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## **TLV Vertical Track Strength Follow-up Testing Using TTCI's Cone Penetrometer**

by **Randy Thompson, Dingqing Li, and Previn Marquez**

### **Summary**

The Cone Penetrometer Test (CPT) vehicle can quickly and efficiently evaluate unsafe vertical track support conditions identified by the Track Loading Vehicle (TLV).

In a joint effort between a participating railroad and Transportation Technology Center, Inc. (TTCI), vertical track stiffness monitoring was taken a step further. The TLV data was used to pinpoint areas of low vertical support and the CPT was then used to further investigate the track substructure conditions.

A variety of track substructure conditions were determined for the areas identified by TLV testing. Without this information, it would be difficult to select an effective remedy for areas of low vertical support due to many different causes. Using its TLV consist, TTCI, a subsidiary of the Association of American Railroads (AAR), measured the vertical track support on a high tonnage rail line late in 2002 under an AAR-funded research program. This route, located in the midwestern United States, has had a history of vertical track support problems. This digest describes three sections of track as examples of using combined data from the TLV and CPT to diagnose the underlying causes of weak track structure.

The TLV measured vertical track deflections while the train was in motion. These measurements provide an automated means of testing vertical track stiffness variation along a track, and characterizing track load carrying capacity. Still, the TLV stiffness profile data alone does not provide a complete picture of the exact causes of the weakness in the vertical track support. Further evaluations of the track substructure conditions are needed to determine the causes of the problem and to provide a cost-effective remedy.

In the near future, the CPT capability will be added to the TLV so that a detailed track substructure profile can be obtained immediately at the locations of interest as identified by the TLV in-motion, vertical track stiffness testing.



#### **Suggested Distribution:**

- Safety
- Maintenance-of-Way
- Track Maintenance
- Planning & Analysis

## INTRODUCTION AND CONCLUSIONS

TTCI's CPT vehicle is uniquely designed to perform extensive measurements through the ballast and deep into the subgrade (Figure 1). Typical measurements are taken to a depth of 15 feet. The CPT uses hydraulic actuators to push an instrumented cone attached to a drill rod down through the ballast and into the subgrade (Figure 2). The instrumented cone was specially designed to withstand the high penetrating stresses from the granular layer with high durability while retaining the sensitivity necessary to measure soft subgrade conditions.



Figure 1. The CPT Vehicle



Figure 2. The CPT Probe

TTCI performed evaluations using the CPT in conjunction with TLV in-motion vertical track strength and stiffness tests that were being conducted on a high tonnage rail line in the midwestern United States. The train route selected was a heavy haul coal line that carried about 170 MGT of traffic annually. The line was made up of double track. The track carrying loaded train traffic was constructed of concrete ties while the track carrying empty train traffic was constructed of wood ties. The tests were performed on the loaded track (concrete ties).

## CPT MEASUREMENT TECHNIQUE

During a cone penetrometer test, the two measurements obtained are tip resistance and sleeve friction. The tip

resistance is related to soil strength and stiffness (Table 1); thus, its distribution with depth directly indicates layer strength characteristics. Using results of both tip resistance and the friction ratio, estimation of soil types can be made based on available CPT soil identification charts (Figure 3).

Table 1. CPT Strength Comparisons

Cone Tip Resistance (psi)	Compressive Strength (psi)	Modulus (psi)	Subgrade Support
> 1,000	> 100	> 10,000	Hard
500-1,000	50-100	5,000-10,000	Very Stiff
300-500	30-50	3,000-5,000	Stiff
150-300	15-30	2,000-3,000	Medium
70-150	7-15	1,000-2,000	Soft
< 70	< 7	< 1,000	Very Soft

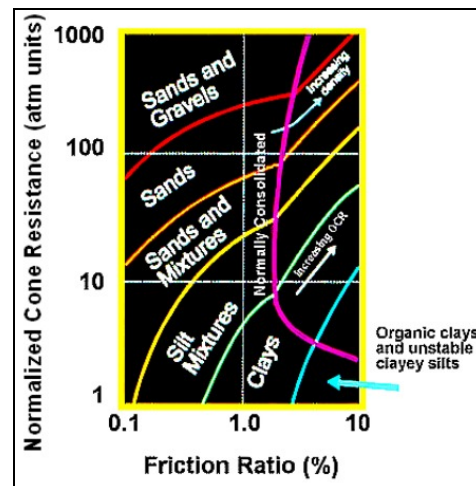


Figure 3. - CPT Soil Identification Chart

## TEST RESULTS

The CPT locations were picked based on the earlier TLV vertical track strength tests. The TLV uses a measure known as the *Vertical Strength Index* to monitor the strength variation along the track.<sup>1</sup> When this measure exceeds a specific threshold, a paint spray system marks that particular location. Figure 4 shows an example of an exception where the peak deflection of 0.4 inch occurred at the same place as the peak in the vertical strength index.

The results of the CPT measurements at this location showed a large depth of soft to medium subgrade support (Figure 5). The resulting friction ratio showed that the soil was made up of clay (Figure 6).

Another CPT test site was chosen at a TLV paint spot. This location is only about 25 feet from a road crossing and it had visible mud pumping from underneath the ties. As can be seen from the TLV test results in Figure 7, large deflections (greater than 0.5 inch) were found, as were large variations in vertical strength index.

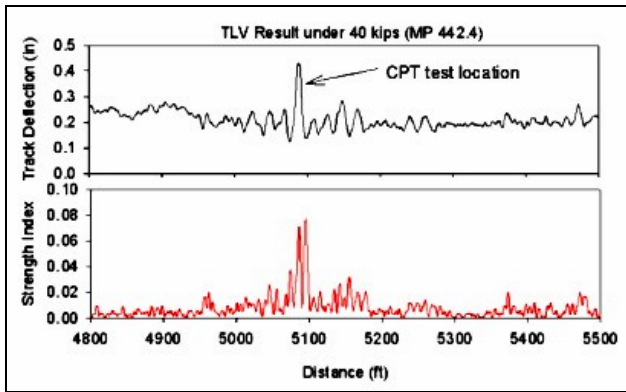


Figure 4. TLV In-Motion Test Results

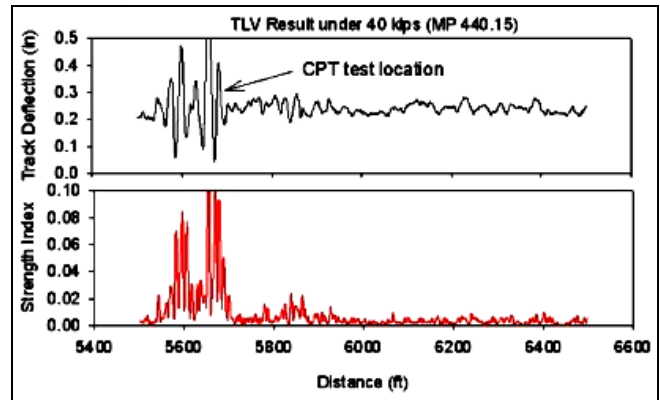


Figure 7. TLV In-Motion Test Results

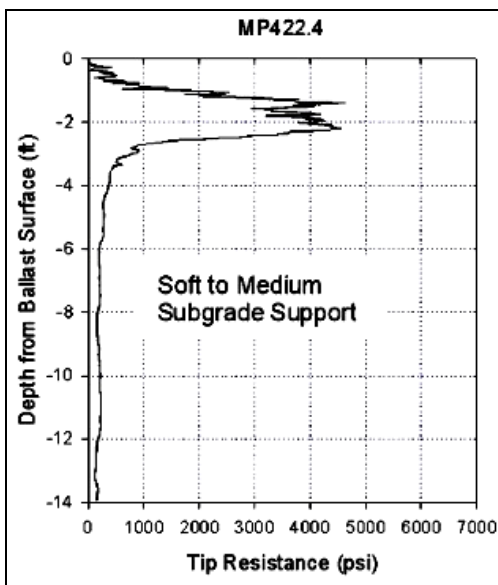


Figure 5. CPT Test Results

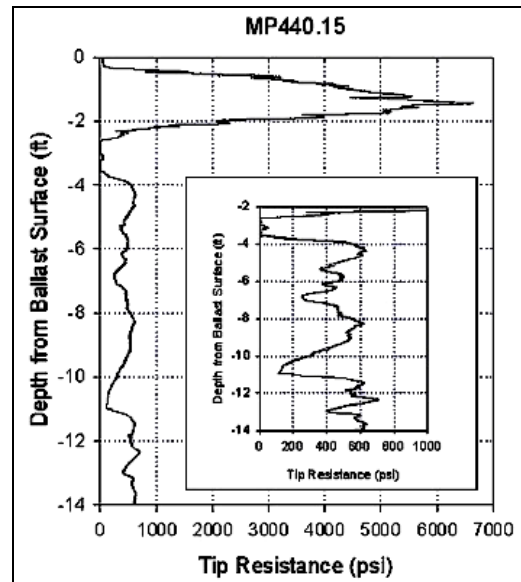


Figure 8. CPT Test Results

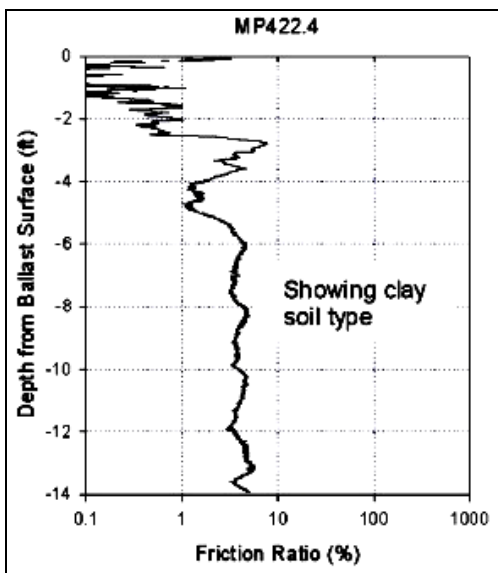


Figure 6. CPT Test Results

CPT results showed a thin but very soft subgrade layer roughly 1 foot deep (Figure 8). The tip resistance in this area was only about 10-20 psi.

Figure 9 illustrates a third example. This is an area that had neither a vertical deflection nor a strength index large enough to be an exception. Therefore, the TLV data suggests that this area is of medium track support.

Examining the CPT data in Figure 10, there are a few points that should be noted. First, the data shows that there is almost four feet of granular layer thickness. Just below the ballast, there is an area of considerable weakness. The large granular layer thickness might be one of the reasons why the track showed a medium support. The other contribution might come from cross drains and shear keys installed in this area. This was an area that was worked on in 1997 to address weak subgrade conditions.

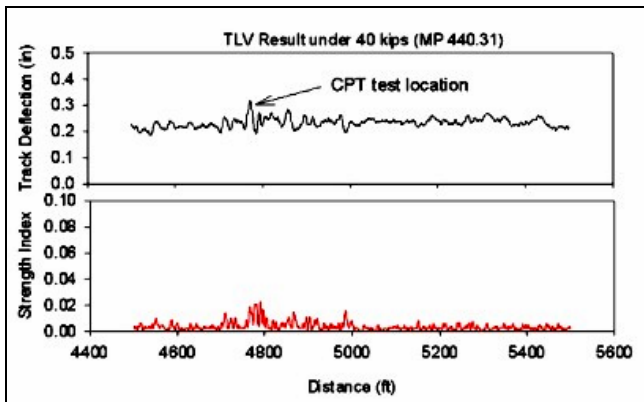


Figure 9. TLV In-Motion Test Results

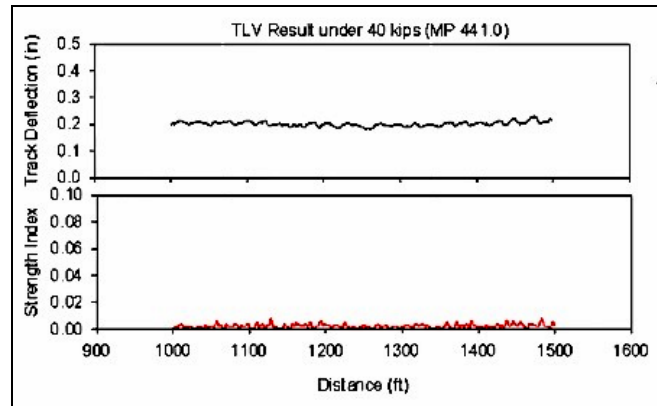


Figure 11. TLV In-Motion Test Results

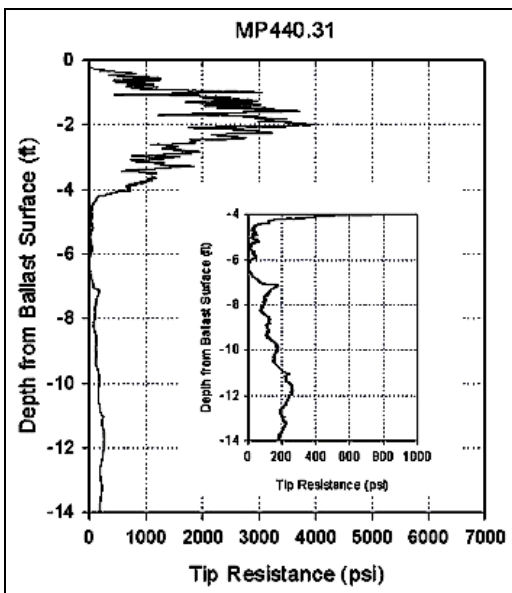


Figure 10. CPT Test Results

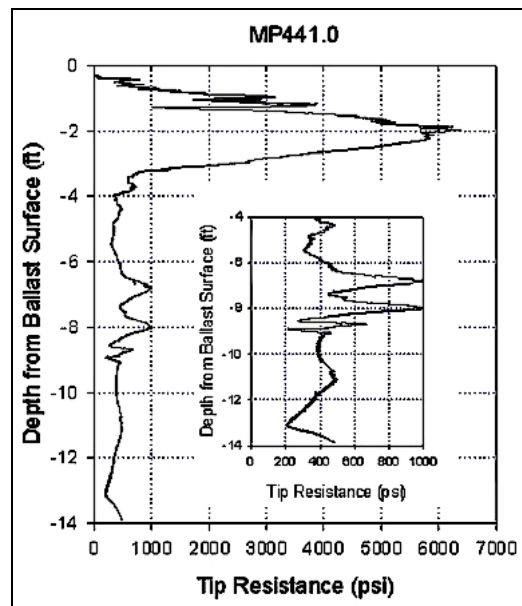


Figure 12. CPT Test Results

To illustrate the track substructure condition for strong track support as shown by the TLV results (Figure 11), a CPT test was performed at this location. Figure 12 shows that the tip resistance indicated medium to stiff subgrade support with an adequate granular layer thickness.

## Reference

1. Thompson, R., and Li, D., "Automated Vertical Track Strength Testing Using TTCI's Track Loading Vehicle", Transportation Technology Center Inc., Technology Digest No. 02-002.

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