TECHOLOGY DIGEST

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Cost Comparisons of Remedial Methods to Correct Track-Substructure Instability

by Steven Chrismer

Summary

The effectiveness and costs of various remedies aimed at stabilizing track over a soft clay subgrade are being tested and compared in the Low Track Modulus test zone at the Facility for Accelerated Service Testing (FAST) at the Federal Railroad Administration's (FRA) Transportation Technology Center (TTC) near Pueblo, Colorado. To date, the techniques of repeated tamping, increasing granular layer thickness, and placing a GEOWEB® layer[1] have been tested under 315-kip traffic. In the future, an asphalt-concrete layer will be placed in the subballast.

Using typical industry cost figures, the economic analysis shows that the most cost-effective selection is very dependent on traffic volume. For the heavy-axle-load conditions studied at FAST, our analysis indicates that continued tamping of the ballast can be the best choice when the annual tonnage is less than 40 million gross tons (MGT). For annual tonnage levels greater than 50 MGT, fixing the problem by use of a remedial technique is less costly. Of the two remedies tested, increasing the granular-layer thickness appears to be the lower-cost option, mainly because of the lower material cost compared to asphalt and GEOWEB®. This conclusion is based on assumptions of material, equipment, and productivity-related expenses that were deemed to be "industry standard." For a different set of assumptions, another conclusion could be reached. Clearly this analysis applies to the unique operation of 315,000-pound traffic at TTC and is solely an economic comparison for a specific application; its intent is to help railroads make decisions between temporary low initial cost repairs and more permanent, but higher-cost, remediation.

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Suggested Distribution:

- ❑ Maintenance of Way
- ❑ Planning & Analysis
- ❑ Track Maintenance
- ❑ R&T Department

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INTRODUCTION AND CONCLUSIONS

A comparison of estimated annual costs of two remedial track-maintenance techniques and tamping in the heavy-axle-load (HAL) environment at the Facility for Accelerated Service Testing (FAST) has shown that the most cost-effective choice is heavily dependent upon the annual tonnage. While tamping does not fix a subgrade problem, it may provide economically maintainable track geometry for low-tonnage track. For track with moderate to high tonnage levels, it may be cost-effective to more permanently fix the problem, even if this involves removing the track from service for a short time and a higher initial capital investment.

NATURE OF SUBSTRUCTURE INSTABILITY

A critical, but often overlooked, aspect of track engineering is investigating the cause of an unstable substructure. This will provide a basis for considering which of the available remedial techniques is appropriate and which can be ruled out. In the analysis that follows, it is assumed that the track subgrade is soft and over-stressed, and is failing by progressive shear (subgrade squeeze). This common type of failure is also occurring in the clayey subgrade section of the FAST track. The observed performance and degree of improvement in track geometry provided by each method is the basis for the benefit used in the analyses for the FAST operation.

INCREASED GRANULAR THICKNESS

After 60 million gross tons (MGT) of 315-kip-traffic over the low track modulus (LTM) zone at the Facility for Accelerated Service Testing, with tamping cycles approximately every 15 MGT, it was decided to determine the effect of increasing the thickness of the granular layer. The subballast layer was increased from 6 to 16 inches. This 10-inch increase in the granular layer over the subgrade was based on a design analysis[2] to reduce the subgrade stresses to an acceptable amount. Initially the geometry-degradation rate slowed significantly by the addition of granular material. However, after a severe storm, an abundance of water was standing in the subballast. This caused a rapid track settlement under loading, possibly due to liquefaction in the subballast and/or impaired ability of the subballast to reduce the stresses passed on to the subgrade. Although this condition was probably temporary, lasting only until the water would have drained away, it impaired track operations significantly

This occurrence is not taken to mean that increasing the thickness of the granular layer is ineffective. In fact, this is one of the more cost-effective methods for stabilizing track, as will be shown. However, it does point out how normally adequate track drainage may be unable to handle an extreme rainfall event.

The costs used in the analysis for increased granular-layer thickness are shown in Exhibit 1. The $10 per ton includes the costs of material, equipment, and labor for placing the subballast and ballast to provide a 28-inch granular layer (10,000 tons per mile) over the subgrade. The stress reduction provided by increasing the layer thickness from 18 to 28 inches is estimated to be roughly equvalent to that from the GEOWEB® or hot-mix asphalt (HMA) layers.

	Unit Cost ($)	Cost/mile ($/mile)
Ballast/Subballast (28”)	$10/ton	$100,000
COST / MILE		**$100,000**

Exhibit 1. Assumed Costs for Renewal with Increased Granular Thickness

GEOWEB®

Geoweb® is a synthetic material which, when placed in the track substructure, can substantially reduce the stresses passed on to the underlying subgrade. A granular material is placed in the open cells of the GEOWEB®. By compacting the granular infill material, a stiff composite layer, which can provide a stress reduction to the subgrade, results. Tests in the FAST Low Track Modulus section have indicated that by placing GEOWEB® in the subballast, the tamping cycle has been extended from 15 to at least 160 MGT.

The estimated costs associated with GEOWEB® are shown in Exhibit 2. The width of installation is 12 feet across track, and the GEOWEB® layer thickness is 6 inches. Labor rates are included in the placement costs.

TAMPING – THE "DO-NOTHING" OPTION

Although it may be recognized that a more permanent remedy is needed to arrest the instability, tamping is often used as an expedient because the initial cost is low and it does not require removing the track from service. However, this does not mean that it is the most cost-effective option. An economic analysis, such as described here, may be performed to confirm this.

	Unit Cost ($)	Cost/mile ($/mile)
BALLAST	$10/ton	$45,000
GEOWEB®		
Material	$1.25/ft^2	$79,000
Placement	$0.06/ft^2	$3,800
INFILL		
Material	$8/ton	$14,000
Placement	$0.03/ft^3	$1,300
TOTAL COST / MILE		**$143,100**

Exhibit 2. Assumed Costs for GEOWEB®

The cost of tamping a track-mile was estimated at $6,100. This figure includes the cost of labor and equipment to regulate and tamp ballast. Additionally, the cost of adding ballast with every other tamping cycle was calculated to be $16,000 per mile, which includes the ballast material price (for sufficient material to fill the cribs for a one- to two-inch track raise), unloading, and redistributing costs.

As the annual tonnage is increased, the time between tamping cycles gets shorter and the costs increase accordingly. The cost of shortening the ballast-life cycle by tamping degradation was also determined. It is estimated that each tamping squeeze causes about a 1 percent decrease in ballast life.[3] For an assumed ballast life of 900 MGT, the costing model[3] showed that tamping every 15 MGT decreases the life by about 43 percent. The resulting increase in equivalent annual cost caused by the shortened ballast life is $4,000, $10,000, $17,000, and $27,000 respectively for annual tonnages of 30, 60, 90, and 120 MGT per year. These costs were added to the equivalent annual costs of tamping for each tonnage class. Finally, the costs of train delay due to slow orders after tamping were estimated as $1,000, $8,400, $30,000, and $124,000 per year for the respective tonnages.

COST COMPARISON

The present value of all costs for tamping and for the remedial methods were then obtained. These costs were then annualized over a 15-year planning horizon with a 10-percent interest rate. The final equivalent annual costs are shown in Exhibit 3 for all methods.

Note that the most cost-effective choice will depend heavily on the annual tonnage. For relatively low tonnages, tamping can be the best choice even though it addresses the

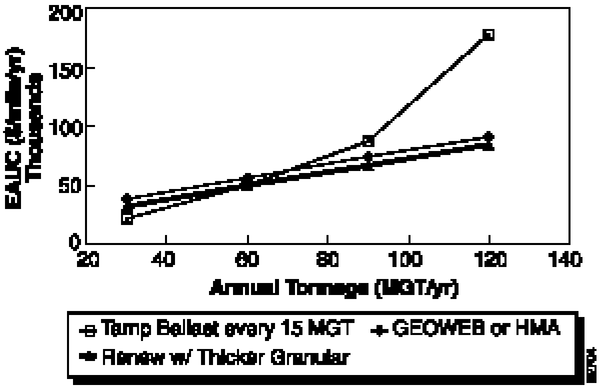

Exhibit 3. Final Equivalent Annual Costs for All Methods

symptoms and not the cause of the instability. For higher tonnage levels, there can be a savings associated with removing the track from service and addressing the problem with a more permanent solution.

Exhibit 3 cannot be taken as the final word on the relative merits or costs of these remedial techniques. Each application merits its own analysis using appropriate data. The outcome shown is heavily dependent upon the assumptions made in this set of analyses. For example, by changing the rerouting assumption from 25 to 100 added miles to the route, the costs of removing the track from service may make this option prohibitively expensive, even for very high-tonnage track. For such a case, continual tamping may be the most cost-effective selection.

To show how a different set of assumptions may affect the outcome, a cost sensitivity analysis was performed to show the effect of varying some of the model input variables by 50 percent. As shown by Exhibit 4, the amount of added miles to the route caused by rerouting or service interruption is the most sensitive parameter. This is for the option of removing the track from service and placing the GEOWEB®. The costs of the GEOWEB® material and of renewing the track were relative small. The costs associated with tamping every 15 MGT (the "do-nothing" option) displayed a moderate amount of sensitivity to the cost of tamping and the cost of ballast.

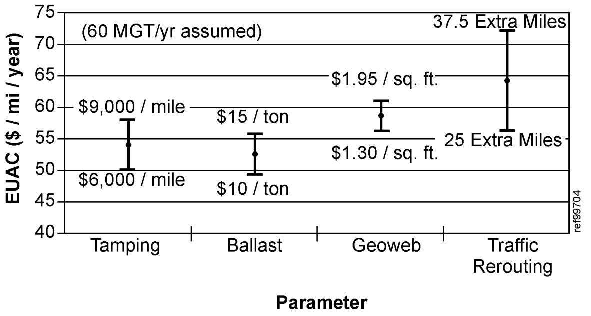

Exhibit 4. Cost Sensitivity for Selected Parameters

REFERENCES

1. Chrismer, Steven; AAR *Technology Digest*, TD97-045.
2. Li, Dingqing; Sussman, Theodore, and Selig, Ernest; AAR Report No. R-898.
3. Chrismer, Steven; AAR Report No. R-863.

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