TECHNOLOGY DIGEST

Timely Technology Transfer — 00-023

Evaluation of Foundations for Special Track Work

by David D. Davis, Satya P. Singh, and Don Guillen

Summary

Transporation Technology Center, Inc.'s performance evaluation of four subgrade improvement methods has concluded that these methods can improve the properties of the foundations of special track work. These methods include placing a Portland cement concrete slab (concrete), a hot mix asphalt slab (HMA), a reinforced subballast (GEOWEB™) and a roller-compacted subballast (compacted) over the subgrade. The first three of these methods were tested under heavy axle load conditions at the Facility for Accelerated Service Testing (FAST). The fourth was evaluated under revenue service conditions. The primary objective of the overall special trak work initiative is to reduce the life cycle cost of components using improved designs and maintenance procedures. Reduction in impact loads and increases in component life are expected from foundation improvements.

After 60 million gross tons (MGT) of 39-kip wheel load traffic, the subgrade improvements were able to increase the stiffness of the track by 23 to 35 percent, as measured by track modulus. The average deflection under a 40-kip load was decreased by 35 and 17 percent for the HMA and concrete sections, respectively, as compared to the conventional ballast control section. Average deflection increased by about 7 percent for the GEOWEB section, despite the increase in track stiffness.

Settlement in the test sections at FAST has been higher than in the ballast control section. This is due to the larger thickness of construction in these sections. A 6-inch subballast was placed below the test subgrade improvement layer. A 12-inch layer of ballast was placed above the HMA and GEOWEB. An 8-inch layer was placed above the concrete. The control ballast section was constructed by placing a 12-inch ballast layer above the existing subballast. At the revenue service site, the subballast was roller compacted, a geotextile was placed, and a 10-inch layer of ballast was placed and tamped. The diamond has shown little settlement in 80 MGT.

Testing was performed on the High Tonnage Loop at FAST, and in revenue service on the Belt Railway of Chicago (BRC). The test sections were constructed by placing the test foundation upon the native subgrade. The test layers included a 12-inch reinforced concrete slab, an 8-inch HMA pavement, an 8-inch subballast reinforced with cellular confinement (GEOWEB), and a roller-compacted subballast. The first three were built on a strong, well-drained subgrade on site. The fourth was constructed on a weak clay subgrade at the BRC's Hayford crossing in Chicago. Conventional track was placed on the three sections at FAST, and 76-degree crossing diamonds of three-rail design were placed in service on the BRC.

Suggested Distribution:
- ☐ Maintenance of Way
- ☐ Planning & Analysis
- ☐ Track Maintenance
- ☐ Safety

Work performed by TTCI™ Transportation Technology Center, Inc.
a subsidiary of the Association of American Railroads
November 2000

INTRODUCTION AND CONCLUSIONS

The foundations of special track work often create high-maintenance situations due to three factors:

- Dynamic loading
- Design
- Maintenance

Special track work may have the same foundation as surrounding track. However, the loading conditions can be quite different. For example, a crossing diamond has the combined traffic of the two crossing lines. Since frogs generate dynamic loads from the flangeways and vertical stiffness changes, the dynamic load environment at a turnout or crossing diamond can be significantly more severe than in surrounding track. Dynamic loads that are two or more times the static wheel load are not uncommon in special track work. Thus, frogs and switches tend to become low spots in track.

Further complications arise in trying to maintain track surface and alignment at special track work. The large timbers, control rods, and plate work make surfacing with mechanized methods more difficult. Conventional tamping can sometimes be ineffective at correcting surface defects at large frogs and crossing diamonds. Some machines have difficulty in manipulating such large and atypically placed track components. Tamping further breaks down the ballast and, over time, can foul the drainage at the frog or crossing diamond.

There is a lack of fundamental knowledge about the dynamic characteristics of special track work and conventional track work. This prevents the vehicle and track designers from developing optimal, compatible products. Previous analytical work by TTCI, for the AAR, suggested that optimizing the vertical damping of the frog could substantially lower maximum vertical forces. [1] Varying track stiffness had less effect on vertical forces at frogs. The described field tests allowed TTCI to verify the previous analytical studies and evaluate the benefits of some typically used foundation improvement techniques as well as to develop methods to measure track damping characteristics. Initial conclusions from the first 60 MGT of traffic include:

- After 60 MGT of 39-kip wheel load traffic, the subgrade improvements were able to increase the stiffness of the track by 23 to 35 percent, as measured by track modulus.

- The average deflection under a 40-kip load was 35 and 17 percent less for the hot mix asphalt (HMA) and concrete sections, respectively, as compared to the conventional ballast control section.

- The average deflection was about 7 percent more for the GEOWEB section as compared to the control section.The GEOWEB section had more deflection under load than the control section despite being stiffer. This is due to the different load ranges of the settlements and track modulus measurements. The GEOWEB section had large deflections during the application of the seating load (10 kips) used in the track modulus measurements. This deflection is not included in the stiffness calculations.

- Settlement in the test sections at FAST has been higher than in the ballast control section. This is due to the larger thickness of construction in these sections.

- Settlement of the roller-compacted foundation at the Belt Railway of Chicago (BRC) test site has been less than that typically seen in crossing replacements. The vertical surface of the track has remained good for 80 MGT following construction and initial surfacing.

- Disturbed control or transition sections, created by construction of the test zones where ballast had been disturbed adjacent to each test zone, became problem areas, with significant settlement, low surface, and higher dynamic loads resulting.

Track damping characteristics were measured in the test and control sections using an experimental method developed by TTCI for ballasted track. This method was successful in characterizing the track's damping characteristics under dynamic loading. Measurements were able to distinguish between the different subgrade structures at each test section. Damping test results will be presented in a future Technology Digest.

TEST SECTIONS

Exhibit 1 shows the configuration of the test sections in FAST. Each test section consists of a subgrade remediation layer 12 feet wide and 40 or 50 feet long. The test layers were constructed by excavating the track to a common elevation of 42 inches below the top of rail. Each test layer was installed over a 6-inch layer of rolled granular subbase material.

The concrete slab consisted of 12 inches of reinforced Portland cement concrete. The slab has three 12 by 13.3-foot panels. The HMA section consists of a 12 by 50-foot slab of 8-inch thick HMA, paved and roller-

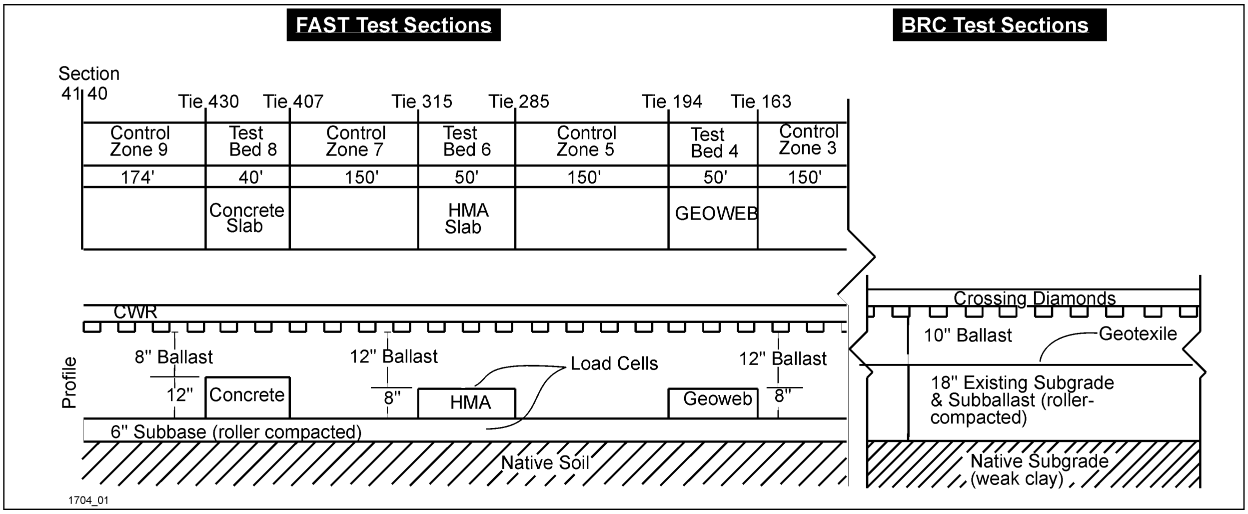

Exhibit 1. FAST Foundation Test Section Configuration

compacted. One end is vertical and one end has a tapered transition zone. The GEOWEB section consists of an 8-inch-thick cellular confinement material that is backfilled with subballast. The layer was also roller compacted. The BRC test section consisted of an 18-inch layer of subgrade and subballast that was roller compacted. A geotextile was placed over the subballast prior to placement of 10 inches of ballast.

Track modulus was calculated from measuring deflections under controlled loads from 10 to 40 kips. The results presented in Exhibit 2 are the averages of four to six measurements in each test section. The subgrade remediation techniques all produced track that was stiffer than the control sections. After about 57 MGT of heavy axle load (HAL) traffic the HMA, Concrete and GEOWEB sections were about 35, 27, and 23 percent stiffer than the control sections.

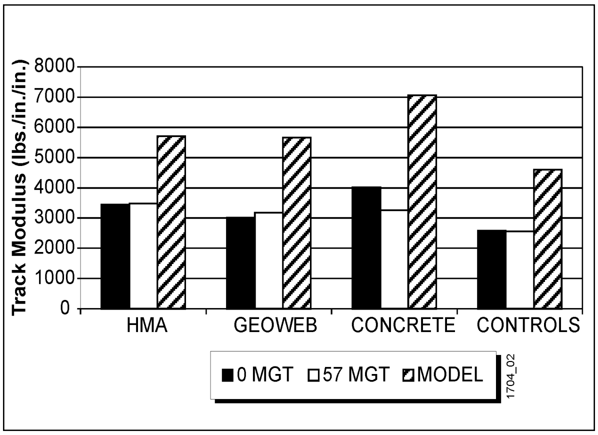

Exhibit 2. Actual vs. Predicted Track Modulus in FAST Test Sections

However, none of the test sections has had a sustained increase in stiffness and none has approached the stiffness values expected from elastic layer modeling. The test sections have not become stiffer under HAL traffic with the exception of a seasonal variation during cold weather. Measurements made in September are similar to measurements made the following May after 57 MGT.

SETTLEMENT

Exhibit 3 shows the long-term track settlement of each test section. The results shown are for loaded settlement over the first 60 MGT of HAL traffic. The sections appear to be approaching a steady state rate of settlement. The undisturbed control sections are consolidating at the typical rate for the FAST HTL. Exhibit 4

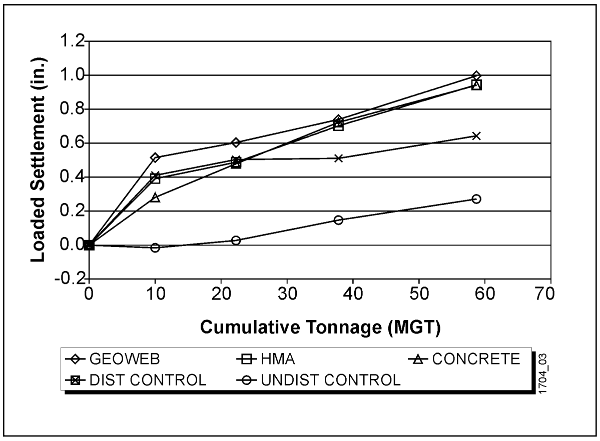

Exhibit 3. FAST Foundation Test Section Average Settlement

shows that the disturbed transition zones have settled the most, followed by the newly constructed sections.

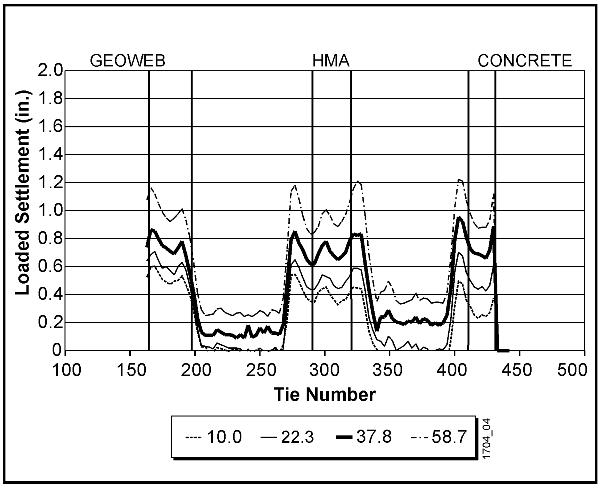

Exhibit 4. FAST Foundation Test Section Settlement vs. Tie Number

DYNAMIC LOADING

Dynamic wheel loads over each section were measured with strain-gaged wheel sets under a 315-kip hopper car at speeds of 10 to 40 mph. The results are shown in Exhibit 5. The test sections show the typical dynamic load and speed effect seen in conventional mainline track. At 40 mph, the maximum dynamic load is approximately 1.25 times static load. The concrete test section showed lower maximum loads than the other two sections. This may be due to the shorter section analyzed in the test. A bridge joint is in test above the concrete slab foundation. Due to the impacts generated at the joint, the data from the section at and downstream of the joint was eliminated from the analysis.

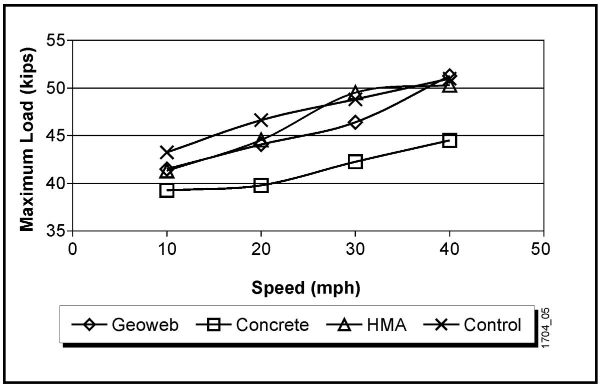

Exhibit 5. Maximum Dynamic Wheel Loads in FAST Foundation Test Sections

FUTURE WORK

Additional tonnage will be accumulated to determine the long-term performance of the test sections. Comparison will be made to similar test sections in place in bridge approaches on the Union Pacific railroad. These test sections are part of the Association of American Railroads' Heavy Axle Load Revenue Service Monitoring project. The traffic on this line consists of approximately 60 percent cars with loaded gross weights of 268 to 286 kips. The subgrade conditions on the bridge approaches, being in flood plains and/or on newly constructed fill sections, are generally poorer than at FAST.

Reference

1. Singh, Satya and David Davis,"Reducing Impact Forces on High-Angle Crossing Diamonds," *Technology Digest*, TD98-021, August 1998.

Note: Please contact Dave Davis at (719) 584-0754 with questions or comments about this document.

E-mail: david_davis@ttci.aar.com

Web site: www.ttci.aar.com

A MORE DETAILED REPORT, WHICH MAY CONTAIN REVISED INFORMATION, MAY BE AVAILABLE AT A LATER DATE THROUGH AAR/TTCI, PUBLICATIONS, P.O. Box 79780, BALTIMORE, MD, 21279-0780.