

## **PROGRESS REPORT 7/14/2021**

### **SOUND MITIGATION STUDY: WSDOT MODULAR BRIDGE EXPANSION JOINTS - PHASE 2**

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#### **BACKGROUND**

Expansion joints are connections in bridges that allow the structure to expand and contract with changing conditions such as temperature, lake level, wind/wave conditions and traffic loads. Allowing this expansion and contraction is necessary to keep the bridge from becoming overstressed and getting damaged.

The noise created by vehicles driving over modular expansion joints is a nuisance to residents in several parts of the State of Washington, with the Washington State Department of Transportation (WSDOT) receiving noise complaints from bridges throughout the state. Large expansion joints in particular have been problematic, such as those installed on the Evergreen Point Floating Bridge (SR520 bridge). Shortly after opening in 2016, WSDOT started receiving noise complaints relating to the large, 16 center beam, expansion joints on the east and west ends.

Several WSDOT bridges – more than 50 state-wide – have the modular expansion joints like those used on the SR 520 bridge. Modular expansion joints are typically used when six inches or greater expansion/contraction is required at a joint. Numerous noise complaints associated with modular bridge expansion joints have been received at bridges throughout the state. This study aims to develop a noise mitigation method that reduces environmental noise levels. Environmental noise is well known to decrease the quality of life of those exposed to it, so the results from this study can lead to the improvement of the quality of life for residents living in the vicinity of these bridges. The results of this research project can be applied to all existing and future bridges with these types of expansion joints.

Phase 1 of this study examined the noise generation mechanism and its radiation from expansion joints. The objective of this phase 2 study is to develop ways to mitigate the noise as there is no commercially available noise abatement that is cost effective, safe, and durable. The study includes both laboratory and field studies of novel sound mitigation systems to determine their effectiveness, viability, durability, and safety.

#### **PROGRESS TO DATE**

The project was started January 4, 2021.

The following research team was assembled:

Per Reinhall, Professor of Mechanical Engineering  
Jeff Lipton, Assistant Professor of Mechanical Engineering  
Waiel Elmadih, Post-Doctoral Fellow, Mechanical Engineering  
Sawyer Thomas, PhD student, Mechanical Engineering

The following outlines the progress made with the four tasks associated with the project.

**Task 1: Design of solution for reducing noise from modular bridge expansion joint.**

As was shown in Phase 1 of this study, the noise from the expansion joints originates on the top of the joints and is due to resonances excited in the air gap between the center beams as air is compressed by the deformation of the passing tire. The generated noise can thus be decreased by decreasing the deformation of the tires as it passes of the gap between the beams or by preventing resonance of the trapped air between the beams.

To decrease the deformation of the tire we are pursuing a novel lattice structure that will be attached between the beams. This material will allow for the necessary longitudinal and transvers motion of the expansion joint but will prevent vertical deformation of the passing tire.

We have been making good progress with the lattice design, analysis, and fabrication. In January we took delivery of a state-of-the-art 3D printer (Carbon L1 Series) that allows us to print flexible polymeric lattices of the correct stiffness and durometer for fatigue testing in the lab. We have also identified extrudable rubber like materials that have the potential of having high resistance against wear from studded tire.

**Task 2: Modeling and laboratory testing of noise mitigation solutions including the design and construction of a test bench for controlled testing of mitigation solutions.**

A complete and detailed finite element model of the SR 520 Bridge expansion joint has been completed. In addition, a finite element model of a parametrized vehicle tire to predict tire deflection has been completed. Coupled together these models can predict the noise generated as a tire travels across the expansion joint.

The acoustic performance of each attenuation design is being evaluated using the finite element models. This includes the vibration of the tire and the expansion joint beams, the deformation of the acoustic mitigation system, and the coupling with the surrounding air. The finite element analysis allows us to conveniently determine the stiffness of the mitigation system for optimum performance. Together our models are helping us to quickly explore our designs by decreasing the need for time consuming prototyping and testing (Fig 1).

We are currently examining a set of possible designs (Figure 2). To do this, we run numerical simulations for each potential solution. These produce pressure curves, representing the tire rolling across the gap between the expansion joint beams. Through this process, we aim to reduce the impact pressure on the rails and the tires, subsequently limiting the source of the vibrations.

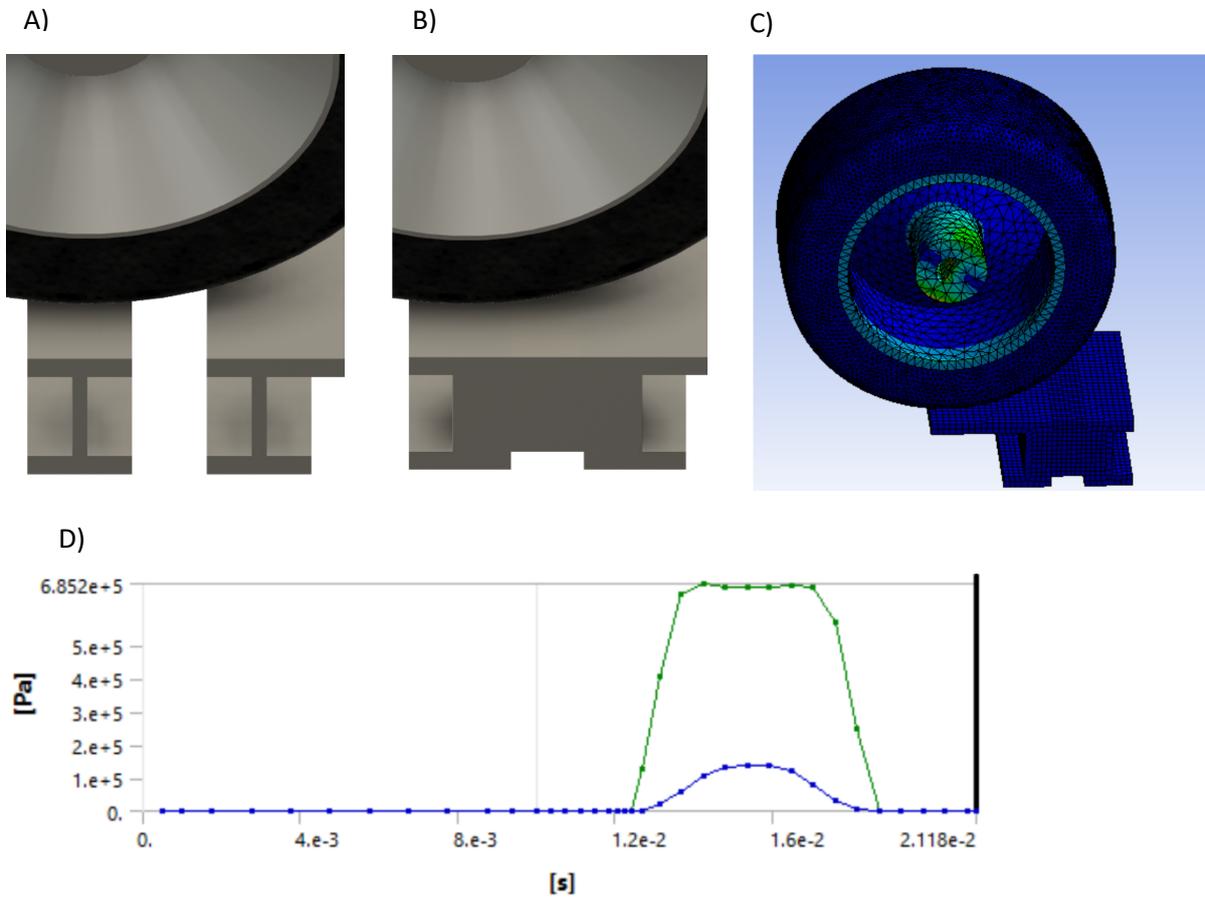


Figure 1. Numerical Simulation. A) Original MEJ beam gap setup. B) Best case MEJ solution (fully filled gap). C) Solved simulation demonstrating setup and mesh. D) Example of a beam pressure profile as the tire rolls over the gap. Green – maximum pressure, blue – average pressure.

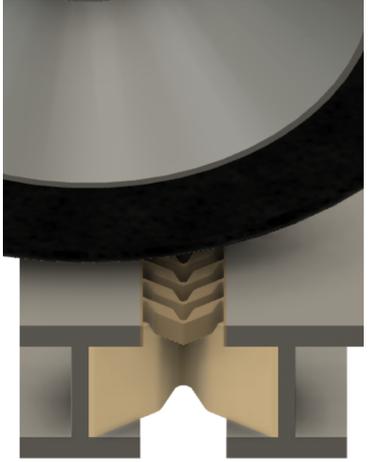
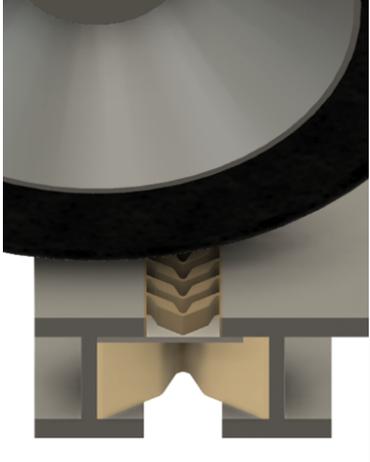
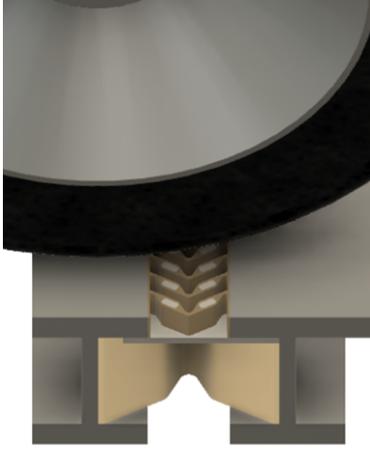
Solution Type	Rendering	Simulation Metrics	Pros
<p>Rubber extrusion supported by the I-beam interior</p>		<p>Reduces the gap's maximum I-beam pressure by ~75%.</p> <p>Pressure reduction comparable to filling the gap with solid rubber.</p> <p>No significant reduction in maximum tire deflection.</p>	<p>Easy to fabricate and install.</p> <p>High reduction in pressure.</p> <hr/> <p align="center"><b>Cons</b></p> <p>Least resistant to deformation.</p>
<p>Rubber extrusion supported by metal plate and the I-beam Interior</p>		<p>Reduces the gap's maximum I-beam pressure by ~86%.</p> <p>~70% reduction in tire deformation in the gap.</p> <p>Rolling simulation for pressure still in progress.</p>	<p><b>Pros</b></p> <p>second best for resistance to deformation and pressure reduction.</p> <hr/> <p><b>Cons</b></p> <p>Installation might be more challenging.</p>
<p>Metal-rubber combination supported by metal plate and the I-beam Interior</p>		<p>Reduces the gap's maximum I-beam pressure by ~90%.</p> <p>Pressure reduction comparable to removing the gap.</p>	<p><b>Pros</b></p> <p>Expected to be the best solution for resistance to deformation and pressure reduction.</p> <hr/> <p><b>Cons</b></p> <p>High part count means that fabrication will be more complex. Installation might be more challenging.</p>

Figure 2. Potential mitigation designs.

**Task 3: Field testing of noise mitigation solutions to assess noise reduction and durability.**

We are soon ready to field test our most promising noise attenuation designs for effectiveness and durability. WSDOT is currently trying to find a suitable bridge with an expansion joint with a single gap or with multiple gaps. The bridge needs to have significantly less traffic than the SR520 bridge so we can install our treatments without causing traffic congestion. The site should also allow us to conduct periodic evaluation of noise attenuation and durability for about a period of four months.

**Task 4: Optimize installation methodology to ensure durability and corrosion prevention**

We are currently evaluating commercially available, highly wear resistant, extrudable polymer for our lattice structures.

The final design will contain seals so that no water penetration will take place.

**SCHEDULE**

Task 1: July 2020 – Jan 2022

Task 2: July 2020 – Dec 2021

Task 3: Sept 2021 – Mar 2022

Task 4: Aug 2021 – Nov 2021

Final Report: March 2022