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Testing of 115-foot Girder Span for Fatigue Loading and Railcar Length Effects

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SUMMARY

Transportation Technology Center, Inc. (TTCI) tested a steel railroad bridge under revenue service operation to evaluate fatigue concepts related to the effect of railcar length on fatigue of steel railroad bridges. The analysis and preliminary test results show that the stress cycles can be higher at locations other than the mid-span location. Therefore, the quarter-span location and the cover plate terminations should be considered in addition to the traditional mid-span location for many typical railroad spans.

On a tested span, the highest cyclic stress ranges for fatigue consideration were measured under the longer railcars (53-foot coal cars and 60-foot grain cars) as compared to the shorter cars (42-foot cement cars and 45-foot tank cars). However, the highest maximum live load stresses were measured under the shorter railcars as compared to standard 53-foot coal cars and 60-foot grain cars.

Results for this particular span further indicate:

- The highest measured stress ranges were at the terminations of cover plates within about 30 feet of the ends of the span.
- The mid-span location generally has the smallest stress cycles from all the measured locations along the girder.
- The 42-foot railcars produced maximum live load stresses of 22 and 26 percent higher than 53-foot railcars at mid-span locations of the 113’10” girder and 115’ girder, respectively.

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INTRODUCTION

The understanding of the fatigue life of steel railroad bridge components is of particular importance. Fatigue life depends on the size of the live load stress cycles more so than the maximum stress. Longer spans do not experience full unloading and in that case the cyclic stress ranges are more important than the one maximum live load stress cycle per train.

For a certain span to railcar length ratio, the number of cycles may be higher at quarter-span locations than at mid-span locations. In that case, the bridge components at or close to a quarter span location may accumulate higher fatigue over the service life of the bridge than those components at or close to a mid-span location. The effect of span to railcar length ratio on fatigue life was discussed already in previous publications.[1,2]

This *Technology Digest* (TD) presents more test data to confirm the analytical calculations. It focuses on: (1) differences of stress cycles resulting from different railcar lengths for various locations along the span, including cover plate terminations; and (2) the peak stress comparisons between loaded short cars and loaded 53-foot railcars.

BRIDGE DESCRIPTION

BNSF Railway Company (BNSF) Bridge 617 on the Pueblo Subdivision over the Fountain River has five ballasted deck spans with north girders (G1) of 113’10” overall length and 111’6” between bearing centers and south girders (G2) of 115’ overall length and 112’8” between bearing centers. Figure 1 shows an overall view of the bridge, and Figure 2 illustrates detailed dimensions. The bridge is located just east of Pueblo Jct., so train speeds over the bridge are generally under 15 mph.

Figure 1. View of BNSF Bridge 617

ANALYTICAL CALCULATIONS

Analytical predictions on this long girder span show that mid span is not the most critical location for fatigue for common railcars. Figure 3 shows the stress ranges that were calculated for three common unit train cars (42-foot sand or cement hoppers, 53-foot coal cars, and 60-foot grain cars) using gross section and zero impact. As the stress range envelopes show, the mid-span location has stress cycle sizes close to zero for the coal and grain cars, while other locations, specifically cover plate terminations, show higher cyclic stress ranges. Therefore, cover plate terminations are critical areas for fatigue evaluation, particularly on longer spans.

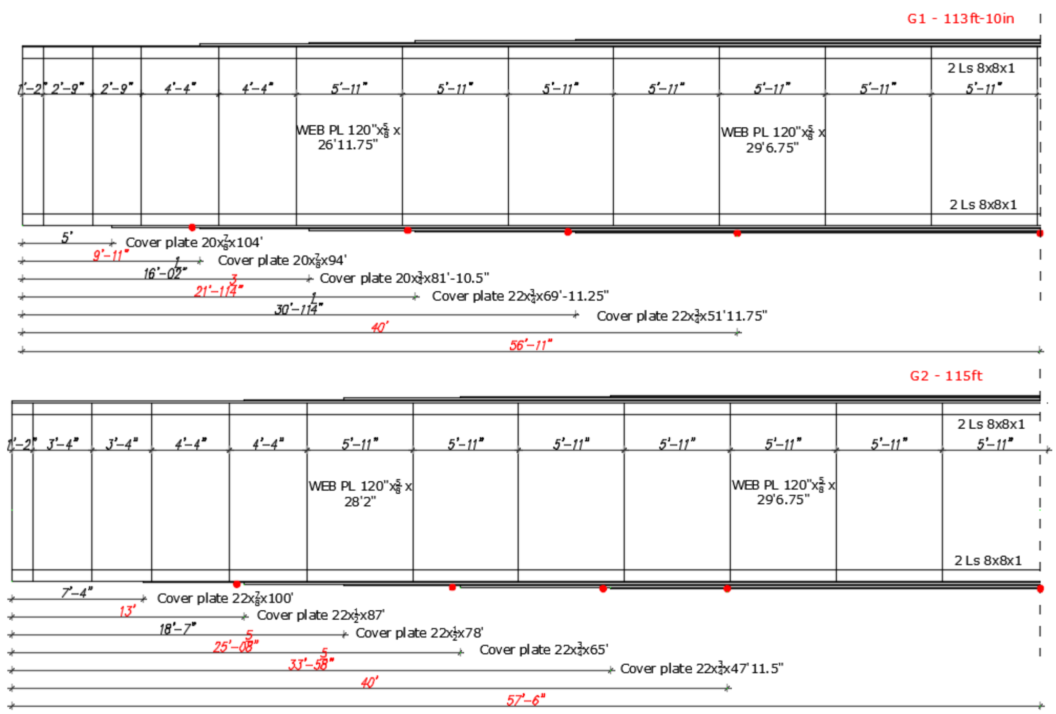

Figure 2. Investigated Bridge Dimensions and Strain Gage Locations

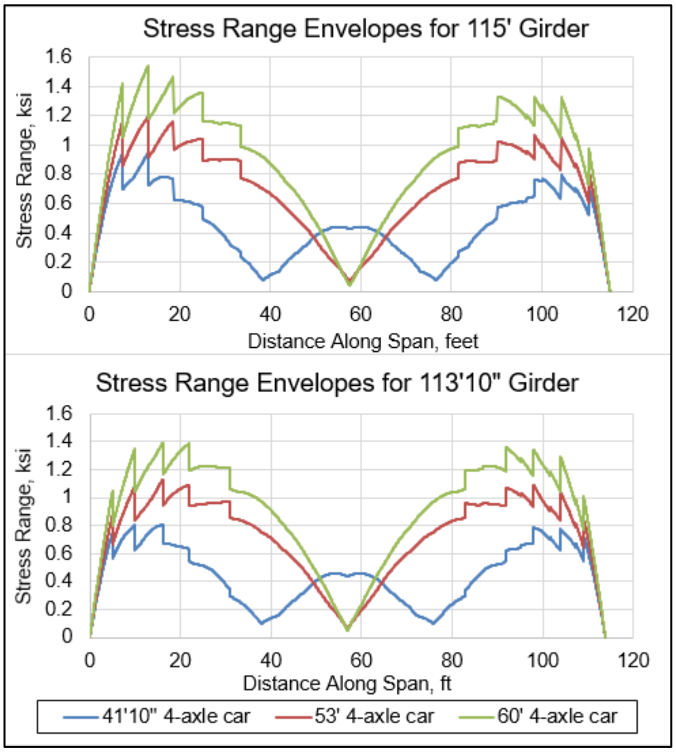

Figure 3. Calculated Cyclic Stress Range Envelopes

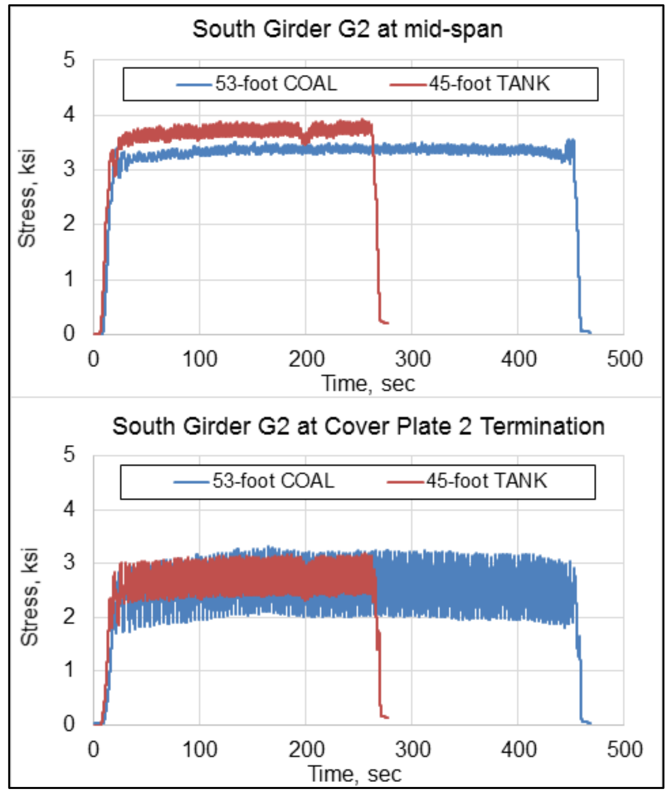

Figure 4. Measured Stress Histories in South Girder G2

MEASUREMENTS

Measurements were taken under revenue service Union Pacific Railroad (UP) and BNSF trains. Data was collected for loaded coal trains, as well as other loaded unit trains (grain, tank).

Five strain gages were installed on each of the girders to evaluate bending stresses: mid-span, 40 feet from the end, and three cover plate cutoffs (see Figure 2 for more details). In Figure 2, the locations of cover plate terminations are shown for the south girder (G2) and for the north girder (G1). Note that the location of cover plate terminations and the overall lengths of each of the two girders are slightly different. The girders are asymmetric due to the bridge location on a curve.

TEST DATA

Strains due to unit coal trains, unit grain trains and a unit tank train along with several mixed freight trains were recorded. One of the mixed freight trains contained a block of short (42-foot) cement cars that was also used in the analysis.

Figure 4 compares the stress histories for a train with 45-foot tank cars and a train with 53-foot coal cars.

As predicted by analysis, higher cyclic stress ranges were measured at cover plate terminations than at mid span. The mid-span stress histories show one large stress cycle due to a train and very small stress cycles due to individual railcars.

Figure 5 compares cyclic stress ranges at various locations along the span for four types of railcars: grain cars, 53-foot coal cars, 45-foot tank cars, and unit trains of 42-foot cement cars. The highest stress ranges are due to 53-foot coal cars and 60-foot grain cars. Based on the span length from center to center of bearings, the span to railcar length ratio is 2.13 for the coal cars, and about 1.92 for the grain cars. The span to railcar length ratio for the tank cars is about 2.56 and 2.70 for the cement cars.

The span locations that experienced the highest stress ranges are at cover plates terminations as was predicted analytically and shown on Figure 3. The measured stress range due to 53-foot coal cars at cover plate 2 termination on girder G2 is about 1.15 ksi. This matches analytical calculation of cyclic stress range of 1.2 ksi (red line, Figure 3). The measured stress range due to 53-foot coal cars at mid-span of girder G2 is about 0.1 ksi. The analytical calculation shows a stress range of 0.07 ksi which essentially matches the measurements.

The differences between girders G1 and G2 are related to the differences in geometry. The beams vary slightly in overall length and also have different lengths of cover plates.

Figure 6 illustrates the typical peak stresses caused by unit trains of 42-foot cement cars, 45-foot tank cars, 53-foot coal cars, and unit trains of grain cars on girders G2 and G1.

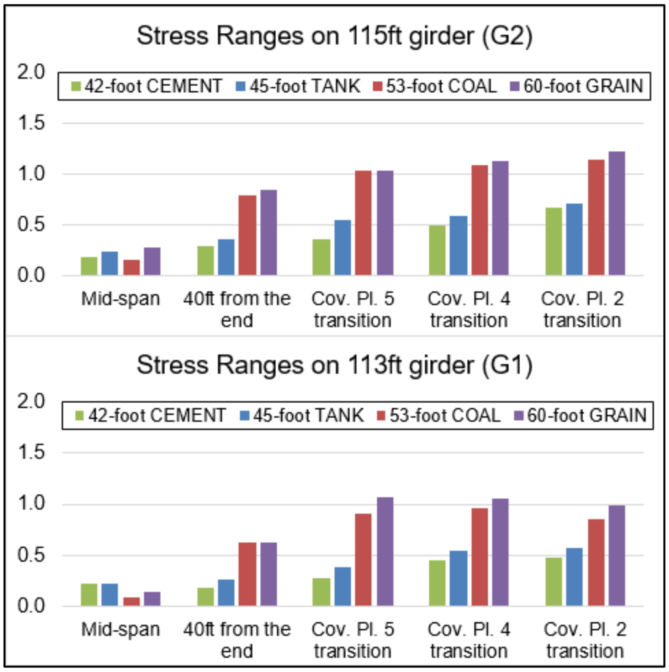

Figure 5. Measured Stress Range Comparisons for Girder G1 and G2

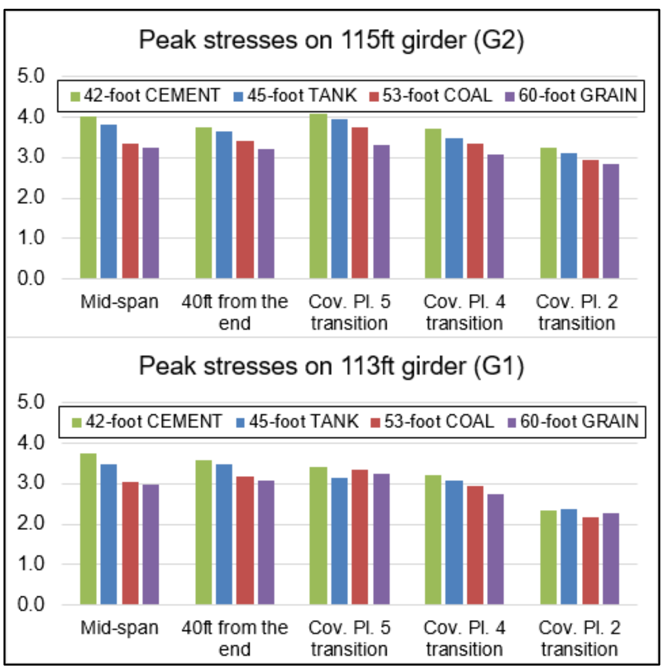

Figure 6. Measured Effect of Car Length on Maximum Girder Stress for South Girder (top) and North Girder (bottom)

The mid-span location of the south girder experienced bending stresses 26 percent higher due to short cars when compared to standard 53-foot cars. Stresses at 40 feet from the end were also more than 10 percent higher due to shorter cars.

Also, the 42-foot and 45-foot cars caused slightly higher stresses at the mid-span location than the 53-foot coal cars as was predicted by analytical calculations, as well as measurements on other long spans.[3,4]

The test yielded similar results for the north girder. Compared to 53-foot coal cars, the shorter cars produced mid-span bending stresses 22 percent higher and stresses at 40 feet from the end 10 percent higher. The maximum bending stresses at other locations along the span were less prominent.

CONCLUSION

This tested span further validated the analytical bridge fatigue models that TTCI has developed. The analytical calculations indicated that the mid span might not be the most critical location for fatigue depending on railcar length and span length considerations. Stress ranges at cover plates terminations are the highest for this particular span. The test data confirmed the analytical predictions. The measured stresses closely matched predicted stresses calculated using zero impact and gross section properties of the girders.

ACKNOWLEDGEMENTS

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REFERENCES

1. Dick, Stephen M. and Steven L. McCabe. 2002. "Fatigue Analysis of Steel Railway Girder Bridges." *American Railway Engineering & Maintenance of Way Association 2002 Annual Conference*.
2. Akhtar, Muhammad, Brian Doe, and Duane Otter. 2008. "Validation Test of New Steel Bridge Fatigue Consideration." *Technology Digest* TD-08-053, TTCI/AAR, Pueblo, Colorado. December 2008
3. Rakoczy, Anna, Duane Otter, and Stephen Dick. "Short Heavy Axle Load Cars: Analysis." *Technology Digest* TD-16-013, TTCI/AAR, Pueblo, CO. April 2016.
4. Rakoczy, Anna, Brach Prough, Duane Otter, and Stephen Dick. "Short Heavy Axle Load Cars: Testing of Longer Bridge Spans." *Technology Digest* TD-16-048, TTCI/AAR, Pueblo, CO. November 2016.