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Study on The Properties of Plant Fiber-reinforced Cement-based Composites

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Abstract: The tensile strength, flexural strength and toughness of cement-based composites can be effectively improved by adding an appropriate amount of plant fibers. The main way to improve the durability of cement-based composites is to add ash materials and plant fibers to the cement. Only by improving the durability of cement-based composites, the building structure can be more long-term and safer. This paper summarizes the classification and properties of plant fiber, studies the current situation and analysis of plant fiber, analyzes the results, discusses the development of plant fiber, and should pay more attention to engineering application in the future.

1. Introduction

The aging and destruction of concrete is mainly caused by load and environmental impact caused by small cracks and mixing, condensate cracking, coupled with undense water and other soluble substances to increase the process of damage. It is particularly important to improve the material composition of concrete and to prevent the production of cracks [1]. Since 1963, when studying the mechanism of steel fiber reinforced concrete, the close relationship between fiber and concrete has been found, and the research of fiber reinforced concrete has been developed vigorously. Plant fiber is the most abundant natural polymer material in nature, and the total amount of 100 billion tons of cellulose grown in nature every year far exceeds the total existing oil reserves on earth. Research and development of plant fiber-reinforced cement matrix composite materials can not only reduce the cost of concrete, but also be conducive to environmental protection and sustainable development. In recent years, increasing interest in using relatively inexpensive plant fibers to enhance concrete in developing countries and regions [2-4].

2. Properties and Their Enhancing Effects of Plant Fibers

2.1. Classofication of Plant Fibers

Plant fiber can be divided into the following types and different parts of the plant according to the source: ① phloem fiber, ② leaf fiber, ③ seed fiber, ④ stem fiber [5]. Bloem fiber is usually

extracted from the outer skin of the plant stem. The common phloem fiber are ramie, flax, hemp and banana hemp and red hemp fiber. Leaf fiber is a thick and hard vascular fiber extracted from herbaceous monocot leaves, and coconut shell fiber is a typical seed fiber, which is extracted from coconut shell. Stem fibers are derived from plant stems and are usually derived from plant stems of sugarcane, corn, eggplant, sun, sunflower and various food crops such as barley, wheat and rice.

2.2. Enhancement Properties of the Fibers

2.2.1. Subtitle

Plant fibers are mainly composed of cellulose, hemicellulose, lignin, pectin, wax, etc., and the hardness of the fibers depends on the cellulose content and the rotation angle of the microfibers formed in the inner cell wall and the fiber axis [6]. The use of plant fiber reinforced cement matrix composite material has the characteristics of ordinary Portland cement, such as green, environmental protection, strong toughness, low cost, the rational use of waste, and reduces part of the social problems caused by the unreasonable use of resources. And plant nano fiber production process simple green environmental protection, nanocellulose itself has a better than other nano fiber hydrophilic, the mechanical strength of cement composite, water absorption has improved, makes the performance of the composite material better, in the strength of masonry material requires higher wet environment can play its advantages[7], as shown in Fig. 1.

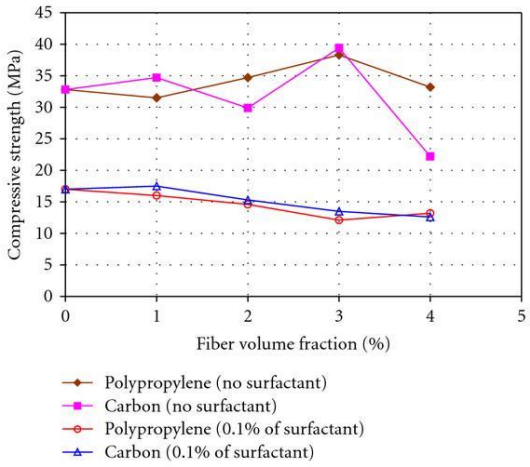

Figure 1. Relationship between fiber volume fraction and compressive strength

3. Research Status of Plant Fiber-reinforced Cement-based Materials

Nilsson et al[8]CMF to cement mortar was added for its fluidity, compressive strength and bending strength.The results show that the high fiber incorporation increases the small crack resistance, through the observation of the microstructure, the material forms a more compact microstructure, and increases the absorption resistance of the material.

Wei[9]The degradation mechanism of jianma fibers in the alkaline and mineral-enriched environment of cement matrix, et al.The experimental results show that the tensile strength of the fibers immersed in the alkali solution is reduced by the amorphous phase (lignin and hemicellulose) compared with the untreated fibers.Lignin and hemicellulose are amorphous, and the solution is hydrolyzed in an alkaline environment.

Mejdoub et al[10]The thermal properties, mechanical properties and microstructural effects of CNF on cement are studied.The results show that the thermal, mechanical and microstructural

properties of CNF cement composite are significantly improved.They believed that the main reasons for the improved performance are the high hydrophilic nature, high reactivity and high specific surface area of CNF.

Comprehensive research of foreign researchers, research on plant fiber reinforced cement still has many unsolved problems, but the recent research surface, plant fiber has delaying effect on cement hydration, and plant fiber easy to absorb water loss, fiber in high alkali environment easy degradation, and the influence of plant fiber on the durability of cement composite remains to be studied.

4. Mechanical Properties of Cement-based Composites

In the experiment, the toughness, ductility, and impact resistance of the material were enhanced by the addition of different plant fibers to the cement composite.Hwand[11]The results show that the coconut shell fiber with volume fraction of 4% increases by 44%, 29% and 302% by 44% compared with the reference specimen, and effectively improve the impact resistance of the material.

Guo et al[12]The three-point bending loading test studied the bending mechanical properties of cement mortar, the test results show that the incorporation of hemp fiber significantly increased the bending strength of the material, until the bending strength is 30mm, 39.9% compared with the reference specimen.Through the above results, we conclude that adding different plant fibers will increase the material toughness, ductility and impact resistance to varying degrees[13].

5. Study on the Incorporation Process of Plant Fiber

5.1. Main Research Content

This paper studied the influence of water absorption of wheat straw under different treatment methods[14]. The pretreatment of wheat straw in different ways was made, and the properties of the composite material under different treatment methods and straw fiber mixing was investigated.

5.2. Steaw Fiber Pretreatment

In the pretreatment test of wheat straw fiber, the wheat straw was removed from impurities and dried naturally, then cut into about 5cm, and several pieces of M1 straw were taken to wait for pretreatment. The pretreatment of wheat straw is mainly used in the following two ways:

(1) Cold water treatment at room temperature, soak the wheat straw in room temperature cold water for 2h and put it in the oven for 1h, repeat 4 times, and finally take out the oven and air naturally for reserve.

(2) Treatment with 4% sodium hydroxide solution, soak the wheat straw in 4% sodium hydroxide solution for 12h, and then wash the residual sodium hydroxide solution on the straw with tap water for many times, and dry it naturally for reserve. When the mass of the pretreatment straw is not significantly changed, the mass loss rate of the straw is calculated by weighing the mass M2 with an electronic balance, as shown in Eq. (1).

$$\text{Straw mass loss rate}=(M1-M2)/M1 \quad (1)$$

The pretreated wheat straw and untreated wheat straw by two ways of weighing equal mass M3 were then soaked in water separately. The water on the surface was taken out every 2h and the mass M4 was weighed by electronic balance, and the measurement was stopped after 7 times, namely 14h.The water absorption rate of the straw was calculated[15], as shown in Eq. (2).

Straw water absorption=(M4-M3)/M1 (2)

In the laboratory, the untreated straw was crushed and screened over 10 eyes to prepare it as a composite material. Effect of pretreatment on the water absorption rate of wheat straw.

In the test, three groups of untreated wheat straw, often treated with warm water and 4% sodium hydroxide solution, were invaded into normal temperature cold water after the above test methods, and weighed every 2h, and the water absorption rate of the treated straw was measured. With the increase of treatment time, the water absorption rate of wheat straw is increasing. The water absorption rate of straw in the three treatment methods is the same in that the water absorption rate in the first 6 hours increases rapidly, and then there is a gentle period. After this period, only the untreated wheat straw continues to grow.

Through comparative analysis of untreated and two pretreatment of wheat straw water absorption, can be found in 4% of wheat straw fiber surface damage is the most serious, can deal with more wheat straw fiber surface of cement composite material, is conducive to the composite wheat straw fiber and cement contact surface of higher bonding[16].

6. Durability Performance and Improvement Measures of Cement Base Composite Material

Durability is an important indicator to be considered in the design of engineering structure, which has an important impact on the long-term service life of the structure.Studies show that plant fibers are prone to deteriorate in cement-based composites, mainly for two reasons[17]: First, plant fiber has strong absorbance, and the lignin in plant fiber and hemicellulose connecting to single fiber cells will dissolve in the alkaline pore solution of cement-based composite; second, calcium hydroxide in the solution will migrate to the hollow lumen of plant fiber, leading to mineralization of plant fiber, which greatly reduces the mechanical properties of the fiber and then affects the durability of the overall structure[18], as shown in Fig.2.

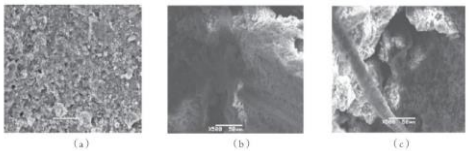

Figure 2. The SEM diagram of the concrete with different fiber mixing amount

At present, there are two main measures to improve the durability of plant fiber[19]: 1. Add volcanic ash material to the cement-based composite material to reduce the concentration of calcium hydroxide in the pore solution. 2.At present, the modified plant fiber treatment methods used in reinforced cement matrix composite materials are mainly divided into physical and chemical methods[20]The physical methods are also divided into: heat treatment, steam blasting treatment, plasma treatment and ultrasonic treatment, and the chemical methods can also be divided into: acid treatment, alkali treatment, coating treatment, dry and wet circulation texture[21].

7. Conclusions

Comprehensive above research, in different plant cement composite fiber will effectively improve its bending strength, bending toughness, tensile strength and impact resistance, and improve the durability of cement base composite material is mainly add ash materials and modified treatment of plant fiber added in cement, only improve the durability of cement composite material, building structure can be more long-term and safe. Then, most of the research on plant fiber-reinforced cement matrix composites in China is limited to the laboratory stage, and more attention should be turned to engineering applications in the future.

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