

# Rheological Properties of Asphalt Mortar with High Viscosity

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**Abstract.** In order to study the rheological and rotary viscosity characteristics of asphalt mortar with high viscosity containing different asphalt and filler, the component, filler-bitumen ratio and temperature are considered. The results show that among these factors, viscosity and specific surface area are the main factors that influence the ability of resistance to high temperature deformation. The temperature sensitivity and  $G^*/\sin\delta$  increase with increasing filler-bitumen ratio. The growth rate changes corresponding to the filler-bitumen ratio of 1.2. A good exponential relationship exists between  $G^*/\sin\delta$  and Brookfield rotary viscosity at 135°C and 150°C. Thus, the results of Brookfield rotary viscosity can be used to estimate the influence of filler-bitumen ratio to asphalt mortar characteristics at high temperature instead of filler-bitumen ratio to asphalt mortar characteristics at high temperature instead of  $G^*/\sin\delta$ .

## 1. Introduction

Asphalt mortar combined with asphalt and mineral powder plays an important role in asphalt mixture. In the mixture of porous asphalt pavement, the strength lies on the character of asphalt mortar mainly because of its structure with skeleton space and large air void. E. Ray Brown found that the use of the Dynamic Shear and Bending Beam Rheometers does seem to be viable with mortars and the data obtained with the Dynamic Shear and Brookfield suggests the good correlation to Bending Beam Rheometers [1]. Dr. Dru used the PG64-22 asphalt binder test data initially to predict mastics' performance parameters - shear modulus ( $G^*$ ) and accumulated permanent shear strain and then same properties for asphalt mixtures, in order to find a correlation between the three materials. Binder and mastics were tested at three temperatures (46°, 55°, and 64°C) using a dynamic shear rheometer (DSR), while the mixtures were tested at two temperatures (55° and 64°C) using the Superpave shear tester. Newly developed Hirsch model was used for estimating the shear moduli of asphalt mastics and mixtures. Zhang, Z.Q. and Guo, Pan analysed the influence of fibre to performance of mortar at different temperature by Dynamic Shear and Bending Beam Rheometers [3-5]. Liu, L verified that the matrix asphalt of 90# is approximately Newtonian fluid when the temperature is higher than 90°C [6-7]. And all of studies which had been done aim to the common asphalt mortar, but rarely to the characters of asphalt mortar with high viscosity.

In this paper, influences of asphalt, mineral powder and ratio of filler to bitumen to rheological behavior are studied by Dynamic Shear Rheometers and Brookfield. And the influences of asphalt, mineral powder, and asphalt mortar are analysed basing on the testing results.



## 2. Experimental

### 2.1. Bitumen

Two kinds of modified bitumen are made from matrix bitumen, ESSO70#. One (named B1) is modified with TPS being 12% of bitumen in weight, and the other (named B2) is 5% SBS.

### 2.2. Mineral powder

Two types of limestone powder from different resource are used in the study. And their specific surface areas and particle sizes are tested by different methods. The table 2 shows the results.

### 2.3. Asphalt mortar

Asphalt mortar is the mixture of bitumen and mineral powder. Firstly, mineral powder is heated and dried to a constant weight at  $105 \pm 5^\circ\text{C}$ . Then, a certain quality mineral powder is added into modified asphalt under  $160^\circ\text{C}$ . And the mixture is stirred until it is up to the best. So three kinds of asphalt mortar are chosen for studied from 2 types of bitumen and 2 kinds of mineral powder.

**Table 1.** Indexes of bitumen.

Properties	Test values	
	B1	B2
Softening point ( $^\circ\text{C}$ )	90.2	79.2
Penetration ( $25^\circ\text{C}$ , 0.1mm)	50.3	56.4
Ductility (cm) ( $5^\circ\text{C}$ )	44.1	37.9
Toughness ( $\text{N}\cdot\text{m}$ )	29.6	30.2
Tenacity ( $\text{N}\cdot\text{m}$ )	16.9	20.9
Dynamic viscosity ( $60^\circ\text{C}$ , $\text{Pa}\cdot\text{s}$ )	41743	16713

**Table 2.** Indexes of mineral powder.

Properties		1#	2#
Apparent density ( $\text{t}/\text{m}^3$ )		2.64	2.68
Size range	<0.6mm (%)	100	100
	<0.15mm (%)	99.4	98.4
	<0.075mm (%)	86.4	79.4
Specific surface area (<0.075mm) ( $\text{m}^2/\text{kg}$ )		2392.5	3224.6
Average particle size (<0.075mm) ( $\mu\text{m}$ )		5.476	4.879

**Table 3.** Asphalt mortar.

Asphalt mortar	Modified asphalt	Mineral powder	Ratio of filler to bitumen
B1+1	B1	1#	0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6
B1+2	B1	2#	
B2+1	B2	1#	

### 2.4. Dynamic Shearing Rheological and Brookfield Testing

The Bohlin c-VOR dynamic shear rheometer produced by Malvern is used in this test. Strain control mode is adopted during the test. And the testing parameters are as follows:  $\gamma=10\%$ ,  $\omega=10\text{rad/s}$ . The diameter of sample is 25mm and the thickness is 1mm. Temperature for testing changes from  $64^\circ\text{C}$  to  $84^\circ\text{C}$ . While, Brookfield testing is carried out at the temperature of  $135^\circ\text{C}$ ,  $150^\circ\text{C}$ ,  $165^\circ\text{C}$ ,  $175^\circ\text{C}$  separately.

### 3. Results and discussion

#### 3.1. Dynamic Shearing Rheology

DSR for three kinds of asphalt mortar with high viscosity are done at different temperature and different ratio of filler to bitumen. Results of  $G^*/\sin\delta$  are showed in Figure 1.

Fig.1. shows that  $G^*/\sin\delta$  increases with the increase of the filler-bitumen ratio at the same temperature. And the anti-rutting capability of asphalt mortar is enhanced. This is because with increasing of the filler-bitumen ratio, the content of filler with larger specific surface area increased gradually. And more asphalt is needed to form the structural asphalt which resulted in the reduction of free asphalt in asphalt mortar. Consequently the relative increase of solid content in asphalt mortar led to the decrease of flow deformation at high temperature. Therefore the anti-rutting ability of asphalt mortar is enhanced. Also  $G^*/\sin\delta$  decreases with the increasing of temperature. Then the rate of descent is influenced by the characters of asphalt and mineral filler and the ratio of filler to asphalt. Figure 2 shows the difference rate of descent between the three asphalt mortars at the ratio of filler to asphalt being 1.0. It is obviously that the  $G^*/\sin\delta$  is influenced by characters of asphalt mortar when the ratio of filler to asphalt being at the same. And from Fig.2, it can be seen that the value of  $G^*/\sin\delta$  for B1+1 and B1+2 is remarkably higher than that of B2+1. This result indicates that the character of bitumen is the most important factor which influences the value of  $G^*/\sin\delta$  for asphalt mortar. And it also shows that the higher the viscosity of the asphalt is, the stronger the resistance to deformation at high temperature will be. The trend of  $G^*/\sin\delta$  with temperature can be expressed as following formula [f1].

$$G^* / \sin \delta = Ae^{BT} \quad (f1)$$

Where, A and B are the regression coefficients, and T is the temperature. The smaller the absolute value of B is, the less temperature sensitivity of the asphalt mortar is. The regression results of  $G^*/\sin\delta$  to temperature are shown in Table 4.

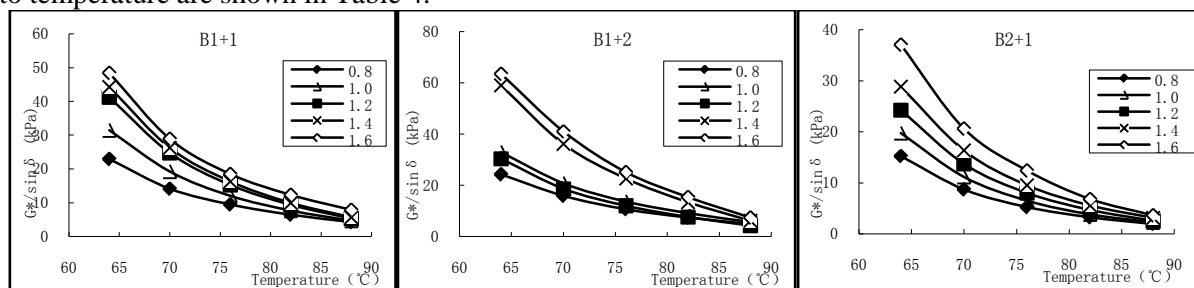


Fig.1 Results of  $G^*/\sin\delta$  for three different asphalt mortar

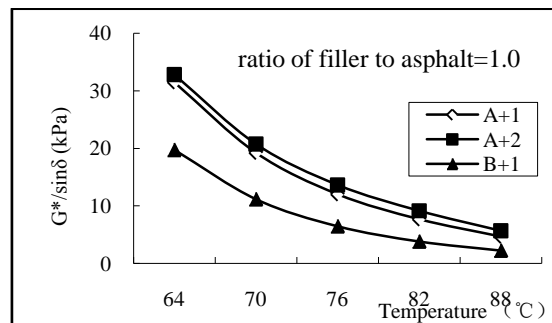


Fig.2. Curves of  $G^*/\sin\delta$  with temperature and type of asphalt mortar

Table 4. Regression results of  $G^*/\sin\delta$  to temperature

Type of mortar	Ratio of filler to bitumen	Equation formula	Correlation coefficient $R^2$	B
B1+2	0.8	$y = 1628.7e^{-0.066x}$	0.9985	-0.066
	1.0	$y = 3323e^{-0.0723x}$	0.9992	-0.0723
	1.2	$y = 5260.6e^{-0.0804x}$	0.9973	-0.08
	1.4	$y = 23128e^{-0.0923x}$	0.9869	-0.0923
	1.6	$y = 19015e^{-0.088x}$	0.9894	-0.088

Results in Table 4 show that the temperature sensitivity of asphalt mortar increases with the increasing of filler-bitumen ratio. Also the characters of asphalt and filler influence the temperature sensitivity of asphalt mortar, especially the dynamic viscosity of asphalt and the specific surface area.

### 3.2 Brookfield Rotary Viscosity

Figure 3 shows the trend of Brookfield rotary viscosity changing with the temperature in different types of asphalt mortar. Brookfield rotary viscosity of asphalt increase with the increasing of filler-bitumen ratio. However, the growth of rotary viscosity is different between the asphalt mortars with different ratio of filler to bitumen. Among the testing range from 0.8 to 1.2, the growth of rotary viscosity is lower than that of ratio changing from 1.2 to 1.6. So the rotary viscosity of asphalt mortar with this is closely related to the type of filler, temperature and the ratio of filler to bitumen. And the rotary viscosity decreases with the increasing of temperature which can be described by the equation of power function (f2).

$$y = Mt^N \quad (f2)$$

Where,  $y$  is Brookfield rotary viscosity,  $t$  is temperature, and  $M$  and  $N$  are the regression coefficients.

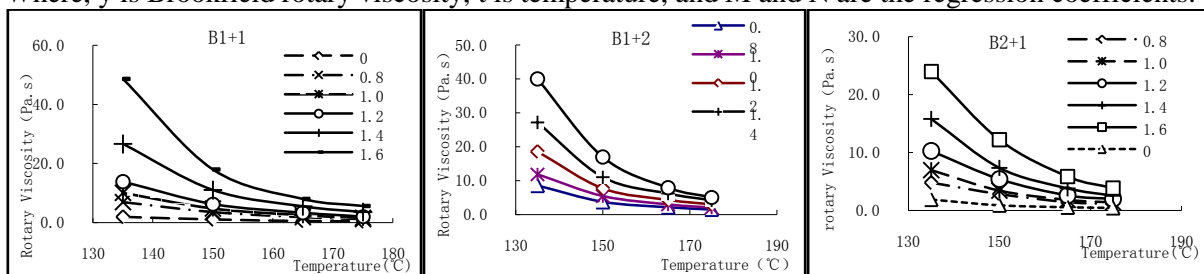


Fig.3. Curves of rotary viscosity and temperature

$M$  stands for the value of rotary viscosity and  $|N|$  indicates the temperature sensitivity. Therefore, the large value of  $|N|$  means the mortar is more sensitive to temperature.

According to ASTM D2463-95a, the logarithm of viscosity is proportional to the temperature. Then, figure 4 shows the results of regression curves between Brookfield rotary viscosity and temperature.

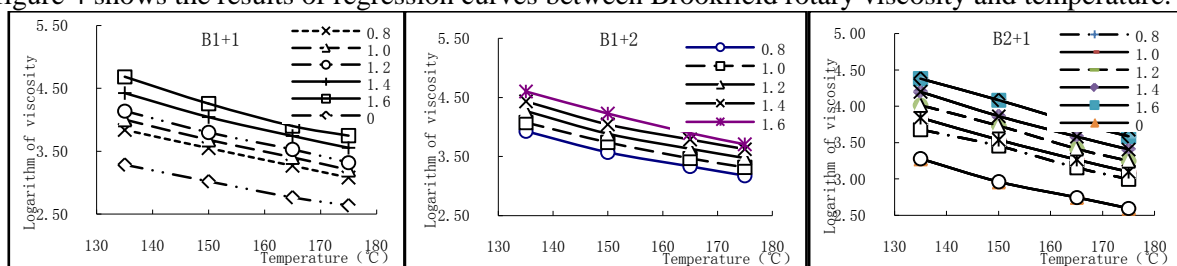


Fig.4. Curves of asphalt mortar and temperature

Curves in figure.4 also verifies the linear relationship between the logarithm of rotary viscosity and temperature. For one kind of asphalt mortar, the slope of the curves increase with the ratio of filler to bitumen. And this result also reveals the more temperature sensitivity. At the same ratio of filler to bitumen,  $|N|_{B1+2} < |N|_{B1+1}$  means that the temperature sensitivity of asphalt named B1+2 is lower than that of B1+1.

### 3.3 Correlation Analysis of Different Rheological Results

Brookfield rotary viscosity indicates the ability of asphalt mortar to resist shearing deformation under external force. And  $G^*/\sin \delta$  is another parameter which can indicate the ability of asphalt mortar to resist permanent deformation. Therefore, it is necessary to analysis the correlation between  $G^*/\sin \delta$  at 64°C and Brookfield rotary viscosity at different temperature (The viscosity of 135°C and 150°C, for example) . The results of correlation between Brookfield rotary viscosity and  $G^*/\sin \delta$  are showed in figure 5. It can be seen from the curves of figure 5 that there is a good exponential relationship between Brookfield rotary viscosity and  $G^*/\sin \delta$ . And these result indicate that the influence regularity of the filler-bitumen ratio to Brookfield rotary viscosity is consistent with that to  $G^*/\sin \delta$ . Therefore, to some extent, results of Brookfield rotary viscosity can be used to estimate the influence of filler-bitumen ratio to asphalt mortar character at high temperature instead of  $G^*/\sin \delta$ .

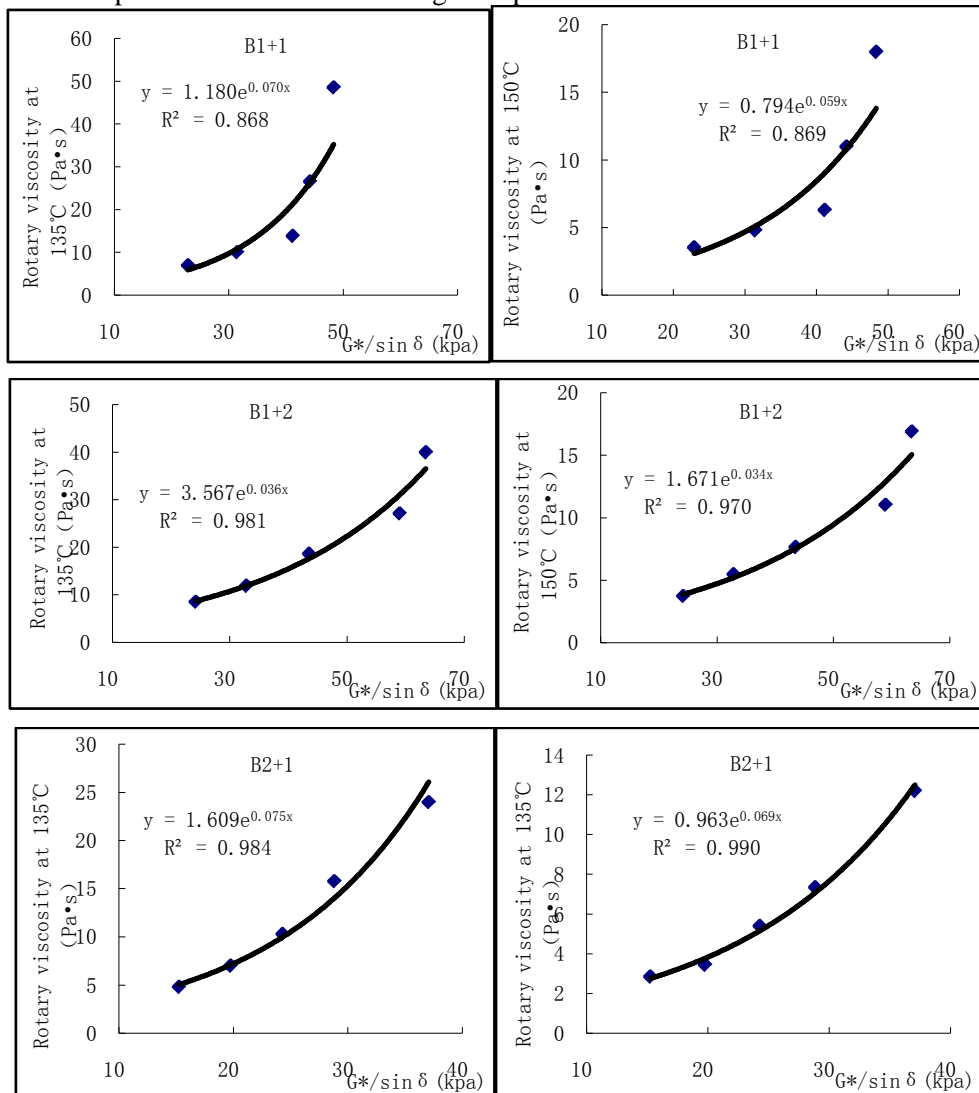


Fig.5. Correlation between rotary viscosity and  $G^*/\sin \delta$

#### 4. Conclusions

This study investigated Dynamic shearing rheology and Brookfield rotaryviscosity of asphalt mortar with different ratio of filler to bitumen. The value of  $G^*/\sin\delta$  is influence by character of asphalt and filler. Asphalt with higher viscosity and filler with larger specific surface area can both improve the value of  $G^*/\sin\delta$ . Therefore, the  $G^*/\sin\delta$  of mortar B1+2 is the highest, and the  $G^*/\sin\delta$  of mortar B2+1 is the lowest. When the ratio of filler to bitumen changes from 0.8 to 1.2,  $G^*/\sin\delta$  increases quickly with the increase of filler-bitumen ratio. But, it increases slowly when the ratio of filler to bitumen is higher than 1.2. Also the temperature sensitivity increases with the increase of the filler-bitumen ratio. To some extent, increasing the specific surface area of filler can decrease the temperature sensitivity of asphalt mortar. Meanwhile, there is a good exponential relationship between  $G^*/\sin\delta$  and Brookfield rotaryviscosity at 135°C and 150°C. So that, the results of Brookfield rotaryviscosity can be used to estimate the influence of filler-bitumen ratio to asphalt mortar character at high temperature instead of  $G^*/\sin\delta$ .

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