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Research on the Application of High-Content Rubber Powder Modified Asphalt

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ABSTRACT: With the increase in traffic volume and the rise in vehicle load, the performance insufficiency of traditional base asphalt under extreme climatic conditions has become particularly evident. As an innovative solution, rubber powder modified asphalt can not only significantly improve the high-temperature stability and low-temperature crack resistance of pavement, but also effectively reduce the environmental problems of waste tires and realize the recycling of resources. In this paper, the advantages and preparation methods of high-content rubber powder modified asphalt are discussed in detail, and the modification mechanism of high-content rubber powder modified asphalt is analyzed, which provides a reference for the application of high-content rubber powder modified asphalt.

KEYWORDS: Rubber powder modified asphalt; High-content rubber powder; Mechanism of rubber powder modified asphalt; Road materials

I. INTRODUCTION

In the construction and maintenance of modern transportation infrastructure, the choice of road materials is very important. With the continuous growth of traffic volume and the significant increase of vehicle load, the shortcomings of traditional matrix asphalt under extreme weather conditions and high load are exposed. In high temperature environment, asphalt is easy to soften and deform, leading to rutting; at low temperature, asphalt is prone to brittle crack, which affects the service life and safety of pavement. In addition, traditional asphalt has obvious limitations in fatigue resistance, durability and environmental protection, which is difficult to meet the demand of modern road engineering for high-performance materials.

On the other hand, with the rapid development of the automotive industry, the number of waste tires has increased sharply, which has become a major environmental problem worldwide. By processing waste tires into rubber powder and using it in modified asphalt, the problem of "black pollution" can be effectively solved, and the recycling of resources can be realized, which meets the requirements of sustainable development. Therefore, in addition to SBS modified asphalt, which is widely used, asphalt rubber (AR) as an innovative pavement material solution has attracted extensive attention. Rubber powder modified asphalt can not only significantly improve the high-temperature stability, low-temperature crack resistance, durability and fatigue resistance of pavement, but also reduce the generation and development of pavement cracks because rubber powder particles can absorb and disperse stress. In addition, rubber

powder modified asphalt also has the advantages of reducing noise and vibration, which is helpful to improve driving comfort.

In practical application, the content of rubber powder has a great impact on the performance of rubber powder modified asphalt. High-content rubber powder modified asphalt has more performance advantages than low content of rubber powder modified asphalt. However, with the increase of rubber powder content, the viscosity of asphalt will also increase, resulting in the difficulty of rubber powder dispersion in asphalt. The higher the content of rubber powder, the more rubber powder needs to be mixed with asphalt, which will also increase the difficulty of processing, so it needs higher temperature and longer time to ensure uniform dispersion and reaction. The preparation and application of high-content rubber powder modified asphalt provide a new idea for the resource utilization of waste tires and the high performance of road materials. In order to solve the production problem of high-content rubber powder modified asphalt, the research on different modified processing methods and processes is carried out more and more widely.

II. ADVANTAGES OF HIGH-CONTENT RUBBER POWDER MODIFIED ASPHALT

2.1 Improvement of Material Performance

High content of rubber powder can significantly improve the high temperature performance of asphalt, reduce the rutting and pushing phenomenon of pavement under high temperature conditions in summer, and improve the high temperature deformation resistance of pavement. The addition of high-content rubber powder improves the temperature sensitivity of asphalt, enhances its resistance to flow deformation, and strengthens the stability and durability of the road surface. High-content rubber powder can improve the low-temperature ductility and flexibility of asphalt, and enhance its low-temperature performance. By using specific pretreatment methods, the compatibility of rubber powder modified asphalt can be improved, and the storage stability of rubber powder modified asphalt can be effectively enhanced.

2.2 Improvement of Pavement Performance

Rubber powder modified asphalt can improve the road performance of asphalt and asphalt mixtures, enhance the quality and service life of road surfaces, and has the potential to improve the quality of road construction; it can reduce noise pollution, increase the grip between vehicle tires and the road surface, and improve driving safety ^[1].

2.3 Economic and Environmental Benefits

The use of rubber powder modified asphalt, especially high-content rubber powder modified asphalt, can not only reduce the processing cost of waste tires through economies of scale, but also reduce the paving cost of asphalt roads, with significant economic benefits. With the increasing number of cars, the amount of waste tires generated has been increasing year by year, causing a serious burden on the environment. The use of rubber powder modified asphalt can recycle a large amount of waste tires, reduce environmental pollution, and save resources.

III. DEFINITION OF HIGH-CONTENT RUBBER POWDER MODIFIED ASPHALT

3.1 Ordinary Rubber Powder Modified Asphalt

Ordinary rubber powder modified asphalt is prepared by adding no more than 20% rubber powder to the base asphalt and stirring at high speed for 45 minutes at a temperature of 180 °C -200 °C. It is difficult for the content of rubber powder to exceed 20% without using other means. Studies have shown that ordinary rubber asphalt can improve the high-temperature rutting resistance, low-temperature crack resistance, fatigue resistance, and reflective crack resistance of road surfaces. It can also reduce road noise and extend the service life of road surface [2]. However, ordinary rubber asphalt also has a series of problems such as easy segregation, high viscosity, and difficulty in construction [3].

3.2 High-Content Rubber Powder Modified Asphalt

High-content rubber powder modified asphalt usually refers to modified asphalt with a rubber powder content of more than 20%. This modified asphalt is prepared using chemical activation technology. It can reduce the particle size of rubber powder in asphalt while retaining some of the elastic of the rubber powder. Additionally, it degrades a portion of the rubber powder into small rubber molecules that dissolve in asphalt, forming a new phase distribution (rubber powder-small rubber molecules-asphalt ternary co-blend system). This high-content rubber powder modified asphalt can not only increase the content of rubber powder, but also significantly improve the performance of modified asphalt, including viscosity, low-temperature crack resistance, uniformity, and has a lower glass transition temperature, suitable for lower environmental temperatures.

3.3 Ultra-High-Content Rubber Powder Modified Asphalt

Ultra-high-content rubber powder modified asphalt refers to a higher proportion of rubber powder added to the asphalt, usually referring to the addition of 30% to 40% rubber powder. The performance study of this modified asphalt shows that its viscosity is similar to that of the ordinary rubber powder modified asphalt, but its low-temperature crack resistance and uniformity performance are better than that of the ordinary rubber powder modified asphalt. At the same time, the high-temperature rutting resistance of ultra-high-content rubber powder modified asphalt slightly decreases, but its fatigue limit temperature is lower than that of ordinary content rubber powder modified asphalt, which has lower glass transition temperature and can be applied to lower ambient temperature. Through the analysis of infrared spectrum and scanning electron microscope, the chemical composition of ultra-high-content rubber powder modified asphalt is basically the same as that of ordinary rubber powder modified asphalt. The particle size distribution of rubber powder is mainly concentrated in 10~100 μ m, and submicron rubber powder particles and dissolved rubber powder are uniformly distributed in ultra-high-content rubber powder modified asphalt. The mechanism of the ultra-high-content rubber powder modified asphalt is that the modified asphalt system forms a new phase distribution form, which improves the content of rubber powder and the performance of modified asphalt [4].

IV. PREPARATION METHODS OF HIGH-CONTENT RUBBER POWDER MODIFIED ASPHALT

At present, the research on high-content rubber powder modified asphalt focuses on how to improve the content of rubber powder and the influence of preparation technology on the performance of asphalt through various methods. The

preparation process usually includes the method of high temperature degradation to reduce the viscosity and increase the content of rubber powder, and the method of adding cracking agent and other additives to reduce the production temperature.

4.1 Production at Ultra-High Temperatures

With the increase of the content of rubber powder in asphalt, the dispersion of rubber powder becomes more and more difficult. In the actual preparation process, it is necessary to increase the preparation temperature and extend the mixing time to fully swell and disperse rubber powder. The common preparation process is as follows: mix and grind the activated rubber powder with the base asphalt, and add the compatibilizer at the same time. The grinding condition is usually 6000-8000r/min, the temperature is controlled at 200-220°C, and the grinding time is 4-6 hours. The modified asphalt obtained by grinding is further developed at high temperature (180-190°C), and stabilizer is added at the same time, the development time is 30-60 minutes, and the high-content rubber modified asphalt was prepared. In the laboratory, the heating temperature was raised to 230°C, 250°C, and 270°C, with an extended mixing time. We studied the impact of high-temperature pyrolysis process on the storage stability of high-content rubber asphalt. It was found that the optimal storage stability of rubber asphalt was achieved when the heating temperature was set at 250°C and the mixing time was extended to 1 hour [5].

4.2 Adding Cracking Agents to Lower Production Temperature

In order to prepare high-content rubber powder modified asphalt at relatively low temperatures, the cracking agent can be added to the matrix asphalt at a temperature of 180-200°C along with the rubber powder, and they can be thoroughly mixed and allowed to swell. The common preparation process is as follows: heat the base asphalt to a temperature between 180-200°C, slowly add rubber powder and cracking agent, mix and stir for a period of 2-3 hours, shear and grind for 2 hours at a speed of 4000-6000 r/min, and control the temperature at 180-200°C. The modified asphalt obtained through grinding was further processed at high temperatures (180-190°C), and the polymerization agent was added at the same time. The processing time was 1 hour, and finally, high-content rubber modified asphalt was prepared.

V. MECHANISM OF HIGH-CONTENT RUBBER POWDER MODIFIED ASPHALT

In the preparation process, the primary reaction that occurs in high-content rubber powder modified asphalt is physical swelling, which aids in enhancing the compatibility between rubber powder and asphalt [6]. The changes of chemical composition and functional groups of high-content rubber powder modified asphalt before and after aging were analyzed by infrared spectrum experiment. It was found that the carbon base and sulfoxide index of high-content rubber powder modified asphalt increased more significantly, which may lead to the decrease of compatibility between rubber and asphalt, showing more intensive vulcanization phenomenon and molecular chain crosslinking change [7]. High-content rubber powder modified asphalt forms a new phase distribution form. By retaining part of the elasticity of the rubber powder, the particle size of the rubber powder in asphalt is reduced, and some of the rubber powder is degraded into small rubber molecules that are soluble in asphalt, creating a ternary co-mixing system of "rubber powder-small rubber molecules-asphalt." This not only increases the content of rubber powder but also significantly enhances the

performance of the modified asphalt. ^[8].

VI. CONCLUSION

High-content rubber powder modified asphalt shows broad development and application prospects because it can improve pavement performance, has significant environmental friendliness, and has significant advantages in resource recycling. With the continuous progress of preparation technology and the enhancement of environmental awareness, this material is expected to be more widely used in road construction and maintenance in future, especially in improving pavement durability, reducing noise pollution and coping with extreme weather conditions.

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