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Short Heavy Axle Load Cars: Testing 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 related to minimum length (approximately 42 feet) interchange cars. Significant differences between maximum effects of shorter cars and common 53-foot cars were predicted in analysis for spans longer than 60 feet, and the difference was more prominent on spans of 80 feet and longer. Therefore, this study investigated differences in stresses on longer spans. A two-span truss bridge, with spans of 200 feet and 110 feet, was measured for 2 months to compare the response under typical 53-foot coal cars as well as shorter cars of cement trains and rock trains to show the differences due to car lengths. Test results showed that short cars produce higher stresses on longer bridge spans, as follows:

- The 42-foot cars produced stresses 29–31 percent higher than 53-foot cars in top and bottom chords on the 200-foot span.
- The end post and primary diagonal of the 200-foot span were subjected to stresses between 20–21 percent higher due to short cars as compared to common 53-foot cars.
- The stresses in intermediate diagonal members are 4–6 percent higher due to short cars on the 200-foot span.
- Short cars caused a 30 percent increase in stress in both the top and bottom chords of the 110-foot span.
- The end post experienced an 18 percent stress increase due to short cars, while the diagonal stress increased 13 percent on the 110-foot span.
- As predicted, stringers of the 200-foot span did not experience any increase in stresses due to short cars. The 42-foot cars did not create an increase in fatigue cycle accumulation in the stringers.
- Shipment of the short cars should be carefully planned, especially on the lines that have longer spans with low ratings.

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. The majority of these short HAL cars are covered hoppers approximately 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 42-foot cars are about a 25 percent increase in load per unit length (6.8 kip/foot) compared to 53-foot coal cars (5.4 kip/foot). This increases the load on bridges, especially on longer spans that accommodate multiple short cars. For example, on a 210-foot span, five 42-foot cars can fit instead of only four 53-foot cars.

This *Technology Digest* focuses on: (1) the methods and instrumentation used in order to collect data; (2) the stress comparisons between loaded short cars and loaded 53-foot cars; (3) providing recommendations for future bridge ratings.

BRIDGE DESCRIPTION

Bridge 93.94 is on Track 2 of the Colorado Springs Subdivision owned by Union Pacific Railroad (Figure 1). The ballasted deck bridge contains two spans with lengths of 110 feet and 200 feet and it is located over the Fountain River. Figure 2 shows the general dimensions of the bridge.



Figure 1. View of Bridge 93.94

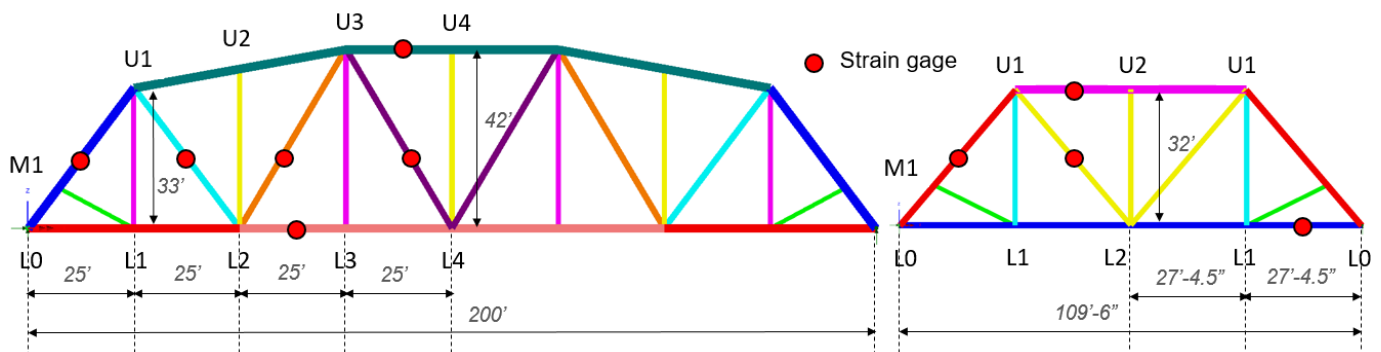


Figure 2. Investigated Bridge Dimensions and Strain Gage Locations

All members are built-up sections. Two types of the sections are used for the main span members – interlaced two C-sections and a reverse U-section. The stringers are built-up 48-inch deep girder sections. Table 1 shows geometry properties of the span members.

Table 1. Geometry Properties of Span Members

| | 200-Foot Span | 110-Foot Span |
|--|---|--|
| | Lower Chords (L0L2, L2L4), Diagonals (U1L2, L2U3, U3L4) | Lower Chords (L0L2), Diagonals (U1L2) |
| | Upper Chords (U1U3, U3U3) and End Posts (LOU1) | Upper Chords (U1U3) and End Posts (LOU1) |

MEASUREMENTS

Based on the results from a finite element analysis, the members of both spans were selected for the measurements. Strain gages were installed on the bottom chords, top chords, and diagonal members on each span of the bridge to evaluate stresses due to axial forces. The red circles in Figure 2 show strain gage locations. In addition, four strain gages were installed on the stringers of the 200-foot span to evaluate bending stresses.

Data was collected for two months from a total of 465 trains. Among these trains, 299 were unloaded, 120 had mixed freight, and 46 were loaded unit trains. Because the experiment focused specifically on loaded trains, the 46 loaded unit trains were then separated by the length of their cars.

Thirteen loaded unit coal trains of 53-foot cars, nineteen loaded unit rock trains of 43-foot cars, and eight loaded unit cement trains of 42-foot cars were analyzed in order to validate results.

TEST DATA

Figure 3 compares the stress histories for a train with 42-foot cars and a train with 53-foot cars.

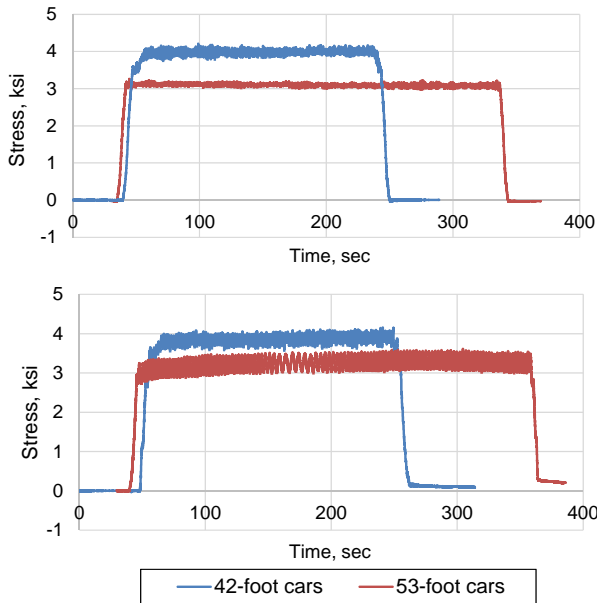


Figure 3. Stress Histories in 200-foot Span – Upper Chord (top) and End Post (bottom)

As predicted by analysis, the 42-foot cars caused higher stresses in the upper chord and end post of the 200-foot span.² Figure 4 illustrates the typical peak stresses caused by unit trains of 53-foot cars and unit trains of 42-foot cars on the top, bottom, and diagonal members of the 200-foot span.

The top and bottom chords experienced a stress increase of 31 percent and 29 percent, respectively. The end post saw a 20 percent stress increase, whereas the primary diagonal saw a 21 percent stress increase. A 4–6 percent stress increase was recorded in the intermediate diagonals.

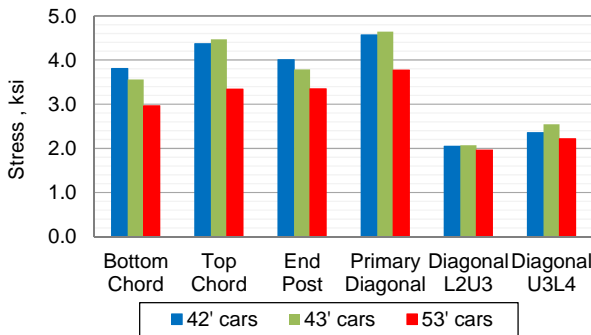


Figure 4. Typical Peak Stress Comparison for 200-foot Span

The test yielded similar results for the 110-foot span. Figure 5 shows the comparison of stresses between

42-foot and 53-foot cars along the members of the 110-foot span.

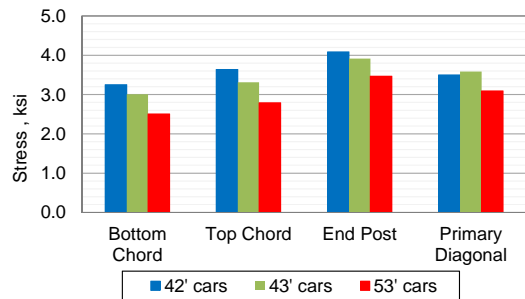


Figure 5. Typical Peak Stress Comparison for 110-foot Span

The lower and upper chords each experienced a 30 percent increase in stresses due to the short cars. The end post saw an 18 percent increase, and the primary diagonal saw a 13 percent stress increase due to short cars.

The stress ranges were calculated to determine the fatigue that each member experienced. Figure 6 shows the stress ranges for both sets of the 42- and 53-foot cars on the 110- and 200-foot spans. The stress ranges of the upper chord were not included, because they were close to zero.

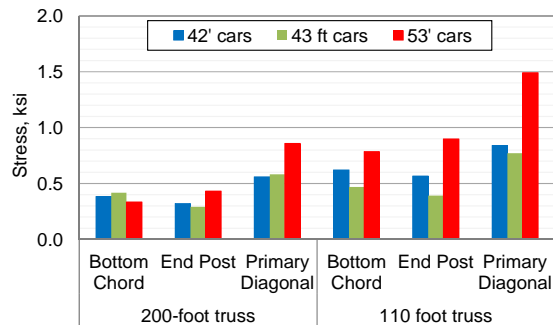


Figure 6. Stress Range Comparisons

All of the measured stress ranges for the main span members were well below the variable amplitude fatigue limit of 6 ksi. For the main span members, fatigue is not a concern for either the common 53-foot cars or the short 42-foot cars.

TEST DATA – STRINGERS

Strain gages were also placed on the stringers of the 200-foot span. Figure 7 shows the general location of these gages. Figure 8 shows the comparison of stress time histories for both types of cars in Stringer S2. The typical peak stresses due to each car type on the stringers were calculated using the same methods as on the other bridge members. Figure 9 shows these comparisons.

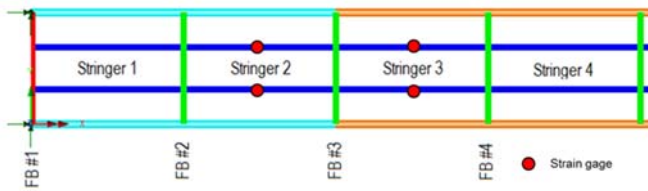


Figure 7. Gage Locations in Stringers

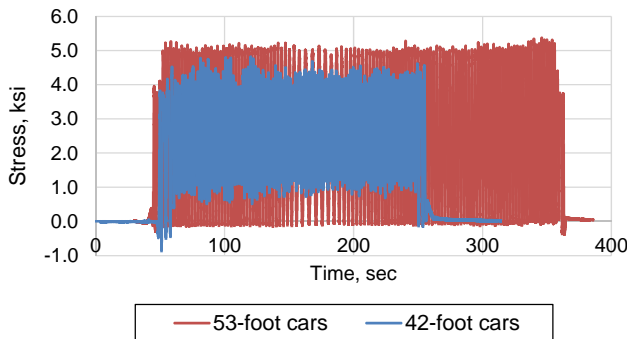


Figure 8. Stress Comparison for SES2

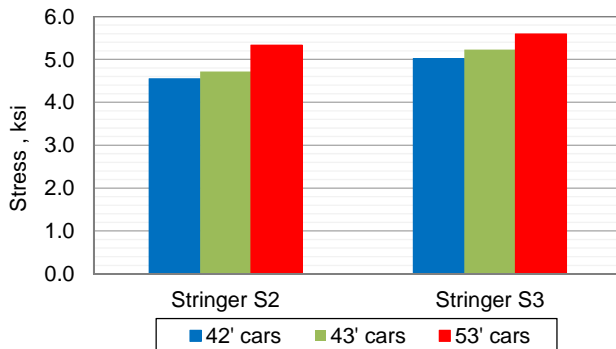


Figure 9. Typical Peak Stress Comparisons for Stringers

The stringers behaved differently due to the short cars than the other members of the bridge. For example, Stringer S2 experienced 15 percent less stress, and S3 experienced 10 percent less stress due to short cars. This could have been related to the ratio of the car length and stringer length. The stringers connected by floor beams develop partial continuity that also affects the results.

The effect of car length on stringers is also visible when evaluating stress ranges. The stringers develop higher stress cycles due to common 53-foot cars than the short cars (Figure 10).

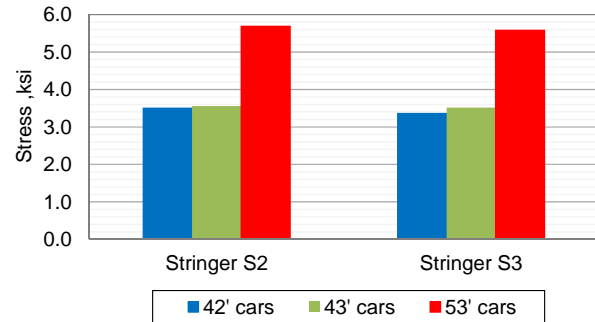


Figure 10. Stress Range Comparisons for Stringers

CONCLUSION

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. The test data indicated short cars produce higher stresses on longer bridge spans, as follows:

- The 42-foot cars produced stresses 29–31 percent higher than 53-foot cars in top and bottom chords and stresses 20–21 percent higher on the end post and primary diagonal on the 200-foot span.
- Short cars caused a 30 percent increase in stress in both the top and bottom chords of the 110-foot span. The end post experienced an 18 percent stress increase due to short cars.
- These members govern the overall load capacity of the bridge, so shipments of multiple car blocks of short cars should be carefully planned for bridge spans longer than 60 feet and with a marginal rating.

ACKNOWLEDGEMENTS

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