Construction and Building Materials 113 (2016) 404–414

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Performance evaluation of directly fastened asphalt track using a full-scale test

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ARTICLE INFO

Article history:
Received 12 October 2015
Accepted 28 February 2016
Available online 22 March 2016

Keywords:
Full-scale test
Asphalt trackbed
Wide sleeper
Static loading
Asphalt performance
Railroad track
Asphalt mixture

ABSTRACT

Asphalt concrete has never been used in railroad trackbeds in South Korea. In this study, full-scale testing was conducted to evaluate the performance of asphalt concrete mixtures developed for use in railroad trackbeds. Asphalt trackbeds of three thicknesses were constructed at full scale and subjected to static loading. Measurements of earth pressure, strain, and displacement indicate that a thickness of approximately 30 cm is appropriate for an asphalt trackbed subjected to train loadings. In addition, the measurements provide information on the behavior characteristics of asphalt trackbeds.

1. Introduction

The first high-speed railway in South Korea was constructed with ballast trackbeds. The ballast constructed on top of a reinforcement layer was designed to support high-speed trains operating at speeds exceeding 300 km/h. However, ballast trackbed systems require frequent maintenance [1,2]. In this regard, concrete track system has been used more often for high-speed railways. While concrete track system has many advantages, such as lower maintenance costs and high resistance to track fracture and buckling, this system requires high construction costs and long construction times because of the time required for concrete curing. Furthermore, it is very difficult to rehabilitate a concrete track system when it becomes structurally damaged. Noise and vibration are other issues associated with the concrete track system [3–5].

Asphalt pavements currently make up more than 80% of the highways in South Korea because of their low maintenance costs and good ride quality, in spite of the advantages of Portland Cement Concrete (PCC) pavement [6], which is believed to have a longer service life than asphalt pavement. In addition, PCC pavements require frequent maintenance due to mainly partial damage and produce noise and vibration that make drivers uncomfortable.

Countries such as Germany, France, Italy, and the U.S. [7] have used asphalt trackbed systems for railway lines [8]. Germany employs asphalt trackbeds in the GETRAC and ATD track systems [9]. These asphalt trackbed systems can support high-speed trains operating at up to 330 km/h. The GETRAC system has been used for approximately 50 years without any problems or maintenance.

There has been no previous research on asphalt trackbeds in South Korea. This study was 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.

The asphalt binders used in this study were developed by improving conventional binders. As a result, the binders and the asphalt mixtures are believed to resist to fatigue cracking and permanent deformation. The performance and characteristics of these asphalt binders and mixtures could be found elsewhere [10,11]. This paper focused on the performance of the asphalt trackbed system through a full-scale test.

2. Objective

Because the performance of the asphalt binders and mixtures used in this study has been evaluated at the material level, this

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http://dx.doi.org/10.1016/j.conbuildmat.2016.02.221
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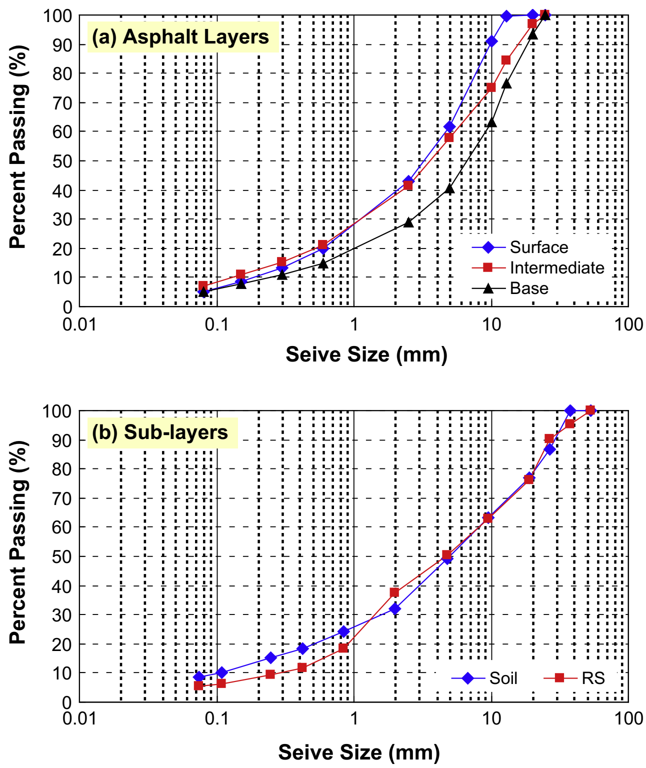

Fig. 1. Aggregate gradation used for (a) asphalt mixture and (b) sublayers.

study focused on evaluating the performance of an asphalt trackbed system in full-scale testing. Ultimately, this paper proposes an optimal cross section for an asphalt trackbed system identified by analyzing the measured performance of the asphalt trackbed system in full-scale testing.

3. Materials

Two asphalt binders for surface mixtures, called *Railphalt*-I and *Railphalt*-II, were developed in previous research to resist high temperatures better than conventional binders. *Railphalt*-II was used in the surface mixture in this study. A conventional styrene–butadiene–styrene block copolymer (SBS) modified PG64-22 binder was used in the intermediate and base mixtures. The conventional PG64-22 binder was designated as *Railphalt64-22*. *Railphalt*-I consists of PG64-22 unmodified binder and 7% crumb rubber with a small portion of an additive added to prevent segregation between the crumb rubber and the binder. *Railphalt*-II consists of PG76-22 binder and RS-10 modifier. The RS-10 is a sort of SBS modifiers and contains heavier polymer than the conventional SBS modifier.

The mixtures for the surface, intermediate, and base layers were fabricated using different aggregate sizes and gradations, as shown in Fig. 1. The Nominal Maximum Aggregate Size (NMAS) were 13, 19, and 25 mm for the surface, intermediate, and base layers, respectively. The optimal asphalt contents of the surface, intermediate, and base layers were 5.6%, 4.8%, and 4.3%.

The soil layer was compacted well at the optimal water content (OWC) of 7.3%, and the reinforced layer was compacted at an OWC of 7.2%. The maximum dry densities of the soil and reinforced layers were 2.098 and 2.169 kN/m^3, respectively. Detailed information on the materials used in the asphalt mixtures and soil layers are presented in Tables 1 and 2.

Table 2
Volumetric properties of asphalt mixtures.

Mixtures	NMAS (mm)	Asphalt binder content (%)	Air Void (%) (SSD method)	VMA (%)	VFA (%)
Surface	13	5.6	3.14	16.30	80.70
Intermediate	19	4.8	2.77	14.17	80.43
Base	25	4.3	2.55	13.46	81.39

4. Testing plan

Asphalt thickness was the key variable examined in this study to evaluate the performance of asphalt concrete trackbeds; thus, a standard cross section for directly fastened asphalt concrete track could be suggested. Total asphalt thicknesses of 20, 29, and 35 cm were constructed, considering that the NMASs of the mixtures govern the minimum thicknesses of the asphalt layers. A thickness of 20 cm represents a thin layer, 29 cm an intermediate layer, and 35 cm a thick layer. The ballast, composed of crushed stone, was approximately 35 cm from the bottom of the sleepers; thus, the maximum thickness of the asphalt concrete was determined to be 35 cm.

Static loading was applied to evaluate the performance of the asphalt concrete and sublayers as a trackbed. The load level was increased from 0 to 200 kN and then decreased from 200 to 0 kN in 20-kN intervals. The load was maintained for a few minutes at each level until all of the measurements, such as earth pressure and displacement, became stable. The static loading sequence is illustrated in Fig. 2. The testing was conducted at room temperature. The static loading test was completed within a relatively short period of time, so the effect of temperature change can be ignored.

5. Construction of full-scale test sections

Korea Railroad Research Institute (KRRI) has a test pit 4 m (width) × 4 m (depth) × 20 m (length) in size. Because the reinforced soil layer is usually 40 cm thick, the sublayer was compacted to a thickness of 3.6 m. The asphalt layers were constructed by changing the thicknesses on top of the reinforced soil layer. Fig. 3 illustrates the cross sections constructed for the full-scale testing.

5.1. Soil layers (subgrade and reinforced soil layer)

The subgrade represents the original ground that satisfies the minimum requirements for a sublayer. The subgrade was

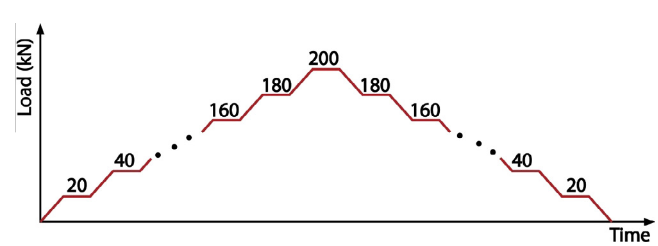

Fig. 2. Applied loading: (a) static loading and (b) dynamic loading.

Table 1
Material properties of sub-layers.

Layers	Optimal water content (%)	Max. dry density (kN/m^3)	Max. particle size (mm)	Modified CBR	Passing No. 4 (%)	Passing No. 200 (%)	Plasticity index	Remarks
Subgrade soil	7.4	20.7	37.5	20.4	49.3	8.7	N.P.	–
Reinforced soil	7.2	21.3	2.68	0.9	30.3	5.4	N.P.	Well-graded crushed stone mixed soil (KS F2525, M-40)