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Study on Properties of Asphalt Mixture with Rice Straw Fiber

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Abstract. To solve the problem of asphalt pavement cracks and save non-renewable resources, RSF were selected as reinforcements, and silane coupling agents were used to modify RSF surface to study the impact of RSF on the road performance of AM. The results indicate that RSF can improve the high-temperature stability and low-temperature cracking resistance of AM, increasing by 19.9% and 4.9% respectively; Compared with the original RSF, the high-temperature rutting resistance and low-temperature cracking resistance of modified RSF for AM are improved by 2.9% and 1.1%, respectively. The splitting strength of the modified RSF AM is 3.6% and 0.9% higher than that of the original AM with RSF and the non-fiber AM, respectively. The modified RSF can delay the aging of asphalt and improve the aging resistance of the AM.

Keywords. asphalt pavement, crack, fiber, road performance, aging performance

1. Introduction

The asphalt pavement fiber has mineral fiber, polymer fiber, lignin fiber, etc. These artificial fibers have their defects in the use process, and the price of mineral fiber and polymer fiber is relatively high. Researchers at home and abroad have used natural fiber in asphalt pavement, and proved the feasibility of using some natural fiber as fibers for asphalt pavement through tests. The use of rice straw fiber (RSF) in the construction of asphalt pavement can not only improve the performance of asphalt mixture (AM) , but also avoid environmental pollution caused by burning straw[1][2][3].

However, due to the natural properties of plants, the straw surface has a waxy layer, and the inner fiber surface is attached to a large number of hydroxyl groups. After mechanical crushing, the wax content on the fiber rice straw surface can be effectively reduced, but the number of hydroxyl groups has no effect. Because the hydroxyl group has polarity and the more the number, the greater the polarity, the RSF itself has a greater polarity, while the common asphalt has a lower polarity, the polarity difference between the two is large, resulting in the difficulty in binding RSF and asphalt. Therefore, it is necessary to modify RSF to reduce the content of hydroxyl on the surface and effectively improve the surface bonding ability between rice fiber and asphalt[4][5][6].

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In this study, RSF was used as reinforcement, and a silane coupling agent was used to modify the surface of the RSF. The influence of RSF on the pavement performance of the AM was studied, and the strengthening effect of RSF was analyzed.

2. Experimental Part

2.1. Experimental Materials

70# matrix asphalt, Guangrao Klida Petrochemical Technology Co. LTD. RSF, length of 3cm, products of Heilongjiang Jile Agricultural Science and Technology Development Co., LTD.; Silane coupling agent, Model KH550, as a modifier of common RSF, Shandong Juneng Chemical Co., LTD.; Basalt gravel, the particle size of 0-3mm, 5-10mm, 10-15mm, limestone powder filler, are Zhuokuang (Shandong) Municipal Construction Co., LTD products; The technical indicators of asphalt and mineral materials meet the requirements of the "Technical Specification for Construction of Highway Asphalt Pavements".

2.2. Experimental Instruments

BH-20 intelligent automatic mixer, Shanghai Shengshihuike Testing Equipment Co., LTD.; HYCX-3 AM rutting sample forming machine, products of Hebei Guanghui Test Instrument Co., LTD.; Automatic asphalt rutting tester, Tianjin Ke 'an Instrument Technology Co., LTD.; LWD-5 computer numerical control AM Marshall stability tester, Cangzhou Huaheng Test Instrument Co., LTD.; LHPL-6 AM low-temperature bending test system, Cangzhou Changzhi Construction Instrument Co., LTD[7].

2.3. Experimental Preparation

AC-13 gradation is selected, and the optimal amount of asphalt for ordinary AC-13 AM is 4.5% (asphalt accounts for AM). The optimal asphalt content of AM with RSF AC-13 was 4.7%, and the RSF content was 0.2% (fiber accounted for the AM). The optimum asphalt content of the modified RSF AM AC-13 was 4.7%, The fiber content of rice straw is 0.2%, and the fiber was modified by a silane coupling agent. The preparation process of AC-13 AM: the ore material is heated to 160°C, and the asphalt is heated to 150°C until it is molten. The ore material is mixed in the mixing pot for the 60s, then fiber is added for 120s, then asphalt is added for 90s, and finally, the material is discharged.

2.4. Test Method

High temperature anti rutting performance. Use a rut forming machine to form rut board specimens and conduct testing in accordance with the "Test Specification for Asphalt and Asphalt mixture in Highway Engineering" (TSAAMHE).
Low temperature crack resistance. Form the test piece of the rut board, and then test it according to the TSAAMHE Resistance to water damage. Formed Marshall specimens shall be tested in accordance with the TSAAMHE.

Aging performance. Both short-term and long-term aging samples were prepared in accordance with the TSAAMHE (T0734). Conduct high-temperature, low-temperature, and water stability tests on the samples separately.

3. Conclusion and Analysis

3.1. High Temperature Rutting Resistance

Rut test was carried out on different fiber AM, and the test results were shown in Figure 1 below.

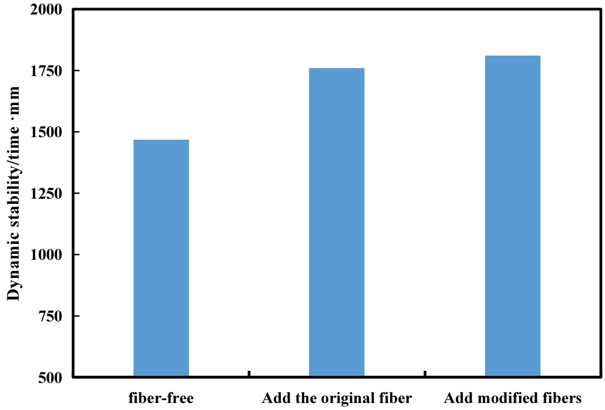

FIG .1 Dynamic stability test results of different AM

FIG. 1 shows that RSF can improve the dynamic stability of the AM, and the dynamic stability of the original RSF is 19.9% higher than that of the non-fiber AM. This is because the rice straw is made into a fiber after mechanical crushing, and the fiber surface is uneven and distributed with many small cracks. In the mixing process, more asphalt can be absorbed and infiltrated on the RSF surface to form structural asphalt.

The dynamic stability of modified rice straw AM has been improved by 23.4% and 2.9% compared to non fiber AM and original RSF AM, respectively. This is because after RSF surface is modified by the silane coupling agent, the pectin, waxy layer, and impurities on the surface are largely removed, which reduces the polarity difference between RSF and asphalt, and the specific surface area of RSF is increased by many silane particles attached to the surface[8].

3.2. Low Temperature Cracking Resistance

Low-temperature trabecular bending tests were conducted on different fiber AM, as shown in FIG. 2 and FIG. 3 below.

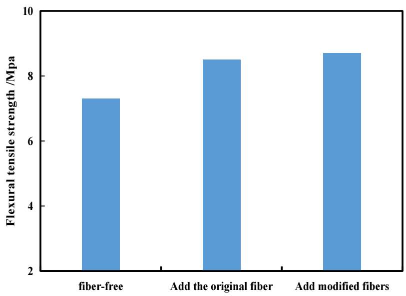

FIG.2 Flexural strength of different fiber AM

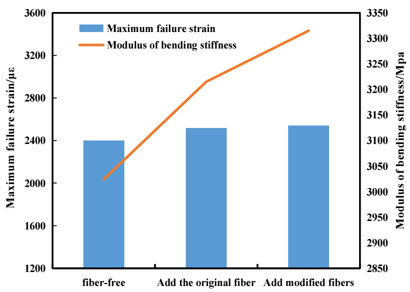

FIG.3 Maximum failure strain and bending stiffness modulus of AM

The results of FIG. 2 and FIG. 3 show that the flexural tensile strength and maximum flexural tensile strain of the original RSF are 16.6% and 4.9% higher than those of the non-fiber AM, respectively. Compared with the original RSF, the flexural tensile strength and maximum flexural tensile strain of modified RSF were increased by 1.7% and 1.1%, respectively. This is because the interface bonding property between the modified RSF and asphalt is improved compared with the original RSF, thus forming a stronger anchoring effect with asphalt. When the modified RSF forms the bridging action at the crack, it is accompanied by the extension of the crack, and it requires more energy to pull out the fiber from the asphalt matrix. The modified RSF AM can withstand larger deformation during the stress process and has good cracking resistance at low temperatures[9][10].

3.3. Resistance to Water Damage

Freeze-thaw splitting tests were carried out on different fiber AM, and the test results are shown in Figure 4 below.

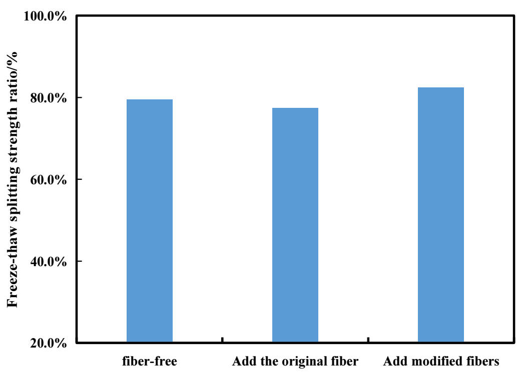

FIG.4 Freeze-thaw splitting test results of different fiber AM

FIG. 4 shows that the tensile strength ratio of the original RSF AM is 2.7% lower than that of the non-fiber AM. This is because the original RSF and asphalt structure in the presence of water in the environment of greater peeling power, so that the asphalt more easily from the surface of the RSF spalling, when the asphalt on the surface of the fiber began to spall, since the original RSF itself has strong hydrophilicity, water quickly intrude into the fiber to accelerate the asphalt spalling process.

Modified RSF increased by 3.6% compared to non fiber AM. This is because after the modification of RSF, on the one hand, the surface area of the modified RSF is larger than that of the original fiber, which can absorb more free asphalt. On the other hand, the use of a silane coupling agent in the bond between asphalt and fiber can enhance the adhesion of the two and improve the adhesion of the fiber-asphalt interface in a water-free environment, so that the fiber is not easy to pull out from the asphalt[11].

3.4. Aging Properties

The results of the rut test, freezing and thawing split test, and low-temperature trabecular bending test of the aging AM are shown in the figure below.

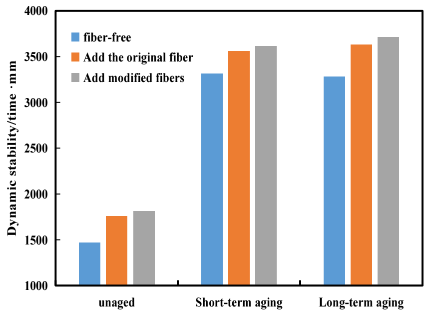

FIG. 5 Effect of aging on high temperature properties of AM

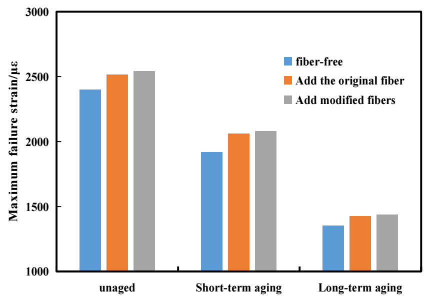

FIG. 6 Effect of aging on low temperature property of AM

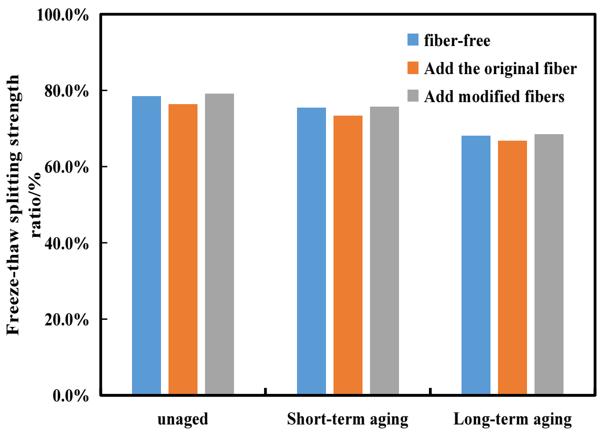

FIG. 7 Influence of aging on the freeze-thaw splitting of different fiber AM

The results in FIG. 5-7 show that the dynamic stability of the AM increases gradually with the aging degree, and the maximum flexural tensile strain and the ratio of tensile strength ratio change in the same trend, and both show a decreasing trend with the deepening of the aging degree of the AM. After short-term and long-term aging, the dynamic stability of fiber-free AM increases by 126.0% and 123.8%

compared to the non aging state, respectively. The maximum flexural strain decreases by 20.0% and 43.6%, respectively. The freeze-thaw splitting strength ratio decreased by 3.8% and 13.1%, respectively.

The dynamic stability and flexural tensile strength of the original RSF AM are increased by 19.9% and 4.9% in the non aging stage, 7.5% and 7.4% in the short-term aging stage, and 10.6% and 5.4% in the long-term aging stage compared to the non fiber AM.The freeze-thaw splitting strength of the original rice straw fiber AM is 2.7%, 2.6%, and 2.2% lower than that of the non fiber AM in the non aging stage, short-term aging stage, and long-term aging stage.

The dynamic stability, flexural tensile strength, and freeze-thaw splitting strength of modified RSF AM are increased by 2.9%, 1.1%, and 3.7% in the non aging stage, 1.4%, 1.0%, and 3.1% in the short-term aging stage, and 2.3%, 1.0%, and 2.7% in the long-term aging stage compared to the original RSF AM. The silane coupling agent on the surface of RSF can block oxygen to a certain extent and play a certain anti-aging role, thus improving the aging performance of asphalt mixture[12].

4. Conclusion

(1) RSF improved the high-temperature stability and low-temperature cracking resistance of AM by 19.9% and 4.9%, respectively; Compared with the original RSF, the high-temperature stability and low-temperature cracking resistance of the modified rice straw were improved by 2.9% and 1.1%, respectively.

(2) The water stability of RSF AM is slightly less than that of non-fiber AM, which is 2.7% lower than that of RSF AM. The splitting strength of the modified RSF AM is 3.6% and 0.9% higher than that of the original RSF AM and non-fiber AM, respectively. The modified RSF can effectively improve the water stability of the AM.

(3) Because of the heat insulation effect of rice straw itself, the aging of asphalt can be delayed by adding RSF into the AM. After modification, the RSF surface composition is simple, improving the thermal stability of RSF, silane coupling agent can play a certain role in oxygen isolation, prevent air oxygen contact with asphalt, reduce the degree of asphalt aging, and further improve the anti-aging performance of AM.

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