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Effects of Articulated Double-Stack Cars on Bridges

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Summary

Transportation Technology Center, Inc.'s (TTCI) ongoing research on the effects of articulated double-stack car traffic on bridges indicates that articulated double-stack cars can apply greater loads to short bridge spans and floor system members. The nominal truck weights and actual net truck vertical forces from Wheel Impact Load Detectors (WILD) were used in this study. The load effects on bridges were calculated for various span lengths. Detailed calculations were performed for four steel spans at the Facility for Accelerated Service Testing (FAST) in Pueblo, CO, using finite element (FE) models.

The results from this research indicate the following preliminary conclusions:

- Articulated double-stack cars apply greater loads than common, 53-foot coal cars on bridge spans and floor system members up to 15 feet long.
- Depending on location 5 to 12 percent of all articulated truck loads measured using WILD exceeded the maximum allowable truck load for four-axle interchange cars (143 kips).
- Only 3 percent of all truck weights measured using WILD exceed the nominal truck weight of articulated double-stack cars (157.5 kips).
- Member stresses are more than 10 percent higher under double-stack cars on spans shorter than 15 feet when compared to 53-foot coal cars.
- The FE modeling of four spans at FAST also indicates that articulated double-stack cars should not govern for spans longer than 15 feet.

It is recommended that future research consider testing of shorter bridge spans under revenue service traffic with different types of double-stack cars.

This work was performed as part of the AAR's Strategic Research Initiative on bridge life extension.

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INTRODUCTION AND MOTIVATION

With recent increases in double-stack intermodal traffic on a number of lines, railroad bridge engineers have requested a study on the effects of those double-stack cars on bridges. Of particular concern are articulated double-stack cars, with nominal truck loads on the intermediate trucks that exceed the maximum allowable 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 the 286-kip freight cars with truck loads of 143 kips.

This *Technology Digest* summarizes an investigation of net truck vertical forces produced by articulated double-stack cars in revenue service and calculations of internal forces for various bridge span lengths. Results indicate that some short bridge spans may experience a load effect close to the current E-80 design load. A recommendation for future testing is presented.

ARTICULATED DOUBLE-STACK CARS

Intermodal double-stack cars come in different configurations. As illustrated in Figure 1, common cars are five-unit, articulated railcars with platforms for carrying 40-foot international containers; and five-unit, articulated railcars for transporting 48-foot and 53-foot domestic containers.[1] The nominal weights and car dimensions for typical double-stack cars are presented in Table 1.

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).[2] 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 bridges currently in service were originally designed for lesser loads, such as E-60.

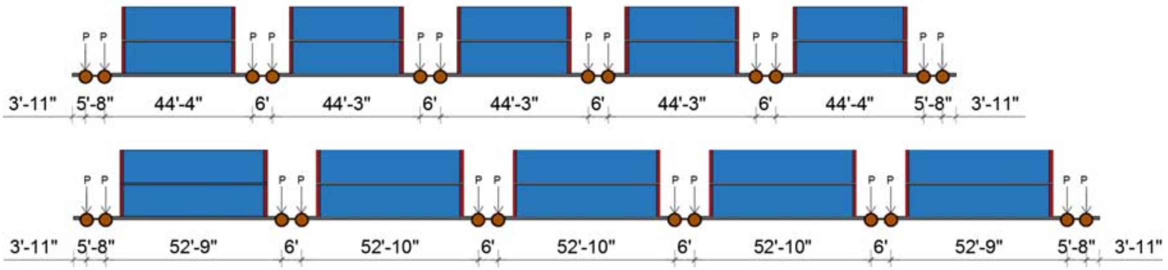
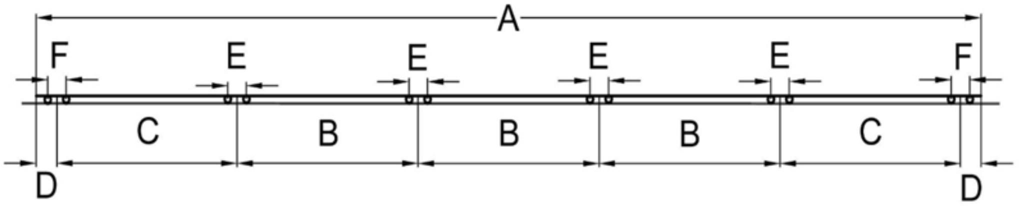


Figure 1. Dimensions of Five-Platform Intermodal Cars

Table 1. Dimensions and Weights of Articulated Cars[1]

Railcar Type	Number of		Weight (lbs.)		Length dimensions (ft.)				Truck Wheelbase (ft.)	
			Platform Loaded	Total Loaded		Truck Centers				
	Axles	Trucks			A	B	C	D	E	F
TOFC Spine Car, Five Platforms	12	6	97,000	485,000	263.75	51.5	47.83	6.79	5.5	5.5
International Stack, Three Platforms	8	4	157,500	482,000	165.42	50	50	6.79	6	5.67
International Stack, Five Platforms	12	6	157,500	800,000	264.67	50.25	50.17	6.79	6	5.67
Domestic Stack, Three Platforms	8	4	157,500	485,000	203.25	63.5	63.08	6.79	6	5.67
Domestic Stack, Five Platforms	12	6	157,500	800,000	307.25	58.83	58.58	6.79	6	5.67
Note: (A) - Overall Length, (B) - Truck Centers Interior, (C) - Truck Centers End, (D) - Coupler Overhang, (E) - Interior Trucks, (F) - End Trucks.										



The results are presented only for spans up to 100 feet long, since the double-stack car effects are most visible on shorter spans. Figure 2 shows double-stack cars have equivalent Cooper loads greater than common, 53-foot coal cars for spans up to 15 feet long. In addition, end shear is higher for double-stack cars on spans shorter than 15 feet, and the floor beam reaction is higher for spans up to 5 feet long (Figure 2).

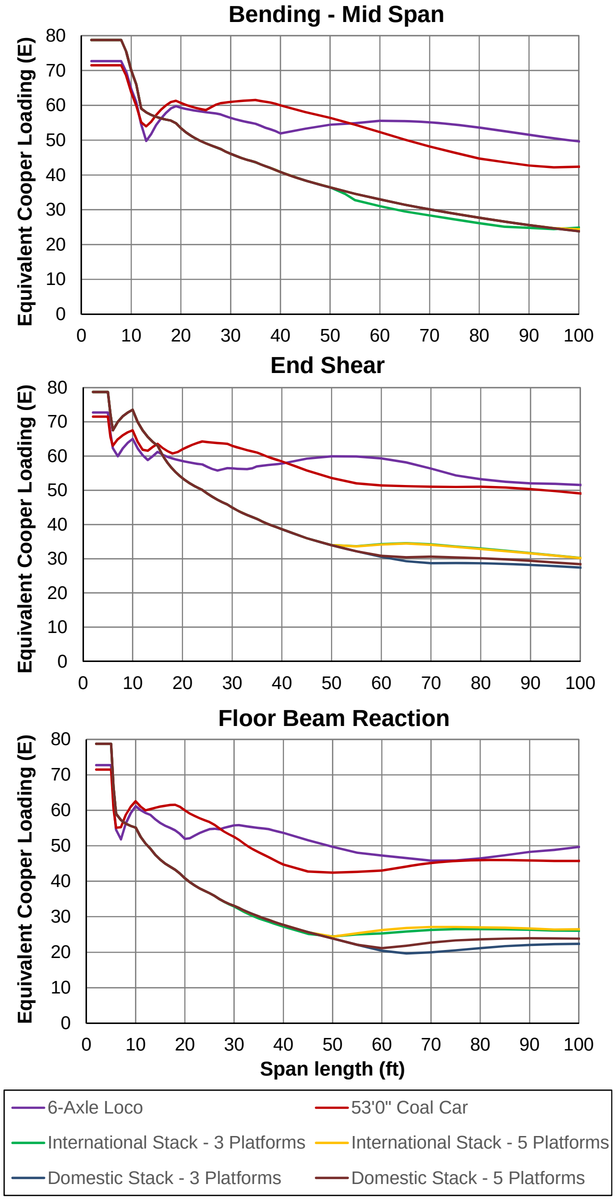


Figure 2. Equivalent Cooper Loading up to 100 feet – Bending Moment, End Shear and Floor Beam Reaction

WAYSIDE DATA

TTCI used wayside data from Wheel Impact Load Detectors (WILD) to estimate loadings from double-stack cars. Wayside measurements are capable of gathering data from a large number of passing trains including different types of equipment. Wayside detectors are currently in use at many locations throughout North America. This study uses measured net truck vertical (NTV) forces (sum of the vertical forces from the four wheels in a truck) from WILDs on tangent track from articulated double-stack cars only.

Wayside truck force data was obtained from four different sites: Bagdad, California; Gothenburg, Nebraska; Vine Creek, Indiana, and Goodeve, Saskatchewan, Canada. Results are mainly presented for Bagdad since that location contained the highest number of records. Data was analyzed by quarter starting with the third quarter of 2014 through the second quarter of 2016. Figure 3 presents a frequency histogram of net truck weights for the considered time periods. The end trucks of the cars have been excluded. The data is only for the interior trucks at the articulated connections.

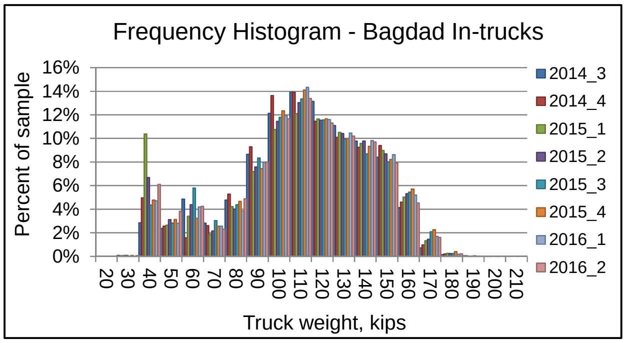


Figure 3. Frequency Histogram of Net Truck Weight for Considered Time Periods

The distribution looks consistent for all time periods; therefore, the changes of the truck weight due to seasonality can be treated as minimal. The frequency histogram of net truck weight calculated as an average of all periods of time is presented in Figure 4. The coefficient of variation is about 30 percent for all recorded data, including empty cars.

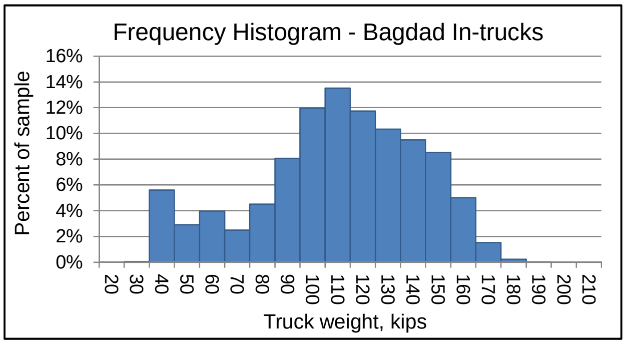


Figure 4. Frequency Histogram of Net Truck Weight Calculated as an Average of All Considered Time Periods

The average interior truck weight is 105 kips — this is below the nominal value of 157.5 kips. However, there are some exceptions where the truck weights exceeded the nominal value.

As shown in Figure 5, net truck weights were further calculated for five probabilities of occurrence: 68, 95, 97, 99.5, and 99.95 percent. About 3 percent of all truck weights exceeded the nominal truck weight, but 97 percent were below that value.

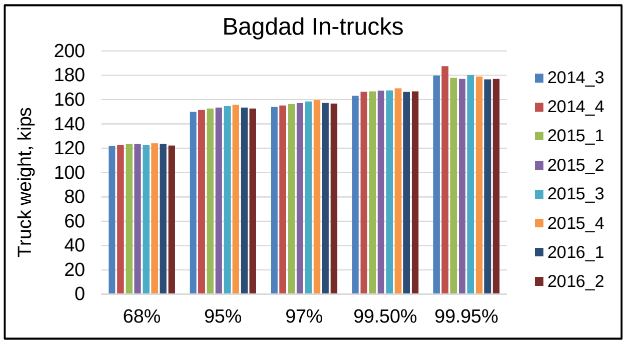


Figure 5. Net Truck Weight for Five Probabilities of Occurrence

EVALUATION OF FAST BRIDGES

This section provides results from a three-dimensional FE model of four steel spans at FAST developed in LUSAS™ software. Details of the bridge span at FAST can be found in a previously published *Technology Digest*, TD-15-024.[3]

The three-dimensional analysis provides more valuable information for structural members not only at the center of the span, but also at other locations — the model includes all members and the track structure. The maximum stresses were checked at mid-span, quarter span, and at cover plate transitions under various loads including: double-stack cars, typical 53-foot cars, and short, 42-foot cars. For all span lengths, the intermodal cars did not produce higher stresses than 42-foot short cars or 53-foot standard cars.

Figure 6 presents bending stress comparisons at various locations along the four FAST spans due to four considered car types. As predicted previously in Figure 2, intermodal cars show higher bending stresses only for very short spans (≤15 feet); therefore, testing shorter spans or spans with short floor system members in revenue service is recommended.

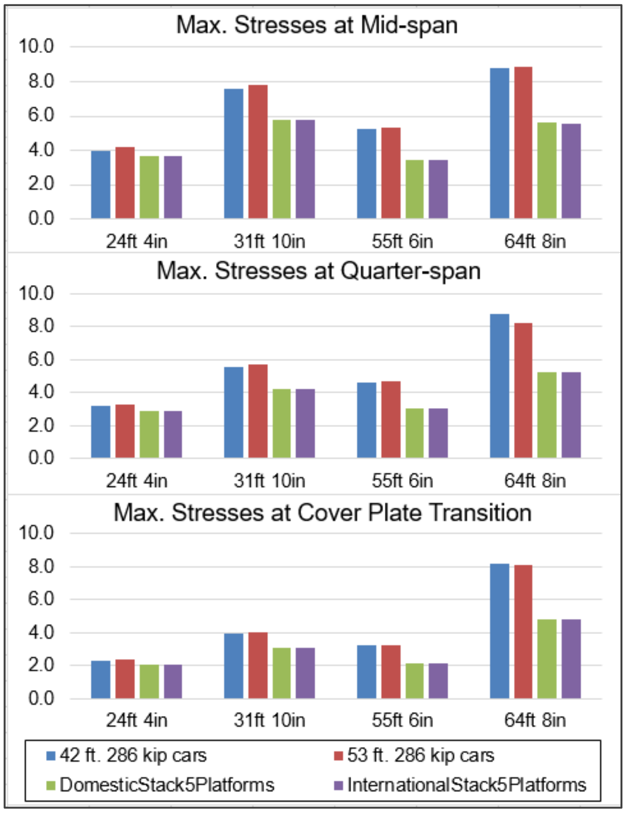


Figure 6. Bending Stresses at Mid-span, Quarter-span, and at Cover Plate Transition

RECOMENDATION AND FUTURE WORK

The analysis of spans of various lengths, using simple supported beam assumptions and various types of double-stack cars, indicates that double-stack cars should cause larger maximum moments only on spans shorter than 15 feet. Finite element modeling of four spans at FAST indicates that intermodal cars should not govern the loading for the FAST steel spans, which range in length from 24 to 65 feet. It is recommended that future research consider testing of shorter bridge spans and/or floor systems under unit train traffic with different types of double-stack cars.

References

1. Dick, S. "Legacy Train Configurations for Fatigue Life Evaluation of Steel Railway Bridges," *Proceedings of the AREMA Annual Conference*, 2016.
2. American Railway Engineering and Maintenance of Way Association (AREMA), *Manual for Railway Engineering,* Chapter 15, Washington, D.C., 2015.
3. Otter, D., A.M. Rakoczy, and S.M. Dick. "Steel Bridge Life Extension for Riveted Steel Girder Spans at FAST." TD-15-024, AAR/TTCI, Pueblo, CO, August 2015.