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Determination of Hydrated Lime Content Based on Asphalt Mastic High Temperature Performances

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Abstract. The aim of this paper is to study the hydrated lime to the high temperature characters, resist ability of aging, together with workability. Different contents of hydrated lime in asphalt mastic were tested with Dynamic Shear Rheological and Viscosity Tests. The results illustrated that hydrated lime was an appropriate addition agent which can improve asphalt mastic properties greatly, however, too much hydrated lime may result in the decrease of asphalt mixture performances.

1 Introduction

The CPC Central Committee and the State Council Issue the Program of Building National Strength in Transportation recently. Ecological environmental protection, intensive conservation and green development concept were applied throughout the process of transportation infrastructure planning, construction, operation and maintenance. The quality of mastics, the combination of asphalt binder and filler, influences the overall mechanical performance of asphalt mixtures as well as placement workability[1]. Generally, the effect of the filler is based on a volumetric filler effect or an interactive role between the filler and the bitumen due to the fineness and surface characteristics of the filler. The latter effect is related to physico-chemical aspects that explain the specific interfacial interaction of bitumen-filler systems. Studies before found that higher surface activity contributes to stronger bonds at the filler-bitumen interface and a relative increase in the amount of fixed bitumen. However, the role of fillers in paving mixtures is extremely complex and has not been fully explained [2][3][4][5][6]. Limestone filler was selected because it is broadly used filler while hydrated lime represents controlled filler whose effect can be compared with that of the limestone filler. Since hydrated lime is often used to improve moisture resistance in asphalt mixtures, it has been demonstrated to be efficient and interactive filler. This paper concentrates on the performances of asphalt mastic at high temperature, and the optimum hydrated lime content was proposed in terms of some tests.

2 Material and experimental program

2.1 Material

The asphalt employed was graded as AH-90# according to Technical Specification for Construction of Highway Asphalt Pavement (JTG F40-2004), with a penetration of 82dmm at 25 ºC, and softening point of 59.8 ºC. Hydrated lime, supplied by Chuzhou, Anhui Province, was used in the experimental program. Table1 lists the basic properties of hydrated lime. The neat binders were mixed with mineral powder and hydrated lime at three different volume fractions. The ratio of asphalt mastic was illustrated in table2.

Table1. Physical properties of hydrated lime.

CaO+MgO(%)	CO_2(%)	Passing of 0.9mm Sieve (%)	Passing of 0.125mm Sieve (%)
84.51	8.17	37	10.51

Table2. Components of asphalt mastic for hydrated lime and cement instead of mineral filler.

F/A Ratio	Sample code	Proportion (hydrated lime: mineral powder: asphalt)
0.8	I-0.8	0.16:0.64:1.00
	II-0.8	0.24:0.56:1.00
	III-0.8	0.32:0.48:1.00
1.0	I-1.0	0.2:0.8:1.00
	II-1.0	0.3:0.7:1.00
	III-1.0	0.4:0.6:1.00
1.2	I-1.2	0.24:0.96:1.00
	II-1.2	0.36:0.84:1.00
	III-1.2	0.48:0.72:1.00

2.2 Preparation of asphalt mastic

Mineral fillers were fist put into a 165°C oven for 24 h to ensure moisture-free particle surfaces, and asphalt cements originally stored in a one-quart (0.95L) can needed 2 h to preheat the whole can in a 165°C oven and

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to make asphalt cements liquid and ready to mix. Experimental protocol is developed to obtain homogeneous asphalt-mineral filler mastics. The mixer can apply a constant mixing speed to ensure no voids are created in the mixtures. Asphalt was then transferred to the mixing bath maintained at 165℃, and the filler was added slowly while the mechanical stirring is continued at 500 rpm.

2.3 Dynamic-Shear-Rheometer (DSR)

The Dynamic Shear Rheometer has been used with asphalt binders and mastic for many years. To test an asphalt mastic sample, it is placed between two 25-mm diameter circular plates with 1 mm gap. The plates are in a sinusoidal manner with respect to one another, the bottom plate is stationary while the top plate oscillates. Testing is performed at 10 rad/s to simulate the rate of traffic loading. The provisional test procedure for the DSR is TP5.

2.4 Softening Point

The softening point of asphalt is measured in the laboratory using the procedure outlined in Standard Test Methods of Bitumen and Bituminous Mixtures for Highway Engineering (JTJ E20-2011). Using this procedure, asphalt samples are poured into two tapering brass rings. The asphalt is allowed to cool and immersed in water. A 3.5- g steel ball is placed on each asphalt sample and the fluid heated at a rate of 5 ºC min-1 until the asphalt is soft enough to fall through the ring and drop 25mm to a base plate. The temperature of the fluid at the time the ball touches the base plate is deemed to be the softening point of the asphalt.

2.5 Brookfield Viscometer (BV)

The Brookfield Viscometer, ASTM (D 4402), is used as a means of determining the viscosity of an asphalt mastics at high temperatures. Most asphalt mastics behave as Newtonian fluids (stress response not dependent on shear rate) at high temperatures (above 175℃) and have a totally viscous response; the viscosity measurement is therefore sufficient to represent workability. The Rotational Viscometer test method uses a standard spindle that is placed in the asphalt binder sample and turned at a constant rotational speed of 20 revolutions per minute to determine the viscosity of the mastics.

3 Results and discussion

3.1 Dynamic-Shear-Rheometer (DSR)

The asphalt mixture became aged during construction and the process of application. Therefore, the SHRP specification requires that the rutting factor G*/sinθ of a residual asphalt binder after rolling thin film oven test (RTFOT) have a minimum of 2.2kPa. This paper quotes the criterion of rutting factor to study the influences of short-term aging, and the temperature of G*/sinθ=2.2kPa was regarded as the critical temperature of that type of asphalt mastics. The back-calculated critical temperature was illustrated in figure1.

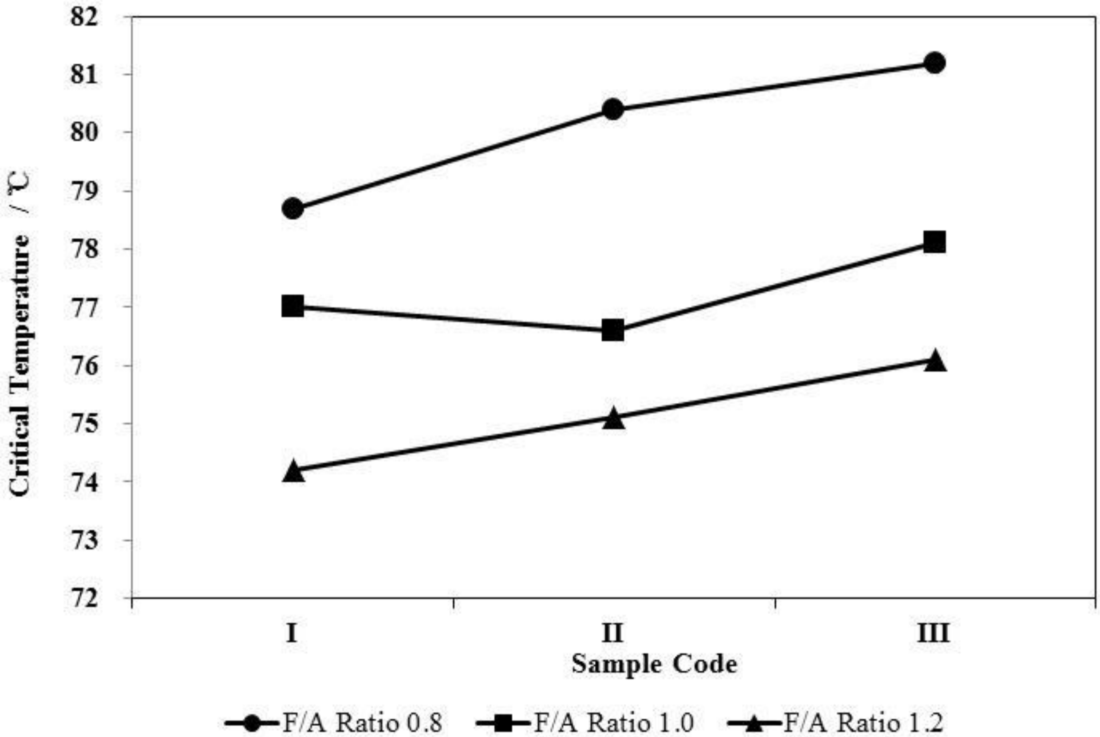

Figure1. Critical temperature of aged asphalt mastics

As can be seen in figure1, with the increase of F/A ratio from 0.8 to 1.2, the aged critical temperature of aged asphalt mastic enhanced gradually. The total trend is that with the increase of hydrated lime, the critical temperature of aged asphalt mortar become high at different types of F/A ratios. The increase in aged critical temperature with the augment of F/A ratio and enhance of hydrated lime may be attributed to the physical effect, which is the higher proportion of hydrated lime, the higher sealing effect is shown, resulting in the decrease of degree of aged asphalt mortar. That is, propriety of F/A ratio and the replacement of hydrated lime avail the increase of anti-age property of asphalt mortar.

3.2 Softening Point

The softening point of different F/A ratios and replacement of hydrated lime was illustrated in figure2.

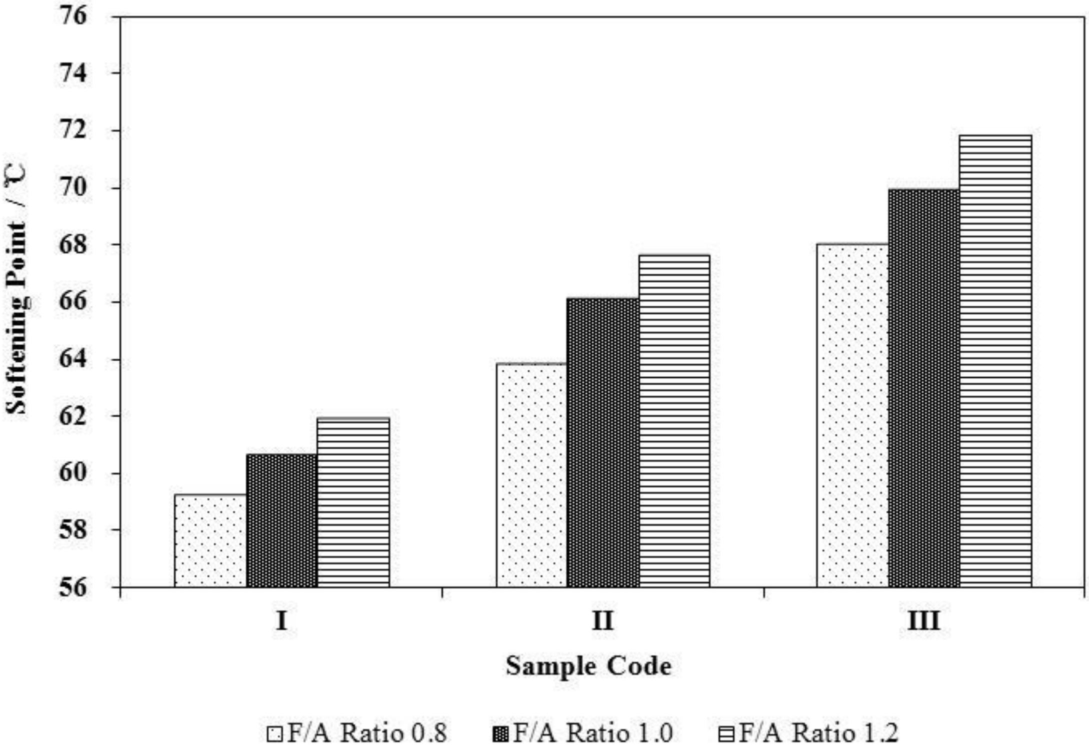

Figure 2. Softening point of different hydrated lime replacement

As showed in figure2, it was increased in general as the F/A ratio increased, and the higher replacement ratio of hydrated lime showed significant increase in the soft point. The reason is that there are some Carboxylic and Sulfoxide in asphalt, and the asphalt showed some acidity. The main component of hydrated lime is calcium oxide (CaO), the formation of calcium hydroxide, $Ca(OH)_2$, occurred during hydration. And the calcium hydroxide is high alkalinity, resulting in the pH value normally exceeds 12. However, $Ca(OH)_2$ may gradually disappear by combining with carbon dioxide (CO_2) to form calcium carbonate ($CaCO_3$) in the process known as carbonation, resulting in the rise of asphalt viscosity and improve the high temperature performances of asphalt mortar.

Previous studies reported that the addition of mineral powder improve the softening point of asphalt, and the difference between before and after should be less than 11°C. Otherwise, the great increase of stiffness of asphalt mortar may result in the decrease of other performances of asphalt mixture. The softening point is 59.8 °C before the addition of mineral powder, according to the results studied before, the softening point should be less than 70.8°C. It can be seen that at the ratio of F/A of 1.2, the softening point of NO. III asphalt mortar was 72.7 °C, exceeding the requirement above. And it can be concluded that when the F/A ratio is 1.2, the replacement of hydrated lime should be less than 30%.

3.3 Viscosity

The viscosity-temperature relationship of a binder or is key to identifying the temperature range for successful mixing and compaction of asphalt mixtures. If the viscosity of the asphalt is too high, the binder may not completely coat the particles in the asphalt mixture; if the viscosity is too low, binder drainage is likely to occur during the storage and transportation of the mix. It is the same with the asphalt mortar.

The workability of the mortar (as measured by viscosity test) increased with increasing hydrated lime replacement level. It was more difficult to compact the mortar as hydrated lime replacement level increased too much. This paper focuses on the 1.2 F/A ratio, which is the usual F/A ratio on the construction field. The hydrated lime was added to the mortar as a partial replacement of the mineral powder at three levels. The viscosity of the asphalt mortar is measured at 135 °C. And the test results can be seen in figure3.

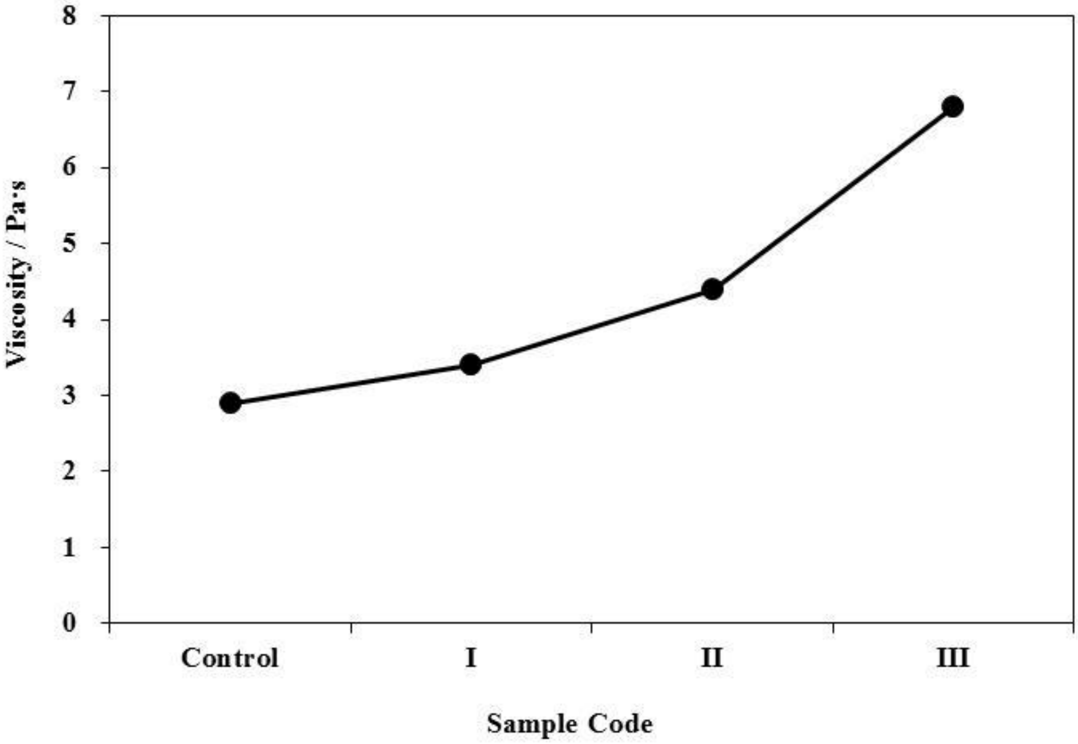

Figure 3. Viscosity of three level replacement of hydrated lime at 1.2 F/A ratio

The introduction of hydrated lime had a pronounced effect on the properties of the asphalt mortar blend. The effect on viscosity was notable, leading to significant increase in recorded viscosity value, as shown in figure 3. As can be seen with the increase of hydrated lime replacement, the viscosity of asphalt mortar enhanced greatly. This may attributed to the fact that the surface area and surface energy of hydrated lime is much larger than mineral powder, resulting in the selection absorption of light molecular weight compounds (such as saturates and aromatics) of asphalt.

It can be seen that the viscosity of control mortar without additional hydrated lime was 2.9Pa·s, and the result of NO.III, which is of 40% replacement, was 6.8Pa·s, with the increase percent of 142.9%. When the replacement proportion of hydrated lime was more than 30%, which is II-1.2, the viscosity of mortar improved rapidly. If too much selection absorption occurred, most of light molecular components will be absorbed at the surface of mineral powder, and the structure of asphalt may be changed. That is, the contents of high molecular weight compounds (such as resins and asphaltenes) enhance comparatively, attributing to the increase of asphalt mortar viscosity. However, too much viscosity may result in the rise of mixing and paving temperatures, which is not friendly and harmonious to the energy saving and environment protection. From the respect of workability of field construction, the replacement of hydrated lime should be less than 30%.

4 Conclusion

The replacement of hydrated lime instead of mineral powder to the performances of asphalt mortar was investigated and can be summarized as follows.

(a)The replacement of hydrated lime improves the performances of asphalt mortar greatly.

(b)Critical temperature of asphalt mortar was suggested for the first time, proper F/A ratio and replacement of hydrated lime improve the critical temperature, resulting the ageing resistance of asphalt mortar.

(c)Too much replacement of hydrated lime may attribute to the reduction of workability of asphalt mixture.

Finally, correlation studies of laboratory and field tests are necessary before the possible practical importance of the results presented in this paper can be determined.

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