Influence of Test Condition on Rheological Property of Asphalt Combined Binder

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Abstract. In order to study the influence of test condition on rheological property of asphalt combined binder, the paper uses five kinds of filler-bitumen ratio and different temperature condition by the rheological test, it studies the asphalt combined binder on the high-low temperature and fatigue performance. The result indicates that mineral powder can strength the high temperature performance, but it is bad for low temperature performance and fatigue performance; when test temperature is more higher, it’s high temperature performance and fatigue performance weaker, but it's low temperature performance strength; considering the high-low temperature and fatigue performance, it suggests the reasonable filler-bitumen ratio range is 0.8-1.0.

Keywords: asphalt combined binder, filler-bitumen ratio, rheological property, high temperature performance, fatigue performance

1. Introduction

At present, asphalt pavement occupies an absolute proportion in domestic high-grade highways, which has greater advantages than cement pavement in terms of construction workability, maintenance convenience, driving comfort and aesthetics, etc.. Asphalt pavement is favored by the road industry due to its advantages such as good flatness, low noise, short construction period, convenient maintenance and renewable utilization of asphalt mixture. According to statistics, the coverage rate of asphalt pavement in national and provincial trunk highways in China has reached more than 90% at present. It is well known that asphalt mixture is a kind of tertiary spatial reticulated structure system, and the asphalt as the dispersion medium, mineral filler as binary system - the composition of the dispersion of filler bitumen (asphalt rubber paste), is the most initial asphalt mixture spatial reticulated structure of disperse system, relevant research results show that its performance directly determines the performance of asphalt mixture[1-2]. The asphalt mortar composed of mineral powder and asphalt plays a role of filling the gap between aggregates on the one hand and bonding on the other hand in the asphalt mixture, which has a great impact on the performance of the mixture. Mineral powder can increase the thickness of asphalt. The thickness of the film can enhance the bonding property of the binder, improve the stiffness of the mixture, and improve the rutting resistance of the road surface. According to some studies, after asphalt interacts with mineral powder, the asphalt will produce a rearrangement of chemical components on the surface of the mineral powder, and then form a diffusion structural film of thickness on the surface of the mineral powder. The asphalt within the thickness of this structural film is called structural asphalt, while
the asphalt outside the structural film is called free asphalt. At present, the rapid development of economy makes the demand for road transport capacity increases, which to some extent resulted in the universal phenomenon of overload and overrun the transportation vehicles, and overweight loads will increase the bending tensile strain of asphalt layer bottom, with the increase of load repeatedly function and overloading, will produce fatigue damage asphalt mortar, modulus is reduced, so as to make the bending tensile strain of asphalt layer bottom than material ultimate flexural strain, fatigue failure eventually, transverse crack, longitudinal crack during the asphalt pavement diseases, such as crack like, and serious when will develop into a crack, crack and other area is kind of disease, This has a negative effect on the smoothness and comfort of the road surface. It can be seen that the macroscopic performance of high temperature and fatigue of asphalt pavement is closely related to the rheological properties of asphalt mortar. Rheological properties are the inherent special properties of asphalt, asphalt mortar and asphalt mixture. For asphalt mortar, changes in external temperature and different composition of the mortar (powder to binder ratio) have a great impact on the rheological state and performance of asphalt mortar. According to relevant research results, asphalt and bitumen slurry show three mechanical states with the change of temperature: glass state, high elastic state, viscous flow state. In the glass state, asphalt is hard and brittle, with weak stress relaxation ability and prone to low-temperature fracture. Under high elastic state, the proportion of elastic component of asphalt becomes larger, the non-recoverable creep flexibility is smaller, and the resistance to permanent deformation is enhanced. Under viscous flow, the viscosity of asphalt decreases, the bonding strength weakens, and the resistance to deformation gradually loses. At present, the rheological theory has been applied in many industries, and it has also been popularized in the road industry. Especially, researches on the rheological properties of asphalt and asphalt mixture have been carried out for many years. In this paper, based on the rheological test of bitumen slurry and the setting of the powder ratio and test temperature conditions, the influence of test conditions on the rheological properties of bitumen slurry-high temperature, low temperature and fatigue performance was studied, aiming to serve as a reference for the future research on rheological properties of bitumen slurry.

2. Raw aterial performance index

(1) Performance index of mineral powder

The ore powder selected in this paper is east bluestone limestone ore powder. According to the Highway Engineering Aggregate Test Regulations (JTG E42-2005), the physical and chemical indexes of the ore powder obtained through experiments are shown in Table 1 below.

| Indexes of mineral powder | Density | Coefficient of hydrophilic | Specific surface area | CaO(%) | SiO2 (%) | Methylene blue value(mg/g) |
|---------------------------|---------|---------------------------|-----------------------|--------|---------|--------------------------|
| mineral powder            | 2.770   | 0.621                     | 3.7141                | 34.95  | 1.52    | 1.73                     |

(2) General index of asphalt

The asphalt selected in this paper is no. 70 matrix asphalt. According to the technical requirements of road petroleum asphalt, the technical indexes of the measured asphalt are shown in Table 2.

| The serial number | The test items | Technical indicators | Test results |
|-------------------|----------------|----------------------|--------------|
| 1                 | penetration(25℃,5s,100g,0.1mm) | ≮60-80 | 66 |
| 2                 | Softening point(R&B)(℃) | ≯46 | 47.0 |
| 3                 | 60℃Dynamic viscosity(Pa·s) | ≯180 | 258 |
| 4                 | 10℃Ductility(cm) | ≯20 | 31 |
| 5                 | 15℃Ductility(cm) | ≯100 | >100 |
| 6                 | Wax content (distillation)(%) | ≯2.2 | 1.7 |
| 7                 | Flash point(℃) | ≯260 | 320 |
| 8                 | solubility (%) | ≯99.5 | 99.92 |
| 9                 | density (15℃,g/cm3) | measured records | 1.035 |
| 10                | Film heating test | The quality change (%) | ≯±0.8 | -0.022 |
|                   |                  | Residual needle penetration ratio (%) | ≯61 | 71 |
|                   |                  | Residual ductility(10℃)(cm) | ≯6 | 9 |
3. Rheological properties test of bitumen slurry

According to the United States SHRP research plan, dynamic shear rheological test (DSR) and bending beam rheological test (BBR) can reflect respectively under the condition of high temperature asphalt mortar and ability to resist deformation under the condition of low temperature crack resistance property of asphalt mortar and through the setting of the DSR test conditions, can realize the test on the fatigue test performance of the asphalt mortar. In order to study the influence of different temperatures and the ratio of powder to glue on the rheological properties of asphalt paste, five powder to glue ratios were used in this paper: 0.6, 0.8, 1.0, 1.2 and 1.4, respectively, to prepare asphalt paste samples. The test temperature set for high temperature performance test was 64°C, 70°C, 76°C, and the evaluation index was anti-rut factor G*/sin. The test temperature of low-temperature performance test was set as -12°C and -18°C, and the evaluation indexes were creep stiffness modulus S and creep rate M. For fatigue performance research, it usually refers to medium temperature fatigue. Therefore, the test temperature set for fatigue performance test in this paper is 25°C, 28°C, and 31°C, and the evaluation index is fatigue factor G*sin. It should be noted that, in order to obtain more accurate test data and reduce the test error, multiple parallel tests were adopted in this paper, and the mean value was calculated after deleting the variation point data, and the mean value was taken as the experimental analysis data.

3.1 Influence of powder ratio on high temperature performance of asphalt cement

Paste Dynamic shear rheometer DSR was used to determine the rutting resistance factor of bitumen slurry with different powder ratio at temperature levels of 64 °C, 70 °C and 76 °C, as shown in Figure 1 to Figure 2.

![Figure 1](image1.png)

**Figure 1** Relationship between Filler-bitumen Ratio and rut factor before aging

![Figure 2](image2.png)

**Figure 2** Relationship between Filler-bitumen Ratio and rut factor after aging
As can be seen from the figure 1 and figure 2 above, before and after aging of asphalt mortar anti-rutting factor changing with powder cement ratio, testing temperature generally similar, increases with the rubber powder, the rutting resistance of asphalt mortar factor G * / sin the delta generally present incremental change, show that ore powder to improve the ability of asphalt to resist deformation and modulus showed evident synergistic behavior, from the micro level, when kuangfen join the asphalt, mineral powder particles and asphalt molecular interaction, such as molecular force, interface adsorption force under the action of asphalt molecular weight distribution in the interface, as the asphalt molecular aggregation, gradually formed in the mineral surface coated layer, This coating layer is structural asphalt, and with the increase of the ratio of powder to binder, it is equivalent to the increase of the proportion of structural asphalt. When the aggregate of structural asphalt at the interface reaches an adequate number, the asphalt cement paste will have a strong cohesive force, and the stability of the asphalt cement paste will be enhanced. In addition, from the above curve can clearly powder glue ratio 0.8 was a turning point, when the rubber powder ratio greater than 0.8, at this time the rutting resistance factor of the growth is reduced, and the rubber powder than rutting resistance factor increases obviously after more than 1.0, the number of visible kuangfen for mucilage, the influence of high temperature performance is relatively complex, instability, ore is not the more the better. Therefore, when the ratio of powder to binder is between 0.8 and 1.0, the high-temperature performance of bitumen slurry is relatively stable. Therefore, the value range of the ratio of powder to binder is suggested to be 0.8 to 1.0.

In addition, the rutting resistance factor of asphalt cement paste after aging is higher than that before aging at the same powder/cement ratio and test temperature, because asphalt will become hard and brittle after aging and its internal structure will change. Moreover, the larger the powder/cement ratio is, the greater the difference between the two is, which to some extent reflects that the amount of mineral powder has an impact on the aging performance of asphalt cement paste. The higher the test temperature is, the smaller the rutting resistance factor will be. This is mainly because the rise in temperature makes the asphalt soft and tends to viscous flow, so the resistance to deformation at high temperature will be weakened. Under the condition of the same powder/glue ratio, the higher the temperature is, the smaller the rutting resistance factor of asphalt cement paste will be. It can be seen that the temperature has a great influence on the rutting resistance of asphalt cement paste.

### 3.2 Influence of the ratio of powder to binder on the low temperature performance of asphalt cement

The flexural creep stiffness modulus S and creep change rate M of bituminous slurry with different powder ratio at temperature of -18°C and -12°C were measured by bending beam rheometer BBR. As shown in Figure 3 ~ Figure 4.

![Figure 3](image-url)  
**Figure 3** The relation between Filler-bitumen Ratio and the creep stiffness modulus
Figure 4 The relation between Filler-bitumen Ratio and creep rate

As can be seen from the figure above, the creep stiffness modulus with powder cement ratio increases, this is because after the asphalt adding mineral powder, the number of structure of asphalt in asphalt increased, free asphalt decreased, displayed the elastic performance enhancement, cohesive performance, makes the creep stiffness modulus of asphalt mortar increases, the performance of asphalt mortar crack resistance; In addition, under the condition of -18℃, the variation range of creep stiffness modulus is much larger than -12℃, and the maximum difference between the two is about 600MPa under the same powder ratio. It can be seen that external temperature has a great influence on the low-temperature performance of asphalt cement paste, and the lower the temperature is, the weaker the low-temperature flexible deformation capacity of asphalt cement paste is.

In addition, the creep rate first decreases, then increases and then decreases with the increase of the powder to cement ratio. When the powder to cement ratio is 1.0, the turning point of the increase and decrease is when the powder to cement ratio is greater than 1.0, the creep rate of asphalt cement paste rapidly decreases, indicating that when the powder to cement ratio is 1.0, the asphalt cement paste has a better stress relaxation ability. Therefore, considering the anti-cracking performance of asphalt cement paste at low temperature, the powder to cement ratio of asphalt cement paste is reasonable about 1.0.

3.3 Influence of powder binder ratio on fatigue performance of asphalt binder
The fatigue properties mainly refer to the rheological properties at moderate temperature. In the Superpave asphalt binder specification, the equipment used to evaluate the fatigue performance of asphalt is exactly the same as that used to evaluate the high temperature performance, that is, dynamic shear rheometer DSR is used, but the test method and evaluation parameters are different. Because fatigue usually occurs after the asphalt pavement has been used for a period of time, the Superpave asphalt binder specification provides for the use of pressure aged PAV asphalt to evaluate fatigue performance. The evaluation parameter is expressed as the anti-fatigue factor $G*sin\sigma$ of the product of the complex modulus and the phase Angle. The value is larger, the anti-fatigue performance will be the worse.

In this paper, dynamic shear rheometer DSR was used to determine the fatigue factors of different powder/glue ratios after long-term aging OF PAV at three temperature levels of 25℃, 28℃ and 31℃, as shown in Figure 5.
As can be seen from the figure above, three temperature fatigue factor of asphalt mortar $G \times \sin \sigma$ the delta with powder cement ratio increases, and fatigue factor of numerical basic with the rubber powder than present obvious linear increase, visible from the point of view of fatigue performance, kuangfen mucilage to join to improve asphalt fatigue performance, so in real engineering can't blind to add mineral filler, it has great influence for the performance of asphalt pavement, need careful choose powder cement ratio. In addition, the fatigue factors of asphalt cement paste are significantly different at different temperatures. Under the same powder ratio, the higher the temperature is, the greater the fatigue factor of asphalt cement paste is, and the worse the anti-fatigue performance is. At 25°C, the variation amplitude of the fatigue factor of asphalt cement paste with the ratio of powder to cement was greater than 28°C and 31°C, indicating that the fatigue damage of asphalt cement paste was more serious at 25°C, indicating that the low-temperature area was the core area of asphalt cement paste fatigue damage.

4. Conclusion
(1) Before and after aging, the anti-rut factor $G*/ \sin \sigma$ of bitumen slurry generally increases with the increase of powder, indicating that the ore powder has the behavior of modulus enhancement. The increase of rutting resistance factor is obvious under different ratio of powder and cement, which indicates that the influence of the amount of mineral powder on the high-temperature performance of cement paste is complex and unstable. Therefore, when the ratio of powder to binder is between 0.8 and 1.0, the high-temperature performance of bitumen slurry is relatively stable. Therefore, the value range of the ratio of powder to binder is suggested to be from 0.8 to 1.0. The anti-rutting factor of asphalt cement paste after aging is greater than that before aging under the same powder ratio and test temperature. Under the condition of the same powder glue ratio, the higher the temperature is, the smaller the rutting resistance factor of asphalt cement paste will be. It can be seen that the temperature has a great influence on the rutting resistance of asphalt cement paste.

(2) The creep stiffness modulus increases with the increase of the powder glue ratio. Under the condition of -18°C, the variation range of creep stiffness modulus is much larger than that of -12°C, and the maximum difference between the two is about 600MPa, indicating that the lower the temperature, the weaker the low-temperature flexible deformation capacity of asphalt paste. The creep rate decreased first, then increased and then decreased with the increase of the powder to cement ratio, and the asphalt cement paste had better stress relaxation ability when the powder to cement ratio was the turning point of 1.0. Therefore, considering the anti-cracking performance of asphalt cement paste at low temperature, the powder to cement ratio of asphalt cement paste is reasonable about 1.0.

(3) The logarithm value of fatigue factor of asphalt cement paste basically increases linearly with the ratio of powder to cement, indicating that the addition of mineral powder is not favorable to the fatigue performance of asphalt cement paste. Therefore, the ratio of powder to cement should be carefully selected in solid engineering. At 25°C, the variation amplitude of asphalt cement paste fatigue factor with the ratio of powder to cement was greater than 28°C and 31°C, indicating that the low-temperature...
area was the core area of asphalt cement paste fatigue damage. The reasonable ratio range of powder to glue is from 0.8 to 1.0.

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