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

Part I -- Introduction to Asphalt Trackbeds and International Applications and Practices

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ABSTRACT

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

This 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 or capacity improvements of existing lines. Increasingly, asphalt is also specified for new urban tail transit/commuter lines.

The primary documented benefits described in this three-part paper are to: 1) provide additional support to improve load distributing capabilities of the trackbed layered components, 2) decrease load-induced subgrade pressures, 3) increase confinement for the ballast, 4) improve and control drainage, 5) maintain consistently low moisture contents in the subgrade, 6) insure maintenance of specified track geometric properties for heavy tonnage freight lines and high-speed passenger lines, and 7) decrease subsequent expenditures for trackbed maintenance and component replacement costs.

In Part I, various factors are discussed that are considerations in the design phases. Illustrations of the trackbed/roadbed components, construction phases, and finished projects are presented for various asphalt trackbed applications in several countries, including Italy, Austria, and France. Part II describes applications in the United States. Part III presents performance-based tests and analyses.

1 INTRODUCTION

All-Granular support trackbed, also termed "ballasted" trackbed has been used since the early days of the railroad. Ballast properly designed and in good condition provides excellent longitudinal, vertical and lateral support for the ties, and transfers loads to subballast or base, thereon to the natural subgrade material.

To accommodate increasing wheel loads, train frequencies, and speeds, engineers specify larger rail size, larger ties that are more closely spaced, and improved quality and quantity of ballast around and below the ties. Drainage is also recognized as critical, as most subgrade materials lose load-carrying capacity when wet or saturated. To further provide support, a thickness of granular "subballast" may be specified for placement between the ballast and subgrade. Typically this is locally available aggregate material with smaller top size than typical ballast, containing considerably more fine-sized particles. Subballast compacts to a very low void content with very low permeability and is 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.

Factors affecting the design of track structures and resultant guidelines originated from the A.N. Talbot reports. Based on research conducted in the first half of the twentieth century, empirical relationships for determining subgrade pressures and selecting ballast thicknesses were developed(AREA, 1980). Mechanistic designs are now available for assessing a variety of trackbed designs.

Figure 1 depicts the "*All-Granular*" trackbed. 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. High-traffic mainline tracks require higher quality and thicker layers of ballast and subballast to resist the loads and to effectively distribute the loads to the underlying subgrade layer. Variations of this design are currently the predominate design of railway track structures throughout the world. However, during the past 30 or so years, additional designs, incorporating Asphalt layers, have been gaining favor for specific applications in-lieu-of the classic All-Granular design.

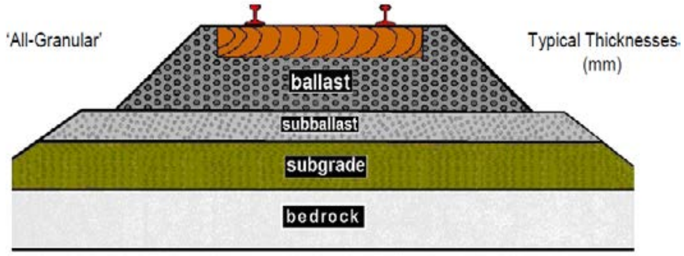

Figure 1. Classic All-Granular trackbed without asphalt layer.

For over 30 years, and in response to the challenges of providing higher quality and longer lasting track and support structures to accommodate growth in rail traffic volumes and axle loadings, 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. A layer of asphalt, similar in composition to that commonly used for highway construction, distinguishes the track structure from the classic All-Granular trackbed. 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 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. Differences include the substitution of the asphalt layer for the granular subballast layer and continuation of the ballast downwards at the edges to cover the asphalt and prevent exposure of the asphalt to sunlight. 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.

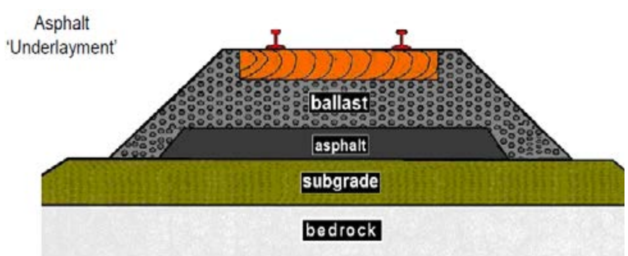

Figure 2a.Asphalt Underlayment trackbed without granular subballast layer.

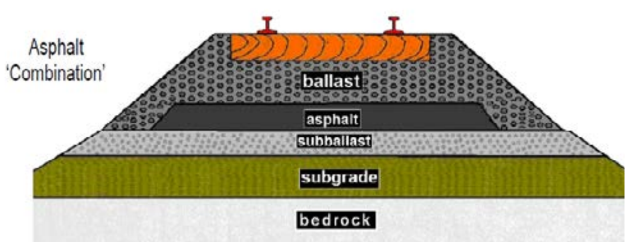

Figure 2b. Asphalt Combination trackbed containing both asphalt and subballast layers.

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 are typically covered by patents.

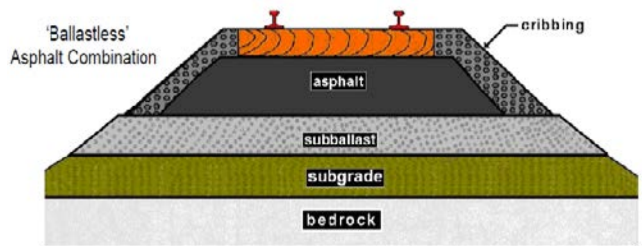

Figure 2c. Ballastless trackbed containing asphalt and subballast layers.

2 TYPICAL ASPHALT TRACKBED DESIGNS

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 has not been as readily accepted by the heavy axle-load U.S railroads as has been the ballasted designs.. This discussion of 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 wide and is approximately 125 to 150 mm thick. For poor trackbed support conditions and high impact areas, a 200-mm thickness is commonly used. Thickness of the overlying ballast ranges from 200 to 300 mm. Thickness of a granular subballast layer, if utilized, is usually 150 to 200 mm 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. 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.

3 TYPICAL TRACKBED INSTALLATION PRACTICES

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. Based on relative cost analyses for numerous installations, 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; about 5%, to the total track removal and replacement costs which 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 open-track 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.

4 INTERNATIONAL APPLICATIONS AND PRACTICES

4.1 *Germany*

In the past 30 years, Germany's rail network has undergone constant improvements to allow for high-speed lines with maximum speeds of 300 km/hr. The Germans have selectively implemented the "ballastless" slab into the new high-speed track designs in order to provide the structure with good elasticity independent of the foundation stiffness. The most recent asphalt ballastless track system used in Germany is the Getrac, which includes an asphalt support layer with concrete ties anchored into the asphalt (RailOne, 2008).

4.2 *Austria*

Since the 1960s, Austrian Railways has developed technical experience with asphalt layers in trackbeds and realized the economic benefits of the material. Austrian Railways uses an 8 to12 cm asphalt layer beneath the ballast bed which provides a clear separation between substructure and superstructure. Main advantages include preventing rain water from penetrating the substructure, obtaining optimum elasticity, providing consistent support to equalize stresses on the substructure, and prevent pumping of fines upward. Annual deterioration rates for asphalt trackbeds are 50% less than that of granular trackbeds and leveling-lining-tamping frequency has decreased by 67% (Veit, 2009).

4.3 *France*

In 2007 the French National Railways (SNCF) opened the TGV-East high-speed line connecting Paris to Strasbourg. It included a 3 km long test section of asphalt subballast trackbed for tests and analyses under high-speed operations. The test zone was fitted with accelerometers on the sleepers, pressure sensors, extension gauges, and thermometers. Figure 3 shows a layout of the test zone instruments.

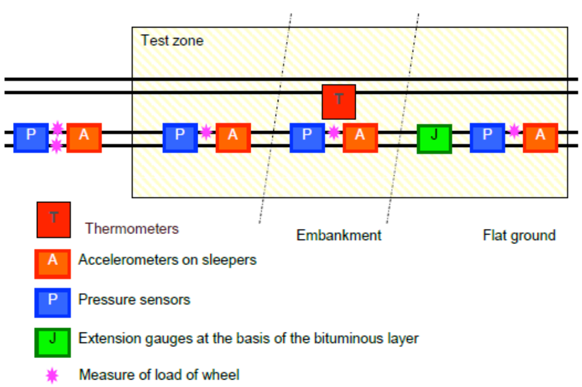

Figure 3. Instrument layout for SNCF & Colas asphalt trackbed tests (Robinet, 2013).

The sleepers of the asphalt track experienced roughly the same accelerations as a granular track, but the trackbed subgrade pressure readings for the asphalt track were half as large as the readings on the granular track. Extension readings for the asphalt track were three times below the maximum allowable. Plans for a similar study that will introduce the use of recycled asphalt are being made and an experiment in Lingolsheim is testing the use of asphalt without ballast, but no results have been published yet (Robinet and Cuccaroni, 2010).

4.4 *Italy*

The Italian State Railways were one of the initial developers of asphalt trackbeds and they continue to widely utilize the material for their extensive high-speed rail network. The Italian High-Speed Rail network consists of East-West and North-South lines with a total of around 1200 km of track. The line between Rome and Florence, known as the Direttissima, is the original and most frequently trafficked high-speed line. Figure 4 shows a typical cross section for an Italian high-speed rail trackbed. Figure 5 shows the installation of the asphalt trackbed layer.

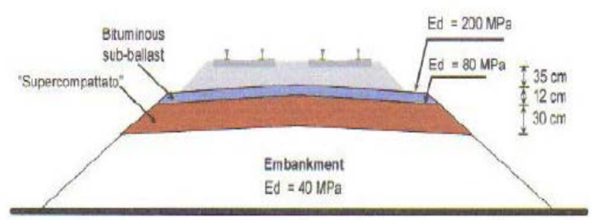

Figure 4. Cross section of Italian trackbed (Buonnano, 2000).

Figure 5. Installation of asphalt trackbed layer.

The Italian railways determined that all new lines were to be constructed using an asphalt subballast layer and this method has been used for the past 20 years (Teixeira, 2009).

4.5 *Japan*

For many years the Japanese have used asphalt trackbeds in ballasted track for both high-speed and regular lines with the purpose of providing substantial support for the ballast and to reduce track irregularities. In 2007, the Design Standard for Railway Structures was revised to consider the fatigue life of the track as it is affected by the number of passing trains (Momoya, 2007). This allows designers to choose various layer compositions and thicknesses to satisfy roadbed performance requirements. Japan has three classifications of trackbeds based on their performance ranks, with asphalt specified for the two highest quality trackbed classifications (Momoya and Sekine, 2007).

4.6 *Spain*

Spanish high speed train reach maximum speeds of 300 km/hr and currently operate on 2600 km of track with that track total expected to increase to 5600 km in the coming years. Spanish Railways has started testing asphalt trackbeds on the Madrid-Valladolid high-speed line and the Barcelona-French border high-speed line which is still under construction. The design for these trackbeds typically follows technology developed by Italian State Railways and includes a 12 to14 cm layer of asphalt subballast over a form layer with a minimum thickness of 30 cm, and minimum bearing capacity of 80 MPa.

The feasibility of implementing an asphalt based high-speed railway network in Spain is heavily dependent on the price of bituminous material compared to granular material. An analysis of the availability and cost of granular and bituminous material in Spain showed that transport distance is the key factor in overall cost. When transportation and material costs are applied to the high-speed lines planned for Spain, the difference in cost between bituminous and granular subballast is only around five percent (Teixeira, et al., 2010).

5 CLOSURE

This paper has described various factors that are considerations in the railroad design phase. Illustrations of the trackbed/roadbed components, construction phases, and finished projects were presented for various asphalt trackbed applications in several countries, including Italy, Austria, and France. Part II will describe applications in the United States. Part III will present U.S. Asphalt Trackbed Materials Evaluations and Tests and provide overall analysis and closure.

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