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Evaluation of a Track Transition Design for Soft Subgrade Bridge Approaches

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Summary

Track transitions, areas where the track structure changes, such as at bridges or road crossings, are problem areas for track maintainers and can become chronic maintenance areas. This *Technology Digest* describes the development and testing of a prototype track section designed for soft subgrade bridge approaches.

The dynamic and long-term performance of these transition zones can vary from the surrounding track, resulting in differential settlement that produces track surface and alignment defects. While elimination of changes in track stiffness, damping, or long-term settlement across transitions is unlikely, it may be possible to provide adequate transitions, smoothly ramping from one track structure to another. This is the approach taken by the project design team of the Association of American Railroads' (AAR) Affiliated Laboratory at Texas A&M (TAMU) and Transportation Technology Center, Inc., Pueblo, Colorado, under sponsorship of the AAR's Strategic Research Initiatives (SRI) Program.

TAMU geotechnical experts designed a prototype track section intended to smoothly ramp track deflection from a soft subgrade track (representing a poorly drained clay bridge approach) to a relatively stiff subgrade track (representing a ballasted deck bridge). The prototype was built by driving steel bars (minipiles) of varying lengths through the existing soft subgrade track leading up to the boundary with the stiff subgrade.

A comparison of the performance of the track before and after the pile installation was made. Preliminary results from about 100 million gross tons (MGT) of traffic (35 MGT before and 65 MGT after installation) show:

- The as-built track had an abrupt change in track stiffness.
- The as-built track developed a vertical surface defect at the stiffness transition.
- The minipiles were successful in reducing ballast/subgrade bearing pressures on the soft subgrade.
- The minipiles were successful at reducing the low spot at the stiffness transition.
 - Initial settlement was reduced by about 50 percent.
 - Surfacing cycles were more than doubled, going from 35 MGT to beyond 90 MGT to maintain FRA class 4 surface.

This study was funded by AAR's SRI Programs for Technology Scanning and Reduced Impact Track.



INTRODUCTION

Track transition problems are well documented in railway engineering literature and can be divided into two main categories: (1) degradation of stiff track on bridges, which may result in broken rail fasteners, cracked concrete ties, powdered ballast and mud pumping on the bridge (Figure 1 shows a typical example.)¹ and (2) degradation of less stiff track on the bridge approaches, which most likely results in track surface and alignment defects.² There is often lateral spreading of the embankment and ballast section. Figure 2 shows a low spot on a ballast deck bridge approach.



Figure 1. Example of Track Degradation on a Ballasted Deck Concrete Bridge



Figure 2. Track Surface Low Spot on the Approach to a Ballasted Deck Bridge

Degradation of bridge approaches can be further categorized by the foundation layer showing the most degradation. Some bridge approach degradation problems are due largely to ballast spreading and degradation. Others are mostly due to subgrade deformation. The latter case is the one addressed here. Drainage issues are common at track transitions due to the interruption of ditches and the rapid degradation of the ballast at high dynamic load locations. The load carrying capacity of many soils is greatly affected by moisture content.

Transition Design for Soft Subgrades

A prototype track transition was installed in the High Tonnage Loop at the Facility for Accelerated Service Testing (FAST) to address the case where a soft clay subgrade

abruptly changed to a significantly stronger silty sand subgrade. The stiffness change caused by the difference in subgrade conditions was increased at this location by installing concrete ties over the stronger silty sand subgrade. The track stiffness was 300,000 lb/inch and 500,000 lb/inch on the soft subgrade and strong subgrade track, respectively.

Figure 3 shows the recommended solution developed by the AAR Affiliated Lab at TAMU, which involved placing four rows of varying length 1.375-inch diameter DYWIDAG steel bars into the soft subgrade at the low track modulus (LTM) section (Section 29) at FAST.

The design is intended to replace the abrupt transition with one that is ramped uniformly in long-term settlement over several feet. The total length of the solution, measured as the center-to-center distance between the first and last bars, is 16.25 feet. The longest bars are 7 feet and the shortest bars are 1 foot. Four rows of each length were installed: two in between the rails and two outside of the rails. The two bars inside the tracks are located approximately 12.6 inches from the base of the rail, and the center-to-center spacing of the two bars is 25.3 inches. The two bars outside of the tracks are 9.9 inches from the base of the rail.

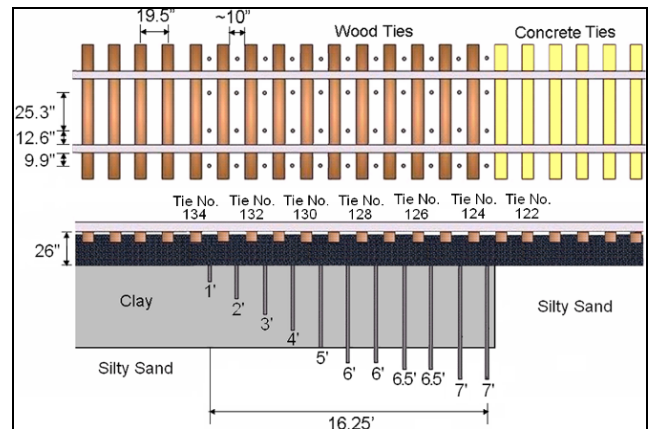


Figure 3. Schematic of Recommended Prototype Solution for the LTM Section

The recommended solution was chosen based on numerical simulations performed using LS-DYNA, a general purpose transient dynamic finite element program. The results indicate that the magnitude and slope of track deflection are both decreased by adding the steel bars into the subgrade (Figure 4).³ The soil around the bar is stiffened by the presence of that inclusion. The bars are longest near the bridge abutment to approach the value of the stiffness of the bridge and shortest away from the bridge to approach the value of the natural ground. This gradual transition softens the difference in stiffness at the end of the bridge and distributes it over a longer distance, thereby making the bump less severe. The same is true when looking at subgrade pressures (Figure 5). The solution reduces the subgrade pressure in the LTM section from the base case.

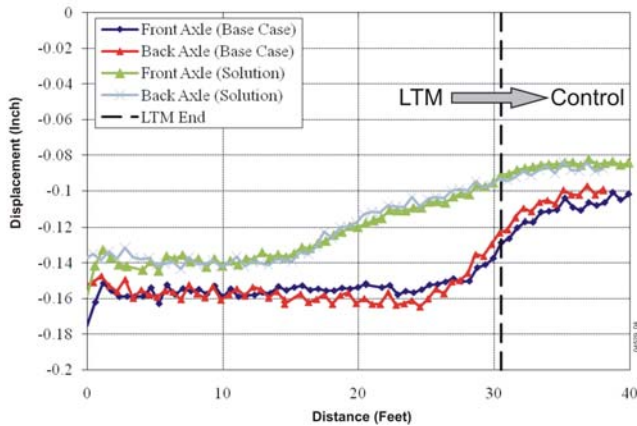


Figure 4. Track Deflection Results using LS-DYNA for the LTM Base Case and Recommended Solution

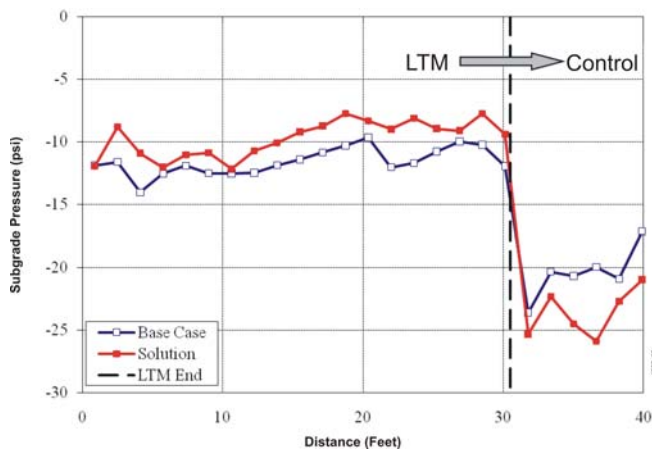


Figure 5. Subgrade Pressure Results using LS-DYNA for the LTM Base Case and Recommended Solution

Prototype Location

The solution is intended to reduce and mitigate the problem of the “bump at the end of the bridge” for railroad bridges. The bridges at FAST, however, do not have any bump/dip problems. To mimic and model the bridge/approach location, the LTM section at FAST was chosen because this section provides a low track modulus in comparison to the surrounding track.

The test location is in a tangent section of the High Tonnage Loop at FAST. The LTM section consists of imported Buckshot clay with a cross section of 12 feet by 5 feet (shown as Clay in Figure 3). The clay section is lined with a geomembrane to prevent moisture loss to the surrounding silty sand.

Before its use for the prototype design test, the LTM section was used to test hot mix asphalt (HMA) sections above the subgrade. A 100-foot section of the 8-inch HMA had to be removed before testing the prototype solution.

Installation of the minipiles was done using a vibratory hammer to drive the piles through the track, as Figure 6 shows. This procedure could be used to strengthen approaches in revenue service using short work windows to install each row of piles.



Figure 6. Installation of the Minipiles at the FAST

Initial Prototype Performance

To ensure that a bump would, in fact, form between the LTM section and the control section, traffic was allowed to pass over the LTM section (with no HMA) as a base case. Figure 7 shows the top of rail (TOR) elevation after various levels of traffic: 5 MGT, 34 MGT, and 65 MGT. A dip has developed at the stiff-to-soft subgrade transition (distance ~38 feet in the plot).

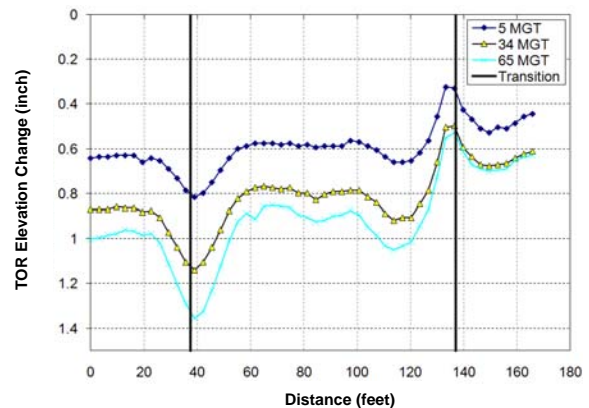


Figure 7. Track Surface of LTM Section (Base Case)

Figure 8 shows the same TOR elevations with additional data added after the prototype minipiles were installed. It shows that the minipiles were at least partially successful in reducing or delaying the onset of the low spot at the transition. The objective of the transition is to provide a smooth ramp from one track structure to another. In addition, the track settlement rate at the transition has been reduced by about 50 percent after installation of the minipiles.

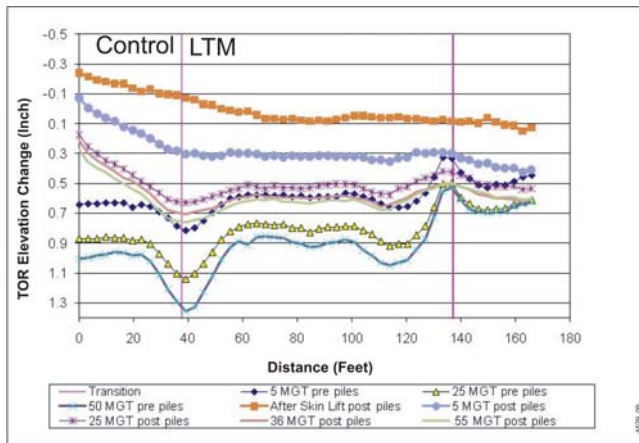


Figure 8. Track Surface of LTM Section before and after Minipile Installation

Figure 9 summarizes the settlement data, showing the average settlement at the transition from strong subgrade to weak subgrade versus cumulative tonnage. Note that the installation of the minipiles has reduced the rate of settlement in the first 25 MGT of operation by about 50 percent. The subsequent rate of settlement after the first 25 MGT has decreased further. Thus, the minipiles have strengthened the subgrade so that it can more effectively support the track and better maintain track surface.

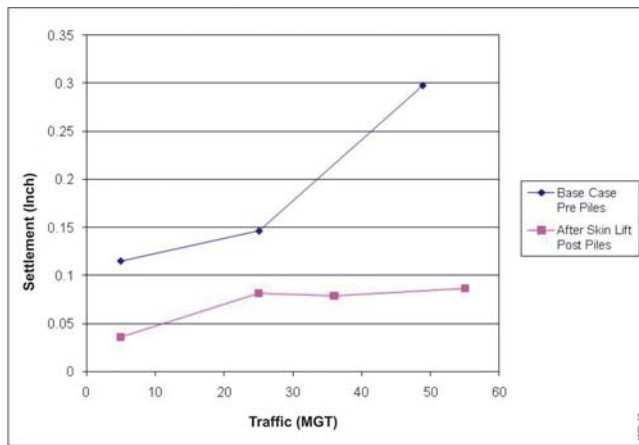


Figure 9. Track Transition Settlement before and after Minipile Installation

Measurements of subgrade pressure, measured near the bottom of the ballast layer at the track transition (Figure 10), show a reduction in average and maximum pressures after installation of the minipiles. The loading is from the same train, with 315,000-pound cars running at 40 mph in each case. As Figure 10 shows, the measured average subgrade pressures, match reasonably well with the predicted values for the pre- and post-minipile installation.

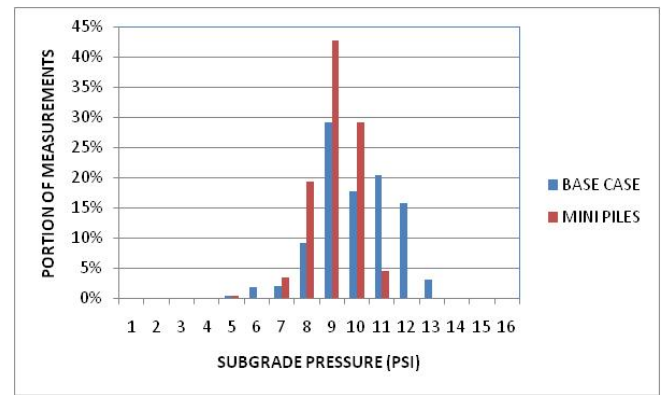


Figure 10. Measured Subgrade Pressures before and after Minipile Installation

Preliminary Conclusions

While more traffic is needed to draw definitive conclusions about the prototype bridge approach track tested, the preliminary results after 60 MGT traffic suggest that the minipiles were effective at reducing the track settlement rate and the differential settlement at the track transition. It is encouraging to see that the slope of the track at the low spot did not increase with additional tonnage after the minipile installation, while the surface error at the transition grew more severe with tonnage in the as-built track. This will lower the rate of occurrence of track surface defects at this location.

Future Work

The track transition test section will be monitored throughout the next two surfacing cycles to determine the full life cycle benefits of the design. Additionally, candidate sites will be selected for revenue service testing.

REFERENCES

1. Li, Dingqing et al. December 2007. "Dynamic Load and Track Response: Bridge Approach Test at the Western Mega Site." *Technology Digest* TD-07-042, Association of American Railroads, Transportation Technology Center, Inc., Pueblo, CO
2. Plotkin, Donald and David Davis. February 2008. "Bridge Approaches and Track Stiffness." DOT/FRA/ORD-08-01, Federal Railroad Administration, Washington, D.C.
3. Briaud, Jean-Louis and Jennifer Nicks. December 2008. "Development of a Prototype Track Transition Design." Report to AAR Technology Scanning Committee, College Station, TX.