TTCI R&D
Transportation Technology Center, Inc.

Soft subgrade remedies under heavy axle loads

TTCI is investigating and testing potential soft-subgrade remedies under heavy axle loads.

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Rapid track geometry degradation can occur under heavy axle loads. Several proposed remedies for this deterioration have been evaluated on the Heavy Tonnage Loop at the Transportation Technology Center, Inc., Pueblo, Colo.

A 700-foot-long, soft-subgrade test track, installed in the HTL, provides a nominal track modulus of 2,000-to-2,500 lb/in./in. This section is referred to as the low track modulus section.

Extensive tests and investigations provided valuable insights into the rapid track-geometry deterioration that occurred in the LTM section under 39-ton heavy axle loads.

With an 18-inch granular layer construction, the surfacing cycles required to maintain an acceptable track geometry averaged only 15 mgt, ranging from about 60 mgt to less than one mgt. The variance was mainly due to the effects of water on the clay subgrade surface.

To date, several remedy methods with GEOWEB®[1] have been used for correcting the soft-subgrade failure. These include an increased granular-layer thickness and reinforcement of granular layer. Use of a 27-inch granular-layer thickness improved track performance, but did not prevent failure following a heavy rainfall.

Use of the granular layer with GEOWEB (24 inches of total thickness) greatly improved track performance.

In the Summer of 1999, upon completion of the GEOWEB test, a hot-mix-asphalt underlayment was to be applied over the soft subgrade to measure its effectiveness under heavy axle loads.

The investigations and tests of potential soft-subgrade remedies under heavy axle loads are a cooperative effort between TTCI, a subsidiary of the Association of American Railroads; the Federal Railroad Administration; the railroad industry and various suppliers.

Low track modulus tests

Excessive subgrade deformation frequently causes rapid track geometry degradation, especially when a subgrade is made up of clayey soils, and heavy axle loads. It is important to realize that an effective remedy for track geometry deviations may largely depend on the source of the deformation.

For example, if excessive geometry degradation is due to soft subgrade support, ballast tamping may not be the most effective remedy in the long term.

To define soft-subgrade failures under heavy axle loads, the LTM section was installed in 1991 by excavating a 700-foot-long, 12-foot-wide and five-foot-deep trench, which was then backfilled with buckshot clay brought from Vicksburg, Miss.

The average moisture content is approximately 33 percent (optimum moisture content is 23 percent).

To prevent the loss of clay moisture over time, the sides and bottom of the clay subgrade were lined with a plastic membrane.

The clay subgrade has a low strength (i.e., 13 psi unconfined strength as an average), and the track (with 18-inch ballast and subballast) has a corresponding track modulus of 2,000-to-2,500 lb/in./in.

From 1991 to 1996, approximately 130 mgt was accumulated over the LTM section. Under 39-ton axle loads, the LTM track with the early conventional construction (ballast and subballast) required frequent surfacing and three track rebuildings (or three phases) in order to maintain an acceptable track geometry for normal train operation.

From Phase One to Phase Three, the track structures changed from 18-inch granular-layer thickness (12-inch ballast and six-inch subballast) to 27-inch granular layer (12-inch ballast and 15-inch subballast), and to 18-inch granular layer with a plastic membrane on top of the clay.

The track cross sections used for those three different phases are illustrated in Figure 1 (a)(b).

During the first and third phases (each having an accumulation of 40 to 60 mgt), the subgrade deformed and track geometry deteriorated progressively in the early

The geosynthetic GEOWEB was installed as part of the soft-subgrade-remedy testing program.

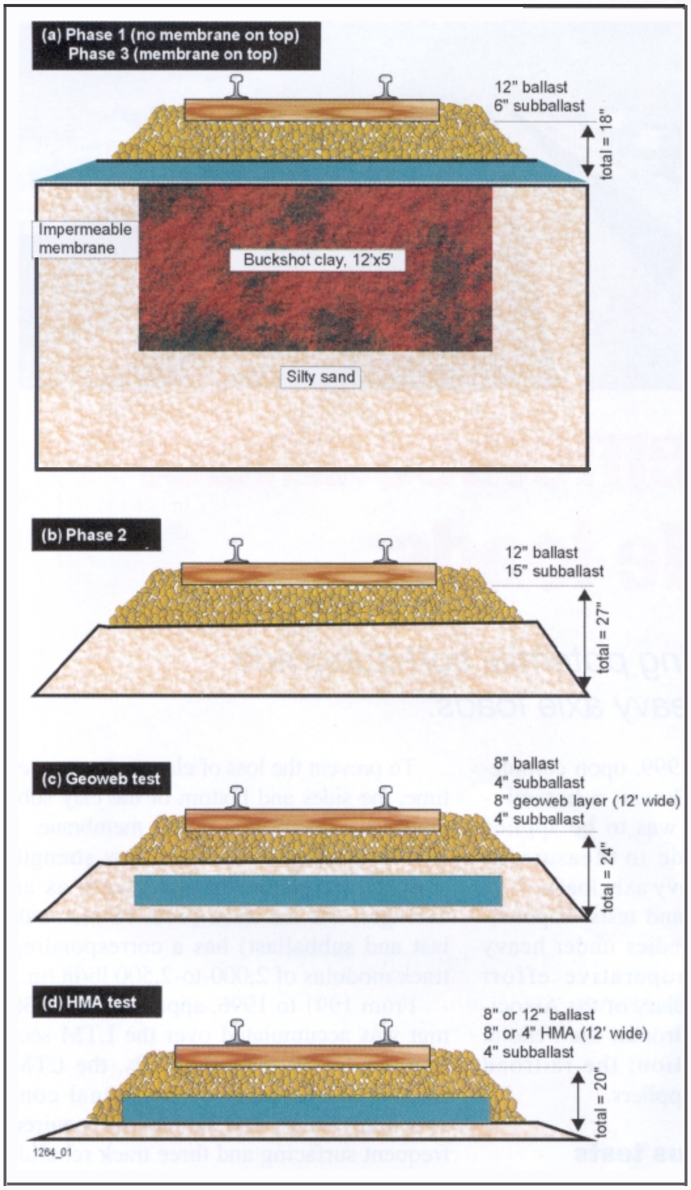


Figure 1 shows LTM subgrade and track cross sections.

to mid portion of each phase. The track required surfacing at intervals of 10 to 30 mgt.

However, near end of each phase, track-geometry deterioration became so rapid that surfacing was required every one to two mgt. Eventually traffic had to be stopped for complete track rebuilding.

Subsequent investigations of each subgrade failure indicated significant subgrade squeezing (progressive shear failure) in the test zone. Subgrade surface soil from under the rail to the tie end was pushed outward and upward to the ballast shoulder.

Free water was often observed in the depression formed at the subgrade surface (even with the presence of the plastic membrane above the clay in Phase Three).

During Phase Two, the granular-layer thickness was increased to 27 inches by increasing subballast thickness from six to 15 inches. Traffic resumed and a track geometry car recorded little geometry degradation until 9.3 mgt, indicating acceptable track and subgrade performance. This improved track performance resulted from decreased subgrade stresses under larger granular-layer thickness.

However, at 9.3 mgt, a heavy rainfall completely flooded the thick subballast layer, limiting the ability of the subballast layer to distribute traffic-load-induced stresses to the subgrade.

Due to increased subgrade stresses, the subgrade deformed rapidly and track geometry was out of specification within the next several mgt.

Application, performance

In early 1997, following the Phase Three test, the track was rebuilt again with the application of a geosynthetic reinforcement called GEOWEB. *(The Dictionary of Railway Track Terms,* Simmons-Boardman, 1993, defines GEOWEB as a material consisting of honeycomb shapes placed in the roadbed to stabilize weak soil.)

When expanded from its collapsed state, the interconnected cells attain an approximate honeycomb structure with open tops and bottoms, as show shown on page 15. GEOWEB cell height can vary, but is eight inches for the LTM application.

Figure 1 (c) shows the cross section of the LTM track with the geo-synthetic reinforcement. As shown, the GEOWEB was placed over a four-inch subballast layer. Upon its placement, the openings of cells were backfilled with granular material (i.e., subballast).

A steel drum vibratory roller was then used to compact the fill material, as Figure 2 (b) shows. For this LTM test, subballast also extended a few inches above the cells, providing a nominal subballast/GEOWEB layer thickness of 16 inches. With eight inches of ballast, the total reinforced granular thickness above the subgrade is 24 inches.

One of the most effective methods to reduce the stresses transmitted to a soft subgrade is to increase the stiffness of the overlying layer. This is one of the benefits that the reinforced granular layer can provide.

Because the sides of the cell walls provide lateral confinement to the subballast, the composite subballast layer becomes much reinforced, resulting in increased stiffness and, therefore, more load-bearing capacity than the subballast alone. (Note: Transportation Research Record 1188, 1988, "Large-Scale Mode1 Tests of Geocomposite Mattresses over Peat Subgrades," stated that a GEOWEB-reinforced layer could be considered to be equivalent to about twice the thickness of an unreinforced gravel base.)

For the LTM track, the increased layer stiffness and decreased subgrade stresses due to use of GEOWEB can be seen in Figure 2. In this figure, the track modulus and subgrade vertical stress are compared for the conventional track (18-inch granular-layer thickness) and the reinforced track (24-inch total thickness).

The average track modulus for the GEOWEB track was 2,500 lb/in./in. compared to 2,000 lb/in./in. for the conventional LTM track. Consequently, the average subgrade stress under the rail seat was decreased from 13 psi for the conventional track to 10 psi for the GEOWEB track.

Since the installation of the GEOWEB reinforced track, more than 180 mgt has been accumulated over the LTM section.

As stated earlier, the average tamping cycle duration before the GEOWEB placement was about 15 mgt. However, after more than 180 mgt of traffic, the track geometry is still well within the limits of FRA Class 4 track.

Figure 3 shows vertical profile (offsets based on 62-foot chord length) degradation with the amount of traffic since the placement of GEOWEB.

The results are the measured 95th percentile values (a 95th percentile value-a magnitude larger than 95 percent of the measured results) versus traffic. The FRA limit is two inches.

As shown, the degradation of track vertical profiles was not significant, and the track has been stable throughout more than 180 mgt of heavy-axle-load traffic.

Hot-mix asphalt underlayment

Following two-and-a-half years of heavy-axle-load traffic (a total of more than 200 mgt), the GEOWEB test concluded in the Summer of 1999.

Upon completion of the test, a hot-mix asphalt underlayment was to be placed under the ballast and above the subgrade.

The LTM zone will be divided into two subsections (each 350 feet in length).

One subsection will have a four-inch HMA layer, the other will have an eight-inch HMA. The planned HMA track cross sections are shown in Figure 1 (d).

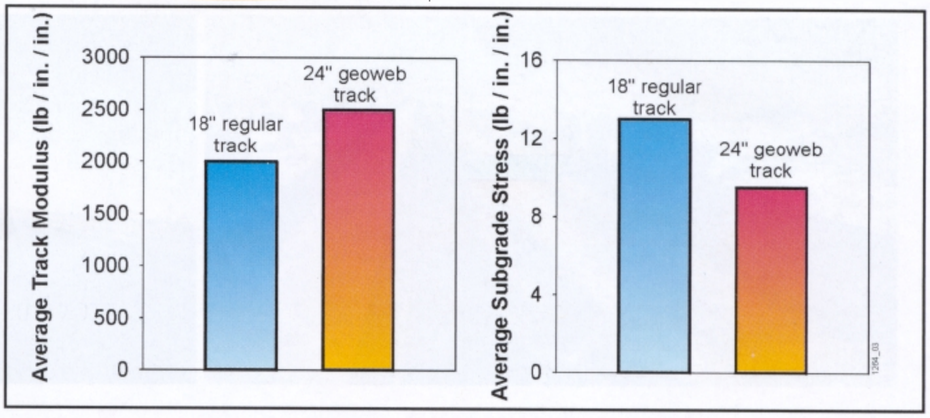
For the entire test zone, a four-inch subballast layer will be used between the HMA and the subgrade. The ballast thickness above the HMA will be 12 inches over the four-inch HMA, but will be eight inches over the eight-inch HMA.

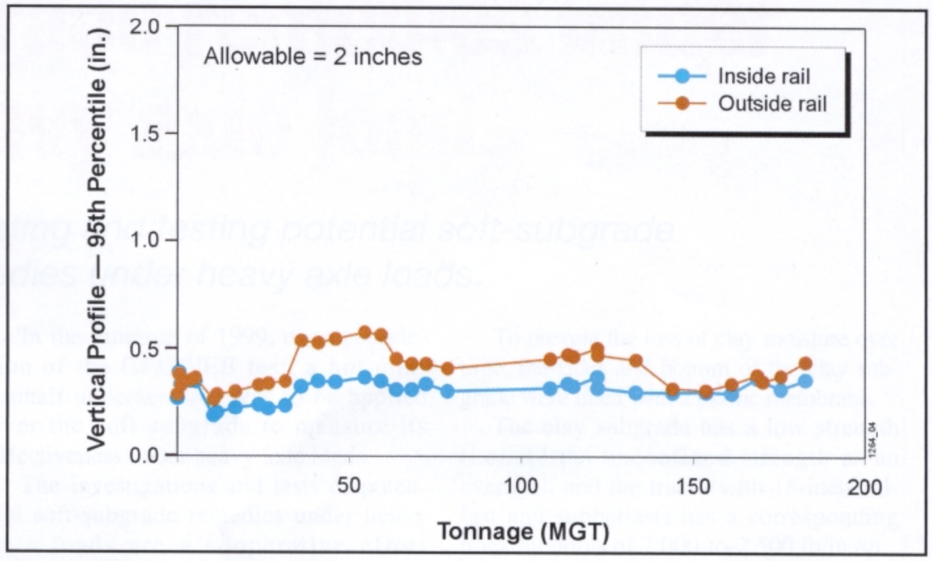
For both HMA subsections, the total granular/HMA thickness will be 20 inches.

This test will be the first to apply the HMA underlayment over a soft subgrade under 39-ton axle loads. The purpose of the HMA underlayment is to reduce traffic-load-induced stresses to the subgrade (like the GEOWEB layer does) and to provide a waterproof layer over the underlying soil.

The HMA performance will be evaluated in terms of the surfacing cycles required, the amount of subgrade stress reduction compared to the convention granular layer construction, and the asphalt fatigue life in terms of cracking. If the test section does not fail, the HMA test is planned to last at least 200 mgt over a period at least two years.

1. GEOWEB is a registered trademark of Presto Products Co.





Above: Figure 2 illustrates the comparisons of test results in track modulus and subgrade vertical stress under rail seats.
Below: Figure 3 shows geometry degradation for GEOWEB track section.