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Short Heavy Axle Load Cars: Analysis of Longer Bridge Spans

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Summary

Transportation Technology Center, Inc. (TTCI) is investigating the effects of heavy axle load (HAL) traffic on infrastructure, specifically as related to minimum length (approximately 42 feet) interchange cars. Significant differences between maximum stresses due to shorter cars and common 53-foot cars were observed in the analytical calculations for spans longer than 60 feet, and the difference was more prominent on spans of 80 feet and longer. Therefore, this study focused on investigating differences in stresses on the longer spans. A two-span truss bridge, with spans of 200 feet and 110 feet, was modeled to predict the response under typical 53-foot coal cars as well as shorter 42-foot minimum interchange length cars. The findings and recommendations from the finite element analysis (FEA) are as follows:

- The 42-foot cars are about a 25 percent increase in load per unit length compared to coal cars; however the stresses in the truss are not directly 25 percent higher due to short cars. The stresses vary depending upon location of the member and its influence length.
- Modeling predicted that the effect of short cars is more prominent on the members with long influence lines such as end post, end diagonals, and upper and lower chords.
- The hangers and floor beams are primarily influenced by the axle load not by the car length.
- The FEA predicts that stringers are not subjected to the bottom chord effect and did not experience any increase in stresses due to short cars. The results however, show partial continuity through connection with the floor beams.
- Several models were developed, with and without deck and track. The model without track best matched the test data for this particular bridge. Modeling guidelines are provided herein.

Based on these findings, various members of both trusses were selected for the testing to show the differences due to car lengths.

This research was conducted as part of the Association of American Railroads' Strategic Research Initiatives Program.



INTRODUCTION

TTCI is investigating the effects of HAL traffic on infrastructure related to minimum length interchange cars. For the purpose of this study, HAL cars are considered to be cars with a gross rail load of 286 kips or more. Data from the railroad industry equipment database, UMLER®, shows the number of HAL cars shorter than 42 feet have increased from 40,000 to more than 85,000 during the last 5 years. The majority of these short HAL cars are covered hoppers ~42 feet long. The areas of particular focus are those that might be different for cars of minimum interchange length (about 42 feet long) as compared to the common 53-foot coal cars that have been used in past HAL studies. Preliminary studies identified embankments and bridges as the most likely areas of concern.¹

The increased number of short cars operating in revenue service increases the loading on bridges. The 42-foot cars are a ~25 percent increase in load per unit length (6.8 kip/foot) compared to coal cars (5.4 kip/foot), which may require weight restrictions on bridges, especially on longer spans that accommodate multiple short cars; e.g., on a 210-foot span, five 42-foot cars can fit instead of four 53-foot cars (Figure 1).

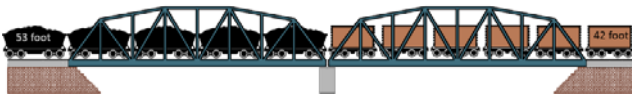


Figure 1. Loading on 210-foot Span

Previous research results show short cars are causing greater bridge stresses in spans 60 feet and longer, and the difference was more prominent on spans of 80 feet and longer. Of particular importance are the long truss spans, which are used in many major crossings and longer bridges.

This *Technology Digest* focuses on: (1) modeling of two span trusses using FEA software, (2) calculating the differences in stresses due to trains with two different car lengths, (3) providing recommendations for testing, (4) and validating of the models.

BRIDGE DESCRIPTION

This study focuses on Bridge 93.94 on Track 2 of the Colorado Springs Subdivision owned by Union Pacific Railroad. The ballasted deck bridge contains two truss spans with lengths of 110 feet and 200 feet and it is located over the Fountain River. Figure 2 presents the general dimensions of the bridge.

All member sections are built-up sections. Two types of sections are dominating over the main truss members – interlaced two C-sections and a reverse U-section. The stringers and floor beams are built-up 48-inch deep girder sections. Table 1 provides more information about the geometry properties of the main members within the trusses.

Table 1. Geometry Properties of Truss Members

Lower Chords and Diagonals	Upper Chords and End Posts

FINITE ELEMENT MODELING

The analytical calculations are performed to provide guidance for the test plan. Effects of car lengths on truss span members depends on the type and location of the member, as well as the type and length of the truss. To evaluate the effects, a 3D model was developed in LUSAS™ software. The advantage of a 3D model is that it contains all components and connections that can closely replicate the actual behavior of the structure.

The bridge model was created using beam and shell elements. All truss members were created using beam elements with appropriate cross sections, which can be used when modeling truss members that carry primarily axial forces. The floor beams and stringers were modeled using shell elements appropriate for members in which the primary stresses are due to bending.

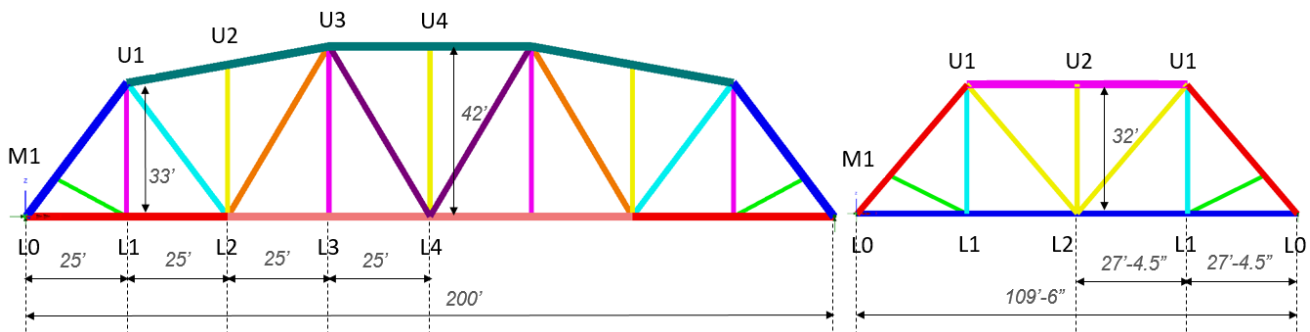


Figure 2. Investigated Bridge Dimensions

The LUSAS bridge models were created both with and without the deck and ballasted track. The best results for this particular bridge were achieved using the model without the deck and track (Figure 3). The load was applied directly onto the stringers. When the track components: rail, ties, and ballast (modeled as a volume in LUSAS) were added to the model, the stresses in the bottom flange of stringers were much lower than the test data. It seems likely that the ballast used in the model was not only distributing the load, but also influenced the stress distribution in the cross section of the stringer.

Stresses were calculated under moving loads for the entire span using common 53-foot cars and short 42-foot cars. Figure 4 presents examples of bending stress histories on selected bridge members due to a moving set of cars.

The calculated stresses in the 200-foot truss due to short cars are 15–25 percent higher than for standard length cars in most of the members. The intermediate diagonals L2U3 and U3L4 experience 13 and 7 percent higher stresses due to standard length cars when compared to the short cars. Figure 5 (top) presents a comparison of predicted peak stresses for the main bridge components on the 200-foot span.

Comparison of predicted peak stresses for the main bridge components on the 110-foot span are presented in Figure 5 (bottom). In the 110-foot-long truss, predicted stresses are 7–26 percent higher due to short cars when compared to the standard length cars for all truss members.

The stringers have only a small variation in stresses of ~5 percent due to different car lengths, which is likely related to the axle spacing and the panel length of the truss.

Figure 6 shows the stress histories for the stringers. The stress histories indicate that stringers experience a slight up-lift effect, which is due to partial continuity of the stringers connected with the floor beams. They behave somewhat like a single continuous beam rather than separate simply supported beams.

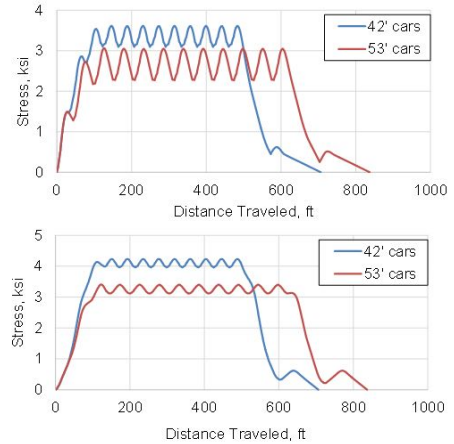


Figure 4. Stress Histories in End Post (top) and Upper Chord (bottom) of 200-foot Span

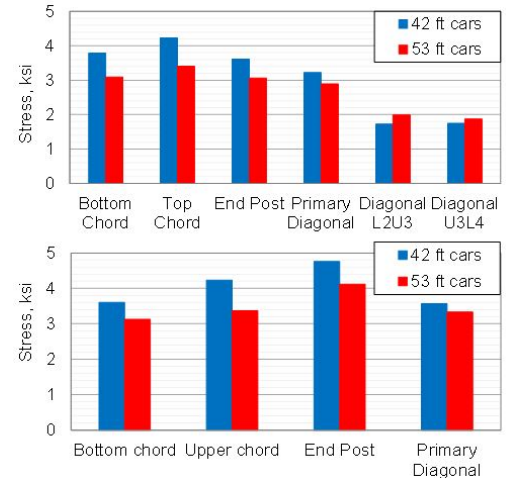


Figure 5. Stress Comparison, 200-foot Span (top) and 110-foot Span (bottom)

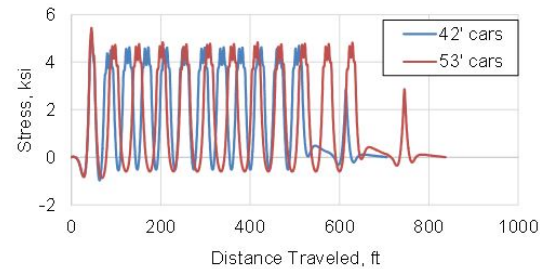


Figure 6. Stress Histories for Stringer, 200-foot Span

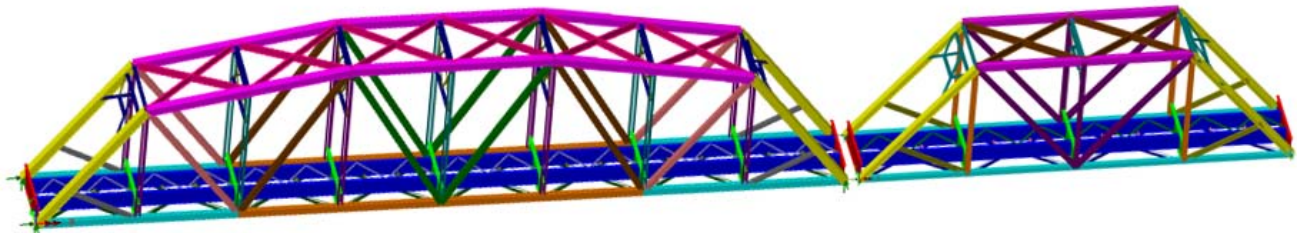


Figure 3. FEA Bridge Model

The stress cycles due to 42-foot short cars and common 53-foot cars are predicted to be less than 1.0 ksi for all primary members in both trusses. Higher cycles, up to 2.0 ksi, were predicted on secondary diagonals due to common 53-foot cars. As expected, the largest stress cycles were seen on stringers, as noted above.

TEST RECOMMENDATIONS

Based on the analysis results, the members of both trusses were selected to be instrumented to demonstrate the differences due to various car lengths.

Strain gages to evaluate axial forces were installed on the bottom chord (L2L3) and top chord (U3U4) close to the center span, end post (LOU1), diagonals (U1L2, L2U3, and U3L4) on the 200-foot span. Similarly, on the 110-foot span, the strain gages were installed on the bottom (L1L2) and top (U1U2) chords close to the center span, end post (LOU1), and diagonal (U1L2). The bottom chords were instrumented on both the inside and outside of the cross section.

Strain gages to evaluate bending on the east and west stringers closest to the center span (Stringers 3 and 4) were proposed, but after further consideration of the water level and access, it was decided to instrument Stringer 2 and Stringer 3 on the 200-foot span instead.

MODEL VALIDATION

To validate the model, the stresses from the FEA were compared to the field data. Figure 7 presents comparisons between the test data and the calculated stresses from the FE model. In the field, the stresses on the east and west sides of the trusses were slightly different; whereas in the FE model, both sides were the same since the model was created to be symmetrical. For comparison, the average of east and west test results was used. Most of the model results were within 15 percent variation of the test results.

For the 110-foot truss, the model was more conservative and overestimated the stresses compared to the actual measurements. The relative differences due to car length were predicted accurately. For the 200-foot truss, the model was less conservative. The measured stresses were higher than those predicted by the model.

In the calculations, the assumption was made that each of the C-shapes in built-up members takes 50 percent of the load; however, it is possible that the axial force is not distributed equally between two parts of the members.

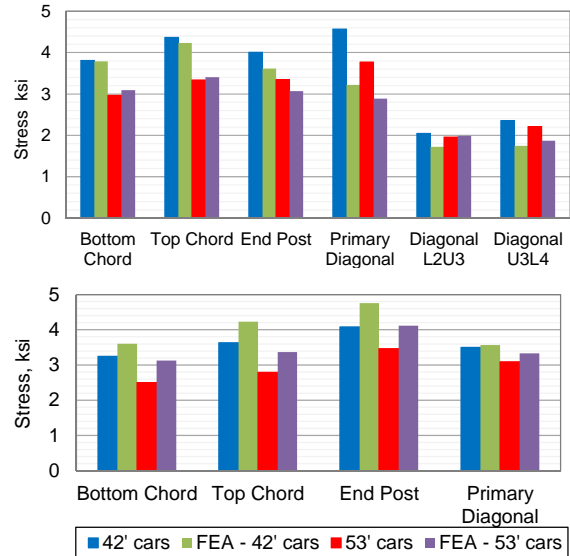


Figure 7. Stress Comparison of Test Data and FEA Results, 200-foot Span (top) and 110-foot Span (bottom)

CONCLUSIONS

In an effort to evaluate the performance of the bridges under railcars of different lengths, analytical calculations and tests were performed. Significant differences between member stresses of shorter 42-foot cars and common 53-foot cars were observed in the analytical calculations for bridge spans longer than 60 feet, and the differences were more prominent on spans of 80 feet and longer. To verify the analysis, a test was performed in 2016 on a two-span truss bridge, with spans of 200 feet and 110 feet. The analytical calculations indicated that the effect of short cars was most prominent on the primary members such as end posts, primary diagonals, and top and bottom chords.

REFERENCES

1. Rakoczy, Anna, Duane Otter, and Stephen Dick. "Short Heavy Axle Load Cars: Analysis." *Technology Digest* TD-16-013, Association of American Railroads, Transportation Technology Center, Inc. Pueblo, CO. April 2016.
2. Rakoczy, Anna, Brach Prough, Duane Otter, and Stephen Dick. "Short Heavy Axle Load Cars: Testing of Longer Bridge Spans." *Technology Digest* TD-16-048, Association of American Railroads, Transportation Technology Center, Inc. Pueblo, CO. November 2016.

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