Research on Different Additives to Improve the Moisture Susceptibility of Granite Asphalt Mixtures

X. Huang, S.P Wu, W. Zhang
Key Laboratory of Silicate Materials Science and Engineering of Ministry of Education, Wuhan University of Technology, Wuhan, China

ABSTRACT: This paper focuses on improvement of the moisture resistance of granite asphalt mixtures by means of additives. The used additives, which are a replacement for common mineral filler, include hydrated lime, Portland cement, and active mineral filler consisting of fly ash, anti-stripping agent, and limestone filler. Asphalt mixtures with common mineral filler were chosen as control mixtures. The moisture susceptibility of asphalt mixtures was investigated by means of retained Marshall stability under water immersion and indirect tensile strength ratio (TSR) after subjected to freeze-thaw cycles. The wheel tracking rutting tests under water immersion were also conducted on small slabs of asphalt mixtures prepared in the laboratory. Test results showed that the resistance to moisture of granite asphalt mixtures was improved by the addition of different additives. However, the improvement was dependent on the type of additive. Among these additives, the active mineral filler showed the best effect. It indicated that a mixture of different additives could be more promising with respects to improvement of moisture resistance.

KEY WORDS: Asphalt mixture, granite aggregate, active filler, moisture susceptibility

1 INTRODUCTION

In the field of asphalt mixtures, moisture damage or stripping is a big concern. Such a concern may arise when acid aggregates obtained from granite, quartz sandstone, etc are being used in asphalt mixtures. The reason for this is the weak interface adhesion between bitumen and acid aggregates. The result from this moisture damage is commonly referred to as stripping (Aksoy et al. 2005 and B. Birgisson et al. 2003). In order to improve moisture resistance in granite asphalt mixtures, particularly stripping, the use of additives such as hydrated lime or Portland cement is the commonly used treatment method (Cheng et al. 2002 and D. N. Little et al. 2005). Furthermore, active mineral filler consisting of a mixture of different types of additives was used to deal with moisture damage. The main objective of this research is to study the effects of three additives (hydrated lime, Portland cement and active filler) on stripping resistance of granite asphalt mixtures. Laboratory tests including Marshall stability testing, indirect tensile strength testing and immersion wheel-tracking testing were performed (R. B Mallick et al. 2005 and M. S. Buchanan et al. 2005).

2 EXPERIMENTAL

2.1 Raw Materials

2.1.1 Bitumen

The use bitumen is SBS modified asphalt produced by Shell Asphalt Co. Ltd (Hubei Province, China) was used. It is main properties is as follows: penetration of 52 (0.1 mm at 25 °C, 100g and 5s), ductility at 5°C of 37.5 cm and softening point of 88.5 °C according to ASTM D 3381. The used bitumen also meets the performance degree of PG 76-22, which is defined according to Superpave binder specifications (David et al. 1993).

2.1.2 Additives

In this paper, the contents of hydrated lime, Portland cement and active mineral filler were 1.5%, 1.5% and 3% by the total weight of aggregates, respectively. Hydrated lime and Portland cement is a replacement for a part of common mineral filler. Active mineral filler, which consists of fly ash (class F), anti-stripping agent (organic polymer and powdered solid), and limestone filler at a mass ratio of 3:0.5:7 was used to replace all of common mineral filler. Some related properties of these additives are shown in Table 1.

Table 1: Some related properties of various additives

Additives	Gravity (g/cm^3)	Water content (%)	Passing percentage (%)		
			0.3	0.15	0.075
Hydrated lime	2.323	0.2	99.3	95.7	89.4
Portland cement	2.960	0.3	100	98.3	96.9
Active mineral filler	2.538	0.5	99.8	97.6	91.2

2.1.3 Aggregate

Granite aggregate obtained from Macheng (Hubei Province, China) was used, and the physical properties the aggregate are shown in Table 2.

Table 2: some properties of granite aggregates

Properties	Abrasion loss (%) (Los Angeles)	Specific gravity (g/cm^3)	Water absorption (%)
Measured values	18.3	2.736	1.0

2.1.4 Mixture Design

The Marshall Mix design procedure was employed to design the mixture. Mix gradation was selected on the basis of the design method recommended by Technical Specification for Construction of Highway Asphalt Pavements (JTJ F40-2004). In this study, asphalt mixture of AC-13 was used and its aggregate gradation is shown in Table 3. A bitumen content of 5.0% was used for mixture blending.

Table 3: Aggregate gradation of asphalt mixture AC-13

Sieve size[mm]	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
Scope	100	90~100	68~85	38~68	24~50	15~38	10~28	7~20	5~15	4~8
Gradation	100	96.5	81.7	54.5	31.4	22.5	17.8	13.7	10.8	6.8

3 TEST METHODS

3.1 Marshall Stability Test

Marshall specimens were prepared by using the standard Marshall hummer with 75 blows on each side of cylindrical samples. In total 16 specimens were prepared. The specimens were divided in four groups according to the average air void content of 5%±0.2. The first group of specimens were immersed in water at 60 °C for 30 min and then loaded to failure by using Marshall test machine at a rate of 50 mm/min. The maximum load was recorded as Marshall stability (MS_1), and the vertical deformation as flow value (FL); the other three groups were used for longer periods of water conditioning. Water immersion at 60 °C for 48h, 72h and 96h was considered. After water conditioning, all the specimens were conducted Marshall stability testing as mentioned before. The maximum loads of the specimens represented by MS_2, MS_3 and MS_4. The retained Marshall stability (RMS) was calculated using:

$$\mathrm{RMS}=\frac{\mathrm{MS}_{\mathrm{condition}}}{\mathrm{MS}_{\mathrm{uncondition}}}\times 100 \tag{1}$$

where RMS is the retained Marshall stability, %; $\mathrm{MS}_{\mathrm{condition}}$ is the average Marshall stability for conditioned specimens (kN) and $\mathrm{MS}_{\mathrm{uncondition}}$ is the average Marshall stability for specimens which were immersed in water at 60 °C for 30min (kN).

3.2 Indirect Tensile Strength Test

Marshall specimens were prepared by using the standard Marshall hummer with 50 blows on each side. In total 16 specimens were prepared. The specimens were divided in four groups to make sure that the average air void of each group should be 7%±0.5. Firstly, the conditioned specimens were placed into a leak-proof plastic bag containing approximately 10 ml of distilled water, then the specimens placed in vacuum container with 98.5 kPa for 15 min. Finally, specimens were subjected to successive freeze–thaw cycling. One freeze–thaw cycle consists of freezing for 16h at -18 °C, followed by soaking in a 60 °C water bath for 24h. Different numbers of freeze–thaw cycles including 1, 2, and 4 were applied to granite asphalt mixtures. . All the specimens were immersed in water at 25 °C for 2h, and then loaded to failure by using splitting clamp perpendicular to specimens at a rate of 50 mm/min (X. W. Chen et al. 2008). The indirect tensile strength and indirect tensile strength ratio (TSR) were determined as follows:

$$R = 0.006287P / h \tag{2}$$

$$TSR=\frac{R_{condition}}{R_{uncondition}}\times 100 \quad (3)$$

Where $R_{uncondition}$ is the indirect tensile strength of specimens without F-T cycle (MPa), $R_{condition}$ is he indirect tensile strength of specimens with different number F-T cycles (MPa), P is the maximum load (kN), h is the height of specimen (mm).

3.3 Immersion Wheel-tracking Test

The small slabs of asphalt mixture were prepared by wheel molding instrument with size of 300mm×300mm×50mm, at an air void of 4-6%. The samples were immersed in 60 ^{o}C water bath for 4±0.5h, and then tested by the wheel-tracking machine. The loading pressure introduced by the wheel was 0.7MPa. The Rolling speed was 42 cycles/min. The duration of test was 60min (S. Mansour et al. 2007).

4 RESULTS AND DISCUSSION

4.1 Marshall stability and Retained Marshall stability

Figure 1 shows the results of Marshall stability of asphalt mixtures containing different additives. Compared with the controlled mixtures containing common mineral filler, the addition of additives results in an increase on Marshall stability. Among these additives, the effect of active filler is the best. This figure also shows that the controlled mixtures became loose after 96h water immersion so that the corresponding Marshall stability can not be measured.

Figure 2 shows the results of retained Marshall stability after subjected to different periods of water immersion at 60 ^{o}C. As showed in the figure, the improvement of three types of the additives is quite significant compared with common mineral filler. However, all the additives show a similar improvement and only slight differences can be observed.

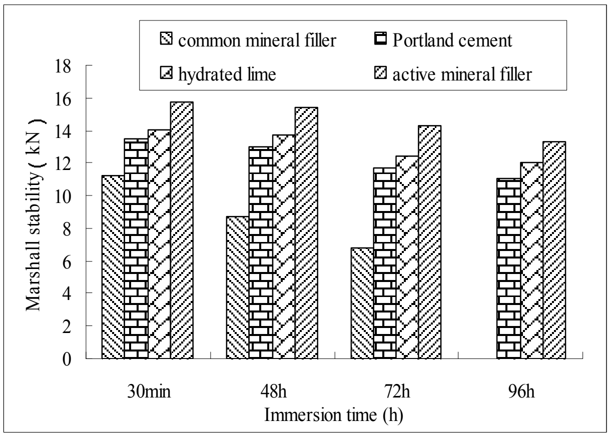

Figure 1: Test results on Marshall stability

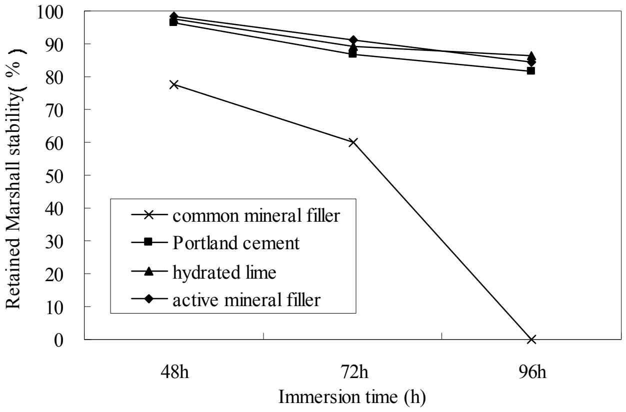

Figure 2: Test results on retained Marshall stability

4.2 Marshall tensile strength and Marshall tensile strength ratio

Figure 3 shows the test results on the indirect tensile strength after subjected to freeze-thaw condition. Compared to the controlled mixtures, the addition of additives obviously increases the indirect tensile strength. The active filler shows the best improvement, while hydrated lime and Portland cement exhibits the similar effect on indirect tensile strength. After subjected to four cycles of freeze-thaw action, the controlled mixture was destroyed and thus no value of indirect tensile strength is shown in Figure 3.

Figure 4 presents the results of indirect tensile strength ratio obtained from various mixtures with or without additives. As shown in the figure, the indirect tensile strength ration of controlled mixture is about 60 percent, lower than the minimum acceptable limit of 75 percent as defined by Chinese specification. After adding additives in granite asphalt mixtures, the indirect tensile strength ratio increases and meets the requirement of the minimum acceptable limit. Among three types of additives, the improvement of active filler is the most significant, followed by hydrated lime and then Portland cement. The indirect tensile strength ratio reduces with increasing number of freeze-thaw cycles. After four cycles of freeze-thaw action, asphalt mixtures containing active filler still remains 80 percent of indirect tensile strength, while asphalt mixtures containing others two types of additives show an indirect tensile strength ratio below or close to the minimum acceptable limit. It indicates that the indirect tensile strength ratio after accelerated freeze-thaw test can be used as a more reasonable index for assessment of water susceptibility.

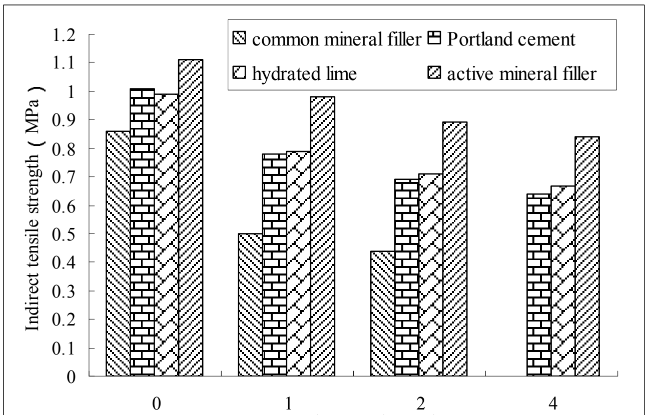

Figure 3: Test data obtained from indirect tensile strength testing

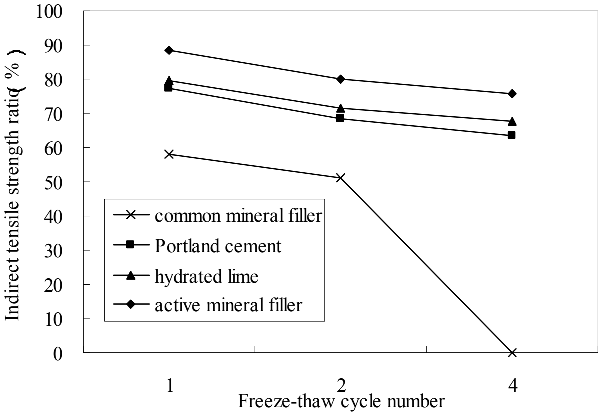

Figure 4: Test results on indirect tensile strength ratio of various asphalt mixtures

4.3 Immersion wheel-tracking test

Figure 5 presents the results of immersion wheel-tracking test on various mixtures containing different additives. As shown in Figure 5, different typed of mixture exhibit different rutting resistance under water condition. Asphalt mixture with active mineral filler show the minimum rut depth after subjected to one hour repeated loading. Portland cement shows the minor effect while the effect of hydrated lime is the minimum.

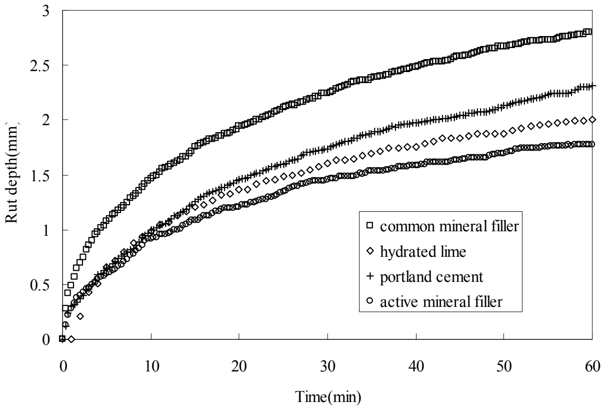

Figure 5: Immersion wheel-tracking test results

5 CONCLUSIONS

The water susceptibility of granite asphalt mixtures containing various additives was investigated by means of retained Marshall stability test, indirect tensile strength ratio test and water immersion wheel tracking test. Based on the obtained results and discussions presented above, the following conclusions were drawn:

1) Granite asphalt mixtures containing common mineral filler show poor water resistance. The mixtures became loose after subjected to 96h water immersion at 60°C or four cycles of freeze-thaw action.

2) The indirect tensile strength ratio of granite asphalt mixture can not meet the minimum

acceptable limit of 75 percent. It indicates that the addition of anti-stripping additives is very necessary.

3) It has shown that the introduction of various types of additive can significantly improve the resistance to water damage of granite asphalt mixtures. Compared to single additives, the effect of active filler consisting of multi-additives seems to be more promising.

4) The indirect tensile strength ratio reduces with increasing number of freeze-thaw cycles. It indicates that accelerated indirect tensile strength test can be used as a more reasonable method for mixture ranking purpose with respects to water susceptibility.

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