TECHNOLOGY DIGEST
TD-16-013
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Short Heavy Axle Load Cars: Analysis

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Summary

An investigation into the effects of heavy axle load traffic on infrastructure, specifically as related to minimum length interchange cars, has shown that shorter cars cause larger maximum moments on spans of 60 feet and longer. The equivalent Cooper Loading due to short cars exceeds E60 for spans over 225 feet. This can be a problem for most older bridges, which generally have been designed for E60 and below. Transportation Technology Center, Inc., explored data from the railroad industry equipment database, UMLER®, to identify the most common short cars and their dimensions. The analysis of various bridge span lengths was performed to select the spans that will show maximum difference in the deflection and stresses due to short cars. The findings of the comparative analysis of spans under short cars and typical length cars were developed to provide recommendation for future testing. The findings from this study are as a follows:

- The most common short car is the 42-foot covered hopper.
- The analysis of various span lengths shows that shorter cars cause larger maximum moment on bridge spans of 60 feet and longer. Only slightly higher moment, about 5 percent, was observed on the longest span (64' 8") at the Facility for Accelerated Service Testing (FAST) due to short cars when compared to standard rotary dump (53-foot length) cars.
- Finite element modeling of the 64' 8" span at FAST shows negligible difference at mid-span, but more noticeable effects (about 7 percent increase in maximum stress) at the quarter span locations.
- Moment range, used for fatigue evaluation, was observed to be higher for longer spans; such as 84 feet, 106 feet, and 126 feet.
- Short cars have higher equivalent Cooper loadings compared to standard length cars for spans longer than 60 feet, and the difference is more prominent on spans of 80 feet and longer.
- It is recommended that future research consider testing of longer bridge spans under unit train traffic with different length cars.

Testing at FAST was conducted to determine differences in bridge responses due to two car types and to confirm the analytical results. The test results are presented in *Technology Digest* TD-16-014.[1]

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INTRODUCTION

Transportation Technology Center, Inc. (TTCI) is investigating the effects of heavy axle load (HAL) traffic on infrastructure, specifically as 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 286,000 pounds or more. Data from the railroad industry equipment database, UMLER®, shows the number of HAL cars shorter than 42 feet has increased from 40,000 to more than 85,000 during the last 5 years, and 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.

The increase in shipments in short cars increases the loading on bridges. The 42-foot cars are about a 25 percent increase in load per unit length compared to coal cars. This may require weight restrictions 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. Increased weight per foot of length can also effect track embankments and bridge approaches.

This *Technology Digest* focuses on: (1) identifying the most common type of short cars; (2) selecting span lengths of bridges that show maximum effects due to short cars; (3) comparing the bridge performance under short cars and typical 53-foot cars; and (4) providing recommendations for future testing.

SURVEY FINDINGS BASED ON UMLER® DATA

The focus is on short cars, 48 feet long or less, with a gross rail load of 286,000 pounds or more.

The overall number of railcars recorded in the UMLER® database increased about 5 percent since January 2010; the number of all HAL cars increased 19 percent. The biggest increase was seen in short HAL cars — the number of cars shorter than 42 feet doubled indicating that the vast majority of the increase in HAL cars is short cars. Figure 1 shows the increase in the portion of short cars as a percentage of the entire car fleet. Figure 2 shows the numbers of HAL cars in UMLER® from 2010 to 2015 that are less than 48 feet in length. The increase in the number is virtually all in those just under 42 feet in length.

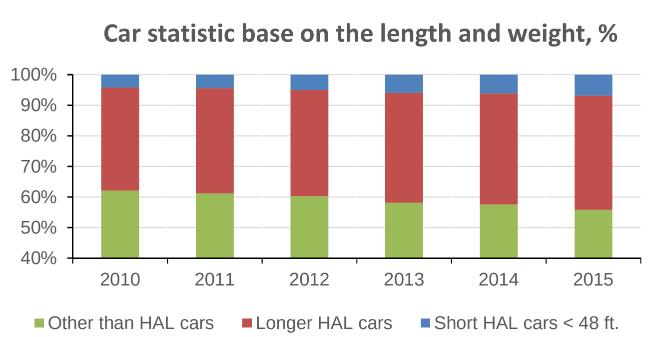

Figure 1. Cars Statistics from 2010 to 2015

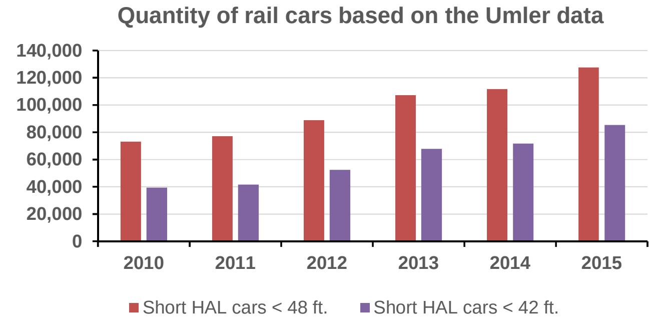

Figure 2. Quantity of Short Cars from 2010 to 2015

Of all car types, the covered hopper is the most common of all short HAL cars. Over 85 percent in 2010 and 90 percent in 2015 of all HAL cars shorter than 42 feet are covered hoppers. HAL cars shorter than 48 feet are primarily covered hoppers — about 62 percent in 2010 and 70 percent in 2015. Figure 3 presents statistics of various car types shorter than 48 feet, and Figure 4 presents statistics of short covered hoppers of various lengths.

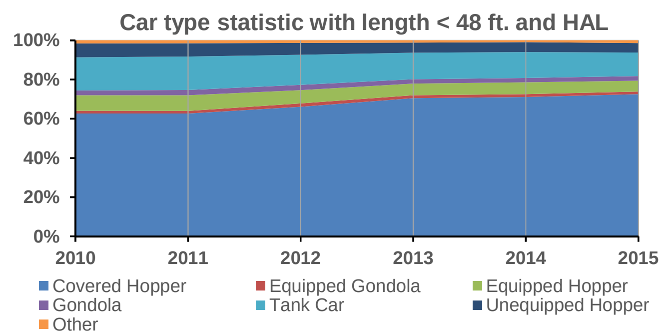

Figure 3. Statistics of Various Type Short Cars, 2010 to 2015

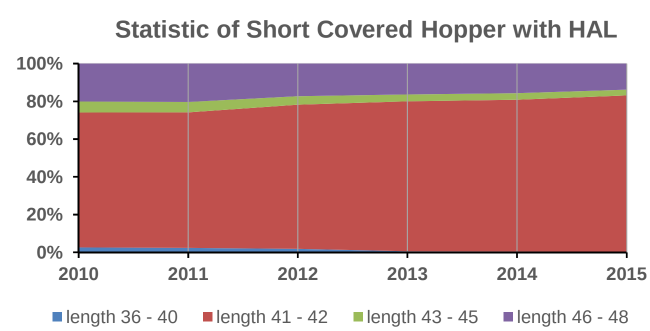

Figure 4. Statistics of Short Covered Hoppers, Various Lengths, 2010 to 2015

BENDING MOMENT CALCULATIONS

Bending moment envelopes were calculated for several span lengths: four steel spans as at FAST (24' 4", 31' 10", 55' 5", and 64' 8") and additional spans of 84, 106, and 126 feet. The calculations were performed for various car lengths, but only a few cars were chosen for presentation in this *Technology Digest*. The car types used for the analysis are presented in Table 1.

An increase in the loading effects for short cars (less than 48 feet) was visible on longer spans. Slightly bigger maximum moments for shorter cars were noticed on the 64' 8" span. More significant differences between maximum moments of shorter cars and typical 53-foot cars were observed on spans of 84, 106, and 126 feet. Figure 5 presents a comparison of maximum moment on seven spans due to five cars with different lengths.

Table 1. Car Types and their Dimensions

	Car length	Truck center
38-foot car	38' 1"	25' 5"
42-foot car	41' 11"	29' 5"
45.5-foot car	45' 6"	31' 8"
47-foot car	47'	34'
53-foot car	53'	40' 6"

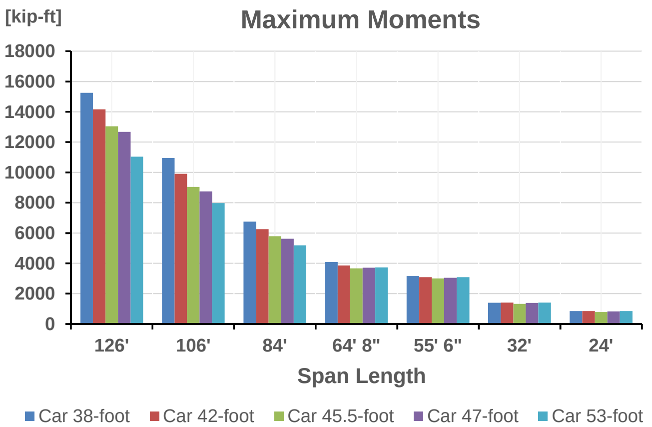

Figure 5. Maximum Bending Moment for Various Car Lengths

Equivalent moment ranges were also calculated based on moment histories developed for each span length due to various car lengths. Moment histories were calculated under unit trains of 20 cars. The equivalent moment range summary is presented in Figure 6.

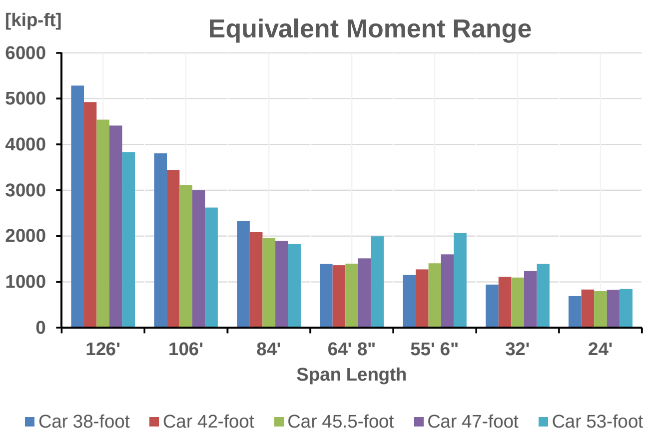

Figure 6. Equivalent Moment Range for Various Car Lengths

In terms of fatigue evaluation, the effect of shorter cars was observed to be greater only on the longer spans of 84, 106, and 126 feet. For the shorter spans, the 53-foot standard length car caused larger equivalent moment ranges due to larger intermediate cycles. Longer truck spacing in 53-foot cars produced greater unloading resulting in larger intermediate cycles. Figure 7 shows how the 32-foot span experiences full unloading under the 53-foot cars, but not under the 42-foot cars.

Figure 8 presents moment history for the 126-foot span, and it is noticeable that not only the maximum bending moment is larger, but also intermediate cycles are higher due to the 42-foot cars.

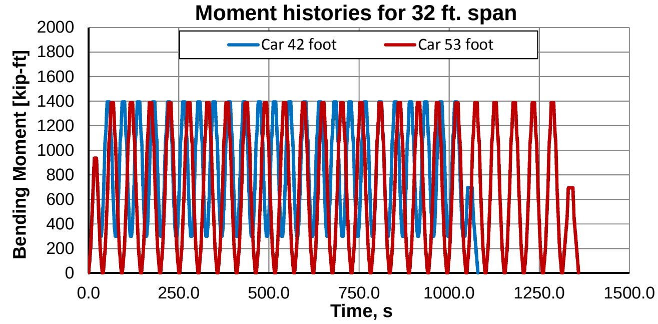

Figure 7. Moment History for 32-foot Span Due to HAL Cars

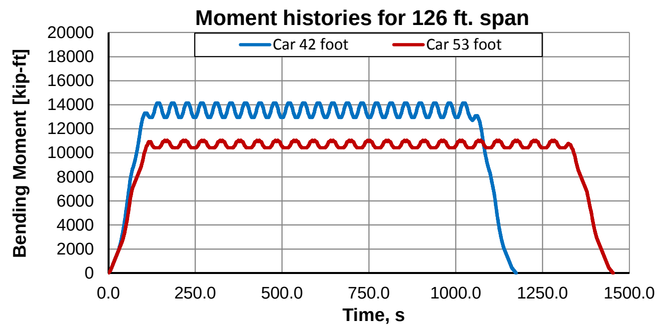

Figure 8. Moment History for 126-foot Span due to HAL Cars

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] A large portion of the current steel bridge inventory was designed for E60 and below. The equivalent Cooper Loading due to short cars exceeds E60 for span over 225 feet.

In this study, the equivalent Cooper loading was calculated for a large number of bridge spans from 5 to 400 feet long. As shown in Figure 9, short cars have greater equivalent Cooper loads compared to standard length 53-foot cars for spans 60 feet and longer. A typical six-axle locomotive governs for spans from 55 to 80 feet long.

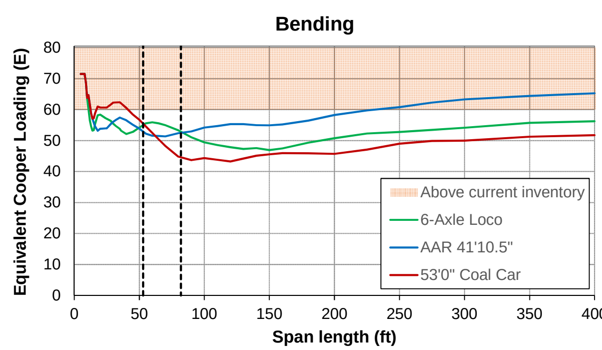

Figure 9. Equivalent Cooper Loading for Spans up to 400 feet

FINITE ELEMENT MODELING AND VALIDATION

Analysis above was made on the two-dimensional simple supported beam. This section provides results from a three-dimensional finite element (FE) model of a 64' 8" bridge span at FAST developed in LUSAS™ software. Details of the bridge span at FAST can be found in a previously published *Technology Digest*.[3] The 3-dimensional analysis provides more valuable findings for structural members not only at the center of the span — the advantage of the model is that it includes all members and the track structure.

Displacements and stresses are calculated under various loads for the entire span. Typical 53-foot cars and short 42-foot cars are considered in the analysis. Figures 10 and 11 present vertical displacement and bending stress distributions on the considered bridge due to a four-axle load close to the mid-span.

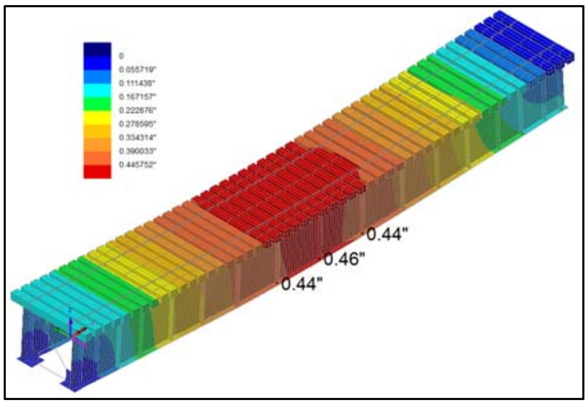

Figure 10. Vertical Displacement of 64' 8" Span

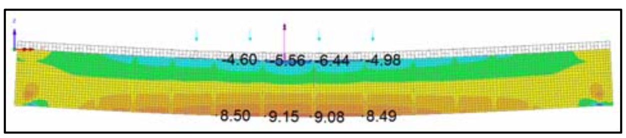

Figure 11. Bending Stress Distribution on 64' 8" Span

To validate the model, the stresses are compared to the field data. Figure 12 presents a comparison between the north and south girders and the FE model. In the field, the stresses on the north and south girders are slightly different; while in the FE model, both girders are the same since the model is created to be symmetrical.

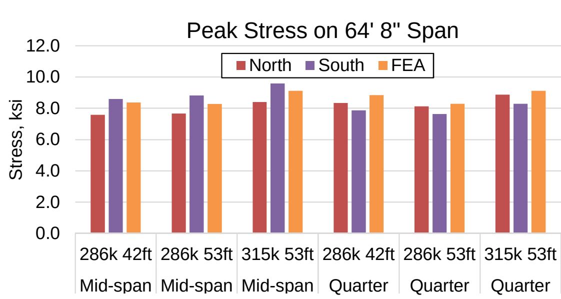

Figure 12. Comparison of the Field Data and FEM

The peak stresses due to various car types were compared and are presented in Figure 13. It appears that stresses due to the 42-foot car are larger than for the 53-foot car at the quarter points. However, they are almost the same at mid-span.

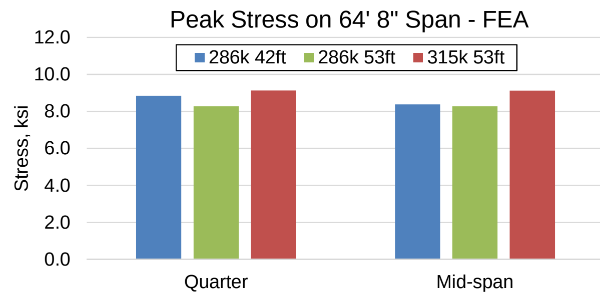

Figure 13. Maximum Peak Stress

CONCLUSIONS

Exploration of UMLER® data shows that the most common short HAL car is the 42-foot covered hopper. The analysis of various span lengths, using simple supported beam assumption and 42-foot cars, shows that shorter cars cause larger maximum moments on spans longer than 60 feet. Only slightly higher moment, about 5 percent, was observed on the longest span at FAST (64' 8") due to short cars when compared to the standard length cars. Whereas, FE modeling of a 64' 8" span at FAST shows negligible difference at mid-span, but visible effects at the quarter span location (about 7 percent higher).

In addition, moment range, used for fatigue evaluation, was observed to be higher for longer spans of 84, 106, and 126 feet. For shorter spans, 53-foot cars create larger moment ranges and reduced fatigue lives. In addition, short cars have higher Cooper ratings compared to standard length car for spans longer than 60 feet. The common design load for older steel spans was E60 and sometimes even less. The equivalent Cooper Loading due to short cars exceeds E60 for spans 225 feet and longer, which may cause a problem.

It is recommended that future research consider testing of longer bridge spans under unit train traffic with different length cars.

REFERENCES

1. Rakoczy, Anna M., Duane Otter, and Stephen M. Dick. April 2016. “Short Heavy Axle Load Cars: Bridge Test at FAST.” *Technology Digest* TD-16-014, AAR/TTCI, Pueblo, CO.
2. American Railway Engineering and Maintenance of Way Association (AREMA). 2015. *Manual for Railway Engineering*, Chapter 15, Washington, D.C.
3. Otter, Duane, Anna M. Rakoczy, and Stephen M. Dick. August 2015. “Steel Bridge Life Extension for Riveted Steel Girder Spans at FAST.” *Technology Digest* TD-15-024, AAR/TTCI, Pueblo, CO.