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SELECTED IN-TRACK APPLICATIONS AND PERFORMANCES OF HOT-MIX ASPHALT TRACKBEDS

by

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ABSTRACT
The use of a layer of asphalt within railway trackbeds has steadily grown since the early 1980s in the United States. Its primary use has been for maintenance and rehabilitation applications in existing tracks, particularly at special trackworks, to improve trackbed performance, and to a lesser extent for new trackbed applications where the projected long-term performance of the asphalt trackbed is anticipated to be economically justified. Normally the asphalt layer is 6 in. (150 mm) thick, placed on a prepared subgrade or granular subballast, and is subsequently topped with a layer of typical ballast. Accepted highway/railway construction practices are adhered to, including adequate preparation and compaction of the support layers. In addition, surface and sub-surface drainage aspects are evaluated on a site-specific basis and improvements are specified based on accepted engineering practices. This application does not deviate significantly from conventional all-granular trackbed designs, except the asphalt layer is substituted for a portion of the thickness of the granular subballast and ballast support materials.

Described herein are 1) typical trackbed designs, 2) in-track applications, and 3) long-term performance evaluations for various types of major applications on several U.S. Class I railroads, namely NS, UP, CSX, and BNSF, and a limited number of Shortline railroads. Specifically addressed are rehabilitation applications for special trackworks – tunnel floors/approaches, wheel impact load detectors, bridge approaches, rail-highway crossings, turnouts, rail crossings, and rail crossovers – plus descriptions for a limited number of new double-tracking open-track installations. Brief descriptions are provided for international applications in six countries.

Particular detail is given to factors affecting the economic justification for utilizing this technology based on long-term performances and historical evaluations of numerous installations. Details are provided relative to unique conditions and logistics related to the application of the layer of asphalt within the trackbed support for the special trackworks and selected open-track installations. Several specific installations are highlighted.

I. INTRODUCTION
In recent years, U.S. freight railway traffic volumes, revenue ton-miles, axle loadings, and tonnages have grown to unprecedented levels. Levels of service expected by customers have risen as well. This has prompted a resurgence of research to evaluate new technologies to provide higher-quality and longer-lasting track and support structures. Numerous capacity improvement projects are already in service and many more are being planned, designed, and constructed to meet the increasing demands for efficient freight transport. These trends are expected to increase significantly as more reliance is placed on economical, fuel-efficient, and environmentally-friendly railway transportation.

In addition, increasing emphasis is being placed on expanding rail passenger lines within commuting distances to the larger urban areas of the U.S. Many of these projects are ongoing. However, the expected concentration of efforts will be providing rapid-rail (high speed) passenger service radiating out from the larger metro areas to connect cities within approximately 200 miles (322 km). This noble emphasis will require large investments in new and upgraded rail lines designed and constructed to the highest structural and geometric standards. This is necessary to provide a system that is capable of accommodating high speeds while achieving safe operations and acceptable passenger comfort levels.

In the early 1980s, several U.S. railroad companies saw the impending need for higher-quality and longer-lasting track and support structures. They worked with the asphalt paving industry to develop designs and applications for using hot-mix asphalt within the track structure to replace a portion of the conventional granular material. The initial emphasis was primarily on heavy-tonnage freight railroads, employing asphalt for trackbed maintenance applications and solving instability problems in existing trackbeds. These trackbed solutions included selectively installing a layer of asphalt during the rehabilitation of turnouts, railroad crossings, bridge approaches, defect detectors, hump tracks, tunnel floors and approaches, highway crossings, and loading facilities where conventional trackbed designs and support structures had not performed satisfactorily. These asphalt maintenance installations currently number in the thousands. Based on its proven performance as a maintenance solution, asphalt is now selectively considered as an option on new mainline tracks, yards, and terminal construction in the U.S.

Similar cooperative efforts in several European and Asian countries have been primarily directed at high-speed passenger lines. This involves the construction of new segments or complete rail lines using asphalt (frequently termed *bituminous*) trackbeds. Their engineering and construction approaches are relevant in the U.S. today because it is believed that the next large expansion of our rail system will be high-speed passenger rail or a combination of heavy-tonnage freight/high-speed passenger lines.

Two Types of Designs

Two basic asphalt trackbed designs are used to support the railway track structure as shown in Fig. 1. The most common design in the U.S. is known as **Asphalt Underlayment**, in which the asphalt layer is placed directly on select subgrade/subballast or an existing roadbed. Some consideration must be given to the quality of the existing subgrade/roadbed on which to place the asphalt layer.

A layer of ballast is placed on the asphalt layer on which the track is positioned. This design changes little from normal trackbed design, since the asphalt layer merely replaces the granular subballast layer. The asphalt layer is similar to a paved lane of a highway, except it is contained within the track structure to form a structural hardpan layer between the ballast and the subgrade or existing roadbed.

The second design**, Asphalt Overlayment**, involves placing the asphalt layers in a similar manner, except no ballast is used between the asphalt layer and the ties. The ties are placed directly on the asphalt surface. Cribbing aggregate is then placed between the ties and at the end of the ties to restrain track movement. This design is used primarily in Europe as a version of slab track with two-block concrete ties.

Asphalt Mix Design

Recommended asphalt mix specifications, trackbed section designs, and application practices have evolved over the years. Slight variations from the initial mix designs and construction techniques are typical and have not affected trackbed performance. Asphalt trackbed design construction standard practices for railways typically follow recommendations set forth by the Asphalt Institute [1,2].

The asphalt mix that has the ideal properties for the track structure environment is a low to medium modulus (plastic) mix, having design air voids of 1 to 3%. The mix will easily compact to less than 5% air voids in place. A local dense-graded highway base mix with a maximum aggregate size of 1.0 to 1.5 in. (25 – 37 mm) is typically specified.

Ideally, the asphalt binder content can be increased by about 0.5% above optimum for highway applications because rutting and bleeding of exposed highway pavement surfaces are not concerns in the insulated trackbed environment. This is similar to the bottom, or fatigue-resistant, asphalt layer of the perpetual pavement system being discussed for highway pavements in the U.S. The mix performance is significantly different in a trackbed application than in a highway application. Long-term monitoring and testing of in-service trackbeds indicate that this low voids, impermeable mix undergoes minimal oxidation from the effects of air and water. The mix is also isolated from extreme temperature fluctuation within the insulated trackbed environment [3].

The mix provides a layer having a reasonably consistent stiffness in hot weather and being slightly resilient in cold weather. Furthermore, compared to highway applications, in trackbed applications, this mix is much less likely to rut and bleed in hot weather and crack in cold weather, ensuring a long fatigue life.

Tests on subgrade/roadbed samples, obtained directly under the asphalt layer, indicate that the in-situ moisture contents are very close to optimum values for maximum density of the materials. For structural design analyses, it is reasonable to base bearing capacity values at optimum conditions for the soil/roadbed material under the asphalt layer [3].

Typical Width and Thickness

The typical asphalt layer width is 12 ft (3.6 m) for open track, but it is placed wider under special trackwork, such as turnouts, to provide support under the longer ties.

The thickness of the asphalt layer depends on the quality of the roadbed's subgrade support and traffic loadings. A 6-in. (15 cm) thick layer is normally used for average conditions. For unusually poor roadbed support conditions, and for high-impact areas, a minimum of 8 in. (20 cm) is used. Ballast thickness normally ranges from 8 to 12 in. (20-30 cm). A 6-in. (15 cm) thick asphalt layer that is 12 ft (3.6 m) wide requires 0.42 tons of asphalt per track foot.

The asphalt layer should extend a reasonable length beyond the ends of the special trackwork so that subsequent track surfacing operations and any impact from track stiffness changes will not infringe on the area.

The roadbed should be reasonably well-compacted, well-drained, and capable of accommodating the hauling and spreading equipment without excessive rutting or deformation. A slight crown or side slope is desirable. Subsurface drainage or roadbed support improvements can be implemented prior to

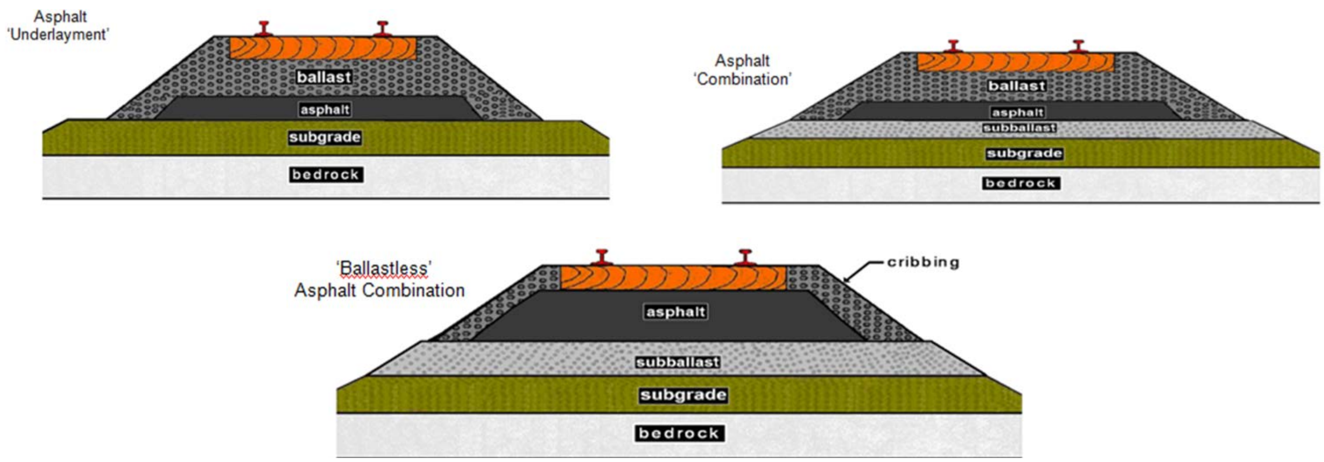

Fig. 1. Various asphalt trackbed designs.

placing the asphalt if site conditions warrant, based on an engineering analysis.

II. INTERNATIONAL INSTALLATIONS

Several international rail authorities have been actively involved with the development and application of asphalt trackbeds during the past 40 or more years. Brief descriptions for several countries follow. This is not an all-encompassing listing, only representative for select countries [4].

Italian State Railways Applications

The Italian State Railways have been active in the initial development and continued application of asphalt (bituminous) trackbeds for their extensive high-speed rail network. The Italian High-Speed Rail network consists of both East-West and North-South lines that currently extends 900 km and will soon reach more than 1200 km. The original and most frequently trafficked high-speed line is the Rome to Florence line known as the "Direttissima." Construction of this line began in the 1970s.

The typical high-speed railway cross sectional profile is shown in Fig. 2, including the thicknesses and the minimum specified bearing capacities for the various layers. It is a multilayered system consisting of an embankment, supercompacted sublayer, asphalt subballast, ballast, ties, and rail. Construction practices for achieving this cross section places important emphasis on the placement of these layers in order to maintain proper geometrical alignment for high-speed rail operations. The asphalt subballast has the ability to distribute loads, provide an impermeable uniform drainage layer, and reduce the effects of freeze/thaw action. The Italian railways soon determined that all new lines were to be constructed using this method and for nearly 20 years they have done so. Fig. 3 shows typical views of asphalt paving.

Austrian Federal Railways Applications

Austrian Railways has developed considerable technical experience and economic effect evaluations of asphalt layers in railway trackbeds beginning in 1963. The asphalt layer is viewed as an investment and typically consists of an 8 to 12-cm thickness beneath the ballast bed. The primary purpose of the asphalt layer is to provide a clear separation between sub- and superstructure – the main advantages being to prevent rain

Typical Cross Section

- 12 cm of asphalt with 200 MPa modulus
- 30 cm of super compacted subgrade with 80 MPa Modulus
- 35 cm of ballast on top

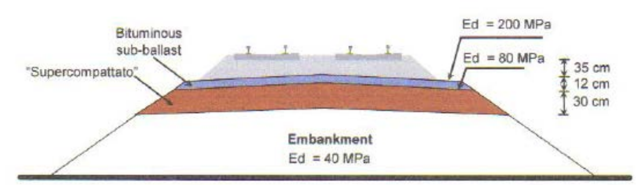

Fig. 2. Typical Italian Trackbed Design

Fig. 3. Italian asphalt trackbed construction.

water from penetrating the substructure, prevent pumping of fines upward, obtain optimum level of elasticity, and provide consistent support to homogenize stresses on the substructure. All of these expected benefits of the asphalt layer positively influence the future track quality behavior.

Results from analyses of track quality behaviors show significant differences for sections with asphalt layers compared with sections with all-granular layers which were also built to high quality standards. The rate of deterioration per year is reduced by 50% for the asphalt trackbeds; and leveling-lining-tamping cycles have increased 67% for the asphalt trackbeds, based on threshold values.

Japan Railways Group Applications

The Japanese have widely used asphalt trackbeds in ballasted track for many years on both high-speed lines and regular lines. The primary focus of using asphalt trackbeds has been to provide a firm support for the ballast and to reduce track irregularities. This will reduce the load level on the subgrade to prevent subgrade deformation. The Design Standard for Railway Structures was revised in 2007 to a performance-based design standard. It considers the fatigue life of the track, as affected by the number of passing trains, thus designers can select various layer compositions and thicknesses to satisfy roadbed performance requirements.

The performance-based design procedure ranks or classifies three different standard track designs. Asphalt trackbed designs are either required, or are an option, for the two premium trackbed performance rank classifications. The conventional all-granular trackbed is ranked as the lowest quality trackbed.

German Federal Railway Authority Applications

Germany has focused on using asphalt primarily for ballast-less trackbed designs, which are referred to as overlayment, or full-depth asphalt trackbeds. The main asphalt track in use in Germany consists of two-block concrete ties or concrete slab track placed on a 10 to 12-in. (250 to 300-mm) thick layer of asphalt. Various designs are incorporated into the system.

French and Spanish National Railways Applications

Recently the French installed a 2.1 mile (3 km) test section of underlayment asphalt on their Paris to Strasbourg eastbound high-speed line. The French are currently observing the effects of world record high-speed trains traversing various test sections to determine how beneficial the use of asphalt trackbeds will be for future ultra-high-speed passenger lines. The sections are heavily instrumented for analyzing numerous trackbed-induced effects on ride quality, vibrations, and other aspects.

The Spanish are similarly involved with test sections of asphalt trackbeds on their Madrid-Valladolid high-speed passenger line and on the Barcelona-French Border high speed/mixed traffic line. The design is similar to the Italian design. The asphalt sections have been fully equipped with numerous test sensors to monitor various responses of the track structural layers.

III. DOMESTIC OPEN TRACK INSTALLATIONS

The vast majority of the asphalt trackbed installations in the U.S. have been utilized for special trackworks, typically short sections, ranging to 300 ft (90 m) in length. These will be discussed in Sections IV through VIII.

BNSF Transcon Double-Tracking Project

The largest open-track asphalt underlayment trackbed construction projects placed in service in the U.S. are on a portion of BNSF's high-speed, heavy-tonnage, and high-traffic transcontinental main line east of Amarillo, TX, through the panhandles of Texas and Oklahoma, and southern Kansas. This largely single track line was selected for double-tracking to increase capacity. The ongoing project is being done in phases over a period of years and is nearing completion. The initial sub-projects specified an asphalt combination trackbed design. It had a 6-in. (150-mm) granular base, to provide a stable surface, topped with 4 in. (100 mm) asphalt layer, 12 in. (300 mm) of ballast, and concrete ties. The granular base was deleted from succeeding projects and the asphalt layer was placed directly on the select soil subgrade. An initial 4 in. (100 mm) compacted lift of asphalt was placed followed by the final 2 in. (50 mm). Densities and other asphalt and subgrade parameters were closely monitored. Nearly 200 miles (322 km) of asphalt trackbed design have been placed during new track construction in the area [5]. Figure 4 shows the placing of the asphalt and the track. This represents the norm for other U.S. railroads, although the thickness of the asphalt layer is frequently increased for special trackwork installations, particularly if trackbed instability in the area has been evident.

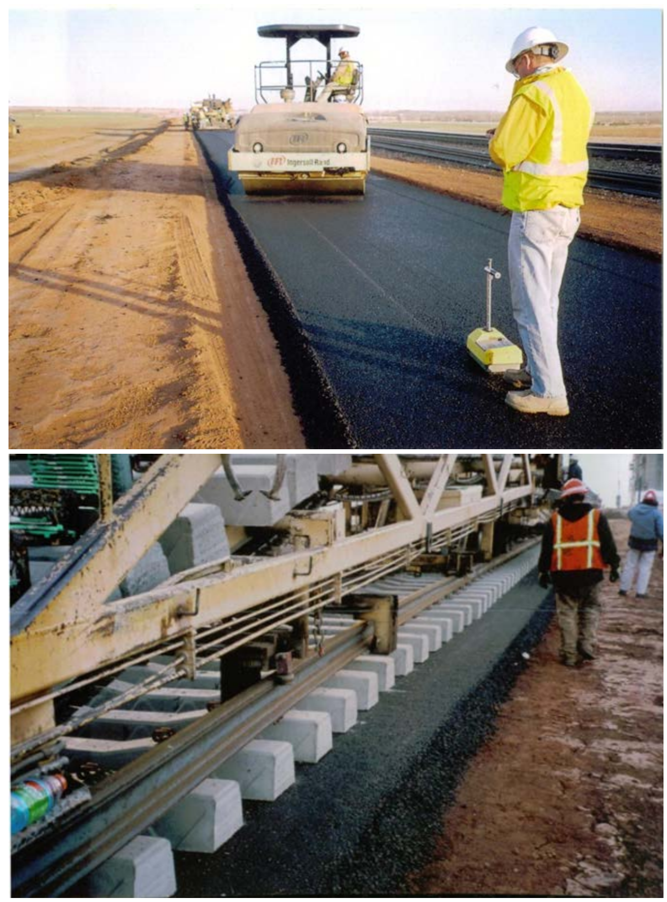

Fig. 4. BNSF Transcon asphalt trackbed construction.

UP/BNSF Grade Separation Project

An example of a recent asphalt trackbed installation is the vertical clearance and highway/rail crossing elimination project on the UP/BNSF trackage through Wichita, KS. Approximately 2.5 miles (4.0 km) of trackage was elevated using granular fill. An asphalt combination trackbed was selected. Figure 5 shows the typical paving operation and completed project.

Fig. 5. UP/BNSF elevated trackbed in Wichita, KS.

IV. TUNNEL FLOORS AND APPROACHES

Discussion

Maintaining a consistently high-quality trackbed support system in tunnels is vital for optimum operating conditions. A properly designed and maintained trackbed system provides adequate support for the track and facilitates drainage. Maintenance costs and 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 all-granular trackbed, which is more subject to ballast/floor intermingling

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

Typical rehabilitation procedures, while maintaining traffic, involve first removing the equivalent of 3 to 4 track panels 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 asphalt is hauled by dump truck from a hot mix plant and is either spread with a highway paver or, as is 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 asphalt mat and joined to the existing track prior to unloading ballast. An alternate procedure is to dump a layer of ballast on the asphalt mat prior to dragging the track to final position. Final ballast application and surfacing follow to achieve the specified top-of-rail elevation. The process is repeated during the following days to effectively provide 100 to 150 ft (30 to 45 m) per day.

The asphalt mat should extend the full width for the typical 12-ft (3.6 m) wide tunnels. Provisions can be made for longitudinal perforated pipes along the tunnel walls to facilitate collection and drainage of water. Asphalt thickness is often limited by vertical clearance requirements. It often ranges from 1 in. (25 mm) to possibly 10 in. (250 mm) at low spots. The average thickness is typically 4 in. (100 mm). Since the major purpose of the asphalt mat is to level the floor, the thickness will necessarily vary considerably.

Previous Applications

During the mid-1990s, CSX Transportation rehabilitated all portions of nine tunnels on mainlines in the eastern Kentucky/Tennessee area. Each one had historically been a "wet" tunnel and exhibiting similar characteristics – soft support and inadequate drainage in low areas which "ponded" water contributing to rapid loss of acceptable track geometry. The adversely affected track geometry resulted in slow orders, excessive maintenance costs, and operational interferences. Previous efforts, such as undercutting the track and adding various fabrics had not been considered effective.

The performance of these tunnels during the intervening 15 or more years has been significantly improved. CSX has utilized this procedure for additional tunnels. The prevailing problem is being able to obtain an adequate time frame to accomplish the work. Normally a 10- to 12-hour curfew is necessary for changing out an equivalent of 3 to 4 panels.

Recent Applications

More recent tunnel projects involve the final three tunnel clearance improvement projects on the Norfolk Southern line just west of Williamson, WV during August 2010. This was part of the Heartland Corridor capacity improvement project. Clearances were increased in 28 tunnels between Norfolk, VA and Columbus, OH to accommodate double-stack intermodal trains. This was a two to three-year long project. Most of the tunnels were amenable to removing sufficient roof material to achieve the required clearances. This was accomplished using four approximate 12-hour track curfews each week.

However, three of the single-track tunnels in close proximity to Kermit, WV had the track lowered to achieve most of the vertical clearance. These three tunnels had a long history of soft support and attendant drainage problems requiring frequent maintenance interfering with normal train operations on this mainline. The decision was made to do this work during a 72-hour total shutdown of the line as the last major tunnel clearance activity.

Three contractors were used to perform the work simultaneously on the three tunnels. The initial 24-hour period was used to remove the track and excavate/remove sufficient floor material to provide space for the approximate 6-in. (150 mm) thickness of asphalt. This involved hydraulic hammers to remove portions of the floor. The intermediate 24-hour period was used to place, level, and compact the asphalt. About 7000 tons (6350 metric tons) of asphalt was used for the 6543 ft (2000 m) of tunnel length for the three tunnels plus the tunnel approaches. The final 24-hour period was used to replace the ballast and track panels. The work was finished within 68 hours and opened on September 1 as planned. Figure 6 shows the asphalt mat.

The three tunnels are performing extremely well after over two years of train traffic. This process of utilizing asphalt is planned for floor replacement in an additional tunnel on the same line during 2013.

Fig. 6. NS Heartland Corridor tunnel floor construction.

V. WHEEL IMPACT LOAD DETECTORS

Trackbed Considerations

A major consideration for the track support structure for WILD installations is that it be reasonably stiff and maintain a consistent stiffness along the length and width of the installation during the year. One of the main factors influencing the maintenance of consistent track stiffness is the existing moisture content, and variations of the moisture content, of the subgrade/subballast layers.

In addition, the ballast layer must have consistent and uniform support so that it can develop maximum density/compaction to behave linearly elastic achieving maximum shear strength for distributing pressures, but still maintain a reasonable degree of elasticity. These factors will minimize rail deflection and track galloping thus providing a smoother ride with less vibration and deflection.

In recent years the use of a layer of hot-mix asphalt, similar to highway paving mixtures, has gained widespread acceptance as a subballast to provide the desirable attributes of the support layer for the WILD's support track and ballast. The asphalt binder, within the aggregate matrix, serves to bind and cement the individual aggregate particles into an aggregate mass. The binder is visco-elastic so the mixture has a limited degree of flexibility, but is not overly rigid and stiff. Thus, the layer stiffness is higher than an all-granular layer, but considerably less stiff than a Portland cement concrete layer. The binder is also thermoplastic to a limited degree, thereby being somewhat stiffer during colder temperatures. However, this is not a particular concern in the insulated trackbed environment as the asphalt layer is covered by 20 or more inches (500 mm) of an insulating layer of ballast.

The asphalt layer also serves to basically waterproof the underlying subgrade layer. Ideally, a subgrade soil should maintain a uniform moisture content at or slightly above optimum throughout the year ensuring consistent support along the instrumented test area.

As the subgrade moisture content increases above optimum, the strength and rate of deformation under repeated loading increases with attendant loss of strength and load carrying capacity. The resulting increased deformations and abrasion tend to degrade the ballast by producing fines which vary the stiffness and support characteristics of the ballast. Pumping and loss of track surface elevation levels result in uneven ride quality and increased and variable impacts resulting from the variable support conditions.

The objective is to specify and construct a track support structure that provides consistent support similar in magnitude to the typical trackbed over which the trains will be traversing. Therefore, variations in test data will be indicative of the effect due to wheel-rail interface surface abnormalities affecting the impact measurements.

Installations

Class I railroad companies have been actively involved with the installation of a layer of asphalt under WILDS for several years. In fact, Conrail, prior to its dissolution, was using asphalt under WILDS some 20 or more years ago. NS and CSX inherited some of these.

During the past few years, NS has installed seven asphalt underlayments under WILDS. A typical installation is shown in Fig. 7. Three of these were for new installations and four were for rehabilitating previously installed WILDS that had not performed satisfactorily on all-granular trackbed support.
CSX has multiple WILD sites with asphalt underlayments. These include the eight Supersites, containing additional trackside measuring and detection equipment, plus additional WILD-only sites. CSX's typical track section containing the asphalt underlayment detail was issued in 2006. The last three WILDS that UP has installed contain asphalt underlayments. The asphalt layer is typically 600 ft (183 m) long. Based on the performances of these installations, UP considers using an asphalt layer for all additional new installations and when existing WILDS need to be rehabilitated or retrofitted.

VI. HUMP RETARDER TRACKS AND BRIDGE APPROACHES

Minimizing settlement and track stiffness variations at these two specific track sites are paramount in maintaining requisite track geometric parameters to minimize impact stresses and excessive wear of the track components. Asphalt trackbeds are being used to achieve these qualities. A few examples follow:

NS Hump Retarder Tracks

NS began using this application in 2006. NS has 13 hump yards, of these 5 master retarders, 3 sub-master retarders, and 12 group retarders have asphalt for a total of 20 installations. Performance has been very satisfactory with less deviations in track geometry and less attendant maintenance and better overall performance. It is considered a standard procedure for new or rehabilitated retarder track installations.

It is very likely that other Class I railroads are having similar experiences with hump retarder track installations.

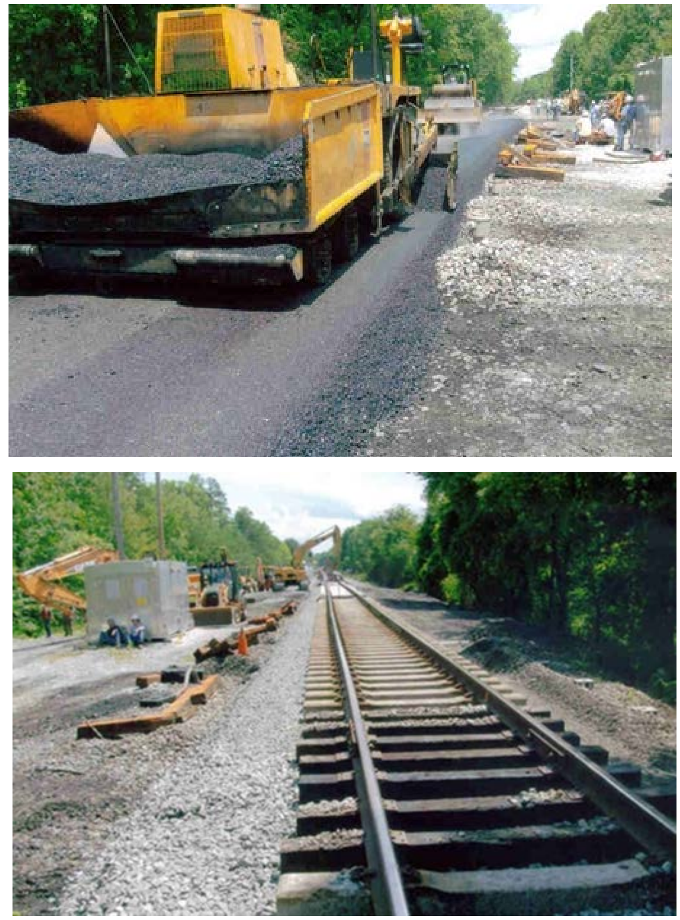

Fig. 7. NS Flatrock, KY WILD installation.

Bridgeport, AL Bridge Approaches

This 1475-ft (450-m) long heavy-tonnage bridge across the Tennessee River Slough was built in 1998 to replace an existing bridge. This required re-alignment of approximately 1400 ft (425 m) of mainline track for both approaches.

Asphalt underlayment was selected to improve track substructure strength and reduce future maintenance. A 5-in. (125 mm) thick mat of asphalt was placed on a 6-in. (150 mm) thick granular subballast. Granite ballast (10 in. thick) (250 mm) concrete ties and RE 136 CWR rail completed the track section on the two approaches. Figure 8 is a view of the asphalt underlayment and finished track.

The CSX line also carries NS traffic. The total annual tonnage over this heavy tonnage and traffic line is about 70 mgt. During the 14 years since the bridge was opened to traffic, the approaches have required minimal track maintenance and the speed has been increased from 10 to 30 mph.

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 (945 m) of approaches. The new grade was constructed with local materials and asphalt underlayment. The asphalt was laid with a paver 4 in. (100 mm) thick on a select subgrade and topped with 10 in. (250 mm) of ballast. This heavy tonnage Chicago to Texas route traverses some very poor quality engineering soils.

The approaches have performed extremely well for the 23 years of service. No additional maintenance has been required other than the programmed system surfacing.

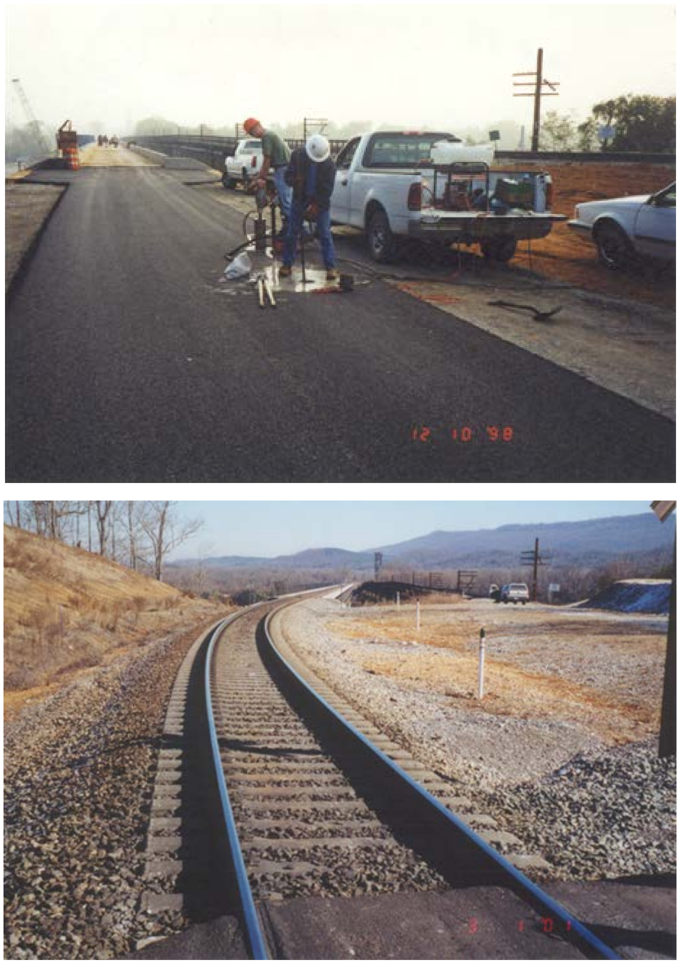

Fig. 8. CSX Bridgeport, AL new bridge approach.

VII. SPECIAL TRACKWORKS

Considerable research and development has been accomplished during the past few years to improve the performance of special trackworks – rail crossings, crossovers, turnouts – to withstand heavy axle loads and other high-dynamic loadings. Optimizing foundation stiffness is considered important for controlling track settlement and alignment; whereas, foundation damping is considered important for minimizing vertical dynamic loads, thus minimizing the detrimental effects of high dynamic loadings [6].

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. Also, the ballast is difficult to tamp and consolidate in the maze of rails and track components. Asphalt 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 rail crossings, crossovers, and turnouts have been underlain with a mat of asphalt during the replacement of the special trackwork. For example, CSX has used asphalt underlayment for the replacement of numerous rail crossings in the Chicago area since 1995. CSX's B&O line east of Chicago had 30 rail crossings underlain with asphalt in northern Indiana and Ohio during the B&O double-track project. There are 12 rail crossings on the CSX and CSX/NS lines in Fostoria, OH underlain with asphalt.

Additional rail systems using asphalt underlayment for special trackworks include Caltrain and Metrolink in California. It is a standard procedure for both systems. For example, Caltrain has 10 crossovers and 12 turnouts underlain with asphalt.

Recently, NS replaced four No. 20 turnouts on the Heartland Corridor line near Kermit, WV. Each turnout was changed out during a 16-hour traffic curfew. The concrete turnouts were about 300 ft (90 m) long and pre-assembled in four sections. Two cranes were used to place the sections. The total time allocated for placing and compacting the 6-in. (150 mm) thick asphalt layer was 1 ¼ hours. The asphalt was placed with a typical paver in two 3-in. (75-mm) lifts.

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 amount of time. Normally, the track can be opened to traffic within 9 to 10 hours for a 4-diamond rail crossing. Single crossing and smaller size turnout replacements can be accomplished within 6 to 7 hours if properly planned. Figure 9 is a typical view of a 4-diamond rail crossing.

Minimal tamping or surfacing is required provided the ballast is pre-compacted and care is exercised in positioning the special trackwork unit on the compacted ballast bed.

VIII.HIGHWAY-RAILWAY AT-GRADE CROSSINGS

Railways and highways are typically designed structurally very differently for the common areas at crossings. The all-granular railroad roadbed and track system is designed to be flexible, deflecting as much as 0.25 in. (6.5 mm) under normal railroad traffic. This support is normally carried through the crossing. The highway pavement structure is designed to be essentially rigid, deflecting a minuscule amount even under heavy trucks. The crossing (track) support is basically the track structure composed of granular (crushed aggregate or ballast) that may provide a different level of load-carrying capacity as that of the highway approaches. Thus the crossing area deflects excessively with subsequent permanent settlement. This results in rapid abrasion and wear of the crossing surface and support materials and the surface often fails prematurely due to deterioration and settlement of the crossing.

Fig. 9. CSX 4-diamond rail crossing installation in Chicago.

It is paramount that crossing structures provide adequate structural integrity to support the imposed loadings. Typical crossing designs only provide for the crossing surface to be placed beside the rails and above the ties. Only unbound granular materials and possibly a geosynthetic are placed under the ties. The open granular trackbed permits surface water entering along the rail and the joints within the surface to penetrate and subsequently saturate the underlying subgrade/roadbed, thus lowering the structural integrity of the structure support. Groundwater, if present due to inadequate drainage, can further lower the structural integrity of the trackbed support layer.

Crossing structures having inadequate structural support deflect excessively under combined highway/ railroad loadings, which increase effective impact stresses and fatigue on the crossing components. The surface deteriorates prematurely. Permanent settlement occurs within the crossing area imparting additional impact stresses and fatigue from both highway and railroad loadings.

Periodically, the trackbed on both sides of the crossing may be raised with additional ballast prior to normal surfacing of the track to restore the desired geometric features. The crossing can become a permanent low spot in the railroad profile if the track profile is not equally raised through the crossing, which further increases impact stresses from the railroad loadings. In addition, the low spot collects water, and the impaired drainage can further weaken the underlying structure.

When the roughness and deterioration of the crossing adversely affects the safety and reasonable traffic operations across the crossing, the crossing must be removed and replaced at tremendous cost and inconvenience to the traveling public and railroad operations. Typically, the crossing is replaced using similar materials and techniques, thus assuring a similar series of events.

The typical crossing renewed with conventional granular materials often isn't structurally adequate to withstand the combined highway/railroad loadings. A high-quality substructure (or base) is needed below the trackbed to provided similar load carrying, confining, and waterproofing qualities to the common crossing area – as typically exists in the abutting pavement sections.

The use of a layer of hot mix asphalt within the track substructure, in lieu of conventional granular subballast, is becoming widely utilized to provide ideal properties to the crossing [7]. Perhaps thousands of crossings have been rehabilitated or initially constructed using this procedure. The basic process involves removing the old crossing surface and track panel followed by excavating the underlayment mixture of ballast, subballast, and subgrade to the required depth. These are replaced with a compacted layer of hot mix asphalt (termed asphalt underlayment), a compacted layer of ballast, a new track panel, and a new crossing surface (Fig 10).

Fig. 10. Rail/highway crossing on P&W RR in Oregon.

When the renewal process is "fast tracked," this insinuates that the track will be back in service in four hours and the highway back in service in 8 to 12 hours depending on the extent of the approach installations. The enhanced support provided by the asphalt layer in combination with immediate compaction of the ballast precludes the need to facilitate compaction with train traffic over a period of days. Thus, renewing a crossing can be accomplished in a single day with minimal closing of the crossing and attendant benefits to the traveling public.

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 (140 k Pa) at the underside of the compacted ballast layer for the 36 ton (33 metric ton) axle loads [8].

In addition, long-term settlement measurements and assessments for several crossings indicate significantly reduced long-term settlements of crossings incorporating the rapid-renewal, layered system, while maintaining acceptable smoothness levels. These long-term performance evaluations indicate this practice ensures long-life, economical, and smooth crossings. [9].

Essentially all of the large Class I railroad companies are selectively using asphalt underlayments for crossings based on engineering analyses of the benefits and logistics for the particular crossing site. Many Shortline railroad companies are involved as well. Numerous public agencies are participating with railroad companies in specifying and funding this technology. These include – Caltrain, Metrolink, Iowa DOT, MDOT, WVDOT, Tri-MetWES, KYDOT, Hillsborough Co. FL, IDOT, INDOT, and many others.

IX. CLOSURE

The international railway industry continues to emphasize the importance of developing innovative trackbed design technologies for both heavy tonnage freight lines and high-speed passenger lines. The purposes are to achieve high levels of track geometric standards for safe and efficient train operations while minimizing long-term track maintenance costs and extending track component service lives.

During the past several decades designs incorporating a layer of asphalt (or bituminous) paving material as a portion of the railway track support structure have steadily increased until it is considered as a common or standard practice. This technology has demonstrated applications for the construction of numerous new high-speed passenger lines in Europe and Asia. Asphalt trackbeds have been primarily limited to heavy tonnage freight lines in the United States, most often for maintenance/rehabilitation of special trackworks – such as turnouts, rail crossings, highway crossings, WILDS, tunnel floors, bridge approaches, etc., or capacity improvements of existing lines. It is also being specified for new urban rail transit/commuter lines.

The asphalt layer is normally used in combination with traditional granular layers to achieve various component configurations. This practice augments or replaces a portion of the traditional granular support layers and is considered to be a premium trackbed design. The primary documented benefits are to provide additional support to improve load distributing capabilities of the trackbed layered components, decrease load-induced subgrade pressures, increase confinement for the ballast, improve and control drainage, maintain consistently low moisture contents in the subgrade, insure maintenance of specified track geometric properties for heavy tonnage freight lines and high-speed passenger lines, and decrease subsequent expenditures for trackbed maintenance and component replacement costs.

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