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Asphalt Underlayment Railway Trackbeds: Designs, Applications, and Long-Term Performance Evaluations

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DISCLAIMER

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TECHNICAL SUMMARY

Title

Asphalt Underlayment Railway Trackbeds:
Designs, Applications, and Long-Term Performance Evaluations

Introduction

This compendium of practices report documents the justification, design and implementation of technical advancements for a wide variety of asphalt trackbed applications. Documented are over forty specific projects on four Class I railroads, two regional/shortline railroads, plus significant applications on three public commuter/transit rail lines These include special trackworks (crossovers, rail crossings, turnouts), wheel impact load detectors (WILD), bridge approaches, tunnel floors and portals, open-track, and middle-of-street trackage applications.

Approach and Methodology

Typical and specific design and application practices were evaluated. The longevity of these applications varied from recent to over thirty years of in-track service. Emphasis was placed on evaluations of performance metrics affecting subsequent train operations, track maintenance requirements and costs, and overall maintenance of track geometric parameters. The performance evaluations are largely based on anecdotal and qualitative observations and historical evaluations augmented with limited quantitative track geometry adherence data and subsequent track maintenance cost data

The projects were designed and installed using highly technical standards of engineering practice relating to the developed technology for using a layer of asphalt, termed "underlayment", within the track structure to achieve specified high standards for trackbed performance. The coverage reported herein is not all-inclusive, but represents typical, pertinent, and unique applications of which the author is familiar.

Findings

In the early 1980s, several U.S. railway companies saw the impending need for higher-quality trackbed materials to provide higher performance and longer-lasting track and support structures. The railway companies worked with the asphalt paving industry to assess the applicability for using a layer of 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. The majority of these trackbed applications involved 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 also selectively considered as an option on new mainline track installations in the U.S.

During the intervening years since the early1980s, the specified use of a layer of hot-mix asphalt underlayment in the track structure (trackbed) -- as a replacement or partial replacement for granular subballast below the ballast -- has grown substantially on U.S. freight railways and public commuter/transit rail lines. Typically this practice is specified at specific sites on existing trackage where conventional all-granular trackbed designs have not performed satisfactorily and/or where trackbed enhancement features potentially afforded by the asphalt layer were deemed particularly desirable.

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.

Conclusions

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 often considered as a common or standard practice.

The observed conditions and evaluated performances of all described projects indicate that asphalt trackbeds are meeting or exceeding anticipated longevity and performance expectations.

Recommendations

The United States railway industry continues to emphasize the importance of developing innovative trackbed design technologies for both heavy tonnage freight lines and commuter/transit 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.

Based largely on its proven performance it is considered a standard engineering design practice for specified types of applications on a variety of freight railroads and commuter/transit rail lines in the United States. This technology also has demonstrated applications for the construction of numerous new high-speed passenger lines in Europe and Asia.

Publications

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SECTION 1 INTRODUCTION

During the intervening years since the early1980s, the specified use of a layer of hot-mix asphalt underlayment in the track structure (trackbed) -- as a replacement or partial replacement for granular subballast below the ballast -- has grown substantially on US freight railways and public commuter/transit rail lines. Typically this practice is specified at specific sites on existing trackage where conventional all-granular trackbed designs have not performed satisfactorily and/or where trackbed enhancement features potentially afforded by the asphalt layer were deemed particularly desirable.

This compendium of practices report documents the justification, design and implementation for a wide variety of applications of this technology involving over forty specific projects on four Class I railroads, two regional/shortline railroads, plus significant applications on three public commuter/transit rail lines These include special trackworks (crossovers, rail crossings, turnouts), wheel impact load detectors (WILD), bridge approaches, tunnel floors and portals, open-track, and middle-of-street trackage applications.

Typical and specific design and application practices are described. The longevity of these applications varies from recent to over thirty years of in-track service. Emphasis is placed on evaluations of performance metrics affecting subsequent train operations, track maintenance requirements and costs, and overall maintenance of track geometric parameters. The performance evaluations are largely based on anecdotal and qualitative observations and historical evaluations augmented with limited quantitative track geometry adherence data and subsequent track maintenance cost data. The observed conditions and evaluated performances of all described projects indicate they are meeting or exceeding anticipated longevity and performance expectations.

SECTION 2 BACKGROUND

In the early 1980s, several U.S. railroad companies saw the impending need for higher-quality trackbed materials to provide higher performance and longer-lasting track and support structures (1,2,3). They worked with the asphalt paving industry to assess the applicability for using a layer of 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. The majority of these trackbed applications involved 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 (4,5). These asphalt maintenance installations currently number in the thousands.

Based on its proven performance as a maintenance solution, asphalt is also selectively considered as an option on new mainline track installations 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 the next large expansion of our rail system may be high-speed passenger rail. The contents of this paper are limited to U.S. freight railroads and passenger commuter/transit lines. Its applications on European and Asian countries are described in previous papers (6,7).

SECTION 3 ASPHALT TRACKBED DESIGN PARAMETERS

Typical asphalt trackbed design parameters have changed significantly since the initial trials during the early 1980s. Design specifications have become more specific and stringent relative to using basic engineering principles and practices for selecting materials quality, layer thicknesses, and in-track installation best practices. Accepted practices from long-standing highway and airfield technologies have influenced the technical aspects specified in the railway recommended practices.

3.1 Trackbed Cross-Sectional Configurations

Three basic types of asphalt trackbeds are being utilized, as depicted in the cross-sections contained in Figure 3.1. Two of them incorporate the traditional ballast layer as a portion of the support. The so-called "*Asphalt Underlayment*" trackbed is similar to the classic all-granular trackbed; the sole difference being the substitution of the asphalt layer for the granular subballast layer. The asphalt is placed on a select subgrade.

The "*Asphalt Combination*" trackbed includes both an asphalt layer and a granular subballast layer placed on either new subgrade or existing trackbed. The thickness of the asphalt layer can be somewhat less than that used for underlayment since a relatively thick specified granular subballast layer is placed below. This is normally the type of asphalt trackbed that is in existing trackage since the in-place supporting material is typically a mixture of degraded ballast, soil, and other fine materials that have accumulated over the years. This is mainly granular material with a grading similar to subballast. It is quite variable in composition and quality, but typically has higher strength than native soil. The native subgrade soil is normally imbedded several more inches below the degraded subballast layer.

The "*Ballastless Asphalt Combination*" trackbed consists of rail/tie track, or slab track, placed directly on a relatively thick layer of asphalt and a relatively thick underlying layer of granular subballast. These thickened sections compensate for the absence of the ballast layer. The exact design and configuration of the ties, monolithic or two-block, slab track if used, and profile of the asphalt surface varies significantly as a function of preferential specifications. The

application of cribbing rock, or some other means, is necessary to restrain the track from lateral and longitudinal movement. Its use in the U.S. has been restricted to a limited number of low volume highway crossings and small rail terminals and included yard tracks.

3.2 Asphalt Layer Thicknesses and Widths

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, crossovers, and bridge approaches 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. (150 mm) 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 to12 in. (200 to 300 mm). A 6 in. (150 mm) thick asphalt layer that is 12 ft (3.6 m) wide requires 0.42 tons of asphalt per track foot (1.25 metric tons per track meter). Thicker asphalt layers are normally specified for WILDs and high impact special trackworks.

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 transition lengths may range from 10 to 25 ft (3.0 to 7.7 m) or longer.

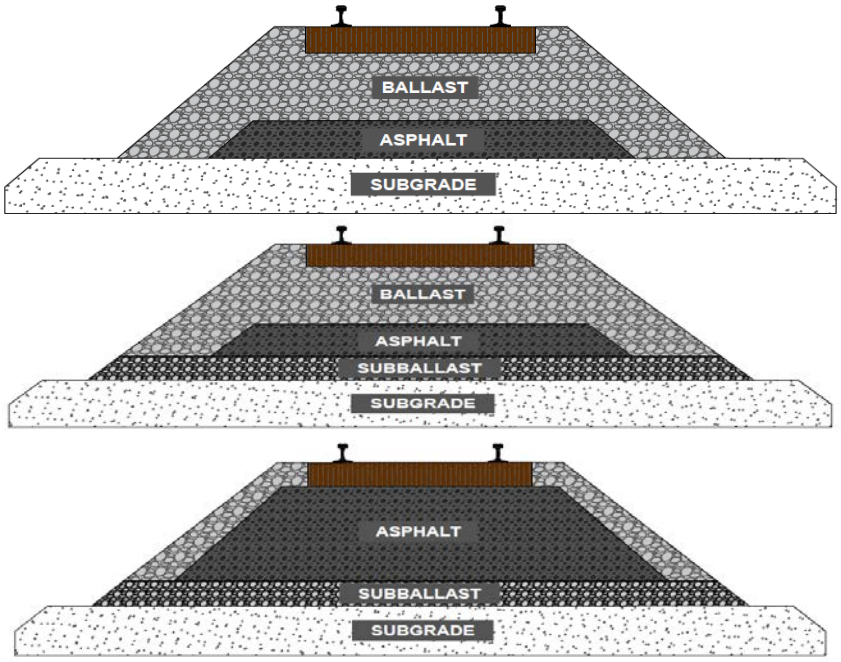

Figure 3.1 Asphalt Underlayment Trackbed (top), Combination Asphalt Trackbed (middle), and Ballastless Asphalt Combination Trackbed (bottom).

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

3.3 Asphalt Mixture Designs

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 (8,9). Figure 3.3 shows an asphalt core taken from a trackbed.

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 to 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 as adopted 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 (10).

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 (10).

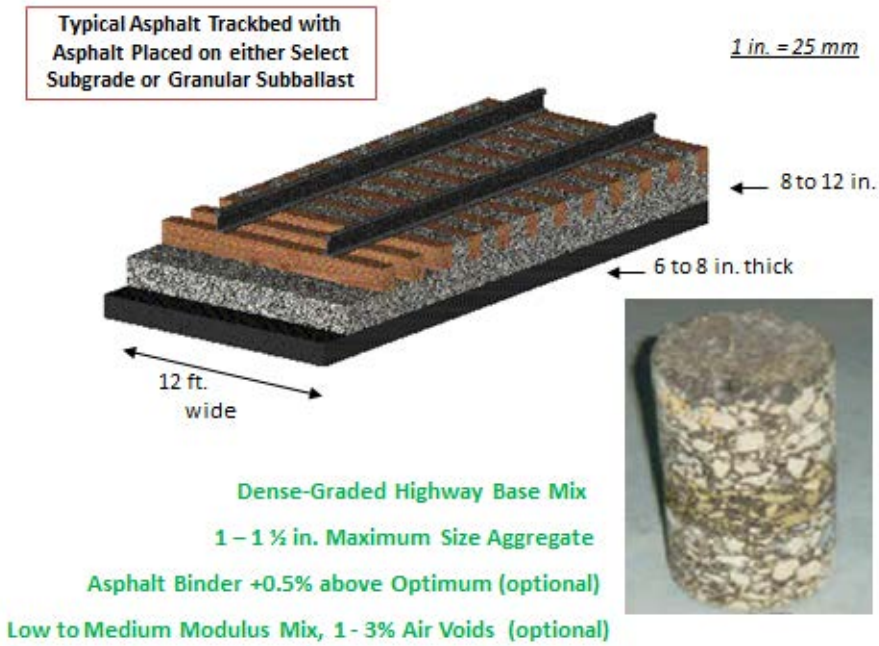

Figure 3.3 Configuration of Asphalt Trackbed and an Extracted Core.

SECTION 4. SPECIFIC PROJECT DESIGNS AND PERFORMANCE EVALUATIONS

The applications described herein were taken from:

- Four large Class I freight railroads two in the eastern portion of the country – Norfolk Southern Railway and CSX Transportation, and two in the western portion of the country – BNSF Railway and Union Pacific Railroad,
- Two Class II railroads – Paducah & Louisville Railroad, a 270 mile (434 km) long Class II freight railroad in western Kentucky, and Portland & Western Railroad, a 520 mile (837 km) long Class II freight railroad and commuter rail line in western Oregon, and
- Three Urban Commuter/Light Rail Transit lines – Caltrain, a 55 mile (88 km) long line traversing the length of the San Francisco Bay Peninsular, Metrolink, a 534 mile (860 km) long line in the Los Angeles Basin, and the Denver Eagle P3 project, a 40 mile (64 km) long line.

The individual projects are described based on these types of applications -- Special Trackworks, Bridge Approaches, Tunnel Floors and Approaches, Wheel Impact Load Detectors, Middle-of - Street Trackage, Piedmont Improvement Program, and Open Track.

SECTION 5 SPECIAL TRACKWORKS

Considerable research and development has been conducted to improve the performance of special trackworks – specifically rail-to-rail crossings, crossovers, and turnouts – to withstand heavy tonnages and axle loads and other high-dynamic loadings. Optimizing foundation stiffness is considered important for minimizing track settlement and minimizing track geometric variations; whereas, foundation damping is considered important for minimizing vertical dynamic loads, thus reducing the detrimental effects of high dynamic loadings (5).

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 obtain, particularly in the switch point and frog areas. Also, the ballast is difficult to tamp and consolidate within the maze of rails and track components. Asphalt underlayment has been shown to increase trackbed strength while enhancing drainage thereby providing adequate and consistent support to obtain high ballast modulus to withstand and distribute the added vertical impact forces in the switch point and frog areas.

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 nighttime and 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. Minimal tamping or surfacing is required provided the ballast is pre-compacted on well-compacted asphalt subballast.

Literally hundreds of rail crossings, crossovers, and turnouts have been underlain with a mat of asphalt during the renewal and replacement of special trackwork. For example, CSX used asphalt underlayment for the replacement of numerous rail crossings in the Chicago area during the mid-1990s. CSX's B&O line east of Chicago had numerous 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 (2,3).

Following are typical projects for turnouts and crossovers on four railroads.

5.1 Caltrain

This 55 mile (88 km) long regional rail link along the San Francisco Peninsula began using asphalt underlayment in 1999 for the rehabilitation/renewal of turnouts. During the intervening 18 years, 85 turnouts, predominately # 20s, at 24 sites have been rehabilitated/renewed using this technology. This number includes 13 of the 14 track crossovers on the main line. This mixed traffic line carries predominately frequent commuter trains and a limited number of UP local freight trains during the evening hours.

Construction details are contained in Caltrain's "Standard Drawings and Practices". An engineering evaluation is performed to determine unique conditions at each site that might influence the specific design. After removing the old turnout and roadbed materials, considerable attention is given to preparing the roadbed for the trackbed. This involves drainage considerations and thorough compaction of the existing or modified roadbed assuring a well-compacted 6 in. (150 mm) minimum thickness of compacted subgrade/roadbed.

The materials for the asphalt underlayment layer must conform to the provisions of Caltrain's "Standard Specifications". The underlayment mix is designated dense-graded Type A Mix with ¾ in. (19 mm) maximum size aggregate gradation. It is placed as a layer 8 in. (200 mm) thick, with either a machine or blade, and thoroughly compacted. The asphalt layer is placed 12 ft (3.7 m) wide and extends a minimum of 10 ft (3 m) along the track beyond the ends of the turnout. A layer of ballast, 9 in. (225 mm) thick, is placed above the asphalt.

The turnouts and crossovers have exhibited acceptable performance since installation. No subgrade support issues have been observed and the turnouts remain solid and serviceable. Based on demonstrated performance and engineering evaluations, the use of asphalt underlayment is considered the standard design for turnouts and crossovers when engineering evaluations indicate that the use of the technology is warranted. Figure 3 depicts a typical Caltrain crossover with asphalt underlayment.

5.2. Metrolink

This large commuter rail system in the Los Angeles area of Southern California presently consists of seven lines totaling 534 miles (860 km) in extent and continues to expand with additional lines. Metrolink began using asphalt underlayment in 2007 for turnouts, crossovers, and rail crossings. Since that time, numerous turnouts have been underlain with asphalt. It is considered standard practice for all newly constructed and rehabilitated turnouts. The design is similar to that specified by Caltrain, except that only 6 in. (150 mm) thickness of asphalt underlayment is used. The designs are contained in Metrolink's Standard Book of Specifications. A typical Metrolink crossover with asphalt underlayment is shown in Figure 5.1. The performances of these special trackworks have been satisfactory. Minimal settlement has been observed and they have remained solid and serviceable, requiring minimal maintenance.

5.3 NS Heartland

In 2012, NS replaced three No. 20 equilateral 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 1¼ hours. The asphalt was placed with a typical paver in two 3 in. (75 mm) lifts. Views of one of the turnouts are shown in Figure 5.3.

Figure 5.1. Views of a Universal Crossovers on Caltrain at CP Palm (left) and on Metrolink's Antelope Valley Line (right). These Crossovers have been Maintenance Free for Many Years.

The performance of the three turnouts has been significantly improved during the past four years compared to the performance of the previous wood tie turnouts on existing trackbed/roadbed. No special surfacing has been required, just programmed surfacing every two years. Also no switch point failures, no guard rail adjustments with shims, no gage problems, and no pumping or fouled ballast have occurred and frog wear has been minimal.

Figure 5.3. A No. 20 Equilateral Turnout at Greyeagle, WV before Positioning on the Asphalt Pad on left which had been Placed Earlier That Morning and After Four Years of Traffic on right.

5.4 Denver's RTD FasTracks – Eagle P3 Project

FasTracks is Denver's RTD (Regional Transportation District) voter-approved transit expansion program – the largest in the nation – transforming transportation through the Denver metro area.

This program, approved in 2004, augments the earlier completed light rail passenger lines serving the Denver Metro Area.

The Eagle P3 Project was approved in 2010. It includes the construction of three commuter lines as part of RTD's commuter rail line system. The project was delivered and is being operated under a concession agreement that RTD entered into with a "Concessionaire" known as Denver Transit Partners (DTP); the team is composed of several large companies. The Eagle P3 Project concession agreement requires DTP to design, finance, build, operate, and maintain the three lines -- A, G, and B, totaling 40 miles (64 km). The A & B lines opened in 2016; the G line is anticipated to open in 2017.

Of specific interest to this discussion was the decision by the DTP's design team to specify the use of asphalt underlayment designs for trackbed support for the turnouts and crossovers for the three new lines. The fact that the long-term maintenance agreemen that DTP must adhere to for the next thirty years dictated that premium designs, materials, and construction techniques should be used to minimize subsequent maintenance expenditures.

There are numerous turnouts along the three routes. The specific asphalt underlayment trackbed design layer consists of 5 in. (125 mm) asphalt underlayment, placed a minimum 3 ft 3 in. (1.0 m) past the ends of the ties extending nearly12 ft (3.7 m) beyond the point of switches and the last long ties. The asphalt layer is topped with 12 in. (300 mm) ballast for the typical ballasted track.

Maintenance requirements and serviceability measures will be closely monitored during succeeding years for these three lines to determine the effects of the specific designs on the costs and warranty implications of the executed contractual obligations of the concessionaire. One of these studies will evaluate whether the additional cost of installing asphalt underlayments under turnouts will be recovered due to expected lowered maintenance costs and improved service metrics.

SECTION 6 BRIDGE APPROACHES

Minimizing differential settlement and track stiffness variations at bridge approaches 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, documented examples follow:

6.1 Bridgeport, AL

This 1,475 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 1,400 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. (250 mm) thick, concrete ties, and RE 136 CWR rail completed the track section on the two approaches. Figure 6.1 is a view of the asphalt underlayment and the finished bridge and north approach.

The CSX line also carries NS traffic. The total annual tonnage over this heavy tonnage and traffic line is about 70 MGT. During the 17 years since the bridge was opened to traffic, the approaches have required minimal track maintenance and the speed was increased from 10 to 30 mph (16 to 48 km/h). No mud or ballast fouling has been observed.

Figure 6.1. Core Drilling the Asphalt Layer in 1998, the Day after the Asphalt was placed on the North Approach and a View of the North Approach in 2014, 16 Years after Construction of the Bridge.

The native soil on the north approach was composed of highly plastic red clay with intermingled cherty aggregate. The native soil on the island was composed of silty sandy stream deposited material, much different from the clay soil on the Alabama approach. Both approaches, although constructed on wildly differing soil compositions, have performed admirably.

6.2 Ft. Estill, KY

Three short open deck bridges, just south of Richmond, KY, on CSX's Cincinnati to Atlanta mainline had habitually exhibited settlement, loss of ballast, and pumping near the bridge abutments. This situation required frequent maintenance to restore the track surface to minimize the effects on the ride quality of the locomotives and impact on the bridge and track approaches.

During a planned curfew on the line in the summer of 2001 the trackbed support materials on four approaches to three closely spaced open-deck bridges were replaced. For each approach, a 40-ft (12-m) long panel was removed, the old trackbed was dozed out and about 6 in. (150 mm) of asphalt was placed and compacted. Ballast was dumped on the asphalt and the panel was replaced. This process was accomplished in about four hours. Two of the approaches had not exhibited trackbed problems so they were not included in the four day blitz.

The use of asphalt underlayments for the three bridge approaches is considered a complete success. Recent inspections revealed no mud in the track and essentially no approach settlement after 15 years of service, in contrast to previous performances. Typically the crosslevel drops off slightly at the bridge abutments if the accompanying ballast shoulders are not adequately supported laterally. These approaches must be typically surfaced once per year while replacing ballast that has cascaded down the embankments, a low cost activity. Figure 6.2 shows views of the bridge during renewal and after 15 years of traffic.

Figure 6.2. Renewal Process for Approach to a Short Open-Deck Bridge on CSX Line near Ft. Estill, KY (left) and Condition after 15 Years of Traffic (right).

6.3 Kentucky Dam and Muldraugh Hill

The Paducah & Louisville Railroad has used asphalt on approaches to several bridges; particularly bridges replaced requiring new trackbed approaches on different track alignments. Between 2004 and 2009 a new 3,100 ft (945 m) long bridge was built across the Tennessee River just below Kentucky Dam in far western Kentucky. The project was in conjunction with the widening and lengthening of the navigation locks at the dam site. Both the US 62 and P&L track were removed from the dam and relocated downstream on separate bridges.

The relocated alignment required a 4,000 ft (1,200 m) long, 75 ft (23 m) high compacted earth fill on the west approach which was constructed five years early to allow for settlement. The new west alignment on the fill and the east alignment, mainly in a cut for 2,000 ft (600 m) length, had 6 in. (150 mm) thick layers of asphalt topped with 12 in. (300 mm) of ballast. The wood tie trackbed abuts the ballast deck approach spans. The class 3 track has a 25 mph (40 km/h) speed limit across the bridge. Figure 6.3a shows views of the approach paving and the finished approach to the bridge.

The bridge was placed in service in 2009. Its yearly traffic tonnage is 7 MGT. In the intervening seven years the approaches have required essentially no track maintenance. The 2000 ft (600 m) long, 75 ft (23 m) high west end fill has shown minimal settlement, likely due in part to the waterproofing effect of the asphalt cap for shedding the rainwater.

Following the excellent performance of the approaches to the relocated Kentucky Dam Bridge, the P&L also chose to use similar trackbed designs for the approaches to two additional new bridges built off-line to replace two steel trestles. These 240 and 470 ft. (73 and 143 m) long concrete ballast deck bridges are near Louisville on the P&L's line on Muldraugh Hill. The bridges were built during 2012 and 2013. The asphalt trackbed approaches are 50 ft (15 m) long. Wood ties were used throughout both bridges and approach trackage. The approaches to the two bridges have required no track maintenance since opening to traffic. Figure 6.3b contains recent views of the west approach to the longer Muldraugh Hill Bridge.

Figure 6.3a. Paving the North End Approach Prior to Erecting the Bridge (left) and a Recent View of the West End of the Kentucky Dam Bridge (right).

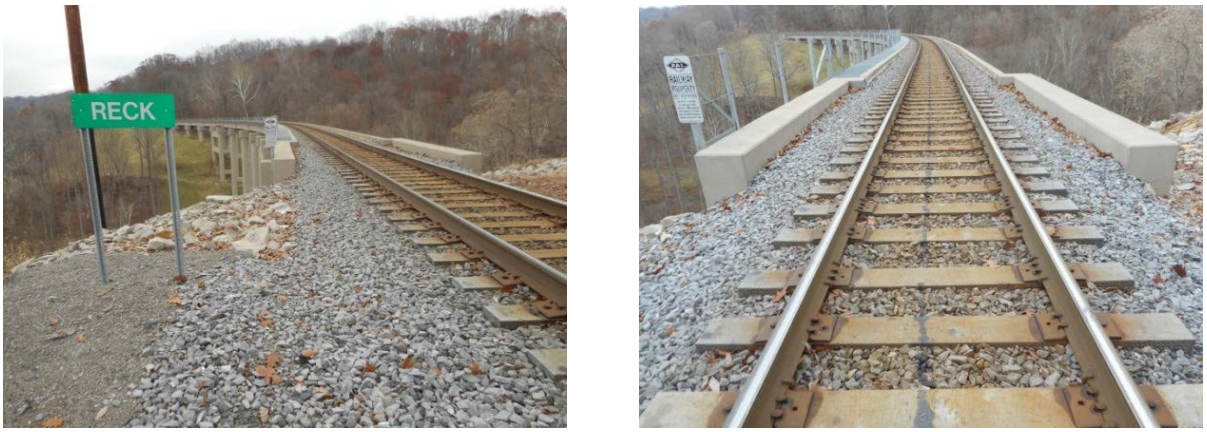

Figure 6.3b. Muldraugh Hill Bridge containing Asphalt Approaches that are 50 ft (15 m) Long the Full Width of the Wing Walls for 25 ft (7.5 m) and an Additional 25 ft (7.5 m). This Particular Bridge Contains Composite Ties; the other one Contains Wood Ties.

6.4 Caltrain

Caltrain has used asphalt underlayment during the renewal of 16 approaches to bridges associated with the replacement of 8 bridges during the past eighteen years. It is considered a normal practice to place an 8-in. (200-mm) thick layer of asphalt while the track has been removed in preparation for installing new ballast and track to renew the track on the bridge approaches. The primary purpose is to minimize settlement and transition the track stiffness so that the ride quality at the bridge will not be compromised.

SECTION 7 TUNNEL FLOORS AND APPROACHES

Maintaining a consistently high-quality trackbed support system in tunnels is vital for achieving optimum operating conditions and minimizing maintenance costs and track-induced slow orders. 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 in the tunnel during wet weather. Water may flow out of the tunnel portals 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 for 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 a 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 asphalt provides an impermeable, semi-rigid underlayer to fill in the low spots and provide an asphalt thickness that may vary from 0 to 4-6 in. (0 to 100-150 mm) above the prevailing tunnel floor. Minor track surface adjustments can be made in the ballast.

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. 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 loader bucket or 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 change out 120 to 160 ft (36 to 48 m) of track 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.

7.1 CSX Transportation

During the mid-1990s, CSX Transportation rehabilitated all or portions of nine tunnels on mainline in the eastern Kentucky/Tennessee area. Each one had historically been a “wet” tunnel exhibiting similar characteristics – soft support and inadequate drainage in low areas which “ponded” water contributing to rapid loss of acceptable track geometry. This adversely affected track geometry resulting 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 views for two of the tunnels after 19 years since paving with asphalt, north of Knoxville, TN, are shown in Figure 7.1.

Figure 7.1. Vasper Tunnel (left), 1500 ft (457 m) has been Dry all the Way Through only Requiring Maintenance Surfacing for Crosslevel Twice during Five-Year Spans. Similar Success for the Cove Lake Tunnel (right), 1750 ft (533 m) except for a Couple of Waterfalls Requiring Maintenance to Periodically Clean the Ditches. Both are on the KD Subdivision.

7.2 Norfolk Southern

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, totaling 8,098 ft. (2,468 m) long, in close proximity to Kermit, WV had the tunnel floors 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 to 8 in. (150 to 200 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 7,000 tons (6,350 metric tons) of asphalt was used for the 6,543 ft (1,994 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 7.2 shows the asphalt mat.

The three tunnels are performing extremely well after six years of train traffic. At a few sites, mud will seep along the seam of the asphalt floor and the tunnel wall. It is still difficult to maintain drainage along the ditches. When this is impaired, mud will migrate to the track. The

performance of all three tunnels is considered to represent major improvements compared to pre-Heartland performance prior to placing the asphalt and increasing the clearances. Pumps were re-installed in one of the tunnels; which requires periodic ditch maintenance when the pumps fail to operate adequately.

Figure 7.2. Big Sandy Tunnel No. 3 near Greyeagle, WV with the Paved Trackbed during the Tunnel Clearance Project in 2010 and the Finished Approach to the Tunnel in 2016. Maintenance Costs have been Minimal since 2010.

7.3 Caltrain

Within the past eighteen 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 accommodates daily upwards of 75 commuter trains and additional freight trains. The approaches to all four tunnels have asphalt underlayments and the inverts to two of the tunnels have asphalt underlayments throughout the tunnels. The performance of the trackbeds has been substantially improved and the remaining two tunnel inverts are scheduled to be paved with asphalt. Figure 7.3 contains views of two of the tunnels containing asphalt underlayments. .

Figure 7.3. Two of the Caltrain Tunnels paved with Asphalt just South of San Francisco. Tunnel 4 (left) and Tunnel 2 (right.).

SECTION 8 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 of the installation throughout the year. A main factor influencing the maintenance of consistent track stiffness is maintaining consistent moisture content of the subgrade/subballast layers throughout the year.

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 uniformly, 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 reasonably stiff 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 mineral 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 for the track on 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. Actually, Conrail, prior to its dissolution, was using asphalt under WILDs some 25 or so years ago. NS and CSX inherited some of these.

8.1 Norfolk Southern

During the past several years, NS has installed asphalt underlayments under twelve WILDs at nine locations. A typical installation is shown in Figure 8.1. These are specified for new installations and for rehabilitating previously installed WILDs. Asphalt underlayment is a standard practice for all WILDs. It is specified as a matter of initial track design for new installations and it is added when performing major renewal or rehabilitation of existing WILDs.

The specified dimensions of the asphalt layer vary from site-to-site depending on the prevailing conditions. Typically the layer is 12 in. (250 mm) thick and 12 ft (3.6 m) wide and extends a distance of 150 ft (46 m) or longer.

8.2 CSX Transportation

During the past few years, CSX has installed asphalt underlayments at majority of the WILD sites. These include WILDs at Supersites that contain additional trackside measuring and detection equipment, and WILD-only sites. CSX's typical WILD track section containing asphalt underlayment was issued in 2006. It specifies a layer of asphalt underlayment 6 in. (150 mm) thick and 12 ft (3.6 m) wide, crowned and sloped 2% transversely, topped with 12 in. (300 mm) of ballast under the concrete ties. Figure 8.2 depicts a CSX WILD installation. The WILDs with the asphalt underlayments have served satisfactorily eliminating mud, pumping, and wavy track within the measurement area.

Figure 8.1. Asphalt Paving in Preparation for Installing the Salient Process WILD on NS Line at Flatrock,KY in 2009.

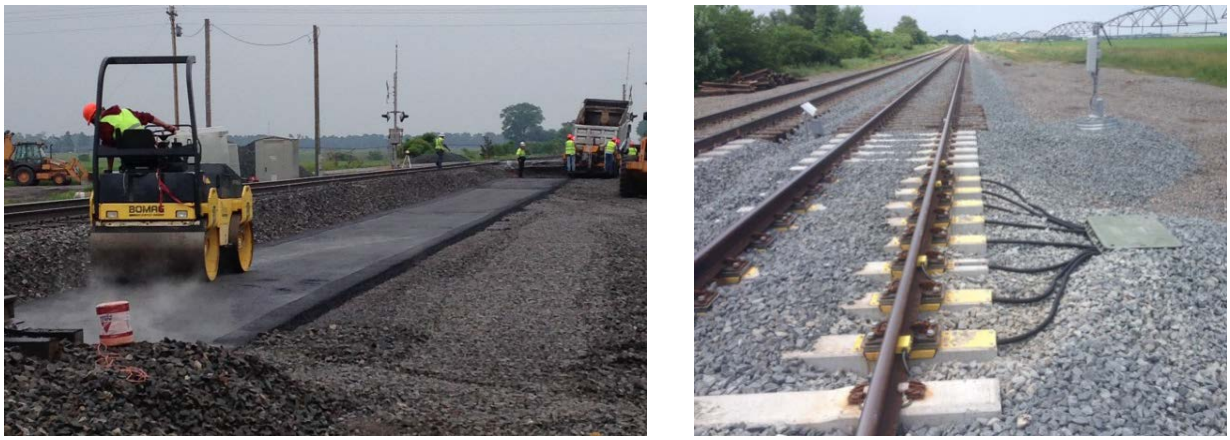

Figure 8.2. Asphalt Paving in Preparation for Installing the Schenck Process WILD on CSX Mainline at Webster, IN.

SECTION 9 MIDDLE-OF-STREET TRACKAGE

A unique type of a railway/street jointly shared facility is the situation where the railroad track occupies the middle of the street for a considerable length. This is basically a continuously closed crossing so that street vehicles have continuous access beside and across the track. Typically on-street parking is permitted in urban areas if the street is sufficiently wide to accommodate parking.

Drainage from within the crossing is difficult to achieve and maintain at these locations which can adversely affect the load carrying capability of the track. The track can settle non-uniformly resulting in a wavy track negatively impacting the track geometry and street ride quality.

Access to the track to perform maintenance is time consuming and expensive and impacts normal train and street traffic. The crossing surface and surrounding surface approaches must be removed and replaced. It is very desirable for mid-street closed tracks to have proper structural support below the track so that the track and street components do not settle with attendant roughness requiring frequent removal and renewal.

9.1 Portland & Western in Oregon

Of particular significance to the P&W is the predominance of long-distance middle-of-street running trackage in several cities. This was common to the predecessor Oregon Electric Line that operated frequent interurban passenger trains in the southern Portland suburbs. Crossings ranging from 2,000 to 3,500 ft (600 to 1,100 m) long are common. These have typically required frequent and costly track maintenance activities to maintain smooth surfaces for both train and highway vehicle passage. This has included frequent surface replacements, roadbed injection, pavement milling, etc. Providing adequate drainage throughout these long distances to minimize settlement and deterioration and provide adequate trackbed support for the jointly used crossings has been difficult to achieve, for selected crossings, using conventional all-granular support structures.

Renewing the crossing surfaces and support structures for the poorly performing middle-of-street crossings began in 2009 in Independence with a 2000-ft (600-m) long Main Street crossing installed over four years using asphalt/rubber seal surfaces with concrete at selected cross streets.. This was followed with a 3,500-ft (1,100-m) long Holly Street concrete crossing in Junction City, also installed over four years. The P&W trackage has 2.9 miles (4.7km) of middle-of-street-running crossings, scattered over six cities. Recent views of the two crossings are shown in Figure 9.1.

Performance of the two crossings to date has been very satisfactory. During 2017 P&W plans similar projects in two cites – 2,800 ft (850 m) long Front Street in Salem and 1,400 ft (425 m) long 4th Street in Harrisburg. These will be multi-year projects following the specifications and procedures used for the initial two long-distance street crossings.

Figure 9.1. Two of P&W's Middle-of-Street Paving Projects Utilizing Asphalt Underlayments. The 3,500 ft (1,100 m) long Holly Street Trackage in Junction City (left) and the 2000 ft (600 m) long Main Street Crossing in Independence (right).

9.2 NS in West Brownsville, PA

NS recently completed the renewal of a 3300 ft (1,000 m) long crossing on Main Street in West Brownsville, PA. NS renewed this crossing in four sections, each about 800 ft (244 m) long over a four-year period during 2011 to 2014 to rectify a previous chronic maintenance expense due to having to renew portions of the crossing at frequent intervals. The final one-fourth of the crossing was renewed during a maintenance blitz on this line in 2014. The crossing, located on the heavy tonnage coal-hauling Monongahela line, has asphalt underlayment support and a concrete surface utilized along the entire distance during the 2011–2014 renewals. Previously the trackbed and crossing surface were being renewed every four years using conventional all-granular subballast support.

A longitudinal trench 13 ft (4 m) wide was excavated and a 4 in. (100 mm) thickness of granular subballast was added topped with an 8 in. (200 mm) thick layer of asphalt that replaced a portion of the all-granular subballast. A 12 in. (300 mm) thickness of ballast was placed and compacted. Wood tie track panels were positioned on the compacted ballast. The addition of typical concrete crossing panels completed the installation within the trackbed. Figure 9.2 shows the crossing during the renewing and the south end after five years of service.

The crossing is performing very well since the adoption of the asphalt support. The oldest section has been in service for five years. The crossing is showing no indication of distress or deterioration and all indications that it will serve adequately for many more years.

Figure 9.2. Main Street Paved Trackage in West Brownsville, PA. The Earliest Placed Section after Five Years of Traffic (left) and Paving one of the Sections within the Excavated Trench (right).

SECTION 10 PIEDMONT IMPROVEMENT PROGRAM

The Piedmont Improvement Program (PIP) is a largely federally-funded railway/highway project in the Piedmont area of North Carolina. The primary project involves a portion of the Southeast High Speed Rail Corridor between Greensboro and Charlotte, also part of the Norfolk Southern Railway's Crescent mainline. The actual railway is owned by the North Carolina Railroad, a state owned entity, and the project is primarily administered by the North Carolina Department of Transportation and the Norfolk Southern Railway Company. The primary purpose of the project is to increase passenger and freight rail capacity, increase train speeds, and improve railway and highway safety.

A primary aspect of the project is to add 26 miles (42 km) of second track between Greensboro and Charlotte to complete the double-tracking of that 92 mile (148 km) portion of the Southeast High Speed Rail Corridor. Passenger train speeds on the Crescent line will be increased from 50 mph (80 km/h) to 60 mph (96 km/h) on diverging moves through the No. 24 crossovers. Two additional round trip passenger trains will be added increasing the Charlotte to Greensboro line, continuing to Raleigh, to ten daily trains. Also, the line can accommodate increased numbers of higher-speed freight trains on the higher capacity line.

For many years this section had portions of double track with three interspersed single track portions. These required the use of a series of lateral turnouts for the trains to change from single to double track on the 52 MGT heavy traffic line. Five new No. 24 high-speed concrete tie double crossover special trackworks were installed to provide the capability to direct traffic from one track to the other as required to achieve the increased level of operating efficiency to accommodate increased numbers and speeds of trains. The decision was made to utilize asphalt trackbeds for the 20 turnouts at the five double crossovers.

The trackbed design for the five double-track crossovers included a 6 in. (150 mm) thickness of crushed stone subballast on the prepared subgrade topped with a 6 in. (150 mm) thickness of asphalt meeting NCDOT section 610 specifications. The asphalt extended for a continuous 1,135 ft (346 m) length to include the four turnouts. The same design was used for transitions extending additional 125 ft (38 m) lengths beyond the point of switch on both ends for a total length of 1,385 ft (422 m) for each double crossover. A 12 in. (300 mm) thickness of ballast was placed above the asphalt. The existing track was shifted as necessary to maintain traffic so that the asphalt could be placed under the existing track and the new track achieving a 29 ft (8.8 m) wide continuous asphalt pad under the two tracks while maintaining 14 ft (4.3 m) wide track centers. The logistical plan was designed to minimize delays to existing traffic while the asphalt paving and track shifting were underway.

A new WILD near China Grove was placed on No. 1 track. The track design included a 12 in. (300 mm) thickness of crushed stone subballast on the prepared subgrade topped with a 12 in. (300 mm) thickness of asphalt and 12 in. (300 mm) thickness of ballast. The asphalt pad was placed 12 ft (3.6 m) wide and 400 ft (122 m) long. The existing WILD on No. 2 track was removed and re-installed using the same track structure design as the new WILD.

The crossovers and WILDs are performing perfectly. The structural aspects of the trackbed appear to provide ideal combination of stiffness and flexibility for smooth passage of wheels over the rail flanges in the crossovers and provide consistent support along the measurement length of the WILD. Figure 10 shows construction views of the asphalt underlayment for one of the crossovers, a completed crossover at CP Lake, and the two WILDs near China Grove.

SECTION 11 OPEN TRACK

Asphalt trackbeds are selectively utilized for numerus open-track applications. Many of these have involved reasonably routine double-tracking and capacity improvement projects consisting of new roadbed construction for variable lengths. Therefore the asphalt can be rapidly and efficiently placed with conventional asphalt paving equipment normally used for highway paving.

Additional projects involve rehabilitating short sections of in-service tracks to enhance load carrying and drainage properties of the trackbed support. Depending on the lengths of the sections rehabilitated, track closures can range from 6 to 18 hours with adequate pre-project planning and successful project execution.

Following are description for two significant triple-track capacity improvements projects on the BNSF/UP railroads in the central portion of the U.S. Both of these required maintaining traffic during the construction processes.

Figure 10. Compacting the Layer of Asphalt and the Finished Asphalt Underlayment Layer in Preparation for Placing a No. 24 Crossover (top), a Finished Crossover at CP Lake and the Two WILDs near China Grove (bottom).

11.1 BNSF/UP Central Corridor Project in Wichita, KS

A multi-benefit application for asphalt trackbeds was incorporated into the design of the Wichita Central Corridor Railroad Grade Separation Project. This 4 1/2- year long project, recipient of national recognition and several awards, was completed in 2009. Two miles (3.2 km) of track was raised above the roadway providing five new bridges to carry trains over the five arterial streets below. Between the bridges, the tracks were elevated on a 25 ft (7.6 m) high embankment supported by precast concrete T walls. The primary benefits were to mitigate issues related to highway traffic congestion, delays, and vertical clearances for trucks while minimizing train-induced noise. The safety aspects for both highway and train traffic were enhanced by improvements provided by elevating the train tracks above the street and providing enhanced clearances for the street traffic. The elevated track also served to minimize noise from the 40-plus daily trains. Context sensitive solutions were incorporated throughout the project.

Various geotechnical innovations were used to insure that the embankment fill was sufficiently competent to withstand the loadings with minimum settlement of the fill material and underlying native materials. This included installing 3,000 stone columns ranging in length from 2 to 27 ft (0.5 to 8.2 m). The existing foundation materials consisted of highly variable sand and clay fill overlying various thicknesses of compressible silt and clay soils as deep as 27 ft (8.2 m).

The reinforcement measure used for the embankment permitted the use of economical, locally available sand for the embankment material. This was topped with a graded granular layer consisting of the salvaged ballast that met the required gradation for granular subballast. However it was deemed necessary to minimize water intrusion into the marginal quality embankment material to insure that its structural properties were not compromised inducing settlement and increased pressures on the retaining walls.

These issues were addressed by placing a layer of impermeable asphalt over the graded granular layer. The asphalt was placed 6 in. (150 mm) thick for the total width of 66 ft (20 m) between the vertical walls. The asphalt extended from the transition from the at-grade existing track at the north end to the tie-in with the existing elevated track 2.5 miles (4 km) south near the former train station. The asphalt was topped with 12 in. (250 mm) of mainline-grade ballast. The numerous surface mounted inlet grates were designed to intercept and convey rain water to drainage pipes that exit as weep holes near the bottom of the retaining walls. The paved trackbed is sufficiently wide to accommodate three tracks, although only two tracks were installed initially to handle existing railway traffic. Figure 11.1 shows construction views and the finished trackbed.

The performance of the paved trackbed over the past seven years has been excellent. This is viewed as a specific benefit of the asphalt layer by increasing the load carrying capabilities of the trackbed and decreasing water intrusion into the underlying trackbed support. No specific track maintenance has been required other than normal programed surfacing. The track geometry has consistently maintained conformance to the FRA requirements for Class 4 track with no track-related slow orders.

The traffic flow on the arterial streets has improved substantially. The improved bridge horizontal and vertical clearances provide for improved safety for street vehicles and marked improvement in aesthetics of the surrounding areas. The train induced noise has been significantly reduced which can be attributed to the sound-attenuating effects of the dissimilar graduated granular fill and the somewhat viscous layer of asphalt serving as a vibration damping and attenuation medium. Additional noise damping is attributed to the protruding vertical walls atop the T-walls and the elimination of train horns throughout the grade-separated corridor.

11.2 BNSF/UP Capacity Improvement Project near Eton, MO

An interesting application of an asphalt trackbed, based on engineering evaluation, was for a short section of an 8-mile (12.9 km) third track addition and curve reduction capacity improvement project on the BNSF Transcon Mainline east of Kansas City, MO. The trackage along the Missouri River between Congo and Eton Junction, near Eton, contained this section of trackage that had historically required frequent track maintenance. Track surfacing was extensively utilized, at times nearly continuously, to maintain required geometric parameters. This was due to the native shale in a cut area exhibiting poor quality engineering properties. In

addition, there were several 6 degree horizontal curves that required 35 mph (56 km/h) speed restrictions on this very heavy traffic 70 mph (113 km/h) BNSF and UP combined trackage line.

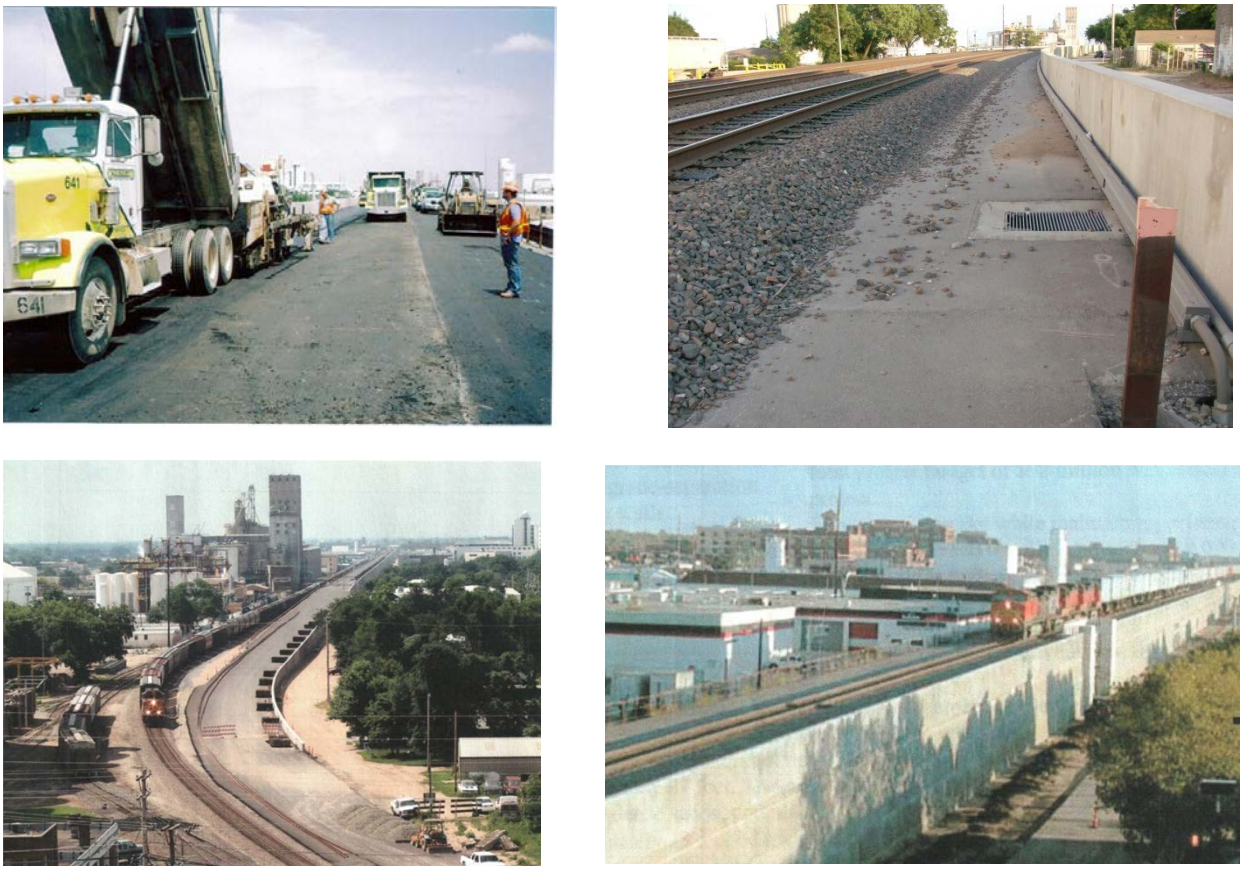

Figure. 11.1. Paving the Elevated Trackbed and the Finished Trackbed are shown in the top views. The bottom Views show the Exposed Asphalt on the North End of the Elevated Track prior to Placing the Track and the Precast Concrete T-Walls and Mechanically Stabilized Earth Walls.

Studies indicated that a third track was needed to increase capacity for efficiently accommodating the projected increased BNSF and UP traffic in this area. Also a solution was sought to mitigate the adverse performance of the shale, assumed to be an even more significant problem with newly exposed materials. In addition, the horizontal curves resulted in reducing train capacity and performance while accruing added track maintenance costs which included frequent curve rail replacement. There were also some environmental constraints relative to impacting restricted areas within the flood plain that could be disturbed and encroachment restraints on previous environmentally sensitive areas. This required considerable excavation in the adjoining hillsides to move the extra track closer to the hillside and farther from the river.

Therefore the decision was made to decrease the curvature of several horizontal curves to straighten the horizontal alignment to improve operating performance during the construction of the third track. In addition an asphalt trackbed was selected to minimize the adverse effects of the poor performing native shale material through the cut for 900 ft (275 m). As soon as the subgrade was prepared, the grade was immediately paved with a 6 in. (150 mm) thickness of asphalt.

This was considered necessary to minimize the high shrinkage values and associated loss of strength of the shale material since it slaked upon exposure to weather, resulting in excessive cracking and water absorption. This process was performed while maintaining traffic on the existing line. The use of asphalt on other non-shale segments of prepared subgrade was evaluated, but the abundance of on-site limestone available for crushing resulted in a 12 in. (300 mm) thickness of aggregate subballast sections being significantly less costly than a 6 in. (150 mm) thickness of asphalt for the remainder of the project.

Asphalt was placed under all three tracks for a distance of 900 ft (275 m) from MP 437.45 to 437.62 during the period in April, 2010. Figure 11.2 contains views of the construction process and the finished track in service.

During the six years since the re-aligned track and third main have been in service the section of track over which the asphalt underlayment was used has shown no instability due to subgrade problems. The only maintenance required is regular surfacing. No geometry defects have been noted. The use of the asphalt underlayment appears to have mitigated possible trackbed instability problems due to constructing the re-aligned track over the native shale material.

SECTION 12 CONCLUDING COMMENTS

The United States railway industry continues to emphasize the importance of developing innovative trackbed design technologies for both heavy tonnage freight lines and commuter/transit 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 often considered as a common or standard practice. Asphalt trackbeds have been primarily limited to heavy tonnage freight lines and commuter/rail transit 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. Based largely on its proven performance it is considered a standard engineering design practice for specified types of applications on a variety of freight railroads and commuter/transit

Figure 11.2. Construction Views (top) in 2009 showing the Asphalt Paving through the Shale Cut for the Curve Reduction Project. Finished Views (bottom) of the Re-Aligned Track through the Shale Cut; 2011 View on left and Recent View on right.

rail lines in the United States. This technology also has demonstrated applications for the construction of numerous new high-speed passenger lines in Europe and Asia.

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.

The projects described herein were all designed and installed using highly technical standards of engineering practice relating to the developed technology for using a layer of asphalt, termed "underlayment", within the track structure to achieve specified high standards for trackbed performance. This factor is largely responsible for the perfect to near-perfect performances for all of the forty projects included and evaluated in this study. The coverage reported herein is not

all-inclusive, but represents typical, pertinent, and unique applications of which the author is familiar.

SECTION 13 ACKNOWLEDGEMENTS

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