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Implementing Track Transition Solutions

by Charity D. Sasaoka, David D. Davis, Kevin Koch, Richard P. Reiff, and William GeMeiner*

Summary

Transportation Technology Center, Inc. (TTCI), a subsidiary of the Association of American Railroads (AAR), evaluated the effectiveness of currently accepted track designs and a number of track design prototypes in terms of track stiffness. This work, sponsored by the AAR and the Federal Railroad Administration, is part of an effort to develop effective and economic designs for track transitions. The work described in this *Technology Digest* deals specifically with the bridge approach/ bridge transition.

Track transition areas, such as bridge approaches, road crossings, and special trackwork, can become significant maintenance problems in mainline track under heavy axle load (HAL) traffic. These areas can generate impacts that contribute to accelerated degradation and shortened component life resulting in service disruptions. Some of the issues that contribute to this problem are differential settlement, stiffness and damping changes, and high dynamic loads. An estimated $200 million is spent annually on track transition maintenance.

The following observations were made from theoretical work and field testing at Union Pacific and the FRA's Facility for Accelerated Service Testing (FAST) located at the Transportation Technology Center Pueblo, Colorado:

- Data has been collected to assist in characterizing track stiffness and damping at track transitions.
- Track models, such as Geotrack™ and **NUCARS™ were used to model the performance of track at transitions. These models can serve as design tools for track transitions.
- *From these parametric studies:*
  - The best method of raising approach track stiffness is subgrade treatment
  - The best method of reducing bridge/ track stiffness is to alter tie/pad properties. This method can also add damping.
- *From field testing:*
  - Track on ballasted deck bridges was found to be stiffer than the surrounding approach tracks.
- Different tie materials can provide effective improvements to the track transition stiffness change. Replacing ties on existing bridge track can be cost-effective in comparison with modifying the subgrade or bridge structure, provided the approaches have modulus values similar to open track.
- Plastic ties installed on concrete span bridges decreased the difference in track stiffness between the approach and the bridge. The modulus difference between a concrete tie approach and bridge track is approximately 2,500 lbs/in/in; whereas using plastic ties on the bridge reduced the difference to 1,500 lbs/in/in. Plastic ties may provide a good transition in concrete tie territory.
- Concrete ties with rubber pads were installed on both a concrete span bridge and a steel beam span bridge. These modified concrete ties were able to decrease bridge track stiffness below the level of the approaches. Thus, this method of reducing track stiffness appears capable of addressing the transition problem. Some fine-tuning will be necessary to match approach track stiffness.
- Track modulus is variable over a short distance. Several measurements are needed on a short bridge or approach to adequately characterize a site.

** Senior Manager, Engineering Methods and Research, Union Pacific Railway Company*

***NUCARS™ is a trademark of Transportation Technology Center, Inc. (TTCI)*

Please contact **Charity Sasaoka (719) 584-7176** with questions or concerns regarding this *Technology Digest.* E-mail: charity_sasaoka@ttci.aar.com.

INTRODUCTION AND CONCLUSIONS

One of the most significant maintenance problems in mainline track is the performance of track transitions such as those found at bridge approaches, road crossings, and special trackwork. In these locations, the track structure, and often the load environment, changes significantly over a very short distance. This can result in increased dynamic loading and track maintenance. While Transportation Technology Center, Inc. (TTCI) is addressing track transition issues at special trackwork as well, this *Technology Digest* will focus on the track transitions that occur at a bridge and its approaches.

Problems at a bridge/bridge approach transition can be divided into three categories, as illustrated in Figures 1 and 2. The first is the differential settlement case. Here, the track on the approach and on the bridge have similar stiffness, but the approach track has settled over time. Due to the nature of railroad bridge design and construction methods, this case is also relatively common. Railroad bridges are built on deep foundations and are relatively immune to subgrade settlement. This case is commonly known as the "dipped approach."

The second case is track stiffness. This case has the more fundamental problem of a significant mismatch in track stiffness. Open deck bridges lack the ballast and subgrade layers found in conventional track. However, the problem also exists on ballasted deck bridges. Here, relatively short and stiff concrete spans can produce track with stiffness about double that of open track. This results in poor ride quality and broken track components on the bridge, as well as higher dynamic loading on the bridge.

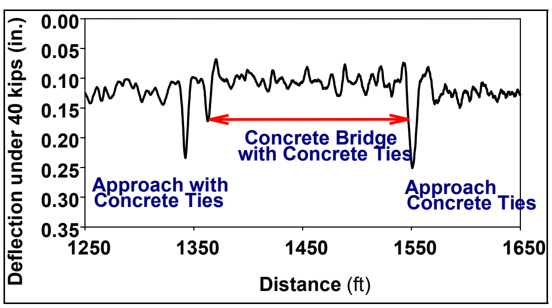


Figure 1. Track Transition Problems: the Differential Settlement Case

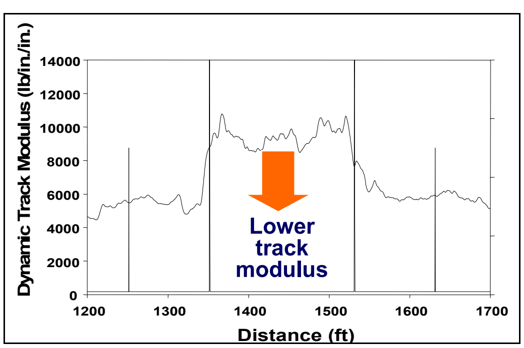


Figure 2. Track Transition Problems: the Track Stiffness and Damping Cases

The third case is track damping (Figure 3). This case exists where track damping is different in each track structure. Vehicle dynamic behavior is different (i.e., worse) on the side with less damping. Two types of impact loads can be generated:

- Higher frequency impact loads resulting from the vibration of the wheelset on the wheel/rail contact surface. This type of loading is primarily dependent on wheel/rail stiffness.
- Lower frequency impact loads resulting from wheel bounce. These transient vibrations are highly influenced by track stiffness. They may resonate with the movement of rails and ties on the ballast elastically, and contribute to surface/alignment degradation and ballast/subgrade deterioration. These vibrations can be minimized by enhancing the damping in the track structure.

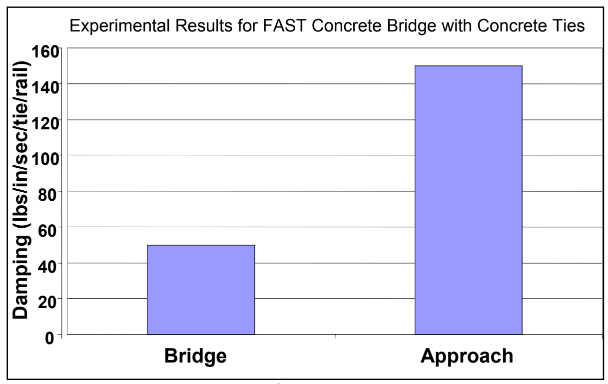


Figure 3. Examples of Track Transition Problems

A bridge structure is inherently stiffer than the surrounding track, thus providing less damping. There is also no subgrade to provide additional absorption of the vibrations, thereby increasing the potential for these dynamic loads to affect components on the bridge. Adding damping to the track structure on a bridge is an important step to alleviating increased degradation on the bridge.

FIELD TESTS

Several test sites on a western coal route in revenue service have been monitored to determine the effect of different tie materials. Table 1 summarizes the test locations and conditions and Figure 4 provides the results from all locations. Concrete ties installed on a concrete span bridge have a dynamic modulus approximately 2,500 lbs/in/in higher than the approach track at the Marysville test location. Between the two test intervals, which accumulated roughly 100 million gross tons (MGT) of heavy haul traffic, the difference in modulus between the approach and the bridge increased. This may be an indication that the stiffness transition problem may increase with the onset of increased tonnage and degradation. While weather or moisture content changes may cause the approach track to decrease in stiffness, the track on the bridge, with a confined ballast sections, is expected to become stiffer with tonnage.

Table 1. Tests and Locations

Date	Tie Type on Bridge	Tie Type on Approach	Bridge Type	Location	MGT
11/17/03	Plastic	Concrete	Concrete Span	Marysville, KS	5
5/25/04	Plastic	Concrete			85
4/17/03	Concrete	Concrete	Concrete Span	Marysville, KS	40
5/25/04	Concrete	Concrete			120
11/17/03	Concrete w/Phoenix Rubber Pad	Concrete	Concrete Span	Marysville, KS	40
11/17/03	Concrete w/NW Rubber Pad	Concrete	Steel Beam Span, Steel Floor	Marysville, KS	40
5/25/04	Concrete w/NW Rubber Pad				120
4/15/04	Concrete Tie	Concrete	Concrete Span	FAST	9

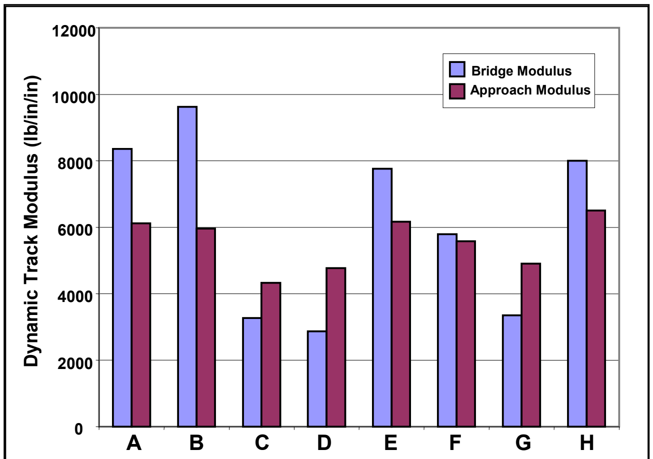


Figure 4. Summary of Dynamic Modulus for All Test Locations

The first measurement on the test site with plastic ties installed on a concrete span bridge at Marysville showed a difference in modulus from the approach to the bridge of approximately 1,500 lbs/in/in. The second measurement showed a difference of approximately 500 lbs/in/in. The transition difference is minimized by use of plastic ties.

Two different types of rubber pads were adhered to the bottom of concrete ties and installed on both a concrete span bridge and a steel beam span bridge. Both types of pads made the dynamic modulus on the bridge approximately 1,500 lbs/in/in lower than the approach track. The rubber pads provided a relief in the track stiffness transition. The manufacturers are developing several variations of these pads that will provide different amounts of relief.

The use of plastic ties and concrete ties with rubber pads did contribute to some relief of the stiffness transition. These materials are also being evaluated to determine the contribution to the damping characteristics on the bridge.

PARAMETRIC STUDY OF TRACK DESIGN

TTCI conducted a parametric study of track designs for the approach-bridge transition problem. Typical track structures were modeled for the bridge approach and ballasted deck bridge using Geotrack™. For this study, a base case track structure was selected as 136 RE rail, wood ties on 19-inch spacing, 18 inches of ballast and subballast, and a medium strength subgrade. Foundation properties for the track on bridge "foundation" were derived from track modulus measurements made on ballasted deck bridges at FAST and in revenue service.[1] Table 2 lists the base case track parameters used in the study.

Predicted track modulus values for the base cases indicate future track transition problems. For example, the change in modulus from concrete tie track on a bridge approach to concrete tie track on a ballasted deck concrete bridge is about 4,000 lbs/in/in (or about double the approach value). Figure 5 shows the results of the parametric study of track stiffness, using the wood tie track as the base case. This study concludes that stiffening the subgrade is the most effective way to increase track stiffness on the bridge approaches. More design options are an effective means of lowering the modulus of the track on the bridge. Altering the stiffness of the tie pad or the tie itself can reduce track modulus and increase track damping.

Another factor in track design for bridges is the bridge deck configuration. Use of liner materials such as timber planks, ballast mats, or waterproofing "protection board" might be effective in reducing the stiffness of the track laid on the bridge.

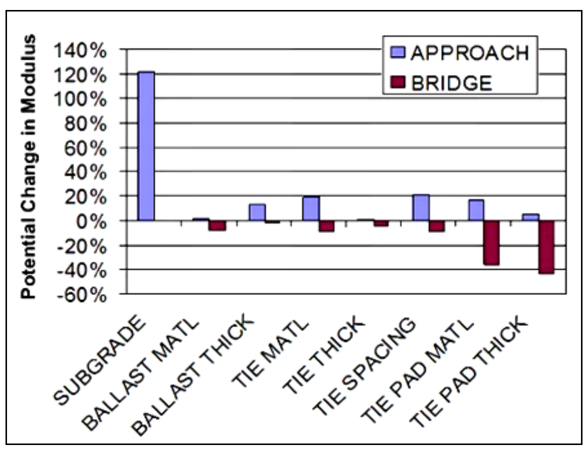


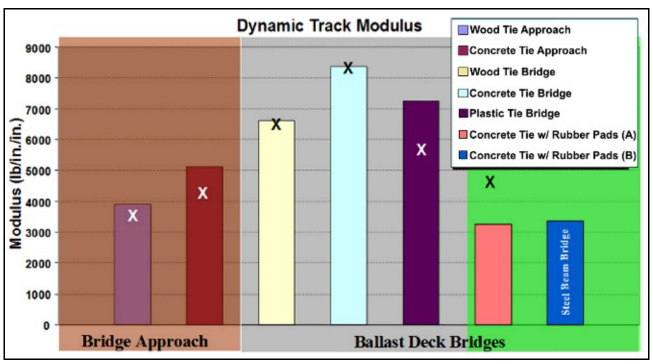
Figure 5. Parametric Study of Track Stiffness

Table 2. Base Case Track Parameters

	Wood Tie Approach	Wood Tie on Concrete Bridge	Concrete Tie Approach	Concrete Tie on Concrete Bridge
Rail Section	136RE	136RE	136RE	136RE
Ties: Material/ Spacing	7×9 hardwood/19″	7×9 hardwood/19″	Tangent track concrete tie/24″	Tangent track concrete tie/24″
Ballast: Material, Thickness	Traprock, 12″ + 6″ subballast	Traprock, 12″ + 6″ subballast	Traprock, 12″ + 6″ subballast	Traprock, 12″ + 6″ subballast
Subgrade: Material, Thickness	Typical medium strength silt-loam	Pre-stressed concrete box; equivalent stiffness derived from field measurements	Typical medium strength silt-loam	Pre-stressed concrete box; equivalent stiffness derived from field measurements
Track Modulus (lbs/in/in)	3,400	6,400	4,000	8,000

IMPLEMENTATION OF TRACK STIFFNESS TRANSITION SOLUTIONS

Figure 6 shows results of Geotrack™ model predictions and field measurements of track stiffness. Considering the variability of track modulus in the field, the results show that the model is a useful tool designing track transitions.



X = Model Prediction (using nominal design values)

Figure 6. Measured versus Predicted Track Modulus

CONCLUSIONS

Different tie materials are an effective way to improve the track stiffness transition. Replacing ties on existing track and bridges is cost effective in comparison with modifying the subgrade or bridge structure. Long-term evaluation is needed to determine the improvement in the degradation rate these materials provide.

The parametric study suggests the best method for raising approach track stiffness is subgrade treatment. The study also suggests the best method of reducing bridge track stiffness is to alter tie/pad properties. These methods can also add damping to the track structure.

FUTURE WORK

The tie materials used on the bridges at Marysville and FAST are being evaluated to determine the contribution to the damping of the track structure. Damping characteristic tests were conducted at these sites and the data is currently being analyzed.

Concrete ties with rubber pads have been installed on a bridge at FAST. The bridge has been strain gauged and will be monitored to determine if the modified ties reduce the impact loads on the bridge compared with standard concrete ties. The long-term performance of these pads will also be monitored to determine if they can withstand the harsh railroad environment.

The results from the parametric study using Geotrack™ will be used to develop a differential settlement model.

References

1. Li, D., Thompson, R., and GeMeiner, W. "Vertical Track Stiffness Tests of Revenue Service Bridges and Approaches," *Technology Digest* TD03-013, Transportation Technology Center, Inc., Pueblo, CO; June 2003.
2. Sasaoka, C., Davis, D., and Guillen, D. "Evaluations of Track Damping Pads and Track Designs for Reducing Impacts at Special Trackwork," *Technology Digest* TD04-002, Transportation Technology Center, Inc., Pueblo, CO; February 2004.