Hot-Mix Asphalt (Bituminous) Railway Trackbeds: In-Track Tests, Evaluations, and Performances -- A Global Perspective

Part II -- United States Asphalt Trackbed Applications and Practices

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ABSTRACT

The railway industry throughout the world 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, similar to a highway pavement asphalt base layer, as a portion of the railway track support structure have steadily increased until it is becoming a common or standard practice. This, the second part of a three part paper, presents applications and practices of asphalt underlayment in the United States.

1 UNITED STATES ASPHALT TRACKBED APPLICATIONS AND PRACTICES

The vast majority of the asphalt trackbed installations in the U.S. have been utilized for special trackworks, typically short sections, up to about 90 m in length. Descriptions for two examples of new open-track projects follow (Rose, 2013).

2 BNSF TRANSCON DOUBLE-TRACKING PROJECT

The largest open-track asphalt underlayment trackbed construction project placed in service in the U.S. is 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 has been conducted in phases over a period of years and is nearing completion. The initial sub-projects specified an asphalt combination trackbed design. The design included a 150 mm granular base to provide a stable surface, topped with a 100 mm asphalt layer, 300 mm of ballast, and concrete ties. The granular base was omitted from succeeding projects where the asphalt layer was placed directly on the select soil subgrade. The asphalt is placed in two lifts: an initial 100 mm compacted lift and a final 50 mm lift. Densities and other asphalt and subgrade parameters were closely monitored. Nearly 322 km of asphalt trackbed design have been placed during new track construction in the area (Lusting, 2007). Figure 1 shows the placement of the asphalt and track.

Figure 1. BNSF Transcon asphalt trackbed construction.

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.

3 WICHITA, KS 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 4.0 km of trackage was elevated using granular fill. An asphalt combination trackbed was selected. Figure 2 shows the typical paving operation and completed project.

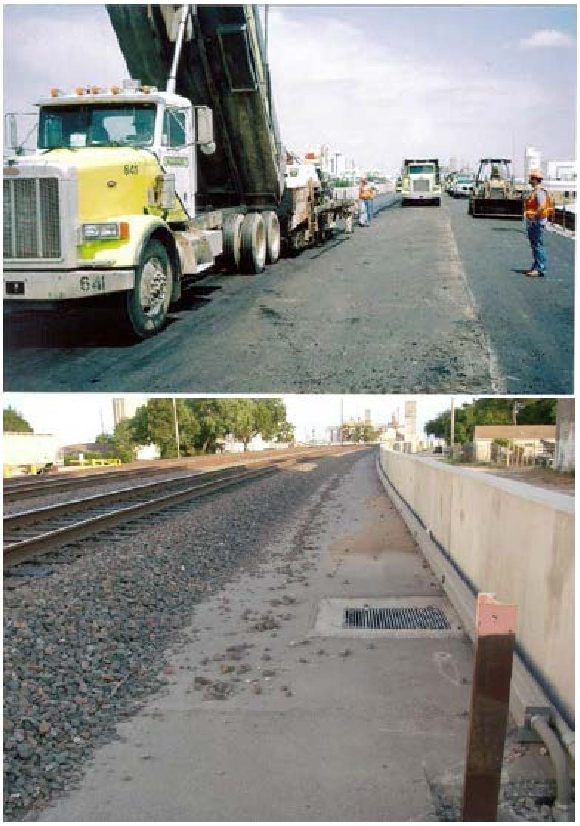

Figure 2. UP/BNSF elevated trackbed Wichita, KS.

4 TUNNEL FLOORS AND APPROACHES

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 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 nearly 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 daytime rehabilitation procedures, while maintaining overnight 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 30 to 45 m per day.

The asphalt mat should extend the full width for the typical 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 25 mm to possibly 250 mm at low spots. The average thickness is typically 100 mm. Since the major purpose of the asphalt mat is to level the floor, the thickness will necessarily vary considerably.

4.1 *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. 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. In fact, CSX has utilized this procedure for additional tunnels in the meantime. The prevailing problem is the need 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.

Within the past 10 to 15 years, Caltrain has used asphalt underlayment to correct historically poor support and improve drainage in its four tunnels just south of San Francisco. This predominately rail commuter line extends through the Silicon Valley to San Jose and accommodates upwards of 75 trains daily. All of the approaches to the four tunnels have asphalt underlayments and the inverts to two of the tunnels have asphalt underlayments.

4.2 *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.

The work was finished within 68 hours. Figure 3 shows the asphalt mat. The three tunnels are performing extremely well after over two years of train traffic.

5 WHEEL IMPACT LOAD DETECTORS

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.

Figure 3. NS Heartland Corridor tunnel floor construction.

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 has gained widespread acceptance to provide the desirable attributes of support for WILDs. 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, and is therefore somewhat stiffer during colder temperatures. However, this is not a particular concern in the insulated trackbed environment as the asphalt layer is covered by 500 mm or more of an insulating layer of ballast.

In the vicinity of the WILD, 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.

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. 4. 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 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. Their asphalt layers are typically 183 m long. Based on the performance of these installations, UP considers using an asphalt layer for all additional new installations and when existing WILDS need to be rehabilitated or retrofitted.

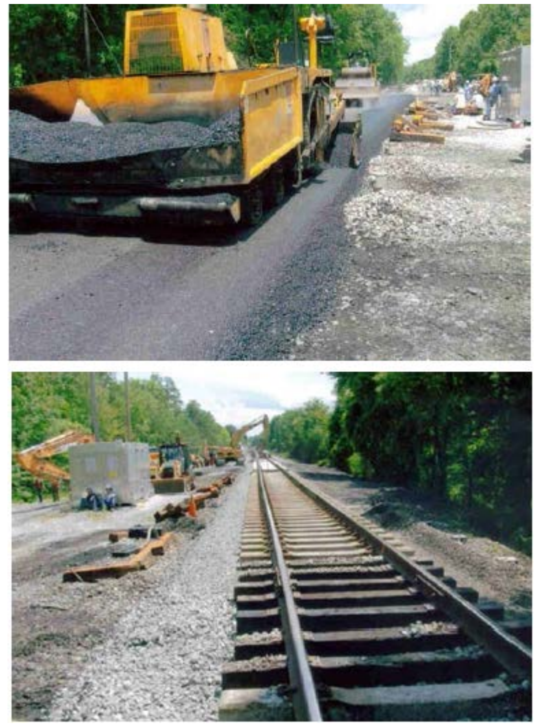

Figure 4. NS Flatrock, KY WILD installation.

6 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 now used to achieve these qualities. A few examples follow:

6.1 *Hump Retarder Tracks*

The earliest recorded use of asphalt underlayment for hump tracks was at the former Santa Fe Railway's Flynn Yard in the mid-1980s. This new yard began experiencing problems with subgrade pumping and track irregularities soon after constructing, requiring extensive re-construction of the track sections. The hump was also affected and asphalt underlayment minimized the effects of the poorly performing subgrade.

NS began using this application in 2006. NS has 13 hump yards, in 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 fewer deviations in track geometry and less attendant maintenance and better overall performance. Asphalt underlayment is now 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.

6.2 *Bridge Approaches*

Numerous bridge approaches have been underlain with asphalt. Discussions for two projects follow:

At Bridgeport, AL, this 450-m long heavy-tonnage CSX bridge across the Tennessee River Slough was built in 1998 to replace an existing bridge. This required re-alignment of approximately 425 m of mainline track for both approaches.

Asphalt underlayment was selected to improve track substructure strength and reduce future maintenance. A 125 mm thick mat of asphalt was placed on a 150 mm thick granular subballast. Granite ballast (250 mm thick) concrete ties and RE 136 CWR rail completed the track section on the two approaches. Figure 5 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 16 to 48 km/hr.

During 1989, the Santa Fe Railway Co. (now BNSF) replaced the bridge across Skeleton Creek north of Oklahoma City with a new bridge adjacent to the old one. This required re-alignment of 945 m of approaches. The new grade was constructed with local materials and asphalt underlayment. The asphalt was laid with a paver 100 mm thick on a select subgrade and topped with 250 mm of ballast. This heavy tonnage Chicago to Texas route traverses some very poor quality engineering soils.

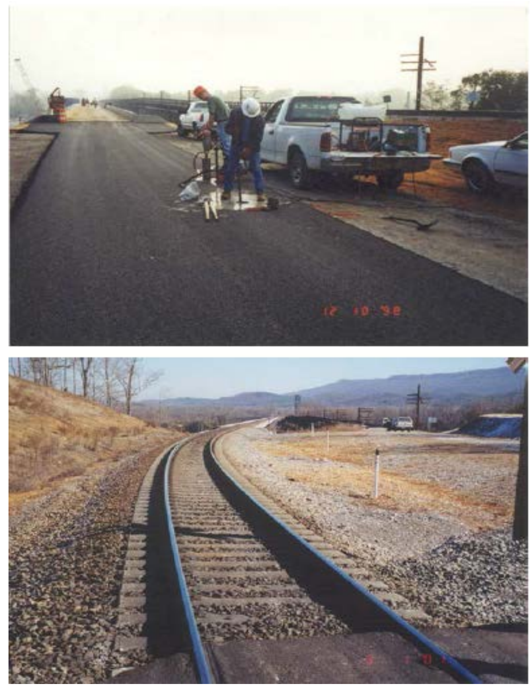

Figure. 5 CSX Bridgeport, AL new bridge approach.

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

7 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 (Rose and Anderson, 2006).

These special trackworks are traditionally high impact areas due to the wheels traversing the flangeway gaps in the rails. Adequate drainage is often difficult to attain, 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. Underlayment 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 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 150 mm thick asphalt layer was 75 minutes. The asphalt was placed with a typical paver in two 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 6 is a typical view of a 4-diamond rail crossing.

Figure 6. CSX 4-diamond rail crossing installation in Chicago.

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

8 HIGHWAY-RAILWAY AT-GRADE CROSSINGS

Structurally, railways and highways are typically designed 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 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.

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 therefore 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 high 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 (Rose, 2011). 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 7).

Figure 7. 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 140 kPa at the underside of the compacted ballast layer for the 33 metric ton axle loads (Rose, Li and Walker, 2002).

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 (Rose, Swiderski and Anderson, 2009).

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.

9 CLOSURE

This paper (Part II) has discussed U.S. applications of asphalt underlayment. Part I of this paper covered an Introduction to Asphalt Trackbeds and International Applications and Practices. Part III documents U.S. Asphalt Trackbed Materials and Evaluations and Tests and provides overall analysis and closure.

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