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# CHARACTERIZATION OF TRACK SUBSTRUCTURE USING FALLING WEIGHT DEFLECTOMETER AND AUTOMATIC BALLAST SAMPLING

## SUMMARY

Transportation Technology Center, Inc. (TTCI) tested a falling weight deflectometer (FWD) diagnostic apparatus and verified it using automatic ballast sampling (ABS). The company examined the ability of the apparatus to measure track substructure characteristics by determining shear wave speed and deflection signatures for various substructure soil types and conditions. Since the tests showed good results and the FWD's signal information was correlated to the ABS depth data, potentially identifying problem areas, so remediation could be determined for a particular area of track.

To decide when to perform maintenance on track ballast and sub-ballast sections, knowledge of the level of degradation and support of the ballast over time is needed. The FWD apparatus showed promise in characterizing track substructure (ballast, sub-ballast, and subgrade) layer-stiffness characteristics. As a result, lower modulus soil areas could be identified and problem areas could be scheduled for maintenance or remediation before they become emergencies.

The process employed by FWD technology begins when a loading beam, which has been placed on a tie that has been unfastened from the rail, is struck with a falling weight force of 14 tons (Figure 1).

Geophones are spaced out and are in contact with the ballast at precise distances from the impact point; they record the travel time and magnitude of the shear wave as it passes (Figure 2). These metrics can reveal physical subtrack parameters, such as modulus, moisture content, and layer thickness to a depth of approximately 3.3 feet.

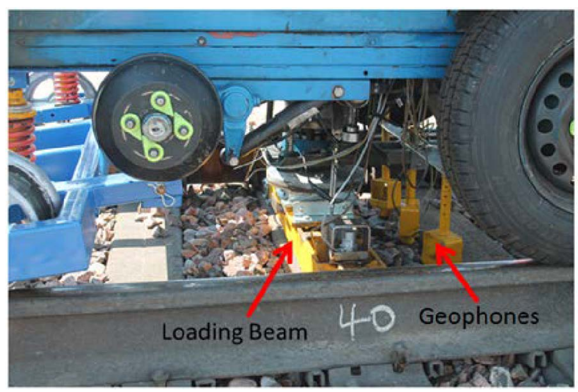


Figure 1 Falling Weight Deflectometer Apparatus

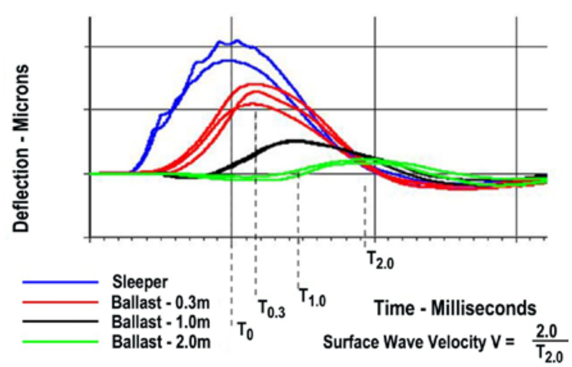


Figure 2 FWD Time History

During the testing, results of the FWD tests were verified using a subsurface sampling technology called automatic ballast sampling (ABS). ABS was used in the same areas where FWD was employed. The ABS system used a hydraulic hammer to drive and retrieve a 3-inch diameter hollow sampling tube up to 6.6 feet vertically into the track subsurface. It obtained a core of material for visually inspection, testing, and photographing. The results were used to verify the FWD results and adjust the interpretation of the subgrade properties if necessary.

## BACKGROUND

The High Tonnage Loop (HTL) is a 2.7-mile long track located at the Transportation Technology Center (TTC) test facility in Pueblo, Colorado. The track is used for imposing heavy test loads on various grades, types, and combinations of rail, tie, ballast, and sub-ballast. Test results are used to improve safety and economic factors associated with the rail industry.

Before FWD testing began, the HTL was characterized with respect to variables that may affect the signal interpretation and results. Factors such as tie and ballast type, fouling, moisture, bridge effects, slab track areas, and other inputs were carefully described and tied to Global Positioning System (GPS) and section/tie numbers for orientation purposes.

The natural subgrade at the HTL is native silty sand that has good engineering support characteristics for the loads that are imposed. In 1991, a 700-foot long by 12-foot wide by 5-foot deep section of the subgrade was removed and high plasticity clay was placed in the trench for research purposes. The test zone was designated as Section 29, and most of it was later covered with a 4- to 8-inch thick layer of hot mix asphalt.

## OBJECTIVES

This research initiative was designed to test the track-mounted FWD system's ability to characterize railway ballast and sub-ballast conditions, such as layer thickness, modulus, and fouling.

To verify the FWD results, the ABS system followed the FWD along the track, and obtained transparent, 2-inch diameter sleeved cores of the ballast to a depth of 6.6 feet (Figure 3).

Figure 3 Automatic Ballast Sampling (

## METHODS

The FWD apparatus took 189 measurements around the loop, using random sampling techniques in some areas, and focusing on anomalies and specific structures in other areas. The ABS trailer followed, taking a total of 74 cores of the ballast and sub-ballast to a depth of approximately 3.3 feet in most areas.

## RESULTS

At the HTL, bridge approaches and decks, fouled and clean ballast, clay subgrade covered by hot mix asphalt, clay with a simulated bridge approach, new versus old tie responses, wood versus concrete versus plastic tie signatures, and various types of ballast were measured and compared. ABS samples were digitized after they were photographed and prepared for correlation with FWD results (Figure 4).

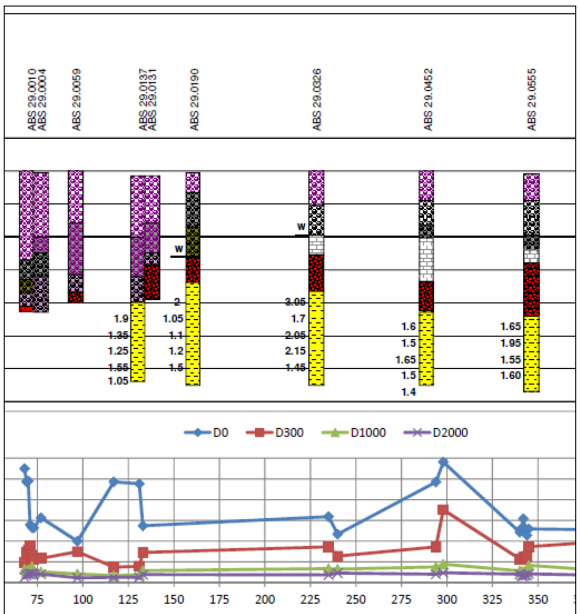


FIGURE 2
**ABS LONGITUDINAL SECTION - 28 to 30**
North America - TTCI TBI Trials - Trackbed Investigation
Colorado Testing Facilities

**Figure 4 Split ABS Cores and Interpreted Data**

The FWD results were correlated with ABS photographs and measurements to form a continuous log of the 2.7-mile loop. Results showed adequate correlation, and ABS sampling proved to be a reliable and effective means of spot sampling for ballast to subgrade sections. Time and reflectance signatures were used to discriminate between various subgrade conditions and to estimate maximum train speeds for subgrade conditions logged (Figure 5).

Stiffer layers showed less deflection, as noted in lower values for discrete portions along the red and yellow dots (Figure 5), which represent the response of various layers.

The clay in HTL Section 29 was encountered at depths varying between 2.9 and 3.6 feet below top of ballast, and was overlaid by an average of 4 to 8 inches of sand and gravel. Formation deflections on the asphalt varied between 0.024 and 0.035 inch; the maximum formation deflection measured on the clay was approximately 0.071 inch. Tests undertaken directly above pin pile sections (simulated bridge approach) showed that the formation deflections had been reduced to between 0.019 and 0.024 inch, showing a gradual increase from low to high tie number. The range of results found showed that the formation stiffness over a soft subgrade was highly dependent on the nature of the sub-ballast layers.

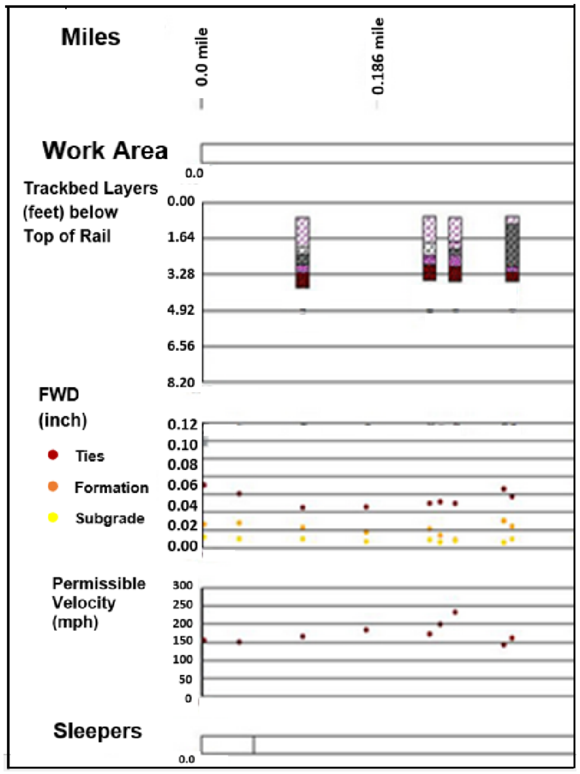


Figure 5 Correlation of FWD and ABS Samples

## CONCLUSIONS

After testing, FWD technology's capability to perform nonintrusive characterization of ballast and subgrade was deemed promising. Further development of FWD technology will involve automating phases that are currently performed manually.

## ACKNOWLEDGEMENTS

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## KEYWORDS

Falling Weight Deflectometer, Track Substructure Characterization, Raleigh Wave