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Comprehensive service properties evaluation of composite grouting materials with high-performance cement paste for semi-flexible pavement

Jun Cai [a], Jianzhong Pei [a], Qinghui Luo [a], Jiupeng Zhang [a,*], Rui Li [a], Xiangfeng Chen [a,b]

[a] School of Highway, Chang'an University, Xi'an, Shaanxi 710064, China
[b] Tianchi Highway Technology Development Co., Ltd., Nanchang, Jiangxi 330103, China

HIGHLIGHTS

- Mechanics characteristics at different temperature and air voids are investigated.
- Strength and compressive resilient modulus are compared.
- Contributive rate and contributive efficiency of each part are studied.
- Pavement performance and durability of different composite grouting materials are compared.

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ABSTRACT

In this paper, high-performance cement pastes (i.e. h2 and h3) and pure cement paste (s) are respectively grouted into matrix asphalt mixtures (porous asphalt concrete 13, PAC-13) to service as semi-flexible pavement materials, and the comprehensive service properties of these composite grouting materials (H2, H3 and S), including mechanics feature and pavement performance are measured and compared with those of the traditional dense-graded asphalt concrete. Test results show that these composite grouting materials have similar mechanics characteristics, and H2 and H3 possess better pavement performance and durability than S. From the contribution of two-phase material (matrix asphalt mixture and grouting material) of composite grouting material, it can be concluded that both contributive efficiency and contributive rate of matrix asphalt mixture are lower than those of the grouting material. The uniaxial compressive strength of composite grouting materials approaches to that of the grouting material, which is much higher than that of asphalt mixture (matrix asphalt mixture and AC-13); while, the compression resilient modulus of composite grouting materials quite approaches to that of the asphalt mixture. To meet the requirements on moisture susceptibility of dense-graded asphalt concrete, the air void of matrix asphalt mixture should reach 21% for grouting high-performance cement pastes, and 24% for grouting pure cement paste.

1. Introduction

Asphalt pavement has been widely adopted in various pavements for its good pavement performance and driving comfort. Compared with the cement pavement, asphalt pavement possesses advantages such as no shrinkage joints, good anti-skid performance, low driving noise, short construction period and convenient maintenance, but also defects including poor resistance to aging, inadequate moisture susceptibility and temperature stability [1–3]. Nowadays, traffic volume and the traffic axle load increasing rapidly, the traditional asphalt pavement and cement pavement cannot satisfy the pavement requirement in the long term. Therefore, researchers have been looking for a new kind of pavement that combines advantages of both cement and traditional asphalt pavement, and the semi-flexible pavement is one of typical pavements [4,5].

Semi-flexible pavement, with open-graded matrix asphalt mixture (air void of which can be as high as 20%–25%) filled with special cement grouting materials [5], is featured with the flexibility of asphalt pavement and the rigidity of cement pavement in different degrees, has been widely used in many countries [6,7]. Fig. 1 shows the semi-flexible pavement outside the Deft railway station in Netherlands.

* Corresponding author.
E-mail address: zhjiupeng@chd.edu.cn (J. Zhang).

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(a) Overall (b) Detail

Fig. 1. Semi-flexible pavement outside the Deft railway station, Netherlands.

Peiwen Hao et al. [8] studied differences on pavement performance between the semi-flexible pavement and dense-graded asphalt mixture, and came up with methods to improve low-temperature performance and moisture susceptibility of the semi-flexible pavement. Bowen Fang et al. [9] determined a cement slurry formulation containing polycarboxylene based superplasticizer and SBR latex, which improved the working performance and balance the flexible and rigid characteristics of semi-flexible pavement. Shuguang Hou et al. [10] investigated the mechanical properties and durability of grouted macadam composite materials (GMCM), and concluded that the high-temperature stability, fatigue performance and moisture stability were much better than those of traditional asphalt mixtures, while its low-temperature crack resistance also met the practical requirement based on a proper formulation. Bohan Yang and Xingzhong Weng [11] studied the durability of semi-flexible pavement based on different raw materials, determined influence of different raw materials, and established damage model of semi-flexible pavement based on cyclic wheel load test. Guo-xiong Wu et al. [12] proposed and validated a modified method to test the resilient modulus of composite grouting materials, and established a relationship between resilient modulus of the semi-flexible composite pavement material and void ratio of the matrix asphalt mixture. A. Setyawan et al. [13] studied the compressive strength of different cementitious grout, bitumen-type and aggregate-type grouted macadam composites, and compared compressive strength of porous asphalt and the resulting grouted macadam. In addition, A. Setyawan et al. [14] determined the design and properties of matrix asphalt mixture for semi-flexible pavement by studying different type of bitumen, bitumen content, filler addition and aggregate gradation.

From above studies, it can be found that most researchers focus on the several aspects of semi-flexible pavement. For example, some researches investigate on grouting material and matrix asphalt mixture, and some study new properties of semi-flexible pavement. There still need much more investigation to systematically and continually study on types and properties of grouting materials, and application of composite grouting materials. And this paper is a further study and application based on studies on grouting materials and grouting features in the previous two papers [15,16]. This paper studied the mechanics feature, pavement performance and durability of grouting composites with high-performance cement paste for semi-flexible pavement, and some interesting conclusions were got.

2. Methodologies

2.1. Raw materials

2.1.1. Cement

The study adopts Qinling 42.5 grade Ordinary Portland cement produced in Yaoxian, Shaanxi, the initial setting time of which is 150 min, final setting time 225 min, 3 d compressive strength 28.8 MPa and 28 d compressive strength 45.7 MPa, meeting the quality standard in accordance with *Test Methods of Cement and Concrete for Highway Engineering* (JTG E30-2005, China) [17].

2.1.2. Asphalt

A-70 matrix asphalt is used in this study, and its main indicators meet the relevant technical requirements, as shown in Table 1 [18].

2.1.3. Aggregate

Basalt, produced in Tongchuan, Shaanxi Province, is used as aggregate in this study, and its physical properties and mechanical properties were shown in Table 2. Testing results show that its physical properties and mechanical properties all meet the requirements specified in *Technical Specification for Construction of Highway Asphalt Pavements* (JTG F40-2004, China) [18].

2.1.4. Other materials

High-performance cement paste is used as the grouting material in this study. Cement additives of high-performance cement paste include TH-928 polycarboxylate superplasticizer, U-type expansive agent for concrete admixture (UEA expansion admixture) and ZY-99 high performance triterpenoid saponin air-entraining agents, and their performance is qualified through tests; as for the modifier for A-70 matrix asphalt, TAFPACK Super (TPS) is adopted, and its color is yellow and density is 0.98 g/cm^3, which meets the requirement.

2.2. Preparation of specimens

In this study, specimens of composite grouting material H2 and H3, control sample S, TPS modified asphalt, matrix asphalt mixtures (porous asphalt concrete 13, PAC-13) specimens with 18%, 21% and 24% target air void and each composite grouting material were prepared strictly in accordance with the methods and processes specified in *Design and Performance Validation of High-performance Cement Paste as a Grouting Material* [16].

2.3. Test methods

In order to evaluate the comprehensive service properties of composite grouting materials with high-performance cement paste for semi-flexible pavement, a series of laboratory tests were conducted, including mechanics features and pavement performance, as shown in Table 3. In later sections, the results of each test would be presented and analyzed.

2.3.1. Uniaxial compressive test with prismatic specimen

In Section 3, the uniaxial compressive test with prismatic specimen was employed to test the characteristics of compressive strength, compressive strain and stiffness modulus (see Section 3.1), the contributive rate and contributive efficiency of each part of composite grouting materials (see Section 3.2), strength and compressive resilient modulus characteristics (see Section 3.3).

The test was conducted almost totally in accordance with ASTM D 1074-09 [19] except that the specimen is a 40 mm × 40 mm × 80 mm prism instead of a cylinder with 101.6 mm of diameter. The preparation of specimens are as follows: Firstly, matrix asphalt mixture specimens in 300 mm × 300 mm × 50 mm were prepared by rolling method; then composite grouting materials H2, H3 and control sample

Table 1
Basic indexes of A-70.

Test items	Unit	Technical requirements	Results
Penetration (25 °C, 5 s, 100 g)	0.1 mm	60–80	72.4
Ductility (15 °C)	cm	≥100	>120
Softening point	°C	≥46	48.2
Brookfield viscosity (60 °C)	Pa·s	≥180	190.0
Flash point	°C	≥260	330
Density (15 °C)	g/cm^3	–	1.030