Effect of Alkali Treatment of Straw Fiber on Mechanical Properties of Alkali Slag Cement Composites

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Abstract. In this paper, NaOH solution was used to treat straw fiber modified alkali slag cement, which enhanced the interfacial bonding between straw fiber and cementitious materials. The results showed that the best modification effect of straw fibers was obtained by soaking 3% NaOH solution for 16 hours. The compressive strength and flexural strength of alkali slag cement specimens cured for 28 days are 81.5 MPa and 10.9 MPa respectively. The toughness of the composites increases with the increase of fiber content. The flexural strength of straw fiber composites treated with NaOH solution and without NaOH solution increased by 5.6% and 11.3% compared with those without NaOH solution, and the compressive strength of straw fiber composites treated with NaOH solution increased by 34.08% compared with those without NaOH solution when the content of straw fiber was 10%.

1. Introduction
Alkali slag cement is a kind of green high performance material, which has the characteristics of early strength, fast hardening and easy shrinkage and cracking. Straw fibers have a wide range of sources, low prices, low elastic modulus and high specific strength, which can effectively inhibit the early cracking of cement and improve the toughness of cement. However, the outer surface of straw contains a large number of smooth lipid substances, which reduces the bonding between cement and straw fibers\textsuperscript{[1]}. Biomass straw fibers precipitate a large amount of polysaccharides in alkaline environment, which hinders the hydration process of cement and reduces the interfacial strength between cement and straw fibers \textsuperscript{[2]}. As early as 1921, German chemist Beckman proposed to treat straw fibers with low concentration of NaOH solution. In low alkaline solution, OH\textsuperscript{-} weakens the hydrogen bond between hemicellulose and cellulose, and saponifies the ester bond between lignin and hemicellulose. Macromolecular polysaccharides are dissolved and precipitated by fragmentation\textsuperscript{[3]}, which reduces the precipitation of fiber mixing time and improves the interfacial strength of composites.

2. Experimental process
2.1 Test Material
Slag: specific surface area 1.0373 m\textsuperscript{2}/g, its chemical composition is shown in Table 1; alkali activator: water glass and solid NaOH (analytical purity) are combined, the chemical composition of water glass is shown in Table 2; fly ash: grade II fly ash, density 2.56 g/cm\textsuperscript{3}, specific surface area 675 kg/m\textsuperscript{3}; silica ash: SiO\textsubscript{2} (>90%); water reducing agent: polycarboxylic acid superplasticizer with water reducing...
efficiency 30%; straw fiber: Jilin Province for one year. Raw corn straw is crushed to 1-5 mm after dust removal.

| Component | CaO | SiO₂ | Al₂O₃ | MgO | TiO₂ | Fe₂O₃ | SO₃ |
|-----------|-----|------|-------|-----|------|-------|-----|
| Content(%) | 35.8| 31.6 | 14.7  | 10.8| 2.11 | 0.65  | 0.31|

| Reagent     | SiO₂ (%) | Na₂O (%) | baume degrees | modulus |
|-------------|----------|----------|---------------|---------|
| Water glass | 26       | 11.3     | 0.45          | 2.3     |

Table 1. Chemical composition of slag

Table 2. Chemical constituents of sodium silicate

2.2 Preparation and testing of specimens

Alkali slag cement was prepared by mixing slag and fly ash at a mass ratio of 3:1, adding sodium silicate and NaOH as alkali activator, and water with a water binder ratio of 0.26. Then, 0% - 10% untreated raw straw fibers and NaOH treated straw fibers were mixed with alkali slag cement and put into a 40mm x 40mm x 160mm mold. The mold was hardened at room temperature and maintained under standard curing conditions for 28 days after demoulding. The compressive strength and flexural strength of cement mortar were determined according to GB/T 17671 "Test Method for Cement Mortar Strength".

3. Experiments and discussions

3.1 Loss of Straw fiber quality by NaOH solution

Figure 1 is the relationship curve between different concentration of NaOH solution and the loss of straw fiber quality under the same treatment time. Figure 2 is the relationship curve between different treatment time and the loss of straw fiber quality under the same concentration of NaOH solution. Loss rate of straw fiber quality=$\frac{m_1-m_2}{m_1}\times100\%$. In the formula, $m_1$ is the initial weight of the fibers; $m_2$ is the quality of the fibers treated with NaOH solution.

It can be seen from Figure 1 that the mass loss of straw increases with the increase of NaOH solution concentration. When the concentration of NaOH solution is between 1% and 3%, the mass loss increases obviously. The more organic substances such as sugar and wax are soaked in this concentration range, but when the concentration of NaOH solution exceeds 3%, the mass loss is relatively stable and the loss rate increases slightly. Figure 2 shows that the quality loss of straw increases with the prolongation of treatment time. When the soaking time is less than 16 hours, the quality loss increases obviously. At this time, a large number of organic substances such as sugars are dissolved. However, when the soaking time is more than 16 hours, the quality change trend tends to be gentle and the dissolved substances decrease. According to Figure 1 and Figure 2, soaking in NaOH solution with 3% concentration for 16 hours is the best straw fiber treatment scheme.
3.2 Effect of Different Straw Fibers on Strength of Alkali Slag Cement

Figure 3 is a column diagram of the effect of the amount of raw and treated straw fibers on the compressive strength of alkali slag cement. Figure 4 is a column diagram of the effect of two kinds of fibers on the flexural strength of alkali slag cement. Figure 5 is a column diagram showing the effect of two kinds of fibers on the compression ratio of alkali slag cement.

Figure 3 is a column diagram of the compressive strength of two kinds of straw fiber composites with the content of 0% - 10%. The compressive strength of the two kinds of straw fiber alkali slag composites decreases gradually with the increase of the content of the fiber. The column diagram of compressive strength of straw fiber composite treated with NaOH is higher than that of untreated straw fiber composite. Figure 3 shows that the compressive strength of the blank group without straw is 81.5 MPa. When the two kinds of straw fibers are 10%, the compressive strength of the straw fibre composites without NaOH treatment decreases to 11.8 MPa, while the compressive strength of the straw fibre composites treated with NaOH remains at 17.9 MPa, which is 34.08% higher than that of the straw fibre composites without NaOH treatment.

Figure 4 shows that with the increase of straw fiber content, the flexural strength increases at first and then decreases gradually. With the increase of straw fiber content to a certain extent, the fiber cannot be fully wrapped in cementitious materials, resulting in the decrease of the interfacial bonding strength between the fiber and cement-based materials, and the flexural strength decreases accordingly[4]. The flexural strength of the blank group without straw was 10.9 MPa, and that of the original straw alkali slag composite was 11.6 MPa when the content of straw fiber was 4%. The flexural strength of straw alkali slag composites treated with NaOH can reach 12.3 MPa. The flexural strength of the latter was increased by 5.6% compared with the former, and by 11.3% compared with the blank group. The folding pressure increases gradually as shown in Figure 5, which fully illustrates that the addition of straw fibers can greatly reduce the compressive strength, but improve its toughness and improve the brittleness of alkali slag cementitious materials.

Figure 6 shows that the bond between the treated straw and the cementitious material is more closer. Figure 6 is the scanning electron microscope picture of the straw fiber after NaOH treatment.
The surface of the treated straw is rough, the smooth wax layer is removed, and the bonding force of the cementitious material to the straw fiber increases, which improves the interfacial strength[5]. Scanning electron microscopy (SEM) of Figure 7 shows clearly that the interface between treated straw and composite materials is firmly bonded. At the same time, sugar is leached in the process of straw surface treatment, so in the hydration process of composite materials, the negative effect of retarding on strength is greatly reduced, so NaOH treatment of straw surface can effectively enhance the interface bond between fiber and cement matrix.

4. Conclusion

(1) When the concentration of NaOH solution is 3% and the soaking time is 16 hours, the surface roughness of the straw fiber can be effectively increased, the precipitation of carbohydrates in the fiber can be promoted, the interface of the fiber and the cementitious material can be more closely bonded, and the negative effect of the fiber on the strength of the composite material can be reduced.

(2) The mechanical properties of straw fiber composites treated with NaOH solution were significantly better than those without NaOH solution. The 28day compressive strength and flexural strength of straw fiber composites were increased by 34.08%, 5.6% and 11.3% respectively.

(3) Adding straw fiber can increase the toughness of the composites, and the results show that the toughness of the composites treated with NaOH solution is better than that of the untreated ones.

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