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Comparative study on performance of basalt fiber asphalt concrete after environmental action

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Jingchen Yan[1*], Junjie Yan[1] and Jianlong Zheng[1]

[1]School of Civil Engineering, Inner Mongolia University of Technology, Hohhot, Inner Mongolia Autonomous Region, 010051, China

[*]E-mail: yjc@imut.edu.cn

Abstract: The AC-16 asphalt concrete with A grade 90# asphalt and A grade 90# asphalt mixed with 0.3% basalt fiber as the binder was taken as the research object, passing the rutting test, trabecular bending test and freeze-thaw splitting test. The high temperature stability, low temperature crack resistance and water stability of the two asphalt mixtures after different environmental impact factors showed that the dynamic stability, maximum bending strain and residual strength ratio of the basalt fiber reinforced asphalt concrete were significantly higher. In the matrix asphalt concrete. The dynamic stability of basalt fiber asphalt concrete compared with matrix asphalt concrete increased by 15.79%, 14.7%, 16.51%, 18.18%, respectively, after environmental influence factors and UV, high and low temperature alternating, freeze-thaw and salt freezing environment. 17.95%; after the same environmental action, the maximum bending strain of basalt fiber asphalt concrete increased by 14.99%, 30.57%, 18.77%, 19.29%, 15.94%, respectively; the residual strength ratio increased by 3.82%, 5.61%, 8.82%, 10.76%, 10.36%; and the accuracy of the test data was verified microscopically from the action of basalt fiber by scanning electron microscopy.

1. Introduction

In recent years, basalt fiber asphalt concrete pavement has been widely used in China. China has a vast territory and a large difference in road environment. The impact on basalt fiber asphalt concrete pavement has its own characteristics. The ultraviolet rays in the Qinghai-Tibet Plateau and the Inner Mongolia Plateau are strong; in most areas, the temperature difference between day and night is large and the temperature is low; the road surface in the snow-covered frozen area will be subjected to the freeze-thaw effect of the snow melting agent solution. Therefore, different areas have different requirements for the use of basalt fiber asphalt pavement, and different environmental conditions have different effects on basalt fiber asphalt pavement. The high temperature rutting, low temperature cracking and water damage characteristics of basalt fiber asphalt concrete pavement under these road environment are the musts for pavement design.

In 1957, Vallerga and Monismit performed infrared aging and UV aging on asphalt, and evaluated the aging of asphalt with three indicators. Compared with infrared rays, ultraviolet radiation has a greater impact on asphalt. Zhang Juan et al simulated the aging effect of outdoor atmospheric ultraviolet radiation on asphalt pavement by indoor accelerated ultraviolet aging test; in the impact of freeze-thaw cycle on asphalt concrete, from 1970, Lottman frozen asphalt concrete specimens.[1] The cycle treatment, under natural conditions, simulates the effect of water on asphalt concrete specimens through freeze-thaw cycles.[2] Martin McCann used ultrasonic energy to simulate the effect of asphalt mixture under water and temperature, and gave the correlation between the asphalt mixture and the strength of the unfrozen and thawed specimen after 18 freeze-thaw cycles.[3] Li Zhen took asphalt concrete as the research object, and carried out freeze-thaw split test, Marshall stability test, trabecular bending creep test and uniaxial dynamic modulus test on the specimens under different salt-freezing cycles.[4] It is used to study the change of mechanical properties of asphalt concrete specimens before and after salt-freezing cycle. The high-temperature performance changes of ordinary asphalt concrete after salt-freezing cycle and self-melting snow asphalt concrete after freezing and thawing are compared and analyzed by scanning electron microscopy. The surface of the asphalt concrete specimen was observed to further reveal the mechanism of asphalt concrete performance change from the perspective of microstructure.

Most domestic and foreign scholars have only carried out routine experimental research on ordinary asphalt concrete pavement and fiber-reinforced asphalt concrete pavement. There is very little research on the application of basalt fiber asphalt concrete pavement after road environment. In view of this, the high temperature stability, low temperature crack resistance and water stability performance of basalt fiber asphalt concrete pavement are combined with scanning electron microscopy for ultraviolet aging, high and low temperature alternating cycle, freeze-thaw cycle, salt-free cycle and other pavement environments. Research has important significance for the application of basalt fiber in asphalt pavement.

2. The nature of raw materials and asphalt concrete mix design

According to the *"Technical Specifications for Construction of Highway Asphalt Pavement"* (JTG-F40-2004), the inspection of raw materials meets the test requirements. The asphalt is produced by Inner Mongolia Shiji Refining & Chemical Co., Ltd., and the basalt fiber is short-cut (6mm) basalt fiber produced by Zhejiang Shijin Basalt Fiber Co., Ltd. [5]

According to the "Code for the Collection of Highway Engineering Aggregates" (JTG E42-2005), the four-stage aggregates are screened and graded to form a design.Each set of aggregates is equipped with the following:

0-3mm material: 3-5mm material: 5-10mm material: 10-20mm material: mineral powder = 44%: 3%: 22%: 26%: 5%.

According to the *"Technical Specifications for Construction of Highway Asphalt Pavement"* (JTG-F40-2004), Marshall design method is used to design the mix ratio of asphalt concrete. The relative volume density, void ratio, ore gap ratio, asphalt saturation of Marshall test piece, Stability, flow value, etc. determine the best oil-stone ratio of asphalt concrete. The optimum oil-stone ratio for AC-16 matrix asphalt concrete (MA) is 4.7%, and the optimum whetstone ratio for basalt fiber asphalt concrete (BFAM) is 5.1%.

3. Determination of test parameters

3.1. Determination of the annual amount of ultraviolet radiation

The total solar radiation energy in western China is basically higher than that in the eastern plains. The average ultraviolet light intensity of Lhasa in Tibet from June to September is 295.375MW/m2, and the annual sunshine time is about 3006h. At 246.638 MJ/m2, the annual total ultraviolet radiation of Dawu Town, Guoluo County, Qinghai Province is 350 MJ/m2, and the annual total ultraviolet radiation of Shanghai is 149.6 MJ/m2. [6] After investigating the annual total ultraviolet radiation in the country, this paper used 300 MJ/m2 for experimental research.

3.2. Determination of high and low temperature, duration, and number of cycles

Refer to the *“Test Procedure for Asphalt and Asphalt Concrete for Highway Engineering”* （JTG E20–2011）for freeze-thaw splitting test. The low temperature is -18℃± 2℃, maintained in the constant temperature refrigerator for 16 ± 1 h; the high temperature is 60℃± 0.5℃, and the constant temperature water tank is kept for 24 h. Considering that the road surface conversion temperature under extreme cold conditions in China's high latitudes and high altitudes is around -30℃, this test mainly studies the influence of low temperature environment on asphalt concrete and the temperature environment greater than 0℃only melts. Function, my research team's research on ordinary asphalt concrete salt-free electron microscope scanning reveals that the extreme low temperature will make the deicing salt crystal puncturing the asphalt film become more intense, so the temperature of this test is determined to be low temperature -30℃for 16 h; High temperature 60℃, heat preservation 8h. In order to better influence the effect of temperature cycling on asphalt concrete, this test selected continuous cycle 10 times.

3.3. Determination of salt solution content

Referring to the research results of Wang lan [7], when the concentration of deicing salt is medium to low concentration (4%-8%), the damage to asphalt concrete is the most serious. In this test, the snow melting agent solution with a concentration of 5% is used for salt freezing. (SF) cycle test.

4. High temperature stability analysis of basalt fiber asphalt concrete

According to the requirements of *"Testing Regulations for Asphalt and Asphalt Concrete of Highway Engineering"*(JTG E20-2011), the rutting test was used to evaluate the high temperature stability of basalt fiber asphalt concrete. [8]

Three parallel tests were carried out for each test condition, and the calculated dynamic stability was averaged. The analysis of the test results of the rutting test is shown in Figure 1:

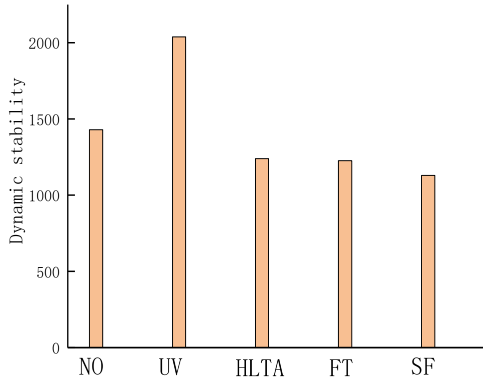

Fig 1 Comparison of dynamic stability of basalt fiber asphalt concrete under different environmental factors

The damage caused by different environmental factors is not the same for the basalt fiber asphalt concrete: the dynamic stability is increased by 42.64% after UV aging; the dynamic stability is reduced by 13.24% after the high and low temperature alternating cycle; after the freeze-thaw cycle The dynamic stability was reduced by 14.18%; after the salt freezing cycle, the dynamic stability was reduced by 20.94%. After the basalt fiber asphalt concrete has been affected by different environmental factors, the change law of dynamic stability is: ultraviolet aging> high and low temperature alternating cycle> freeze-thaw cycle> salt freezing cycle.

5. Low temperature stability analysis of basalt fiber asphalt concrete

According to China's *"Testing Regulations for Asphalt and Asphalt Concrete for Highway Engineering"* (JTG E20-2011), the trabecular bending test was adopted as a test method for determining the low temperature stability of asphalt concrete.[9]

The low temperature crack resistance of asphalt concrete is usually evaluated by the maximum bending strain. The concrete is subjected to three parallel tests under each condition, and the maximum bending strain of the specimen is obtained and calculated. The trabecular bending test results are obtained. Analysis of the following figure:

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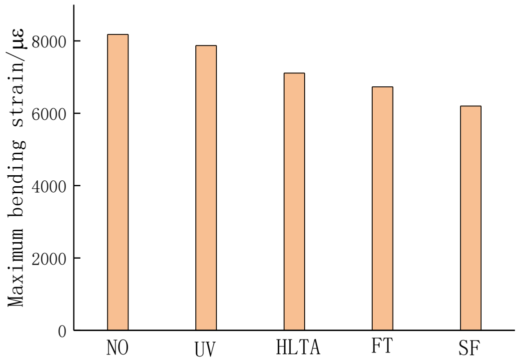


Fig 2 Comparison of maximum bending strain of basalt fiber asphalt concrete after different influencing factors

The influence of different environmental influence factors on the low temperature performance of basalt fiber asphalt concrete is different: the maximum bending strain of basalt fiber asphalt concrete is reduced by 3.77% after ultraviolet aging; the maximum bending strain after high temperature and low temperature alternating cycle is reduced. 13.05%; the maximum bending strain after freezing and thawing cycles decreased by 17.7%; after the salt freezing cycle, the maximum bending strain decreased by 24.2%. The effect of basalt fiber asphalt concrete on the low temperature stability after different environmental factors: the salt freezing cycle has the strongest influence, followed by the freeze-thaw cycle, and again the high and low temperature alternating cycle, the least affected is ultraviolet aging.

6. Water stability analysis of basalt fiber asphalt concrete

According to *"Testing Regulations for Asphalt and Asphalt Concrete of Highway Engineering"*(JTG E20-2011), the freeze-thaw splitting test was selected as the test method for determining the water stability of concrete. [10]

Standard Marshall specimens for concrete are subjected to ultraviolet aging, high and low temperature alternating cycles, freeze-thaw cycles and salt freezing cycles. Then a freeze-thaw split test was performed. The test results are shown in Figure 3:

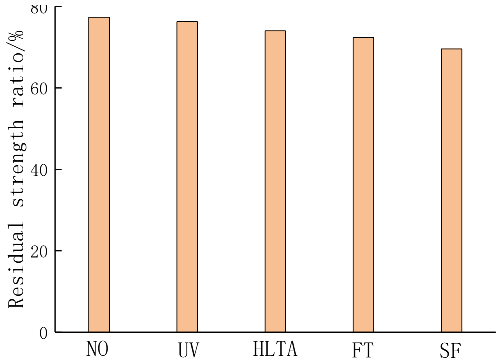


Fig 3 Comparison of residual strength ratio of basalt fiber asphalt concrete after different influencing factors

The effects of different environmental factors on the water stability of basalt fiber asphalt concrete are different: the residual strength ratio of basalt fiber asphalt concrete is reduced by 1.41% after UV aging; the residual strength ratio is reduced after high and low temperature alternating cycle 4.34%; the residual strength ratio decreased by 6.49% after freeze-thaw cycle; the residual strength ratio decreased by 10.07% after salt-freezing cycle. After the basalt fiber asphalt concrete has been affected by different environmental factors, the effect on the water stability is that the salt freezing cycle has the strongest influence, followed by the freeze-thaw cycle, and again the high-low temperature alternating cycle, and the ultraviolet aging has the least influence.

7. Comparative analysis of performance with ordinary matrix asphalt concrete

UV-aging, high-low temperature alternating cycle, freeze-thaw cycle and salt-free road environment treatment were carried out on A-grade 90# asphalt and A-grade 90# asphalt with basalt fiber as binder. , low temperature, water stability test, the changes in the indicators after adding basalt fiber, as follows:

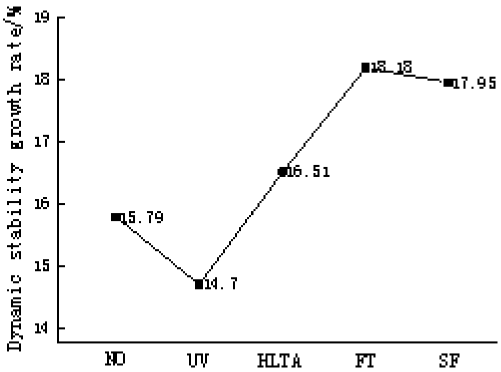


Fig 4 The dynamic stability increasing range curve of basalt fiber asphalt mixtures after different influence factors

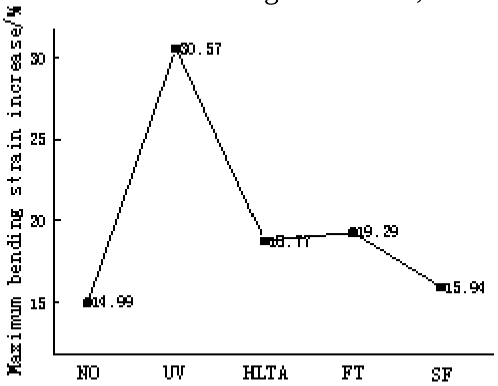


Fig 5 The maximum bending strain increasing range curve of asphalt mixtures adding basalt fiber after different influence factors

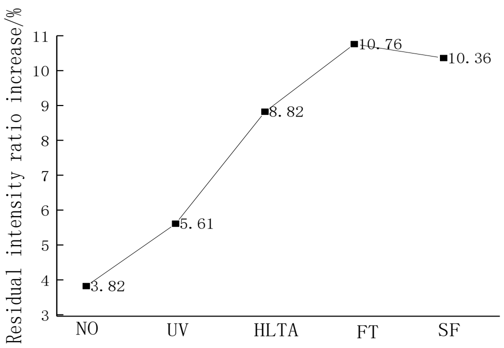


Fig 6 The residual stability increasing range curve of asphalt mixtures adding basalt fiber after different influence factors

Figure 4 shows that the dynamic stability of the basalt fiber asphalt mixture is 15.79% higher than that of the matrix asphalt mixture before the two asphalt mixtures are not affected by environmental factors. After the action of ultraviolet aging, the dynamic stability of the basalt fiber asphalt mixture is 14.7% higher than that of the matrix asphalt mixture. After the high-low temperature alternating (HLTA) cycle affects the basalt fiber asphalt The dynamic stability of the mixture is 16.51% higher than that of the matrix asphalt mixture. After the effects of freeze-thaw (FT) cycle, the dynamic stability of the basalt fiber asphalt mixture is more stable than that of the matrix asphalt mixture. The degree is 18.18% higher. After the action of the salt-freezing cycle, the dynamic stability of the basalt fiber asphalt mixture is 17.95% higher than that of the matrix asphalt mixture.

Due to the adsorption and thickening effect of basalt fiber, the adsorption of free asphalt in the asphalt mixture becomes a structural asphalt with good stability, which increases the thickness of the asphalt film and increases the adhesion of the asphalt cement to the aggregate. , thereby improving the high temperature stability of the asphalt mixture; due to the reinforcement of the basalt fiber, the basalt fiber randomly distributed in the asphalt mixture can effectively spread the load and reduce the concentrated stress under the action of external load, thereby reducing Plastic deformation to improve the high temperature stability of asphalt mixture.

Figure 5 shows that the maximum bending strain of the basalt fiber asphalt mixture is 14.99% higher than that of the matrix asphalt mixture before the two asphalt mixtures are affected by environmental influences. After the effect of ultraviolet aging, the maximum bending strain of the basalt fiber asphalt mixture is 30.57% higher than that of the matrix asphalt mixture. After the high temperature and low temperature alternating circulation factors, the maximum bending of the basalt fiber asphalt mixture The strain is 18.77% higher than that of the matrix asphalt mixture. After the influence of the freeze-thaw cycle, the maximum bending strain of the basalt fiber asphalt mixture is 19.29% higher than that of the matrix asphalt mixture. After the salt-freezing cycle affects the factors, The maximum bending strain of the basalt fiber asphalt mixture is 15.94% higher than that of the matrix asphalt mixture.

Since the basalt fiber has oil absorption, the surface of the fiber absorbs a large amount of asphalt, which increases the amount of asphalt used in the asphalt mixture, which is beneficial to the improvement of the low-temperature crack resistance of the asphalt mixture; due to the cracking action of the basalt fiber, the fiber can be effectively incorporated. Bridging from the micro-cracks between the aggregates, [10] the high tensile strength of the fibers itself further prevents the development of micro-cracks and diffusion polymerization, preventing or even delaying the occurrence of pavement cracks; the formation of space in the asphalt mixture due to the distribution of basalt fibers The mesh structure can effectively disperse and bear the temperature stress, reduce the damage of the temperature stress to the asphalt mixture, thereby improving the low temperature crack resistance of the asphalt mixture.

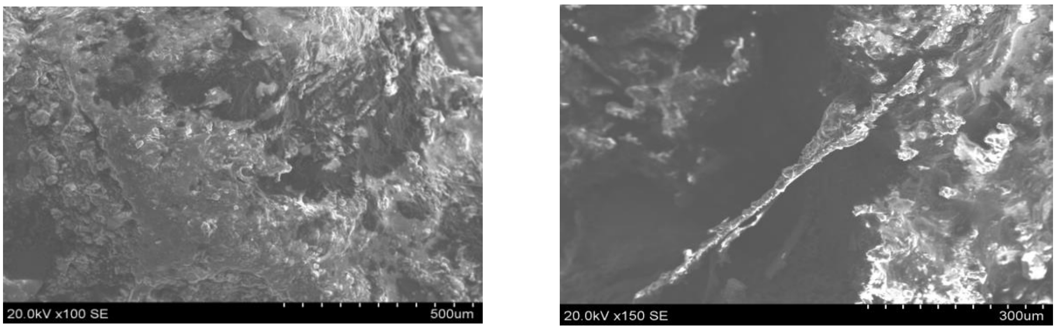
Figure 6 shows that the residual strength ratio of the basalt fiber asphalt mixture is 3.82% higher than that of the matrix asphalt mixture before the two asphalt mixtures are affected by environmental influences. After the effect of ultraviolet aging, the residual strength ratio of the basalt fiber asphalt mixture is 5.61% higher than that of the matrix asphalt mixture. After the high and low temperature alternating circulation factors, the residual strength ratio of the basalt fiber asphalt mixture is higher than that of the matrix asphalt. The mixture was 8.82% higher. After the influence of the freeze-thaw cycle, the residual strength ratio of the basalt fiber asphalt mixture was 10.76% higher than that of the matrix asphalt mixture. After the salt-freezing cycle affected factors, the basalt fiber asphalt mixture was mixed. The residual strength ratio is 10.36% higher than that of the matrix asphalt mixture.

Due to the adsorption of basalt fiber, the asphalt mortar is more, the thickness of the asphalt film is improved, the interface strength is also improved, and the adhesion between the asphalt and the aggregate is effectively increased. The asphalt is added due to the incorporation of basalt fiber. The saturation of the mixture also reduces the void ratio of the asphalt mixture, the compactness is improved, and the moisture is not easily penetrated. Due to the poor hydrophilicity of the basalt fiber, the interface expansion between the asphalt and the aggregate is avoided due to the basalt fiber being exposed to water. It reduces the peeling of aggregates and thus improves water stability.

8. Microscopic analysis of basalt fiber asphalt concrete

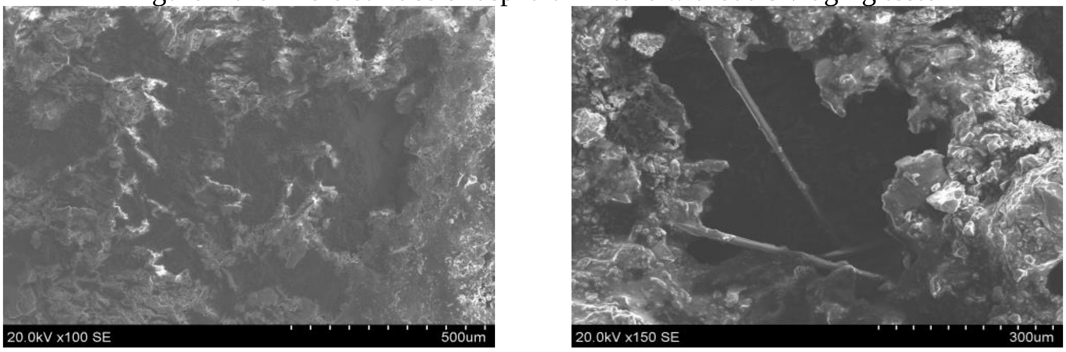
8.1. Microanalysis

The instrument chosen for this test was a S-3400N scanning electron microscope.[12] The rut test piece is cut into strips, and then the strip test piece is gradually broken into the size of the test piece by using pliers and other tools, and the length of each side is about 1 cm. Before the test, the test piece should be polished with tweezers, and then the surface of the test piece should be blown off with a water absorbing ball, and then placed under a scanning electron microscope. The basalt fiber asphalt concrete specimens before and after UV aging are representative specimens, and the microscopic images of the electron microscope are as follows:



a）Unfiber blended b）Fiber blending

Figure 7 the micro surface of asphalt mixture without UV aging tester



a）Unfiber blended b）Fiber blending

Figure 8 the micro surface of asphalt mixture after UV aging tester

It can be seen from Fig. 7 and Fig. 8 that after UV aging, the surface of the fiber still adsorbs a large amount of asphalt, which improves the thickness of the asphalt film; the adhesion between the fiber and the asphalt concrete is strong, and it is adsorbed at the root of the fiber. A large amount of asphalt mortar; the fibers that overlap each other form a spatial network structure in the asphalt concrete, and the asphalt concrete is closely connected.

Because of the adsorption, thickening, cracking, and reinforcement of basalt fiber [13,14], it has been widely concerned by related scholars. During the mixing process, the basalt fibers overlap each other in the matrix, and expand into a bundle of filaments, which increases the contact area between the fibers and the asphalt cement. In addition, the basalt fiber has excellent ability to adsorb the asphalt, so that a solid structure is formed between the asphalt and the fibers. The asphalt adheres to the surface of the basalt fiber and has an angular bulge at the end of the fiber. It plays an interlocking role in the interlaced structure of the fiber, which enhances the adhesion and bonding strength between the materials and significantly improves the asphalt. The properties of the material. The basalt fiber forms a spatial network structure with the ore powder and asphalt. This positional relationship and the reinforcement of the fiber jointly produce internal friction resistance to the flow of the asphalt, inhibit the relative slip between the fillers, and enhance the overall performance of the asphalt cement; basalt The fiber has a high modulus of elasticity and plays a positive role in the overall elastic modulus of the glue, thereby improving the resistance to deformation .[15]

8.2. Analysis of the reinforcing effect of fiber on asphalt interface

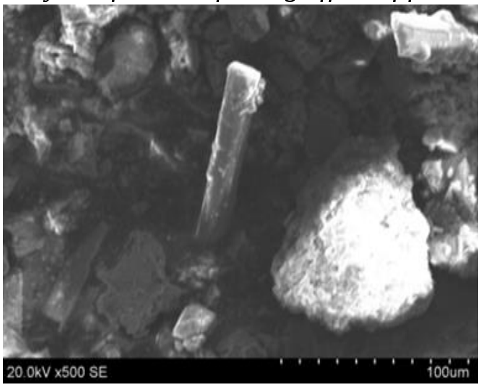


Figure 9 Bond interface diagram without UV aging

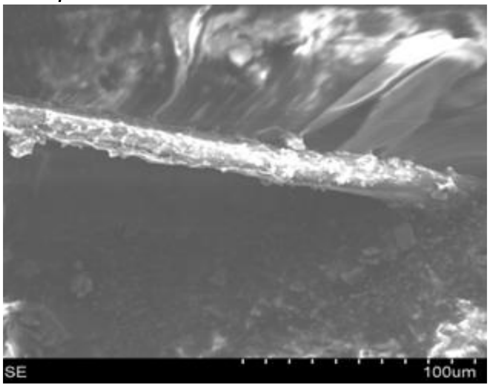


Figure 10 Bond interface diagram after UV aging

It can be seen from Fig. 9 and Fig. 10 that after the ultraviolet aging effect, the asphalt is evenly wrapped on the surface of the basalt fiber to form an asphalt film, which indicates that the asphalt and the basalt fiber surface have good wettability or form a chemical bond. Wettability is the degree to which a liquid spreads over a solid surface. Good wetting will greatly increase the strength of the interface, even better than the cohesive strength of the substrate itself. From the knowledge of physics and chemistry, there is an interface between phases and phases in all systems where different phases coexist. [15] The above analysis of the reinforcement effect and theoretical explanation of the fiber-to-asphalt interface is carried out by the following theory:

The fiber length is 6 mm, the diameter is generally less than 20 μm, and the surface area per 10 g of fiber is greater than 1 m 2.[16] In the contact between asphalt and fiber, fiber adsorption asphalt forms many large new infiltration interface layers with thickness between mm and μm, ie transition layer, and the transition layer can transmit and dissipate stress, which plays an active role in inhibiting crack growth. . At the same time, there is a component in the asphalt which is an acidic resin, and the surface has an active substance, which can adsorb and infiltrate the fiber, and the chemical bond in the asphalt makes it monomolecularly arranged on the surface of the fiber, thereby forming a firm interface layer. The mediator acts to bond the chemical bonds to chemically react with the two phases.[17] The viscosity of the mixture after adding the basalt fiber is higher than the viscosity of the matrix asphalt concrete, and the fiber can be uniformly distributed inside the space and form a network structure, thereby inhibiting the flow of the asphalt. Therefore, the incorporation of fibers increases the adhesion of asphalt concrete.

It can be seen from the above theoretical analysis that a good interface strength can improve the toughness of the material, and the stress is transmitted to make the strengthening phase bear a large external load and improve the bearing capacity of the asphalt concrete. Furthermore, it can disperse and absorb the energy of various mechanical shocks and thermal shocks, improve the ability to resist external shocks, and make basalt fiber and asphalt produce mutually independent and coordinated functions, make up for their respective shortcomings, and obtain new material use performance.

9. conclusion

(1) After the basalt fiber asphalt concrete has been affected by different environmental factors, the ultraviolet aging causes the high temperature performance to be improved, and the high and low temperature alternating, freezing and thawing cycles and salt freezing increase the concrete high temperature performance in turn;

(2) After the basalt fiber asphalt concrete has different environmental factors, the effects on the low temperature stability and water stability are the same: the salt freezing cycle has the strongest influence, followed by the freeze-thaw cycle, and the high-low temperature alternating cycle again, with the least impact. For UV aging.

(3) After UV aging, high and low temperature alternating, freezing and thawing, salt freezing and

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other environmental factors, basalt fiber asphalt concrete is superior to matrix asphalt concrete in high temperature, low temperature and water temperature performance.

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