TECHOLOGY DIGEST

Timely Technology Transfer — 01-009

Test of Hot-Mix Asphalt Trackbed over Soft Subgrade under Heavy Axle Loads

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Summary

Tests of hot-mix asphalt (HMA) underlayments as a method for strengthening soft subgrade support show that this technique facilitates the development of adequate track modulus, reduces subgrade stresses under heavy axle loads, and impoves track geometry performance. Since its installation, approximately 100 million gross tons (MGT) have been accumulated over this test track. To date, the track has been performing well, without requiring any surfacing maintenance. As comparison, 18-inch conventional track construction on this subgrade required surfacing at an average cycle of 15 million gross tons.

The test track, using HMA underlayments, was built over the soft subgrade in the Heavy Tonnage Loop (HTL) at the Transportation Technology Center, in the summer of 1999. The entire test section is about 700 feet long and consists of two segments: 4-inch HMA and 8-inch HMA underlayments. A 4-inch subballast layer was used between the soft subgrade and the two HMA underlayments. The total combined thickness of ballast, HMA and subballast for the entire section was 20 inches at the time of construction.

Preliminary test results indicate that both the 4- and 8-inch HMA underlayments facilitate the development of adequate track modulus in the range of 2,600 to 3,500 lbs/in/in, compared to approximately 2,000 lbs/in/in for an 18-inch conventional granular track over this soft subgrade. The subgrade stresses generated under 39-ton axle load train operations have also been reduced to an acceptable level.

The HMA underlayments are also being measured to determine their effective- ness in stabilizing both subgrade moisture content and avoiding oxidation. Ultimately, it is the intent of this test program to provide sufficient data for the development and acceptance of specifications for HMA underlayment.

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Suggested Distribution:

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

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INTRODUCTION AND BACKGROUND

One of the main causes for track geometry deterioration is the deterioration of soft subgrade support. Without remedy, a subgrade of fine-grained soils will develop excessive deformation under heavy axle loads, which in turn will lead to excessive track maintenance costs. Geometry deterioration due to soft subgrade support will worsen with an increase in train axle loads or operating speeds. In recent years, the effects of heavy axle loads upon track substructure performance have been studied at the High Tonnage Loop (HTL) at the Transportation Technology Center near Pueblo, Colorado. 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 tested and their effectiveness judged.

The soft subgrade test track was built in the 2.7-mile HTL. The soft subgrade was built by excavating into 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. Since its installation, this subgrade has remained at high moisture content (appproximately 33 percent).

To date, several methods to remedy soft subgrade deformation have been tested, including an increased granular layer thickness, geocell reinforcement, and the application of hot-mix asphalt (HMA) underlayments. Use of a 27-inch granular layer thickness (15-inch subballast) improved track performance, but did not prevent a rapid geometry degradation under and following a heavy rainfall due to water building up in the thick and dense subballast layer.[1] Use of the granular layer with geocell (24 inches of total thickness) improved track performance, with no surfacing maintenance needed in 200 MGT of traffic.[2] The current HMA underlayment test started in the summer of 1999 and this digest summarizes the preliminary results from this ongoing test.

DESIGN AND CONSTRUCTION OF HMA UNDERLAYMENTS

In the summer of 1999, two HMA underlayments were placed as a course under the ballast but above the soft subgrade. Each segment is about 350 feet long. One segment has a 4-inch HMA, and the other has an 8-inch HMA. Exhibit 1 illustrates the longitudinal cross section of these two segments. For the entire test section, a 4-inch subballast layer was used between the subgrade and the two HMA underlayments. At construction, the ballast thickness above the HMA was 12 inches over the 4-inch HMA, but was 8 inches over the 8-inch HMA. For both segments, the total granular/HMA thickness was therefore 20 inches.

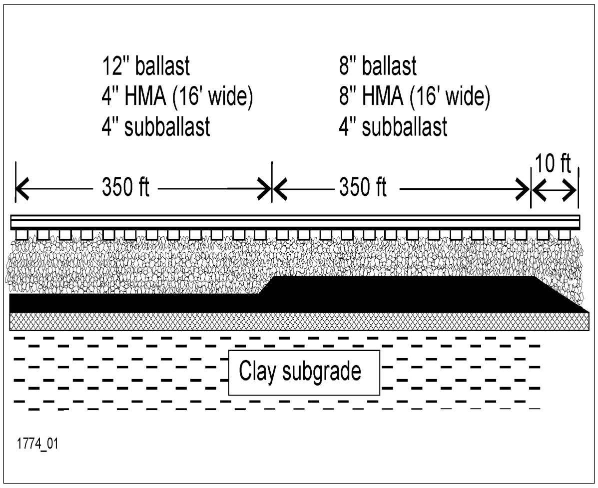

Exhibit 1. Longitudinal Cross Section of HMA Test Track

The asphalt mix design was based on the guidelines recommended by the Asphalt Institute.[3] Exhibit 2 gives the recommended and the actual compositions for the HMA mix, which is essentially similar to a base course for highway construction.

The required HMA strength and the ability in reducing the access of water into the subgrade were achieved by meeting the Marshall design criteria.[3] Exhibit 3 lists the recommended design criteria as well as the actual test results for the mix composition as defined in Exhibit 2.

Sieve size (inch)	Amount finer, weight %	
	Recommended	Actual
1.5	100	100
3/4	70 – 98	76
3/8	44 – 76	52
No. 4	30 – 58	41
No. 8	21 – 45	30
No. 16	14 – 35	23
No. 30	8 – 25	17
No. 50	5 – 20	11
No. 200	2 – 6	4.5
Asphalt	3.5 – 6.5	6.4

Exhibit 2. Composition of Dense-Graded HMA Mix

TTCI = Transportation Technology Center, Inc.; AAR = Association of American Railroads

Property	Required range	Actual test results
Compaction	50 blows	50 blows
Stability (lbs)	750 minimum	1729
Flow (inch)	0.15 – 0.25	0.24
Percent air voids	1 – 3%	2%
Voids filled w/asphalt	80 – 90%	86%
In-place density*	92 - 98%	94%**

* Maximum density =151 pcf
** Average nuclear density test results

Exhibit 3. Marshall Mix Design Criteria for HMA Underlayment

During the construction, the HMA placement was done in one lift for the 4-inch HMA, but in two lifts for the 8-inch HMA. To achieve the desired HMA density listed in Exhibit 3, a steel-wheeled, vibratory roller was used to compact the HMA layer while the mix was still between 185- to 300-degrees Fahrenheit. Following compaction, a nuclear density gage was used to obtain the final in-situ HMA density results. In addition, a number of HMA core samples were obtained for further laboratory testing.

TEST RESULTS OF TRACK PERFORMANCE

This test is the first to apply HMA underlayment over a soft subgrade under 39-ton axle loads. The use of HMA underlayment is intended to reduce traffic load induced stresses to the subgrade and to provide a waterproof layer over the underlying soil. Since its installation, the performance of this test track has been evaluated in terms of track geometry degradation with traffic as well as the amounts of track modulus increase and subgrade stress reduction compared to conventional granular layer construction.

Exhibit 4 gives the track modulus test results obtained at 92 million gross tons (MGT) and the subgrade stress results under a static wheel load of 40 kips. As shown, the average modulus values for the two HMA segments are 2,800 and 3,300 lbs/in/in for the fully consolidated ballast (increased from 2,600 and 2,800 lbs/in/in, respectively, at 0 MGT). Obviously, the HMA underlayment application significantly increased track modulus from the 18-inch granular track with an average track modulus of 2,000 lbs/in/in. As a result, the measured subgrade stresses were lower for the asphalt trackbeds than for the 18-inch granular track. Under 40-kip static wheel load, only 7 to 8 psi of subgrade stress was generated under the HMA underlayments, compared to 12 psi under the 18-inch granular track structure.

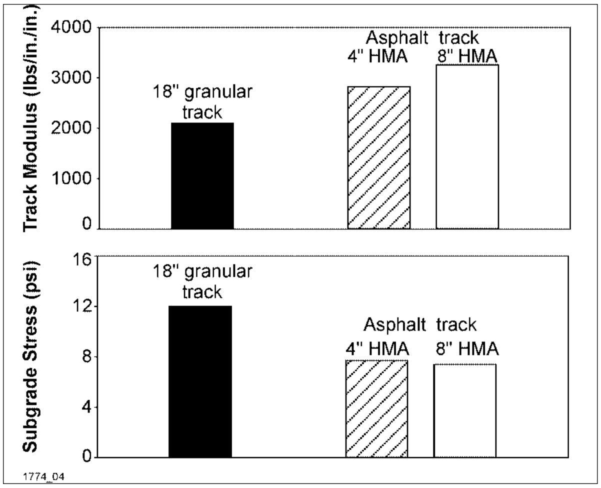

Exhibit 4. Test Results in Track Modulus (consolidated ballast) and Subgrade Stress (under 40-kip static wheel load)

To show how stresses induced by wheel loads are reduced from the HMA to the subgrade, Exhibit 5 shows the dynamic stress results under an actual train operation (40 mph) measured on the 8-inch HMA surface as well as on the subgrade surface. As illustrated, use of an 8-inch HMA underlayment reduced the subgrade stress approximately by half.

Exhibit 6 shows the results of average track settlement as a function of traffic for both the segments. As illustrated, after the initial higher rate due to early ballast consolidation, the settlements became gradual,

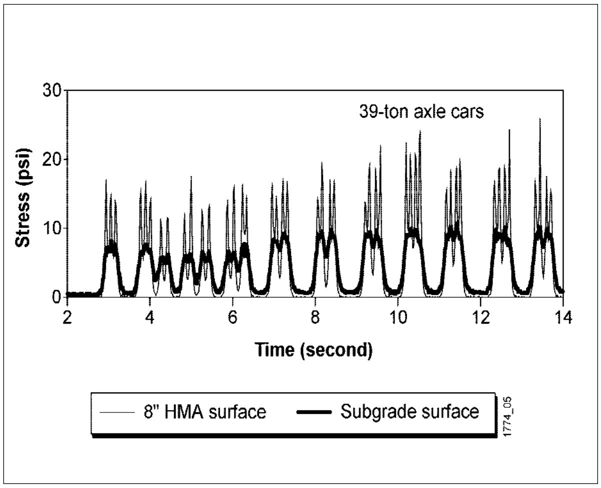

Exhibit 5. Reduction of Dynamic Stresses from 8-inch HMA to Subgrade

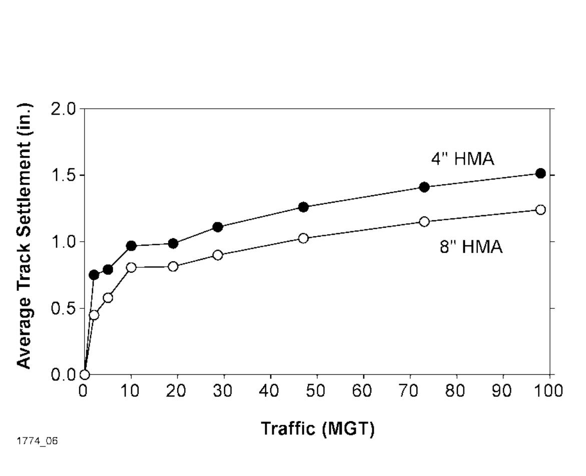

Exhibit 6. Track Settlement as a Function of Traffic

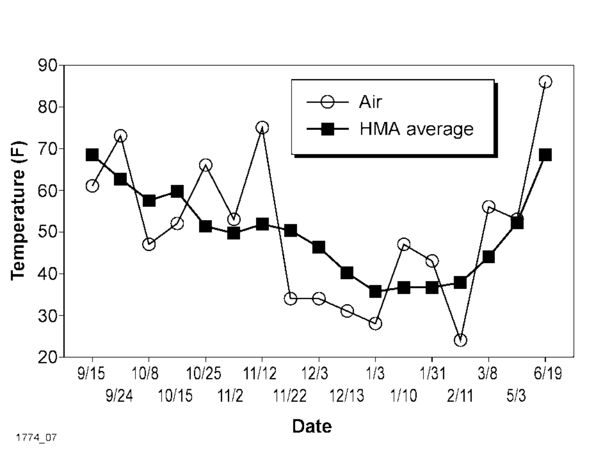

Exhibit 7. HMA Temperature vs. Air Temperature

characteristic of typical and normal track deformation. After almost 100 MGT, about 1.5 inches of total settlement was accumulated for the 4-inch HMA segment, while about 1.3 inches of total settlement was observed for the 8-inch HMA segment. Nevertheless, the settlements (mainly due to ballast deformation) have been uniform along and across the test track. No geometry maintenance has been required to date.

Another benefit of using HMA underlayment beneath ballast is insulating the asphalt layer from the air. This should keep the asphalt less susceptible (compared to highway construction) to the oxidation and temperature effects, thus leading to longer asphalt life without weathering and cracking. In Exhibit 7, temperature recordings were made over a span of about one year for both the HMA underlayment and the air. As shown, HMA temperature experienced much less variation than air temperature.

ACKNOWLEDGMENTS

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