Research and Mechanism Analysis on Improving the Performance of Granite Asphalt Mixture

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Abstract. Granite is widely distributed in coastal areas of China, but granite, as an acid stone, can not be used directly in asphalt mixture. Combined with the climatic conditions in coastal areas, we can prepare materials for local projects, save engineering costs, and prepare composite modified asphalt. The 5% nano-calcium carbonate and the 5% rock asphalt are added to prepare modified asphalt. The results indicate that the adhesion level between granite and asphalt is increased to 4th grade. The dynamic stability is increased to 3652 times/mm. The residual stability is increased to 91%. The high temperature and water stability of the modified asphalt mixture are increased, and the modification mechanism is researched with the chemical composition of the modifier.

1. Introduction

With the development of China's economy, the transportation industry is developing rapidly. The traffic volume is large and the traffic is heavy. More and more road material is required. For the coastal areas of China, the rainfall is large and the temperature is relatively high in summer. These traffic conditions and climate conditions lead to rut and water damage in many roads.

As a pavement material, in order to ensure the water stability of asphalt mixture, alkaline aggregate or neutral aggregate are generally used such as limestone, basalt and so on. In coastal areas, granite has a wide distribution area. Granite has a large hardness and good wear resistance compared with the limestone used in engineering, but the content of silicon dioxide is high and belongs to acid rock. It is poor in adhesion to asphalt, and the water stability of asphalt mixture is poor. What’s more, its application is limited. In engineering, lime is used as modifier in mineral powder to improve the water stability of asphalt mixture[1][2]. Some coupling agents are used as modifiers to prepare modified asphalt[3], but the coupling agent is organic and the stability is poor at high temperature. In the process of mixing, the chemical reaction is easy to occur, and it can not play a corresponding role in the asphalt mixture. If the adhesion of granite and asphalt and the high temperature performance of asphalt pavement can be improved[5], the study of modified asphalt and asphalt mixture suitable for the asphalt pavement in coastal areas can make local engineering take local materials, reduce the cost of engineering, save cost and improve the performance of asphalt pavement.

2. Experimental research

Nanomaterials are easy to disperse in asphalt because of its small size. The suitable nanomaterials was selected can improve the water stability of asphalt mixtures. In order to improve the water stability and high temperature performance of the granite asphalt mixture, the modified asphalt was prepared by adding nano-calcium carbonate and Qingchuan rock asphalt in the A-70# matrix asphalt. The nano-
calcium carbonate particles are small and easy to disperse, so it can be used to prepare the modified asphalt with uniform performance. The amount is 5% (the ratio of nano-calcium carbonate to the mass of matrix asphalt). The rock asphalt can have better compatibility with the matrix asphalt, because the components are similar to the asphalt. The rock asphalt is processed into powder with a dosage of 5% (the ratio of rock asphalt to base asphalt).

2.1 Influence on basic properties of asphalt

The preparation process is as follows: the two modifiers are added to the matrix asphalt with a temperature of 160 degrees in accordance with a certain amount of content and are stirred for two hours at a high speed to prepare the test samples.

The basic performance test results of matrix asphalt and composite modified asphalt are shown in Table 1.

| Table 1. Test results of asphalt technical index |
|-----------------------------------------------|
| Index | Unit | A-70# asphalt | Modified asphalt (nano-calcium carbonate 5% + rock asphalt 5%) |
|-------|------|----------------|---------------------------------------------------------------|
| Penetration degree | 0.1mm | 61 | 43 |
| (25°C, 100g, 5s) | | | |
| Ductility (5°C, 5cm/min) | cm | 10 | brittle failure |
| Softening point | °C | 48 | 54 |
| Residual penetration degree ratio | % | 75 | 86 |

From Table 1, it can be seen that after adding nano-calcium carbonate and rock asphalt, the softening point of the composite modified asphalt is increased and the ratio of residual needle penetration is increased, so the high temperature and aging resistance of the modified asphalt are improved. Ductility decreases, which indirectly indicates its low temperature performance.

2.2 Influence of asphalt and aggregate adhesion properties

Adhesion test can indirectly represent the water stability of asphalt mixture. The test results of adhesion between modified asphalt and granite are shown in Table 2.

| Table 2. Experimental results of asphalt and granite adhesion (Boiling method) |
|--------------------------------|----------------|
| Asphalt type | Adhesion grade |
| A-70# asphalt | 2nd |
| Modified asphalt (nano-calcium carbonate 5% + rock asphalt 5%) | 4th |

From table 2, it can be seen that the adhesion grade of asphalt and granite is increased from 2nd to 4th, and the adhesion grade is increased more, which indirectly indicates that the water stability of the modified asphalt mixture is improved.

2.3 Influence of asphalt mixture on high temperature performance

In order to study the water stability of asphalt mixture with compound modified asphalt, the asphalt mixture uses coarse asphalt concrete AC-20C, coarse and fine aggregate is selected with granite, and limestone mineral powder is selected. The rutting test parts were made with reference to the test
regulations of asphalt and asphalt mixture of Highway Engineering (JTG E20-2011) in China. The size of the rutting test was 300mm*300mm *50mm, test the dynamic stability of 60 degrees. The test results are shown in Table 3.

Table 3. Rutting test results of asphalt mixture

| Asphalt type                                      | Dynamic stability (times /mm) |
|--------------------------------------------------|------------------------------|
| A-70# asphalt                                    | 1960                         |
| Modified asphalt (nano-calcium carbonate 5%+ rock asphalt 5%) | 3652                         |

The asphalt mixture modified by composite modified asphalt is improved dynamically and steady. The results showed that the high temperature performance of asphalt mixture increased after adding nano-calcium carbonate and rock asphalt.

2.4 Influence of asphalt mixture on water stability

In order to study the water stability of asphalt mixture with compound modified asphalt, the asphalt mixture uses coarse asphalt concrete AC-20C, coarse and fine aggregate is selected with granite, and limestone mineral powder is selected. According to the test regulations of asphalt and asphalt mixture in Highway Engineering (JTG E20-2011), the standard Marshall is made. The number of compaction times was 75 times on both sides, and Marshall test and immersion Marshall test were carried out. The test temperature was 60 degrees. The results of the test are shown in Table 4.

Table 4. Marshall test results

| Asphalt type                                      | Stability (kN) | Water immersion stability (kN) | Residual stability (%) |
|--------------------------------------------------|----------------|------------------------------|------------------------|
| A-70# asphalt                                    | 14.80          | 10.02                        | 67.7                   |
| Modified asphalt (nano-calcium carbonate 5%+ rock asphalt 5%) | 17.50          | 15.93                        | 91.0                   |

The stability of the modified asphalt mixture increases, which indicates that the water stability of the asphalt mixture is improved.

3. Results and analysis

The nano-Calcium Carbonate Granules used in the modifier is small and can be easy to disperse in the asphalt. Because of the large surface area, more asphalt can be formed in the asphalt mixture. Thus, the high temperature performance of asphalt mixture can be improved. At the same time, the nano-calcium carbonate belongs to the alkaline material. Adding the modified asphalt with nano-calcium carbonate, which is wrapped on the surface of the granite and makes the granite surface present alkaline, so the adhesion of granite to asphalt and the water stability of the asphalt mixture are improved.

Rock asphalt belongs to natural asphalt, and its composition is similar to ordinary asphalt. It has good compatibility as a modifier in ordinary asphalt. The composition of Qingchuan rock asphalt and the mineral composition of ash were analyzed. From Table 5, we can see that the asphaltene content of the rock asphalt component is much higher than that of the ordinary asphalt, so the high temperature performance of the asphalt mixture is improved. In addition to asphaltene, colloid, saturation and
aromatic components, the rock asphalt also has some main minerals as calcium carbonate. As a small particle, it can also improve the water stability of the asphalt mixture.

Table 5. Analysis results of Qingchuan rock asphalt components

| Component name          | Saturate | Aromatics | Colloid | Asphaltenes | Calcium carbonate |
|-------------------------|----------|-----------|---------|-------------|-------------------|
| Content (%)             | 2        | 13        | 11      | 46          | 7                 |

4. Conclusion
Nano-calcium carbonate has been mass produced and the cost is relatively low. The composition of rock asphalt is similar to that of matrix asphalt, and has good compatibility with matrix asphalt. It can be used as modifier to prepare modified asphalt. The research shows that:

4.1 Adding 5% nano-calcium carbonate and 5% rock asphalt, the adhesion of granite to asphalt can be improved to 4th and meet the needs of engineering.

4.2 As the granite used as aggregate to prepare modified asphalt mixture, the high temperature performance and water stability can be improved. (meeting the needs of the project.) The prepared composite modified asphalt is suitable for the climatic conditions of the granite distribution areas along the coast of China, and at the same time, it can reduce the project cost and protect the environment.

References
[1] Ai CF, Xu TB, Chen J. (2008) The study on improving performance of granite asphalt mixture [J]. Highway traffic science and technology, 25:21-26.
[2] Zhang YL, Yan ZX. (2003) Analysis of the influence of lime and anti stripping agent on the water stability of granite asphalt mixture [J]. Traffic standardization, 9:71-73.
[3] Guo RC, Liu LQ. (2013) The effect of anti stripping agent and cement on the performance of granite asphalt mixture [J]. Chinese and foreign highway, 33:280-283.
[4] Wu YJ, Wang FM, (2016) Zhang Yiluo. Influence of different types of anti stripping agents on the performance of granite asphalt mixture [J]. Chinese and foreign roads, 36:289-292.
[5] Liu DL, Yue AJ, Chen L. (2004) Study on properties of nano calcium carbonate modified asphalt and mixture [J]. Journal of Changsha Jiaotong University, 20:70-72.