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Effects of Compaction Method and Temperature on Warm Mix Asphalt

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Key words: Warm-Mix Asphalt; asphalt mixture; temperature; compaction; volumetric properties.

Abstract: A laboratory investigation was carried out on the volumetric properties of WMA fabricated using the Superpave gyratory compactor (SGC) and the Marshall compactor as a function of compaction temperature. The volumetric properties were obtained and analyzed at the six compaction temperatures 170℃,150℃,130℃,110℃,100℃,90℃. The results show that: Evotherm® can improved the compatibility of the mixtures; Warm Mix Asphalt is sensitivity to the temperature when the compaction method is Marshall; the method of SGC is conducive to dense asphalt pavement for WMA; the best compaction temperature of WMA is not lower than 125℃; the compaction temperature can decreased more than 20℃ for WMA comparison with the HMA.

Introduction

European countries are using technologies that appear to allow a reduction in the temperatures at which asphalt mixes are produced and placed. These technologies have been labeled Warm Mix Asphalt (WMA). The immediate benefit to producing WMA is the reduction in energy consumption required by burning fuels to heat traditional hot mix asphalt (HMA) to temperatures in excess of 150℃ at the production plant [1,2]. These high production temperatures are needed to allow the asphalt binder to become viscous enough to completely coat the aggregate in the HMA, have good workability during laying and compaction[3].

Compaction is a essential factor in the design and subsequent production of asphalt of asphalt mixture [4].Mix properties, such as density and air voids are highly dependent on the degree and the method of compaction. There are several factors that affect the strength of bituminous mixtures[5]. One of them is the method of forming a realistic test specimen in the laboratory that represents the structure of the paving mixture when it is placed in the field. The method of Gyratory Compactor (SGC) and Marshall compaction is always used. It is indicated that the Texas Gyratory Compactor was best in terms of its ability to produce compacted mixtures with engineering properties similar to those produced in the field and it is a better compaction method to situate and to evaluate the compaction process of mixture. However, the equipment of Marshall is simple, the Marshall method has been used in China and many other countries worldwide [6].

The compaction temperature influences workability, which is related to the achieved density of the mixture. The compaction temperature recommended in the current Superpave procedures for asphalt mixtures is determined as the range of temperatures where an unaged asphalt binder has a viscosity of 0.28 ± 0.3Pa.s [7]. This requirement was based on the experience with conventional asphalt binders. In general, the binder in modified asphalt mixtures is stiffer than in conventional mixtures. Therefore, there is a need for higher compaction temperature. Previous studies on the effect of compaction temperature on the volumetric properties of asphalt mixtures reported that specimens could have the same volumetric properties over a very wide range of compaction temperatures [8,9].

However, WMA is a new technology. Compared with the traditional hot mix asphalt, the mixing and compaction temperatures are relatively low, there are many difference for compaction characteristics between Warm Mix Asphalt and the traditional hot mix asphalt, Therefore, it is important for WMA to select the method and temperature of compaction.

Experimental

Raw materials

Bitumen

In the study, SBS modified asphalt was used, which was produced by Kelamayi Asphalt Co. Ltd, and the performance indexes of SBS modified bitumen are shown in Table 1.

Table 1. Performance index of SBS modified bitumen

Parameters	Result	Specification
Penetration(0.1mm at 25℃,100g&5sec)	64.6	60-80
Ductility at 5℃	41.1	≮30
Softening point/℃	72.9	≮55
Penetration index	-0.0662	≮-0.4
Rotation viscosity at 135℃/Pa.s	2.13	≯3
RTFOT(163℃,85min)		
Mass loss/%	0.243	≯±1.0
Ductility at 5℃	25.7	≮20
Penetration ratio/%	62.54	≮60

Mineral and gradation

The crashed basalt mineral was employed for AC-16 asphalt mixture as aggregate.Basalt coarse aggregate and fine(bulk specific gravity of 2.96g/cm3 and 2.94g/cm3, respectively) were used in the specimens preparation. Limestone was used as mineral filler. Table 2 presents the selected mix gradation.

Table 2. Gradation of aggregate (by mass)

Mixture type	Sieve size/mm										
	19.0	16.0	13.2	9.5	4.75	2. 36	1.15	0.6	0.3	0.15	0.075
AC-16	100.0	92.6	85.0	63.3	43.3	30.5	22.6	18.2	11.4	8.0	5.9

Warm mix asphalt processes

Warm mix asphalt was obtained by the Evotherm™. It is developed by MeadWestvaco(MWV) Asphalt Innovations. The second generation product, Evotherm™ Dispersed Asphalt Technology (DAT), uses the same chemical package contained in the emulsion. Evotherm™ DAT is injected directly into the asphalt binder supply line just prior to entering the mixing chamber of a drum mix plant or directly into the pug mill of a batch plant. The DAT process, has for the most part, replaced the emulsion process[10].

Method

The mixing of the aggregates with the asphalt binders was conducted at temperatures recommended by the manufacturers of asphalt binder and warm mix additives. The loose asphalt-aggregate mixtures were oven aged at the compaction temperatures for 2h prior to the compaction. The six compaction temperatures used were 170℃,150℃,130℃,110℃,100℃,90℃. The specimens were fabricated using gyrations of SGC and Marshall compactor at the above compaction temperatures.

Results and discussions

Volumetric properties as a function of compaction method

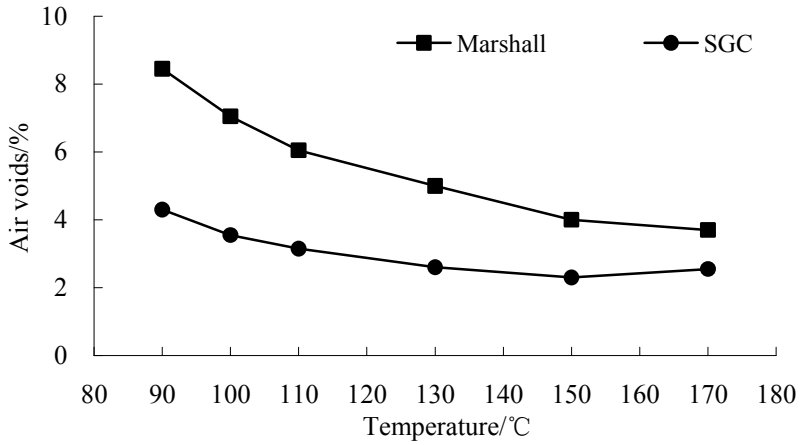


Fig.1 The air voids of WMA compacted by the method of Marshall and SGC at the different temperature

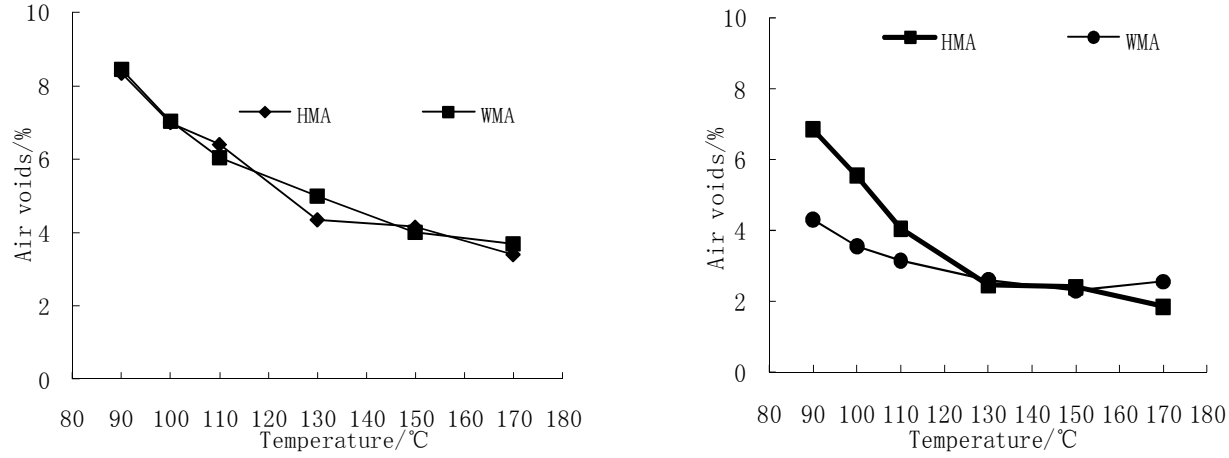
Fig.1 shows that the change of air void of WMA specimen compacted by the method of Marshall are more obvious. It indicates that Warm Mix Asphalt is sensitivity to the temperature when the compaction method is Marshall. In contrast, the change of air void of Warm Mix Asphalt compacted by the SGC is smaller when the compaction temperature below 150℃. And its air voids is smaller then that by the method of Marshall. It is suggested that the method of SGC is conducive to dense asphalt pavement for WMA .

The reason may be that Marshall method is itself a way of hammering which can not can not simulate the effect of roller in the process of pavement. And the impact is not helpful to the directional rearrangement of aggregate. At same time the aggregate is easy crushed by the method of Marshall which may be affect the lubrication of water Film. SGC quietly simulate field compaction, which can reduce the chance of crush in the process of compaction and the lubricating water film can effectively play the role.

Air voids as a function of compaction temperature

Fig.2a) show that that air voids has almost the same trend with temperature, whether it is HMA or WMA by the method of Marshall. It indicates that the compaction of Marshall can not reflect the advantage of WMA additives. And the method of Marshall is not suitable to the WMA.

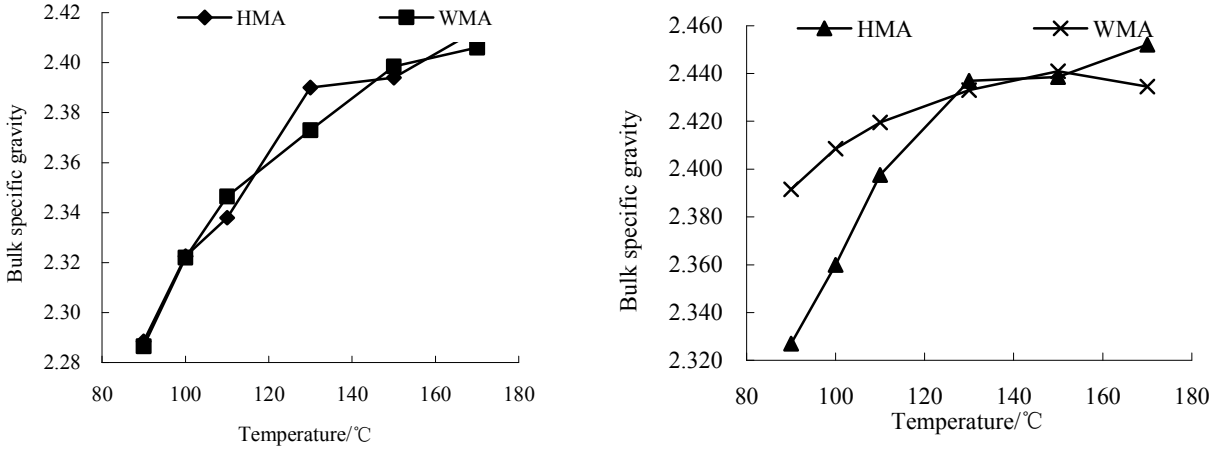
Fig.2b) that the air voids of WMA is smaller than that of HMA when the compaction method is SGC. It is worth noting that the disparity of air voids between HMA and WMA is larger when the compaction is below 125℃. It is indicated that the best compaction temperature of WMA is not lower than 125℃.



a) Specimen by the Marshall b) Specimen by SGC

Fig.2 The air voids of HMA and WMA compacted at the different temperature

Bulk specific gravity as a function of compaction temperature



a) Specimen by the Marshall b) Specimen by SGC

Fig.3 The bulk specific gravity of HMA and WMA compacted at the different temperature

Fig.3a) show that that bulk specific gravity have almost the same trend with temperature, whether it is HMA or WMA by the method of Marshall. It again indicates that the compaction of Marshall can not reflect the advantage of WMA additives. And the method of Marshall is not suitable to the WMA.

Fig.3b) show that bulk specific gravity of WMA increases when the temperature was increasing. And there is a peak of bulk specific gravity at a temperature. After this temperature, the bulk specific gravity is decreasing with the increasing compaction temperature. The specific gravity is not increased with the compaction temperature increases linearly.

Because the effect of temperature changes on the theoretical maximum density of asphalt mixture is little, the best of compaction temperature can be selected by the bulk specific gravity is at the peak. Therefore, the best compaction temperature of WMA and HMA by the method of SGC is 150℃ and 170℃. It is indicate that the compaction temperature can decreased more than 20℃ for WMA comparison with the HMA.

Conclusions

Within the limitations of materials and test used in this study the following conclusions are drawn:

(1) Evotherm® can improve the compatibility of the asphalt mixtures. Statistics indicated an average reduction in air voids up to 1.6 percent than traditional hot mixture asphalt.

(2) The change of air void of WMA specimen compacted by the method of Marshall are more obvious. It indicates that Warm Mix Asphalt is sensitivity to the temperature when the compaction method is Marshall. It indicates that the compaction of Marshall can not reflect the advantage of WMA additives. And the method of Marshall is not suitable to the WMA.

(3) The change of air void of Warm Mix Asphalt compacted by the SGC is smaller when the compaction temperature below 150℃. It is suggested that the method of SGC is conducive to dense asphalt pavement for WMA

(4) It is worth noting that the disparity of air voids between HMA and WMA is larger when the compaction is below 125℃. It is indicated that the best compaction temperature of WMA is not lower than 125℃.

(5) The best compaction temperature of WMA and HMA by the method of SGC is 150℃ and 170℃. It is indicate that the compaction temperature can decreased more than 20℃ for WMA comparison with the HMA.

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