TECHNOLOGY DIGEST

TD-05-035

©December 2005

TIMELY TECHNOLOGY TRANSFER

The work described in this document was performed by Transportation Technology Center, Inc., a wholly owned subsidiary of the Association of American Railroads.

Long-Term Performance of Hot-Mix Asphalt over Soft Subgrade at FAST

Joseph LoPresti and Dingqing Li

Summary

A long-term test of a 700-foot long section of hot-mix asphalt (HMA) underlayment at the Facility for Accelerated Service Testing (FAST) at the Transportation Technology Center (TTC) has shown that this method of strengthening track built on soft subgrade can sufficiently increase track modulus and reduce subgrade stresses to provide good performance under heavy axle loads (HAL). Both the 4-inch asphalt and 8-inch asphalt segments provided good performance. Three hundred seventy one million gross tons (MGT) were accumulated on the HMA track before surfacing was required on 65 feet of track. This compares to an average cycle of 15 MGT on 18-inch conventional track construction over the same subgrade. Following the initial surfacing of the HMA track, similar maintenance was needed seven more times in 35 MGT as it became evident that a short segment of the asphalt was damaged, and subgrade failure had occurred.

The problem area of the track was removed in July of 2005 for a thorough investigation.

- Approximately 80 feet of asphalt had cracked longitudinally near the inside rail, and was pushed upward and outward.
- There was water under and along the asphalt that failed.
- The water contributed to the start of the failure by weakening the subballast and clay, and accelerated the degradation following failure initiation.
- The underlying cause of the asphalt failure was progressive shear failure of the clay. The clay was also pushed upward and outward.
- There is no indication of any significant weathering or deterioration of the asphalt.

Following the investigation, the damaged and displaced asphalt and the subballast below it were removed. Ten to 12 inches of asphalt was placed directly on the clay. Drainage in the area was improved with the installation of a trench to intercept and divert surface water from the clay. The repair effectively strengthened the damaged track and no surfacing has been required in 14 MGT. The need for improved drainage indicates that, while asphalt can divert water from problem subgrades, other aspects of proper drainage need to be considered.

The HMA track was built over the soft subgrade section of the Heavy Tonnage Loop (HTL) at the TTC, in the summer of 1999. The section consists of two segments: 4-inch HMA and 8-inch HMA. A 4-inch subballast layer was placed between both HMA underlayments and the soft subgrade. The total combined thickness of ballast, HMA and subballast for the entire section was 20 inches at the time of construction.

Tests to asses the performance of soft subgrade under HAL and various methods of strengthening soft subgrade track have been conducted at FAST since 1991. The FAST/HAL program is funded by the Association of American Railroads and the Federal Railroad Administration. This Technology Digest (TD) is the fifth in a series reporting on the results of these tests (TD 95-028, TD 97-020, TD 97-045, and TD 01-009) with FRA Report DOT/FRA/ORD-04/04 summarizing results.

Please contact **Joe LoPresti (719) 584-0589** with questions or concerns regarding this *Technology Digest.* E-mail: Joe_LoPresti@ttci.aar.com.

Introduction

One of the primary causes of track geometry problems is the deterioration of soft subgrade support. This can be exacerbated by heavy axle loads, causing track that had provided acceptable performance under lighter loads to deteriorate rapidly. An increase in train operating speeds can have a similar effect. The effects of heavy axle loads upon track substructure performance have been studied at the High Tonnage Loop (HTL) at the Transportation Technology Center (TTC) near Pueblo, Colorado since 1991.

A low track modulus (LTM) test section was built in the 2.7-mile HTL by excavating the native subgrade soil (silty sand). A 700-foot-long, 12-foot-wide, and 5-foot-deep trench was then backfilled with Vicksburg (Buckshot) clay. To prevent the loss of clay moisture over time, the sides and bottom of the clay subgrade are lined with a plastic membrane. The moisture of the clay was approximately 33 percent at installation. It was found that a track with track modulus of 2,000 lbs/in/in or less (i.e., a conventional 18-inch granular layer over a soft clayey subgrade) required frequent surfacing maintenance under 39-ton axle loads. Therefore, various remedies aimed at limiting excessive subgrade deformation have been evaluated.

Methods of remedying soft subgrade deformation tested at FAST include increased granular layer thickness, geocell reinforcement, and the application of hot-mix asphalt (HMA) underlayments. Increased granular layer thickness (12 inches of ballast and 15 inches of subballast) improved track performance, but did not prevent rapid geometry degradation during and following a heavy rainfall. Geocell in the granular layer improved track performance with no surfacing maintenance needed in 200 MGT of traffic. The current HMA test started in the summer of 1999; this Technology Digest summarizes the results.

HMA Design and Construction

The HMA track was built over the soft subgrade section of the HTL in the summer of 1999. The 700 feet long section consists of a 4-inch HMA segment and an 8-inch HMA segment. Four inches of subballast was placed between both HMA segments and the soft subgrade. The total combined thickness of ballast, HMA and subballast for the entire section was 20 inches at the time of construction. The asphalt mix was a Colorado Department of Transportation (DOT) Grade G Base Mix, using Conoco AC-10 asphalt cement. Its design was based on the recommendation of the Asphalt Institute. The installation of the asphalt increased the track modulus from 2,000 lbs/in/in to 2,800 lbs/in/in in the 4-inch HMA segment and to 3,300 lbs/in/in in the 8-inch HMA segment. Construction and design details, and early test results can be found in TD 01-009.

HMA Track Performance

Following installation, there was some settlement of the track as measured by taking top-of-rail elevations. The initial settlement rate was higher, with about one inch in the first 10 MGT. After that, settlement was gradual and uniform through 342 MGT, when a slight cross level deviation was noted in the 4-inch HMA segment. No maintenance was needed at that time. Figure 1 shows the general test section layout and location of the geometry deviation.

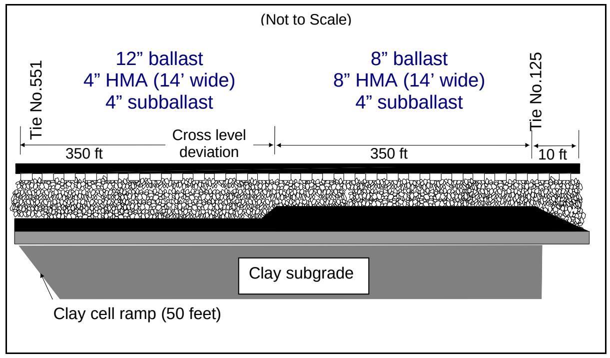

Figure 1. HMA Test Segments and Location of Geometry Problem

Little change in geometry was noted in an additional 17 MGT; however, the left rail then began to settle more rapidly. The first surfacing was needed in February 2005 with 371 MGT on the HMA track when cross level exceeded 1.75 inches. Sixty five feet of track were surfaced. Similar maintenance was needed seven more times in the next 35 MGT. The interval between the first and second tamping was 16 MGT. Between the seventh and eighth, it was 2 MGT. As the rate of degradation increased, it became evident that the asphalt had been damaged. Figure 2 shows early evidence of the asphalt pushed up and outward from the ends of the ties.

Figure 2. Early Indication of Asphalt Damage

After 406 MGT, with surfacing needed every 2 MGT and the asphalt damage becoming more severe, it was decided that the track should be removed to allow investigation and repair.

Investigation

The track was removed from several locations over the damaged asphalt and in additional locations where no geometry problems were evident. Observations include:

- Approximately 80 feet of asphalt cracked longitudinally near the inside rail, and was pushed upward and outward. The asphalt that had been pushed up was about two feet higher than the asphalt that had not.
- There was water under and along the asphalt that failed. This was at a low spot in the track, and where geometry problems had occurred earlier in the LTM test. This low spot has historically collected water from rain and snow fall in the surrounding area.
- The permeable subballast provided an entry path for the water to get under the asphalt.
- The water contributed to the start of the failure by weakening the subballast and clay and accelerated the degradation following failure initiation.
- The underlying cause of the asphalt failure was progressive shear failure of the clay. The clay also pushed upward and outward. This is consistent with previous subgrade failures in the LTM section.

Figure 3 shows the HMA where the cross level deviation was the greatest. For comparison, Figure 4 shows undamaged asphalt approximately 210 feet away.

Figure 3. Asphalt Damage and Standing Water

Figure 4. Undamaged Asphalt 210 Feet from the Damaged Asphalt shown in Figure 3

Asphalt cores were taken from damaged and undamaged asphalt, in the 4-inch and 8-inch segments. Dr Jerry Rose, University of Kentucky (UK) Lexington, assisted in the coring and investigation, and Colorado DOT provided the coring machine. Clay samples were also taken to determine whether moisture content had changed and to measure the current strength of the clay.

The cores taken from the track and cores that had been taken at the time of HMA installation were tested at Auburn University. The cores taken at installation had been stored at the UK in the basement, where there was little temperature variation and no exposure to sunlight. The following tests were conducted:

- Bulk Specific Gravity
- Maximum Theoretical Specific Gravity
- Washed Sieve Analysis
- Centrifuge Extraction with Rotovapor Recovery
  - Kinematic Viscosity at 135°C
  - Absolute Viscosity at 60°C
  - Dynamic Shear Rheometer

The tests were to determine whether the properties of the asphalt had changed since the asphalt was installed. Of primary importance, and most likely to change, were the viscosity and dynamic shear values, as they provide an indication of the strength of the asphalt. In summary, there is no indication of any significant deterioration of the asphalt. The 1999 and 2005 cores do not differ significantly in gradations, asphalt contents, or volumetrics. The materials do differ, however, in asphalt binder properties, with the 1999 cores being stiffer than the 2005 materials, i.e., the cores from in track have hardened less. It is possible that the asphalt in the trackbed was worked and stayed active due to loading.

But, the asphalt in the UK basement was under no strain and case hardened somewhat. The tops of the trackbed cores, in contact with the ballast, were only slightly harder than the bottoms. There is no indication that the asphalt mix will fail by fatigue under the conditions at FAST.

Clay samples were taken for moisture content at two locations along the track as well as at the left, center, and right across the clay trench at each of those locations. Samples were taken from 1, 2, and 3 feet below the top of the clay. Average moisture content for the 18 measurements was 31 percent, slightly lower than the 33 percent at the time of installation. Figure 5 shows average moisture content since installation. There were variations among the recent samples with the averages from a site 210 feet from the failure being drier than from the failure site (27 versus 34 percent), and the averages from 1 foot drier than those from three feet (28 versus 34 percent).

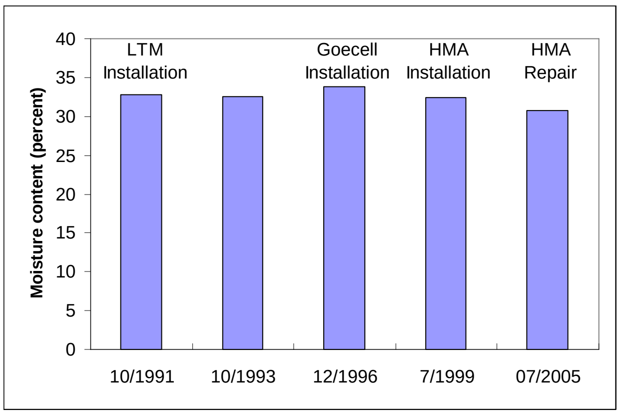

Figure 5. Moisture Content of Clay

Additional samples were sent to UK and tested at Gregg Laboratories. Those results confirm that the clay is very weak. Its USCS classification is CH, and AASHTO classification is A-7-6 (38), highly plastic clay. The California Bearing Ratio (CBR) at 95 percent maximum density at 0.5 percent penetration is 1.0 percent, and indicative of very low strength. The CBR value was the second lowest ever recorded in 55 years of business by the testing lab.

Repair

The damaged and displaced asphalt and the subballast were removed. Ten to 12 inches of asphalt was then placed directly on the clay. The placement of the asphalt directly on the clay differed from the original installation and was thoroughly discussed at TTC. The primary reason for placing the asphalt on the clay was to better seal surface water from the clay and remaining subballast by removing the permeable entry path. A subballast layer may be preferable in other situations. The clay may be too soft to support paving operations, and the subballast can provide necessary support and load distribution. In addition, if groundwater is present, the subballast can allow the water to escape from under the asphalt.

Drainage in the area was improved with the installation of a trench to intercept and divert surface water from the clay (Figure 6 and 7). The trench was filled with coarse gravel. The need for improved drainage indicates that, while asphalt can divert water from problem subgrades, other aspects of proper drainage need to be considered. The repair effectively strengthened the damaged track and no surfacing has been required in 14 MGT.

Figure 6. Drainage Trench along the LTM Section

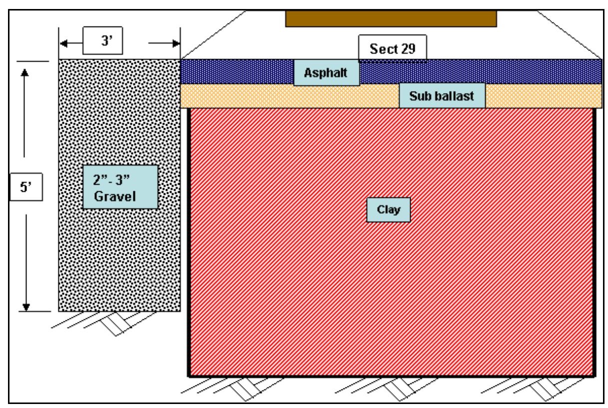

Figure 7. Drainage Trench Illustration along the LTM Section

Future Work

Both old and new asphalt will be monitored as tonnage accumulation continues. The primary metric will be track surface condition.

Acknowledgements

The author would like to thank Dr. Jerry Rose at the University of Kentucky Lexington, the Colorado Department of Transportation, the National Center for Asphalt Technology at Auburn University, and Gregg Laboratories for their help in this investigation.