimen 1 - Post-Test

Specimen 2 - Post-Test

Specimen 3 - Post-Test

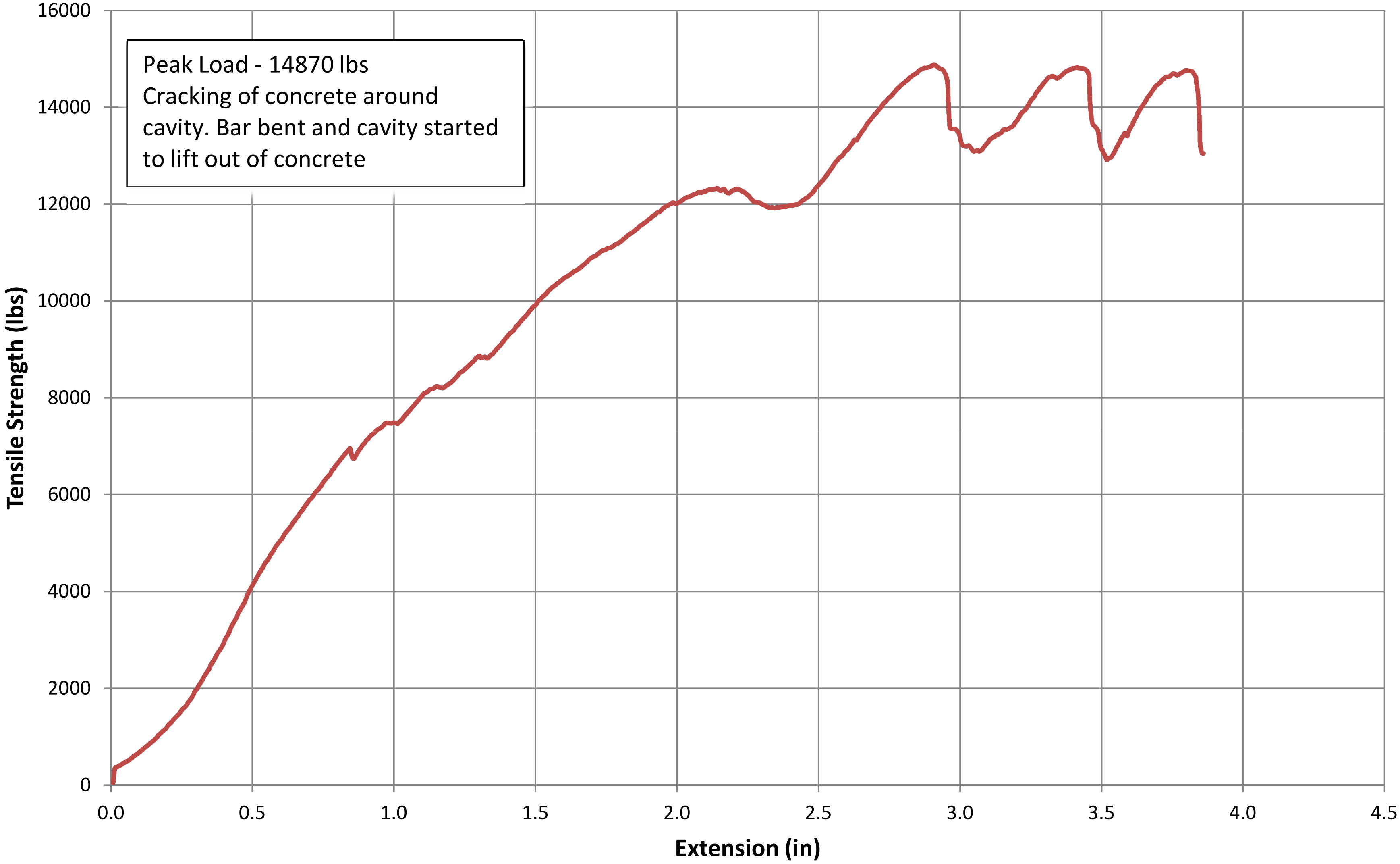
Specimen 4 - Post-Test

Tensile Test Results
TRI: Client: Maccaferri, Inc.
Product: Concrete Block with Steel Bar



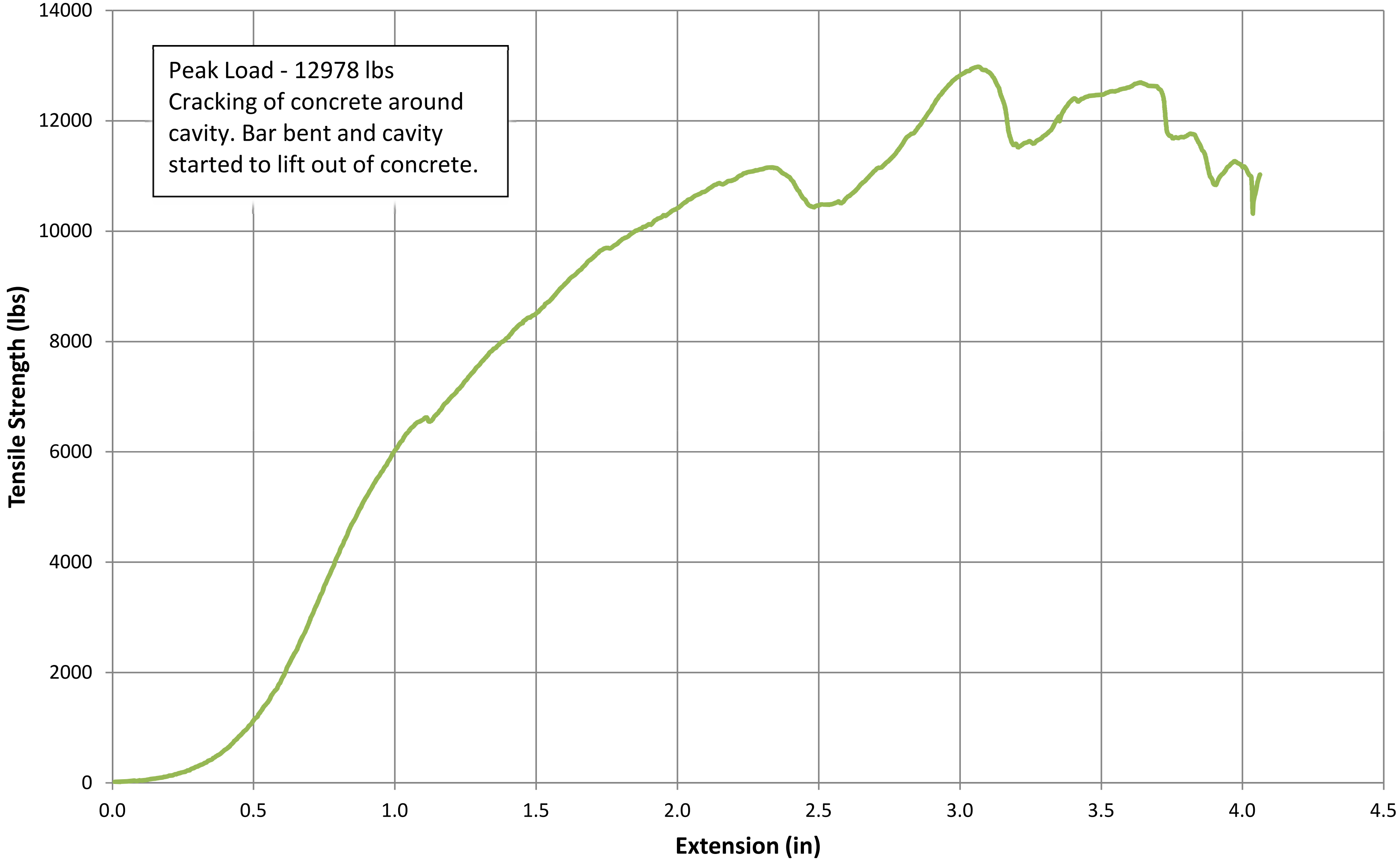
Peak Load - 14731 lbs
Cracking of concrete around cavity. Bar bent and cavity started to lift out of concrete.

Tensile Test Results
TRI: Client: Maccaferri, Inc.
Product: Concrete Block with Steel Bar

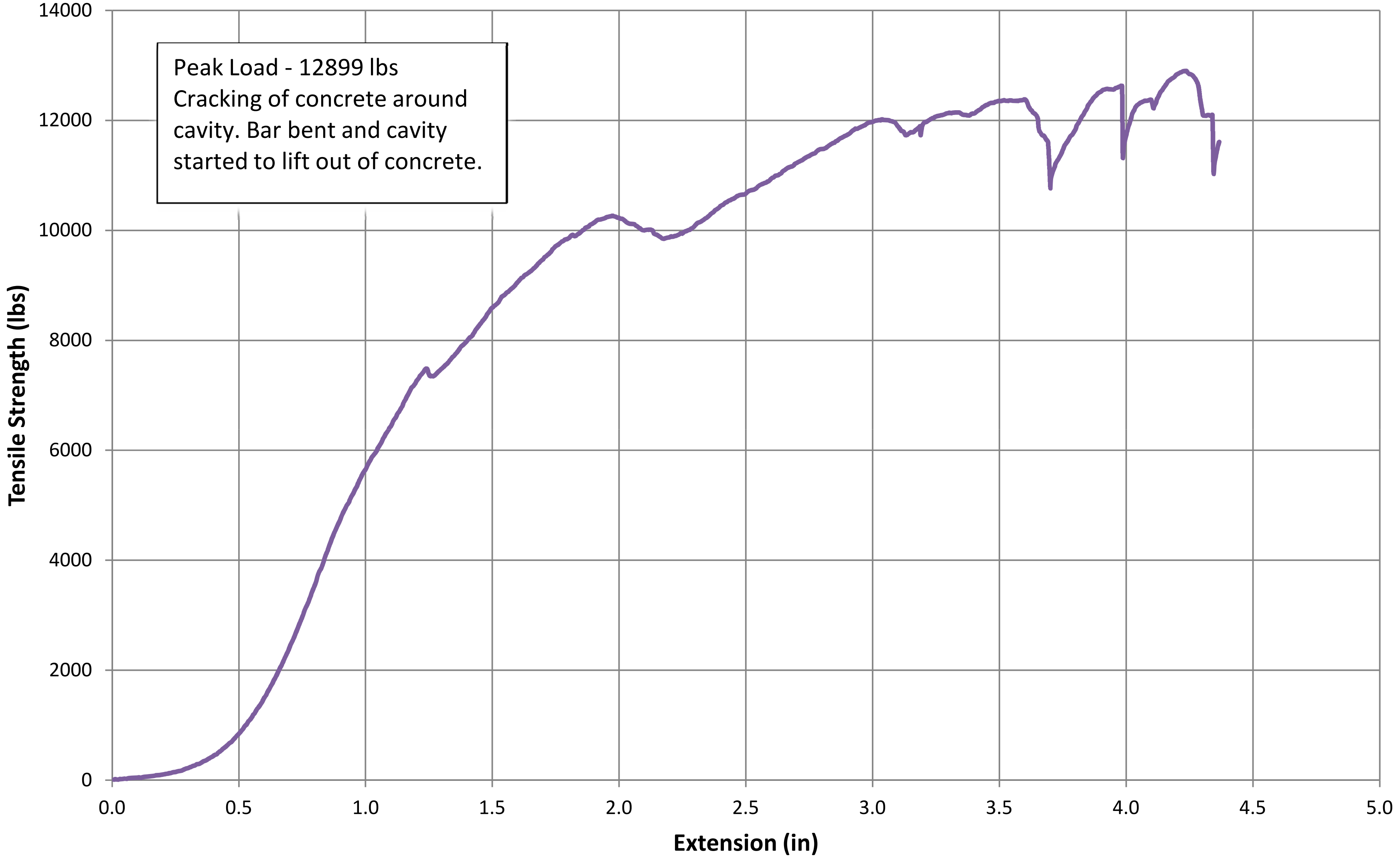


Peak Load - 14870 lbs
Cracking of concrete around cavity. Bar bent and cavity started to lift out of concrete

Tensile Test Results
TRI: Client: Maccaferri, Inc.
Product: Concrete Block with Steel Bar


Peak Load - 12978 lbs
Cracking of concrete around cavity. Bar bent and cavity started to lift out of concrete.

Tensile Test Results
TRI: Client: Maccaferri, Inc.
Product: Concrete Block with Steel Bar



Peak Load - 12899 lbs
Cracking of concrete around cavity. Bar bent and cavity started to lift out of concrete.

Addendum A1

TRI Client: Maccaferri, Inc.
TRI Log #: E2371-04-09

Steel Anchor Bar #5 (16 mm) ASTM A615 Grade 60

Concrete Block Dimensional Drawings

Casting Photographs

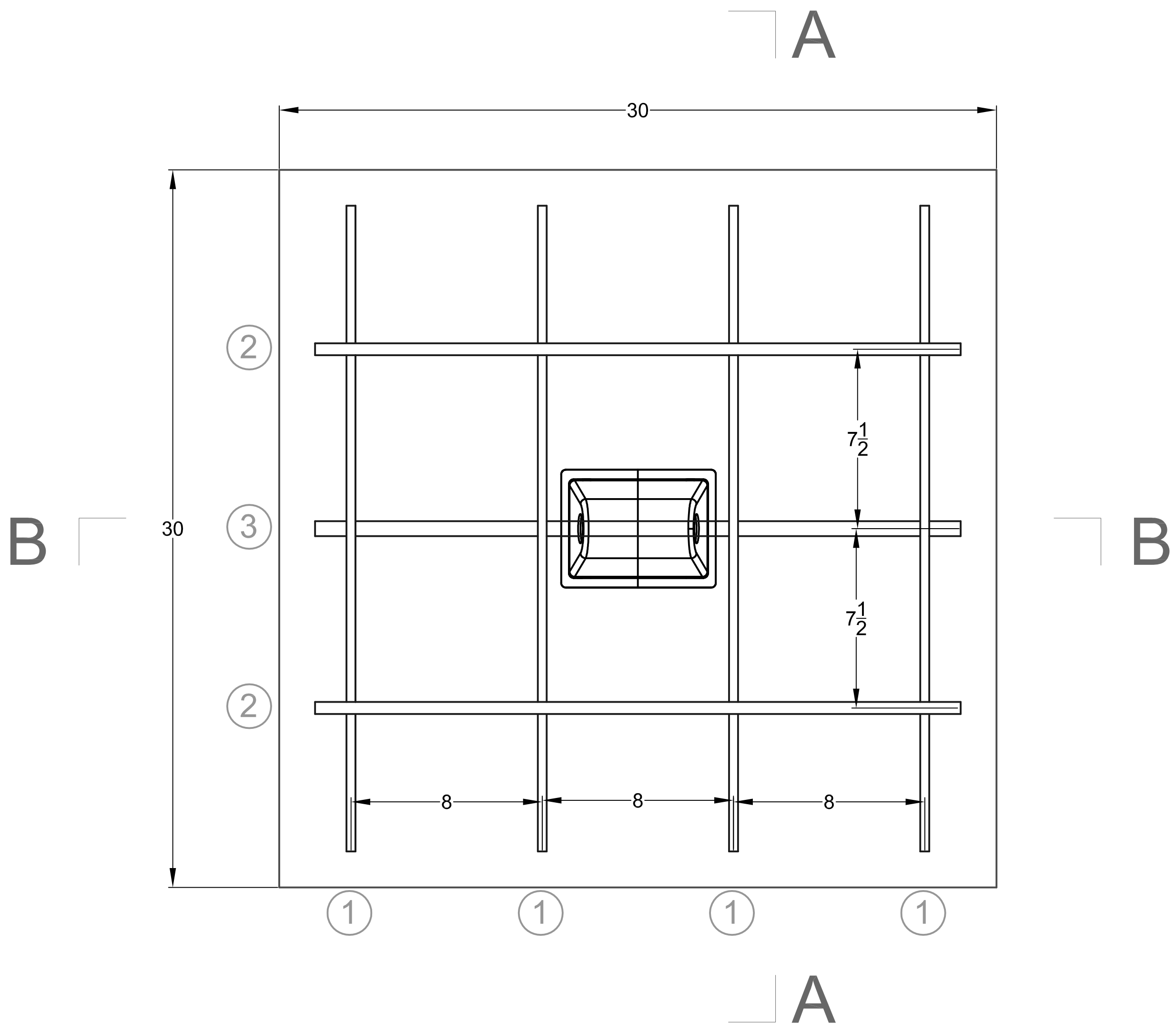
Class A4 Concrete Mix Designs

Addendum A1

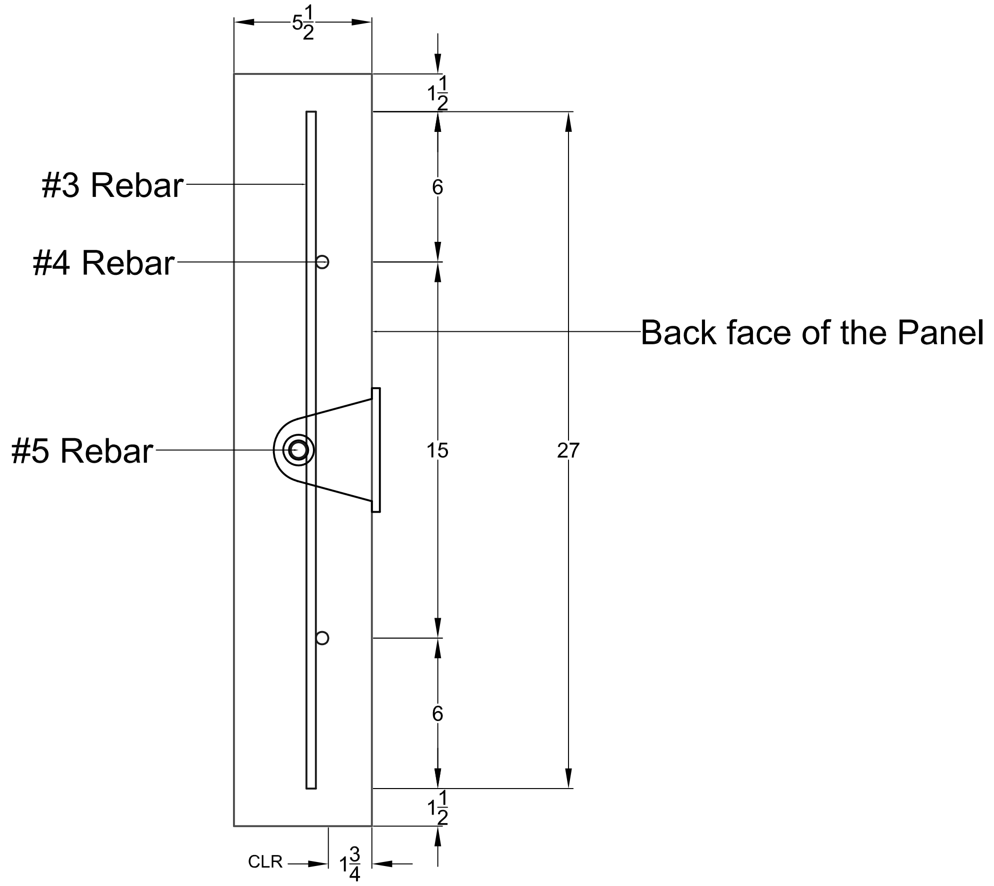
TRI Client: Maccaferri, Inc.
TRI Log #: E2371-04-09

Steel Anchor Bar #5 (16 mm) ASTM A615 Grade 60

Concrete Block Dimensional Drawings



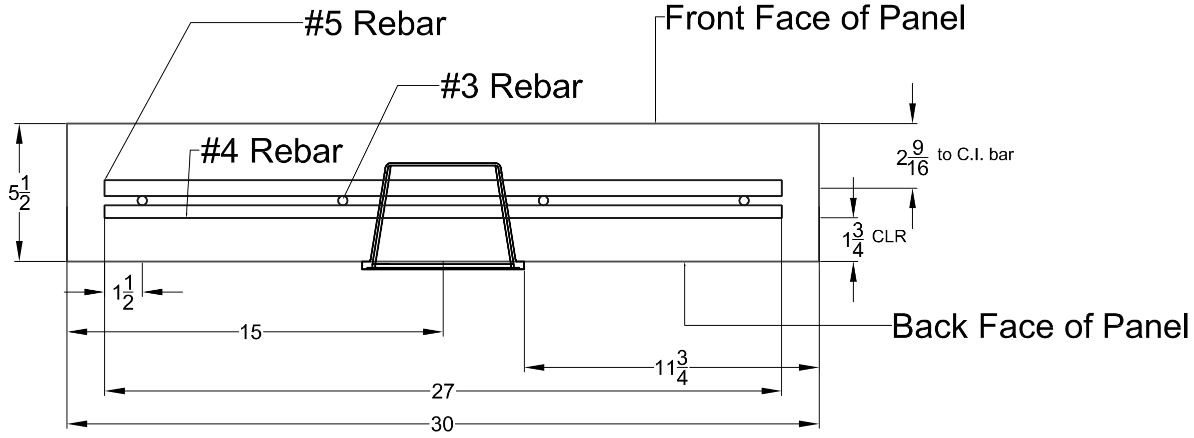
Section A-A



REINFORCEMENT SCHEDULE			
Ref.	Ø	Number	Length
①	# 3	4	27"
②	# 4	2	27"
③	# 5	1	27"

All lifting inserts to th back face (for handling)

Section B-B



Notes:

(1) Reinforcing steel shall conform to ASTM A615
Grade 60 (uncoated)

(2) Concrete compressive strength at 28 days,
fc'= 4000psi (max)

Maccaferri Inc. assumes no responsibility for the drawings and calculations it provides, as they must be intended as a general indication to suggest the proper use of its products.

Rev:	Issue / Revision:	Drawn:	App:	Date:

Drawing Title: Macres Samples
Steel Bars

Project No: #

Client: ####

Drawing No: 1 / #

Units: Inch

Scale: NTS

Rev: #

Printed on: 3/17/15

Designed: ## Date: ########

Drawn: ## Date: ########

Checked: ## Date: ########

Project: ####

NOT FOR CONSTRUCTION

MACCAFERRI

Maccaferri, Inc.
10303 Governor Lane Blvd.
Williamsport, MD 21795-3116 USA
Ph. (301) 223-6910 Fax (301) 223-6134

Addendum A1

TRI Client: Maccaferri, Inc.
TRI Log #: E2371-04-09

Steel Anchor Bar #5 (16 mm) ASTM A615 Grade 60

Casting Photographs

Addendum A1

TRI Client: Maccaferri, Inc.
TRI Log #: E2371-04-09

Steel Anchor Bar #5 (16 mm) ASTM A615 Grade 60

Class A4 Concrete Mix Designs

CEMEX

Main Office: 3990 E Concours St . #200 Ontario, California 91764
Phone (909) 974-5500 Fax (909) 974-5497 Dispatch 1-800-801-7625

STATEMENT OF MIX DESIGN FOR CONCRETE

Project: **Various Projects**
Various Locations

Date: 5/13/2014
Mix Design No.: 1418596

Contractor: **Surecast West**

Mix Description: **4000 PSI 1" Pump/Place Mix Design CLASS "1"**

Strength: 4000 PSI at 28 Days
Cementitious Material: 7.18 Sacks / Cu. Yd.
Penetration 2.0 Inches
Slump: 4.00 Inches
W/C Ratio: 0.44 By Weight

Batch Plants: Redlands
Aggregate Source: Cemex - Lytle Creek (91-36-0040)
Aggregate: CalTrans Section 90
Cement: ASTM C 150 - Type II Modified
Fly Ash: ASTM C 618 - Class F

ONE CUBIC YARD MIX PROPORTIONS, SSD:

MATERIAL		BATCH WEIGHT, LBS.	SP. GR.	ABS. VOL., CU. FT.
CEMENT	75 %	506	3.15	2.58
FLY ASH	25 %	169	2.30	1.18
WATER (TOTAL)	35.5 GALS.	296	1.00	4.74
AIR CONTENT	1 %	0		0.27
W. C. SAND	44 %	1318	2.62	8.06
# 4 - 3/8 IN. AGG.	0 %	0	2.62	0.00
# 3 - 1 IN. AGG.	56 %	1677	2.64	10.18
# 2 - 1.5 IN. AGG.	%	0	2.66	0.00
ADMIXTURE	15.1 to 25.3 fl. oz. of WRDA 64 (3 to 5/cwt cement) ASTM C 494 - Type A			
UNIT WEIGHT:	146.9 Lbs./Cu.Ft.	3965 Lbs.		27.00 Cu.Ft.

AGGREGATE GRADATIONS:

		Percent Passing U. S. Standard Sieves			Comb.	Caltrans
SIEVE SIZE	W C SAND	# 4 - 3/8 In.	# 3 - 1 In.	# 2 - 1.5 I	Grading	Limit
1.5 In.	100	100	100	98	100.0	100.0
1 In.	100	100	97	27	98.3	90-100
3/4 In.	100	100	73	6	84.9	55-100
3/8 In.	100	90	16	2	53.0	45-75
No. 4	97	15	4	0	44.9	35-60
No. 8	81	5	3	0	37.3	27-45
No. 16	61	4	0	0	26.8	20-35
No. 30	38	0	0	0	16.7	12-25
No. 50	18	0	0	0	7.9	5-15
No. 100	7	0	0	0	3.1	1-8
No. 200	3	0	0	0	1.3	0-4

X Values

WCSand
No. 16 X = 61
No. 30 X = 38
No. 50 X = 18

1" x No. 4
3/4" X = 73
3/8" X = 15

Respectfully submitted
Cemex

Randy Johnston

Technical Services

REGISTERED PROFESSIONAL ENGINEER
AN R. WADDELL
C041219
EXP 3-31-15
CIVIL
STATE OF CALIFORNIA

This mix design represents a combination of materials evaluated and established in accordance with section 1905B.3.1.1 Method B of the California Building Code. This mix is to be used only as designated, with no substitutions or additions. This mix to be used only for the job address indicated or as approved. FAILURE TO ADHERE TO ASTM STANDARDS IN SAMPLING, SLUMP, MAKING AND CURING SAMPLES, TRANSPORTING SAMPLES AND TESTING WILL RESULT IN A SUBSTANTIAL REDUCTION IN COMPRESSIVE STRENGTHS LISTED ABOVE. Notes: SOUTHWEST SPECIAL TESTING HAS NOT SEEN THE SOILS REPORT FOR THE PROJECT. CONTRACTOR MUST ADHERE TO THE GUIDELINES OF UBC TABLE 19.

Addendum A2

TRI Client: Maccaferri, Inc.
TRI Log #: E2371-04-09

Polymeric Anchor bar 20 mm

Polymeric Anchor Bar Technical Data Sheet

Concrete Block Dimensional Drawings

Casting Photographs

Class A4 Concrete Mix Designs

Addendum A2

TRI Client: Maccaferri, Inc.
TRI Log #: E2371-04-09

Polymeric Anchor bar 20 mm

Polymeric Anchor Bar Technical Data Sheet

MateenBar – Technical Submittal

Reference Standards and Reports

The references below should be referred to by the engineer regarding the application of Mateenbar for concrete reinforcement. Additional information is available from Pultron Composites for design assistance for specific applications.

References	Titles
ACI 318-95	"Building Code Requirements for Concrete" (1995) American Concrete Institute, Farmington Hills, MI, USA.
ACI 440.1 R-06	"Guide for the Design and Construction of Concrete Reinforced with FRP Bars" American Concrete Institute, Farmington Hills, MI, USA.
AASHTO GFRP - 1	"American Association of State Highway and Transport Officials" ISBN 978 – 1 – 56051-458-9

Mechanical Properties

The following table gives mechanical properties of MateenBar.

Property / Diameter	Unit	6	8	10	12	14	16	18	20	22	25	32	38[2]	Standard
MateenBar generation		GII	GII	GII			GII				GII	GII		
Root diameter	mm	5.2	7.2	9.2	11.0	13.2	15.2	17.2	19.2	21.0	24.2	30.6	36.7	
Outside diameter	mm	6.0	8.0	10.0	11.8	14.0	16.0	18.0	20.0	21.8	25.0	31.4	37.5	
Nominal area	mm2	21.2	40.7	66.5	95.0	136.8	181.5	232.4	289.5	346.4	460.0	735.4	1,057.8	
Tensile strength (average)	MPa	1100	1241	1350			1245				1220	1254		ACI 440.3R-04, ASTM D 7205
Tensile strength (Guaranteed)[1]	MPa	1000	1085	1240	750	750	1045	690	690	690	1025	1110	550	ACI 440.3R-04, ASTM D 7205
Ultimate tensile load (Average)	kN	23.3	53.4	92.0	86.0	122.5	234.0	203.8	251.6	303.9	570.0	935.0	837.8	
Tensile modulus of elasticity	GPa	57	57	60	53	53	58	51	51	51	58	56	49	ACI 440.3R-04, ASTM D 7205
Ultimate tensile strain (rupture)		0.019	0.022	0.021	0.014	0.014	0.018	0.014	0.014	0.014	0.018	0.020	0.011	ACI 440.6-08 8.4
Transverse shear strength	MPa	> 150	> 150	> 150	> 150	> 150	> 150	> 150	> 150	> 150	> 150	> 150	> 150	ACI 440.3R-04
Flexural strength	MPa	> 900	> 900	> 900	> 900	> 900	> 900	> 900	> 900	> 900	> 900	> 900	> 900	ASTM D790
Flexural modulus	GPa	> 53	> 53	> 53	> 53	> 53	> 53	> 53	> 53	> 53	> 53	> 53	> 53	ASTM D790
Compressive strength	MPa	> 400	> 400	> 400	> 400	> 400	> 400	> 400	> 400	> 400	> 400	> 400	> 400	ASTM D695
Short beam shear strength	MPa	> 50	> 50	> 50	> 50	> 50	> 50	> 50	> 50	> 50	> 50	> 50	> 50	ASTM D447
Bond strength at failure	MPa	16	16	16	16	16	16	16	16	16	16	16	16	ACI 440.3R-04
Barcol hardness		> 60	> 60	> 60	> 60	> 60	> 60	> 60	> 60	> 60	> 60	> 60	> 60	ASTM D2583
Glass transition temperature	ºC	> 110	> 110	> 110	> 110	> 110	> 110	> 110	> 110	> 110	> 110	> 110	> 110	ASTM E1640-4 (DMTA)
Thermal expansion coefficient transverse	/ ºC	22x10^{-6}	22x10^{-6}	22x10^{-6}	22x10^{-6}	22x10^{-6}	22x10^{-6}	22x10^{-6}	22x10^{-6}	22x10^{-6}	22x10^{-6}	22x10^{-6}	22x10^{-6}	ASTM D696
Thermal expansion coefficient longitudinal	/ ºC	7.2x10^{-6}	7.2x10^{-6}	7.2x10^{-6}	7.2x10^{-6}	7.2x10^{-6}	7.2x10^{-6}	7.2x10^{-6}	7.2x10^{-6}	7.2x10^{-6}	7.2x10^{-6}	7.2x10^{-6}	7.2x10^{-6}	ASTM D696
Volume resistivity	Ω.m	1.0x10^{9}	1.0x10^{9}	1.0x10^{9}	1.0x10^{9}	1.0x10^{9}	1.0x10^{9}	1.0x10^{9}	1.0x10^{9}	1.0x10^{9}	1.0x10^{9}	1.0x10^{9}	1.0x10^{9}	DIN 53 481
Dielectric strength	kV/m	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	ASTM D149
Moisture uptake (maximum)	%	< 0.1%	< 0.1%	< 0.1%	< 0.1%	< 0.1%	< 0.1%	< 0.1%	< 0.1%	< 0.1%	< 0.1%	< 0.1%	< 0.1%	ISO 62-1980 / ASTM D570
Specific gravity		2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	
Weight	kg/m	0.052	0.095	0.152	0.214	0.305	0.401	0.511	0.634	0.770	0.998	1.585	2.270	

[1] Guaranteed Ultimate Tensile Strength = Average – 3 Standard Deviations.

[2] The tensile properties of 38mm MateenBar cannot be guaranteed due to inability to achieve a valid bar as per the requirements of ASTM D7205 and ACI440.3R-04.

Design Requirements

Please refer to the appropriate design guide for your project or jurisdiction, e.g. ACI 440.1R “Guide for the Design and Construction of Concrete Reinforced with FRP Bars “for guidance on the use of GFRP Bars such as MateenBar.

Requirements
Do not substitute FRP reinforcing bars for steel or other supplier GFRP bars on an equal area basis, due to differences in material properties.
Design requirements on crack width, moment capacity and deflection with respect to material properties such as tensile strength, elastic modulus must be accounted for. Please consult with Pultron for structural design considerations.
In most cases, deflection will control design of concrete structures reinforced with FRP bars based on value of modulus of elasticity of FRP bars.
Stress under sustained load should be limited in accordance with the *ACI 440.1R Section 8.4 - Creep rupture and fatigue* recommendations for GFRP bars.
A minimum overlap length of 40 diameters is recommended.

Bends

MateenBar cannot be bent on site and must be fabricated into the required shape at the Pultron factory.

Due to the differences in GFRP manufacturing processes compared to steel rebar bends, there are limitations in the shape and sizes of bends available.

GFRP bends are significantly slower to fabricate than the steel rebar equivalent, please allow sufficient lead time in your schedule to avoid delays.

Please contact Pultron Composites to discuss your specific bends requirements and estimated lead times.

Durability

Property	**Value**	**Test Method**
Moisture Uptake	< 0.1%	ISO 62-1980 ASTM D 570
Resistance to alkaline environment	After 6 months (typical): • Tensile strength retention by 87% • Elastic modulus retained by 100% • Transverse shear strength retention by 92% • Short beam shear strength retention by 100% • Moisture absorption ≤ 0.4% • vi) Glass transition temperature retention by 100%	ACI 440.3R-4 B.6 pH: 12.6-13.0 at 60 ^{o}C

Manufacturing QC Testing Standards

MateenBar is a GFRP rebar manufactured from materials fully conforming to ACI 440-6 *Specification for Carbon and Glass Fiber-Reinforced Polymer Bar Materials for Concrete Reinforcement.*

MateenBar is manufactured from materials sourced on long term supply contracts with internationally approved suppliers. Raw materials purchased on the “spot market” are not used in MateenBar.

Quality Control requirements for raw materials:

Property	Value	Test Method / Comment
Resin Type ACI 440-6 6.2-Matrix Resins	Epoxy vinyl ester resin	Required for long term corrosion resistance and mechanical strength. *Polyester resin not allowed for permanent structures in accordance with ACI 440-6.*
Glass Type ACI 440-6 6.1-Fibers	ECR-glass	ECR Glass (ASTM D578) is essential due to long-term corrosion resistance and immunity to alkaline attack. *E-Glass not allowed*
Fillers ACI 440-6 6.3-Fillers and additives	Commercial Grade Inorganic Filler	Commercial grade inorganic fillers only used < 20% by mass.
Glass Content	> 75% by weight	ASTM D 3171

Manufacturing Quality Control Testing Standards:

A test certificate with every shipment shall be supplied which contains:

Test with every shipment	Test Method / Requirement
Incoming resin	Enthalpy of reaction and Glass transition temperature analysis by DSC prior processing Minimum of 1 per resin batch (may apply to more than one batch of dowel production)
Diameter	As measured from tolerance sheets at 2 hourly checks.
Glass fibre content ACI 440-6 7.1-Fibre Content	Fibre content > 55% by Volume Glass fibre content continuously monitored and manually confirmed every 2 hours
Short Beam Shear Strength (ASTM D 4475)	Average and standard deviation Derived from production tolerance sheets Short beam shear tests performed from each product stream every 2 hours
Glass transition temperature (ASTM E1640-04 DMTA Method) ACI 440-6 7.2-Glass Transition Temperature	Tg >= 100°C. Minimum of 1 test every 10,000 meters. For production runs of less than 10,000 meters, one test per batch is considered
Surface	That the surface is crack free, as per the two hourly tolerance sheet information

Handling and Storage Instructions

Instructions	Notes
Placement and Fastening	• Place Mateenbar in accordance to CRSI Placing Reinforcing Bars, unless otherwise specified. • Place Mateenbar accurately in accordance with approved placing drawings, schedules, typical details and notes. • Secure Mateenbar in formwork to prevent displacement by concrete placement or workers. • Fasten Mateenbar with nylon ties (preferable), coated or stainless steel tie wire.
Form Ties	• Use plastic or nylon form ties
Splicing	• Use lap splices
Tolerances	• Do not exceed placing tolerances as per ACI117
Cutting Mateenbar	• Mateenbar can be cut in the field with a standard handsaw or small grinder or cutoff saw. • For long blade life time use diamond blades.
Storage	• Mateenbar not used immediately should be kept on a pallet and covered with a tarp. • Mateenbar can be kept for an indefinite period of time without losing its performance.
Scrapes and cuts	• Nicks, scrapes, and cuts that do not exceed 5% of the depth of the bar are acceptable. • Beyond 5% we recommend replacement of the bar.
Handling	• It is recommended that gloves are worn when handling Mateenbar.
Comparison	• Mateenbar can be handled in the same way as steel equivalents in the field.
Chemical reaction	• With Mateenbar there is no concern regarding contact with salt, alkaline, diesel, gas, or other typical chemicals.

Warranty

Mateenbar is sold subject to Pultron Composite's standard warranty and nothing herein shall expand or extend such warranty.

Disclaimer

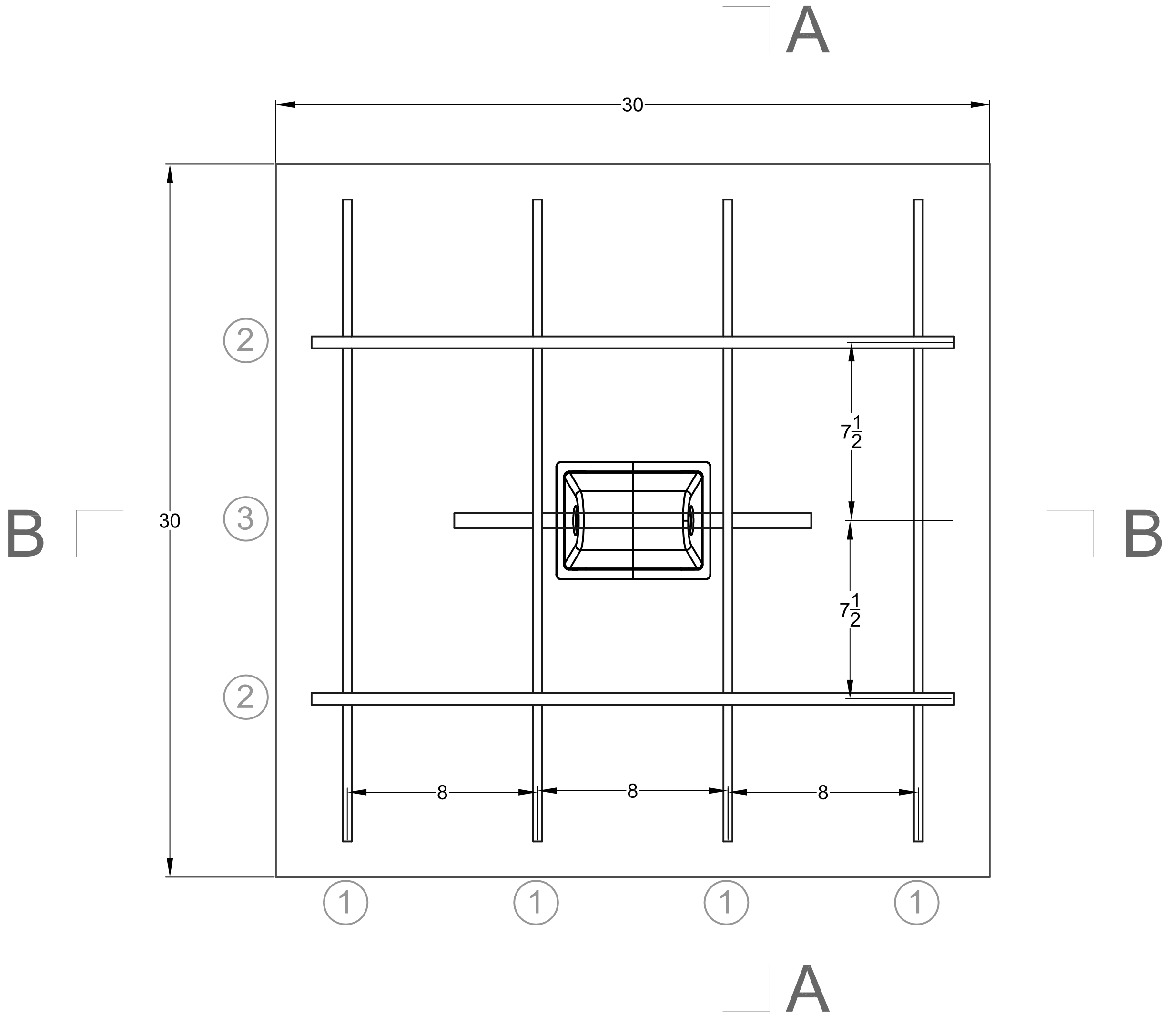
The data contained herein is considered representative of present production and believed to be reliable. Pultron Composites Limited reserves the right to make improvements in the product and process which may result in benefits and/or changes to some physical and mechanical properties.

Addendum A2

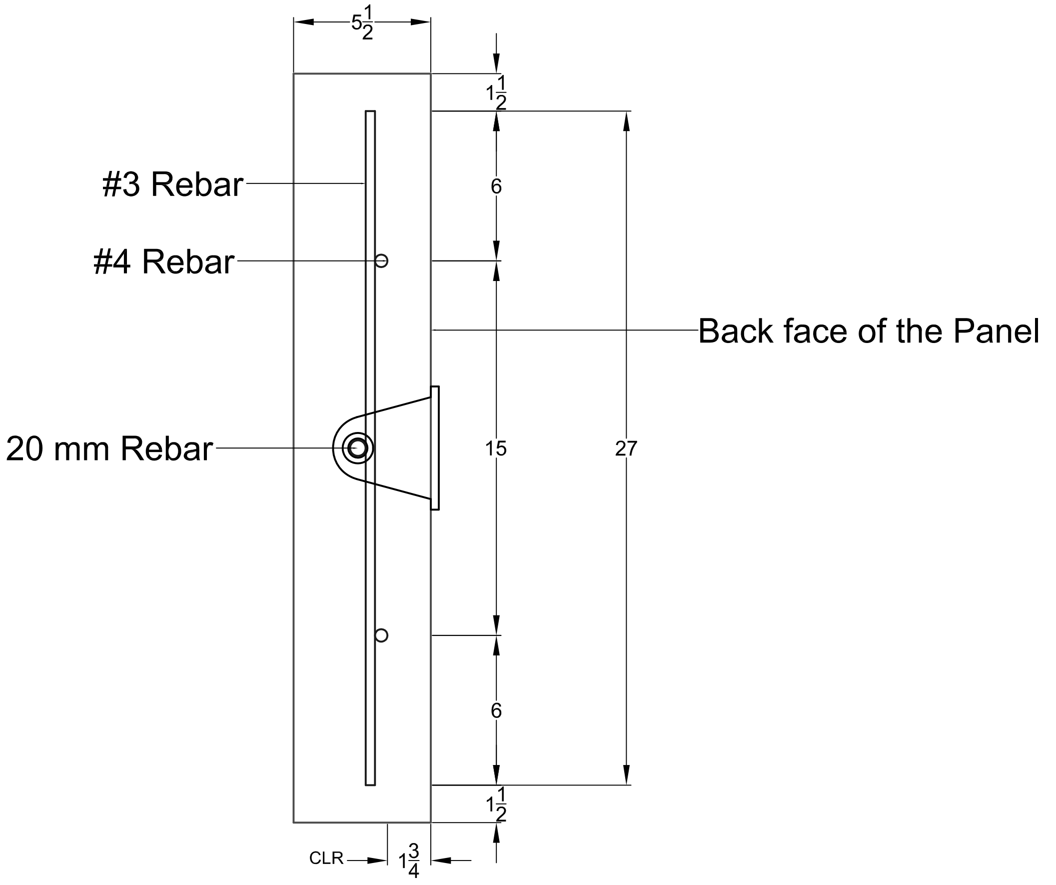
TRI Client: Maccaferri, Inc.
TRI Log #: E2371-04-09

Polymeric Anchor bar 20 mm

Concrete Block Dimensional Drawings



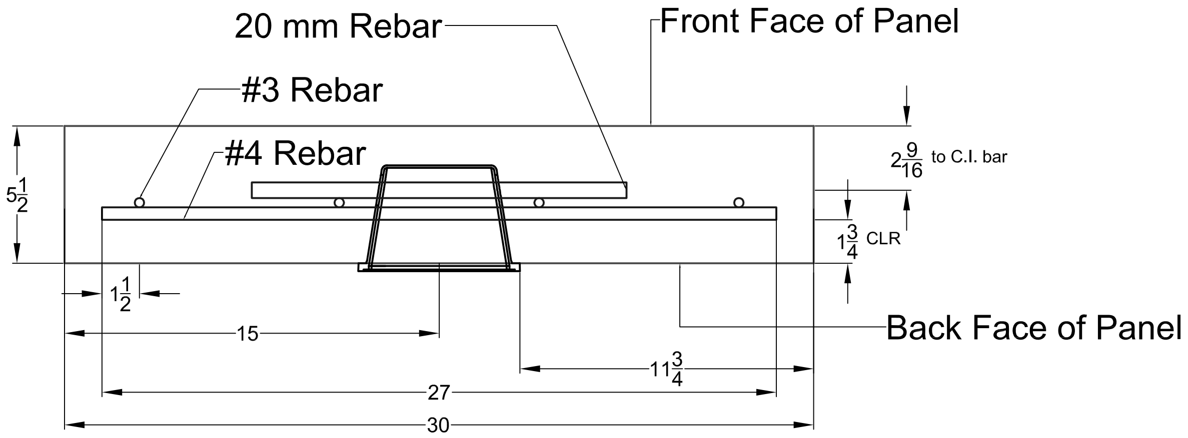
Section A-A



REINFORCEMENT SCHEDULE			
Ref.	Ø	Number	Length
①	# 3	4	27"
②	# 4	2	27"
③	20mm	1	15"

All lifting inserts to th back face (for handling)

Section B-B



Notes:

(1) Reinforcing steel shall conform to ASTM A615
Grade 60 (uncoated)

(2) 20 mm Polymeric bars is provided by
Maccaferri

(3) Concrete compressive strength at 28 days,
fc'= 4000psi (max)

Rev:	Issue / Revision:	Drawn:	App:	Date:

Drawing Title: Macres Samples
Polymeric and Steel Bars

Project No: #
Client: ####
Drawing No: 1 / #
Units: Inch
Scale: NTS
Rev: #
Printed on: 3/17/15

Designed: ## Date: ########
Drawn: ## Date: ########
Checked: ## Date: ########

Project: ####

NOT FOR CONSTRUCTION

MACCAFERRI

Maccaferri, Inc.
10303 Governor Lane Blvd.
Williamsport, MD 21795-3116 USA
Ph. (301) 223-6910 Fax (301) 223-6134

Addendum A2

TRI Client: Maccaferri, Inc.
TRI Log #: E2371-04-09

Polymeric Anchor bar 20 mm

Casting Photographs

Addendum A2

TRI Client: Maccaferri, Inc.
TRI Log #: E2371-04-09

Polymeric Anchor bar 20 mm

Class A4 Concrete Mix Designs

CEMEX

Main Office: 3990 E Concours St . #200 Ontario, California 91764
Phone (909) 974-5500 Fax (909) 974-5497 Dispatch 1-800-801-7625

STATEMENT OF MIX DESIGN FOR CONCRETE

Project: **Various Projects**
Various Locations

Date: 5/13/2014
Mix Design No.: 1418596

Contractor: **Surecast West**

Mix Description: **4000 PSI 1" Pump/Place Mix Design CLASS "1"**

Strength: 4000 PSI at 28 Days
Cementitious Material: 7.18 Sacks / Cu. Yd.
Penetration 2.0 Inches
Slump: 4.00 Inches
W/C Ratio: 0.44 By Weight

Batch Plants: Redlands
Aggregate Source: Cemex - Lytle Creek (91-36-0040)
Aggregate: CalTrans Section 90
Cement: ASTM C 150 - Type II Modified
Fly Ash: ASTM C 618 - Class F

ONE CUBIC YARD MIX PROPORTIONS, SSD:

MATERIAL		BATCH WEIGHT, LBS.	SP. GR.	ABS. VOL., CU. FT.
CEMENT	75 %	506	3.15	2.58
FLY ASH	25 %	169	2.30	1.18
WATER (TOTAL)	35.5 GALS.	296	1.00	4.74
AIR CONTENT	1 %	0		0.27
W. C. SAND	44 %	1318	2.62	8.06
# 4 - 3/8 IN. AGG.	0 %	0	2.62	0.00
# 3 - 1 IN. AGG.	56 %	1677	2.64	10.18
# 2 - 1.5 IN. AGG.	%	0	2.66	0.00
ADMIXTURE	15.1 to 25.3 fl. oz. of WRDA 64 (3 to 5/cwt cement) ASTM C 494 - Type A			
UNIT WEIGHT:	146.9 Lbs./Cu.Ft.	3965 Lbs.		27.00 Cu.Ft.

AGGREGATE GRADATIONS:

		Percent Passing U. S. Standard Sieves			Comb.	Caltrans
SIEVE SIZE	W C SAND	# 4 - 3/8 In.	# 3 - 1 In.	# 2 - 1.5 I	Grading	Limit
1.5 In.	100	100	100	98	100.0	100.0
1 In.	100	100	97	27	98.3	90-100
3/4 In.	100	100	73	6	84.9	55-100
3/8 In.	100	90	16	2	53.0	45-75
No. 4	97	15	4	0	44.9	35-60
No. 8	81	5	3	0	37.3	27-45
No. 16	61	4	0	0	26.8	20-35
No. 30	38	0	0	0	16.7	12-25
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No. 200	3	0	0	0	1.3	0-4

X Values

WCSand
No. 16 X = 61
No. 30 X = 38
No. 50 X = 18

1" x No. 4
3/4" X = 73
3/8" X = 15

Respectfully submitted
Cemex

Randy Johnston

Technical Services

C041219
EXP 3-31-15
CIVIL

This mix design represents a combination of materials evaluated and established in accordance with section 1905B.3.1.1 Method B of the California Building Code. This mix is to be used only as designated, with no substitutions or additions. This mix to be used only for the job address indicated or as approved. FAILURE TO ADHERE TO ASTM STANDARDS IN SAMPLING, SLUMP, MAKING AND CURING SAMPLES, TRANSPORTING SAMPLES AND TESTING WILL RESULT IN A SUBSTANTIAL REDUCTION IN COMPRESSIVE STRENGTHS LISTED ABOVE. Notes: SOUTHWEST SPECIAL TESTING HAS NOT SEEN THE SOILS REPORT FOR THE PROJECT. CONTRACTOR MUST ADHERE TO THE GUIDELINES OF UBC TABLE 19.

Addendum A3

TRI Client: Maccaferri, Inc.
TRI Log #: E2371-04-09

Concrete Break Strength Test Results

Concrete Laboratory Credentials

Addendum A3

TRI Client: Maccaferri, Inc.
TRI Log #: E2371-04-09

Concrete Break Strength Test Results

SURECAST WEST

PROJECT	Macre Test Samples	DATE	6/2/2015
LOCATION	SURECAST WEST	DAY	Tuesday

CONCRETE INFORMATION

CONC. SUPPLIER	CEMEX	BATCH TIME	9:22 AM	CONCRETE	TYPE II
LOAD NUMBER	4	CAST TIME	9:35 AM	MIX DESIGN	1418596
TICKET NUMBER	25890743	FINISH TIME	10:08 AM	USE	PANELS

TEST RESULTS

WEATHER	sunny	AIR CONTENT %	N/A	VOLUME cy	10.5
AMBIENT TEMP.	71	SLUMP "	4.25	UNIT WEIGHT lb	na
CONCRETE TEMP.	80	KELLY BALL	na	CYLINDERS	5

COMPRESSION TEST RESULTS

CYLINDER MARK	DIA. "in"	DATE TESTED	AGE DAYS	MAX LOAD (LBS.)	COMPRESSIVE STRENGTH psi	MPa	TESTED BY	na	COMMENTS
A	6.0	6-12-15	10	97,590	3580	-	AJS		
B	6.0	6-12-15	10	102,340	3620	-	AJS		
C									
D									
				AVG.	3600				

BREAK TYPES TYPE 1 TYPE 2 TYPE 3 TYPE 4 TYPE 5

PRODUCT PRODUCED

MSE PANELS

6-12-15

DATE OF REPORT

TECHNICIAN SIGNATURE

SURECAST WEST

PROJECT	Macre Test Samples	DATE	6/2/2015
LOCATION	SURECAST WEST	DAY	Tuesday

CONCRETE INFORMATION					
CONC. SUPPLIER	CEMEX	BATCH TIME	9:22 AM	CONCRETE	TYPE II
LOAD NUMBER	4	CAST TIME	9:35 AM	MIX DESIGN	1418596
TICKET NUMBER	25890743	FINISH TIME	10:08 AM	USE	PANELS

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AMBIENT TEMP.	71	SLUMP "	4.25	UNIT WEIGHT lb	*na*
CONCRETE TEMP.	80	KELLY BALL	na	CYLINDERS	5

COMPRESSION TEST RESULTS

CYLINDER MARK	DIA. "in"	DATE TESTED	AGE DAYS	MAX LOAD (LBS.)	COMPRESSIVE STRENGTH psi	MPa	TESTED BY	na	COMMENTS
A	6.0	6-15-15	13	116,550	4120	-	AJS		
B	6.0	6-15-15	13	115,670	4090	-	AJS		
C									
D									
				AVG. -	4105				

BREAK TYPES [✓ TYPE 1] TYPE 2 TYPE 3 TYPE 4 TYPE 5

PRODUCT PRODUCED
MSE PANELS

6-15-15
DATE OF REPORT

TECHNICIAN SIGNATURE

Addendum A3

TRI Client: Maccaferri, Inc.

TRI Log #: E2371-04-09

Concrete Laboratory Credentials

hereby Certifies that

Andrew J. Soria

has met the prescribed requirements for

Quality Control
Personnel Certification
Level III

PCI™
Certified Level III
Technician/Inspector

Issued Date: October 28, 2010

Expiration Date: 10/5/2015

Certification No.: 11484

James Toscas, President

STATE OF CALIFORNIA - BUSINESS, TRANSPORTATION AND HOUSING AGENCY EDMUND G. BROWN Jr., Governor

DEPARTMENT OF TRANSPORTATION
Southern Regional Independent Assurance
13970 Victoria St.
Fontana, CA 92336

CALTRANS QUALIFIED LABORATORY INSPECTION REPORT

Form TL-0113 (Southern IA, 01-06)

Expiration date: March 12, 2016
Inspection by: Daniel Stewart
IA No.: 111
Phone: (909) 350-9096
File: Materials Category 500

Laboratory: Surecast West
Address: 8203 Alabama Street
City: Highland State: CA Zip: 92346
Lab Manager: Andrew Soria e-mail: Rustysurecast@hughes.net
Phone #: (909) 335-6336 Fax #: (909) 335-6331

A certified Independent Assurance (IA) Sampler and Tester visited this laboratory on February 27, 2014. Only equipment to be used on Caltrans construction projects and/or local construction projects on the National Highway System projects was checked for qualification.

At the time of Caltrans Qualification, this laboratory had all necessary equipment to perform the tests methods indicated below. Testing personnel shall be Caltrans Qualified and possess a current Caltrans Certificate of Proficiency Form TL-0111 prior to performing any sampling or testing.

CT 504 CT 518 CT 521 CT 539 CT 540 CT 556 CT 557

A visual check was performed and documents provided as necessary for the following items:

☒ Facility Safety Manual
☒ Laboratory Procedures Manual
☒ Laboratory Quality Control Manual
☒ Proper Test Equipment
☒ Copies of current applicable test procedures
☒ Calibration and Service Documentation
☒ Calibration/Service stickers affixed to test equipment

Laboratory Qualification is valid for one year

On March 3, 2015 this laboratory was qualified by:

Daniel Stewart
Southern Regional
Independent Assurance

Project Number: 2020.548.001

DESIGN COMPUTATIONS FOR

Stone Strong MacBox Connection

PREPARED FOR:

Stone Strong Systems
13460 Chandler Road
Suite 100
Omaha, Nebraska 68138

PREPARED BY:

DELTA
SPECIALTY PRECAST CONCRETE ENGINEERS

State License # 111870

860 Hooper Road, Endwell, New York 13760
TEL: 607-231-6600 FAX: 607-231-6650
EMAIL: precast@delta-eas.com
www.delta-eas.com

STATE OF NEW YORK
DARYL D. BURNS
082899
LICENSED PROFESSIONAL ENGINEER

10-19-2020

JOB	2020.548.001		
DESCRIPTION	Macbox Insert Connection		
SHEET NO.	OF	SCALE	
CALCULATED BY	YL	DATE	10/18/2020
CHECKED BY		DATE	

Table of Contents

DELTA
SPECIALTY PRECAST CONCRETE ENGINEERS
860 Hooper Road, Endwell, NY 13760
www.delta-eas.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB 2020.548.001
DESCRIPTION Macbox Connection
SHEET NO. OF SCALE
CALCULATED BY YL DATE 10/19/2020
CHECKED BY DATE

Estimated Macbox Connection Capacity

Reduction Factor ϕ = 0.6 ACI 318-14 17.3.3

Note: 0.6 instead of 0.7 is used to account for uncertainties, conservative.

Unit	Ultimate Capacity (kips)	**Recommended Capacity (kips)**
24SF-P	14.00	**8.40**
24SF-HDP	17.04	**10.22**
6SF-P	14.00	**8.40**
6SF-HDP	17.06	**10.24**
6-28-P	14.00	**8.40**
6-28-HDP	17.06	**10.24**

Note: recommended capacitys are for factored loads.

JOB 2020.548.001
DESCRIPTION Macbox Insert Connection
SHEET NO. OF SCALE
CALCULATED BY YL DATE 10/18/2020
CHECKED BY DATE

Macbox Insert Capacity Based on Anchor Embedment Theory

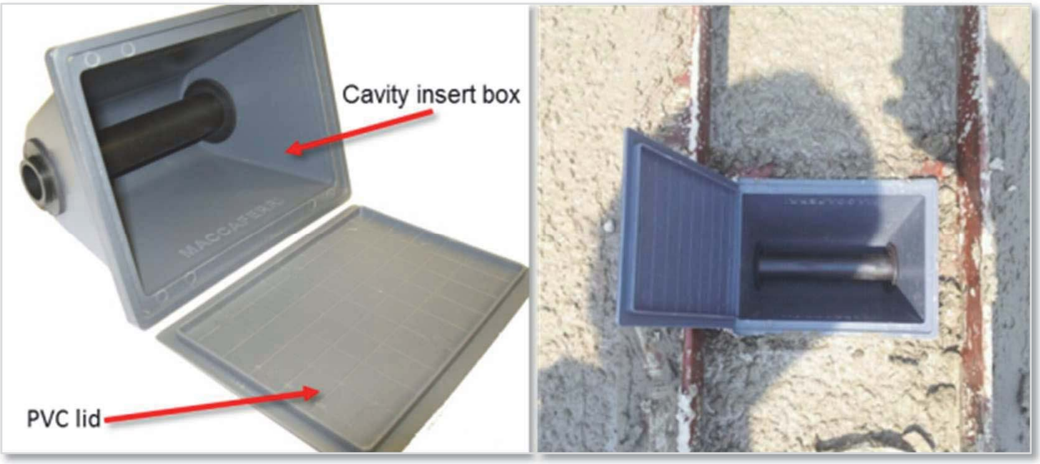
Maccaferri MacBox Connecting System

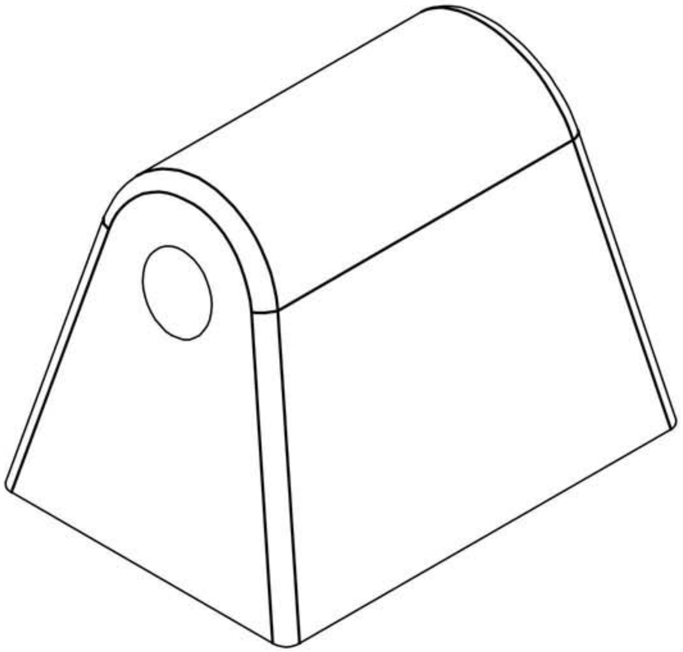
Polymeric Cavity Connection Assembly

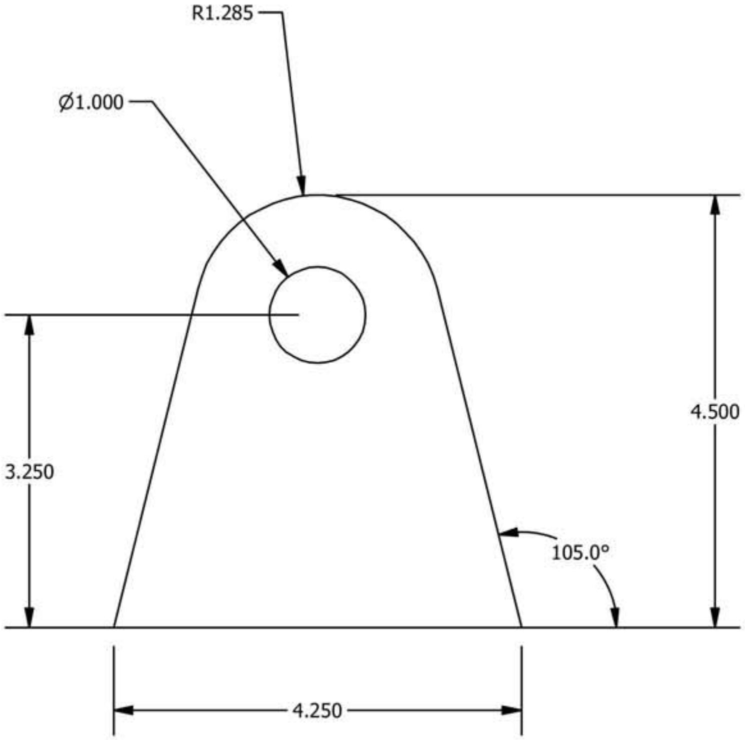
The Maccaferri connection assembly is composed of a (High Density Polyethylene (HDPE) cavity insert box secured by a steel rebar (anchor bar) in the precast concrete element. The steel embedded rebar is encased in a polymeric sleeve for corrosion protection. The sleeve prevents water and concrete for entering during the casting phase and prevents damage to

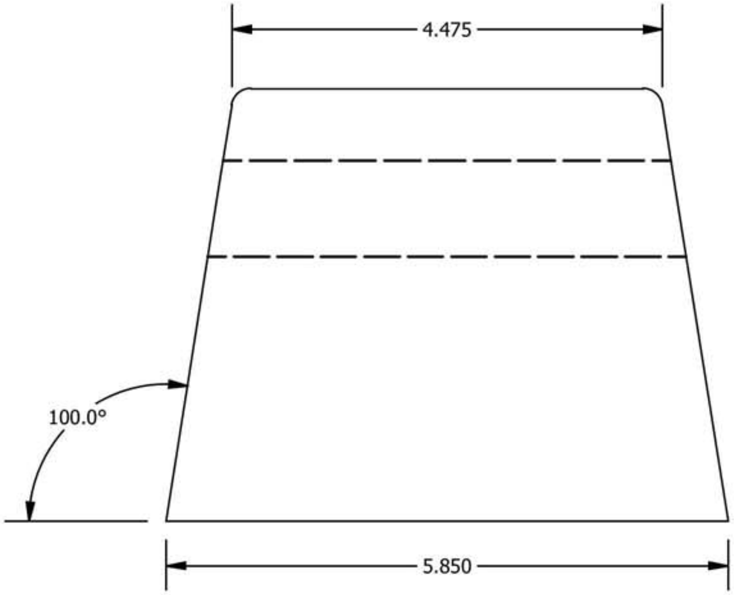
the polymeric soil reinforcing strips in contact with the deformed rebar.

The connection system is supplied with a HDPE lid, which is closed during the casting phase to prevent the wet concrete from entering the cavity insert box.





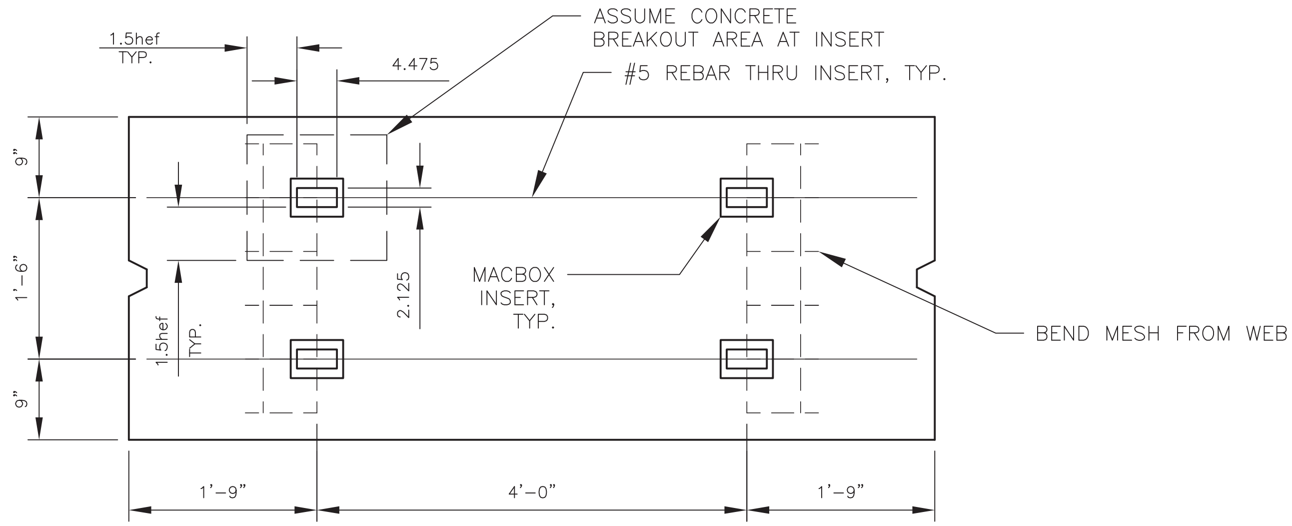




MATERIAL: A36 PLATE	DATE: 12/6/2017	REV : A	DRAWN BY: D. HOWARD	APPROVED BY: S. EVANS
PROPRIETARY AND CONFIDENTIAL THE INFORMATION CONTAINED IN THIS DRAWING ID THE SOLE PROPERTY OF TLK PRECISION. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PROMISSION OF TLK PRECISION IS PROHIBITED	UNLESS OTHERWISE NOTED .X : ± .020 .XX : ± .010 .XXX : ± .005		TITLE : STRAP RECESS PART NUMBER : STRAP RECESS	

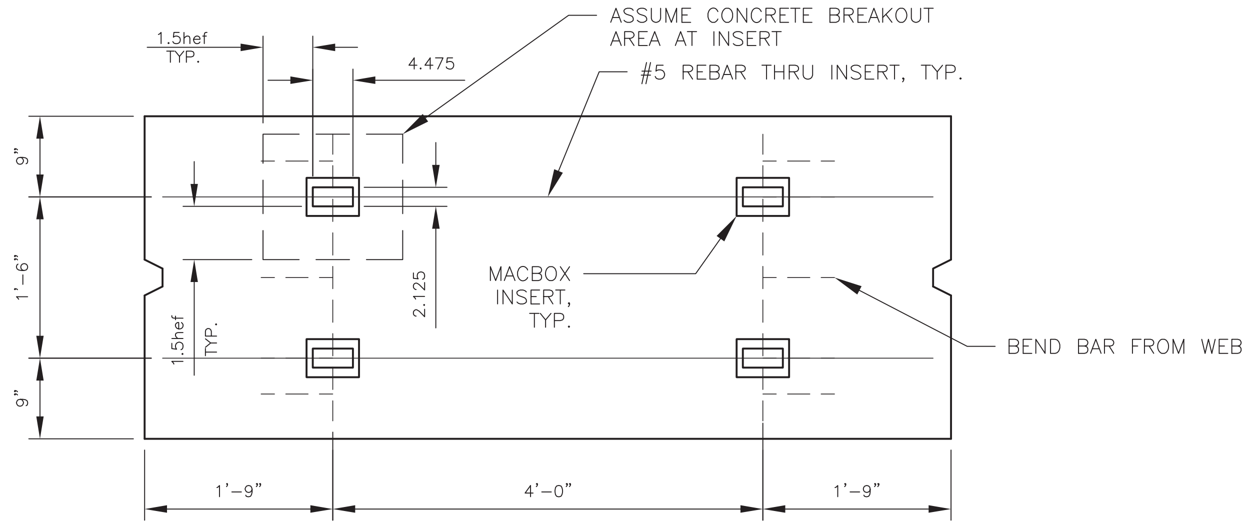
CREATED FROM DRAWING :
NA

TLK PRECISION



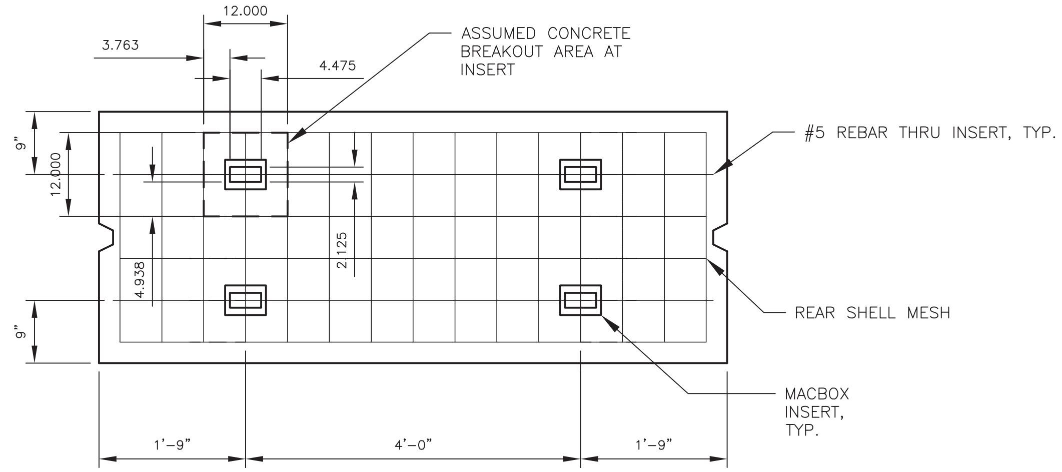
REAR SHELL ELEVATION VIEW

24SF PARAWEB UNIT (24SF-P) - MESH OPTION



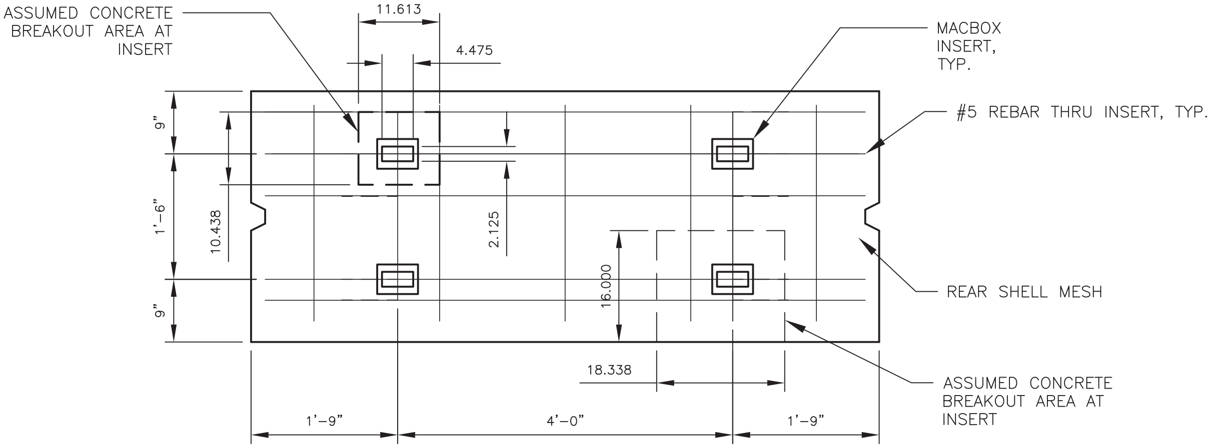
REAR SHELL ELEVATION VIEW

24SF PARAWEB UNIT (24SF-P) - REBAR OPTION



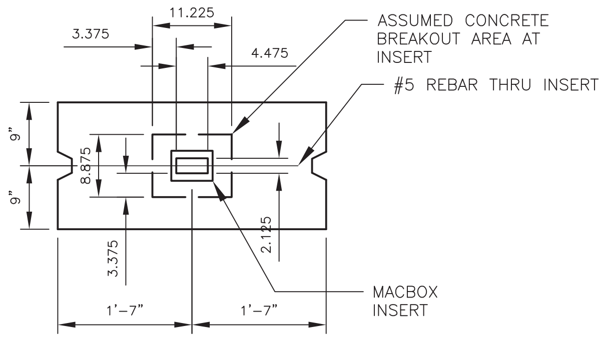
REAR SHELL ELEVATION VIEW

24SF HEAVY DUTY PARAWEB UNIT (24SF-HDP) – MESH OPTION



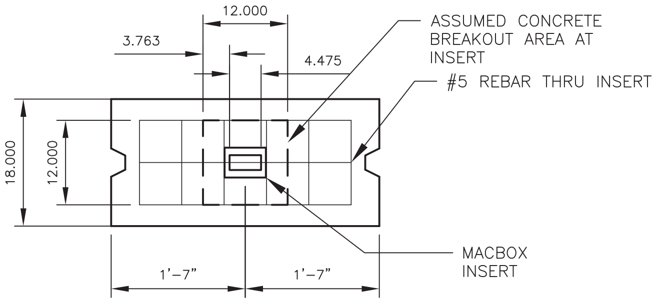
REAR SHELL ELEVATION VIEW

24SF HEAVY DUTY PARAWEB UNIT (24SF-HDP) – REBAR OPTION



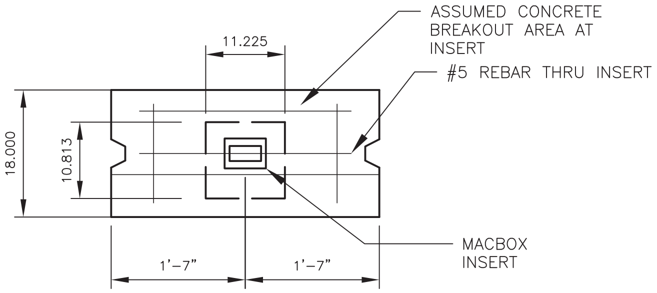
REAR SHELL ELEVATION VIEW

6SF PARAWEB UNIT (6SF-P)



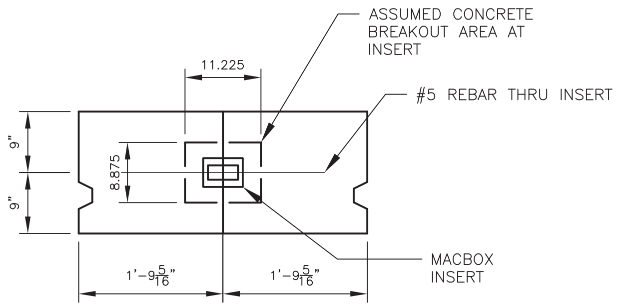
REAR SHELL ELEVATION VIEW

6SF HEAVY DUTY PARAWEB UNIT (6SF-HDP) – MESH OPTION



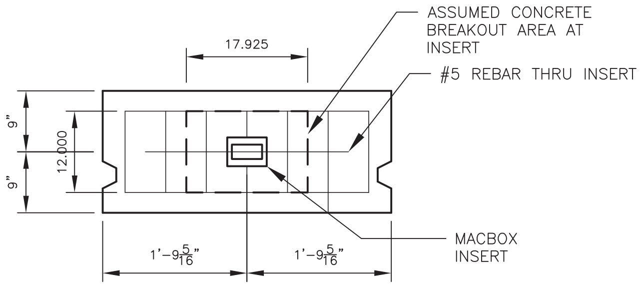
REAR SHELL ELEVATION VIEW

6SF HEAVY DUTY PARAWEB UNIT (6SF-HDP) – REBAR OPTION



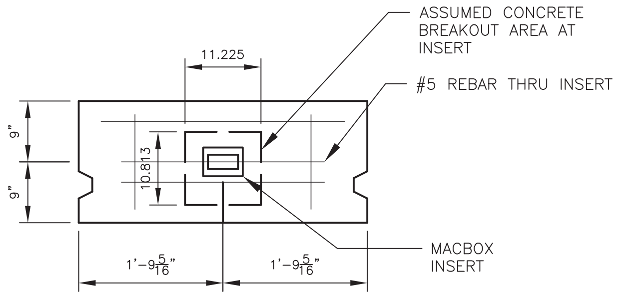
REAR SHELL ELEVATION VIEW

6-28 PARAWEB UNIT (6-28-P)



REAR SHELL ELEVATION VIEW

6-28 HEAVY DUTY PARAWEB UNIT (6-28-HDP) - MESH OPTION



REAR SHELL ELEVATION VIEW

6-28 HEAVY DUTY PARAWEB UNIT (6-28-HDP) - REBAR OPTION

JOB 2020.548.001

DESCRIPTION Macbox Connection

SHEET NO. OF SCALE

CALCULATED BY YL DATE 10/14/2020

CHECKED BY DATE

Use Concrete Tension Breakout Strength to Estimate the Connection Capacity ACI 318-14 17.4.2

$N_{cb} = A_{Nc}/A_{Nco}\ \psi_{ed,N}\psi_{c,N}\psi_{cp,N}\ N_b$ Eqn. 17.4.2.1a

$N_b = k_c\lambda_a f_c'^{\wedge}0.5 h_{ef}^{1.5} =$ 5.12 kips

$h_{ef} =$ 2.25 in

$A_{Nco} = 9h_{ef}^2 =$ 45.563 in^2

$\lambda_a =$ 1

$k_c =$ 24

$f_c' =$ 4000 psi

$\psi_{ed,N} =$ 1.0 17.4.2.5

$\psi_{c,N} =$ 1.25 17.4.2.6

$\psi_{cp,N} =$ 1.00 17.4.2.7

24SF Paraweb Unit (24SF-P) Mesh Option and Rebar Option

Assume Conc. Break Area Length = 11.23 in

$N_{cb} =$ 14.00 kips

Assume Conc. Break Area Width = 8.88 in

$A_{NC} =$ 99.622 in^2

24SF Heavy Duty Paraweb Unit (24SF-HDP) Mesh Option

Assume Conc. Break Area Length = 12.00 in

$N_{cb} =$ 20.24 kips

Assume Conc. Break Area Width = 12.00 in

$A_{NC} =$ 144 in^2

24SF Heavy Duty Paraweb Unit (24SF-HDP) Rebar Option

Assume Conc. Break Area Length = 11.61 in

$N_{cb} =$ 17.04 kips

Assume Conc. Break Area Width = 10.44 in

$A_{NC} =$ 121.22 in^2

6SF Paraweb Unit (6SF-P)

Assume Conc. Break Area Length = 11.23 in

$N_{cb} =$ 14.00 kips

Assume Conc. Break Area Width = 8.88 in

$A_{NC} =$ 99.622 in^2

Use Concrete Tension Breakout Strength to Estimate the Connection Capacity (Con't)

6SF Heavy Duty Paraweb Unit (6SF-HDP) Mesh Option

Assume Conc. Break Area Length = 12.00 in

Ncb = 20.24 kips Assume Conc. Break Area Width = 12.00 in

A_{NC} = 144 in^2

6SF Heavy Duty Paraweb Unit (6SF-HDP) Rebar Option

Assume Conc. Break Area Length = 11.23 in

Ncb = 17.06 kips Assume Conc. Break Area Width = 10.81 in

A_{NC} = 121.38 in^2

6-28 Paraweb Unit (6-28-P)

Assume Conc. Break Area Length = 11.23 in

Ncb = 14.00 kips Assume Conc. Break Area Width = 8.88 in

A_{NC} = 99.622 in^2

6-28 Heavy Duty Paraweb Unit (6-28-HDP) Mesh Option

Assume Conc. Break Area Length = 17.93 in

Ncb = 30.23 kips Assume Conc. Break Area Width = 12.00 in

A_{NC} = 215.1 in^2

6-28 Heavy Duty Paraweb Unit (6-28-HDP) Rebar Option

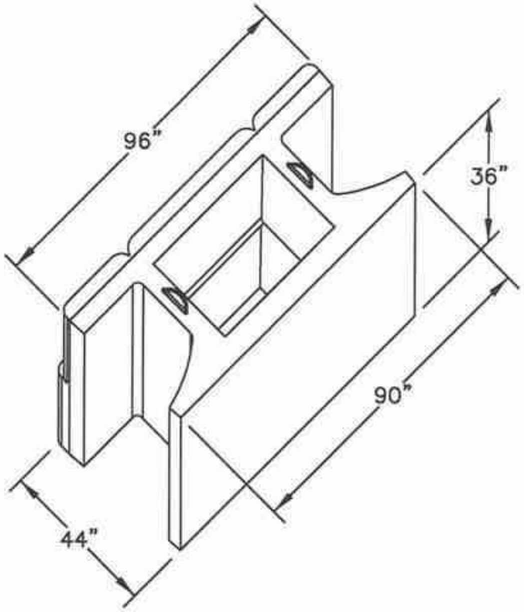
Assume Conc. Break Area Length = 11.23 in

Ncb = 17.06 kips Assume Conc. Break Area Width = 10.81 in

A_{NC} = 121.38 in^2

JOB 2020.548.001
DESCRIPTION Macbox Insert Connection
SHEET NO. OF SCALE
CALCULATED BY YL DATE 10/18/2020
CHECKED BY DATE

24SF-P and 24SF-HDP Units Risa Analysis



REAR VIEW
STONE STRONG 24SF UNIT

NOT TO SCALE

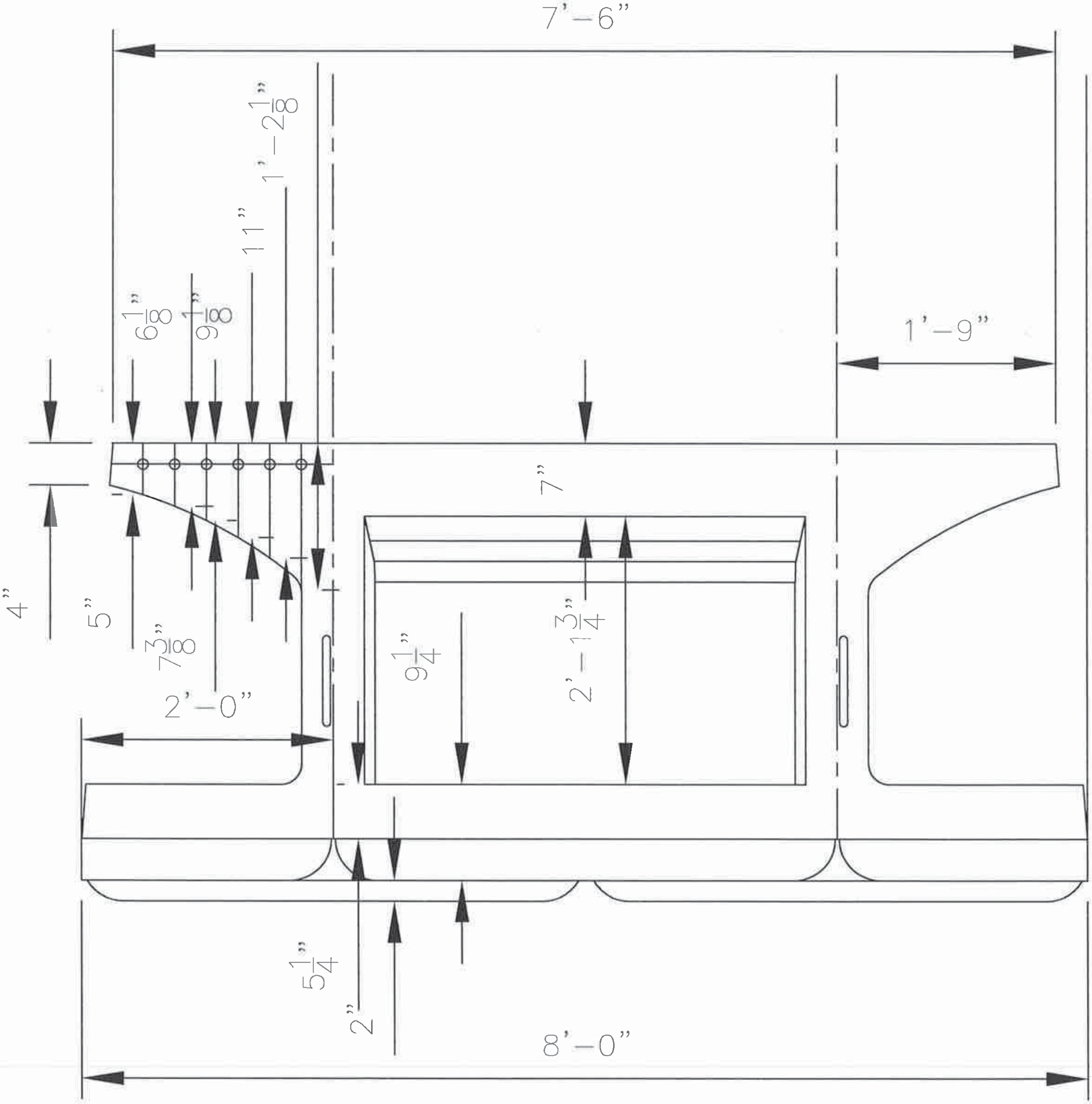
STONE STRONG
SYSTEMS®

www.stonestrong.com

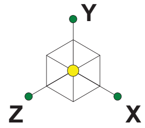
PROJECT

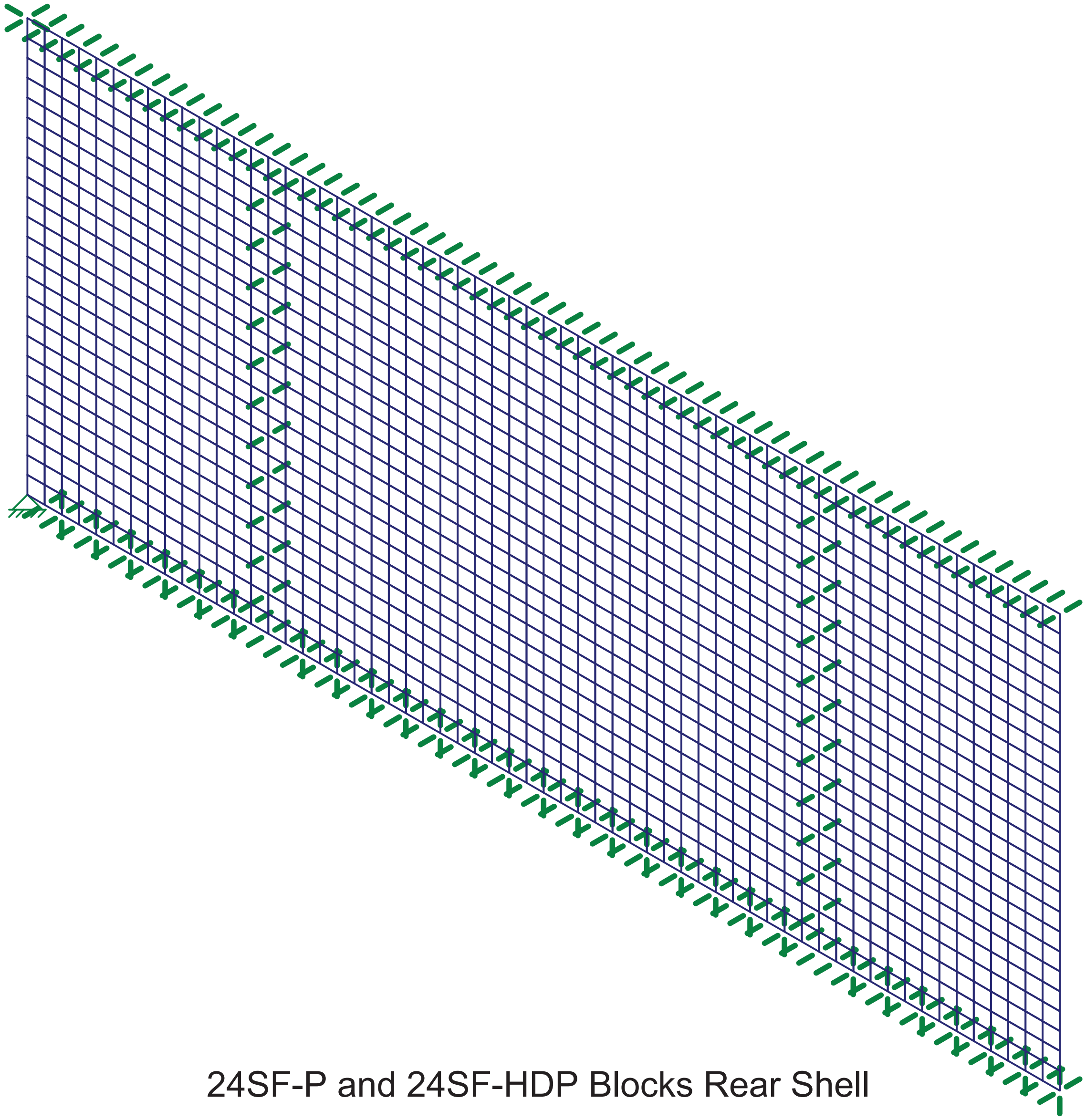
COMPONENTS
STONE STRONG SYSTEMS

DATE: 2/10/16
FILE: 05_Block.24sf.Rear


7'–6"
1'–2$\frac{1}{8}$"
11"
6$\frac{1}{8}$"
9$\frac{1}{8}$"
1'–9"
4"
5"
7$\frac{3}{8}$"
7"
9$\frac{1}{4}$"
2'–1$\frac{3}{4}$"
2'–0"
5$\frac{1}{4}$"
2"
8'–0"

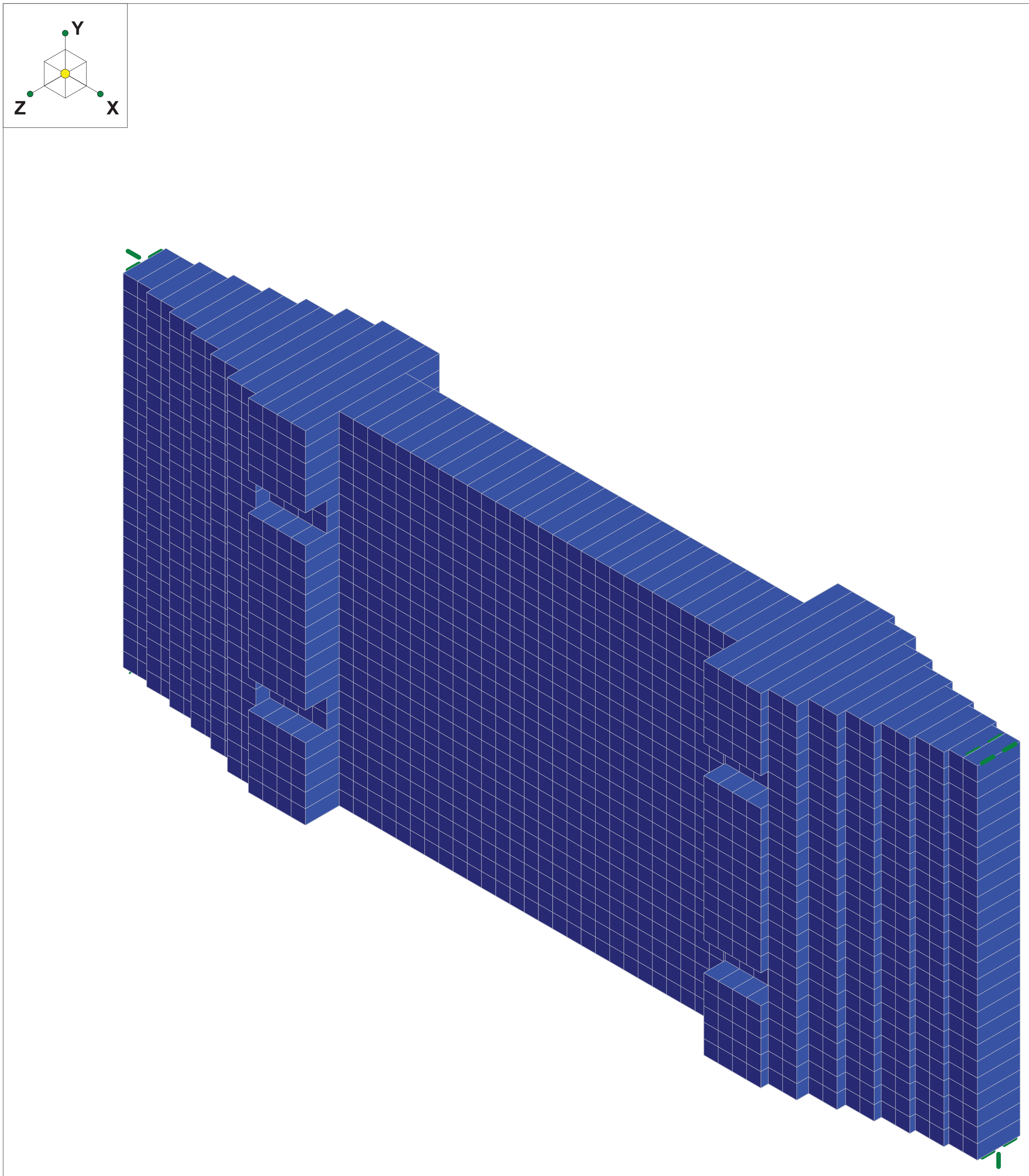
24 SF UNIT



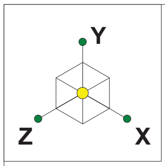


24SF-P and 24SF-HDP Blocks Rear Shell

Delta Engineers,Inc	24SF-P and 24SF-HDP	SK - 1
YL		Oct 14, 2020 at 8:36 PM
2020.548.001		24SF-P and 24SF-HDP.r3d



Delta Engineers,Inc	24SF-P and 24SF-HDP	SK - 2
YL		Oct 14, 2020 at 8:37 PM
2020.548.001		24SF-P and 24SF-HDP.r3d



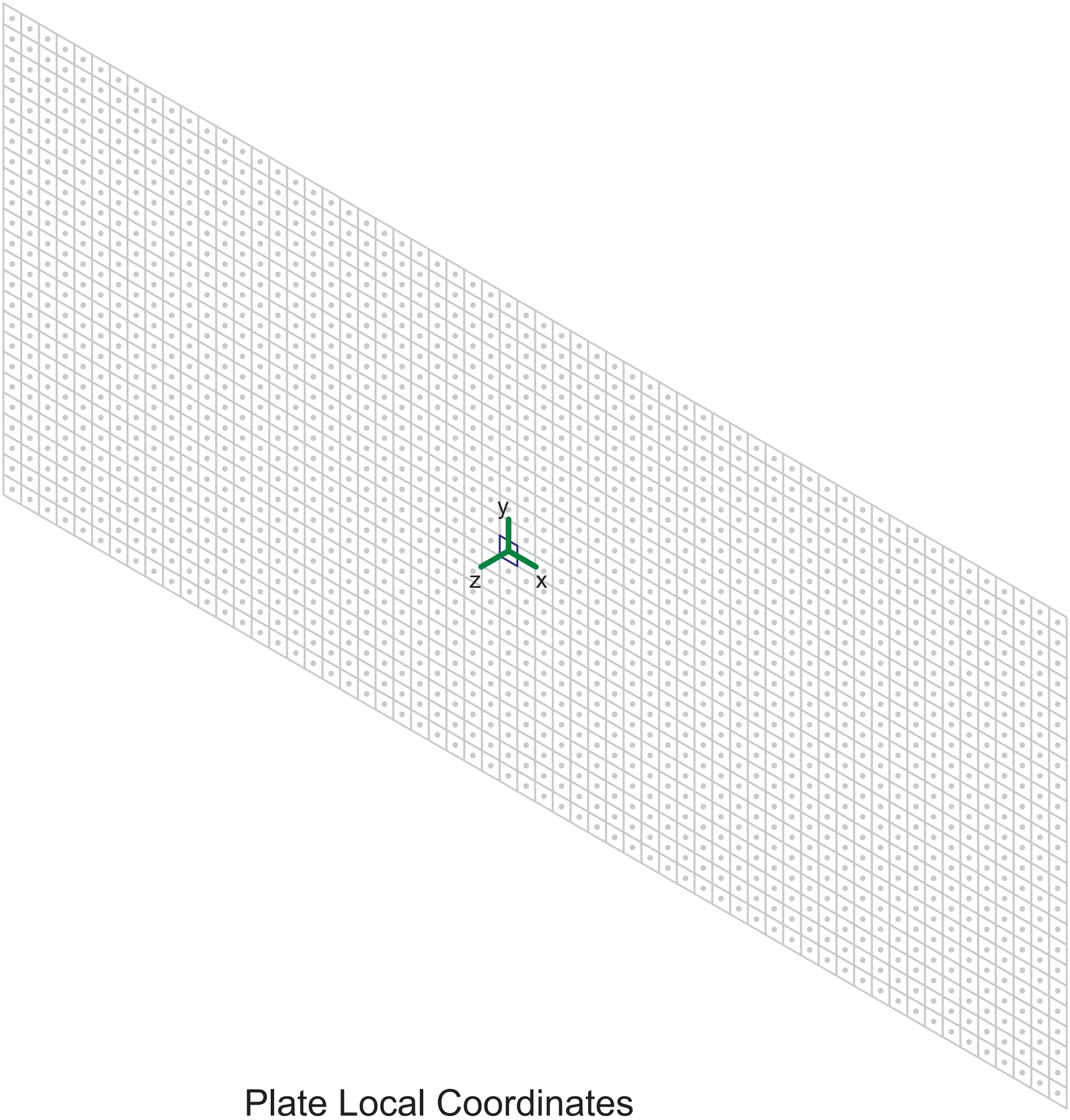
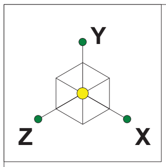


Plate Local Coordinates

Delta Engineers,Inc	24SF-P and 24SF-HDP	SK - 3
YL		Oct 14, 2020 at 8:38 PM
2020.548.001		24SF-P and 24SF-HDP.r3d



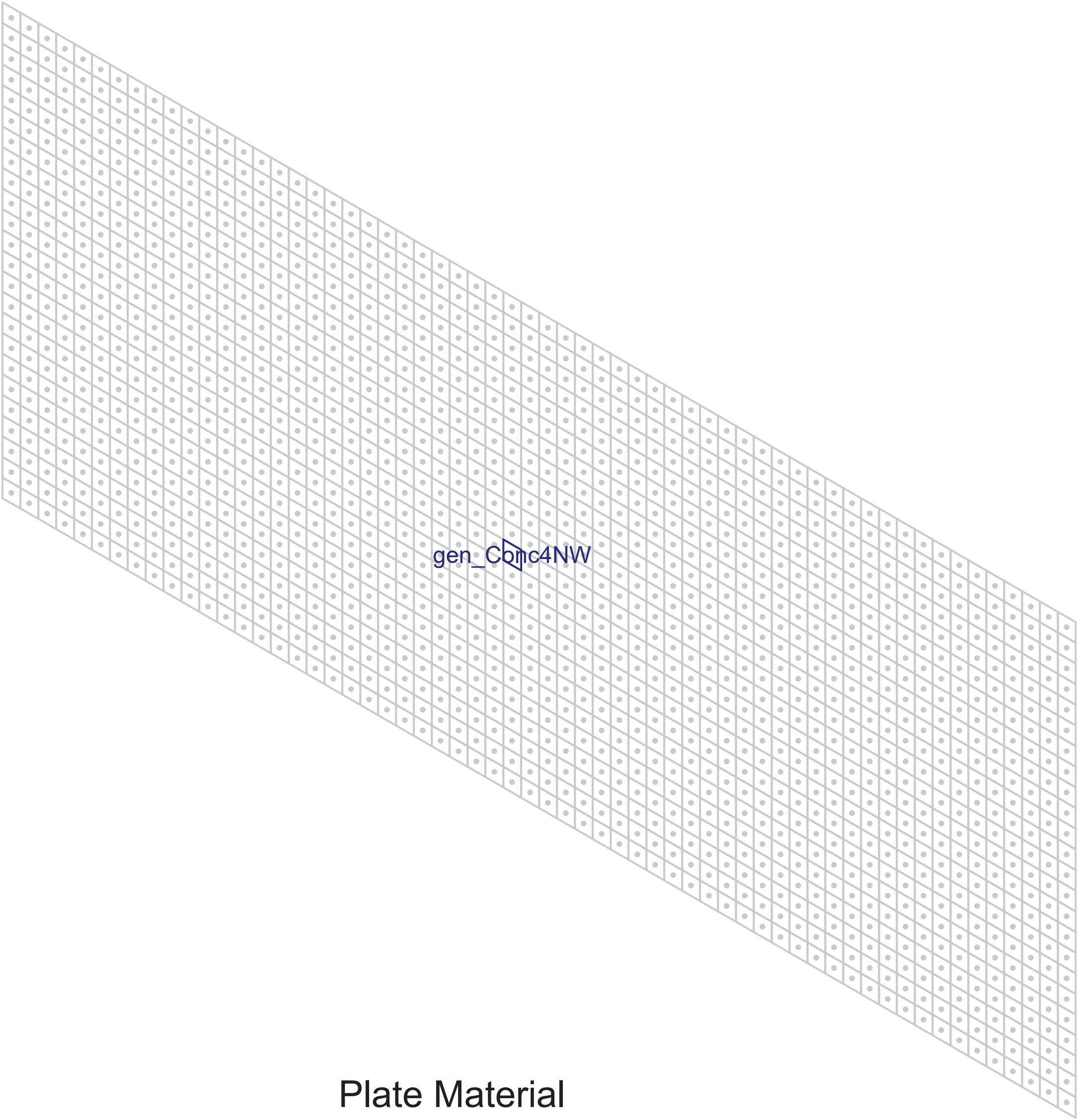
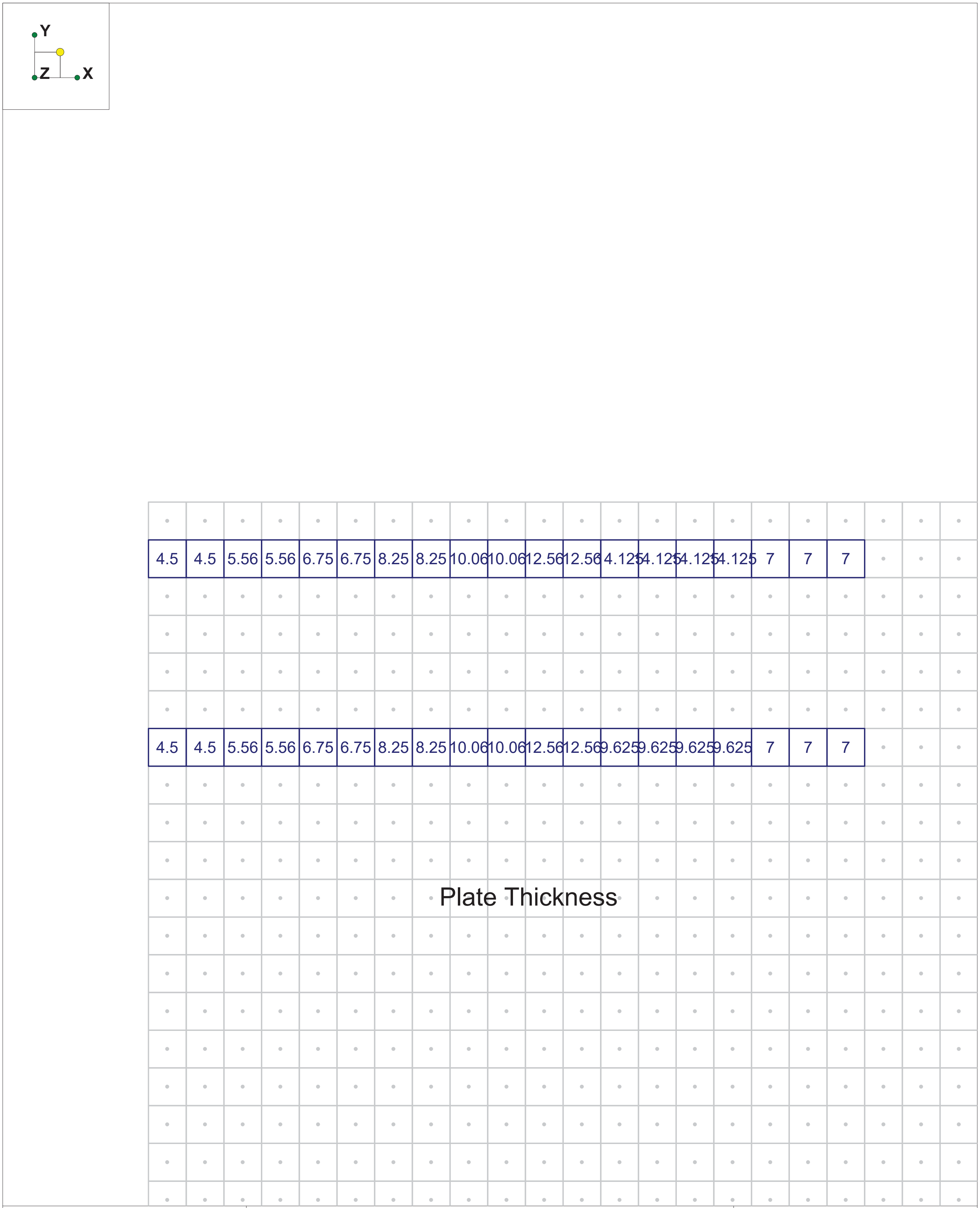
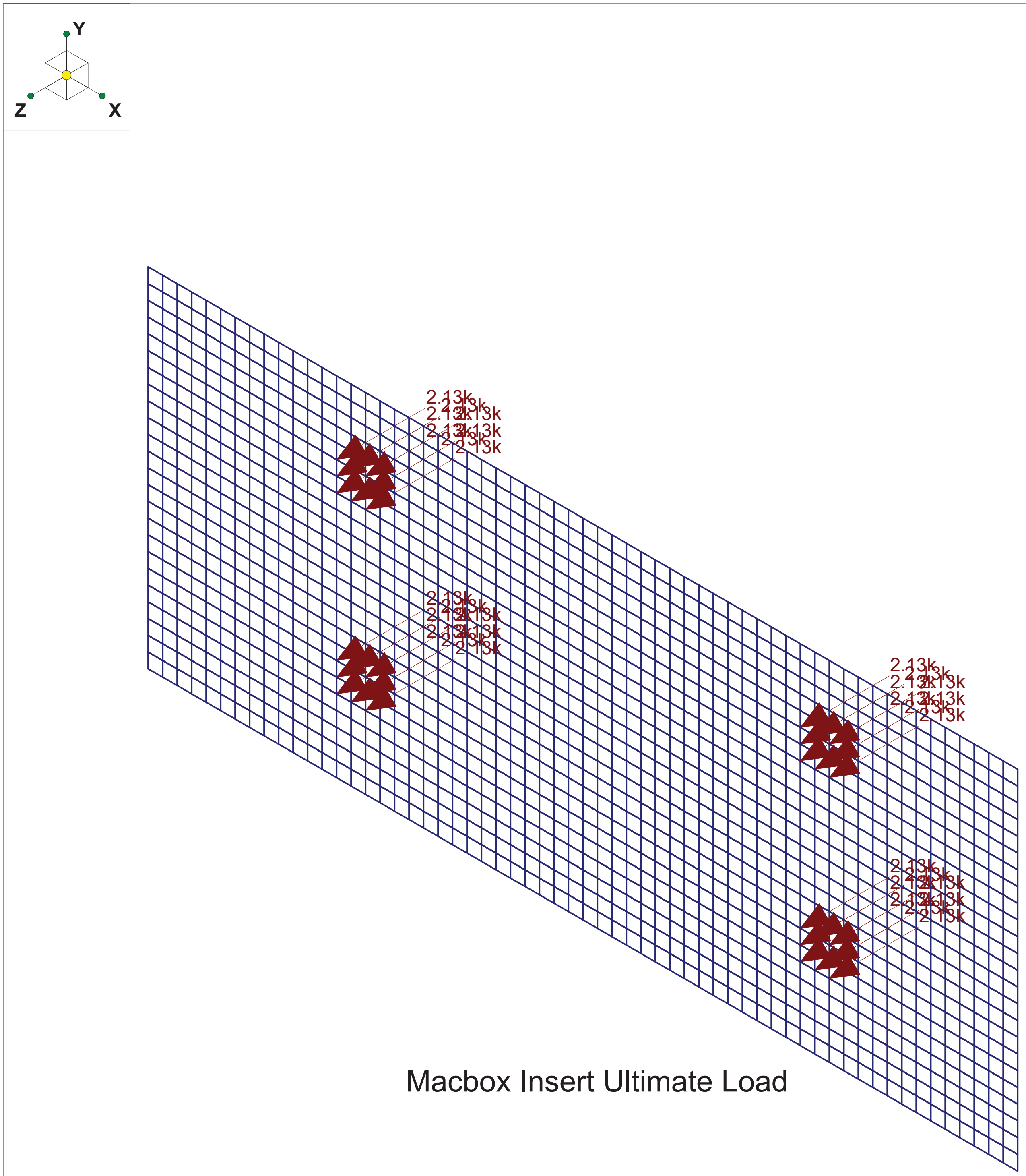


Plate Material

Delta Engineers,Inc	24SF-P and 24SF-HDP	SK - 4
YL		Oct 14, 2020 at 8:40 PM
2020.548.001		24SF-P and 24SF-HDP.r3d



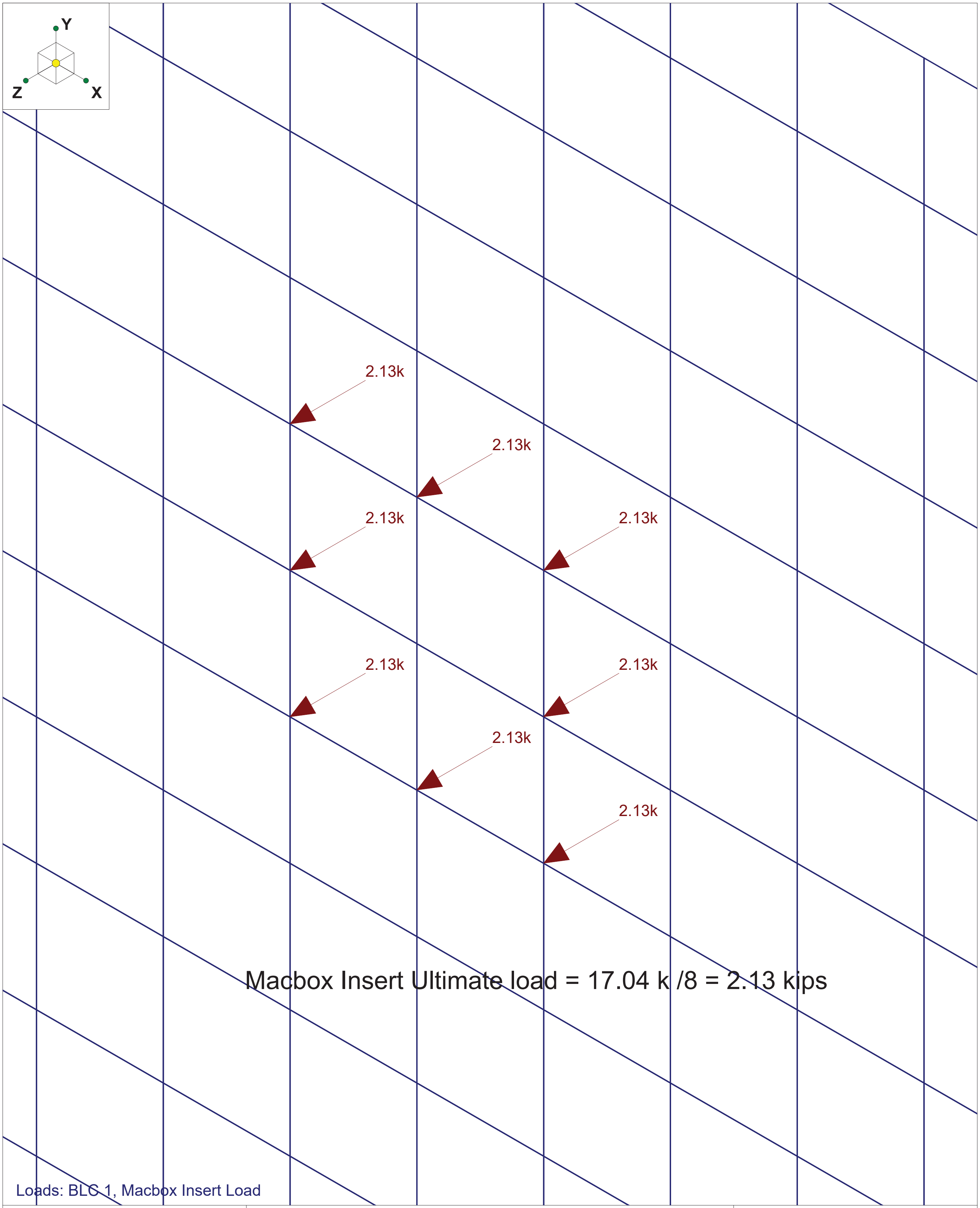
Delta Engineers,Inc	24SF-P and 24SF-HDP	SK - 5
YL		Oct 16, 2020 at 3:57 PM
2020.548.001		24SF-P and 24SF-HDP.r3d



Macbox Insert Ultimate Load

Loads: BLC 1, Macbox Insert Load

Delta Engineers,Inc	24SF-P and 24SF-HDP	SK - 6
YL		Oct 16, 2020 at 3:58 PM
2020.548.001		24SF-P and 24SF-HDP.r3d



Macbox Insert Ultimate load = 17.04 k /8 = 2.13 kips

Loads: BLC 1, Macbox Insert Load

Delta Engineers,Inc	24SF-P and 24SF-HDP	SK - 7
YL		Oct 16, 2020 at 4:00 PM
2020.548.001		24SF-P and 24SF-HDP.r3d

General Material Properties

	Label	E [ksi]	G [ksi]	Nu	Therm (/1E5 F)	Density[k/ft^3]
1	gen_Conc3NW	3155	1372	.15	.6	.145
2	gen_Conc4NW	3644	1584	.15	.6	.145
3	gen_Conc3LW	2085	906	.15	.6	.11
4	gen_Conc4LW	2408	1047	.15	.6	.11
5	gen_Alum	10600	4077	.3	1.29	.173
6	gen_Steel	29000	11154	.3	.65	.49
7	RIGID	1e+6		.3	0	0

Basic Load Cases

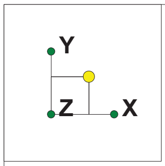
	BLC Description	Category	X Gravity	Y Gravity	Z Gravity	Joint	Point	Distribut..	Area(M...	Surface...
1	Macbox Insert Load	None		-1		32				

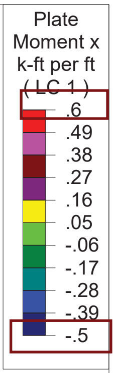
Joint Loads and Enforced Displacements (BLC 1 : Macbox Insert Load)

	Joint Label	L,D,M	Direction	Magnitude[(k,k-ft), (in,rad), (k*s^2/ft, k*s^2*ft)]
1	N500	L	Z	2.13
2	N501	L	Z	2.13
3	N502	L	Z	2.13
4	N522	L	Z	2.13
5	N523	L	Z	2.13
6	N632	L	Z	2.13
7	N633	L	Z	2.13
8	N634	L	Z	2.13
9	N654A	L	Z	2.13
10	N655A	L	Z	2.13
11	N752A	L	Z	2.13
12	N753A	L	Z	2.13
13	N755A	L	Z	2.13
14	N774A	L	Z	2.13
15	N775A	L	Z	2.13
16	N884	L	Z	2.13
17	N885	L	Z	2.13
18	N887	L	Z	2.13
19	N906	L	Z	2.13
20	N907	L	Z	2.13
21	N1082A	L	Z	2.13
22	N1084	L	Z	2.13
23	N1127	L	Z	2.13
24	N1128	L	Z	2.13
25	N1129	L	Z	2.13
26	N1174	L	Z	2.13
27	N1364	L	Z	2.13
28	N1366	L	Z	2.13
29	N1409	L	Z	2.13
30	N1410	L	Z	2.13
31	N1411	L	Z	2.13
32	N1456	L	Z	2.13

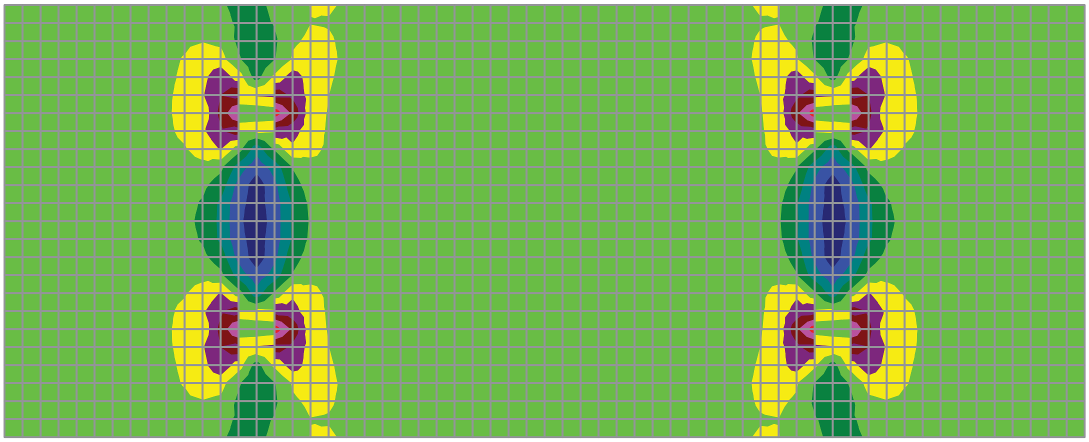
Load Combinations

	Description	S...	P...	S...	B...	Factor	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...
1	Ultimate Macbox Insert Load	Y...			1	1																



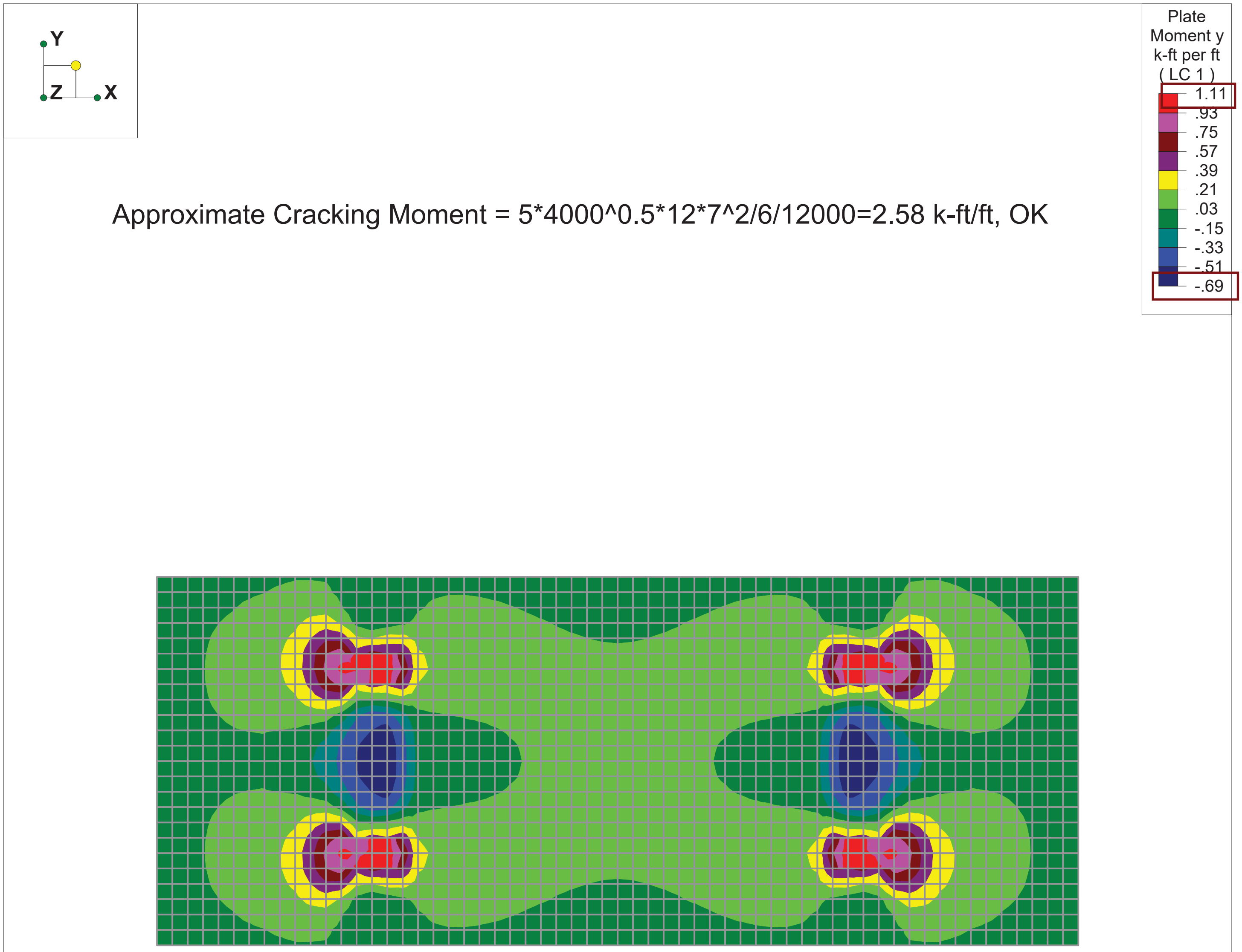


Approximate Cracking Moment = 5*4000^0.5*12*7^2/6/12000=2.58 k-ft/ft, OK



Results for LC 1, Ultimate Macbox Insert Load

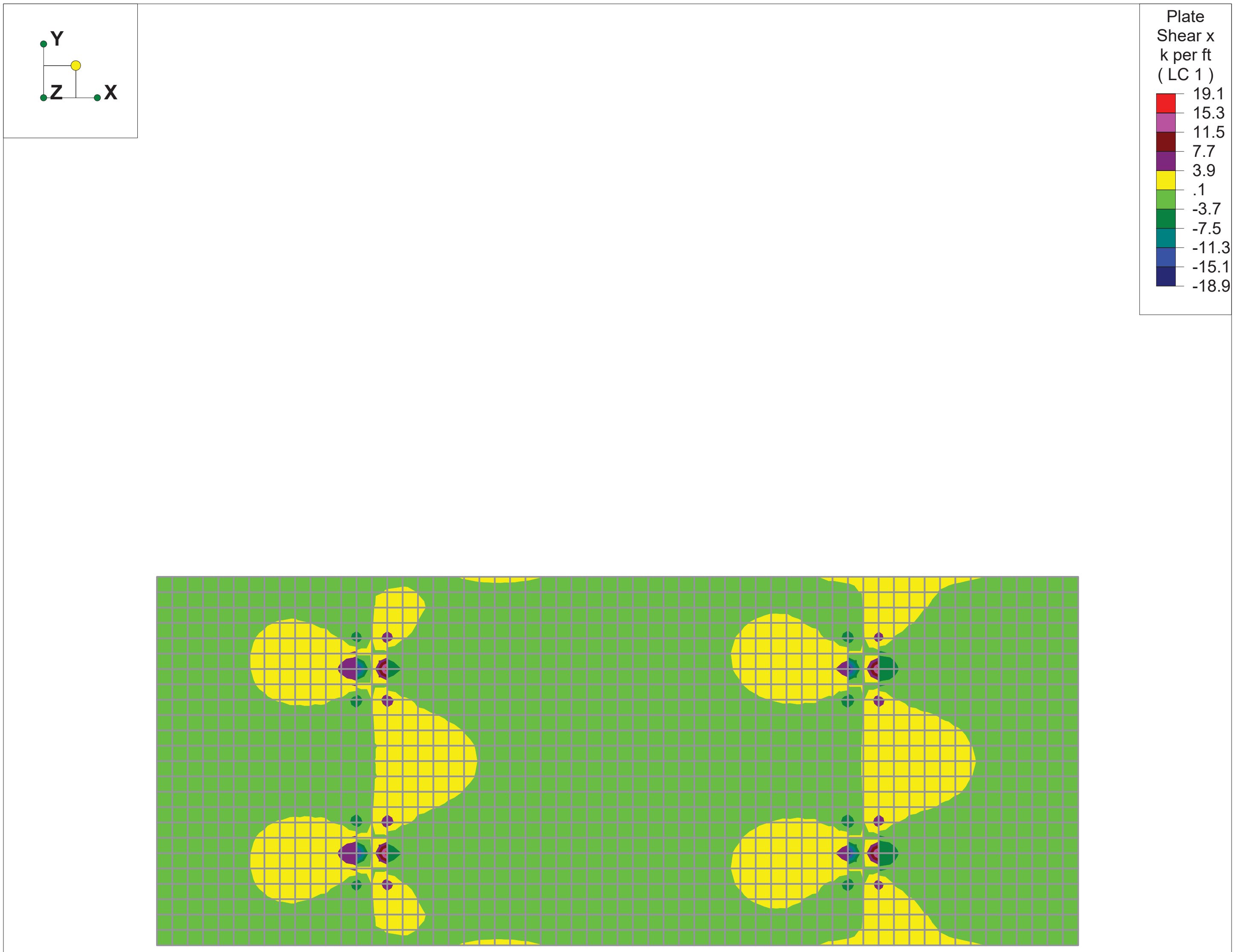
Delta Engineers,Inc	24SF-P and 24SF-HDP	SK - 8
YL		Oct 16, 2020 at 4:01 PM
2020.548.001		24SF-P and 24SF-HDP.r3d



Approximate Cracking Moment = 5*4000^0.5*12*7^2/6/12000=2.58 k-ft/ft, OK

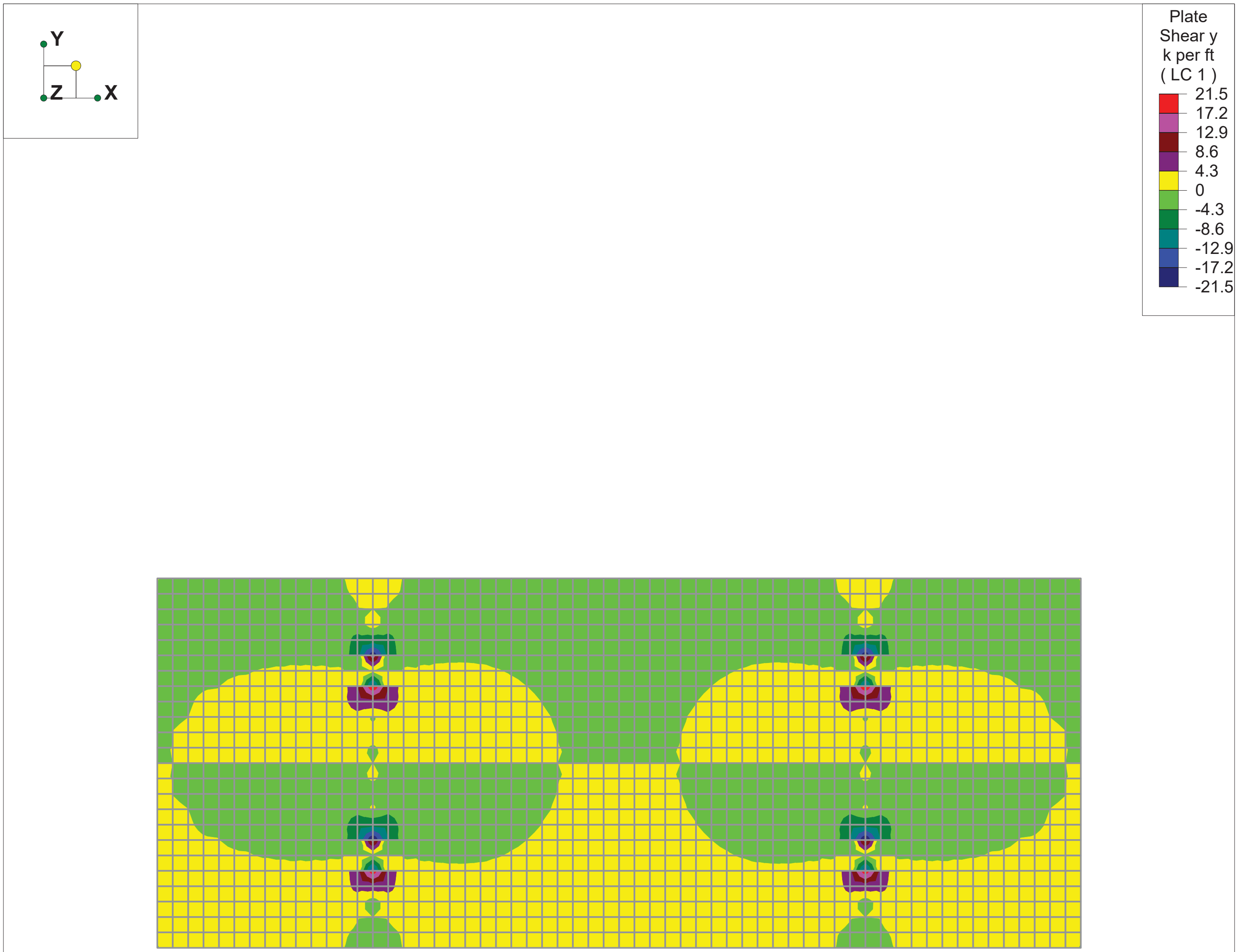
Results for LC 1, Ultimate Macbox Insert Load

Delta Engineers,Inc	24SF-P and 24SF-HDP	SK - 9
YL		Oct 16, 2020 at 4:03 PM
2020.548.001		24SF-P and 24SF-HDP.r3d



Results for LC 1, Ultimate Macbox Insert Load

Delta Engineers,Inc	24SF-P and 24SF-HDP	SK - 10
YL		Oct 16, 2020 at 4:04 PM
2020.548.001		24SF-P and 24SF-HDP.r3d

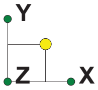


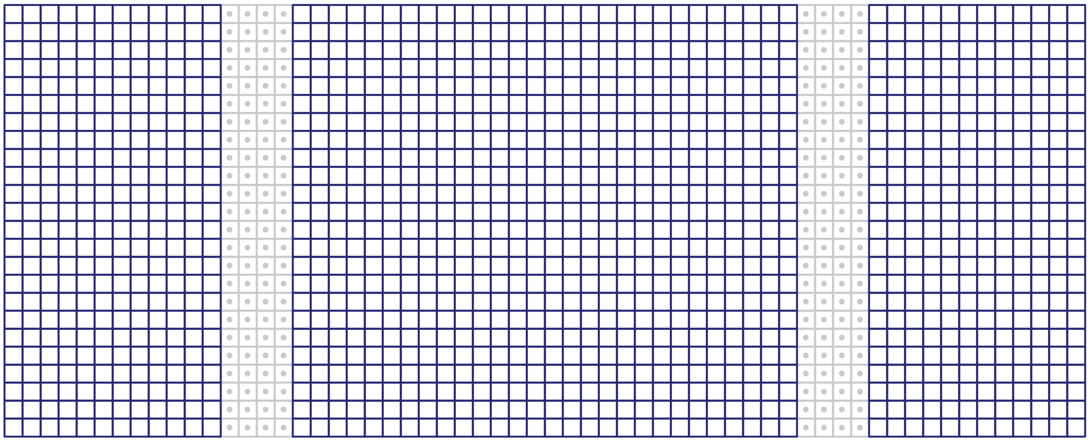
Results for LC 1, Ultimate Macbox Insert Load

Delta Engineers,Inc
YL
2020.548.001

24SF-P and 24SF-HDP

SK - 11
Oct 16, 2020 at 4:04 PM
24SF-P and 24SF-HDP.r3d





Selected Plates for Shear Results

Delta Engineers,Inc	24SF-P and 24SF-HDP	SK - 12
YL		Oct 16, 2020 at 4:23 PM
2020.548.001		24SF-P and 24SF-HDP.r3d

Plate Forces (per ft) (By Combination)

Max. Ultimate Shear X

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P805A	-2.318	.555	.171	1.073	.121	0	-.388	0
2	1	P566A	2.318	.555	.171	1.073	-.121	0	-.388	0
3	1	P421	2.318	-.555	.171	1.073	.121	0	-.116	0
4	1	P660A	-2.318	-.555	.171	1.073	-.121	0	-.117	0
5	1	P547	2.228	-1.229	.167	1.039	.193	0	-.37	0
6	1	P786	-2.228	-1.229	.167	1.039	-.193	0	-.369	0
7	1	P440	2.228	1.229	.167	1.039	-.193	0	-.135	0
8	1	P679B	-2.228	1.229	.167	1.039	.193	0	-.135	0
9	1	P1006	1.547	-.384	.163	.338	.051	0	-.067	0
10	1	P1340	1.547	.384	.163	.338	-.051	0	-.225	0
11	1	P1300A	-1.547	.384	.163	.338	.051	-.01	-.224	0
12	1	P966	-1.547	-.384	.163	.338	-.051	0	-.067	0
13	1	P1052	1.469	.852	.147	.322	-.047	0	-.077	0
14	1	P1254	-1.469	-.852	.147	.322	-.047	-.009	-.214	0
15	1	P1294	1.469	-.852	.147	.322	.047	0	-.214	0
16	1	P1012A	-1.469	.852	.147	.322	.047	0	-.077	0
17	1	P568A	1.312	1.611	.181	.631	-.218	0	-.371	0
18	1	P807	-1.312	1.611	.181	.631	.218	0	-.371	0
19	1	P419	1.312	-1.611	.181	.631	.218	0	-.088	0
20	1	P658B	-1.312	-1.611	.181	.631	-.218	0	-.088	0

Approximate Plain Conc. Shear Capacity = 0.6*4/3*4000^0.5*12*7 = 4.25 kips, OK

Plate Forces (per ft) (By Combination)

Max. Ultimate Shear Y

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P526	-.229	-2.224	.059	.171	.249	0	-.293	0
2	1	P765	.229	-2.224	.059	.171	-.249	0	-.292	0
3	1	P700B	.229	2.224	.059	.171	.249	0	-.157	0
4	1	P461	-.229	2.224	.059	.171	-.249	0	-.157	0
5	1	P545	1.08	-2.19	.148	.541	.272	0	-.318	0
6	1	P442	1.08	2.19	.148	.541	-.272	0	-.141	0
7	1	P784A	-1.08	-2.19	.148	.541	-.272	0	-.317	0
8	1	P681A	-1.08	2.19	.148	.541	.272	0	-.141	0
9	1	P826A	-.126	1.71	.134	.325	.192	0	-.383	0
10	1	P587A	.126	1.71	.134	.325	-.192	0	-.383	0
11	1	P400	.126	-1.71	.134	.325	.192	0	-.067	0
12	1	P639A	-.126	-1.71	.134	.325	-.192	0	-.068	0
13	1	P568A	1.312	1.611	.181	.631	-.218	0	-.371	0
14	1	P807	-1.312	1.611	.181	.631	.218	0	-.371	0
15	1	P658B	-1.312	-1.611	.181	.631	-.218	0	-.088	0
16	1	P419	1.312	-1.611	.181	.631	.218	0	-.088	0
17	1	P763A	1.05	-1.475	-.022	-.08	-.164	0	-.27	0
18	1	P463	-1.05	1.475	-.022	-.08	-.164	0	-.175	0
19	1	P702A	1.05	1.475	-.022	-.08	.164	0	-.175	0
20	1	P524	-1.05	-1.475	-.022	-.08	.164	0	-.271	0

Approximate Plain Conc. Shear Capacity = 0.6*4/3*4000^0.5*12*7 = 4.25 kips, OK

SPECIALTY PRECAST CONCRETE ENGINEERS
860 Hooper Road, Endwell, NY 13760
www.delta-eas.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB 2020.548.001

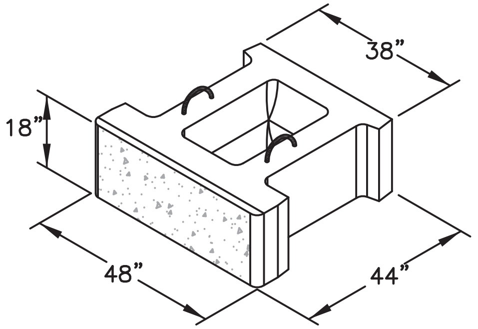
DESCRIPTION Macbox Insert Connection

SHEET NO. OF SCALE

CALCULATED BY YL DATE 10/18/2020

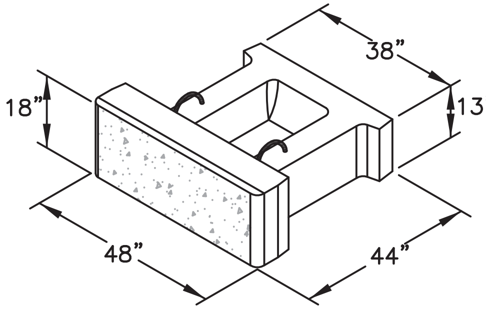
CHECKED BY DATE

6SF-P and 6SF-HDP Units Risa Analysis



STONE STRONG 6SF UNIT

NOT TO SCALE



STONE STRONG 6SF TOP UNIT

NOT TO SCALE

STONE STRONG SYSTEMS®

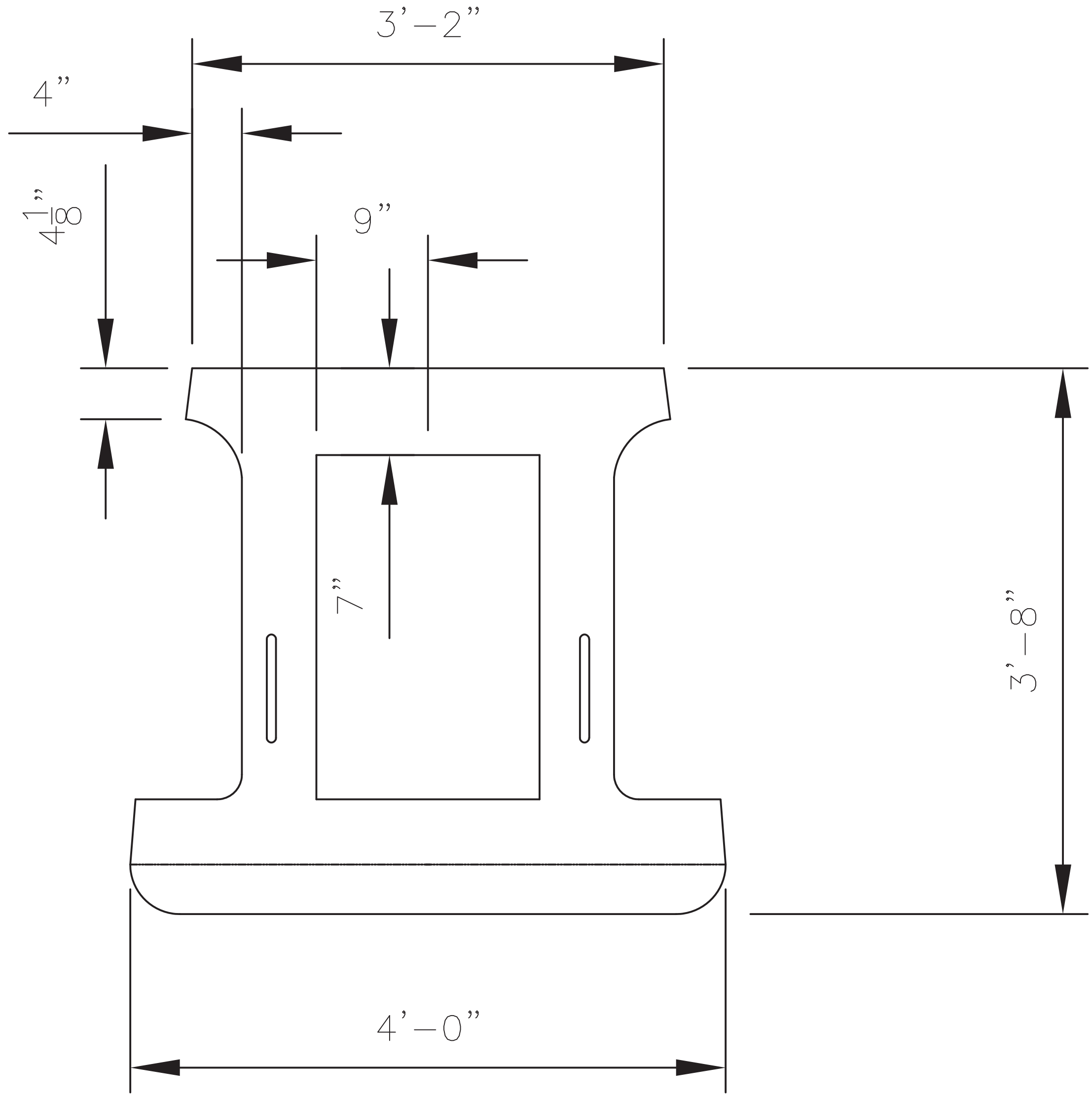
www.stonestrong.com

PROJECT

COMPONENTS
STONE STRONG SYSTEMS

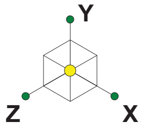
DATE: 2/10/16

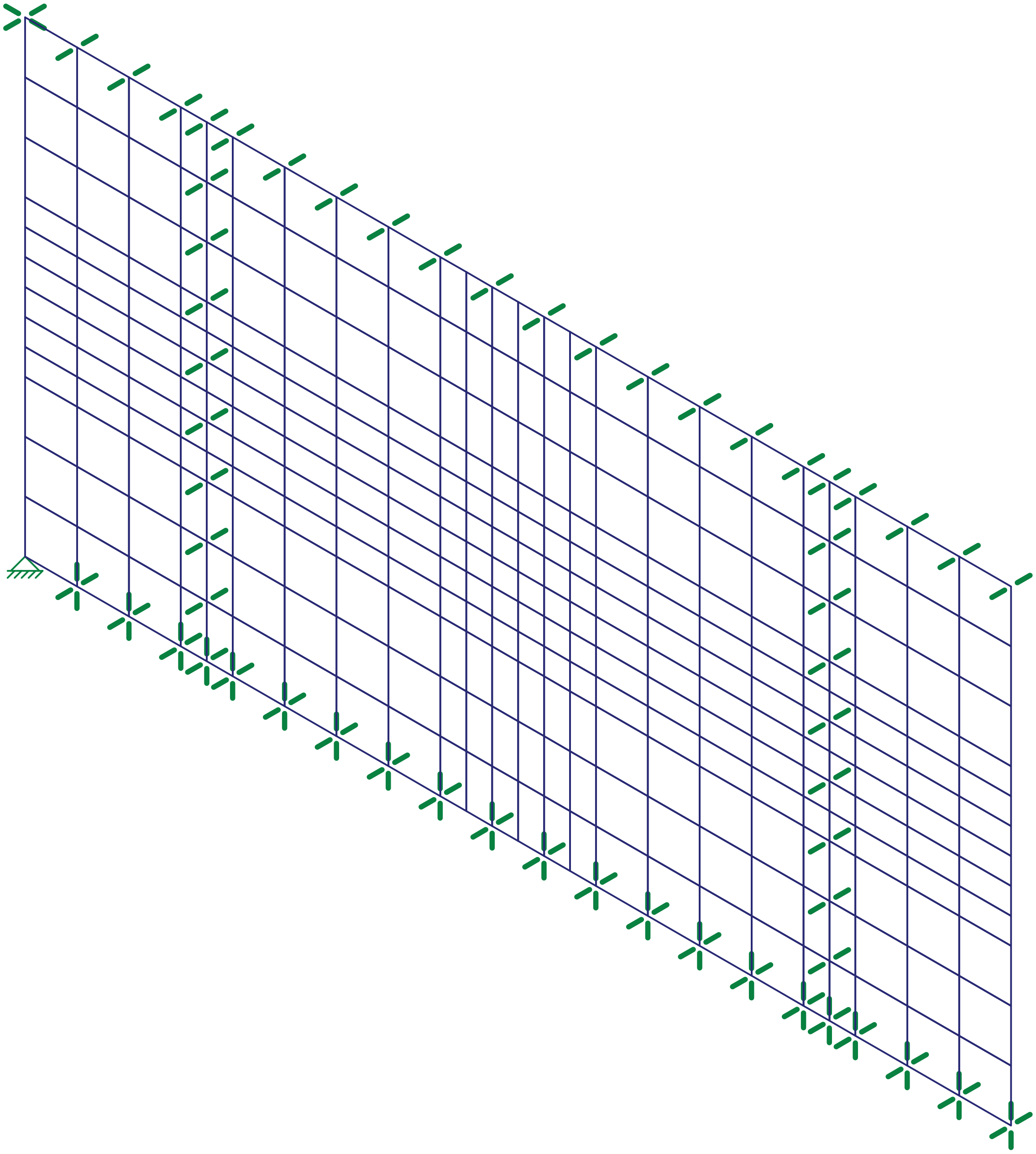
FILE: 14_Block.6sf



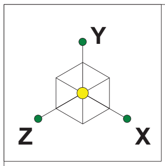
6SF UNIT

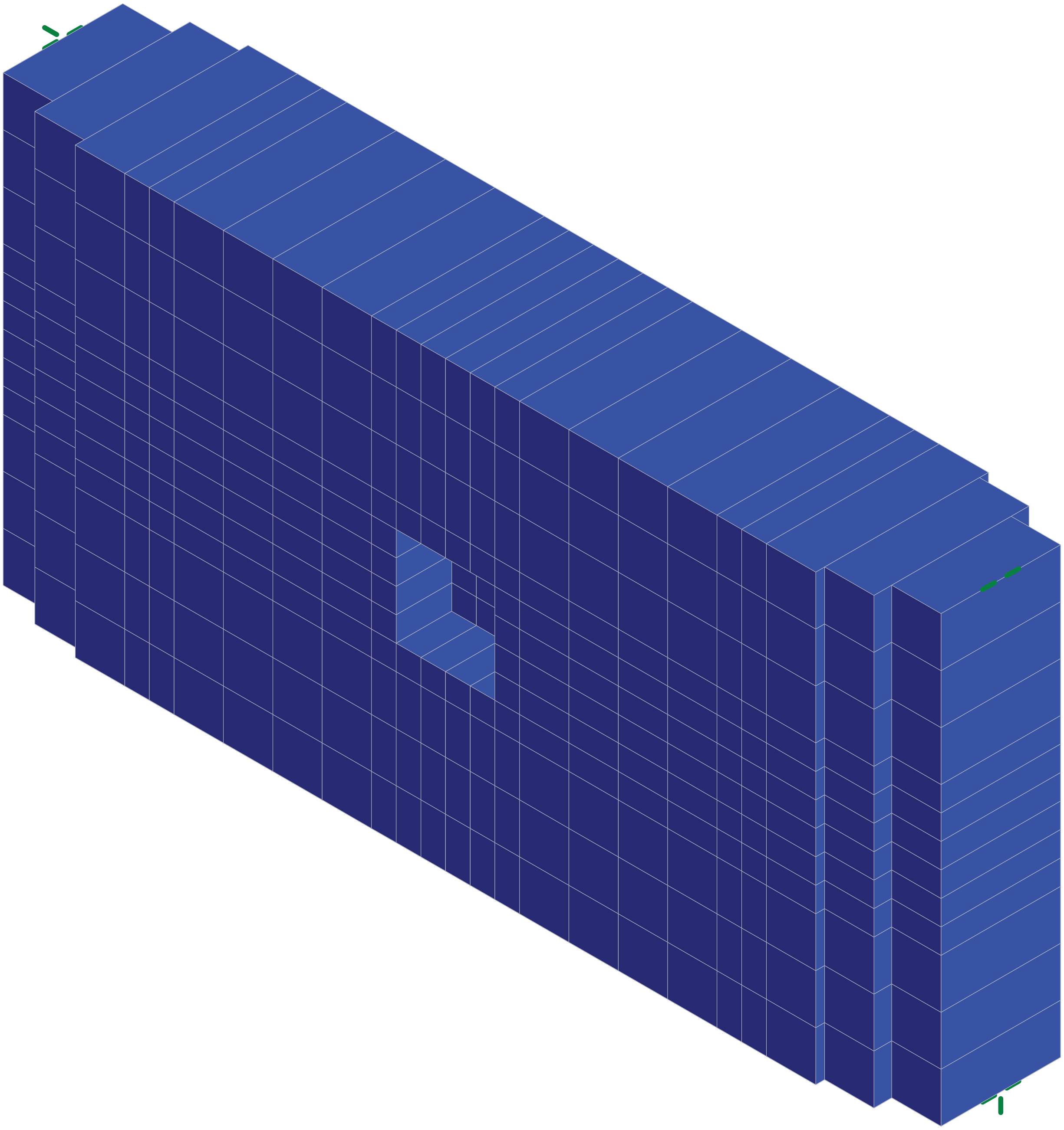
PLAN VIEW





Delta Engineers,Inc	6SF-P and 6SF-HDP	SK - 1
YL		Oct 18, 2020 at 7:29 PM
2020.548.001		6SF-P and 6SF-HDP.r3d





Delta Engineers,Inc	6SF-P and 6SF-HDP	SK - 2
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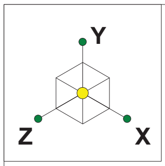
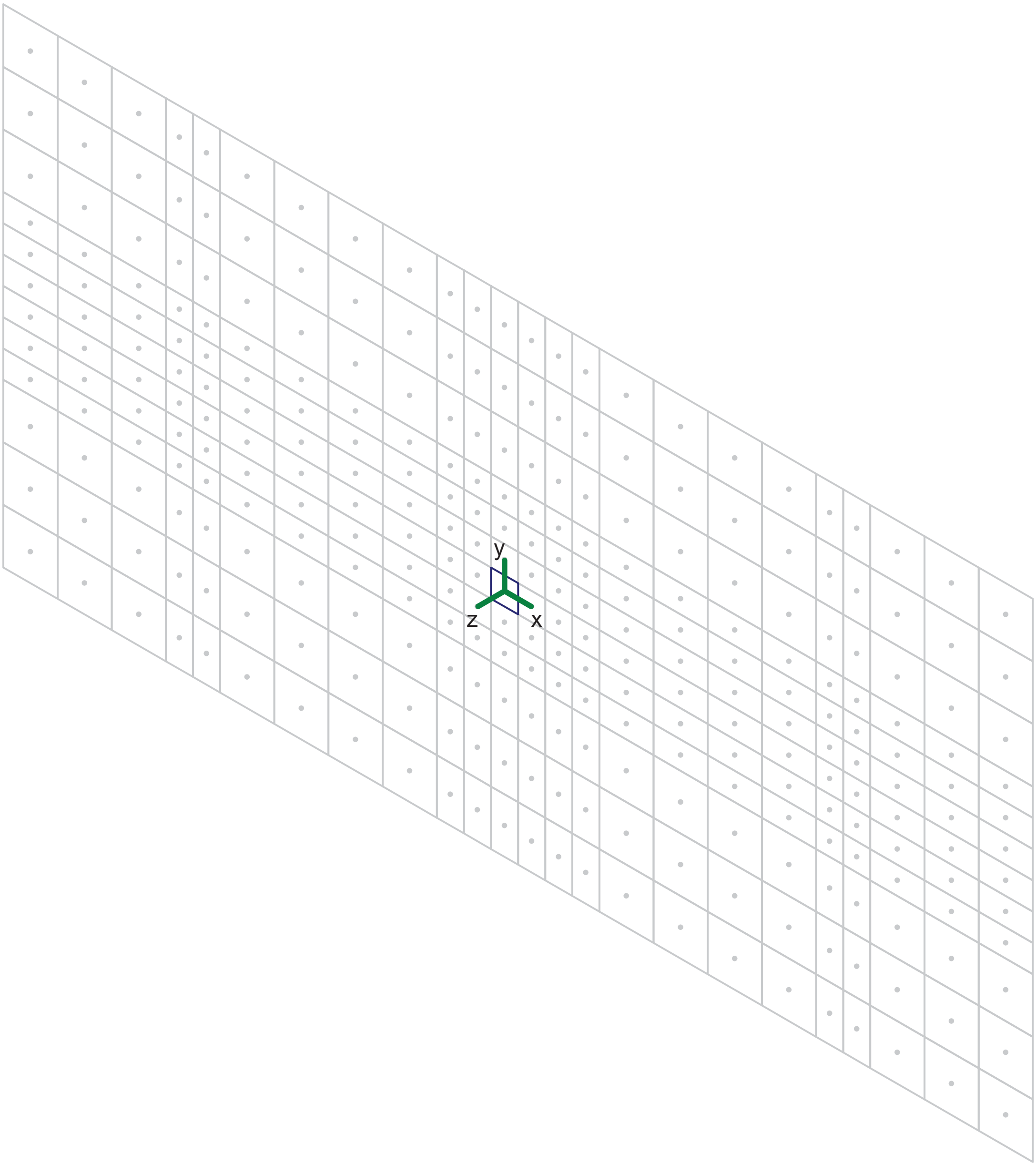
2020.548.001		6SF-P and 6SF-HDP.r3d





Delta Engineers,Inc	6SF-P and 6SF-HDP	SK - 3
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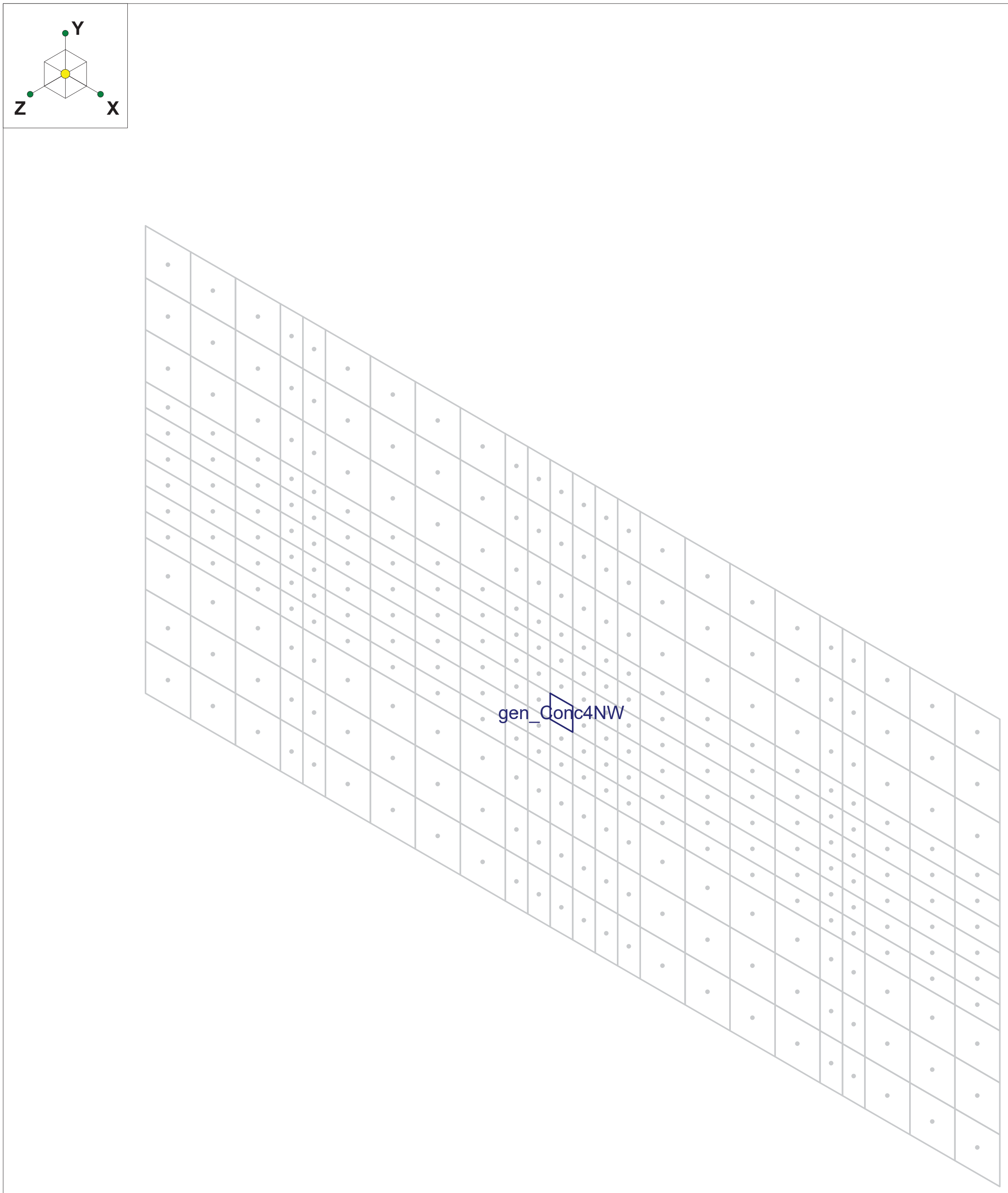
2020.548.001		6SF-P and 6SF-HDP.r3d



Delta Engineers,Inc	6SF-P and 6SF-HDP	SK - 4
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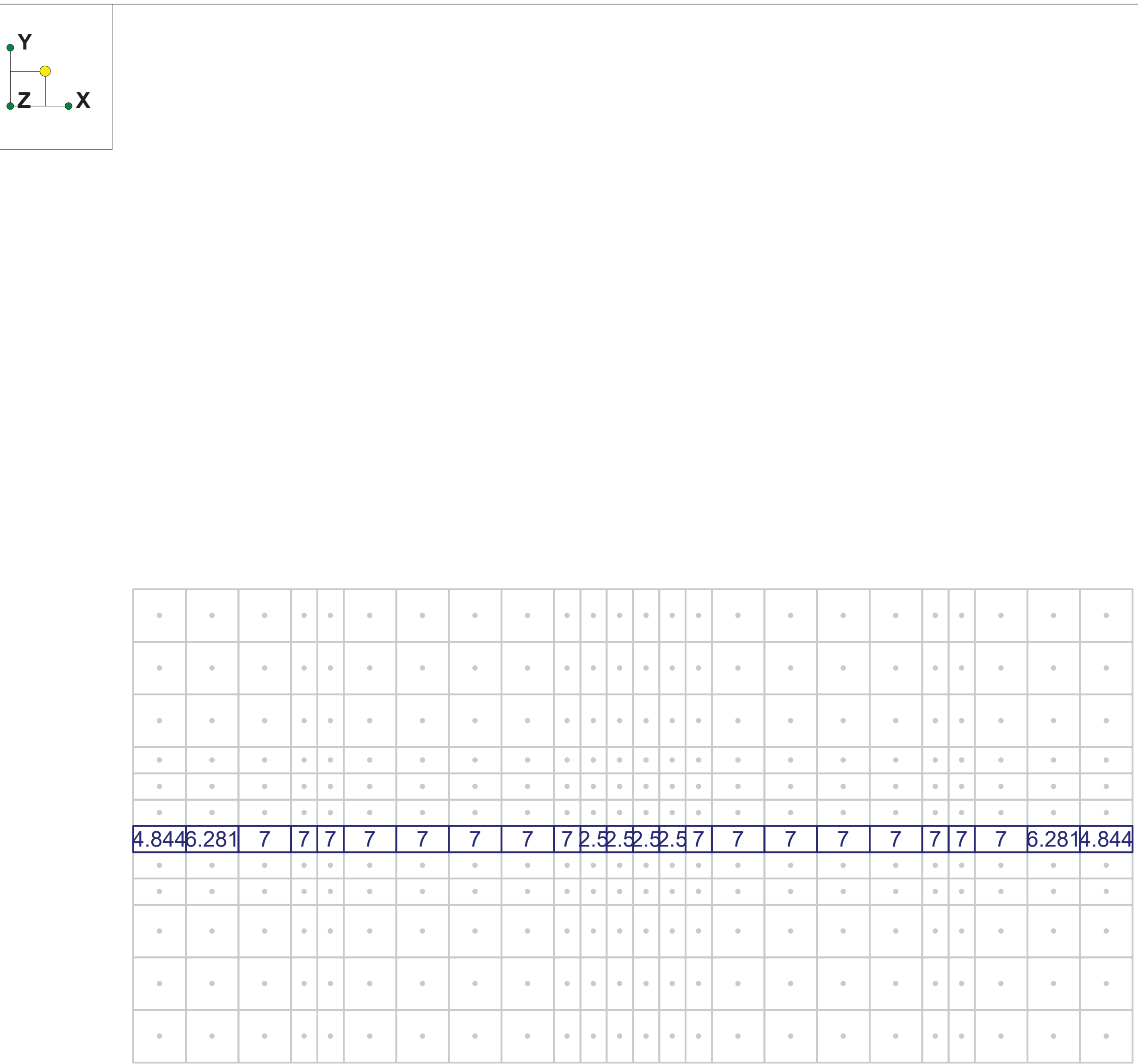

Delta Engineers,Inc	6SF-P and 6SF-HDP	SK - 5
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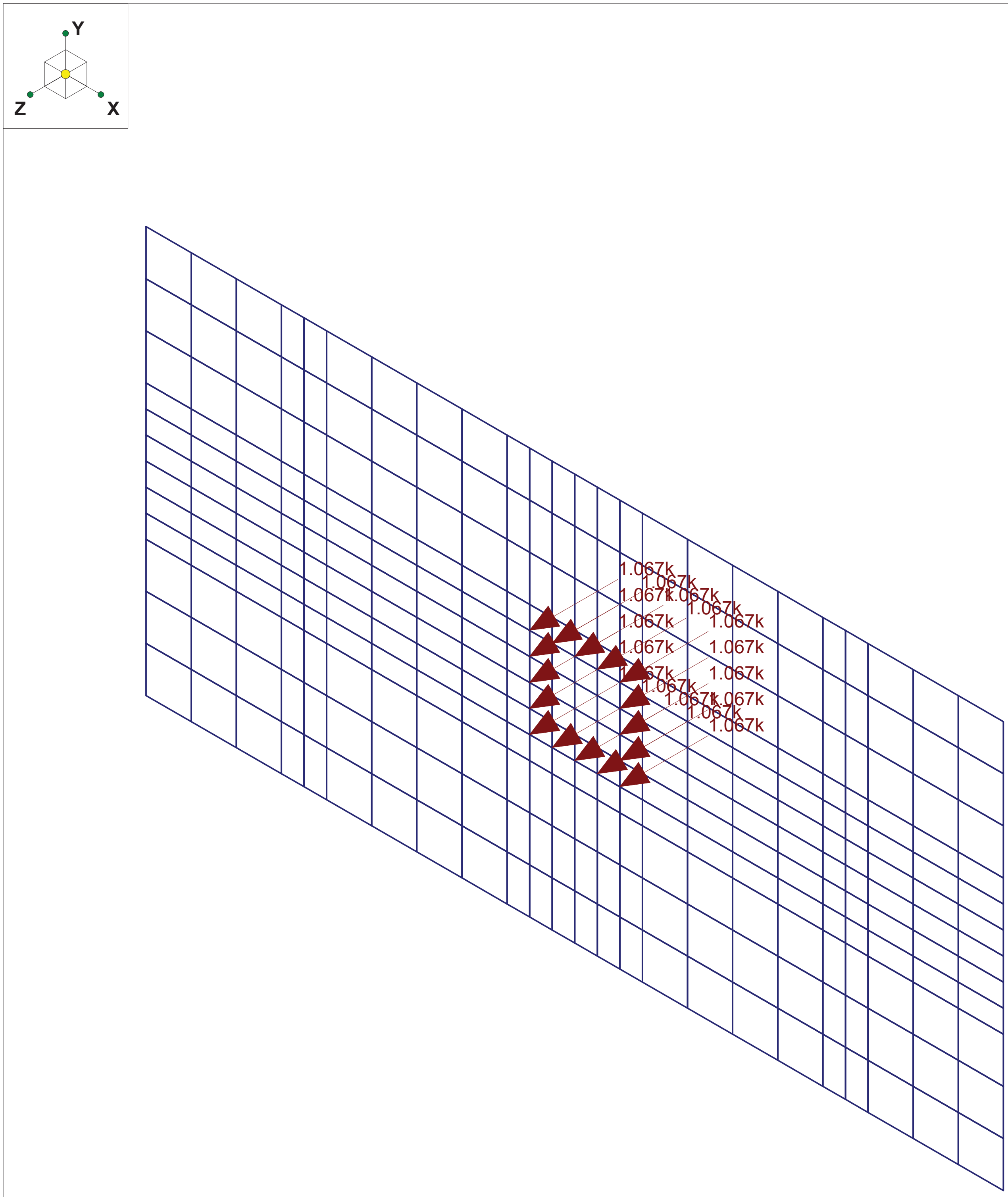
2020.548.001		6SF-P and 6SF-HDP.r3d



Loads: BLC 1, Macbox Insert Load

Delta Engineers,Inc	6SF-P and 6SF-HDP	SK - 6
YL		Oct 18, 2020 at 7:35 PM
2020.548.001		6SF-P and 6SF-HDP.r3d

General Material Properties

	Label	E [ksi]	G [ksi]	Nu	Therm (/1E5 F)	Density[k/ft^3]
1	gen_Conc3NW	3155	1372	.15	.6	.145
2	gen_Conc4NW	3644	1584	.15	.6	.145
3	gen_Conc3LW	2085	906	.15	.6	.11
4	gen_Conc4LW	2408	1047	.15	.6	.11
5	gen_Alum	10600	4077	.3	1.29	.173
6	gen_Steel	29000	11154	.3	.65	.49
7	RIGID	1e+6		.3	0	0

Basic Load Cases

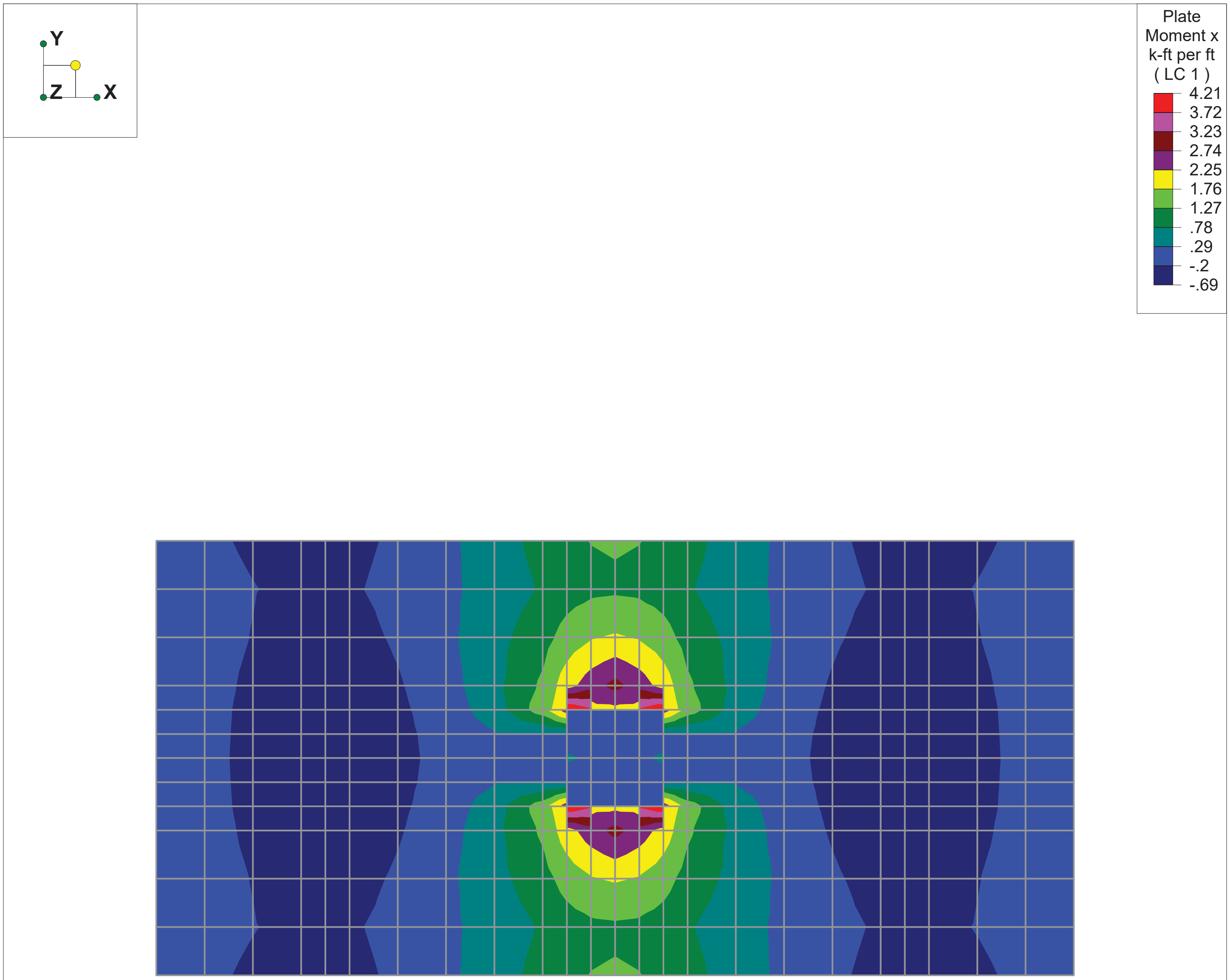
	BLC Description	Category	X Gravity	Y Gravity	Z Gravity	Joint	Point	Distribut...	Area(M...	Surface...
1	Macbox Insert Load	None		-1		16				

Joint Loads and Enforced Displacements (BLC 1 : Macbox Insert Load)

	Joint Label	L,D,M	Direction	Magnitude[(k,k-ft), (in,rad), (k*s^2/ft, k*s^2*ft)]
1	N252	L	Z	1.067
2	N253	L	Z	1.067
3	N272	L	Z	1.067
4	N273	L	Z	1.067
5	N298	L	Z	1.067
6	N299	L	Z	1.067
7	N316	L	Z	1.067
8	N317	L	Z	1.067
9	N318	L	Z	1.067
10	N319	L	Z	1.067
11	N320	L	Z	1.067
12	N321	L	Z	1.067
13	N322	L	Z	1.067
14	N323	L	Z	1.067
15	N324	L	Z	1.067
16	N325	L	Z	1.067

Load Combinations

	Description	S...	P...	S...	B...	Factor	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...
1	Macbox Insert Ultimate Load	Y...			1	1																



Results for LC 1, Macbox Insert Ultimate Load

Delta Engineers,Inc	6SF-P and 6SF-HDP	SK - 7
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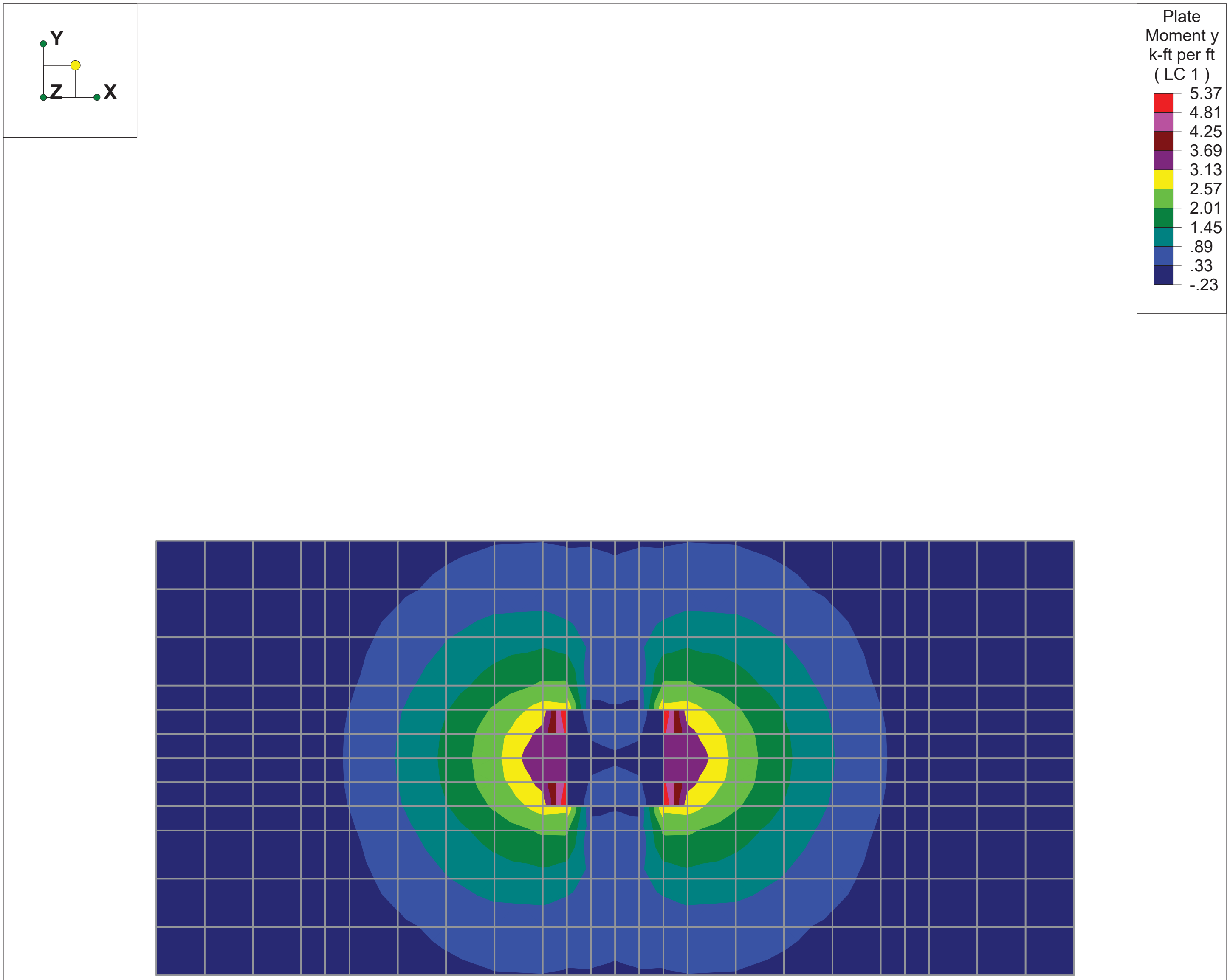
2020.548.001		6SF-P and 6SF-HDP.r3d



Results for LC 1, Macbox Insert Ultimate Load

Delta Engineers,Inc	6SF-P and 6SF-HDP	SK - 8
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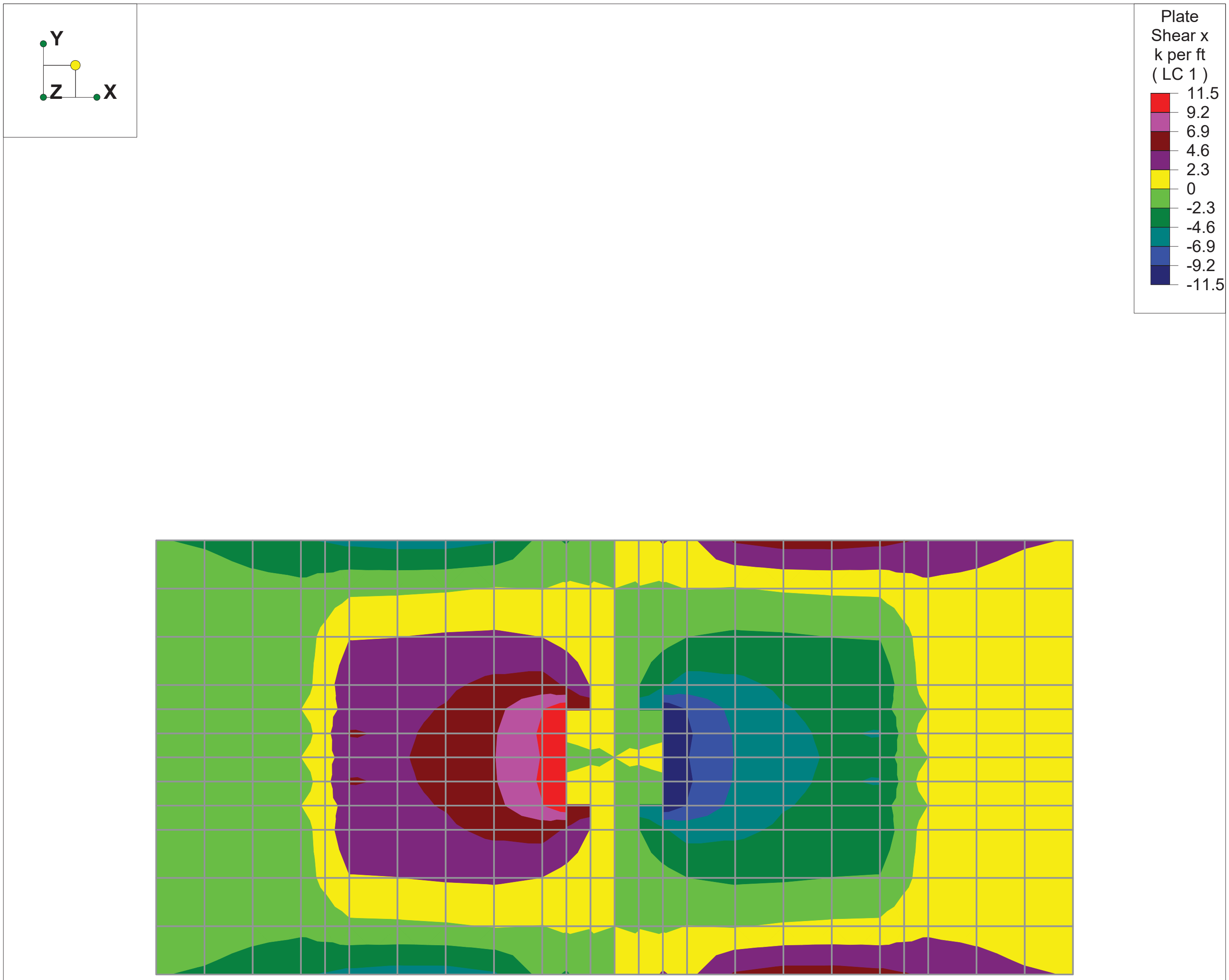
2020.548.001		6SF-P and 6SF-HDP.r3d



Results for LC 1, Macbox Insert Ultimate Load

Delta Engineers,Inc	6SF-P and 6SF-HDP	SK - 9
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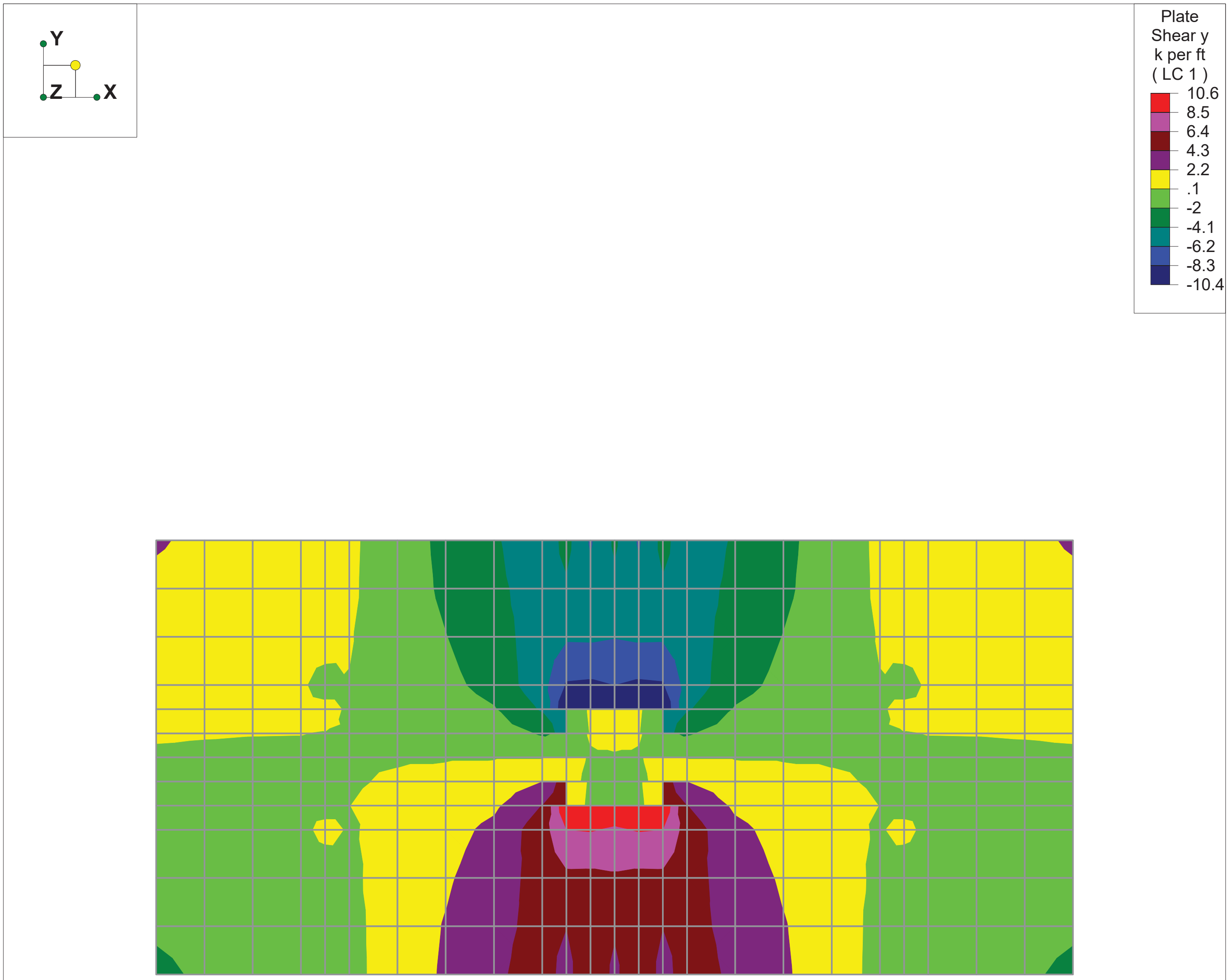
2020.548.001		6SF-P and 6SF-HDP.r3d



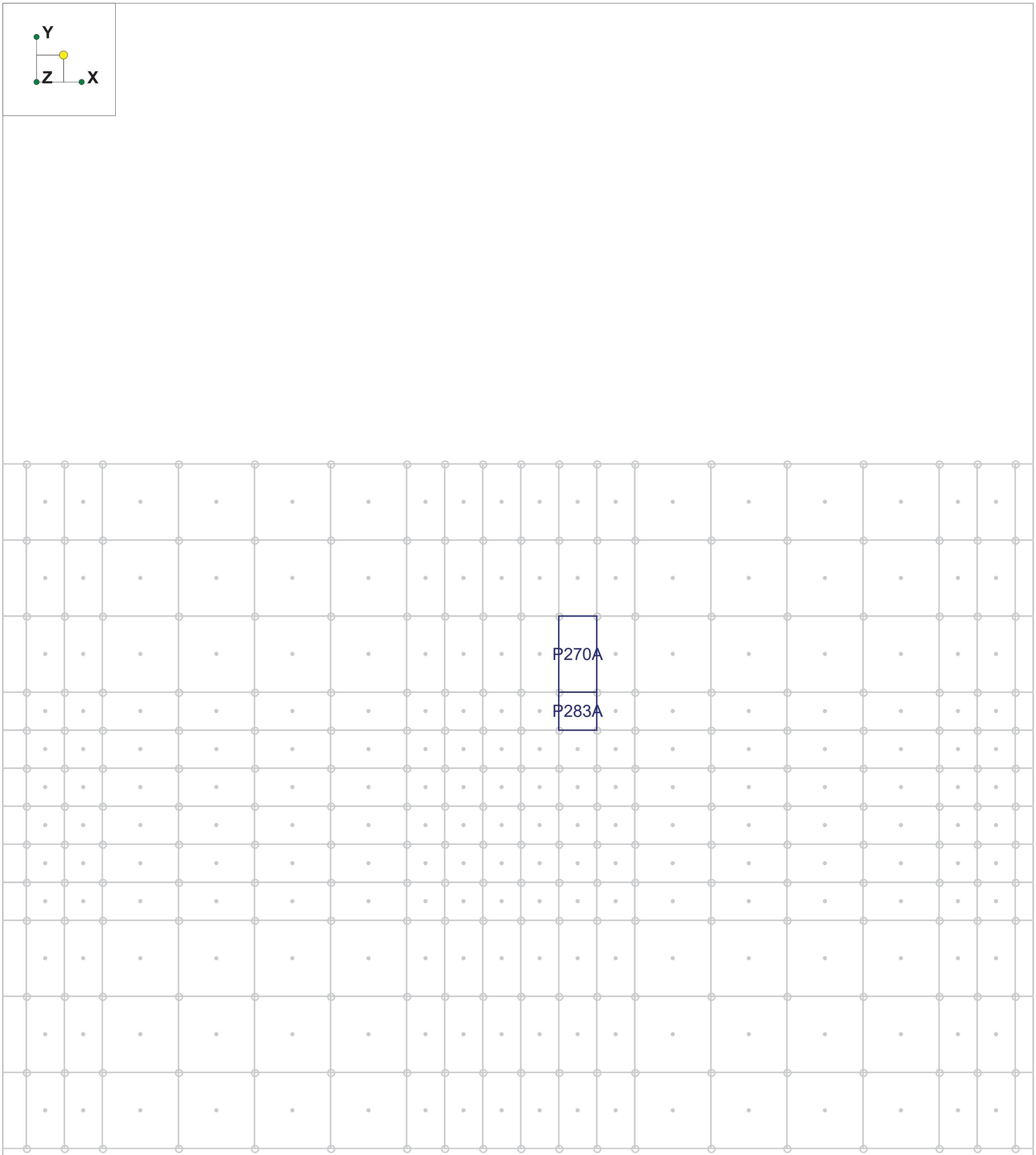
Results for LC 1, Macbox Insert Ultimate Load

Delta Engineers,Inc	6SF-P and 6SF-HDP	SK - 10
YL		Oct 18, 2020 at 7:37 PM
2020.548.001		6SF-P and 6SF-HDP.r3d

Plate Forces (per ft) (By Combination)

Max. Ultimate Mx

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P283A	-5.08	-10.291	3.141	1.608	-1.573	0	-.039	0
2	1	P282	5.08	-10.291	3.141	1.608	1.573	0	-.039	0
3	1	P287	5.08	10.291	3.141	1.608	-1.573	0	-.062	.009
4	1	P288A	-5.08	10.291	3.141	1.608	1.573	0	-.062	-.01
5	1	P262	-1.505	-10.017	2.494	.292	-.287	0	-.032	0
6	1	P261A	1.505	-10.017	2.494	.292	.287	0	-.032	0
7	1	P265	-1.505	10.017	2.494	.292	.287	0	-.051	0
8	1	P264A	1.505	10.017	2.494	.292	-.287	0	-.051	0
9	1	P255A	.801	-6.889	2.373	.644	.421	0	-.027	0
10	1	P256	-.801	-6.889	2.373	.644	-.421	0	-.027	0
11	1	P256A	.801	6.889	2.373	.644	-.421	0	-.069	0
12	1	P257	-.801	6.889	2.373	.644	.421	0	-.069	0
13	1	P286A	8.132	7.821	1.961	2.65	-1.247	0	-.079	0
14	1	P281A	8.132	-7.821	1.961	2.65	1.247	0	-.05	0
15	1	P284	-8.132	-7.821	1.961	2.65	-1.247	0	-.05	0
16	1	P289	-8.132	7.821	1.961	2.65	1.247	0	-.08	0
17	1	P270	2.159	-6.821	1.943	1.125	.966	0	-.031	0
18	1	P272	2.159	6.821	1.943	1.125	-.966	0	-.076	0
19	1	P270A	-2.159	-6.821	1.943	1.125	-.966	0	-.031	0
20	1	P272A	-2.159	6.821	1.943	1.125	.966	0	-.076	0



Selected Plates for Max. Average Ultimate Mx

Delta Engineers,Inc	6SF-P and 6SF-HDP	SK - 11
YL		Oct 18, 2020 at 8:05 PM
2020.548.001		6SF-P and 6SF-HDP.r3d

Plate Forces (per ft) (By Combination)

Selected Plates for Max. Average Ultimate Mx

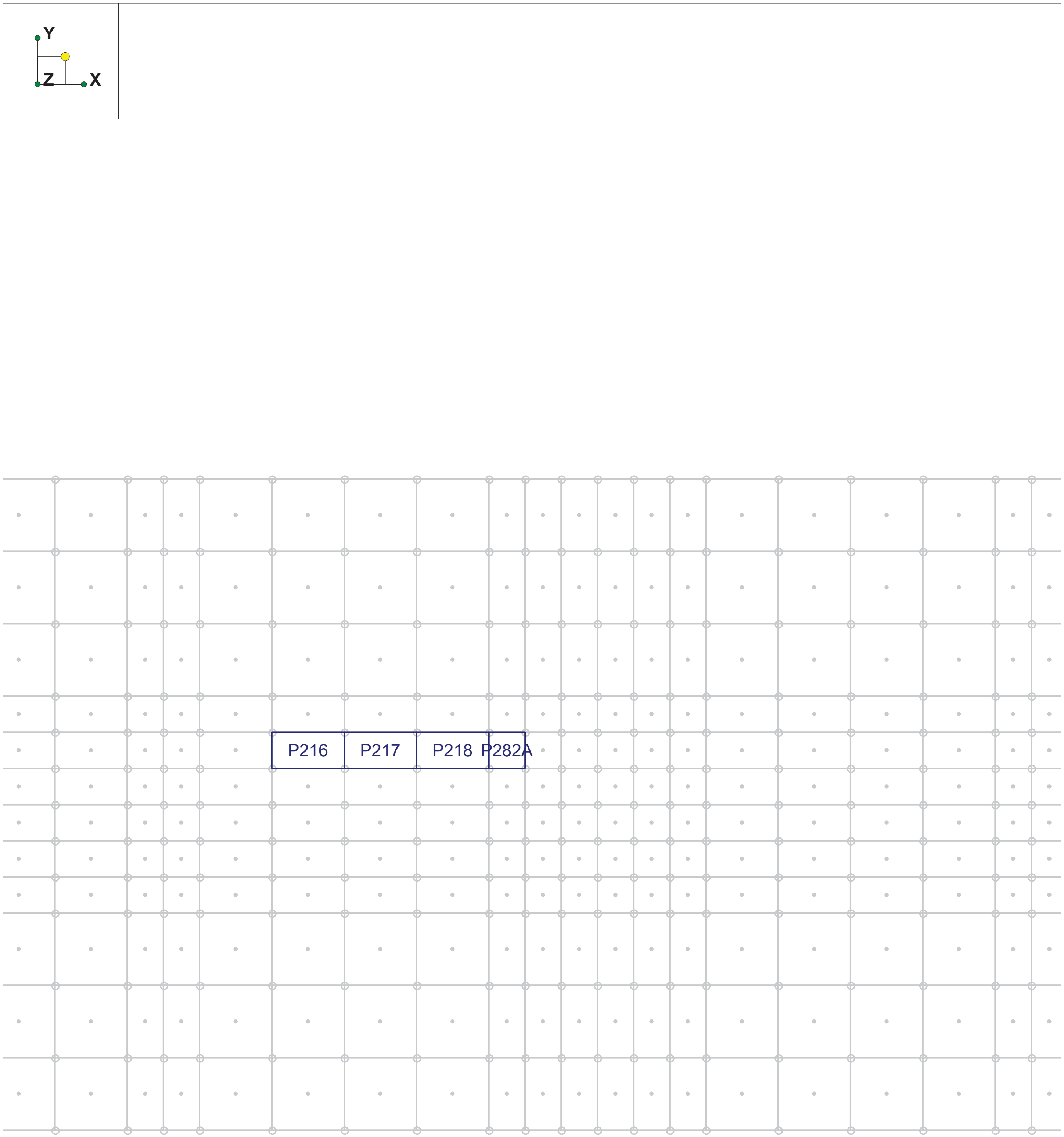
	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P283A	-5.08	-10.291	3.141	1.608	-1.573	0	-.039	0
2	1	P270A	-2.159	-6.821	1.943	1.125	-.966	0	-.031	0

Max. Average Ultimate Mx = 2.54 k-ft/ft
Approximate Cracking Moment = 5*4000^0.5*12*7^2/6/12000=2.58 k-ft/ft, OK

Plate Forces (per ft) (By Combination)

Max. Ultimate My

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P282A	11.085	-4.571	1.276	4.124	1.494	0	-.07	0
2	1	P285	-11.085	-4.571	1.276	4.124	-1.494	0	-.07	0
3	1	P285A	11.085	4.571	1.276	4.124	-1.494	0	-.091	0
4	1	P288	-11.085	4.571	1.276	4.124	1.494	0	-.091	0
5	1	P277A	10.951	-1.35	.155	3.506	.292	0	-.078	0
6	1	P278A	10.951	1.35	.155	3.506	-.292	0	-.085	0
7	1	P280	-10.951	-1.35	.155	3.506	-.292	0	-.078	0
8	1	P281	-10.951	1.35	.155	3.506	.292	0	-.085	0
9	1	P196A	7.872	-.775	.281	3.071	.383	0	-.068	0
10	1	P197	7.872	.775	.281	3.071	-.383	0	-.074	0
11	1	P200A	-7.872	-.775	.281	3.071	-.383	0	-.068	0
12	1	P201	-7.872	.775	.281	3.071	.383	0	-.075	0
13	1	P284	-8.132	-7.821	1.961	2.65	-1.247	0	-.05	0
14	1	P281A	8.132	-7.821	1.961	2.65	1.247	0	-.05	0
15	1	P289	-8.132	7.821	1.961	2.65	1.247	0	-.08	0
16	1	P286A	8.132	7.821	1.961	2.65	-1.247	0	-.079	0
17	1	P218	7.548	-2.404	.655	2.638	.869	0	-.06	0
18	1	P234A	7.548	2.404	.655	2.638	-.869	0	-.079	0
19	1	P222	-7.548	-2.404	.655	2.638	-.869	0	-.06	0
20	1	P238A	-7.548	2.404	.655	2.638	.869	0	-.079	0



Selected Plates for Max. Average Ultimate My

Delta Engineers,Inc	6SF-P and 6SF-HDP	SK - 12
YL		Oct 18, 2020 at 8:20 PM
2020.548.001		6SF-P and 6SF-HDP.r3d

Plate Forces (per ft) (By Combination)

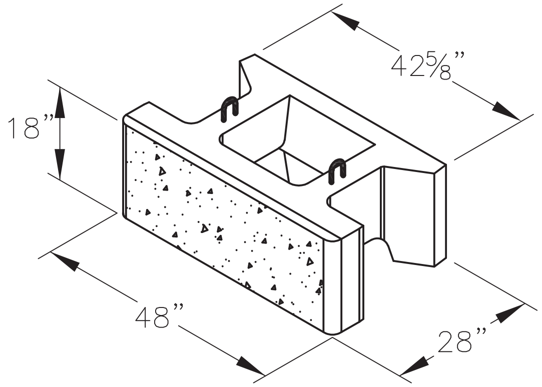
Selected Plates for Max. Average Ultimate Mx

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P282A	11.085	-4.571	1.276	4.124	1.494	0	-.07	0
2	1	P218	7.548	-2.404	.655	2.638	.869	0	-.06	0
3	1	P217	5.41	-1.097	.16	1.861	.486	0	-.056	0
4	1	P216	4.411	-.532	-.151	1.183	.359	0	-.054	0

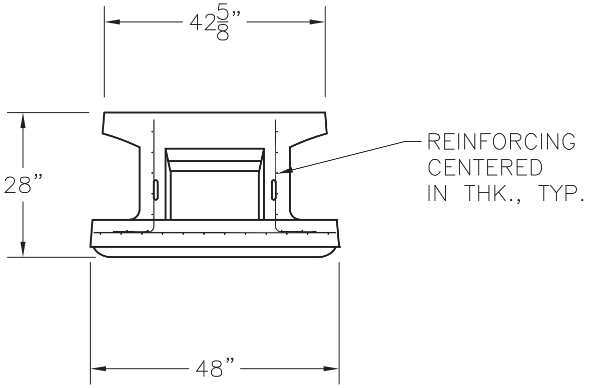
Max. Average Ultimate My = 2.45 k-ft/ft
Approximate Cracking Moment = 5*4000^0.5*12*7^2/6/12000=2.58 k-ft/ft, OK

JOB	2020.548.001		
DESCRIPTION	Macbox Insert Connection		
SHEET NO.		OF	
SCALE			
CALCULATED BY	YL	DATE	10/18/2020
CHECKED BY		DATE	

6-28-P and 6-28-HDP Units Risa Analysis



STONE STRONG 6–28 UNIT



6–28 UNIT
PLAN VIEW

DISCLAIMER: These typical details are preliminary and conceptual in nature. They are provided for general information purposes only. Anyone making use of these details and related information does so at their own risk and assumes all liability for such use. Site specific design should be performed by a licensed Professional Engineer based on actual site conditions, materials, and local practices. Stone Strong LLC retains al common law, statutory, and other reserved rights to these drawings including the copyright. Limited license is granted to copy, reproduce, or modify the details to prepare construction drawings for Stone Strong retaining walls. Stone Strong LLC makes no warranties, either expressed or implied, of merchantability or fitness for any particular purpose, and accepts no responsibility for the accuracy, suitability, or completeness of information contained herein.

REV.NO.	DATE	REVISION

PREPARED FOR:

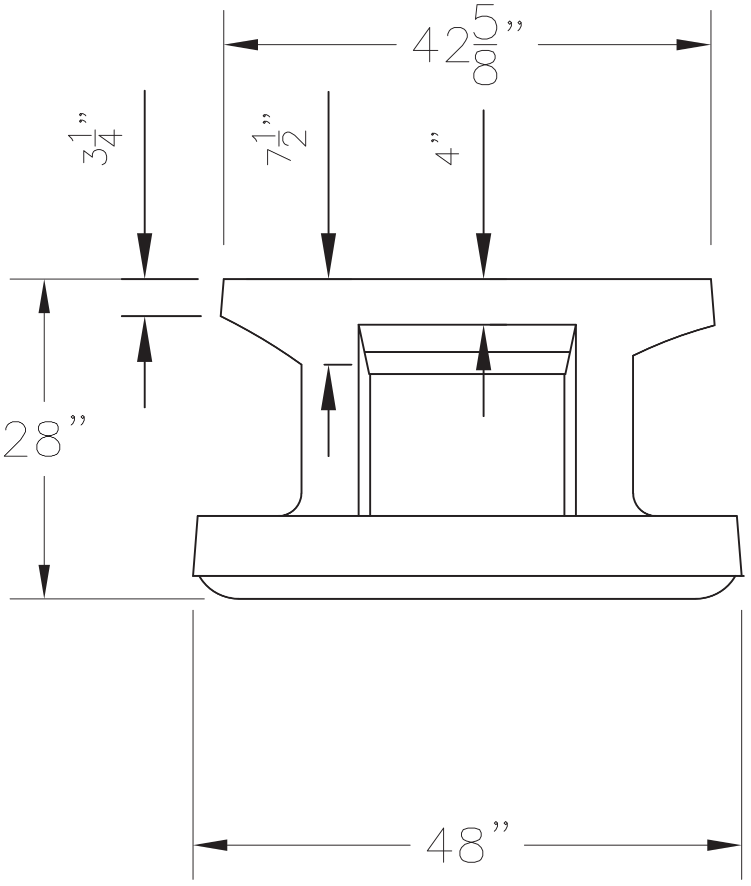
STONE
STRONG
SYSTEMS®

www.stonestrong.com

PREPARED BY:

DELTA
SPECIALTY PRECAST CONCRETE ENGINEERS
860 HOOPER ROAD, ENDWELL, NY 13760–1564
TEL: (607) 231–6600 FAX: (607) 231–6650

DATE: 11/22/17
SCALE: N.T.S.
SHEET TITLE: BLOCK GEOMETRY
DRWN BY: YL
CKD BY:
PROJECT: STONE STRONG 6–28 UNITS
CONTRACTOR:
DWG. I.D.
DELTA PROJ. NO.: 2017.478.001
SHT. NO.



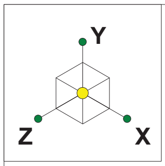
6-28 UNIT PLAN VIEW

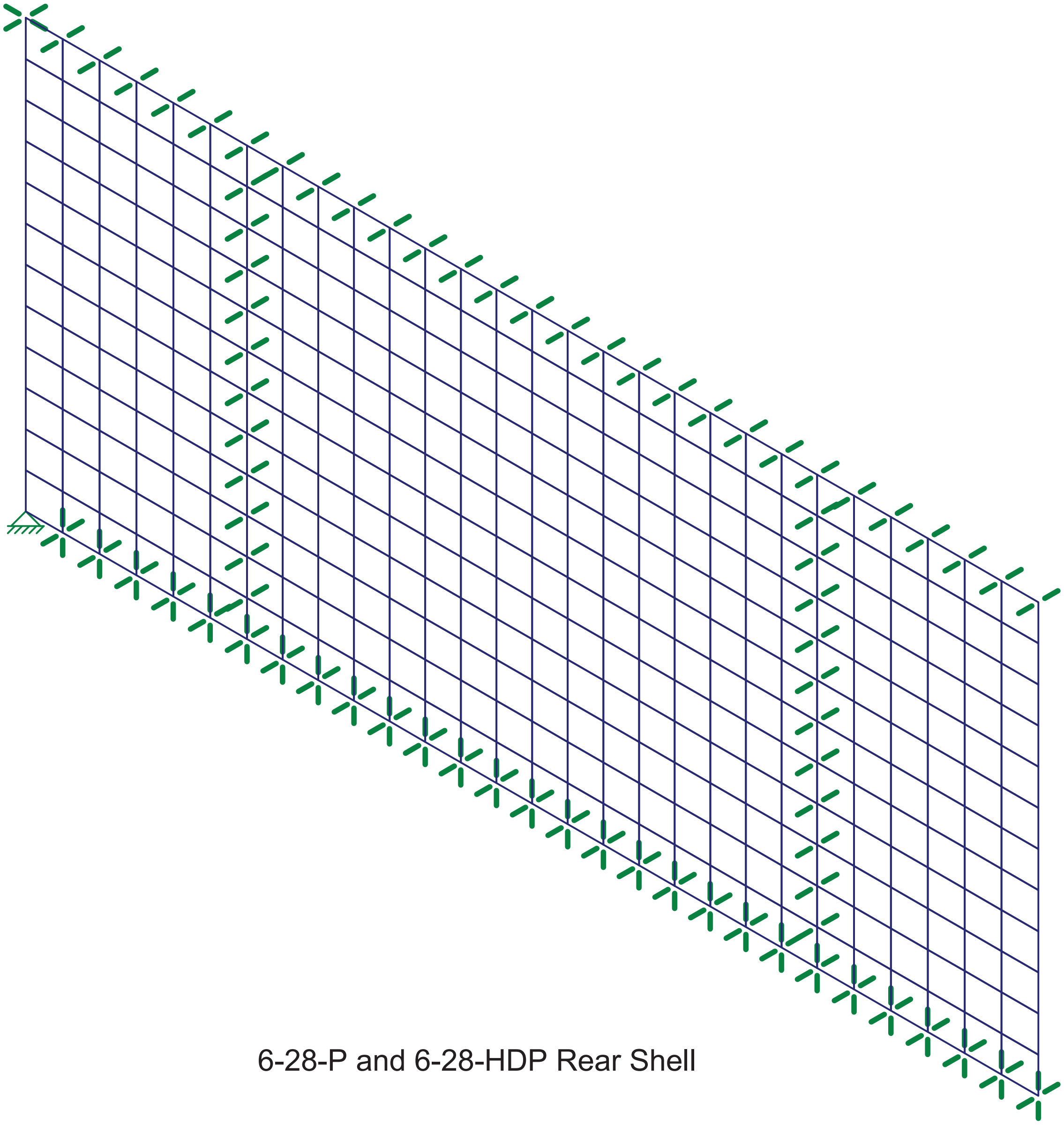
DELTA
SPECIALTY PRECAST CONCRETE ENGINEERS
860 Hooper Road, Endwell, NY 13760
www.delta-eas.com
Phone: (607) 231-6600
Fax: (607) 231-6650

JOB	2020.548.001		
DESCRIPTION	Macbox Insert Connection		
SHEET NO.		OF	
SCALE			
CALCULATED BY	YL	DATE	10/16/2020
CHECKED BY		DATE	

6-28-P and 6-28 HDP Block Rear Shell Thickness for Risa Input

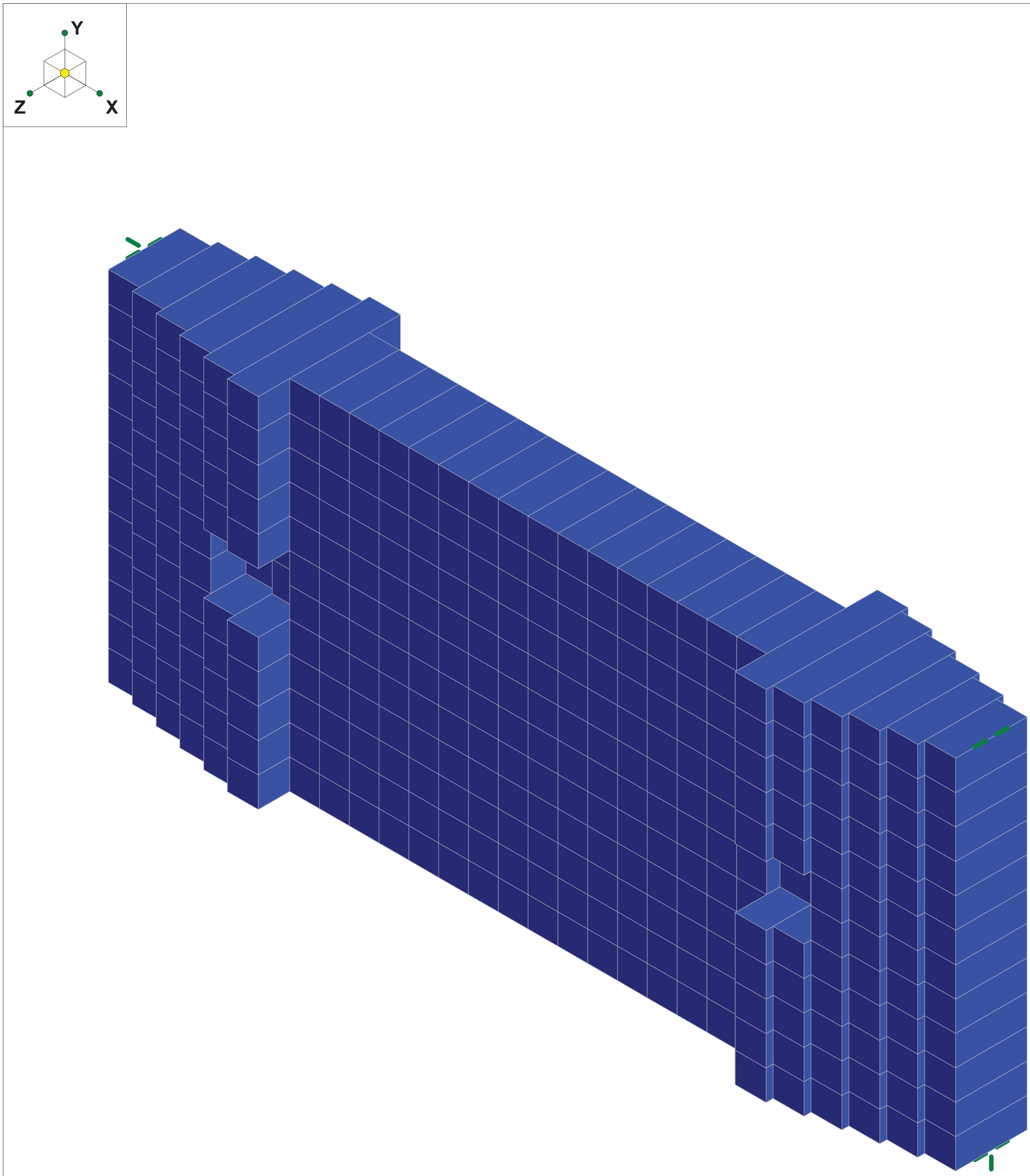
	Thickness at Joint (in)	Plate Thickness (in)
1	3.25	
2	3.96	3.60
3	4.67	4.31
4	5.38	5.02
5	6.08	5.73
6	6.79	6.44
7	7.50	7.15



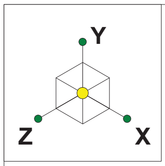


6-28-P and 6-28-HDP Rear Shell

Delta Engineers,Inc	6-28-P and 6-28-HDP	SK - 1
YL		Oct 17, 2020 at 4:03 PM
2020.548.001		6-28-P and 6-28-HDP.r3d



Delta Engineers,Inc	6-28-P and 6-28-HDP	SK - 2
YL		Oct 17, 2020 at 4:04 PM
2020.548.001		6-28-P and 6-28-HDP.r3d



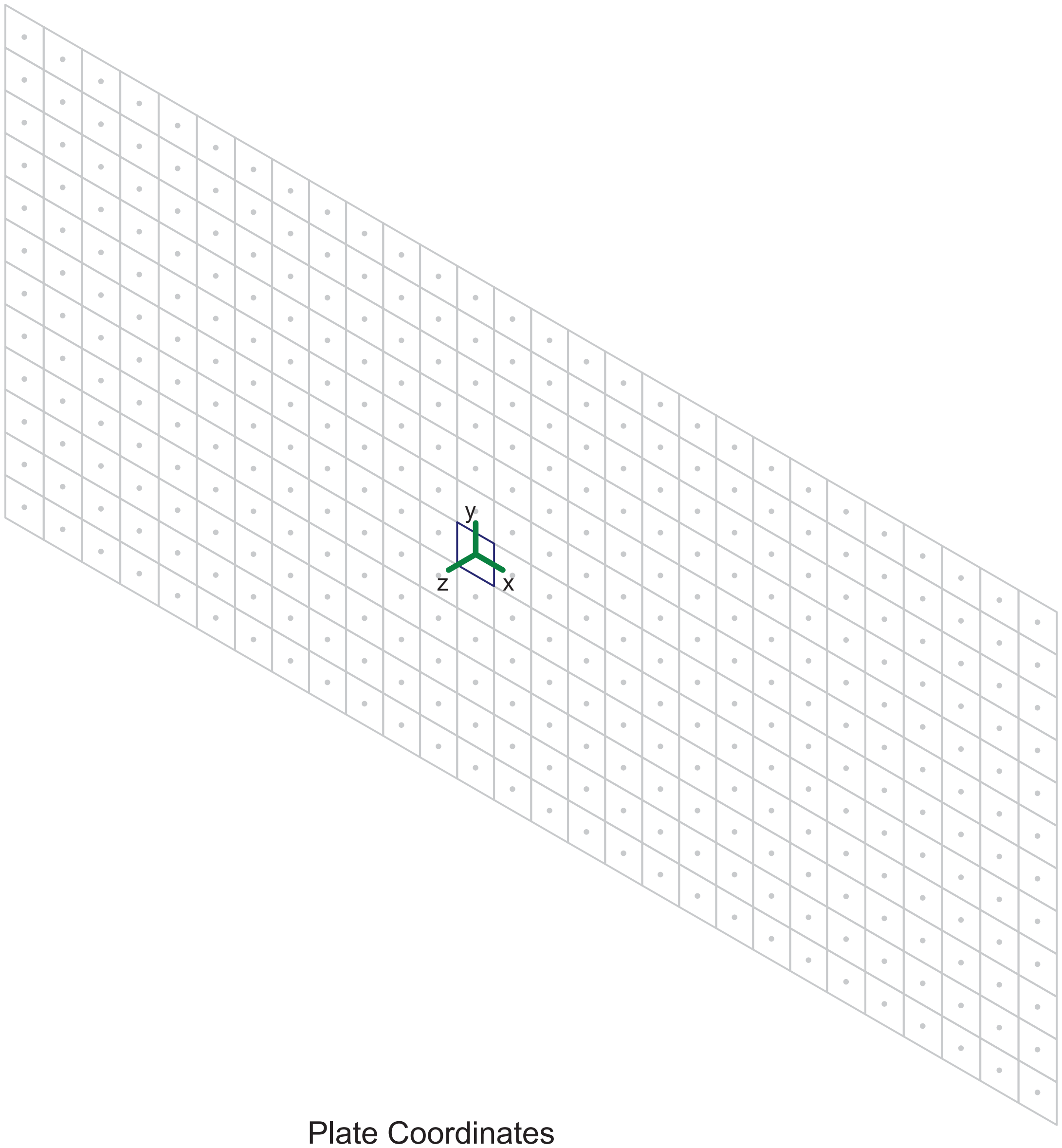


Plate Coordinates

Delta Engineers,Inc	6-28-P and 6-28-HDP	SK - 3
YL		Oct 17, 2020 at 4:05 PM
2020.548.001		6-28-P and 6-28-HDP.r3d

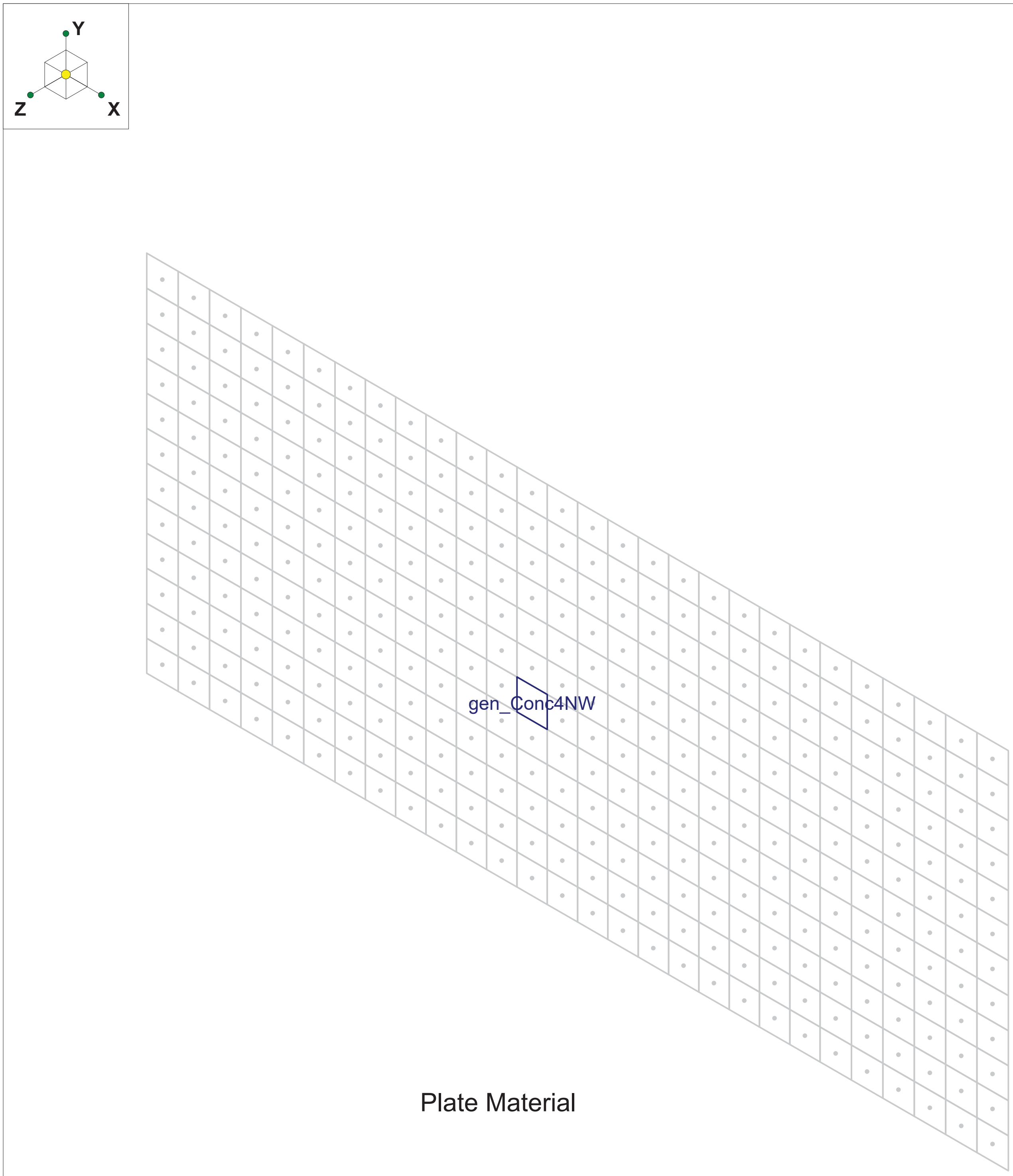


Plate Material

Delta Engineers,Inc	6-28-P and 6-28-HDP	SK - 4
YL		Oct 17, 2020 at 4:05 PM
2020.548.001		6-28-P and 6-28-HDP.r3d

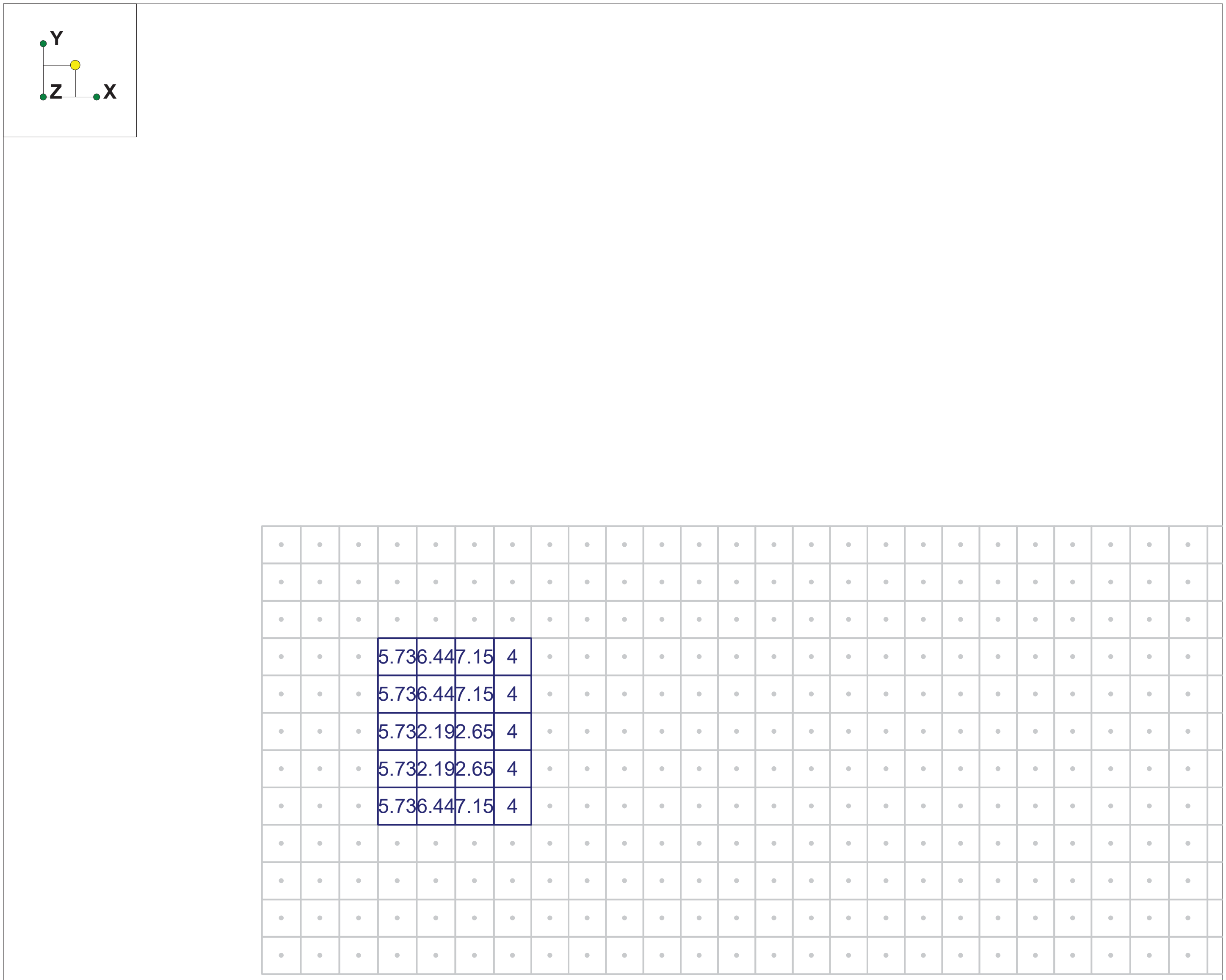
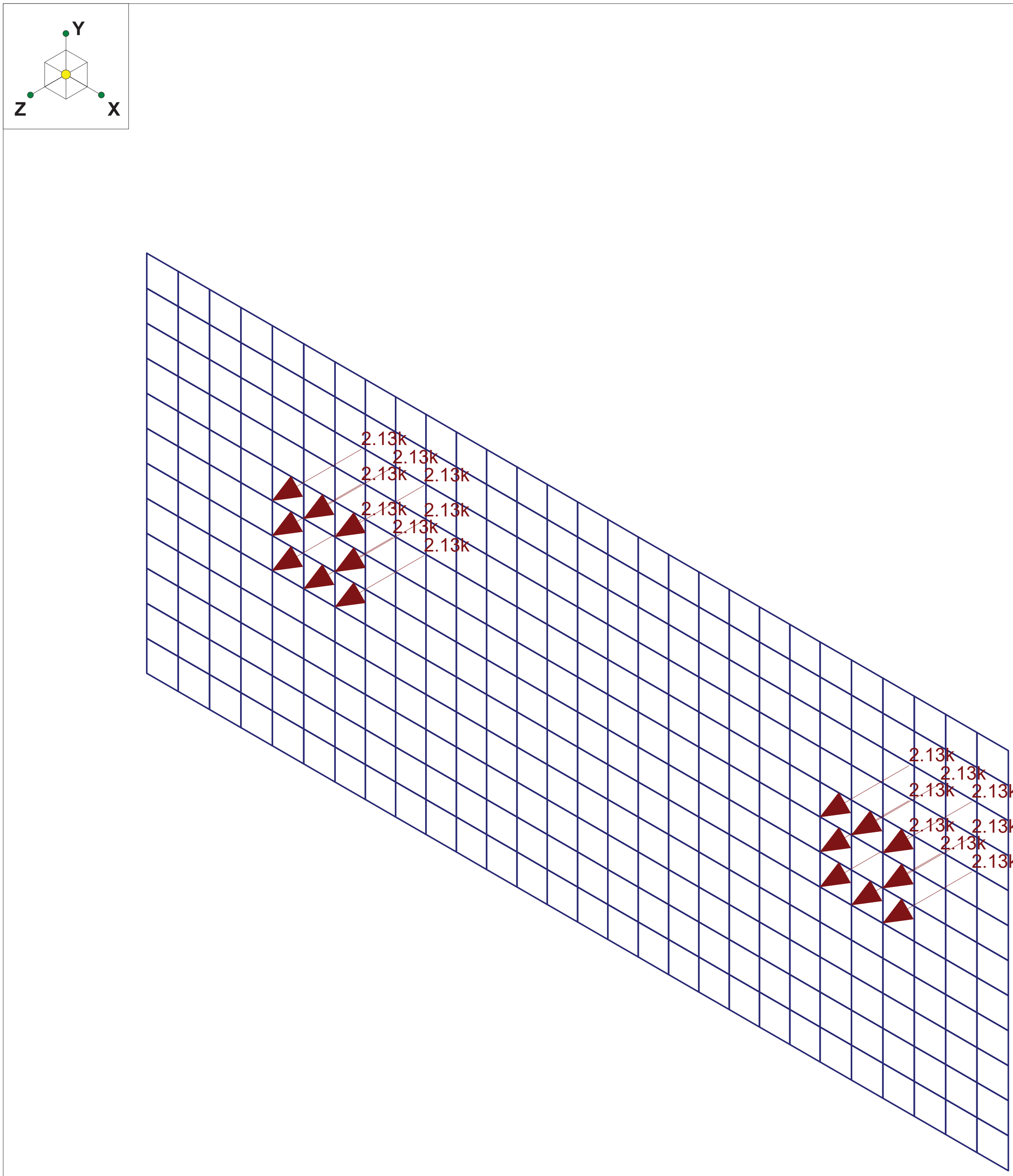


Plate Thickness

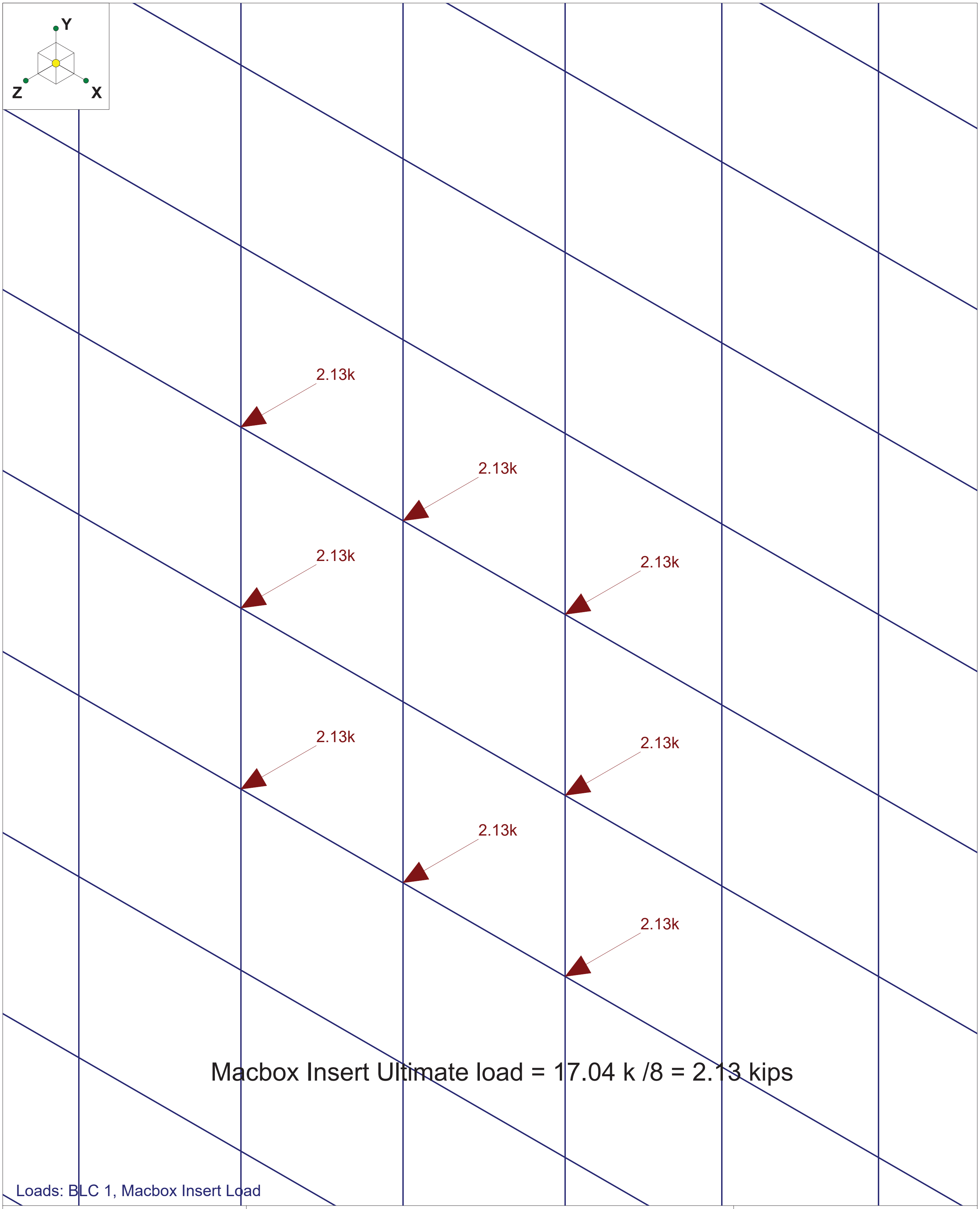
Delta Engineers,Inc	6-28-P and 6-28-HDP	SK - 5
YL		Oct 17, 2020 at 4:07 PM
2020.548.001		6-28-P and 6-28-HDP.r3d



Macbox Insert Ultimate load = 17.04 k /8 = 2.13 kips

Loads: BLC 1, Macbox Insert Load

Delta Engineers,Inc	6-28-P and 6-28-HDP	SK - 6
YL		Oct 17, 2020 at 4:25 PM
2020.548.001		6-28-P and 6-28-HDP.r3d



Delta Engineers,Inc	6-28-P and 6-28-HDP	SK - 7
YL		Oct 17, 2020 at 4:26 PM
2020.548.001		6-28-P and 6-28-HDP.r3d

General Material Properties

	Label	E [ksi]	G [ksi]	Nu	Therm (/1E5 F)	Density[k/ft^3]
1	gen_Conc3NW	3155	1372	.15	.6	.145
2	gen_Conc4NW	3644	1584	.15	.6	.145
3	gen_Conc3LW	2085	906	.15	.6	.11
4	gen_Conc4LW	2408	1047	.15	.6	.11
5	gen_Alum	10600	4077	.3	1.29	.173
6	gen_Steel	29000	11154	.3	.65	.49
7	RIGID	1e+6		.3	0	0

Basic Load Cases

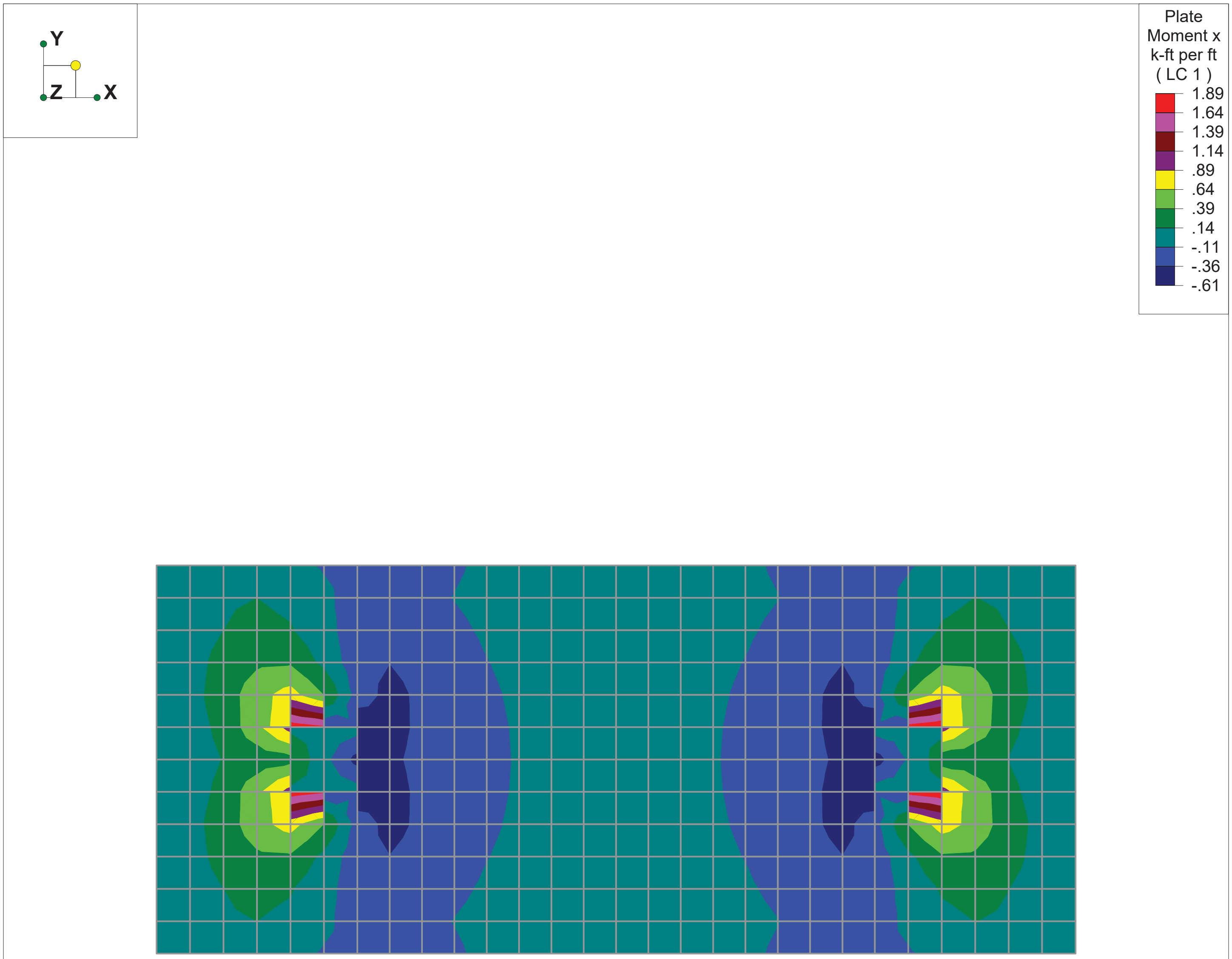
	BLC Description	Category	X Gravity	Y Gravity	Z Gravity	Joint	Point	Distribut...	Area(M...	Surface...
1	Macbox Insert Load	None		-1		16				

Joint Loads and Enforced Displacements (BLC 1 : Macbox Insert Load)

	Joint Label	L,D,M	Direction	Magnitude[(k,k-ft), (in,rad), (k*s^2/ft, k*s^2*ft)]
1	N91	L	Z	2.13
2	N92	L	Z	2.13
3	N113	L	Z	2.13
4	N114	L	Z	2.13
5	N134	L	Z	2.13
6	N136	L	Z	2.13
7	N137	L	Z	2.13
8	N144	L	Z	2.13
9	N146	L	Z	2.13
10	N147	L	Z	2.13
11	N192A	L	Z	2.13
12	N193A	L	Z	2.13
13	N194A	L	Z	2.13
14	N202A	L	Z	2.13
15	N203A	L	Z	2.13
16	N204A	L	Z	2.13

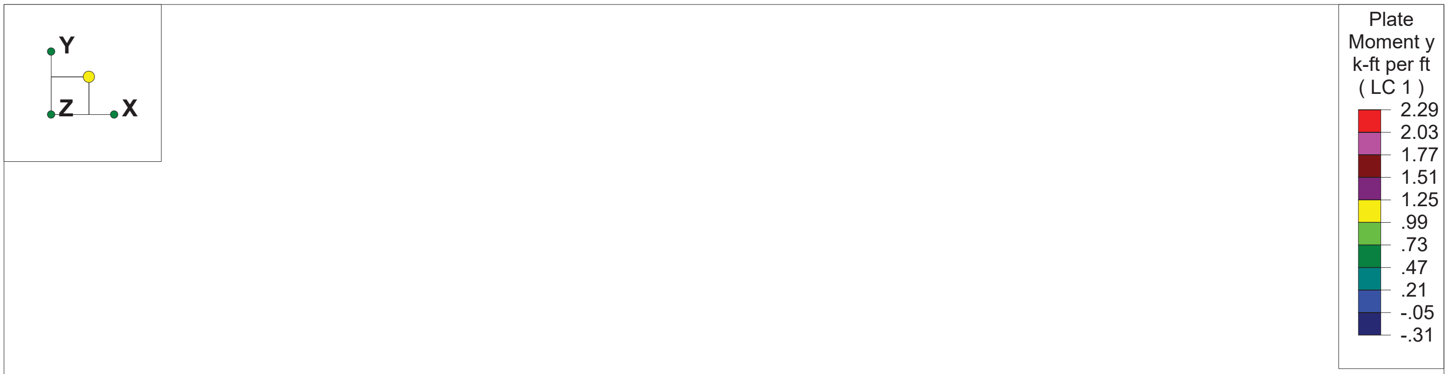
Load Combinations

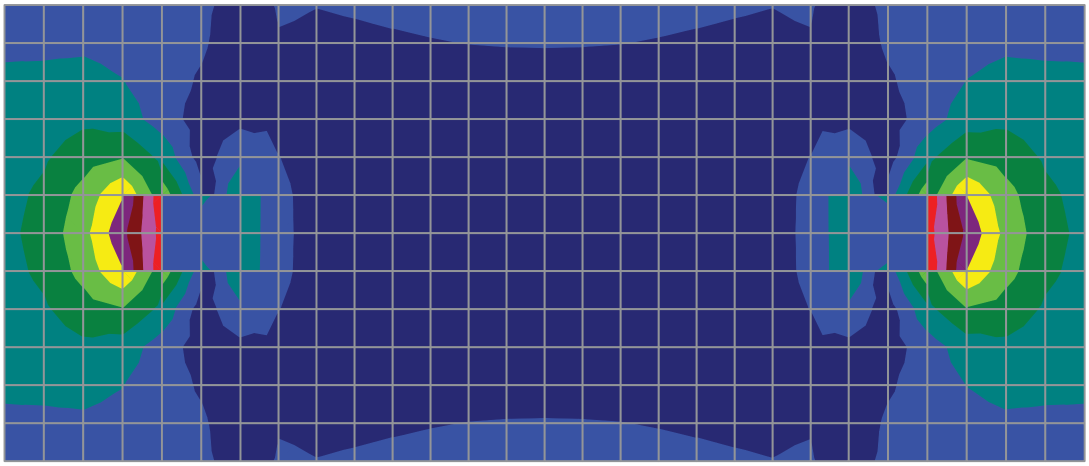
	Description	S...	P...	S...	B...	Factor	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...
1	Macbox Insert Ultimate Load	Y...			1	1																		



Results for LC 1, Macbox Insert Ultimate Load

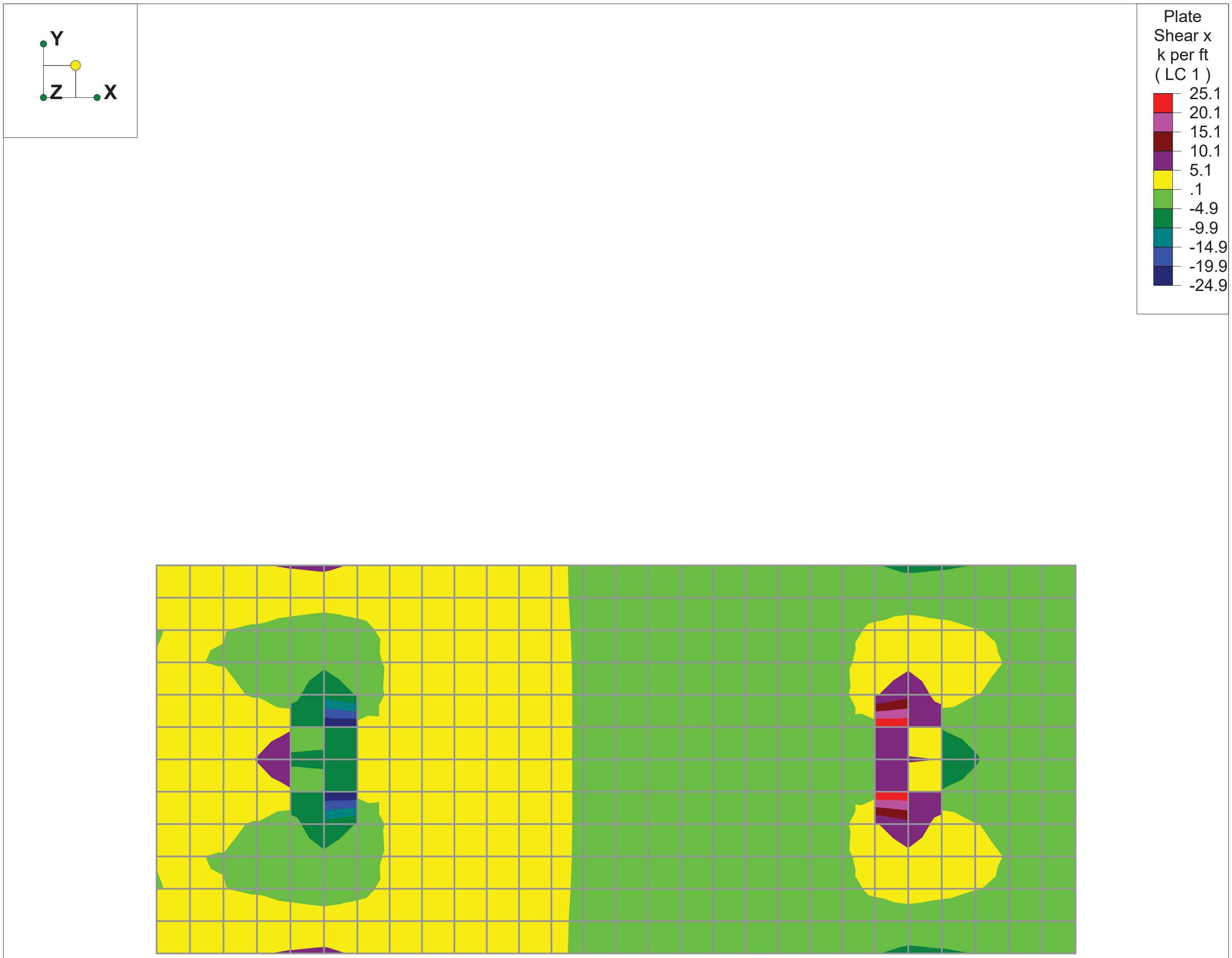
Delta Engineers,Inc	6-28-P and 6-28-HDP	SK - 8
YL		Oct 17, 2020 at 4:32 PM
2020.548.001		6-28-P and 6-28-HDP.r3d





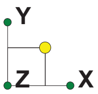
Results for LC 1, Macbox Insert Ultimate Load

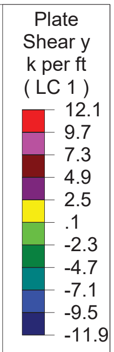
Delta Engineers,Inc	6-28-P and 6-28-HDP	SK - 9
YL		Oct 17, 2020 at 4:42 PM
2020.548.001		6-28-P and 6-28-HDP.r3d

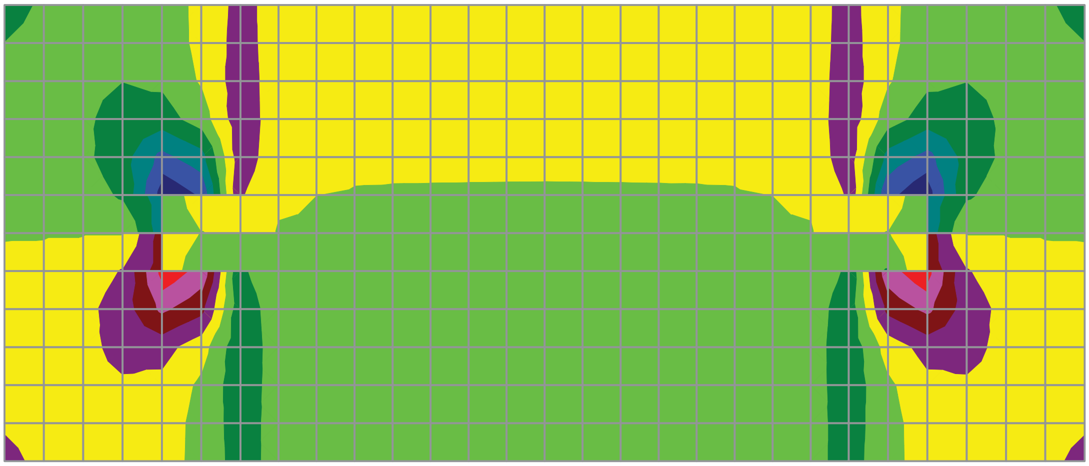


Results for LC 1, Macbox Insert Ultimate Load

Delta Engineers,Inc	6-28-P and 6-28-HDP	SK - 10
YL		Oct 17, 2020 at 4:43 PM
2020.548.001		6-28-P and 6-28-HDP.r3d







Results for LC 1, Macbox Insert Ultimate Load

Delta Engineers,Inc	6-28-P and 6-28-HDP	SK - 11
YL		Oct 17, 2020 at 4:44 PM
2020.548.001		6-28-P and 6-28-HDP.r3d

Plate Forces (per ft) (By Combination)

Max. Ultimate Mx

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P169A	7.402	10.236	1.295	.412	-.122	0	-.057	0
2	1	P158A	7.402	-10.236	1.295	.412	.122	0	-.035	0
3	1	P120	-7.161	10.181	1.257	.416	.13	0	-.058	0
4	1	P109A	-7.161	-10.181	1.257	.416	-.13	0	-.036	0
5	1	P160B	-1.77	-7.271	.788	.871	-.179	0	-.041	0
6	1	P171A	-1.77	7.271	.788	.871	.179	0	-.064	0
7	1	P107	1.816	-7.172	.778	.873	.161	0	-.041	0
8	1	P118	1.816	7.172	.778	.873	-.161	0	-.065	0
9	1	P109	6.36	-3.804	.616	1.974	.33	0	-.062	0
10	1	P116	6.36	3.804	.616	1.974	-.33	0	-.071	0
11	1	P162A	-6.424	-3.999	.582	2.001	-.364	0	-.063	0
12	1	P169B	-6.424	3.999	.582	2.001	.364	0	-.072	0
13	1	P289	-1.2	-1.652	-.576	-.013	-.252	0	-.045	0
14	1	P263	-1.2	1.652	-.576	-.013	.252	0	-.03	0
15	1	P241A	1.198	1.643	-.575	-.013	-.251	0	-.029	0
16	1	P267	1.198	-1.643	-.575	-.013	.251	0	-.045	0
17	1	P178B	1.241	4.148	.564	.322	-.296	0	-.069	0
18	1	P153A	1.241	-4.148	.564	.322	.296	0	-.03	0
19	1	P100	-1.213	-4.125	.554	.328	-.298	0	-.03	0
20	1	P125	-1.213	4.125	.554	.328	.298	0	-.07	0

Approximate Cracking Moment = 5*4000^0.5*12*6.44^2/6/12000=2.18 k-ft/ft, OK

See following pages for plate thickness information.

Plate Primary Data

	Label	A Joint	B Joint	C Joint	D Joint	Material	Thickness[in]
33	P109A	N87	N128	N136	N134	gen_Conc4NW	6.44
34	P110	N128	N88	N137	N136	gen_Conc4NW	7.15
35	P111	N134	N136	N138	N91	gen_Conc4NW	2.19
36	P112	N136	N137	N92	N138	gen_Conc4NW	2.65
37	P112A	N89	N132	N140	N139	gen_Conc4NW	3.6
38	P113	N132	N90	N141	N140	gen_Conc4NW	4.31
39	P114	N139	N140	N142	N93	gen_Conc4NW	3.6
40	P115	N140	N141	N94	N142	gen_Conc4NW	4.31
41	P115A	N90	N135	N143	N141	gen_Conc4NW	5.02
42	P116	N135	N91	N144	N143	gen_Conc4NW	5.73
43	P117	N141	N143	N145	N94	gen_Conc4NW	5.02
44	P118	N143	N144	N95	N145	gen_Conc4NW	5.73
45	P118A	N91	N138	N146	N144	gen_Conc4NW	2.19
46	P119	N138	N92	N147	N146	gen_Conc4NW	2.65
47	P120	N144	N146	N148	N95	gen_Conc4NW	6.44

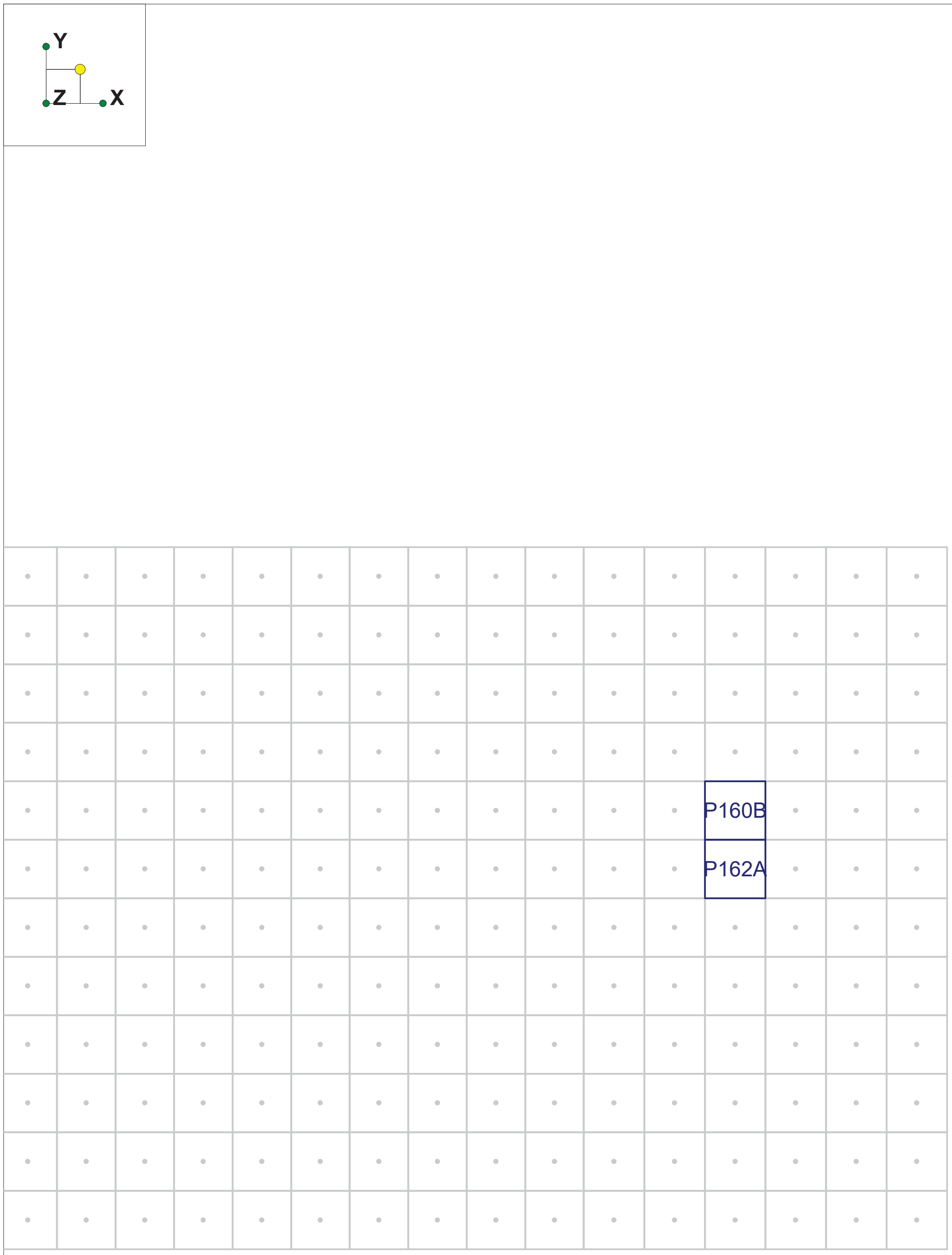
Plate Primary Data

	Label	A Joint	B Joint	C Joint	D Joint	Material	Thickness[in]
98	P158A	N185A	N110	N194A	N193A	gen_Conc4NW	6.44
99	P159A	N192A	N193A	N195A	N113	gen_Conc4NW	2.65
100	P160A	N193A	N194A	N114	N195A	gen_Conc4NW	1.94
101	P160B	N110	N188A	N196A	N194A	gen_Conc4NW	5.73
102	P161A	N188A	N111	N197A	N196A	gen_Conc4NW	5.02
103	P162A	N194A	N196A	N198A	N114	gen_Conc4NW	5.73
104	P163A	N196A	N197A	N115	N198A	gen_Conc4NW	5.02
105	P163B	N111	N191A	N199A	N197A	gen_Conc4NW	4.31
106	P164A	N191A	N112	N200A	N199A	gen_Conc4NW	3.6
107	P165A	N197A	N199A	N201A	N115	gen_Conc4NW	4.31
108	P166A	N199A	N200A	N116	N201A	gen_Conc4NW	3.6
109	P166B	N113	N195A	N203A	N202A	gen_Conc4NW	2.65
110	P167A	N195A	N114	N204A	N203A	gen_Conc4NW	1.94
111	P168A	N202A	N203A	N205A	N117	gen_Conc4NW	7.15
112	P169A	N203A	N204A	N118	N205A	gen_Conc4NW	6.44

Plate Forces (per ft) (By Combination)

Max. Ultimate My

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P162A	-6.424	-3.999	.582	2.001	-.364	0	-.063	0
2	1	P169B	-6.424	3.999	.582	2.001	.364	0	-.072	0
3	1	P109	6.36	-3.804	.616	1.974	.33	0	-.062	0
4	1	P116	6.36	3.804	.616	1.974	-.33	0	-.071	0
5	1	P163A	-2.297	-1.079	.251	1.159	-.059	0	-.044	0
6	1	P170A	-2.297	1.079	.251	1.159	.059	0	-.051	0
7	1	P108	2.312	-1.086	.264	1.144	.051	0	-.045	0
8	1	P115A	2.312	1.086	.264	1.144	-.051	0	-.052	0
9	1	P107	1.816	-7.172	.778	.873	.161	0	-.041	0
10	1	P118	1.816	7.172	.778	.873	-.161	0	-.065	0
11	1	P160B	-1.77	-7.271	.788	.871	-.179	0	-.041	0
12	1	P171A	-1.77	7.271	.788	.871	.179	0	-.064	0
13	1	P161A	-1.391	-2.604	.314	.83	-.053	0	-.037	0
14	1	P172A	-1.391	2.604	.314	.83	.053	0	-.058	0
15	1	P106A	1.391	-2.588	.315	.828	.042	0	-.038	0
16	1	P117	1.391	2.588	.315	.828	-.042	0	-.059	0
17	1	P172B	-.894	.442	.088	.71	.009	0	-.041	0
18	1	P165A	-.894	-.442	.088	.71	-.009	0	-.035	0
19	1	P106	.905	-.445	.092	.705	.007	0	-.036	0
20	1	P113	.905	.445	.092	.705	-.007	0	-.042	0



Selected Plates for Max. Average Ultimate My

Delta Engineers,Inc	6-28-P and 6-28-HDP	SK - 13
YL		Oct 17, 2020 at 7:55 PM
2020.548.001		6-28-P and 6-28-HDP.r3d

Plate Forces (per ft) (By Combination)

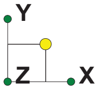
Selected Plates for Max. Average Ultimate My

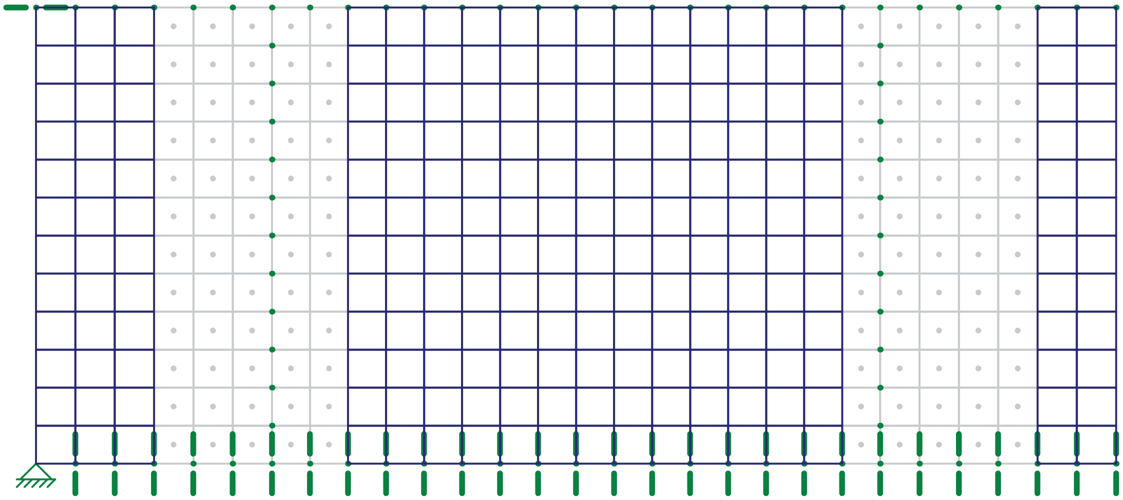
	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P160B	-1.77	-7.271	.788	.871	-.179	0	-.041	0
2	1	P162A	-6.424	-3.999	.582	2.001	-.364	0	-.063	0

Max. Average Ultimate My = 1.44 k-ft/ft

Approximate Cracking Moment = 5*4000^0.5*12*5.73^2/6/12000=1.73 k-ft/ft, OK

See previous pages for plate thickness information.





Selected Plates for Shear Results

Delta Engineers,Inc	6-28-P and 6-28-HDP	SK - 12
YL		Oct 17, 2020 at 4:54 PM
2020.548.001		6-28-P and 6-28-HDP.r3d

Plate Forces (per ft) (By Combination)

Max. Utlimate Qx

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P88B	2.822	-2.164	.131	.096	-.214	0	0	0
2	1	P135	2.822	2.164	.131	.096	.214	0	-.084	0
3	1	P108	2.312	-1.086	.264	1.144	.051	0	-.045	0
4	1	P115A	2.312	1.086	.264	1.144	-.051	0	-.052	0
5	1	P145B	-2.172	-2.094	.102	.101	.141	0	0	0
6	1	P192	-2.172	2.094	.102	.101	-.141	0	-.071	0
7	1	P86A	2.171	-2.098	.101	.102	-.142	.006	0	0
8	1	P133	2.171	2.098	.101	.102	.142	-.005	-.072	0
9	1	P214A	-1.544	1.271	-.195	-.042	.083	0	0	0
10	1	P336	-1.544	-1.271	-.195	-.042	-.083	0	-.068	0
11	1	P106A	1.391	-2.588	.315	.828	.042	0	-.038	0
12	1	P117	1.391	2.588	.315	.828	-.042	0	-.059	0
13	1	P85A	1.36	-2.429	.036	.094	-.061	.008	0	0
14	1	P132	1.36	2.429	.036	.094	.061	-.007	-.063	0
15	1	P193	-1.36	2.422	.036	.093	-.061	0	-.059	0
16	1	P146A	-1.36	-2.422	.036	.093	.061	0	0	0
17	1	P334	-1.005	-.901	-.14	-.042	-.038	0	-.069	0
18	1	P212	-1.005	.901	-.14	-.042	.038	0	0	0
19	1	P318	1.003	-.898	-.14	-.042	.038	0	-.069	0
20	1	P196A	1.003	.898	-.14	-.042	-.038	0	0	0

Approximate Plain Conc. Shear Capacity = 0.6*4/3*4000^0.5*12*5.02 = 3.05 kips, OK

Plate Forces (per ft) (By Combination)

Max. Ultimate Qy

	LC	Plate Label	Qx[k]	Qy[k]	Mx[k-ft]	My[k-ft]	Mxy[k-ft]	Fx[k]	Fy[k]	Fxy[k]
1	1	P99	.316	-2.778	.303	.484	-.134	0	-.028	0
2	1	P124A	.316	2.778	.303	.484	.134	0	-.064	0
3	1	P106A	1.391	-2.588	.315	.828	.042	0	-.038	0
4	1	P117	1.391	2.588	.315	.828	-.042	0	-.059	0
5	1	P85A	1.36	-2.429	.036	.094	-.061	.008	0	0
6	1	P132	1.36	2.429	.036	.094	.061	-.007	-.063	0
7	1	P146A	-1.36	-2.422	.036	.093	.061	0	0	0
8	1	P193	-1.36	2.422	.036	.093	-.061	0	-.059	0
9	1	P97A	-.021	-2.208	.226	.308	-.314	0	-.019	0
10	1	P126	-.021	2.208	.226	.308	.314	0	-.07	0
11	1	P88B	2.822	-2.164	.131	.096	-.214	0	0	0
12	1	P135	2.822	2.164	.131	.096	.214	0	-.084	0
13	1	P86A	2.171	-2.098	.101	.102	-.142	.006	0	0
14	1	P133	2.171	2.098	.101	.102	.142	-.005	-.072	0
15	1	P145B	-2.172	-2.094	.102	.101	.141	0	0	0
16	1	P192	-2.172	2.094	.102	.101	-.141	0	-.071	0
17	1	P90	.682	-1.926	.166	.225	-.378	0	-.011	0
18	1	P133A	.682	1.926	.166	.225	.378	0	-.077	0
19	1	P88A	.594	-1.676	.088	.24	-.223	0	-.009	0
20	1	P131	.594	1.676	.088	.24	.223	0	-.067	0

Approximate Plain Conc. Shear Capacity = 0.6*4/3*4000^0.5*12*5.02 = 3.05 kips, OK

JOB 2020.548.001

DESCRIPTION Macbox Insert Connection

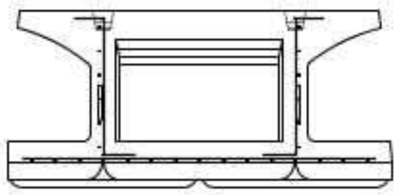
SHEET NO. OF SCALE

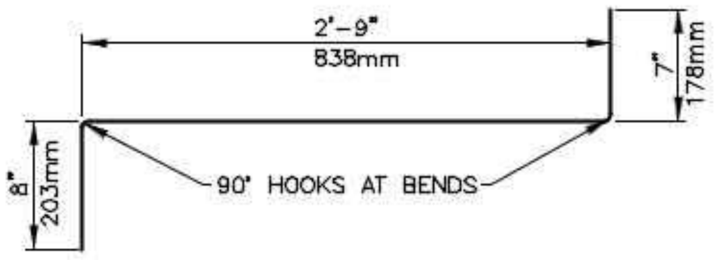
CALCULATED BY YL DATE 10/18/2020

CHECKED BY DATE

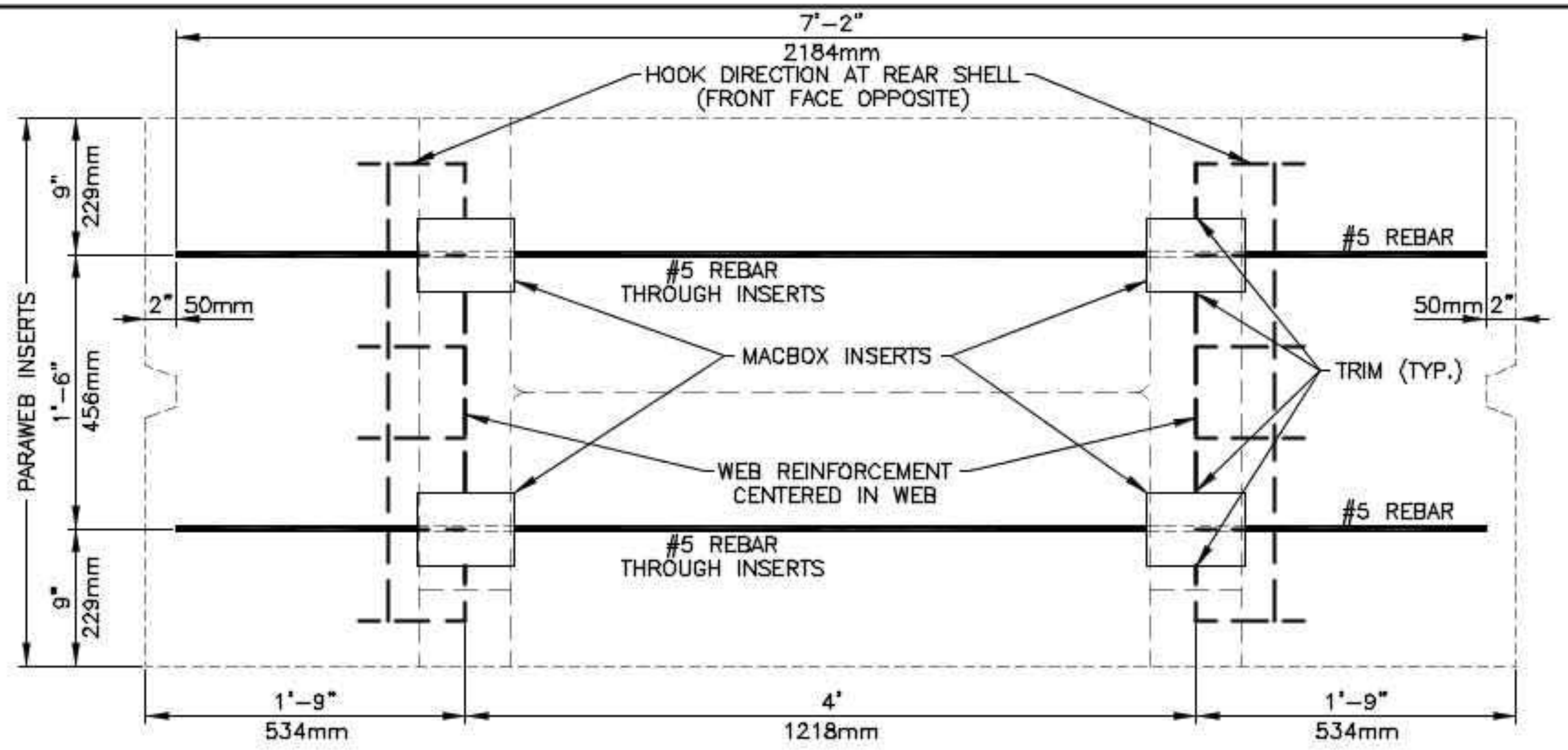
Paraweb/Macbox Insert Blocks Reinforcing Information

NOTES:
1. ALL MESH SHALL BE W8xW8-6x6 WWF PER ASTM A185/A497/A1064, GRADE 65 U.N.O.
2. ALL #5 BARS SHALL BE GRADE 60.
3. USE FOR PARAWEB MSE WALL IN TOP 36 FEET.

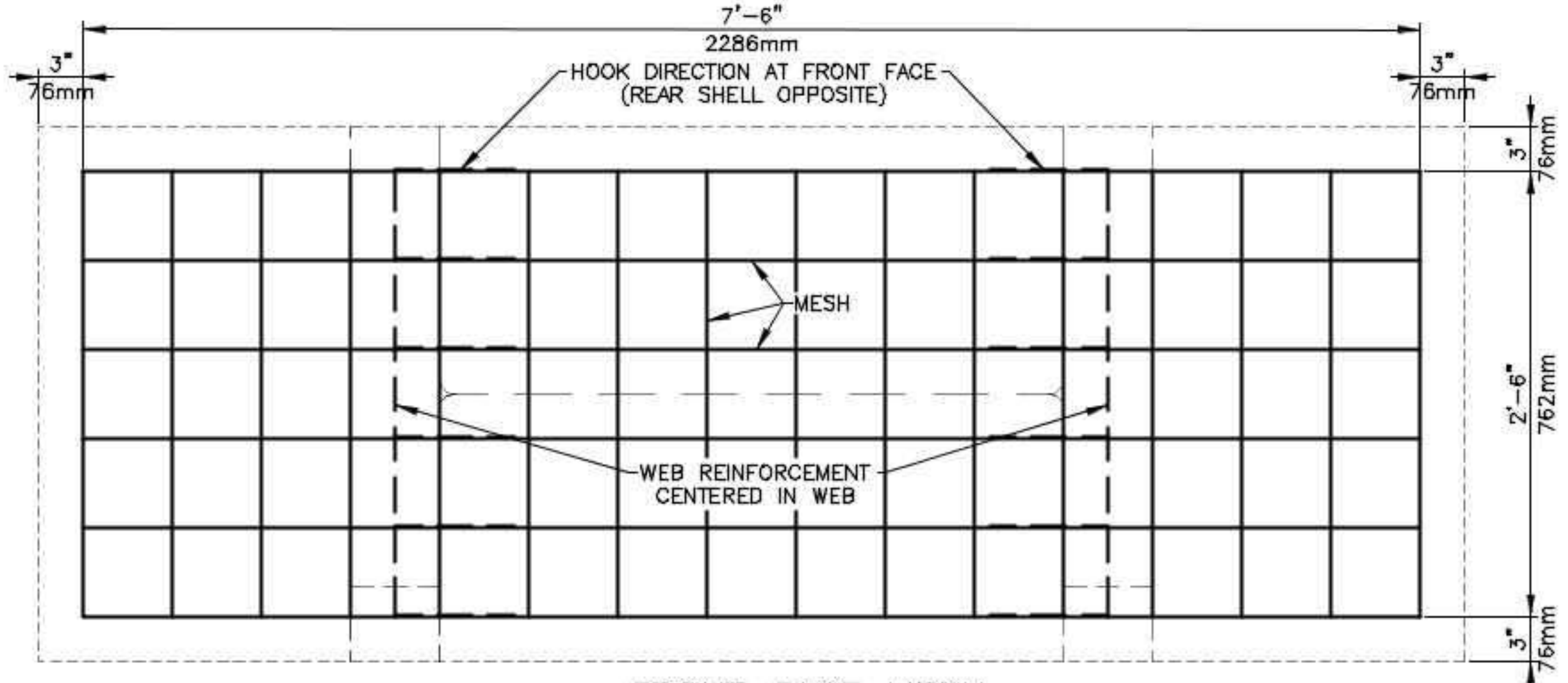




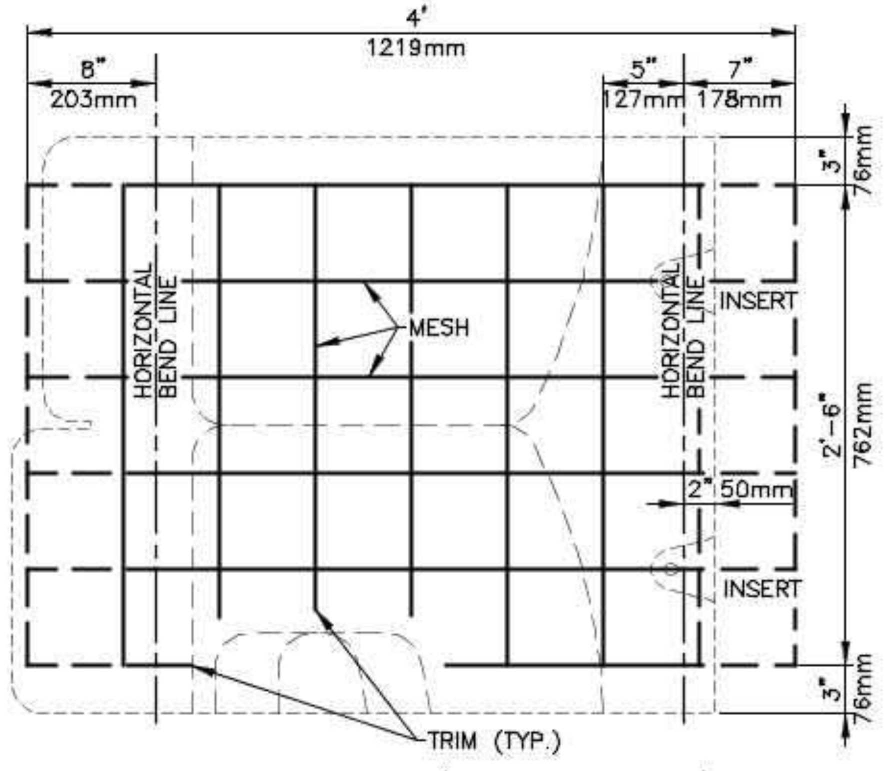
BENT WEB MESH – PLAN VIEW



REAR SHELL MESH w/PARAWEB INSERTS



FRONT FACE MESH



BENT WEB MESH (2 REQUIRED)

24SF PARAWEB UNIT (24SF-P) – MESH OPTION

NOT TO SCALE

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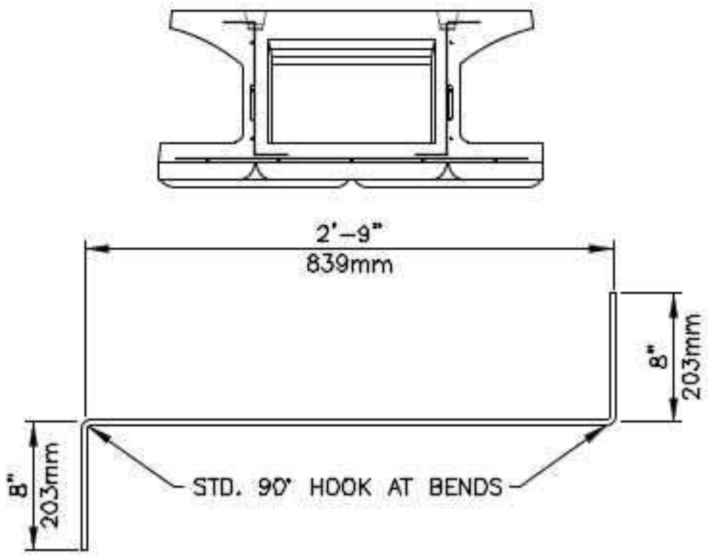
REINFORCING DETAILS
STONE STRONG SYSTEMS

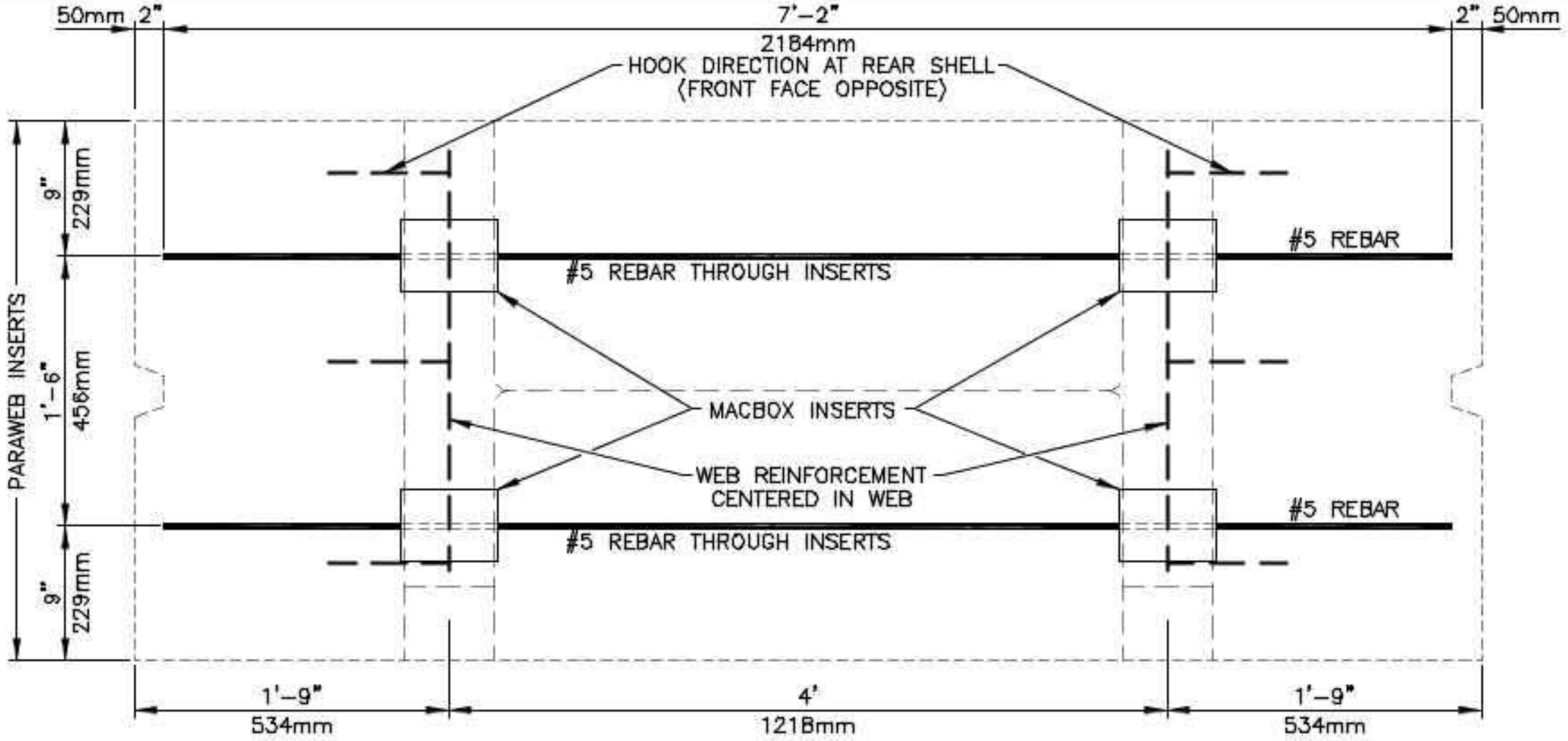
DATE: 12/16/19 | FILE: 07_24SF-P Mesh

NOTES:

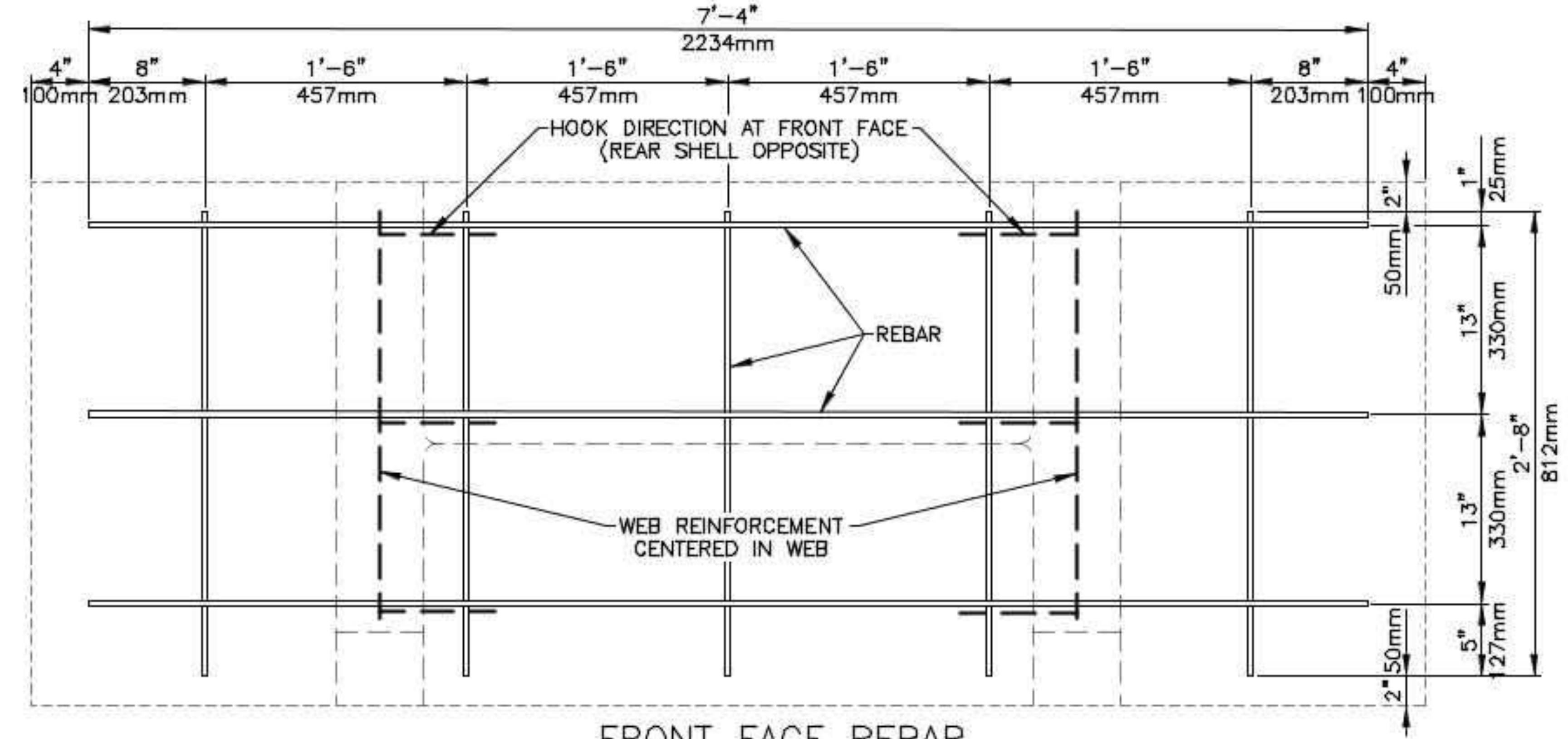
1. ALL STEEL SHALL BE #4 BARS, GRADE 60, U.N.O.
2. ALL #5 BARS SHALL BE GRADE 60.
3. USE FOR PARAWEB MSE WALL IN TOP 36 FEET.



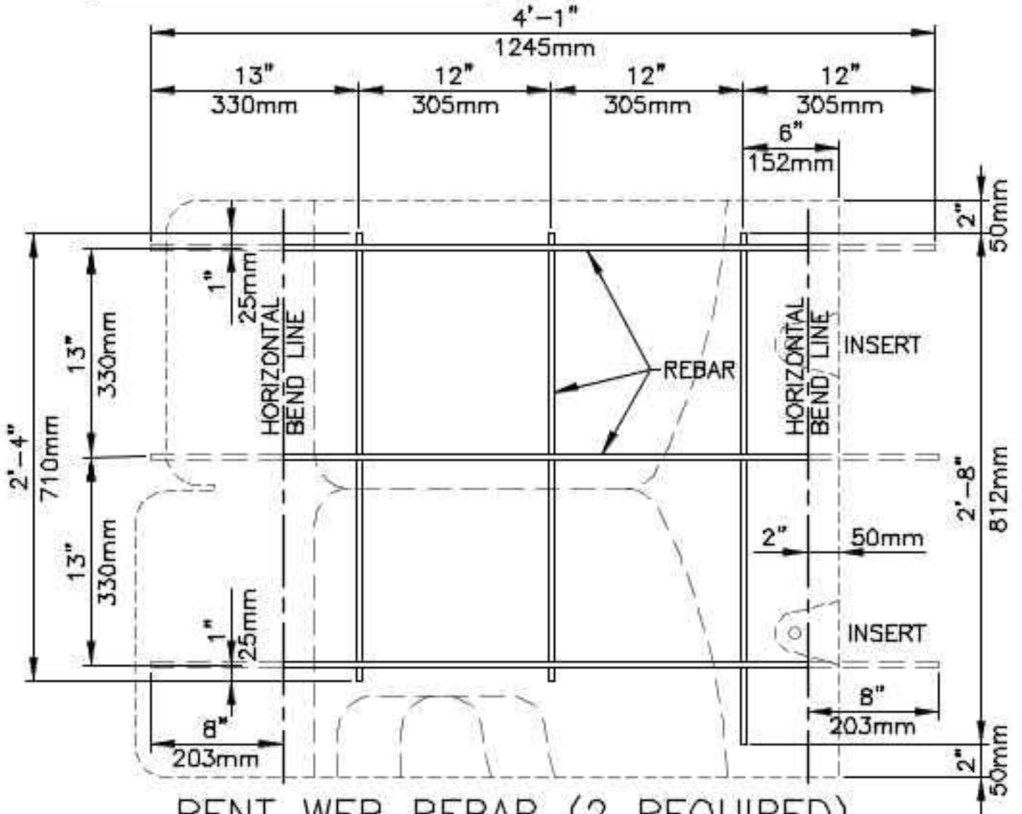
BENT WEB REBAR - PLAN VIEW



REAR SHELL REBAR



FRONT FACE REBAR



BENT WEB REBAR (2 REQUIRED)

24SF PARAWEB UNIT (24SF-P) - REBAR OPTION

NOT TO SCALE

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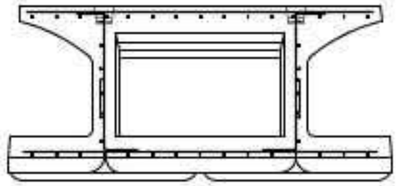
REINFORCING DETAILS

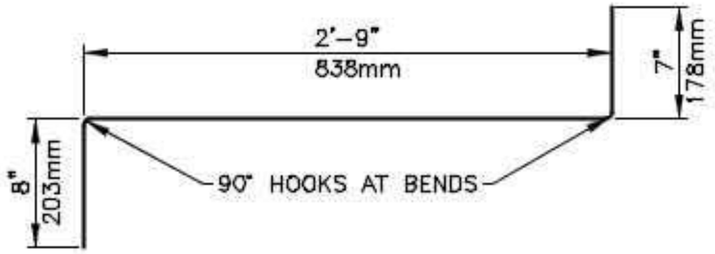
STONE STRONG SYSTEMS

DATE: 12/16/19	FILE: 08_24SF-P Rebar

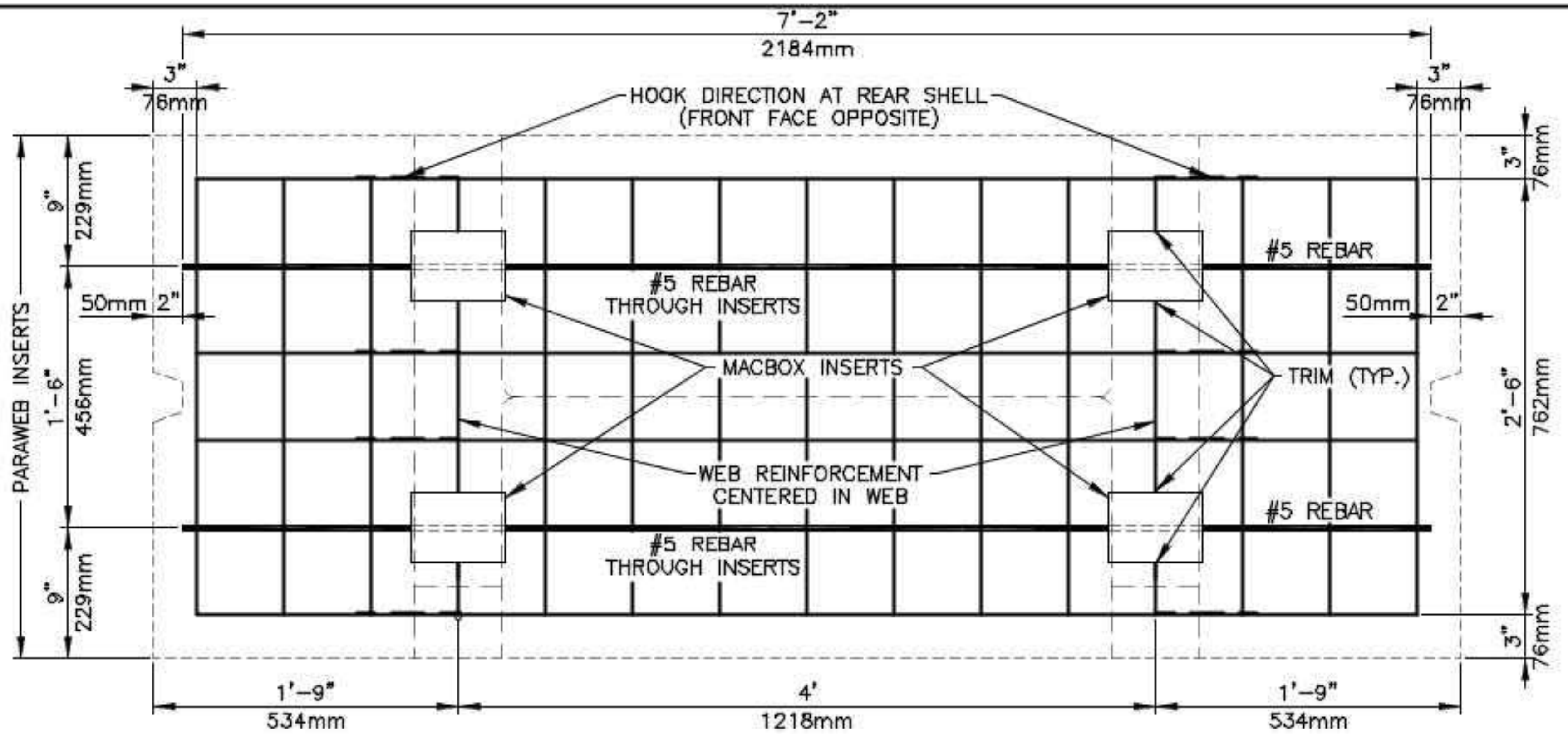
NOTES:

1. ALL MESH SHALL BE W8xW8-6x6 WWF PER ASTM A185/A497/A1064, GRADE 65 U.N.O.
2. ALL #5 BARS SHALL BE GRADE 60.
3. USE IN PARAWEB MSE WALL BETWEEN 36 AND 51 FEET BELOW TOP OF WALL.

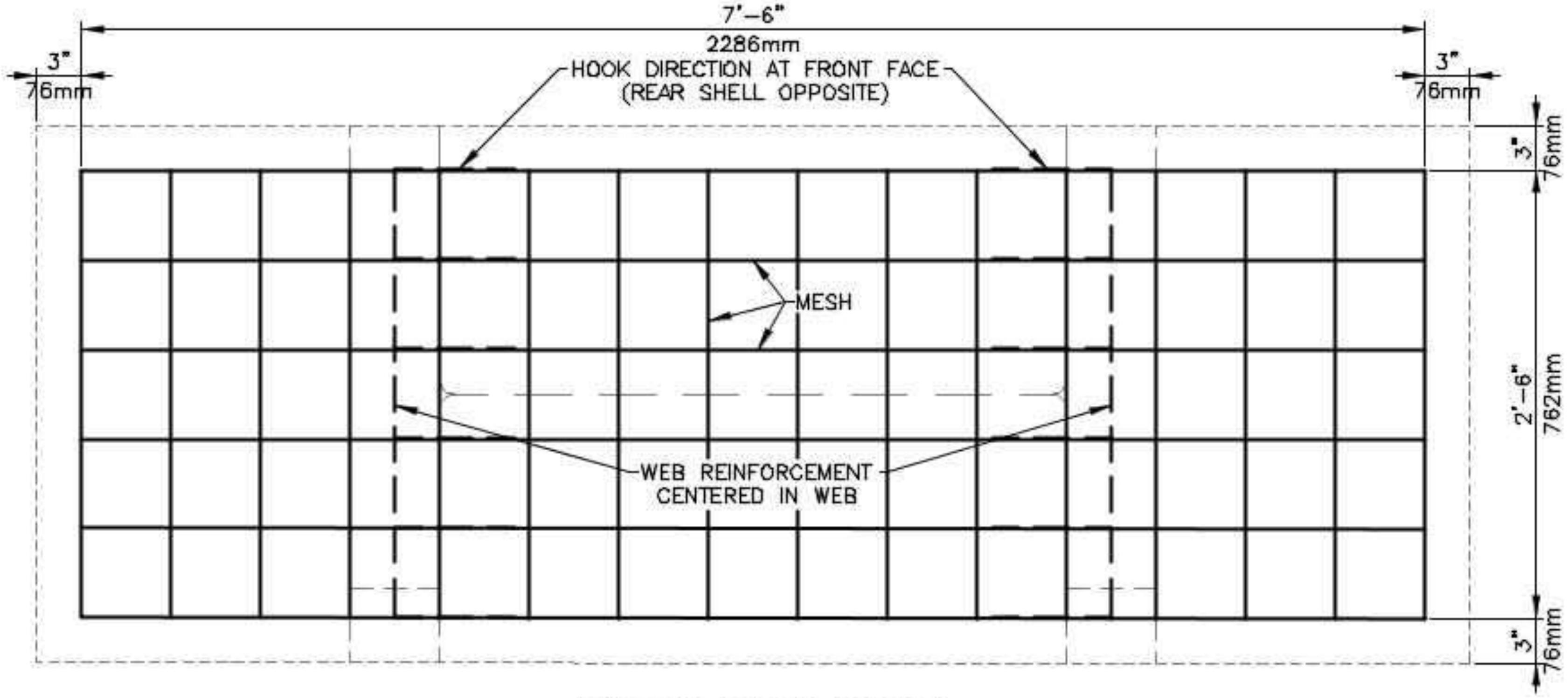




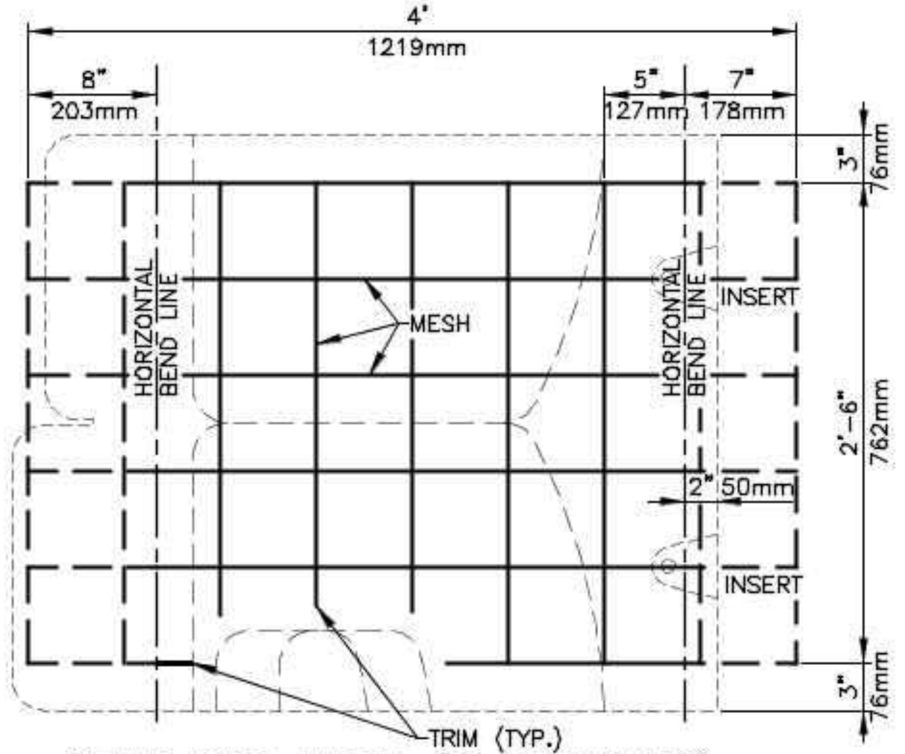
BENT WEB MESH – PLAN VIEW



REAR SHELL MESH w/PARAWEB INSERTS



FRONT FACE MESH



BENT WEB MESH (2 REQUIRED)

24SF HEAVY DUTY PARAWEB UNIT (24SF-HDP) – MESH OPTION

NOT TO SCALE

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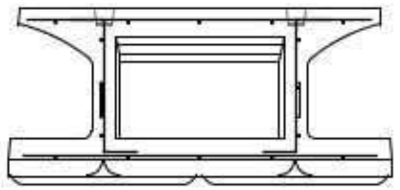
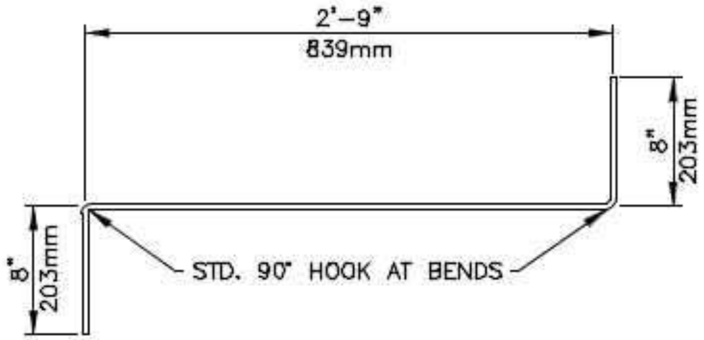
REINFORCING DETAILS
STONE STRONG SYSTEMS

DATE: 12/16/19 | FILE: 09_24SF-HDP Mesh

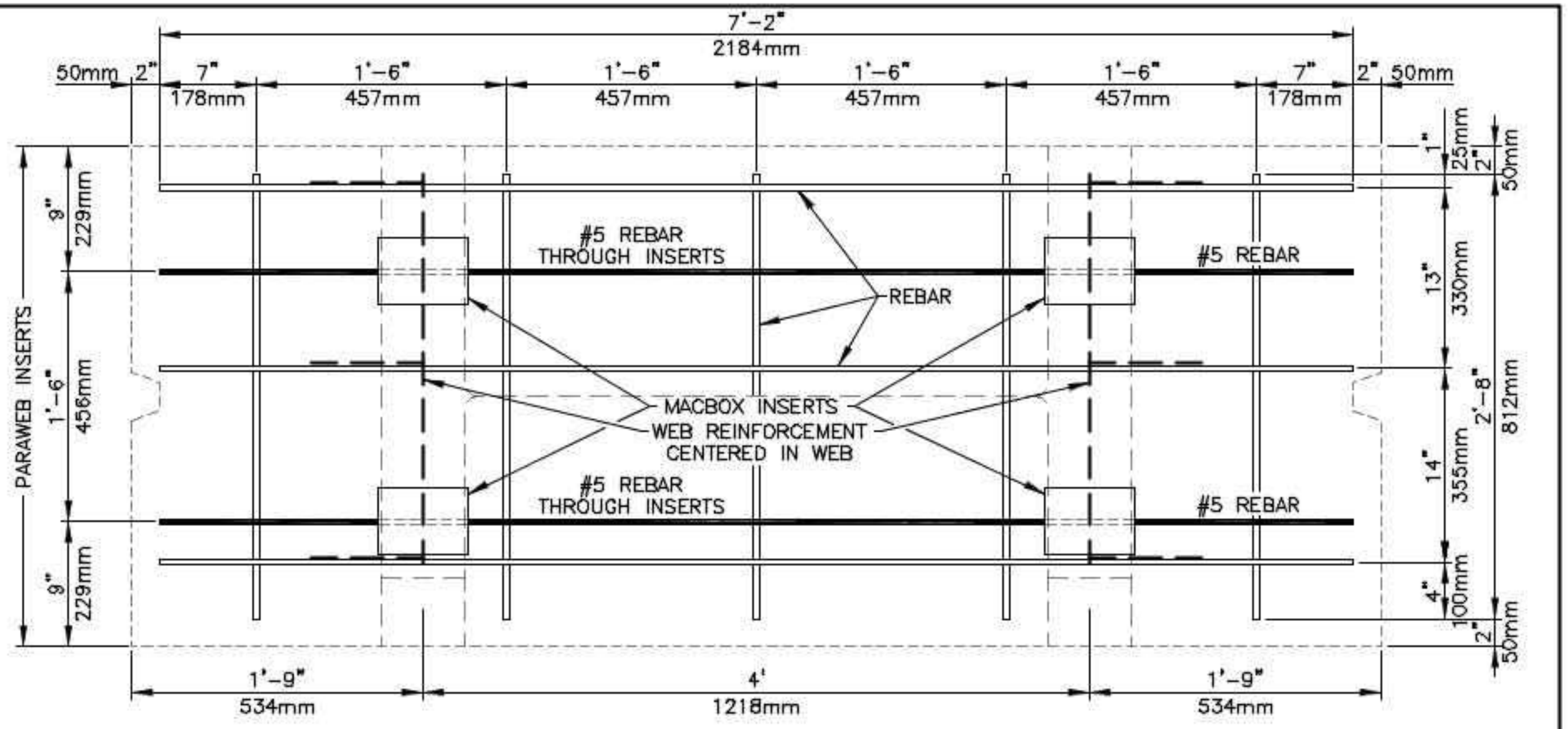
NOTES:

1. ALL STEEL SHALL BE #4 BARS, GRADE 60, U.N.O.
2. ALL #5 BARS SHALL BE GRADE 60.
3. USE IN PARAWEB MSE WALL BETWEEN 36 AND 51 FEET BELOW TOP OF WALL.

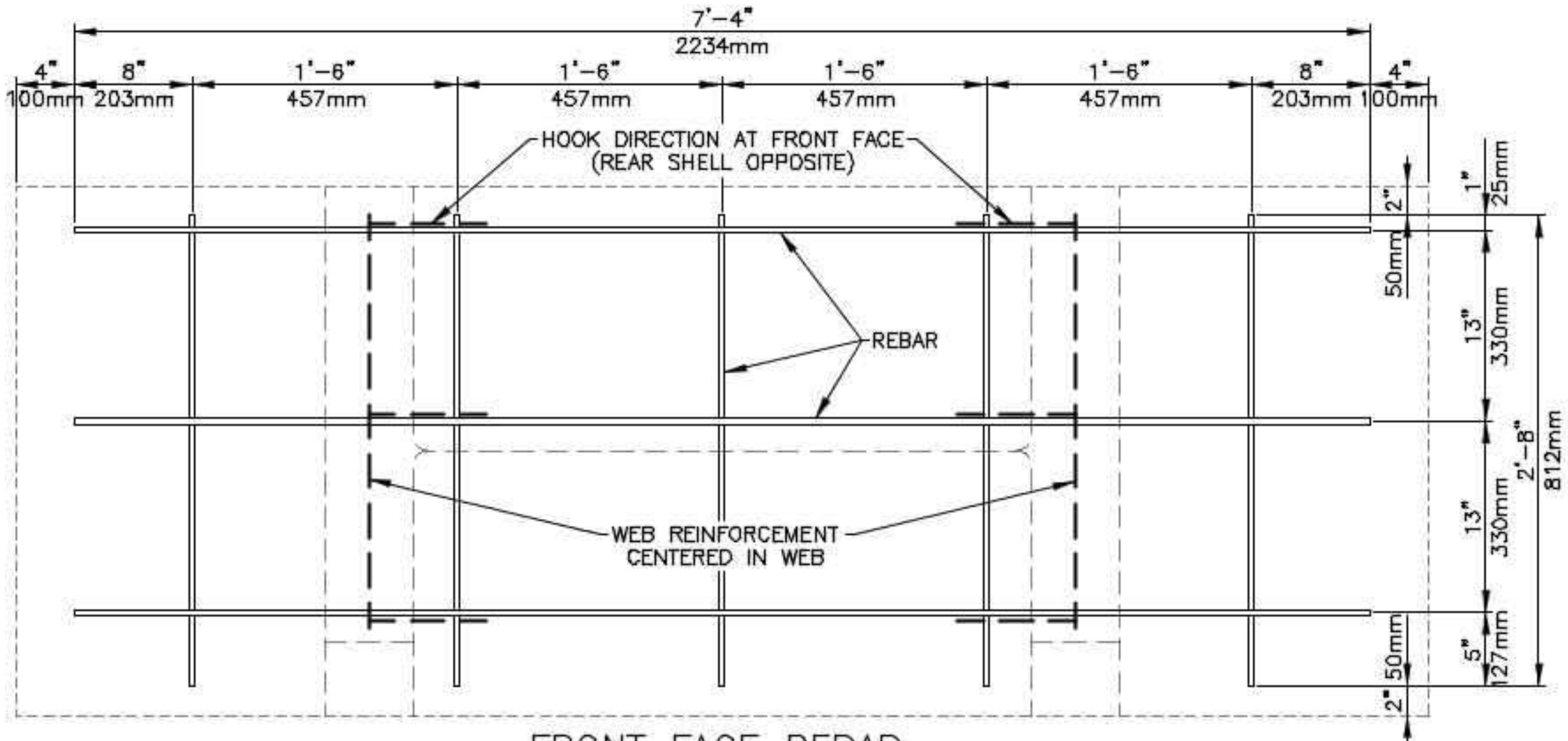




BENT WEB REBAR – PLAN VIEW



REAR SHELL REBAR



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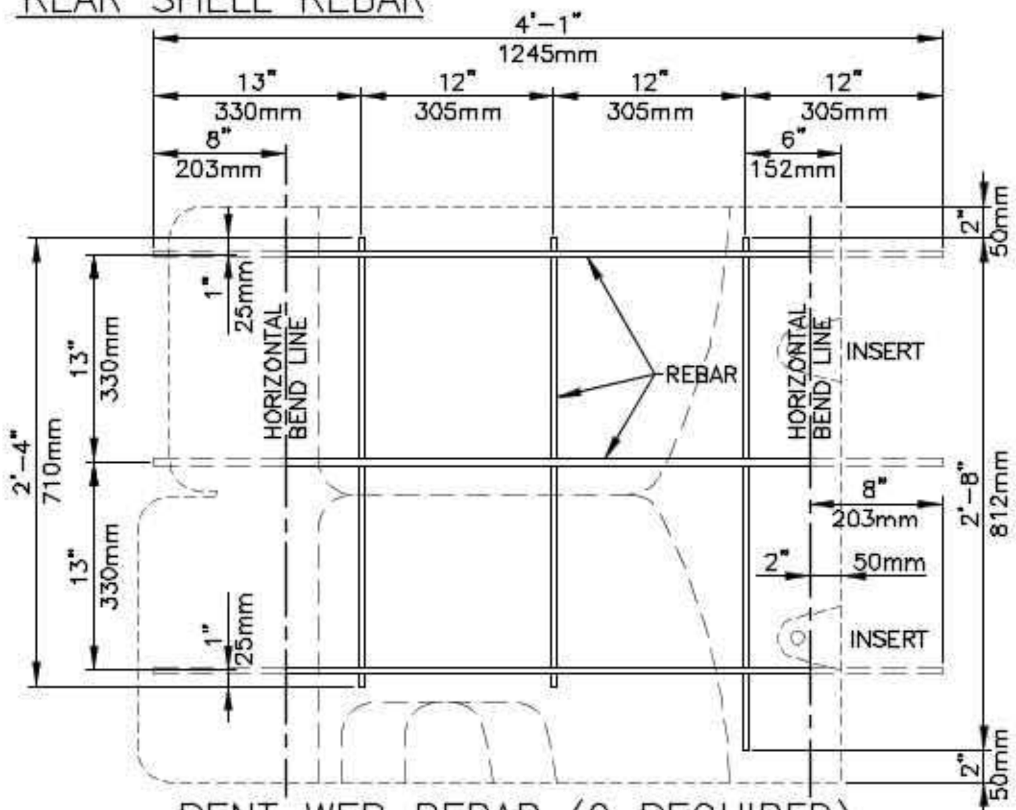

BENT WEB REBAR (2 REQUIRED)

24SF HEAVY DUTY PARAWEB UNIT (24SF-HDP) – REBAR OPTION

NOT TO SCALE

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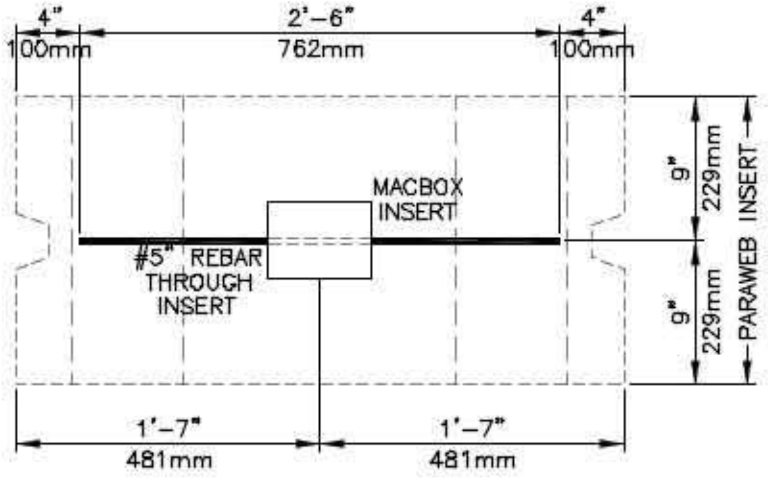
PROJECT
REINFORCING DETAILS
STONE STRONG SYSTEMS

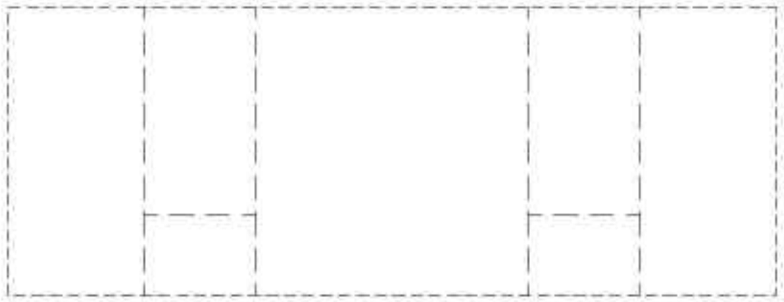
DATE: 12/16/19 FILE: 10_24SF-HDP Rebar

NOTES:

1. ALL #5 BARS SHALL BE GRADE 60.
2. USE IN PARAWEB MSE WALL IN TOP 12 FEET.
3. MAY ALSO BE USED IN BOTTOM COURSE ONLY OF PARAWEB MSE WALL USING 24SF UNITS ABOVE.



REAR SHELL



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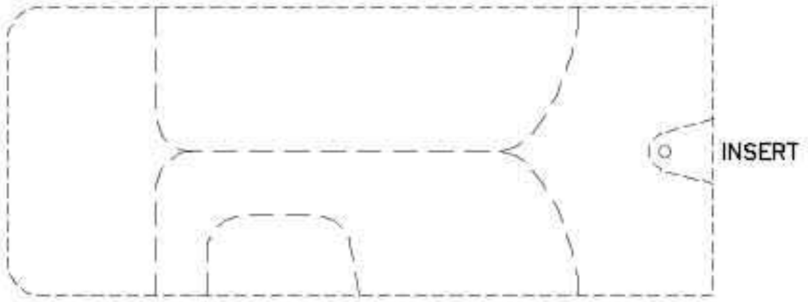

SIDE ELEVATION

6SF PARAWEB UNIT (6SF-P)

NOT TO SCALE

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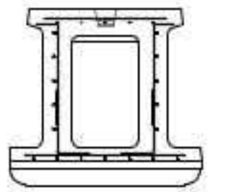
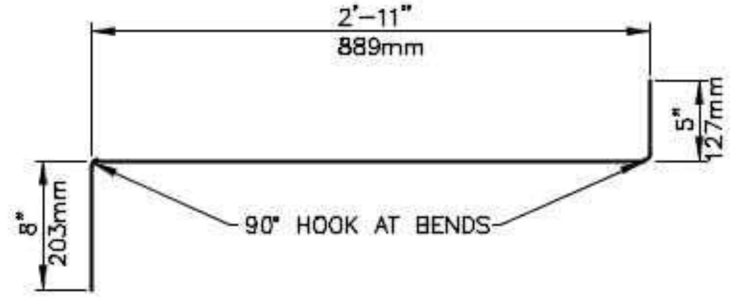
REINFORCING DETAILS
STONE STRONG SYSTEMS

DATE: 12/16/19 FILE: 11_6SF-P

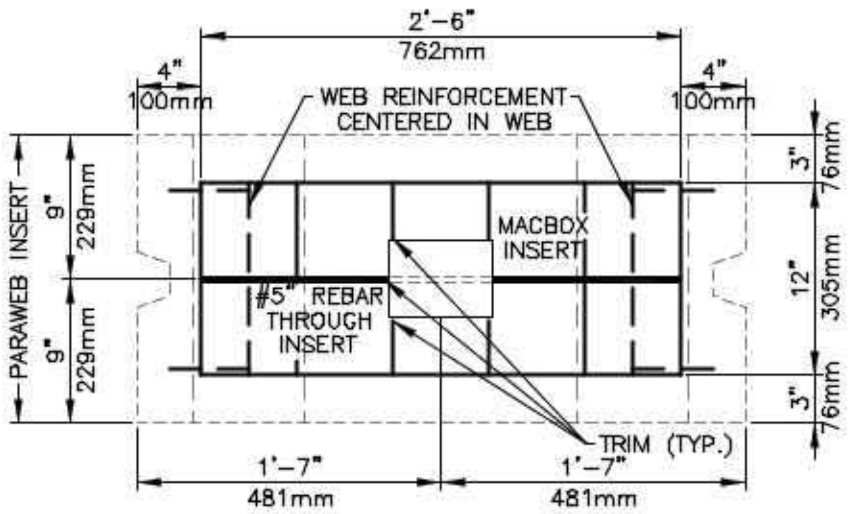
NOTES:

1. ALL MESH SHALL BE W8xW8-6x6 WWF PER ASTM A185/A497/A1064, GRADE 65 U.N.O.
2. ALL #5 BARS SHALL BE GRADE 60.
3. USE IN PARAWEB MSE WALL BETWEEN 12 AND 51 FEET BELOW TOP OF WALL.

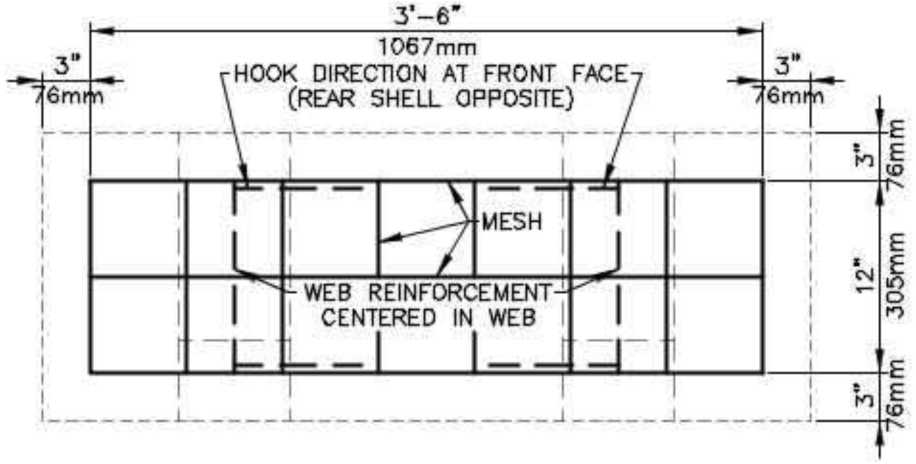




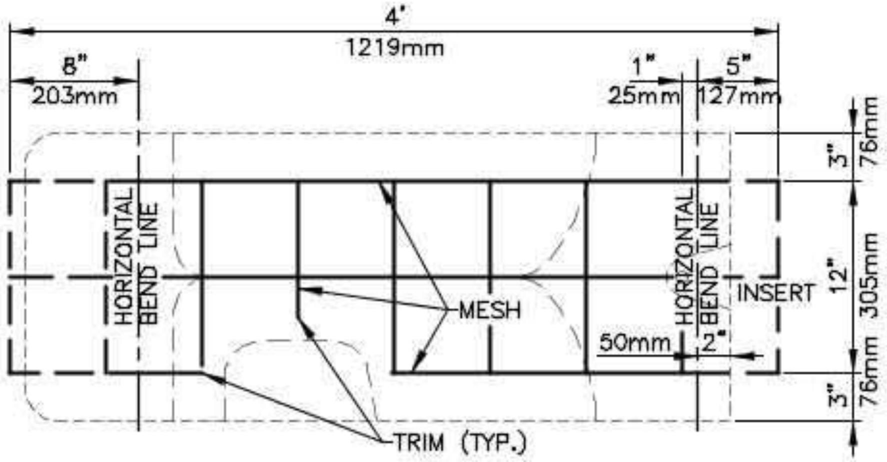
BENT WEB MESH – PLAN VIEW



REAR SHELL MESH



FRONT FACE MESH



BENT WEB MESH (2 REQUIRED)

6 SF HEAVY DUTY PARAWEB UNIT (6SF-HDP) – MESH OPTION

NOT TO SCALE

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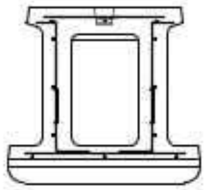
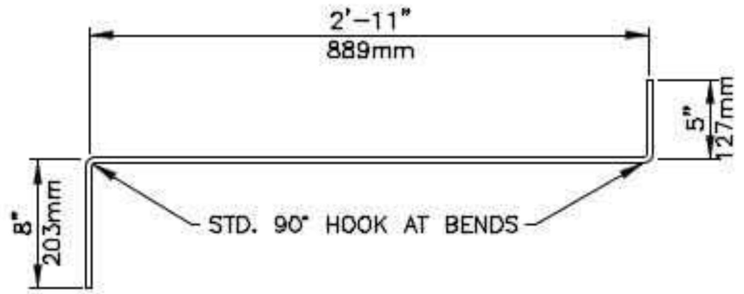
STONE STRONG SYSTEMS

DATE: 12/16/19 FILE: 12_6SF-HDP Mesh

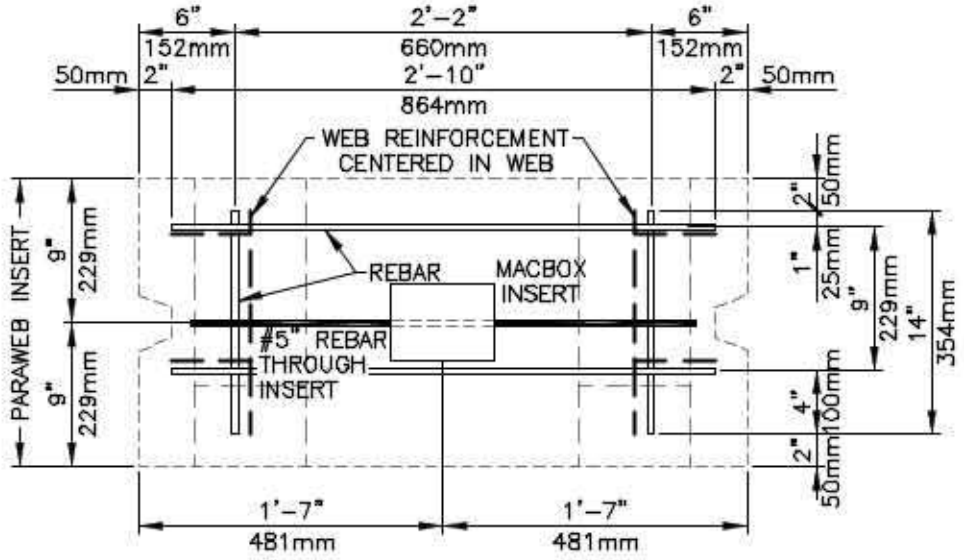
NOTES:

1. ALL STEEL SHALL BE #4 BARS, GRADE 60, U.N.O.
2. ALL #5 BARS SHALL BE GRADE 60.
3. USE IN PARAWEB MSE WALL BETWEEN 12 AND 51 FEET BELOW TOP OF WALL.

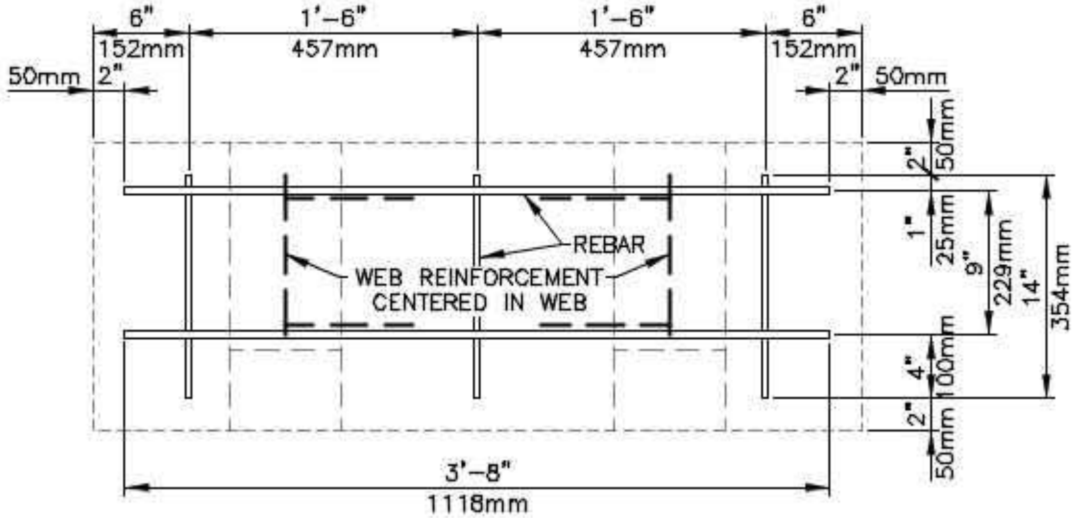




BENT WEB REBAR – PLAN VIEW



REAR SHELL REBAR



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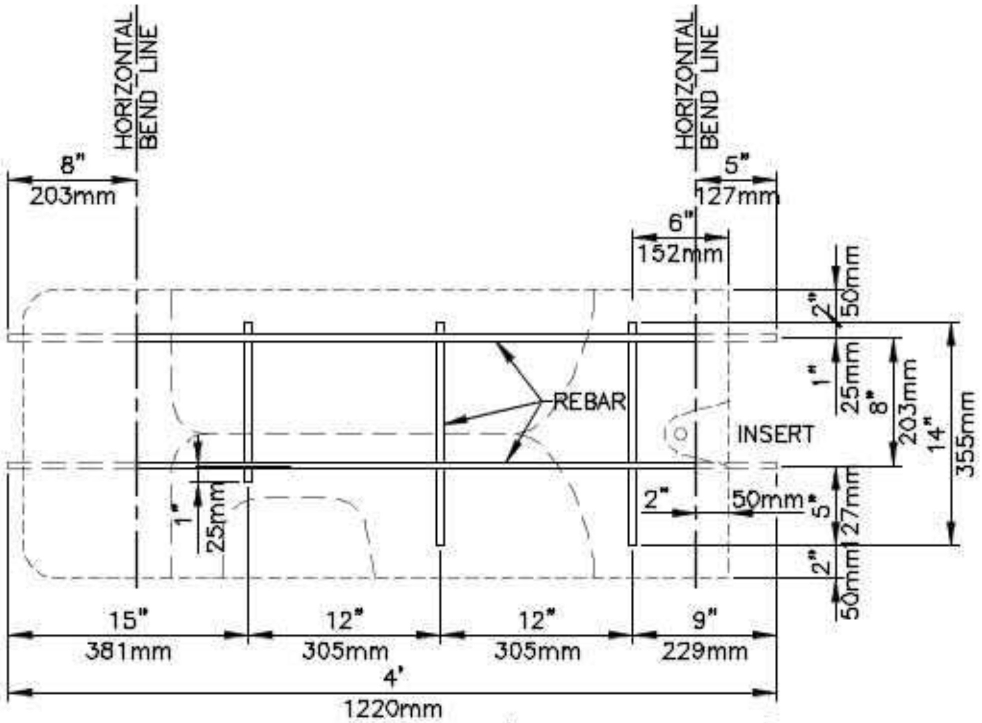

BENT WEB REBAR (2 REQUIRED)

6 SF HEAVY DUTY PARAWEB UNIT (6SF–HDP) – REBAR OPTION

NOT TO SCALE

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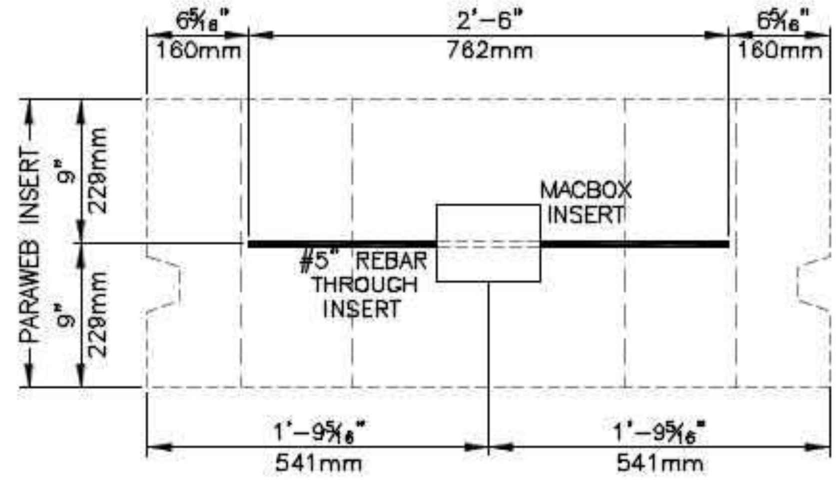
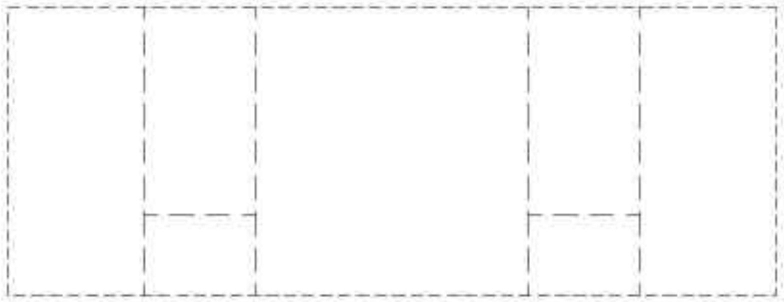
DATE: 7/22/19 | FILE: 13_6SF–HDP Rebar

NOTES:

1. ALL #5 BARS SHALL BE GRADE 60.
2. USE IN PARAWEB MSE WALL IN TOP 12 FEET ONLY.



REAR SHELL



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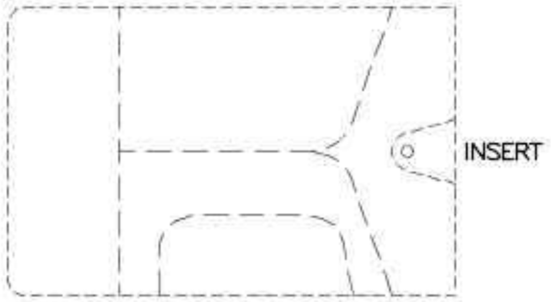

SIDE ELEVATION

6–28 PARAWEB UNIT (6–28–P)

NOT TO SCALE

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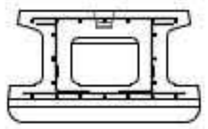
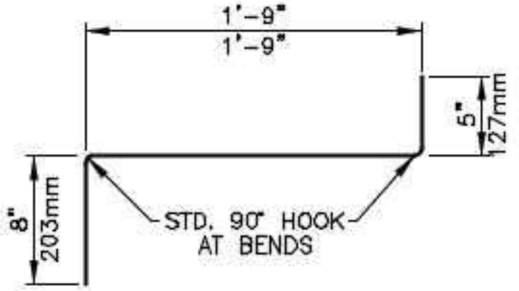
DATE: 12/16/19 | FILE: 14_6-28-P

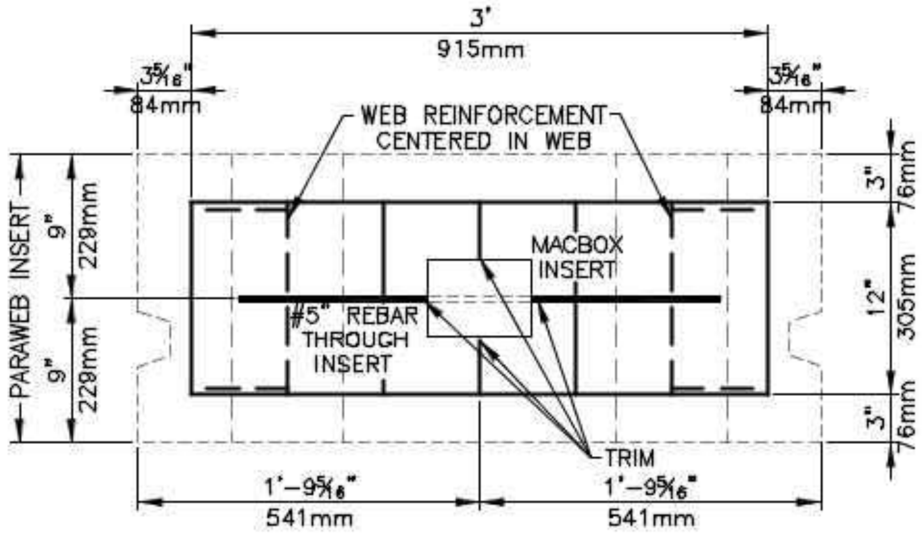
NOTES:

1. ALL MESH SHALL BE W8xW8-6x6 WWF PER ASTM A185/A497/A1064, GRADE 65 U.N.O.
2. ALL #5 BARS SHALL BE GRADE 60.
3. USE IN PARAWEB MSE WALL BETWEEN 12 AND 51 FEET BELOW TOP OF WALL.

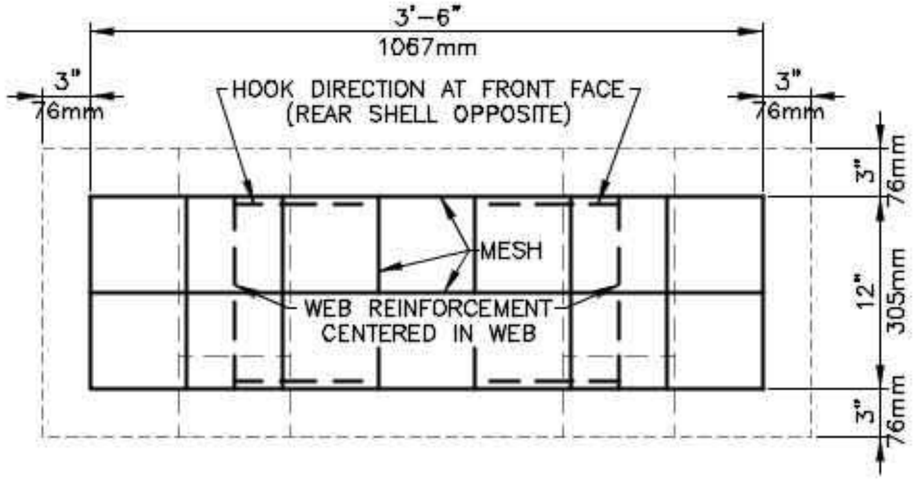




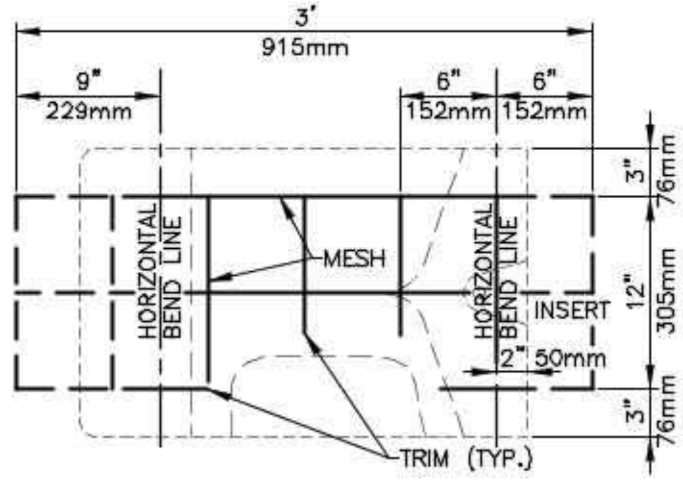
BENT WEB MESH – PLAN VIEW



REAR SHELL MESH



FRONT FACE MESH



BENT WEB MESH (2 REQUIRED)

6-28 HEAVY DUTY PARAWEB UNIT (6-28-HDP) – MESH OPTION

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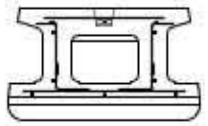
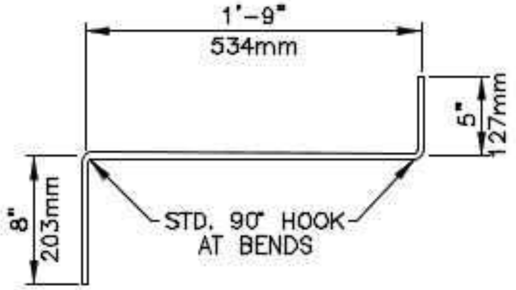
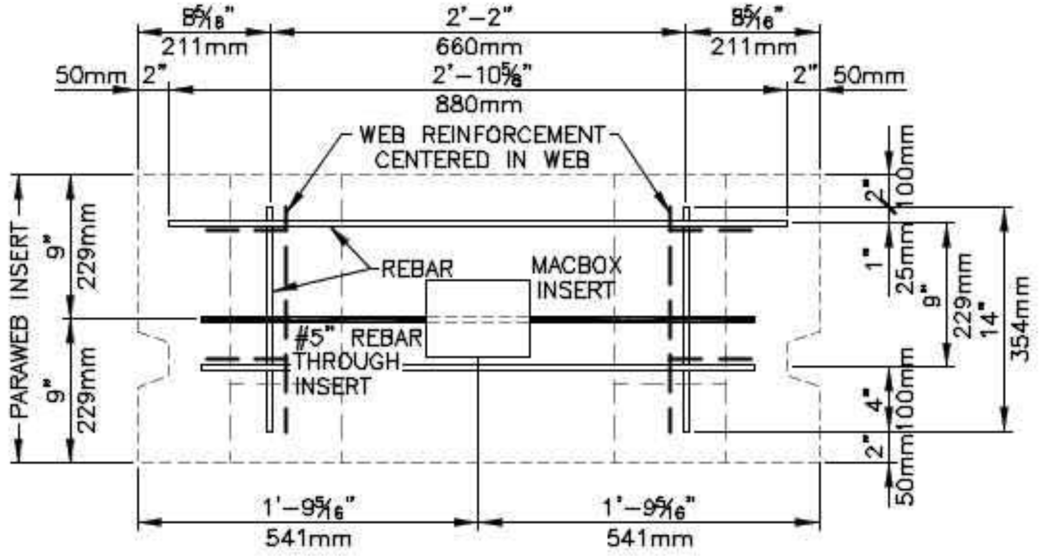
DATE: 12/16/19 | FILE: 15_6-28-HDP Mesh

NOTES:
1. ALL STEEL SHALL BE #4 BARS, GRADE 60, U.N.O.
2. ALL #5 BARS SHALL BE GRADE 60.
3. USE IN PARAWEB MSE WALL BETWEEN 12 AND 51 FEET BELOW TOP OF WALL.

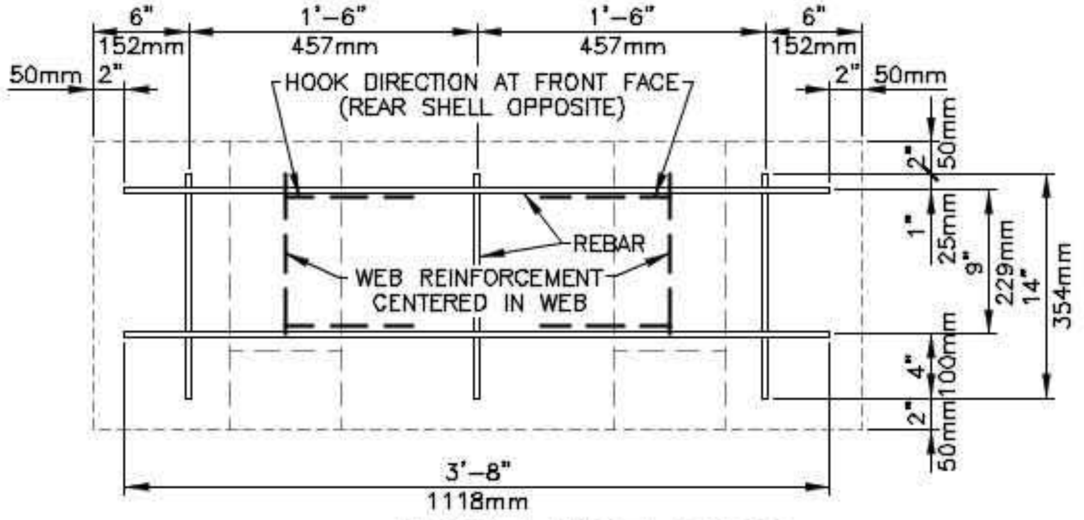




BENT WEB REBAR – PLAN VIEW



REAR SHELL REBAR



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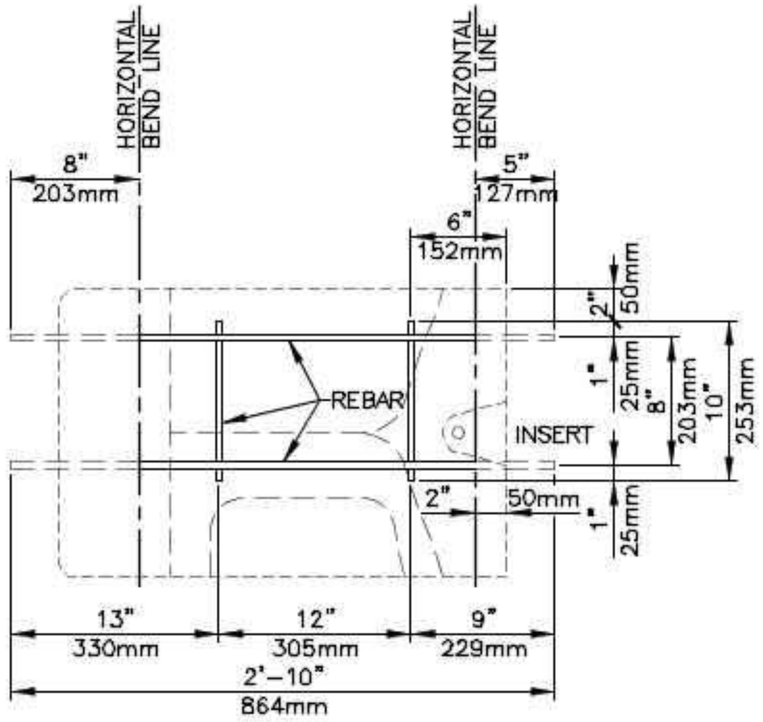

BENT WEB REBAR (2 REQUIRED)

6-28 HEAVY DUTY PARAWEB UNIT (6-28-HDP) – REBAR OPTION

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REINFORCING DETAILS
STONE STRONG SYSTEMS

DATE: 12/16/19 FILE: 16_6-28-HDP Rebar

TRI
ENVIRONMENTAL
TESTING, RESEARCH, CONSULTING AND FIELD SERVICES
Austin, TX - USA | CA - USA | SC - USA | Gold Coast - Australia | Suzhou - China | Sao Paulo, Brazil | Johannesburg - Africa

December 3, 2020

Mail To:

Mr. John Gran
Stone Strong LLC
13460 Chandler Road, Suite 100
Omaha, NE 68138

email: jgran@stonestrong.com
email: dthiele@thielegeotech.com

Bill To:

Sara Gran
Stone Strong LLC
13460 Chandler Road, Suite 100
Omaha, NE 68138

sgran@stonestrong.com

Dear Mr. Gran:

Thank you for consulting TRI/Environmental, Inc. (TRI) for your geosynthetics testing needs.
TRI is pleased to submit this final report of the laboratory testing for the sample(s) listed below.

TRI Job Reference Number:	60553
Material(s) Tested:	One, ParaWeb 2D-50
Test(s) Requested:	Wide Width Tensile (ASTM D6637, Method B)

Test Results:

If you have any questions or require any additional information, please call us at 1-800-880-8378

Sincerely,

Jarrett A. Nelson

Jarrett A. Nelson
Technical Director
Geosynthetic Services Division

LABORATORY TEST RESULTS
TRI Client: Stone Strong LLC

Material: ParaWeb 2D-50
Sample ID: ParaWeb 2D-50
TRI Log #: 60553

PARAMETER	TEST REPLICATE NUMBER					MEAN	STD. DEV.
	1	2	3	4	5		
Wide Width Tensile (ASTM D6637, Method B)							
Ultimate Strength (lbs)	11200	10958	10739	11258	11202	11071	219
Ultimate Strength (kN)	49.8	48.8	47.8	50.1	49.8	49.3	1.0
Strength @ 2% Strain (lbs)	1940	1947	1900	1966	1907	1932	28
Strength @ 2% Strain (kN)	8.63	8.66	8.46	8.75	8.49	8.60	0.12
Strength @ 5% Strain (lbs)	3569	3779	3672	3748	3710	3696	81
Strength @ 5% Strain (kN)	15.9	16.8	16.3	16.7	16.5	16.4	0.4
Strength @ 10% Strain (lbs)	9732	9979	9864	9773	9765	9823	100
Strength @ 10% Strain (kN)	43.3	44.4	43.9	43.5	43.5	43.7	0.4
Break Elongation (%)	12.6	11.7	11.8	12.5	12.7	12.3	0.5
Wide Width Tensile (ASTM D6637, Method B) - modified by wrapping strap around 1" steel rod							
Ultimate Strength (lbs)	21949	22038	20874			21620	648
Ultimate Strength (kN)	97.7	98.1	92.9			96.2	2.9

jump to TOC

jump to Appendix TOC

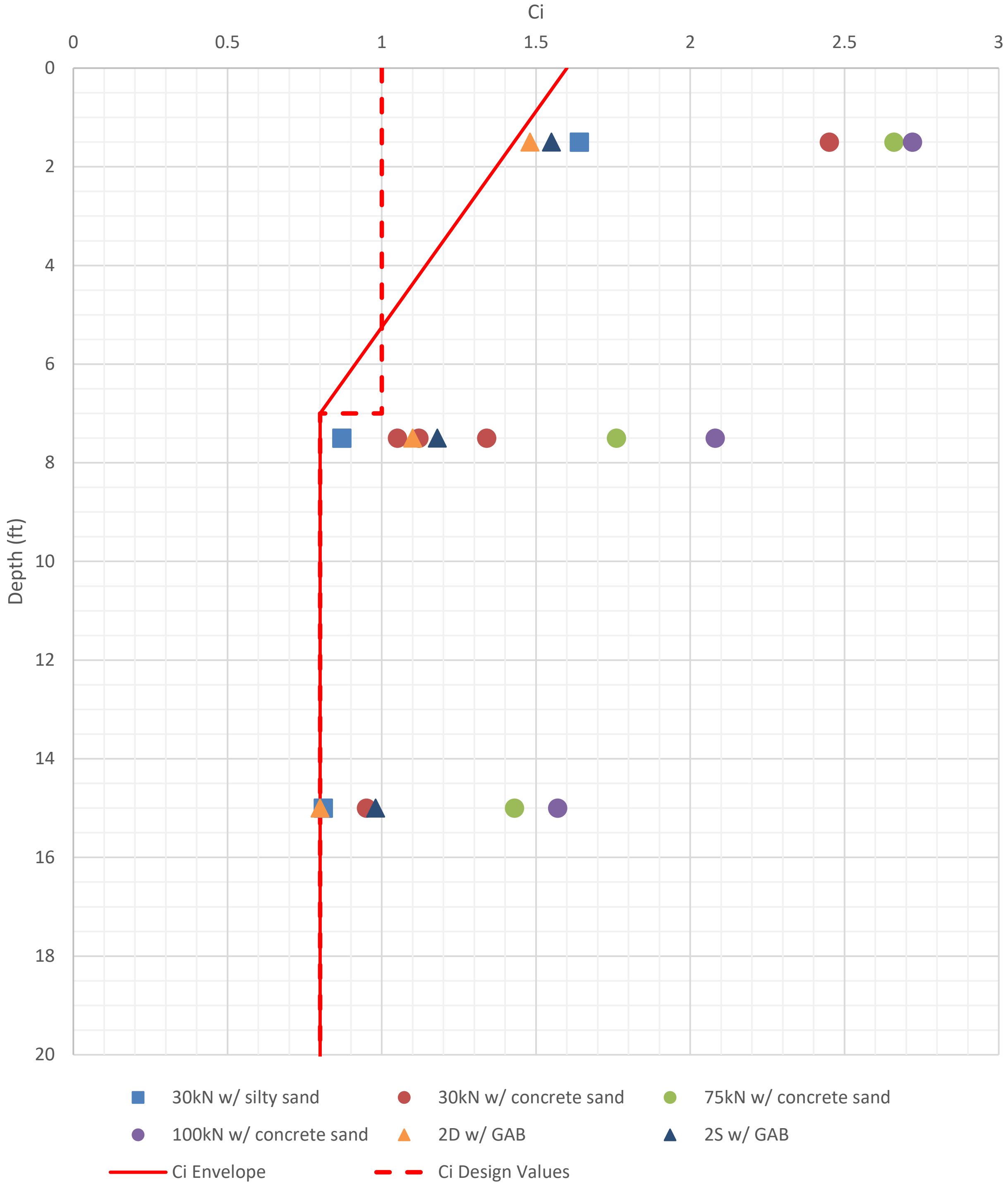
1.2.7 REINFORCEMENT PULLOUT PROPERTIES

Pullout Test Data Summary Plot
Paraweb Pullout Tests

PULLOUT TEST DATA SUMMARY

30kN to 100 kN Paraweb straps 10/29/20
tested in silty sand, concrete sand, and graded aggregae base materials

see SGI test reports for complete test procedures and data



SGI TESTING SERVICES

A Georgia Limited Liability Company

26 November 2008

Mr. Robert Lozano
Linear Composites, Ltd
7830 Laurelton Drive
Chattanooga, TN 37421-1953

Subject: Laboratory Test Results Transmittal
Pullout Testing
ParaWeb Polymeric Strips within Graded Aggregate Base Material

Dear Mr. Lozano,

SGI Testing Services, LLC (SGI) is pleased to present the attached test results for the above-mentioned testing program. The note section below addresses sample preparation, sample disposal and a disclosure statement.

SGI appreciates the opportunity to provide laboratory testing services to Linear Composites, Ltd. Should you have any questions regarding the attached document, or if you require additional information, please do not hesitate to contact the undersigned.

Sincerely,

Zehong Yuan, Ph.D., P.E.
Laboratory Manager

Attachment

Notes:
(1) Unless otherwise noted in the test results the sample(s)/specimen(s) were prepared in accordance with the applicable test standards or generally accepted sampling procedures.
(2) Contaminated/chemical samples and all related laboratory generated waste (i.e., test liquids, PPE, absorbents, etc.) will be returned to the client or designated representative(s), at the client's cost, within 60 days following the completion of the testing program, unless special arrangements for proper disposal are made with SGI$_{sm}$.
(3) Materials that are not contaminated will be discarded after test specimens and archived specimens are obtained. All of the tested and archived specimens will be discarded 30 days after the completion of testing, unless long-term storage arrangements are specifically made with the laboratory.
(4) The reported results apply only to the materials and test conditions used in the laboratory testing program. The results do not necessarily apply to other materials or test conditions. The test results should not be used in engineering analysis unless the test conditions model the anticipated field conditions. The testing was performed in accordance with general engineering testing standards and requirements. The reported results are submitted for the exclusive use of the client to whom they are addressed.

SGI7018.REPORT.08.04

Mail To: SGI Testing Services, LLC
P.O. Box 2427
Lilburn, Georgia 30048-2427

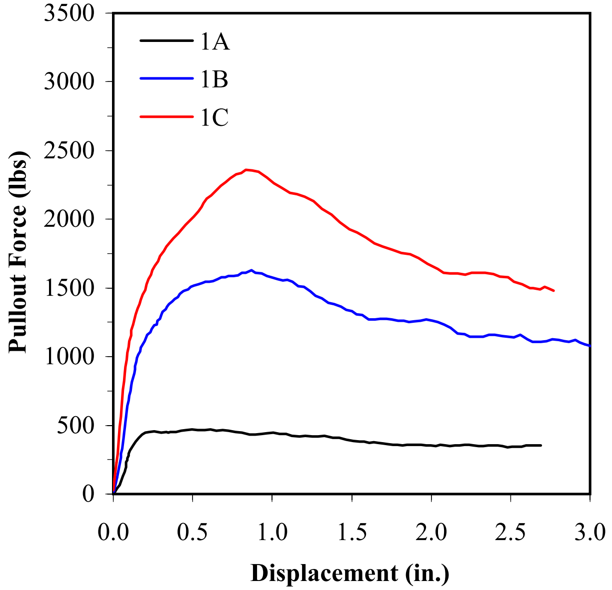
Web Site: www.interactionspecialists.com

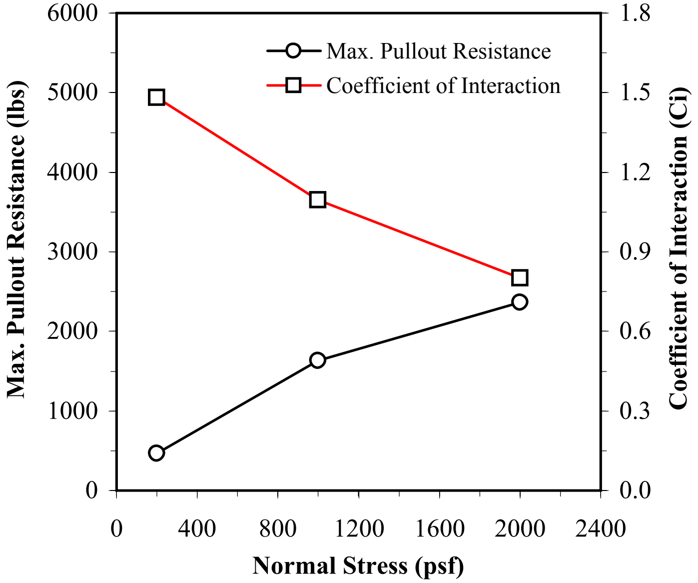
Facility Location
4405 International Boulevard
Suite B-117
Norcross, Georgia 30093

Phone: 770.931.8222 Fax: 770.931.8240

LINEAR COMPOSITES, LTD
POLYESTER STRIP PULLOUT TESTING (ASTM D 6706 MODIFIED)

TEST SERIES NO. 1: 30 kN Paraweb (Style 2D) in machine direction within graded aggregate base (GAB) material compacted to approximately 95% of maximum modified Proctor density at optimum moisture content





Test No.	Test Specimen Width *W* (in.)	Embedment Length *L* (in.)	Normal Stress σ (psf)	Pullout Rate (in./min)	Soil Compaction		Residual Soil Shear Strength$^{(1)}$		Max. Pullout Resistance *P* (lbs)	Coefficient of Interaction$^{(2)}$ C_i (-)	Failure Mode$^{(3)}$
					Initial Dry Unit Weight (pcf)	Initial Moisture Content (%)	ϕ (degree)	c (psf)			
1A	3.3	36.0	200	0.04	136.0	5.5	42	15	470	1.48	Pullout
1B	3.3	36.0	1000	0.04	135.5	4.3	42	15	1629	1.10	Pullout
1C	3.3	36.0	2000	0.04	134.1	5.9	42	15	2363	0.80	Pullout

NOTES:

(1) The residual shear strength parameters of the soil material were obtained from a series of direct shear tests.

(2) $C_i = (P/2.W.L)/(\sigma.\tan \phi + c)$

(3) Pullout failure was indicated by a minimum displacement of 0.5 in measured at the tell-tail wire attached to the rear end of the strip.

(4) Paraweb specimen trimmed by hot knife.

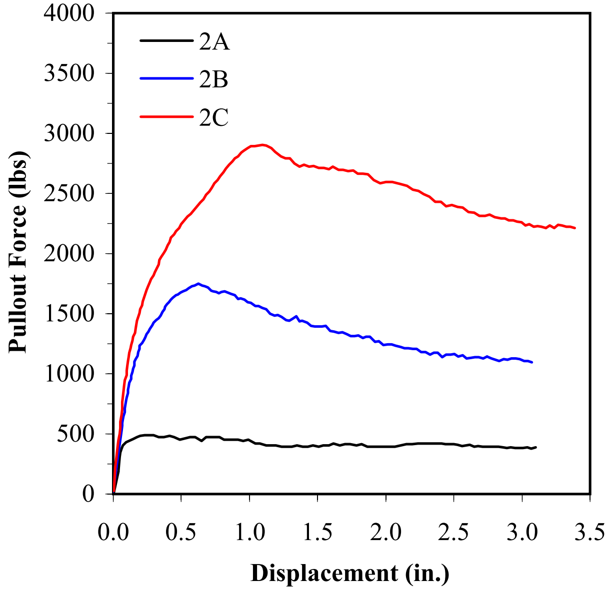
DATE REPORTED: 6/1/2008

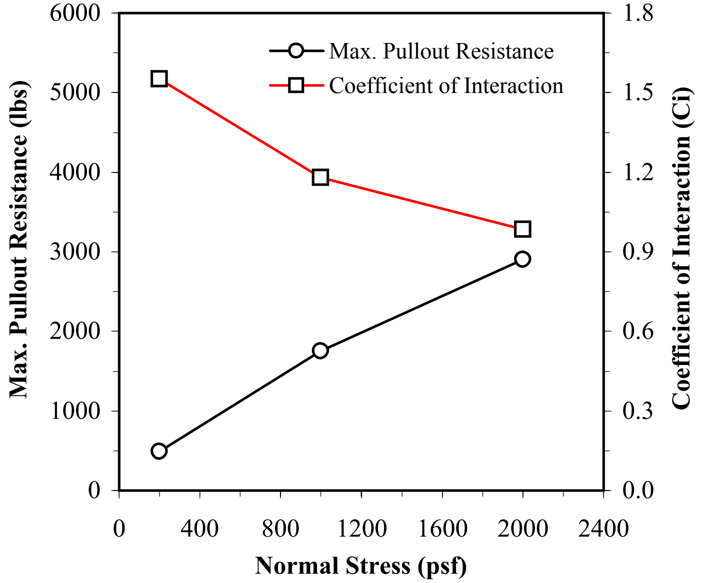
SGI TESTING SERVICES, LLC

FIGURE NO.	C-1
PROJECT NO.	SGI7018
DOCUMENT NO.	SGI08022
FILE NO.	

LINEAR COMPOSITES, LTD
POLYESTER STRIP PULLOUT TESTING (ASTM D 6706 MODIFIED)

TEST SERIES NO. 2: 30 kN Paraweb (Style 2S) in machine direction within graded aggregate base (GAB) material compacted to approximately 95% of maximum modified Proctor density at optimum moisture content





Test No.	Test Specimen Width W (in.)	Embedment Length L (in.)	Normal Stress σ (psf)	Pullout Rate (in./min)	Soil Compaction		Residual Soil Shear Strength(1)		Max. Pullout Resistance P (lbs)	Coefficient of Interaction(2) C_i (-)	Failure Mode(3)
					Initial Dry Unit Weight (pcf)	Initial Moisture Content (%)	ϕ (degree)	c (psf)			
2A	3.3	36.0	200	0.04	133.9	5.2	42	15	492	1.55	Pullout
2B	3.3	36.0	1000	0.04	135.8	4.9	42	15	1756	1.18	Pullout
2C	3.3	36.0	2000	0.04	136.2	4.7	42	15	2906	0.98	Pullout

NOTES:

(1) The residual shear strength parameters of the soil material were obtained from a series of direct shear tests.

(2) $C_i = (P/2.W.L)/(\sigma.\tan\phi + c)$

(3) Pullout failure was indicated by a minimum displacement of 0.5 in measured at the tell-tail wire attached to the rear end of the strip.

(4) Paraweb specimen trimmed by hot knife.

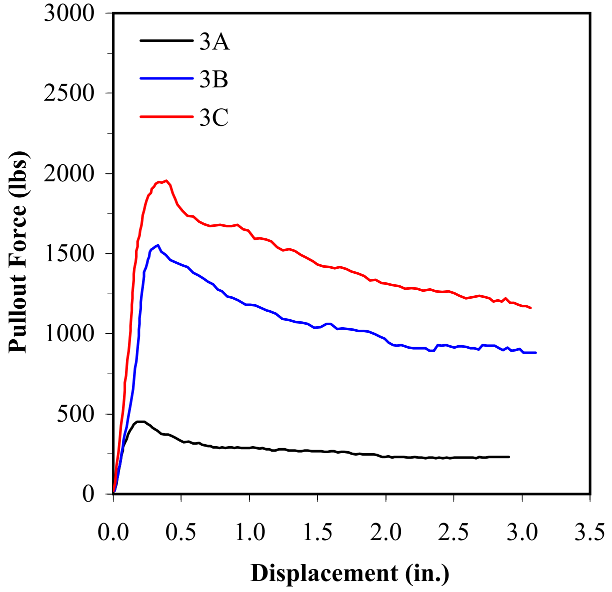
DATE REPORTED: 6/1/2008

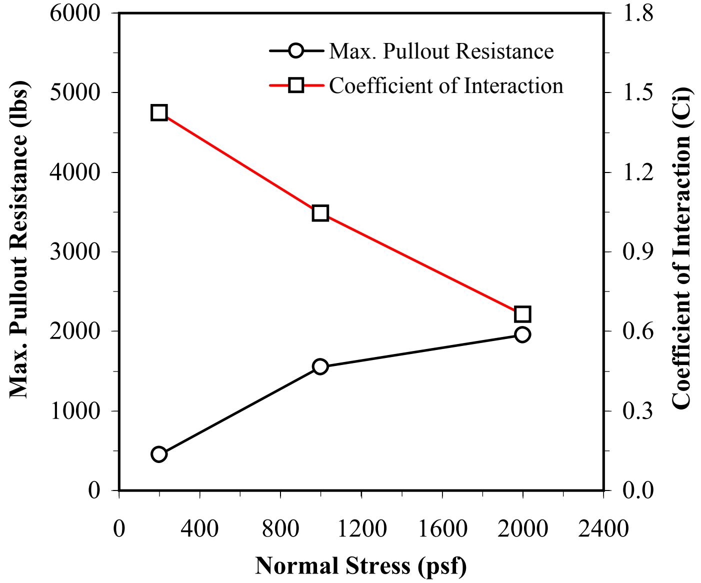
SGI TESTING SERVICES, LLC

FIGURE NO.	C-2
PROJECT NO.	SGI7018
DOCUMENT NO.	SGI08022
FILE NO.	

LINEAR COMPOSITES, LTD
POLYESTER STRIP PULLOUT TESTING (ASTM D 6706 MODIFIED)

TEST SERIES NO. 3: 30 kN Paraweb (Style 2E+) in machine direction within graded aggregate base (GAB) material compacted to approximately 95% of maximum modified Proctor density at optimum moisture content





Test No.	Test Specimen Width W (in.)	Embedment Length L (in.)	Normal Stress σ (psf)	Pullout Rate (in./min)	Soil Compaction		Residual Soil Shear Strength$^{(1)}$		Max. Pullout Resistance P (lbs)	Coefficient of Interaction$^{(2)}$ C_i (-)	Failure Mode$^{(3)}$
					Initial Dry Unit Weight (pcf)	Initial Moisture Content (%)	ϕ (degree)	c (psf)			
3A	3.3	36.0	200	0.04	135.2	4.7	42	15	451	1.42	Pullout
3B	3.3	36.0	1000	0.04	133.6	5.6	42	15	1555	1.05	Pullout
3C	3.3	36.0	2000	0.04	136.4	5.0	42	15	1955	0.66	Pullout

NOTES:

(1) The residual shear strength parameters of the soil material were obtained from a series of direct shear tests.

(2) $C_i = (P/2.W.L)/(\sigma.\tan\phi + c)$

(3) Pullout failure was indicated by a minimum displacement of 0.5 in measured at the tell-tail wire attached to the rear end of the strip.

(4) Paraweb specimen trimmed by hot knife.

DATE REPORTED: 6/1/2008

SGI TESTING SERVICES, LLC

FIGURE NO.	C-3
PROJECT NO.	SGI7018
DOCUMENT NO.	SGI08022
FILE NO.	

SGI TESTING SERVICES

A Georgia Limited Liability Company

14 December 2008

Mr. Robert Lozano
Linear Composites, Ltd
7830 Laurelton Drive
Chattanooga, TN 37421-1953

Subject: Final Report
Pullout Testing
ParaWeb Polymeric Strips within Concrete Sand

Dear Mr. Lozano,

SGI Testing Services, LLC (SGI) is pleased to present the enclosed final report of the pullout testing program performed for Linear Composites, Ltd. The pullout tests were performed in accordance with the ASTM D 6706, "*Measuring Geosynthetic Pullout Resistance in Soil*". All of the pullout tests were conducted at SGI located in Norcross, Georgia.

SGI appreciates the opportunity to provide laboratory testing services to Linear Composites, Ltd. Should you have any questions regarding the enclosed report or if you require additional information, please do not hesitate to contact the undersigned.

Sincerely,

Zehong Yuan

Zehong Yuan, Ph.D., P.E.
Laboratory Manager

Enclosure

SGI7018.REPORT.08.06.LTR

Mail To: SGI Testing Services, LLC
P.O. Box 2427
Lilburn, Georgia 30048-2427

Web Site: www.interactionspecialists.com

Facility Location
4405 International Boulevard
Suite B-117
Norcross, Georgia 30093

Phone: 770.931.8222 Fax: 770.931.8240

Prepared for:

Linear Composites, Ltd
7830 Laurelton Drive
Chattanooga, TN 37421-1953
USA

FINAL REPORT
PULLOUT TESTING

PARAWEB POLYMERIC STRIPS WITHIN CONCRETE SAND

Prepared by:

SGI TESTING SERVICES, LLC

4405 International Blvd., Suite B-117
Norcross, GA 30093

Project Number SGI7018

12 December 2008

CAVEAT

The reported results apply only to the materials and test conditions used in the laboratory testing program. The results do not necessarily apply to other materials or test conditions. The test results should not be used in engineering analysis unless the test conditions model the anticipated field conditions. The testing was performed in accordance with general engineering testing standards and requirements. This testing report is submitted for the exclusive use of the client to whom it is addressed.

1. INTRODUCTION

SGI Testing Services, LLC (SGI) conducted a laboratory testing program to evaluate the pullout resistance of Paraweb polymeric strips within concrete sand. The sample preparation procedures and testing conditions were specified by Mr. Robert Lozano of Linear Composites, Ltd. to model anticipated field conditions. All of the pullout tests were conducted at SGI located in Norcross, Georgia.

2. TEST MATERIALS

Two types of materials were used in this testing program. Descriptions of these materials are given below:

- *Reinforcement*: ParaWeb 30kN, 75kN, and 100 kN polymeric strips.
- *Soil Material*: concrete sand manufactured by crushing granite rock. A particle size analysis, standard Proctor compaction, and direct shear testing were conducted on the concrete sand and the test results are presented in Appendix A.

The three ParaWeb polymeric strips were provided by Linear Composites. Bulk samples of the concrete sand were obtained by SGI from a local quarry.

3. PULLOUT TEST EQUIPMENT

The pullout testing device used in this testing program had plan dimensions of 0.6 m by 1.5 m (2 ft by 5 ft) and an overall depth of 300 mm (12 in.). Normal (vertical) stresses were applied to the testing specimen through six hydraulic cylinders and pullout (horizontal) loads were applied to the test specimen through two hydraulic cylinders as shown in Figures B-1 and B-2.

4. TEST METHOD AND PROCEDURES

The pullout tests were performed in general accordance with the ASTM D 6706, "*Measuring Geosynthetic Pullout Resistance in Soil*", with appropriate modifications. The specific testing procedures used to conduct pullout testing are described in Appendix B.

5. PULLOUT TEST RESULTS

Three series of pullout tests were performed in this testing program. For each pullout test series, the test results are presented in a summary page in Appendix C. The summary page includes:

- Pullout force versus displacement figure;
- Pullout resistance versus normal stress figure; and
- A table that summarizes test conditions, maximum pullout resistance, coefficient of interaction (C_i), and failure modes.

The coefficient of interaction (C_i) was calculated using the equation as follows:

$$C_i = \frac{F}{2(L_e W)(\sigma_n \tan\phi + c)}$$

where:

F = maximum pullout load;
L_e = initial embedded length of the polymeric strip specimen;
W = initial width of the polymeric strip specimen;
σ_n = total normal stress applied to the polymeric strip specimen;
ϕ = residual total-stress friction angle of soil; and
c = residual total-stress cohesion of soil.

The shear strength parameters (ϕ and c) of the concrete sand used in pullout testing were determined from a series of direct shear tests.

For each pullout test, the polymeric strip specimen was pulled until a pullout failure occurred. The pullout failure was assumed when the tell-tail wire attached to the rear end of the specimen displaced at least 12 mm (0.5 in.).

6. CLOSURE

The reported test results apply only to the materials and test conditions used in the laboratory testing program. The test results do not necessarily apply to other materials or test conditions. The test results should not be used in engineering analysis unless the test conditions model the anticipated field conditions. The testing was performed in accordance with general engineering testing standards and requirements. This testing report is submitted for the exclusive use of Linear Composites.

APPENDIX A

SUMMARY
PARTICLE SIZE ANALYSIS, COMPACTION, AND DIRECT SHEAR TEST RESULTS

SGI Testing Services, LLC

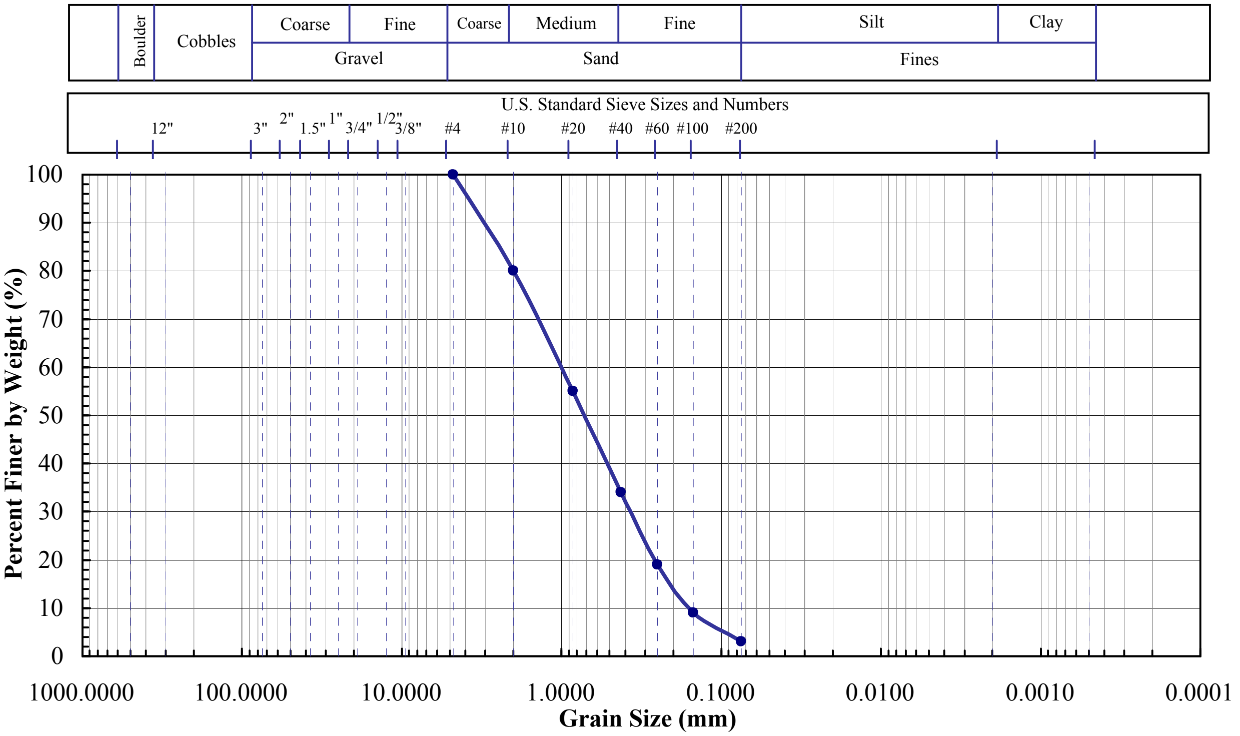
4405 International Blvd., Suite B-117, Norcross, GA 30093
Ph: (770) 931 8222 Fax: (770) 931 8240

Project Name:	Shear Strength Testing
Project No:	
Client Sample ID:	Concrete Sand
Lab Sample No:	S11648

ASTM D 2216, D 1140, D 422,
C 136, D 4318, D 2487

SOIL INDEX PROPERTIES

Moisture Content, Grain Size, Atterberg Limits, Classification

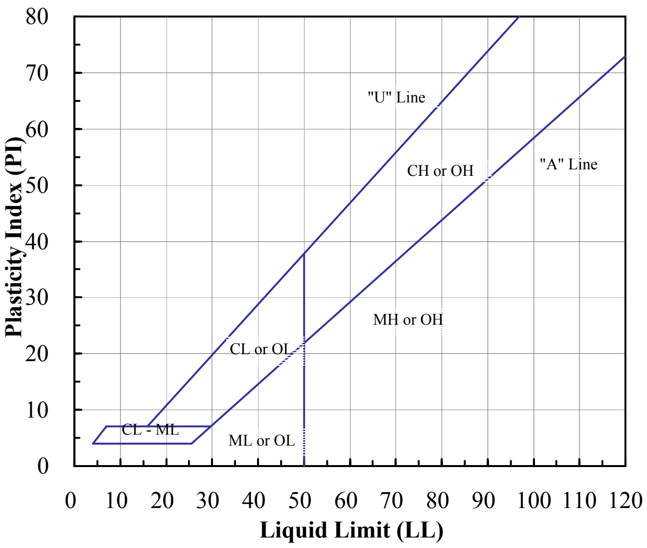


Sieve No.	Size (mm)	% Finer
3"	75	100.0
2"	50	100.0
1.5"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
1/2"	12.5	100.0
3/8"	9.5	100.0
#4	4.75	100.0
#10	2.00	80.0
#20	0.850	55.0
#40	0.425	34.0
#60	0.250	19.0
#100	0.150	9.0
#200	0.075	3.0

Hydrometer Particle Diameter (mm)	% Finer
0.0500	
0.0200	
0.0050	
0.0020	
0.0012	

Gravel (%):	
Sand (%):	97.0
Fines (%):	3.0
Silt (%):	
Clay (%):	

Coeff. Unif. (Cu):	-
Coeff. Curv. (Cc):	-



Client Sample ID.	Lab Sample No:	Moisture Content (%)	Fines Content < No. 200 (%)	Atterberg Limits LL (%)	Atterberg Limits PL (%)	Atterberg Limits PI (-)	Engineering Classification
Concrete Sand	S11648	-	3.0	NP	NP	NP	SP (Poorly Graded Sand)

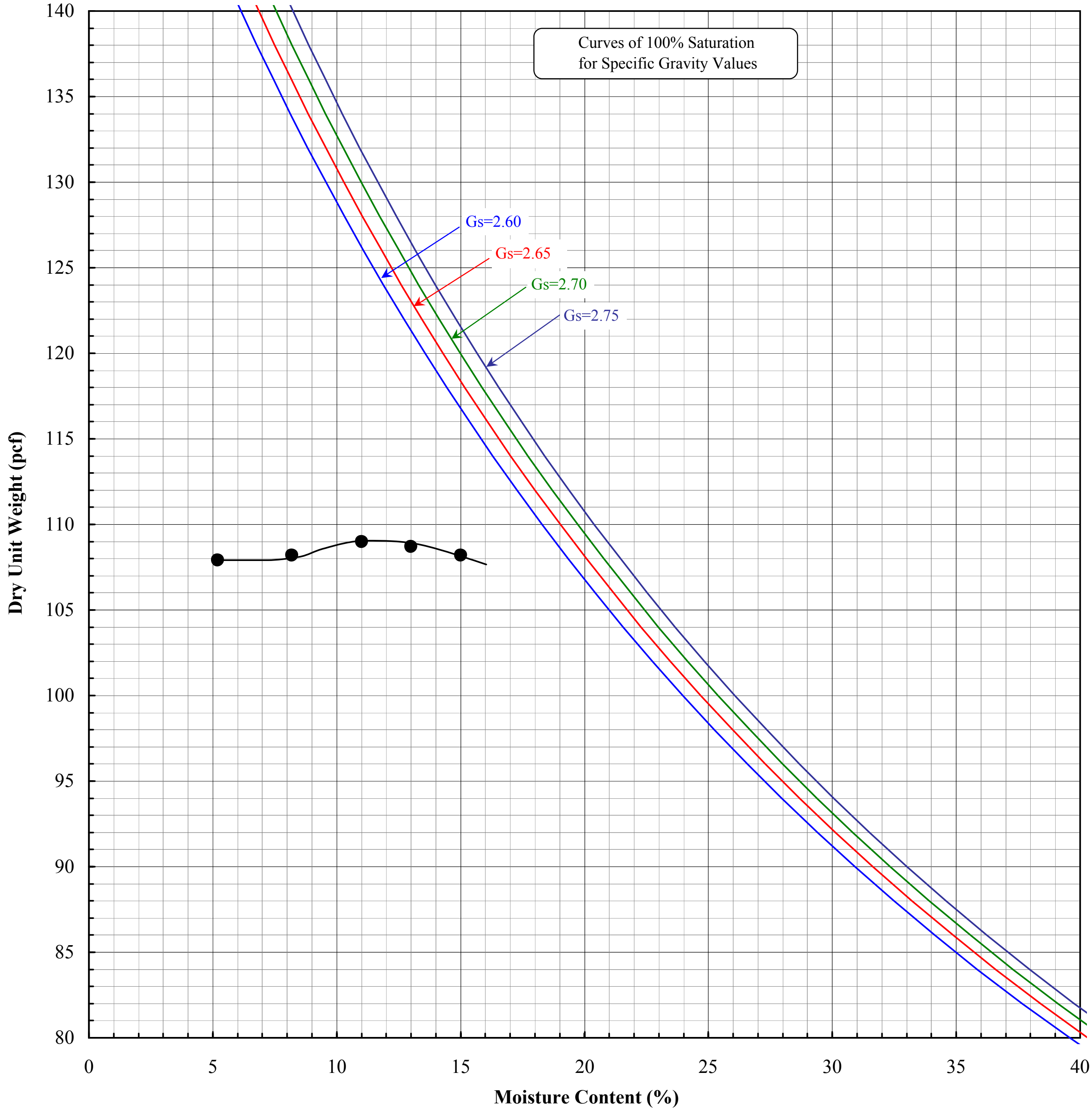
Note(s):

SGI Testing Services, LLC

4405 International Blvd., Suite B-117, Norcross, GA 30093
Ph: (770) 931 8222 Fax: (770) 931 8240

Project Name:	Shear Strength Testing
Project No:	
Client Sample ID:	Concrete Sand
Lab Sample No:	S11648

ASTM D698 **COMPACTION MOISTURE-DENSITY RELATIONSHIP** **Standard - Method A**

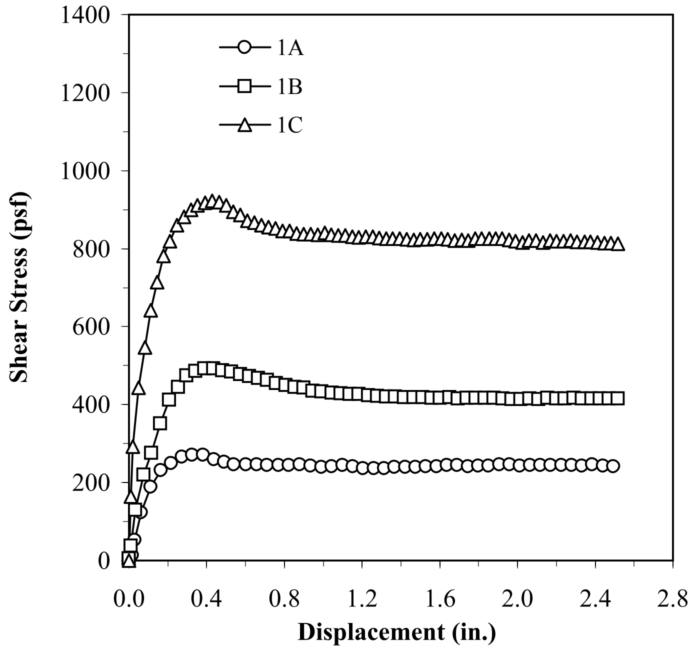


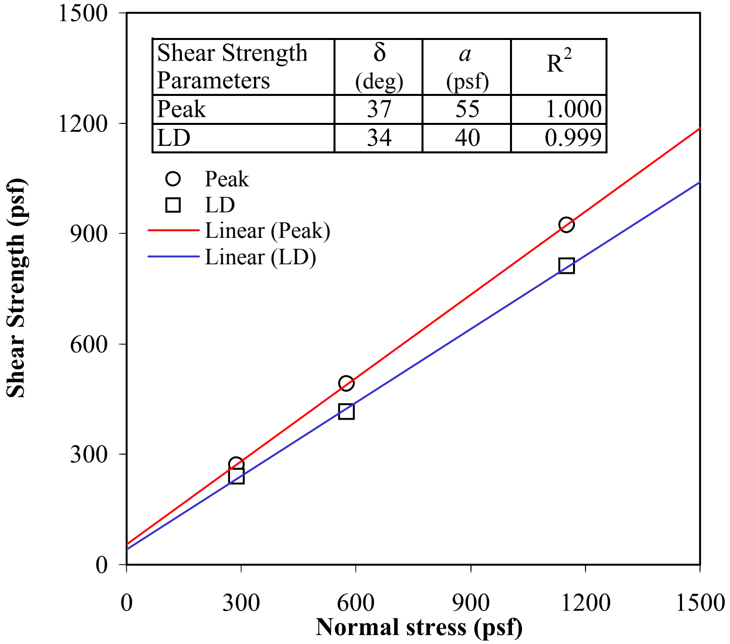
Client Sample ID.	Lab Sample No:	Maximum Dry Unit Weight (pcf)	Optimum Moisture Content (%)	Remarks
Concrete Sand	S11648	109.0	11.0	Concrete Sand

Note(s):

SGI TESTING SERVICES
DIRECT SHEAR TESTING (ASTM D 3080)

Concrete sand compacted to approximately 95% of max. standard Proctor density at optimum moisture content under as-placed moisture conditions




Shear Strength Parameters	δ (deg)	*a* (psf)	R^2
Peak	37	55	1.000
LD	34	40	0.999

Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking		Consolidation		Soil Compaction			Soil Shear Strength Parameters				Shear Strength		Coefficient of Direct Sliding	
				Stress (psf)	Time (hour)	Stress (psf)	Time (hour)	γ_d (pcf)	ω_i (%)	ω_f (%)	ϕ_P (deg)	c_P (psf)	ϕ_{LD} (deg)	c_{LD} (psf)	τ_P (psf)	τ_{LD} (psf)	C_{DS-P}	C_{DS-LD}
1A	12 x 12	288	0.04	-	-	-	-	103.4	12.3	11.9	-	-	-	-	271	240	NA	NA
1B	12 x 12	576	0.04	-	-	-	-	103.5	12.2	12.0	-	-	-	-	492	415	NA	NA
1C	12 x 12	1152	0.04	-	-	-	-	103.3	11.9	11.3	-	-	-	-	923	812	NA	NA

NOTES:

(1) Sliding (i.e., shear failure) occurred internally through the soil specimen at the predetermined plane between the upper and lower shear box during each test.

(2) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test

SGI TESTING SERVICES, LLC

DATE OF TEST:
FIGURE NO. A-3
PROJECT NO. SGI6013
DOCUMENT NO.
FILE NO.

APPENDIX B

SUMMARY
PULLOUT TEST PROCEDURES

For each pullout test, the test specimen was set up in accordance with the following procedures and tested under the specific conditions as described below:

- The concrete sand was placed in the lower half of the pullout box and compacted by hand tamping to form a 150 mm (6 in.) thick layer. For each pullout test, the soil was compacted to the dry unit weight and moisture content presented in the summary table in Appendix C;
- For each pullout test, a polymeric strip was trimmed from the received sample and placed on top of the compacted soil as shown in Figures B-1 and B-2. The front end of the strip was connected to the pullout loading harness using a mechanical connection system;
- Four "tell-tail" wires were connected to selected locations along each test specimen. Displacements at these locations were monitored during testing using linear variable differential transformers (LVDTs) attached to each of the "tell-tail" wires;
- The concrete sand was placed in the upper half of the pullout box and compacted by hand tamping to form a 150 mm (6 in.) thick layer. For each pullout test, the soil was compacted to the dry unit weight and moisture content in the summary table in Appendix C;
- A load cell was then attached to the pullout loading harness to measure the pullout load at the specimen clamp. An LVDT was also fixed to the specimen clamp to measure the total pullout displacement at the specimen clamp;
- A specific normal stress was then applied to the test specimen through hydraulic cylinders;
- After application of the normal stress, the test specimen was immediately subjected to a pullout load by displacing the pullout test specimen at a constant displacement rate of 0.04 in./min as measured on the specimen clamp. Pullout was continued until the pullout failure occurred;
- Each pullout test was tested under as-placed moisture conditions; and

- The strips used during this testing program were pulled in the longitudinal direction.

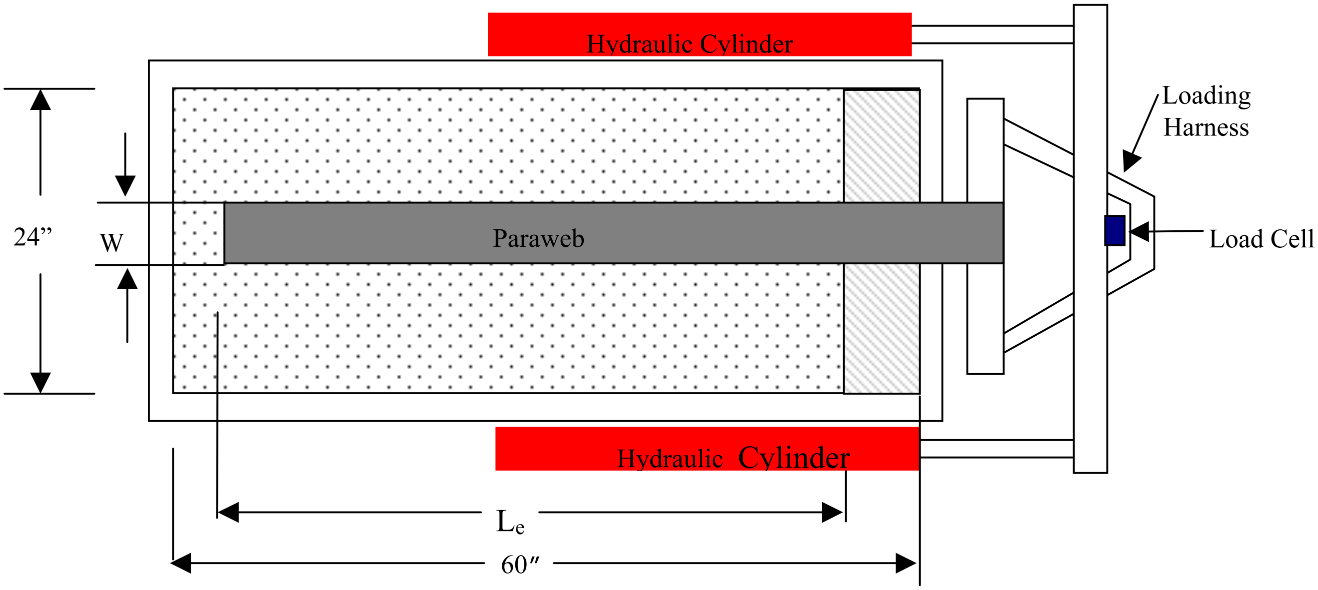


Figure B-1. Plan view of pullout test setup (Note: not to scale).

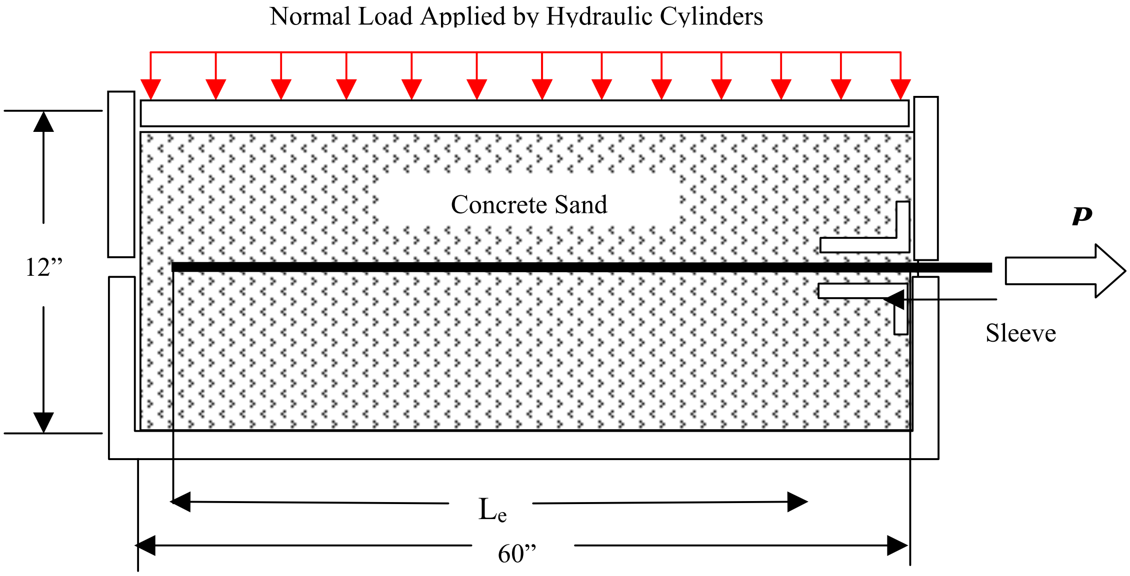


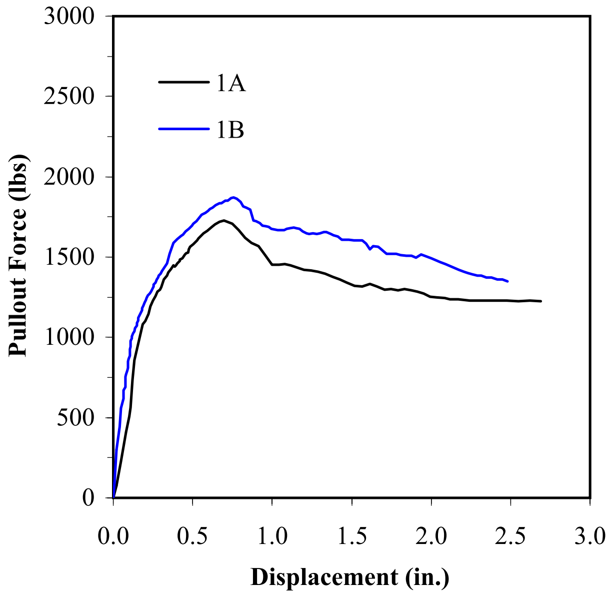
Figure B-2. Cross-section of pullout test setup (Note: not to scale)

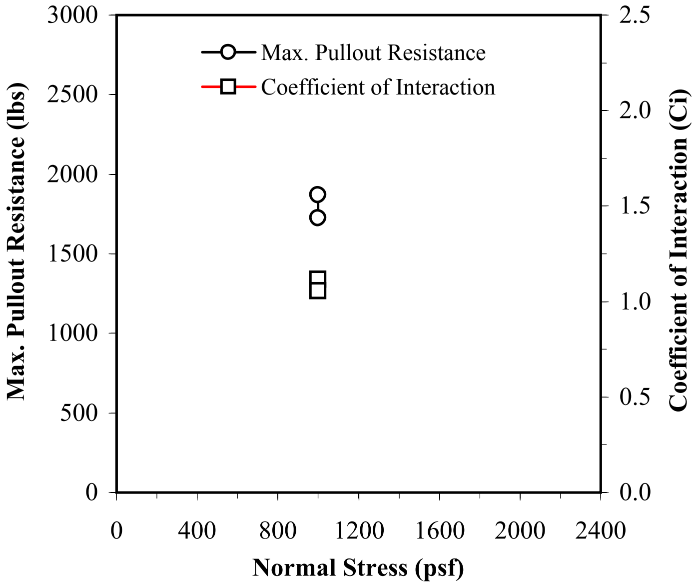
APPENDIX C

SUMMARY OF
PULLOUT TEST RESULTS

LINEAR COMPOSITES, LTD
POLYESTER STRIP PULLOUT TESTING (ASTM D 6706 MODIFIED)

TEST SERIES NO. 1: 30 kN Paraweb (coated polyester strip) in machine direction within concrete sand compacted to approximately 95% of maximum standard Proctor density at optimum moisture content





Test No.	Test Specimen Width W (in.)	Embedment Length L (in.)	Normal Stress σ (psf)	Pullout Rate (in./min)	Soil Compaction		Residual Soil Shear Strength[(1)]		Max. Pullout Resistance P (lbs)	Coefficient of Interaction[(2)] C_i (-)	Failure Mode[(3, 4)]
					Initial Dry Unit Weight (pcf)	Initial Moisture Content (%)	ϕ (degree)	c (psf)			
1A	3.3	48.0	1000	0.04	102.9	9.8	34	40	1727	1.12	Pullout
1B	3.3	55.0	1000	0.04	103.5	9.6	34	40	1871	1.05	Pullout

NOTES:

(1) The residual shear strength parameters of the soil material were obtained from a series of direct shear tests.

(2) $C_i = (P/2.W.L)/(\sigma.\tan\phi + c)$

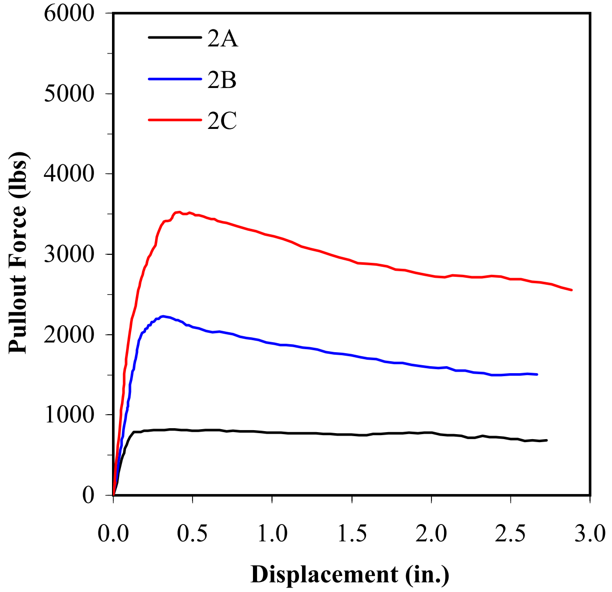
(3) Pullout failure was indicated by a minimum displacement of 0.5 in measured at the tell-tail wire attached to the rear end of the strip.

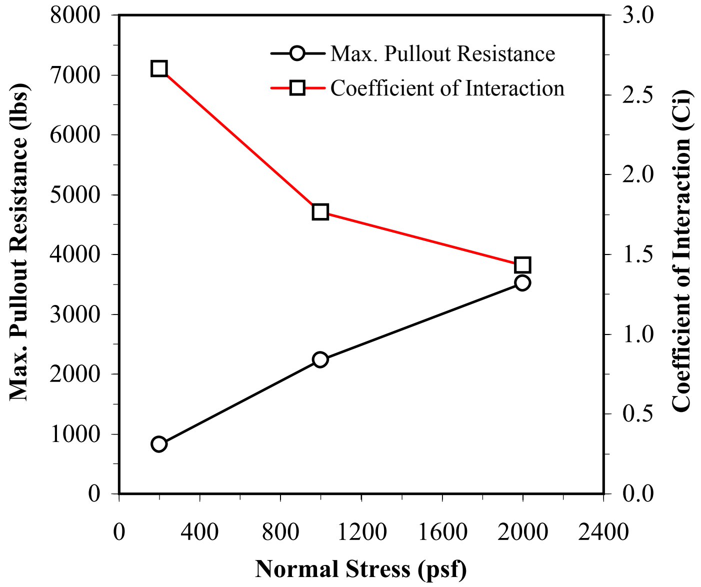
SGI TESTING SERVICES, LLC

DATE REPORTED:	7/30/2007
FIGURE NO.	C-1
PROJECT NO.	SGI7018
DOCUMENT NO.	SGI7018.08.06
FILE NO.	

LINEAR COMPOSITES, LTD
POLYESTER STRIP PULLOUT TESTING (ASTM D 6706 MODIFIED)

TEST SERIES NO. 2: 75 kN Paraweb (coated polyester strip) in machine direction within concrete sand compacted to approximately 95% of maximum standard Proctor density at optimum moisture content





Test No.	Test Specimen Width *W* (in.)	Embedment Length *L* (in.)	Normal Stress σ (psf)	Pullout Rate (in./min)	Soil Compaction		Residual Soil Shear Strength[1]		Max. Pullout Resistance *P* (lbs)	Coefficient of Interaction[2] C_i (-)	Failure Mode[3]
					Initial Dry Unit Weight (pcf)	Initial Moisture Content (%)	ϕ (degree)	c (psf)			
2A	3.5	36.0	200	0.04	102.9	11.1	34	40	825	2.66	Pullout
2B	3.5	36.0	1000	0.04	102.4	10.7	34	40	2231	1.76	Pullout
2C	3.5	36.0	2000	0.04	103.4	10.9	34	40	3522	1.43	Pullout

NOTES:

(1) The residual shear strength parameters of the soil material were obtained from a series of direct shear tests.

(2) $C_i = (P/2.W.L)/(\sigma.\tan\phi + c)$

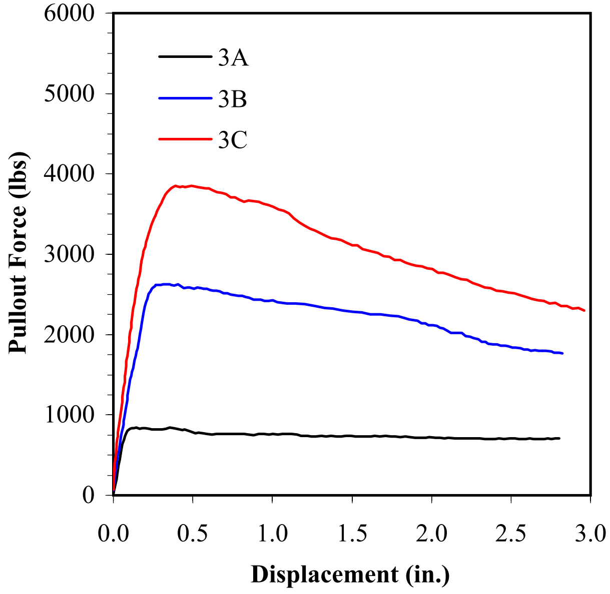
(3) Pullout failure was indicated by a minimum displacement of 0.5 in measured at the tell-tail wire attached to the rear end of the strip.

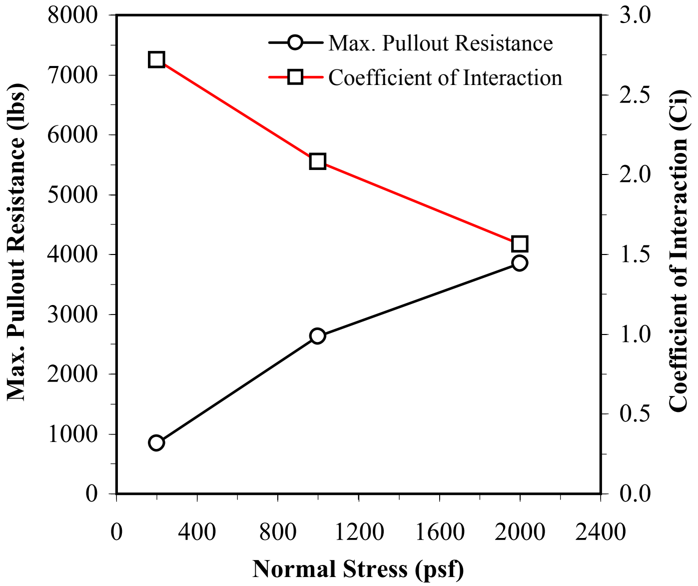
DATE REPORTED:	12/10/2007
FIGURE NO.	C-2
PROJECT NO.	SGI7018
DOCUMENT NO.	SGI7018.08.06
FILE NO.	

SGI TESTING SERVICES, LLC

LINEAR COMPOSITES, LTD
POLYESTER STRIP PULLOUT TESTING (ASTM D 6706 MODIFIED)

TEST SERIES NO. 3: 100 kN Paraweb (coated polyester strip) in machine direction within concrete sand compacted to approximately 95% of maximum standard Proctor density at optimum moisture content





Test No.	Test Specimen Width W (in.)	Embedment Length L (in.)	Normal Stress σ (psf)	Pullout Rate (in./min)	Soil Compaction Initial Dry Unit Weight (pcf)	Soil Compaction Initial Moisture Content (%)	Residual Soil Shear Strength[(1)] ϕ (degree)	Residual Soil Shear Strength[(1)] c (psf)	Max. Pullout Resistance P (lbs)	Coefficient of Interaction[(2)] C_i (-)	Failure Mode[(3)]
3A	3.5	36.0	200	0.04	103.8	10.3	34	40	842	2.72	Pullout
3B	3.5	36.0	1000	0.04	102.7	10.8	34	40	2633	2.08	Pullout
3C	3.5	36.0	2000	0.04	103.1	10.2	34	40	3850	1.57	Pullout

NOTES:

(1) The residual shear strength parameters of the soil material were obtained from a series of direct shear tests.

(2) $C_i = (P/2.W.L)/(\sigma.\tan\phi + c)$

(3) Pullout failure was indicated by a minimum displacement of 0.5 in measured at the tell-tail wire attached to the rear end of the strip.

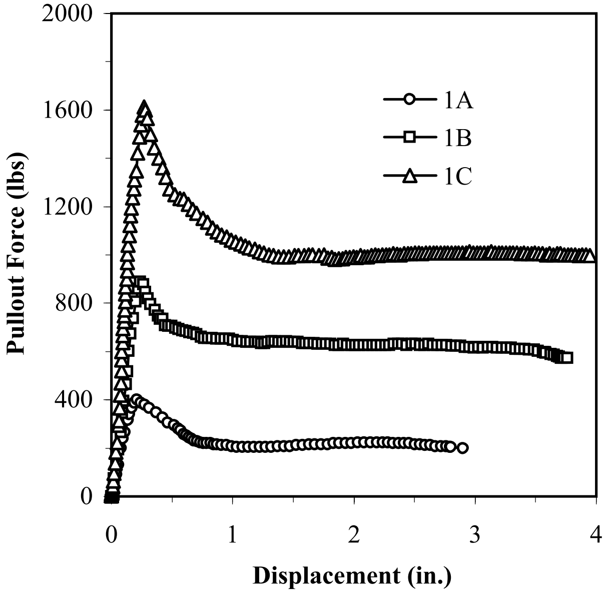
DATE REPORTED: 12/10/2007

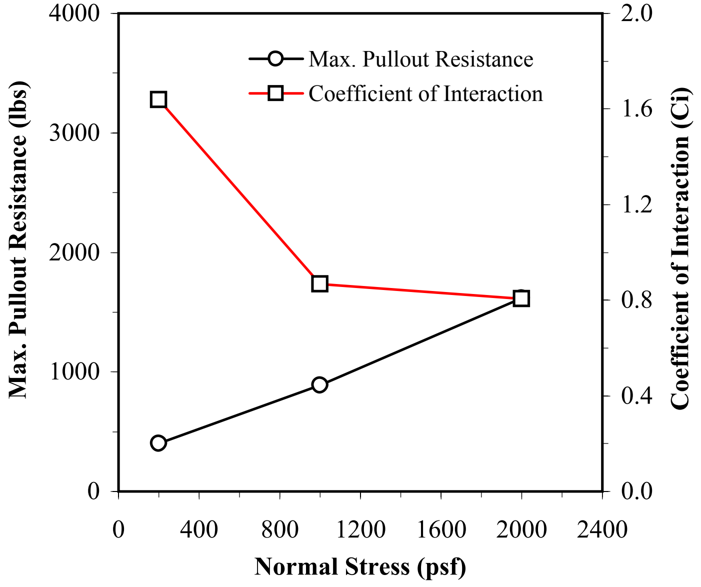
SGI TESTING SERVICES, LLC

FIGURE NO.	C-3
PROJECT NO.	SGI7018
DOCUMENT NO.	SGI7018.08.06
FILE NO.	

LINEAR COMPOSITES, LTD
POLYESTER STRIP PULLOUT TESTING (ASTM D 6706 MODIFIED)

TEST SERIES NO. 1: 85mm 30kN/m coated polyester strip in machine direction within silty sand compacted to approximately 95% of maximum standard Proctor density at optimum moisture content





Test No.	Test Specimen Width *W* (in.)	Embedment Length *L* (in.)	Normal Stress σ (psf)	Pullout Rate (in./min)	Soil Compaction		Residual Soil Shear Strength[1]		Max. Pullout Resistance *P* (lbs)	Coefficient of Interaction[2] C_i (-)	Failure Mode[3]
					Initial Dry Unit Weight (pcf)	Initial Moisture Content (%)	ϕ (degree)	c (psf)			
1A	3.3	36.0	200	0.04	93.2	19.2	31	30	400	1.64	Pullout
1B	3.3	36.0	1000	0.04	93.7	18.7	31	30	889	0.87	Pullout
1C	3.3	36.0	2000	0.04	93.9	18.5	31	30	1615	0.81	Pullout

NOTES:

(1) The residual shear strength parameters of the soil material were obtained from a series of direct shear tests.

(2) $C_i = (P/2.W.L)/(\sigma.\tan\phi + c)$

(3) Pullout failure was indicated by a minimum displacement of 0.5 in measured at the tell-tail wire attached to the rear end of the strip.

DATE TESTED: 2/27 to 3/5/2007

SGI TESTING SERVICES, LLC

FIGURE NO.	C-1
PROJECT NO.	SGI7018
DOCUMENT NO.	
FILE NO.	

SGI TESTING SERVICES, LLC

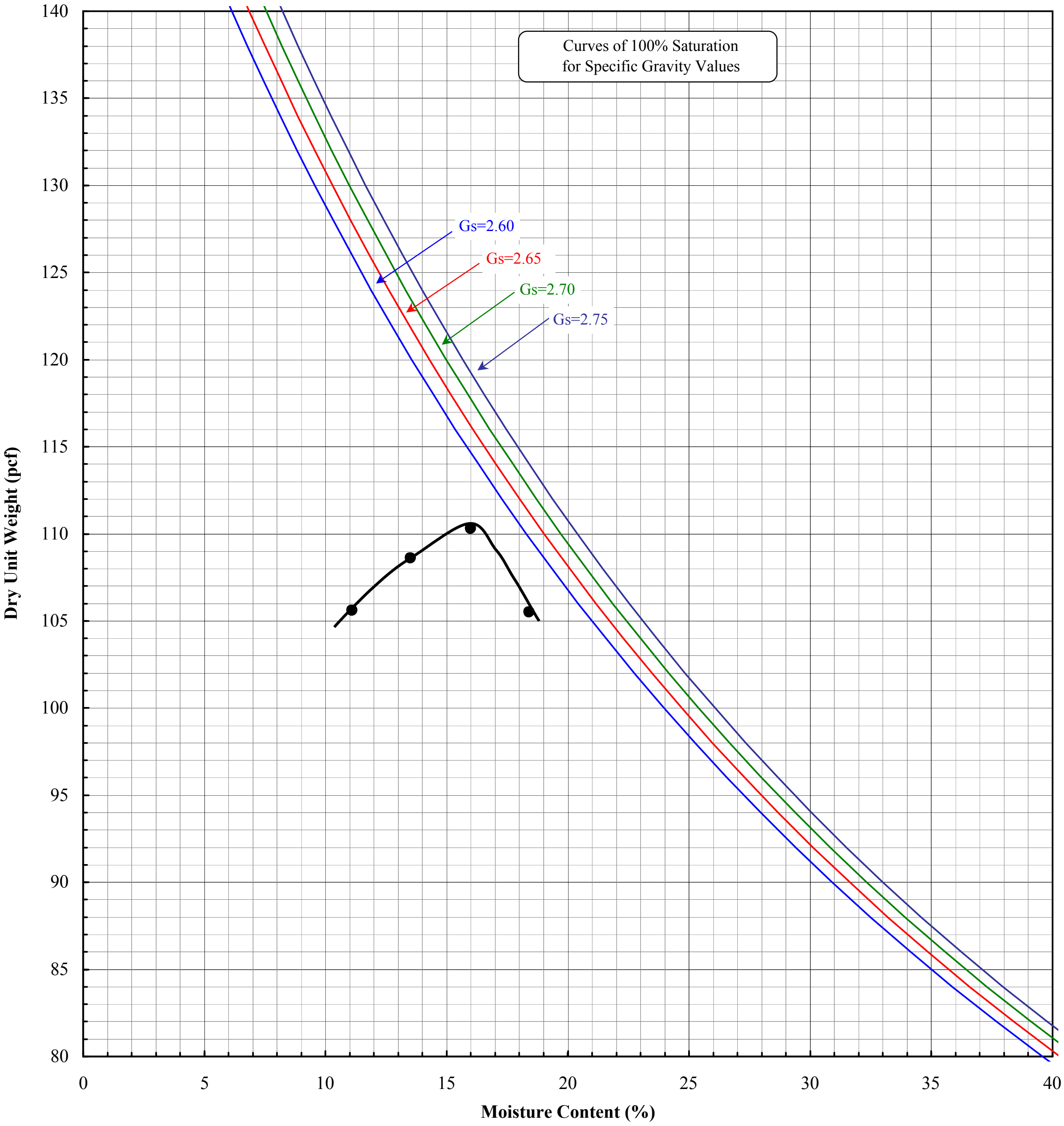
4405 International Blvd., Suite B-117, Norcross, GA 30093
Ph: (770) 931-8222 Fax: (770) 931-8240

Project Name: Installation Damage
Project No: SGI4062
Client Sample ID: Silty Sand
Lab Sample No: S11082

ASTM D698

COMPACTION MOISTURE-DENSITY RELATIONSHIP

Standard - Method A



Client Sample ID.	Lab Sample No:	Maximum Dry Unit Weight (pcf)	Optimum Moisture Content (%)	Remarks
Silty Sand	S11082	110.4	15.8	

Note(s):

SGI TESTING SERVICES, LLC

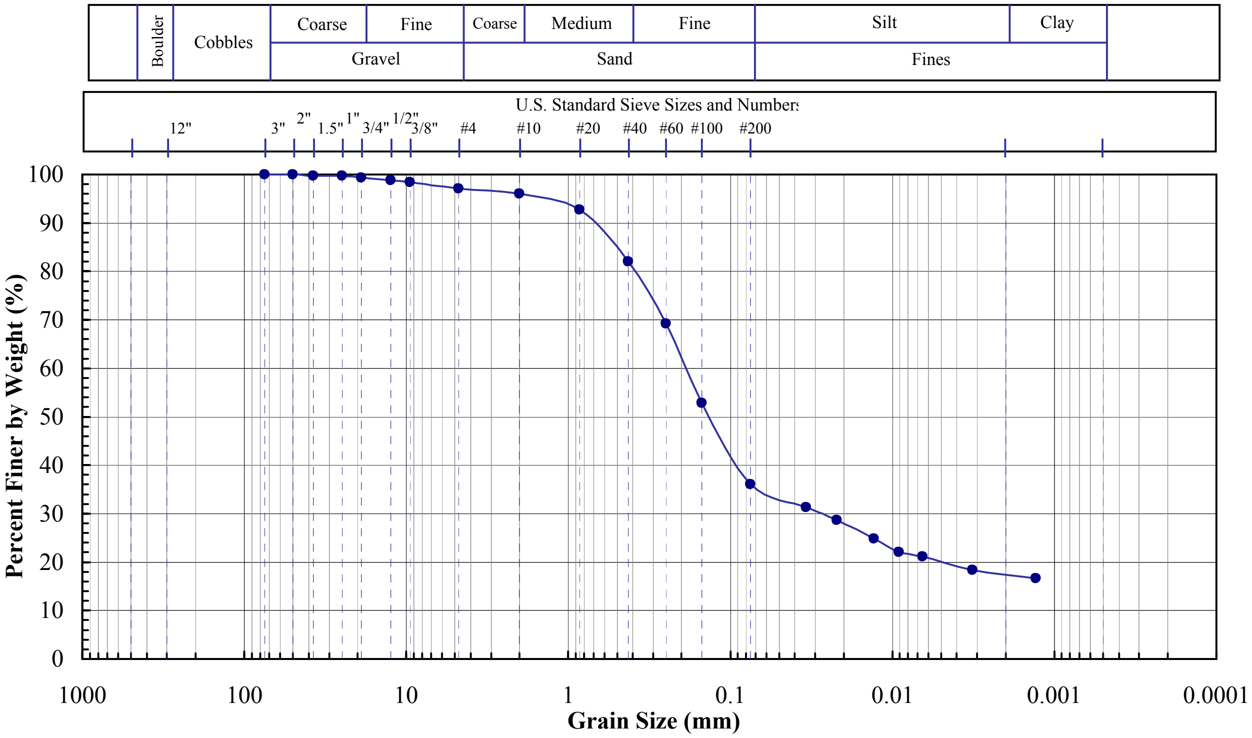
4405 International Blvd., Suite B-117, Norcross, GA 30093
Ph: (770) 931-8222 Fax: (770) 931-8240

Project Name:	Installation Damage
Project No:	SGI4062
Client Sample ID:	Silty Sand
Lab Sample No:	S11082

ASTM D 2216, D 1140, D 422, C 136, D 4318, D 2487

SOIL INDEX PROPERTIES

Moisture Content, Grain Size, Atterberg Limits, Classification

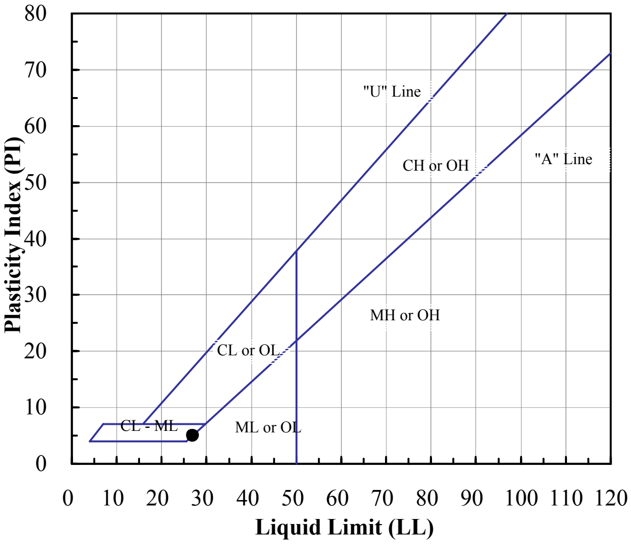


Sieve No.	Size (mm)	% Finer
3"	75	100.0
2"	50	100.0
1.5"	37.5	99.7
1"	25	99.7
3/4"	19	99.4
1/2"	12.5	98.8
3/8"	9.5	98.4
#4	4.75	97.1
#10	2.00	96.1
#20	0.850	92.7
#40	0.425	82.0
#60	0.250	69.2
#100	0.150	52.9
#200	0.075	36.1

	31.3
	28.6
	21.2
	18.4
	16.6

Gravel (%):	2.9
Sand (%):	61.0
Fines (%):	36.1

	-
	-

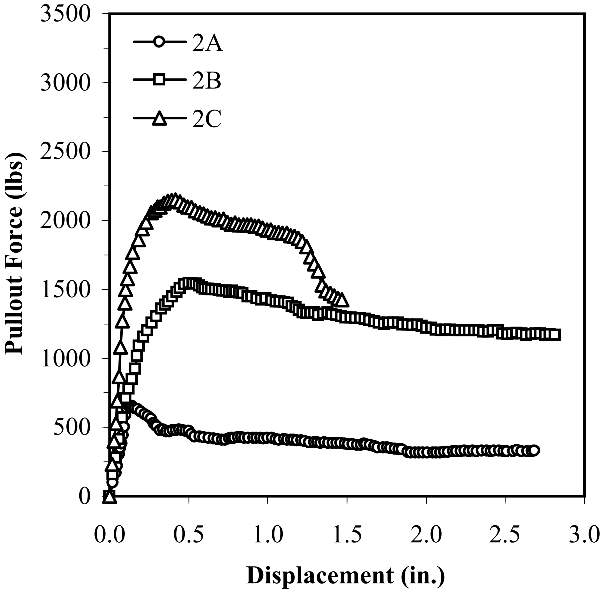


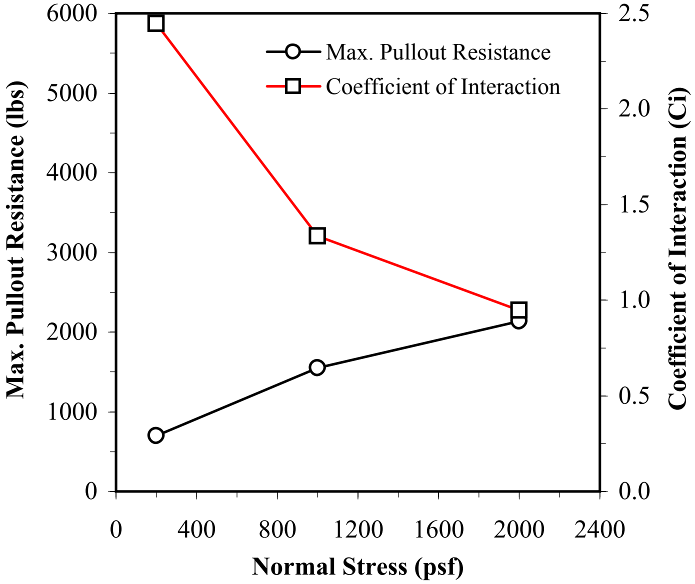
				LL (%)	PL (%)	PI (-)	
				27	22	5	

Note(s):

LINEAR COMPOSITES, LTD
POLYESTER STRIP PULLOUT TESTING (ASTM D 6706 MODIFIED)

TEST SERIES NO. 2: 85mm 30kN/m coated polyester strip in machine direction within concrete sand compacted to approximately 95% of maximum standard Proctor density at optimum moisture content





Test No.	Test Specimen Width *W* (in.)	Embedment Length *L* (in.)	Normal Stress σ (psf)	Pullout Rate (in./min)	Soil Compaction		Residual Soil Shear Strength[1]		Max. Pullout Resistance *P* (lbs)	Coefficient of Interaction[2] C_i (-)	Failure Mode[3]
					Initial Dry Unit Weight (pcf)	Initial Moisture Content (%)	ϕ (degree)	c (psf)			
2A	3.3	36.0	200	0.04	103.2	10.7	34	40	695	2.45	Pullout
2B	3.3	36.0	1000	0.04	102.9	10.4	34	40	1551	1.34	Pullout
2C	3.3	36.0	2000	0.04	103.8	10.9	34	40	2140	0.95	Rupture

NOTES:

(1) The residual shear strength parameters of the soil material were obtained from a series of direct shear tests.

(2) $C_i = (P/2.W.L)/(\sigma.\tan\phi + c)$

(3) Pullout failure was indicated by a minimum displacement of 0.5 in measured at the tell-tail wire attached to the rear end of the strip.

DATE TESTED: 3/5 to 3/20/2007

SGI TESTING SERVICES, LLC

FIGURE NO.	C-2
PROJECT NO.	SGI7018
DOCUMENT NO.	
FILE NO.	

SGI TESTING SERVICES, LLC

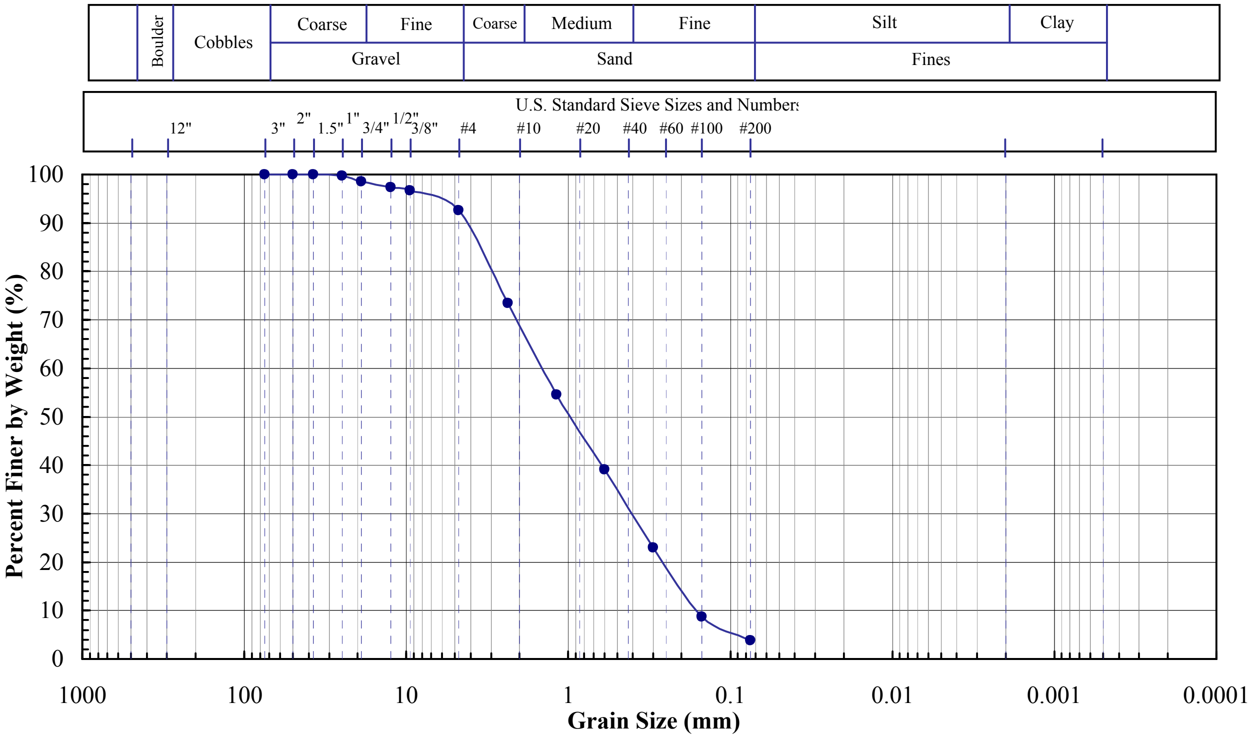
4405 International Blvd., Suite B-117, Norcross, GA 30093
Ph: (770) 931-8222 Fax: (770) 931-8240

Project Name:	Installation Damage
Project No:	SGI4062
Client Sample ID:	Concrete Sand
Lab Sample No:	S11083

ASTM D 2216, D 1140, D 422,
C 136, D 4318, D 2487

SOIL INDEX PROPERTIES

Moisture Content, Grain Size, Atterberg Limits, Classification

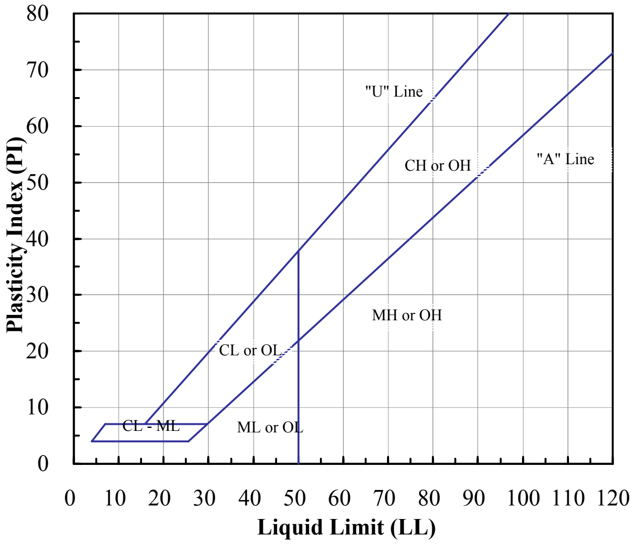


Sieve No.	Size (mm)	% Finer
3"	75	100.0
2"	50	100.0
1.5"	37.5	100.0
1"	25	99.8
3/4"	19	98.6
1/2"	12.5	97.4
3/8"	9.5	96.7
#4	4.75	92.6
#10	2.00	73.5
#20	0.850	54.6
#40	0.425	39.1
#60	0.250	23.0
#100	0.150	8.7
#200	0.075	3.8

Hydrometer Particle Diameter (mm)	% Finer
0.0340	
0.0220	
0.0065	
0.0032	
0.0013	

Gravel (%):	7.4
Sand (%):	88.8
Fines (%):	3.8
Silt (%):	
Clay (%):	

Coeff. Unif. (Cu):	-
Coeff. Curv. (Cc):	-



Client Sample ID.	Lab Sample No:	Moisture Content (%)	Fines Content < No. 200 (%)	Atterberg Limits			Engineering Classification
				LL (%)	PL (%)	PI (-)	
Concrete Sand	S11083	5.3	3.8				SP

Note(s):

SGI Testing Services, LLC

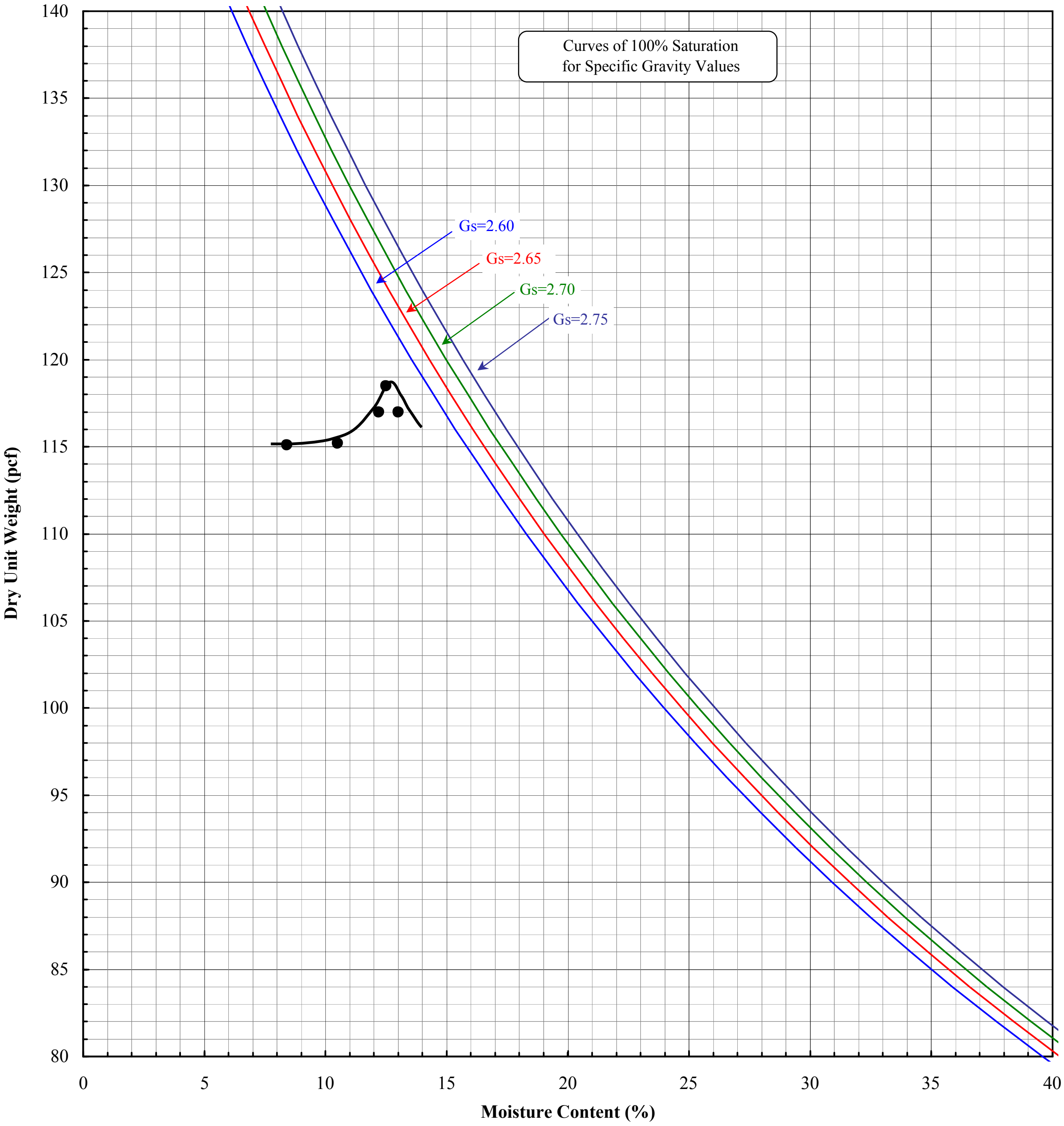
4405 International Blvd., Suite B-117, Norcross, GA 30093
Ph: (770) 931-8222 Fax: (770) 931-8240

Project Name:	Installation Damage
Project No:	SGI4062
Client Sample ID:	Concrete Sand
Lab Sample No:	S11083

ASTM D698

COMPACTION MOISTURE-DENSITY RELATIONSHIP

Standard - Method A



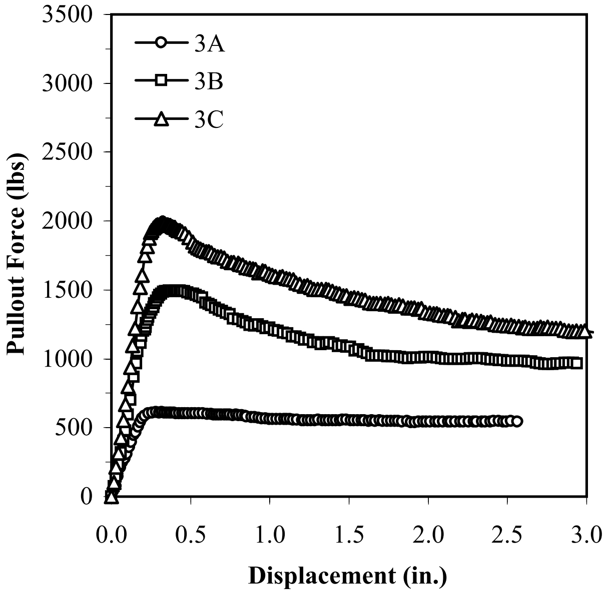
Client Sample ID.	Lab Sample No:	Maximum Dry Unit Weight (pcf)	Optimum Moisture Content (%)	Remarks
Concrete Sand	S11083	118.5	12.7	

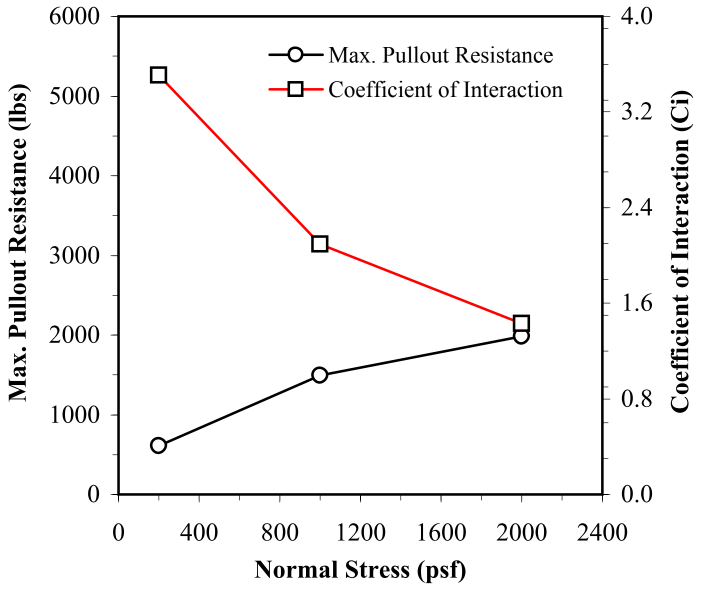
Note(s):

Corrected Maximum Dry Unit Weight (pcf) 121.1
Corrected Optimum Moisture Content (%) 11.9

LINEAR COMPOSITES, LTD
POLYESTER STRIP PULLOUT TESTING (ASTM D 6706 MODIFIED)

TEST SERIES NO. 3: 50mm (coated polyester) strip in machine direction within concrete sand compacted to approximately 95% of maximum standard Proctor density at optimum moisture content





Test No.	Test Specimen Width *W* (in.)	Embedment Length *L* (in.)	Normal Stress σ (psf)	Pullout Rate (in./min)	Soil Compaction: Initial Dry Unit Weight (pcf)	Soil Compaction: Initial Moisture Content (%)	Residual Soil Shear Strength[1]: ϕ (degree)	Residual Soil Shear Strength[1]: c (psf)	Max. Pullout Resistance *P* (lbs)	Coefficient of Interaction[2] C_i (-)	Failure Mode[3]
3A	2.0	36.0	200	0.04	104.1	10.5	34	40	613	3.50	Pullout
3B	2.0	36.0	1000	0.04	103.9	11.0	34	40	1496	2.09	Pullout
3C	2.0	36.0	2000	0.04	103.2	10.7	34	40	1986	1.43	Pullout

NOTES:

(1) The residual shear strength parameters of the soil material were obtained from a series of direct shear tests.

(2) $C_i = (P/2.W.L)/(\sigma.\tan\phi + c)$

(3) Pullout failure was indicated by a minimum displacement of 0.5 in measured at the tell-tail wire attached to the rear end of the strip.

DATE TESTED: 3/20 to 3/26/2007

SGI TESTING SERVICES, LLC

FIGURE NO.	C-3
PROJECT NO.	SGI7018
DOCUMENT NO.	
FILE NO.	

1.2.8 DIRECT SLIDING PROPERTIES

Paraweb Interface Direct Shear Tests

SGI TESTING SERVICES

A Georgia Limited Liability Company

26 November 2008

Mr. Robert Lozano
Linear Composites, Ltd
7830 Laurelton Drive
Chattanooga, TN 37421-1953

Subject: Laboratory Test Results Transmittal
Interface Direct Shear Testing
Soil/ParaWeb Polymeric Strips

Dear Mr. Lozano,

SGI Testing Services, LLC (SGI) is pleased to present the attached test results for the above-mentioned testing program. The note section below addresses sample preparation, sample disposal and a disclosure statement.

SGI appreciates the opportunity to provide laboratory testing services to Linear Composites, Ltd. Should you have any questions regarding the attached document, or if you require additional information, please do not hesitate to contact the undersigned.

Sincerely,

Zehong Yuan, Ph.D., P.E.
Laboratory Manager

Attachment

Notes:
(1) Unless otherwise noted in the test results the sample(s)/specimen(s) were prepared in accordance with the applicable test standards or generally accepted sampling procedures.
(2) Contaminated/chemical samples and all related laboratory generated waste (i.e., test liquids, PPE, absorbents, etc.) will be returned to the client or designated representative(s), at the client's cost, within 60 days following the completion of the testing program, unless special arrangements for proper disposal are made with SGI$_{sm}$.
(3) Materials that are not contaminated will be discarded after test specimens and archived specimens are obtained. All of the tested and archived specimens will be discarded 30 days after the completion of testing, unless long-term storage arrangements are specifically made with the laboratory.
(4) The reported results apply only to the materials and test conditions used in the laboratory testing program. The results do not necessarily apply to other materials or test conditions. The test results should not be used in engineering analysis unless the test conditions model the anticipated field conditions. The testing was performed in accordance with general engineering testing standards and requirements. The reported results are submitted for the exclusive use of the client to whom they are addressed.

SGI7018.REPORT.08.03

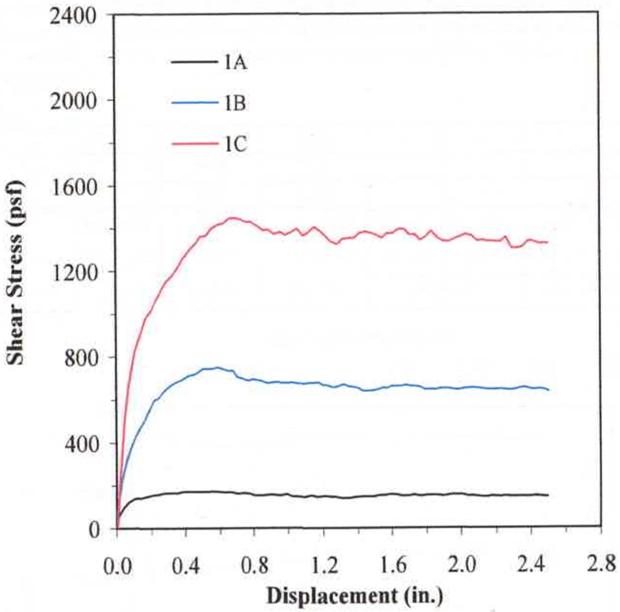
Mail To: SGI Testing Services, LLC
P.O. Box 2427
Lilburn, Georgia 30048-2427
Web Site: www.interactionspecialists.com

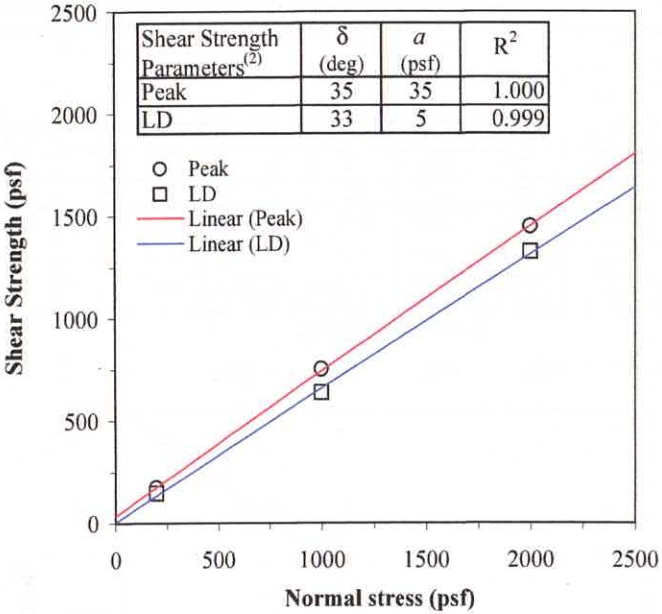
Facility Location
4405 International Boulevard
Suite B-117
Norcross, Georgia 30093
Phone: 770.931.8222 Fax: 770.931.8240

LINEAR COMPOSITES, LTD
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Upper Shear Box: Graded aggregate base (GAB) material compacted to approximately 95% of max. modified Proctor density at optimum moisture against 30 kN Paraweb Style 2S (100% coverage)

Lower Shear Box: Graded aggregate base (GAB) material compacted to approximately 95% of max. modified Proctor density at optimum moisture





Shear Strength Parameters[(2)]	δ (deg)	a (psf)	R^2
Peak	35	35	1.000
LD	33	5	0.999

Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking		Consolidation		Soil Compaction			Soil Shear Strength Parameters				Shear Strength[(1)]		Coefficient of Direct Sliding	
				Stress (psf)	Time (hour)	Stress (psf)	Time (hour)	γ_d (pcf)	ω_i (%)	ω_f (%)	ϕ_P (deg)	c_P (psf)	ϕ_{LD} (deg)	c_{LD} (psf)	τ_P (psf)	τ_{LD} (psf)	C_{DS-P}	C_{DS-LD}
1A	12 x 12	200	0.04	-	-	-	-	135.5	4.7	4.8	45	45	42	15	172	146	0.70	0.75
1B	12 x 12	1000	0.04	-	-	-	-	134.7	5.3	5.1	45	45	42	15	751	637	0.72	0.70
1C	12 x 12	2000	0.04	-	-	-	-	134.3	5.6	5.3	45	45	42	15	1450	1323	0.71	0.73

NOTES:

(1) Sliding (i.e., shear failure) occurred at intended test interface in each test.

(2) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

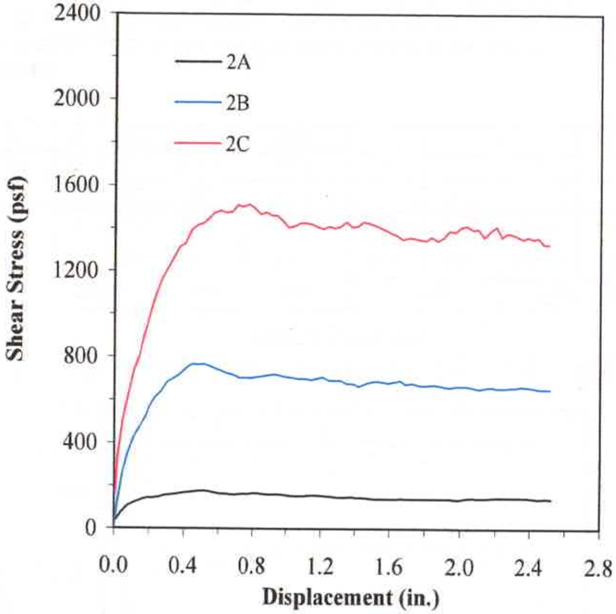
DATE OF REPORT:	6/30/2008
FIGURE NO.	C-1
PROJECT NO.	SGI7018
DOCUMENT NO.	SGI08023
FILE NO.	

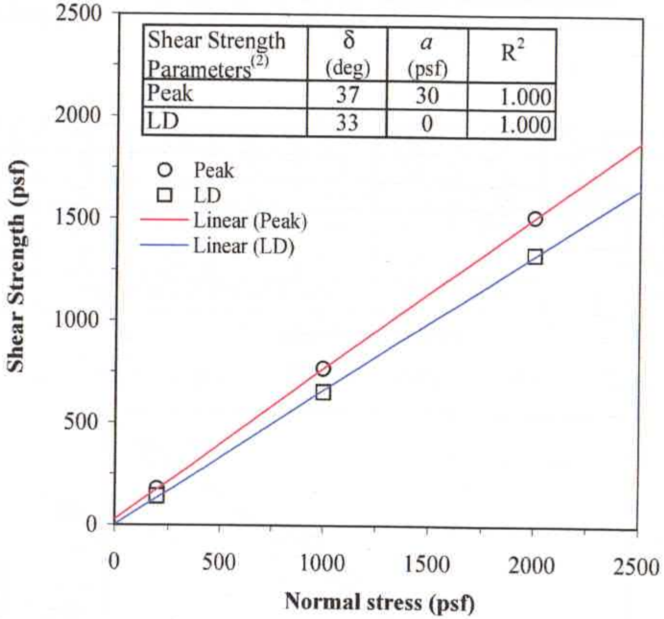
SGI TESTING SERVICES, LLC

LINEAR COMPOSITES, LTD
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Upper Shear Box: Graded aggregate base (GAB) material compacted to approximately 95% of max. modified Proctor density at optimum moisture against 30 kN Paraweb Style 2D (100% coverage)

Lower Shear Box: Graded aggregate base (GAB) material compacted to approximately 95% of max. modified Proctor density at optimum moisture





Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking		Consolidation		Soil Compaction			Soil Shear Strength Parameters				Shear Strength(1)		Coefficient of Direct Sliding	
				Stress (psf)	Time (hour)	Stress (psf)	Time (hour)	γ_d (pcf)	ω_i (%)	ω_f (%)	ϕ_P (deg)	c_P (psf)	ϕ_{LD} (deg)	c_{LD} (psf)	τ_P (psf)	τ_{LD} (psf)	C_{DS-P}	C_{DS-LD}
2A	12 x 12	200	0.04	-	-	-	-	134.8	5.2	5.0	45	45	42	15	177	139	0.72	0.71
2B	12 x 12	1000	0.04	-	-	-	-	134.5	5.5	4.8	45	45	42	15	767	652	0.73	0.71
2C	12 x 12	2000	0.04	-	-	-	-	135.2	4.9	5.1	45	45	42	15	1511	1328	0.74	0.73

NOTES:

(1) Sliding (i.e., shear failure) occurred at intended test interface in each test.

(2) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

SGI TESTING SERVICES, LLC

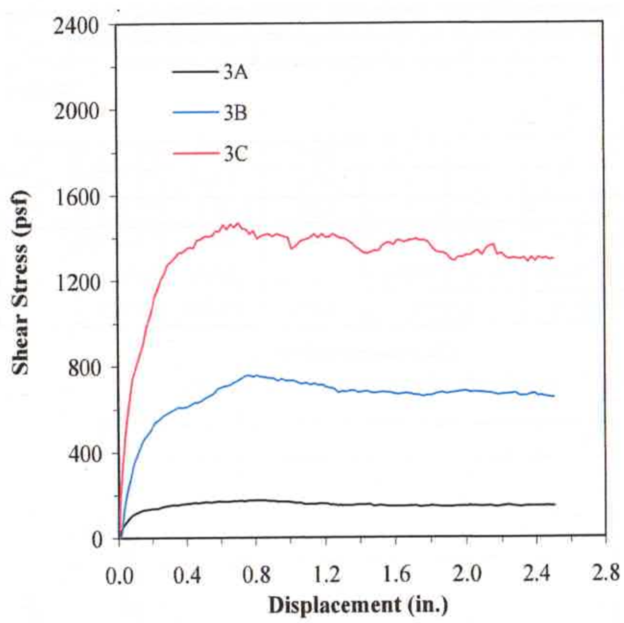
DATE OF REPORT:	6/30/2008
FIGURE NO.	C-2
PROJECT NO.	SGI7018
DOCUMENT NO.	SGI08023
FILE NO.	

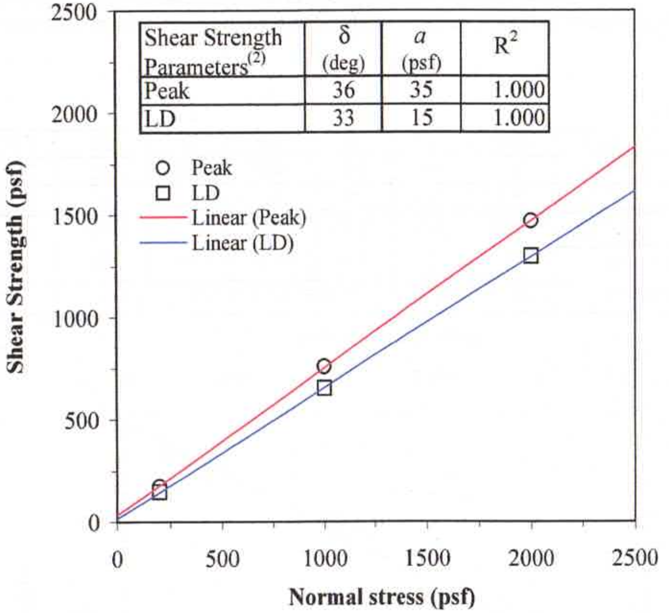
LINEAR COMPOSITES, LTD

INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Upper Shear Box: Graded aggregate base (GAB) material compacted to approximately 95% of max. modified Proctor density at optimum moisture against 30 kN Paraweb Style 2E+ (100% coverage)

Lower Shear Box: Graded aggregate base (GAB) material compacted to approximately 95% of max. modified Proctor density at optimum moisture





Shear Strength Parameters[(2)]	δ (deg)	*a* (psf)	R^2
Peak	36	35	1.000
LD	33	15	1.000

Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking Stress (psf)	Soaking Time (hour)	Consolidation Stress (psf)	Consolidation Time (hour)	Soil Compaction γ_d (pcf)	Soil Compaction ω_i (%)	Soil Compaction ω_f (%)	Soil Shear Strength Parameters ϕ_P (deg)	c_P (psf)	ϕ_{LD} (deg)	c_{LD} (psf)	Shear Strength[(1)] τ_P (psf)	τ_{LD} (psf)	Coefficient of Direct Sliding C_{DS-P}	C_{DS-LD}
3A	12 x 12	200	0.04	-	-	-	-	134.6	5.4	5.5	45	45	42	15	174	145	0.71	0.74
3B	12 x 12	1000	0.04	-	-	-	-	135.1	5.0	4.9	45	45	42	15	759	652	0.73	0.71
3C	12 x 12	2000	0.04	-	-	-	-	134.3	5.6	5.3	45	45	42	15	1470	1297	0.72	0.71

NOTES:

(1) Sliding (i.e., shear failure) occurred at intended test interface in each test.

(2) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

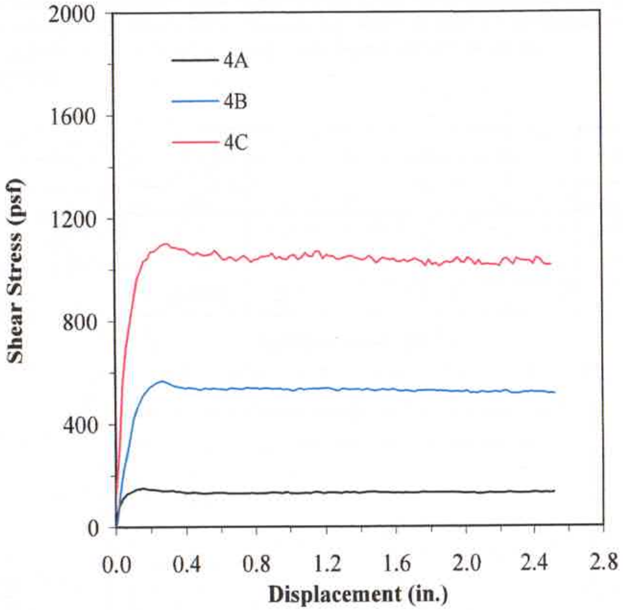
DATE OF REPORT:	6/30/2008
FIGURE NO.	C-3
PROJECT NO.	SGI7018
DOCUMENT NO.	SGI08023
FILE NO.	

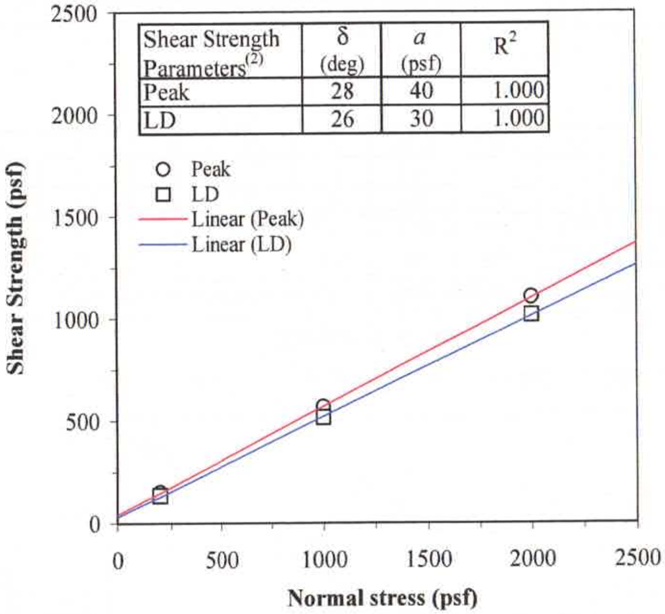
SGI TESTING SERVICES, LLC

LINEAR COMPOSITES, LTD
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Upper Shear Box: Concrete sand compacted to approximately 95% of max standard Proctor density at optimum moisture against 30 kN Paraweb Style 2D (100% coverage)

Lower Shear Box: Concrete sand compacted to approximately 95% of max standard Proctor density at optimum moisture





Shear Strength Parameters$^{(2)}$	δ (deg)	*a* (psf)	R^2
Peak	28	40	1.000
LD	26	30	1.000

Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking		Consolidation		Soil Compaction			Soil Shear Strength Parameters				Shear Strength$^{(1)}$		Coefficient of Direct Sliding	
				Stress (psf)	Time (hour)	Stress (psf)	Time (hour)	γ_d (pcf)	ω_i (%)	ω_f (%)	ϕ_P (deg)	c_P (psf)	ϕ_{LD} (deg)	c_{LD} (psf)	τ_P (psf)	τ_{LD} (psf)	C_{DS-P}	C_{DS-LD}
4A	12 x 12	200	0.04	-	-	-	-	103.9	10.7	10.2	37	55	34	40	149	132	0.72	0.76
4B	12 x 12	1000	0.04	-	-	-	-	104.3	10.3	10.1	37	55	34	40	568	515	0.70	0.72
4C	12 x 12	2000	0.04	-	-	-	-	104.1	10.5	10.4	37	55	34	40	1102	1016	0.71	0.73

NOTES:

(1) Sliding (i.e., shear failure) occurred at intended test interface in each test.

(2) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

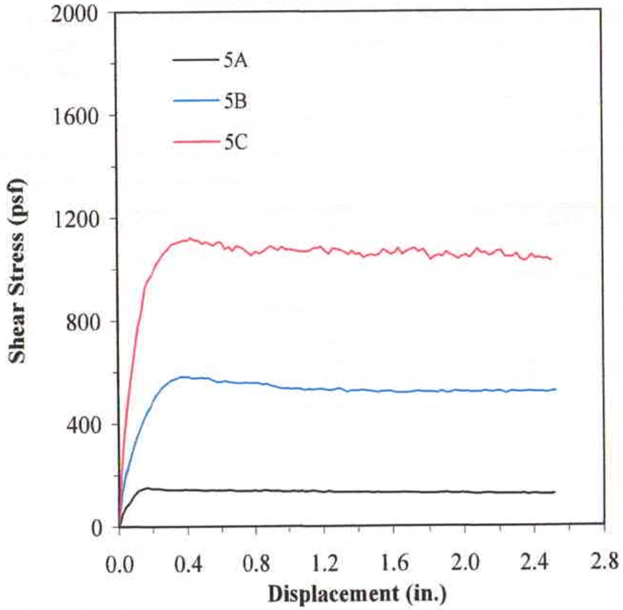
DATE OF REPORT:	6/30/2008
FIGURE NO.	C-4
PROJECT NO.	SGI7018
DOCUMENT NO.	SGI08023
FILE NO.	

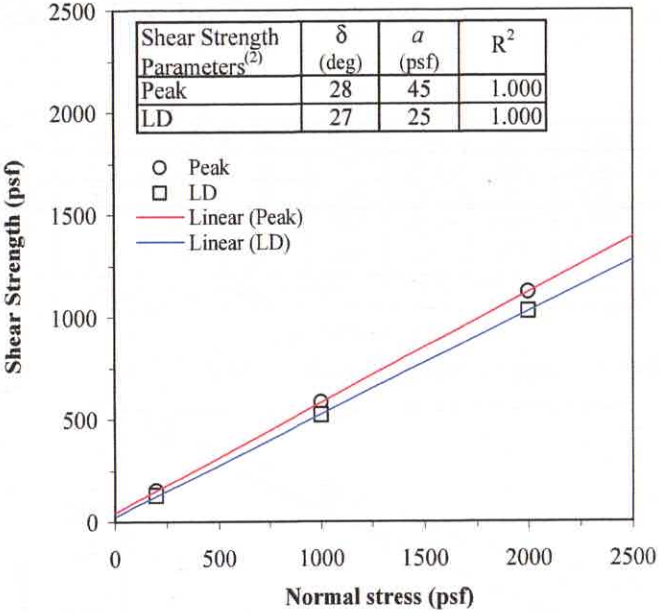
SGI TESTING SERVICES, LLC

LINEAR COMPOSITES, LTD
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Upper Shear Box: Concrete sand compacted to approximately 95% of max standard Proctor density at optimum moisture against 30 kN Paraweb Style 2E+ (100% coverage)

Lower Shear Box: Concrete sand compacted to approximately 95% of max standard Proctor density at optimum moisture





Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking		Consolidation		Soil Compaction			Soil Shear Strength Parameters				Shear Strength[1]		Coefficient of Direct Sliding	
				Stress (psf)	Time (hour)	Stress (psf)	Time (hour)	γ_d (pcf)	ω_i (%)	ω_f (%)	ϕ_P (deg)	c_P (psf)	ϕ_{LD} (deg)	c_{LD} (psf)	τ_P (psf)	τ_{LD} (psf)	C_{DS-P}	C_{DS-LD}
5A	12 x 12	200	0.04	-	-	-	-	103.4	11.2	10.8	37	55	34	40	152	126	0.74	0.72
5B	12 x 12	1000	0.04	-	-	-	-	103.9	10.7	10.9	37	55	34	40	582	522	0.72	0.73
5C	12 x 12	2000	0.04	-	-	-	-	103.7	10.9	10.3	37	55	34	40	1122	1028	0.72	0.74

NOTES:

(1) Sliding (i.e., shear failure) occurred at intended test interface in each test.

(2) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

DATE OF REPORT:	6/30/2008
FIGURE NO.	C-5
PROJECT NO.	SGI7018
DOCUMENT NO.	SGI08023
FILE NO.	

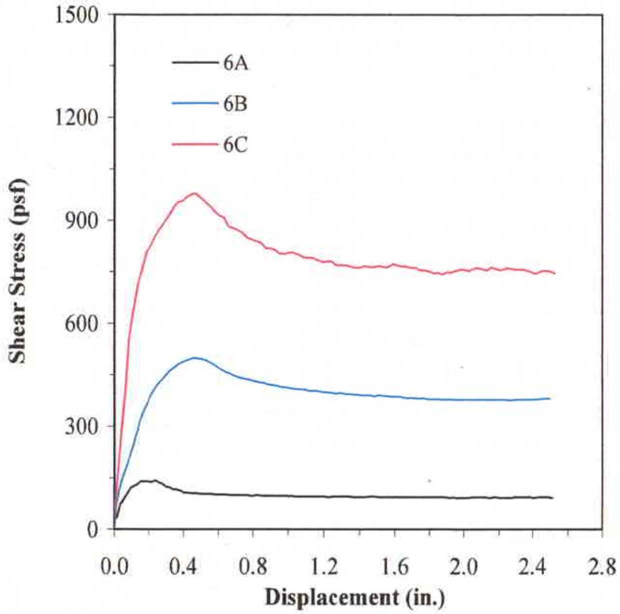
SGI TESTING SERVICES, LLC

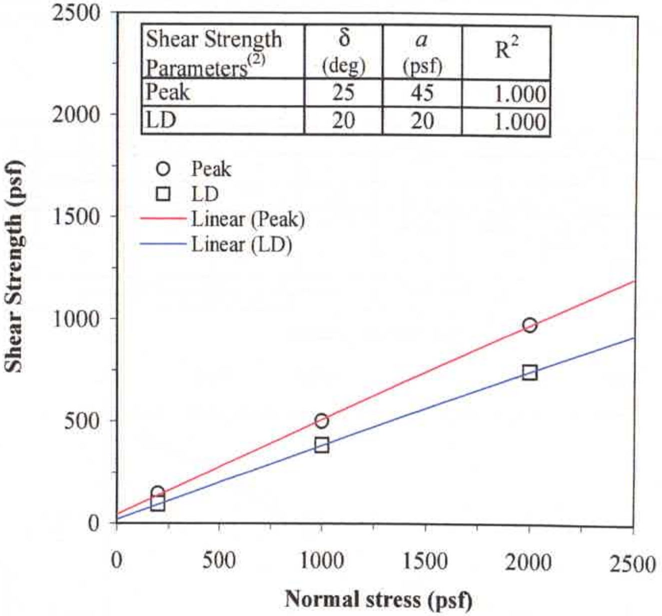
LINEAR COMPOSITES, LTD

INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Upper Shear Box: Silty sand compacted to approximately 95% of max standard Proctor density at optimum moisture against 30 kN Paraweb Style 2D (100% coverage)

Lower Shear Box: Silty sand compacted to approximately 95% of max standard Proctor density at optimum moisture





Shear Strength Parameters[2]	δ (deg)	*a* (psf)	R^2
Peak	25	45	1.000
LD	20	20	1.000

Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking		Consolidation		Soil Compaction			Soil Shear Strength Parameters				Shear Strength[1]		Coefficient of Direct Sliding	
				Stress (psf)	Time (hour)	Stress (psf)	Time (hour)	γ_d (pcf)	ω_i (%)	ω_f (%)	ϕ_P (deg)	c_P (psf)	ϕ_{LD} (deg)	c_{LD} (psf)	τ_P (psf)	τ_{LD} (psf)	C_{DS-P}	C_{DS-LD}
6A	12 x 12	200	0.04	-	-	-	-	93.4	19.2	19.0	32	75	31	30	142	93	0.71	0.62
6B	12 x 12	1000	0.04	-	-	-	-	93.1	19.6	19.1	32	75	31	30	499	382	0.71	0.61
6C	12 x 12	2000	0.04	-	-	-	-	94.1	18.4	18.5	32	75	31	30	979	746	0.74	0.61

NOTES:

(1) Sliding (i.e., shear failure) occurred at intended test interface in each test.

(2) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

DATE OF REPORT:	6/30/2008
FIGURE NO.	C-6
PROJECT NO.	SGI7018
DOCUMENT NO.	SGI08023
FILE NO.	

SGI TESTING SERVICES, LLC

Figure 1. 100% coverage achieved by placing 4 Parawebs side by side and no gaps between Parawebs

Figure 2. Soil placed in the upper shear box and compacted on top of Parawebs to a specified unit weight

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1.3.1 OTHER INNOVATIONS

No attachments

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jump to Appendix TOC

1.3.2 REINFORCED SOIL

No attachments

jump to TOC

jump to Appendix TOC

1.3.3 DRAINAGE

No attachments

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[jump to Appendix TOC](#)

1.3.4 COPING

No attachments

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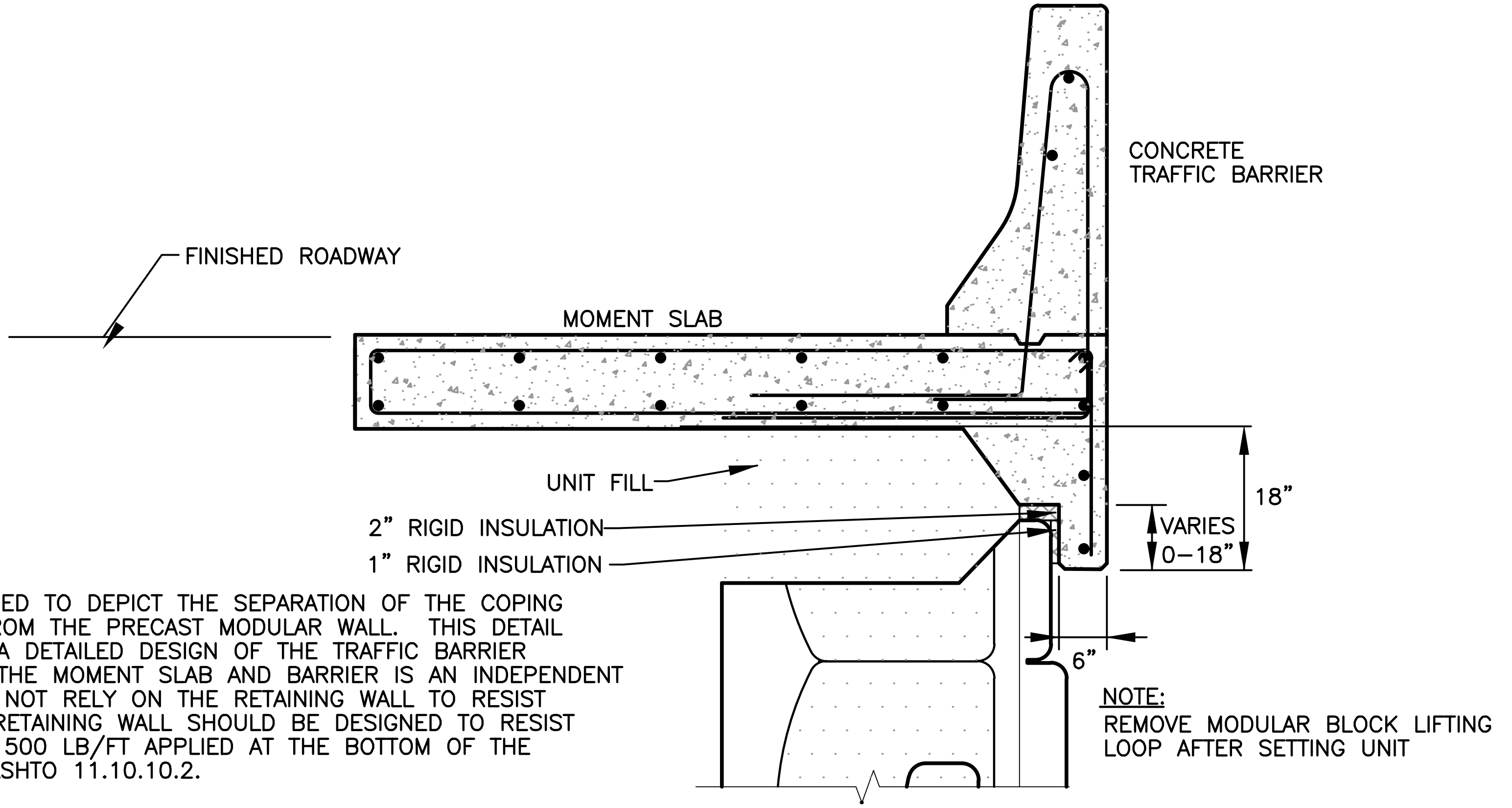
1.3.5 TRAFFIC BARRIERS



NOTE:
REMOVE MODULAR BLOCK LIFTING LOOP AFTER SETTING UNIT

THIS DETAIL IS INTENDED TO DEPICT THE SEPARATION OF THE COPING AND MOMENT SLAB FROM THE PRECAST MODULAR WALL. THIS DETAIL IS NOT INTENDED AS A DETAILED DESIGN OF THE TRAFFIC BARRIER AND MOMENT SLAB. THE MOMENT SLAB AND BARRIER IS AN INDEPENDENT DESIGN, AND SHOULD NOT RELY ON THE RETAINING WALL TO RESIST CRASH LOADS. THE RETAINING WALL SHOULD BE DESIGNED TO RESIST A LATERAL FORCE OF 500 LB/FT APPLIED AT THE BOTTOM OF THE MOMENT SLAB PER AASHTO 11.10.10.2.

BARRIER & COPING W/ COPING SKIRT

NOT TO SCALE

DISCLAIMER:

These typical details are preliminary and conceptual in nature. They are provided for general information purposes only. Anyone making use of these details and related information does so at their own risk and assumes all liability for such use. Site specific design should be performed by a licensed Professional Engineer based on actual site conditions, materials, and local practices.

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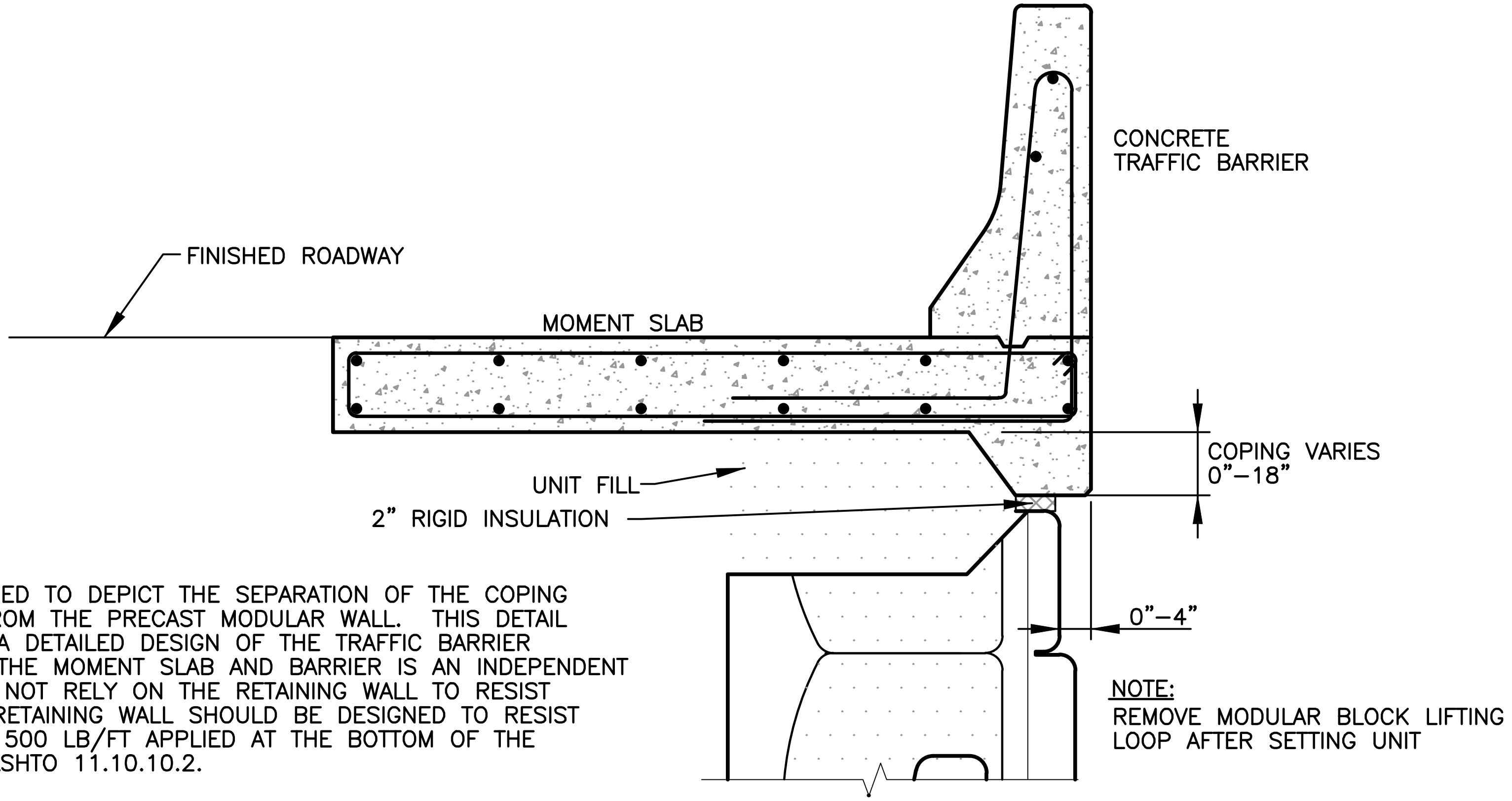
PROJECT

TYPICAL DETAILS
STONE STRONG SYSTEMS

DATE: 4/13/20
FILE: Barrier_Coping_W/SKIRT



NOTE:
REMOVE MODULAR BLOCK LIFTING LOOP AFTER SETTING UNIT

THIS DETAIL IS INTENDED TO DEPICT THE SEPARATION OF THE COPING AND MOMENT SLAB FROM THE PRECAST MODULAR WALL. THIS DETAIL IS NOT INTENDED AS A DETAILED DESIGN OF THE TRAFFIC BARRIER AND MOMENT SLAB. THE MOMENT SLAB AND BARRIER IS AN INDEPENDENT DESIGN, AND SHOULD NOT RELY ON THE RETAINING WALL TO RESIST CRASH LOADS. THE RETAINING WALL SHOULD BE DESIGNED TO RESIST A LATERAL FORCE OF 500 LB/FT APPLIED AT THE BOTTOM OF THE MOMENT SLAB PER AASHTO 11.10.10.2.

BARRIER & COPING

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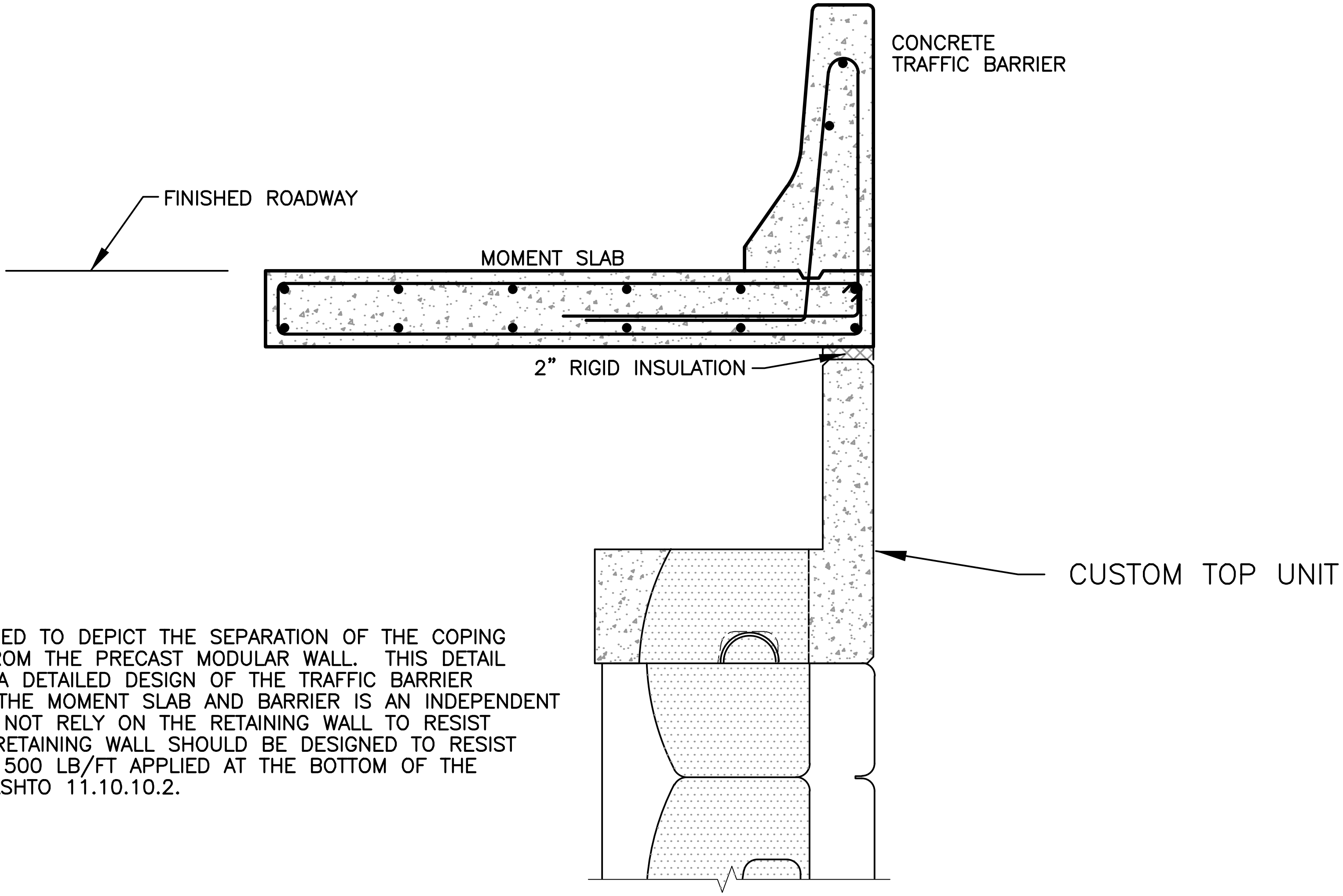
PROJECT
TYPICAL DETAILS
STONE STRONG SYSTEMS

DATE: 4/13/20
FILE: Barrier_Coping



THIS DETAIL IS INTENDED TO DEPICT THE SEPARATION OF THE COPING AND MOMENT SLAB FROM THE PRECAST MODULAR WALL. THIS DETAIL IS NOT INTENDED AS A DETAILED DESIGN OF THE TRAFFIC BARRIER AND MOMENT SLAB. THE MOMENT SLAB AND BARRIER IS AN INDEPENDENT DESIGN, AND SHOULD NOT RELY ON THE RETAINING WALL TO RESIST CRASH LOADS. THE RETAINING WALL SHOULD BE DESIGNED TO RESIST A LATERAL FORCE OF 500 LB/FT APPLIED AT THE BOTTOM OF THE MOMENT SLAB PER AASHTO 11.10.10.2.

CUSTOM TOP UNIT–BARRIER & COPING

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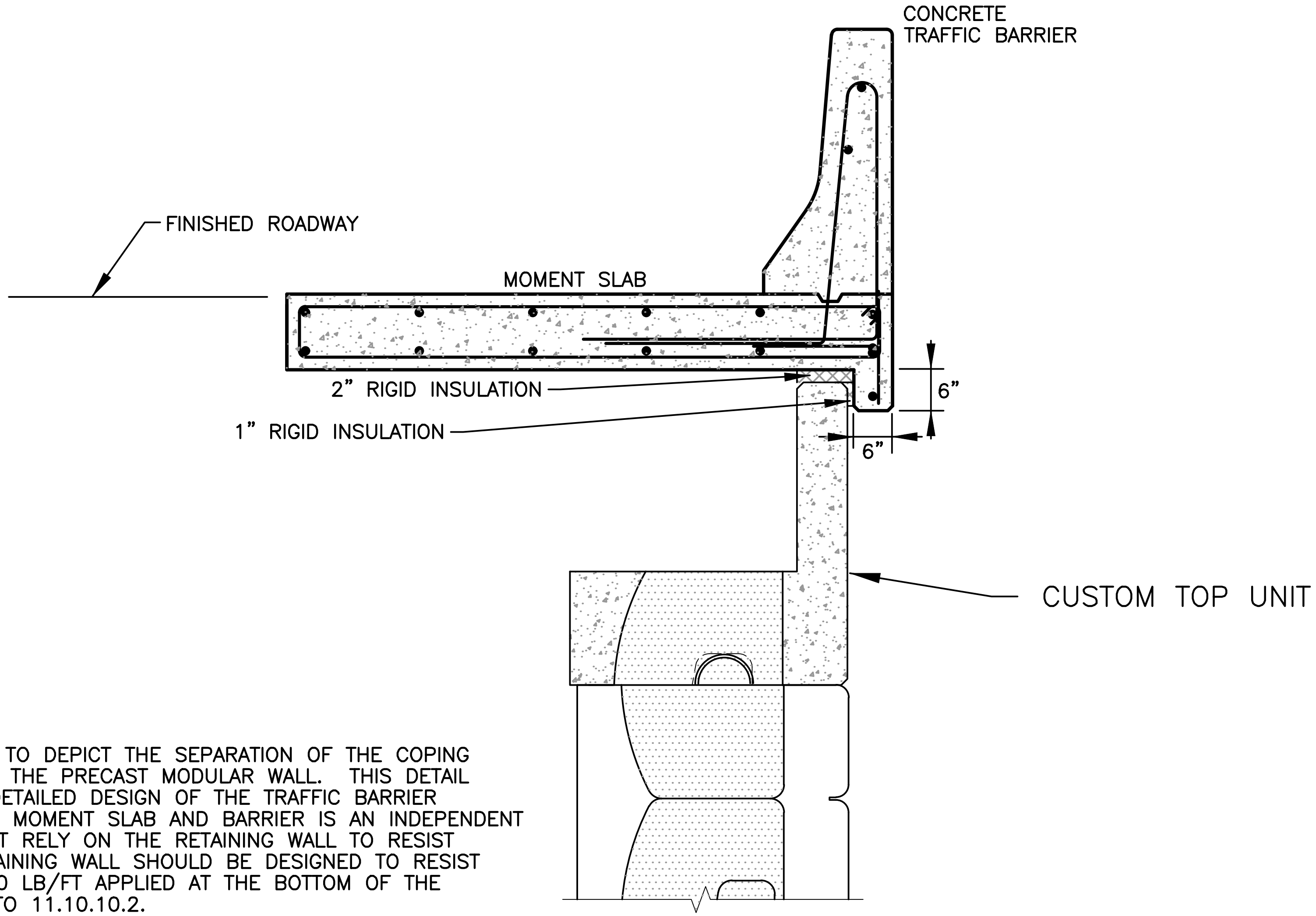
PROJECT

TYPICAL DETAILS
STONE STRONG SYSTEMS

DATE: 4/6/20 | FILE: CT– Barrier_Coping



THIS DETAIL IS INTENDED TO DEPICT THE SEPARATION OF THE COPING AND MOMENT SLAB FROM THE PRECAST MODULAR WALL. THIS DETAIL IS NOT INTENDED AS A DETAILED DESIGN OF THE TRAFFIC BARRIER AND MOMENT SLAB. THE MOMENT SLAB AND BARRIER IS AN INDEPENDENT DESIGN, AND SHOULD NOT RELY ON THE RETAINING WALL TO RESIST CRASH LOADS. THE RETAINING WALL SHOULD BE DESIGNED TO RESIST A LATERAL FORCE OF 500 LB/FT APPLIED AT THE BOTTOM OF THE MOMENT SLAB PER AASHTO 11.10.10.2.

CUSTOM TOP UNIT & COPING W/ COPING SKIRT

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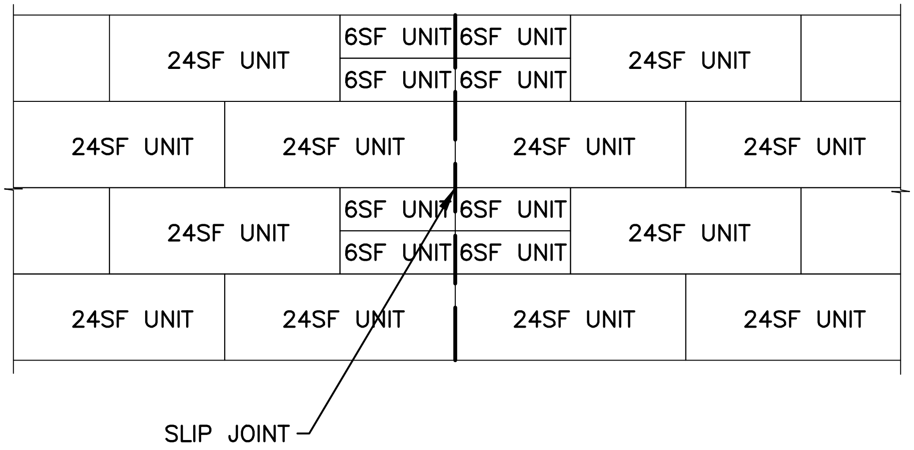
PROJECT

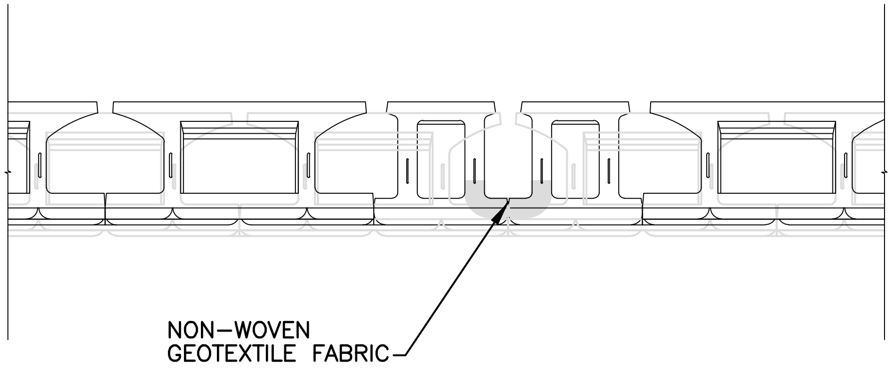
TYPICAL DETAILS
STONE STRONG SYSTEMS

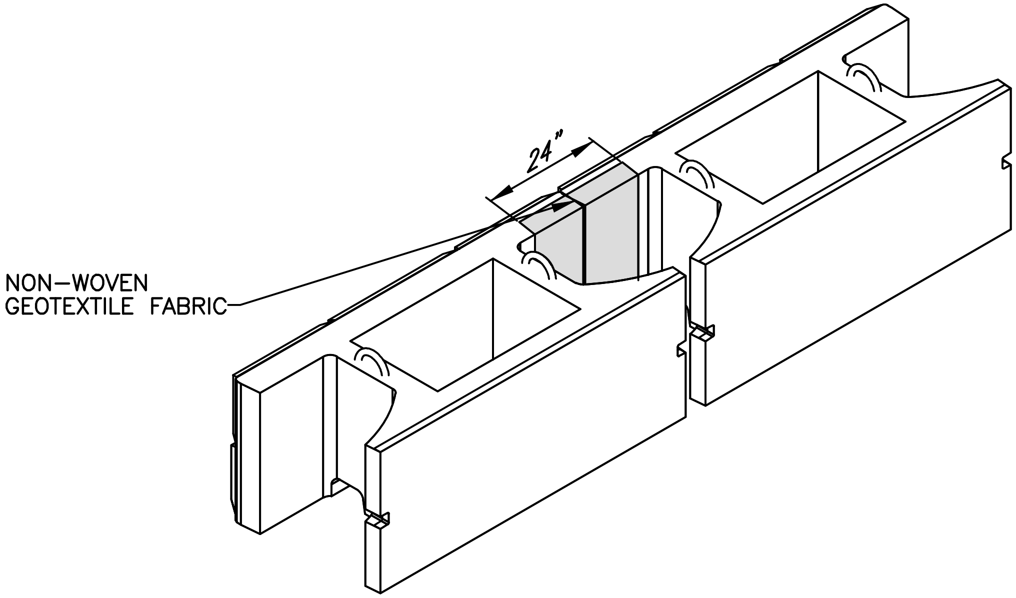
DATE: 4/6/20
FILE: CT–Barrier_Coping_W/SKIRT

1.3.6 SLIP JOINTS

Slip Joint Detail







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PROJECT

SLIP JOINT DETAIL
STONE STRONG SYSTEMS

DATE: 3/30/20 | FILE: SLIP JOINT DETAIL

[jump to TOC]

[jump to Appendix TOC]

2.1.1 DESIGN INNOVATIONS

click here to request download of Gravity Analysis spreadsheet

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jump to Appendix TOC

2.1.2 DESIGN METHODOLOGIES

Project	Project #	Date
Gravity Wall Design - LRFD	20004.00	2/20/20

GRAVITY WALL DESIGN - LRFD

STONE STRONG PRECAST MODULAR BLOCK

This engineering section presents information for design of Stone Strong retaining walls in a gravity configuration using Load and Resistance Factor Design (LRFD) procedures.

The design methodologies presented conform substantially to AASHTO specifications (LRFD Bridge Specifications, 8th Edition, 2017). This section includes the following documents:

LRFD Gravity Wall Design Methodology (17 pages)
Example LRFD Gravity Wall Calculations (20 pages)
Example LRFD Spreadsheet Output (12 pages)

The example calculations and example spreadsheet output match identical design conditions and are intended as verification of the spreadsheet method. Note that the Gravity Analysis Spreadsheet is available on the Stone Strong website.

Project LRFD Design Methodology	**Project #** 20004.00	**Date** 2/20/20

GRAVITY WALL LRFD DESIGN METHODOLOGY

STONE STRONG PRECAST MODULAR BLOCK

Evaluate gravity retaining wall using strength design approach (Load and Resistance Factor Design) following AASHTO analytical techniques – refer to:

AASHTO LRFD Bridge Design Specifications, 8th Edition 2017

Additional analytical methods and theories are taken from previous AASHTO specifications and other FHWA guidelines – refer to:

Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes, NHI-10-024

AASHTO Standard Specifications for Highway Bridges 2002, 17th Addition

Properties of Soil/Aggregate

Soil and material properties should be determined for the specific materials to be used:

unit fill - γ_u = 110 pcf (17.3 kN/m^3) max (see AASHTO 2002 5.9.2) & ϕ_u

leveling base –γ_b & ϕ_b for typical aggregate base (or concrete base may be substituted)

retained soil - γ & ϕ by site conditions (where select backfill is used, select material must encompass entire retained soil influence zone)

foundation soil - γ ϕ & c by site conditions

interface angle (see AASHTO LRFD Table C3.11.5.9-1)

For stepped modules, when the block width varies within a vertical section, $\delta = ¾\ \phi$

For cases where all blocks are substantially uniform width, $\delta = ½\ \phi$

Note: infill weight is reduced to account for infill not engaged by modular units in overturning. Only 80% of the weight of aggregate is included in the overturning calculations, W' (see AASHTO LRFD 11.11.4.4)

Precast Modular Unit Geometric Properties

(not all units available from all dealers, verify availability)

Block Library – Imperial Units

(not all units available from all dealers, verify availability)

Block Type	Description	Conc. Wt. (lbs)	Void Vol. (ft^3)	Length (ft)	Height (ft)	Unit Width (in)	Conc. Cen. of Gravity x_b (in)	Void Cen. of Gravity x_a (in)
6-28	6SF-28 unit (6 square feet)	950	6.65	4	1.50	28	12.8	14.0
6SF	6SF unit (6 square feet)	1,500	10.95	4	1.50	44	21.0	23.5
24SF	24SF unit (24 square feet)	6,000	43.21	8	3.00	44	21.2	24.8
24-ME	24SF Mass Extender unit	10,000	44.94	8	3.00	56	32.7	25.8
24-62	24SF-62 unit	6,800	76.05	8	3.00	62	29.1	33.0
24-86	24SF-86 unit	7,600	117.90	8	3.00	86	40.0	45.1

dimensions are for battered units - for vertical stack 24SF units, the width and center of gravity dimensions are all reduced by 1 inch

Block Library – Metric Units

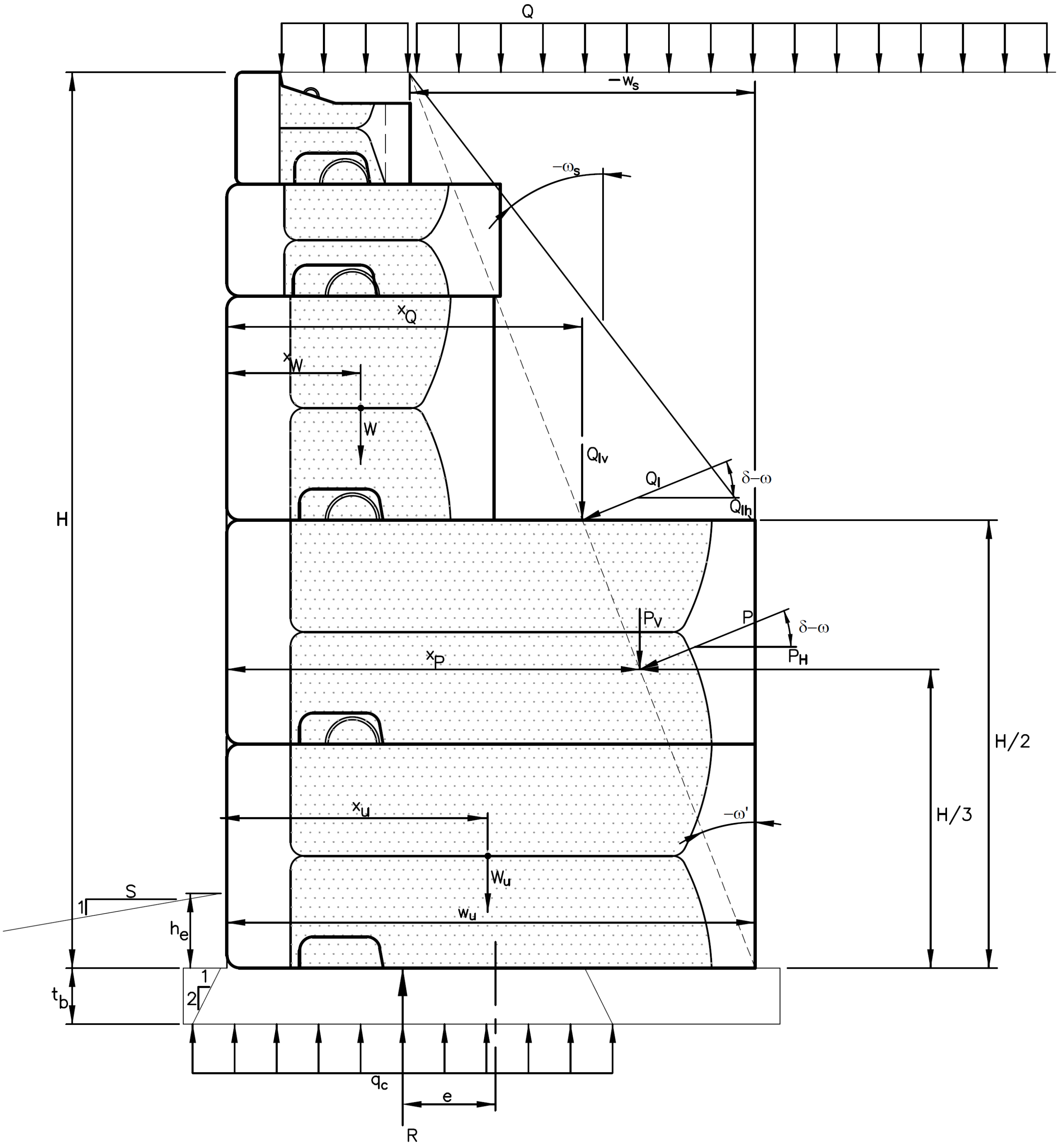
(not all units available from all dealers, verify availability)

Block Type	Description	Conc. Wt. (kN)	Void Vol. (m^3)	Length (m)	Height (m)	Unit Width (mm)	Conc. Cen. of Gravity x_b (mm)	Void Cen. of Gravity x_a (mm)
6-28	6SF-28 unit (6 square feet)	4.23	0.19	1.22	0.46	711	324	356
6SF	6SF unit (6 square feet)	6.67	0.31	1.22	0.46	1,118	533	597
24SF	24SF unit (24 square feet)	26.69	1.22	2.44	0.91	1,118	538	630
24-ME	24SF Mass Extender unit	44.48	1.28	2.44	0.91	1,422	831	655
24-62	24SF-62 unit	30.25	2.16	2.44	0.91	1,575	739	838
24-86	24SF-86 unit	33.8	3.35	2.44	0.91	2,184	1,016	1,146

dimensions are for battered units - for vertical stack 24SF units, the width and center of gravity dimensions are all reduced by 25 mm

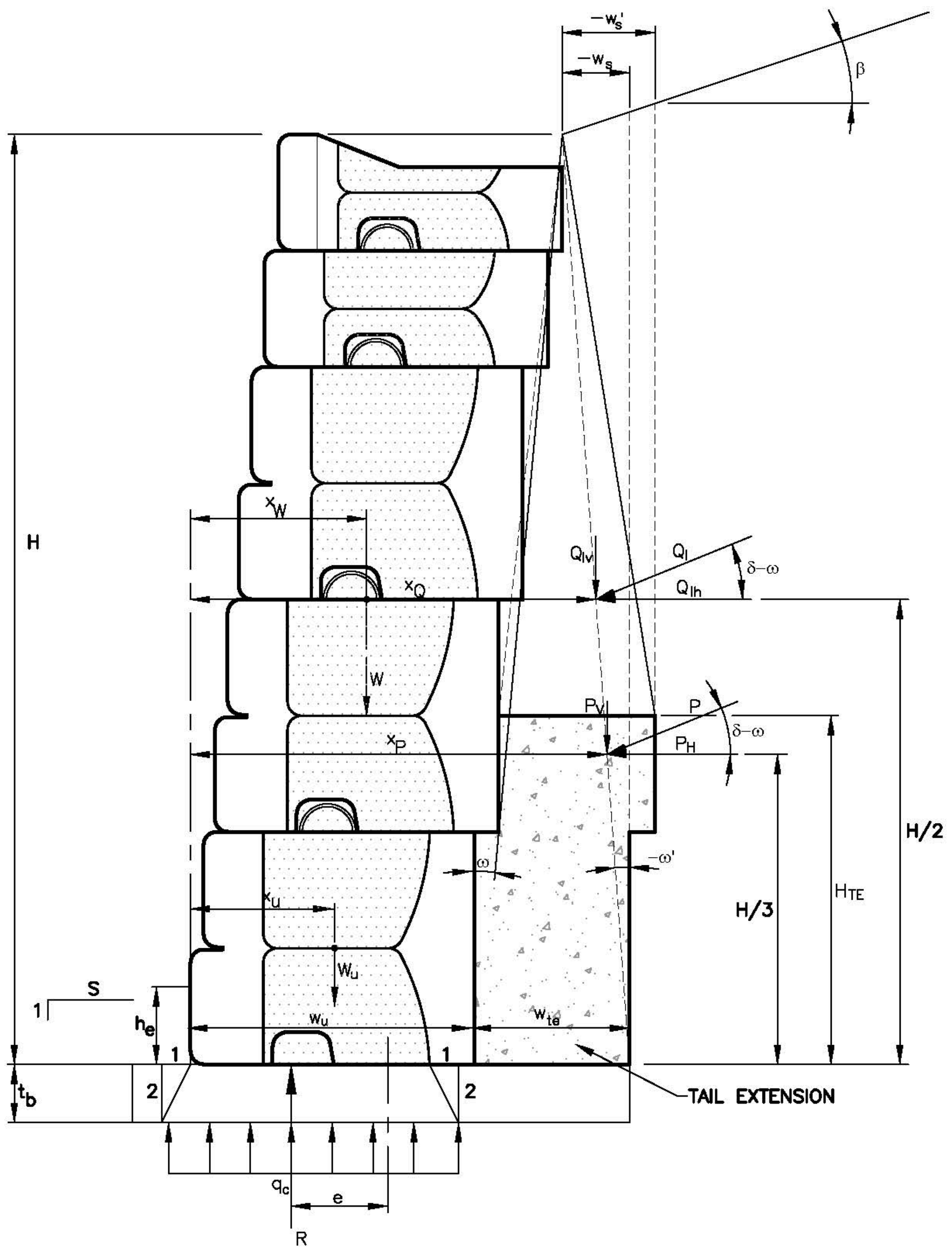
Wall stability calculations are performed per unit length of wall, so all weights and forces are expressed per foot or m of wall length.

Typical gravity wall configuration with precast stepped modules, variables, and nomenclature:



Note that surcharge loads over the top of the wall are treated separately from surcharge behind the wall.

Typical gravity wall with cast in place tail extension, variables, and nomenclature:



Wall units that vary in width are referred to as “stepped” modules. Wider wall units are typically placed at the bottom of the wall. In addition to using wider precast units, the stability of a gravity wall can be improved by using cast-in-place tail extensions to increase the width of the units. The width of the CIP extension is not limited, but it is recommend that the height be at least 2 times the width to provide shear through the tail openings (unless connecting with reinforcing steel).

Wall batter

The block units may be installed with either a vertical face or a battered face. In vertical applications, the units are be installed with no batter or setback between units, ω = 0°

In a battered configuration, the 24 SF, 24-62, 24-86, and 24-ME units are 36 inches (914 mm) high and the next block atop a 24 SF block will batter back 4 inches (102 mm). The 6 SF and 6-28 units are 18 inches (457 mm) tall, and the next block atop a 6 SF block will batter 2 inches (51 mm). These blocks may be interchanged within a wall stack, but the batter is determined by the height of the unit below.

4 in. setback per 24 SF block (36 in. tall)	102 mm setback per 24SF block (914 mm tall)
2 in. setback per 6 SF block (18 in. tall)	51 mm setback per 6SF block (457 mm tall)

The face batter is calculated as:

$\omega = \arctan(4/36) = 6.34°$	$\omega = \arctan(102/914) = 6.34°$
or $\omega = \arctan(2/18) = 6.34°$	$\omega = \arctan(51/457) = 6.34°$

For uniform modules, the batter of the back face matches the batter of the front face. For stepped modules, the batter is recalculated along the back of the wall from the rear of the bottom unit to the rear of the top of the wall. Use ω' in Coulomb equation and earth pressure component calculations. To calculate ω' it is necessary to know the effective setback width, w_s, which is the horizontal distance between the back edge of the top block and the back edge of the lower unit including any tail extension. w_s is negative when the mass extender projects further than the back of the top block. Knowing this distance and the height of wall:

$$\omega' = \arctan(w_s / H_w)$$

Base Thickness/Embedment

The type and thickness of wall base or leveling pad and depth of embedment can vary by site requirements. A granular base with a thickness of 9 inches is commonly used, but the thickness can be adjusted to reduce the contact pressure. A concrete leveling pad or footing can also be used. The required embedment to the top of the base is related to the exposed height of the wall and by the slope at the toe, as well as other factors. The required embedment can be calculated for slopes steeper than 6H:1V using the following equation (see AASHTO LRFD Table C11.10.2.2-1):

$$h_e = H'/(20*S/6)$$

where S is the run of the toe slope per unit fall and H’ is the exposed height

A minimum embedment of 12 inches (300 mm) for level toe and 24 inches (600 mm) for toe slopes of 4H:1V or steeper is recommended for highway applications (AASHTO LRFD 11.10.2.2)

Project	Project #	Date
LRFD Design Methodology	20004.00	2/20/20

Weight of Wall

The weight of the wall includes the contributions of the blocks, the aggregate unit fill, the tail extension, and the soil wedge atop extended modules or tail extension

The weight of the tail extension is calculated:

$W_{te} = (w_{te} * H_{te}) * 145$ pcf (22.8 kN/m^3) (typical unit weight for concrete)

where w_{te} is the width of the tail extension and H_{te} is the height of the extension (both in ft.)

The angle of the batter (from vertical) of the soil wedge above the tail extension, ω_s, is calculated:

$\omega_s = \arctan(-w_s'/H_{wedge})$

The weight of soil in the wedge above the tail extension is calculated for the trapezoidal area of the wedge that lies behind each block

h_s = height of the soil trapezoid behind the block (may differ from height of the block)

w_u = width of the block

h_1 = dist. from the top of wall to top of the soil trapezoid behind the block

h_2 = dist. from the top of wall to bottom of the soil trapezoid behind the block

s = dist. from the face of wall to face of the block

s_u = dist. from the face of wall to back of the block = $s + w_u$

s_T = dist. from the face of wall to the back of top-most block of wall

b_1 = length of top side of trapezoid of soil behind block = $h_1 * \tan(\omega_s)+(s_T - s_u)$

b_2 = length of bottom side of trapezoid of soil behind block = $h_2 * \tan(\omega_s)+(s_T - s_u)$

The weight of the soil wedge above the tail extension behind each block, W_s, is calculated as the trapezoidal area multiplied by the lesser of the unit weight of the retained soil or the unit fill:

$W_s = [h_s * (b_1+b_2)/2] * (\text{min of } \gamma_{ret} \text{ or } \gamma_u)$

The center of gravity of the trapezoidal wedge behind each block, measured from the face of the wall at the bottom course, is calculated:

$x_s = [(b_1*b_2+(b_2^2-2*b_1*b_2+b_1^2)/3)/(b_1+b_2)]+ s + w_u$

$y_s = [h_s/3*(2b_1+b_2)/(b_1+b_2)]+ H - h_2$

W_s is treated as aggregate infill subject to 80% limitations for overturning calculations (conservative)

Static Forces

Coulomb active earth pressure coefficient (see AASHTO LRFD 3.11.5.3)

$$K_a = \frac{\cos^2(\phi + \omega')}{\cos^2(\omega')\cos(\omega' - \delta)\left[1 + \sqrt{\frac{\sin(\phi + \delta)\sin(\phi - \beta)}{\cos(\omega' - \delta)\cos(\omega' + \beta)}}\right]^2}$$

As an alternate, a trial wedge technique may be used to determine the earth pressure forces acting on the modular wall.

Earth Load Components (see AASHTO LRFD 11.10.5.2)

Vertical forces:

$P_v = 0.5\ K_a\ \gamma\ H^2 * \sin(\delta - \omega')$

$Q_{lv} = K_a\ Q\ H * \sin(\delta - \omega')$ where Q is the effective surcharge in psf (kPa)

Horizontal forces:

$P_h = 0.5\ K_a\ \gamma\ H^2 * \cos(\delta - \omega')$

$Q_{lh} = K_a\ Q\ H * \cos(\delta - \omega')$ where Q is the effective surcharge in psf (kPa)

Resultants of earth load components:

$y_P = H/3$

$x_P = (H/3) * \tan(\omega') + w_u$

$y_{Ql} = H/2$

$x_{Ql} = (H/2) * \tan(\omega') + w_u$

where w_u is the width of the bottom unit, including any tail extension (w_{te})

Weight Components

Vertical forces:

W_b – Weight of wall units

W_{te} – Weight of concrete tail extension, if used

W_a – Weight of infill aggregate (use 80% aggregate weight for overturning)

W_s – Weight of soil atop tail extension (use 80% aggregate weight for overturning)

$W_b = \sum(W_{b1} + W_{b2} + \cdots\cdots + W_{bn})$

$W_{te} = \sum(W_{te1} + W_{te2} + \cdots\cdots + W_{te})$

$W_a = \sum(W_{a1} + W_{a2} + \cdots\cdots + W_{an})$

$W_s = \sum(W_{s1} + W_{s2} + \cdots\cdots + W_{sn})$

Resultants of weight components:

The center of mass of the stack of blocks is calculated as:

$x_b = \sum(W_{b1}{*}x_{b1} + W_{b2}{*}x_{b2} + \cdots\cdots + W_{bn}{*}x_{bn}) / \sum(W_{b1} + W_{b2} + \cdots\cdots + W_{bn})$

$y_b = \sum(W_{b1}{*}y_{b1} + W_{b2}{*}y_{b2} + \cdots\cdots + W_{bn}{*}y_{bn}) / \sum(W_{b1} + W_{b2} + \cdots\cdots + W_{bn})$

The center of mass of the aggregate fill is:

$x_a = \sum(W_{a1}{*}x_{a1} + W_{a2}{*}x_{a2} + \cdots\cdots + W_{an}{*}x_{an}) / \sum(W_{a1} + W_{a2} + \cdots\cdots + W_{an})$

$y_a = \sum(W_{a1}{*}y_{a1} + W_{a2}{*}y_{a2} + \cdots\cdots + W_{an}{*}y_{an}) / \sum(W_{a1} + W_{a2} + \cdots\cdots + W_{an})$

The center of mass of the soil wedge over the tail is:

$x_s = \sum(W_{s1}{*}x_{s1} + W_{s2}{*}x_{s2} + \cdots\cdots + W_{sn}{*}x_{sn}) / \sum(W_{s1} + W_{s2} + \cdots\cdots + W_{sn})$

$y_s = \sum(W_{s1}{*}y_{s1} + W_{s2}{*}y_{s2} + \cdots\cdots + W_{sn}{*}y_{sn}) / \sum(W_{s1} + W_{s2} + \cdots\cdots + W_{sn})$

The center of mass of the tail extension can be calculated with the following equation:

$x_{te} = \sum(W_{te1}{*}x_{te1} + W_{te2}{*}x_{te2} + \cdots\cdots + W_{ten}{*}x_{ten}) / \sum(W_{te1} + W_{te2} + \cdots\cdots + W_{te})$

$y_{te} = \sum(W_{te1}{*}y_{te1} + W_{te2}{*}y_{te2} + \cdots\cdots + W_{ten}{*}y_{ten}) / \sum(W_{te1} + W_{te2} + \cdots\cdots + W_{te})$

The overall adjusted center of mass of the blocks and tail extension:

$x_{b+te} = (W_b{*}x_b + W_{te}{*}x_{te}) / (W_b + W_{te})$

$y_{b+te} = (W_b{*}y_b + W_{te}{*}y_{te}) / (W_b + W_{te})$

The overall adjusted center of mass of the aggregate and the soil above the tail is:

$x_{a+s} = (W_a{*}x_a + W_s{*}x_s) / (W_a + W_s)$

$y_{a+s} = (W_a{*}y_a + W_s{*}y_s) / (W_a + W_s)$

Seismic Loads

Seismic components of force are calculated according to the procedures in FHWA 4.2h.

The maximum acceleration $A_m = (1.45 - A)*A$ where A is the peak horizontal ground acceleration.

The seismic earth pressure coefficient is calculated with the following equation:

$$K_{ae} = \frac{\cos^2(\phi+\omega'-\xi)}{\cos(\xi)\cos^2(-\omega')\cos(\delta-\omega'+\xi)\left[1+\sqrt{\frac{\sin(\phi+\delta)\sin(\phi-\xi-\beta)}{\cos(\delta-\omega'+\xi)\cos(\omega'+\beta)}}\right]^2}$$

where $\xi = \arctan [k_h/(1 - k_v)]$

The trial wedge technique is recommended in high seismicity regions to determine the dynamic thrust forces acting on the modular wall.

Seismic Earth load components

k_v is generally taken as 0. k_h is the maximum horizontal acceleration of the wall, and is a function of the maximum allowable displacement of the wall during a seismic event. It is calculated with the following equation:

$$k_h = 1.66 * A_m * [A_m/(d*C)]^{0.25}$$

d is the maximum horizontal displacement, and is typically set at 2 inches (50 mm) as conservative. Note that this equation has embedded units of mm, and C is a conversion factor (25.4 when d is in units of inches, and 1 when d is in units of mm).

$$A_m = (1.45\text{-}PGA)*PGA$$

The horizontal inertial force P_{ir} is calculated as follows:

$$P_{ir} = (W_b+W_{te}+W_a+W_s)*k_h$$

The seismic thrust is calculated as follows:

$$\Delta P_{ae} = 0.5 * \gamma * H^2 * (K_{ae} - K_a)$$

$$\Delta P_{aeh} = 0.5 * \gamma * H^2 * (K_{ae} - K_a) * \cos(\delta - \omega')$$

$$\Delta P_{aev} = 0.5 * \gamma * H^2 * (K_{ae} - K_a) * \sin(\delta - \omega')$$

Resultants of Seismic Earth load components

In overturning analysis, the inertial force is applied at the vertical center of gravity of the wall, while the seismic thrust is applied at 1/3 of the wall height.

$x_{Pae} = H/3*\tan(\omega') + w_u$

$y_{Pae} = H/3$

$y_{Pir} = (W_b*y_b + W_{te}*y_{te} + W_a*y_a + W_s*y_s) / (W_b + W_{te} + W_a + W_s)$

The combined earth pressure P_{ae} is the sum of the static earth pressure P_a and the seismic thrust ΔP_{ae}. By AASHTO LRFD requirements, two seismic load conditions must be evaluated (AASHTO LRFD 11.6.5.1):

$P_{ae}/2 + P_{ir} = P_a/2 + \Delta P_{ae}/2 + P_{ir}$ (but not less than $P_a + P_{ir}$)

$P_{ae} + P_{ir}/2 = P_a + \Delta P_{ae} + P_{ir}/2$

Load cases a & b are separately evaluated to include the alternate combinations above.

Base Friction

Friction across the base of the wall is used to resist sliding failure. Frictional resistance must be determined both between the wall assembly and the base and between the base and the foundation soil (or through the foundation soil).

The unfactored sliding resistance is calculated as the smaller result of the following equations:

For base to foundation soil failure, use:

$R_{s(\text{foundation soil})} = (W_b + W_{te} + W_a + W_s + P_v + t_b*w_b*\gamma_b) \tan\phi + B_w*c$

$= (F_v+W_{base})* \tan\phi + B_w*c$

where ϕ represents foundation soils, B_w is base width (block width plus ½H:1V distribution through base), and c represents foundation soil cohesion.

For block to base material sliding, use:

$R_{s(\text{footing})} = \mu_b (W_b + W_{te} + W_a + W_s + P_v) = \mu_b (F_v)$

where μ_b represents a composite coefficient of friction for the base

The composite friction coefficient is calculated using contributory areas. The base of a Stone Strong unit consists of a percentage of open void space to be filled with aggregate and a percentage of concrete. These percentages are calculated as follows:

$\%_{void} = V_{void}/(V_{void}+V_{concrete})$

$\%_{concrete} = V_{concrete}/(V_{void}+V_{concrete})$

If a cast-in-place tail extension is used, the area of the tail extension must also be calculated and the total area is also increased accordingly. Thus, the equation for composite friction coefficient across the base becomes:

$\mu_b = (\%_{void}*w_{u(bottom)}*\mu_{p\text{ - unit fill/base}} + \%_{concrete}*\ w_{u(bottom)}*\mu_{p\text{ - block/base}} + w_{te}*\mu_{p\text{ - extension/base}})/(\ w_{u(bottom)} + w_{te})$

Partial friction coefficients can be interpreted from the following table:
(see AASHTO LRFD 10.6.3.4)

	Coefficient of Friction
Block to Aggregate Base formed precast surface on compacted aggregate surface (includes Mass Extender)	0.8*tan ϕ_b
Unit Fill to Aggregate Base screened aggregate (loose to moderate relative density - dumped) on compacted aggregate surface	lower tan ϕ_b or tan ϕ_u
Block to Concrete Base formed precast surface on floated concrete surface (includes Mass Extender)	0.60
Unit Fill Aggregate to Concrete Base screened aggregate (loose to moderate relative density - dumped) on floated concrete surface	0.8*tan ϕ_u
Concrete Tail Extension to Aggregate Base cast in place concrete on aggregate surface	tan ϕ_b
Concrete Tail Extension to Concrete Base cast in place concrete on floated concrete surface	0.75
Concrete Tail Extension Directly on Foundation Soil (Sand) cast in place concrete on granular soil	tan ϕ_f
Note: These typical values may be used for evaluation of base sliding at the discretion of the user. The licensed engineer of record is responsible for all design input and for evaluating the reasonableness of calculation output based upon his/her knowledge of local materials and practices and on the specific design details.	

Since the unit fill aggregate is typically placed to a moderately loose state, the friction angle for the screened unit fill aggregate typically controls for the interface between the unit fill and the base aggregate.

If actual test data for the project specific materials is not available, or for preliminary design, the following conservative friction angles are suggested for base and infill aggregates:
(see AASHTO LRFD Fig. 10.4.6.2.4-1)

	Friction Angle (degrees)		
	Well Graded, Aggregate, Densely Compacted	Screened Aggregate, Compacted	Screened Aggregate, Loose to Moderate Relative Density
Crushed Hard Aggregate >75% w/ 2 fractured faces, hard natural rock	42	40	36
Crushed Aggregate >75% w/ 2 fractured faces, medium natural rock or recycled concrete	40	38	35
Cracked Gravel >90% w/ 1 fractured face	36	35	32
Note: Physical testing of specific aggregates is recommended. When test data is not available, these typical values may be used at the discretion of the user. The licensed engineer of record is responsible for all design input and for evaluating the reasonableness of calculation output based upon his/her knowledge of local materials and practices and on the specific design details.			

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Table of Unfactored Forces & Moments

	Force **(lb) or (kN)**	**Arm** **(ft) or (m)**	**Moment about toe** **(lb*ft) or (kN *m)**
Vertical Forces			
weight of blocks	$W_b + W_{te}$	x_{b+te}	$(W_b + W_{te})* x_{b+te}$
weight of agg. & soil over tail	$W_a + W_s$	x_{a+s}	$(W_a + W_s) * x_{a+s}$
modified weight of a & s (80%)	$0.8*(W_a + W_s)$	x_{a+s}	$0.8*(W_a + W_s) * x_{a+s}$
earth pressure	P_v	x_{Pv}	P_v*x_{Pv}
LL surcharge	Q_{lv}	x_{Qlv}	$Q_{lv}*x_{Qlv}$
Horizontal Forces			
static earth pressure*	P_h	x_{Ph}	P_h*y_{Ph}
seismic thrust*	ΔP_{aeh}	x_{Paeh}	$\Delta P_{aeh}* y_{Paeh}$
inertial force*	P_{ir}	x_{Pir}	$P_{ir}* y_{Pir}$
LL surcharge	Q_{lh}	x_{Qlh}	$Q_{lh}*y_{Qlh}$

* For seismic load case, separate analysis should be run using **a)** reduced combined earth pressure (50% of P_h + ΔP_{aeh}, but not less than P_h) with the full inertial force (P_{ir}) and **b)** full earth pressure (P_h + ΔP_{aeh}) with reduced inertial force (50% of P_{ir}).

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Table of Load and Resistance Factors for the relevant load cases
(based on AASHTO LRFD Tables 3.4.1-1, 3.4.1-2, and 10.5.5.2.2-1)

	Strength I-a	**Strength I-b**	**Strength IV**	**Extreme I-a (EQ)**	**Extreme I-b (EQ)**	**Extreme II (CT)**	**Service I**
Load Factors							
LL	1.75	1.75	0.00	0.00	0.00	0.5	1.00
EH	1.50	1.50	1.50	1.00	1.00	1.00	1.00
EQ	0.00	0.00	0.00	1.00	1.00	0.00	0.00
CT	0.00	0.00	0.00	0.00	0.00	1.00	0.00
LL Surcharge Over Wall	0.00	1.75	0.00	0.00	0.00	0.00	1.00
Resistance Factors							
DC	0.90	1.25	1.50	1.00	1.00	1.00	1.00
EV	1.00	1.35	1.35	1.00	1.00	1.00	1.00
BC	0.45	0.45	0.45	1.00	1.00	1.00	1.00
ϕ_τ **precast to agg**	0.90	0.90	0.90	1.00	1.00	1.00	1.00
ϕ_τ **CIP to agg/soil**	0.80	0.80	0.80	1.00	1.00	1.00	1.00
ϕ_τ **soil to soil**	0.90	0.90	0.90	1.00	1.00	1.00	1.00
ϕ_τ **precast to precast**	0.90	0.90	0.90	1.00	1.00	1.00	1.00

For each of the load cases, the unfactored vertical and horizontal forces are multiplied by the corresponding load and resistance factors for each.

Table of Calculated Factored Forces and Moments

	Force **(lb) or (kN)**	**Moment** **(lb*ft) or (kN*m)**
Vertical Forces		
block weight	$(W_b + W_{te})*DC$	$(W_b + W_{te})*x_{b+te} *DC$
aggregate & soil weight	$(W_a + W_s)*EV$	$(W_a + W_s)*x_{a+s} *EV$
modified agg & soil weight	$0.8*(W_a + W_s)*EV$	$0.8*(W_a + W_s)*x_{a+s} *EV$
earth pressure	P_v*EH	$P_v*x_{Pv}*EH$
LL surcharge	$Q_{lv}*LL$	$Q_{lv}*x_{Qlv}*LL$
seismic thrust*	$\Delta P_{aev}*EQ$	$\Delta P_{aev}* x_{P_{aeh}}*EQ$
Horizontal Forces		
static earth pressure*	P_h*EH	$P_h*y_{P_h}*EH$
LL surcharge	$Q_{lh}*LL$	$Q_{lh}*y_{Qlh}*LL$
seismic thrust*	$\Delta P_{aeh}*EQ$	$\Delta P_{aeh}* y_{P_{aeh}}*EQ$
inertial force*	$P_{ir}*EQ$	$P_{ir}* y_{P_{ir}} *EQ$

* For seismic load case, separate analysis should be run using **a)** reduced combined earth pressure (50% of $P_h + \Delta P_{aeh}$, but not less than P_h) with the full inertial force (P_{ir}) and **b)** full earth pressure ($P_h + \Delta P_{aeh}$) with reduced inertial force (50% of P_{ir}).

Overturning/Eccentricity

For overturning, the modified weights using 80% of the aggregate weight (including the soil over the tail extension) are used for all overturning calculations.

Although not an explicit requirement of the AASHTO specification, the driving and resisting overturning moments should be compared:

M'_V	Σ factored moments from vertical forces (using 80% W_s & W_a)
M_H	Σ factored moments from horizontal forces

For each load case, the factored overturning resistance should be greater than the factored overturning load

Check that $M'_V > M_H$

This behavior rarely controls. The AASHTO specification uses eccentricity as a proxy for overturning (but still using 80% of the infill weight).

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Eccentricity should be calculated to check overturning. For an aggregate base, the resultant of the vertical forces must fall within the center 2/3 of the base, so eccentricity must be less than 1/3 times the base width (see AASHTO LRFD 11.6.3.3)

$B/3 = (w_{u(bottom\ unit)} + w_{te})/3$

For a concrete base, or a base bearing on rock, the resultant of the vertical forces must fall within the center 90% of the base, so eccentricity must be less than 45% of the base width (see AASHTO LRFD 11.6.3.3).

$B*0.45 = (w_{u(bottom\ unit)} + w_{te})*0.45$

For the Extreme load cases, the resultant of the vertical forces must fall within the center 80% of the base, so eccentricity must be less than 40% times the base width (see AASHTO LRFD 11.6.5.1)

$B*0.4 = (w_{u(bottom\ unit)} + w_{te})*0.4$

(note that for EQ between 0.0 and 1.0, interpolate between 1/3 and 0.4)

Eccentricity or the location of the vertical resultant is calculated as:

F'_V	Σ factored vertical forces (using 80% W_s & W_a)
M'_v	Σ factored moments from vertical forces (using 80% W_s & W_a)
M_H	Σ factored moments from horizontal forces
e	$e = (w_{u(bottom)} + w_{te})/2 + (M_H - M'_V)/F'_V$

For each load case, verify that the eccentricity is less than 1/3 of the base width (or 45% for concrete base, or 40% for Extreme load cases)

Check that $e < B/3$, or $B*0.45$, or $B*0.40$

Sliding

For each load case, the minimum value for sliding resistance is calculated. A resistance factor of 0.8 is used for a cast in place interface (concrete base or a cast in place tail extension), and a factor of 0.9 is used in all other cases.

F_H	Σ factored horizontal forces
F_V	Σ factored vertical forces (using 100% W_s & W_a)
$R_{s\ (\text{footing})}$	$\mu_b\ F_V{*}\phi_\tau$
$R_{s\ (\text{foundation soil})}$	$[(F_V + W_{base}){*}\tan(\phi) + B_w{*}c]{*}\phi_\tau$
ϕ_τ	0.8 for cast in place base or extension, 0.9 for other cases
min R_s	smaller of $R_{s\ (\text{footing})}$ or $R_{s\ (\text{foundation soil})}$

For each load case, the factored sliding resistance should be greater than the sum of factored horizontal forces

check that min $R_s > F_H$

Bearing

Load Case Strength I-b generally controls bearing.

B_f' is the equivalent bearing area. This is the base block width adjusted for eccentricity, and including a ½H:1V distribution through granular base or 1H:1V distribution through concrete base.

$B_f' = w_u + w_{te} + t_b - 2{*}e$ or

$B_f' = w_u + w_{te} + 2{*}t_b - 2{*}e$ (for concrete base)

F_V	Σ factored vertical forces (using 100% W_s & W_a)
surcharge over wall	$q_{LL}{*}w_{u(top)}{*}LL$
weight of base	$t_b\ {*}\ \gamma_b{*}EH$
M_v	Σ factored moments from vertical forces (using 100% W_s & W_a)
M_H	Σ factored moments from horizontal forces
e	$(w_u + w_{te})/2 - (M_V - M_H)/F_V$
B_f' (granular base)	$w_u + w_{te} + t_b - 2{*}e$
B_f' (concrete base)	$w_u + w_{te} + 2{*}t_b - 2{*}e$
contact pressure q_c	$(F_V + q_{LL}{*}w_{u(top)}{*}LL)/B_f' + t_b{*}\gamma_b{*}EH$
bearing resistance q_b	$[c{*}N_c + (h_e + t_b){*}\gamma_{found}{*}N_q{+}0.5{*}\gamma_{found}{*}B_f'{*}N_\gamma]{*}BC$

For each load case, the factored bearing resistance should be greater than the factored contact pressure Check that $q_b > q_c$

Internal Analysis

Internal stability analysis is conducted for each section above the wall base. Since bearing conditions are addressed in the external stability analysis, only toppling and shear failures are evaluated.

Toppling is evaluated similarly to external overturning analysis, except that the overturning point is set in 1 inch (25 mm) to account for face rounding. Eccentricity for block to block contact should be within the middle 90% of the base as required for a rock foundation.

For each load case:

check that $e < B*0.45$

Shear, or sliding, resistance is calculated based on the interface shear test (see interaction test reports for complete test data)

$R_s = [S_i + (W + P_v + Q_{dv})* \tan(35.2°)]*\varphi_T$

where $\varphi_T = 0.90$ (precast to precast and aggregate to aggregate)

$S_i = 362$ lb/ft or 5.28 kN/m

For each load case, the factored sliding resistance must be greater than the factored horizontal force:

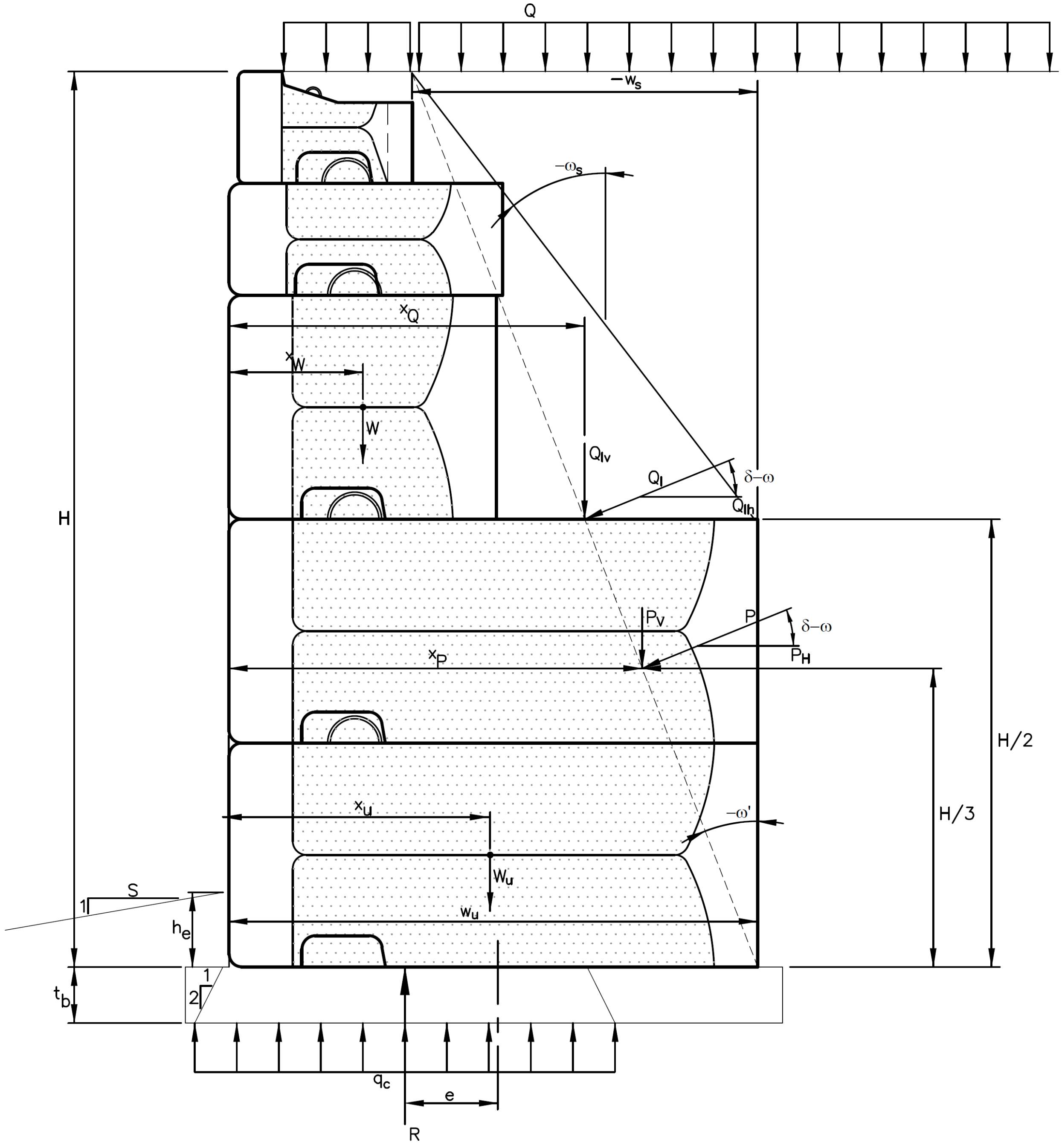
check that $R_s > F_H$

At a minimum, internal stability should be evaluated at each change in block width (including any tail extension), at the base of any dual-face units, and for the top course(s) if a surcharge or lateral load is applied.

EXAMPLE GRAVITY WALL CALCULATIONS
LRFD METHOD USING AASHTO LOAD/RESISTANCE FACTORS

Example 1: **12 feet tall wall, vertical face, level back slope, 250 psf traffic surcharge**

Retained Soil:	sand with γ = 120 pcf and ϕ = 30 degrees
Foundation Soil:	clay with γ = 125 pcf, ϕ = 26 degrees, and c' = 150 psf
Infill Aggregate:	screened crushed aggregate with γ = 110 pcf and ϕ = 35 degrees
Base Aggregate:	well graded crushed aggregate with γ = 125 pcf and ϕ = 40 degrees



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Wall Configuration (all weights per foot along length of wall)

Modular Units			Setback (in)		Concrete (/ft.)		Unit Fill (/ft.)		Soil Wedge (/ft.)	
unit	**w (in)**	**h (ft)**	**face**	**tail**	**W_b (lb)**	**x_b (in)**	**W_a (lb)**	**x_a (in)**	**W_s (lb)**	**x_s (in)**
V6-28	28.0	1.50	0.0	-57.0	238	12.8	183	14.0	110	33.3
V6	44.0	1.50	0.0	-41.0	375	21.0	301	23.5	94	48.6
V24	43.0	3.00	0.0	-42.0	750	20.2	594	23.8	779	58.3
V24-86	85.0	3.00	0.0	0.0	950	39.0	1,621	44.1	0	0.0
V24-86	85.0	3.00	0.0	0.0	950	39.0	1,621	44.1	0	0.0

External Stability Analysis

Weight and Center of Gravity of Wall Components

W_b = 950+950+750+375+238 = 3,263 lb/ft

W_a = 1,621+1,621+594+301+183= 4,320 lb/ft

W_s = 779+94+110 = 983 lb/ft

Total Wall Weight = 3,263+4,320+983 = 8,490 lb/ft

x_b = (950*39.0+950*39.0+750*20.2+375*21.0+238*12.8) / 3,263 =30.7 in

y_b = (950*18+950*54+750*90+375*117+238*135) / 3,263 = 64.9 in

x_a = (1,621*44.1+1,621*44.1+594*23.8+301*23.5+183*14.0) / 4,320 = 38.6 in

y_a = (1,621*18+1,621*54+594*90+301*117+183*135) / 4,320 = 53.3 in

x_s = (779*58.3+94*48.6+110*33.3) / 983 = 54.5 in

y_s = (779*89.9+94*117.0+110*132.0) / 983 = 97.1 in

x_{a+s} = (4,320*38.6+983*54.5) / (4,320+983) = 41.5 in

y_{a+s} = (4,320*53.3+983*97.1) / (4,320+983) = 61.4 in

Earth Pressure Components

ω' = arctan(-57/12/12.0) = -21.6° δ = 0.75*30 = 22.5°

$$K_a=\frac{\cos^2(30+-21.6)}{\cos^2(-21.6)\cos(-21.6-22.5)\left[1+\sqrt{\dfrac{\sin(30+22.5)\sin(30-0)}{\cos(-21.6-22.5)\cos(-21.6+0)}}\right]^2}$$

K_a = 0.503

P_h = 0.5*(0.503)*120*$(12)^2$*cos(22.5+21.6) = 3,119 lb/ft

P_v = 0.5*(0.503)*120*$(12)^2$*sin(22.5+21.6) = 3,022 lb/ft

Q_{lh} = 0.503*250*12*cos(22.5+21.6) = 1,083 lb/ft

Q_{lv} = 0.503*250*12*sin(22.5+21.6) = 1,049 lb/ft

x_P = (12/3)*tan(-21.6)+85/12 = 5.50 ft y_P = 12/3 = 4.00 ft

x_{Ql} = (12/2)*tan(-21.6)+85/12 = 4.71 ft y_{Ql} = 12/2 = 6.00 ft

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Table of Unfactored Forces & Moments (per foot of wall)

	Unfactored Force (lb)	**arm (ft)**	**Unfactored Moment about toe (lb*ft)**
Vertical Forces			
W_b	3,263	2.56	8,346
$W_a + W_s$	5,304	3.46	18,366
$0.80*(W_a + W_s)$	4,243	3.46	14,693
P_v	3,022	5.50	16,622
Q_{lv}	1,049	4.71	4,941
$Q_{l\text{ over wall}}$	583	1.17	681
Horizontal Forces			
P_h	3,119	4.00	12,477
Q_{lh}	1,083	6.00	6,498

Table of Load & Resistance Factors

	Strength I-a	**Strength I-b**	**Strength IV**	**Service I**
Load Factors				
LL	1.75	1.75	0.00	1.00
EH	1.50	1.50	1.50	1.00
EQ	0.00	0.00	0.00	0.00
CT	0.00	0.00	0.00	0.00
LL over wall	0.00	1.75	0.00	1.00
Resistance Factors				
DC	0.90	1.25	1.50	1.00
EV	1.00	1.35	1.35	1.00
BC	0.45	0.45	0.45	1.00
ϕ_τ precast to agg	0.90	0.90	0.90	1.00
ϕ_τ CIP to agg/soil	0.80	0.80	0.80	1.00
ϕ_τ soil to soil	0.90	0.90	0.90	1.00
ϕ_τ precast to precast	0.90	0.90	0.90	1.00

Project LRFD Example Calculations	**Project #** 20004.00	**Date** 11/16/20

Table of Calculated Factored Forces (lbs per foot of wall)

	Unfactored Force	**Load Factor**	**Strength I-a**	**Strength I-b**	**Strength IV**	**Service I**
Vertical Forces						
W_b	3,263	DC	2,936	4,078	4,894	3,263
$W_a + W_s$	5,304	EV	5,304	7,160	7,160	5,304
$0.80^*(W_a + W_s)$	4,243	EV	4,243	5,728	5,728	4,243
P_v	3,022	EH	4,533	4,533	4,533	3,022
Q_{lv}	1,049	LL	1,836	1,836	0	1,049
$Q_{l\text{ over wall}}$	583	LL over	0	1,021	0	583
Horizontal Forces						
P_h	3,119	EH	4,679	4,679	4,679	3,119
Q_{lh}	1,083	LL	1,895	1,895	0	1,083

Table of Calculated Factored Moments (lb*ft per foot of wall)

	Unfactored Moment	**Load Factor**	**Strength I-a**	**Strength I-b**	**Strength IV**	**Service I**
Vertical Forces						
W_b	8,346	DC	7,511	10,433	12,519	8,346
$W_a + W_s$	18,366	EV	18,366	24,794	24,794	18,366
$0.80^*(W_a + W_s)$	14,693	EV	14,693	19,835	19,835	14,693
P_v	16,622	EH	24,933	24,933	24,933	16,622
Q_{lv}	4,941	LL	8,646	8,646	0	4,941
$Q_{l\text{ over wall}}$	681	LL over	0	1,191	0	681
Horizontal Forces						
P_h	12,477	EH	18,715	18,715	18,715	12,477
Q_{lh}	6,498	LL	11,372	11,372	0	6,498

Overturning/Eccentricity

Check that $M'_V > M_H$

Check that e>B/3 (40% of B for extreme load cases)

Strength Case I-a:

M'_V = 7,511+14,693+24,933+8,646 = 55,784 lb*ft/ft

M_H = 18,715+11,372 = 30,087 lb*ft/ft

$M'_V > M_H$ **OK!!**

e = (85/12)/2+(30,087-55,784)/(2,936+4,243+4,533+1,836) = 1.65 ft

B/3 = (85/12)/3 = 2.36 ft

e < B/3 **OK!!**

Table for all load cases

	Strength I-a	Strength I-b	Strength IV	Service I
F'_v	13,549	17,196	15,155	12,160
M'_v	55,784	65,038	57,287	45,282
M_h	30,087	30,087	18,715	18,975
e	1.65	1.51	1.00	1.38

All load cases **OK!!**

Sliding

Check that $R'_s > F_h$

Strength Case I-a:

Use the smaller sliding resistance, R'_s, across footing or through foundation soil:

$R'_{s\ (soil)}$ = [(2,936+5,304+4,533+1,836+ (85/12)*(9/12)*125*1.0)*tan(26)+((85+9)/12*150)]*0.9
= 7,762 lb/ft

$\%_{void}$ = (1,621/110) / (950/145+1,621/110) = 0.6922

$\%_{concrete}$ = (950/145) / (950/145+1,621/110) = 0.3078

μ_b = 0.6922*tan(35)+0.3078*0.8*tan(40) = 0.69

$R'_{s\ (footing)}$ = [0.69*(2,936+5,304+4,533+1,836)]*0.9
= 9,090 lb/ft

F_h = 4,679+1,895 = 6,574 lb/ft

$R'_s > F_h$ **OK!!**

Table for all load cases

	Strength I-a	Strength I-b	Strength IV	Service I
F_h	6,574	6,574	4,679	4,202
F_v	14,610	18,628	16,587	13,221
F_v w/ base weight	15,274	19,525	17,483	13,885
ϕ_τ	0.90	0.90	0.90	1.00
$R'_{s\ (\text{foundation soil})}$	7,762	9,628	8,732	7,947
$R'_{s\ (\text{footing})}$	9,090	11,590	10,320	9,140

All Load Cases **OK!!**

Bearing

Check that $q_b > q_c$

Strength Case I-a:

$e = (85/12)/2-((7{,}511+18{,}366+24{,}933+8{,}646)-(18{,}715+11{,}372))\ /$
$(2{,}936+5{,}304+4{,}533+1{,}836) = 1.53$

$B_f' = (85+9)/12-2*1.53\ \text{ft} = 4.77\ \text{ft}$

Bearing Factors (Vesic):

$N_q = 11.85$ $N_c = 22.25$ $N\gamma = 12.54$

$q_b = [150*22.25+(12+9)/12*125*11.85+0.5*125*4.76*12.54]*0.45 = 4{,}351\ \text{psf}$

weight of base $= t_b *\gamma_{base}*EH = 9/12*125*1.5 = 141\ \text{psf}$

$q_c = (14{,}610)/4.77+141 = 3{,}203\ \text{psf}$

$q_b > q_c$ **OK!!**

Table for all load cases

	Strength I-a	Strength I-b	Strength IV	Service I
F_v	14,610	18,628	16,587	13,221
M_v	59,457	69,997	62,246	48,955
M_h	30,087	30,087	18,715	18,975
e	1.53	1.40	0.92	1.27
B_f	4.77	5.03	6.00	5.29
q_c	3,203	3,841	2,906	2,595
q_b	4,351	4,445	4,785	10,073

All Load Cases **OK!!**

Internal Stability

Internal stability should be checked at each change in block width, at all dual-face unit, and at the top unit at a minimum. The following is taken at the first change from 24-86 to 24SF. Internal stability of the block stack above this interface is calculated as follows:

Wall Configuration (all weights per foot along length of wall)

Modular Units			Setback (in)		Concrete (/ft.)		Unit Fill (/ft.)		Soil Wedge (/ft.)	
unit	w (in)	h (ft)	face	tail	W_b (lb)	x_b (in)	W_a (lb)	x_a (in)	W_s (lb)	x_s (in)
V6-28	28.0	1.50	0.0	-15.0	238	11.8	183	13.0	110	32.3
V6	44.0	1.50	0.0	1.0	375	20.0	301	22.5	0	0.0
V24	43.0	3.00	0.0	0.0	750	19.2	594	22.8	0	0.0

Weight and Center of Gravity of Wall Components

W_b = 750+375+238 = 1,363 lb/ft

W_a = 594+301+183 = 1,078 lb/ft

W_s = 110 lb/ft

x_b= (750*19.2+375*20.0+238*11.8) / 1,363 = 18.1 in

y_b = (750*18+375*45+238*63) / 1,363 = 33.3 in

x_a = (594*22.8+301*22.5+183*13.0) / 1,078 = 21.1 in

y_a = (594*18+301*45+183*63) / 1,078 = 33.2 in

x_s = 32.3 in

y_s = 110*60/110 = 60 in

x_{a+s} = (1,078*21.1+110*32.3) / (1,078+110) = 22.1 in

y_{a+s} = (1,078*33.3+110*60) / (1,078+110) = 35.7 in

Earth Pressure Components

ω' = arctan(-15/12/6.0) = -11.77° δ = 0.75*30 = 22.5°

$$K_a=\frac{\cos^2(30+-11.77)}{\cos^2(-11.77)\cos(22.5--11.77)\left[1+\sqrt{\frac{\sin(30+22.5)\sin(30-0)}{\cos(22.5--11.77)\cos(-11.77+0)}}\right]^2}$$

K_a = 0.394

P_h = 0.5*(0.394)*120*(6)^2*cos(22.5+11.77) = 703 lb/ft

P_v = 0.5*(0.394)*120*(6)^2*sin(22.5+11.77) = 479 lb/ft

Q_{lh} = 0.394*250*6*cos(22.5+11.77) = 488 lb/ft

Q_{lv} = 0.394*250*6*sin(22.5+11.77) = 333 lb/ft

x_P = (6/3)*tan(-11.77)+43/12 = 3.17 ft y_P = 6/3 = 2.0 ft

x_{Ql} = (6/2)*tan(-11.77)+43/12 = 2.96 ft y_{Ql} = 6/2 = 3.00 ft

Project	Project #	Date
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Table of Unfactored Forces & Moments (per foot of wall)

	Unfactored Force (lb)	**arm (ft)**	**Unfactored Moment about toe (lb*ft)**
Vertical Forces			
Wb	1,363	1.51	2,058
Wa + Ws	1,188	1.84	2,188
0.80*(Wa + Ws)	951	1.84	1,750
Pv	479	3.08	1,478
Qlv	333	2.88	957
$Ql_{\text{over wall}}$	583	1.08	632
Horizontal Forces			
Ph	703	2.00	1,407
Qlh	488	3.00	1,465

Table of Load & Resistance Factors

	Strength I-a	**Strength I-b**	**Strength IV**	**Service I**
Load Factors				
LL	1.75	1.75	0.00	1.00
EH	1.50	1.50	1.50	1.00
EQ	0.00	0.00	0.00	0.00
CT	0.00	0.00	0.00	0.00
LL over wall	0.00	1.75	0.00	1.00
Resistance Factors				
DC	0.90	1.25	1.50	1.00
EV	1.00	1.35	1.35	1.00
$\phi\tau_{\text{precast to precast}}$	0.90	0.90	0.90	1.00

Table of Calculated Factored Forces (lbs per foot of wall)

	Unfactored Force	Load Factor	Strength I-a	Strength I-b	Strength IV	Service I
Vertical Forces						
W_b	1,363	DC	1,226	1,703	2,044	1,363
$W_a + W_s$	1,188	EV	1,188	1,604	1,604	1,188
$0.80*(W_a + W_s)$	951	EV	951	1,283	1,283	951
P_v	479	EH	719	719	719	479
Q_{lv}	333	LL	582	582	0	333
$Q_{l\text{ over wall}}$	583	LL over	0	1,021	0	583
Horizontal Forces						
P_h	703	EH	1,055	1,055	1,055	703
Q_{lh}	488	LL	855	855	0	488

Table of Calculated Factored Moments (lb*ft per foot of wall)

	Unfactored Moment	Load Factor	Strength I-a	Strength I-b	Strength IV	Service I
Vertical Forces						
W_b	2,058	DC	1,852	2,572	3,086	2,058
$W_a + W_s$	2,188	EV	2,188	2,954	2,954	2,188
$0.80*(W_a + W_s)$	1,750	EV	1,750	2,363	2,363	1,750
P_v	1,478	EH	2,216	2,216	2,216	1,478
Q_{lv}	957	LL	1,674	1,674	0	957
$Q_{l\text{ over wall}}$	632	LL over	0	1,106	0	632
Horizontal Forces						
P_h	1,407	EH	2,110	2,110	2,110	1,407
Q_{lh}	1,465	LL	2,564	2,564	0	1,465

Overturning/Topple

Check that $M'_V > M_H$

Check that $e < B*0.45$ (40% of B for extreme load cases)

Strength Case I-a:

M'_V = 1,852+1,750+2,216+1,674 = 7,493 lb*ft/ft

M_H = 2,110+2,564 = 4,674 lb*ft/ft

$M'_V > M_H$ **OK!!**

e = (42/12)/2+(4,674-7,493)/(1,226+951+719+582) = 0.94 ft

B*0.45 = (42/12)*0.45 = 1.58 ft

e < B*0.45 **OK!!**

Table for all load cases

	Strength I-a	**Strength I-b**	**Strength IV**	**Service I**
F'_v	3,478	5,308	4,046	3,708
M'_v	7,493	9,932	7,666	6,874
M_h	4,674	4,674	2,110	2,872
e	0.94	0.76	0.38	0.67

All Load Cases **OK!!**

Interface Shear

Check that $R'_s > F_h$

Strength Case I-a:

R'_s = [362+ (1,226+1,188+719+582)*tan(35.2)]* 0.9 = 2,685

F_h = 1,055+855 = 1,910 lb/ft

$R'_s > F_h$ **OK!!**

Table for all load cases

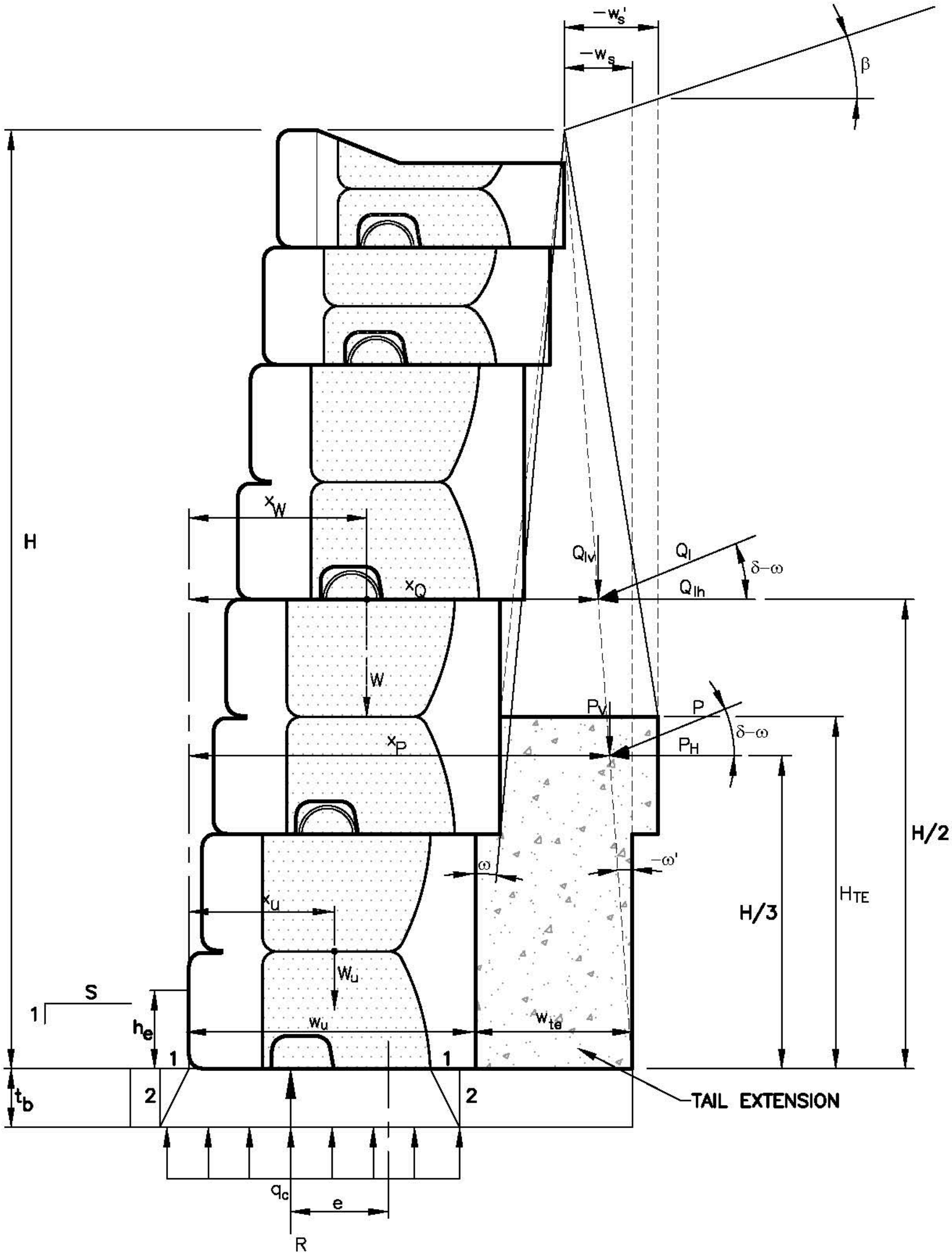
	Strength I-a	**Strength I-b**	**Strength IV**	**Service I**
Fh	1,910	1,910	1,055	1,192
Fv	3,716	5,629	4,367	3,946
$\phi\tau$	0.90	0.90	0.90	1.00
R's	2,685	3,900	3,098	3,146

All Load cases **OK!!**

External & Internal Stability **OK!!**

<u>Example 2:</u> 12 feet tall wall, battered face, 3H:1V back slope, CIP tail extension

Retained Soil:	sand with γ = 120 pcf and ϕ = 30 degrees
Foundation Soil:	clay with γ = 125 pcf, ϕ = 26 degrees, and c' = 150 psf
Infill Aggregate:	screened crushed aggregate with γ = 110 pcf and ϕ = 35 degrees
Base Aggregate:	well graded crushed aggregate with γ = 125 pcf and ϕ = 40 degrees
Tail Extension:	24 inches wide by 54 inches tall, placed on aggregate base



Wall Configuration including CIP tail extension (all weights per foot along length of wall)

Modular Units			**Setback (in)**		**Concrete (/ft.)**		**Unit Fill (/ft.)**		**Soil Wedge (/ft.)**	
unit	**w (in)**	**h (ft)**	**face**	**tail**	**W_b (lb)**	**x_b (in)**	**W_a (lb)**	**x_a (in)**	**W_s (lb)**	**x_s (in)**
6	44.0	1.50	14.0	-10.0	375	35.0	301	37.5	19	58.9
6	44.0	1.50	12.0	-12.0	375	33.0	301	35.5	85	59.2
24	44.0	3.00	8.0	-16.0	750	29.2	594	32.8	396	59.3
24	68.0	3.00	4.0	4.0	1,185	38.0	594	28.8	311	71.1
24	68.0	3.00	0.0	0.0	1,620	39.9	594	24.8	0	0.0

External Stability Analysis

Weight and Center of Gravity of Wall Components

$W_b + W_{te}$ = (750+145*2.0*3.0)+ (750+145*2.0*1.5)+750+375+375 = 4,305 lb/ft

W_a = 594+594+594+301+301 = 2,385 lb/ft

W_s = 311+396+85+19 = 811 lb/ft

x_{b+te} = (1,620*39.9+1,185*38.0+750*29.2+375*33.0+375*35.0) / 4,305 = 36.5 in

y_{b+te} = (1,620*18+1,185*54+750*90+375*117+375*135) / 4,305 = 59.3 in

x_a = (594*24.8+594*28.8+594*32.8+301*35.5+301*37.5) / 2,385 = 30.7 in

y_a = (594*18+594*54+594*90+301*117+301*135) / 2,385 = 72.2 in

x_s = (311*71.1+396*59.3+85*59.2+19*58.9) / 811 = 63.8 in

y_s = (311*60.0+396*88.8+85*116.3+19*132) / 811 = 81.7 in

x_{a+s} = (2,385*30.7+811*63.8) / (2,385+811) = 39.1 in

y_{a+s} = (2,385*72.2+811*81.7) / (2,385+811) = 74.6in

Earth Pressure Components

ω' = arctan(-10/12/12.0) = -3.97°

δ = 0.75*30 = 22.5°

$$K_a = \frac{\cos^2(30+-3.97)}{\cos^2(-3.97)\cos(-3.97-22.5)\left[1+\sqrt{\frac{\sin(30+22.5)\sin(30-18.4)}{\cos(-3.97-22.5)\cos(-3.97+18.4)}}\right]^2}$$

K_a = 0.444

$P_h = 0.5*(0.444)*120*(12)^2*\cos(22.5+3.79)$ = 3,436 lb

$P_v = 0.5*(0.444)*120*(12)^2*\sin(22.5+3.79)$ = 1,711 lb

x_p = (12/3)*tan(-3.97)+(68/12) = 5.39 ft

y_p = (12/3) = 4.00

Project LRFD Example Calculations | **Project #** 20004.00 | **Date** 11/16/20

Table of Unfactored Forces & Moments (per foot of wall)

	Unfactored Force (lb)	**arm (ft)**	**Unfactored Moment about toe (lb*ft)**
Vertical Forces			
W_b	4,305	3.04	13,085
$W_a + W_s$	3,196	3.26	10,421
$0.80*(W_a + W_s)$	2,557	3.26	8,337
P_v	1,711	5.39	9,221
Q_{lv}	0	5.25	0
$Q_{l\text{ over wall}}$	0	2.92	0
Horizontal Forces			
P_h	3,436	4.00	13,744
Q_{lh}	0	6.00	0

Table of Load & Resistance Factors

	Strength I-a	**Strength I-b**	**Strength IV**	**Service I**
Load Factors				
LL	1.75	1.75	0.00	1.00
EH	1.50	1.50	1.50	1.00
EQ	0.00	0.00	0.00	0.00
CT	0.00	0.00	0.00	0.00
LL over wall	0.00	1.75	0.00	1.00
Resistance Factors				
DC	0.90	1.25	1.50	1.00
EV	1.00	1.35	1.35	1.00
BC	0.45	0.45	0.45	1.00
ϕ_τ precast to agg	0.90	0.90	0.90	1.00
ϕ_τ CIP to agg/soil	0.80	0.80	0.80	1.00
ϕ_τ soil to soil	0.90	0.90	0.90	1.00
ϕ_τ precast to precast	0.90	0.90	0.90	1.00

Project LRFD Example Calculations	**Project #** 20004.00	**Date** 11/16/20

Table of Calculated Factored Forces (lbs per foot of wall)

	Unfactored Force	**Load Factor**	**Strength I-a**	**Strength I-b**	**Strength IV**	**Service I**
Vertical Forces						
W_b	4,305	DC	3,875	5,381	6,458	4,305
$W_a + W_s$	3,196	EV	3,196	4,314	4,314	3,196
$0.80*(W_a + W_s)$	2,557	EV	2,557	3,452	3,452	2,557
P_v	1,711	EH	2,567	2,567	2,567	1,711
Q_{lv}	0	LL	0	0	0	0
$Q_{l \text{ over wall}}$	0	LL over	0	0	0	0
Horizontal Forces						
P_h	3,436	EH	5,154	5,154	5,154	3,436
Q_{lh}	0	LL	0	0	0	0

Table of Calculated Factored Moments (lb*ft per foot of wall)

	Unfactored Moment	**Load Factor**	**Strength I-a**	**Strength I-b**	**Strength IV**	**Service I**
Vertical Forces						
W_b	13,085	DC	11,777	16,356	19,628	13,085
$W_a + W_s$	10,421	EV	10,421	14,069	14,069	10,421
$0.80*(W_a + W_s)$	8,337	EV	8,337	11,255	11,255	8,337
P_v	9,221	EH	13,831	13,831	13,831	9,221
Q_{lv}	0	LL	0	0	0	0
$Q_{l \text{ over wall}}$	0	LL over	0	0	0	0
Horizontal Forces						
P_h	13,744	EH	20,615	20,615	20,615	13,744
Q_{lh}	0	LL	0	0	0	0

Overturning/Eccentricity

Check that $M'_V > M_H$

Check that e>B/3 (40% of B for extreme load cases)

Strength Case I-a:

M'_V = 11,777+8,337+13,831 = 33,944 lb*ft/ft

M_H = 20,615 lb*ft/ft

$M'_V > M_H$ **OK!!**

e = (68/12)/2+(20,615-33,944) / (3,875+2,557+2,567) = 1.35 ft

B/3 = (68/12)/3 = 1.89 ft

e < B/3 **OK!!**

Table for all load cases

	Strength I-a	**Strength I-b**	**Strength IV**	**Service I**
F'_v	8,998	11,399	12,476	8,573
M'_v	33,944	41,442	44,713	30,643
M_h	20,615	20,615	20,615	13,744
e	1.35	1.01	0.90	0.86

All load cases **OK!!!**

Sliding

Check that $R'_s > F_h$

Strength Case I-a:

Use the smaller sliding resistance, R'_s, across footing or through foundation soil:

$R'_{s\,(soil)}$ = [(3,875+3,196+2,567+(68/12)*(9/12)*110*1.0)*tan(26)*((68+9)/12)*150]*0.9
= 5,330 lb/ft

Tail extension is assumed to be on aggregate base

$\%_{void}$ = (594/110) / (594/110+750/145+24/12*3) = 0.2281

$\%_{precast}$ = (750/145) / (594/110+750/145+24/12*3) = 0.2095

$\%_{CIP}$ = (24/12*3) / (594/110+750/145+24/12*3) = 0.3038

μ_b = (0.2281*tan(35)+0.2095*0.8*tan(40)+0.3038*tan(40)) = 0.74

$R'_{s\,(footing)}$ = 0.9*0.74*(3,875+3,196+2,567)
= 6,419 lb/ft

F_h = 5,154 lb/ft

$R'_s > F_h$ **OK!!**

Table for all load cases

	Strength I-a	Strength I-b	Strength IV	Service I
F_h	5,154	5,154	5,154	3,436
F_v	9,637	12,262	13,339	9,212
F_v w/ base weight	10,168	12,979	14,056	9,743
ϕ_τ	0.90	0.90	0.90	1.00
R'_s (foundation soil)	5,330	6,564	7,036	5,715
R'_s (footing)	6,419	8,167	8,884	6,817

All Load Cases **OK!!**

Bearing

Check that $q_b > q_c$

Strength Case I-a:

$e = ((68/12)/2+(20{,}615-11{,}777+10{,}421+13{,}831) / (3{,}875+3{,}196+2{,}567) = 1.23$

$B_f' = (68+9)/12-2*1.23$ ft = 3.95 ft

Bearing Factors (Vesic):

$N_q = 11.85$ $N_c = 22.25$ $N\gamma = 12.54$

$q_b = [150*22.25+(12+9)/12*125*11.85+0.5*125*3.96*12.54]*0.45 = 4{,}062$ psf

weight of base = $t_b *\gamma_{base}*EH = 9/12*125*1.5 = 141$ psf

$q_c = (9{,}637)/3.95+141 = 2{,}581$ psf

$q_b > q_c$ **OK!!**

Table for all load cases

	Strength I-a	Strength I-b	Strength IV	Service I
Fv	9,637	12,262	13,339	9,212
Mv	36,029	44,256	47,527	32,727
Mh	20,615	20,615	20,615	13,744
e	1.23	0.91	0.82	0.77
Bf	3.95	4.61	4.79	4.87
qc	2,581	2,803	2,928	1,985
qb	4,062	4,293	4,357	9,749

All Load Cases **OK!!!**

Internal Stability

Internal stability should be checked at each change in block width, at all dual-face units, and at the top unit at a minimum. The following is taken at the first change from 24SF with tail extension to a standard 24SF units. Internal stability of the block stack above this interface is calculated as follows:

Wall Configuration (all weights per foot along length of wall)

Modular Units			Setback (in)		Concrete (/ft.)		Unit Fill (/ft.)	
unit	w (in)	h (ft)	face	tail	W_b (lb)	x_b (in)	W_a (lb)	x_a (in)
6	44.0	1.50	6.0	6.0	375	26.0	301	28.5
6	44.0	1.50	4.0	4.0	375	24.0	301	26.5
24	44.0	3.00	0.0	0.0	750	20.2	594	23.8

Weight and Center of Gravity of Wall Components

W_b = 750+375+375 = 1,500 lb/ft

W_a = 594+301+301 = 1,196 lb/ft

x_b= (750*20.2+375*24.0+375*26.0) / 1,500 = 22.6 in

y_b = (750*18+375*45+375*63) / 1,500 = 36.0 in

x_a = (594*23.8+301*26.5+301*28.5) / 1,196 = 25.7 in

y_a = (594*18+301*45+301*63) / 1,196 = 36.1 in

Earth Pressure Components

$\omega' = 6.34°$ $\delta = 0.5*30 = 15.0°$

$$K_a = \frac{\cos^2(30+6.34)}{\cos^2(6.34)\cos(6.34-15.0)\left[1+\sqrt{\frac{\sin(30+15.0)\sin(30-18.4)}{\cos(6.34-15.0)\cos(6.34+18.4)}}\right]^2}$$

K_a = 0.340

$P_h = 0.5*(0.340)*120*(6)^2*\cos(15-6.34)$ = 727 lb

$P_v = 0.5*(0.340)*120*(6)^2*\sin(15-6.34)$ =111 lb

x_P = (6/3)*tan(6.34)+(43/12) = 3.81 ft

y_P = 6/3 = 2.00 ft

Project LRFD Example Calculations	**Project #** 20004.00	**Date** 11/16/20

Table of Unfactored Forces & Moments (per foot of wall)

	Unfactored Force (lb)	**arm (ft)**	**Unfactored Moment about toe (lb*ft)**
Vertical Forces			
W_b	1,500	1.88	2,825
$W_a + W_s$	1,196	2.14	2,559
$0.80*(W_a + W_s)$	957	2.14	2,047
P_v	111	3.81	421
Q_{lv}	0	3.92	0
$Q_{l\text{ over wall}}$	0	2.92	0
Horizontal Forces			
P_h	727	2.00	1,453
Q_{lh}	0	3.00	0

Table of Load & Resistance Factors

	Strength I-a	**Strength I-b**	**Strength IV**	**Service I**
Load Factors				
LL	1.75	1.75	0.00	1.00
EH	1.50	1.50	1.50	1.00
EQ	0.00	0.00	0.00	0.00
CT	0.00	0.00	0.00	0.00
LL over wall	0.00	1.75	0.00	1.00
Resistance Factors				
DC	0.90	1.25	1.50	1.00
EV	1.00	1.35	1.35	1.00
ϕ_{τ} precast to precast	0.90	0.90	0.90	1.00

Project	Project #	Date
LRFD Example Calculations	20004.00	11/16/20

Table of Calculated Factored Forces (lbs per foot of wall)

	Unfactored Force	Load Factor	Strength I-a	Strength I-b	Strength IV	Service I
Vertical Forces						
W_b	1,500	DC	1,350	1,875	2,250	1,500
$W_a + W_s$	1,196	EV	1,196	1,615	1,615	1,196
$0.80*(W_a + W_s)$	957	EV	957	1,292	1,292	957
P_v	111	EH	166	166	166	111
Q_{lv}	0	LL	0	0	0	0
$Q_{l \text{ over wall}}$	0	LL over	0	0	0	0
Horizontal Forces						
P_h	727	EH	1,090	1,090	1,090	727
Q_{lh}	0	LL	0	0	0	0

Table of Calculated Factored Moments (lb*ft per foot of wall)

	Unfactored Moment	Load Factor	Strength I-a	Strength I-b	Strength IV	Service I
Vertical Forces						
W_b	2,825	DC	2,543	3,531	4,238	2,825
$W_a + W_s$	2,559	EV	2,559	3,454	3,454	2,559
$0.80*(W_a + W_s)$	2,047	EV	2,047	2,763	2,763	2,047
P_v	421	EH	632	632	632	421
Q_{lv}	0	LL	0	0	0	0
$Q_{l \text{ over wall}}$	0	LL over	0	0	0	0
Horizontal Forces						
P_h	1,453	EH	2,180	2,180	2,180	1,453
Q_{lh}	0	LL	0	0	0	0

Overturning/Topple

Check that $M'_V > M_H$

Check that $e<B*0.45$ (40% of B for extreme load cases)

Strength Case I-a:

M'_V = 2,543+2,047+642 = 5,221 lb*ft/ft
M_H = 2,180 lb*ft/ft
$M'_V > M_H$ **OK!!**

e = (43)/12/2+(2,180-5,221) / (1,350+957+166) = 0.56 ft
B*0.45 = (43/12)*0.45 = 1.61 ft
e < B*0.45 **OK!!**

Table for all load cases

	Strength I-a	**Strength I-b**	**Strength IV**	**Service I**
F'_v	2,473	3,333	3,708	2,568
M'_v	5,221	6,926	7,632	5,293
M_h	2,180	2,180	2,180	1,453
e	0.56	0.37	0.32	0.30

All Load Cases **OK!!**

Interface Shear

Check that $R'_s > F_h$

Strength Case I-a:

R'_s = [362+ (1,350+1,196+166)*tan(35.2)]*0.9 = 2,048
F_h = 1,090 lb/ft
$R'_s > F_h$ **OK!!**

Table for all load cases

	Strength I-a	**Strength I-b**	**Strength IV**	**Service I**
F_h	1,090	1,090	1,090	727
F_v	2,712	3,656	4,031	2,807
ϕ_τ	0.90	0.90	0.90	1.00
R'_s	2,048	2,647	2,885	2,342

All Load cases **OK!!**

External & Internal Stability **OK!!**

STONE STRONG SYSTEMS®

STONE STRONG GRAVITY CALCULATIONS - ver 6.0

Project Name: Example Calculations
Location:
Job#: 20004.00
Section: Example #1
Calc by: D Thiele

(AASHTO 8th Edition, 2017)

2/20/20 15:51

Notes
12.0 tall wall with extended precast units, vertical face
level back slope, no foreslope or siesmic, 250 psf roadway surcharge
External Stability

Wall Configuration

			setback (in)		modular units		unit fill		soil wedge		CIP Extension		
unit	w (in)	h (ft)	face	tail	Wb (lb)	xb (in)	Wa (lb)	xa (in)	Ws (lb)	xs (in)	we (in)	h_t	Internal
V6-28	28.0	1.50	0.0	-57.0	238	12.8	183	14.0	110	33.3			Internal Stability OK!
V6	44.0	1.50	0.0	-41.0	375	21.0	301	23.5	94	48.6			Internal Stability OK!
V24	43.0	3.00	0.0	-42.0	750	20.2	594	23.8	779	58.3			Internal Stability OK!
V24-86	85.0	3.00	0.0	0.0	950	39.0	1,621	44.1	0	0.0			Internal Stability OK!
V24-86	85.0	3.00	0.0	0.0	950	39.0	1,621	44.1	0	0.0			
													External Stability OK!
	85.0	12.00	0.0	-57.0	3,263	30.7	4,320	38.6	983	54.5			

backfill height 12.00 feet
exposed height 11.00 feet

$\omega =$ 0.00 deg
$\omega' =$ -21.60 deg

interface friction angle
δ 22.5 deg

Retained Soil
γ 120 pcf
ϕ 30 deg

Foundation Soil
γ 125 pcf
ϕ 26 deg
c' 150 psf

base embedment 12 in
base thickness 9 in
base material agg
toe slope H:1V slope

bearing pressure n/a psf
(if specified) (net)

Aggregate Unit Fill
γ 110 pcf

composite friction coefficient μ_b 0.69

STONE STRONG GRAVITY CALCULATIONS - ver 6.0

Project Name: Example Calculations
Location:
Job#: 20004.00
Section: Example #1
Calc by: D Thiele

Seismic Load

PGA		G	site class (A to E or 1)	D	Fpga	1.60	Fa	1.60

k_h 0.00

Backfill Slope & Surcharge

			rise in grade		LL surcharge		tier height	
length 1	30	feet (horizontal)		ft	250	psf		ft
length 2		feet (horizontal)		ft		psf		ft
length 3		feet (horizontal)		ft		psf		ft
length 4		feet (horizontal)		ft		psf		

effective slope H:1V slope

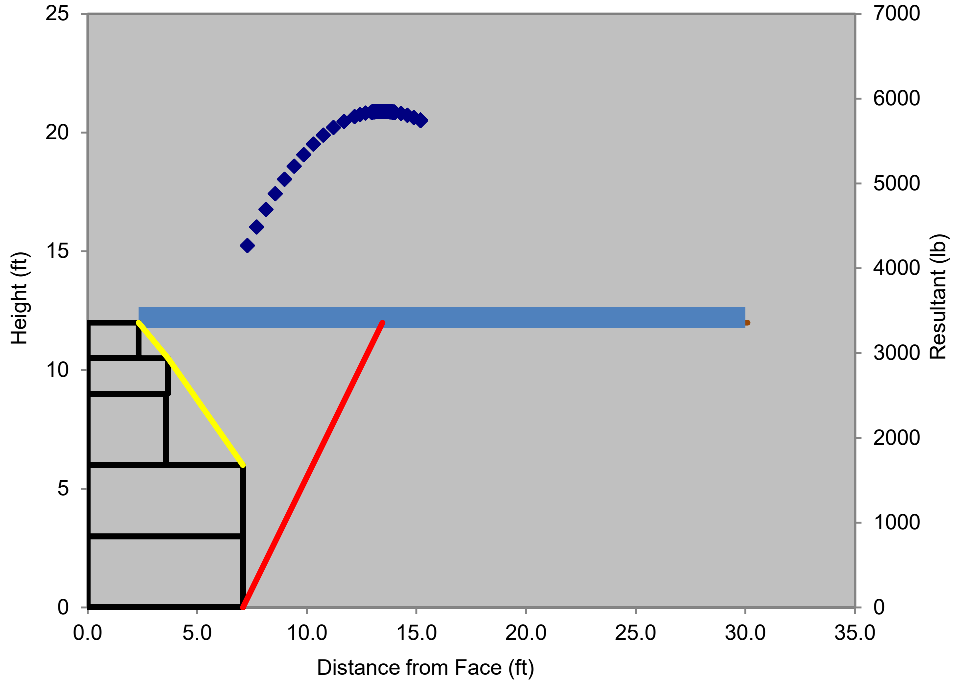
β 0.0 deg

avg q 250 psf

failure plane α 62.06 deg

zone of influence 13.45 ft

Ground Surface & Trial Wedge Plot



Unfactored Loads

K_a = 0.503

P_h = 3,119 lb

P_v = 3,022 lb

Q_{lh} = 1,083 lb

Q_{lv} = 1,049 lb

K_{AE} = 0.503

ΔK_{AE} = 0.000

P_{IR} = 0 lb

ΔP_{AEh} = 0 lb

ΔP_{AEv} = 0 lb

STONE STRONG GRAVITY CALCULATIONS - ver 6.0

Project Name: Example Calculations
Location:
Job#: 20004.00
Section: Example #1
Calc by: D Thiele

	Load Cases:	Strngth I-a	Strngth I-b	Strngth IV	Extrme I-a (EQ)	Extrme I-b (EQ)	Extrme II (CT)	Service I	
Factored Loading	*Overturning (lb-ft):*	30,087	30,087	18,715	12,477	12,477	15,726	18,975	**OK!**
	Sliding (lb):	6,574	6,574	4,679	3,119	3,119	3,661	4,202	**OK!**
	Bearing (psf):	3,203	3,841	2,906	2,001	2,001	2,213	2,595	**OK!**
	e (ft):	1.65	1.51	1.00	0.96	0.96	1.15	1.38	**OK!**
	Bf' (ft):	4.77	5.03	6.00	6.08	6.08	5.72	5.29	
Factored Resistance	*Overturning (lb-ft):*	55,784	65,038	57,287	39,661	39,661	42,131	45,282	
	Sliding (lb):	7,762	9,628	8,732	7,151	7,151	7,407	7,947	
	Bearing (psf):	4,351	4,445	4,785	10,693	10,693	10,411	10,073	
	(@ top of base) Max e (ft):	2.36	2.36	2.36	2.83	2.83	2.83	2.36	
Load & Resistance Factors	LL	1.75	1.75	0.00	0.00	0.00	0.50	1.00	
	EH	1.50	1.50	1.50	1.00	1.00	1.00	1.00	
	EQ	0.00	0.00	0.00	1.00	1.00	0.00	0.00	
	CT	0.00	0.00	0.00	0.00	0.00	1.00	0.00	
	LL Surcharge over Wall	0.00	1.75	0.00	0.00	0.00	0.00	1.00	
	DC	0.90	1.25	1.50	1.00	1.00	1.00	1.00	
	EV	1.00	1.35	1.35	1.00	1.00	1.00	1.00	
	BC	0.45	0.45	0.45	1.00	1.00	1.00	1.00	
	ϕt precast to agg	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	ϕt CIP to agg/soil	0.80	0.80	0.80	1.00	1.00	1.00	1.00	
	ϕt soil to soil	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	ϕt precast to precast	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	concrete interface - eccentricity limit	0.45	0.45	0.45	0.40	0.40	0.45	0.45	
	bearing on soil - eccentricity limit	0.33	0.33	0.33	0.40	0.40	0.40	0.33	

STONE STRONG SYSTEMS

STONE STRONG GRAVITY CALCULATIONS - ver 6.0

Project Name: Example Calculations
Location:
Job#: 20004.00
Section: Example #1
Calc by: D Thiele

(AASHTO 8th Edition, 2017)

Notes
12.0 tall wall with extended precast units, vertical face
level back slope, no foreslope or siesmic, 250 psf roadway surcharge
Internal Stability

Wall Configuration

			setback (in)		modular units		unit fill		soil wedge		CIP Extension		
unit	w (in)	h (ft)	face	tail	Wb (lb)	xb (in)	Wa (lb)	xa (in)	Ws (lb)	xs (in)	we (in)	h_t	Internal
V6-28	28.0	1.50	0.0	-15.0	238	11.8	183	13.0	110	32.3			Internal Stability OK!
V6	44.0	1.50	0.0	1.0	375	20.0	301	22.5	0	0.0			Internal Stability OK!
V24	43.0	3.00	0.0	0.0	750	19.2	594	22.8	0	0.0			
													Internal Stability OK!
	43.0	6.00	0.0	-15.0	1,363	18.1	1,078	21.1	110	32.3			

backfill height 6.00 feet

ω= 0.00 deg
ω'= -11.77 deg

interface friction angle
δ 22.5 deg

Retained Soil

γ 120 pcf
ϕ 30 deg

Internal ONLY

Aggregate Unit Fill

γ 110 pcf

STONE STRONG GRAVITY CALCULATIONS - ver 6.0

Project Name: Example Calculations
Location:
Job#: 20004.00
Section: Example #1
Calc by: D Thiele

Seismic Load

PGA G | site class (A to E or 1) D | Fpga 1.60 | Fa 1.60 | k_h 0.00

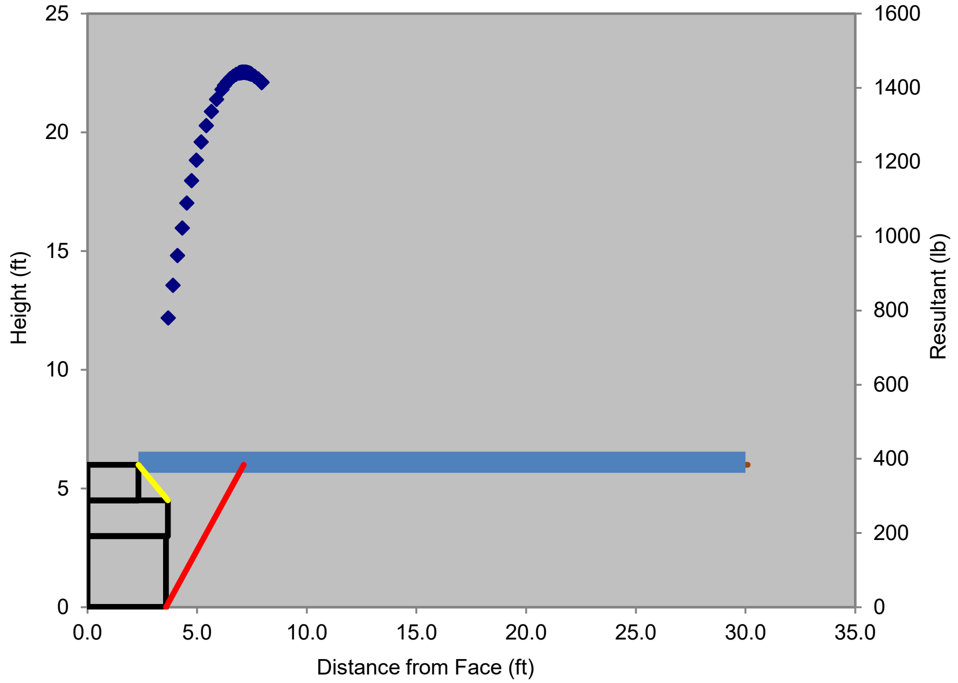
Backfill Slope & Surcharge

			rise in grade		LL surcharge		tier height	
length 1	30	feet (horizontal)		ft	250	psf		ft
length 2		feet (horizontal)		ft		psf		ft
length 3		feet (horizontal)		ft		psf		ft
length 4		feet (horizontal)		ft		psf		

effective slope H:1V slope | β 0.0 deg | avg q 250 psf

failure plane α 59.43 deg | zone of influence 7.13 ft

Ground Surface & Trial Wedge Plot



Unfactored Loads

K_a = 0.394
P_h = 703 lb
P_v = 479 lb
Q_{lh} = 488 lb
Q_{lv} = 333 lb

K_{AE} = 0.394
ΔK_{AE} = 0.000
P_{IR} = 0 lb
ΔP_{AEh} = 0 lb
ΔP_{AEv} = 0 lb

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STONE STRONG GRAVITY CALCULATIONS - ver 6.0

Project Name: Example Calculations
Location:
Job#: 20004.00
Section: Example #1
Calc by: D Thiele

	Load Cases:	Strngth I-a	Strngth I-b	Strngth IV	Extrme I-a (EQ)	Extrme I-b (EQ)	Extrme II (CT)	Service I	
Factored Loading	*Overturning (lb-ft):*	4,674	4,674	2,110	1,407	1,407	2,139	2,872	**OK!**
	Sliding (lb):	1,910	1,910	1,055	703	703	948	1,192	**OK!**
	Bearing (psf):								**OK!**
	e (ft):	0.94	0.76	0.38	0.36	0.36	0.52	0.67	**OK!**
	Bf' (ft):								
Factored Resistance	*Overturning (lb-ft):*	7,493	9,932	7,666	5,285	5,285	5,764	6,874	
	Sliding (lb):	2,685	3,900	3,098	2,499	2,499	2,617	3,146	
	Bearing (psf):								
	(@ interface) Max e (ft):	1.58	1.58	1.58	1.40	1.40	1.58	1.58	
Load & Resistance Factors	LL	1.75	1.75	0.00	0.00	0.00	0.50	1.00	
	EH	1.50	1.50	1.50	1.00	1.00	1.00	1.00	
	EQ	0.00	0.00	0.00	1.00	1.00	0.00	0.00	
	CT	0.00	0.00	0.00	0.00	0.00	1.00	0.00	
	LL Surcharge over Wall	0.00	1.75	0.00	0.00	0.00	0.00	1.00	
	DC	0.90	1.25	1.50	1.00	1.00	1.00	1.00	
	EV	1.00	1.35	1.35	1.00	1.00	1.00	1.00	
	BC	0.45	0.45	0.45	1.00	1.00	1.00	1.00	
	ϕt precast to agg	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	ϕt CIP to agg/soil	0.80	0.80	0.80	1.00	1.00	1.00	1.00	
	ϕt soil to soil	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	ϕt precast to precast	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	concrete interface - eccentricity limit	0.45	0.45	0.45	0.40	0.40	0.45	0.45	
	bearing on soil - eccentricity limit	0.33	0.33	0.33	0.40	0.40	0.40	0.33	

STONE STRONG
SYSTEMS®

STONE STRONG GRAVITY CALCULATIONS - ver 6.0

Project Name: Example Calculations
Location:
Job#: 20004.00
Section: Example #2
Calc by: D Thiele

(AASHTO 8th Edition, 2017)

2/20/20 15:51

Notes
12.0 tall wall with tail extension, battered face
3H:1V backslope, no foreslope or siesmic
External Stability

Wall Configuration

			setback (in)		modular units		unit fill		soil wedge		CIP Extension		
unit	w (in)	h (ft)	face	tail	Wb (lb)	xb (in)	Wa (lb)	xa (in)	Ws (lb)	xs (in)	we (in)	h_t	Internal
6	44.0	1.50	14.0	-10.0	375	35.0	301	37.5	19	58.9			Internal Stability OK!
6	44.0	1.50	12.0	-12.0	375	33.0	301	35.5	85	59.2			Internal Stability OK!
24	44.0	3.00	8.0	-16.0	750	29.2	594	32.8	396	59.3			Internal Stability OK!
24	68.0	3.00	4.0	4.0	1,185	38.0	594	28.8	311	71.1	24	1/2 h	Internal Stability OK!
24	68.0	3.00	0.0	0.0	1,620	39.9	594	24.8	0	0.0	24		
													External Stability OK!
	68.0	12.00	14.0	-10.0	4,305	36.5	2,385	30.7	811	63.8			

backfill height 12.00 feet
exposed height 11.00 feet

$\omega=$ 6.34 deg
$\omega'=$ -3.97 deg

interface friction angle
δ 22.5 deg

Retained Soil

γ 120 pcf
ϕ 30 deg

Foundation Soil

γ 125 pcf
ϕ 26 deg
c' 150 psf

bearing pressure n/a psf
(if specified) (net)

base embedment 12 in
base thickness 9 in
base material agg
toe slope H:1V slope

composite friction coefficient μ_b 0.74

Aggregate Unit Fill

γ 110 pcf

STONE STRONG GRAVITY CALCULATIONS - ver 6.0

Project Name: Example Calculations
Location:
Job#: 20004.00
Section: Example #2
Calc by: D Thiele

Seismic Load

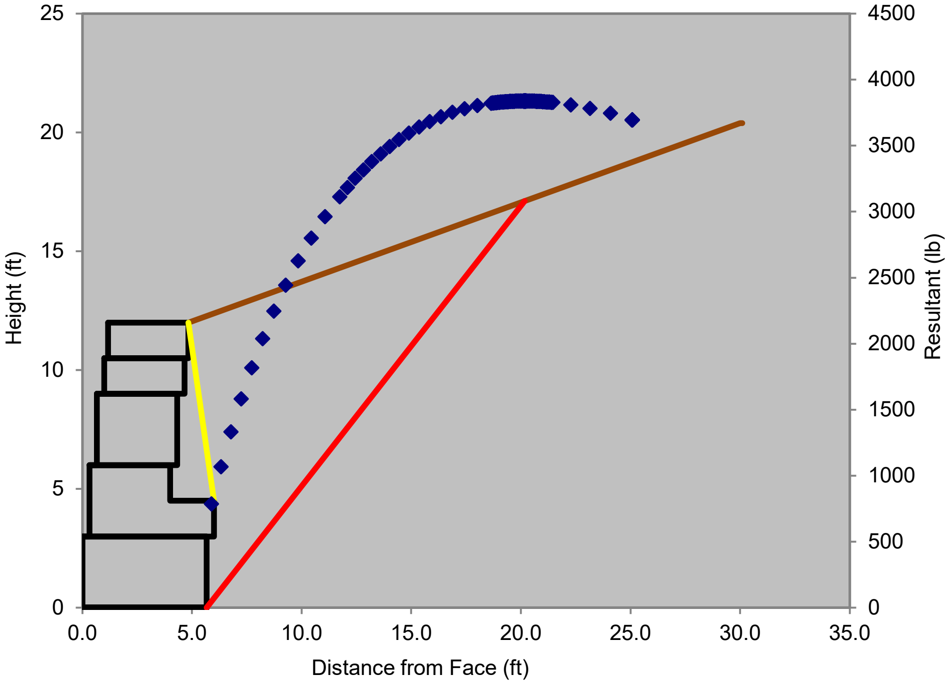
PGA G
site class (A to E or 1) D
Fpga 1.60
Fa 1.60
k_h 0.00

Backfill Slope & Surcharge

			backslope		LL surcharge		tier height	
length 1	30	feet (horizontal)	3	H:1V slope		psf		ft
length 2		feet (horizontal)		H:1V slope		psf		ft
length 3		feet (horizontal)		H:1V slope		psf		ft
length 4		feet (horizontal)		H:1V slope		psf		

effective slope 3.00 H:1V slope
β 18.4 deg
avg q 0 psf
failure plane α 49.71 deg
zone of influence 20.18 ft

Ground Surface & Trial Wedge Plot



Unfactored Loads

K_a = 0.444
P_h = 3,436 lb
P_v = 1,711 lb
Q_{lh} = 0 lb
Q_{lv} = 0 lb

K_{AE} = 0.444
ΔK_{AE} = 0.000
P_{IR} = 0 lb
ΔP_{AEh} = 0 lb
ΔP_{AEv} = 0 lb

STONE STRONG GRAVITY CALCULATIONS - ver 6.0

Project Name: Example Calculations
Location:
Job#: 20004.00
Section: Example #2
Calc by: D Thiele

	Load Cases:	Strngth I-a	Strngth I-b	Strngth IV	Extrme I-a (EQ)	Extrme I-b (EQ)	Extrme II (CT)	Service I	
Factored Loading	*Overturning (lb-ft):*	20,615	20,615	20,615	13,744	13,744	13,744	13,744	**OK!**
	Sliding (lb):	5,154	5,154	5,154	3,436	3,436	3,436	3,436	**OK!**
	Bearing (psf):	2,581	2,803	2,928	1,985	1,985	1,985	1,985	**OK!**
	e (ft):	1.35	1.01	0.90	0.86	0.86	0.86	0.86	**OK!**
	Bf' (ft):	3.95	4.61	4.79	4.87	4.87	4.87	4.87	
Factored Resistance	*Overturning (lb-ft):*	33,944	41,442	44,713	30,643	30,643	30,643	30,643	
	Sliding (lb):	5,330	6,564	7,036	5,715	5,715	5,715	5,715	
	Bearing (psf):	4,062	4,293	4,357	9,749	9,749	9,749	9,749	
	(@ top of base) Max e (ft):	1.89	1.89	1.89	2.27	2.27	2.27	1.89	
Load & Resistance Factors	LL	1.75	1.75	0.00	0.00	0.00	0.50	1.00	
	EH	1.50	1.50	1.50	1.00	1.00	1.00	1.00	
	EQ	0.00	0.00	0.00	1.00	1.00	0.00	0.00	
	CT	0.00	0.00	0.00	0.00	0.00	1.00	0.00	
	LL Surcharge over Wall	0.00	1.75	0.00	0.00	0.00	0.00	1.00	
	DC	0.90	1.25	1.50	1.00	1.00	1.00	1.00	
	EV	1.00	1.35	1.35	1.00	1.00	1.00	1.00	
	BC	0.45	0.45	0.45	1.00	1.00	1.00	1.00	
	ϕt precast to agg	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	ϕt CIP to agg/soil	0.80	0.80	0.80	1.00	1.00	1.00	1.00	
	ϕt soil to soil	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	ϕt precast to precast	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	concrete interface - eccentricity limit	0.45	0.45	0.45	0.40	0.40	0.45	0.45	
	bearing on soil - eccentricity limit	0.33	0.33	0.33	0.40	0.40	0.40	0.33	

STONE STRONG SYSTEMS®

STONE STRONG GRAVITY CALCULATIONS - ver 6.0

Project Name: Example Calculations
Location:
Job#: 20004.00
Section: Example #2
Calc by: D Thiele

(AASHTO 8th Edition, 2017)

2/20/20 15:51

Notes
12.0 tall wall with tail extension, battered face
3H:1V backslope, no foreslope or siesmic
Internal Stability

Wall Configuration

			setback (in)		modular units		unit fill		soil wedge		CIP Extension		
unit	w (in)	h (ft)	face	tail	Wb (lb)	xb (in)	Wa (lb)	xa (in)	Ws (lb)	xs (in)	we (in)	h_t	Internal
6	44.0	1.50	6.0	6.0	375	26.0	301	28.5					Internal Stability OK!
6	44.0	1.50	4.0	4.0	375	24.0	301	26.5					Internal Stability OK!
24	44.0	3.00	0.0	0.0	750	20.2	594	23.8					
													Internal Stability OK!
	44.0	6.00	6.0	6.0	1,500	22.6	1,196	25.7	0	0.0			

backfill height 6.00 feet

ω= 6.34 deg

ω'= 6.34 deg

interface friction angle

δ 15.0 deg

Retained Soil

γ 120 pcf
ϕ 30 deg

Internal ONLY

Aggregate Unit Fill

γ 110 pcf

STONE STRONG SYSTEMS®

STONE STRONG GRAVITY CALCULATIONS - ver 6.0

Project Name: Example Calculations
Location:
Job#: 20004.00
Section: Example #2
Calc by: D Thiele

2/20/20 15:51

Seismic Load PGA G site class (A to E or 1) D Fpga 1.60 Fa 1.60 k_h 0.00

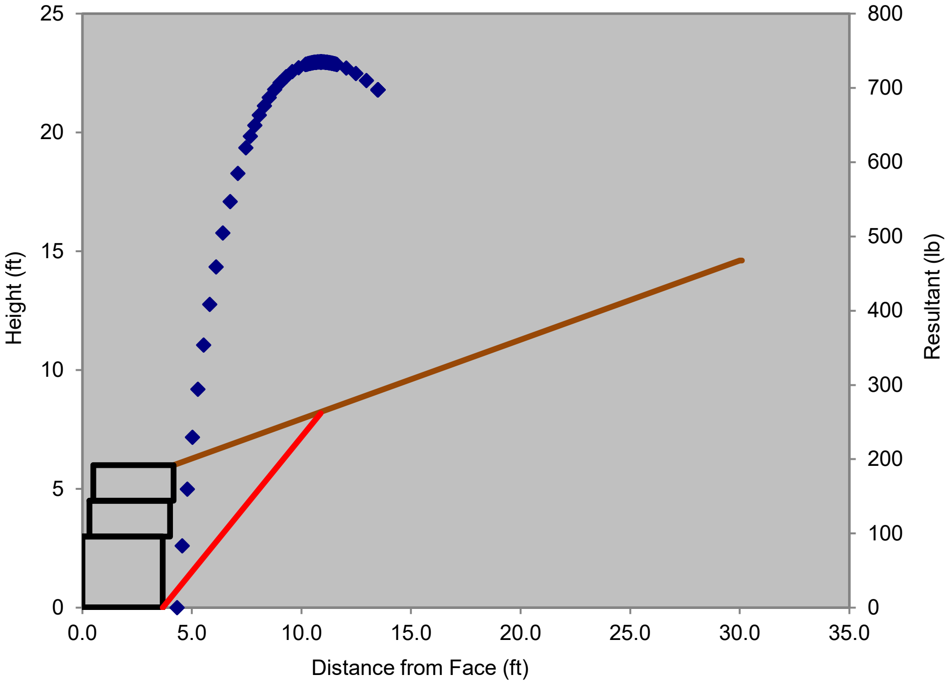
Backfill Slope & Surcharge

			backslope		LL surcharge		tier height	
length 1	30	feet (horizontal)	3	H:1V slope		psf		ft
length 2		feet (horizontal)		H:1V slope		psf		ft
length 3		feet (horizontal)		H:1V slope		psf		ft
length 4		feet (horizontal)		H:1V slope		psf		

effective slope 3.00 H:1V slope β 18.4 deg avg q 0 psf

failure plane α 48.61 deg zone of influence 10.88 ft

Ground Surface & Trial Wedge Plot



Unfactored Loads

K_a = 0.340
P_h = 727 lb
P_v = 111 lb
Q_{lh} = 0 lb
Q_{lv} = 0 lb

K_{AE} = 0.340
ΔK_{AE} = 0.000
P_{IR} = 0 lb
ΔP_{AEh} = 0 lb
ΔP_{AEv} = 0 lb

STONE STRONG SYSTEMS

STONE STRONG GRAVITY CALCULATIONS - ver 6.0

Project Name: Example Calculations
Location:
Job#: 20004.00
Section: Example #2
Calc by: D Thiele

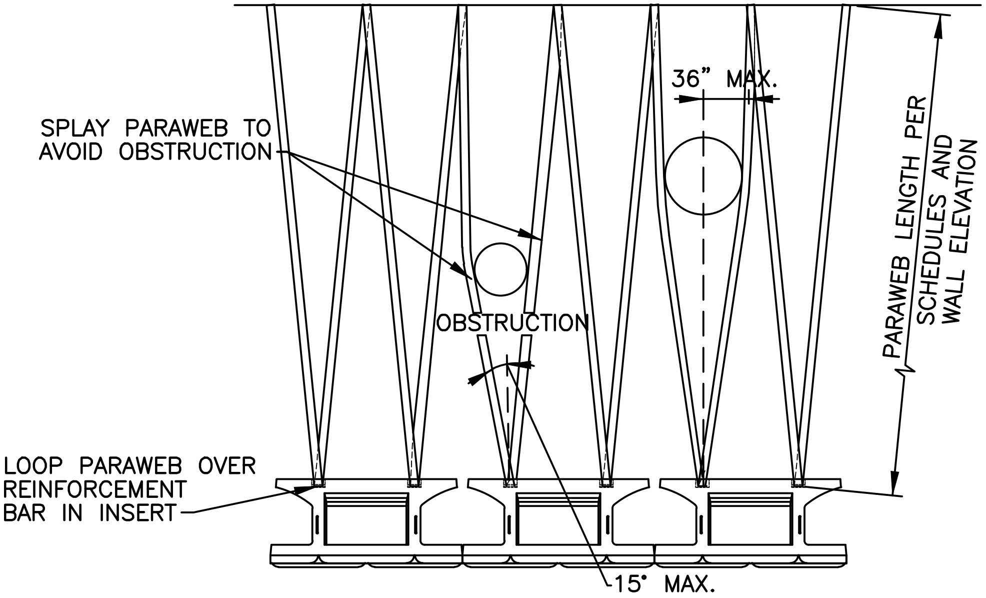
Load Cases:		Strngth I-a	Strngth I-b	Strngth IV	Extrme I-a (EQ)	Extrme I-b (EQ)	Extrme II (CT)	Service I	
Factored Loading	*Overturning (lb-ft):*	2,180	2,180	2,180	1,453	1,453	1,453	1,453	**OK!**
	Sliding (lb):	1,090	1,090	1,090	727	727	727	727	**OK!**
	Bearing (psf):								**OK!**
	e (ft):	0.56	0.37	0.32	0.30	0.30	0.30	0.30	**OK!**
	Bf' (ft):								
Factored Resistance	*Overturning (lb-ft):*	5,221	6,926	7,632	5,293	5,293	5,293	5,293	
	Sliding (lb):	2,048	2,647	2,885	2,342	2,342	2,342	2,342	
	Bearing (psf):								
	(@ interface) Max e (ft):	1.61	1.61	1.61	1.43	1.43	1.61	1.61	
Load & Resistance Factors	LL	1.75	1.75	0.00	0.00	0.00	0.50	1.00	
	EH	1.50	1.50	1.50	1.00	1.00	1.00	1.00	
	EQ	0.00	0.00	0.00	1.00	1.00	0.00	0.00	
	CT	0.00	0.00	0.00	0.00	0.00	1.00	0.00	
	LL Surcharge over Wall	0.00	1.75	0.00	0.00	0.00	0.00	1.00	
	DC	0.90	1.25	1.50	1.00	1.00	1.00	1.00	
	EV	1.00	1.35	1.35	1.00	1.00	1.00	1.00	
	BC	0.45	0.45	0.45	1.00	1.00	1.00	1.00	
	ϕt precast to agg	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	ϕt CIP to agg/soil	0.80	0.80	0.80	1.00	1.00	1.00	1.00	
	ϕt soil to soil	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	ϕt precast to precast	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	concrete interface - eccentricity limit	0.45	0.45	0.45	0.40	0.40	0.45	0.45	
	bearing on soil - eccentricity limit	0.33	0.33	0.33	0.40	0.40	0.40	0.33	

jump to TOC

jump to Appendix TOC

2.1.3 REINFORCEMENT OBSTRUCTIONS

Paraweb Obstruction Details



PLAN VIEW

PARAWEB OBSTRUCTION DETAIL

NOT TO SCALE

STONE STRONG SYSTEMS®

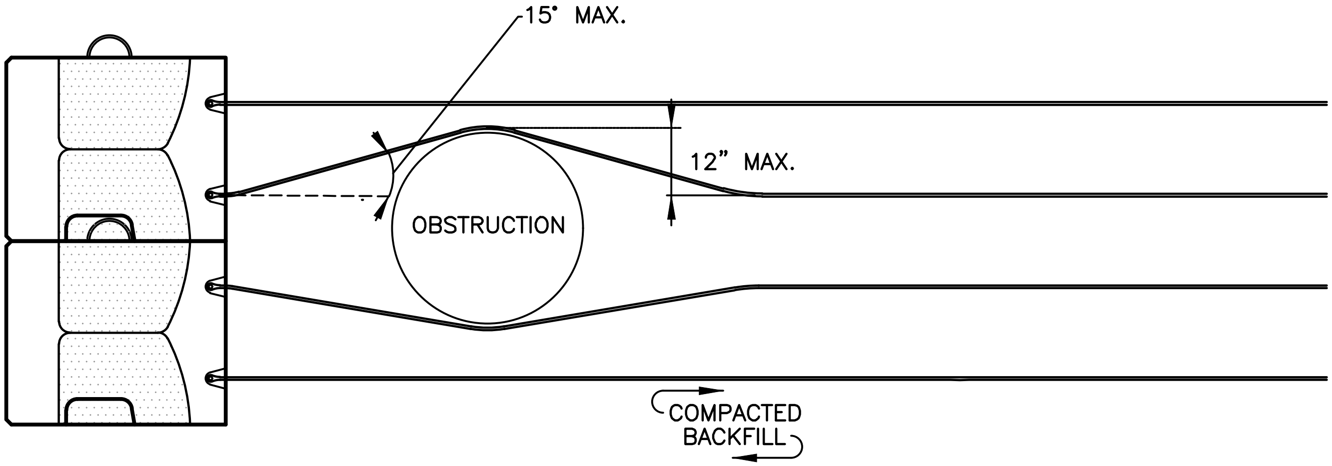
www.stonestrong.com

PROJECT

TYPICAL DETAILS
STONE STRONG SYSTEMS

DATE: 9/30/20

FILE: PARAWEB OBSTRUCTION DETAIL



CROSS SECTION

PARAWEB OBSTRUCTION CROSS SECTION

NOT TO SCALE

STONE STRONG SYSTEMS®

www.stonestrong.com

PROJECT

PARAWEB DETAILS
STONE STRONG SYSTEMS

DATE: 9/29/20
FILE: PARAWEBCSOBSTRUCTION

jump to TOC

jump to Appendix TOC

2.2.1 MSE DESIGN PROBLEM 1 (C1 CHECKLIST)

MSEW Output

FHWA-NHI-10-024
Stone Strong - IDEA Submittal

MSEW(3.0): Update # 14.981

PROJECT IDENTIFICATION

Title: Stone Strong - IDEA Submittal
Project Number: 20004 00
Client: Stone Strong Systems
Designer: BJP
Station Number: 134

Description:

Problem 1. Traffic Load with barrier. 30 ft Height Wall with 4 connections per unit. Installation strap lengths shall be 3 ft less than calculated.

Company's information:

Name: Thiele Geotech
Street: 13478 Chandler Road

Omaha, NE 68138
Telephone #: (402) 556-2171
Fax #: (402) 556-7831
E-Mail:

Original file path and name: P:\20004.00\Agency Approvals\Geo-Institute\IDEA\MSEW\Pr..... .....- Revised 1-6-21.BEN
Original date and time of creating this file: Thu Mar 31 08:22:52 2016

PROGRAM MODE: ANALYSIS
of a SIMPLE STRUCTURE
using GEOGRID as reinforcing material.

SOIL DATA

REINFORCED SOIL

Unit weight, γ	135.0 lb/ft ^{3}
Design value of internal angle of friction, ϕ	34.0 °

RETAINED SOIL

Unit weight, γ	120.0 lb/ft ^{3}
Design value of internal angle of friction, ϕ	30.0 °

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{\text{equiv.}}$	120.0 lb/ft ^{3}
Equivalent internal angle of friction, $\phi_{\text{equiv.}}$	30.0 °
Equivalent cohesion, $c_{\text{equiv.}}$	0.0 lb/ft ^{2}

Water table does not affect bearing capacity

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Inclination of internal slip plane, $\psi = 62.00°$ (see Fig. 28 in DEMO 82).
Ka (external stability) = 0.3333 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 30.14 $N_\gamma = 22.40$

SEISMICITY

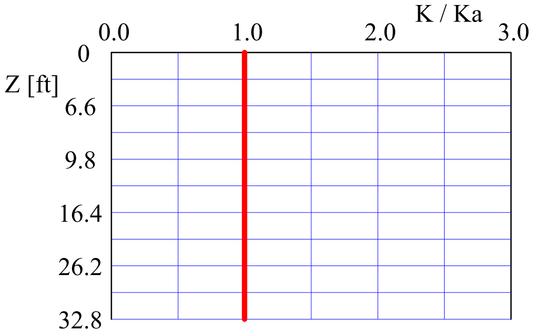
Not Applicable

INPUT DATA: Geogrids (Analysis)

D A T A	Geogrid type #1	Geogrid type #2	Geogrid type #3	Geogrid type #4	Geogrid type #5
Tult [lb/ft]	38101.0	38101.0			
Durability reduction factor, RFd	1.15	1.15			
Installation-damage reduction factor, RFid	1.10	1.10			
Creep reduction factor, RFc	1.36	1.36	N/A	N/A	N/A
CDR for strength	N/A	N/A			
Coverage ratio, Rc	0.147	0.147			
Friction angle along geogrid-soil interface, ρ	25.27	25.27			
Pullout resistance factor, F*	1.00·tan ϕ	0.80·tan ϕ	N/A	N/A	N/A
Scale-effect correction factor, α	0.8	0.8			

Variation of Lateral Earth Pressure Coefficient With Depth

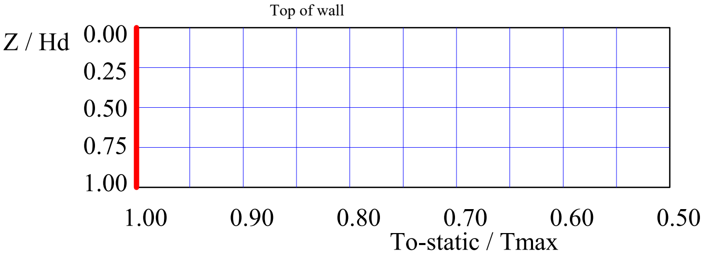
Z	K / Ka
0 ft	1.00
3.3 ft	1.00
6.6 ft	1.00
9.8 ft	1.00
13.1 ft	1.00
16.4 ft	1.00
19.7 ft	1.00



INPUT DATA: Facia and Connection (according to revised Demo 82) (Analysis)

FACIA type: Facing enabling frictional connection of reinforcement (e.g., modular concrete blocks, gabions)
Depth/height of block is 3.67/3.00 ft. Horizontal distance to Center of Gravity of block is 1.90 ft.
Average unit weight of block is γ_f = 122.20 lb/ft ³

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



Geogrid Type #1		Geogrid Type #2		Geogrid Type #3		Geogrid Type #4		Geogrid Type #5	
σ ⁽¹⁾	CRult ⁽²⁾	σ	CRult	σ	CRult	σ	CRult	σ	CRult
0.0	0.63	0.0	0.63						
10000.0	0.63	10000.0	0.63	N/A		N/A		N/A	

Geogrid Type #1⁽³⁾		Geogrid Type #2		Geogrid Type #3		Geogrid Type #4		Geogrid Type #5	
σ	CRcr	σ	CRcr	σ	CRcr	σ	CRcr	σ	CRcr
0.0	0.63	0.0	0.63						
10000.0	0.63	10000.0	0.63	N/A		N/A		N/A	

(1) σ = Confining stress in between stacked blocks [lb/ft ²]
(2) CRult = Tc-ult / Tult
(3) CRcr = Tcre / Tult

D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	Paraweb 2..	Paraweb 2..	N/A	N/A	N/A
Connection strength reduction factor, RFd	1.00	1.00	N/A	N/A	N/A
Creep reduction factor, RFc	N/A	N/A	N/A	N/A	N/A

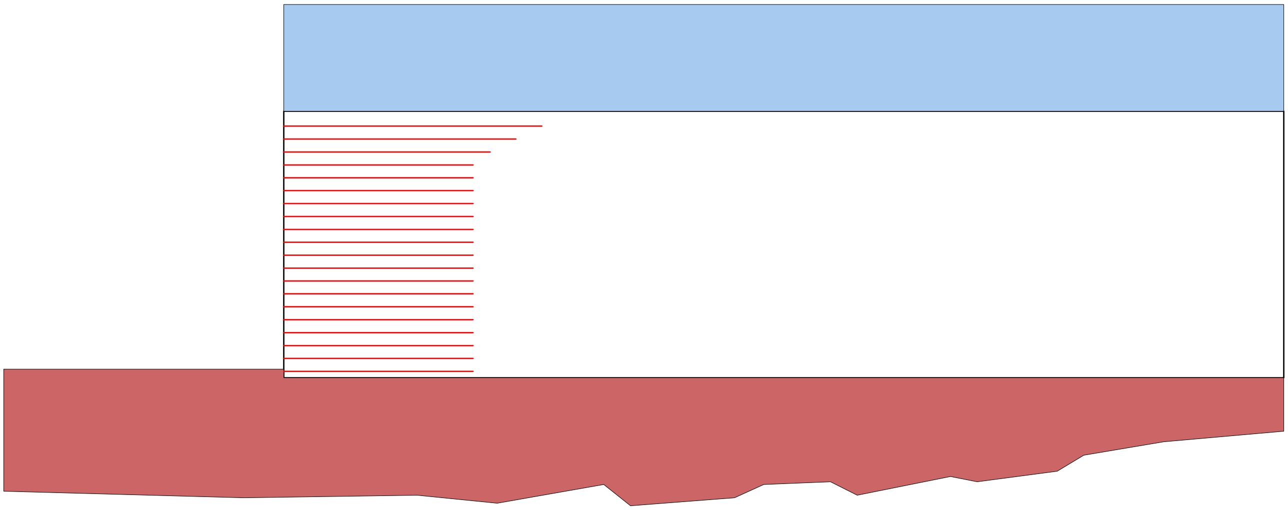
INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	31.00	[ft]	{ Embedded depth is E = 1.00 ft, and height above top of finished bottom grade is H = 30.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	0.0	[deg]	
Backslope rise	0.0	[ft]	Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

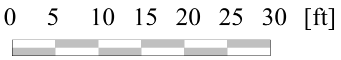
UNIFORM SURCHARGE

🟦 Uniformly distributed dead load is 0.0 [lb/ft ²], and live load is 250.0 [lb/ft ²]

ANALYZED REINFORCEMENT LAYOUT:



SCALE:



INPUT DATA: Traffic Barrier

IMPORTANT: Traffic surcharge and its load factor for Impact Load could be different than the values specified for LL in internal / external stability. Traffic surcharge is modeled as a uniform load generated by a reinforced soil layer; typically 2 ft (0.6 m) high. Traffic surcharge is equal to: 250.00 [psf]

Load factor on traffic surcharge, γ p-EV-impact =1.35 Note that it make sense to use the same default load factor as for soil weight (γ p-EV = 1.35) since this surcharge is modeled as an equivalent soil layer.

Considering reinforcement rupture, the impact equivalent load in: Top layer 250.00 [lb/ft]
Layer underneath 250.00 [lb/ft]

Creep reduction factors, RFcr, NEGLECTED for impact load component

Considering increase in pullout capacity, the added pullout load in: Top layer 0.00 [lb/ft]
Layer underneath 0.00 [lb/ft]

Resistance factors for tensile strength and connection for combined static and traffic barrier impact loads:

	Strength	Connection
Geosynthetics	1.200	1.200
Metal Mat	0.850	0.850
Metal Strip	1.000	1.000

Pullout resistance factor 1.000

RESULTS: Traffic Barrier

Rupture is considered at connection.

	Layer Number	Elevation	STRENGTH T max + T impact / RFc	 CDR	CONNECTION To + T impact / RFc	 CDR	PULLOUT T max + T impact	 CDR
		[ft]	[lb/ft]		[lb/ft]		[lb/ft]	
Top Layer	20	29.25	583.38	6.719	583.38	6.719	399.56	5.825
Layer Below	19	27.75	578.13	6.780	578.13	6.780	394.31	7.499

AASHTO 2007-2010 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-}EV}$	1.35
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-}EQ}$	1.00
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50

Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic
Geogrid:		0.90	1.20
Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic
Geogrid:		0.90	1.20
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90	1.20

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:

		Static		Combined Static/Seismic
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00

Resistance factor for shear resistance along common interfaces from Table 11.5.6-1:

		Static	Combined Static/Seismic
Reinforced Soil and Foundation	ϕ_τ	1.00	1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00	1.00

Resistance factor for bearing capacity of shallow foundation from Table 11.5.6-1:

	Static	Combined Static/Seismic
ϕ_b	0.65	0.65

ANALYSIS: CALCULATED FACTORS (Static conditions)

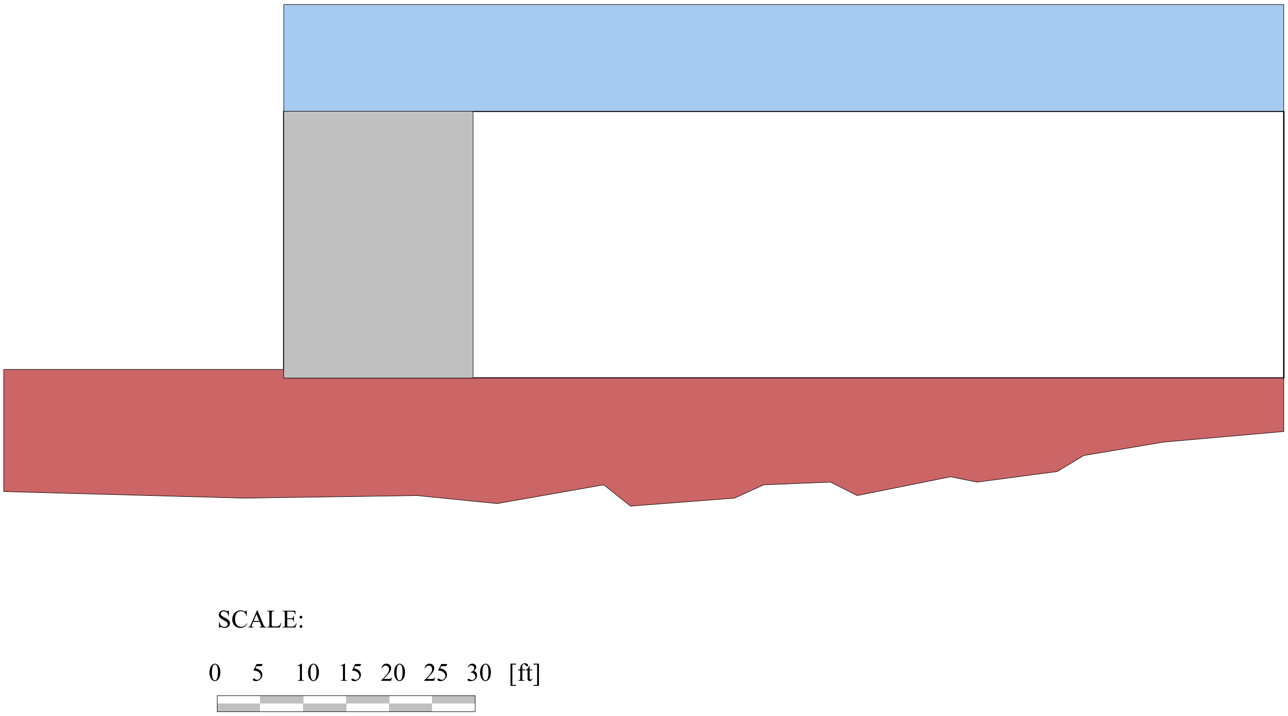
Bearing capacity, CDR = 1.78, factored bearing load = 8114 lb/ft².
Foundation Interface: Direct sliding, CDR = 1.594, Eccentricity, e/L = 0.1817, CDR-overturning = 2.75

GEOGRID				CONNECTION						
#	Elevation [ft]	Length [ft]	Type #	CDR [connection strength]	CDR [geogrid strength]	Geogrid strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	0.75	22.00	2	1.26	1.17	1.165	4.005	1.818	0.1738	Paraweb 2D..
2	2.25	22.00	2	1.32	1.22	1.221	3.843	1.899	0.1586	Paraweb 2D..
3	3.75	22.00	2	1.39	1.28	1.283	3.681	1.987	0.1441	Paraweb 2D..
4	5.25	22.00	2	1.46	1.35	1.351	3.516	2.085	0.1302	Paraweb 2D..
5	6.75	22.00	2	1.55	1.43	1.427	3.353	2.192	0.1171	Paraweb 2D..
6	8.25	22.00	2	1.64	1.51	1.512	3.189	2.311	0.1046	Paraweb 2D..
7	9.75	22.00	2	1.74	1.61	1.608	3.023	2.444	0.0928	Paraweb 2D..
8	11.25	22.00	2	1.86	1.72	1.717	2.858	2.593	0.0817	Paraweb 2D..
9	12.75	22.00	2	2.00	1.84	1.842	2.693	2.761	0.0713	Paraweb 2D..
10	14.25	22.00	2	2.15	1.99	1.986	2.524	2.953	0.0616	Paraweb 2D..
11	15.75	22.00	2	2.34	2.16	2.155	2.356	3.173	0.0526	Paraweb 2D..
12	17.25	22.00	2	2.55	2.36	2.355	2.186	3.429	0.0443	Paraweb 2D..
13	18.75	22.00	2	2.81	2.60	2.596	2.012	3.730	0.0366	Paraweb 2D..
14	20.25	22.00	2	3.14	2.89	2.893	1.837	4.088	0.0297	Paraweb 2D..
15	21.75	22.00	2	3.54	3.27	3.265	1.658	4.523	0.0234	Paraweb 2D..
16	23.25	22.00	2	4.06	3.75	3.748	1.472	5.061	0.0178	Paraweb 2D..
17	24.75	22.00	1	4.77	4.40	4.397	1.597	5.744	0.0130	Paraweb 2D..
18	26.25	24.00	1	5.77	5.32	5.320	1.668	7.244	0.0074	Paraweb 2D..
19	27.75	27.00	1	7.30	6.73	6.732	1.762	9.656	0.0035	Paraweb 2D..
20	29.25	30.00	1	6.78	6.25	6.252	1.040	13.164	0.0013	Paraweb 2D..

BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table does not affect bearing capacity)			
Factored bearing resistance. q-n	14420	N/A	[lb/ft ^{2}]
Factored bearing load, σ_V	8114.2	N/A	[lb/ft ^{2}]
Eccentricity, e	2.75	N/A	[ft]
Eccentricity, e/L	0.125	N/A	
CDR calculated	1.78	N/A	
Base length	22.00	N/A	[ft]

Unfactored applied bearing pressure = (Unfactored R) / [L - 2 * (Unfactored e)] =
Unfactored R = 97569.94 [lb/ft], L = 22.00, Unfactored e = 2.45 [ft], and Sigma = 5703.12 [lb/ft ^{2}]



DIRECT SLIDING for GIVEN LAYOUT (for GEOGRID reinforcements)

Along reinforced and foundation soils interface: CDR-static = 1.594

#	Geogrid Elevation [ft]	Geogrid Length [ft]	CDR Static	CDR Seismic	Geogrid Type #	Product name
1	0.75	22.00	1.818	N/A	2	Paraweb 2D50 - 7+ ft
2	2.25	22.00	1.899	N/A	2	Paraweb 2D50 - 7+ ft
3	3.75	22.00	1.987	N/A	2	Paraweb 2D50 - 7+ ft
4	5.25	22.00	2.085	N/A	2	Paraweb 2D50 - 7+ ft
5	6.75	22.00	2.192	N/A	2	Paraweb 2D50 - 7+ ft
6	8.25	22.00	2.311	N/A	2	Paraweb 2D50 - 7+ ft
7	9.75	22.00	2.444	N/A	2	Paraweb 2D50 - 7+ ft
8	11.25	22.00	2.593	N/A	2	Paraweb 2D50 - 7+ ft
9	12.75	22.00	2.761	N/A	2	Paraweb 2D50 - 7+ ft
10	14.25	22.00	2.953	N/A	2	Paraweb 2D50 - 7+ ft
11	15.75	22.00	3.173	N/A	2	Paraweb 2D50 - 7+ ft
12	17.25	22.00	3.429	N/A	2	Paraweb 2D50 - 7+ ft
13	18.75	22.00	3.730	N/A	2	Paraweb 2D50 - 7+ ft
14	20.25	22.00	4.088	N/A	2	Paraweb 2D50 - 7+ ft
15	21.75	22.00	4.523	N/A	2	Paraweb 2D50 - 7+ ft
16	23.25	22.00	5.061	N/A	2	Paraweb 2D50 - 7+ ft
17	24.75	22.00	5.744	N/A	1	Paraweb 2D50 - 0-7..
18	26.25	24.00	7.244	N/A	1	Paraweb 2D50 - 0-7..
19	27.75	27.00	9.656	N/A	1	Paraweb 2D50 - 0-7..
20	29.25	30.00	13.164	N/A	1	Paraweb 2D50 - 0-7..

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.1817; Overturning: CDR-static = 2.75

#	Geogrid Elevation [ft]	Geogrid Length [ft]	e / L Static	e / L Seismic	Geogrid Type #	Product name
1	0.75	22.00	0.1738	N/A	2	Paraweb 2D50 - 7+ ft
2	2.25	22.00	0.1586	N/A	2	Paraweb 2D50 - 7+ ft
3	3.75	22.00	0.1441	N/A	2	Paraweb 2D50 - 7+ ft
4	5.25	22.00	0.1302	N/A	2	Paraweb 2D50 - 7+ ft
5	6.75	22.00	0.1171	N/A	2	Paraweb 2D50 - 7+ ft
6	8.25	22.00	0.1046	N/A	2	Paraweb 2D50 - 7+ ft
7	9.75	22.00	0.0928	N/A	2	Paraweb 2D50 - 7+ ft
8	11.25	22.00	0.0817	N/A	2	Paraweb 2D50 - 7+ ft
9	12.75	22.00	0.0713	N/A	2	Paraweb 2D50 - 7+ ft
10	14.25	22.00	0.0616	N/A	2	Paraweb 2D50 - 7+ ft
11	15.75	22.00	0.0526	N/A	2	Paraweb 2D50 - 7+ ft
12	17.25	22.00	0.0443	N/A	2	Paraweb 2D50 - 7+ ft
13	18.75	22.00	0.0366	N/A	2	Paraweb 2D50 - 7+ ft
14	20.25	22.00	0.0297	N/A	2	Paraweb 2D50 - 7+ ft
15	21.75	22.00	0.0234	N/A	2	Paraweb 2D50 - 7+ ft
16	23.25	22.00	0.0178	N/A	2	Paraweb 2D50 - 7+ ft
17	24.75	22.00	0.0130	N/A	1	Paraweb 2D50 - 0-7..
18	26.25	24.00	0.0074	N/A	1	Paraweb 2D50 - 0-7..
19	27.75	27.00	0.0035	N/A	1	Paraweb 2D50 - 0-7..
20	29.25	30.00	0.0013	N/A	1	Paraweb 2D50 - 0-7..

RESULTS for STRENGTH

Live Load included in calculating Tmax

#	Geogrid Elevation [ft]	Tavailable [lb/ft]	Tmax [lb/ft]	Tmd [lb/ft]	Specified minimum CDR static	Actual calculated CDR static	Specified minimum CDR seismic	Actual calculated CDR seismic	Product name
1	0.75	19932	2523.47	N/A	N/A	1.165	N/A	N/A	Paraweb 2D..
2	2.25	19932	2407.54	N/A	N/A	1.221	N/A	N/A	Paraweb 2D..
3	3.75	19932	2291.61	N/A	N/A	1.283	N/A	N/A	Paraweb 2D..
4	5.25	19932	2175.68	N/A	N/A	1.351	N/A	N/A	Paraweb 2D..
5	6.75	19932	2059.75	N/A	N/A	1.427	N/A	N/A	Paraweb 2D..
6	8.25	19932	1943.81	N/A	N/A	1.512	N/A	N/A	Paraweb 2D..
7	9.75	19932	1827.88	N/A	N/A	1.608	N/A	N/A	Paraweb 2D..
8	11.25	19932	1711.95	N/A	N/A	1.717	N/A	N/A	Paraweb 2D..
9	12.75	19932	1596.02	N/A	N/A	1.842	N/A	N/A	Paraweb 2D..
10	14.25	19932	1480.09	N/A	N/A	1.986	N/A	N/A	Paraweb 2D..
11	15.75	19932	1364.16	N/A	N/A	2.155	N/A	N/A	Paraweb 2D..
12	17.25	19932	1248.23	N/A	N/A	2.355	N/A	N/A	Paraweb 2D..
13	18.75	19932	1132.30	N/A	N/A	2.596	N/A	N/A	Paraweb 2D..
14	20.25	19932	1016.37	N/A	N/A	2.893	N/A	N/A	Paraweb 2D..
15	21.75	19932	900.44	N/A	N/A	3.265	N/A	N/A	Paraweb 2D..
16	23.25	19932	784.51	N/A	N/A	3.748	N/A	N/A	Paraweb 2D..
17	24.75	19932	668.58	N/A	N/A	4.397	N/A	N/A	Paraweb 2D..
18	26.25	19932	552.65	N/A	N/A	5.320	N/A	N/A	Paraweb 2D..
19	27.75	19932	436.71	N/A	N/A	6.732	N/A	N/A	Paraweb 2D..
20	29.25	19932	470.23	N/A	N/A	6.252	N/A	N/A	Paraweb 2D..

RESULTS for PULLOUT

Live Load included in calculating Tmax

NOTE: Live load is not included in calculating the overburden pressure used to assess pullout resistance.

#	Geogrid Elevation [ft]	Coverage Ratio	Tmax [lb/ft]	Tmd [lb/ft]	Le [ft] (see NOTE)	La [ft]	Avail.Static Pullout, Pr [lb/ft]	Specified Static CDR	Actual Static CDR	Avail.Seism. Pullout, Pr [lb/ft]	Specified Seismic CDR	Actual Seismic CDR
1	0.75	0.147	2523.5	N/A	21.60	0.40	10106.8	N/A	4.005	N/A	N/A	N/A
2	2.25	0.147	2407.5	N/A	20.80	1.20	9252.2	N/A	3.843	N/A	N/A	N/A
3	3.75	0.147	2291.6	N/A	20.01	1.99	8434.6	N/A	3.681	N/A	N/A	N/A
4	5.25	0.147	2175.7	N/A	19.21	2.79	7649.9	N/A	3.516	N/A	N/A	N/A
5	6.75	0.147	2059.7	N/A	18.41	3.59	6906.3	N/A	3.353	N/A	N/A	N/A
6	8.25	0.147	1943.8	N/A	17.61	4.39	6199.4	N/A	3.189	N/A	N/A	N/A
7	9.75	0.147	1827.9	N/A	16.82	5.18	5526.3	N/A	3.023	N/A	N/A	N/A
8	11.25	0.147	1712.0	N/A	16.02	5.98	4893.5	N/A	2.858	N/A	N/A	N/A
9	12.75	0.147	1596.0	N/A	15.22	6.78	4297.5	N/A	2.693	N/A	N/A	N/A
10	14.25	0.147	1480.1	N/A	14.42	7.58	3735.9	N/A	2.524	N/A	N/A	N/A
11	15.75	0.147	1364.2	N/A	13.63	8.37	3213.9	N/A	2.356	N/A	N/A	N/A
12	17.25	0.147	1248.2	N/A	12.83	9.17	2728.8	N/A	2.186	N/A	N/A	N/A
13	18.75	0.147	1132.3	N/A	12.03	9.97	2278.7	N/A	2.012	N/A	N/A	N/A
14	20.25	0.147	1016.4	N/A	11.23	10.77	1867.5	N/A	1.837	N/A	N/A	N/A
15	21.75	0.147	900.4	N/A	10.44	11.56	1493.3	N/A	1.658	N/A	N/A	N/A
16	23.25	0.147	784.5	N/A	9.64	12.36	1154.7	N/A	1.472	N/A	N/A	N/A
17	24.75	0.147	668.6	N/A	8.84	13.16	1068.0	N/A	1.597	N/A	N/A	N/A
18	26.25	0.147	552.6	N/A	10.04	13.96	922.0	N/A	1.668	N/A	N/A	N/A
19	27.75	0.147	436.7	N/A	12.25	14.75	769.7	N/A	1.762	N/A	N/A	N/A
20	29.25	0.147	470.2	N/A	14.45	15.55	488.9	N/A	1.040	N/A	N/A	N/A

RESULTS for CONNECTION (static conditions)

Live Load included in calculating Tmax

#	Geogrid Elevation [ft]	Connection force, To [lb/ft]	Reduction factor for connection (short-term strength) CRult	Reduction factor for connection (long-term strength) CRcr	Available connection strength [lb/ft]	Available Geogrid strength, Tavailable [lb/ft]	CDR connection strength		CDR Geogrid strength		Product name
							Specified	Actual	Specified	Actual	
1	0.75	2523	0.63	0.63	21603	22147	N/A	1.26	N/A	1.17	Paraweb 2D..
2	2.25	2408	0.63	0.63	21603	22147	N/A	1.32	N/A	1.22	Paraweb 2D..
3	3.75	2292	0.63	0.63	21603	22147	N/A	1.39	N/A	1.28	Paraweb 2D..
4	5.25	2176	0.63	0.63	21603	22147	N/A	1.46	N/A	1.35	Paraweb 2D..
5	6.75	2060	0.63	0.63	21603	22147	N/A	1.55	N/A	1.43	Paraweb 2D..
6	8.25	1944	0.63	0.63	21603	22147	N/A	1.64	N/A	1.51	Paraweb 2D..
7	9.75	1828	0.63	0.63	21603	22147	N/A	1.74	N/A	1.61	Paraweb 2D..
8	11.25	1712	0.63	0.63	21603	22147	N/A	1.86	N/A	1.72	Paraweb 2D..
9	12.75	1596	0.63	0.63	21603	22147	N/A	2.00	N/A	1.84	Paraweb 2D..
10	14.25	1480	0.63	0.63	21603	22147	N/A	2.15	N/A	1.99	Paraweb 2D..
11	15.75	1364	0.63	0.63	21603	22147	N/A	2.34	N/A	2.16	Paraweb 2D..
12	17.25	1248	0.63	0.63	21603	22147	N/A	2.55	N/A	2.36	Paraweb 2D..
13	18.75	1132	0.63	0.63	21603	22147	N/A	2.81	N/A	2.60	Paraweb 2D..
14	20.25	1016	0.63	0.63	21603	22147	N/A	3.14	N/A	2.89	Paraweb 2D..
15	21.75	900	0.63	0.63	21603	22147	N/A	3.54	N/A	3.27	Paraweb 2D..
16	23.25	785	0.63	0.63	21603	22147	N/A	4.06	N/A	3.75	Paraweb 2D..
17	24.75	669	0.63	0.63	21603	22147	N/A	4.77	N/A	4.40	Paraweb 2D..
18	26.25	553	0.63	0.63	21603	22147	N/A	5.77	N/A	5.32	Paraweb 2D..
19	27.75	437	0.63	0.63	21603	22147	N/A	7.30	N/A	6.73	Paraweb 2D..
20	29.25	470	0.63	0.63	21603	22147	N/A	6.78	N/A	6.25	Paraweb 2D..

jump to TOC

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2.2.2 MSE DESIGN PROBLEM 2 (C1 CHECKLIST)

MSEW Output

AASHTO 2007-2010 (LRFD)
Stone Strong - IDEA Submittal

MSEW(3.0): Update # 14.981

PROJECT IDENTIFICATION

Title:	Stone Strong - IDEA Submittal
Project Number:	20004 00
Client:	Stone Strong Systems
Designer:	BJP
Station Number:	134

Description:

Problem 2. 2H:1V backslope. 30 ft Height Wall with 4 connections per unit. Installation strap legnths shall be 3 ft less than calculated.

Company's information:

Name: Thiele Geotech
Street: 13478 Chandler Road

Omaha, NE 68138
Telephone #: (402) 556-2171
Fax #: (402) 556-7831
E-Mail:

Original file path and name: P:\20004.00\Agency Approvals\Geo-Institute\IDEA\MSEW\Pr..... .....- Revised 1-6-21.BEN

Original date and time of creating this file: Thu Mar 31 08:22:52 2016

PROGRAM MODE: ANALYSIS
of a SIMPLE STRUCTURE
using GEOGRID as reinforcing material.

SOIL DATA

REINFORCED SOIL

Unit weight, γ	135.0 lb/ft^3
Design value of internal angle of friction, ϕ	34.0 °

RETAINED SOIL

Unit weight, γ	120.0 lb/ft^3
Design value of internal angle of friction, ϕ	30.0 °

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{\text{equiv.}}$	120.0 lb/ft^3
Equivalent internal angle of friction, $\phi_{\text{equiv.}}$	30.0 °
Equivalent cohesion, $c_{\text{equiv.}}$	0.0 lb/ft^2

Water table does not affect bearing capacity

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Inclination of internal slip plane, $\psi = 62.00°$ (see Fig. 28 in DEMO 82).
Ka (external stability) = 0.5378 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

BEARING CAPACITY

Bearing capacity coefficients (calculated by MSEW): Nc = 30.14 $N\gamma = 22.40$

SEISMICITY

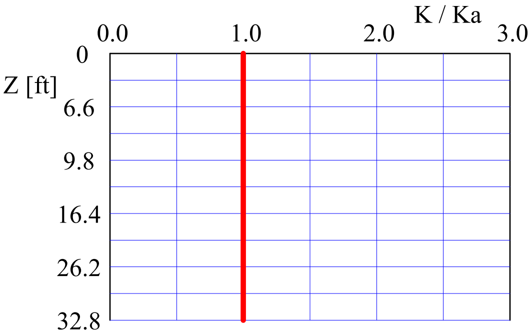
Not Applicable

INPUT DATA: Geogrids
(Analysis)

D A T A		Geogrid type #1	Geogrid type #2	Geogrid type #3	Geogrid type #4	Geogrid type #5
Tult [lb/ft]		38101.0	38101.0			
Durability reduction factor, RFd		1.15	1.15			
Installation-damage reduction factor, RFid		1.10	1.10			
Creep reduction factor, RFc		1.36	1.36	N/A	N/A	N/A
CDR for strength		N/A	N/A			
Coverage ratio, Rc		0.147	0.147			
Friction angle along geogrid-soil interface,	ρ	25.27	25.27			
Pullout resistance factor, F*		1.00·tan ϕ	0.80·tan ϕ	N/A	N/A	N/A
Scale-effect correction factor,	α	0.8	0.8			

Variation of Lateral Earth Pressure Coefficient With Depth

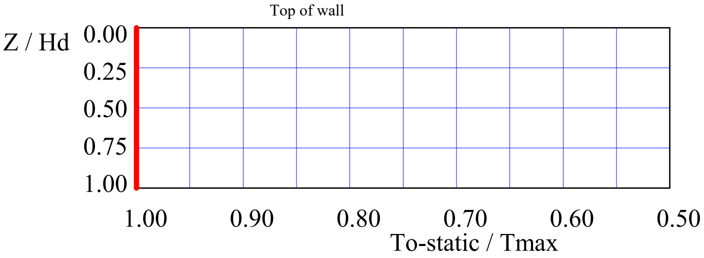
Z	K / Ka
0 ft	1.00
3.3 ft	1.00
6.6 ft	1.00
9.8 ft	1.00
13.1 ft	1.00
16.4 ft	1.00
19.7 ft	1.00



INPUT DATA: Facia and Connection (according to revised Demo 82)
(Analysis)

FACIA type: Facing enabling frictional connection of reinforcement (e.g., modular concrete blocks, gabions)
Depth/height of block is 3.67/3.00 ft. Horizontal distance to Center of Gravity of block is 1.90 ft.
Average unit weight of block is $\gamma_f = 122.20$ lb/ft ³

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



Geogrid Type #1		Geogrid Type #2		Geogrid Type #3		Geogrid Type #4		Geogrid Type #5	
σ (1)	CRult (2)	σ	CRult	σ	CRult	σ	CRult	σ	CRult
0.0	0.63	0.0	0.63						
10000.0	0.63	10000.0	0.63	N/A		N/A		N/A	

Geogrid Type #1(3)		Geogrid Type #2		Geogrid Type #3		Geogrid Type #4		Geogrid Type #5	
σ	CRcr	σ	CRcr	σ	CRcr	σ	CRcr	σ	CRcr
0.0	0.63	0.0	0.63						
10000.0	0.63	10000.0	0.63	N/A		N/A		N/A	

(1) σ = Confining stress in between stacked blocks [lb/ft ²]
(2) CRult = Tc-ult / Tult
(3) CRcr = Tcre / Tult

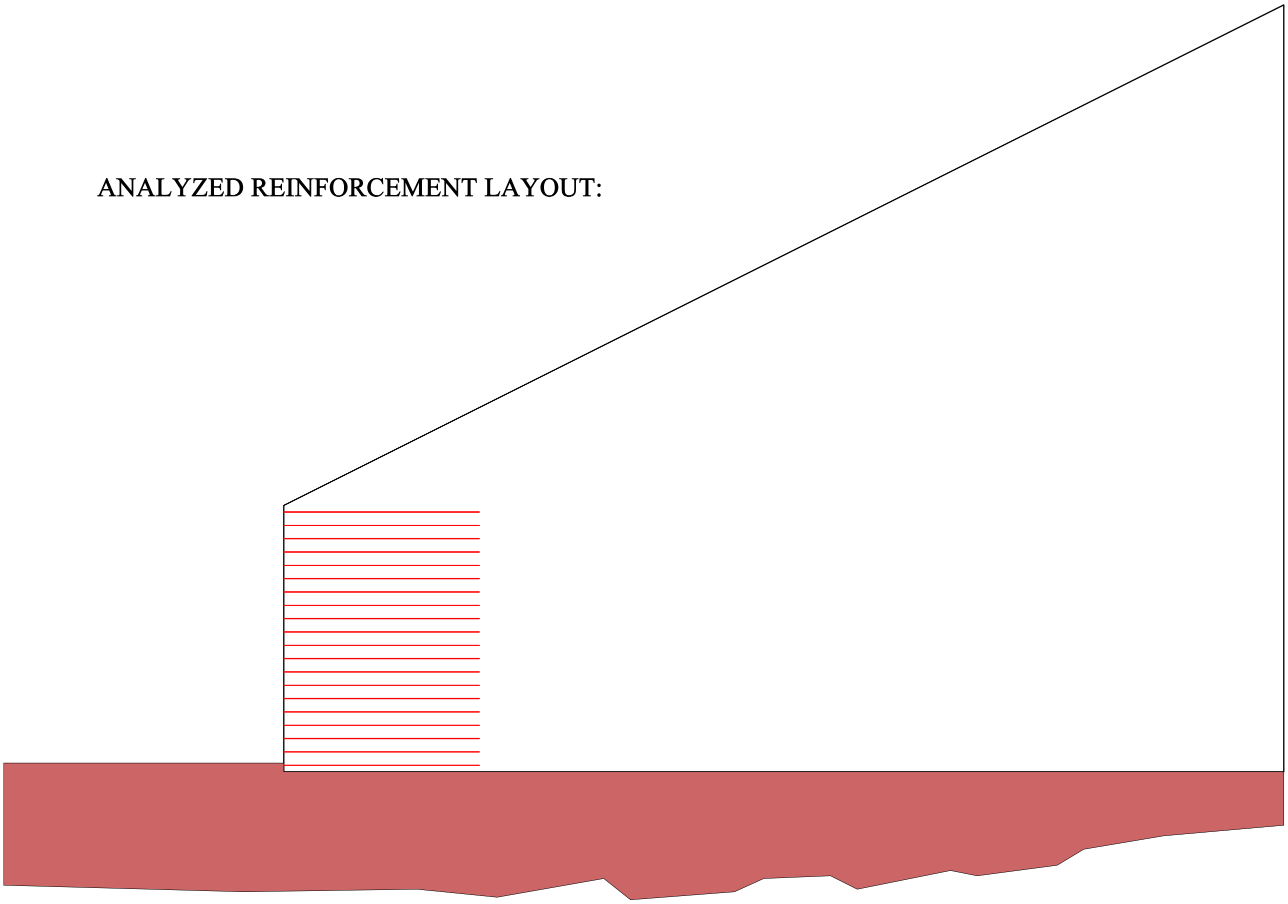
DATA (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	Paraweb 2..	Paraweb 2..	N/A	N/A	N/A
Connection strength reduction factor, RFd	1.00	1.00	N/A	N/A	N/A
Creep reduction factor, RFc	N/A	N/A	N/A	N/A	N/A

INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd	30.00	[ft]	{ Embedded depth is E = 1.00 ft, and height above top of finished bottom grade is H = 29.00 ft }
Batter, ω	0.0	[deg]	
Backslope, β	26.6	[deg]	
Backslope rise	1000.0	[ft]	Broken back equivalent angle, I = 26.60° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE
Uniformly distributed dead load is 0.0 [lb/ft ²]

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

AASHTO 2007-2010 (LRFD) Input Data

INTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2:	$\gamma_{p\text{-EV}}$	1.35	
Load factor for earthquake loads, EQ, from Table 3.4.1-1:	$\gamma_{p\text{-EQ}}$	1.00	
Load factor for live load surchrge, LS, from Figure C11.5.5-3(b): (Same as in External Stability).	$\gamma_{p\text{-LS}}$	1.75	
Load factor for dead load surchrge, ES: (Same as in External Stability).	$\gamma_{p\text{-ES}}$	1.50	
Resistance factor for reinforcement tension from Table 11.5.6-1:	ϕ	Static	Combined static/seismic
Geogrid:		0.90	1.20
Resistance factor for reinforcement tension in connectors from Table 11.5.6-1:	ϕ	Static	Combined static/seismic
Geogrid:		0.90	1.20
Resistance factor for reinforcement pullout from Table 11.5.6-1:	ϕ	0.90	1.20

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV, from Table 3.4.1-2 and Figure C11.5.5-2:		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-EV}}$	1.00	$\gamma_{p\text{-EQ}}$	1.00
Bearing Capacity	$\gamma_{p\text{-EV}}$	1.35	$\gamma_{p\text{-EQ}}$	1.35

Load factor of active lateral earth pressure, EH, from Table 3.4.1-2 and Figure C11.5.5-2:	$\gamma_{p\text{-EH}}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-EH}})_{EQ}$	1.50
Load factor for earthquake loads, EQ, from Table 3.4.1-1 (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-EQ}}$	1.00

Resistance factor for shear resistance along common interfaces from Table 11.5.6-1:		Static	Combined Static/Seismic
Reinforced Soil and Foundation	ϕ_τ	1.00	1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00	1.00
Resistance factor for bearing capacity of shallow foundation from Table 11.5.6-1:		Static	Combined Static/Seismic
	ϕ_b	0.65	0.65

ANALYSIS: CALCULATED FACTORS (Static conditions)

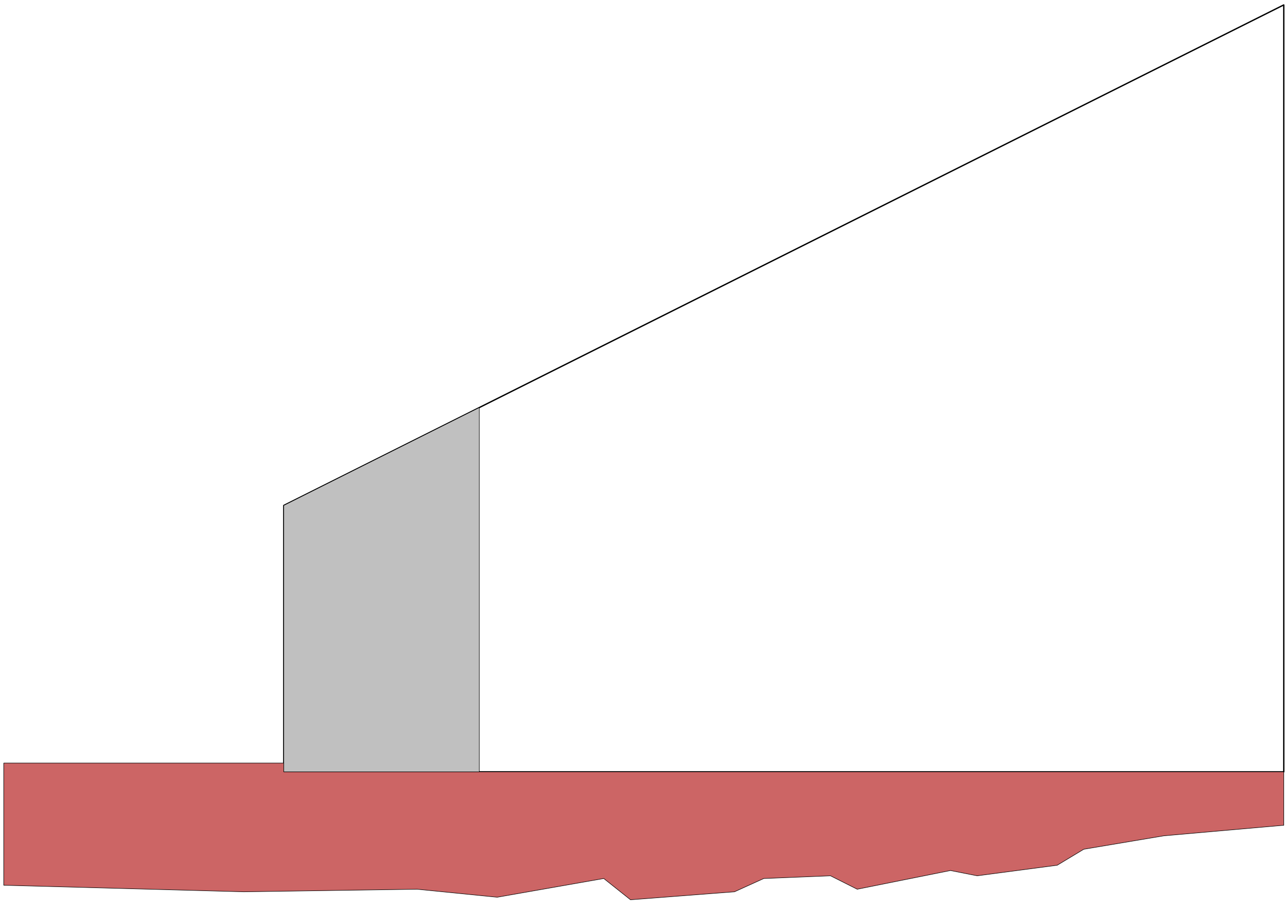
Bearing capacity, CDR = 1.29, factored bearing load = 11000 lb/ft².
Foundation Interface: Direct sliding, CDR = 1.125, Eccentricity, e/L = 0.1712, CDR-overturning = 2.03

GEOGRID				CONNECTION						
#	Elevation [ft]	Length [ft]	Type #	CDR [connection strength]	CDR [geogrid strength]	Geogrid strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	0.75	22.00	2	1.19	1.10	1.102	4.368	1.271	0.1627	Paraweb 2D..
2	2.25	22.00	2	1.25	1.15	1.152	4.234	1.302	0.1461	Paraweb 2D..
3	3.75	22.00	2	1.31	1.21	1.207	4.098	1.334	0.1299	Paraweb 2D..
4	5.25	22.00	2	1.37	1.27	1.268	3.965	1.369	0.1141	Paraweb 2D..
5	6.75	22.00	2	1.45	1.33	1.334	3.832	1.406	0.0986	Paraweb 2D..
6	8.25	22.00	2	1.53	1.41	1.408	3.701	1.446	0.0836	Paraweb 2D..
7	9.75	22.00	2	1.62	1.49	1.491	3.569	1.488	0.0688	Paraweb 2D..
8	11.25	22.00	2	1.72	1.58	1.584	3.439	1.534	0.0544	Paraweb 2D..
9	12.75	22.00	2	1.83	1.69	1.690	3.310	1.583	0.0403	Paraweb 2D..
10	14.25	22.00	2	1.96	1.81	1.811	3.182	1.635	0.0265	Paraweb 2D..
11	15.75	22.00	2	2.11	1.95	1.950	3.055	1.692	0.0129	Paraweb 2D..
12	17.25	22.00	2	2.29	2.11	2.112	2.931	1.753	-0.0007	Paraweb 2D..
13	18.75	22.00	2	2.50	2.30	2.304	2.809	1.818	-0.0142	Paraweb 2D..
14	20.25	22.00	2	2.75	2.53	2.535	2.690	1.888	-0.0279	Paraweb 2D..
15	21.75	22.00	2	3.05	2.82	2.816	2.575	1.962	-0.0421	Paraweb 2D..
16	23.25	22.00	1	3.43	3.17	3.168	3.084	2.041	-0.0571	Paraweb 2D..
17	24.75	22.00	1	3.92	3.62	3.620	2.955	2.121	-0.0735	Paraweb 2D..
18	26.25	22.00	1	4.58	4.22	4.223	2.846	2.201	-0.0924	Paraweb 2D..
19	27.75	22.00	1	5.49	5.07	5.067	2.762	2.273	-0.1155	Paraweb 2D..
20	29.25	22.00	1	6.86	6.33	6.331	2.723	2.322	-0.1463	Paraweb 2D..

BEARING CAPACITY for GIVEN LAYOUT

	STATIC	SEISMIC	UNITS
(Water table does not affect bearing capacity)			
Factored bearing resistance. q-n	14204	N/A	[lb/ft ²]
Factored bearing load, σ_V	10999.8	N/A	[lb/ft ²]
Eccentricity, e	2.87	N/A	[ft]
Eccentricity, e/L	0.131	N/A	
CDR calculated	1.29	N/A	
Base length	22.00	N/A	[ft]

Unfactored applied bearing pressure = (Unfactored R) / [L - 2 * (Unfactored e)] =
Unfactored R = 129767.62 [lb/ft], L = 22.00, Unfactored e = 2.59 [ft], and Sigma = 7716.51 [lb/ft ²]



SCALE:

0 2 4 6 8 10[ft]

DIRECT SLIDING for GIVEN LAYOUT (for GEOGRID reinforcements)

Along reinforced and foundation soils interface: CDR-static = 1.125

#	Geogrid Elevation [ft]	Geogrid Length [ft]	CDR Static	CDR Seismic	Geogrid Type #	Product name
1	0.75	22.00	1.271	N/A	2	Paraweb 2D50 - 7+ ft
2	2.25	22.00	1.302	N/A	2	Paraweb 2D50 - 7+ ft
3	3.75	22.00	1.334	N/A	2	Paraweb 2D50 - 7+ ft
4	5.25	22.00	1.369	N/A	2	Paraweb 2D50 - 7+ ft
5	6.75	22.00	1.406	N/A	2	Paraweb 2D50 - 7+ ft
6	8.25	22.00	1.446	N/A	2	Paraweb 2D50 - 7+ ft
7	9.75	22.00	1.488	N/A	2	Paraweb 2D50 - 7+ ft
8	11.25	22.00	1.534	N/A	2	Paraweb 2D50 - 7+ ft
9	12.75	22.00	1.583	N/A	2	Paraweb 2D50 - 7+ ft
10	14.25	22.00	1.635	N/A	2	Paraweb 2D50 - 7+ ft
11	15.75	22.00	1.692	N/A	2	Paraweb 2D50 - 7+ ft
12	17.25	22.00	1.753	N/A	2	Paraweb 2D50 - 7+ ft
13	18.75	22.00	1.818	N/A	2	Paraweb 2D50 - 7+ ft
14	20.25	22.00	1.888	N/A	2	Paraweb 2D50 - 7+ ft
15	21.75	22.00	1.962	N/A	2	Paraweb 2D50 - 7+ ft
16	23.25	22.00	2.041	N/A	1	Paraweb 2D50 - 0-7..
17	24.75	22.00	2.121	N/A	1	Paraweb 2D50 - 0-7..
18	26.25	22.00	2.201	N/A	1	Paraweb 2D50 - 0-7..
19	27.75	22.00	2.273	N/A	1	Paraweb 2D50 - 0-7..
20	29.25	22.00	2.322	N/A	1	Paraweb 2D50 - 0-7..

ECCENTRICITY for GIVEN LAYOUT

At interface with foundation: e/L static = 0.1712; Overturning: CDR-static = 2.03

#	Geogrid Elevation [ft]	Geogrid Length [ft]	e / L Static	e / L Seismic	Geogrid Type #	Product name
1	0.75	22.00	0.1627	N/A	2	Paraweb 2D50 - 7+ ft
2	2.25	22.00	0.1461	N/A	2	Paraweb 2D50 - 7+ ft
3	3.75	22.00	0.1299	N/A	2	Paraweb 2D50 - 7+ ft
4	5.25	22.00	0.1141	N/A	2	Paraweb 2D50 - 7+ ft
5	6.75	22.00	0.0986	N/A	2	Paraweb 2D50 - 7+ ft
6	8.25	22.00	0.0836	N/A	2	Paraweb 2D50 - 7+ ft
7	9.75	22.00	0.0688	N/A	2	Paraweb 2D50 - 7+ ft
8	11.25	22.00	0.0544	N/A	2	Paraweb 2D50 - 7+ ft
9	12.75	22.00	0.0403	N/A	2	Paraweb 2D50 - 7+ ft
10	14.25	22.00	0.0265	N/A	2	Paraweb 2D50 - 7+ ft
11	15.75	22.00	0.0129	N/A	2	Paraweb 2D50 - 7+ ft
12	17.25	22.00	-0.0007	N/A	2	Paraweb 2D50 - 7+ ft
13	18.75	22.00	-0.0142	N/A	2	Paraweb 2D50 - 7+ ft
14	20.25	22.00	-0.0279	N/A	2	Paraweb 2D50 - 7+ ft
15	21.75	22.00	-0.0421	N/A	2	Paraweb 2D50 - 7+ ft
16	23.25	22.00	-0.0571	N/A	1	Paraweb 2D50 - 0-7..
17	24.75	22.00	-0.0735	N/A	1	Paraweb 2D50 - 0-7..
18	26.25	22.00	-0.0924	N/A	1	Paraweb 2D50 - 0-7..
19	27.75	22.00	-0.1155	N/A	1	Paraweb 2D50 - 0-7..
20	29.25	22.00	-0.1463	N/A	1	Paraweb 2D50 - 0-7..

RESULTS for STRENGTH

Live Load included in calculating Tmax

#	Geogrid Elevation [ft]	Tavailable [lb/ft]	Tmax [lb/ft]	Tmd [lb/ft]	Specified minimum CDR static	Actual calculated CDR static	Specified minimum CDR seismic	Actual calculated CDR seismic	Product name
1	0.75	19932	2667.03	N/A	N/A	1.102	N/A	N/A	Paraweb 2D..
2	2.25	19932	2551.10	N/A	N/A	1.152	N/A	N/A	Paraweb 2D..
3	3.75	19932	2435.16	N/A	N/A	1.207	N/A	N/A	Paraweb 2D..
4	5.25	19932	2319.23	N/A	N/A	1.268	N/A	N/A	Paraweb 2D..
5	6.75	19932	2203.30	N/A	N/A	1.334	N/A	N/A	Paraweb 2D..
6	8.25	19932	2087.37	N/A	N/A	1.408	N/A	N/A	Paraweb 2D..
7	9.75	19932	1971.44	N/A	N/A	1.491	N/A	N/A	Paraweb 2D..
8	11.25	19932	1855.51	N/A	N/A	1.584	N/A	N/A	Paraweb 2D..
9	12.75	19932	1739.58	N/A	N/A	1.690	N/A	N/A	Paraweb 2D..
10	14.25	19932	1623.65	N/A	N/A	1.811	N/A	N/A	Paraweb 2D..
11	15.75	19932	1507.72	N/A	N/A	1.950	N/A	N/A	Paraweb 2D..
12	17.25	19932	1391.79	N/A	N/A	2.112	N/A	N/A	Paraweb 2D..
13	18.75	19932	1275.86	N/A	N/A	2.304	N/A	N/A	Paraweb 2D..
14	20.25	19932	1159.93	N/A	N/A	2.535	N/A	N/A	Paraweb 2D..
15	21.75	19932	1044.00	N/A	N/A	2.816	N/A	N/A	Paraweb 2D..
16	23.25	19932	928.06	N/A	N/A	3.168	N/A	N/A	Paraweb 2D..
17	24.75	19932	812.13	N/A	N/A	3.620	N/A	N/A	Paraweb 2D..
18	26.25	19932	696.20	N/A	N/A	4.223	N/A	N/A	Paraweb 2D..
19	27.75	19932	580.27	N/A	N/A	5.067	N/A	N/A	Paraweb 2D..
20	29.25	19932	464.34	N/A	N/A	6.331	N/A	N/A	Paraweb 2D..

RESULTS for PULLOUT

Live Load included in calculating Tmax

#	Geogrid Elevation [ft]	Coverage Ratio	Tmax [lb/ft]	Tmd [lb/ft]	Le [ft]	La [ft]	Avail.Static Pullout, Pr [lb/ft]	Specified Static CDR	Actual Static CDR	Avail.Seism. Pullout, Pr [lb/ft]	Specified Seismic CDR	Actual Seismic CDR
1	0.75	0.147	2667.0	N/A	21.60	0.40	11649.9	N/A	4.368	N/A	N/A	N/A
2	2.25	0.147	2551.1	N/A	20.80	1.20	10801.6	N/A	4.234	N/A	N/A	N/A
3	3.75	0.147	2435.2	N/A	20.01	1.99	9980.0	N/A	4.098	N/A	N/A	N/A
4	5.25	0.147	2319.2	N/A	19.21	2.79	9196.0	N/A	3.965	N/A	N/A	N/A
5	6.75	0.147	2203.3	N/A	18.41	3.59	8444.1	N/A	3.832	N/A	N/A	N/A
6	8.25	0.147	2087.4	N/A	17.61	4.39	7724.3	N/A	3.701	N/A	N/A	N/A
7	9.75	0.147	1971.4	N/A	16.82	5.18	7036.6	N/A	3.569	N/A	N/A	N/A
8	11.25	0.147	1855.5	N/A	16.02	5.98	6380.9	N/A	3.439	N/A	N/A	N/A
9	12.75	0.147	1739.6	N/A	15.22	6.78	5757.2	N/A	3.310	N/A	N/A	N/A
10	14.25	0.147	1623.6	N/A	14.42	7.58	5165.7	N/A	3.182	N/A	N/A	N/A
11	15.75	0.147	1507.7	N/A	13.63	8.37	4606.2	N/A	3.055	N/A	N/A	N/A
12	17.25	0.147	1391.8	N/A	12.83	9.17	4078.7	N/A	2.931	N/A	N/A	N/A
13	18.75	0.147	1275.9	N/A	12.03	9.97	3583.3	N/A	2.809	N/A	N/A	N/A
14	20.25	0.147	1159.9	N/A	11.23	10.77	3120.0	N/A	2.690	N/A	N/A	N/A
15	21.75	0.147	1044.0	N/A	10.44	11.56	2688.7	N/A	2.575	N/A	N/A	N/A
16	23.25	0.147	928.1	N/A	9.64	12.36	2861.9	N/A	3.084	N/A	N/A	N/A
17	24.75	0.147	812.1	N/A	8.84	13.16	2400.0	N/A	2.955	N/A	N/A	N/A
18	26.25	0.147	696.2	N/A	8.04	13.96	1981.4	N/A	2.846	N/A	N/A	N/A
19	27.75	0.147	580.3	N/A	7.25	14.75	1602.9	N/A	2.762	N/A	N/A	N/A
20	29.25	0.147	464.3	N/A	6.45	15.55	1264.4	N/A	2.723	N/A	N/A	N/A

RESULTS for CONNECTION (static conditions)

Live Load included in calculating Tmax

#	Geogrid Elevation [ft]	Connection force, To [lb/ft]	Reduction factor for connection (short-term strength) CRult	Reduction factor for connection (long-term strength) CRcr	Available connection strength [lb/ft]	Available Geogrid strength, Tavailable [lb/ft]	CDR connection strength		CDR Geogrid strength		Product name
							Specified	Actual	Specified	Actual	
1	0.75	2667	0.63	0.63	21603	22147	N/A	1.19	N/A	1.10	Paraweb 2D..
2	2.25	2551	0.63	0.63	21603	22147	N/A	1.25	N/A	1.15	Paraweb 2D..
3	3.75	2435	0.63	0.63	21603	22147	N/A	1.31	N/A	1.21	Paraweb 2D..
4	5.25	2319	0.63	0.63	21603	22147	N/A	1.37	N/A	1.27	Paraweb 2D..
5	6.75	2203	0.63	0.63	21603	22147	N/A	1.45	N/A	1.33	Paraweb 2D..
6	8.25	2087	0.63	0.63	21603	22147	N/A	1.53	N/A	1.41	Paraweb 2D..
7	9.75	1971	0.63	0.63	21603	22147	N/A	1.62	N/A	1.49	Paraweb 2D..
8	11.25	1856	0.63	0.63	21603	22147	N/A	1.72	N/A	1.58	Paraweb 2D..
9	12.75	1740	0.63	0.63	21603	22147	N/A	1.83	N/A	1.69	Paraweb 2D..
10	14.25	1624	0.63	0.63	21603	22147	N/A	1.96	N/A	1.81	Paraweb 2D..
11	15.75	1508	0.63	0.63	21603	22147	N/A	2.11	N/A	1.95	Paraweb 2D..
12	17.25	1392	0.63	0.63	21603	22147	N/A	2.29	N/A	2.11	Paraweb 2D..
13	18.75	1276	0.63	0.63	21603	22147	N/A	2.50	N/A	2.30	Paraweb 2D..
14	20.25	1160	0.63	0.63	21603	22147	N/A	2.75	N/A	2.53	Paraweb 2D..
15	21.75	1044	0.63	0.63	21603	22147	N/A	3.05	N/A	2.82	Paraweb 2D..
16	23.25	928	0.63	0.63	21603	22147	N/A	3.43	N/A	3.17	Paraweb 2D..
17	24.75	812	0.63	0.63	21603	22147	N/A	3.92	N/A	3.62	Paraweb 2D..
18	26.25	696	0.63	0.63	21603	22147	N/A	4.58	N/A	4.22	Paraweb 2D..
19	27.75	580	0.63	0.63	21603	22147	N/A	5.49	N/A	5.07	Paraweb 2D..
20	29.25	464	0.63	0.63	21603	22147	N/A	6.86	N/A	6.33	Paraweb 2D..

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jump to Appendix TOC

2.2.3 GRAVITY DESIGN PROBLEM 1 (C7 CHECKLIST)

Gravity Wall Analysis, Spreadsheet Output:
External Analysis – 12 feet height plus coping/moment slab
Internal Analysis – top 9 feet
Internal Analysis – top 6 feet
Internal Analysis – top 3 feet

STONE STRONG GRAVITY CALCULATIONS - ver 6.1

Project Name: IDEA Submittal
Location:
Job#: 20004.00
Section: Problem 1 (checklist C7, Gravity Wall)
Calc by: D Thiele

(AASHTO 8th Edition, 2017)

Notes
assumed properties for foundation soil
Barrier load (500 plf, CT in Extereme Load Case 2) applied at base of moment slab

Wall Configuration

			setback (in)		modular units		unit fill		soil wedge		CIP Extension		
unit	w (in)	h (ft)	face	tail	Wb (lb)	xb (in)	Wa (lb)	xa (in)	Ws (lb)	xs (in)	we (in)	h_t	Internal
12" cp	50.0	1.00	0.0	-35.0	604	25.0	0	25.0	16	51.2			Internal Stability OK!
V24	43.0	3.00	0.0	-42.0	750	20.2	594	23.8	433	51.2			Internal Stability OK!
V24	43.0	3.00	0.0	-42.0	750	20.2	594	23.8	722	56.3			Internal Stability OK!
V24-62	61.0	3.00	0.0	-24.0	850	28.1	1,046	32.0	516	70.6			Internal Stability OK!
V24-86	85.0	3.00	0.0	0.0	950	39.0	1,621	44.1	0	0.0			
													External Stability OK!
	85.0	13.00	0.0	-35.0	3,904	27.2	3,855	34.6	1,687	59.3			

backfill height 13.00 feet
exposed height 12.00 feet

ω= 0.00 deg
ω'= -12.65 deg

interface friction angle
δ 25.5 deg

lateral load above wall 500 plf
height above top of wall -1 feet

Retained Soil

γ 135 pcf
ϕ 34 deg

Foundation Soil

γ 125 pcf
ϕ 30 deg
c' psf

base embedment 12 in
base thickness 9 in
base material agg
toe slope H:1V slope

bearing pressure n/a psf
(if specified) (net)

Aggregate Unit Fill

γ 110 pcf

composite friction coefficient μ_b 0.69

STONE STRONG GRAVITY CALCULATIONS - ver 6.1

Project Name: IDEA Submittal
Location:
Job#: 20004.00
Section: Problem 1 (checklist C7, Gravity Wall)
Calc by: D Thiele

Seismic Load PGA G site class (A to E or 1) D Fpga 1.60 Fa 1.60 k_h 0.00

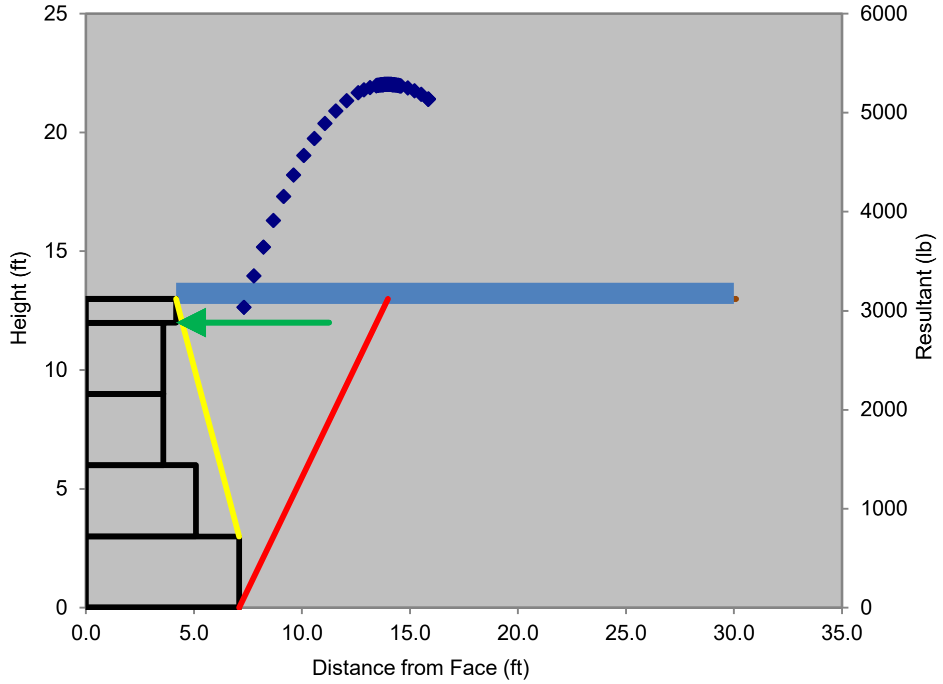
Backfill Slope & Surcharge

			rise in grade	LL surcharge	tier height
length 1	30	feet (horizontal)	ft	250 psf	ft
length 2		feet (horizontal)	ft	psf	ft
length 3		feet (horizontal)	ft	psf	ft
length 4		feet (horizontal)	ft	psf	

effective slope H:1V slope β 0.0 deg avg q 250 psf

failure plane α 62.07 deg zone of influence 13.98 ft

Ground Surface & Trial Wedge Plot



Unfactored Loads

K_a = 0.361
P_h = 3,235 lb
P_v = 2,541 lb
Q_{lh} = 922 lb
Q_{lv} = 724 lb

K_{AE} = 0.361
ΔK_{AE} = 0.000
P_{IR} = 0 lb
ΔP_{AEh} = 0 lb
ΔP_{AEv} = 0 lb

STONE STRONG GRAVITY CALCULATIONS - ver 6.1

Project Name: IDEA Submittal
Location:
Job#: 20004.00
Section: Problem 1 (checklist C7, Gravity Wall)
Calc by: D Thiele

Load Cases:		Strngth I-a	Strngth I-b	Strngth IV	Extrme I-a (EQ)	Extrme I-b (EQ)	Extrme II (CT)	Service I	
Factored Loading	*Overturning (lb-ft):*	31,511	31,511	21,028	14,018	14,018	23,014	20,009	**OK!**
	Sliding (lb):	6,465	6,465	4,853	3,235	3,235	4,196	4,157	**OK!**
	Bearing (psf):	3,299	4,067	3,189	2,188	2,188	2,868	2,779	**OK!**
	e (ft):	1.82	1.58	1.21	1.16	1.16	1.85	1.47	**OK!**
	Bf' (ft):	4.47	4.91	5.62	5.72	5.72	4.45	5.12	
Factored Resistance	*Overturning (lb-ft):*	53,942	66,284	57,577	39,940	39,940	41,975	46,181	
	Sliding (lb):	7,689	10,475	9,377	7,304	7,304	7,513	8,323	
	Bearing (psf):	4,631	4,902	5,355	12,039	12,039	10,257	11,196	
	(@ top of base) Max e (ft):	2.36	2.36	2.36	2.83	2.83	2.83	2.36	
Load & Resistance Factors	LL	1.75	1.75	0.00	0.00	0.00	0.50	1.00	
	EH	1.50	1.50	1.50	1.00	1.00	1.00	1.00	
	EQ	0.00	0.00	0.00	1.00	1.00	0.00	0.00	
	CT	0.00	0.00	0.00	0.00	0.00	1.00	0.00	
	LL Surcharge over Wall	0.00	1.75	0.00	0.00	0.00	0.00	1.00	
	DC	0.90	1.25	1.50	1.00	1.00	1.00	1.00	
	EV	1.00	1.35	1.35	1.00	1.00	1.00	1.00	
	BC	0.45	0.45	0.45	1.00	1.00	1.00	1.00	
	ϕt precast to agg	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	ϕt CIP to agg/soil	0.80	0.80	0.80	1.00	1.00	1.00	1.00	
	ϕt soil to soil	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	ϕt precast to precast	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	concrete interface - eccentricity limit	0.45	0.45	0.45	0.40	0.40	0.45	0.45	
	bearing on soil - eccentricity limit	0.33	0.33	0.33	0.40	0.40	0.40	0.33	

Max Utiliization
84%

Min Capacity/Demand Ratio
1.19

STONE STRONG GRAVITY CALCULATIONS - ver 6.1

Project Name: IDEA Submittal
Location:
Job#: 20004.00
Section: Problem 1 (checklist C7, Gravity Wall)
Calc by: D Thiele

(AASHTO 8th Edition, 2017)

3/24/20 11:31

Notes
assumed properties for foundation soil
Barrier load (500 plf, CT in Extereme Load Case 2) applied at base of moment slab

Complete internal anaalysis results for top 9 feet

Wall Configuration

			setback (in)		modular units		unit fill		soil wedge		CIP Extension		
unit	w (in)	h (ft)	face	tail	Wb (lb)	xb (in)	Wa (lb)	xa (in)	Ws (lb)	xs (in)	we (in)	h_t	Internal
12" cp	50.0	1.00	0.0	-11.0	604	24.0	0	24.0	7	49.5			Internal Stability OK!
V24	43.0	3.00	0.0	-18.0	750	19.2	594	22.8	301	47.5			Internal Stability OK!
V24	43.0	3.00	0.0	-18.0	750	19.2	594	22.8	430	49.9			Internal Stability OK!
V24-62	61.0	3.00	0.0	0.0	850	27.1	1,046	31.0	0	0.0			
													Internal Stability OK!
	61.0	10.00	0.0	-11.0	2,954	22.5	2,234	26.6	738	48.9			

backfill height 10.00 feet

ω= 0.00 deg
ω'= -5.24 deg

interface friction angle
δ 25.5 deg

lateral load above wall 500 plf
height above top of wall -1 feet

Retained Soil

γ 135 pcf
ϕ 34 deg

Internal ONLY

Aggregate Unit Fill

γ 110 pcf

STONE STRONG GRAVITY CALCULATIONS - ver 6.1

Project Name: IDEA Submittal
Location:
Job#: 20004.00
Section: Problem 1 (checklist C7, Gravity Wall)
Calc by: D Thiele

3/24/20 11:31

Seismic Load

PGA		G	site class (A to E or 1)	D	Fpga	1.60	Fa	1.60	k_h	0.00

Backfill Slope & Surcharge

			rise in grade		LL surcharge		tier height	
length 1	30	feet (horizontal)		ft	250	psf		ft
length 2		feet (horizontal)		ft		psf		ft
length 3		feet (horizontal)		ft		psf		ft
length 4		feet (horizontal)		ft		psf		

effective slope H:1V slope

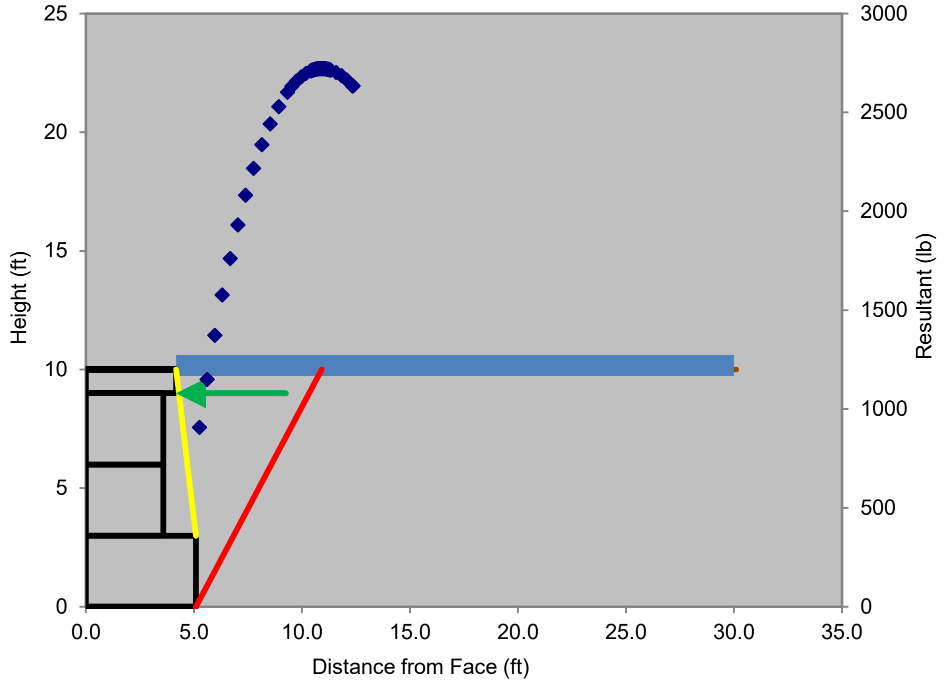
β 0.0 deg

avg q 250 psf

failure plane α 59.75 deg

zone of influence 10.92 ft

Ground Surface & Trial Wedge Plot



Unfactored Loads

K_a =	0.294	K_{AE} =	0.294
P_h =	1,707 lb	ΔK_{AE} =	0.000
P_v =	1,015 lb	P_{IR} =	0 lb
Q_{lh} =	632 lb	ΔP_{AEh} =	0 lb
Q_{lv} =	376 lb	ΔP_{AEv} =	0 lb

STONE STRONG GRAVITY CALCULATIONS - ver 6.1

Project Name: IDEA Submittal
Location:
Job#: 20004.00
Section: Problem 1 (checklist C7, Gravity Wall)
Calc by: D Thiele

3/24/20 11:31

Load Cases:		Strngth I-a	Strngth I-b	Strngth IV	Extrme I-a (EQ)	Extrme I-b (EQ)	Extrme II (CT)	Service I		
Factored Loading	*Overturning (lb-ft):*	14,071	14,071	8,537	5,692	5,692	11,772	8,853	**OK!**	**Max Utiliization**
	Sliding (lb):	3,668	3,668	2,561	1,707	1,707	2,524	2,340	**OK!**	72%
	Bearing (psf):								**OK!**	
	e (ft):	1.47	1.10	0.81	0.77	0.77	1.62	1.01	**OK!**	
	Bf' (ft):									
Factored Resistance	*Overturning (lb-ft):*	21,488	29,299	24,047	16,669	16,669	17,522	20,460		**Min Capacity/Demand Ratio**
	Sliding (lb):	5,285	7,759	6,653	5,259	5,259	5,391	6,259		1.39
	Bearing (psf):									
	(@ interface) Max e (ft):	2.25	2.25	2.25	2.00	2.00	2.25	2.25		
Load & Resistance Factors	LL	1.75	1.75	0.00	0.00	0.00	0.50	1.00		
	EH	1.50	1.50	1.50	1.00	1.00	1.00	1.00		
	EQ	0.00	0.00	0.00	1.00	1.00	0.00	0.00		
	CT	0.00	0.00	0.00	0.00	0.00	1.00	0.00		
	LL Surcharge over Wall	0.00	1.75	0.00	0.00	0.00	0.00	1.00		
	DC	0.90	1.25	1.50	1.00	1.00	1.00	1.00		
	EV	1.00	1.35	1.35	1.00	1.00	1.00	1.00		
	BC	0.45	0.45	0.45	1.00	1.00	1.00	1.00		
	ϕt precast to agg	0.90	0.90	0.90	1.00	1.00	1.00	1.00		
	ϕt CIP to agg/soil	0.80	0.80	0.80	1.00	1.00	1.00	1.00		
	ϕt soil to soil	0.90	0.90	0.90	1.00	1.00	1.00	1.00		
	ϕt precast to precast	0.90	0.90	0.90	1.00	1.00	1.00	1.00		
	concrete interface - eccentricity limit	0.45	0.45	0.45	0.40	0.40	0.45	0.45		
	bearing on soil - eccentricity limit	0.33	0.33	0.33	0.40	0.40	0.40	0.33		

STONE STRONG SYSTEMS

STONE STRONG GRAVITY CALCULATIONS - ver 6.1

Project Name: IDEA Submittal
Location:
Job#: 20004.00
Section: Problem 1 (checklist C7, Gravity Wall)
Calc by: D Thiele

(AASHTO 8th Edition, 2017)

3/24/20 11:31

Notes
assumed properties for foundation soil
Barrier load (500 plf, CT in Extereme Load Case 2) applied at base of moment slab

Complete internal analaysis results for top 6 feet

Wall Configuration

			setback (in)		modular units		unit fill		soil wedge		CIP Extension		
unit	w (in)	h (ft)	face	tail	Wb (lb)	xb (in)	Wa (lb)	xa (in)	Ws (lb)	xs (in)	we (in)	h_t	Internal
12" cp	50.0	1.00	0.0	7.0	604	24.0	0	24.0	0	0.0			Internal Stability OK!
V24	43.0	3.00	0.0	0.0	750	19.2	594	22.8	0	0.0			Internal Stability OK!
V24	43.0	3.00	0.0	0.0	750	19.2	594	22.8	0	0.0			
													Internal Stability OK!
	43.0	7.00	0.0	7.0	2,104	20.6	1,188	22.8	0	0.0			

backfill height **7.00** feet

ω= 0.00 deg

ω'= 4.76 deg

interface friction angle

δ 25.5 deg

lateral load above wall **500** plf

height above top of wall **-1** feet

Retained Soil

γ **135** pcf

ϕ **34** deg

Internal ONLY

Aggregate Unit Fill

γ **110** pcf

STONE STRONG GRAVITY CALCULATIONS - ver 6.1

Project Name: IDEA Submittal
Location:
Job#: 20004.00
Section: Problem 1 (checklist C7, Gravity Wall)
Calc by: D Thiele

Seismic Load PGA ____ G site class (A to E or 1) D Fpga 1.60 Fa 1.60 k_h 0.00

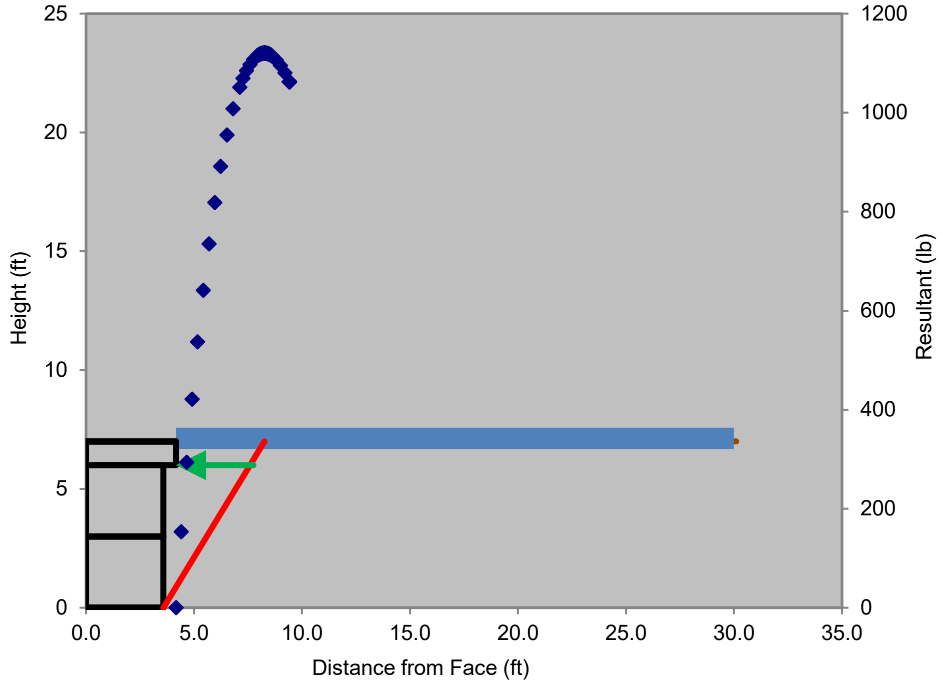
Backfill Slope & Surcharge

			rise in grade		LL surcharge		tier height	
length 1	30	feet (horizontal)		ft	250	psf		ft
length 2		feet (horizontal)		ft		psf		ft
length 3		feet (horizontal)		ft		psf		ft
length 4		feet (horizontal)		ft		psf		

effective slope H:1V slope β 0.0 deg avg q 250 psf

failure plane α 56.24 deg zone of influence 8.26 ft

Ground Surface & Trial Wedge Plot



Unfactored Loads

K_a =	0.222	K_{AE} =	0.222
P_h =	685 lb	ΔK_{AE} =	0.000
P_v =	259 lb	P_{IR} =	0 lb
Q_{lh} =	363 lb	ΔP_{AEh} =	0 lb
Q_{lv} =	137 lb	ΔP_{AEv} =	0 lb

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STONE STRONG GRAVITY CALCULATIONS - ver 6.1

Project Name: IDEA Submittal
Location:
Job#: 20004.00
Section: Problem 1 (checklist C7, Gravity Wall)
Calc by: D Thiele

3/24/20 11:31

Load Cases:		Strngth I-a	Strngth I-b	Strngth IV	Extrme I-a (EQ)	Extrme I-b (EQ)	Extrme II (CT)	Service I	
Factored Loading	*Overturning (lb-ft):*	4,619	4,619	2,398	1,599	1,599	5,233	2,868	**OK!**
	Sliding (lb):	1,662	1,662	1,028	685	685	1,367	1,048	**OK!**
	Bearing (psf):								**OK!**
	e (ft):	0.95	0.44	0.32	0.31	0.31	1.34	0.39	**OK!**
	Bf' (ft):								
Factored Resistance	*Overturning (lb-ft):*	7,402	12,943	9,289	6,373	6,373	6,633	8,977	
	Sliding (lb):	2,682	4,571	3,595	2,868	2,868	2,916	3,699	
	Bearing (psf):								
	(@ interface) Max e (ft):	1.58	1.58	1.58	1.40	1.40	1.58	1.58	
Load & Resistance Factors	LL	1.75	1.75	0.00	0.00	0.00	0.50	1.00	
	EH	1.50	1.50	1.50	1.00	1.00	1.00	1.00	
	EQ	0.00	0.00	0.00	1.00	1.00	0.00	0.00	
	CT	0.00	0.00	0.00	0.00	0.00	1.00	0.00	
	LL Surcharge over Wall	0.00	1.75	0.00	0.00	0.00	0.00	1.00	
	DC	0.90	1.25	1.50	1.00	1.00	1.00	1.00	
	EV	1.00	1.35	1.35	1.00	1.00	1.00	1.00	
	BC	0.45	0.45	0.45	1.00	1.00	1.00	1.00	
	ϕt precast to agg	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	ϕt CIP to agg/soil	0.80	0.80	0.80	1.00	1.00	1.00	1.00	
	ϕt soil to soil	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	ϕt precast to precast	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	concrete interface - eccentricity limit	0.45	0.45	0.45	0.40	0.40	0.45	0.45	
	bearing on soil - eccentricity limit	0.33	0.33	0.33	0.40	0.40	0.40	0.33	

Max Utiliization

85%

Min Capacity/Demand Ratio

1.18

STONE STRONG GRAVITY CALCULATIONS - ver 6.1

Project Name: IDEA Submittal
Location:
Job#: 20004.00
Section: Problem 1 (checklist C7, Gravity Wall)
Calc by: D Thiele

(AASHTO 8th Edition, 2017)

3/24/20 11:31

Notes
assumed properties for foundation soil
Barrier load (500 plf, CT in Extereme Load Case 2) applied at base of moment slab

Complete internal analaysis results for top 3 feet

Wall Configuration

			setback (in)		modular units		unit fill		soil wedge		CIP Extension		
unit	w (in)	h (ft)	face	tail	Wb (lb)	xb (in)	Wa (lb)	xa (in)	Ws (lb)	xs (in)	we (in)	h_t	Internal
12" cp	50.0	1.00	0.0	7.0	604	24.0	0	24.0	0	0.0			Internal Stability OK!
V24	43.0	3.00	0.0	0.0	750	19.2	594	22.8	0	0.0			
													Internal Stability OK!
	43.0	4.00	0.0	7.0	1,354	21.3	594	22.8	0	0.0			

backfill height 4.00 feet

ω= 0.00 deg
ω'= 8.30 deg

interface friction angle
δ 25.5 deg

lateral load above wall 500 plf
height above top of wall -1 feet

Retained Soil

γ 135 pcf
ϕ 34 deg

Internal ONLY

Aggregate Unit Fill

γ 110 pcf

STONE STRONG GRAVITY CALCULATIONS - ver 6.1

Project Name: IDEA Submittal
Location:
Job#: 20004.00
Section: Problem 1 (checklist C7, Gravity Wall)
Calc by: D Thiele

Seismic Load PGA G site class (A to E or 1) D Fpga 1.60 Fa 1.60 k_h 0.00

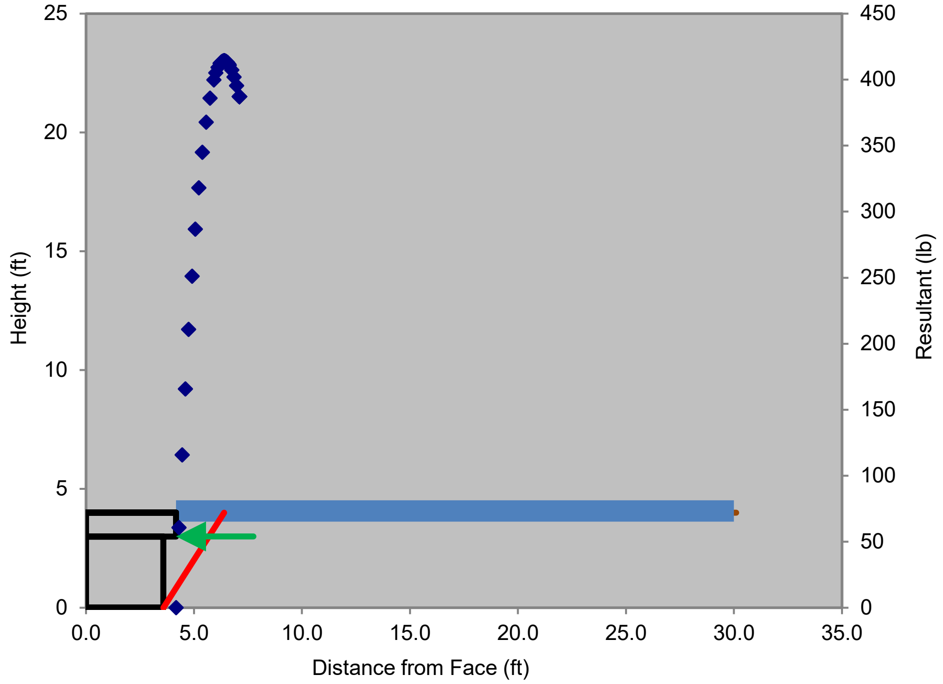
Backfill Slope & Surcharge

			rise in grade		LL surcharge		tier height	
length 1	30	feet (horizontal)		ft	250	psf		ft
length 2		feet (horizontal)		ft		psf		ft
length 3		feet (horizontal)		ft		psf		ft
length 4		feet (horizontal)		ft		psf		

effective slope H:1V slope β 0.0 deg avg q 250 psf

failure plane α 54.90 deg zone of influence 6.39 ft

Ground Surface & Trial Wedge Plot



Unfactored Loads

K_a =	0.199	K_{AE} =	0.199
P_h =	205 lb	ΔK_{AE} =	0.000
P_v =	64 lb	P_{IR} =	0 lb
Q_{lh} =	190 lb	ΔP_{AEh} =	0 lb
Q_{lv} =	59 lb	ΔP_{AEv} =	0 lb

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STONE STRONG GRAVITY CALCULATIONS - ver 6.1

Project Name: IDEA Submittal
Location:
Job#: 20004.00
Section: Problem 1 (checklist C7, Gravity Wall)
Calc by: D Thiele

3/24/20 11:31

Load Cases:		Strngth I-a	Strngth I-b	Strngth IV	Extrme I-a (EQ)	Extrme I-b (EQ)	Extrme II (CT)	Service I		
Factored Loading	*Overturning (lb-ft):*	1,077	1,077	411	274	274	1,964	654	**OK!**	**Max Utiliization**
	Sliding (lb):	641	641	308	205	205	801	396	**OK!**	55%
	Bearing (psf):								**OK!**	
	e (ft):	0.30	0.02	0.03	0.02	0.02	0.87	0.01	**OK!**	
	Bf' (ft):									
Factored Resistance	*Overturning (lb-ft):*	3,814	8,619	5,184	3,546	3,546	3,658	5,853		**Min Capacity/Demand Ratio**
	Sliding (lb):	1,603	3,193	2,185	1,781	1,781	1,802	2,558		1.81
	Bearing (psf):									
	(@ interface) Max e (ft):	1.58	1.58	1.58	1.40	1.40	1.58	1.58		
Load & Resistance Factors	LL	1.75	1.75	0.00	0.00	0.00	0.50	1.00		
	EH	1.50	1.50	1.50	1.00	1.00	1.00	1.00		
	EQ	0.00	0.00	0.00	1.00	1.00	0.00	0.00		
	CT	0.00	0.00	0.00	0.00	0.00	1.00	0.00		
	LL Surcharge over Wall	0.00	1.75	0.00	0.00	0.00	0.00	1.00		
	DC	0.90	1.25	1.50	1.00	1.00	1.00	1.00		
	EV	1.00	1.35	1.35	1.00	1.00	1.00	1.00		
	BC	0.45	0.45	0.45	1.00	1.00	1.00	1.00		
	ϕt precast to agg	0.90	0.90	0.90	1.00	1.00	1.00	1.00		
	ϕt CIP to agg/soil	0.80	0.80	0.80	1.00	1.00	1.00	1.00		
	ϕt soil to soil	0.90	0.90	0.90	1.00	1.00	1.00	1.00		
	ϕt precast to precast	0.90	0.90	0.90	1.00	1.00	1.00	1.00		
	concrete interface - eccentricity limit	0.45	0.45	0.45	0.40	0.40	0.45	0.45		
	bearing on soil - eccentricity limit	0.33	0.33	0.33	0.40	0.40	0.40	0.33		

2.2.4 GRAVITY DESIGN PROBLEM 2 (C7 CHECKLIST)

Gravity Wall Analysis, Spreadsheet Output:
External Analysis – 12 feet height
Internal Analysis – top 9 feet
Internal Analysis – top 6 feet
Internal Analysis – top 3 feet

STONE STRONG GRAVITY CALCULATIONS - ver 6.1

Project Name: IDEA Submittal
Location:
Job#: 20004.00
Section: Problem 2 (checklist C7, Gravity Wall)
Calc by: D Thiele

(AASHTO 8th Edition, 2017)

3/24/20 11:34

Notes assumed properties for foundation soil

Wall Configuration

			setback (in)		modular units		unit fill		soil wedge		CIP Extension		
unit	w (in)	h (ft)	face	tail	Wb (lb)	xb (in)	Wa (lb)	xa (in)	Ws (lb)	xs (in)	we (in)	h_t	Internal
V24	43.0	3.00	0.0	-42.0	750	20.2	594	23.8	193	47.7			Internal Stability OK!
V24	43.0	3.00	0.0	-42.0	750	20.2	594	23.8	578	53.9			Internal Stability OK!
V24-62	61.0	3.00	0.0	-24.0	850	28.1	1,046	32.0	468	70.0			Internal Stability OK!
V24-86	85.0	3.00	0.0	0.0	950	39.0	1,621	44.1	0	0.0			
													External Stability OK!
	85.0	12.00	0.0	-42.0	3,300	27.6	3,855	34.6	1,238	59.0			

backfill height 12.00 feet
exposed height 11.00 feet

ω= 0.00 deg
ω'= -16.26 deg

interface friction angle
δ 25.5 deg

Retained Soil
γ 135 pcf
ϕ 34 deg

Foundation Soil
γ 125 pcf
ϕ 30 deg
c' psf

bearing pressure n/a psf
(if specified) (net)

base embedment 12 in
base thickness 9 in
base material agg
toe slope H:1V slope

Aggregate Unit Fill
γ 110 pcf

composite friction coefficient μ_b 0.69

STONE STRONG GRAVITY CALCULATIONS - ver 6.1

Project Name: IDEA Submittal
Location:
Job#: 20004.00
Section: Problem 2 (checklist C7, Gravity Wall)
Calc by: D Thiele

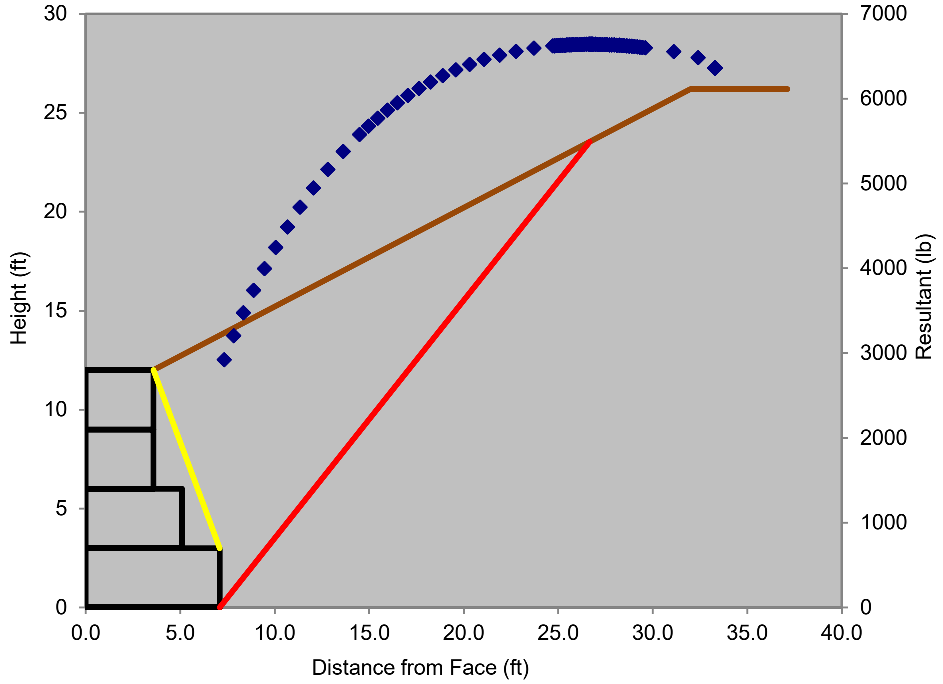
Seismic Load

PGA		G	site class (A to E or 1)	D	Fpga	1.60	Fa	1.60	k_h 0.00

Backfill Slope & Surcharge

				backslope		LL surcharge		tier height	
length 1	32	feet (horizontal)		2	H:1V slope		psf		ft
length 2	5	feet (horizontal)			H:1V slope		psf		ft
length 3		feet (horizontal)			H:1V slope		psf		ft
length 4		feet (horizontal)			H:1V slope		psf		
effective slope	2.00	H:1V slope	β	26.6	deg	avg q	0	psf	
failure plane α	50.25	deg	zone of influence	26.66	ft				

Ground Surface & Trial Wedge Plot



Unfactored Loads

K_a =	0.683		K_{AE} =	0.683
P_h =	4,954 lb		ΔK_{AE} =	0.000
P_v =	4,423 lb		P_{IR} =	0 lb
Q_{lh} =	0 lb		ΔP_{AEh} =	0 lb
Q_{lv} =	0 lb		ΔP_{AEv} =	0 lb

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STONE STRONG GRAVITY CALCULATIONS - ver 6.1

Project Name: IDEA Submittal
Location:
Job#: 20004.00
Section: Problem 2 (checklist C7, Gravity Wall)
Calc by: D Thiele

3/24/20 11:34

	Load Cases:	Strngth I-a	Strngth I-b	Strngth IV	Extrme I-a (EQ)	Extrme I-b (EQ)	Extrme II (CT)	Service I	
Factored Loading	*Overturning (lb-ft):*	29,722	29,722	29,722	19,814	19,814	19,814	19,814	**OK!**
	Sliding (lb):	7,430	7,430	7,430	4,954	4,954	4,954	4,954	**OK!**
	Bearing (psf):	2,905	3,323	3,477	2,378	2,378	2,378	2,378	**OK!**
	e (ft):	1.34	1.23	1.23	1.19	1.19	1.19	1.19	**OK!**
	Bf' (ft):	5.32	5.54	5.53	5.61	5.61	5.61	5.61	
Factored Resistance	*Overturning (lb-ft):*	59,845	67,319	69,220	47,521	47,521	47,521	47,521	
	Sliding (lb):	7,982	9,629	10,058	7,782	7,782	7,782	7,782	
	Bearing (psf):	5,162	5,302	5,297	11,881	11,881	11,881	11,881	
	(@ top of base) Max e (ft):	2.36	2.36	2.36	2.83	2.83	2.83	2.36	
Load & Resistance Factors	LL	1.75	1.75	0.00	0.00	0.00	0.50	1.00	
	EH	1.50	1.50	1.50	1.00	1.00	1.00	1.00	
	EQ	0.00	0.00	0.00	1.00	1.00	0.00	0.00	
	CT	0.00	0.00	0.00	0.00	0.00	1.00	0.00	
	LL Surcharge over Wall	0.00	1.75	0.00	0.00	0.00	0.00	1.00	
	DC	0.90	1.25	1.50	1.00	1.00	1.00	1.00	
	EV	1.00	1.35	1.35	1.00	1.00	1.00	1.00	
	BC	0.45	0.45	0.45	1.00	1.00	1.00	1.00	
	ϕt precast to agg	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	ϕt CIP to agg/soil	0.80	0.80	0.80	1.00	1.00	1.00	1.00	
	ϕt soil to soil	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	ϕt precast to precast	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	concrete interface - eccentricity limit	0.45	0.45	0.45	0.40	0.40	0.45	0.45	
	bearing on soil - eccentricity limit	0.33	0.33	0.33	0.40	0.40	0.40	0.33	

Max Utiliization

93%

Min Capacity/Demand Ratio

1.07

STONE STRONG GRAVITY CALCULATIONS - ver 6.1

Project Name: IDEA Submittal
Location:
Job#: 20004.00
Section: Problem 2 (checklist C7, Gravity Wall)
Calc by: D Thiele

(AASHTO 8th Edition, 2017)

Notes assumed properties for foundation soil

Complete internal analaysis results for top 9 feet

Wall Configuration

			setback (in)		modular units		unit fill		soil wedge		CIP Extension		
unit	w (in)	h (ft)	face	tail	Wb (lb)	xb (in)	Wa (lb)	xa (in)	Ws (lb)	xs (in)	we (in)	h_t	Internal
V24	43.0	3.00	0.0	-18.0	750	19.2	594	22.8	124	45.0			Internal Stability OK!
V24	43.0	3.00	0.0	-18.0	750	19.2	594	22.8	371	49.0			Internal Stability OK!
V24-62	61.0	3.00	0.0	0.0	850	27.1	1,046	31.0	0	0.0			
													Internal Stability OK!
	61.0	9.00	0.0	-18.0	2,350	22.1	2,234	26.6	495	48.0			

backfill height 9.00 feet

ω= 0.00 deg

ω'= -9.46 deg

interface friction angle

δ 25.5 deg

Retained Soil

γ 135 pcf

ϕ 34 deg

Internal ONLY

Aggregate Unit Fill

γ 110 pcf

STONE STRONG SYSTEMS®

STONE STRONG GRAVITY CALCULATIONS - ver 6.1

Project Name: IDEA Submittal
Location:
Job#: 20004.00
Section: Problem 2 (checklist C7, Gravity Wall)
Calc by: D Thiele

Seismic Load PGA ☐ G site class (A to E or 1) D Fpga 1.60 Fa 1.60 k_h 0.00

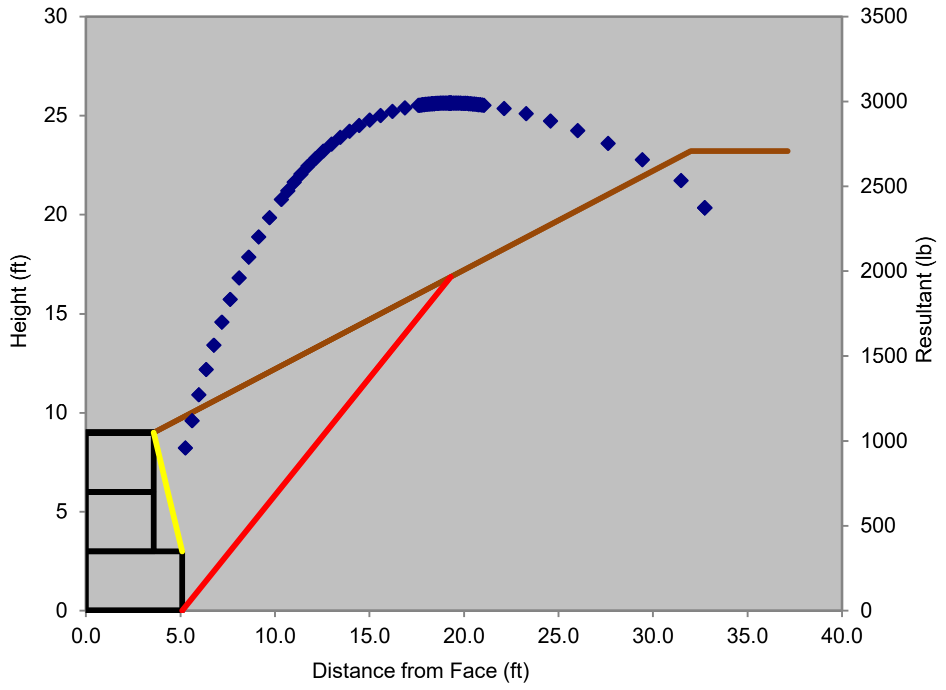
Backfill Slope & Surcharge

		backslope	LL surcharge	tier height
length 1	32 feet (horizontal)	2 H:1V slope	psf	ft
length 2	5 feet (horizontal)	H:1V slope	psf	ft
length 3	feet (horizontal)	H:1V slope	psf	ft
length 4	feet (horizontal)	H:1V slope	psf	

effective slope 2.00 H:1V slope β 26.6 deg avg q 0 psf

failure plane α 49.86 deg zone of influence 19.30 ft

Ground Surface & Trial Wedge Plot



Unfactored Loads

K_a =	0.547	K_{AE} =	0.547
P_h =	2,451 lb	ΔK_{AE} =	0.000
P_v =	1,714 lb	P_{IR} =	0 lb
Q_{lh} =	0 lb	ΔP_{AEh} =	0 lb
Q_{lv} =	0 lb	ΔP_{AEv} =	0 lb

STONE STRONG GRAVITY CALCULATIONS - ver 6.1

Project Name: IDEA Submittal
Location:
Job#: 20004.00
Section: Problem 2 (checklist C7, Gravity Wall)
Calc by: D Thiele

Load Cases:		Strngth I-a	Strngth I-b	Strngth IV	Extrme I-a (EQ)	Extrme I-b (EQ)	Extrme II (CT)	Service I		
Factored Loading	*Overturning (lb-ft):*	11,032	11,032	11,032	7,354	7,354	7,354	7,354	**OK!**	**Max Utiliization**
	Sliding (lb):	3,677	3,677	3,677	2,451	2,451	2,451	2,451	**OK!**	73%
	Bearing (psf):								**OK!**	
	e (ft):	1.05	0.91	0.90	0.86	0.86	0.86	0.86	**OK!**	
	Bf' (ft):									
Factored Resistance	*Overturning (lb-ft):*	21,009	24,464	25,544	17,584	17,584	17,584	17,584		**Min Capacity/Demand Ratio**
	Sliding (lb):	5,034	6,162	6,535	5,154	5,154	5,154	5,154		1.37
	Bearing (psf):									
	(@ interface) Max e (ft):	2.25	2.25	2.25	2.00	2.00	2.25	2.25		
Load & Resistance Factors	LL	1.75	1.75	0.00	0.00	0.00	0.50	1.00		
	EH	1.50	1.50	1.50	1.00	1.00	1.00	1.00		
	EQ	0.00	0.00	0.00	1.00	1.00	0.00	0.00		
	CT	0.00	0.00	0.00	0.00	0.00	1.00	0.00		
	LL Surcharge over Wall	0.00	1.75	0.00	0.00	0.00	0.00	1.00		
	DC	0.90	1.25	1.50	1.00	1.00	1.00	1.00		
	EV	1.00	1.35	1.35	1.00	1.00	1.00	1.00		
	BC	0.45	0.45	0.45	1.00	1.00	1.00	1.00		
	ϕt precast to agg	0.90	0.90	0.90	1.00	1.00	1.00	1.00		
	ϕt CIP to agg/soil	0.80	0.80	0.80	1.00	1.00	1.00	1.00		
	ϕt soil to soil	0.90	0.90	0.90	1.00	1.00	1.00	1.00		
	ϕt precast to precast	0.90	0.90	0.90	1.00	1.00	1.00	1.00		
	concrete interface - eccentricity limit	0.45	0.45	0.45	0.40	0.40	0.45	0.45		
	bearing on soil - eccentricity limit	0.33	0.33	0.33	0.40	0.40	0.40	0.33		

STONE STRONG GRAVITY CALCULATIONS - ver 6.1

Project Name: IDEA Submittal
Location:
Job#: 20004.00
Section: Problem 2 (checklist C7, Gravity Wall)
Calc by: D Thiele

(AASHTO 8th Edition, 2017)

Notes assumed properties for foundation soil

Complete internal analaysis results for top 6 feet

Wall Configuration

			setback (in)		modular units		unit fill		soil wedge		CIP Extension		
unit	w (in)	h (ft)	face	tail	Wb (lb)	xb (in)	Wa (lb)	xa (in)	Ws (lb)	xs (in)	we (in)	h_t	Internal
V24	43.0	3.00	0.0	0.0	750	19.2	594	22.8					Internal Stability OK!
V24	43.0	3.00	0.0	0.0	750	19.2	594	22.8					
													Internal Stability OK!
	43.0	6.00	0.0	0.0	1,500	19.2	1,188	22.8	0	0.0			

backfill height 6.00 feet

ω= 0.00 deg

ω'= 0.00 deg

interface friction angle

δ 17.0 deg

Retained Soil

γ 135 pcf

ϕ 34 deg

Internal ONLY

Aggregate Unit Fill

γ 110 pcf

STONE STRONG GRAVITY CALCULATIONS - ver 6.1

Project Name: IDEA Submittal
Location:
Job#: 20004.00
Section: Problem 2 (checklist C7, Gravity Wall)
Calc by: D Thiele

3/24/20 11:34

Seismic Load PGA G site class (A to E or 1) D Fpga 1.60 Fa 1.60 k_h 0.00

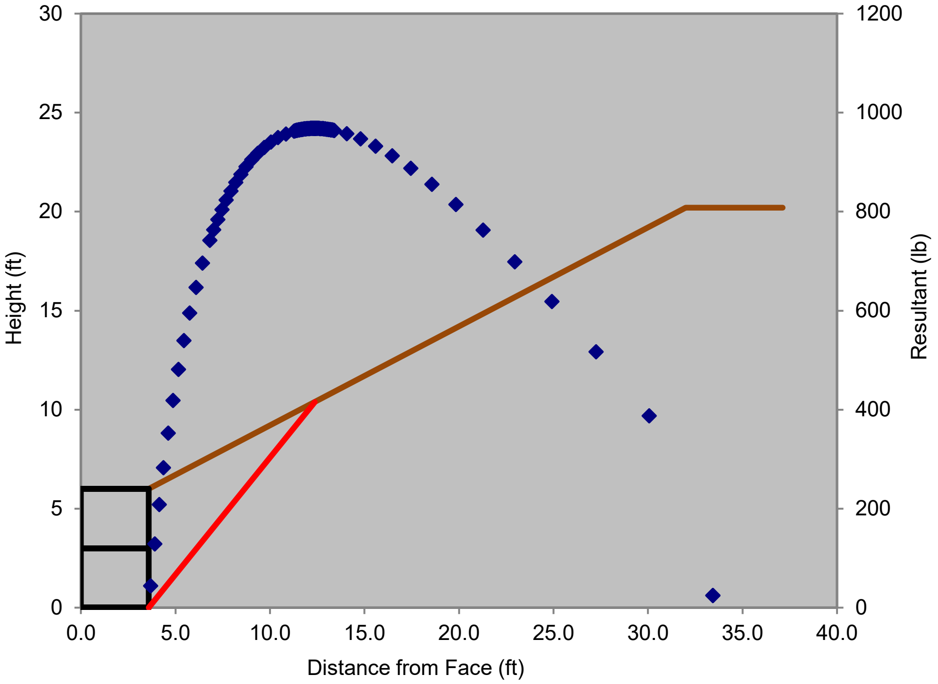
Backfill Slope & Surcharge

			backslope		LL surcharge		tier height	
length 1	32	feet (horizontal)	2	H:1V slope		psf		ft
length 2	5	feet (horizontal)		H:1V slope		psf		ft
length 3		feet (horizontal)		H:1V slope		psf		ft
length 4		feet (horizontal)		H:1V slope		psf		

effective slope 2.00 H:1V slope β 26.6 deg avg q 0 psf

failure plane α 49.80 deg zone of influence 12.36 ft

Ground Surface & Trial Wedge Plot



Unfactored Loads

K_a =	0.399	K_{AE} =	0.399
P_h =	926 lb	ΔK_{AE} =	0.000
P_v =	283 lb	P_{IR} =	0 lb
Q_{lh} =	0 lb	ΔP_{AEh} =	0 lb
Q_{lv} =	0 lb	ΔP_{AEv} =	0 lb

STONE STRONG GRAVITY CALCULATIONS - ver 6.1

Project Name: IDEA Submittal
Location:
Job#: 20004.00
Section: Problem 2 (checklist C7, Gravity Wall)
Calc by: D Thiele

3/24/20 11:34

Load Cases:		Strngth I-a	Strngth I-b	Strngth IV	Extrme I-a (EQ)	Extrme I-b (EQ)	Extrme II (CT)	Service I	
Factored Loading	*Overturning (lb-ft):*	2,778	2,778	2,778	1,852	1,852	1,852	1,852	**OK!**
	Sliding (lb):	1,389	1,389	1,389	926	926	926	926	**OK!**
	Bearing (psf):								**OK!**
	e (ft):	0.77	0.59	0.55	0.53	0.53	0.53	0.53	**OK!**
	Bf' (ft):								
Factored Resistance	*Overturning (lb-ft):*	5,453	6,925	7,525	5,197	5,197	5,197	5,197	
	Sliding (lb):	2,207	2,804	3,042	2,458	2,458	2,458	2,458	
	Bearing (psf):								
	(@ interface) Max e (ft):	1.58	1.58	1.58	1.40	1.40	1.58	1.58	
Load & Resistance Factors	LL	1.75	1.75	0.00	0.00	0.00	0.50	1.00	
	EH	1.50	1.50	1.50	1.00	1.00	1.00	1.00	
	EQ	0.00	0.00	0.00	1.00	1.00	0.00	0.00	
	CT	0.00	0.00	0.00	0.00	0.00	1.00	0.00	
	LL Surcharge over Wall	0.00	1.75	0.00	0.00	0.00	0.00	1.00	
	DC	0.90	1.25	1.50	1.00	1.00	1.00	1.00	
	EV	1.00	1.35	1.35	1.00	1.00	1.00	1.00	
	BC	0.45	0.45	0.45	1.00	1.00	1.00	1.00	
	ϕt precast to agg	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	ϕt CIP to agg/soil	0.80	0.80	0.80	1.00	1.00	1.00	1.00	
	ϕt soil to soil	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	ϕt precast to precast	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	concrete interface - eccentricity limit	0.45	0.45	0.45	0.40	0.40	0.45	0.45	
	bearing on soil - eccentricity limit	0.33	0.33	0.33	0.40	0.40	0.40	0.33	

Max Utiliization
63%

Min Capacity/Demand Ratio
1.59

STONE STRONG SYSTEMS®

STONE STRONG GRAVITY CALCULATIONS - ver 6.1

Project Name: IDEA Submittal
Location:
Job#: 20004.00
Section: Problem 2 (checklist C7, Gravity Wall)
Calc by: D Thiele

(AASHTO 8th Edition, 2017)

Notes
assumed properties for foundation soil

Complete internal analaysis results for top 3 feet

Wall Configuration

			setback (in)		modular units		unit fill		soil wedge		CIP Extension		
unit	w (in)	h (ft)	face	tail	Wb (lb)	xb (in)	Wa (lb)	xa (in)	Ws (lb)	xs (in)	we (in)	h_t	Internal
V24	43.0	3.00	0.0	0.0	750	19.2	594	22.8					
													Internal Stability OK!
	43.0	3.00	0.0	0.0	750	19.2	594	22.8	0	0.0			

backfill height 3.00 feet

ω= 0.00 deg
ω'= 0.00 deg

interface friction angle
δ 17.0 deg

Retained Soil

γ 135 pcf
ϕ 34 deg

Internal ONLY

Aggregate Unit Fill

γ 110 pcf

STONE STRONG SYSTEMS

STONE STRONG GRAVITY CALCULATIONS - ver 6.1

Project Name: IDEA Submittal
Location:
Job#: 20004.00
Section: Problem 2 (checklist C7, Gravity Wall)
Calc by: D Thiele

3/24/20 11:34

Seismic Load PGA G site class (A to E or 1) D Fpga 1.60 Fa 1.60 k_h 0.00

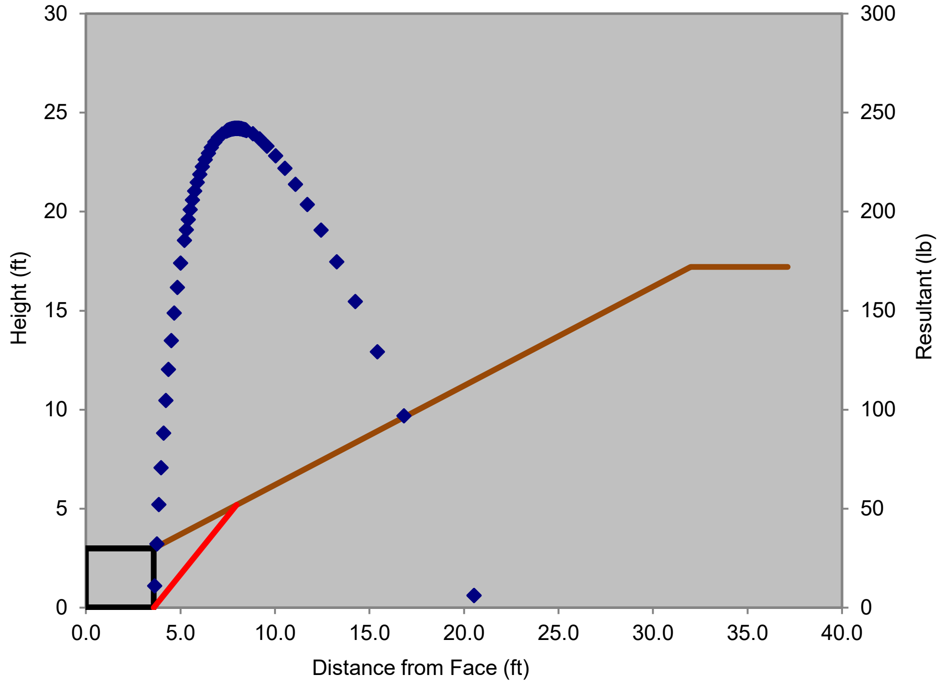
Backfill Slope & Surcharge

			backslope		LL surcharge		tier height	
length 1	32	feet (horizontal)	2	H:1V slope		psf		ft
length 2	5	feet (horizontal)		H:1V slope		psf		ft
length 3		feet (horizontal)		H:1V slope		psf		ft
length 4		feet (horizontal)		H:1V slope		psf		

effective slope 2.00 H:1V slope β 26.6 deg avg q 0 psf

failure plane α 49.80 deg zone of influence 7.97 ft

Ground Surface & Trial Wedge Plot



Unfactored Loads

K_a = 0.399
P_h = 232 lb
P_v = 71 lb
Q_{lh} = 0 lb
Q_{lv} = 0 lb

K_{AE} = 0.399
ΔK_{AE} = 0.000
P_{IR} = 0 lb
ΔP_{AEh} = 0 lb
ΔP_{AEv} = 0 lb

STONE STRONG GRAVITY CALCULATIONS - ver 6.1

Project Name: IDEA Submittal
Location:
Job#: 20004.00
Section: Problem 2 (checklist C7, Gravity Wall)
Calc by: D Thiele

3/24/20 11:34

Load Cases:		Strngth I-a	Strngth I-b	Strngth IV	Extrme I-a (EQ)	Extrme I-b (EQ)	Extrme II (CT)	Service I	
Factored Loading	*Overturning (lb-ft):*	347	347	347	232	232	232	232	**OK!**
	Sliding (lb):	347	347	347	232	232	232	232	**OK!**
	Bearing (psf):								**OK!**
	e (ft):	0.15	0.12	0.12	0.11	0.11	0.11	0.11	**OK!**
	Bf' (ft):								
Factored Resistance	*Overturning (lb-ft):*	2,355	3,091	3,391	2,351	2,351	2,351	2,351	
	Sliding (lb):	1,199	1,498	1,617	1,360	1,360	1,360	1,360	
	Bearing (psf):								
	(@ interface) Max e (ft):	1.58	1.58	1.58	1.40	1.40	1.58	1.58	
Load & Resistance Factors	LL	1.75	1.75	0.00	0.00	0.00	0.50	1.00	
	EH	1.50	1.50	1.50	1.00	1.00	1.00	1.00	
	EQ	0.00	0.00	0.00	1.00	1.00	0.00	0.00	
	CT	0.00	0.00	0.00	0.00	0.00	1.00	0.00	
	LL Surcharge over Wall	0.00	1.75	0.00	0.00	0.00	0.00	1.00	
	DC	0.90	1.25	1.50	1.00	1.00	1.00	1.00	
	EV	1.00	1.35	1.35	1.00	1.00	1.00	1.00	
	BC	0.45	0.45	0.45	1.00	1.00	1.00	1.00	
	ϕt precast to agg	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	ϕt CIP to agg/soil	0.80	0.80	0.80	1.00	1.00	1.00	1.00	
	ϕt soil to soil	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	ϕt precast to precast	0.90	0.90	0.90	1.00	1.00	1.00	1.00	
	concrete interface - eccentricity limit	0.45	0.45	0.45	0.40	0.40	0.45	0.45	
	bearing on soil - eccentricity limit	0.33	0.33	0.33	0.40	0.40	0.40	0.33	

Max Utiliization
29%

Min Capacity/Demand Ratio
3.45

jump to TOC

jump to Appendix TOC

3.1.1 CONSTRUCTION INNOVATIONS

No attachments

jump to TOC

jump to Appendix TOC

3.1.2 INSTALLATION MANUAL

Stone Strong Field Construction Manual

Field Construction Manual

Stone Strong Systems Precast Modular Unit Retaining Wall System

2020

Stone Strong, LLC

INTRODUCTION

This manual is designed to provide general information and assist in the proper techniques required to build Stone Strong walls. The manual covers the basics of wall construction, and contains many of the details encountered in site work. Look to our web site stonestrong.com or the local Stone Strong Producer for more information.

CONSTRUCTION RESPONSIBILITIES

Stone Strong Dealer

Stone Strong representatives may assist the owner, contractor and inspectors in scheduling of materials, construction procedures, contract documents, plans and specifications. The representatives are available to assist and train the contractor and inspectors as requested and necessary.

Engineer or Owner’s Representative

Owner representative or engineer is responsible for the enforcement of the contract documents, plans and specifications. Owner shall employ services of a material engineering firm to provide quality control testing during embankment construction. Owner and engineer shall not be responsible for means or methods of construction or for safety of workers or of the public.

Contractor

The contractor will be responsible for:

- Checking the materials upon delivery to assure that proper materials have been received.
- Protecting the materials from damage. Damaged material shall not be in corporated into the wall or the reinforced soil embankments.
- Preventing excessive mud, concrete, adhesives and other substances that may adhere from coming in contact with the materials.
- Furnishing and installing Stone Strong unit to the lines and grades shown on the plans and as specified herein.
- The contractor is solely responsible for safety.

MATERIALS, DELIVERY STORAGE AND HANDLING

Precast modular unit will be manufactured under license from Stone Strong, LLC.

Dimension tolerances for precast modular unit shall be +/- 1/8 inch for horizontal and vertical dimensions of the face and 1/2 inch to -1/4 inch for the face-to-tail width.

Concrete for precast modular unit shall have a minimum 28-day compressive strength of 4,000psi. Entrained air content shall be between 5 and 7%.

Reinforcing steel (if used) shall be Grade 60. Minimum clear cover to reinforcement shall be 1½ inches.

Check the materials upon delivery to assure that proper material has been received. Remove damaged or otherwise unsuitable material from the site.

Exposed faces of Stone Strong unit shall be free of chips, cracks, bug holes, stains, and other imperfections distracting from their appearance when viewed from a distance of 10 feet.

Prevent mud, concrete, adhesives and other substances that may harm appearance of unit from coming in contact with the system components.

Geogrid filter, prefabricated drainage composite shall be delivered, stored, and handled in accordance with ASTM D 4873.

STONE
STRONG
SYSTEMS®

1/4/2019

Unit Type	Description	Conc. Wt. (lbs)	Void Vol (ft3)	Length (ft)	Height (ft)	Unit Width (in)
Standard units (verify availability - not all units available from every producer)						
24	24SF unit (24 square feet)	6,000	43.21	8.00	3.00	44.0
24-ME	24SF Mass Extender unit	10,000	44.94	8.00	3.00	56.0
24-62	24-62 unit (extended 24SF)	6,800	76.05	8.00	3.00	62.0
24-86	24-86 unit (extended 24SF)	7,600	117.90	8.00	3.00	86.0
6	6SF unit (6 square feet)	1,500	10.95	4.00	1.50	44.0
3	3SF unit (3 square feet)	750	5.48	2.00	1.50	44.0
6-28	Mini 6SF unit	950	6.65	4.00	1.50	28.0
3-28	Mini 3SF unit	475	3.33	2.00	1.50	28.0
Alternate top units (not typically used - regular 24SF top unit is used in most applications, analyzed as regular 24SF unit)						
Cap	Cap unit	1,600	0.00	8.00	0.58	32.0
DF	Dual Face unit	3,500	0.00	8.00	1.50	28.0
Vertical stack units (modified recess and face to permit construction of a vertical face)						
V24	24SF unit (24 square feet)	6,000	43.21	8.00	3.00	43.0
V24-ME	24SF Mass Extender unit	10,000	44.94	8.00	3.00	55.0
V24-62	24-62 unit (extended 24SF)	6,800	76.05	8.00	3.00	61.0
V24-86	24-86 unit (extended 24SF)	7,600	117.90	8.00	3.00	85.0
V6	6SF unit (6 square feet)	1,500	10.95	4.00	1.50	44.0
V3	3SF unit (3 square feet)	750	5.48	2.00	1.50	44.0
V6-28	Mini 6SF unit	950	6.65	4.00	1.50	28.0
V3-28	Mini 3SF unit	475	3.33	2.00	1.50	28.0

Note: Check on availability of all units w/ local Producer/Dealer. Some units may have limited availabilty.

EQUIPMENT AND SUPPLIES

Contractor Supplied Materials and Tools

The following tools are recommended, but should not be limited to this list. Site conditions may require other equipment, tools and materials.

Tools and Equipment

Excavator	Laser Level
Skid Steer	4 foot Level
Front Loader	Shovels
Compactor	Brooms
Spreader Bar (48”)	Pry Bars
Chains	Labor

Materials

Wall Base Material	Off Site Borrow (if required)
Unit Fill Material	Filter Fabric (if required)
Drain Tile (if required)	Hand Rail (if required)

Geosynthetic strap reinforcement shall be Paraweb 2D-50 manufactured by Maccaferri, Inc.

Geogrid reinforcement shall be SF55 or SF110 manufactured by Synteen Technical Fabrics, Inc.

Substitution of a different type of geosynthetic shall not be allowed unless approved by the Architect/Engineer or Owner after submittal of shop drawings and test data.

SITE PREPARATION

- Review the approved site plan to confirm lot lines, wall location, length and elevations.
- Schedule preconstruction meeting.
- Verify the on-site soil conditions.
- Call the local utility companies to confirm the location of underground utilities.
- Obtain all necessary building permits.
- Confirm drainage to avoid erosion or buildup of water behind the wall.

EXCAVATION

Lay out the location and length of the wall. If possible, start the wall base as the lowest elevation of the wall. Set wall elevations using a laser level and stakes prior to excavating; due to the size of the Stone Strong unit this method will increase efficiency.

Excavate as required for installation of the retaining wall system. Use caution not to over-excavate beyond depth needed for the foundation.

Slope or shore excavation as necessary for safety and for conformance with applicable OSHA requirements.

FOUNDATION PREPARATION

Foundation soils shall be excavated as required for wall base to the dimensions shown on the plans. Foundation soil shall be observed by the Geotechnical Engineer to confirm that the bearing soils are similar to the design conditions or assumptions.

Foundation soil shall be proof rolled and compacted a minimum of 95 percent of the maximum dry density (ASTM D 698, Standard Proctor) and inspected by the Owner’s engineer prior to placement of leveling pad materials. The contractor shall replace any unsuitable soils discovered during excavation at the direction of the engineer.

WALL BASE CONSTRUCTION

Construct base to the material and dimensions shown on the plans. Over excavated areas shall be filled with additional concrete or granular base material. Wall base shall consist of concrete with a minimum 28-day compressive strength of 3,000 psi, or a dense graded crushed aggregate. A minimum of 75% of coarse material shall have 2 or more fractured faces. Wall base material shall meet the following gradation:

Us Standard Sieve Size	**Percent Passing**
1-1/2”	100
3/4”	50-75
#4	0-10
#8	0-5

WALL BASE CONSTRUCTION

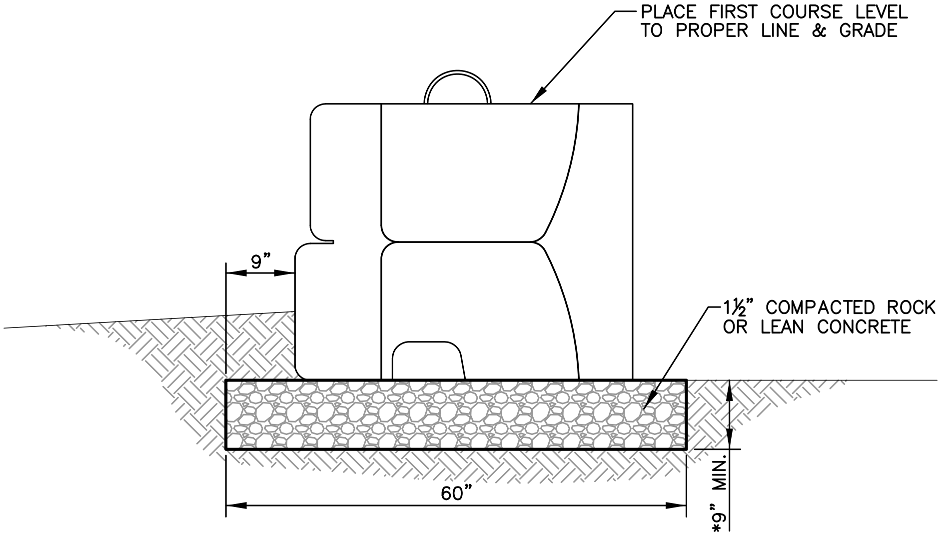
Compact the wall base to provide a hard and level surface to support the Stone Strong unit. Base material shall be compacted to a minimum of 95 percent of the maximum dry density (ASTM D 698, Standard Proctor).

Prepare and smooth the granular material to ensure complete contact of the first course with the wall base. The surface of granular base may be dressed with finer aggregate to aid leveling, provided that the thickness of dressing layer should not exceed 3 times the maximum particle size used OR 1/2 inch, whichever is greater.

WALL UNIT INSTALLATION

First Course

Place the first course of Stone Strong unit directly on the wall base (see detail 1). If possible, begin placing Stone Strong unit at the lowest section of the wall. The unit shall be leveled side-to-side, front-to-rear and with adjacent unit. Ensure Stone Strong units are in full contact with the compacted base. Adjacent unit should be in contact.
The first course is the most important to ensure accurate and acceptable results.
Leveling should be done by means of a 4 foot level across the top of the unit.



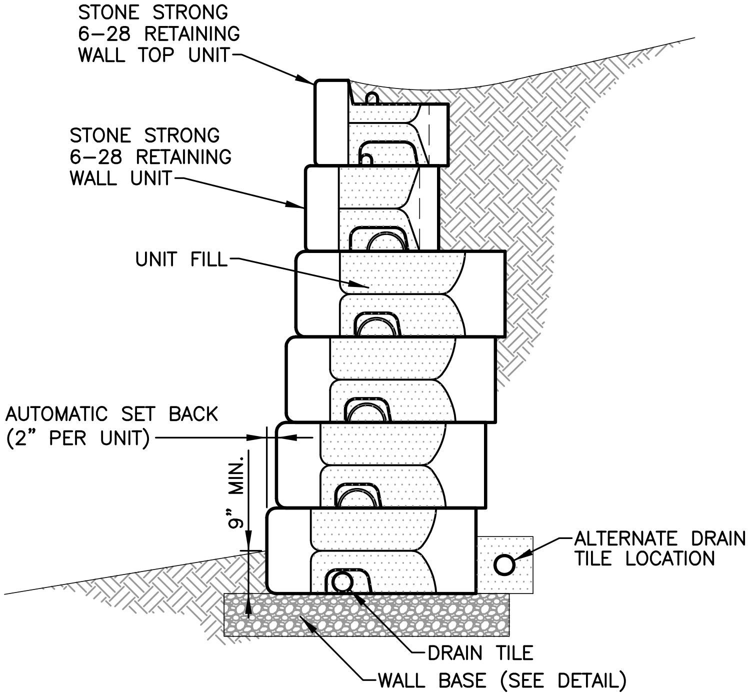
PLACE FIRST COURSE LEVEL
TO PROPER LINE & GRADE

1½" COMPACTED ROCK
OR LEAN CONCRETE

NOTE: BEARING CONDITIONS SHALL BE OBSERVED BY THE SITE GEOTECHNICAL ENGINEER. BASE DIMENSIONS MAY BE INCREASED TO ADDRESS DEFICIENT SOIL BEARING CONDITIONS.

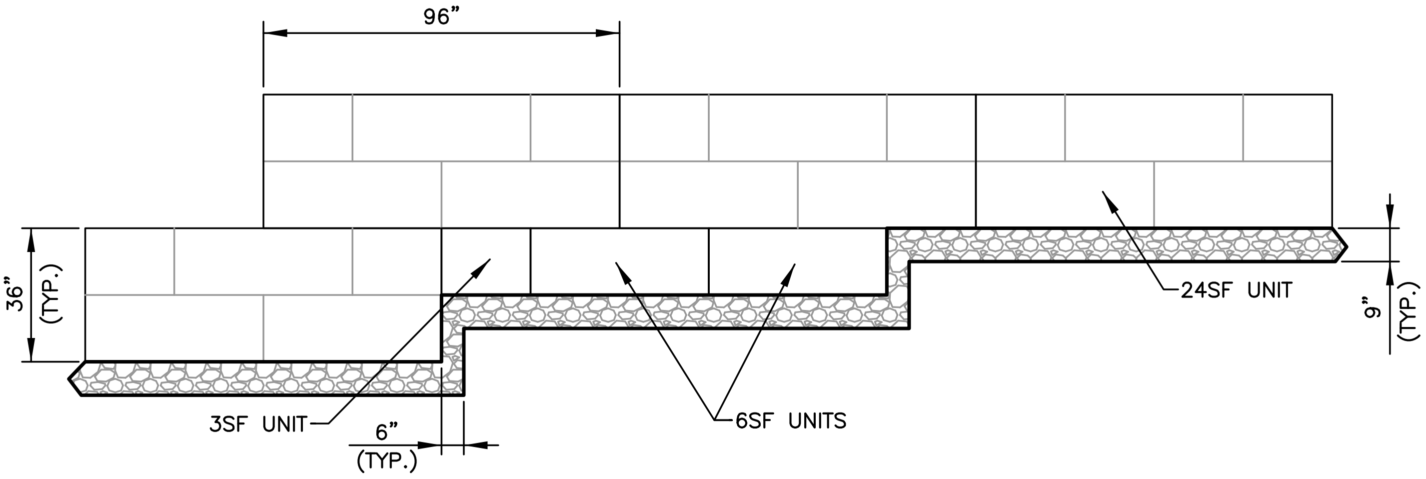
*FOR WALL HEIGHTS OF 6' OR LESS, BASE THICKNESS MAY BE REDUCED TO 6".

If the wall base elevation varies refer to detail for wall base steps.



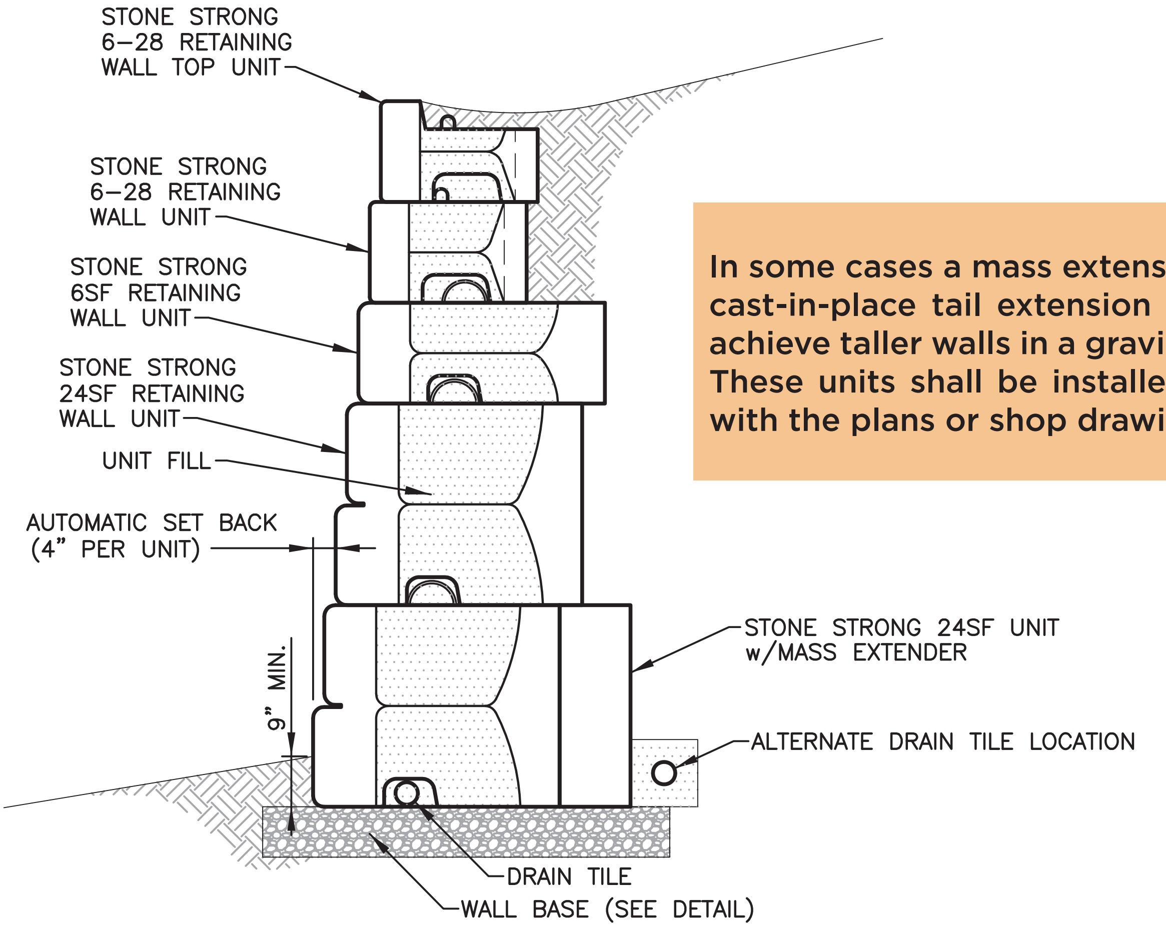
6SF GRAVITY WALL CROSS SECTION

NOT TO SCALE

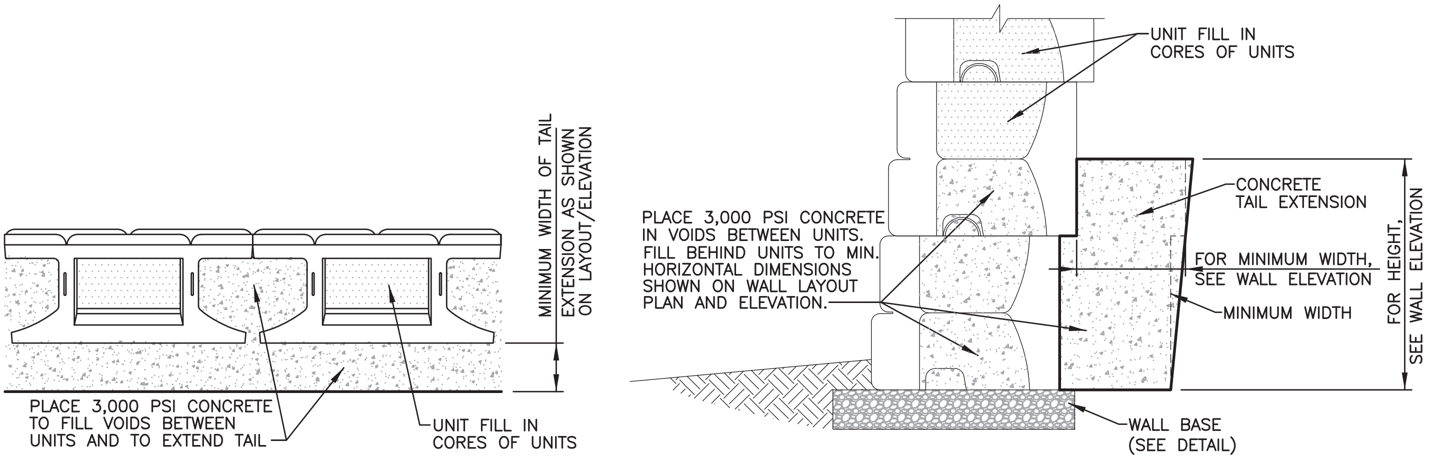


WALL BASE STEP

In some cases a mass extension unit or cast-in-place tail extension may be used to achieve taller walls in a gravity configuration. These units shall be installed in accordance with the plans or shop drawings.



GRAVITY WALL
CROSS SECTION w/MASS EXTENDER
NOT TO SCALE

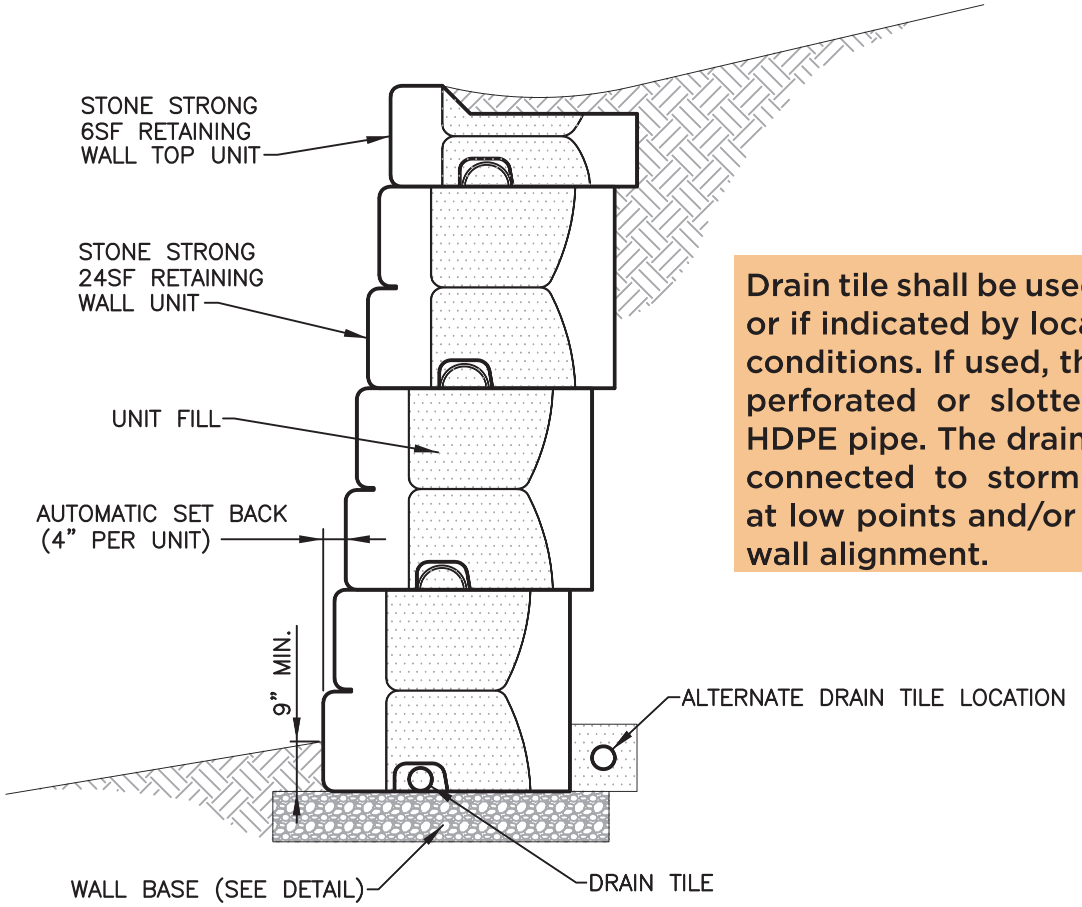


24SF CONCRETE TAIL EXTENSION DETAIL (CAST–IN–PLACE)
NOT TO SCALE

Fill all voids between and within the unit with granular unit fill. Unit fill shall consist of a screened crushed aggregate. A minimum of 75% of coarse material shall have 2 or more fractured faces. Wall base material shall meet the following gradation:

Us Standard Sieve Size	Percent Passing
1-1/2"	100
3/4"	50-75
#4	0-10
#8	0-5

If shown on the plans or the shop drawings, provide a geotextile filter for separation from backfill at the tails of the unit. The geotextile shall be a needle punched non-woven fabric with a minimum grab tensile strength of 120 pounds according to ASTM D 4632. If used, the geotextile may cover the entire back face of the unit or may be cut in strips to cover the gaps between tail unit with a minimum of 6 inches of overlap over the concrete tail on both sides.



Drain tile shall be used if shown on the plans or if indicated by local practices and conditions. If used, the drain tile should be perforated or slotted PVC or corrugated HDPE pipe. The drain tile should be connected to storm drains or daylighted at low points and/or periodically along the wall alignment.

GRAVITY WALL CROSS SECTION
NOT TO SCALE

Subsequent Courses

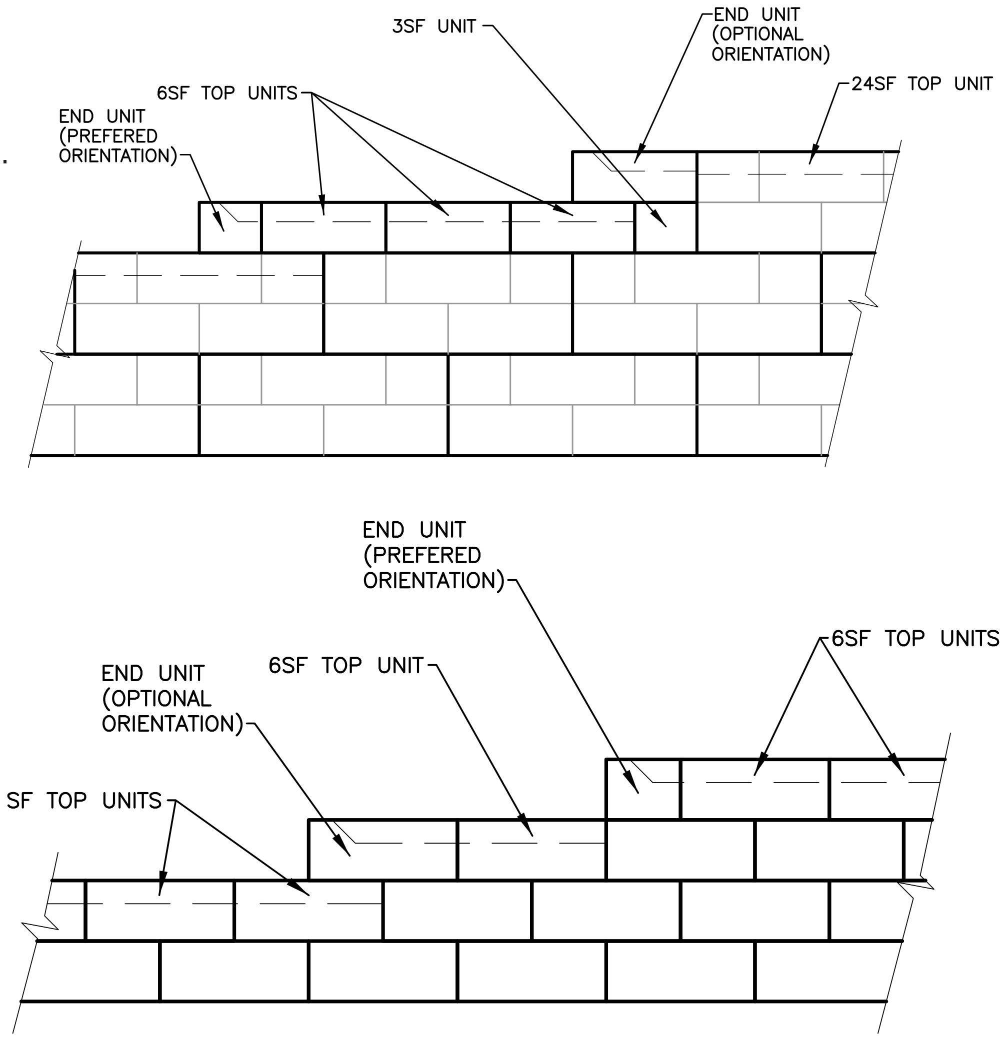
Remove all excess aggregate and other materials from the top of the unit before laying up the next course. Place the next course of segmental unit in running bond with the previous course. Place the web recess over the alignment loop from the unit below, and pull the unit forward to contact the loop. This alignment will produce a batter of 2 inches for every 18 inches of vertical wall height. Check the unit for level and alignment.

The layout of radius and corners shall be installed in accordance with the plans or shop drawings. See radius tables included at the end of this manual.

Continue placing successive courses to the elevations shown on the plans. Construct wall in level stages, placing the unit at each course for the entire length of the wall, if possible. Unit fill and backfill should be placed to the level of the top of the facing unit before placing the next course to step the top of the wall.

Provide temporary swales to divert runoff away from wall excavation and away from face during the construction phase.

Install the Stone Strong top unit. Place unit fill and backfill level with the back face of the unit.



TOP OF WALL STEPS

NOT TO SCALE

BACKFILL PLACEMENT AND COMPACTION

Place backfill behind the unit in maximum loose lifts of 8 inches and compact. Backfill and compact behind the first course before installing other courses. If select granular fill is required, it shall consist of fill sand or other clean aggregate.

Compact all backfill to a minimum of 95 percent of the maximum dry density (ASTM D 698, Standard Proctor). For cohesive soils, the moisture content at the time of compaction should be adjusted to within -3 and +4 percent of optimum. Place backfill in successive lifts until level with the top of the facing unit. Additional unit fill is not required behind the unit, but may be placed for the convenience of the contractor.

All other backfill behind and in front of the wall shall consist of suitable on-site soil or imported borrow approved by the Geotechnical Engineer. Backfill shall consist of sands, silts, or lean clays with a liquid limit less than 45 and a plasticity index less than 20. Fat clay soils, cobbles, and large rock should be avoided unless approved by the Geotechnical Engineer based on local practices. Frozen soils, excessively wet or dry soils, debris, and harmful materials should not be used.

Final grade above and below the retaining wall shall provide for positive drainage and prevent ponding. Protect completed wall from other construction. Do not operate large equipment or store materials above the wall that exceed the design surcharge loads.

Paraweb Strap Installation

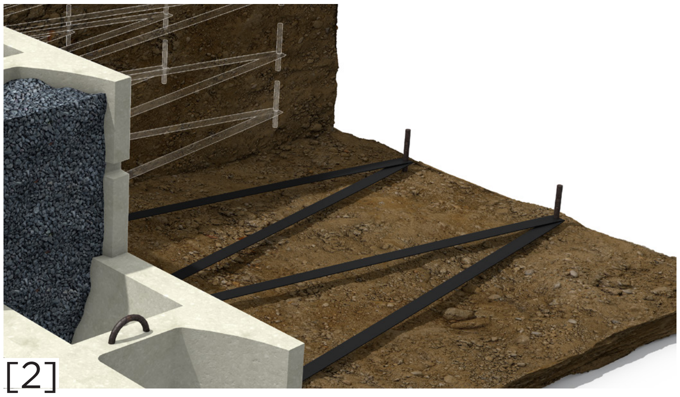
Paraweb straps can be cut or continuously wound through the Macbox inserts. Paraweb strap shall extend to the length specified by the site engineer.

Strap is inserted through box as shown (image 1)
Pull strap tight, a pin can be used (image 2) to hold straps taut until buried. Alternatively, weight put on the end of the strap (image 3) is an acceptable way to hold straps taut until buried.
This process is repeated every subsequent half course.


[1]


[4]

Note: cutting Paraweb strap at angle as shown (image 4) helps reduce friction when inserting strap through box.


[2]


[3]

Paraweb straps can be driven over with equipment after covering with minimum 3 inches of backfill.

CLEANUP

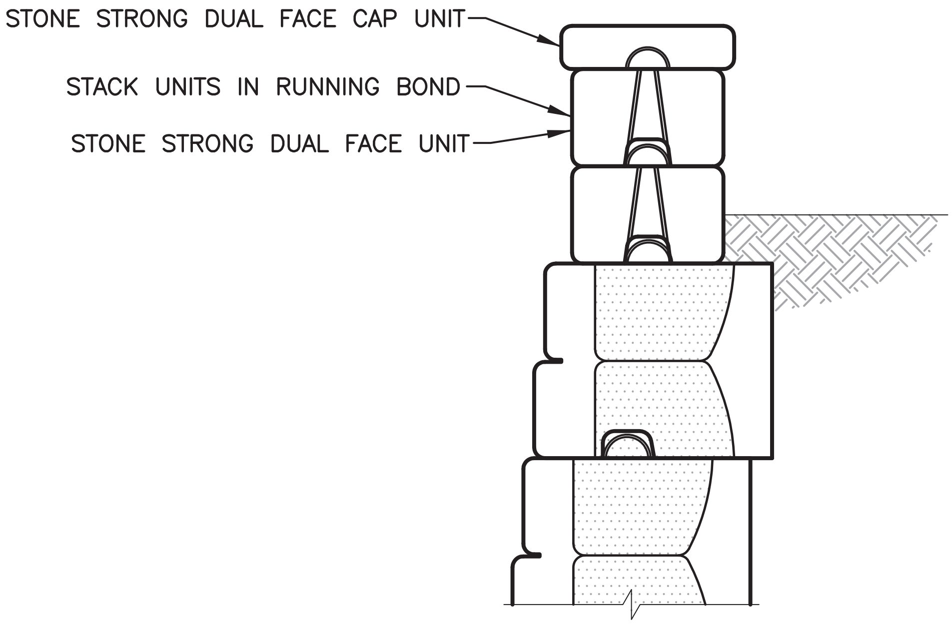
Remove any damaged or unused Stone Strong unit.

Remove any unit fill or backfill material.

Remove debris caused by wall construction.

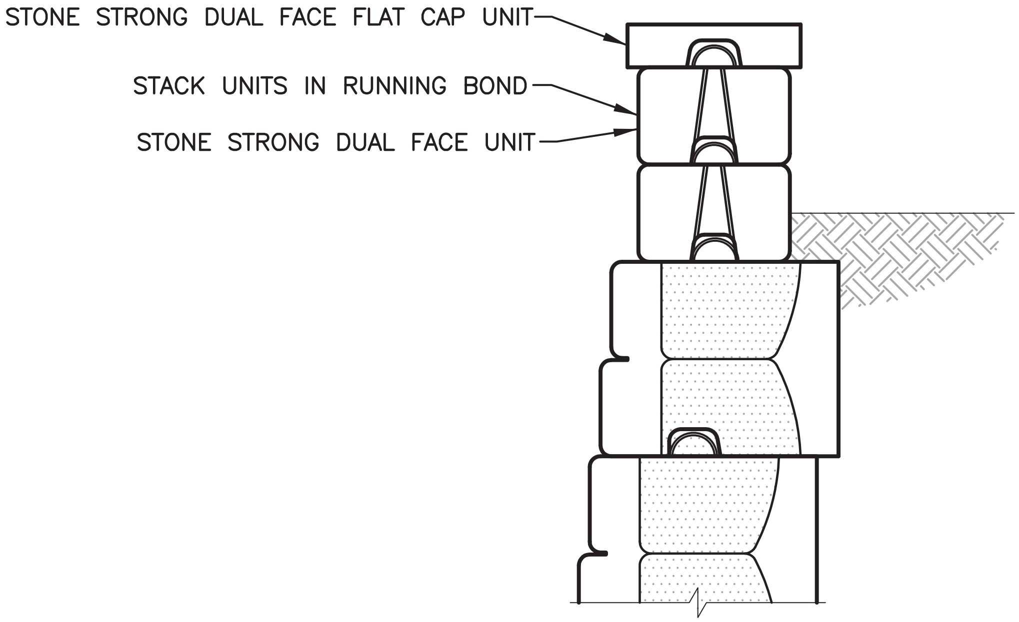
TROUBLESHOOTING

First course not level.	Wall base not level. Unit does not meet manufacturing specifications.
Wall leaning in.	Alignment loops not engaged. Unit not level.
Wall leaning out.	Alignment loops not engaged. Unit not level.
Wall has a dip.	Wall base not level. Wall base not properly compacted.
Unit will not stack flat.	Wall base not level. Unit does not meet manufacturing specifications. Excess aggregate or other material on top of unit.



DUAL FACE PARAPET WALL w/CAP

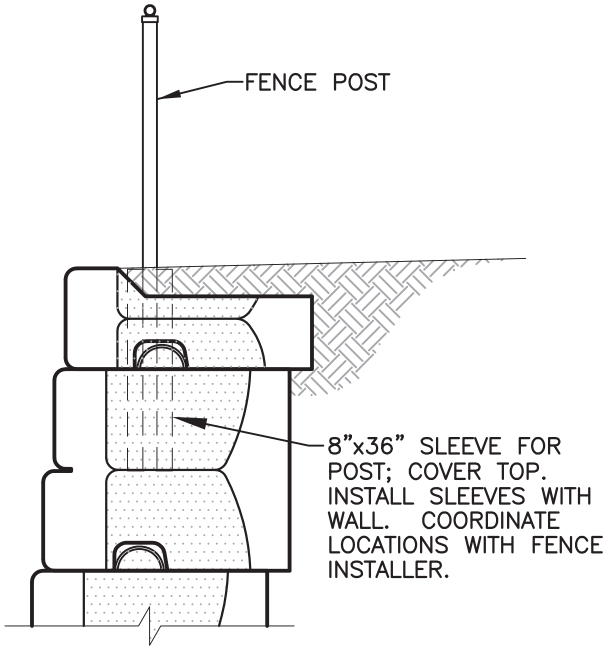
NOT TO SCALE



DUAL FACE PARAPET WALL w/FLAT CAP

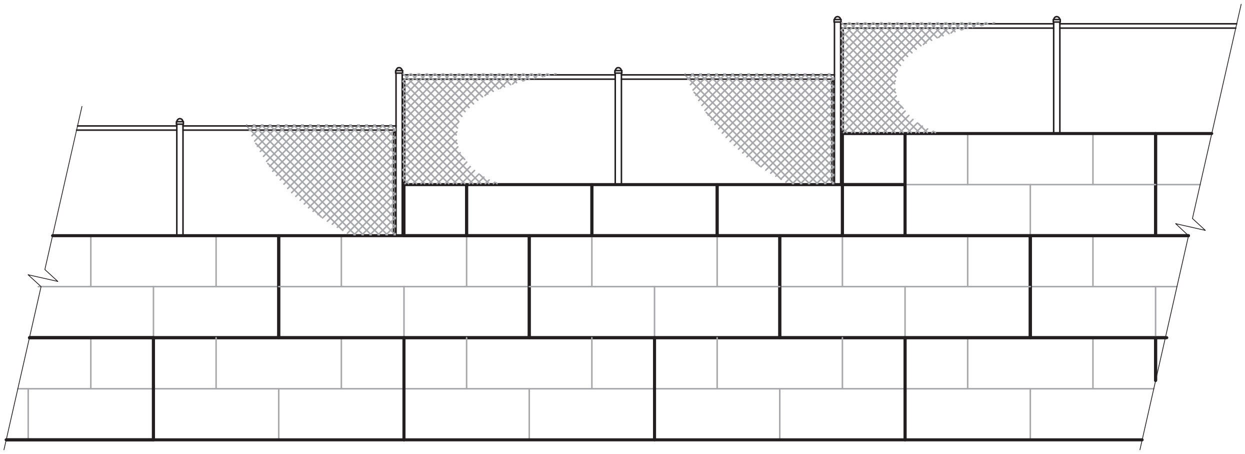
NOT TO SCALE

Top of Wall Treatments:
Fencing

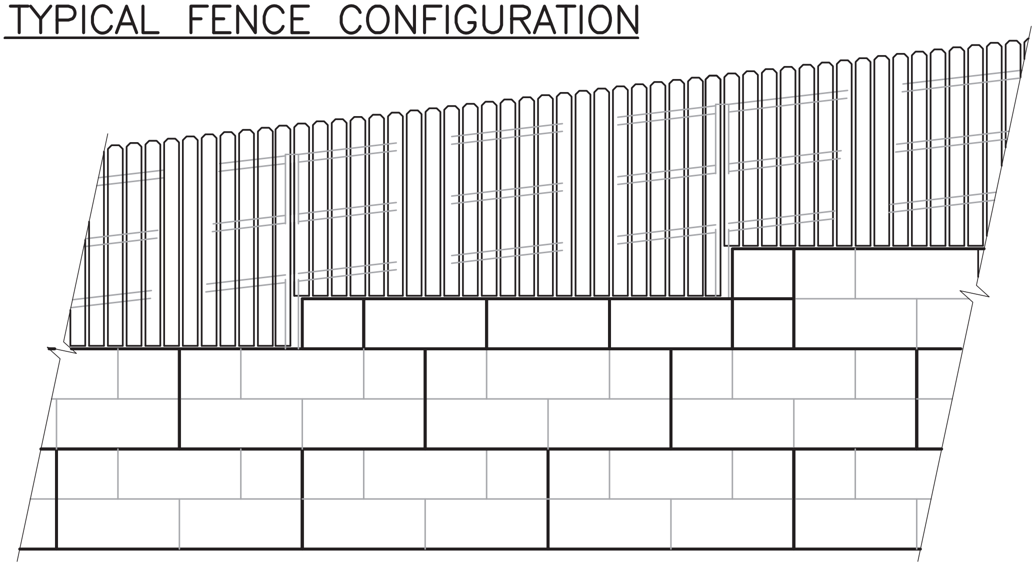


FENCE SLEEVE

NOT TO SCALE



TYPICAL FENCE CONFIGURATION

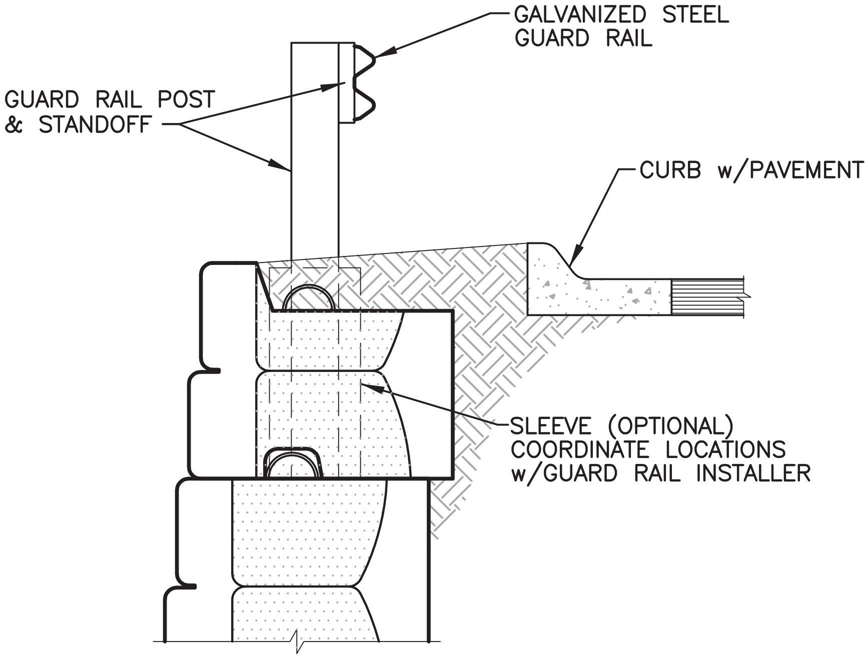


OPTIONAL FENCE CONFIGURATION

NOT TO SCALE

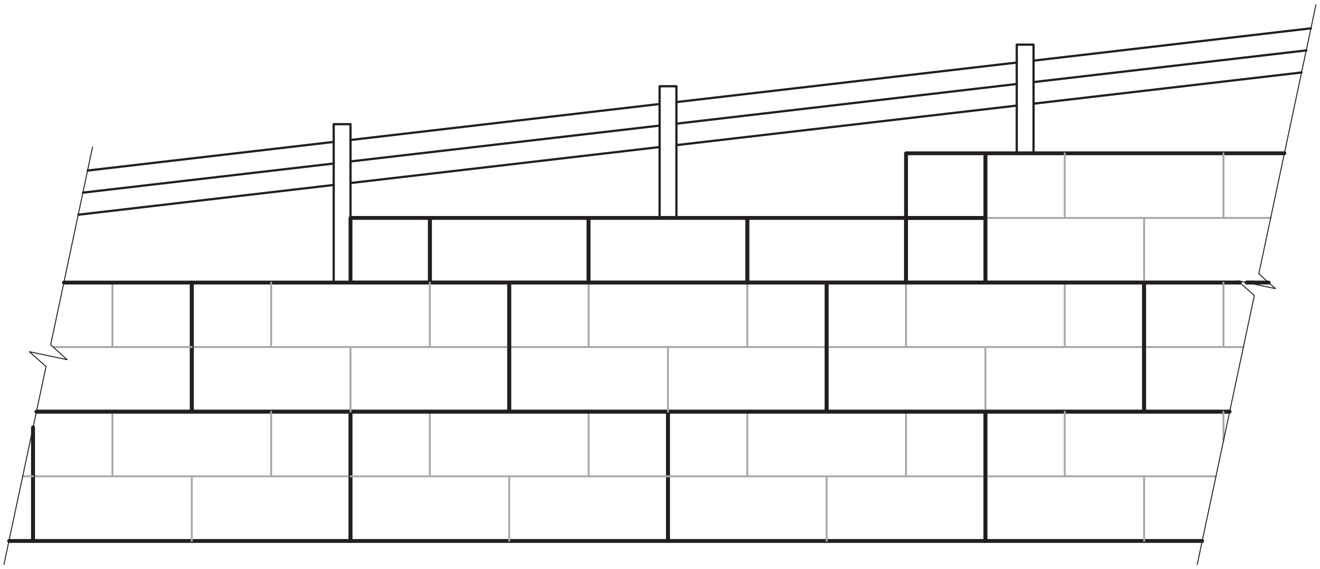
Top of Wall Treatments:

Guardrail



WALL w/GUARD RAIL

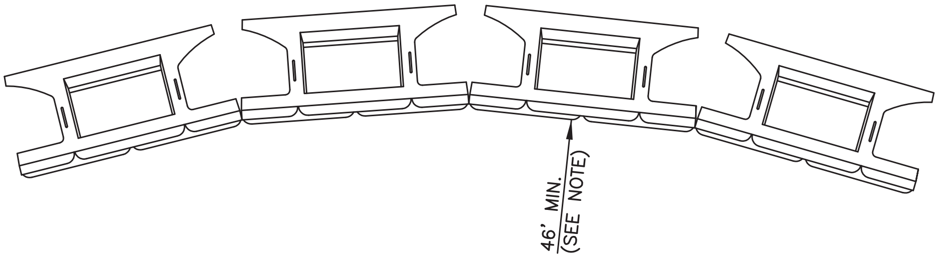
NOT TO SCALE



TYPICAL GUARDRAIL CONFIGURATION

NOT TO SCALE

Radius:
24SF

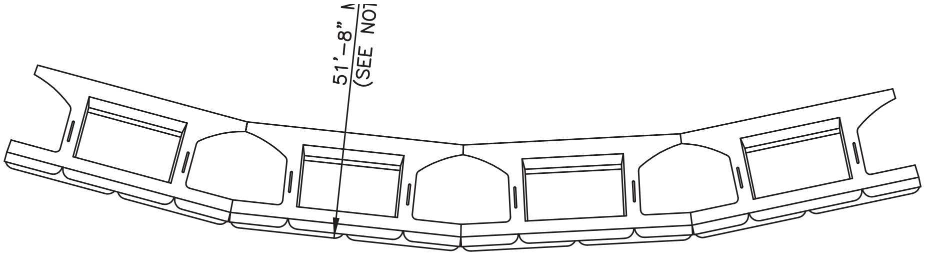


Minimum Concave Radius		
Wall Height (ft)	**Total # of Courses**	**Reqd. Radius at Top Course**
6	2	46' 4"
9	3	46' 8"
12	4	47' 0"
15	5	47' 4"
18	6	47' 8"
21	7	48' 0"
24	8	48' 4"

NOTE:
MINIMUM RADIUS OCCURS AT LOWEST COURSE.
RADIUS INCREASES 4" PER COURSE ABOVE,
AS SHOWN ON TABLE.

MINIMUM CONCAVE RADIUS—24SF UNITS

NOT TO SCALE



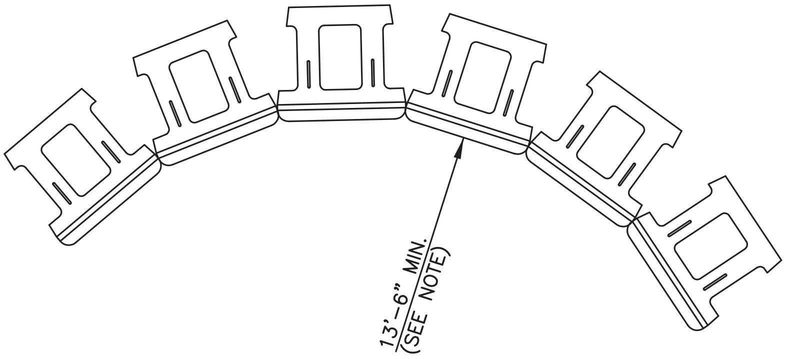
Minimum Convex Radius		
Wall Height (ft)	**Total # of Courses**	**Reqd. Radius at First Course**
6	2	52' 0"
9	3	52' 4"
12	4	52' 8"
15	5	53' 0"
18	6	53' 4"
21	7	53' 8"
24	8	54' 0"

NOTE:
MINIMUM RADIUS OCCURS AT TOP COURSE.
REQUIRED RADIUS INCREASES 4" PER COURSE
BELOW, AS SHOWN ON TABLE.

MINIMUM CONVEX RADIUS—24SF UNITS

NOT TO SCALE

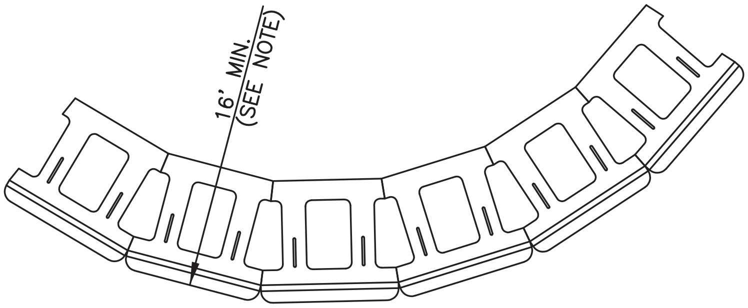
Radius:
6SF



Minimum Concave Radius		
Wall Height (ft)	Total # of Courses	Reqd. Radius at Top Course
3	2	13' 8"
4 1/2	3	13' 10"
6	4	14' 0"
7 1/2	5	14' 2"
9	6	14"4"
10 1/2	7	14' 6"
12	8	14' 8"

NOTE:
MINIMUM RADIUS OCCURS AT LOWEST COURSE.
RADIUS INCREASES 2" PER COURSE
ABOVE, AS SHOWN ON TABLE.

MINIMUM CONCAVE RADIUS—6SF UNITS
NOT TO SCALE



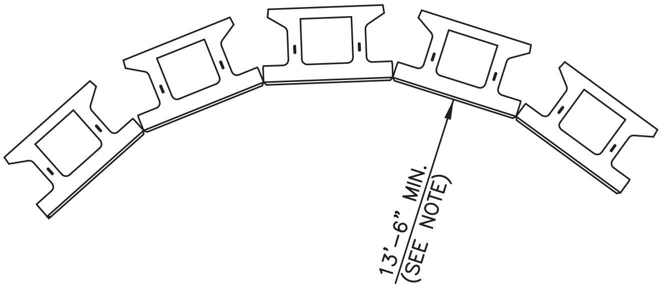
Minimum Convex Radius		
Wall Height (ft)	Total # of Courses	Reqd. Radius at First Course
3	2	16' 2"
4 1/2	3	16' 4"
6	4	16' 6"
7 1/2	5	16' 8"
9	6	16' 10"
10 1/2	7	17' 0"
12	8	17' 2"

NOTE:
NOTE: MINIMUM RADIUS OCCURS AT TOP COURSE.
REQUIRED RADIUS INCREASES 2" PER COURSE
BELOW, AS SHOWN ON TABLE.

MINIMUM CONVEX RADIUS—6SF UNITS
NOT TO SCALE

Radius:

6-28

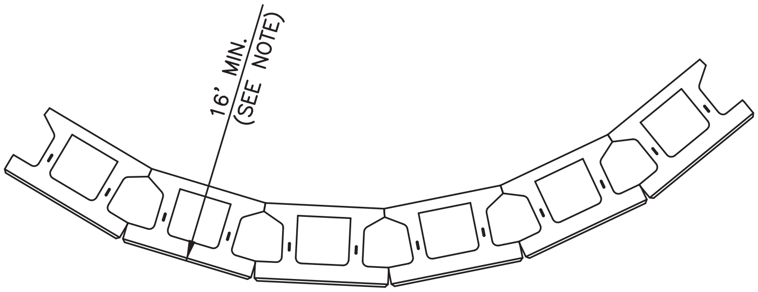


Minimum Concave Radius		
Wall Height (ft)	Total # of Courses	Reqd. Radius at Top Course
3	2	13' 8"
4 1/2	3	13' 10"
6	4	14' 0"
7 1/2	5	14' 2"
9	6	14"4"
10 1/2	7	14' 6"
12	8	14' 8"

NOTE:
MINIMUM RADIUS OCCURS AT LOWEST COURSE.
RADIUS INCREASES 2" PER COURSE
ABOVE, AS SHOWN ON TABLE.

MINIMUM CONCAVE RADIUS–6–28 UNITS

NOT TO SCALE



Minimum Convex Radius		
Wall Height (ft)	Total # of Courses	Reqd. Radius at First Course
3	2	16' 2"
4 1/2	3	16' 4"
6	4	16' 6"
7 1/2	5	16' 8"
9	6	16' 10"
10 1/2	7	17' 0"
12	8	17' 2"

NOTE:
NOTE: MINIMUM RADIUS OCCURS AT TOP COURSE.
REQUIRED RADIUS INCREASES 2" PER COURSE
BELOW, AS SHOWN ON TABLE.

MINIMUM CONVEX RADIUS–6–28 UNITS

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Omaha, Nebraska 68138

Toll-Free: 1-877-501-5652
Phone: 402-973-1292

www.stonestrong.com

info@stonestrong.com

Issue Date: 7/1/2020

jump to TOC

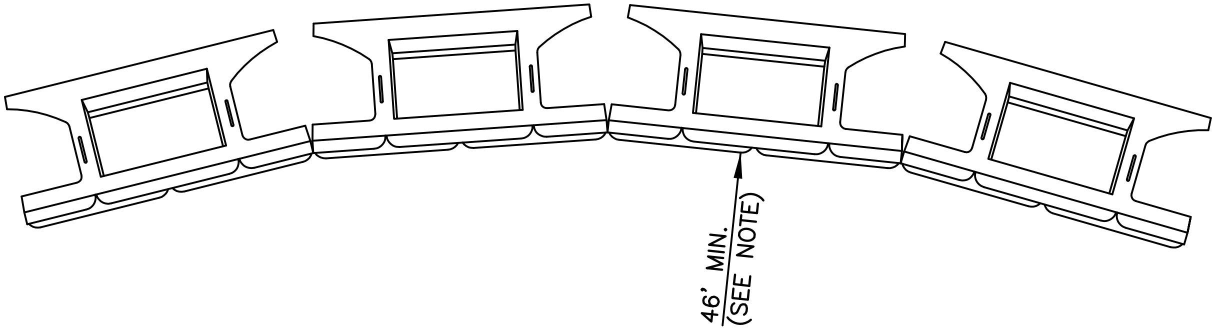
jump to Appendix TOC

3.1.3 FACING UNIT INSTALLATION

No attachments

3.1.4 FACING ON CURVED SECTIONS & CORNERS

Minimum Radius Details
Corner Details



Minimum Concave Radius		
Wall Height (ft)	**Total # of Courses**	**Reqd. Radius at Top Course**
6	2	46' 4"
9	3	46' 8"
12	4	47' 0"
15	5	47' 4"
18	6	47' 8"
21	7	48' 0"
24	8	48' 4"

NOTE:
MINIMUM RADIUS OCCURS AT LOWEST COURSE. RADIUS INCREASES 4" PER COURSE ABOVE, AS SHOWN ON TABLE.

MINIMUM CONCAVE RADIUS–24SF UNITS

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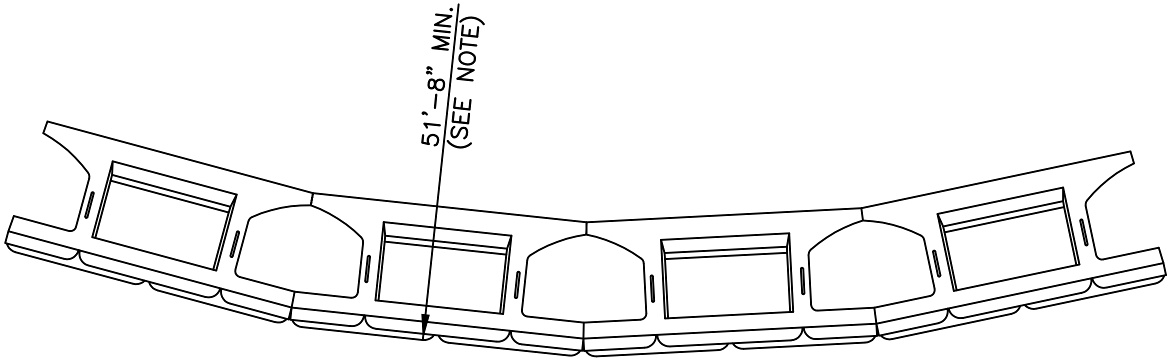
DATE: 2/10/16 | FILE: 11_24sf.RadMin.Concave



Minimum Convex Radius		
Wall Height (ft)	**Total # of Courses**	**Reqd. Radius at First Course**
6	2	52' 0"
9	3	52' 4"
12	4	52' 8"
15	5	53' 0"
18	6	53' 4"
21	7	53' 8"
24	8	54' 0"

NOTE:
MINIMUM RADIUS OCCURS AT TOP COURSE.
REQUIRED RADIUS INCREASES 4" PER COURSE BELOW, AS SHOWN ON TABLE.

MINIMUM CONVEX RADIUS-24SF UNITS

NOT TO SCALE

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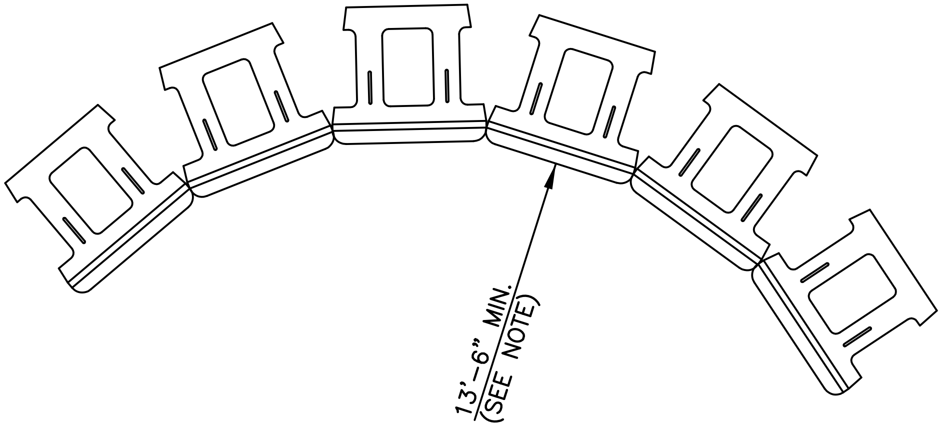
TYPICAL DETAILS
STONE STRONG SYSTEMS

DATE: 2/10/16
FILE: 12_24sf.RadMin.Convex



Minimum Concave Radius		
Wall Height (ft)	**Total # of Courses**	**Reqd. Radius at Top Course**
3	2	13' 8"
4 1/2	3	13' 10"
6	4	14' 0"
7 1/2	5	14' 2"
9	6	14"4"
10 1/2	7	14' 6"
12	8	14' 8"

NOTE:

MINIMUM RADIUS OCCURS AT LOWEST COURSE.
RADIUS INCREASES 2" PER COURSE
ABOVE, AS SHOWN ON TABLE.

MINIMUM CONCAVE RADIUS-6SF UNITS

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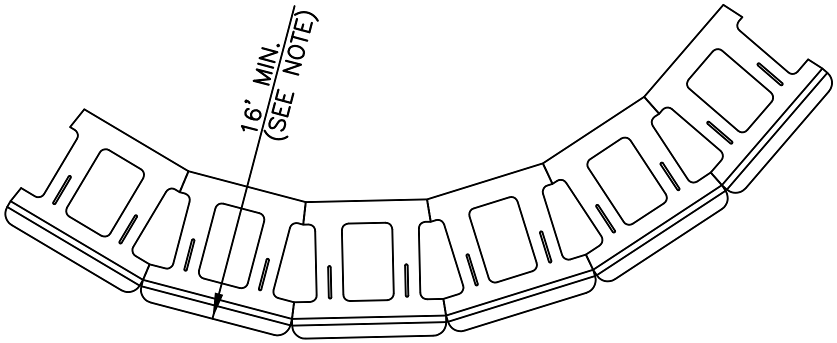
STONE STRONG SYSTEMS

DATE: 2/10/16
FILE: 13_6sf.RadMin.Concave



Minimum Convex Radius		
Wall Height (ft)	Total # of Courses	Reqd. Radius at First Course
3	2	16' 2"
4 1/2	3	16' 4"
6	4	16' 6"
7 1/2	5	16' 8"
9	6	16' 10"
10 1/2	7	17' 0"
12	8	17' 2"

NOTE:

NOTE: MINIMUM RADIUS OCCURS AT TOP COURSE. REQUIRED RADIUS INCREASES 2" PER COURSE BELOW, AS SHOWN ON TABLE.

MINIMUM CONVEX RADIUS–6SF UNITS

NOT TO SCALE

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TYPICAL DETAILS
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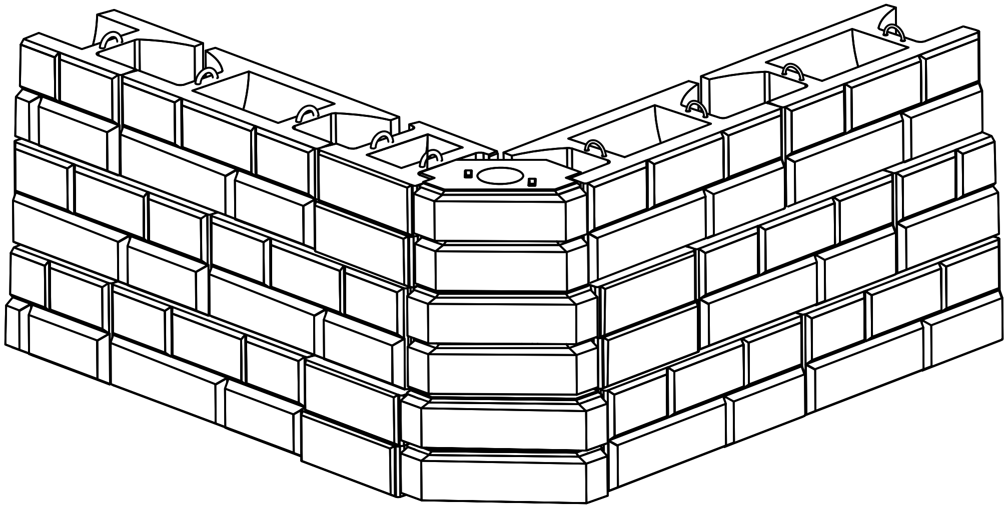
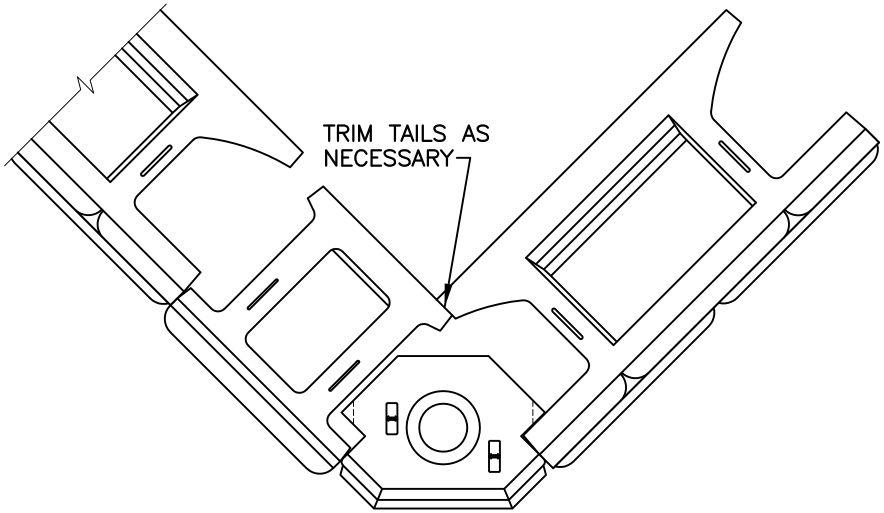
DATE: 2/10/16
FILE: 14_6sf.RadMin.Convex





NOTE:
CORNER BLOCK SIZE CHANGES EACH 3 FEET VERTICALLY

STONE STRONG OUTSIDE CORNER BLOCK ASSEMBLY

NOT TO SCALE

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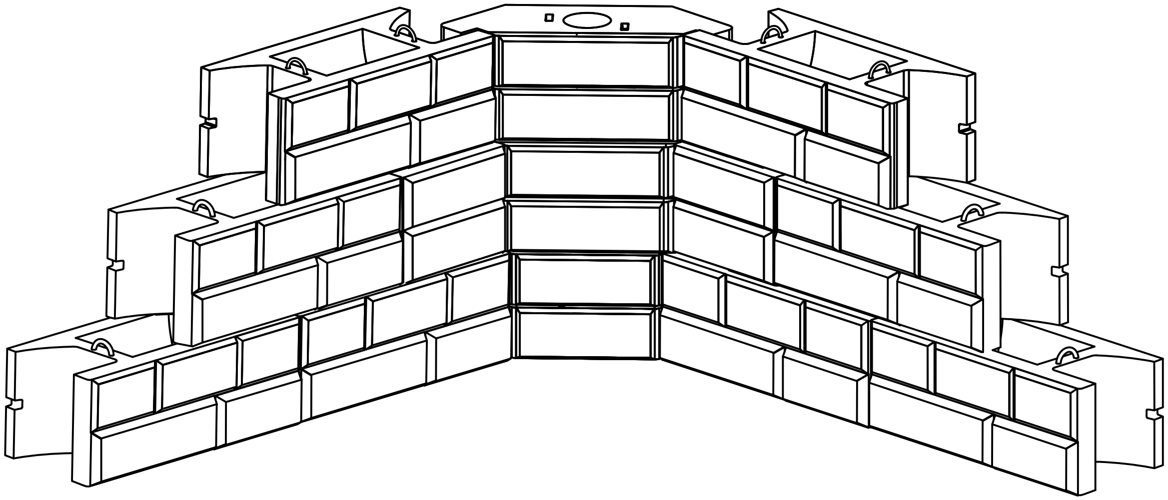
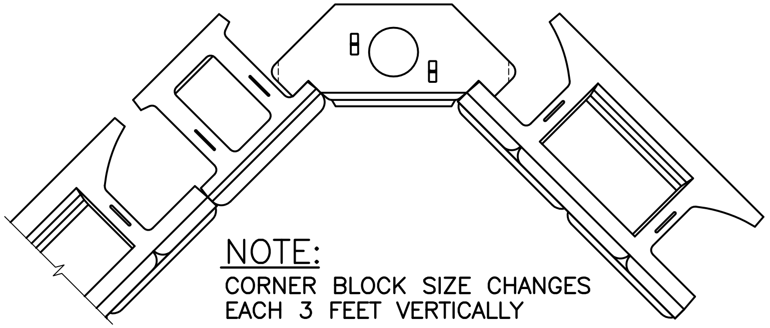
CORNER DETAILS
STONE STRONG SYSTEMS

DATE: 6/29/18 | FILE: 01_Corner Outside





NOTE:
CORNER BLOCK SIZE CHANGES
EACH 3 FEET VERTICALLY

STONE STRONG INSIDE CORNER BLOCK ASSEMBLY

NOT TO SCALE

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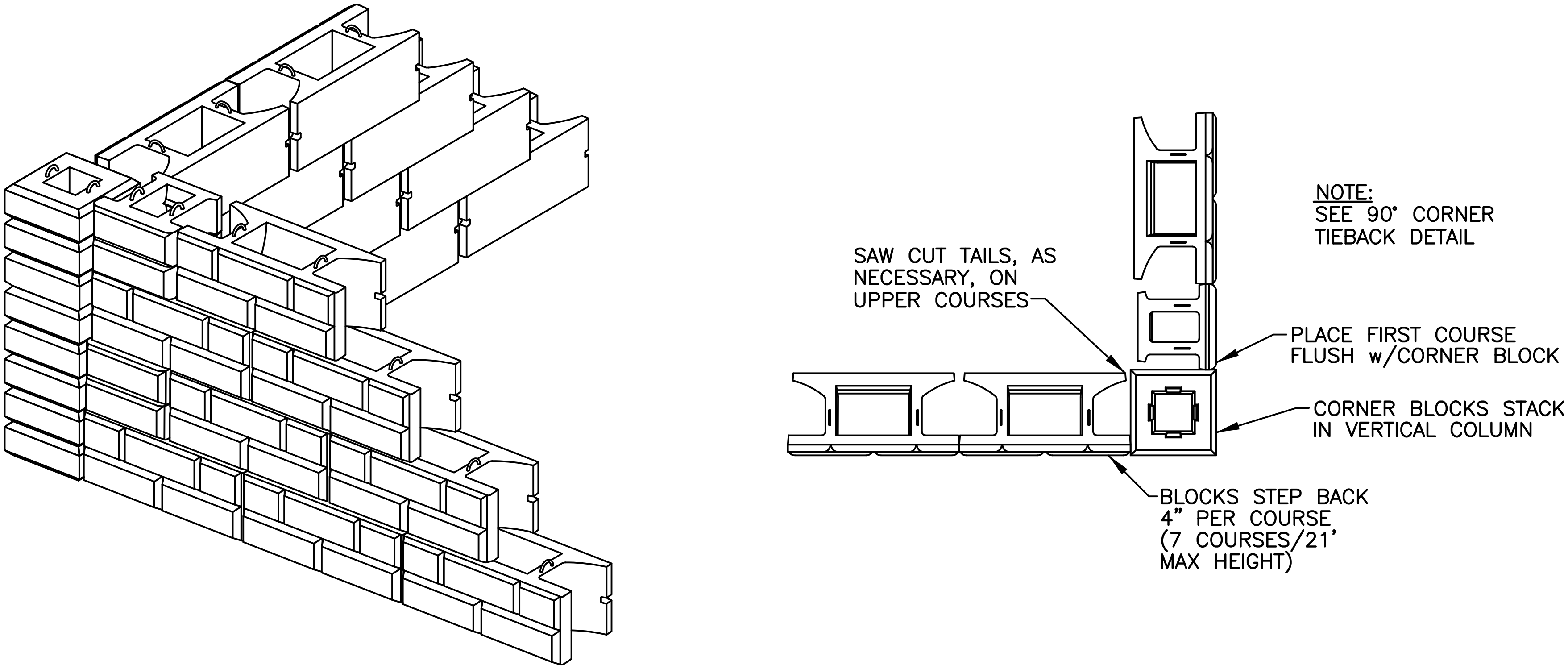
CORNER DETAILS
STONE STRONG SYSTEMS

DATE: 6/29/18
FILE: 02_Corner Inside



OUTSIDE 90° CORNER

NOT TO SCALE

CHECK ON AVAILABILITY OF ALL UNITS w/ LOCAL PRODUCER/ DEALER. SOME UNITS MAY HAVE LIMITED AVAILABILITY.

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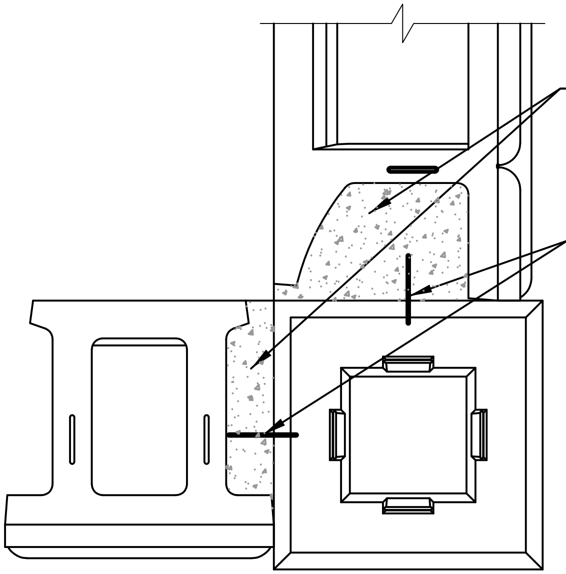
CORNER DETAILS
STONE STRONG SYSTEMS

DATE: 6/29/18 | FILE: 03_90.OC

NOTE:
RECOMMENDED FOR CORNERS 12' AND TALLER.
INSTALL TIEBACK EVERY 3' VERTICALLY STARTING
AT 3' ABOVE THE BASE.



FILL VOID WITH
3,000 PSI CONCRETE

#4 BAR, 12" LONG. DRILL & EPOXY
GROUT 4" DEEP INTO MIDDLE OF CORNER
UNIT. (TYP. OF EVERY OTHER CORNER
UNIT STARTING @ 3rd UNIT FROM BOTTOM)

90° CORNER TIEBACK

NOT TO SCALE

CHECK ON AVAILABILITY OF ALL UNITS w/ LOCAL PRODUCER/
DEALER. SOME UNITS MAY HAVE LIMITED AVAILABILITY.

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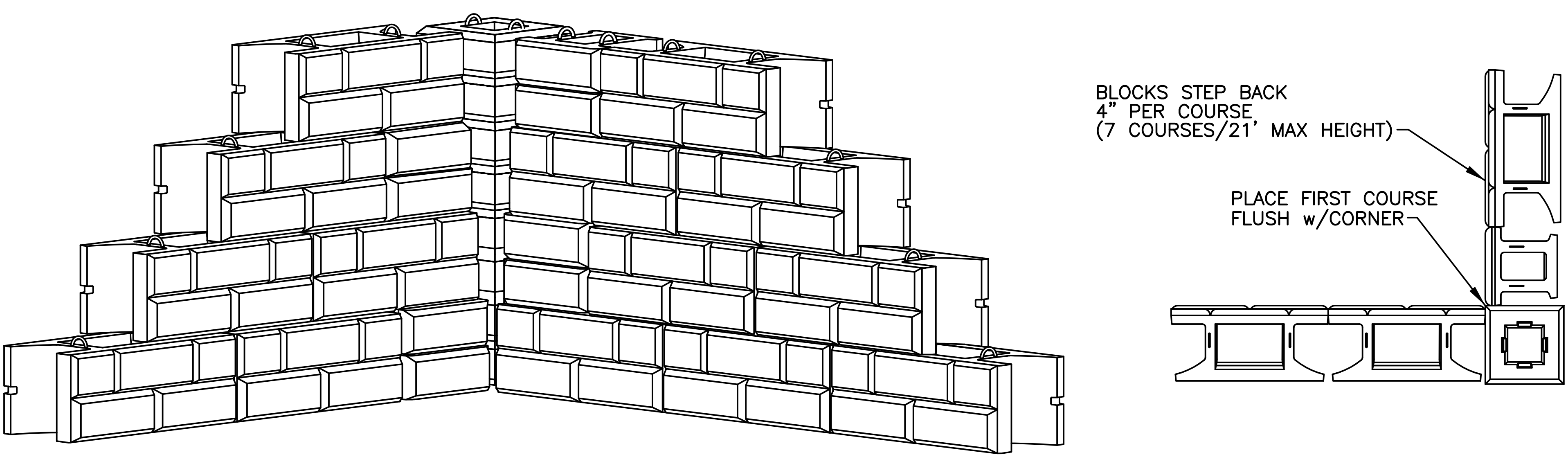
CORNER DETAILS
STONE STRONG SYSTEMS

DATE: 6/29/18 FILE: 04_Tieback.90



INSIDE 90° CORNER

NOT TO SCALE

CHECK ON AVAILABILITY OF ALL UNITS w/ LOCAL PRODUCER/ DEALER. SOME UNITS MAY HAVE LIMITED AVAILABILITY.

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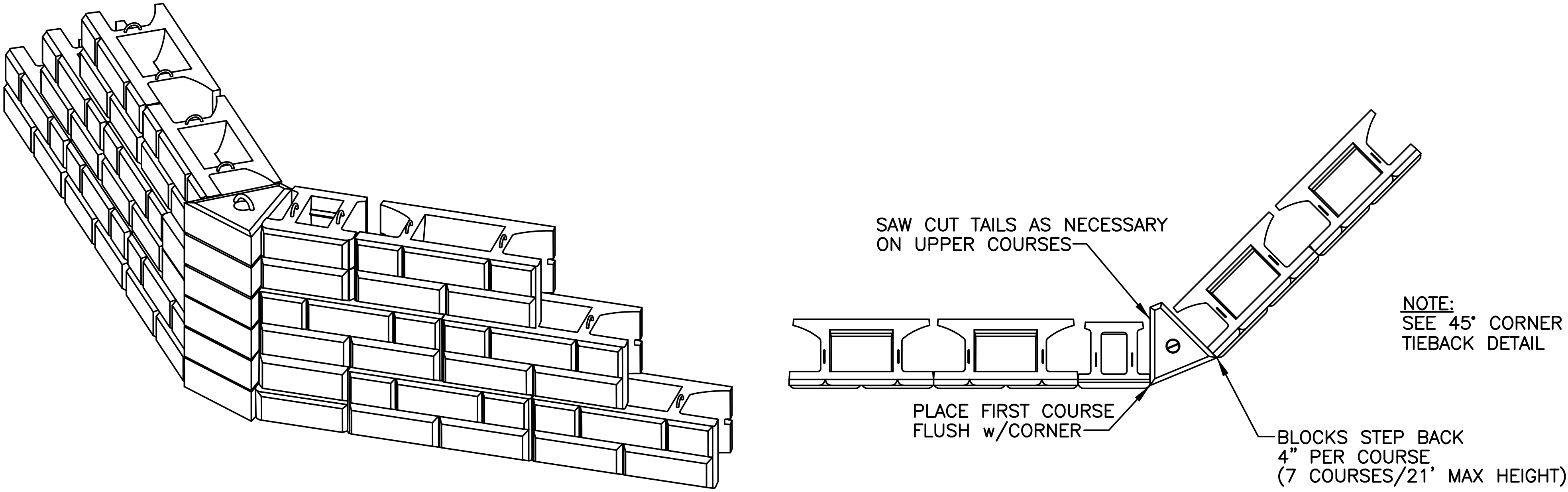
CORNER DETAILS
STONE STRONG SYSTEMS

DATE: 6/29/18 | FILE: 05_90.IC



OUTSIDE 45° CORNER

NOT TO SCALE

CHECK ON AVAILABILITY OF ALL UNITS w/ LOCAL PRODUCER/ DEALER. SOME UNITS MAY HAVE LIMITED AVAILABILITY.

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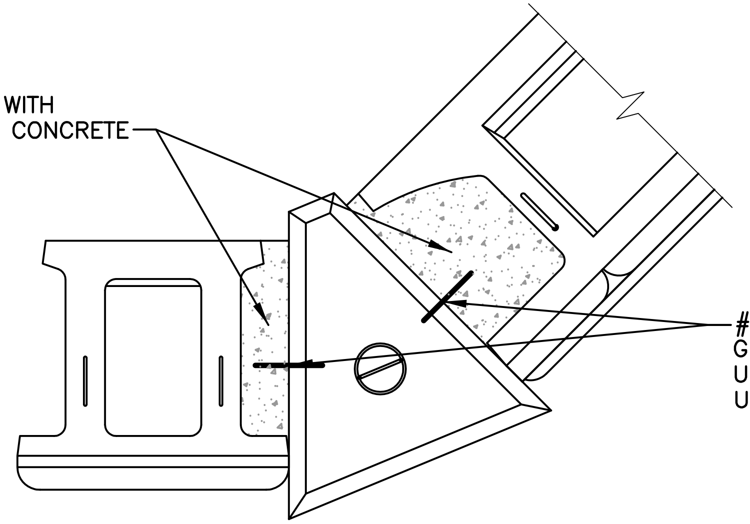
CORNER DETAILS
STONE STRONG SYSTEMS

DATE: 6/29/18 | FILE: 08_45.0C

NOTE:

RECOMMENDED FOR CORNERS 12' AND TALLER.
INSTALL TIEBACK EVERY 3' VERTICALLY STARTING
AT 3' ABOVE THE BASE.



FILL VOID WITH
3,000 PSI CONCRETE

#4 BAR, 12" LONG. DRILL & EPOXY
GROUT 4" DEEP INTO MIDDLE OF CORNER
UNIT. (TYP. OF EVERY OTHER CORNER
UNIT STARTING @ 3rd UNIT FROM BOTTOM)

45° CORNER TIEBACK

NOT TO SCALE

CHECK ON AVAILABILITY OF ALL UNITS w/ LOCAL PRODUCER/
DEALER. SOME UNITS MAY HAVE LIMITED AVAILABILITY.

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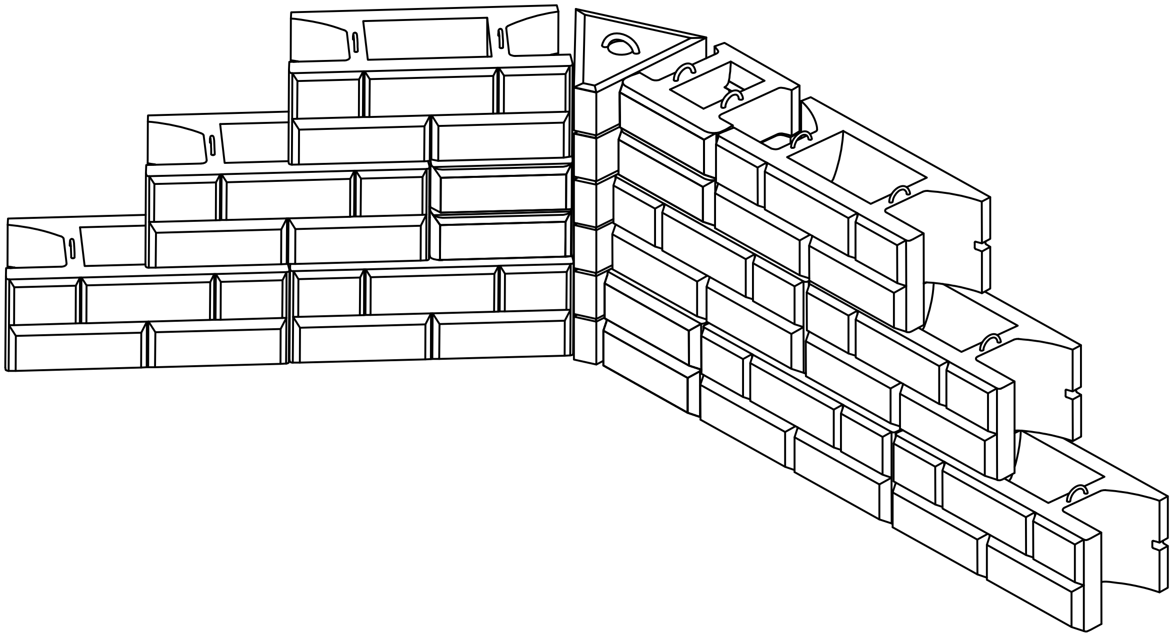
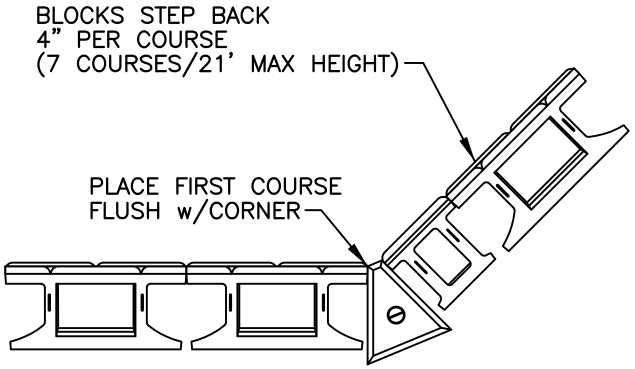
CORNER DETAILS
STONE STRONG SYSTEMS

DATE: 6/29/18 FILE: 09_Tieback.45





INSIDE 45° CORNER

NOT TO SCALE

CHECK ON AVAILABILITY OF ALL UNITS w/ LOCAL PRODUCER/ DEALER. SOME UNITS MAY HAVE LIMITED AVAILABILITY.

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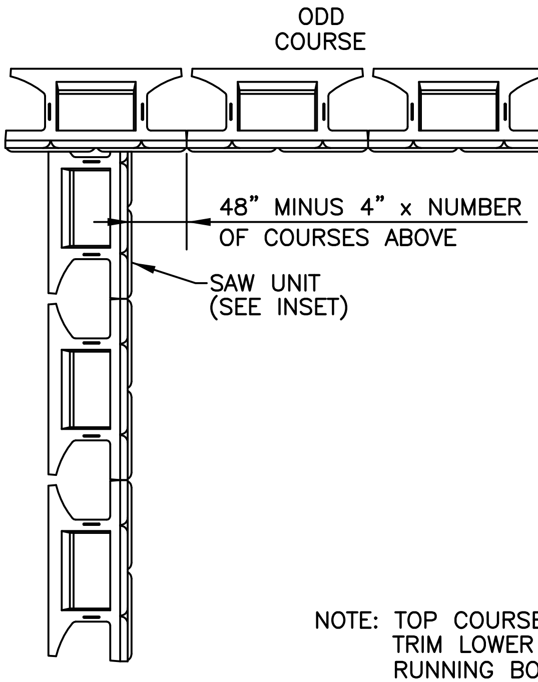
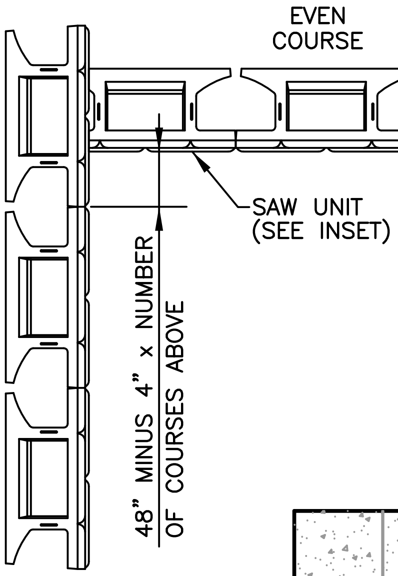
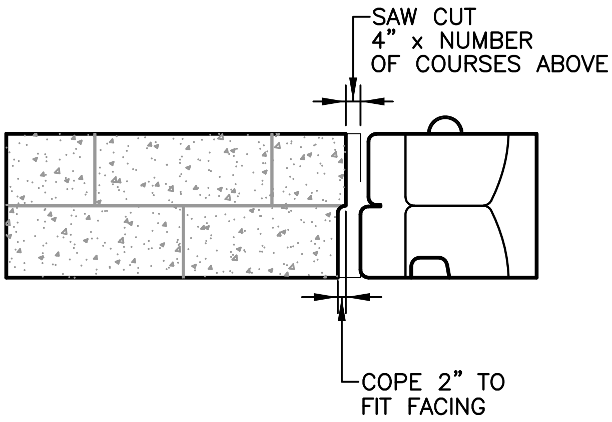
CORNER DETAILS
STONE STRONG SYSTEMS

DATE: 6/29/18 | FILE: 10_45.IC







NOTE: TOP COURSES WILL USE FULL BLOCKS.
TRIM LOWER COURSES TO MAINTAIN
RUNNING BOND, EXCEPT AS NOTED
ON LAYOUT DRAWING.

24SF LACED INSIDE CORNER

NOT TO SCALE

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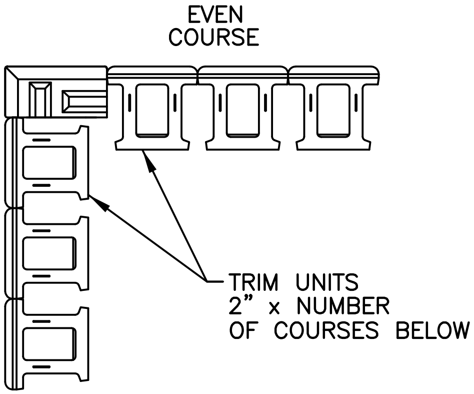
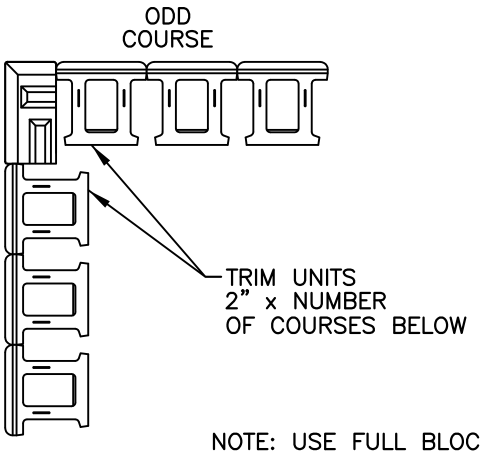
CORNER DETAILS
STONE STRONG SYSTEMS

DATE: 6/29/18 | FILE: 11_24sf.LIC





NOTE: USE FULL BLOCKS FIRST COURSE. TRIM SUBSEQUENT COURSES TO MAINTAIN RUNNING BOND, EXCEPT AS NOTED ON LAYOUT DRAWING.

CAST SLEEVE FOR FENCE POST IN TOP CORNER BLOCK.

6SF LACED OUTSIDE CORNER

NOT TO SCALE

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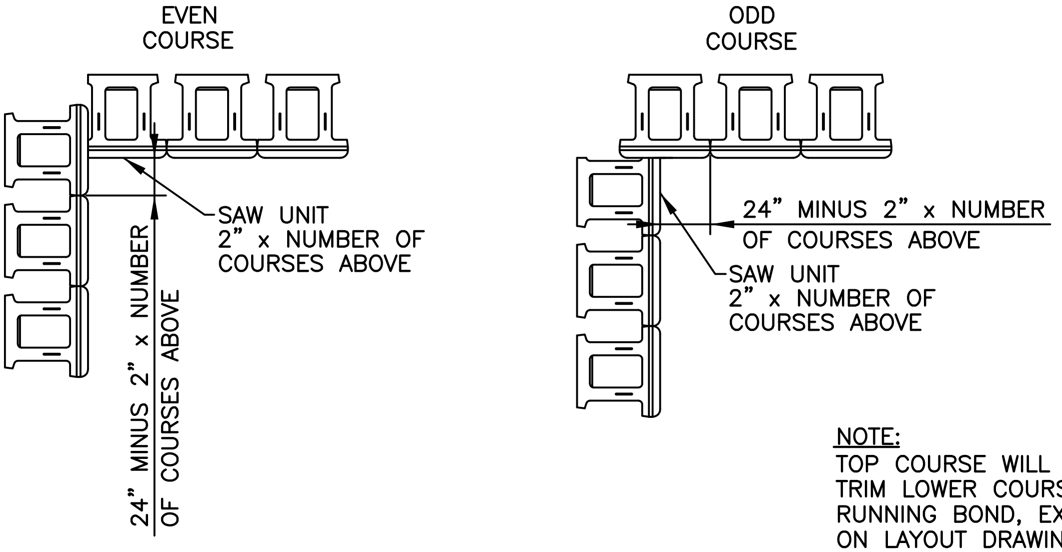
CORNER DETAILS
STONE STRONG SYSTEMS

DATE: 6/29/18 | FILE: 12_6sf.LOC



NOTE:
TOP COURSE WILL USE FULL BLOCKS.
TRIM LOWER COURSES TO MAINTAIN
RUNNING BOND, EXCEPT AS NOTED
ON LAYOUT DRAWING.

6SF LACED INSIDE CORNER

NOT TO SCALE

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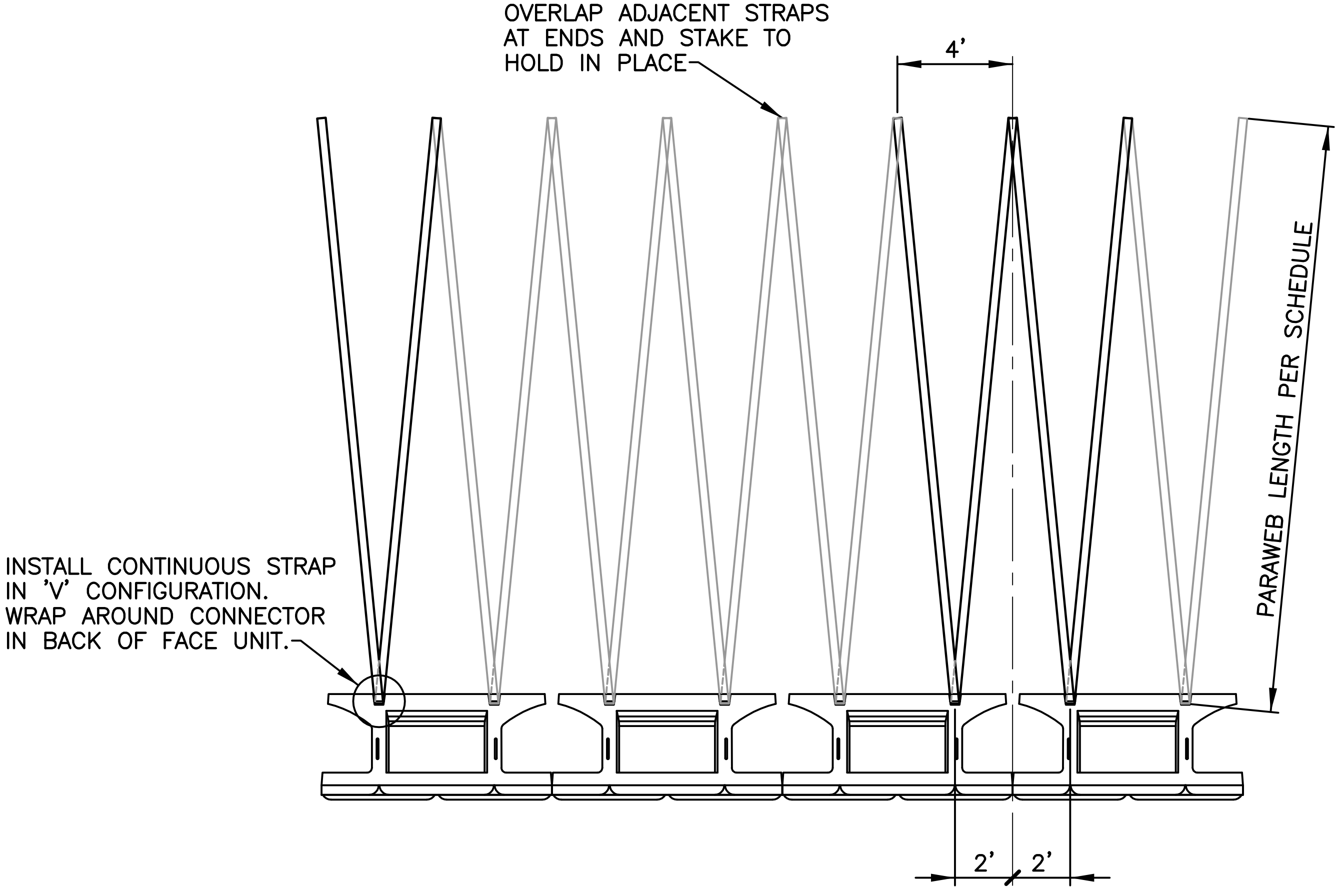
PROJECT

CORNER DETAILS
STONE STRONG SYSTEMS

DATE: 6/29/18 | FILE: 13_6sf.LIC

3.1.5 REINFORCEMENT ON CURVED SECTIONS & CORNERS

Paraweb Layout Details



TYPICAL PARAWEB LAYOUT

NOT TO SCALE

DISCLAIMER:

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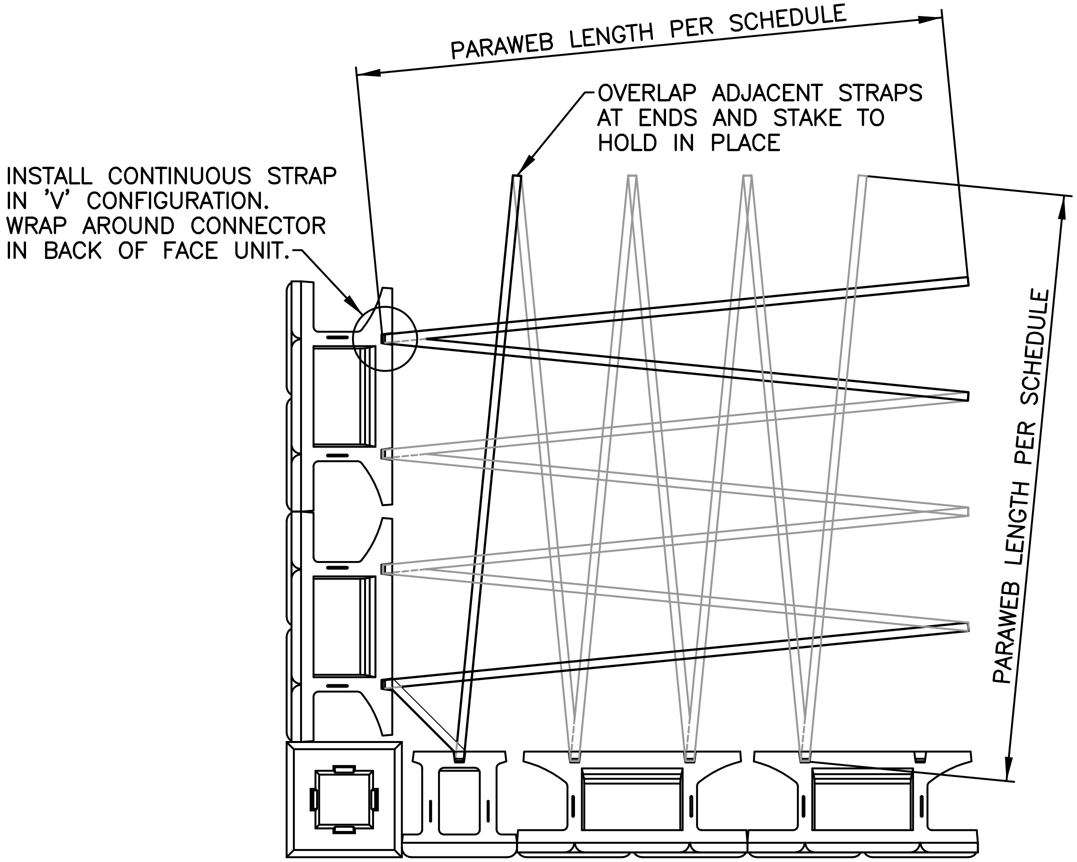
TYPICAL DETAILS
STONE STRONG SYSTEMS

DATE: 6/29/18 | FILE: 18_Typical Paraweb Layout



PARAWEB ON OUTSIDE CORNER

NOT TO SCALE

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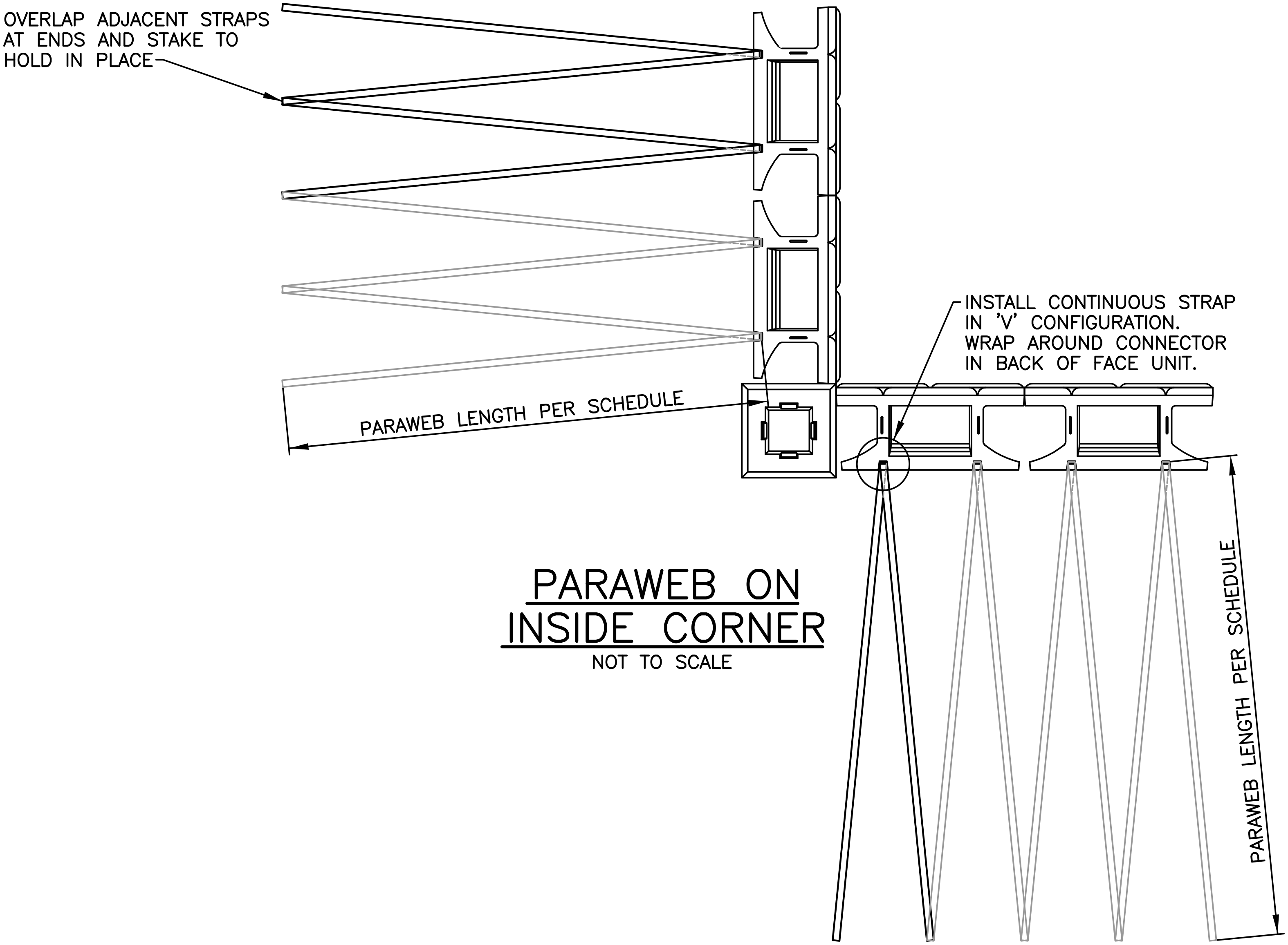
TYPICAL DETAILS
STONE STRONG SYSTEMS

DATE: 6/29/18 | FILE: 21_Paraweb.Outside Corner



PARAWEB ON INSIDE CORNER

NOT TO SCALE

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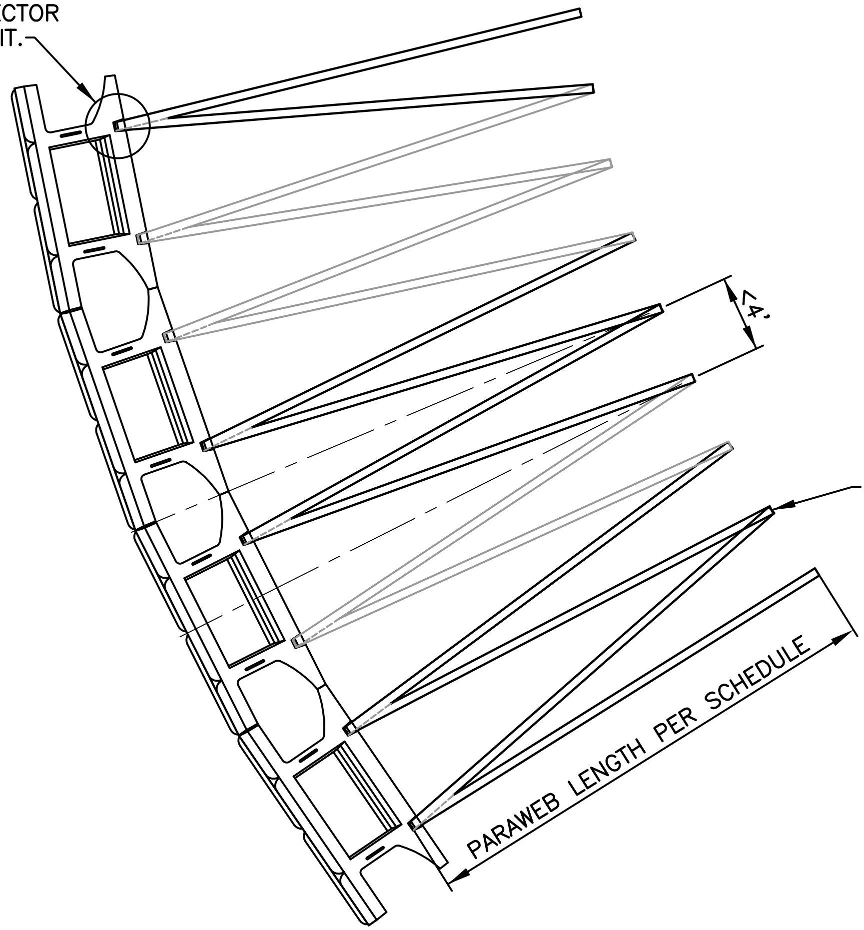
TYPICAL DETAILS
STONE STRONG SYSTEMS

DATE: 6/29/18

FILE: 22_Paraweb.Inside Corner

INSTALL CONTINUOUS STRAP
IN 'V' CONFIGURATION.
WRAP AROUND CONNECTOR
IN BACK OF FACE UNIT.



OVERLAP ADJACENT STRAPS
AT ENDS AND STAKE TO
HOLD IN PLACE

PARAWEB ON
LONG RADIUS CONVEX CURVE

NOT TO SCALE

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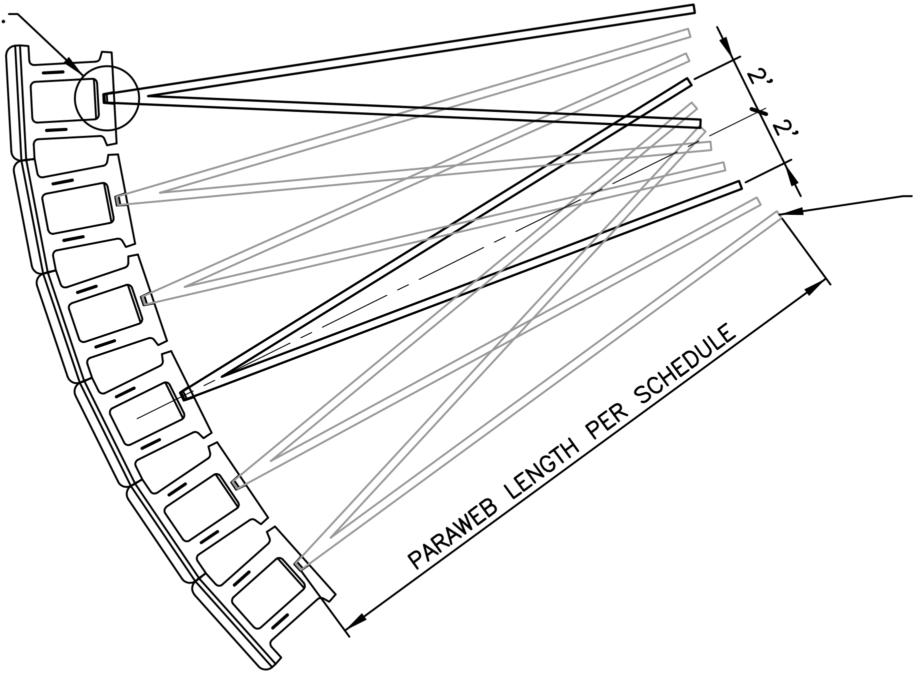
TYPICAL DETAILS
STONE STRONG SYSTEMS

DATE: 6/29/18
FILE: 23_Para.LgRad.Convex

INSTALL CONTINUOUS STRAP
IN 'V' CONFIGURATION.
WRAP AROUND CONNECTOR
IN BACK OF FACE UNIT.



STAKE ENDS TO
HOLD IN PLACE

NOTE:
USE THIS MODIFIED LAYOUT
WHEN CURVE RADIUS IS
LESS THAN PARAWEB LENGTH
PLUS 10 FEET

PARAWEB ON
SHORT RADIUS CONVEX CURVE

NOT TO SCALE

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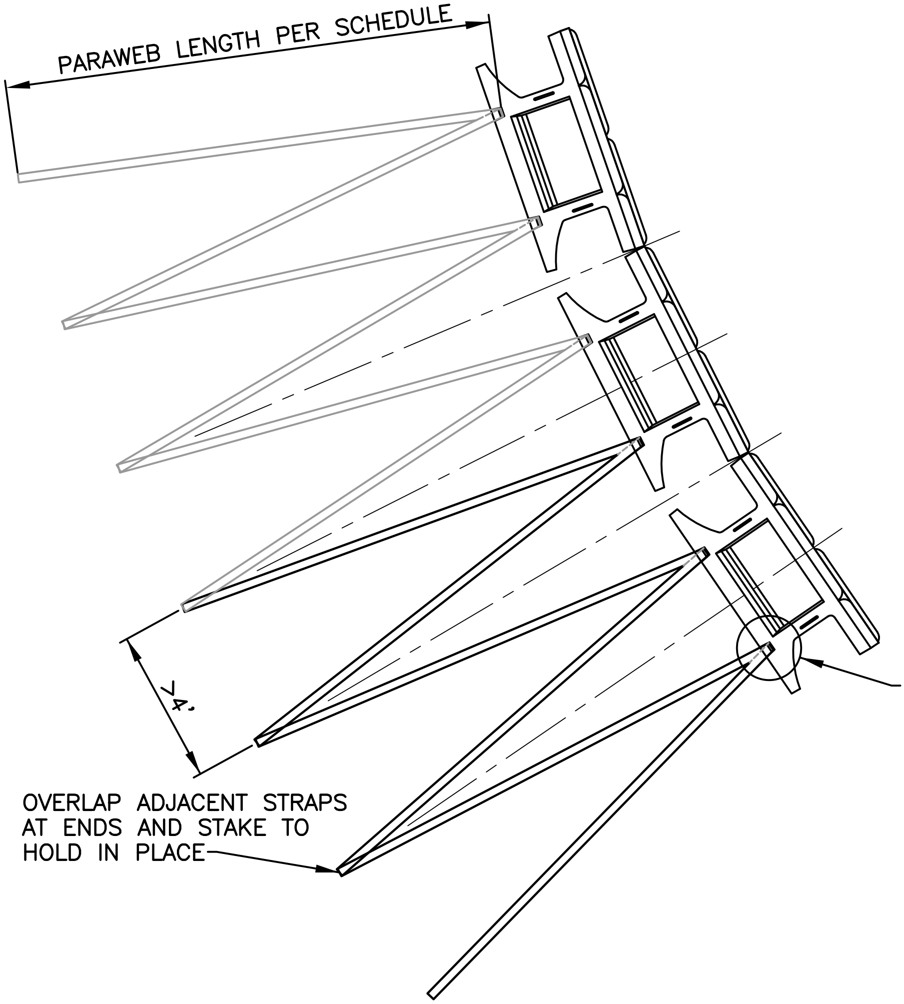
TYPICAL DETAILS
STONE STRONG SYSTEMS

DATE: 6/29/18
FILE: 24_Para.ShRad.Convex



PARAWEB ON CONCAVE CURVE

NOT TO SCALE

DISCLAIMER:

These typical details are preliminary and conceptual in nature. They are provided for general information purposes only. Anyone making use of these details and related information does so at their own risk and assumes all liability for such use. Site specific design should be performed by a licensed Professional Engineer based on actual site conditions, materials, and local practices.

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TYPICAL DETAILS
STONE STRONG SYSTEMS

DATE: 6/29/18
FILE: 25_Paraweb.Concave Rad

[jump to TOC]
[jump to Appendix TOC]

3.1.6 FACING ALIGNMENT

No attachments

jump to TOC

jump to Appendix TOC

3.1.7 BACKFILL PLACEMENT

No attachments

jump to TOC

jump to Appendix TOC

3.1.8 EROSION DURING CONSTRUCTION

No attachments

[jump to TOC](#)
[jump to Appendix TOC](#)

3.1.9 INSTALLER QUALIFICATIONS

No attachments

4.1.1 FACING PRODUCTION QUALITY CONTROL

Stone Strong QA/QC Manual

Quality Control and Quality Assurance Manual

Issue Date: 8/1/2008

Revised: 6/1/2020

Version 2.32

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info@stonestrong.com

QC/QA Manual for STONE STRONG Systems precast modular block retaining wall system.

TABLE OF CONTENTS

INTRODUCTION

This Quality Control and Quality Assurance Manual addresses Quality Control (QC) performed by licensed STONE STRONG Dealers and the role of Quality Assurance (QA) performed by STONE STRONG. This Manual presents roles and responsibilities, relationship of Quality Control and Quality Assurance functions, general information pertinent to Quality Control and Quality Assurance, and discusses Quality Control and Quality Assurance associated with manufacturing, design, and installation of STONE STRONG systems precast modular block (PMB) retaining walls.

Building structurally sound earthen retaining walls requires a high level of care and expertise. STONE STRONG is dedicated to the quality and performance of our wall system manufacturing components and precast modular blocks. Quality Control and Quality Assurance functions are vital to the success of our products.

IMPLEMENTATION TIMELINE

STONE STRONG implemented the QCQA Manual in 2008. As STONE STRONG has maintained a QCQA Manual since 2008, all active Dealers as of January 1, 2015 are required to have the Quality Control mechanisms discussed within this Manual in-place.

In the case of future Dealers, their Quality Control program(s) will be reviewed concurrently with the initial start visit and approval of being a Licensee. After the initial review and acceptance of the Dealer's programs, the Dealer will submit Quality Control documentation to STONE STRONG for review per the Dealer's Quality Control Submittal schedule presented in a later section of this Manual.

MANUAL VERSION

The last significant version of the STONE STRONG Quality Control/Quality Assurance Manual was Version 2.1, issued on September 15, 2009. STONE STRONG has adopted additions and revisions to the Quality Control/Quality Assurance Manual as revised on October 1, 2015 and identified as Version 2.3.

REFERENCED DOCUMENTS

The following STONE STRONG Manuals are referenced within the Quality Control Quality Assurance Manual. These documents can be provided by STONE STRONG Licensed Dealers. Additionally, these documents will be available on the STONE STRONG website at www.stonestrong.com.

- Stone Strong Production Manual
- Stone Strong Engineering Manual
- Stone Strong Field Construction Manual

RESPONSIBILITIES OF PARTIES

STONE STRONG

The STONE STRONG Quality Control/Quality Assurance program has been established to provide the Dealer (precaster licensee) with the proper tools and education to ensure the consistency and the quality of the Retaining Wall System.

STONE STRONG in its role as the patent holder and designer of the system is responsible to educate the Dealer (precaster licensee) to ensure that the system is produced within the tolerances permitted by STONE STRONG, project specific drawings and the STONE STRONG Production Manual. STONE STRONG shall use document control, plant start-up visits and periodic plant inspections to assure that the Dealer's Quality Control programs are being followed. STONE STRONG will:

- Evaluate each potential Dealer (precaster licensee) in terms of their plant, plans, facilities, existing plant quality control, plant certifications and fiscal strength. Review the potential Dealer's prior experience and reputation in the industry.
- Define the Dealer (precaster licensee's) responsibilities and obligations in terms of the License Agreement.
- Issue an Agreement which conveys particular performance functions to the licensee and grant access to the precaster licensee's plant and quality control information.
- Review with the precaster licensee:
    - The standard drawings and specifications to assure understanding of the drawing nomenclature and the various system components.
    - The Production Manual to assure understanding of the required testing and inspection procedures, casting techniques and quality control.
    - The qualified material sources from which to order the specified system components.
- Review monthly production reports.
- Periodically review concrete break reports and testing certifications.
- A STONE STRONG representative or a trained Dealer licensee representative is on site at the start of each project to assure compliance with project specifications and the Installation Manual and trains the Contactor and his crew in the proper techniques of construction.
- Visit each new Dealer licensee for a start-up visit to assist the precaster licensee in setting up the manufacturing operation and makes periodic follow up visits to each licensed plant. The STONE STRONG representative's role is to assure that the precast modular block is

manufactured in accordance with specifications and to verify that the established procedures are being adhered to.

- For established Dealers, STONE STRONG or their designee may conduct plant visits and oversight. The frequency of reoccurring visits/oversight will be determined by STONE STRONG based on the Dealer's performance, documentation reviews, periodic Quality Control submittals, and history of complaints and nonconformances

STONE STRONG LICENSED DEALERS

STONE STRONG Licensed Dealers will produce precast modular blocks following the most current version of the STONE STRONG Systems Production Manual at the time of manufacturing. The Dealer is responsible for the manufacturing of the STONE STRONG systems precast modular blocks and to ensure that units meet the dimensional tolerances and materials specifications as required by STONE STRONG. Dimensional tolerances are defined within the QC/QA Manual. Materials specifications are found in a standalone STONE STRONG document, the *Manufacturing Specifications for Precast Modular Block retaining Wall System.*

Updates to STONE STRONG Manuals will be distributed either by mail or by email. Updates sent via email will be sent in PDF format. Dealers will be required to sign and return an acknowledgment form noting the receipt of updates to Manuals.

Licensed Dealers also may assist the engineer, owner, contractor and inspectors in scheduling of materials, construction procedures, contract documents, plans, and specifications. The STONE STRONG Dealer shall not be responsible for means or methods of design, construction or for safety of workers or of the general public.

STONE STRONG Dealers can be available to assist and train contractors and inspectors as requested and as necessary. Dealers may also refer interested parties to the STONE STRONG Quality Assurance Officer for additional information, technical support, and resource materials. To support our Dealers, the STONE STRONG website provides numerous resources on our components, design considerations, and installation guidelines.

STONE STRONG Dealers shall have product liability insurance and will provide Certificates of Insurance annually to STONE STRONG. The required limits of insurance coverage shall be 2 Million each occurrence and 2 Million aggregate per the License Agreement.

SUPPLIERS OF MATERIALS TO DEALERS

Materials Suppliers will be responsible for materials delivered and utilized to manufacture STONE STRONG precast modular blocks. Materials Suppliers materials may include: Ready Mixed Concrete, wire or reinforcing steel, aggregates, Portland cement, or other materials utilized in the manufacturing of the precast modular blocks. Material suppliers will provide STONE STRONG Dealers with materials test data and or statements of conformance to specifications. Test data and or statements of conformance will be submitted to STONE STRONG Dealers at the intervals presented in later sections of this Manual.

Materials Suppliers will provide STONE STRONG Dealers with Certificates of Insurance. The coverages shall include Workers Compensation and Product Liability.   The required limits of coverage shall be 1 Million each occurrence and 1 Million in aggregate coverage.

ENGINEER OR OWNER'S REPRESENTATIVE

The Engineer or Owner's representative is responsible for the preparation and enforcement of the wall construction contract documents, plans, and specifications. STONE STRONG recommends that the Engineer or Owner employ services of a geotechnical/materials engineering firm to provide Quality Control testing during embankment construction and backfilling operations. It is further recommended to employ an Engineer or inspection firm to document installation procedures and conformance of the installed system to the plans and specifications. The Engineer and Owner shall not be responsible for means or methods of manufacturing, construction or for safety of workers or of the general public.

INSTALLATION CONTRACTOR

Installation Contractors shall follow shop drawings or construction procedures and recommendations cited in the most current version of STONE STRONG's *Field Construction Manual* at the time of installation. The Installation Contractor is responsible for checking materials upon delivery to assure that proper materials have been received. Contactors will protect materials from damage. Damaged materials shall not be incorporated into the wall or reinforced soil embankments, and should be disposed of properly off site. Furnishing and installing STONE STRONG precast modular blocks to the lines and grades shown on the plans and as specified is the responsibility of the Installation Contractor. The Installation Contractor is responsible for proper embankment, construction, placement in fill materials, backfilling and localized drainage control. The contractor is solely responsible for site safety.

QUALITY CONTROL AND QUALITY ASSURANCE OVERVIEW

QUALITY CONTROL ROLE - DEALERS

Quality Control refers to the quality related activities associated with manufacturing of the precast modular blocks. Quality Control is used to monitor and document that the precast modular blocks are manufactured to meet specified quality requirements. Quality Control functions will focus on monitoring, auditing, and improving the manufacturing process. STONE STRONG Dealers will implement their own internal Quality Control systems and provide documentation of Quality Control activities to STONE STRONG. Dealer's Quality Control documentation must be acceptable to the standards presented within this Manual.

STONE STRONG Dealers may utilize documents presented within this or other STONE STRONG Manuals, may develop their own documentation formats, or may follow accepted QC programs developed by organizations such as the National Precast Concrete Association (NPCA), the Precast/Prestressed Concrete Institute (PCI), the Pre-Cast Concrete Association of America **(**PCA), or similar national or regional organizations.

QUALITY ASSURANCE ROLE – STONE STRONG

STONE STRONG or their designee will act as the Quality Assurance reviewer. The role of Quality Assurance is intended to further review and document product quality, support Dealer's Quality Control systems, and improve manufacturing processes related to the product.

Quality Assurance will focus on reviews of the Dealer's plant certifications, personnel certifications, form and liner inspections, Quality Control records, materials test data, manufacturing documentation, addressing technical complaints, and installation monitoring. The role of Quality Assurance by STONE STRONG will also include product research and development, product improvements, and design modifications. Quality Assurance will include emphasis on reviewing each Dealer's Quality Control activities and related documentation through a periodic Dealers' Quality Control submittal and Quality Assurance review process.

DEALER'S QUALITY CONTROL SUBMITTALS

ANNUAL SUBMITTAL SCHEDULE

Each STONE STRONG Dealer will be assigned a deadline date to submit an **ANNUAL** summary of the Dealer's Quality Control documentation to STONE STRONG for Quality Assurance review. The required items for the ANNUAL submittal are presented in later sections of this Manual. A Quality Assurance response will be issued by STONE STRONG within 30 business days from receipt of the Dealer's Annual Submittal.

FORMAT OF ANNUAL SUBMITTAL

STONE STRONG Dealers are required to submit Quality Control documentation for Quality Assurance Review. Dealers may utilize forms or formats developed in-house, developed by other organizations or agencies, or utilize the generic forms provided by STONE STRONG. It is not the intent herein to specify specific forms and formats, but to provide a general overview of STONE STRONG's expectations for the Dealer's Quality Control submittal. The Dealer's Quality Control submittal must include the items identified in later sections of this Manual.

CERTIFIED PLANT STATUS

If a Dealer is a member firm of and is operating a Certified Plant through an organization such as the National Precast Concrete Association (NPCA) or other nationally or regionally recognized organization or program, the Dealer is required to submit copies of their inspections or assessments to STONE STRONG as part of their annual submittal.

It is important to understand that the contents of the Quality Control submittal differs significantly depending on if the Dealer is a member of the NPCA, or another organization considered equivalent by STONE STRONG, and the Dealer's Plant Certification status. **STONE STRONG highly encourages its Dealer's to achieve an acceptable plant certification.** To determine if an organization will be considered equivalent to the NPCA, contact the STONE STRONG Quality Assurance Officer.

The following are examples of Plant Certifications deemed acceptable by STONE STRONG. The plant certification must be in active status. A copy of the plant certification must be provided and the certification shall be on letterhead or certificate form with the certification agency name provided.

- National Precast Concrete Association (NPCA)
- Precast Concrete Institute (PCI)
- State Department of Transportation (DOT)
- State Department of Roads (DOR)

The Dealer's Quality Control annual submittal package shall follow one of the two following formats. One format is for Dealers with their production facility currently certified by an organization or agency deemed acceptable by STONE STRONG. A second format is for Dealer's production facilities lacking any approved production facility certification status. The production facility certification must be for the facility producing STONE STRONG units, not an affiliated location.

QC SUBMITTAL PACKAGE FOR CERTIFIED PLANTS

FOR DEALERS WITH NPCA OR EQUIVALENT PLANT CERTIFICATION the QUALITY ASSURANCE REVIEW SUBMITTAL PACKAGE CONTENTS shall include:

ANNUAL SUBMITTALS

PROOF OF PLANT CERTIFICATION

- Submit copies of most current inspection or assessment
- Submit documentation stating certification status is current.

FORMS, LINERS AND RELATED INVENTORY & POLICIES

- Inventory of all molds (forms) and liners, both in-service and out-of-service
- Provide copies of:
    - Mold (form) removal from service records
    - Mold (form) and liner maintenance records, policies and programs
    - Mold (form) and liner storage policies and procedures for system components
    - Records of nonconformances

INSTALLATION MONITORING

- A brief written summary of at least two projects completed within the most recent 12 months. If two or less projects have been constructed, this section may be omitted.

PRODUCTION RELATED TECHNICAL COMPLAINTS

- Provide a brief written summary or copies of any technical complaints related to the manufacturing process.

INSURANCE COVERAGE

- Provide a Certificate of Insurance

QC SUBMITTAL PACKAGE FOR NON-CERTIFIED PLANTS

FOR DEALERS WITHOUT NPCA OR EQUIVALENT PLANT CERTIFICATION the QUALITY ASSURANCE REVIEW SUBMITTAL PACKAGE CONTENTS shall include:

ANNUAL SUBMITTALS

FORMS, LINERS AND RELATED INVENTORY & POLICIES

- Inventory of all molds (forms) and liners, both in-service and out-of-service
- Provide copies of:
    - Mold (form) removal from service records
    - Mold (form) and liner maintenance records, policies and programs
    - Mold (form) and liner storage policies and procedures for system components
    - Records of nonconformances

INSTALLATION MONITORING

- A brief written summary of at least two projects completed within the most recent 12 months. If two or less projects have been constructed, this section may be omitted.

PRODUCTION RELATED TECHNICAL COMPLAINTS

- Provide a brief written summary or copies of any technical complaints related to the manufacturing process.

INSURANCE COVERAGE

- Provide a Certificate of Insurance

SUPPORTING DOCUMENTATION - QUALITY

- *Records of Quality Control personnel training and certifications*
- *Certificates of calibration or verification of testing and reference equipment*

SUPPORTING DOCUMENTATION - MANUFACTURING / PRODUCTION

- *Policies for curing and handling*
- *Post pour inspection forms*
- *Records of non-conformances – units damaged, destroyed or repaired*

SUPPORTING DOCUMENTATION – LOADING / TRANSPORT / UNLOADING

- *Dealers handling & transport procedures*
- *Precast modular blocks damaged or destroyed*

Above items presented in *italics* are those items in additional to the minimum submittal requirements for certified plants.

SUPPLEMENTAL SUBMITTALS

STONE STRONG **may request** any of the below Quality Control documentation **at its discretion at any time.** All Dealers should perform the below indicated Quality Control measurements and record keeping and have this information available for review. These items may be requested in addition to the Dealer's annual submittal or at periodic unannounced intervals.

QUARTERLY SUBMITTALS

FORMS, LINERS AND RELATED provide copies of:

Items	Inspect for	Frequency
Mold (form)	Dimensions, Condition & Compliance with Tolerances	Quarterly – all units
Mold (form) – Short Doors	Straightness & Compliance with Tolerances	Quarterly – all units
Mold (form) – Long Doors	Straightness & Compliance with Tolerances	Quarterly – all units
Liners	Dimensions & Condition	Quarterly – all units
Lifting Loops	Dimensions & Condition	As Received - Min. 10 units from each shipment

MONTHLY SUBMITTALS

FORMS, LINERS AND RELATED provide copies of:

Items	Inspect for	Frequency
Random Block Checks	Dimensions	Weekly - Min. of 2 blocks of each size being cast

SUPPLEMENTAL INFORMATION

- Results of air content, slump, unit weight, and compressive strength testing
- Welded wire or block mesh – manufacturer's production Quality Control
- Records of non-conformances

EQUIPMENT OUT OF SERVICE

If the STONE STRONG production molds, liners, and related components required to produce STONE STRONG precast modular blocks were not utilized during a calendar quarter, the DEALER shall record on all pertinent inspection records that these ITEMS WERE REMOVED FROM SERVICE during this time period.

Any specified Annual inventories and other Quality Control monitoring and documentation will still be required.

REVIEW OF DEALER’S QC SUBMITTALS

These submittals and reviews are not intended to be an economic or time burden to our Dealers. Our intentions are to assure the quality of the deliverable product, to improve the product and to protect the product image, brand, and name.

QC SUBMITTAL REVIEWER

STONE STRONG Dealers are required to submit Quality Control (QC) documentation to a designated STONE STRONG reviewer. Submittals should be directed to STONE STRONG to the attention of the Quality Assurance Officer. STONE STRONG may assign Dealers different submittal reviewers at their discretion.

QA REVIEW RESPONSE

STONE STRONG will review the Dealer’s Quality Control submittal and respond with any comments, requests for additional information, and or required corrective actions. The STONE STRONG response will be issued within 45 days of receipt of the Dealer’s Quality Control submittal.

DEALER CORRECTIVE ACTIONS

If the Dealer is requested to perform corrective actions and or submit additional materials for review to STONE STRONG, the Dealer’s responses and supporting documentation must be submitted within 30 days the date of the response letter issued by STONE STRONG. Any further resolution and correspondence of outstanding issues will be issued specific dates for final resolution on a case by case basis.

DISCRETIONARY AUDITS

STONE STRONG reserves the right to conduct Quality Control and production quantity audits at their sole discretion. Discretionary Quality Control and production quantity audits may be performed by STONE STRONG or their designee.

QUALITY CONTROL PERSONNEL & METHODS

QC PERSONNEL CERTIFICATIONS

Dealer's Quality Control technicians will be certified to perform concrete sampling and testing. Certifications for Quality Control personnel and materials testing technicians shall be acquired through nationally, regionally, or locally recognized programs. Organizations providing certification programs include the American Concrete Institute (ACI), the National Institute for Certification in Engineering Technologies (NICET), and Departments of Transportation. To determine if a certification organization or program other than those identified will be considered as acceptable, contact the STONE STRONG Quality Assurance Officer.

The American Concrete Institute (ACI) offers several applicable certification programs for testing technicians working with concrete materials and precast products. Some of the certification programs offered by the American Concrete Institute (ACI) are shown below, as examples of certifications available. STONE STRONG recommends that concrete sampling and testing technicians obtain ACI Concrete Field Testing Technician Grade I status or an equivalent at a minimum.

- **ACI Aggregate Technician Certification Program**
  - Aggregate Testing Technician - Level 1
- **ACI Craftsman Certification Program**
  - Concrete Flatwork Finisher/Technician
- **ACI Field Technician Certification Program**
  - Concrete Field Testing Technician - Grade I
- **ACI Inspector Certification Program**
  - Concrete Construction Special Inspector
- **ACI Laboratory Technician Certification Program**
  - Concrete Laboratory Testing Technician - Level 1
  - Concrete Strength Testing Technician

TRAINING PROGRAM FOR DEALER QC TECHNICIANS

In addition to being certified to perform materials testing, Dealer’s Quality Control testing technicians shall be trained in regards to the Dealer’s specific forms and procedures prior to performing tests not previously performed. The following training procedures shall be followed for each test. The Dealer is responsible for technician training per their procedures.

- The trainee shall obtain a copy of the most current applicable test method procedures and test data report forms.
- The trainee shall study the test procedures and test report forms to become familiar with the equipment, terminology, test procedures, calculations and test reports.
- A certified technician shall demonstrate the test procedures for the trainee.
- The trainee shall repeatedly perform the test procedures under the direction of the certified technician until the desired degree of proficiency is achieved.
- A certified technician or supervisor shall observe the trainee demonstrating the procedure(s) and document that the trainee has successfully demonstrated the ability to perform the test procedure(s), if it is performed properly, by making an entry in the trainee's training records.

QUALITY CONTROL TEST METHODS

The following table presents the testing methods that will be utilized for testing concrete, aggregates, Portland cement, wire reinforcement or other raw materials. It is preferred to utilize the ASTM test methods, but either the ASTM or AASHTO methodologies are acceptable for Quality Control testing. Always reference the most current version of the test methods being utilized.

ASTM	AASHTO	Materials	Description
C31	T23	Concrete	Making/Curing Concrete Test Specimens in Field
C39	T22	Concrete	Compressive Strength of Cylindrical Concrete Specimens
C42	T24	Concrete	Obtaining and Testing Drilled Cores or Sawed Beams
C138		Concrete	Unit Weight, Yield and Air Content (Gravimetric) of Concrete
C143	T119	Concrete	Slump of Concrete
C172	T141	Concrete	Sampling Freshly Mixed Concrete
C173		Concrete	Air Content by Volume Method
C192		Concrete	Making/Curing Concrete Test Specimens in Laboratory
C231	T152	Concrete	Air Content by Pressure Method
C617		Concrete	Capping of Cylindrical Concrete Specimens
C1064		Concrete	Temperature of Concrete
C1231		Concrete	Use of Unbonded Caps - Compressive Strength
C29	T19	Aggregates	Unit Weight and Voids of Aggregate
C40	T21	Aggregates	Organic Impurities in Sands for Concrete
C117	T11	Aggregates	Amount of Material Finer than 0.075-mm Sieve
C127	T85	Aggregates	Specific Gravity and Absorption of Coarse Aggregate
C128	T84	Aggregates	Specific Gravity and Absorption of Fine Aggregate
C136	T27	Aggregates	Sieve Analysis of Fine & Coarse Aggregate
C566	T255	Aggregates	Total Moisture Content of Aggregate by Drying
C702	T248	Aggregates	Reducing Field Samples of Aggregate to Testing Size
C150	M85	Cement	Portland Cement
A82	M32	Reinforcement	Steel Wire, Plain, for Concrete Reinforcement
A184	M54	Reinforcement	Deformed Steel Bar Mats for Reinforcement
A185	M55	Reinforcement	Steel welded wire fabric
A123	M111	Reinforcement	Zinc (hot-dip galvanized) coatings on steel
A496	M225	Reinforcement	Steel Wire, Deformed, for Concrete Reinforcement
A615	M31	Reinforcement	Deformed & Plain Billet Steel Bars for Reinforcement
D3963	M284	Reinforcement	Epoxy Coated Reinforcing Steel

QUALITY SYSTEMS RECORDS RETENTION

The minimum recommended retention periods for various Dealers’ Quality Control documentation retention timeframes are shown in the following table.

Test Equipment Calibrations/Verifications	5 years minimum
Form, Block Insert & Liner Inventories & Condition Assessments	5 years minimum
Inspections by Outside Organizations or Agencies	5 years minimum
Post Pour Inspections	5 years minimum
QC Personnel Training & Certifications	5 years minimum
QC Testing Records	5 years minimum

PROCEDURES FOR HANDLING TECHNICAL COMPLAINTS

A technical complaint is a real or perceived issue that could result in adverse performance of an individual precast modular block or a completed installed system. A technical complaint is defined as an issue occurring between the start of the manufacturing process and lasting through the life of the installed system.

Upon receipt of a manufacturing technical complaint at the Dealer level, the following actions shall be taken as Quality Control by the Dealers:

- The Dealer's Quality System Manager shall be notified orally or by written statement.
- The Complaint is brought to the attention of the Supervisor of the department or section in question by the Quality Control System Manager.
- A designated representative at the Dealer will contact the complainant to verify aspects of the complaint and establish a resolution date, if necessary.
- Review reports, records and pertinent data. Review calculations for accuracy.
- A designated representative shall formulate an appropriate reply and issue it to the complainant, in either verbal or written form, preferably both.
- The Dealer will notify the STONE STRONG Quality Control Officer of the complaint, the key factors associated with the complaint, any pertinent QC documentation and the resolution.
- STONE STRONG can assist in the resolution process, if requested by the Dealer.

QUALITY CONTROL OF MANUFACTURING

STONE STRONG Systems is dedicated to overall quality and performance, to assure that the wall system will perform to the requirements of the project.

STONE STRONG Manufacturers Shall:

- Be a licensed dealer.
- Have knowledge and experience in processes necessary to manufacture precast modular blocks.
- Have a thorough understanding of the STONE STRONG system.
- Have proper equipment and adequate labor to manufacture the STONE STRONG system.
- Directly employ or subcontract personnel certified to perform materials testing services.

Proper manufacturing techniques should include the following:

- Conformance with the most current version of the STONE STRONG Production Manual as available at the time of production.
- Sample and test concrete in compliance with the most current version of either AASHTO's Standard Specifications for Transportation and Methods of Sampling and Testing or the most current applicable versions of ASTM testing methodologies.
- Block should be clearly marked with the date of manufacture and as required by project specifications.
- Record and keep on file for future reference each day's production to include mix design, date of manufacture.
- Check tolerances of the forms and blocks per the previous identified inspection intervals and record for compliance with specifications. Tolerances should be recorded and kept on file for future reference.
- Check liners on a monthly basis to ensure proper fit when the mold door is closed. Liners shall meet the same specifications as above in areas effecting critical dimensions.
- Cleaning forms prior to pouring product. It is recommended to use steel wool for removal of any residual concrete prior to each pour and power wash entire form monthly.
- Installing lift/alignment loops manufactured to the materials specifications in accordance with the STONE STRONG Production Manual.
- Handling and storage of units in accordance with the STONE STRONG Production Manual.

SPECIFIED TOLERANCES

- **Form Tolerances**
  - ± 1/8 inch across side doors and end doors
  - ± 1/8 inch at side door stops
  - ± 1/8 inch at squaring pins on side doors
  - ± 1/16 inch at door hinge pins

- **Block Tolerances**
  - ± 1/8 inch in height
  - ± 1/8 inch in length
  - ± 1/8 inch differential from plane across the top and base of unit
  - Minus 1/4 inch to plus 1/2 inch maximum width (face to tail)

Note: When using Paraweb, refer to pgs.25-28 of Stone Strong's "Typical Detail" library for placement of connection inserts.

STONE STRONG or their representative will provide the following:

- Technical assistance to the manufacture at their request
- Production Manual
- Engineering Manual
- Field Construction Manual
- Maintenance Guide

ADDRESSING NON-CONFORMANCES

A nonconformity is any raw materials deficiency, any damage that occurs from normal handling/storage, and/or exceeding the tolerances as described within the Form and or Block tolerances section in the Quality Control of Manufacturing section of this Manual.

When a nonconformity is detected it must be documented in writing. Nonconformance documentation may include photographs, specific observations, measurements, test data, or other data. The Dealer shall document the nonconformity and submit documentation to STONE STRONG for review within 5 days of becoming aware of the nonconformity.

The Dealer will investigate and attempt to define how long the nonconformity has existed and the production output that may be affected. If more than a single unit is expected to have a related nonconformity, the Dealer will inspect the production run in question. Furthermore, the Dealer will attempt to define the impact of the nonconformity. The impact could include effects of product nonconformity on wall system performance in terms of durability or structural capacity, changes in product manufacture, and product liability concerns.

The Dealer shall consider the factors that allowed the nonconformity to exist or occur. Consider the possible casual factors in regards to what sequence of event(s) lead to the nonconformity, what conditions allowed the nonconformity to occur, what other nonconformities may surround the occurrence of the central nonconformity. Then identify the root causes for causal factors to exist and the reason(s) the nonconformity occurred.

After indentifying the root cause of the nonconformity, recommend and implement solutions to resolve the root causes of the nonconformity. Identify what can be done to prevent the nonconformity from happening again. In addition, consideration shall be given to what improvements to the Dealer's Quality Control system can be implemented to prevent a similar nonconformity. Document the plan to monitor the effective implementation of the corrections and or improvements. The Dealer will identify in writing how and when the resolution will be implemented, who will be responsible for it, and what the risks of implementing the solution are.

QUALITY CONTROL OF DESIGN

STONE STRONG Systems is dedicated to overall quality and performance to assure that the wall system will perform to the requirements of the project. The Design Engineer shall be able to demonstrate and document experience with earth retaining systems design. STONE STRONG will be available to provide additional support for assessing the Design Engineer's ability to design earth retaining systems utilizing the STONE STRONG precast modular blocks. Furthermore, STONE STRONG Design software is available to licensed engineers to assist in wall design of gravity retaining walls. The engineer of record is responsible for conforming to customary engineering standards.

The Design Engineer shall:

- Be a licensed engineer in the state of the project.
- Have knowledge and experience in the process necessary to design precast modular block retaining walls.
- Have a thorough understanding of the STONE STRONG system.
- Have knowledge of local codes as they pertain to the process necessary to design precast modular block retaining walls.
- Be familiar with the requirements of the AASHTO Standard Specifications for Bridge Construction and FHWA-NHI-00-043, or other relevant design standards.
- Be familiar with the STONE STRONG System Engineering Manual.
- Be familiar with the most current version of the STONE STRONG Systems Field Construction Manual.
- Be solely responsible for the design of the individual walls issued under his/her seal.
- Provide a Certificate of Insurance to the Dealer manufacturing the precast modular blocks (does not apply if engineer is retained by owner or contractor).
- Provide a complete set of calculations showing how the wall meets design criteria and AASHTO or other relevant safety factors. External design should be evaluated at each critical section of the wall, including different boundary and loading conditions. Internal design should be evaluated at each critical section for each change in size of units (stepped modules) and for each module layer where the wall is subjected to lateral loading at the top of the wall or to seismic load conditions. Global stability may or may not be the responsibility of the wall engineer. Responsibility for global stability shall be noted within the drawings.
- Provide drawing review and design review checklists to the dealer (does not apply if engineer is retained by owner or contractor).

Design Review

- The wall design shall be reviewed by at least one qualified engineer other than the engineer of record.
- In cases where STONE STRONG or STONE STRONG Dealers have control or employ the Design Engineer, STONE STRONG may elect to perform a Quality Assurance review of the Design.
- In cases when the Design Engineer is employed by others, the Design Engineer may request a design review by approved STONE STRONG Dealers or Engineers recommended by STONE STRONG Systems.
- A design review checklist shall be submitted to the dealer along with the wall drawings and calculations.

STONE STRONG Systems or their representative will provide the following:

- Technical assistance to the design engineer at their request
- Engineering Manual
- Construction Details
- Field Construction Manual
- Maintenance Guide
- Gravity Analysis Software
- Quality Assurance review of design plans as described above

QUALITY CONTROL OF CONSTRUCTION

STONE STRONG Systems is dedicated to overall quality and performance to assure that the wall system will perform to the requirements of the project. The wall system Installation Contractor shall be able to demonstrate and document experience with earth retaining systems installation or demonstrate the ability to install system components with conformance to the most current version of the STONE STRONG Systems Field Construction Manual at the time of installation to the Owner. Licensed STONE STRONG Dealers shall be capable of reviewing an Installation Contractor's ability to install system components. STONE STRONG will be available provide additional support for assessing an Installation Contractor ability to install STONE STRONG precast modular blocks.

Contractor shall:

- Have knowledge and experience in the process necessary to construct precast modular block retaining walls.
- Have knowledge of local codes as they pertain to the installation of precast modular block retaining walls.
- Have a thorough understanding of the project site conditions.
- Review and have an understanding of the project plans and shop drawings.
- Have the proper equipment and adequate labor to assure proper installation of the wall.

Proper installation techniques should include the following:

- Blocks should be inspected prior to installation for quality.
- Excavation of the foundation to line and grade.
- Construction of the wall base to line and grade including compaction and quality control testing.
- Installation of the base course to line and grade. Care should be taken to assure that the base course is level side-to-side and front-to-back. Contractor shall verify base course before processing to next course.
- Installation of each course to assure that it is set to the proper line and grade.
- Grade the site at the end of each day's work so that runoff will be diverted from the wall construction.
- Cleanup site and dispose of excess construction materials at the completion of the installation.
- Site shall be graded as per the plans and verified by the engineer prior to completion of the project.

STONE STRONG Systems or their representative will provide the following:

- Technical assistance to the contractor at their request.
- Field Construction Manual
- Engineering Manual
- Construction Details
- Maintenance Guide

GLOSSARY

AASHTO - American Association of State Highway and Transportation Officials - advocates transportation-related policies and provides technical services in the form of standard specifications for highways and bridges.

ASTM - American Society of Testing and Materials - ASTM International is one of the largest voluntary standards development organizations in the world-a trusted source for technical standards for materials, products, systems, and services.

Contractor - The organization or individual that contracts with another organization or individual (the owner) for the construction of the retaining wall.

Design Engineer – The Engineer of record responsible for the actual design of the retaining wall. The Design Engineer may be the Project Engineer retained by the owner or may be retained by the Stone Strong Dealer or the Contractor to prepare shop drawings to meet the performance requirements established by the owner.

Federal Highway Administration (FHWA) - FHWA-NHI-00-043 Standard Specification.

Manufacturer - See STONE STRONG Dealer.

National Precast Concrete Association (NPCA) - represents manufacturers of plant produced precast concrete products and companies that provide the equipment, supplies and services to make these products.

Owner - The owner of the project for whom a contract has been made for the payment for the work performed under the terms of the contract.

Project Engineer - The owners designated organization or individual with authoritative charge over engineering functions and responsibilities.

Shop Drawings - is a drawing or set of drawings that show details of installations for the contractor

Specifications – STONE STRONG Standard Specifications

STONE STRONG Dealer - Dealer is responsible for the manufacturing of the STONE STRONG systems precast modular block and to ensure that it meets the minimum specifications as required by STONE STRONG. They also may assist the project engineer, owner, and contractor and inspectors in scheduling of materials, construction procedures, contract documents, plans and specifications. The Dealer shall be available to assist and train contractor and inspectors as requested and necessary.

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4.1.2 REINFORCEMENT MANUFACTURE QUALITY CONTROL

Manufacturers Quality Control for Paraweb Reinforcement

Manufacturers Quality Control for ParaWeb Reinforcement

Zwick tensile test machine

RESPONSIBILITY & AUTHORITY

The Geosynthetic Manufacturing Quality Control (MQC) Program is administered by the Manufacturing Manager. It shall be the responsibility of the managers of the laboratory data to adhere to this document at each of the individual plant.

The Manufacturing Manager has the responsibility for the quality of the geosynthetic products produced both internally and externally.

YARN

Consignments of high tenacity polyester yarn is shipped to our manufacturing facility and is accompanied by a certificate of analysis. Each consignment is certified by the manufacturer to meet or exceed physical properties in the certificate of analysis. MSDS sheets are also required from all suppliers for each shipment of yarn received into the facility.

Internal yarn testing is carried out when required.

MANUFACTURING PROCESS

The Manufacturing Department and staff work closely with the Technical staff, MQC and Engineering Department to ensure only first quality material is produced.

Statistical Process Control is the responsibility of the manufacturing manager during the manufacturing operations

During the Manufacturing operation for each production run production operatives complete a production process control record. All process changes are carefully recorded and monitored by manufacturing personnel. A database of all process conditions is maintained for reference. Manufacturing personnel continually monitor production lines for visual defects in the product. All process conditions are monitored to ensure run to run consistency. All Manufacturing jobs and processes are carried out in accordance with the written procedures.

The QA/QC group constantly monitors product property conformance. In case of non-conforming product, the manufacturing group is notified immediately. Both departments work together in solving the problem. The control of non-conforming products is done in accordance with written procedures to ensure proper labeling, segregation, and disposal.

QUALITY CONTROL TESTING

Linear Composites Limited products will meet or exceed the sampling frequency requirements for physical properties outlined in EN ISO 10319:2008 Geosynthetic Wide Width Tensile Test. All samples are taken and tested in accordance with written procedures. Products are regularly sent to independent third party laboratories for quality assurance testing. Non-conformities located during quality control tests are controlled in accordance with written procedures to ensure proper labeling, segregation, and disposal.

Linear Composites is accredited to the EN ISO 9001:2008 Quality Management System and the OHSAS 18001:1999 Occupational Health and Safety Management System

ParaWeb conforms to CE marking standards for the European Construction Products Directive for Geotextiles.

ParaWeb™

The Quality Manager/Laboratory Supervisor is responsible for the QC/QA program at the manufacturing plant. Under their direction, the staff laboratory technicians test the following physical properties:

Testing frequencies for ParaWeb™ High strength geogrids

Property	Units	Test Method	Frequency
Tensile strength	kN	ISO 10319:2008	TPS[1]
Elongation	%		
Mass per unit Length	Kg/100m	Internal test method	TPS[1]
Product width	mm	Internal test method	TPS[1]
Length	Metres	Internal test method	TPS[2]

[1] *TPS = 3 - times per Shift*

[2] *TPS = Once per Shift*

RECORD KEEPING AND DOCUMENT CONTROL

All quality assurance data is maintained on the computer databases, making historical information easily accessible. Data acquisition programs ensure minimal data entry error. Procedures are maintained for the identification, collection, indexing, filing, storage maintenance, and disposition of all records.

Third party lab testing is performed when required to ensure quality.

PACKAGING

Completed coils are palletized and stretch wrapped as per the customer requirements. Each coil has a label applied with appropriate information in order to facilitate product identification. Using this information, we are able to trace the ParaWeb back to the raw materials used during production and the time and date the roll was produced.

All packaging processes are done in accordance with written procedures and/or packaging specifications.

CERTIFICATION

Linear Composites Limited can provide certification letters for finished and delivered product when requested by the customer. The standard certification includes a letter of certification covering the product shipped on a particular bill of lading. Actual QC test data for specific coils can be provided at the time of shipment, when requested. Requests for letters of compliance and certifications should be addressed to Commercial Dept.

REFERENCES

- ‘Process Control – ParaWeb Extrusion’, *Linear Composites (Internal Work Instruction).*
- ‘Statistical Process Control ’, *Linear Composites (Internal Work Instruction).*
- ‘Test Manual’, *Linear Composites (Internal Work Instruction.)*

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4.1.3 CONNECTION MANUFACTURE QUALITY CONTROL

No attachments

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4.2.1 CONSTRUCTION QUALITY CONTROL

Specifications for Precast Modular Retaining Wall System *note to user – This is a draft specification that should be edited and revised to reflect the specific conditions of a project as well as local practices and locally available materials. The draft specification provides general guidance and specific provisions may vary based on site conditions or project requiremnts. This draft specification should not be taken as a minimum or best practice standard.*

STONE STRONG SYSTEMS

SPECIFICATIONS FOR PRECAST MODULAR BLOCK RETAINING WALL SYSTEM

(revised 3/23/20)

PART 1: GENERAL

1.01 Description

A. Work includes furnishing and installing precast modular blocks (PMB) to the lines and grades shown on the plans and as specified herein. Also included is furnishing and installing appurtenant materials required for construction of the complete system.

B. The contractor is solely responsible for safety. The Engineer and Owner shall not be responsible for means or methods of construction or for safety of workers or the public.

1.02 References

note to user – ASTM methods are presented w/ AASHTO comparable methods. Either set of methods may be deleted, as appropriate, for a given project

A. ASTM - American Society for Testing and Materials (AASHTO - American Association of State and Highway Transportation Officials)

B. ASTM C33 - Standard Specification for Concrete Aggregates (AASHTO M43)

C. ASTM C39 - Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens (AASHTO T22)

D. ASTM C136 - Standard Test Method for Sieve Analysis of Fine and Coarse Aggregate (AASHTO T27)

E. ASTM C1776 - Standard Specification for Wet-Cast Precast Modular Retaining Wall Units

F. ASTM D4318 - Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils (AASHTO T89 & T90)

G. ASTM D698 - Standard Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (AASHTO T99)

H. ASTM D4632 - Standard Test Method for Grab Breaking Load and Elongation of Geotextiles

I. ASTM D4595 - Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method

J. ASTM D5262 - Standard Test Method for Evaluating the Unconfined Creep Behavior of Geosynthetics

K. ASTM D6637 - Standard Test Method for Determining Tensile Properties of Geogrids by the Single or Multi-Rib Tensile Method

L. ASTM D6638 - Standard Test Method for Determining Connection Strength Between Geosynthetic Reinforcement and Segmental Concrete Units (Modular Concrete Blocks)

M. ASTM D6916 - Standard Test Method for Determining the Shear Strength Between Segmental Concrete Units

1.03 Submittals

note to user – edit submittal requirements based on type of design and other project features

A. If a complete design is not depicted in the plans, submit for review shop drawings for the retaining wall system prepared by a Professional Engineer registered in the state where the project is located. The shop drawings shall indicate the layout, height, and construction details of the retaining wall system. Design shall conform to relevant requirements and design methodologies of AASHTO Standard Specifications for Highway Bridges. Upon request, design calculations shall also be submitted. Minimum safety factors for design shall be as follows:

note to user – edit safety factors for specific project requirements, including conformance w/ AASHTO spec if required. Safety factors are not applicable to LRFD design.

	Gravity Wall	Geosynthetic Reinforced Wall
Sliding	1.5	1.5
Overturning	1.5	2.0
Bearing	2.0	2.0

B. If stain will be applied to the wall system, a sample shall be stained on site for review and approval by the Engineer. The color sample may be part of the completed wall, but shall be located in an inconspicuous area.

C. If an alternate geosynthetic reinforcement is included in the contractor's design, submit manufacturer's literature and test data for geosynthetic to be used in the reinforced wall system. Test data shall include connection strength data for geogrid with Stone Strong modular units determined in accordance with ASTM D6638, as well as geogrid tensile strength and creep data in accordance with ASTM D4595 and ASTM D5262.

D. Submit grain size test results for aggregates to be used for the wall base and for unit fill.

E. Submit test results on borrow material to be used for common backfill and for select backfill (if used) including Proctor and grain size or Atterberg limits results.

1.05 Delivery, Storage, and Handling

A. Contractor shall check the materials upon delivery to assure that proper materials have been received.

B. Contractor shall protect the materials from damage. Damaged material shall not be incorporated into the wall or the reinforced soil embankments.

C. Contractor shall prevent excessive mud, concrete, adhesives and other substances that may adhere from coming in contact with the materials.

D. Exposed faces of precast modular block units shall be reasonably free of chips, cracks, or stains when viewed from a distance of 10 feet.

PART 2: MATERIALS

2.01 Wall Units

A. Precast modular blocks shall be Stone Strong units manufactured under license from Stone Strong LLC.

B. Wall units shall conform to ASTM C1776.

C. Dimension tolerances for precast modular blocks shall be +/- 1/8 inch for height, +/- 1/8 inch for length (along face), and +1/2 to -1/4 inch for width (face to tail).

note to user – entrained air content may be adjusted based on exposure conditions (based on ACI 318) and on local practice or local agency specifications

D. Concrete for precast modular blocks shall have a minimum 28-day compressive strength of 4,000 psi. Entrained air content shall be between 5 and 7%.

E. Internal unit reinforcement or unreinforced units shall be provided according to published Stone Strong engineering guidance. Reinforced units shall be marked with the type of reinforcement.

F. The face pattern shall be selected from the manufacturer’s standard molds. The color of the units shall be natural gray. A concrete stain may be field applied to color the units if specified by the Engineer or Owner.

2.02 Geosynthetic Reinforcement

note to user – this may be omitted if no geosynthetic reinforcement is included in the design, and the Paraweb or geogrid section may be deleted if it is not applicable

A. Geosynthetic strap reinforcement shall be Paraweb 2D-50 manufactured by Maccaferri, Inc.

B. Geogrid reinforcement shall be SF55 or SF110 manufactured by Synteen Technical Fabrics, Inc.

C. Substitution of a different type of geosynthetic shall not be allowed unless approved of the Architect/Engineer or Owner after submittal of shop drawings and test data.

2.03 Wall Base

note to user – aggregate type and gradation should be adjusted for locally available materials, consistent with the design. Wall base should generally be a well graded aggregate with a maximum size from 1” to 1½”. Materials with a max size as small as ¾” and as large as 2½” may be acceptable at the discretion of the engineer. Recycled concrete aggregate may also be used subject to acceptable gradation, and cracked gravel may be acceptable in some cases. Screened aggregate, such as 57 stone, may be acceptable subject to drainage and other considerations. Some agencies may specify a concrete base. The design should account for the properties of the material specified – see design methodology documents.

A. The wall base shall consist of dense graded crushed aggregate. A minimum of 75% of coarse material shall have 2 or more fractured faces. Wall base material shall meet the following gradation:

US Standard Sieve Size	Percent Passing

1-1/2”	80-100
3/4"	50-90
#4	0-40
#200	0-10

B. The contractor may substitute concrete with a minimum 28-day compressive strength of 3,000 psi for the granular base material. Concrete may be placed full thickness or as a topping over a compacted granular the base. If used as a topping, the concrete shall have a minimum thickness of 3 inches.

2.04 Unit Fill

note to user – aggregate type and gradation should be adjusted for locally available materials, consistent with the design. 57 stone is commonly used for unit fill, and this gradation usually conforms w/ the draft gradation below (although this gradation also allows for coarser materials as well). Unit fill should generally be a screened aggregate with a maximum size around ¾” to 1½”. Materials with max size up to 2½” may be acceptable at the discretion of the engineer. Gradation requirements are sometimes replaced with a reference to 57 stone according to ASTM C33. Recycled concrete aggregate may also be used subject to acceptable gradation, and cracked gravel may be acceptable in some cases. A well graded aggregate is not desirable for unit fill. Rather, the material should be coarse graded so that it will spill into and fill the voids within the blocks and will be free draining. The critical sieve sizes are the #4 sieve to limit loss through the block joints and a limit on the fines (less than 2% minus #200 sieve, but a larger sieve may be used as a proxy for fines) to maintain a free draining condition. The design should account for the properties of the material specified if the gradation varies significantly from below – see design methodology documents.

A. Unit fill shall consist of a screened crushed aggregate. A minimum of 75% of coarse material shall have 2 or more fractured faces. Unit fill material shall meet the following gradation:

US Standard Sieve Size	Percent Passing
1-1/2”	100
3/4"	50-90
#4	0-10
#8	0-5

2.05 Backfill

note to user – edit acceptable backfill to reflect on-site or select backfill as appropriate. Backfill properties must be consistent with design assumptions.

A. If a select granular reinforced zone is indicated, it shall consist of fill sand or other clean aggregate meeting the following gradation:

note to user – edit gradation for locally available materials, or replace w/ reference to DOT or ASTM gradation

US Standard Sieve Size	Percent Passing
3/4"	100
#200	0-5

note to user – edit properties of on-site soil or borrow based on local conditions/practices

B. All other backfill behind and in front of the wall shall consist of suitable on-site soil or imported borrow and shall be approved by the Geotechnical Engineer. Backfill shall generally consist of sands, silts, or lean clays with a liquid limit less than 45 and a plasticity index less than 20. Fat clay soils, cobbles, and large rock should generally be avoided unless approved by the Geotechnical Engineer based on local practices. Frozen soils, excessively wet or dry soils, debris, and deleterious materials should not be used.

2.06 Drain Tile

note to user – drain tile may be omitted at the discretion of the engineer where ground water is not expected and weeping through the face joints will be sufficient to prevent buildup of hydrostatic pressure

A. Drain tile shall be a perforated or slotted PVC or corrugated HDPE pipe. The drain tile should be connected to storm drains or daylighted at low points and/or periodically along the wall alignment as shown on the plans.

2.07 Geotextile Fabric

note to user – for gravity walls, a geotextile filter may be included when seepage from the backfill zone (due to high water table, inundation, etc) is expected to foul the drainage aggregate inside the units or where separation from the backfill zone is required for other reasons. Geotextile may be deleted in other cases at the discretion of the engineer. In most cases, this section may be deleted.

A. Provide a geotextile filter for separation from backfill at the tails of the blocks. The geotextile shall be a needle punched non-woven fabric with a minimum grab tensile strength of 120 pounds. The geotextile may cover the entire back face of the blocks or may be cut in strips to cover the gaps between tail units with a minimum of 6 inches of overlap over the concrete tail on both sides.

2.08 Concrete for Tail Extensions

note to user – this may be omitted if no cast in place tail extensions are included in the design

A. Concrete for tail extensions shall have a minimum 28-day compressive strength of 3,000 psi. Higher mix strength may be necessary to achieve a strength of 2,000 psi before the wall is backfilled above the level of the tail extension.

B. Concrete shall have entrained air content between 5% and 7%.

PART 3: EXECUTION

3.01 Excavation

A. Excavate as required for installation of the retaining wall system. Excavate to the base level for a sufficient distance behind the face to permit installation of the base.

B. Slope or shore excavation as necessary for safety and for conformance with applicable OSHA requirements.

3.02 Wall Base

A. Foundation soils shall be excavated to the dimensions shown on the plans. Foundation soil shall be observed by the Geotechnical Engineer to confirm that the bearing soils are similar to the design conditions or assumptions.

B. Construct the wall base to the lines and grades shown on the plans. Place and consolidate concrete, strike, and finish plane and level. Overexcavated areas shall be filled with additional concrete or granular base material. Compact granular base material to provide a hard and level surface to support the wall units. Base material shall be compacted to a minimum of 95 percent of the maximum dry density (ASTM D698, Standard Proctor). Final base elevation shall be within 0.1 feet of plan elevation.

C. Prepare and smooth the granular material to ensure complete contact of the first course with the base. The base may be dressed with fine aggregate to aid leveling.

3.03 Unit Installation

A. Place the first course of units directly on the wall base. Check units for level and alignment. Units shall be within 1/8 inch of level from end to end and from front to back. Adjacent units should be in contact. If possible, begin placing units at the lowest section of the wall.

B. Fill all voids between and within the blocks with granular unit fill. Additional unit fill is not required behind the units, but may be placed for the convenience of the contractor.

C. Place backfill behind the units in maximum loose lifts of 8 inches and compact. Compact all backfill to a minimum of 95 percent of the maximum dry density (ASTM D698, Standard Proctor). For cohesive soils, the moisture content at the time of compaction should be adjusted to within -2 and +3 percent of optimum. Place backfill in successive lifts until level with the top of the facing unit.

D. Remove all excess aggregate and other materials from the top of the units before laying up the next course.

note to user – for a geogrid reinforced wall, delete the following sections on Paraweb installation

E. For Paraweb reinforced walls, place the correct Paraweb strap at the locations and elevations shown on the plans or the shop drawings. Paraweb reinforcement shall be placed horizontally on compacted backfill in a V-layout. The length of the Paraweb is measured from the embedded connector in the back of the facing unit. Wrap the Paraweb strap around the embedded connector at the point of the V-shaped strap layout. Paraweb straps may be spliced following the manufacturer’s guidance.

F. Ends of the Paraweb straps shall be staked or held in place. Slack shall be removed from straps using an approved method.

G. Do not operate equipment directly on the Paraweb straps. A minimum backfill depth of 6 inches should be placed before operating equipment over the reinforcing straps.

note to user – for a Paraweb reinforced wall, deleted the following sections on geogrid installation

H. For geogrid reinforced walls, place the correct geogrid at the locations and elevations shown on the plans or the shop drawings. Geogrid reinforcement shall be placed horizontally on compacted backfill. The length of the geogrid is measured from the front face of the wall. Extend the grid onto the front face flange of the facing unit. Orient the geogrid with the strong axis (machine direction) placed perpendicular to the wall face. Geogrid shall not be spliced by any means in the roll direction.

I. Geogrids shall be placed side by side to provide complete coverage along the wall face. No overlap is required between adjacent grids on straight sections of the wall. On convex curves, place a minimum of 3 inches of backfill material between overlapping geogrid layers.

J. Pull geogrids taught and stake or hold the loose end in place before placing the next course of backfill. Backfill shall be placed, spread, and compacted in such a manner that minimizes the development of wrinkles in the geogrid and/or movement of the geogrid. Do not operate equipment directly on the geogrid. A minimum backfill depth of 6 inches should be placed before operating equipment over the grids.

note to user – edit setbacks if a vertical face is intended

K. Place the next course of precast modular block units in running bond with the previous course. Place the web recess over the alignment hoop protruding from the unit below, and pull the unit forward to contact the hoop. Batter should be within ¼ inch tolerance (4 inches from 24 SF unit below, 2 inches from 6 SF unit below).

L. Continue placing successive courses to the elevations shown on the plans. Construct wall in level stages, placing the units at each course for the entire length of the wall, if possible. Unit fill and backfill should be placed to the level of the top of the facing unit before placing the next course.

M. Provide temporary swales to divert runoff away from wall excavation and away from face.

N. Final grade above and below the retaining wall shall provide for positive drainage and prevent ponding. Protect completed wall from other construction. Do not operate large equipment or store materials above the wall that exceed the design surcharge loads.

note to user – edit if alternate connection is used, including steel reinforcement into voids, or delete if tail extensions are not used

O. Where tail extensions are indicated on the plans, concrete shall be placed in a continuous placement inside the side voids between the blocks extending to the minimum width behind the blocks indicated on the drawings. Tail extensions may formed or may be placed directly against a cut embankment. Tail extensions should be placed in lifts not to exceed 4½ feet until the previous lift has fully set. The tail extension should be allowed to reach 2,000 psi compressive strength before backfill is placed above the top of the extension.

PART 4: CONSTRUCTION QUALITY CONTROL AND ASSURANCE

4.01 Construction Quality Control

A. The contractor is responsible to ensure that all installation and materials meet the quality specified in the construction drawings.

B. The contractor shall verify that installation is in accordance with the specifications and construction drawings.

4.02 Quality Assurance

A. The owner is responsible to engage testing and inspection services to provide independent quality construction assurance.

B. Compaction testing shall be done a minimum of every 1 foot of vertical fill and every 100 lineal feet along the wall.

C. Testing shall be done at a variety of locations to cover the entire backfill zone.

D. The independent inspection professional should perform sufficient testing and observation to verify that wall installation substantially conforms to the design drawings and specifications.

END OF SECTION

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5.1.1 SYSTEM DEVELOPMENT AND USAGE

No attachments

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5.1.2 OLDEST THREE STRUCTURES

No attachments

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5.1.3 TALLEST THREE STRUCTURES

No attachments

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5.1.4 AGENCY/OWNER APPROVALS

No attachments

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6.1 OTHER INFORMATION

No attachments