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Temperature segregation of warm mix asphalt pavement: Laboratory and field evaluations

Xuelian Li [a,b,*], Zhigang Zhou [a], Xinchao Lv [a], Kuiyuan Xiong [a], Xinji Wang [a], Zhanping You [b]

[a] State Engineering Laboratory of Highway Maintenance Technology, Changsha University of Science and Technology, 960, 2nd Section, Wanjiali South RD, Changsha 410004, China
[b] Department of Civil and Environmental Engineering, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931-1295, USA

HIGHLIGHTS

- Temperature segregation had a remarkable effect on WMA properties.
- Four levels of temperature segregation of WMA were suggested.
- The corresponding temperature differences were <3 °C, 3–8 °C, 8–18 °C and >18 °C, respectively.

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ABSTRACT

Temperature segregation refers to as different mixture cooling areas during construction in asphalt pavements. The objective of this study is to evaluate the effect of temperature segregation on warm mix asphalt (WMA) with laboratory and field tests. The performance of WMA compacted at four various temperatures was evaluated in the laboratory. The temperatures were measured during construction in the field sections with infrared thermography and plug-in thermometers. The pavement quality indicator (PQI) was applied to measure the density and the air void content at 216 testing locations the day after construction. In addition, field cores were collected to verify some of the PQI results. The test results showed that temperature segregation of WMA had a remarkable effect on the aggregate structure, density, water stability, high temperature stability, low temperature cracking and tensile strength. The reason for temperature segregation and related preventive measures are recommended at the same time. Based on the study, the preliminary temperature segregation criteria are recommended with the consideration of the field measurement. In application, the temperature segregation of a typical gradation with a nominal maximum aggregate size of 19 mm, referred to as AC-20 WMA, was suggested to be divided into four levels in view of the air void content: no segregation, low-level segregation, medium-level segregation and high-level segregation. The corresponding temperature differences were <3 °C, 3–8 °C, 8–18 °C and >18 °C, respectively.

1. Introduction

1.1. Background

Segregation of hot mix asphalt (HMA) pavement is a common problem throughout the world. There are two different types of segregation: aggregate segregation and temperature segregation [1]. Aggregate segregation refers to the non-uniform distribution of different sized aggregate components. Temperature segregation refers to different mixture cooling areas during construction, which affects the optimum asphalt content, air void content, density and the asphalt absorption of the compacted mixture. It originates from the cooler crust that forms on top of the asphalt and the edge of the loose asphalt mix during the transportation, paving and compaction process [2]. It occurs as the result of the different cooling of portions of pavement during construction. Then the resulting nonconformity, in turn, affects the road performance of the pavement [3,4]. In recent years, numerous studies have been carried out to identify and mitigate causes of temperature segregation of HMA pavement, such as subjective or visual identification, sand patch testing, and nuclear or non-nuclear density gauges [5,6]. X-ray computed tomography was used to detect the orientation and distribution of aggregates [7]. Infrared thermography and

* Corresponding author at: State Engineering Laboratory of Highway Maintenance Technology, Changsha University of Science and Technology, 960, 2nd Section, Wanjiali South RD, Changsha 410004, China.
E-mail address: lixuelianfj@gmail.com (X. Li).

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laser surface texture measurements were used to recommend air void content and temperature limits for HMA in NCHRP report 441 [8].

WMA can be compacted at least 20–30 °C lower than traditional HMA [9–11]. Several benefits of a lower compaction temperature include savings in fuel consumption, less emissions of harmful gases and asphalt aging, benefits for the environment and construction workers during construction, and a longer construction season [9,12,13]. In the last decades, dozens of field test sections have been constructed throughout the world with different WMA technologies [14–16]. Since temperature segregation is a recurring problem in HMA throughout the world [17,18] and the properties of WMA are much like HMA, WMA may also have a temperature segregation problem. However, limited investigations are available to evaluate the effect of temperature segregation on WMA pavements.

Compaction is a determining process in the design and production of asphalt mixture. The compaction quality affects the road performance of the asphalt pavement. Insufficient compaction due to low temperature leads to various early distresses in pavement. This means the compaction temperature of the asphalt mixture is a key factor that influences compaction quality, workability and final quality of pavement [19,20]. Both the temperatures of the initial compaction and final compaction are provided in the Chinese specification [21]. The variation in initial, secondary and final compaction temperature of each detection point was almost the same during the whole compaction process, as presented in Fig. 1. Therefore, we only need to analyze the effect of the initial compaction temperature segregation on the density and air void content of asphalt mixture [22].

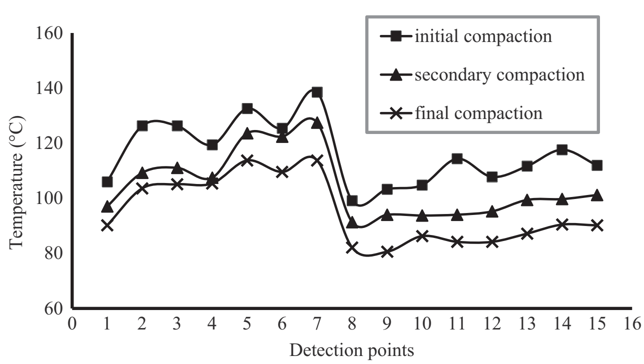

Fig. 1. Temperature variation trends of each detection point (data source: [22].

Table 1
Basic properties of Sasobit.

Appearance	Faint yellow granules
Density (25 °C; g/cm^3)	0.9
Melting point (°C)	115
Flash point (°C)	285
Solubility	Water-immiscible

1.2. Research objective and scope

The objective of this study is to evaluate the effect of temperature segregation on warm mix asphalt (WMA) with laboratory and field tests. In order to achieve such an objective, both laboratory and field evaluations were performed. The properties of WMA compacted at four compaction temperatures were measured in the laboratory. Then test sections were paved at the optimum compaction temperature. During construction, the compaction temperatures in the field were monitored with infrared thermography and plug-in thermometers at the paving site in a range of a 4705 m road section, between the paver and the roller, from standing at the left edge of the lane. PQI was applied to measure the density and the air void content at some part of the same areas the next day. Then some results of the PQI tests were verified by field cores. The compaction quality was evaluated and temperature segregation was analyzed. Finally, based on the proposed temperature segregation evaluation limits of HMA in a report published by NCHRP [23], the criteria for temperature segregation of WMA were suggested in this paper. The scope of this study was limited to Sasobit WMA with AC20 mix commonly used in China.

2. Materials

2.1. WMA additive

Sasobit, a product of Sasol Wax, is white granules, which has longer chemical chains. The longer chains, keeping the wax in solution, decrease the viscosity of the asphalt and compaction temperature of WMA mixture. The melting temperature of Sasobit used in this study was 115 °C. In view of our past studies, the optimum additive content was 3% of the binder mass [16]. The basic properties of Sasobit are shown in Table 1.

2.2. Asphalt

The base styrene-butadienestyrene block co-polymers (SBS) modified asphalt used in this study was provided by a company in Guangxi Province in China. The needle penetration test, ductility test, softening point test, density, flash point viscosity, and RTFO aging tests were carried out to detect the basic properties of this asphalt in accordance with the standard test methods used in China [24]. The related test results are shown in Table 2. They are all in the range of the specification limits, which means that the asphalt is acceptable.

Table 2
Properties of the SBS I-D modified asphalt.

Sample	Test	Standard method	Values	Specification limits
Unaged samples	Density	T0603-2011	1.037	–
	Penetration at 25 °C (0.1 mm)	T 0604-2011	56	40–60
	Ductility at 25 °C (5 cm/min; cm)	T 0605-2011	104.1	>20
	Softening Point (°C)	T 0606-2011	78.1	>60
	Flash point (°C)	T0611-2011	319	>230
	Viscosity at 135 °C(Pa*s)	T0610-2011	2.99	⩽3
After RTFO aging	Retained quality (%)	T0625-2011	0.1	<±1.0
	Retained penetration (25 °C; %)		88	>65
	Retained ductility(5 °C; cm)		63.55	>15