Asphalt in Railway Tracks

EAPA Position paper

EUROPEAN ASPHALT PAVEMENT ASSOCIATION
Contents

1. Introduction ................................................................................... 4
2. Asphalt ......................................................................................... 4
3. Application of asphalt in railway construction........................................... 5
   3.1 Asphalt as sub-ballast layer..................................................... 5
   3.2 The ballast-less track / direct application of the sleepers on the asphalt .. 7
4. Experiences ................................................................................... 8
   4.1 Italy ..................................................................................... 8
   4.2 Germany - Solid Railway Trackbed ........................................... 9
      4.2.1 General Issues ............................................................... 9
      4.2.2 Requirements for the asphalt layers ............................... 10
      4.2.3 Paving ......................................................................... 10
      4.2.4 Advantages .................................................................. 11
   4.3 France .................................................................................. 13
   4.4 Spain ................................................................................... 15
   4.5 Japan .................................................................................... 16
   4.6 United States ........................................................................ 18
5. Literature ..................................................................................... 19
1. Introduction

In railway design, as in highway design, increasing traffic loads and volumes and particularly the introduction of high-speed trains in the last decades, have resulted in the need for new approaches. In addition, concern for the environment requires the concept of sustainability to be taken into account in the design process.

Asphalt mixtures have been shown to provide good technical alternatives for several elements of traditional railway construction. In particular, experience with asphalt in the track superstructure (the traditional superstructure consists of the rails, the sleepers, fastenings and the ballast) and in the sub-ballast layer has shown that these types of construction are able to fully meet the requirements of modern railway tracks.

Worldwide experience has shown that use of asphalt can offer a good alternative in modern railway construction. Thanks to the specific properties of asphalt mixtures the materials are able to comply with many of the requirements.

2. Asphalt

Hot and warm mix asphalts are a mixture of mineral aggregate and bitumen. The mineral aggregate varies from very fine dust (filler) to a maximum particle size, which is usually around 40 mm. Bitumen is the result of the distillation of crude oil. By varying the composition of the mixture, the ratio of the various constituents and the particle size distribution of the aggregate, the properties of the mixture can be adapted to suit the specific requirements of the construction. Depending on the mix composition and the quality of the constituent bitumen and aggregates, the asphalt mixture may be either stiff with high stability or very flexible. Some mixtures are impermeable, whilst other compositions result in permeable porous asphalt.

The use of special additives or polymer-modified bitumen offers the possibilities of complying with specific requirements (heavy duty, lower temperatures) for the mixture or the construction.

The production of asphalt mixes takes place in either mobile or static mixing plants where, in a continuous or batch process, the mineral aggregate is dried and heated and where the hot bituminous binder is added to the required aggregate composition. After production the hot or warm asphalt mix is transported to the site in insulated lorries. On site, application takes place using pavers that place and partially compact the material in the required thickness and width, following which final compaction is achieved using rollers. Immediately after the last passage of the compaction roller the asphalt is ready for use.
An asphalt construction may consist of one or more separate layers of possibly different composition. Depending on the design, the various layers perform a specific role in the construction.

3. Application of asphalt in railway construction

The properties of bitumen and asphalt offer good opportunities to apply this type of material in railway track construction. This has been proven in various applications, both for heavy loaded tracks and for high-speed tracks.

The use of asphalt in railway construction provides a positive contribution to the bearing capacity of the structure. It improves both the stability and the durability of the structure, which contributes to the reduction in the need for maintenance. In addition, the use of asphalt also helps to reduce vibration and noise [1.] and [2.].

The use of asphalt may reduce the total construction height of the superstructure, which is of importance in the case of tunnels and bridges.

Applications of asphalt in railway construction can be divided between use as sub-ballast layers and use as full depth (asphalt) construction, also called the ballast-less track.

3.1 Asphalt as sub-ballast layer.

The rail ballast absorbs the train weight and distributes it from the rails to the sub grade, thereby avoiding any deformation. The railroad can thus keep its geometrical features.

The rapid decay of the railroad level which occurs with traditional ballast construction is mainly due to the unsatisfactory “fatigue behaviour” of the ballast; this is mostly due to embankment settling.

By interposing a special semi-rigid layer (the so-called “sub-ballast”) in the area between the ballast and the embankment, the behaviour of the overall structure is greatly improved. The sub-ballast is normally laid on a highly compacted embankment layer.

![Figure 1: Italian High-Speed Railway Cross-Sectional Profile [1.]](image)
The sub-ballast functions are:
- to create a working platform on which subsequent work operations, such as installation of electric lines, ballast and rail laying, are more easily undertaken;
- to assist in gradually distributing the loads transmitted by passing trains;
- to protect the embankment body from the seepage of rain-water and from seasonal thermal extremes (so protecting the upper part of the embankment from freeze/thaw action)
- to eliminate contamination of the ballast from fine material migrating up from the foundation;
- to distribute the concentrated pressures and eliminate any "rupture" of the embankment.

A railway structure with sub-ballast works almost exclusively on compression and, therefore, differs from a traditional structure. This consequently eliminates fatigue cracking.

Especially on high-speed tracks maintaining levels and profile is of high importance. This can be achieved by increasing the stiffness of the structure. A higher stiffness has as a consequence a better load distribution to the ballast and sub-ballast material. This will prevent an early deterioration of the rail geometric. In this case the use of asphalt in a sub-ballast layer can offer the solution.

The application of asphalt as a sub-ballast layer will contribute to the following aspects:

- **Bearing capacity**
  The application of a monolithic layer (0.1 - 0.2 m) of asphalt, as a sub-ballast layer will increase the stiffness of the total structure. The fact that an asphalt layer is also capable of withstanding tensile forces gives an extra positive contribution to this effect.

- **Geotechnical stability**
  The relatively high stiffness of the asphalt sub-ballast layer will make a positive contribution to the compaction of the layers on top of the asphalt layer. This improves the total stability. So the asphalt mix sub-ballast contributes to keeping the railroad geometry unaltered.

- **Resistance to vertical deformation**
  The relatively high stiffness of the asphalt layer compared to granular material will lead to less permanent vertical deformation by trainloads. The vertical loading conditions and the relatively short loading time are relatively small, so there will be no permanent deformation in the asphalt layer.

- **Drainage**
  When a layer of dense asphaltic concrete is used as a sub-ballast layer, optimal drainage of the total structure will be realised. The impermeable asphalt sub-ballast layer can prevent possible contamination of the sub-structure by vertical hydraulic transport of mud and fines.
- Durability

The asphalt sub-ballast layer increases the foundation modulus, providing a more rigid foundation, with the effect that there is a reduction of tension and shearing stress inside the ballast material, with consequently less fatigue and less degradation and wear of the individual aggregate particles.

Due to the low air voids in the asphalt mix and because the asphalt layer is buried, weather effects (temperature changes, Ultra Violet radiation, oxygen) will not affect the hot mix, so no deterioration (aging) of the asphalt or bitumen will take place.

Even if limited deformation of the sub-soil does take place, this will not affect the asphalt layer because it is capable of withstanding the deformation without losing its integrity because of the visco-elastic properties of asphalt.

- Noise and vibrations

The mechanical properties of the asphalt layer will lead to a reduction in the vibrations and noise produced by passing trains. The use of modified asphalt (polymer modified bitumen, rubber crumb) can further improve the vibration dampening effect of the sub-ballast [1] and [2].

The asphalt sub-ballast also provides several benefits over the conventional granular sub-ballast. These benefits include, but are not limited to [1]:

- Increased safety and structural reliability due to increased modulus and uniformity
- Reduced life-cycle cost on the infrastructure from reduced subgrade fatigue
- Increased homogenization of the track bearing capacity on the longitudinal profile and better ballast confinement
- Reduced ballast fouling due to improved drainage
- Reduced thickness compared to a conventional granular design

3.2 The ballast-less track / The direct application of the sleepers on the asphalt

For many years there have been developments aimed at improving the stability of the traditional rail-track structure of rail, sleepers and ballast. The introduction of high-speed trains and the desire for less maintenance led to the development of the ballast-less track. In this form of construction the ballast is replaced by a rigid monolithic element that directly supports the sleepers. The aim is to find a track structure having a good elasticity, independent of the foundation stiffness.

One of the solutions is a system in which the track frame of rail and sleepers is placed directly on an asphalt construction. The most important requirement of the top asphalt layer is to have a perfectly flat and level surface in order to comply with the narrow tolerances that are required for the rail level (+/-2 mm). Modern asphalt laying machines can fulfil this requirement because they make use of the most sophisticated levelling equipment.
The horizontal anchoring of the rail track in order to prevent transverse movement can be achieved by various anchoring systems.

The advantages of these systems are the elasticity of the asphalt layer, especially when polymer modified asphalt is used, and the ease of construction and maintenance. Another important factor in favour of this system is the ability to carry out minor corrections without demolishing and reconstructing the base.

Because this system eliminates the use of ballast it has the great advantage of lowering the track base, allowing the construction of tunnels with smaller diameter.

The first successful application of the ballast-less tracks dates back to the beginning of the 1990’s, in Germany. Other experimental tracks have been built since then, mostly in Germany.

4. Experiences

4.1 Italy

The first experience with asphalt mixes in high-speed railway construction in Italy date from the early 1970s. Hundreds of kilometres have been built in the last 30 years. The results have been very satisfactory and have shown that the application of an asphalt sub-ballast layer contributed to the stability of the rail geometry. In particular, at critical points such as switch points, expansion joints, level crossings and in areas between concrete structures (bridges) and embankments, where dynamic forces are substantial, the asphalt sub-ballast layer introduced a remarkable improvement of the superstructure stability.

More than 1200 km of high speed lines in Italy are now equipped with an asphalt sub-ballast layer.

Experience with polymer modified bitumen in asphalt mixes for sub-ballast layers has shown that the application of this type of mix is also very promising with regard of the reduction of noise and vibration. This is another positive contribution of asphalt to both the comfort of rail passengers and to the environment.

The Italian Asphalt Association (SITEB) and the Italian Railways (FS) have carried out extensive research in this field.

The Italian High-Speed Railway cross sectional profile is shown in Figure 1. It is a multi-layered system consisting of an embankment, super-compacted sub-layer, asphalt sub-ballast, ballast, sleepers and rail. The embankment has a minimum specified bearing capacity of 40 MPa.

The “super-compacted” layer is then placed on the embankment with a thickness of 300 mm with a minimum subgrade modulus of 80 MPa. The super-compacted layer consists of a sand/gravel mixture and is placed with a cross slope of 3.5%.
The asphalt sub-ballast layer, placed on the super-compacted layer, consists of an asphalt mixture with a maximum aggregate size of 25 mm and has a thickness of 120 mm. It is applied over the entire track cross section, with a total width of around 14 m [3.]. The asphalt sub-ballast is placed by using a standard asphalt paving machine.

When the asphalt mix solution is compared with cement mix solutions for the sub-ballast, the following advantages are evident in favour of asphalt:
- reduced use of aggregates due to the lesser thickness of the asphalt sub-ballast layer (average 120 mm thickness compared to at least 200 mm);
- cracks are less likely to emerge;
- there is no need to protect the finished surface by means of bitumen membranes or emulsion spray;
- time for “hardening” is much shorter.

Experience shows that the presence of an asphalt sub-ballast layer in the railway structure also results in a reduction in the vibrations transmitted by the passing trains to the surrounding environment; the asphalt sub-ballast then acts as a damping medium.

4.2 Germany

4.2.1 General Issues

In Germany the German rail authority, Deutsche Bundesbahn AG (DB AG) came to the conclusion that the rail web (rails and sleepers) with ballast bedding type of construction had reached a level that is hardly capable of improvement as a classical construction method for railway track.

Furthermore, in the case of routes designed for very rapid passenger traffic, it has been found that wear and tear takes place much more quickly than expected through stone displacement, breakage and abrasion because of the dynamic traffic loads on the railway ballast. As a result, track bed deterioration occurred more frequently and required maintenance work at more frequent intervals. This maintenance work was costly and disrupts normal railway operations. So alternatives were necessary.

The load-bearing ballast can be replaced by asphalt. This construction method was used for the first time in Germany around 35 years ago, with an asphalt base course. Since
then several systems of the asphalt construction method have become approved by the DB AG. They are the following, in detail:

- **ATD**: Asphalt base course with a rail web
- **SATO**: Concrete sleeper or Y-steel sleeper with double base
- **Walter**: System Walterbau
- **Getrac**: German Track Corporation Asphalt.

In addition to the fastening technique, paving at the precise height is extremely important. Although, in the beginning, milling off was still necessary in part to achieve the required height precision, evenness of paving has since been improved to ± 2 mm, with reference to 4 m, through multi-layer paving and laser-supported paving technology.

With the above-mentioned systems, several sections have been constructed in Germany to date. In [4.] the details of above mentioned systems are described.

### 4.2.2 Requirements for the asphalt layers

In general, the requirements for the asphalt are determined by the load type. In the case of the solid railway trackbed, loading frequency is at a lower level than with asphalt roads. In contrast, the axle loads and consequently the wheel loads are far higher. On roads, the actual distributed load results in a wheel load of 5.75 tons for a truck with an 11.5-ton axle, which works out to around 0.8 MPa for a surface area of around 710 cm². For railways, however, there is a considerable load distribution over the rail and the sleeper. The wheel load of 11.25 tons results in stress on the bottom of the sleeper of around 0.25 MPa, and thus only around one-third of the load experienced on roads.

The asphalt needs to be designed to be permanent, flexible and dense in order to avoid maintenance work and subsequent improvements, which are practically impossible. The lifetime of the solid railway trackbed has been estimated to be around 60 years. Experience in Germany has shown that asphalt types with a high binder content and a low void content have proven to be reliable.

### 4.2.3 Paving

The paving can be done with the normal types of finishers available today. However, there has to be careful planning of the asphalt work and the paving in order to achieve the required precision (heights, axes). The surveying programs used for road construction cannot be used for the solid railway trackbed; electronic data-processing programs specially developed for this have proven to be reliable.
The guide-wire and supports used to control pavers operating on road construction sites cannot be directly adopted for railway construction. Instead, modifications to the support equipment are necessary to permit fine adjustment. In addition, the supports need to be set up at shorter intervals (< 5 m) in order to avoid sagging of the wire. The structure of the solid railway trackbed will depend on the particular fastening system. As a rule, the asphalt will be laid in at least 4 or 5 layers in order to achieve the required evenness. At least 4 layers are necessary with an overall thickness of 30 cm for the ATD system. The position of the guide wires requires to be checked on a regular basis during the paving. In addition, the height behind the finisher requires to be checked after every layer is paved.

Compaction of the asphalt after paving could result in a change in the finished level and evenness. The use of finishers with a screed providing a high level of pre-compaction is therefore indispensable. The compaction itself needs to be done with a small smooth-wheeled roller.

Further requirements are a uniform composition of the mixture, continuous transport in order to avoid a standstill in the paving, a constant paving speed and a steady paving temperature.

Figure 3: Two examples of the SATO system. In the right figure the Y-steel sleepers on asphalt [5.].

4.2.4 Advantages

The solid railway trackbed laid in Germany to date has been shown to be very successful. This success is fully justified by the reliable paving and by the material-specific characteristics of the construction material asphalt:

- Asphalt can be paved without joints due to its visco-elastic characteristics; stresses arising from the effects of load and temperature are reduced.
- Asphalt can also be used with extreme super-elevation because no separation arises from the high internal friction in the paved state.
- Asphalt can be paved at a precise tolerance (± 2 mm) due to its material characteristics.
- Load can be put on the asphalt immediately after it cools down; shorter construction times are achieved by using it.
- Corrections in the position that may be needed (e.g. due to settlement of the embankment) can be quickly and easily made either by milling off or by putting on another layer.

The solid railway trackbed made of asphalt is a promising alternative to a ballast-type track and other construction methods for the solid railway trackbed.

### 4.2.5 Asphalt in tramways

The systems described before for “Solid Railway Trackbed” can also be used for building tramways. Below is an example of the ATD-system used in Berlin (Germany).

The sleepers are placed directly on the bed of asphalt. The total track bed consists of two-layers of asphalt as a base (in total about 160 mm), and on top a top layer of asphaltic concrete (0/11). The sleepers with the rails are laid directly onto this top layer and therefore the specifications with regard to evenness are extremely high (+/- 2mm in both longitudinal and transverse directions).

![Figure 4: A paver with a special profile screed paving the top layer for the ATD-system to hold the sleepers in place later on [Source Voegele]](image)

![Figure 5: Placing the sleepers on the completed asphalt supporting layer [6.]](image)
4.3 France

In 2005 the French National Railway (SNCF) has built a 3 km long test section in the high speed TGV-East line (connecting Paris to Strasbourg) with an asphalt sub-ballast layer. The goal of this test section was to determine whether an asphalt sub-ballast could be considered as an acceptable alternative for future high speed rail infrastructure projects [7].

![Comparison of traditional and bituminous sub-ballast sections](image)

Figure 6: Traditional and bituminous sub-ballast sections [7.]

Figure 6 shows the comparison of the traditional cross section with an aggregate (sub) ballast layer used in the TGV-East line with the asphalt sub-ballast layer in the 3 km test section.

The traditional system consists of 300 mm thick ballast layer on a 200 mm thick sub-ballast layer. This ballast and sub-ballast layer rest on a 500 mm granular layer of limestone.

In the alternative with the asphalt sub-ballast layer, the 500 mm limestone layer is replaced by 140 mm asphalt sub-ballast and a 200 mm thick adjustment layer (GNT 0/31,5). In this way the total thickness was reduced by 360 mm, which reduces the amount of material used by approximately 5,000 m³ per km track [7.]

On top of the 200 mm adjustment layer, a surface dressing was applied (1,5 kg bitumen/m²) with fine aggregate over the total width of 14,50 m.

The goal of the surface dressing is to protect the adjustment layer against the construction equipment and to improve surface drainage. The asphalt layer had a width of 10,70 m. On top of the asphalt layer a surface dressing was applied (0,8 kg bitumen/m²) and covered with fine aggregate.

After installation of the asphalt test section SNCF did various test during 4 years to evaluate the impact on maintenance and to observe the behaviour during temperature changes. Various sensors were built in to measure the temperature, pressure, acceleration, strains and deformations of the base layer of asphalt and finally the TGV-East line was opened in June 2007.
Since this first trial and the conclusions which have been drawn, SNCF decided to use this solution for all the new tracks for High Speed Train. Now the solution which is applied is the following, either a reduction of around 21cm (see figure 7). Specifications are required for this base asphalt concrete and mainly a good fatigue resistance and a low void content. Below the base asphalt concrete, a surface dressing is applied on the regulating course.

![Figure 7: Traditional and bituminous sub-ballast sections [7.]](image)

Since that, new studies were performed and a trial has been carried out to use 20 and 30% of RAP in the formulation of this specific asphalt concrete.

The mechanical characteristics required for asphalt concrete for being used in High speed train tracks are:

- Stiffness modulus $\geq 11,000$ MPa (15°C and 10 Hz)
- Fatigue $\geq 100$ $\mu$d (micro deformation)

In France asphalt concrete is also used for tramways.
4.4 Spain

4.4.1 Sub-ballast layers

The Spanish Railways decided to test the use of a bituminous sub-ballast layer instead of a granular sub-ballast layer in trial sections in four sites [3.], [8.] and [9.]:

- Valdestillas - Rio Duero (Line Madrid - Valladolid)
- Sils - Riudellots. (Line Barcelona - Figueras)
- Villodrigo - Villazopeque. (Line Valladolid - Burgos)
- Aspe - El Carrús. (Line Alicante - Murcia)

The longest test track (10 km) was built between Villodrigo and Villazopeque, although it is not still in operation. The 1 km trial section between Sils and Riudellots of the Barcelona-French Border is a high-speed line and has been fully equipped with numerous extensometers, soil pressure cells, temperature sensors and soil humidity sensors. It will be monitored during 4 years in commercial operation under mixed traffic conditions (high-speed train sets at 300 km/h together with railway freight trains at maximum speeds of 120 km/h). The results will later be used to support the validation of the use of this technical structure as one of the possible solutions for the more than 2,000 km of new high-speed lines still to be built in the next coming years in Spain.

![Image](image1.png)

*Figure 8: Bituminous sub-ballast sections built on the high-speed line Madrid-Valladolid, section between Segovia and Valdestillas (left) and on the high-speed line Barcelona-French Border, section Sils-Riudellots (right). [3.].*

![Image](image2.png)

*Figure 9: Track design with bituminous sub-ballast for Spanish high-speed lines standards. [3.]*
According to these experiences, ADIF (Spanish Rail Infrastructure Agency) has defined a set of technical prescriptions:

- Bituminous binders: B50/70 or B70/100.
- Aggregates:
  - Sand equivalent > 50 (or >40 if blue methylene tests is <10)
  - Angular particles >90%
  - Flakiness index <25
  - Los Angeles test > 25
  - Added filler > 50%
  - Recommended grading:

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- Binder content; > 4,75% (over mass of asphalt mix)
- Filler/binder relationship: 0,9-1,2
- Void content EN 12697-8 (annex B EN 13108-20): 3-5%
- Water sensitivity (EN 12697-12 ITS test method 15°C): >85%
- Dynamic stiffness modulus (EN 12697-26): 3700-7100 (20°C)
- Fatigue resistance (EN 12697-24 method D): $\varepsilon_6 > 120$ mdef

A further step, in order to collect former experiences, has been provided by Asefma. In its Monograph n° 13 (use of bituminous mixes in railway track-beds) an annex has been edited where specifications for materials and asphalt mixes for bituminous sub-ballast are detailed. Besides, a clear explanation of the criteria required is included.

### 4.4.2 Ballastless asphalt applications

The only test track of this type of application has been constructed between Las Palmas de Castellón and Oropesa del Mar (Castellón) in 2003. It supports both: standard and high speed traffic.

The main goals of these project were: safety, quality and availability of the railtrack besides a reduced maintenance cost.
Six systems were tested in this test track: Edilón, Rheda Dywidag, Rheda 2000, Stedef, GETRAC and ATD. The last two were carried out using bituminous mixes.

By external instrumentation (151 sensors) data from cross-channel relative motions, deflections, dynamic rail noise and vibrations are verified. Regular monitoring is also performed on the track geometry and torques of the fasteners.

The ultimate purpose of the instrumentation is set a valid, rational and consistent approach to the approval models with ballastless configurations.

A further step in on the way, by mean of the R&D project Bituvia where several companies are developing mathematical models for the application of ballastless systems based on asphalt mixes [17].
4.5 Japan

In Japan asphalt track beds have been widely used in railway ballast tracks for many years on both high-speed lines and regular lines [9.].

The first goal of using asphalt track beds was to provide a firm support for the ballast and to reduce track irregularities. It will also reduce the load level on the subgrade to prevent subgrade deformation. In Japan the roadbed design methods are described in the Design Standard for Railway Structures (Earth Structures). In the revised design standard of January 2007 performance-based design was introduced.

Before 2007 the thickness of each layer of the roadbed was specified. Now the performance-based design standard considers the fatigue life of the track based on the number of train passes.

The performance-based design procedure has the following three different standard track designs according to performance [10.]:

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

The Performance Rank I track is a ballast-less slab track that has either a concrete or an asphalt support with concrete ties directly fixed to the slab. It is considered to be the highest quality track. It is designed/checked for track settlement, breakage of concrete reinforcement base, fatigue damage, cracking, contraction, and thermal stresses. Typical dimensions for the Performance Rank I asphalt ballast-less track are [10.]:

- Width of slab: 2220 mm
- Thickness of concrete slab: 190 mm
- Thickness of asphalt-concrete base: 150 mm
- Thickness of well graded crushed stone layer: 150 mm

The Performance Rank II design is a ballasted track with a 50 mm thick asphalt layer. This design has been used for over 30 years in Japan due to the ability of asphalt to distribute loads and facilitate drainage. For performance-based design, the settlements of the track and fatigue damage to the asphalt are the primary design criteria.

Performance Rank II is displayed in Figures 10 and 11.

- Thickness of ballast beneath the sleeper: 250-300 mm
- Thickness of asphalt-concrete layer: 50 mm
- Thickness of well graded crushed stone layer: 150-600 mm

The Performance Rank III design is the typical design using granular layers only.
Figure 10: Ballasted track [10.].

Figure 11: Cross section of ballasted track and asphalt roadbed [10.]

 Drainage pipe

 Draining layer

 Asphalt concrete layer  Well graded crushed stone layer

 Roadbed

 Subgrade

ballast

Rail

Sleeper

Asphalt roadbed
4.6 United States

In the United States the use of asphalt track beds has steadily grown since the early 1980's [9.]. It is primarily used for maintenance applications in existing tracks to improve track bed performance and for new track bed construction where the projected superior performance of asphalt track beds can be justified economically.

In the USA asphalt is used in railway tracks as sub-ballast layer (in the USA called “Asphalt Underlayment” - see figure 12) and to some extent as a partial replacement of the granular sub-ballast layer (in the USA called “Asphalt Combination” - see figure 13).

![Figure 12: “Asphalt Underlayment” trackbed without granular sub-ballast layer [9.]](image1)

![Figure 13: “Asphalt Combination” trackbed containing both asphalt and sub-ballast layers [9.]](image2)

In the USA the asphalt sub-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 track bed support conditions and high impact areas, a 200-mm thickness is commonly used. Thickness of the overlying ballast normally ranges from 200 to 300 mm [9.].

The typical asphalt mixture specification is the prevailing dense-graded highway base mix in the area having a maximum aggregate size of 25 to 37.5 mm. This slight modification to the typical highway mix imparts ideal properties to the track structure. Normally the asphalt binder content is 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 compact to less than 5% in-place air voids and therefore facilitates adequate strength and an impermeable material. Rutting of this mix is not a concern in the track bed since the pressures are applied through the ballast over a wide area.
5 Literature


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4. Georgios Michas; Slab Track Systems for High-Speed Railways; Master Degree Project; Division of Highway and Railway Engineering, TSC-MT 12-005, Stockholm 2012


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