

"SUBBALLAST CONSIDERATIONS FOR HEAVY AXLE LOAD TRACKAGE"

by David Read and Dingqing Li

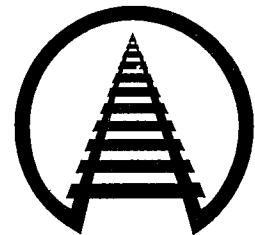
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Summary

Rapid geometry deterioration of previously stable track was observed during and after heavy rainfall in the Low Track Modulus (LTM) test zone at the Facility for Accelerated Service Testing (FAST). An investigation revealed considerable free water in the subballast layer, particularly under the inside rail. Past pavement research has indicated that normally assumed stress distributions provided by structural granular layers are significantly reduced when the layers are filled with excessive free water. The presence of free water in the subballast, therefore, may have reduced its capability to distribute applied loads, resulting in increased subgrade stresses. This possible cause is supported by the observation that LTM subgrade deformation occurred primarily under the inside rail where most of the water had accumulated.

The original LTM design included 12-inch ballast and 6-inch subballast layers over a low-strength clay subgrade. The first 60 million gross tons (MGT) of 39-ton axle load operation caused significant crosslevel deviations resulting in frequent maintenance. At 60 MGT, the subballast thickness was increased to 15 inches to reduce stresses in the subgrade. The geometry was stable during the initial 9 MGT of operation over the rebuilt zone, however, it then deteriorated within a few train passes during a heavy rain. The zone was surfaced and traffic resumed. Geometry degradation continued and the zone was removed from service at 73 MGT. Free water in the subballast was noted during the subsequent investigation.

The observed behavior at FAST suggests that if the existing subballast layer thickness is increased as a means of reducing subgrade stresses, careful consideration should be given to the subballast material drainage specifications.



Suggested Distribution:

- Bridges and Roadway
- Maintenance Planning
- Track Maintenance
- Maintenance of Way

Association of American Railroads
Research and Test Department

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Introduction and Conclusions

The Low Track Modulus (LTM) test zone located at the Facility for Accelerated Service Testing (FAST) experienced rapid and significant loss of profile and crosslevel geometry during and after a heavy rainfall. Prior to the rain, track geometry had been stable following reconstruction of the zone where thickness of the subballast layer had been increased approximately 10 inches. The purpose of increasing the subballast thickness was to reduce subgrade pressures and slow the previous rate of geometry degradation.

The LTM zone was installed in 1991 as part of the FAST Heavy Axle Load (HAL) program to provide track performance data on a "soft" subgrade. Nominal modulus of the LTM zone is 2,000 lb/in/in as compared to the 4,000 lb/in/in to 6,000 lb/in/in modulus found elsewhere on the loop.

The zone was created by excavating a 600-foot long, 12-foot wide by 5-foot deep trench symmetrical to the track center line. The trench was backfilled with the Buckshot clay imported from Mississippi and installed at an average moisture content of 33 percent which is approximately 10 percent higher than optimum moisture content. Resilient modulus of the clay at that moisture content is approximately 2,000 psi to 3,000 psi.¹ The original LTM track design included 12 inches of granite ballast with a 6-inch subballast layer, timber ties with cut spike fasteners and 133-pound welded rail.

The initial 60 Million Gross Tons (MGT) of traffic over the LTM zone produced constant geometry degradation resulting in surfacing cycles of 10 MGT to 15 MGT. An investigation performed at 60 MGT attributed the degradation to subgrade progressive shear failure.² Progressive shear is the result of over stressed subgrade soil squeezing outward and upward from under the rail seat and tie ends.³

The LTM zone was rebuilt at this point with a thicker granular layer to reduce stresses in the subgrade. The Track Granular Layer Design^{4,5} was used to determine analytically the thickness required to reduce

subgrade stresses to less than 12 psi. Accordingly, the original granular thickness of 18 inches was increased to 27 inches (12-inch ballast and 15-inch subballast).

The LTM zone was reconstructed, traffic resumed and EM80 track geometry car data was collected at tonnage intervals of 0, 0.7, and 2 MGT on the rebuilt section. The data showed little geometry degradation, indicating the increased subballast thickness had reduced stresses in the subgrade. The next geometry measurement was scheduled to be performed at 10 MGT, however, heavy rainfall during train operations at 9.3 MGT caused sudden deterioration of the track geometry, particularly cross-level and profile of the inside rail.

The day following the rain, the LTM zone was surfaced, track geometry was measured and train operations resumed. Profile and crosslevel geometry degraded rapidly with traffic even though there had been no further precipitation. The zone required surfacing to correct crosslevel and profile deviations again at 14 MGT.

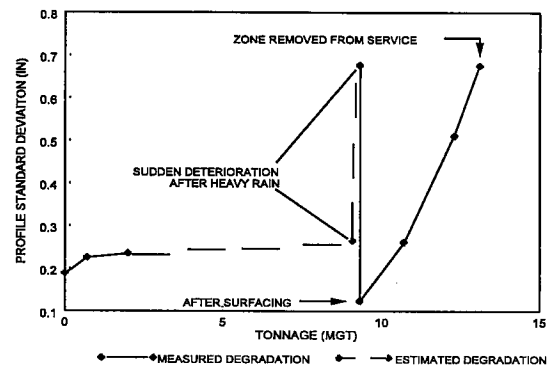
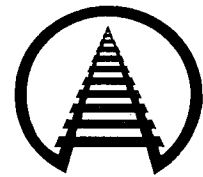


Exhibit 1. LTM Profile Degradation

The profile standard deviation of the inside rail is plotted as a function of tonnage in Exhibit 1 to indicate geometry behavior before and after the rain. The degradation rate between 0 and 2 MGT is typical of newly surfaced track and indicates a stable structure. Since geometry data was not taken between 2 MGT and the rain at 9 MGT, the estimated behavior is shown as a dashed line in the plot.



The degradation measured after surfacing is obviously more severe than that measured during the initial 2 MGT. The Exhibit 1 data after 9 MGT indicates an unstable track structure, necessitating its removal from service.

Possible Causes of Geometry Deterioration

After the zone was removed from service at 73 MGT, an investigation was performed to determine the cause of the track instability on the rebuilt zone. Cross trenches were dug at five locations and measurements of ballast and subballast depth as well as profiles of the clay surface were taken at each location. The cross trenches revealed a great deal of free water within the subballast layer, especially under the inside rail. Plastic deformation of the clay surface beneath the inside rail was also evident.

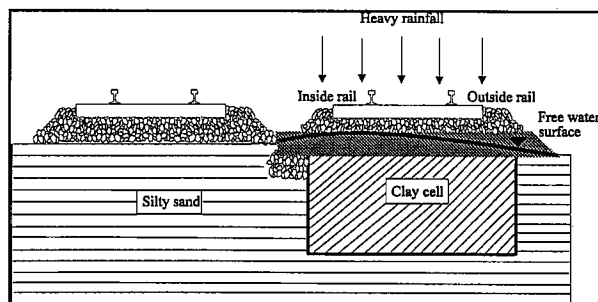


Exhibit 2. Cross Section of LTM Showing Subballast Free Water and Drainage Path

As shown in Exhibit 2, the combined effects of the adjacent HTL bypass track, the impermeable clay layer beneath the subballast and the relatively low permeability of the compacted subballast material and surrounding silty-sand native soil forced the water to drain to the outside ballast shoulder, allowing water to accumulate under the inside rail. Highway pavement research has indicated that the presence of free water in a granular layer designed for structural purposes greatly limits the ability of the layer to distribute applied stresses to underlying layers.⁶

In the case of the LTM failure, excessive free water in the subballast may have caused increases in train induced subgrade stresses. The increased stress would initiate plastic deformation of the clay surface resulting in geometry deviations. Once initiated, the deformation process becomes self-sustaining as water collects in pockets or ruts formed on the subgrade surface. Surfacing the track in this condition provides only short term improvement as the cause of the support instability has not been corrected. LTM geometry was out of specification within 5 MGT of surfacing the zone.

Subballast liquefaction is another possible cause of the rapid track geometry deterioration.⁷ Liquefaction occurs when repeated vibratory stresses are applied to saturated granular soils of the same approximate permeability (0.01 to 0.001 cm/sec) as the LTM subballast material. The stresses induce increased pore water pressures within the subballast layer which cannot dissipate quickly enough, leading to loss of shear strength.⁸

Tests showed no increase in clay moisture content due to the water in the subballast. Therefore, the free water did not cause significant change to the clay strength.

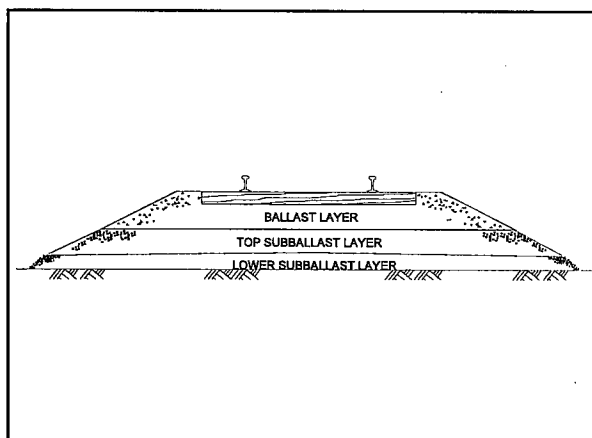
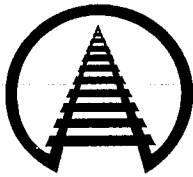


Exhibit 3. Cross Section Showing Granular Layers



Subballast Considerations

AAR has identified granular layer thickness design as an effective method of reducing stresses in subgrades under HAL traffic.⁷ The design allows most of the granular layer thickness to be made up of subballast material rather than the more expensive ballast aggregate. However, as the LTM experience suggests, a thick subballast layer of low permeability may be a source of ongoing track instability if excessive free water is allowed to accumulate within the layer. To facilitate drainage, consideration may be given to designing a subballast layer greater than 6 to 8 inches as a two-layer structure as shown in Exhibit 3. The top layer would consist of coarser sandy-gravel material of higher permeability. The bottom layer would have lower permeability and be shaped to shed water entering from the top.

Further experimental work is necessary to adequately quantify the effects of free water on subballast performance. Experimental data is also required to better define subballast material specifications to be used with granular layer design.

Note: Contact David Read at (719) 584-0559 or Dingqing Li at (719) 584-0740 with questions or comments about this document.

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3. Selig, E. and J. Waters. *Track Geotechnology and Substructure Management*, Thomas Telford, 1994, pp. 10.12-10.16.
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5. Li, D., T. Sussmann and E. Selig. *Procedure for Railway Track Granular Layer Thickness Determination*, AAR Report in Progress.
6. Cedergren, H. *Seepage, Drainage, and Flow Nets*, Third Edition, John Wiley and Sons, 1989, pp. 383-384.
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