Research Article

Study on Pavement Performance of Cement Stabilized Recycled Brick Aggregate Base with Basalt Fiber

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Abstract

The solution to environmental problems caused by the generation of construction brick waste is its use as a substitute for natural gravel aggregate in highway base material. The preparation of basalt fiber cement stabilized recycled brick aggregate base material is by adding basalt fiber to cement stabilized recycled waste brick mixture. With the help of nonlateral compressive strength test, indirect tensile (splitting) strength test, and flexural tensile strength test, the influence of basalt fiber with different dosages on the compressive strength, crack resistance, and durability of cement stabilized recycled waste brick mixture was analyzed. The effects of basalt fiber on water loss rate, dry shrinkage strain, and frost resistance of cement stabilized recycled waste brick mixture were analyzed by dry shrinkage test and freeze-thaw test. The bonding morphology of fiber and cement slurry was studied by scanning electron microscopy. The results show that when the waste brick aggregate content is 30% and basalt fiber content is 1‰, the 28-day compressive strength of cement stabilized waste brick mixture is 19% higher than that of the specimen without fiber; indirect tensile strength increased by 36.6%; flexural strength increased by 37.0%; water loss rate decreased by 15.5%; the coherent shrinkage strain decreased by 30.3%; and BDR value (compressive strength loss percentage) increased by 12.3%. Basalt fiber and cement slurry have good bonding force and friction force, which act as tensile reinforcement in the mixture. Fiber bundle and fiber filament compose a fiber network to enwrap the mixture, so that the fiber network and mixture are embedded with each other, thereby improving the mechanical properties and durability of cement stabilized recycled waste brick mixture.

1. Introduction

With the accelerating process of urbanization in the country, large-scale demolition of the original waste buildings in the process will produce a large amount of solid construction waste, and now demolished buildings are mostly brick-concrete structures built in the 1980s and 1990s, resulting in a large number of waste clay [1]. Using construction waste recycled materials for road engineering construction is a specific measure for the development of green low-carbon transportation [2]. The construction waste can only replace 20%~30% of natural aggregate due to the strength and gradation requirements when it is used in pavement base or subbase [3]. The characteristics of waste brick aggregate are low strength and absorption. With the increase of waste brick mixing ratio, the mechanical properties and durability of cement stabilized recycled waste brick aggregate specimens show a decreasing trend, but its dry shrinkage strain is decreasing, which improves the dry shrinkage performance of cement stabilized [4]. With the continuous improvement of waste brick content, the compressive strength and...
compressive resilient modulus of recycled waste brick base are significantly reduced. The splitting strength is improved [5, 6]. With the increase of waste brick content, the maximum dry density gradually decreases, while the optimum water content significantly increases. Compressive strength and resilient and splitting strength decreased significantly; dry shrinkage performance has a certain degree of improvement, while the temperature shrinkage performance becomes low [7–9]. With the increase of the mass fraction of waste bricks, the freeze-thaw resistance has no obvious change, the antierosion performance is significant, the dry shrinkage coefficient is reduced, and the temperature shrinkage coefficient is increased [10]. Basalt fiber, which is drawn from basalt stone after melting, has high strength and chemical resistance and is not affected by high temperature generally brown or yellow Basalt fiber produces less pollutants and does not cause harm to the environment. It is a real and valuable environmental protection material. Basalt fiber has good resistance to high temperature and tensile properties, which can improve the crack resistance of asphalt [11, 12]. The mechanical properties and erosion resistance of steel slag base are significantly better than ordinary cement stabilized macadam, and steel slag can improve the drying shrinkage resistance of base materials to a certain extent [13]. Rubber particles can well enhance the deformation capacity of cement stabilized macadam to improve the crack resistance [14]. Basalt fiber can enhance the freeze-thaw resistance of concrete under corrosion conditions, effectively extending the service life of concrete under corrosion conditions [15]. Due to the reinforcement of basalt fiber and the low density of recycled aggregate, the specific strength of low-dose basalt fiber combined with high-content recycled aggregate is higher than that of recycled aggregate concrete. In addition to strengthening strength, basalt fiber also reduces the porosity of recycled aggregate concrete and improves the permeability of chloride [16, 17]. Under the combined action of metakaolin, polyvinyl alcohol fiber, and basalt fiber, the splitting tensile strength and flexural strength enhancement was more significant [18]. Basalt fiber can effectively improve the high temperature performance of asphalt mixture and improve the shear resistance of mixture, increase the flexural tensile strain, splitting failure strength, vertical deformation, and failure strain of asphalt mixture, and improve the low temperature cracking resistance of asphalt mixture, improving the water stability of asphalt mixture; it can increase the skid resistance of asphalt mixture to some extent [19–24].

In summary, the incorporation of waste brick will weaken the mechanical properties and durability of cement stabilized, which can improve the dry shrinkage performance of cement stabilized base. Basalt fiber can improve the mechanical properties and durability of recycled concrete and effectively improve the shear resistance, low temperature cracking resistance, water stability, and skid resistance of asphalt. There are few studies on the aggregate base of cement stabilized recycled brick with basalt fiber. Therefore, in order to obtain good dry shrinkage performance of cement stabilized recycled brick base and enhance the mechanical properties and durability of cement stabilized recycled brick base, this paper explores the influence of basalt fibers with the dosages of 0, 0.5‰, and 1‰, respectively, on the road performance of cement stabilized recycled waste brick base with the substitution rates of waste brick for natural gravel of 30%, 60%, and 100%. The mechanical properties, crack resistance, and durability were studied by unconfined compression test, splitting test, bending test, dry shrinkage test, and freeze-thaw test. The composition state of inorganic binder was analyzed microscopically by scanning electron microscope test. The combination morphology of basalt fiber and cement slurry was studied, and the reinforcement and crack resistance mechanism of basalt fiber in the mixture structure was revealed.

2. Raw Materials

2.1. Aggregate. The waste clay red brick selected for this paper comes from the demolition site of the construction site in the northeast of Xiangyang Bridge in Zhengzhou City. PE60 × 100 E crusher was needed for crushing. The recycled waste brick aggregate obtained by crushing will be strictly controlled according to the test method and index requirements of the test procedure (E42-2005) and the basic construction technical rules (JTG/T F34-2015). The jaw crusher and the prepared waste brick aggregate are shown in Figures 1 and 2, respectively.

ZBSX-92A standard vibrating screen machine was used to screen and aggregate broken waste clay brick red brick, and the broken waste clay brick on each screen was put into each woven bag, and the particle size specification was written. The recycled waste brick aggregate and gravel aggregate are shown in Figures 3 and 4, respectively.

The physical properties of recycled aggregate and natural aggregate tested in accordance with the requirements of aggregate test procedures (JTG E42-2005) are shown in Table 1.

2.2. Cement. In this research, P.O.42.5 cement produced by Xinxiang Xinxing Cement Co., Ltd., and its fineness, water consumption, setting time, volume stability, and strength were tested according to technical rules of “Technical Guidelines for Construction of Highway Roadbases” (JTG/T F20 - 2015). The test results are shown in Table 2. According to the technical requirements in the specification, the cement specifications meet the requirements.

2.3. Water. The test mixing water is drinking water of Zhengzhou residents, and the test water fully meets the standard of test water.

2.4. Basalt Fiber. The experimental study adopts 12 mm short cut basalt fiber provided by Haining Anjie Composites Company Ltd., as shown in Figure 5.

Basalt fiber has good tensile properties and good resistance to high temperature and low temperature [25, 26].
The selected mass content of basalt fiber used in this experiment is not more than 1.0‰. Detailed parameters of basalt fiber are shown in Table 3.

3. Test Method

3.1. Mix Proportion Design of Cement Stabilized Recycled Aggregate with Fiber

3.1.1. Mix Proportion Design Gradation. Mix design was based on the recommended ranges for grain size fraction of cement stabilized graded gravel or gravel in the “Technical Guidelines for Construction of Highway Roadbases” (JTG-T-F20-2015). The mixture is configured according to the median gradation. The recommended gradation range and gradation curve are shown in Table 4 and Figure 6.

In order to eliminate the influence of different gradation of recycled aggregate and natural aggregate on the performance analysis of pavement base, the recycled aggregate is rescreened into different particle sizes. According to the grading median in the specification, the recycled aggregate with different particle sizes is used as the final gradation of the mixture, and the natural aggregate used as the comparison test also uses the intermediate gradation to configure the mixture.

3.1.2. Compaction Test. In this experiment, the heavy compaction is selected, and the electric compaction instrument model is LQ-DJ-II as shown in Figure 7.

In the text, according to the “Technical Guidelines for Construction of Highway Roadbases” (JTG-T-F20-2015) in the cement stabilized material mix ratio test recommended cement test dose, the cement stabilized mixture with different percentages of recycled aggregate is designed with 3%, 4%, 5%, 6%, and 7% of five different cement contents, the five kinds of cement mixture compaction test to determine the best moisture content and maximum dry density; the test results are shown in Table 5.

Table 5 shows that, with the increase of cement content, the higher the optimal water content of the mixture, the greater the maximum dry density. The higher the cement content is, the more water is needed in the hydration process of cement, so the optimum water content increases accordingly. Under conditions of the same cement content, the optimal water
content of cement stabilized recycled aggregate is higher than that of cement stabilized natural aggregate, and its maximum dry density is smaller than that of water stabilized natural aggregate.

When the cement content is 6% and 7%, it can also meet the strength requirements of the specification. However, the increase of cement content will not only increase the engineering cost, but also lead to more heat generated by the cement hydration reaction, which leads to the aggravation of the cracking of the water stabilized base. Therefore, when the cement content in the water stabilized base is more than 6%, its crack resistance will deteriorate, and the mixture needs a certain strength, and the 5% cement dosage is the usual design dosage, so the cement dosage is selected as 5%. For the cement stabilized recycled waste brick mixture with substitution rates of 30%, 60%, and 100%, the maximum dry densities were 2.06 kg/cm³, 1.87 kg/cm³, and 1.66 kg/cm³, respectively, and the water contents were 9.4%, 12.6%, and 16.2%, respectively.

3.1.3. Design of Test Blending Ratio. In this experiment, the waste brick aggregate was replaced by coarse and fine aggregate according to the mass percentages of 0, 30%, 60%, and 100%, respectively, and the basalt fibers with mass fractions of 0, 0.5‰, and 1‰ were added, respectively.

3.2. Compressive Strength Test. In this study, the nominal maximum particle size of the aggregate processed by waste red clay brick is greater than 19 mm and is not greater than 37.5 mm, belonging to coarse grains. Cylindrical specimens with diameter and height of 150 mm were prepared. For cement stabilized coarse aggregate at least 13 specimens should be prepared, with a total of $13 \times 3 \times 3 = 117$ unconfined compressive specimens. The standard curing temperature is 20°C ± 2°C; the standard curing humidity is greater than or equal to 95%. The specimens of standard curing and immersion curing are shown in Figures 8 and 9. Hualong WAW-600 microcomputer electrohydraulic servo testing machine was used in the test. The loading rate should be maintained at 1 mm/min during the test. The compression test process is shown in Figure 10.

3.3. Indirect Tensile Strength Test. Splitting test using universal testing loading rate was controlled at 1 mm/min; splitting strength test process is shown in Figure 11.

3.4. Bending Tensile Strength Test. The beam specimen with the size of 100 mm × 100 mm × 400 mm was made, and the curing time was 90 days. The test was carried out by the method of three-point pressure, and the loading speed of the
press was effectively controlled at 50 mm/min. Specimen before and after test is shown in Figure 12.

3.5. Shrinkage Performance Test. The surface of the specimen after water-saturated curing was dried, and the length was measured and weighed. Then, the scaffold method was used for the dry shrinkage test. The preparation of specimens is shown in Figure 13(a), and the dry shrinkage test specimens and devices are shown in Figure 13(b). The specimens were 100 mm × 100 mm × 400 mm beam specimens. After that, the specimens were immediately put at the temperature of 20°C ± 1°C and the relative humidity of 60% ± 5% in drying box for health preservation. The health preservation time was 6 days, and the seventh day was saturated.

Table 3: The performance parameter of basalt fiber.

| Fiber diameter (µm) | Density (kg/cm³) | Fiber length (mm) | Tensile strength (MPa) | Elastic modulus (GPa) | Working temperature (°C) |
|---------------------|------------------|-------------------|------------------------|-----------------------|--------------------------|
| 7–15                | 2.64             | 12                | 3480                   | 91–110                | −269–650                 |

Table 4: Recommended ranges for grain size fractions of cement stabilized materials.

| Size of screen mesh (mm) | 31.5 | 19  | 9.5  | 4.75 | 2.36 | 0.6  | 0.075 |
|--------------------------|------|-----|------|------|------|------|-------|
| Gradation range (%)      | 90–100| 67–90| 45–68| 29–50| 18–38| 8–22 | 0–7   |
| Median gradation (%)     | 95   | 78.5| 56.5 | 39.5 | 28   | 15   | 3.5   |

Figure 6: Gradation curve.

Figure 7: Electric compaction device.
3.6. Freeze-Thaw Test. According to the specification, cylindrical specimens were made. Test specimen was selected to be 150 mm in diameter and height. Test specimens were divided into freeze-thaw specimens and non-freeze-thaw ones. After the completion of the specimen standard curing 28 days, and in the 28 days of soaking a day standby. The freeze-thaw test was carried out. The temperature of the low temperature box was $-18^\circ$C and the freezing time was 16 hours to ensure that there was at least 20 mm gap around the specimen to facilitate the circulation of cold. In the freezing test, the specimen was taken out and weighed and then immediately put into 20°C tank for thawing; thawing time is 8 hours. Water surface in the tank is at least 20 mm higher than the surface of the specimen. After completed thawing, the specimen is wiped out and weighed, and for the freezethaw cycle a total of five freeze-thaw cycles are required.

3.7. SEM. The mixture that destroyed the fresh section in the splitting test was taken to make the sample and then put into the automatic gold plating instrument. The air inside was extracted first, so that the sample was sprayed with gold for 30 seconds in a vacuum state. The sample was prepared and observed on the loading table of the scanning electron microscope. The vacuum gold plating process and the samples after gold plating are shown in Figures 14 and 15. In this microtest, the test instrument of Zhengzhou University was used, and the total model was ZEISS HD 15/Oxford.
Figure 12: Specimen before and after test.

Figure 13: Dry shrinkage test. (a) Production of dry shrinkage specimen. (b) Dry shrinkage test device and specimen.

Figure 14: Vacuum gold plating process.

Figure 15: Sample after gold plating.

Figure 16: Scanning electron microscopy.
X-MaxN scanning electron microscope. The scanning electron microscope is shown in Figure 16.

4. Results and Discussion

4.1. Influence of Basalt Fiber Content Compressive Strength. When the cement dosage of cement stabilized waste brick mixture is 5% and the waste brick dosage is 30%, the influence of basalt fiber mass content on the compressive strength of 7 days, 28 days, and 90 days is shown in Figure 17.

It can be seen from Figure 15 that with the increase of basalt fiber mass fraction in cement stabilized recycled waste brick mixture, the compressive strength of cement stabilized recycled waste brick mixture increases gradually at 7 days, 28 days, and 90 days. The 28-day compressive strength of specimens without basalt fiber is 3.78 MPa. The 28-day compressive strength of specimens with 0.5‰ and 1‰ basalt fiber is 4.02 MPa and 4.50 MPa, respectively, which are 6.3% and 19% higher than those without basalt fiber. The variation coefficient of 28-day compressive strength of specimens with fiber content of 0, 0.5‰, and 1‰ was 6.7%, 9.2%, and 8.3%, respectively.

With the increase of fiber content, the compressive strength of the mixture also increases significantly. The tensile strength of basalt fiber is high, reaching 3480 MPa. Fiber mass content is 0 to 0.5‰, fiber distribution in cement stabilized recycled mixture is too dispersed, there is no connection between each other, it can not form an effective support system, and the improvement of compressive strength is not obvious. When the fiber content is 0.5‰ to 1‰, a uniform mesh support system can be formed inside the cement stabilized recycled waste brick mixture, which can better play the advantages of basalt fiber and significantly improve the compressive strength of cement stabilized recycled waste brick mixture.

4.2. Influence of Basalt Fiber Content on Splitting Strength. When the cement dosage is 5% and the recycled waste brick mass content is different, the influence of basalt fiber mass content on the splitting strength is shown in Figure 18.

It can be seen from Figure 16 that the indirect tensile strength of the specimen is significantly improved by adding basalt fiber into the cement stabilized recycled waste brick mixture. With the increase of fiber content, the 90-day splitting strength of cement stabilized recycled waste brick mixture continues to be improved. Test data were analyzed when the cement dosage was 5% and the waste brick dosage was 60%. When basalt fiber was not added, the splitting strength of the specimen reached 0.41 MPa; the splitting strength of specimens with fiber content of 0.5‰ and 1‰ was 0.47 MPa and 0.56 MPa, respectively, which was 14.6% and 36.6% higher than that of specimens without fiber.

Basalt fiber is uniformly distributed in water-stable macadam, which can connect cement hydration products and enhance the ability of water-stable macadam to resist deformation [27]. The indirect tensile strength of ordinary cement stabilized recycled waste brick aggregate is mainly determined by the interagglomeration between aggregates, the bond between cement hydration-generated cement paste and crystal, and the bond between aggregates. The aggregate of cement stabilized recycled waste brick with basalt fiber not only has these effects, but also has the cementation and friction between the cement bond and crystal generated by the hydration of fiber and cement. Fiber acts as a tensile bond in them, thus significantly improving the indirect tensile strength of cement stabilized recycled waste brick mixture.
The fiber acts as the tensile bond in it, thus significantly improving the indirect tensile strength of cement stabilized recycled waste brick mixture.

4.3. Influence of Basalt Fiber Content on Bending Tensile Strength. When the cement dosage is 5%, the influence curve of basalt fiber on 90 days’ flexural tensile strength under different waste brick aggregate content is shown in Figure 19.

Figure 19 shows that the addition of basalt fiber has a certain improvement effect on the 90-day flexural tensile strength of cement stabilized recycled brick. With the increase of fiber content, the improvement effect of bending strength becomes particularly obvious. The content of waste brick aggregate is 30% and basalt fiber is not added; the flexural strength of 90 days is 0.92 MPa. When the content of fiber is 0.5‰, the flexural strength is 1.01 MPa, an increase of 9.8%. When the fiber content is 1‰, the flexural strength of cement stabilized waste brick aggregate reaches 1.26 MPa.
which is increased by 37.0% compared with the specimen without. Reason why basalt fiber can improve the flexural strength of cement stabilized recycled waste brick aggregate is that when the basalt fiber is subjected to the force of the water stabilized recycled waste brick mixture and cracks occur; the fiber bundle and fiber cross cracks are encountered in the process of crack propagation at the bottom. Jun et al. studied that the addition of calcium-high basalt fiber led to the development of C-S-H and C-A-S-H combined with N-A-S-H or hybrid C(N)-A-S-H gel system, which further enhanced the performance of geopolymer grouting material [28]. The fiber is equivalent to the role of steel in concrete, which plays a certain traction role in the water stabilized recycled waste brick mixture on both sides of the fracture surface of the specimen, thus inhibiting the cracking and failure of the water stabilized recycled waste brick aggregate to a certain extent and improving the flexural strength of the specimen.

4.4. Influence of Basalt Fiber Content on Dry Shrinkage Performance. When the cement dosage is 5%, the recycled waste brick aggregate content is 30%. When the cement stabilized recycled waste brick mixture with basalt fiber changes with the fiber mass content, the relationship curves between the water loss rate and dry shrinkage strain of the specimen and time are shown in Figures 20 and 21.

It can be seen from Figure 20 that the water loss rate of cement stabilized recycled brick specimens increases with time. The water loss rate of specimens in the early stage increases significantly, and the growth rate slows down and slowly stabilizes in the later stage. With the increase of basalt mass content, the water loss rate of cement stabilized recycled waste brick mixture is significantly lower than that of cement stabilized waste brick mixture without fiber. Basalt fiber can well reduce the dry shrinkage coefficient of cement stabilized recycled waste brick mixture.

The water loss rate of the specimens without basalt fiber was 2.74% on the seventh day. The water loss rates of the specimens with fiber mass of 0.5‰ and 1‰ were 2.43% and 2.12% on the seventh day, respectively, which were 11.3% and 22.6% lower than those of the specimens without fiber. With the increasing incorporation of fibers, basalt fiber bundles and filaments cover and fill some small capillary water evaporation channels, resulting in a decrease in water loss area and water evaporation becomes more difficult. At the same time, the tensile effect between basalt fiber and matrix further inhibits the dry shrinkage deformation of the specimen. Another more important reason is that basalt fiber acts as a tie bar in cement stabilized recycled waste brick mixture. When the specimen produces dry shrinkage cracks, it can reduce the width and depth of cracks to a certain extent and further restrict and narrow the channel of water loss, so as to reduce the water loss rate of cement stabilized recycled waste brick mixture.

Figure 21 shows that the dry shrinkage strain increases greatly in the early stage and slowly slows down in the later stage. The dry shrinkage strain of the specimens without basalt fiber is $188.56 \times 10^{-6}$ on the seventh day. The dry shrinkage strain of the specimens with 0.5‰ and 1‰ basalt fiber is $152.34 \times 10^{-6}$ and $131.46 \times 10^{-6}$ on the seventh day, respectively, which is 19.2% and 30.3% lower than that of the specimens without basalt fiber.

With the increase of basalt fiber, the dry shrinkage strain of cement stabilized recycled waste brick mixture gradually decreases. This is because basalt fiber bundle and silk cover and fill the tiny capillary water evaporation channel, resulting in the decrease of water loss area, and the evaporation of water becomes more difficult, so the dry shrinkage strain of the mixture is inhibited. The fiber can produce a disorderly mesh support system in the cement stabilized recycled waste brick mixture, which effectively inhibits the dry shrinkage strain of the mixture.

4.5. Influence of Basalt Fiber Content on Freeze-Thaw Test. When the cement content is 5% and the recycled waste brick content is 30%, the effect of fiber quality content on frost resistance is shown in Figure 22.

It can be seen from Figure 22 that the compressive strength of the specimens after five freeze-thaw cycles is lower than that of the specimens without freeze-thaw cycles. However, with the increase of basalt fiber content, the BDR values of the frost resistance index are all improved.

When basalt fiber was not added, the BDR value of the 28-day specimen was 81.2%, and the fiber mass content was 0.5‰ and 1‰, respectively. The BDR values of the 28-day specimen were 85.3% and 91.2%, respectively, which were 5.04% and 12.3% higher than those without basalt. With the change of BDR value, its very obvious that basalt fiber improves the frost resistance of cement stabilized waste brick mixture. The reason is that fiber bundles and filaments can cover and fill the tiny pores on the surface of recycled waste bricks, thereby reducing the amount of free water entering the pores, so that the expansion stress generated during freezing is relatively reduced. When the matrix is subjected to expansion stress, the fiber in the cement slurry is equivalent to the effect of steel bars in concrete, so as to inhibit the damage of expansion force on cement stabilized recycled waste brick mixture to a certain extent, so as to improve the frost resistance.

4.6. Mechanism Analysis of Enhanced Crack Resistance

4.6.1. Analysis on Strengthening Effect of Fiber Cement Slurry Interface. By scanning electron microscopy, the bond between basalt fiber and cement slurry is shown in Figure 23.

It can be seen from Figure 23 that not only is the surface of basalt fiber completely wrapped by cement slurry, but also the root of fiber is closely cemented with cement. It fully shows that the infiltration between basalt fiber and cement slurry liquid phase is sufficient. From the macroscopic view, the surface appearance of basalt fiber is smooth, but from the microscopic view, it is rough and uneven, which increases the contact area with cement slurry and can significantly enhance the bonding force between them. The incorporation of basalt fiber can make the bonding strength of the interface...
higher than that of the cement slurry phase itself, which can significantly improve the mechanical properties and frost resistance of the water stabilized waste brick. Basalt fiber has little mass content in cement stabilized recycled waste brick mixture, due to its own large specific surface area (the surface area per gram of basalt fiber can reach several square metres) and excellent performance; the fiber and cement slurry have a large bonding area, so that the road performance of fiber water stabilized recycled waste brick mixture is improved to some extent.

4.6.2. Effect of Basalt Fiber on Reinforcement and Crack Resistance of Cement Stabilized Recycled Mixture. The microscopic amplification of basalt fiber section is shown in Figure 24 and the combination of fiber and cement slurry is shown in Figure 24.

It can be seen from Figure 24 that there is an obvious fracture of basalt fiber, indicating that the fiber is pulled out due to the force, which is tensile failure rather than pulling out of cement. It fully shows that the bond between basalt fiber and cement slurry is very strong, and it can also effectively transfer the internal stress, so that basalt fiber can prevent the formation and development of cracks. Huang Min et al. found that the flexural strength and splitting tensile strength of recycled concrete increased significantly after adding basalt fiber [29]. The cement stabilized recycled waste brick mixture is subjected to the load stress and the expansion stress caused by freeze-thaw cycle; the basalt fiber distributed in the mixture matrix can inhibit the occurrence and further expansion of cracks. Like the steel bar in concrete, when the aggregate in the cement stabilized recycled waste brick mixture is separated, the matrix of the cement stabilized mixture is pulled instead of the cement stabilized mixture, so that the cement stabilized recycled waste brick mixture maintains good deformation performance.

It can be seen from Figure 25 that basalt fiber is randomly and irregularly distributed in cement stabilized recycled waste brick mixture, which makes basalt fiber intricately intertwined. Fiber bundles and fibers form a fiber network wrapped with water stabilized mixture, which improves the integrity of fiber and water stabilized recycled waste brick. Fiber network structure can not only transfer stress, but also effectively inhibit the relative movement between particles, connect the damaged parts together, and delay the further expansion of the gap.
5. Conclusion

(1) Basalt fiber forms a uniform messy mesh support system in cement stabilized recycled waste brick aggregate, which can better play the advantages of basalt fiber and significantly improve the compressive strength of the mixture. The basalt fiber mass content does not exceed 1%; the compressive strength increases with the increase of basalt fiber mass content; especially when the fiber mass content exceeds 0.5%, the increase is more. It acts as a tie bar in cement stabilized recycled aggregate, which significantly improves the indirect tensile strength of cement stabilized recycled waste brick mixture. When the fiber content is 1%, the flexural strength of cement stabilized waste brick aggregate reaches 1.26 MPa, which is 37.0% higher than that of the specimen without fiber.

(2) When the waste brick aggregate content is 30% and basalt fiber content is 1%, the water loss rate is 15.5% lower than that of the mixture without basalt fiber. The dry shrinkage strain was reduced by 30.3% compared with that without. The basalt fiber mass content is between 0.5% and 1%, the fiber can produce a disorderly mesh support system in the cement stabilized recycled waste brick mixture, which effectively inhibits the dry shrinkage strain of the mixture and further reduces the dry shrinkage strain.

(3) The addition of fiber significantly improves the frost resistance of cement stabilized recycled waste brick mixture, and the BDR value increases by 12.3% compared with that without basalt. The reason is that fiber bundles and filaments can cover and fill the tiny pores on the surface of recycled waste bricks, thereby reducing the amount of free water entering the pores, so that the expansion stress generated during freezing will be relatively reduced. The matrix is subjected to expansion stress; the fiber is equivalent to the effect of reinforcement in the cement slurry, thereby inhibiting the damage of expansion force on cement stabilized recycled waste brick mixture to a certain extent.

(4) Basalt fiber is well bonded with cement slurry; not only is the surface of basalt fiber wrapped by cement slurry, but also the root of fiber is well bonded with cement slurry. Basalt fiber is randomly and irregularly distributed in cement stabilized recycled waste brick mixture, which makes basalt fiber intertwined. Fiber bundles and fibers form a fiber network wrapped by cement stabilized mixture, which can improve the mechanical properties and durability of cement stabilized recycled waste brick mixture.

Data Availability

Some or all data, models, or codes that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors do not have any conflicts of interest with other entities or researchers.

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