THE EFFECT OF FILLER ASPHALT RATIO ON THE PERFORMANCE OF HOT-MIX ASPHALT

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ABSTRACT

The Marshall design method was used to determine the optimal asphalt content for different filler asphalt ratios of hot-mix asphalts. Based on this method, the pavement performances of different filler asphalt ratios were tested. From the test results, a reasonable range of filler asphalt ratios is recommended. This parameter is very important in the application of hot-mix asphalt.

Keywords: Filler asphalt mix, Marshall design method, Superpave, Performance

1. INTRODUCTION

Mortar composed of asphalt and filler has a great effect on the performance of hot-mix asphalt (HMA), especially on performance at low temperatures. The filler asphalt ratio is frequently the subject of research and field trials. In order to determine the best range of filler asphalt ratios, the Marshall test was used to design asphalt mixtures with different filler asphalt ratios, with the aim of providing a more scientific quantitative basis for the design of asphalt mixes.

2. GENERAL DESCRIPTION OF MORTAR THEORY

Modern mortar theory considers an asphalt mixture as a dispersion system with a multi-dimensional net-like structure. First there is a kind of coarse dispersion system, with the coarse aggregate as the part that disperses in the coarse asphalt mortar. Similarly, the coarse asphalt mortar is a fine dispersion system, with the fine aggregate as the part that dispersed in the asphalt mortar. The mortar itself is a kind of micro-dispersion system, with the filler as the part that disperses in the heavy-consistency asphalt. This theory can be explained by Figure 1.

- Asphalt mixture
  - Dispersed part – coarse aggregate
  - Dispersion medium – mortar
    - Dispersed part – fine aggregate
    - Dispersion medium – asphalt
      - Dispersed part – filler
      - Dispersion medium – asphalt

Figure 1. Three graded dispersion system of asphalt mixture.

3. EXPERIMENTAL DESIGN

Asphalt mortar is composed mainly of asphalt and filler, which usually passes the 0.075 mm sieve. The aggregate retained on the 0.15 mm, 0.075 mm sieve can also form a fine dispersion system. The properties of such aggregates are similar to those of the asphalt mortar. In the experimental design, the percentage of aggregate passing 0.6 mm and that retained on the 0.15 mm, 0.075 mm sieve were kept invariable. Only the percentage retained on 0.3 mm and the percentage passing 0.075 mm were changed, to study the pavement performance of the asphalt mixture with different filler asphalt ratios. We used the Marshall test to determine the mixture’s optimal asphalt content. The test design is shown in Table 1.

Table 1. Grading of different filler asphalt ratio mixtures.

	1	**2**	**3**	**4**	**5**	**6**
Sieve size (mm)	**Percentage passing (%)**					
19	100	100	100	100	100	100
16	96.98	96.98	96.98	96.98	96.98	96.98
13.2	79.84	79.84	79.84	79.84	79.84	79.84
9.5	66.4	66.4	66.4	66.4	66.4	66.4
4.75	44	44	44	44	44	44
2.36	34	34	34	34	34	34
1.18	24	24	24	24	24	24
0.6	17.1	17.1	17.1	17.1	17.1	17.1
0.3	15.4	14.4	13.2	12	11	9.4
0.15	12.7	11.7	10.5	9.3	8.3	6.7
0.075	8.8	7.8	6.6	5.4	4.4	2.8
CA	0.67	0.67	0.67	0.67	0.67	0.67
Fac	0.55	0.55	0.55	0.55	0.55	0.55
Faf	0.64	0.60	0.55	0.50	0.46	0.39

4. MATERIALS

The asphalt binder was KLMY AH-90$^{\#}$. The properties of the asphalt are shown in Table 2.

Table 2. Normal properties of the asphalt.

Penetration, 100 g, 5 s (0.1 mm)		94.3
Penetration Index (PI)		–0.354
Ductility, 10°C, 5 cm/min (cm)		81.9
Softening point (°C)		47.3
Specific gravity (25°C /25°C)		0.980
Solubility, %		99.8
RTFOT (163°C，85 min)	Loss on heating, %	–
	Ductility, 15°C, 5 cm/min (cm)	79.2
	Penetration Ratio, 25°C (%)	73

Gabbro and limestone powder were used in the mixture and the properties of the aggregates are listed in Table 3. Furthermore, the authors used 0.3% AST-□ anti-stripping agent in the mixture to improve the adhesion between asphalt and aggregates.

Table 3. Test results on aggregate properties.

Test item		Result
Firmness value (%)		3.32
Los Angeles Abrasion value (%)		17.7
Crushed Stone value (%)		14.5
Lashed Stone value (%)		9.5
Flat and elongated (%)		17.23
Adhesion	Unaged asphalt	2
	Anti-stripping agent (aged)	4

5. DETERMINATION OF THE OPTIMAL ASPHALT CONTENT

The design method of the Marshall test was adopted to determine the optimal asphalt content of the mixture. The test results are shown in Table 4 and Figure 2.

Table 4. Optimal asphalt content (OAC) and filler asphalt ratio of the mixtures.

	1	**2**	**3**	**4**	**5**	**6**
OAC (%)	4.193	4.224	4.250	4.314	4.536	4.730
Total filler asphalt ratio	2.099	1.847	1.553	1.252	0.970	0.592

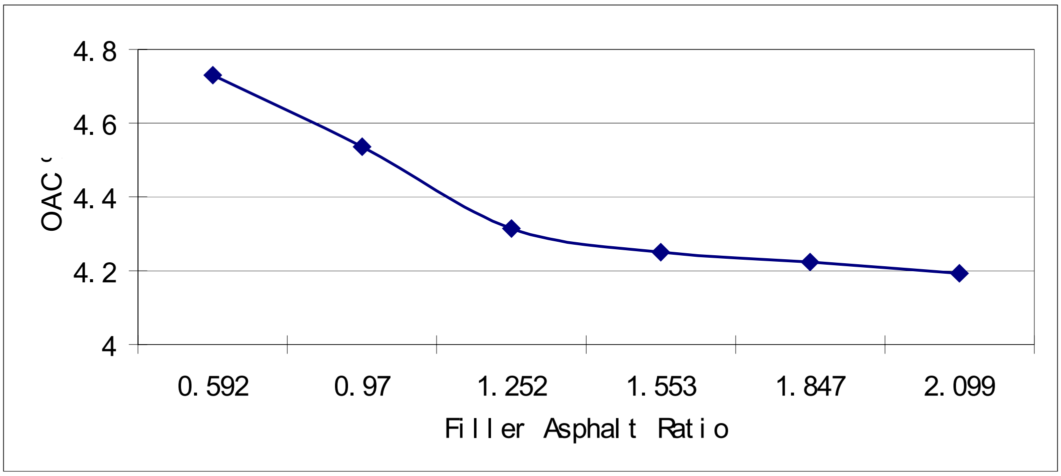

Figure 2. Optimal asphalt content of the mixtures.

As the ratio of filler asphalt increases, the optimal asphalt content of the mixture gradually decreases. The optimal asphalt contents do, however, differ from one another, which has a very great effect on the pavement performance of the mixture.

6. PERFORMANCE

The test results of the mixtures' performance with different filler asphalt ratios are as discussed below.

6.1 High-Temperature Performance

The high-temperature wheel tracking test results on a hot-mix asphalt mixture at 60°C and 0.7 MPa are shown in Figure 3.

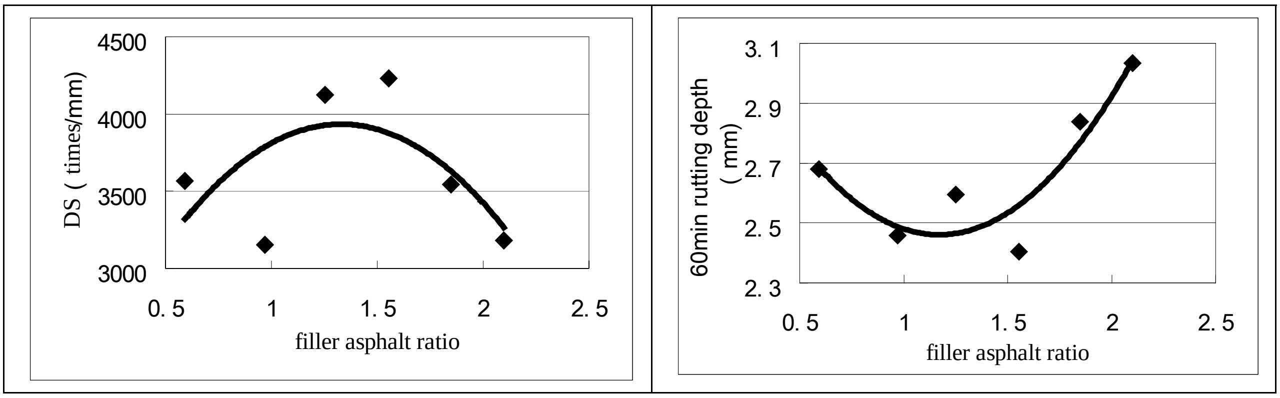

Figure 3. High-temperature performance.

As the ratio of filler asphalt increases, the mixture's dynamic stability changes to a convex curve. There is an optimal filler asphalt ratio at which the dynamic stability reaches its maximum. When the filler asphalt ratio is in the range between 1.07 and 1.85, the mixture's dynamic stability is above 3 500 times/mm. When the filler asphalt ratio is at 1.43, the dynamic stability reaches the maximum. As the filler asphalt ratio increases, so does the filler content, and the asphalt content decreases. The structural asphalt content is then higher and the free asphalt content is relatively lower, so the asphalt mix is quite loose. Under loading, the asphalt mixture will deform easily and considerably in the initial loading phase, in which the dynamic stability is low. As the filler asphalt ratio decreases, the filler content becomes lower and the asphalt content becomes higher. The structural asphalt content is then lower and the free asphalt content is relatively higher, so the mixture looks oily. Under loading, the asphalt and mortar will flow at first. Then the coarse aggregates will start to move along the interface of the aggregates under loading, which also results in large deformation.

As the ratio of filler asphalt increases, the mixture's 60-minute rutting depth changes to a concave curve. When the filler asphalt ratio is in the range between 0.6 and 1.75, the mixture's 60-minute rutting depth is less than 2.6 mm.

6.2 Low -Temperature Performance

The bending test results on the hot-mix asphalt mixture under low temperature at –10°C are shown in Figure 4.

As the filler asphalt ratio increases, the mixture's bending strength changes to a convex curve. There is an optimal filler asphalt ratio at which the bending strength reaches the maximum. When the filler asphalt ratio is in the range between 0.5 and 1.5, the mixture's bending strength is above 9 MPa. When the filler asphalt ratio is at 1.11, the mixture's bending strength reaches the maximum.

As the filler asphalt ratio increases, the mixture's maximum bending strain changes to a convex curve. There is an optimal filler asphalt ratio at which the maximum bending strain reaches the maximum. When the filler asphalt ratio is in the range between 0.78 and 1.45, the mixture's maximum bending strain is above 1 500 με. When the filler asphalt ratio is at 1.09, the bending strain reaches the maximum.

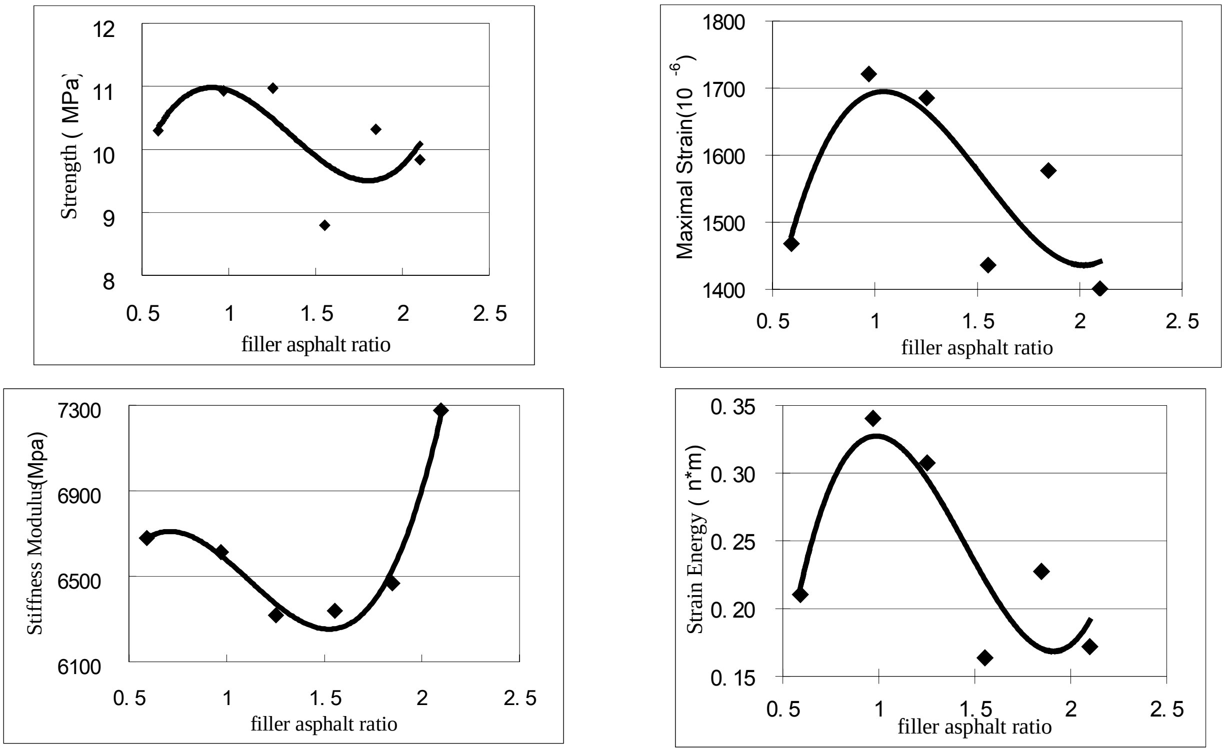

Figure 4. Low-temperature bending test results.

As the filler asphalt ratio increases, the mixture's stiffness modulus changes to a concave curve. There is an optimal filler asphalt ratio at which the stiffness modulus reaches the minimum. When the filler asphalt ratio is in the range between 0.59 and 1.88, the stiffness modulus is below 6 700 MPa. When the filler asphalt ratio is at 1.35, the stiffness modulus reaches the minimum.

As the filler asphalt ratio increases, the mixture's strain energy changes to a convex curve. There is an optimal filler asphalt ratio at which the strain energy reaches the maximum. When the filler asphalt ratio is in the range between 0.59 and 1.46, the strain energy is above 0.20 n*m. When the filler asphalt ratio is at 1.07, the strain energy reaches the maximum.

When the filler asphalt ratio is in the range between 0.78 and 1.45, the asphalt mixture's low-temperature performance is better. When the filler asphalt ratio is near 1.1, the asphalt mixture's low-temperature performance is at its best.

6.3 Water Stability of the Mixture

The water stability test results of the mixture are shown in Figure 5.

With all filler asphalt ratios, the mixture's retained stability is no less than 90%, which meets the requirement of the specification. As the filler asphalt ratio increases, the mixture's retained stability changes to a convex curve. There is an optimal filler asphalt ratio at which the retained stability reaches the maximum. When the filler asphalt ratio is at 1.56, the retained stability reaches the maximum.

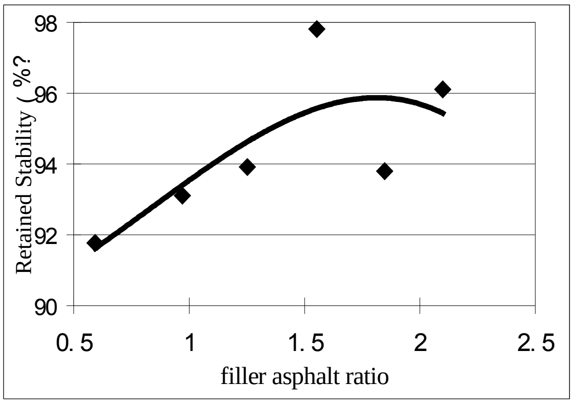

Figure 5. Water stability of the mixture.

7. CONCLUSIONS

- As the filler asphalt ratio increases, the optimal asphalt content gradually decreases.
- When the filler asphalt ratio is in the range between 1.07 and 1.85, the mixture's dynamic stability is above 3 500 times/mm. When the filler asphalt ratio is at 1.43, the dynamic stability reaches the maximum. When the filler asphalt ratio is in the range between 0.6 and 1.75, the mixture's 60-minute rutting depth is less than 2.6 mm.
- When the filler asphalt ratio is about 1.1, the asphalt mixture's low-temperature performance is best. When the filler asphalt ratio is below 0.78 or above 1.45, the mixture's low-temperature performance decreases rapidly.
- When the filler asphalt ratio is in the range between 0.59 and 2.01, the mixture's retained stability is above 90%. When the filler asphalt ratio is at 1.56, the retained stability reaches the maximum.
- Synthesizing all the indices of pavement performance, when the filler asphalt ratio is in the range between 1.07 and 1.45, the mixture's pavement performances are better in all respects. If some aspects of pavement performance need to be strengthened, the filler asphalt ratio can adjusted on this basis.

8. REFERENCES

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