Asphalt Railway Trackbeds: Recent Designs, Applications and Performances

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ABSTRACT

The international railway industry continues to emphasize the importance of developing innovative trackbed design technologies for both heavy tonnage freight lines and high-speed passenger lines. The purposes are to achieve high levels of track geometric standards for safe and efficient train operations while minimizing long-term track maintenance costs and extending track component service lives. During the past several decades designs incorporating a layer of asphalt (or bituminous) paving material as a portion of the railway track support structure have steadily increased until it is considered as a common or standard practice.

This technology has demonstrated applications for the construction of numerous new high-speed passenger lines in Europe and Asia. Asphalt trackbeds have been primarily limited to heavy tonnage freight lines in the United States, most often for maintenance/rehabilitation of special trackworks – such as turnouts, rail crossings, highway crossings, wheel impact load detectors, tunnel floors, bridge approaches, etc., or capacity improvements of existing lines. It is also being specified for new and rehabilitated urban rail transit/commuter lines.

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

Various factors are discussed that are considerations in the design phases. Also included are subsequent performance-based tests and analyses. Illustrations of the trackbed/roadbed components, construction phases, and finished projects are presented for various asphalt trackbed applications in several countries, including Italy, Japan, France, and Austria.

INTRODUCTION

Railway trackbed structural design techniques have evolved from the initial 1830s designs that provided for the two parallel rails positioned on widely-spaced wood cross ties laid on the natural ground. It soon became obvious that the quality of the support under the ties should be improved. Natural stone aggregate (later knows as ballast) was deemed necessary and desired for
placement around and under the ties to restrain excessive horizontal and vertical movements and displacements; thereby providing an improved track structure. Thus, the classic *All-Granular* support trackbed was defined; also termed the “ballasted” trackbed.

As wheel loads, train frequencies, and speeds further increased attention was given to specifying larger rail size, selecting larger size ties that were spaced closer, and specifying a certain quality and width/thickness of ballast around and below the ties. The ultimate objectives were to reduce the imposed loadings to within the bearing capacity of the natural subgrade material, thereby providing uniformly strong support. Drainage was realized early-on as being very important, since most subgrade materials tended to lose considerable load-carrying capacity when they became wet or saturated. Thus draining surface water from within the track and directing water away from the track as expeditiously as possible were prime considerations.

A further refinement of the support structure was the introduction of a specified thickness of a granular “subballast” material between the ballast and subgrade. Typically this was a locally available aggregate material that had smaller top size than typical ballast and contained considerably more fine-sized particles. It would compact to a very low void content with very low permeability and was similar to the aggregate base material widely used for highway construction. Its main purposes were and still are -- to provide support for the ballast, further distribute the loadings, and provide a certain level of waterproofing for the underlying subgrade. This improves the quality and load-carrying capability of the track structure. This trackbed design is known as “All-Granular” since no additional cementing or binding materials are incorporated in the various support materials and layers.

The classic investigation of factors affecting the design of track structures resulted in guidelines presented in the A.N. Talbot reports. These reprinted reports, based on research studies conducted from 1913 to 1942, contain empirical relationships for determining subgrade pressures and selecting ballast thicknesses (AREA, 1980). The reports were reasonably current for the time period, but mechanistic designs applicable for assessing a variety of trackbed designs have been developed during the past few years and currently have limited, but increasing utilization.

Figure 1 depicts the classic or traditional “All-Granular” trackbed design. For high-type trackbeds the quality of the materials and associated dimensions of the materials and layers are specifically selected and specified. It is assumed that proper attention is given to providing surface drainage to minimize the possibility of standing water seeping into the track structure, thus weakening the subballast or subgrade. The high-traffic mainline tracks require higher quality and thicker layers of ballast and subballast to resist the loadings and to effectively distribute the loadings to the underlying subgrade layer. Variations of this design have been common for the majority of trackbed construction since the late 1800s and are currently the predominate design of railway track structures throughout the world. During the past 30 or so years, additional designs, incorporating asphalt layers, have been gaining favor with designers and specifiers for specific applications in-lieu-of the classic all-granular design.
Since the early 1980s, the U.S. railroad industry has been selectively utilizing Hot-Mix Asphalt in the track structure as a support layer. Applications have been gaining favor in other countries as well. The layer of asphalt, similar in composition to that commonly used for highway construction, distinguishes the track structure from the classic all-granular trackbed. This development is in response to the impending challenges to provide higher quality and longer lasting track and support structures to accommodate the unprecedented growth in rail traffic volumes, revenue ton-miles, axle loadings, and tonnages being experienced throughout the world. Primary emphasis has been placed on developing and evaluating the asphalt trackbed technology for heavy-tonnage freight railroads in the United States and high-speed passenger railways in other countries.

Three basic types of asphalt trackbeds are being utilized. 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 typical cross-section is shown in Figure 2a. The “Asphalt Combination” trackbed includes both the asphalt layer and the granular subballast layer. The asphalt layer thickness may be lessened somewhat since a relatively thick subballast layer exists below. Figure 2b depicts this design.
The “Ballastless Asphalt Combination” trackbed consists of ties, 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 ties form lateral and longitudinal movement. Figure 2c contains a generalized view of the ballastless trackbed. Certain designs with unique features and configurations including concrete slab tracks are typically covered by patents.

![Figure 2c. Ballastless trackbed containing asphalt and subballast layers.](image)

TYPICAL ASPHALT TRACKBED DESIGNS IN THE UNITED STATES

Asphalt underlayment and to some extent the asphalt combination trackbed designs represent the bulk of asphalt utilization on U.S. railroads. The ballastless trackbed design is not as readily adaptable to current U.S. railroad construction and maintenance practices as is the ballasted designs. This discussion of typical U.S. practices relates to asphalt applications containing a ballast layer.

Asphalt underlayment design and construction standards for railways typically follow recommendations set forth by the Asphalt Institute (Asphalt Institute, 1998; Asphalt Institute 2007). The typical asphalt layer is approximately 3.7 m (12 ft) wide and is approximately 125 to 150 mm (5 to 6 in.) thick. For poor trackbed support conditions and high impact areas, a 200-mm (8-in.) thickness is commonly used. Thickness of the overlying ballast ranges from 200 to 300 mm (8 to 12 in.). Thickness of a granular subballast layer, if utilized, is usually 150 to 200 mm (6 to 8 in.) thick.

The typical asphalt mixture specification is normally the prevailing dense-graded highway base mix in the area having a maximum aggregate size of 25 to 37.5 mm (1 to 1 ½ in.). The asphalt binder content can be increased by 0.5% above that considered optimum for highway applications resulting in a low to medium modulus (plastic) mix, having design air voids of 1 to 3%. This mix is easier to densify to less than 5% in-place air voids and therefore facilitates adequate strength and an impermeable mat. Rutting of the plastic mix is not a concern in the trackbed since the pressures are applied through the ballast over a wide area. Bleeding and flushing are also of little concern since the wheels do not come in direct contact with the asphalt layer and the temperature extremes are minimized in the insulated trackbed environment.
TYPICAL TRACKBED INSTALLATION PRACTICES IN THE UNITED STATES

The equipment required for installing the asphalt layer varies depending on the size of the installation. For short maintenance/rehabilitation projects, the asphalt is normally back-dumped on grade and spread with a trackhoe, small dozer, bobcat, etc. already on site, prior to compacting with a conventional vibratory roller. This process requires that the old track panel be removed. Thus the cost to place the asphalt is minimal, basically no more than placing conventional granular subballast. The cost of the asphalt material delivered to the job site adds a small percentage to the total track removal and replacement costs but is basically insignificant, since it replaces the granular subballast. The majority of the costs involve equipment, labor, and track materials. The added time to the track outage to place asphalt is insignificant, provided the track is to be removed and the underlying ballast/subballast replaced with new ballast.

For larger out-of-face projects, mainly new construction with a prepared subgrade, the asphalt is placed with conventional asphalt laydown (paving) equipment and compacted with large vibratory rollers. The procedure is similar to highway construction. The cost of the asphalt may be less than the cost of granular subballast if quality granular subballast has to be transported long distances due to insufficient quality or quantity in the immediate area. Normally, asphalt is compatible with a wide variety of aggregates. The thickness and width of the asphalt is less than that of granular subballast, thus about one-half or less material is required, which is also a cost advantage for asphalt. The asphalt can be placed with highway paving equipment as rapidly as highway paving with much less hand-work and concerns of smoothness.

INTERNATIONAL APPLICATIONS AND PRACTICES

Italian Railway Asphalt Applications

The Italian Railways have been active in the initial development and application of bituminous trackbeds for their high-speed rail network that extends more than 1,000 km (620 miles). The original and most traveled Italian high-speed line is the "Direttissima", which spans 254 km (150 miles) between Rome and Florence. In the 1970s, when this line was being constructed, it was determined by the Italian Railway Company (Ferrovie dello Stato) that a minimum bearing capacity of 180 MPa (26,000 psi) was required to properly support the ballast for the lines. Two materials were proposed that met this requirements, a cement treated gravel and a bituminous mix, with the ultimate decision being on the bituminous mix because of its high performance and lower import cost (Teixeira and Lopez-Pita, 2005). It was decided by the Ferrovie dello Stato to implement bituminous mix as subballast on all sections of the Rome to Florence line as long as the material continued to satisfy the following requirements: eliminate high stress loads and failures of the embankment, protect the embankment from freeze/thaw deterioration, eliminate ballast fouling, distribute the static and dynamic stresses from trains, and prevent rainwater from seeping into layers below the embankment (Buonanno, 2000).

The Italian High-speed Railway is a multilayered system consisting of an embankment, super-compacted sublayer, asphalt subballast, ballast, ties, and rail. Its cross sectional profile is shown in Figure 3. To maintain proper geometrical alignment for high-speed operations, construction practices place a heavy emphasis of the placement of these layers. The bottom section of the embankment must provide a minimum specified bearing capacity of 40 MPa (5,800 psi), and is constructed of an anhydrous material that does not exceed 50 cm (20 in.) in thickness. The material is compacted using static and vibratory compaction methods. To ensure
proper compaction, Italian quality control mandates that 2,000 m² (2,390 yd²) of the embankment must be tested.

![Figure 3 Italian High-Speed cross-sectional profile (Teixeira and Lopez-Pita, 2005).](image)

The 30 cm (12 in.) super compacted layer with a minimum subgrade modulus of 80 MPa (11,600 psi) is placed on the embankment. The super compacted layer is consists of sand/gravel mixture and is constructed with a cross slope of 3.5% (Policicchio, 2008). This layer has the ability to withstand the repeated loads of the high-speed trains and it serves as an impermeable layer to help divert surface water.

The asphalt subballast layer is placed above the super compacted layer. It consists of a bituminous mix with a maximum aggregate size of 25 mm (1 in.). This layer has a thickness of 12 cm (5 in.) and is applied over the entire track cross section, a total of around 14 m (46 ft) (Teixeira, 2009). The asphalt subballast must provide a minimum modulus of 200 MPa (29,000 psi) to stand up to the repeated wheel loadings and reduce stress to the embankment. The Ferrovie dello Stato have taken advantage of multiple benefits the asphalt provide over traditional granular subballast including 1) reduced vibration and noise levels, 2) reduced cross sectional thickness, 3) reduced lifecycle cost on the infrastructure from reduced subgrade fatigue, 4) increased homogenization of track bearing capacity and better ballast confinement, 5) reduced ballast fouling due to improved drainage, and 6) increased structural reliability and safety due to increased modulus and uniformity (Teixeira and Lopez-Pita, 2005), (Policicchio, 2008).

Standard asphalt paving machines are used to place the asphalt subballast (see Figure 4). It is then compacted to 98% of its maximum density using vibrating rollers. The asphalt mixtures adhere to all Marshall design standards. To ensure the mixtures adhere to specifications, verification tests are performed every 10,000 m³ (13,000 yd³). A falling weight deflectometer is used to verify dynamic response with three tests for every 100 m (330 ft) of track.

![Figure 4. Placing hot-mix asphalt underlayment on Italian high-speed rail line.](image)
For the past 20 years, all Italian railways have been constructed using this method (Buonanno, 2000). Upon the completion of the North-South and East-West high-speed passenger lines, the Italian High-Speed Network will consist of over 1,200 km (745 miles) of track with asphalt subballast (Teixeira, 2009).

**Japanese Railway Asphalt Applications**

For many years the Japanese have been using asphalt trackbeds on both high-speed and regular lines in order to reduce track irregularities and provide a firm support for the ballast. The asphalt trackbeds help to reduce load level on the subgrade to prevent subgrade deformation (Momoya and Sekine, 2007). "Design Standard for Railway Structures (Earth Structures)" describes the design methods for trackbeds. In January of 2007, a revision was made to the design standard to account for the fatigue life of the track as it is affected by the number of passing trains. This new guideline allows for designers to design asphalt trackbed thicknesses to satisfy their expected roadbed performance requirements (Momoya, 2007). The new performance-based design procedure classifies three standard track designs as follows:

- **Performance Rank I:** Concrete roadbed or asphalt roadbed for ballastless track
- **Performance Rank II:** Asphalt roadbed for ballasted track
- **Performance Rank III:** Crushed stone roadbed for ballasted track

Performance Rank I track is a ballastless slab track that has either concrete or asphalt support with concrete ties directly fixed to the slab and is considered the highest quality track. To ensure the highest level of performance, it is checked for track settlement, breakage of concrete reinforcement base, fatigue damage, cracking, contraction, and thermal stresses. Typical layer thicknesses for the Performance Rank I asphalt ballastless track are: concrete slab = 190 mm (7.5 in.), asphalt concrete base = 150 mm (6 in.), and well-graded crushed stone layer = 150 mm (6 in.).

Performance Rank II design is a ballasted track with only a 50 mm (2 in.) thick asphalt layer. This design has been used for over 30 years in Japan because of asphalt’s ability to distribute loads and expedite drainage. Performance Rank II typically has the following layer thicknesses: ballast = 250 to 300 mm (10 to 12 in.), asphalt concrete layer = 50 mm (2 in.), and well-graded crushed stone layer = 150 to 600 mm (6 to 24 in.).

Performance Rank III is the typical design used for all-granular design. It is comparable to the typical all-granular trackbeds used in the United States.

**French Railway Asphalt Applications**

The French high-speed rail network currently comprises more than 1,800 km (1,120 miles) of double track lines operating at maximum speeds of 300 km/hr (186 mph). In 2009, a new world record was set when a section of the TGV-East line between Paris and Strasbourg reached 574 km/hr (357 mph). The French National Railway (SNCF) has been active in exploring the use of asphalt in railroad trackbed construction. Asphalt is viewed as an attractive building material because it can reduce the thickness of the ballast layers, it allows for easy placement of track and railway equipment, and it optimizes maintenance costs. In 2000, a feasibility study was conducted by SNCF & Colas so measure the effects of asphalt use under a high speed line. A 3-km (1.9-mile) long strip of the European High Speed line between Paris and Strasbourg was
chosen as a test zone. This strip included a variety of track features including cuttings, embankments, and bridges which allows for a thorough view of asphalt's performance in multiple situations.

A traditional granular track bed cross section consists of 35 cm (14 in.) thick ballast resting on 20 cm (8 in.) thick gravel subballast. These both rest on a 50 cm (20 in.) thick capping layer. For their study, the SNCF used a 35 cm (14 in.) thick layer of ballast on a 15 cm (6 in.) layer of bituminous mix all resting on a 35 cm (14 in.) thick capping layer. This reduces the overall cross-sectional thickness by 20 cm (8 in.), which also significantly reduces the quantity of material needed to construct the track bed.

This asphalt test section was constructed in 2004 using machines designed for road building (see Figure 5). In order to continuously collect data, the test zone was outfitted with thermometers, accelerometers on the sleepers, pressure sensors, and extension gauges at the base of the bituminous layer. Figure 6 shows the instrument layout in the test zone.

The results of the comparative study of the asphalt trackbed versus the traditional granular trackbed indicate that 1) the overall cross-sectional thickness can be reduced by 36 cm (14 in.), the quantity of fill material can be reduced by 5,000 m^3/km (10,500 yd^3/mile), 3) pressures under asphalt layer in the bituminous track only reach half of the pressure measured under the granular layer of the traditional track, 4) deflections of the asphalt track are only one-third the maximum allowable deflection, 5) sleepers in both the traditional and bituminous track receive no distinguishable differences in accelerations, 6) variations in track stiffness is 40% lower, 7) track degradation rate is lower based on surfacing requirements, and 8) less maintenance is required on the asphalt track. Based on the superior performance of the asphalt trackbed, several more sections are planned (Bitume Info, 2005), (Robinet, 2013).

Four new high speed lines are being planned in France. A Morocco line and an 80 km (50 miles) CNM line are going to be built using 100% asphalt subballast layer. A 182 km (113 miles) BPL line will use 60% asphalt subballast, and a 280 km (174 miles) SEA line will use 40% asphalt subballast. There are also plans for similar studies at sites using recycled asphalt. Similar methods will be used to confirm the behavior of this asphalt. An experiment in Lingolsheim is testing a 150 m (490 ft) track using asphalt without ballast. No results have been published from this test yet (Robinet, 2013).
Austrian Railway Asphalt Applications

Over the past few decades, the Austrian Federal Railways have developed substantial technical experience and economic effect evaluations on asphalt layers in railway trackbed construction. Typical Austrian trackbeds consist of an 8 to 12 cm (3 to 5 in.) thick layer of asphalt beneath the ballast bed installed with conventional rail unbound equipment. After the asphalt is placed, the superstructure is built using state-of-the-art track laying equipment. The main advantages of using an asphalt layer are as follows: 1) prevention of rain water from penetrating the substructure, 2) prevention of fines pumping upward, 3) obtaining optimum levels of elasticity, and 4) obtaining consistent support to homogenize stresses on the substructure.

The asphalt layer is more costly than a typical granular layer meaning it requires additional investments. The expected benefits of the asphalt must balance the additional cost; therefore a lifecycle economic evaluation was performed to justify using asphalt.

An analysis of 3,800 km (2,360 miles) of Austrian track shows the actual quality ($Q_t$) corresponds to the initial quality ($Q_0$) multiplied by $e$ to the power of the rate of deterioration ($b$) over the elapsed time ($t$) (Veit, 1999). However, due to different track conditions such as transport load, age, and subsoil conditions, the rate of deterioration varies. Research at the Institute for Railway Engineering and Transport Economy at Graz University of Technology, based on more than two million e-functions, the relevance of different parameters has been analyzed in detail (Holzfeind and Hummitzsch, 2009), (Holzfeind and Hummitzsch, 2008).

Analyses of the track quality behavior on the Schoberpass section of the Pyhrn route in Austria show a significant difference in the deterioration rate of asphalt layers compared to sections without asphalt. The deterioration rate per year was reduced by 33 percent by using asphalt. This deterioration rate reduction increases the level-line-tamping cycle from 3 years to 5 years which leads to a 17% increase in the tracks service life and a reduction in annual average track cost.

The first asphalt layer was installed in Austria in 1963. This long-lasting source now allows for studies of the longevity of asphalt layers. In the 1990s, the superstructure of this track was replaced. At this time the asphalt layer was inspected and repairs were found to be unnecessary. Currently asphalt layers of 8 to 12 cm (3 to 5 in.) form a standard element for new high capacity and high speed lines in Austria.

DOMESTIC INSTALLATIONS

Railroads in the United States have been selectively using asphalt trackbed maintenance applications since the early 1980s and more recently for new construction, particularly for line capacity improvements and re-alignment projects.

The Santa Fe Railway (now part of BNSF) in the Kansas and Oklahoma areas, and a predecessor line to CSX Transportation, L&N Railroad/Seaboard System, in the Kentucky area, were the initial railways to become heavily involved with using asphalt underlayment. These initial installations, considered “experimental” were made during the early 1980s. These two large railways and numerous others have placed hundreds of asphalt underlayments in the ensuing years and the numbers continue to increase each year.

The largest open-track asphalt underlayment trackbed construction projects placed in service in the United States are on a portion of BNSF’s high-speed, heavy-tonnage, and high-traffic transcontinental main line east of Amarillo, Texas, through the panhandles of Texas, Oklahoma, and Southern Kansas. This largely single track line was selected for double-tracking.
to increase capacity. The ongoing project is being done in phases over a period of years and is nearing completion.

A select soil subgrade, properly placed and compacted, was selected for each project. A 150-mm (6-in.) thick asphalt layer, placed in two lifts, was paver-laid on the select subgrade. A 300-mm (12-in.) thick layer of ballast and concrete ties were used above the asphalt. Densities and other asphalt and subgrade parameters were closely monitored.

Over 322 km (200 miles) of asphalt trackbed design have been placed during new track construction in the mid-west area (Lusting, 2007). Figures 7 and 8 show the placing of the asphalt and the track, respectively. This represents the norm for other U.S. railroads, although the asphalt layer thickness is frequently increased for special trackwork installations, particularly if trackbed instability in the area is evident.

The majority of the early installations involved the rehabilitation of short trackbed sections that historically had required substantial maintenance. The predominance of these were at special trackwork --- highway crossings, turnouts (switches), railway crossings, and crossovers, bridge approaches, and tunnel floors. Several large classification, automobile-unloading, intermodal, and bulk intermodal distribution yards also utilized large expanses of asphalt underlayments. (Rose, 2013)

Based on the improved performance of these early installations, countless railroads and rail agencies, including short lines and other large-size railroads, routinely consider and often specify asphalt underlayment or asphalt combination trackbeds when renewing special trackworks or chronic track instability sites. These include standard specifications for the materials and structure configuration. Activities for several representative agencies and companies are described.

During the past 15 years, Caltrain in the San Francisco Bay area has installed asphalt underlayments at numerous special trackworks. These include – ten No. 20 crossovers, twelve turnouts, 59 street and pedestrian crossings, track through ten stations, four tunnel approaches, two tunnel inverts, and approaches to 15 bridges. Typical asphalt layer thickness is 200 mm (8 in.).

Metrolink, the large commuter rail system in the Los Angeles area of Southern California, during the past eight years has installed asphalt underlayments at more than 70
highway crossings, plus several bridge approaches, turnouts, crossovers, and yard tracks. It is considered as a standard practice for construction and re-habilitation of special trackworks. The performance has been excellent. Standard practices, similar to Caltrain, have been adopted.

The West Virginia Department of Transportation (WVDOT) has been a lead state in adopting asphalt underlayment during the renewal of highway crossings. WVDOT began applying this technology in 2000 and since that time has averaged 7 or 8 per year, with 14 in 2013. It is estimated that over 125 highway crossings have asphalt underlayment, the oldest having been in service 15 years. These are selected for high volume highway/heavy tonnage railway crossings that have not performed well using conventional practices. Most of these are on CSXT and NS lines. The asphalt is typically 150 mm (6 in.) thick. WVDOT pays for the crossing surface upgrade to premium, the asphalt underlayment and traffic control. It is a standard practice if state funds are used. No failures have been observed due to lack of support for the crossing. It is considered a betterment program to upgrade crossings for improved performance. Figure 9 is typical of an upgraded WVDOT crossing renewed with asphalt underlayment.

Figure 9. WVDOT upgraded crossing project on CSX in Bridgeport, WV.

The Iowa Department of Transportation (IADOT) began a program similar to that of WVDOT in 2000. Since that time over 100 of the 167 crossings on the IADOT primary system have been underlain with asphalt. Railroad production track work can normally skip the crossings since only minor settlement and normal weathering of the crossing material are observed. It is considered a standard practice when IADOT funds are utilized to upgrade crossings. No crossing failures have occurred to date due to structural problems or settlement when IADOT practices are followed. The Iowa protocol is an application-based system that places emphasis on crossings that have historically exhibited structural problems, some crossings requiring renewal on two-year cycles. After installing a properly designed asphalt underlayment, the service lives have increased significantly, and the backlog of poorly performing crossings has been significantly reduced with a minimum number of crossings requiring renewal each year.

The Portland & Western (P&W) Railroad in Western Oregon normally installs 12 to 15 rail/highway crossings per year with asphalt underlayments. The Oregon DOT funds the materials. Several of these involve long stretches of street-running railroad. Also included are all 18 public crossings on the TRIMET Westside Express Service (WES) commuter line rehabilitated on the old Oregon Electric Line during the re-construction of the line for commuter service and freight service. Historically, highway crossings presented challenges in this high
annual rainfall climate and muddy, settled crossings were common. However, since the adoption of asphalt underlayment and attention to insuring that adequate drainage is incorporated with the impervious asphalt mat, the crossings have performed perfectly with no mud and no surfacing/renewal required. Figure 10 is a typical crossing for a street-running section of trackage.

![Figure 10. Street-running P&W rail/highway crossing in Oregon.](image)

The Illinois Department of Transportation (IDOT) and Illinois Commerce Commission (ICC) began the adoption of asphalt underlayment during the rehabilitation/renewal of crossings throughout the state around 2010. It is estimated that over 100 crossings have been underlain with asphalt during the past five years. Various criteria are used to justify the state’s participation with the railroad companies. The majority of the state-assisted funding projects for crossing renewals specify the use of asphalt underlayment.

The utilization of asphalt underlayments is not confined to large Class I railroads. Numerous Shortline and Regional railroads are also involved. A sampling of these include Transkentucky Transportation with over 50 installations, the Louisville & Indiana Railroad with over thirty highway crossings and a similar number on the Indiana Railroad. The Paducah & Louisville has been involved with highway crossings and numerous approaches to realigned bridges. Figure 11 shows a new bridge over the Tennessee River in Kentucky that has 2500 feet of bridge approach trackage underlain with asphalt.

![Figure 11. Approach to P&L Railway bridge at KY Dam (Tennessee River).](image)
During recent years, the use of asphalt underlayment has become a standard practice for new installations and re-habilitating wheel impact load detectors (WILDS). This is particularly the case with the two large Eastern US railroads – Norfolk Southern and CSX. The majority of the WILDS on the NS and CSX have asphalt underlayments. The primary purpose is to gain the advantage of consistent trackbed support provided by the structural and imperious layer of asphalt. Therefore, deviations in measurements are due to variations in wheel smoothness without undue influence from variable support affecting the impact forces and track movement. Figure 12 is view of a WILD installation.

Asphalt underlayment has also been used as a means to level the floor and improve drainage in tunnels and approaches to tunnels. The surface of the asphalt provides uniform support for the ballast and positive drainage to the portals. A notable application is its use in three tunnels that were being enlarged as part of NS’s Heartland Corridor Capacity Improvement project to accommodate double-stack container cars. The three tunnels had a long history of soft support and attendant drainage problems requiring frequent maintenance interfering with normal train operations on NS’s mainline. Figure 13 is a view of one of the tunnels prior to replacing the ballast and track.

Figure 12. CSX WILD in Northern Indiana.

Figure 13. NS tunnel near Williamson, WV on the Heartland Corridor.
Asphalt underlayment has been placed on numerous bridge approaches in order to provide transition in track stiffness and facilitate drainage providing consistent structural support in the immediate area. Perhaps CSX’s 1998 bridge replacement at Bridgeport, AL consisting of 425 m (1400 ft) of re-aligned approach tracks containing asphalt underlayment represents a significant long-term achievement. The approaches have required essentially no surfacing and the track geometry has been near perfect during the intervening 16 years for this heavy tonnage mainline. Figure 14 is a recent view.

Figure 14. CSX bridge at Bridgeport, AL constructed in 1998 with asphalt underlayment approaches.

Special trackworks – turnouts, crossovers, rail crossings, hump retarder tracks, and highway-railway at-grade crossings – containing asphalt underlayments have consistently exhibited improved performance to withstand the heavy axle loads and additional high-dynamic impact loadings inherent to these track anomalies. An example is the placement of No. 20 equilateral turnouts on NS’s Heartland Corridor project, as shown in Figure 15.

Figure 15. No. 20 equilateral turnout on NS near Williamson, WV.
TRACKBED MATERIALS TESTS AND EVALUATIONS

Numerous in-service trackbeds have been subjected to materials sampling and core-drilling to ascertain the properties of the subgrade and asphalt materials. The primary purpose was to determine if any weathering or deterioration of the materials was occurring in the trackbed environment which could adversely affect long-term performance (Rose and Lees, 2008). Summary discussions of the findings follow:

Material characterization evaluations were conducted on asphalt cores and subgrade/roadbed samples from eight asphalt trackbeds. The trackbeds were from 12 to 29 years old when tested and were distributed over five states. The inherent conditions varied significantly from site-to-site. These included asphalt thickness and composition, ballast thickness, trackbed support, and traffic. Previous characterization evaluations were available for the projects and the results were included for comparisons with recent evaluations (Rose, et al., 2000).

The significant finding, relative to the materials (old roadbed/subgrade) directly under the asphalt layer, is that the in-situ moisture contents are very close to laboratory determined optimum values for maximum density of the respective materials. The asphalt layer is not performing as a membrane to collect and trap moisture, thus weakening support. Actually, since the in-situ moisture contents are at or near optimum for maximum density, the strengths and load carrying capacities of the underlying materials are also at or near optimum. Furthermore, average moisture contents remain essentially unchanged, at or near optimum, for the two projects from which previous data was available. For design purposes, it is reasonable to base strength or bearing capacity values at optimum conditions (moisture content and density) for the material under the asphalt layer. Using strength or bearing capacity values determined for the soaked condition, common for highway designs, is inappropriate for asphalt trackbed designs. The unsoaked, optimum moisture content condition is consistent with in-service trackbed conditions.

An equally significant finding, relative to the asphalt cores characterizations, is that the asphalt binders and asphalt mixes do not exhibit any indication of excessive hardening (brittleness), weathering, or deterioration even after many years in the trackbed environment. This is considered to be primarily due to the insulated effects of the overlying ballast which protects the asphalt from excessive temperature extremes and oxidation and hardening of the asphalt binder. These factors will contribute to a long fatigue life for the asphalt layer. There is no indication that the asphalt layers are experiencing any loss of fatigue life based on resilient modulus test on the extracted cores.

The typical failure modes experienced by asphalt highway pavements are 1) rutting at high temperatures, 2) cracking and fatigue at low temperatures, 3) stripping/raveling under the suction of high tire pressures on wet pavements, and 4) progressive fatigue cracking due to inadequate subgrade support, generally augmented by high moisture and improper drainage. These conditions do not exist in asphalt railroad trackbeds. For example, the temperatures are not sufficiently high to promote rutting. Conversely, the temperatures are not sufficiently low to promote low temperature cracking and decreased fatigue life. The asphalt binder does not weather or harden excessively in the insulated trackbed environment which would have further negative influence on cracking and fatigue life. Obviously, the tendency to strip/ravel is essentially eliminated in the trackbed environment since there is no rubber suction action. Also, the moisture contents of the underlying subgrade/roadbed support materials are maintained at or near optimum for maximum density and support strength.
Trackbed pressure (stress) measurements have been obtained at prevailing speeds under heavy tonnage railroad loadings. Pressure measurements were recorded using hydraulic type earth pressure cells. These are imbedded in the track structure above and below the asphalt mat. Peak pressures occur directly below the tie/rail interface (Rose, et al., 2002).

Typical peak dynamic vertical pressures, on top of the asphalt mat, range from 90 to 120 kPa (13 to 17 psi) for a typical 6-axle diesel electric locomotive – wheel load approximately 16,000 kg (35,000 lb) – traveling at 64 km/hr (40 mph). The asphalt mat pressures are reduced to 15 to 30 kPa (2.2 to 4.35 psi) under the empty freight cars, as noted in Figure 16. The beam action of the track, which distributes the concentrated wheel loadings over several ties and the confined, high modulus ballast layer, serve to effectively reduce the heavy axle loadings. The trackbed pressures for the typical locomotive are further reduced to 35 to 50 kPa (5 to 7 psi) under the asphalt layer at the subgrade interface as noted in Figure 17 (Li, et al., 2001).

By comparison, an 82 kg (180 lb) person will exert about 40 kPa (6 psi) pressure while standing on a level surface. Furthermore, typical tire pressures imposed on highway asphalt surfaces under loaded trucks range from 700 kPa (100 psi) to over 1400 kPa (200 psi) depending on the magnitude of loading and tire configurations. Therefore the pressures exerted on the asphalt mat in the track structure are only a fraction in magnitude of the pressures exerted by automotive and truck tires on an asphalt highway pavement surface.

Dynamic track deflections have been recorded in conjunction with the pressure measurements using linear variable displacement transducers referenced to a fixed datum. Rail deflections under 130,000 kg (286,000 lb) loaded freight cars average 6 mm (0.25 in.) for wood tie track, as noted in Figure 18, and around 1 mm (0.04 in.) for concrete tie track. These are considered optimum for both track types. (Rose, et al., 2002)
Calculated dynamic track modulus (stiffness) values are in the 17 MPa (2,500 psi) range for wood tie track and around 52 MPa (7,600 psi) for concrete tie track, as noted in Figure 19. These are also considered optimum. The concrete tie track deflects much less than the wood tie track and is thus much stiffer. This increases pressure values within the ballast. The ballast must be properly supported from below so it can develop high shear strength to reduce the higher than normal imposed loading pressures. The high modulus asphalt layer provides increased support and confinement for the ballast in concrete tie track. (Li, et al., 2001).

RECENT INNOVATIONS

Several modifications to the typical hot-mix asphalt underlayment applications are currently being evaluated. These include 1) the use of ballastless trackbeds on asphalt underlayments for highway/railway at-grade crossings on low speed, light tonnage rail lines, 2) the use of polymer-modified cold mix asphalt mixes in-lieu-of hot-mix asphalt mixes to minimize logistics of hot-mix delivery and storage, and 3) the use of economical all-asphalt crossing surfaces with asphalt underlayment for reasonably low-speed, light traffic lines.

Test Results for Track Modulus and Subgrade Stress*

- Calculated dynamic track modulus (stiffness) values are in the 17 MPa (2,500 psi) range for wood tie track and around 52 MPa (7,600 psi) for concrete tie track, as noted in Figure 19. These are also considered optimum. The concrete tie track deflects much less than the wood tie track and is thus much stiffer. This increases pressure values within the ballast. The ballast must be properly supported from below so it can develop high shear strength to reduce the higher than normal imposed loading pressures. The high modulus asphalt layer provides increased support and confinement for the ballast in concrete tie track. (Li, et al., 2001).

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CLOSURE

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

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

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

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REFERENCES


Asphalt Railway Trackbeds: Recent Designs, Applications and Performances

Jerry G. Rose and Reginald R. Souleyrette
Professors of Civil Engineering
Department of Civil Engineering
University of Kentucky
OUTLINE

I. Introductory Remarks
II. International Applications – Four Countries
III. United States Applications – Special Trackworks
IV. Trackbed Response Measurements, Materials Tests & Evaluations


The Two are Related and Both are Requirements

Railroad Track and Roadbed Designs in the U. S. Evolved Over Time

Then came the Ballast Rock and Ditches

So the All-Granular Trackbed/Roadbed Evolved and is by far the Most Prominent Type of Track Structure today

Idealized Track Cross-Section

- Railroad track and structure are designed to be economical and easy to maintain

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Structural Design
Methods used to design track and cross-section

- Trial and Error – based on experience
- Empirical – based on trial and error
- Empirical/Rational – measure loadings and material properties
- Rational – stress/strain analysis and measurements

Use Standard Section !!!

Asphalt Underlayment trackbed without granular subballast layer
Typical Thickness (in.)
12
6
Asphalt Combination trackbed containing both asphalt and subballast layers
Typical Thickness (in.)
12
6
Ballastless trackbed containing thickened asphalt and subballast layers

Dense-Graded Highway Base Mix
- 1 – 1 ½ in. Maximum Size Aggregate
- Asphalt Binder +0.5% above Optimum (optional)
- Low to Medium Modulus Mix, 1 - 3% Air Voids (optional)

I. Comments – Introductory Remarks

The majority of Railroad Trackbed and Roadbed Designs on the U.S. Railroad System Evolved mainly through Trial and Error; later based on Empirical Measures

Essentially all U.S. Trackbed/Roadbeds are composed of All-Granular Support Layers

Periodic Maintenance (surfacing) of the track is necessary to maintain the required Track Geometric Features

Each Trackbed Support Layer provides specific Qualities; Combined the Layers represent a System

Computer Systems (finite element/layered analysis) can be used to Design and Analyze Layered Track Structures and Determine Relative Effects of Various Layer Compositions

Typical types of Asphalt Trackbed Designs were described
II. International Asphalt Trackbed Applications

**Italy**
- Debated between cement and asphalt
- Asphalt – designated on all future high-speed passenger lines

**Japan**

**France**

**Austria**

- Prevents rainwater from infiltrating the layers below the embankment
- Eliminates high stress loads and failures of the embankment
- Protects the upper part of the embankment from freeze/thaw actions
- Gradually distributes static and dynamic stresses caused by trains
- Eliminates ballast fouling

Buonanno, 2000

**Typical Cross Section**
- 12 cm of asphalt with 200 MPa modulus
- 30 cm of super compacted subgrade with 80 MPa modulus
- 35 cm of ballast on top

Buonanno, 2000

**Italian Trackbed Construction – Improved Subgrade on left, prior to addition of Granular and Asphalt Subballasts on right**

**Advantages of Bituminous Subballast**
- Increased safety and structural reliability due to increased modulus and stability
- Reduced life-cycle cost on the infrastructure from reduced subgrade fatigue
- Increased load distribution of the track bearing capacity on the longitudinal profile and better ballast conformation
- Reduced ballast fouling due to improved drainage
- Reduced vibration levels throughout the track thereby reducing noise
- Reduced thickness compared to a conventional granular design

Policicchio, 2008

Teixeira, 2005
**Italian Railways Bituminous Trackbed Construction**

- Spreading and Compacting Ballast
- Compacting Subgrade and Placing/Compacting Asphalt

**Falling Weight Deflectometer for assessing Structural Competency**

**Station View of Completed Asphalt Trackbed**

**Japan**

- Widely Used
- High Speed/Regular
- Firm Support for Ballast
- Reduce Load Level on Subgrade
- Facilitate Drainage

Momoya and Salwe, 2007

**Performance Rank I**: Concrete roadbed or asphalt roadbed for ballastless track
- Concrete base thickness = 190 mm or
- Asphalt base thickness = 150 mm
- Stone base thickness = 150 mm

**Performance Rank II**: Asphalt roadbed for ballasted track
- Ballast thickness = 250-300 mm
- Asphalt base thickness = 50 mm
- Stone base thickness = 150-600 mm

**Performance Rank III**: Crushed stone roadbed for ballasted track

**Ballastless Cross Section**

- Mainly used for viaducts and tunnels
- Proposed a low noise solid bed track on asphalt pavement

**Ballast 200 mm thick**
**Ballasted Cross Section**

- Asphalt Thickness: 50 mm
- Well-Graded Crushed Stone Thickness: 15-60 cm

**France**

- Paris to Strasbourg high-speed line--2007
- 3 km asphalt subballast
- 574 km/hr (357mph) (test)

**Case Study**

- 3 Km Test zone with Asphalt under ballast
- Instrumentation:
  - Temperature Sensors
  - Accelerometers on the sleepers
  - Strain gauges at the base of the layer of asphalt
  - Pressure cells on subgrade support

**Comparative Cross-Sectional Profiles**
**Testing**

- Conduct tests for 4 years (2007-2011)
- Temperature sensors continuously recording air temperature
- Pressure Sensors and Strain Gages checked twice a year
- Accelerometers

![Image of testing setup]

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**Context**

The coated in the rail:

- Benefits of bituminous mixtures in the railway track:
  - Economies in Materials
  - Equipment Traffic During the yard
  - Increase of the Stability of the structure
  - Reduction of Maintenance efforts
  - Control of the Vibration

**Special features of the rail:***

- High speed → Dynamic efforts
- Axle Loads High
- Exposure to the Humidity
- Effort of Compression Constant (weight of the superstructure)

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**The test area for the LGV EE REX - Maintenance (2)**

- Classical Structure (PK 112):
  - Degradation rate constant
  - even after Maintenance
  - Operations
- Bituminous Structure (PK 110):
  - Lower rate of Degradation;
  - Better effectiveness of
  - Maintenance work, and
  - Attenuation of the Slope
  - After Jam

---

**Comments Relative to French Asphalt Track Section**

- Reduces overall cross-sectional thickness by 36 cm
- Reduces quantity of fill material by 5,000 cubic meters/kilometer
- Pressures under asphalt layer are one-half of granular sections
- Deflections of asphalt track are one-third of allowable
- Sleeper acceleration is not affected
- Less maintenance is required on asphalt track
- Asphalt track performs well

Based on performance, several more sections are planned

Source: Bitume Info, 2005 & Robinette, 2013
Partial Findings

- The use of bituminous layers in structure of railway track allows you to reduce the efforts of maintenance.
- The complex module and the Poisson coefficient complex are strongly dependent on the frequency of solicitation and the temperature.
- In terms of rigidity, the trains running at high speed does not seem to be problematic for bituminous mixtures.
- The mold flow model 2S2P1D is a tool of great value for the study of bituminous materials.

Reference:
Characterization of Thermomechanical Properties of Coated Bituminous Rail
By: Diego Ramirez Cardona
SNCF – French National Railways
October 31, 2014

Austrian Railways

Reasons for Implementing Asphalt Layers

How to install an Asphalt Layer?

Targets of an Asphalt Layer
- to allow road vehicles running on the sub-layer during construction phase independently from weather and sub-soil situation.
- clear separation of sub- and superstructure during the whole service life.

Advantages
- drainage effect for raining water hindering it penetrating the substructure.
- avoiding the pumping up of fines into the ballast.
- delivering a certain amount of elasticity.
- homogenising the stresses affecting the substructure.

Maintenance free asphalt layer since 1962.

Austrian Railways Conclusions

- Asphalt layers improve the quality of track in defining a clear and long lasting separation between superstructure and sub-structure. This separation results in less maintenance demands of track and (thus) longer service lives.
- These benefits must be paid by an additional investment of 10€/m² within the initial construction.
- Life cycle cost analyses show that it is worth to implement asphalt layers on heavy loaded lines (> 15,000 gt per day and track), as then the annual average track cost can be reduced by 3% to 5%.
- However, implementation of asphalt layers cannot be proposed for branch lines carrying small transport volumes.
- Asphalt Layers must be understood as an additional investment in quality, then it pays back its costs. It must not be implemented in order to reduce quality in sub-layers, but by example reducing the thickness of the frost-layers.

Rail Experiences with bituminous mixtures:
- LGV is European Phase 1:
  - 3كم Test Area
- Large PProject proponents:
  - LGV EE phase 2
  - LGV Bretagne Country-de-Loire
  - LGV Atlantic southern Europe-atlantic
  - Workaround
  - Nimes-Montpellier
Due to the long interruption of operation installing of asphalt layers are not proposed within track re-investment and maintenance operations.

Austrian Railways Implementation

Consequently asphalt layers of 8 cm to 12 cm form a standard element for new high capacity and high speed lines in Austria.

III. U.S. Asphalt Trackbed Applications

- Open Track
- Highway Crossings
- Tunnel Floors and Approaches
- Bridge Approaches
- Diamond Crossings
- Turnouts
- WILDS

II. Comments – International Applications

- There is considerable interest presently by selected International Railway Agencies to develop Innovative Trackbed Designs and Construction Techniques using Asphalt Trackbeds for New Line Construction, mainly for High-Speed Lines
- Recent Innovative Trackbed Structural Designs and Construction Techniques Using Asphalt Trackbeds over Periods of Years were featured for Italian, Japanese, French, and Austrian Railways
- The Asphalt Layer augments or replaces a portion of the Traditional Granular Support Layers providing documented Enhanced Properties to the Track Support Structure based on initial results from significant Research Studies and Evaluations
- Longer-term Research Studies and In-Track Performance Evaluations continue to indicate Significantly Improved Performances compared to Conventional Designs, confirming the earlier indicated Benefits
2. -- Railway/Highway At-Grade Crossings

Flemington, NJ
Norfolk Southern RR
MP 51.2 to 51.4
May 2015

600 feet of track removed
Track A (south track)
October 8, 2013

Portland & Western RR
SW Dumps Rd.
May 15-16, 2010

Rail/Highway Crossing Maintenance/Rehabilitation
WES
All 18 Public Crossings
P&W
12 to 15 Installations
Per Year

West Brownsville, PA
Monongahela Line
Hell Week
2011 = 936 feet
2012 = 736 feet
2013 = 704 feet
2014 = 627 feet
2015 = 0 feet
West Virginia Dept. of Transportation
US 50, Bridgeport
5th Avenue, Huntington, 2000
Since 2000
Est. 125 crossings in service
7 to 8 per year, 14 in 2013

Ashton, WV
WV 2
Installed November 2001
CSX – Ohio River Sub

Heartland, Aug. 2010, 3 tunnels in 72 hours
~ 2000 feet total near Williamson, WV
P & L Railway
KY Dam Bridge Approaches
Muldraugh's Hill Bridge Approaches
Ft. Knox, KY

Bridgeport, AL
1998
TN River Slough
CSX/NS 10 mph
70 MGT

Bridge 1470 ft long
AL Mainland – red clay/chert
Long Island – silty loam

Build 1100 feet of new track
Subballast, Asphalt, Ballast, Concrete Ties
Drain away from Abutment

One Day Fast Track

No. 5 — Renewing Railroad Diamond Crossings

Since 1999
15 Bridge Approaches
Caltrain

© AREMA 2015
Bear, DL to refinery – May 18, 2015
Single day in April 2013 to reinstall diamond removed previously
Norfolk Southern RR
Newcastle Secondary, Reybold Connecting Track

Greyeagle, WV Turnouts – 2012
Four No. 20 Equilateral Concrete Tie Turnouts

One Day per Turnout

During the two years, no additional surfacing, no mud, no unequal wear
Piedmont Improvement Program
NCRC, NS, NCDOT
Sumner, NC
No. 24 Crossover on Concrete Ties
Feb. 8, 2015

PIP 12/15/2014

Denver, RTA
Numerous Crossovers, Turnouts, Rail/Highway Crossings

Metrolink
Numerous Turnouts and Crossovers
Ten No. 20 Crossovers

Caltrain

No. 7 -- WILDS
Flat Rock, KY 2009 NS
One Day

New and Rehabilitating WILDS

CSX has ten or so WILDS on Asphalt Underlayments
III. Comments – U.S. Applications

- Use of Asphalt Trackbeds on the U.S. Railroads has been growing steadily over the past several years.
- It has primarily been used for Short-Distance, Quick-Fix applications, including limited numbers of Open-Track sites historically exhibiting Inadequate Subgrade Support and Drainage Conditions.
- It has been used for a Select Number of Long-Distance New Track Applications.
- It’s most widespread uses have been for numerous types of Special Trackworks on many railroads.
- The primary Special-Trackwork use is for Railway/Highway At-Grade Crossings and WILDS, followed closely by Turnouts, Crossovers, and Rail/Rail Crossings.
- Other uses include Bridge Approaches and Tunnel Approaches/Floors.

IV. Trackbed Measurements & Evaluations

- **Earth Pressure Cell**
  - For Track Deflection
  - Track Stiffness
  - Trackbed Material Tests

- **Pressure Cell Placement** on Asphalt

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**Empty Coal Train at Conway**

- **P-Cell 209 on 5 in. HMA Layer**

- **Graph:**
  - Time (s) vs. Pressure (psi)
  - Initial 5 Cars Empty Coal Train at Conway

- **Reduction of Dynamic Stresses*:**

  - Source: AAR Transportation Test Center – Pueblo, CO
IV. Comments -- Trackbed Measurements

- Peak dynamic pressures range from 13 to 17 psi (90 to 120 kPa) on top of the HMA mat under 286,000 lb (130 metric ton) locomotives and heavily loaded cars – only two to three times greater in magnitude than the pressure exerted by an average-size person standing on an asphalt pavement.
- Peak dynamic vertical pressures under similar loading are further reduced to 5 to 7 psi (35 to 50 kPa) under the HMA layer at the subgrade interface.
- Dynamic track deflections for HMA trackbeds under 286,000 lb (130 metric ton) locomotives average 0.25 in. (6.0 mm) for wood tie track and 0.04 in. (1.0 mm) for concrete tie track. These are considered optimum.
- Dynamic track modulus (stiffness) values consistently average 2,500 lb/in/in (17 MPa) for wood tie track and 7,600 lb/in/in (52 MPa) for concrete tie track. These are considered optimum.
- In-track test measurements on HMA underlayment trackbeds obtained on CSXT’s heavy-haul revenue line and obtained at TTCI’s heavy-haul research test facility are consistent.
IV. Comments -- Asphalt Findings/Discussions

- Resilient Modulus Values are Intermediate in Magnitude-Typical of Unweathered Asphalt Mixes
- Asphalt Binders do not Exhibit Excessive Hardening (Brittleness), Weathering, Deterioration or Cracking
- Asphalt is Insulated from Environmental Extremes
- Asphalt Experiences Minimal Loading Induced Stresses
- Conditions Influencing Typical Failure Modes Experienced by Asphalt Highway Pavements don’t Exist in Asphalt Railroad Trackbeds.

Thank You for Your Attention!
Any Questions???

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