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Summary of Stress-State Reduction in Concrete Bridges

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Summary

The Transportation Technology Center, Inc. (TTCI), Pueblo, Colorado, is testing two ballasted deck concrete bridges at the Facility for Accelerated Service Testing (FAST). The bridges were installed in 2003, and have accumulated over 1,300 MGT to date. The prestressed concrete spans have performed well under the heavy axle load traffic with no structural concerns and only minimal maintenance required.

TTCI is investigating techniques and materials to attenuate the effects of impacts imparted to these bridges by optimizing track stiffness. Wood ties, plastic ties, concrete ties with rubber pads, and ballast mats tested at FAST have successfully reduced impacts and track surfacing maintenance of concrete bridges.^{1,2,3} In contrast, decreased ballast depth and installation of a standard bolted rail joint have been found to increase impact on these bridges.^{4,5} Test results are summarized below:

- Testing on the concrete bridges has shown that wheel impacts have been reduced by 20 to 40 percent and time between track surfacing maintenance cycles has been significantly extended by the installation of the following:
 - Under-tie rubber pads (for concrete ties)
 - Plastic ties
 - Wood ties
 - Concrete ties with a ballast mat
- Midspan impact and track surfacing maintenance has increased as a result of the following:
 - Reduction of ballast depth from 12 inches to 8 inches
 - Ballast degradation
 - Installation of standard bolted rail joints

Railroads will benefit in terms of reduced impact loads through lower maintenance costs and extended service lives on concrete bridges, according to results from this study.

This study was conducted by TTCI as part of the Association of American Railroads' Strategic Research Initiatives Program on railroad bridges.



INTRODUCTION

The railroad industry spends about half of its bridge capital on concrete bridge construction. Under the Association of American Railroads’ Strategic Research Initiatives Program, TTCI is evaluating the short- and long-term performance of concrete bridges under heavy axle load traffic (HAL).

The High Tonnage Loop at FAST has two ballasted deck concrete bridges: the conventional concrete bridge and the state-of-the-art (SOA) concrete bridge. Construction of both bridges was completed in late 2003. To date, these bridges have been subjected to 1,347 MGT of mostly 315,000-pound loaded cars.

These bridges were installed to determine the effects of HAL on widely used prestressed concrete spans. TTCI has investigated techniques and materials for track foundations at FAST to improve the dynamic behavior of bridges. Overall, dynamic loads (impacts) have been reduced, resulting in reduced track maintenance over the bridge spans.

Several techniques and materials may be used to attenuate the effects of impacts imparted to ballast deck bridges by reducing the track stiffness on concrete bridges. These may include, but are not limited to, under-tie rubber pads, ballast mats, alternative tie types, and increased ballast depth.

Vehicle dynamics, rocking effects, wheel anomalies, and track geometry conditions cause railcar suspension systems to induce high- and low-frequency impacts into track and bridge spans. High-frequency impacts primarily affect fasteners, ties, and ballast; whereas, low-frequency impacts primarily affect the ballast track foundations and, consequently, the bridge structure.⁶



Figure 1. Conventional Concrete Bridge at FAST



Figure 2. SOA Concrete Bridge at FAST

SPAN PERFORMANCE

All concrete bridge spans at FAST have performed well under 1,300 MGT of HAL traffic since 2003. The concrete bridges include four prestressed concrete box girder spans, as well as one prestressed concrete slab span. None of these spans has required structural repair; they have only required minimal maintenance related to handrails and bearing pads.

IMPACT LOADS

TTCI has evaluated the impact-reducing capabilities of plastic ties, wood ties, concrete ties with rubber pads, and a ballast mat. Figure 3 shows that the use of these materials resulted in a reduction in impacts and track maintenance on the bridges compared to the standard concrete ties previously used. Maximum midspan impacts were greatly increased when ballast depth was reduced from 12 inches to 8 inches. Also, maximum impacts increased over 380 MGT of accumulation on the SOA bridge. This increase was likely caused by ballast degradation. The largest impact value on the concrete bridges occurred when a bolted rail joint was installed over the SOA bridge. The bolted rail joint is typical of what might be found if a plug rail is installed. There was no railhead height mismatch and minimal gap.

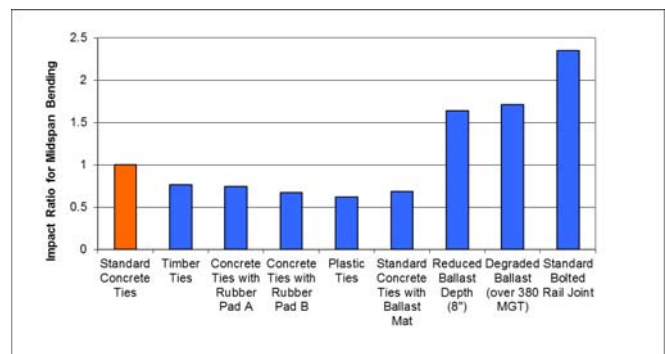


Figure 3. Maximum Relative Impact for Midspan Bending

Figure 4 shows that the averages of the measured impacts were all within the recommended American Railway Engineering and Maintenance-of-Way (AREMA) 2012 design values.⁷ This was expected, because the train at FAST typically does not have any flat wheels. The largest impact value came from a bolted rail joint with a train traveling at 40 mph. Reducing train speed to 30 mph reduced the impact from ~55 percent to ~35 percent for the 15-foot span.

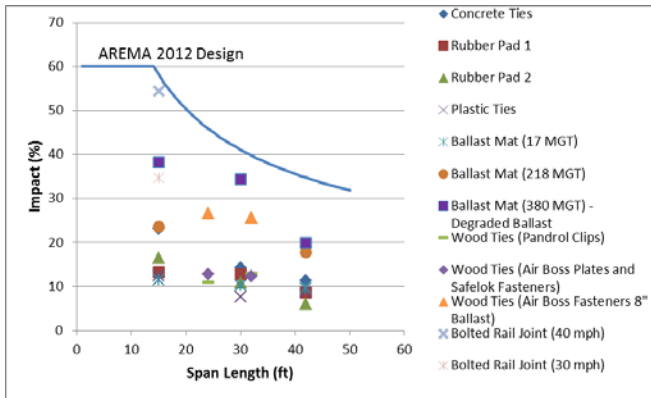


Figure 4. Average Impact as a Function of Span Length

At FAST, flat wheels and mechanical joints are largely absent, thus the impacts are mostly low frequency and are mainly caused by vehicle dynamics due to car bouncing and rocking. However, concrete bridges in revenue service are also subjected to high-frequency wheel impacts. High impacts on concrete bridges in revenue service may effectively be reduced by the use of wood ties, plastic ties, concrete ties with rubber pads, ballast mats, increased ballast depth, and removing standard bolted rail joints over railroad bridges. In cases where bolted rail joints must be installed, consideration should be given to use of a speed restriction to minimize the impact forces generated by train traffic.

BRIDGE DESCRIPTIONS

The conventional concrete bridge has 24- and 32-foot double-cell-box girder spans. The intermediate span of the SOA bridge is a 42-foot double-cell box girder and is made of high-performance concrete. The flanking spans are a 30-foot double-cell box girder and a 15-foot slab span.

Designs of all but the 42-foot span are based on Cooper E-80 loadings and follow the AREMA design guidelines and BNSF Railway and Union Pacific Railroad design practices. The 42-foot span was designed by Canadian National based on E-90 loading. Foundations of both bridges are based on E-100 design loading. The girders are supported on precast pile caps set on H-piles. The bridges are on a 5-degree curve.

The conventional concrete bridge has a ballast depth of 12 inches below the high rail and 8 inches below the low rail. The 30- and 42-foot spans of the SOA concrete bridge have a ballast depth 19 inches below the high rail and 15 inches below the low rail, and the 15-foot slab span has respective

ballast depths of 18 inches below the high rail and 14 inches below the low rail.

BRIDGE MAINTENANCE

A major advantage of using plastic ties, wood ties, concrete ties with rubber pads, and the ballast mat was a reduction in track surfacing requirements. As Figure 5 shows, average ballast tamping cycles were reduced after these materials were installed on the concrete bridges. Reduced tamping is likely the result of reduced impact loads, which cause ballast degradation.

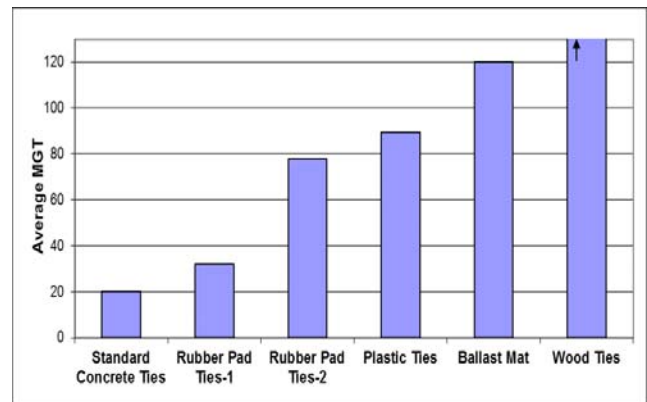


Figure 5. Ballast Tamping Cycles

BALLAST DEGRADATION

The effect of ballast degradation on the concrete bridges has been studied. A sieve analysis of the ballast on the 42-foot SOA bridge span was performed at installation of the ballast mat and after 457 MGT of accumulated traffic. Figure 6 shows an increase in ballast degradation on the SOA bridge, which likely contributed to an increase in wheel impacts. Impacts were immediately measured following installation of the ballast mat, and then again after approximately 380 MGT of accumulated tonnage. Figure 3 shows an increase in impacts.

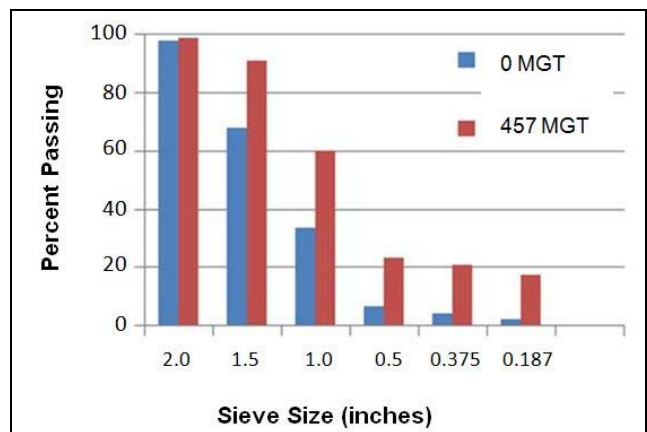


Figure 6. Ballast Sieve Analysis on SOA Bridge

Sieve analysis was also carried out on ballast samples collected periodically from the conventional concrete bridge. Figure 7 shows the ballast distribution at different collection intervals. Figure 8 shows a more detailed view of the percent of the sample passing the 0.5-inch sieve opening. Track structure on this bridge during this period was timber ties with elastic fasteners, 8 inches of ballast beneath ties at the low rail, and no ballast mat.

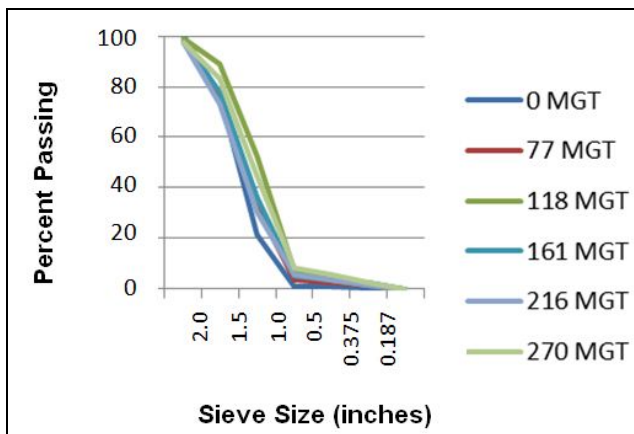


Figure 7. Ballast Sieve Analysis on Conventional Concrete Bridge

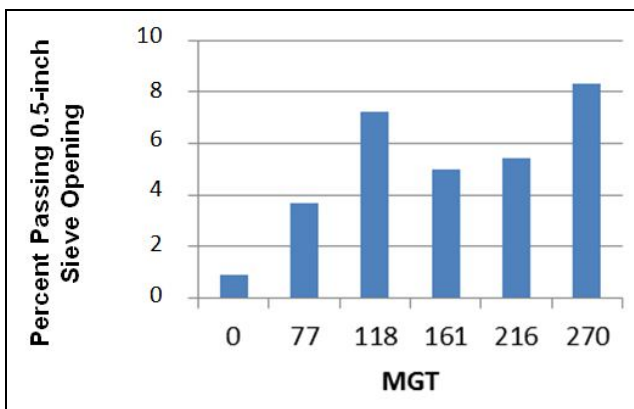


Figure 8. Ballast Passing 0.5-inch Sieve Opening

Both figures indicate ballast degradation with increased MGT accumulation, which is also reinforced from visual inspection. Ballast degradation testing on the conventional concrete bridge is ongoing.

METHODOLOGY AND MEASUREMENTS

Impacts on the concrete bridges at FAST were primarily measured with strain gages. Specific testing methodology and measurement procedures can be found in previous *Technology Digests*.^{1,3,4,5}

CONCLUSIONS AND ONGOING RESEARCH

After 10 years of testing and over 1,300 MGT of HAL traffic, the prestressed concrete bridge spans have performed well with no structural concerns and only minimal maintenance required. Use of a cushion layer in the track over the bridge, such as under tie pads, resilient ties, or a ballast mat, has proven to reduce impact forces in the bridge, and also to reduce track surfacing maintenance demand.

Research will continue with the concrete bridges to reduce dynamic load-induced stresses. Other areas of research that will continue are the ballast degradation study on the conventional concrete bridge and observation on waterproofing materials.

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