LONG-TERM PERFORMANCE OF ASPHALT UNDERLAYMENT TRACKBEDS FOR SPECIAL TRACKBED APPLICATIONS

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ABSTRACT

Since the early 1980s in the United States, CSX Transportation (and its predecessor lines), the other three large Class I railroads, and numerous smaller railroads have been actively involved in utilizing hot mix asphalt (HMA) underlayment during track structure rehabilitation of literally thousands of special trackworks. Typically, special trackworks are more capital intensive to purchase, install, and maintain and the documented life expectancies are many times only a fraction of that obtained on equivalent lengths of open track sections. It is often difficult to obtain and maintain adequate drainage in the vicinity of special trackworks. The added impacts stemming from track geometric deviations, rail irregularities, and vertical track stiffness variations tend to shorten their service lives.

The majority of the special trackworks underlain with HMA underlayment had previously required abnormally intensive maintenance at the specific locations to continuously maintain conformance to the specified track geometric parameters for the particular class of track. These maintenance expenses not only strain engineering budgets, but also have a negative impact on operating efficiencies on the major line haul routes. Documented cost savings from numerous installation sites indicate the minimal increase in initial costs to install HMA underlayments is often recovered in less than a year.

Numerous types of special trackwork installations are described. These include: 1) tunnel floors and approaches; 2) bridge approaches; 3) railroad crossing diamonds, crossovers, and switch turnouts; and 4) rail/highway at-grade crossings. Significant details are provided relative to the unique conditions and situations associated with each type of special trackwork. Brief descriptions are presented for representative projects.

KEYWORDS: hot mix asphalt, asphalt trackbeds, railways, special trackworks, tunnel floors and approaches, bridge approaches, crossing diamonds, crossovers, turnouts, rail/highway crossings, track design, track maintenance, railway track construction

INTRODUCTION

The U.S. freight railroad industry continues to realize the beneficial qualities a mat of HMA can lend to the track structure. Since the early 1980s, HMA has been used as a sub-ballast in place of the conventional all-granular sub-ballast and geotextile in both new construction and maintenance applications (Rose, 2000) (Rose, Li, & Caldwell, 2002).

The common term is "underlayment" since it is placed as a mat, typically 5-6 in. thick, within the track structure between the ballast and new subgrade or existing roadbed (see Figure 1). Its primary use is at track sites where conventional all-granular systems have not performed well or are not expected to perform well on new construction projects. The majority of the individual HMA installations are at special trackworks.

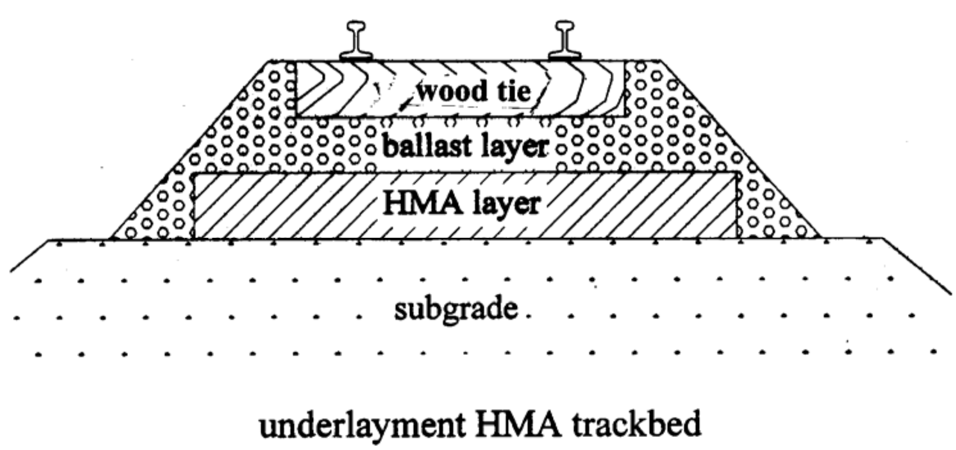

Figure 1. Typical HMA trackbed cross-section

Literally thousands of HMA underlayments have been placed in the United States during the past 20 years and the pace is accelerating as the long-term performance and economic evaluations indicate the superior aspects of the HMA mat. It is not uncommon for the extra cost of the HMA to be recovered through maintenance savings in a matter of months, realizing a return on investment of 300 percent or more per year.

Track sites most applicable for realizing the benefits of an HMA underlayment have heavy tonnage rail traffic and inadequate support to withstand the imposed loadings. The additional impact loadings at special trackworks necessitate superior support be provided to maintain adequate track geometric parameters and to minimize wear and deterioration of the track components. Without adequate support, maintenance costs become excessive to continue safe line speed operations or slow orders must be imposed which reduce operating efficiency.

TYPICAL PRACTICES

Ideal mix specifications, section designs, and application practices have been refined slightly. Variations from the ideal seem to predominate and do not appear to adversely affect the performance of HMA trackbeds.

The desired asphalt mix is a low to medium (plastic) modulus mix, with design air voids of 1 to 3 percent, that will easily compact to less than 5 percent in-place air voids (Asphalt Institute, 1998). This has been achieved by specifying the local dense-graded highway base mix with a maximum aggregate size of 1-1 ½ in. and the asphalt binder content increased by about 0.5 percent above that considered optimum for highway applications. This mix is easier to densify. Rutting and bleeding are not concerns in the insulated trackbed environment.

Long-term monitoring and tests of in-service trackbeds indicate this low voids, impermeable mix undergoes minimal oxidation from the effects of air and water and minimal volume changes and temperature extremes in the insulated trackbed environment (Rose, Brown, & Osborne, 2000). This provides a layer with a reasonably consistent stiffness modulus that is stable but remains slightly resilient. Also, the tendencies for the mix to rut and bleed in hot weather and crack in cold weather are essentially eliminated, helping ensure a long fatigue life for the mix.

Furthermore, in-situ moisture contents of subgrade/old roadbed materials obtained from directly below the HMA in existing trackbeds are very close to laboratory determined optimum values for maximum density and strength of the respective materials (Rose, Brown, & Osborne, 2000). The HMA mat does not appear to be performing as a membrane to collect and trap moisture, thus weakening support.

The typical HMA mat width is 12 ft. This provides for 1 ½ ft beyond the end of the ties. Mat widths are wider under special trackwork, such as turnouts, to provide support under the longer ties. The best situation calls for the HMA mat to extend 25 ft to 100 ft beyond the ends of special trackwork, particularly road crossings, so that subsequent track surfacing operations and any impact which might ensue from track stiffness changes will not infringe on the area.

The specified thickness for the HMA mat varies depending on the quality of the roadbed support, traffic loadings, and type of installation. A 5 to 6 in. thick mat is normally specified for average conditions. For unusually poor roadbed support conditions and high impact areas, a minimum of 8 in. thickness is specified. Ballast thickness normally ranges from 8 to 12 in. The roadbed should be well-compacted, well-drained, and capable of accommodating hauling and spreading equipment without excessive rutting or deformation. A slight crown or side slope is desirable. The need to purposefully improve sub-surface drainage will depend on an analysis of the situation at a specific site.

Quantities of HMA are based on a compacted density of 140 lbs/ft^3. For example, a 6 in. thick HMA mat will require 0.31 ton/yd^2. If the cost of the HMA ranges from $30 to $50 per ton, depending on local conditions, access, and project size; the cost of a 6 in. thick mat will range from $9 to $15 per square yard.

INSTALLATION PRACTICES

The construction of new rail lines represent ideal conditions since the exposed subgrade is available for placing the HMA mat with conventional highway asphalt paving and spreading equipment prior to placing the ballast and track.

For existing lines, the track must first be removed and the underlying material excavated to the desired grade. The depth of the excavation will vary, depending on the replacement thicknesses of the HMA mat and ballast layer, the depth of the existing hardpan, if one exists, and the desired track raise, if any. The depth of the excavation below the bottom of existing ties will equal the sum of the HMA and ballast thicknesses minus the amount of track raise. It is desirable to not excavate into the hardpan area to achieve this depth. It is acceptable to use less ballast thickness or raise the track where possible to minimize the excavation depth where the hardpan would be disturbed.

The top of the HMA – bottom of ballast – should be at or above the elevation of the adjacent side shoulders. This will provide positive drainage away from the ballast so the ballast can purge itself of fines and not foul from degradation of the ballast, wind-blown fines and car droppings. In some situations, it may be possible to lower the shoulder to achieve positive drainage away from the track. The excavation should be accomplished with track-type loaders, dozers, or excavators on track beds of marginal quality. Rubber-tired equipment may rut and pump the roadbed unless the passages are kept to a minimum.

The HMA is hauled by dump trucks from the plant, which is, in most areas, only a few miles. For small projects where track time availability is limited, it is best to have all of the HMA on site before the anticipated placement time. Placement requires a minimum period of time and should be continuous. Delays are normally experienced when trucks have to make additional rounds to the plant. At sites accessible to rubber-tired trucks, the mix can be dumped directly into a standard paver for spreading or back-dumped on grade and spread with a dozer blade, loader bucket, or excavator bucket. For short sections and special track work, it is generally more economical and expeditious to back-dump on grade and spread with on-site equipment.

At sites only accessible by rail, it is necessary to transload the HMA from the highway truck to a hi-rail dump truck, which is backed to the site. The mix can be dumped into a loader bucket and spread or dumped on-grade and spread with a blade or bucket. Procedures selected for transporting and spreading the mix should be expedient to minimize temperature loss.

The HMA mat is normally placed in 4 in. compacted lifts, although lifts of 6 in. can be adequately compacted. Compaction is best achieved with a standard roller, preferably a steel-wheeled, vibratory type, while the mix is between 200º to 300ºF. Other means of obtaining compaction can be applied to small areas if a roller is not available, such as running equipment over it repeatedly. A well-compacted mat with minimum air voids is the best situation but is difficult to achieve if the mix chills excessively before compaction, if the compactive effort is insufficient, or if the underlying support is weak. A compaction level of 95 percent of maximum density or higher is desired. Ideally, the top surface of the HMA is slightly crowned or sloped to one side to facilitate surface drainage. This is accomplished by adjusting the screed on the paver or by tilting the blade on the dozer.

After the HMA mat is compacted, the track is re-built or dragged back on the hot HMA underlayment. The use of rubber-tire equipment is preferred. A crane or hydraulic excavator can be used to lift short panels and special track work. Snaking techniques are applicable for longer sections of track. Adequate space must be available to facilitate removal and replacement of the track and provide access for paving.

The ballast is distributed with conventional unloading and spreading equipment. It is desirable to pre-ballast short sections, mainly rehabilitation of special trackwork, prior to placing the track when conditions permit. This will expedite the process. Ideally the pre-ballast is compacted with a vibratory roller – which is already on-site and used to compact the HMA – to grade so the track can be positioned at the desired elevation. It is possible to eliminate or minimize the need to surface the track using the compacted pre-ballast procedure unless the approaches have to be raised. Normally, the track sections must be lifted into place on the ballast layer. Dragging the track will likely disturb the compacted ballast. Additional ballast can be distributed with a loader or dropped from ballast cars to fill the crib areas between the ties and provide a ½ to 1 ½-ft wide shoulder.

TUNNEL FLOORS AND APPROACHES

Constructing and maintaining a high quality trackbed system in tunnels is vital to reducing the propensity of derailments, which have a higher loss and damage factor in tunnels than on open track sections. A properly designed and maintained trackbed system provides proper support for the rails and facilitates drainage. Maintenance costs are reduced, operational interferences are reduced, and higher levels of service and safety are attainable.

Intercepting and controlling drainage are highly important factors for achieving near maintenance free tunnel trackbeds. Materials comprising many tunnel floors slake and weaken when they become wet. They are not capable of providing a uniformly stable support for the track. Pumping, ballast contamination, and associated track irregularities ensue, particularly on an open trackbed, which is more subject to ballast/floor intermengaling.

Many tunnels have inherent geological drainage problems due to seeps or springs developing within the floor. These situations provide a constant source of water during wet weather and some continue to flow throughout most or all of the year. If the tunnel has a summit vertical curve, the drainage problem is usually less severe. Drainage can flow out both tunnel portals.

Drainage around portal areas should be adequately planned and maintained. Surface drainage must be collected and prevented from entering the portal area. Approach ditches, pipes, and inlets must be kept clear of debris and maintained free flowing away from the portal. Drainage that is backed up within the tunnel trackbed provides the primary source for track instability problems, resulting in deterioration of the track surface and alignment.

Premium trackbed systems proposed for tunnels to minimize the detrimental effects of poor quality (soft) floor support and inadequate drainage, typically involve placement of a solid layer or slab of a near impervious material within the track structure. Direct fixing the rails to a slab of concrete or other rigid material is used. Consistent support and proper dampening of impact forces must be achieved. These systems are typically more expensive than the open ballast trackbed system.

During the past several years HMA has been used successfully to rehabilitate several CSX Transportation tunnel trackbeds, which were exhibiting high maintenance costs due to poor quality trackbed support and inadequate drainage. The procedure provides an impermeable, semi-rigid HMA underlayer with conventional ballast, ties, fasteners, and rail on top. Minor track adjustments can be made with typical aligning/tamping machines.

Typical rehabilitation procedures involve first removing the track from within the tunnel and for a specified distance outside the portal. The contaminated ballast/floor material is excavated to the desired level, preferably to a reasonably dry, solid bed. Localized undercutting may be necessary. The HMA is hauled by dump truck from a hot mix plant and is either spread with a highway paver or, as in more common in tunnels, merely back-dumped and spread with a dozer blade. Close grade control is not required because the layer of ballast will serve as a leveling course. Rolling and compaction of the mat follows.

The track can be immediately dragged back on the HMA mat and joined to the existing track prior to unloading ballast. An alternate procedure is to dump a layer of ballast on the HMA mat prior to dragging the track to final position. Final ballast application and surfacing follow to achieve the specified top-of-rail elevation.

The HMA mat should extend the full width for the typical 12-ft wide tunnels. Provisions can be made for longitudinal perforated pipes along the tunnel walls to facilitate collection and drainage of water. HMA thickness is often limited by vertical clearance requirements. It often ranges from 1 in. to possibly 10 in. at low spots. The average thickness is typically 4 in. Since the major purpose of the HMA is to level the floor, the thickness will necessarily vary considerably.

Initial CSXT Tunnel Project

The initial HMA tunnel placement occurred during the July 4, 1985 two-day holiday shutdown on CSXT’s 50 MGT mainline south of Cincinnati, OH. The north end of the Boone Gap tunnel had been a chronic maintenance problem due to water accumulation and pumping. The affected track was removed for a distance of 90 ft inside the tunnel and 70 ft outside the tunnel. After removing the fouled ballast and geotextile, which had been installed during a 1983 undercutting operation, 75 tons of HMA was placed over the cracked concrete floor. The HMA thickness ranged in cross-section from 18 in. at the center of the tunnel to 2 in. at the walls. This effectively raised the depressed area in the center of the tunnel caused by the cracked concrete floor. The HMA was hauled 40 miles by truck from the plant and dumped on the bank about 200 ft from the portal. A rubber-tired loader transferred the mix to the roadbed and a dozer was used to spread the mix. The mat was rolled and several gallons of driveway sealer were spread on the surface to provide additional sealing prior to adding 6 to 8 in. of ballast and repositioning the track panels.

The affected area had been undercut and a geotextile installed in 1983. This proved ineffective. Information gathered from the local roadmaster, maintenance crew, and retired roadmaster, revealed that during the ten years preceding the HMA application, the section had required frequent maintenance to maintain adequate geometry for safe operations. The crew averaged raising and tamping the section by hand at two-week intervals. Ballast was dropped with mechanized raising and surfacing at three-month intervals. These activities were more frequent during wet weather and less frequent during dry weather.

The annual cost for these routine maintenance operations, excluding the 1983 undercutting and geotextile installation, was averaging more than $20,000 per year. Since the HMA was placed, trackbed maintenance costs have averaged less than $1,000 per year. The HMA cost was recovered in maintenance savings in less than two months. The maintenance cost savings during the ensuing 21 years is over $400,000. In addition, traffic interruptions due to maintenance curfews and slow orders have been essentially eliminated which has provided additional savings. Figure 2 is a recent view of the portal.

Figure 2. Boone Gap, Kentucky tunnel portal

TTI Railroad Tunnel Project

A HMA underlayment was successfully placed at a remote location on the TTI Railroad's 10 MGT mainline Cowan Tunnel near Carlisle in northeastern Kentucky in 1987. The trackbed at the south portal to the tunnel was seated on a poor quality shale/clay floor. Under track and wall seepage provided a continuing source of moisture and wet roadbed. It was expensive and difficult to maintain quality track and provide consistently adequate side-ditch drainage away from the portal. These conditions were the primary contributors to an annual track maintenance cost for this coal-haul line of $11,300 for the periodic cleaning and ditching of the track, as well as restoring its ballast and geometry. In fact, the same segment of track had been completely rehabilitated just 20 months earlier, with select granular material and geotextile construction. Contamination, particularly mud from below, however, continued to take its toll of track quality.

A total of 325 ft of track was removed the first day. This included 230 ft of track and contaminated roadbed inside the south end of the 460-ft long tunnel and 100 ft of abutting track and contaminated roadbed outside the tunnel. The following day the HMA, ballast, and track panels were placed. The mix had to be hi-railed and back-dumped because of the remoteness of the site. Its performance has been equal to the CSXT Boone Gap Tunnel.

During the 19 years since rehabilitation, the HMA underlayment section has required no trackbed maintenance. Since TTI's maintenance costs for the section were averaging $11,300 per year, the $4,000 HMA cost was recovered during the first four months. The railroad has saved, during the ensuing 19 years, over $200,000 in maintenance costs while operating at maximum efficiency. No ballast contamination or track irregularities are evident.

Additional CSXT Tunnel Projects

During the mid-1900s, CSXT rehabilitated all or portions of seven other tunnels on their mainlines in eastern Kentucky and Tennessee. These are listed in Table 1. Each one was exhibiting similar characteristics – soft support, low areas, and inadequate drainage.

The performance of these tunnel floors has been closely monitored. All have been essentially maintenance free and have not been slow ordered a single time.

Six of these projects were performed "under traffic" which means that a curfew of 8 to 10 hours was obtained each day work was performed. Normally four track panels (about 160 feet) were removed and replaced each day. The line was opened to traffic each evening.

The existing track panels and contaminated ballast were removed prior to hi-railing the replacement HMA and new ballast materials. Positioning the new track panels completed the operation. Only the portions of the tunnel floors exhibiting problems were renewed. Figures 3, 4, & 5 depict typical tunnel practices.

Figure 3. Placing HMA in tunnel portal

Figure 4. New track panel on compacted HMA tunnel floor prior to adding ballast and raising track

Figure 5. Completed HMA tunnel floor project

HMA is successfully serving as an acceptable method for rehabbing tunnel floors. The HMA fills in low spots and provides a consistent profile for the ditch lines, so that water does not collect in low spots and soften the support. A more uniform support is obtained while improving track drainage, particularly at the tunnel portals. Conditions in these tunnels had typically adversely affected track geometry, resulting in slow orders and excessive maintenance costs. Previous efforts – such as undercutting the track, improving drainage, and adding various fabrics, and fence mesh had not been totally effective.

BRIDGE APPROACHES

Numerous track transition sections for new and rehabilitated bridge approaches have incorporated HMA underlayments as a means to transition track stiffness levels from the open trackbed to the deck. This minimizes impact stresses and subsequent track settlement. Normally a thicker HMA section is placed next to the bridge and a thinner section is used as a further transitioning medium to the existing all-granular trackbed. Improved performance is evident at both open-deck and ballast-deck bridges. Brief descriptions for several installations follow.

Bridgeport, AL Bridge Replacement

During 1998 CSX Transportation replaced the existing 1475-ft long bridge across the Tennessee River Slough northwest of Chattanooga, TN with a new deck steel plate girder superstructure. The reinforced concrete deck utilized a ballast trackbed. The new bridge was built beside the existing one. This required re-alignment of approximately 1400 ft of mainline track for the approaches (Garro & Lewis, 1999).

HMA underlayment was selected to improve track substructure strength and reduce future maintenance. A 5-in. mat of HMA was placed on a 6-in. thick granular sub-ballast. Granite ballast (10 in. thick) concrete ties and RE 136 CWR rail completed the track section on the two approaches. Figure 6 is a view of the HMA underlayment prior to placing the ballast and track.

Table 1. CSXT HMA Underlayment Tunnel Projects in Kentucky and Tennessee

Tunnel	Date Installed	Extent*
Boone Gap	7/85	3 panels at north portal
Vasper	7/96 2/97	4 panels at north portal 37 panels, nearly all of tunnel
Cove Lake	4/97	51 panels, all of tunnel
Solway	9/97 8/98 7/99	8 panels 20 panels 26 panels, remainder of tunnel
Chenowee	7/97	5 panels
Mud	7/97	3 panels
Typo #2	7/97	3 panels
Grants #1	8/97	47 panels, ½ of tunnel

*A track panel is 39 ft long.

The CSXT line also carries Norfolk Southern traffic. The total annual tonnage over this heavy tonnage and traffic line is about 70 MGT. During the seven years since the bridge was opened to traffic, the approaches have not required any track maintenance and the speed has been increased from 10 to 30 mph.

Deepwater, WV Bridge Approach Re-alignment

One of the earlier uses of HMA underlayment was in 1984 for the approaches to the Loop Creek open-deck bridge on the Chessie System (now CSXT) Railroad's single-track mainline east of Charleston, WV. A 5-mile section of this high-speed, heavy-tonnage freight and passenger line was being upgraded using an adjacent grade from which a second main track had been removed several years ago. The standard section for the rebuilt track consisted of geotextile on the existing grade topped with 12 in. of high quality ballast and new concrete ties.

Figure 6. Bridgeport, Alabama bridge approach

At each end of the bridge HMA was placed on the existing roadbed. The 12-ft wide mats were placed 8 in. thick for the first 100 ft from the ends of the bridge and then reduced to 4 in. thickness for another 100 ft. The 8-in. thick HMA was topped with 8 in. of ballast and the 4-in. thick HMA was topped with 12 in. of ballast.

The existing track at this location had historically required frequent maintenance due to inadequate drainage and increased dynamic impact of loads approaching and exiting the rigid open-deck bridge. The in-service track was retired in favor of the re-constructed line.

With the exception of having the subsequently remove the concrete ties throughout the 5-mile section due to a concrete durability problem and replacing them with wood ties, the bridge approaches have not required any specific maintenance during the 22 years of traffic. The track geometry tests consistently indicate that the geometry is maintained on the approaches equivalent to that expected for open-track sections. No pumping or foaling of the trackbed has been evident.

Guthrie, OK Bridge Replacement

During 1989 the Santa Fe Railway Co. (now BNSF) replaced the bridge across Skeleton Creek with a new bridge adjacent to the old one. This required re-alignment of 3100 ft of approaches. The new grade was constructed with local materials and HMA underlayment. The HMA was laid with a paver 4 in. thick and topped with 10 in. of ballast. This heavy tonnage Chicago to Texas route traverses some very poor quality engineering soils (Figure 7).

The approaches have performed extremely well for the 17 years of service. No additional maintenance has been required other than the programmed system surfacing. Numerous HMA underlayments have been placed over the past 20 years in this area to alleviate trackbed instability due to the effects of soft subgrade. These include crossing diamonds, turnouts, crossovers, and highway crossings.

Routine Bridge Approach Maintenance

CSX Transportation local Bridge and Building forces have demonstrated the process of rehabilitating short sections of bridge approaches during short curfews. Four bridge approaches were renewed in a 4-day period. Typically a track panel (40 ft) was removed and the old trackbed was excavated to about 30 in. below top of rail. The HMA was back-dumped, spread, and compacted to a 6-in. thickness (see Figure 8). This was topped with a compacted lift of ballast about 10 in. thick. The rehabilitated track panel was repositioned and the rails welded.

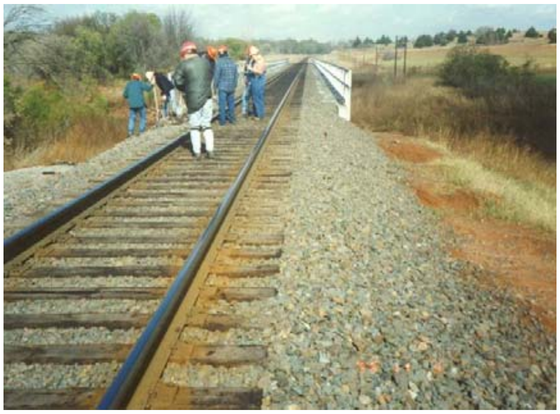

Figure 7. Skeleton Creek, Oklahoma bridge

Figure 8. Compacting HMA underlayment bridge approach approach prior to adding ballast and track panel

Each replacement was accomplished in about four hours. The rail joint welding required additional time. During the five years since the four approaches were renewed, the approaches have not settled or required any surfacing to restore surface geometry. These bridge approaches had been frequently raised and surfaced to maintain the geometry required for line speed. This mainline track in central Kentucky has over 50 MGT annual tonnage with a line speed of 50 to 60 mph.

AAR Bridge Approach Research

The Association of American Railroads' Transportation Technology Center, Inc. (TTCI) and the Union Pacific Railroad are currently conducting revenue service tests of bridge approach strengthening methods (Davis, Pena, & Doe, 2001). Four bridges and their approaches are being monitored – one with standard granular sub-ballast and three with strengthening methods. These are HMA, soil cement, and geocellular confinement subbase layer below the ballast.

The approaches were installed during the 1999 double-tracking of the UP mainline in southeast Nebraska, near Alexandria. This heavy axle load line has over 200 MGT per year. The HMA approaches are performing very well although the study is still ongoing.

CROSSING DIAMONDS, CROSSOVERS, AND TURNOUTS

Considerable research and development has been accomplished during the past few years to improve the performance of special trackwork for heavy axle loads and other high-dynamic load service (Davis, Singh, & Guillen, 2001). Foundation stiffness is considered important for controlling track settlement and alignment, and foundation damping is considered important for minimizing vertical dynamic loads. Track foundations can be designed to minimize the effects of high dynamic loading that develops at crossing frogs and switches.

These special trackworks are traditionally high impact areas due to the wheels traversing the flageway gaps in the rails. Adequate drainage is often difficult to obtain, particularly in the switch point and frog areas. HMA underlayment has been shown to increase trackbed strength while enhancing drainage thereby providing adequate support to obtain high ballast modulus to withstand the added vertical impact forces in the switch point and frog areas.

Literally hundreds of crossing diamonds, crossovers, and turnouts have been underlain with a mat of HMA during the replacement of the special trackwork. For example, CSXT has used HMA underlayment for the replacement of at least 27 crossing diamonds in the Chicago area since 1995 and additional ones are planned. CSXT's B&O line east of Chicago has 34 diamonds underlain with HMA in northern Indiana and Ohio. There are 12 diamonds on the CSXT/NSC crossings in Fostoria, OH underlain with HMA.

HMA underlayment is becoming standard practice for the rehabilitation/renewal of crossing diamonds. Its use at crossovers and turnouts is also gaining widespread acceptance. Performance reports indicate the HMA underlayments essentially eliminate track surface irregularities. An often-sighted example is the UP/BNSF 275 MGT double diamond crossing at Northport, NE. The performances of the crossings have improved significantly since HMA was placed in the track structure. These are likely the heaviest tonnage crossing diamonds in the country. Figure 9 is a recent view of the Northport diamonds.

TTCI is actively evaluating new and different design practices to extend the service lives of rail crossings and turnouts (Davis, Guillen, & Sasaoka, 2003). Bainitic steel rail crossing diamonds continue to show promising results. Three of these diamonds are being extensively tested and evaluated. These have high crossing angles and were selected for their severe service environments. All three bainitic diamonds have HMA underlayments, installed concurrently with the bainitic steel diamonds. Also, transition panels with bigger ties and elastic fasteners were installed to improve vehicle dynamics passing through the crossings. It is reported that a large part of the good performance is believed due to the HMA (underlayment) foundation (Judge, 2003).

Normally special trackworks have to be renewed "under traffic" during a short time period. Adequate planning is of utmost importance. It is even common to restrict the operations to weekends, particularly on lines having commuter and passenger traffic. Equipment and personnel are selected to accomplish the project in a minimum of time.

The initial activity involves removing the existing trackwork. It is desirable to excavate the roadbed approximately 30 in. below desired top-of-rail elevation. Typically one hour is required to dump, spread, and compact a 60-in. thick HMA underlayment. A 4-diamond crossing has area dimensions of about 35 ft by 35 ft (Figure 10). Ballast is placed in a similar manner and compacted to an elevation desired for the bottom of the trackwork ties. The trackwork is positioned to grade on the compacted ballast layer and immediately attached to the existing open track sections. Little tamping or surfacing is required. Normally the track is opened to traffic within 9 to 10 hours for a 4-

diamond crossing. Single crossing and turnout replacements can be accomplished within 4 to 5 hours if properly planned.

The superior performance of HMA underlayment special trackworks is largely due to the desirable properties of the HMA mat and its effect on the track structure. Detailed in-track testing and evaluation studies have been conducted. These results were presented at the AREMA Annual Conferences (Rose, 1998) (Rose, Li, & Caldwell, 2002).

RAIL/HIGHWAY AT-GRADE CROSSINGS

Replacing and rehabilitating highway crossings represent a major track maintenance expense for the U.S. railroad industry. Substantial numbers of crossings deteriorate at a more rapid rate than the abutting trackbed due to excessive loadings from heavy truck traffic and difficulty with maintaining adequate drainage within the immediate crossing area. Others are replaced during out-of-face system maintenance activities such as tie and rail renewals and surfacing operations. At many crossings the disturbed track does not provide adequate support and the replacement crossings soon settle and become rough for vehicular and even train traffic.

Figure 9. Northport, Nebraska UP/BNSF diamonds

Figure 10. HMA underlayment for 4-diamond renewal prior to adding ballast and trackwork

The ideal highway crossing system is one that will maintain a smooth surface and stable trackbed for a long period of time reducing costly and inconvenient disruptions to rail and highway traffic. It will not require frequent rehabilitation and ideally, will not have to be renewed (replaced), but merely skipped, during major scheduled out-of-face track maintenance activities.

CSX Transportation and University of Kentucky researchers (Rose & Tucker, 2002) in cooperation with local highway agencies have developed the technology for rapidly renewing highway crossings using a panel system and premium materials. The procedure involves complete removal of the old crossing panel and trackbed materials and replacing them with an asphalt underlayment, a compacted ballast layer, a new track panel, and a new crossing surface. Numerous documented performance evaluations indicate this design provides a long-life, smooth crossing for heavy rail/highway traffic applications.

The project schedule is for the railroad to be out-of-service for a maximum of four hours and for the highway to open later in the day, typically after eight to ten hours. It is desirable to achieve a cooperative effort between the railroad and local highway agency. The objective is to minimize disruption to both railroad and highway traffic during the renewal process.

Earth pressure cells have been imbedded at various locations in selected crossings to monitor trackbed pressures within the track structure under both railroad and highway loadings. Pressures vary within the crossing structure. Peak dynamic pressures develop directly below the tie/rail interface. These are typically less than 20 psi at the underside of the compacted ballast layer for the 36 ton axle loads (Rose & Tucker, 2002).

It is desirable to use a high modulus, waterproofing layer to properly support the ballast layer/track panel/crossing surface within the track structure. It is particularly important to include transition zones along the track and highway approaches. It is beneficial to pre-compact the ballast to reduce subsequent settlement and maintain smooth crossings. Numerous case studies, based on long-term performance evaluations, indicate these practices ensure long life, economical, smooth crossings for improved safety and operating performances.

CONCLUSIONS

The primary benefits of a HMA layer are to improve load distribution to the subgrade, reduce subgrade pressures, waterproof, and confine the subgrade, and to confine the ballast providing consistent load-carrying capability – even on subgrades of marginal quality. The waterproofing effects are particularly important since the impermeable HMA mat essentially eliminates subgrade moisture fluctuations, which effectively improves and maintains the underlying support. Additionally, the resilient HMA mat provides a positive separation of ballast from the subgrade, thereby eliminating subgrade pumping without substantially increasing the stiffness of the trackbed. The resulting stable trackbed has the potential to provide increased operating efficiency and decreased maintenance costs that should result in long-term economic benefits for the railroad and rail transit industries.

HMA test tracks and specific special trackwork problem-solving installations are performing extremely well. The increased cost of using HMA is most often minimal, and the indications are that at many sites, the long-term savings may be substantial when compared to conventional construction, maintenance, and rehabilitation techniques. Additional improvement and optimization of field construction procedures represent activities of continuing interest.

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