

Economic Analysis of Track Substructure Strengthening with Hot Mix Asphalt versus Tamping for HAL Mainlines: A Case Study

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Summary

Frequent tamping is often found to be more economically attractive than track rebuild on mainline heavy axle load routes with weak subgrades. This finding holds true down to very short tamping intervals, especially if alternative routes add too many miles or are not readily available. The analysis, performed by Transportation Technology Center, Inc. (TTCI), a subsidiary of the Association of American Railroads, examined a wide range of situations and evaluated a location near Alps, New Mexico, that has been monitored by Burlington Northern Santa Fe Railway, the University of Kentucky, the Asphalt Institute, and TTCI. The Alps site has included a long-term test of hot mix asphalt (HMA) used to reduce subgrade stresses.

Conclusions drawn from the study include:

- For the Alps case, which is a 50-MGT per year mainline with tamping cycles as short as 6 MGT, the decision to use HMA underlayment to reduce subgrade stresses was sound.
- Key variables in this analysis are: the tamping cycle and annual tonnage, both in MGT; the cost of capital (interest rate); and the availability of alternate routes for traffic.
 - Train delay costs can become unacceptably large when tamping cycles are short and annual traffic is large.
 - A high cost of capital makes the track substructure strengthening option less attractive because this option requires a significant initial investment.
 - The availability of alternate routes and the additional distance required to haul traffic while the line is shut down are critical to the costs of the track substructure strengthening option.
 - When possible, building a new road bed alongside the existing track can be a cost effective alternative when track out-of-service costs are high.
- Parameters that do not greatly affect the "continue tamping versus track substructure strengthening" decision include: the cost of ballast, the cost of HMA, the cost of tamping, and the thickness of ballast applied above the HMA layer.

TTCI built an economic analysis model for evaluating options to improve the performance of lines built on weak subgrades. The model compares the costs of track substructure strengthening to that of continued tamping. The model can evaluate the effects of various parameters, such as, traffic rate, interest rate, surfacing cycle, material thickness, and material costs. The long-term HMA test at Alps, New Mexico, was evaluated with the model.

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- Maintenance of Way
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INTRODUCTION

TTCI conducted an economic analysis of methods to extend the surface life of mainline track built on weak subgrades. The analysis examined a wide range of situations and evaluated a location near Alps, New Mexico, that has been monitored by Burlington Northern Santa Fe Railway, the University of Kentucky, Asphalt Institute, and TTCI. The Alps site has included a long-term test of hot mix asphalt (HMA) used to reduce subgrade stresses.

The situation at Alps, as it was prior to the HMA installation that was selected, was modeled to compare the options available for track strengthening and maintenance. An analysis of the relevant variables determined the major factors that were considered in the decision to rebuild the track foundation. Exhibit 1 lists the track and traffic data used in modeling the pre-HMA situation at Alps.¹

Exhibit 1. Track and Traffic Data at Alps, New Mexico, prior to HMA Installation

Item	Value
Traffic	50 MGT/year
Surfacing cycle	6 MGT
Cost of Surfacing	\$6,100/mile/cycle
Amount of ballast added	250 tons/mile/cycle
Cost of ballast	\$10/ton
Interest Rate	10 percent

The 6-MGT surfacing cycle (about eight times per year) was causing major disruptions and inefficiencies in the operation of the line. The railroad determined that the surface problems were caused by the overstressing and deformation of the wet, soft, clayey subgrade soils.¹ While several methods are available to strengthen the track substructure, the railroad opted to install an HMA underlayment layer in the subgrade. Exhibit 2 includes some of the cost parameters developed for the economic model.

TTCI conducted an economic analysis of the Alps case using the values listed. The results suggest that installation of HMA was economic for this situation. Additionally, some parametric studies of key input variables were conducted. Results of these studies are presented below as break-even analyses. These plots show the dividing line between situations where continued tamping and

HMA installation are economic. The Alps case appears on each plot as a triangle symbol.

Exhibit 2. HMA Installation Costs for Alps Analysis

HMA Installation costs	Value
Post HMA surfacing cycle	50 MGT
Additional haul distance during HMA installation	25 miles
Cost of removing track to install HMA	\$16,000/mile
Cost of asphalt delivered and compacted	\$40/ton
Asphalt layer thickness	8 inches
Asphalt width	12 feet
Ballast layer thickness	12 inches

EFFECT OF KEY PARAMETERS

Traffic Rate

Exhibit 3 shows the effect of traffic rate on the economics of installing HMA. Using the values listed in the above tables, varying only the traffic rate and tamping cycle, Exhibit 3 shows the cases where continued tamping or HMA installation is economic. Note that more traffic allows HMA to be economic at longer tamping cycles. The break-even line corresponds to three or four tampings per year for the entire range of traffic rates.

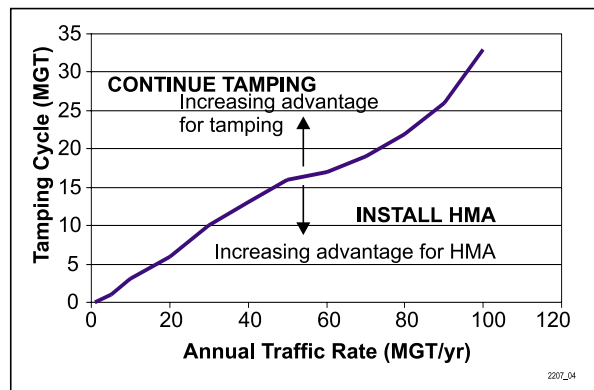


Exhibit 3. Effect of Traffic Rate and Tamping Cycle on the Economics of HMA Installation versus Continued Tamping

Interest Rate

Exhibit 4 shows the effect of the cost of capital on the economics of HMA installation. Since HMA installation requires more capital investment than continued tamping, higher interest rates make this option less desirable. However, the influence of interest rate is relatively insensitive over the range of 4 to 10 percent.

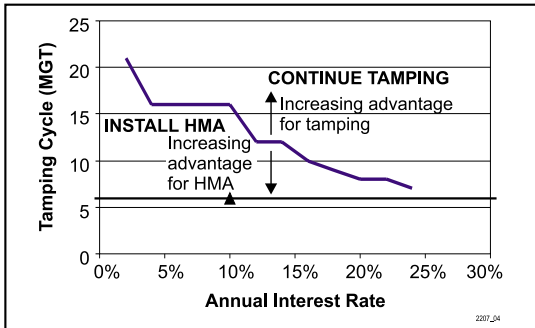


Exhibit 4. Effect of Cost of Capital on Economics of HMA Installation

The flat spots in the curve are caused by two factors. The first is the number of surfacing operations occurring in the first year. While the costs of each option change with interest rate, the relative advantage of continued tamping versus HMA installation does not. The second factor is the variable increment used in the study. A variable, such as interest in 1-percent increments, creates a segmented curve. The graphs are meant to show trends rather than strictly define the range of cases where subgrade strengthening is the best option. For the example case, a tamping cycle of 21 MGT or less is needed to justify an HMA installation when the interest rate is 2 percent. But, when the interest rate is 12 percent, a tamping cycle of 12 MGT or less is needed.

Re-Routing Distance

The effect of additional hauling distance due to line closure during HMA installation is key to the economics of HMA installation. The added costs of the additional hauling distance were derived from an AAR study of average line haul costs for mainline traffic. Exhibit 5 shows the effect of additional route distance on the HMA installation decision. If a good re-route option is not available, subgrade strengthening with HMA becomes uneconomic for all but the worst performing track.

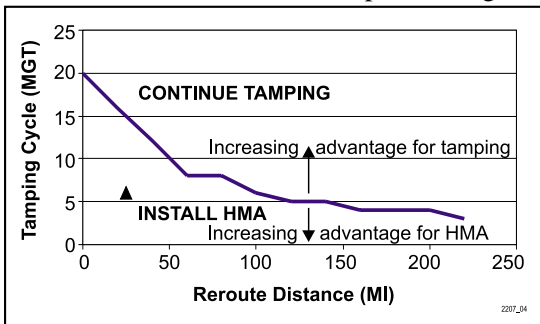


Exhibit 5. Effect of Re-routing Distance and Tamping Cycle on the Economics of HMA Installation versus Continued Tamping

The Parallel Alignment Option

Implicit in the above analysis is that the line will be shut down for one week to install one mile of HMA underlayment on the existing track bed. It may not always be possible to close a line for seven days or more, due to service considerations or lack of an alternate route. In some cases, it may be possible to construct a parallel track bed with HMA pavement next to the existing track. Line closure is then limited to the amount of time needed to move the track superstructure (i.e., rails and ties) to the new track bed. This option may be precluded by line characteristics, such as cuts, fills, or bridges. However, it can provide a viable alternative to re-routing traffic limiting a line closure of about one day.

Exhibit 6 shows the economics of this option (Parallel Alignment) compared to the re-route option (Re-route). The minimum track out-of-service time parallel alignment option extends the range of cases where installing HMA is cost-effective. This is especially true as lines reach capacity and train delay costs rise rapidly above 80 MGT/year.² The parallel alignment option has lower life cycle costs than the track reconstruction HMA installation option for all cases with traffic above 40 MGT/year. Thus, if the right-of-way allows construction of a parallel alignment, this is the preferred option for high tonnage cases. If the right-of-way does not allow construction of a parallel alignment (e.g., large cut or fill widening) the track reconstruction (Re-route) option is economic for a smaller range of cases.

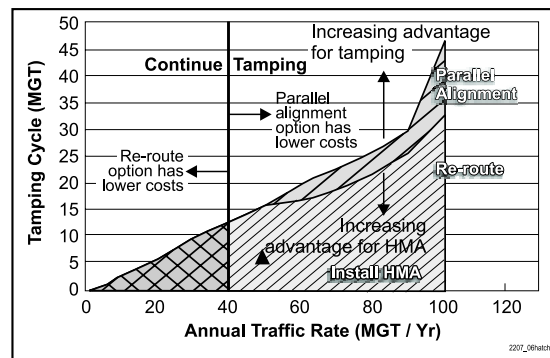


Exhibit 6. The Effect of Construction Method on the Economics of HMA Installation versus Continued Tamping: Break-even Analysis for Alps Case



CONCLUSIONS

Conclusions that can be drawn from the study include:

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- Key variables in this analysis are: the tamping cycle and annual tonnage, both in MGT; the cost of capital (interest rate); and the availability of alternate routes for traffic.
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 - Building a new road bed alongside the existing track can be an effective alternative when track out-of-service costs are high.
- Parameters that do not greatly affect the “continue tamping versus track substructure strengthening” decision include: the cost of ballast, the cost of HMA, the cost of tamping, and the thickness of ballast applied above the HMA layer.

TTCI built an economic analysis model for evaluating options to improve the performance of lines built on weak subgrades. The model compares the costs of track substructure strengthening to that of continued tamping. The model can evaluate the effects of various parameters, such as traffic rate, interest rate, surfacing cycle, material thickness, and material costs. The long-term HMA test at Alps, New Mexico, was evaluated with the model.

While the example is a general analysis using HMA underlayment as the substructure strengthening method, the model is structured such that other methods can be evaluated. User inputs needed are the cost and track outage time for each method, as well as the expected improvement in track surfacing cycle.

REFERENCES

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2. Chrismer, S., “Cost Comparisons of Remedial Methods to Correct Track-Substructure Instability,” *Technology Digest*, TD99-009, Association of American Railroads, Pueblo, Colorado, March 1999.

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