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Measured Effects of Articulated Double-Stack Cars on Bridges

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The work described in this document was performed by Transportation Technology Center, Inc., a wholly owned subsidiary of the Association of American Railroads.

Key Findings:

- The collected data show that the double-stack cars often are not loaded to their full capacity. Therefore, their load effect is comparable to, or less than, the load effect due to coal cars. Nonetheless, loading should be monitored as more frequent maximum loads have the potential to shorten the useful life of short spans.
- The maximum bending stresses recorded for double-stack cars on the short span bridge were slightly higher as compared to those for a coal train.
- In terms of stress cycles, stress ranges under intermodal trains are more variable than the stress ranges under coal trains.
- In terms of fatigue, the equivalent stress range was about 10 percent lower under a typical intermodal train as compared to a coal train. The number of accumulative stress cycles was about 80 percent lower.

Transportation Technology Center, Inc.'s (TTCI) ongoing research on the effects of articulated double-stack cars on bridges indicates that they can apply greater loads to short bridge spans and floor system members. Double-stack cars loaded to their capacity have a nominal truck weight of 157.5 kips, which is higher than the nominal truck weight of 143 kips for a coal car. The previous analytical investigation indicates that double-stack cars should cause larger maximum moments only on spans shorter than approximately 15 feet. To confirm the analytical study, data was collected from a short bridge located near Kirkland, Texas, under intermodal trains and coal trains.

With recent increases in double-stack intermodal traffic on several lines, railroad bridge engineers have requested a study on the effects of double-stack cars on bridges. Of interest are articulated double-stack cars, with nominal truck loads on the intermediate trucks that exceed the maximum interchange truck load on typical four-axle freight cars. The nominal truck load for articulated double-stack cars is 157.5 kips — about a 10 percent increase compared to interchange cars with a maximum truck load of 143 kips. The nominal weights and car dimensions for typical double-stack cars were presented in a previous *Technology Digest*[1] and other reports.[2]

This *Technology Digest* summarizes test results of a revenue service bridge under intermodal trains and coal trains. The measurements included strains from all six beams and deflections from the center beams of each side. The analysis focuses on comparison of peak stress and stress range cycles.

This work was performed as part of the Association of American Railroads' Strategic Research Initiative on bridge life extension.

Equivalent Cooper Loading

The equivalent Cooper loading is based on the design loading recommended by the American Railway Engineering and Maintenance-of-Way Association (AREMA).[3] It is current practice to design railroad bridges for Cooper E-80 loads, which have maximum axle loads of 80 kips. By comparison, the nominal maximum axle load for an articulated double-stack car is 78.75 kips. Many steel bridges currently in service originally were designed for lesser loads, such as E-50 but greater impact representing steam locomotives (per 1906 edition of AREA manual). Double-stack car effects are highest only on shorter spans.

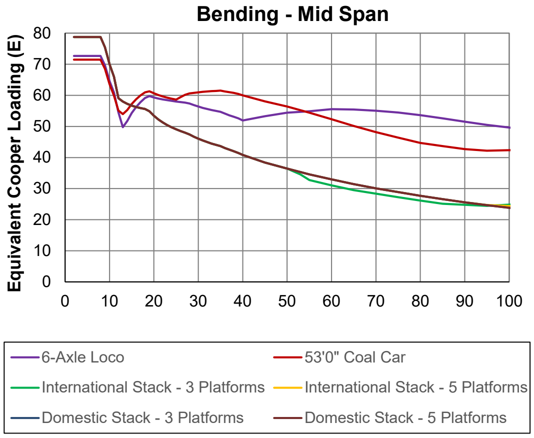

Figure 1. Equivalent Cooper loading up to 100 feet – bending moment

Figure 1 shows double-stack cars have equivalent Cooper loads greater than common 53-foot coal cars for spans up to about 15 feet long.

Bridge description

In conjunction with BNSF Railway, TTCI measured the effects of both articulated double-stack railcars as well as coal cars on a short span bridge near Kirkland, Texas, on the BNSF Red River Valley Subdivision (Figure 2). The span is on a line that carries unit coal and grain traffic as well as intermodal traffic. The bridge is built from six rolled beams 16 feet long (end to end) with an open deck. The beams are 15 inches tall and 6 inches wide (S 15×60).

Figure 2. Bridge 209.22 I-Beam span near Kirkland, Texas

Bridge instrumentation

Strain gages were installed on all six beams as presented in Figures 3 and 4.

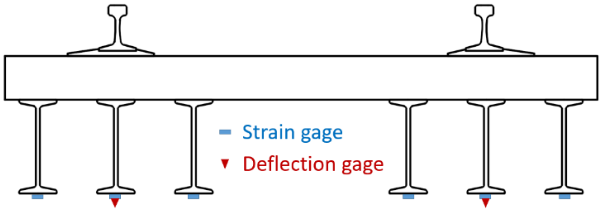

Figure 3. Scheme of gage locations

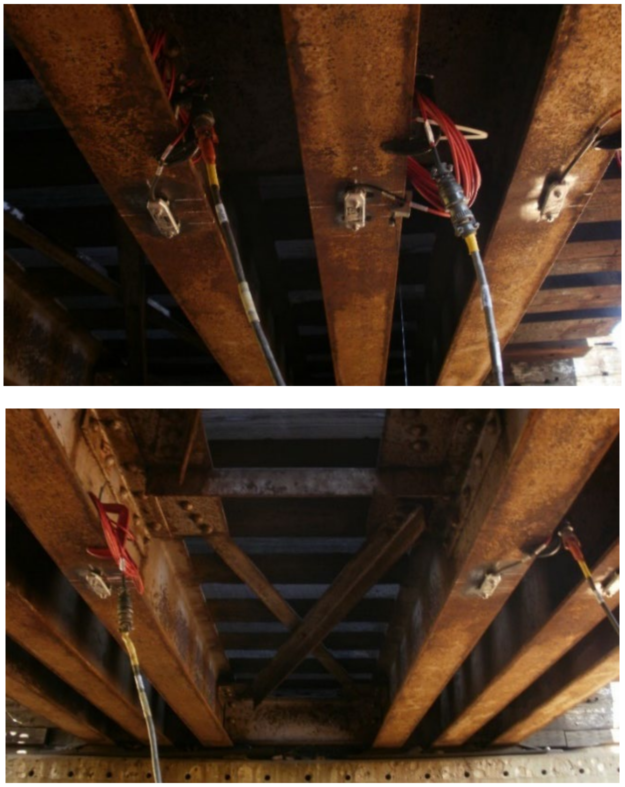

Figure 4. Photos of gage locations

Data sets were collected under revenue service trains passing over the bridge. Loaded articulated double-stack cars were of most interest. For comparison purposes, loaded unit coal or grain trains also were important.

Data was collected for two days and during that time 14 trains passed over the bridge. Among these, three were loaded unit trains and 10 were intermodal trains.

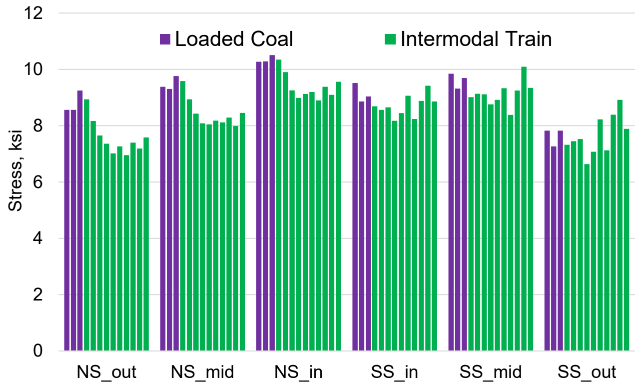

Figure 5. Maximum peak-stress recorded under train passage

The stresses are distributed more consistently on the south side with the highest stresses on the middle beam. The north side is less uniform: the inside to outside beams have up to a 2 ksi difference and the highest stresses are on the inside beam. Most likely track positioning on the span influenced that variation and this is not related to type of train: double-stack cars vs. coal train.

Deflection of the bridge was measured from the middle beams at mid span. The maximum measured deflection was around 0.2 inch. Figure 6 presents deflection under a unit coal train and Figure 7 presents deflection under an intermodal train.

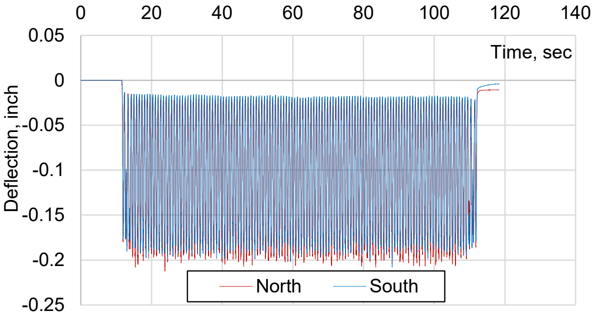

Figure 6. Deflection for middle beams under loaded unit coal train

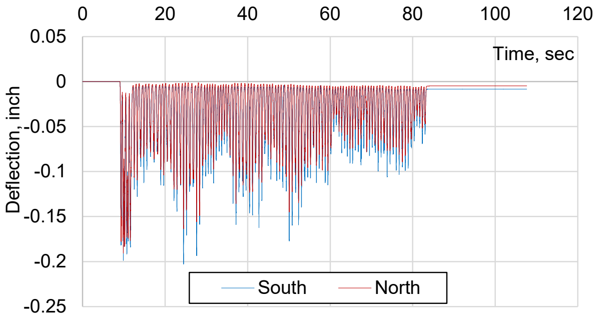

Figure 7. Deflection histories for middle beams under intermodal train

Evaluation of stress cycles

The peak stresses vary from car to car. In order to use the data from a typical train pass for a fatigue life estimate, the cycles should be counted using a rain flow cycle counting method.[2]

The stress history for the center beams under a loaded unit coal train is presented in Figure 8.

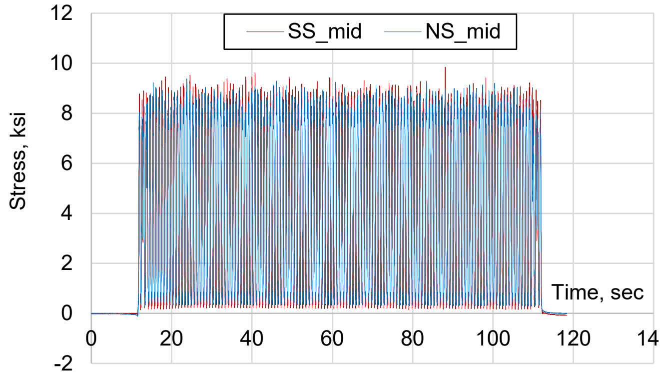

Figure 8. Stress histories for center beams under loaded unit coal train

Distribution of the stress ranges is shown in Figure 9. This distribution shows that majority of the stresses (100-120 counts) are in the range of 8 to 9 ksi. However; there are several cycles in the range of 9 to 10 ksi, especially on south side of the bridge. The equivalent stress range for the south center beam is 8.8 ksi, including only stress ranges above 6 ksi (129 cycles).

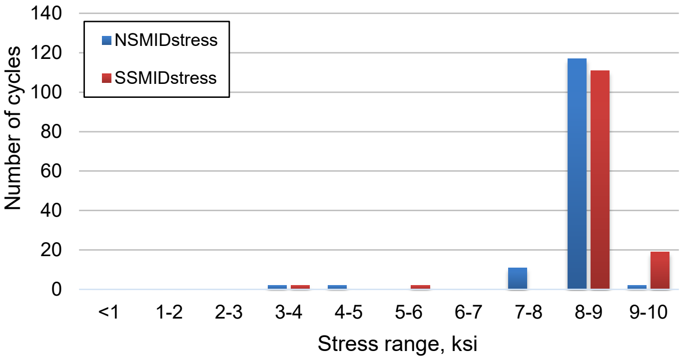

Figure 9. Cycle counts for center beam under unit coal train

The stress history under an intermodal train is presented in Figure 10. It is much more variable than the stress history under the loaded unit coal train. Distribution of the stress ranges is shown in Figure 11. This distribution shows that the stresses are broadly distributed but many of the cycles (~75 counts) are in the range of 3 to 6 ksi. However; there are also higher cycles in the range of 9 to 10 ksi and 10 to 11 ksi. The equivalent stress range for south center beam is 7.9 ksi, including only stress ranges above 6 ksi (24 cycles).

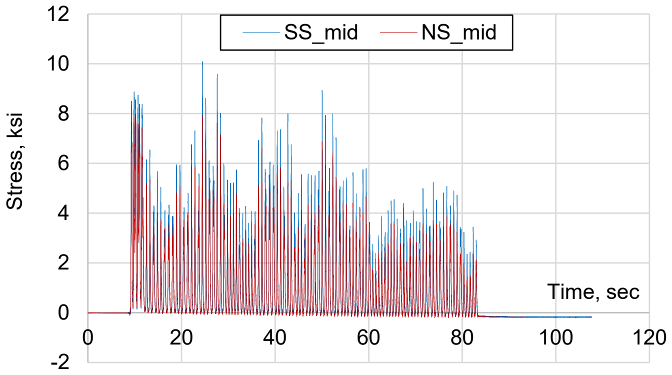

Figure 10. Stress histories for six beams under intermodal train

Again, the higher stress cycles are especially on the center beam on the south side of the bridge.

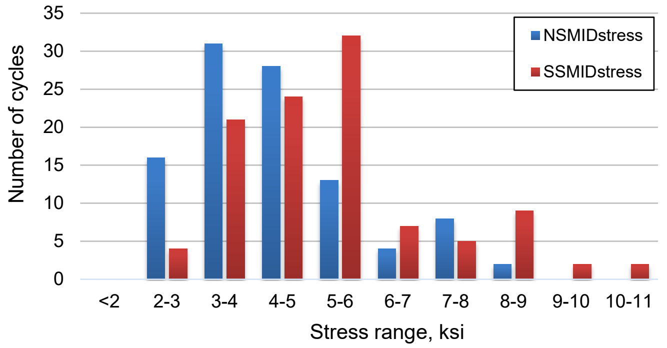

Figure 11. Cycle counts for center beam under intermodal train

CONCLUSION

The test results from a revenue service bridge under articulated double-stack cars and coal cars indicates that double-stack cars may cause larger maximum bending stresses only if the double stack cars are loaded to their full capacity. Often the articulated double-stack cars are less than fully loaded and the load effect on bridges is less than that due to coal cars.

Overall, the tested bridge span experienced comparable maximum load effects due to articulated double-stack cars and coal cars. There was one train in which the double stack cars produced higher stresses.

In terms of stress cycles, the stress ranges under an intermodal train are more variable than the stress ranges under a loaded unit coal train. The loaded unit coal train produces 100-120 cycles per train in the range of 8 to 10 ksi. While, the intermodal train produces only up to 20 cycles in the range of 8 to 11 ksi. Note that short railroad bridges, including the one tested, are often built using rolled beams that are less prone to fatigue than built-up riveted girders.

References

1. Rakoczy A.M., D. Otter, and S.M. Dick. "Effects of Articulated Double-Stack Cars on Bridges" *Technology Digest* TD17-020, AAR/TTCI, Pueblo, CO, August 2017.
2. Dick, S. "Legacy Train Configurations for Fatigue Life Evaluation of Steel Railway Bridges," Proceedings of the AREMA Annual Conference, Orlando, FL, 2016.
3. American Railway Engineering and Maintenance of Way Association (AREMA), *Manual for Railway Engineering*, Chapter 15 – Steel Structures, Lanham, MD. 2016.

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