Study on the Effect of Straw Fiber on the Performance of Volcanic Slag Concrete

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Abstract. In this paper, the effects of straw fiber on the working performance, mechanical properties and frost resistance of volcanic slag lightweight aggregate concrete were studied. The experimental results show that the straw fiber is subjected to surface carbonization treatment and mixed into the volcanic slag light aggregate concrete. The flexural strength and fracture pressure ratio of volcanic slag lightweight aggregate concrete are improved obviously. Improved volcanic slag lightweight aggregate concrete brittleness improves toughness. Carbonized straw fiber greatly improves the frost resistance of volcanic slag lightweight aggregate concrete. So that the volcanic slag light aggregate concrete freeze-thaw cycle can reach 300 times.

1. Introduction
Lightweight aggregate concrete has the advantages of light weight, good shock resistance, high interfacial strength, excellent fire resistance, thermal insulation effect is good, excellent antifreeze and other advantages[1]. The natural volcanic slag resources is very rich in Jilin Province, volcanic slag is a lightweight porous aggregate, it is a natural lightweight aggregate with excellent properties[2]. But the Volcanic slag lightweight aggregate concrete also has the shortcoming of brittleness[3]. Jilin province is a large agricultural province, rich in corn stalk resources[4], In this paper corn straw fiber was used to modify the lightweight aggregate concrete of volcanic slag to increase its toughness, The application of corn straw in the field of building materials reduces the environmental pollution caused by burning straw, and avoids the waste of resources, and has a good social benefit[5].

2. Part of the experiment
2.1 raw materials
Straw fiber: The corn straw skin was crushed to length 5-15mm, Diameter 3-5mm; Cement: 42.5R ordinary Portland cement; Fly ash: grade II fly ash; silica fume: SiO₂ content is more than 90%; Water reducing agent: Polycarboxylate water reducer with a water reducing effect of 25%; Volcano slag: produced from Huinan County of Jilin Province, the main parameters are shown in Table 1.

| Size of grain size(mm) | Bulk density (kg/m³) | Tube crush strength(MPa) | 1h water absorption rate(%) |
|------------------------|----------------------|--------------------------|---------------------------|
| 0-3                    | 1150                 | 5.0                      | 5.4                       |
2.2 Carbonization treatment of straw fiber surface
The prepared straw fiber is evenly placed in the crucible of the high temperature sintering furnace under the protection of nitrogen, 250℃ carbonization 10min. Lower temperature take out then Spare.

2.3 Preparation of volcanic slag concrete block
The volcanic slag lightweight aggregate concrete is made of cement, volcanic slag, fly ash, slag, water reducing agent and water. The ratio of water to binder was 0.48, the amount of water reducing agent is 0.3% of the cementing material. The non carbonized straw fiber and carbonized straw fiber were mixed into 0%, 0.5%, 1%, 2%, 3% and 4% of the cementing material respectively. Preparation of test block, they were labeled as C0, C1, C2, C3, C4 and C5 D0, D1, D2, D3, D4, D5, standard curing 28d, and then tested their flexural strength, compressive strength and frost resistance.

3. Discussion and analysis of results

3.1 Effect of straw fiber on the performance of volcanic slag concrete
The influence of straw fiber on the initial setting time of volcanic slag concrete is shown in Figure 1, and the influence on slump is shown in figure 2.

As can be seen from Figure 1, the effect of two kinds of straw fibers on the initial setting time of concrete is different, the initial setting time of cement added with carbonized straw fiber is lower than the initial setting time of cement added with non carbonized straw fiber. Thus we can see the surface of the straw fiber is carbonized reduce the precipitation of straw polysaccharides so as to reduce the retarding effect on cement. Figure 2 shows that before and after carbonization of straw fiber impact on the slump of volcanic slag concrete is not large. Ordinary straw fiber and carbonized straw fiber are added into concrete to increase its water retention property, the slump is falling.

3.2 Effect of carbonized straw fiber on mechanical properties of volcanic slag concrete
Effect of carbonized straw fiber and non carbonized straw fiber on flexural strength, compressive strength and fracture pressure ratio of volcanic slag concrete as shown in Figure 3, Figure 4 and Figure 5.
As shown in Figure 3, with the increase of two kinds of fiber content, the flexural strength showed an upward trend, the optimum dosage of carbonized straw fiber is about 3%. Under the same dosage, flexural properties of volcanic slag concrete with carbonized straw fiber better than non carbonized straw fiber volcanic slag concrete. Figure 4 shows that with the increase in the amount of straw fiber, the compressive strength of volcanic slag concrete decreases. The compressive strength of carbonized straw fiber reinforced concrete under the same dosage is higher than that of non-carbonized straw fiber concrete. As be seen from Figure 5 with the increase of straw fiber content, the fracture pressure ratio of volcanic slag concrete increases. Fracture pressure ratio of volcanic slag concrete with carbonized straw fiber is higher than that of non-carbonized straw fiber volcanic slag concrete. The results show that carbonized straw fiber can significantly improve the toughness of volcanic slag concrete.

Figure 3. Effect of straw fiber on flexural strength of volcanic slag concrete.

Figure 4. Effect of straw fiber on compressive strength of volcanic slag concrete.

Figure 5. Effect of straw fiber on the fracture pressure ratio of volcanic slag concrete.

Figure 6. The SEM of carbonized straw fiber.

Figure 7. Interface between carbonized straw fiber and cement hydration product.
Figure 8. XRD diagram of carbonized straw fiber.

Figure 6 is the microstructure of carbonized straw fiber under 2000 times electron microscope, it can be seen that carbonized straw fiber is covered with a layer of substance. In order to better analyze the composition of carbonized straw fiber, the XRD diffraction pattern of carbonized straw fiber is shown in Figure 8, the diffraction peak indicated that $\text{SiO}_2$ existed on the surface of carbonized straw, this is beneficial to the interface of cement hydration products and carbonized straw fiber interface. Figure 7 is a scanning electron microscope (SEM) diagram of the interface between carbonized straw fiber and volcanic slag lightweight aggregate concrete at 12000 times electron microscope, the Figure 7 shows that the carbonized straw fiber and cement hydration products have better interface transition layer structure. The carbonized straw fiber and cement hydration products interface tightly, the mechanical properties of straw fiber volcanic slag lightweight aggregate concrete are improved integrally.

3.3 Effect of carbonized straw fiber on frost resistance of volcanic slag lightweight aggregate concrete

Effect of carbonized straw fiber on frost resistance of volcanic slag lightweight aggregate concrete is shown in table 2, from the following table, it can be seen that after 300 freeze-thaw cycles, compared with $D_0$ the strength loss rate of $D_3$ decreased by 21.3%; Mass loss rate decreased by 16.3%. The experimental results show that appropriate amount of carbonized straw fiber can effectively improve the frost resistance of volcanic slag lightweight aggregate concrete.

The addition of fly ash and high efficiency water reducing agent to the volcanic slag lightweight aggregate concrete is beneficial to the frost resistance of concrete. After adding carbonized straw fiber, a number of randomly distributed fibers form a three-dimensional support system in volcanic slag lightweight aggregate concrete. Effectively prevent the sinking of volcanic lightweight aggregate, the internal quality of concrete is improved. Adding carbonized straw fiber increases the water holding capacity of concrete. Prevention of early plastic cracking of concrete, the production and development of cracks in lightweight aggregate concrete of volcanic slag are restrained. The frost resistance of volcanic slag lightweight aggregate concrete is greatly improved.

| Freeze Time | Strength loss rate(%) | Mass loss rate(%) |
|-------------|------------------------|-------------------|
|             | D0  | D1   | D2   | D3   | D4   | D5   | D0  | D1   | D2   | D3   | D4   | D5   |
| 50          | 2.1 | 1.8  | 1.6  | 1.5  | 2.0  | 2.3  | 0.3 | 0.3  | 0.3  | 0.2  | 0.2  | 0.3  |
| 100         | 3.5 | 3.1  | 2.9  | 2.7  | 3.9  | 4.7  | 1.0 | 0.8  | 0.7  | 0.6  | 0.9  | 1.3  |
| 150         | 6.4 | 6.2  | 5.9  | 5.5  | 8.6  | 9.0  | 1.7 | 1.6  | 1.5  | 1.3  | 2.1  | 2.7  |
| 200         | 9.3 | 8.9  | 8.5  | 8.0  | 14.5 | 19.0 | 2.7 | 2.4  | 2.3  | 2.0  | 3.0  | 3.9  |
| 250         | 13.5| 12.7 | 12.1 | 11.3 | 19.4 | 25.1 | 3.4 | 3.1  | 3.0  | 2.9  | 4.1  | 5.1  |
| 300         | 17.4| 16.3 | 15   | 13.7 | 25.3 | 29.7 | 4.3 | 4.1  | 3.8  | 3.6  | 5.2  | 6.2  |
4. Conclusion
Surface carbonization treatment of straw fiber the surface component contains active SiO$_2$. Enhanced interface bonding mixing with volcanic lightweight aggregate concrete, the flexural strength of lightweight aggregate concrete filled with volcanic slag is improved, volcanic slag lightweight aggregate concrete has been improved brittle and easy to crack defects.

Surface carbonization of straw fiber a decrease in the amount of glycans, the retarding effect on cement is reduced. Compared with the straw fiber without carbonization the initial setting time is shortened. Two kinds of straw added to concrete, the water holding capacity increased, but the slump decreased.

The surface carbonization of straw fiber was added to the volcanic slag lightweight aggregate concrete, the frost resistance of volcanic slag concrete has been greatly improved, the freezing thawing cycle can reach 300 times.

Acknowledgments
This work was financially supported by the National Key Technologies Research and Development Program of China (No. 2016YFC0701002).

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