

# THE STATE OF THE ART OF USING ASPHALT CONCRETE AS TRACKBED OF HIGH SPEED RAILWAY

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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. This paper reviewed the development of asphalt used in railway engineering.*

**Keywords:** *Asphalt; Trackbed; Railway; Foundation*

## I. INTRODUCTION

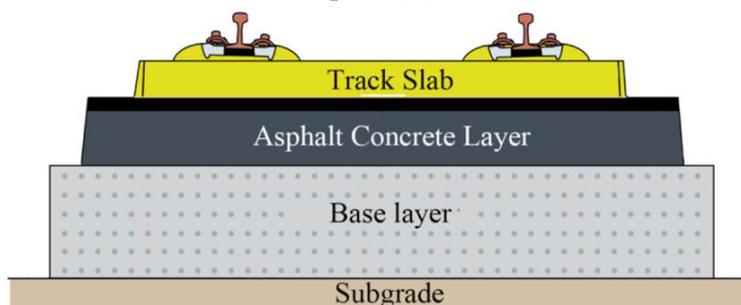
Asphalt concrete (AC) is a material traditionally used in the construction of highway pavement that has several advantages: good bearing capacity, water repellency, shock absorption, noise reduction, and relatively low cost. With the rapid development of high-speed rail in China, the load-bearing infrastructure to support high-speed rail tracks faces challenges in drainage, settlement, and structural fatigue. In recent years AC has been used for constructing the railway infrastructure of China's high-speed railway system. The primary documented benefits described in relative papers 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 [1-4]. The load-bearing infrastructure to support high-speed trains at the required safety level must remain stable, offer superior performance, and be maintained in a cost-effective manner. The materials needed to construct the infrastructure for trains operating at 350 km/h should be able to help reduce vibration and noise and maintain needed drainage.

Many studies have been conducted worldwide on the use of new materials to support high-speed rail slab tracks. However, many issues remain, particularly in terms of maintaining low levels of vibration and noise and excellent drainage to reduce water damage. In addition, AC service life as a top layer for highway pavements is typically 15 to 20 years, while the load-bearing infrastructure for high-speed rail is designed to last much longer, even more than 100 years according to the Chinese Code for Design on Railway Subgrades. AC has been used in recent decades on many occasions around the world as a secondary layer to support the top load bearing surface, known as slab track, which directly interfaces with high-speed rails. The current practice of using AC for high-speed rail is for the construction of high-speed rail subgrade beds and for surface waterproofing layers. However, there is lack of documented research about the material composition, durability, and mechanism of AC layers for high-speed rail infrastructure. Since AC materials could emerge as alternatives and entirely or partially replace traditional railway concrete slabs, subgrades, or waterproofing layers on surfaces.

## II. INTERNATIONAL APPLICATIONS AND PRACTICES

### 2.1. 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 [5].



*Figure 1. GETRAC used in Germany*

### 2.2. 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 to 12 cm asphalt layer beneath the ballast bed which provides a clear separation between substructure and superstructure [6]. 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%.

### 2.3. 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[7]. The test zone was fitted with accelerometers on the sleepers, pressure sensors, extension gauges, and thermometers. Figure 2 shows a layout of the test zone instruments.

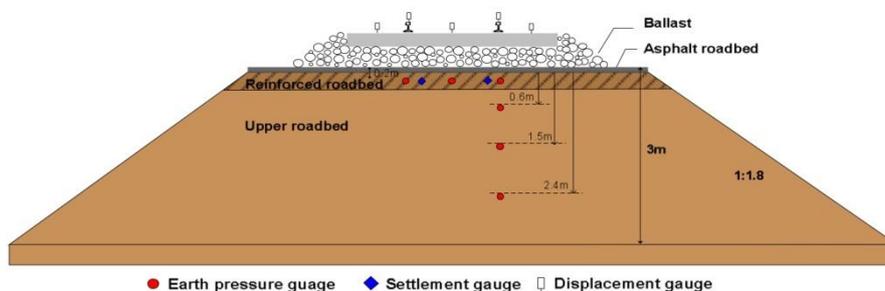


*Figure 2. Asphalt trackbed tests of TGV in France*

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.

### 2.4. 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[8]. 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 3 shows a typical cross section for an Italian high-speed rail trackbed.



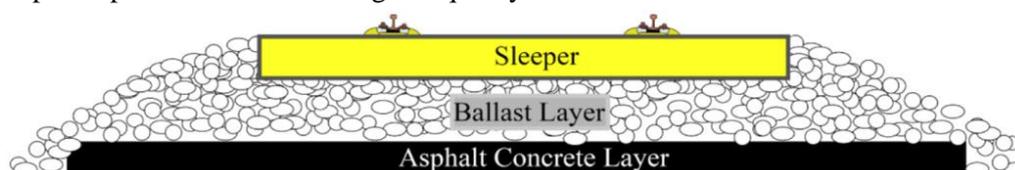
*Figure 3. Cross section of Italian trackbed*

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.

## 2.5. 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. This allows designers to choose various layer compositions and thicknesses to satisfy roadbed performance requirements[9]. Japan has three classifications of trackbeds based on their performance ranks, with asphalt specified for the two highest quality trackbed classifications.



*Figure 4. Railway asphalt concrete structure used in Japan*

## 2.6. 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 to 14 cm layer of asphalt subballast over a form layer with a minimum thickness of 30 cm, and minimum bearing capacity of 80 MPa [10].

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.

## 2.7. Korea

Korea Railroad Research Institute has developed Asphalt Concrete Directly Fastened to the Track (ADFT) in order to speed up of high speed rail train. There has been no previous research on asphalt trackbeds in South Korea. Many research were conducted to evaluate an asphalt concrete trackbed system for Korean High-Speed Railway supporting high-speed trains. The asphalt trackbed is expected to utilize the advantages of ballast track (e.g., easy maintenance and low construction cost) and concrete track (e.g., low maintenance) while compensating for the disadvantages of each. Accordingly, asphalt trackbeds are expected to reduce maintenance costs and make maintenance easy and efficient[11].



*Figure 5. Recent Researches about asphalt trackbed used in Korea*

## 2.8. China

Researchers also have studied railway AC layers in recent decades in China, such as the asphalt mortar layer, and the asphalt emulsion treated cement mortar layer. Given the fast development of high-speed railways in China, many researches has been taken to study AC railway infrastructure in the past few years. Those involved in the research presented in this paper were directly involved in the design of the first AC applications to high speed railways in Wuguang and Jinghu, China (Figure.6). AC layers were used for all waterproofed surfaces. Researchers also proposed using SAMI (Surface Asphalt Mixture Impermeable) provide a waterproof surface of both sides of the track embankment [12].



*Figure 6. RAC surface layer used in China*

## III. SUMMARY AND CONCLUSIONS

(1) The primary benefits of the HMA layer are to improve load distribution to the subgrade, waterproof and confine the subgrade, and to confine the ballast providing consistent load-carrying capability-even on subgrades of marginal quality. The waterproofing effects are particularly eliminates subgrade moisture fluctuations, which effectively improves and maintains the underlying support.

(2) The resilient HMA mat provides a positive separation of ballast from the subgrade, thereby eliminating subgrade pumping without substantially increasing the stiffness of trackbed.

The resulting stable trackbed has the potential to provide increased operating efficiency and decreased maintenance costs that should result in long-term economic benefits for the railroad and rail transit industries.

(3) All of the HMA test tracks and specific problem-solving installations are performing extremely well. The increased cost of using HMA is most often minimal, and the indications are that at many sites, the long-term savings may be substantial when compared to conventional construction, maintenance, and rehabilitation techniques. Additional improvement and optimization of field construction procedures represent activities of continuing interest.

(4) Further development of indoor asphalt track test methods will be done using finite element simulation to better simulate the stress state under foundation of railway track.

(5) Ground-penetrating radar and other equipment for rail NDT assessment of damage detection and repair when using asphalt concrete trackbed.

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## References

- [1]. *Qiu, Y., M. Fang, X. Zhang, and Y. Wei.* Dynamic Analysis of Structural Adaptivity of Ballastless Track Substructure of High-Speed Railway. *Journal of Southwest Jiaotong University*, Vol. 46, No. 2, 2011, pp. 183-188.
- [2]. *Qou, Y., and Y. Wei.* Mixing Design and Application of Impermeable Asphalt Mixture in Subgrade Surface Layer of Ballastless Railway Track Substructure. *Journal of the China Railway Society*, Vol. 30, No. 5, 2008, pp. 85-91.
- [3]. *Liu, L.* Discussion of High-Speed Railway Infrastructure Types and Reinforced Foundations. *Railway Standard Design*, Vol. 5, 1994, pp. 7-11.
- [4]. *Huang, C., and S. Zhongzheng.* Railway Application and Development of Asphalt Track Bed. *Journal of Railway Engineering Society*, Vol. 3, 1991, pp. 132-140.
- [5]. *Ren, J., S. Freudenstein, R. Yang, and X. Liu.* Structural Features and Application of German GETRAC Ballastless Track. *Chinese Railway*, Vol. 4, 2008, pp. 68-71.
- [6]. *Huurman, M., V. L. Markine, and A. P. de Man.* Design Calculations for Embedded Rail in Asphalt. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 1825, Transportation Research Board of the National Academies, Washington, D.C., 2003, pp. 28-37.
- [7]. *Rose, J. G., E. R. Brown, and M. L. Osborne.* Asphalt Trackbed Technology Development: The First 20 Years. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 1713, TRB, National Research Council, Washington, D.C., 2000, pp. 1-9.
- [8]. *Iwnicki, S.* Future Trends in Railway Engineering. *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science*, Vol. 23, No. 2, 2009, pp. 2743-2750.
- [9]. Japanese National Railway Institute. *Geotechnical Structure Design Standards and Commentary* (in Japanese). China Railway Press, Beijing, 2007.
- [10]. *Xu, Y., and J. Liu.* The New Asphalt Track Bed Used for Railway Infrastructure. *Railway Engineering*, Vol. 1, 1980, pp. 4-9.
- [11]. *Lee S-H, Park D-W, Vo HV, Dessouky S.* Asphalt Mixture for the First Asphalt Concrete Directly Fastened Track in Korea. *Advances in Materials Science and Engineering*. 2015;2015:6.
- [12]. *Yang E, Wang KC, Qiu Y, Luo Q.* Asphalt Concrete for High-Speed Railway Infrastructure and Performance Comparisons. *Journal of Materials in Civil Engineering*. 2015:04015202 ♦