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Effect of sample setting time on experimental evaluation of hot mix asphalt

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HIGHLIGHTS

- Effect of sample setting time on laboratory evaluation was investigated.
- Noticeable variation of test results occurred during the initial week after molding.
- Sample setting time effect on result evolution differs with various test methods.
- Oxidative aging and emission behavior of asphalt mixture lead to results change.

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ABSTRACT

Hot mix asphalt (HMA) samples tested randomly after molding might lead to misleading performance prediction of asphalt mixture in laboratory. This paper aims to investigate how the sample setting time affects the laboratory evaluation results for HMA mixes. Nine kinds of test procedures were employed to analyze the performance evolution of asphalt mixture AC-13 for varying sample setting times ranging from 1 day to 90 days. Test results showed that oxidative aging and emission behavior of volatile organic compounds from asphalt might be the causes for stiffness effect of lab-molded samples, and consequently leads to test results change. With the setting time prolonging, permanent deformation resistance of asphalt mixture was improved, while the anti-cracking and fatigue properties were degraded. Noticeable variation of test results occurred during the initial week after HMA sample molded in laboratory. Moreover, sample setting time effect on result evolution of different test methods were relatively diverse due to their particular test procedures and objectives. In consideration of field performance of asphalt mixture, more laboratory test procedures and HMA mixes are recommended to specify the reasonable sample setting time for different test methods.

1. Introduction

Asphalt pavement inevitably serves in some high/low temperature, high ultraviolet radiation or rainy regions, which would cause asphalt mixture to experience some typical distresses, e.g. rutting, cracking, aging and stripping, etc. [1–5]. Asphalt mixture with excellent performance is of highly priority to ensure the pavement free from various deteriorations in field [6]. Previous studies confirmed that mechanical properties and durability of asphalt mixture are strongly dependent on the temperature sensitivity of asphalt binder, the skeleton structure of aggregate, as well as the adhesive characteristic between asphalt binder and aggregate [7,8]. In addition, some additives (such as anti-stripping, anti-rutting, anti-aging agents and fibers) are generally employed to modify and improve the long term performance of asphalt mixture [9–13]. Since material composition are one of the most important factors affecting the durability of an asphalt mixture, how to select the suitable raw materials and determine the reasonable proportion of each material are essential for asphalt mixture design [14,15].

Available laboratory tests provide a relatively objective and effective method to determine the material composition of asphalt mixture. Test results can represent the performance grade of corresponding asphalt mixture with different kinds of asphalt binders, different aggregate gradations and different kinds/contents of modification agents. For example, rutting test is an ordinary laboratory experiment to assess the high temperature performance of asphalt mixture according to the Chinese Specification. In this test, greater dynamic stability and smaller rutting depth mean that asphalt mixture has better resistance to permanent deformation under high temperature [16]. Moreover, current

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laboratory tests are relatively various and focus on comprehensive performance of asphalt mixture with both macro and micro aspects. Therefore, road researchers and engineers usually conduct a series of specific laboratory tests for asphalt mixtures before pavement construction, in order to obtain a sufficient understanding of mechanical properties, such as rutting resistance, moisture resistance, aging resistance, cracking resistance and fatigue life [17,18]. By analyzing and comparing the test results, engineers and researchers would determine the optimum material composition of asphalt mixture within different aspects, such as performance, durability, economy and construction. From this point of view, experimental accuracy is considerably important for asphalt mixture design.

Considering the importance of laboratory tests, different countries have developed a number of test standards for HMA mixes, e.g. American Association of State Highway and Transportation Officials (AASHTO), European Committee for Standardization (CEN) and Research Institute of Highway Ministry of Transport, China, etc. In any standard, researchers and engineers can get the detailed information of each particular test, including how to prepare and treat the samples, how to apply the loading (loading level and rate, loading and rest period, static or dynamic loading), how to control the test conditions (temperature and moisture) and etc. All the standards aim to keep asphalt mixture samples tested under the consistent experimental procedures. Impersonal assessment and prediction of mechanical properties and durability of different asphalt mixtures can be made based on the test results.

Although the current standards specify the test procedure, there is still no time limits for testing after samples lab-molded. Setting time, which refers to a period from the molding time to the actual testing time, can be random including 1 day, 1 week, 1 month, or even much longer period. By Hamburg wheel tracking test (HWTT), Walubita et al. found that rutting resistance of HMA mix improved with increasing the sample setting time. Varied sample setting times would lead to misleading rutting performance prediction of asphalt mixture in the laboratory [19,20]. From this point of view, setting time aspect should be taken into account to ensure consistency and accuracy of laboratory tests. However, in addition to HWTT test, setting time effect on other common laboratory tests are still unknown. Therefore, it is necessary to investigate the performance evolution of asphalt mixture during the laboratory setting periods and specify the acceptably reasonable sample setting time for available experimental methods.

The primary objective of this research is to investigate how the setting time affects the experimental evaluation by different tests for HMA mixes. Evolution of test results with increasing the sample setting time were comparatively studied by nine kinds of laboratory tests. In the subsequent sections, the materials and experimental methodology were described, followed by test results and analysis. The paper then concludes with a synthesis and summary of the findings and recommendations.

2. Materials and experimental methods

2.1. Materials

The 60/80 penetration graded asphalt binder, with a softening point of 49.1 °C, a ductility of 156 cm (5 cm/min, 15 °C) and a penetration of 69 (deci-millimetre, 25 °C, 100 g, 5 s), was supplied by the Hubei Guochuang Hi-tech Material Co. Ltd. in Wuhan, China. Diabase with a density of 2.953 g/cm^3 and a particle size less than 16 mm was obtained from Xianning City, Hubei Province, China. Limestone filler with a density of 2.882 g/cm^3 was also used in this research.

2.2. Sample preparation

Marshall procedure was adopted to design a mixture with the nominal maximum size of 13 mm in this research. The gradation curve of AC-13 is shown in Fig. 1. The content of mineral filler was 4% by weight of aggregate and the optimum asphalt content was 4.9% by weight of asphalt mixture. The volumetric characteristics including air void, voids in mineral aggregate VMA, and voids filled with asphalt VFA, and pavement performance of asphalt mixture satisfied all the corresponding criterions according to the Chinese Specification of JTG F40-2004 [14]. Since the air void content is important to test result, the air void content of HMA samples were about 4.0% ± 1.0 for all the tests, in order to minimize the possible effect caused by air void content.

2.3. Sample setting times

For HMA mix design, the required laboratory test methods are extremely laborious and time consuming. Due to lacking of setting time specification, circumstantial factors may delay the testing procedures and thus hardly permits to test the samples within the shortest practically possible time period after molding. In this study, the sample setting time period ranged from 1 day to 90 days. The lab room temperature and humidity are 25 °C and 50%, respectively. Test results after various setting times were comparatively studied. For each setting time and each laboratory test, four repetitions were tested and the average value was used in this study. Compared to the test result of initial setting time (1 day), delta variation value and variation rate were adopted to better understand the setting time effect on test results, which were calculated as Eqs. (1) and (2):

$$\Delta TS = TS_j - TS_i \tag{1}$$

$$\Delta TS\ per\ day = \frac{\Delta TS}{j\ days\ setting\ time - i\ days\ setting\ time} \tag{2}$$

where TS is the test result; subscripts i and j are the particular setting time, days; ΔTS is the test result difference between different setting times of i days and j days after sample fabricated.

2.4. Test method

2.4.1. Marshall stability test

Marshall Stability test was conducted according to T0709-2011 [16]. Samples with diameter of 101.6 mm and height of 63.5 mm were compacted with 150 blows by the Marshall hammer, 75 blows on each side of the sample. Before testing, samples were first immersed in hot water bath of 60 °C for 30 min. Then the samples were tested under a monotonous loading of 50 mm/min. Marshall Stability (kN) and flow value (mm) were measured to evaluate the high temperature performance of HMA samples.

2.4.2. Freezing-thawing test

Indirect tensile test was carried out according to T0729-2011 [16]. Different with the Marshall test, freezing-thawing samples were compacted with 100 blows by the Marshall hammer, 50 blows on each side of the sample. For each setting time, eight samples were divided into control and conditioned groups. Freezing-thawing procedure were adopted to treat the conditioned group samples, which included 16 h at −18 °C in freezer and 24 h at 60 °C in a hot water bath. Before testing, both the control and conditioned samples were kept in a 25 °C water bath for 2 h. The tensile strength ratio (TSR) can evaluate the moisture resistance of HMA mixes, which was calculated as below in Eq. (3):

$$TSR = \frac{Tensile\ strength\ of\ conditioned\ samples}{Tensile\ strength\ of\ control\ samples} \times 100\% \tag{3}$$

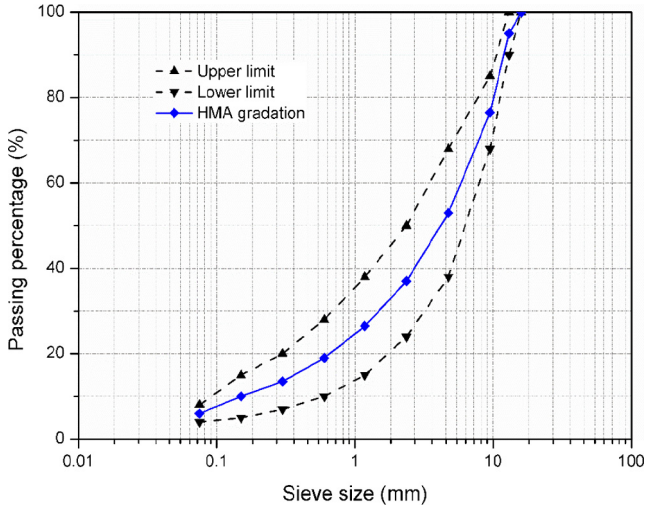

Fig. 1. Chart of aggregate gradation.