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Research and Development of New Polylactic Acid (PLA) Fiber Concrete Materials and Performance Research

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Abstract: Polylactic acid (PLA) fiber concrete has broad application prospects in the field of building materials. This article summarizes the current research status of fiber-reinforced concrete and its importance in improving the mechanical properties of cement-based materials. In view of the modification of the physical properties of PLA fiber, experimental research is conducted to improve its mechanical properties, solve the problem of natural degradation, and explore the application of anti-corrosion materials. In terms of concrete preparation technology, experiments were carried out to study uneven fiber distribution and compatibility with cement slurry to determine the optimal proportion and processing technology. Mechanical property tests and theoretical studies have shown that fiber type and length have a significant impact on the performance of concrete, and it is necessary to further explore the mechanical properties of the transition zone between the fiber and the concrete matrix. Aiming at the durability, fire resistance and other issues of PLA fiber concrete, relevant experimental research plans were proposed. Finally, the mechanical properties of ultra-high toughness PLA fiber concrete were optimized by improving the mix design, optimizing fiber type and dosage, and surface treatment technology. These research results provide an important reference for the wide application of ultra-high toughness PLA fiber concrete in building structures.

Keywords: Polylactic Acid (PLA); Fiber Concrete; Mechanical Properties.

1. Introduction

Fiber concrete, also known as fiber-reinforced cement-based composite materials, is a general term for composite materials composed of fibers and cement base materials (cement stone, mortar or concrete). The main disadvantages of cement stone, mortar and concrete are: low tensile strength, small ultimate elongation, and brittleness. These shortcomings can be overcome by adding fibers with high tensile strength, large ultimate elongation, and good alkali resistance. At present, the main varieties of fiber concrete include asbestos cement, steel fiber concrete, glass fiber concrete, polypropylene fiber concrete and carbon fiber concrete, plant fiber concrete and high elastic modulus synthetic fiber concrete. Research has found that the density of polylactic acid (PLA) fiber is 0.9~0.92 g/cm3, the tensile strength is 40~190 MPa, the elongation at break is 4~10%, and the elastic modulus is 3~4GPa. Its mechanical properties are similar to those of polylactic acid (PLA). The mechanical properties of propylene fiber are close to each other. As shown in Table 1, it can meet the fiber requirements for concrete structural components. Therefore, PLA can be considered to prepare fiber concrete for use in concrete structure buildings.

Table 1. Fiber details

Fiber name	Tensile strength (MPa)	Tensile modulus (GPa)	Elongation at break (%)	Density (g/cm3)
Polyvinyl alcohol	900~1900	25~42	6~10	1.30
Polypropylene	240~690	3~5	25~50	0.91
Para-aramid	3000	60~130	2.1~4.0	1.40
UHMWPE fiber	2000~3500	50~125	3~6	0.97
Sisal	600~700	20~38	2~3	1.33
Alkali-resistant glass fiber	2500	70	3.6	2.78
Carbon fiber	3500~6000	230~600	1.5~2.0	1.60~1.95
Basalt fiber	3000~4840	79~93	3.1	2.70
Ceramic fiber	800~3600	360~480	0.8	2.40~2.60
Steel fiber	500~2000	200	3~4	7.84

Research on fiber-reinforced concrete mainly focuses on the dosage and mix ratio of different fibers. The study found that when polyvinyl alcohol fiber-toughened concrete is used, when the fiber volume fraction is 2%, the ultimate tensile strain of the concrete can be increased. Significant increase, up to 6%, and strain hardening occurs [1]. When the tensile strength of polypropylene fiber concrete is 2. 0 ~ 2. 5 MPa, the strain can reach 4% [2]. Polyethylene fiber can make the tensile strength of composite materials reach 20 MPa and the strain reach 8. 7% [3]. The bonding performance of aramid fiber cement is better than that of polyethylene fiber, giving concrete higher tensile properties [4]. Glass fiber reinforced concrete can reduce the early shrinkage and cracking of concrete [5]. The tensile strength of carbon fiber reinforced concrete with a volume fraction of 1% to 3% increases with the increase in carbon fiber volume fraction [6]. Low volume fraction of basalt fiber reinforced concrete can improve the flexural strength, fracture performance and wear resistance of concrete, but can significantly reduce the compressive performance of concrete. At a doping amount of 1%, the compressive performance is reduced by 26. 4% [7].

2. Research on the Modification of Physical Properties of PLA Fiber

Research on the modification of physical properties of PLA fiber. Comparing the mechanical properties of commonly used fibers in concrete, it can be seen that PLA fiber has low tensile properties. This project plans to conduct experimental research in order to improve its mechanical properties. Previous studies have shown that PLA fibers may have durability problems caused by natural degradation. Through the test The method is to seek suitable anti-corrosion materials to improve their durability, and at the same time design experiments to control the natural degradation time, in order to achieve the goal of matching the degradation time with the design service life of the building, which is conducive to the recycling and reuse of construction solid waste.

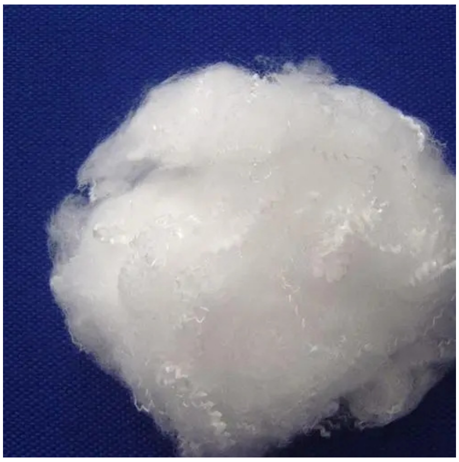

Figure 1. PLA fiber

3. Preparation Method and Process Research of PLA Fiber Concrete

Fiber concrete is mainly divided according to the type of fiber. According to its composition and performance, the fiber can be divided into metal fiber, synthetic fiber, natural organic fiber, inorganic non-metal fiber, low elastic modulus fiber, high elastic modulus fiber, etc.; according to its size, it can be divided into short fiber (oriented, random) and long fiber (single filament, bundle, twisted wire, unidirectional, mesh). Different fibers have different physical properties, and the preparation of concrete requires it to have fluidity, cohesiveness, and water retention. In view of the uneven fiber distribution problem and the poor compatibility of fiber and cement slurry in fiber concrete, it is planned to conduct experimental research on the processing technology in the mixing concrete process and determine the optimal ratio. Then determine the production process of PLA fiber concrete structural components.

4. Mechanical Properties Test and Theoretical Research of PLA Fiber Concrete

Concrete is the most used building material today, but it has prominent defects. Adding fibers to concrete to improve its shortcomings such as high brittleness and low tensile strength is a common way to improve the performance of concrete. Fibers can be divided into high elastic modulus fibers and low elastic modulus fibers according to their elastic modulus. The stiffness of high elastic modulus fibers is greater than that of concrete. After microcracks occur in the matrix, the fibers begin to bear force, share the stress of concrete, and improve the strength of the material. The stiffness of low elastic modulus fibers is less than that of concrete. Force is generally applied after the concrete cracks, and they are mainly used to improve the ductility of the material. It can be found that there are rich types of fibers and large differences in mechanical properties. For this reason, it is necessary to test the basic properties of PLA fiber materials.

In addition, concrete is often affected by dry-wet cycles, which have a great impact on the durability and mechanical properties of concrete. It is necessary to study the durability of PLA fiber concrete; how to reduce economic losses and ensure personal safety in fire accidents is an issue that must be paid attention to in construction. Existing studies have shown that adding certain types of fibers to concrete is beneficial to improving the anti-bursting performance of concrete, and it is necessary to conduct experimental research on the fire resistance of PLA fiber concrete; Considering the influence of recycled aggregate replacement rate and fiber volume rate, in order to further understand the mechanical properties and failure mechanism of PLA fiber concrete, based on the comprehensive analysis of the test data of PLA fiber concrete specimens, it is planned to carry out the stress failure mechanism and toughening and crack resistance mechanism of PLA fiber concrete; The reinforcing effect of fiber on concrete is closely related to the bonding performance of the fiber-concrete matrix interface transition zone. Therefore, the study of the mechanical properties of the interface transition zone has always been an important research topic in the design of fiber concrete structures. In order to study the mechanical properties of the interface transition zone between PLA fiber and concrete, it is planned to model the bonding performance of the fiber-concrete matrix interface transition zone.

5. Optimization of Mechanical Properties of PLA Fiber Concrete

Adding appropriate fibers to concrete can not only improve the mechanical properties of concrete, improve the compressive strength, tensile strength and impact resistance of concrete, but also improve the durability of concrete. However, the type, length, dosage of fiber and the preparation process of fiber concrete have an impact on the mechanical properties of fiber concrete, such as strength, stiffness, and deformation. At present, there are few reports on the mechanical properties of PLA fiber added to concrete. It is necessary to conduct experimental research and theoretical analysis on the influence of the above parameters on the performance of concrete, and then explore its application in engineering structures.

The optimization method of the mechanical properties of ultra-high toughness polylactic acid (PLA) fiber concrete can be considered from multiple angles. The following are several possible optimization methods:

Improved mix design: By adjusting the proportion of cementitious materials, cement, mineral powder, silica fume, and the particle size and water-binder ratio of quartz sand, the crack resistance, ductility and energy absorption capacity of ultra-high toughness fiber concrete can be significantly improved. In addition, by changing the dosage of steel fiber and polypropylene fiber, its mechanical properties can also be further optimized.

Selection of fiber type and dosage: Selecting the appropriate fiber type and determining the optimal fiber dosage are crucial to improving the mechanical properties of ultra-high toughness fiber concrete. Studies have shown that different fiber types and dosages have a significant effect on the basic mechanical properties of ultra-high toughness fiber concrete. For example, using 8mm length fibers and 2% volume dosage can achieve better performance.

Surface treatment technology: Low-pressure plasma surface treatment of PLA fibers can improve their interfacial adhesion with the matrix material, thereby improving the overall mechanical properties of the composite material. This surface treatment technology can reduce setup time and improve flexibility.

Optimizing the interfacial adhesion between fibers and the matrix: The tensile behavior of ultra-high toughness fiber concrete can be optimized by improving the filling density of the matrix and using high-strength fine-diameter steel fibers. In addition, adjusting the interfacial adhesion between fibers and the matrix is also an important aspect of improving mechanical properties.

Adopting multi-layer structure design: The mechanical properties of PLA foam sheets can be effectively improved by manufacturing multi-layer films with a physical foam middle layer and a highly filled cortex. This multi-layer structure design strategy can provide new ideas for optimizing the mechanical properties of ultra-high toughness PLA fiber concrete.

Optimization of experimental parameters: The mechanical properties of Tough PLA materials can be significantly affected by adjusting the parameters in the 3D printing process, such as layer thickness, wall thickness, filling density, board building temperature, printing speed, and printing temperature. This method can be used to optimize the preparation process of ultra-high toughness PLA fiber concrete to obtain better mechanical properties

6. Conclusion

Through the preparation method, mechanical properties test and theoretical research, and mechanical properties optimization of polylactic acid (PLA) fiber concrete. Aiming at the modification of the physical properties of PLA fiber, experimental research is conducted to improve its mechanical properties, solve the problem of natural degradation, and explore the application of anti-corrosion materials. In terms of concrete preparation technology, the uneven fiber distribution and compatibility with cement slurry are experimentally studied to determine the optimal mix ratio and processing technology. Mechanical properties tests and theoretical studies show that the type and length of fiber have a significant impact on the performance of concrete, and it is necessary to further explore the mechanical properties of the transition zone between the fiber and the concrete matrix interface. In view of the durability and fire resistance of PLA fiber concrete, relevant experimental research plans are proposed. Finally, the mechanical properties of ultra-high toughness PLA fiber concrete are optimized by improving the mix ratio design, optimizing the fiber type and dosage, and surface treatment technology.

In the future, the application of PLA fiber concrete in actual engineering can be further explored, and the optimization design can be carried out in combination with the characteristics of different building structures. At the same time, we can also strengthen the research on composite applications with other materials, explore more modification methods, and improve the comprehensive performance of PLA fiber concrete. In addition, the performance of PLA fiber concrete in extreme environments also needs to be studied in depth to ensure that it can be used stably and reliably in various situations. Comprehensively utilizing modern scientific and technological means to continuously improve the performance and quality of PLA fiber concrete will help promote technological progress and sustainable development in the field of building materials.

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