Effect of Using Plant Fiber on The Properties of Concrete

ABSTRACT

With light weight, wide sources, low cost and renewable, plant fiber concrete has become the preferred green building materials.This paper reviews the research status of bamboo fiber, flax, hemp, jute, ramie and other high-strength plant fibers, and discusses their basic properties and defects, such as strength, interface bonding, thermal insulation, as well as fiber corrosion, adhesion, water absorption and workability.In view of these, the strategies of pretreatment, use of mineral admixtures, optimization of bonding materials and improvement of mixing process are put forward.The results show that reasonable improvement measures can significantly improve the performance of plant fiber concrete.This paper provides theoretical and technical support for the application of plant fiber concrete, and looks forward to its wide application prospect in the field of civil engineering.

Keywords: Plant fiber; cement based composites; mechanical properties; plant fiber concrete.

1. INTRODUCTION

As a renewable resource from nature, plant fiber has shown great potential in the field of civil engineering and building materials. Since ancient times, people have used straw, grass and other plant fibers to strengthen soil brick and tile, which is still used in some developing countries.As early as the 1970s, Britain, Sweden and other countries began to study the use of plant fibers as the base material of cementitious materials. The durability improvement of sisal fiber has become a research hotspot. Through the dry wet alternate accelerated aging test (CBI method), researchers found that sisal fiber can interact with alkali metal ions in the humidification process, so as to improve the internal structure of concrete (Wu et al., 2023).

In the 1990s, the application of plant fibers in concrete reinforcement materials has been further expanded. The plant fibers extracted from pine and poplar trees were used to study their role in controlling concrete crack propagation.Compared with polypropylene fiber, 0.5% volume fraction of plant fiber shows better performance in inhibiting dry crack, and has little effect on the free shrinkage and compressive strength of concrete.However, the dry wet cycle will lead to the physical damage of the interface between fiber and concrete and reduce its toughness. Therefore, reducing the water absorption of plant fibers has become the key to improve the durability of concrete (Wu et al., 2023).

In the 21st century, with the intensification of the energy crisis, the use of cheap and easily available plant fiber reinforced concrete has become a research hotspot. Brazilian researchers found that the embrittlement reaction of sisal fiber after carbonization and soaking in silica fume solution was significantly delayed, thus improving the durability of the composite.In China, Guangxi, Guangdong and Fujian are rich in plant fiber resources. Many scholars are committed to the development and application of plant fiber in cement-based composites and have achieved remarkable results.For example, researchers from Shandong Institute of building materials and Hong Kong Polytechnic University have successfully developed a plant fiber cement composite board with low price, anti-seepage and excellent performance (Majumder et al., 2023).

2. BASIC PROPERTIES OF PLANT FIBER REINFORCED CONCRETE

2.1 Chemical Composition and Structure

Plant fiber reinforced concrete is mainly composed of cellulose fiber, hemicellulose and

lignin, in which cellulose fiber plays a key role in toughening, while hemicellulose and lignin are filled between cellulose fibers in the form of gel to play a bonding role. However, these components have an impact on the hydration reaction of cement, which may lead to the decline of early strength, and are prone to hydrolysis in alkaline environment, affecting the later strength of materials.

2.2 Strength Characteristics

Different types of plant fibers have different strength characteristics. Due to their high strength and long fiber length, bamboo fiber, flax, hemp, jute and ramie can obtain higher specific modulus than glass fiber through appropriate raw material selection and processing methods. Although the specific modulus of fibers such as corn stalks is low, they are rich in raw materials, low in cost, and have high cost performance (Huang et al., 2021).

2.3 Interface Bonding Ability

The bonding ability of plant fiber and matrix has an important influence on the strength of plant fiber cement-based composites. The interface zone controls the stress transfer between the fiber and the matrix. High interface strength can ensure that the stress is effectively transmitted from the matrix to the fiber through the interface zone, so as to improve the overall performance of the material. When the matrix is damaged, the fracture mode of the fiber will also affect the energy absorption capacity of the material (Wen et al., 2022).

2.4 Thermal Insulation Performance

Plant fiber reinforced concrete shows significant advantages in thermal insulation performance. Compared with ordinary concrete, rape straw fiber concrete has more and larger pores, which reduces the thermal conductivity. The thermal conductivity of concrete decreases with the increase of fiber content, which is beneficial to building energy conservation (Lima et al., 2022).

2.5 Water Absorption and Corrosion Resistance

The water absorption of plant fiber is also a problem needing attention in the preparation of plant fiber concrete. The plant fiber itself is porous and contains high hydroxyl content, resulting in strong water absorption, increased water consumption of concrete, reduced workability, and easy to form aggregates during mixing. In addition, plant fibers are sensitive to humidity and have expansion and contraction characteristics, which may lead to bond failure with concrete. In terms of corrosion resistance, the performance of plant fiber concrete is not excellent. Both acid and alkali environments will cause serious corrosion to plant fibers, resulting in quality loss and performance degradation (Lima et al., 2024).

3. DEFECTS AND IMPROVEMENT MEASURES

3.1 Fiber Corrosion

The corrosion of plant fiber in alkaline environment of cement can not be ignored. The researchers mainly pretreated the fibers in acidic solution to reduce their corrosion rate in alkaline environment. However, this method may increase the production cost, and the effect still needs to be further verified. In addition, using mineral admixtures such as fly ash and silica fume to replace some cement to reduce the alkalinity of concrete is also an effective method to reduce fiber corrosion (Sabarish, 2020).

3.2 Adhesion

The adhesion between plant fiber and concrete is one of the key factors affecting the performance of plant fiber concrete. The wet expansion and dry shrinkage characteristics of plant fiber will lead to the change of the bonding degree between plant fiber and concrete. Therefore, it is an important research direction to find a suitable bonding material for the treatment of plant fiber to improve its bonding ability with concrete (Asim, 2020).

3.3 Water Absorption

The water absorption of plant fiber affects its application in concrete. Water absorbent plant fibers tend to agglomerate, resulting in uneven distribution of fibers in concrete. Therefore, how to make the fiber evenly distributed in concrete has become an important issue in the popularization and application of plant fiber concrete. This requires in-depth research on the mixing process of plant fiber and improvement of the existing mixing machinery (Liu, 2020).

3.4 Workability Issues

The workability control of plant fiber reinforced concrete is also a problem that needs attention.

Due to the water absorption of plant fibers, adding different amounts of fibers will increase the water consumption of concrete. Therefore, when preparing plant fiber concrete, the amount of water should be calculated according to the change of fiber volume (Bittner & Oettel, 2022).

4. CONCLUSION AND PROSPECT

Under the background of increasingly scarce resources, the exploration of new green materials is imminent. As a widely existing renewable resource, plant fiber is increasingly used as reinforcement of concrete due to its potential excellent mechanical properties, easy processing advantages and environmental benefits. However, the hydrophilicity of plant fiber and its incompatibility with concrete matrix limit its wide use in concrete, so modification is necessary. Looking forward to the future, with the continuous progress of technology and in-depth research, the application of plant fiber in the field of civil engineering and building materials will be more extensive and in-depth. By continuously optimizing the preparation process and construction technology, improving the performance and stability of plant fiber concrete will make an important contribution to the sustainable development of the construction industry. At the same time, it is also necessary to strengthen the research on the long-term performance and environmental impact of plant fiber concrete in order to evaluate its applicability and sustainability in different environments (Zhang et al., 2020; Islam & Ahmed, 2018).

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Asim, M. (2020). Comparative experimental investigation of natural fibers reinforced lightweight concrete as thermally efficient building materials. *Journal of Building Engineering*, 31, 101411.

Bittner, C. M., & Oettel, V. (2022). Fiber reinforced concrete with natural plant fibers—Investigations on the application of bamboo fibers in ultra-high performance concrete. *Sustainability*, 14(19), 12011.

Huang, H., Gao, X., & Teng, L. (2021). Fiber alignment and its effect on mechanical properties of UHPC: An overview. *Construction and Building Materials*, 296, 123741.

Islam, M. S., & Ahmed, S. J. U. (2018). Influence of jute fiber on concrete properties. *Construction and Building Materials*, 189, 768-776.

Lima, T. E. S., et al. (2022). Potential of using Amazon natural fibers to reinforce cementitious composites: A review. *Polymers*, 14(647).

Lima, T. E. S., et al. (2024). Potentiality of using guaruman natural fiber (*Ischinosiphon koern*) in sustainable coating mortars. *Journal of Materials Research and Technology*, 30.

Liu, Y. (2020). Study on properties of sisal fiber modified foamed concrete. In *Materials Science and Engineering* (Vol. 744, Article 012042).

Majumder, A., et al. (2023). Jute fiber-reinforced mortars: Mechanical response and thermal performance. *Journal of Building Engineering*, 66, 105888.

Sabarish, K. V. (2020). An experimental investigation on properties of sisal fiber used in the concrete. *Materials Today: Proceedings*, 22, 439-443.

Wen, X., Zhang, P., Wang, J., & Hu, S. (2022). Influence of fibers on the mechanical properties and durability of ultra-high-performance concrete: A review. *Journal of Building Engineering*, 52, 104370.

Wu, H., Shen, A., Cheng, Q., Cai, Y., Ren, G., Pan, H., & Deng, S. (2023, July 28). A review of recent developments in application of plant fibers as reinforcements in concrete. *Journal of Cleaner Production*, Article 138265.

Zhang, T., Yin, Y., Gong, Y., et al. (2020). Mechanical properties of jute fiber-reinforced high-strength concrete. *Structural Concrete*, 21(2), 703-712.

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