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Study on Mechanical Properties of Plant Fiber reinforced concrete Hollow Block

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Abstract. In this paper, coal gangue and recycled concrete are used as some coarse aggregate instead of natural crushed stone, and plant fibers are added to improve the physical and mechanical properties of concrete. The optimum mix ratio of 28d concrete was selected from the comparative analysis of compressive strength and tensile-compression ratio. A kind of self-insulating concrete block with plant fiber was developed by designing the shape and size of the concrete block. The block has good compressive strength and low cost, can well solve environmental problems, and has good economic value and social benefits.

1. Introduction

Nowadays, China's thermal insulation wall materials are mainly divided into two types: internal insulation and external insulation. The external thermal insulation effect is good and does not occupy space, but the external thermal insulation wall construction cost is high, the construction process requirements are high, and the external wall decoration has an impact. Therefore, it is necessary to develop internal insulation wall materials to make up for the defects of construction materials. The internal insulation material is mainly hollow blocks, but its thermal bridge affects the thermal insulation performance of the wall. Combined with the heat transfer characteristics of the internal thermal insulation wall, the hole shape and filling material are optimized on the basis of ordinary hollow blocks. In view of the current research status, this experiment mainly improves the performance by adding plant fibers to ordinary concrete blocks.

Plant fiber concrete is currently in the research stage. A large amount of research has been done on fiber concrete blocks in China, and research results have been obtained: Lv Xinmin ^[1] found that a small amount of corn fiber was added to resist pressure by comparing corn fiber with glass fiber. The effect of strength is not great, but the tensile strength of concrete is improved. The incorporation of glass fiber greatly increases the compressive and flexural strength of concrete, but the excessive addition of corn fiber causes the compressive strength of the block to decrease rapidly; Su Youwen ^[2] improved the performance of concrete by adjusting the shape and amount of straw fiber. From the research results of Yang Kai ^[3], it can be obtained that corn straw has more fiber content and has stronger mechanical properties, and the smaller the diameter of corn straw fibers, the better the mechanical properties of concrete. Based on the above test results, it can be known that the excessive amount of plant fibers will greatly reduce the mechanical properties of concrete, and the diameter of plant fibers will also affect the mechanical properties of concrete. Combining the above results and considering factors such as convenience of material extraction, fiber composition, etc., this experiment



mainly incorporates flocculent corn stalk fiber, and its mechanical properties are studied by changing the amount of incorporation.

2. Test materials and methods

2.1 Test materials

Natural coarse aggregate: 5-10mm natural stone in Yanji city; broken 5-10mm coal gangue;

Recycled coarse aggregate: recycled concrete with crushed particle size of 5-10 mm;

Natural fine aggregate: Yanji River sand;

Cement: PO42.5 ordinary Portland cement producing area is Jidong cement Rock Co., Ltd., Panshi City, Jilin Province.

Fly ash: Yanji Tienan heating Company Grade II fly Ash;

Water: tap water of Yanji City;

Admixture: Yanji Fangsheng Building Materials Co., Ltd. 's poly-acid water reducing agent;

Plant fiber: flocculent corn straw fiber with a length of about 2 cm.

2.2 Test programme

In this experiment, the water-cement ratio is 0.48, the sand ratio is 0.38, and 20% fly ash and 30% recycled coarse aggregate are used. Plant straw mixed with 0%, 4%, 6%, and 8%, and MS, MZ, and MD were coal gangue with 20%, 30%, and 40%, respectively. The test slump was 8 cm, and 10 groups of 150×150×150mm concrete test blocks were made. Because plant fiber and coal gangue will absorb a large amount of water during the stirring process, pre-wet before testing.

2.3 Design strength

This experimental design is mainly suitable for load-bearing blocks of grade MU10.0.

According to the relationship between the strength of the hollow block and the strength of the cube and the empirical formula of Yong Yuli ^[4]:

$$R_K/R_L=0.9577-1.129K$$

$$R_L=10.0/(0.9577-1.129\times 0.4)=19.76\text{MPa}$$

Therefore, the strength of preparation Derived from formula (1):

$$f_{cu,o}=f_{cu,k}+1.645\sigma=f_{cu,o}=f_{cu,k}+1.645\sigma=19.76+1.645\times 5=27.985\text{MPa} \quad (1)$$

3. Mix proportion design

3.1 Calculation of water-cement ratio (W / C)

The water consumption is fixed to 180 kg.

The amount of cement is obtained according to the formula ^[5].

$$m_c=[0.106\times(f_{ce,g}+2.5)+f_{cu,o}]\times m_w/[0.53\times(f_{ce,g}+2.5)]=374.34\text{kg}$$

The water-cement ratio of concrete is calculated according to the following formula:

$$W/C=180/374.34=0.48$$

3.2 Calculation of unit water consumption and cement consumption per unit cubic meter of concrete:

(1) Cement dosage m_{so}

$$m_F=374.34\times 20\%=74.87\text{kg}, m_{so}=374.34-74.87=299.47\text{kg}$$

(2) Sand coarse aggregate ratio

$$\beta_s=0.255+0.3\times W/C-0.01\times(0.6D_m-3)/2=0.382$$

$$m_{co}+m_{wo}+m_{Fo}+m_{go}+m_{so}=m_{cp}=2400\text{kg}, m_{go}=1142.46\text{kg}, m_s=703.20\text{kg}$$

The mix ratio of plant fiber reinforced concrete test is shown in Table 1.

Table 1. Test mix proportion of Plant Fiber reinforced concrete

Number	Cement	Flyash	Gangue	Natural gravel	Recycled coarse aggregate	Straw	Water	Sand coarse aggregate ratio	Water cement ratio
MH-0	299.47	74.87	456.98	342.74	342.738	0	180	0.38	0.48
MS-1						11.98			
MS-2	299.47	74.87	571.23	228.49	342.738	17.97	180	0.38	0.48
MS-3						23.96			
MZ-1						11.98			
MZ-2	299.47	74.87	456.99	342.74	342.738	17.97	180	0.38	0.48
MZ-3						23.96			
MD-1						11.98			
MD-2	299.47	74.87	342.74	456.99	342.738	17.97	180	0.38	0.48
MD-3						23.96			

3.3 Strength test of plant fiber concrete test block

150×150×150mm concrete test block was used to test the compressive strength and split tensile strength of the test block for 7 days, 14 days and 28 days according to the standard curing conditions. The results are shown in Table 2. Figure 1-5 is drawn with origin software.

Using 150×150×150mm concrete test blocks, according to standard curing conditions, test the compressive strength and split tensile strength of the test blocks 7d, 14d, and 28d. The results are shown in Table 2. Figure 1-4 was drawn using origin (9.1) software.

Table 2. Pressure resistance of each test block

Sample number	Compression strength (Mpa)			Split strength (MPa)	Pull-pressure ratio
	7d	14d	28d	28d	28d
MH-0	29.87	34.36	37.51	2.78	0.074
MS-1	28.74	33.93	36.14	2.81	0.078
MS-2	23.17	28.59	31.62	2.47	0.078
MS-3	19.36	21.67	26.84	2.26	0.084
MZ-1	22.43	27.85	31.66	2.69	0.084
MZ-2	20.98	25.77	29.32	2.45	0.085
MZ-3	16.69	19.34	23.25	2.38	0.102
MD-1	23.16	25.74	28.33	2.54	0.090
MD-2	16.93	22.37	25.65	2.35	0.092
MD-3	14.82	17.98	21.89	2.08	0.095

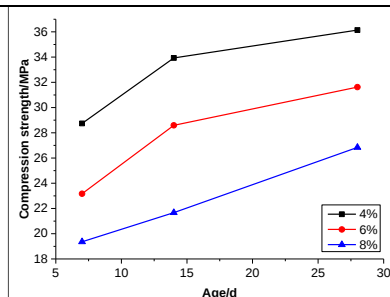


Fig. 1 Relationship between compressive strength and age of concrete blocks with 20% coal gangue

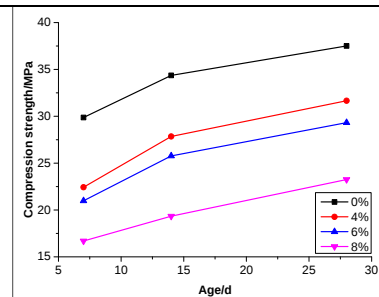


Fig. 2 Relationship between compressive strength and age of concrete blocks with 30% coal gangue

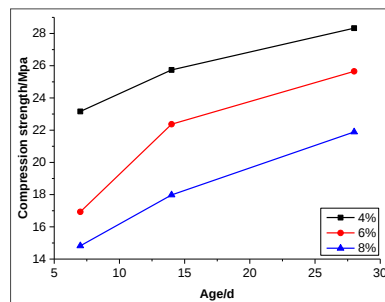


Fig. 3 Relationship between compressive strength and age of concrete blocks with 40% coal gangue

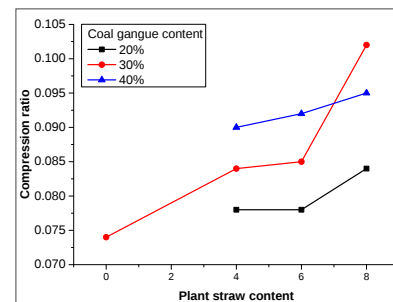


Fig. 4 Tension and compression ratio of concrete test block

3.4 Analysis of results

Fig.1 is a line chart of different age under the condition of the incorporation rate of the coal and the plant fiber of 20% and the plant fiber incorporation rate of 4%,6% and 8%, respectively. When the plant fiber with 4% is added, the compressive strength and age meet the fitting equation. $y=0.32x+27.64$; When 6% plant fiber is added, the compressive strength and age meet the fitting equation. $y=0.38x+21.66$; When 8% plant fiber is added, the compressive strength and age meet the fitting equation. $y=0.36x+16.78$. Fig. 2 shows the fitting equation between compressive strength and age when the blending rate of coal gangue is 30%, the blending rate of plant fiber is 0, 4%, 6%, 8%, and 0% of the plant fiber is added into the plant fiber, and the compressive strength and age of the plant fiber are satisfied with the fitting equation when 0% of the plant fiber is mixed with 0% of the plant fiber, and the compressive strength and age of the plant fiber are satisfied with the fitting equation. $y=0.34x+28.30$; When 4% plant fiber is used, the compressive strength and age meet the fitting equation. $y=0.42x+20.53$; When 6% plant fiber is added, the compressive strength and age meet the fitting equation. $y=0.38x+19.21$; When 8% plant fiber is added, the compressive strength and age meet the fitting equation. $y=0.31x+14.74$. Fig. 3 shows the broken line diagram of different ages when the gangue blending rate is 40%, the plant fiber blending rate is 4%, and the plant fiber blending rate is 6%. When 4% plant fiber is added, the compressive strength and age meet the fitting equation. $y=0.24x+21.9$; When 6% plant fiber is added, the compressive strength and age meet the fitting equation. $y=0.39x+15.24$; When 8% plant fiber is added, the compressive strength and age meet the fitting equation. $y=0.32x+13.52$.

From fig.1,2,3 it can be seen that the compressive strength of concrete decreases with the increase of gangue content. The main reason may be that the strength of coal gangue instead of natural gravel is lower than that of natural gravel, and the porosity of coal gangue is relatively large, which makes the test block produce more stress concentration area in the process of compression. Secondly, because the strength of coal gangue is lower than that of stone, it appears to be broken in the mixing process, resulting in poor gradation of aggregate and low strength of the test block [6]. When more plant fibers are added, the compressive strength of concrete increases slowly in the early stage, and the strength in the later stage also decreases greatly. This is due to the increase in the amount of fiber, and some fibers cannot be dispersed during the mixing, forming a weak area, which greatly reduces its compressive strength [7].

It can be seen from fig. 4 that the addition of plant fiber does not improve the tensile strength of concrete, but increases the compression ratio to a certain extent. The tensile-compressive ratio is one of the indicators for testing the brittleness of concrete materials, and the small tension-compression ratio indicates that the brittleness of concrete is large. As can be seen from fig. 4, the tension-compression ratio of plant fiber concrete increases with the increase of plant fiber addition. Generally speaking, the addition of plant fibers can improve the brittleness of concrete to a certain extent.

By comparison, it can be concluded that the compressive strength of MH-0, MS-1, MS-2, MZ-1, MZ-2, and MD-1 all meets the design strength. Considering the environmental and economic benefits

of concrete comprehensively, concrete with coal gangue content of 30% and plant fiber content rate of 6% was selected.

4. Conclusions

1) Through the compressive strength test of plant fiber concrete test block for 7 days, 14 days and 28 days, the fitting equation of plant fiber concrete is obtained by using origin to draw the age curve. Compared with the variation law of each curve, when the plant fiber content is less, the increase of compressive strength in the early stage of concrete has little effect, when the plant fiber content is too much, it will increase the initial setting and final setting time of concrete, and make the strength increase slowly in the early stage.

2) The addition of coal gangue aggregate and plant fiber reduces the mechanical properties of concrete, but after adding plant fiber, the tension-compression ratio of concrete increases, thus improving the brittleness of concrete, which shows that coal gangue aggregate and plant fiber are feasible as concrete materials, and can solve environmental problems well, thus creating greater economic and social benefits.

3) Based on the compressive strength and tension-compression ratio of concrete, the optimum mix ratio of test block is put forward. That is to say, when the amount of coal gangue is 30% and the plant fiber is 6%, the compressive strength of the test block reaches the design strength and meets the design requirements.

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