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APPLICATION OF FIBER-REINFORCED CONCRETE AND RENEWABLE AGGREGATES IN CONCRETE STRUCTURES

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1 Introduction

In recent years, with the concept of green environmental protection deeply rooted in the hearts of the people, environmental protection has been paid more and more attention, the concept of sustainable development has been gradually proposed, with the concept of green environmental protection gradually applied to the field of building materials, new green environmental protection materials have become one of the hot spots of research, and have made great progress and development. Based on this concept, we studied the renewable aggregate, using shells as additives to replace the traditional aggregate into the concrete soil, and evaluated the mechanical properties and environmental performance of the renewable aggregate, and concluded that the renewable aggregate can provide sufficient strength for the concrete and has lower carbon emissions and higher economic value, in order to achieve higher strength and expand the application range of renewable aggregates, so that they can be applied to concrete structures, with reference to the research of many scientific researchers, Amran found that adding fibers to concrete improved the performance of the concrete, giving it greater strength [1]. It is believed that fiber has the characteristics of light weight, low production cost, easy molding, high tensile strength and flexural strength, and elasticity [2]. We envision that a combination of fibers and renewable aggregates can be added to concrete to make it stronger for better economic and social value. Therefore, we will analyze the possibility of fiber reinforced concrete and renewable aggregate application in concrete structures by evaluating the mechanical properties of concrete with the addition of fiber and renewable aggregates.

2 Additive composition and properties

2.1 Shell composition and properties

The shell is mainly composed of inorganic phase and organic phase, the inorganic phase is about 95~99,9 % $CaCO_3$ (calcite, aragonite, aragonite and amorphous form), and the organic phase is composed of about 0,1~5 % organic matter (protein, glycoprotein, polysaccharide, chitin and lipid, etc.). Generally speaking, the basic structure of the shell is mainly divided into three parts, the outermost layer is the stratum corneum composed of hard protein, the middle layer is the prismatic layer composed of calcite or aragonite crystals, which mainly provides hardness and dissolution resistance for the shell, and the innermost layer is the nacre, which mainly provides hardness and toughness for the shell, which is generally composed of $CaCO_3$ minerals (inorganic phase) and organic matter (organic phase) such as calcite or aragonite [3].

The shell has sterilization and antibacterial, drying adsorption, fire retardant and flame retardant, light weight, high strength, good durability and other properties. The waste shells are crushed, screened, calcined and other processes to make granular materials, and the particle size is generally between 0,15~4,75 mm. When replacing the traditional sand and gravel aggregate, the shell has higher strength, good mechanical properties and solidity than sand and gravel, can withstand the load and stress in the concrete, and ensure the safety and stability of the concrete structure; has low water absorption and adsorption, reduces the loss and evaporation of cement slurry; ensures the workability of concrete, has a reasonable particle gradation and shape, can reduce the porosity in the concrete, improves the compactness and strength of the concrete; has a low alkali activity and harmful substance content, and avoids the reaction with the alkali in the cement, resulting in the cracking of the concrete. In addition, studies have shown that the appropriate proportion of shells can replace fine aggregates to fill the pores of the material, improve the overall compactness, reduce the absorption rate, improve the compressive strength, and improve the workability, strength and durability of the mortar [4]. Therefore, when replacing traditional aggregates, shells have full rationality and feasibility.

2.2 Composition and mechanical properties of reed fiber

The components of reed fiber are mainly cellulose, hemicellulose, lignin, ash and wax. There may be some differences in different reed species and origins, but generally speaking, the cellulose content is the highest, accounting for 40 %~60 % of the dry weight of the reed, followed by the hemicellulose content, accounting for 10 %~20 %, and the lignin content is lower, accounting for 5 %~15 %. The content of other components such as ash and wax is less, accounting for about 1 %~5 % each [5].

Many studies have shown that the application of a large number of reed fibers on concrete is feasible, and many scientists carbonize the reed fibers, grind them into powdery substances and add them to structural concrete. Or the reed fiber is cut and added to the structural concrete, natural fiber in the application of concrete, reed fiber as a fiber material to improve cement or lime-based mortar, it can well enhance the mechanical properties of concrete, and can be well used in green buildings [6, 7]. According to research, the flexural toughness of reed fibers is crucial for construction applications, where it can withstand horizontal stresses such as seismic shocks or wind. A significant advantage of reed composite fiber materials as a brittle reinforced material is the flexural resistance after cracking. In addition, the use of natural fibers plays a fundamental role in improving the mechanical properties of composites, and the reinforcing materials are distributed in composites with effective sealing and bridging crack capabilities under bending or tensile stress, so the post-crack toughness caused by natural fibers in cement materials may allow for large-scale construction use of such composites.

3 Experimental design

3.2 Experimental method

In order to study the mechanical and mechanical properties of reed fiber and shell aggregate concrete in the composite shear state, with the substitution rate, normal stress and reed fiber content as the changing parameters, under the replacement rate of 10 %, 30 % and 50 % shell aggregate replacement rate, the reed fiber was added at the addition rate of 1 %–6 % of the cement mass to design a standard cube specimen for composite shear test. The failure mode of concrete under direct shear and compressive shear was observed, the shear stress-displacement curves of the whole process under direct shear and compressive shear were obtained, and the influence of substitution rate, normal stress and reed fiber content on the shear strength and peak displacement of reed fiber reinforced concrete was analyzed in depth. The purpose of the experiment was to determine the optimal content value of reed fiber and the shear strength of reed fiber reinforced concrete. At the same time, a standard group without additives was added to judge the effect of reed fiber on concrete.

3.3 Experimental Materials

Figure 1 *– Physical properties of the reed fiber*

R42.5 ordinary Portland cement is used, natural coarse aggregate is ordinary gravel (0/5 particle size 5–10 mm, 1/2 particle size 10–20 mm, 1/3 particle size 16–31.5 mm), coarse aggregate particle size is 10~20mm, continuous gradation, fine aggregate is natural river sand in the Minsk Sea, mixing water is laboratory tap water, shell is natural clam shell after salt washing. The mix ratio of coir fiber, (diameter 100–450 μm, length 100–250 mm, width 2–3 mm, density 1,12 g/cm³) reed fiber (length 40 mm, width 3–5 mm, diameter 0,45 mm, density 1,7 g/cm³) treated with 4 % NAOH solution was used as the benchmark for the substitution rate of 0 %, the target design strength was C35, and the design standard slump was 180–220 mm. The physical properties of the reed fiber are shown in Figure 1, and the physical properties of the material are shown in Table 1, and the mix ratio and additives of the material are shown in Table 1.

Table 1 – Physical properties of materials

	Apparent density, kg/m³	Bulk density, kg/m³	Crush Index, %	Moisture content, %	Water Absorption, %
Natural coarse aggregates	2609	1450	18	0,07	0,43
sand	2635	1640		0,45	
Reed fibers				1,10	4,85
Coir				4,8	16,3

4 Conclusion

The study aims at how to solve the shortage of resources in the Republic of Belarus and the environmental protection of green building materials. How to use existing resources to develop new energy-saving and emission-reducing building materials to achieve sustainable development with the concept of green building. This ensures the development of new materials that are economical, environmentally friendly and durable.

When shells and reed fibers are incorporated into shells in a certain proportion, the crack resistance, impact resistance and mechanical properties of the cementitious material system can be improved, and the compressive and flexural strength of the cementitious material system are greatly improved compared with those of ordinary concrete test blocks. Experiments show that the performance test of the specimen is in the test. The strength of the block did not decrease at 28d, and the shell as aggregate did not cause the reduction of the early strength of the concrete, which not only maintained the advantages of ordinary concrete, but also had the advantages of waste utilization, and would not affect the basic properties of the mortar; the microstructure test study showed that the adhesion between the shell and the cement slurry was good, and the irregular shape of the shell significantly improved the distribution of the latter in the cement matrix, which fully demonstrated that the shell was used as a fine aggregate, and even significantly enhanced the workability of the concrete compared with the traditional aggregate. Therefore, under the premise of reducing the consumption of primary aggregates and environmental protection, the use of shell aggregates does not affect the construction quality, and can significantly reduce the price of building materials. In addition, the flexural capriciousness of reed fiber can well improve the flexural strength of concrete, so the use of shell aggregate and reed can produce considerable social and economic benefits, and well realize the sustainable development of green building as the concept.

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METODOLOGY OF STUDY OF THE STRUCTURE OF CEMENT MATERIALS BY THE METHOD OF NANOINDENTATION

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Abstract

The parameters of the nanoindentation method were selected to ensure the final consistent results were obtained. These results are presented by histograms of the distribution of nanoindentation points by elasticity and hardness moduli and distributions by these characteristics in the horizontal XY plane perpendicular to the movement of the nanoindenter. It was revealed that the elastic modulus increases in samples that contain a complex additive containing nano-sized particles. The effect is also observed when introducing an additive containing only one type of nanoparticles (hydrothermal SiO_2 nanoparticles or multiwalled carbon nanotubes MWCNTs. Studies of cement stone samples at W/C = 0,21 and the content of SiO_2 in the combined additive is 0,000006 wt. % and MWCNT 0,00004 wt. % for cement showed that the effect of nanoparticles on the structure of the CSH gel becomes more pronounced, because the volume fraction of the LD phase of the CSH gel with a low packing density of nanograins becomes significantly lower than the fraction of the HD phase with an increased hexagonal packing density of granules. The results obtained indicate that there is a change in the nanostructure of the C–S–H gel, which is compared with an increase in strength, Young's and shear moduli with the introduction of SiO_2 nanoparticles and MWCNT nanoparticles. Using the nanoindentation method, it becomes possible to explain the nanogranular nature of the CSH gel, which is characteristic and determined by the contact forces of the CSH gel particles for these phases.

Keywords: nanoparticles, nanoindentation, nanogranules, packing density.