



DESIGN CONSIDERATIONS FOR CONCRETE PAVER SURFACED ACCESS LANES - SUBJECTED TO FIRE TRUCK LOADING

A common question posed by design professionals is the ability of interlocking concrete pavers (ICPs) and permeable interlocking concrete pavers (PICPs) to withstand fire truck loading. This is due to the relatively large axle weights they exert along with the fact that fire trucks are critical service vehicles that must be able to access sites in emergency situations.

In terms of structural design for entry, access lane and roadway applications, pavements must be designed to resist rutting, bearing capacity of the supporting pavement system and resistance to repeated axle load applications. Pavement design procedures typically utilize information which describe the strength of the subgrade soils, axle loadings and frequency, and strength of the various layered pavement components. The actual design procedures for flexible and rigid pavements are well documented in Civil Engineering texts with ICPs & PICPs well recognized to behave and follow the design procedures set forth for "flexible" pavement design. References for ICP and PICP pavement design are provided in this Technical Note (AASHTO 1993, ASCE 2016 & 2018, Caltrans 2016).

While not a comprehensive primer on pavement design, the focus of this report is to demonstrate that ICP and PICPs are not adversely affected by heavily loaded vehicles and are suitable for use in vehicular areas exposed to fire truck loadings. The primary discussion herein will focus on fire truck loadings on ICP/PICP systems as they relate to:

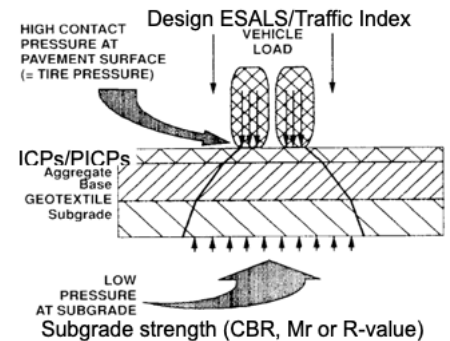
- Design ESALs applied to the pavement system.
- Fire truck wheel and axle loads relative to the strength of the paver
- Point loads that may occur when the stabilizer outriggers are in place.

Because this document focuses on fire truck loading, data on a typical heavily loaded fire truck was obtained for a "ladder truck" used by the City of Scottsdale, AZ. The vehicle chosen is one of the heaviest vehicle in a typical Fire Department's fleet and is considered on the upper end of the fire vehicle loading spectrum. A few images of the vehicle and its characteristics are provided below:



Ladder Engine: Pierce Manufacturing ID Decal; GVWR - 76,800 lbs.
 GAWR - Front = 22,800 lbs. = 11,400 lbs./tire:
 GAWR - Rear = 54,000 lbs. = 27,000 lbs./axle; 6750 lbs./tire
 Cold Tire Inflation Pressure - 120 psi (single and dual)
 Max Load per Single Tire - 11,400 lbs.

DESIGN ESALs



Structural Pavement Section function of Subgrade Strength, Traffic Loadings and Strength of Pavement Section Components

Design references have been developed by several credible organizations including AASHTO, ASCE and Caltrans as shown below. In almost all cases, the design guidelines for the structural aspects of the pavements are based on the 1993 AASHTO Guide for Design of Pavement Structures (AASHTO 1993). As with the design references for ICP and PICPs, the 1993 AASHTO document calculates the thickness of a roadway cross section required to withstand the applied loads for the given lifespan based on the native soils strength and traffic loading. The supporting soil strength is typically described by a CBR value (California Bearing Ratio), Mr (Resilient Modulus), R-value or some other geotechnical measurement describing the strength of the supporting soil. The traffic loading is typically described by TI (Traffic Index), ESALs (Equivalent Single Axle Loads) or other measurement to express the traffic type and equivalent damage (VLF, Vehicle Load Factor) created by each type of vehicle as compared to the passage of a "standard" 18,000-pound axle load (one 18,000 lb. ESAL provides a unit value of 1.0). For perspective on ESALs, passenger cars have a Vehicle Load Factor (VLF) of 0.0004

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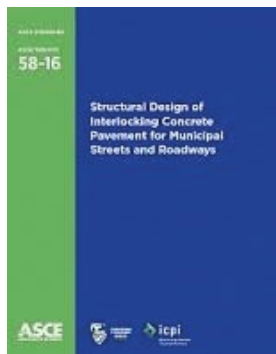
whereas a fully loaded fire truck as shown above would have a VLF of about 10. Hence, it would take over 20,000 cars to affect the same level of deterioration on the pavement as 1 pass of a fire ladder truck. It should be noted that not all fire trucks exhibit this same degradational effect on pavements as most are lighter and exhibit considerably lower axle loads than the Ladder Truck which has a GVWR (Gross Vehicle Weight Rating) of 76,800 lbs.

Although it is evident by the VLFs shown above that fire trucks can exert high ESALs on the pavement surface, it is important to note that typical roads are designed around hundreds of thousands of ESALs, so the impact of the occasional fire truck is relatively small on those pavements. Notable in the design procedure is that the axle/tire loads applied to the completed pavement system is transferred through the pavement to the

subgrade via a series of structural layers which distribute the vehicle loads to a relatively large area of the subgrade. The distribution of the loads through the pavement system enables relatively weak subgrades to support very high concentrated axle/wheel loads much like a snowshoe or wide tracks of low ground pressure vehicles to traverse low strength materials which would otherwise not support the weight of applied loads. Along those same lines, pavement design isn't so much about how much a vehicle weighs but rather the load transfer of axle loads through the pavement system and how many passes can be achieved prior to development of unacceptable rutting or excessive pavement deterioration.

To further expand on this subject, pavement sections for standard asphaltic concrete (AC) and aggregate base systems and interlocking concrete pavement (ICP) systems are essentially identical in thickness with the wearing course being the primary difference in the systems. In essence, an 80mm (3-1/8") thick paver laid on 1" of bedding sand provides a structural number of 1.82 for the pavement layer which is the same as 4-1/8" of asphaltic concrete having a layer coefficient of 0.44/inch ($0.44 \times 4-1/8 = 1.82$). Therefore, a 101.6 mm (4") thick paver laid on 1" of bedding sand provides a structural number of 2.20 for the pavement layer, which is comparable to 5" of asphaltic concrete. The aggregate base and subbase section used to distribute the wearing course loads provide the same support to either an AC or ICP system. The above analogy can be verified by comparing section thicknesses for designs done in accordance with AASHTO (AASHTO 1993) and ICPI (ICPI 2011) or ASCE (ASCE 2016) methods.

Permeable Interlocking Concrete Pavement systems (PICPs) employ essentially the same wearing surface (typically an 80mm paver underlain by 2" of No. 8 stone) and open graded load transfer/water storage/conveyance layer aggregate (No. 57 and No. 2 stone). Because of the introduction of water and the somewhat less dense structure of the base layers, a somewhat lower structural coefficient is employed for the components that make up the PICP system than what is used for conventional ICP systems, but the design concept is identical.



TIRE CONTACT PRESSURES

In terms of being able to withstand the surface pressure exerted by fire truck tires, the gross axle weight rating (GAWR) on a two tire (steering) axle and tandem axle (rear axles) for the 76,800 lb. fire truck referenced above is 22,800 lbs. and 54,000 lbs., respectively. Each tire is rated at a max load rating of 11,400 lbs. at a cold inflation tire pressure of 120 psi. By definition, the maximum applied contact pressure is then 120-psi.

Any concrete paver offered under the Belgard line is made in accordance with ASTM C936, which requires an average compressive strength of 8,000 psi with no individual unit being less than 7,200 psi. So, simply put, the pavers are on average $8000/120 > 60$ times stronger in compression than required to withstand the surface pressure that would be exerted under the extreme loading conditions imposed by a fire truck.

POINT LOADS

When the stabilizer outriggers are in place, a point load of as much as 45,000 pounds can be applied to the pavement surface. Although significant, when distributed over an "un-factored" stabilizer plate surface area of 0.97 square feet (area of 10x14 inches), this equates to a surface pressure of 322 psi, which again is well within the compressive strength capabilities of Belgard pavers.

PAVER DAMAGE

As a final thought, should one or more pavers become damaged, individual units can be removed and replaced without compromising the structural integrity of the system (instruction manual available upon request).



ICPI - Permeable Interlocking Concrete Pavements



Caltrans - Porous Pavement Design Guidance

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EXAMPLE PROJECTS

In order to demonstrate the acceptance of Belgard pavers in the local market, a sample list of permeable interlocking concrete paver (PICP) installations is provided. The list includes project from CA which are in fire access lanes and subject to heavy vehicle loadings. Similar lists are available for ICPs upon request.

- **Shearwater Creek Townhomes 72,000 SF** | Pujol St, Temecula / Entrances and interior streets – Fire Truck rated
- **Villa Catalina Condos 4,100 SF** | 616 Catalina Ave, Redondo Beach – Entrance and shared motor courtyard – Fire truck rated
- **Villa Catalina Condos 5,600 SF** | 618 Catalina Ave, Redondo Beach – entrance and shared motor courtyard – Fire truck rated
- **Hilton Garden Inn 5,700 SF** | 4216 El Camino Real, Palo Alto – Entrance Fire truck rated
- **Buffalo Wild Wings 7,900 SF** | 845 East Ave, Chico – parking Fire truck rated
- **Tahizzle Communities 7,600 SF** | Truckee, Tahoe
- **San Jose Downtown Health Center 12,000 SF** | 777 E Santa Clara St, San Jose – Drive Entrance/Parking areas/Travel Lanes
- **Wisdom Way 8,900 SF** | 1898 Wisdom Way, Modesto – Parking Lot with Heavy Vehicle Access
- **Avanti 64,000 SF** | 23600 Park Sorrento Calabasas – Entrances and interior streets – Fire Truck rated
- **Wren Avenue & Byer St. Pedestrian Crosswalk 9,000 SF** | Wren Ave. & Byer St, Gilroy – Street crosswalks – Fire truck rated
- **Vista Rio Apartments 46,000 SF** | 3901 Briggs St, Jurupa Valley – Entrances and interior streets – Fire truck rated
- **Siena Apartments 69,000 SF** | 7801 Juniper Ave, Fontana – Entrances and interior streets – Fire truck rated.
- **4100 Del Rey Apartments 7,600 SF** | 4100 Del Rey Ave, Marina Del Rey – Parking areas – Fire truck rated.
- **Fountain Valley Town Center 6,500 SF** | Fountain Valley – Parking/Fire Truck Rated
- **Aldi Store #19 6,200 SF** | 112 Lakewood Blvd, Downey – Parking Lot/Drive Entrances
- **Chick Fil A Restaurant 3,200 SF** | 3771 E Thousand oaks Blvd, Thousand Oaks – Parking areas – Fire truck rated
- **ColRich Camel Row 24,000 SF** | Camel Country Rd & Camel Mtn. Rd, San Diego – Community Roadways – Fire Truck Rated
- **San Leandro Tech Campus 10,000 SF** | 1333 Martinez, San Leandro – Entrance to University Parking Lot/Heavy Traffic/Entrance to Parking Garage
- **Gateway Shopping Center / Sprouts Market 20,000 SF** | 1300 Pinole Valley Rd, Pinole – Shopping Center Entrance/Parking/Drive Aisles
- **Bardis Homes – 60,000 SF** | Sacramento, CA – Entrances, Streets all pavements through-out new residential development – Fire Truck Rated.
- **Northwest Land Park – 90,000 SF** | Sacramento, CA – Community Entrances, streets and drive lanes of new housing development – Fire Truck Rated.
- **Calvin Christian Church – 6,000 SF** | Escondido – Fire Lane access to rear of building.

REFERENCES

1. *AASHTO 1993. Guide for Design of Pavement Structures, American Association of State Highway and Transportation Officials, Washington, DC.*
2. *ASCE 2016. Structural Design of Interlocking Concrete Pavement for Municipal Streets and Roadways, ASCE/T&D/ICPI Standard 58-16, American Society of Civil Engineers, Reston, VA.*
3. *Caltrans 2016. Pervious Pavement Design Guidance, California Department of Transportation, Division of Design, Office of Storm Water Management, Sacramento, CA.*
4. *ICPI 2011. Permeable Interlocking Concrete Pavements, Fourth Edition, interlocking Concrete Pavement Institute, Herndon, VA.*
5. *UC Davis 2010. Research Report – Laboratory Testing and Modeling for Structural Performance of Fully Permeable Pavements Under Heavy Traffic: Final Report, U.C. Davis, Department of Civil and Environmental Engineering (CTSW-RT-10-249.04), Davis, CA.*

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