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Effects of Short HAL Cars on Subgrade

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Summary

A test performed by Transportation Technology Center, Inc. (TTCI) shows shorter length cars have a small effect on subgrade under heavy axle loads (HAL). TTCI is investigating the effects of HAL traffic on infrastructure, specifically as related to minimum length interchange cars. The use of short cars with high density commodities doubled in last five years. Of particular importance and focus are those areas that might be different for cars of minimum interchange length (about 42 feet) as compared to the common 53-foot gondola car that has been used in previous HAL studies. This *Technology Digest* focuses on the effects of short HAL car traffic on track and subgrade performance.

The effects on subgrade were evaluated in the low-modulus track section at the Facility for Accelerated Service Testing (FAST) at the Transportation Technology Center (TTC), comparing subgrade pressure transducer readings for short and standard length cars. Observations from the tests are as follows:

- Overall, there was no significant difference in magnitude of subgrade stresses measured under train operations with two different car lengths.
- The effect of speed and direction on average maximum peak stresses was minimal.
- Temporary residual stress was observed in the subgrade that was apparent due to train operations of short cars; however, it was not observed under train operation of standard length cars. Although not large in magnitude at the locations measured, this residual stress does indicate some potentially detrimental effect of shorter cars on subgrade response behavior.

Stability of subgrade as part of a high embankment may be a concern due to larger loading per foot of track length on the embankment for a short car train, but this was not tested as part of the experiment at FAST. This will be addressed in a future research effort.

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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. The HAL cars are considered to be those with a gross rail load (GRL) of 286,000 pounds or more. Data from the railroad industry equipment database, UMLER®, shows a significant increase in the population of HAL cars shorter than 42 feet during last 5 years. The number of cars in the North American rail network that are shorter than 48 feet increased from 40,000 to more than 85,000. Of these short HAL cars, the vast majority are covered hoppers with overall lengths of 41 to 42 feet. The areas of particular importance and focus are those that might be different for cars of minimum interchange length (about 42 feet) compared to the common 53-foot bulk commodity car that has been used in HAL studies. Preliminary studies identified subgrade/embankments and bridges as areas of concern.

TESTING AT FAST

Twelve short HAL cars were provided by a member railroad for testing at FAST to determine the differences, if any, in vertical and lateral load environment in comparison to standard length cars (e.g., 53-foot coal gondola or open-top hopper). The test train included a locomotive; an instrumentation car (passenger car); 12 covered hoppers (approximately 42 feet long, weighing 286 kips); 6 coal gondola or open-top hoppers (53 feet, 286 kips); and 6 coal gondola or open-top hoppers (53 feet, 315 kips). The test train is presented in Figure 1.

Figure 1. Test Train

Test runs were made at speeds of 10, 20, 30, 40, and 45 mph to evaluate the effects of the short and long car types on clay pressure signatures at various speeds, as well as the effects of speed alone on the measurements. For each speed, two to three train passes were made in each direction. In addition, runs were made at 2 mph over all bridges. Static measurements were also made in the low modulus track section under the test train. The test included a variety of components:

- Collection of wayside data using the FAST Truck Performance Detector system to evaluate vertical and lateral forces,
- Stresses, and deflection measurements of all three bridges at FAST,
- Instrumented wheelset (IWS) measurements, and
- Geotechnical transducers in the low track modulus section.

Substructure Evaluation

The soil in the FAST low modulus track section is high plasticity clay with a current moisture content of approximately 26 to 28 percent, compared to the original 33 percent,[1] and is surrounded by a 30 mil liner on three sides to retain moisture. Competent native silty sand surrounds the clay on three sides. The track modulus is approximately 2,000 lbs./in./in. Removable transducers were installed in this section to record lateral and vertical pressure at different locations to evaluate geotechnical track performance.

The shallow and deep lateral earth pressure transducers were located 18 and 30 inches, respectively, below the top of the clay with the vertically oriented sensors parallel to the longitudinal axis of the rail. Similarly, the shallow and deep vertical pressure transducers were also located 18 and 30 inches below the top of the clay, but they were positioned so that the sensors were parallel to the long axis of the rail and looking upwards towards the rail (Figure 2).

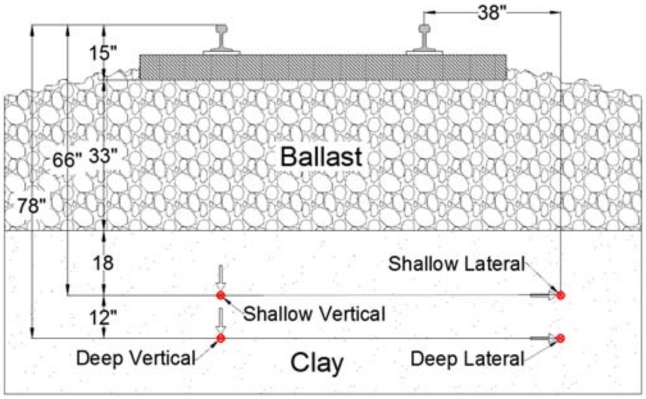

Figure 2. Location of the Transducers

Pressure measurements from all four transducers were recorded during test to evaluate the effects of short HAL cars versus standard length HAL cars on the subgrade.

The spreading of wheel load over a larger area at greater depth, to a large degree, depends on the stiffness characteristic of each layer of the track structure including the rail, ties, ballast, and subgrade. Figure 3 shows an example using the GEOTRACK computer model[2] to illustrate how a wheel load is transmitted from the wheel-rail interface, to the rail-tie interface, to the tie-ballast interface, and to various depths in the ballast and subgrade layers. This example is based on an assumption of a typical wood tie track with a nominal ballast layer thickness of 18 inches with modulus of 60,000 psi, and a subgrade modulus of 8,000 psi. For a lower subgrade track modulus, lower subgrade stress would be expected.

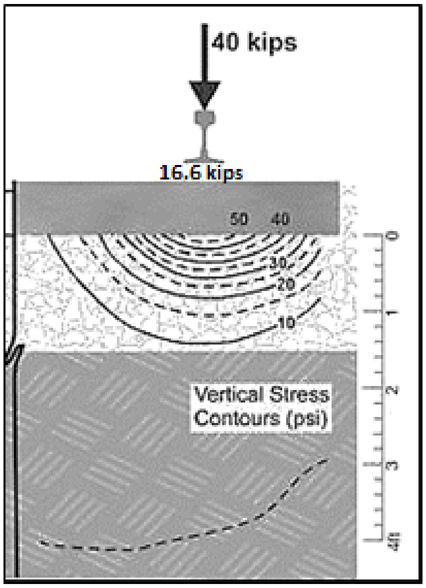

Figure 3. Stress Transmission in Track Substructure

TEST RESULTS

Lateral and vertical soil pressures were recorded for clockwise and counterclockwise train consist movement at various speeds. The effect of the speed and direction was very minimal, and it may be considered indiscernible with respect to the measurement accuracy. Figure 4 presents typical stress histories for all four pressure measurements recorded during the test. Peak stresses in the red box correspond to the short cars of 286-kip weight, and those in the green box correspond to the long cars of 286 kip and 315 kip weights. The maximum peak stresses were measured and averages of the maximum peak stresses were calculated for each car type at different speeds.

It should be noted that each pressure pulse shown actually includes four wheels under two adjacent trucks from two adjacent cars; and each valley corresponds to the distance between two trucks under the same car.

Residual Soil Stress

It can be noted that the short cars exerted approximately the same peak pressure values as the longer cars of the same weight, but the relaxation interval; i.e., the valleys between the pressure pulses, are closer together. Thus, the soil pressure is influenced by the interaction of both the overlying wheel sets and adjacent wheelsets. The closer truck wheel spacing of the 42-foot cars resulted in this “retained” energy at all speeds observed (Figure 5). This results in residual stress in the soil.

The undissipated soil stress is immediately manifest between pressure pulses, and depending on soil properties, may build, decrease, or remain constant. Figure 5 shows a slightly decreasing trend in the state of the stress in the soil, but the residual stress is a relatively small component of the total induced pressure. Residual stresses for each of the pressure histories are presented on Figure 6. Additional work is planned in 2016 to understand the mechanisms of the residual stress and how it may affect subgrade performance under other conditions.

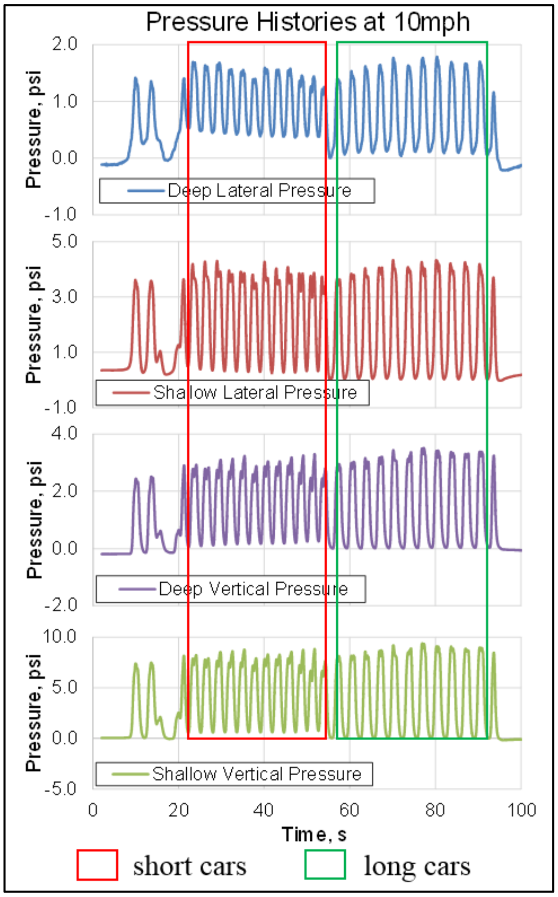

Figure 4. Typical Stress Histories at Various Subgrade Transducer Locations due to Test Train

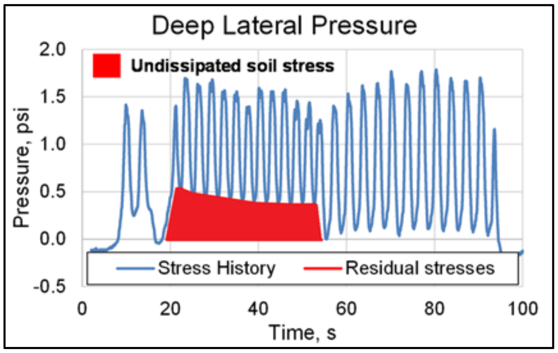

Figure 5. Example of Residual Retained in Soil

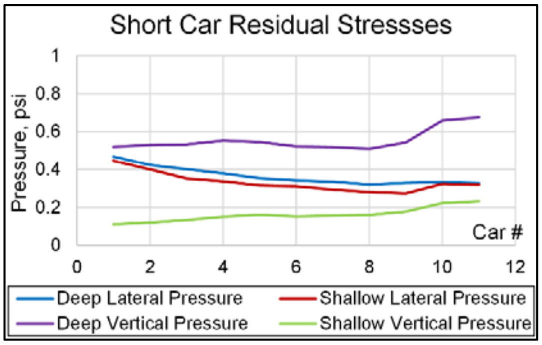

Figure 6. Short Car Residual Stress

Since the short cars have a tendency to produce higher residual stress in this subgrade soil, potentially higher moisture conditions in revenue service may exacerbate the effects observed at FAST. This topic will need further study.

SOIL PRESSURE ANALYSIS

Figure 7 presents a comparison of soil pressures at various depths and distances from the rail seat for this particular configuration of soil type, moisture content, ballast thickness, and loading.

As shown in this figure, there is no significant difference in magnitude of subgrade stresses measured under train operations with two different car lengths. Also, soil pressure values do not appear to be influenced by train speed in the range of 10 to 45 mph.

Since most of the train speeds tested are much lower than those that would produce a shear wave,[3] it is not likely that wave interference would pose a problem. Still, it was considered in the interest of being thorough.

FUTURE RESEARCH

To further understand the residual stress phenomenon due to short car consist and whether it may be a concern under other conditions, investigation will be performed on the effect of trains of short cars on high embankment stability. The increase of the weight per unit length is about 25 percent with short, 42-foot long cars when compared to the standard 53-foot long cars. This increase of live load will likely affect the stability of a high embankment. Further research on for short cars' effects is recommended to address these concerns.

ACKNOWLEDGEMENTS

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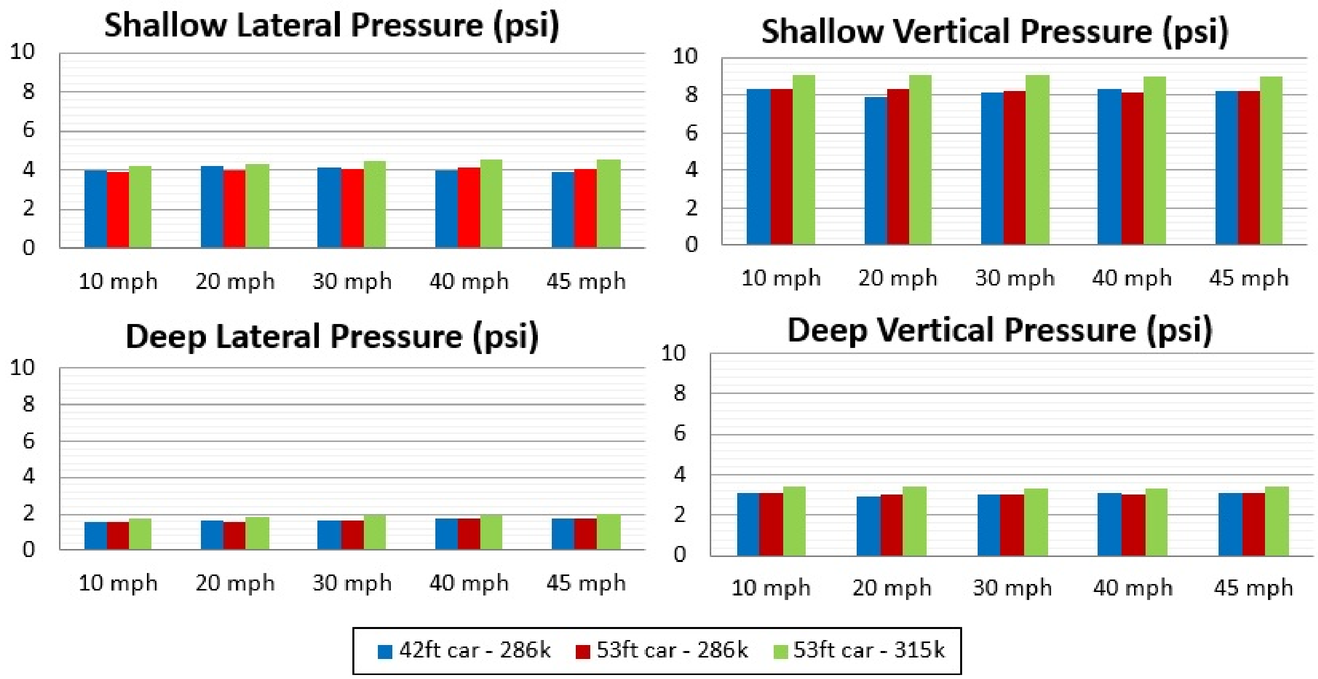

Figure 7. Comparison of Average Maximum Stresses (psi) of Three Car Types at Various Speeds

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