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A Review of Research on The Performance of Warm Mix Rubber Powder Modified Asphalt Mixture Under Freeze-thaw Cycles

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Abstract

The performance of asphalt mixture plays a key role in the service life and driving safety of roads. In the central and western regions of Gansu Province, my country, because the winter lasts for a long time, the ice and snow are not easy to melt, which has a great impact on the performance of road pavement. We often melt snow by spreading deicing salt on the road surface. However, asphalt pavement is in a state of constant alternation of freeze-thaw cycles. At the same time, spreading deicing salt into solution will also cause erosion to the road surface. Therefore, the service life and driving safety of asphalt mixtures have put forward a severe test for the performance of asphalt pavements that have been used for a long time. This paper aims at the influence of freeze-thaw cycles on the performance of asphalt pavement, and changes the performance of asphalt mixtures by adding rubber powder to the mixture. Warm mix rubber powder modified asphalt mixture combines the advantages of warm mix technology and rubber powder modification, and has the advantages of energy saving and emission reduction, cost reduction, and increased utilization of waste tires, providing a reference for the future development direction of this field.

Keywords

Freeze-thaw cycle; Warm mix technology; Performance of crumb rubber modified asphalt.

1. INTRODUCTION

With the change of global climate and the continuous increase of traffic volume, road engineering is facing more and more challenges, especially in the central and western regions, due to the drastic fluctuations in temperature and the frequent occurrence of ice and snow weather, the performance of asphalt pavement has been seriously affected. In order to cope with these problems, researchers are constantly exploring new materials and technologies to improve the durability and adaptability of asphalt pavement. Warm mix rubber powder modified asphalt mixture, as a new type of pavement material, has received extensive attention in recent years. It not only combines the advantages of warm mix technology and rubber powder modification, but also shows great potential in energy conservation and emission reduction, cost reduction and increasing the utilization rate of waste tires. Processing waste tires into rubber powder is a way of utilization that not only helps environmental protection, but also realizes the reuse of resources. Through scientific proportions and processes, mixing rubber powder with asphalt can significantly improve the performance of asphalt mixtures, such as enhancing crack resistance, improving weather resistance and extending service life. Therefore, the research and application of warm mix rubber powder modified asphalt mixtures have important practical significance and broad application prospects [1-3].

Domestic and foreign researchers have conducted decades of research and exploration in the field of rubber-modified asphalt technology and have achieved a series of important results. As

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an innovative way of utilization, rubber-modified asphalt can not only effectively solve the problem of waste tire disposal, but also improve the performance of asphalt pavement. Using rubber-modified asphalt mixture as a pavement material has good performance advantages in high and low temperature performance, fatigue performance, noise reduction and environmental protection. It has also been confirmed that warm mix agents can reduce the temperature sensitivity of rubber-modified asphalt, improve the low-temperature rheology of rubber-modified asphalt and its durability, and effectively improve the high and low temperature stability of rubber-modified asphalt mixtures, which has further promoted the widespread application of rubber-modified asphalt technology [4-6].

The first comprehensive study on the road performance of rubber powder modified asphalt in China began in 2001, with the "Technical Research on the Use of Waste Rubber Powder for Road Construction" hosted by the Highway Research Institute of the Ministry of Communications of my country [7]. The project paved nearly 30km of rubber asphalt pavement. This study put the application of rubber asphalt pavement in my country on the right track and gradually began to be used in large quantities. Compared with rubber asphalt, warm mix technology started late in my country. As early as September 2005, the Transportation Research Institute used emulsified and organic viscosity reducer warm mix technology to complete the first warm mix asphalt mixture experimental road in Changping, Beijing [8-9]. After a period of observation, the section was in good use and no major damage occurred. Twenty years ago, the Highway Research Institute of the Ministry of Communications and Tongji University and other units undertook the western transportation construction science and technology project "Research on the Application Technology of Warm Mix Asphalt Mixtures", aiming to determine the design method of warm mix asphalt mixtures and compile the "Technical Guide for Warm Mix Asphalt Mixtures" [10].

However, although warm mix rubber powder modified asphalt mixture has shown advantages in many aspects, it still faces some challenges in its actual application, especially under extreme climatic conditions, such as the freeze-thaw cycle common in the central and western regions. The performance stability of this new pavement material has become the focus of scientific researchers [11]. Freeze-thaw cycles not only cause changes in the physical and chemical properties of asphalt pavement, but also accelerate its aging process, thus affecting the service life and driving safety of the pavement. Therefore, in-depth research on the performance of warm mix rubber powder modified asphalt mixture under freeze-thaw cycles is of great significance to promote its widespread application in actual engineering.

With the continuous advancement of experimental technology and the improvement of scientific research methods, in 2015, foreign scholars Chamoun and Zahi added anti-stripping agents to two warm-mix rubber powder modified asphalt mixtures, successfully improving the asphalt mixture's resistance to permanent deformation, fatigue cracking, and water damage [12]. In the same year, Willis and J. Richard showed that the splitting strength ratio of warm-mix asphalt mixtures was lower than that of hot-mix asphalt mixtures [13]. In 2019, the research results of domestic scholar Liao Deyang provided strong theoretical support and technical reference for the application of warm-mix rubber powder modified asphalt mixtures in actual engineering, and also laid a solid foundation for subsequent in-depth research [14-15].

From the current research status at home and abroad, it can be seen that there are many studies on the application of warm mix rubber powder modified asphalt mixtures at home and abroad, but the research content is mainly concentrated on the mix design, the dosage of warm mix agent and road performance test. In particular, the water stability of warm mix rubber powder modified asphalt mixtures is only limited to the freeze-splitting test and the immersion Marshall test. There are not many studies on the effects of freeze-thaw cycles and salt erosion on rubber powder modified asphalt mixtures. At the same time, in view of the complexity of

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climatic conditions in the central and western regions, it is not reasonable to guide the construction of warm mix rubber powder asphalt mixtures in this region only by the construction experience of other regions. This paper changes the performance of asphalt mixtures by adding rubber powder to the mixture, and explores the performance change law of warm mix rubber powder modified asphalt mixtures under the action of freeze-thaw cycles, which provides a certain reference for wide application.

2. FREEZE-THAW CYCLES

2.1. Mechanism of freeze-thaw cycles

Freeze-thaw cycle refers to the process of materials freezing at low temperatures and then melting at higher temperatures, and this process is repeated. In asphalt mixtures, freeze-thaw cycles can cause moisture to enter the voids of the asphalt mixture. When the temperature drops, the water freezes and expands in volume, exerting pressure on the mixture, causing changes in the internal structure of the mixture and affecting its performance. When the temperature rises and the ice melts, the water may enter new voids again, further affecting the stability of the mixture. This cycle will accelerate the aging of asphalt mixtures and reduce their service life.

2.2. Indoor simulation method of freeze-thaw cycle

In order to study the effect of freeze-thaw cycles on the performance of warm-mix rubber powder modified asphalt mixture, it is necessary to conduct simulation experiments indoors. The indoor simulation method includes the following steps: first, prepare warm-mix rubber powder modified asphalt mixture specimens that meet the requirements; second, place the specimens in a specific low-temperature environment to freeze the water inside to simulate the low temperature conditions in winter; then, transfer the specimens to a higher temperature environment to melt the ice to simulate the temperature changes in spring or autumn; this process needs to be repeated many times to simulate the long-term freeze-thaw cycle. After each freeze-thaw cycle, the specimens are tested for performance, such as strength, toughness, durability, etc., to evaluate the effect of freeze-thaw cycles on the performance of asphalt mixtures. The indoor simulation method can more accurately simulate the freeze-thaw cycle process in the actual environment and provide reliable data support for the research.

2.3. Effect of freeze-thaw cycles on the performance of modified asphalt mixture

After multiple freeze-thaw cycles, the strength of asphalt mixtures may gradually decrease, toughness weakens, and durability is also impaired. Freeze-thaw cycles have a significant impact on the performance of warm mix rubber powder modified asphalt mixtures. Because during the freeze-thaw cycle, the water inside the mixture freezes and expands in volume, resulting in microcracks inside the mixture. These microcracks will not completely close when the ice melts, but will gradually expand, eventually leading to the destruction of the overall structure of the mixture. In addition, freeze-thaw cycles may also accelerate the aging process of asphalt, further reducing its performance. Therefore, understanding the impact of freeze-thaw cycles on the performance of warm mix rubber powder modified asphalt mixtures is of great significance for improving their service life and durability.

3. CONCLUSION

As a green and environmentally friendly pavement material, warm mix rubber powder modified asphalt mixture has broad prospects in dealing with extreme challenges such as freeze-thaw cycles in the central and western regions of my country. In the road construction in the central and western regions of China, if warm mix rubber powder modified asphalt mixture

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is used, the freeze-thaw cycle factors must be fully considered, and effective measures must be taken to improve its freeze-thaw resistance. Through scientific mix design, adding specific anti-stripping agents and modifiers, and introducing new materials science and chemical engineering technologies, we can effectively improve the overall stability and durability of the mixture. These comprehensive measures not only help reduce the performance degradation caused by freeze-thaw cycles, but also enable the mixture to better adapt to complex climatic conditions, providing more solid technical support for road projects in the central and western regions of my country. In the future, with the continuous deepening of cross-field cooperation and continuous innovation of cutting-edge technologies, warm mix rubber powder modified asphalt mixture will play a more important role in my country's road construction.

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