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Experimental Study on Mechanical Properties of Copper-Plated Steel Fiber Lightweight Concrete

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Abstract

In order TO make the COPPER-plated STEEL fiber LIGHTWEIGHT CONCRETE BE EFFECTIVELY APPLIED IN engineering structures, THE compression, splitting, flexural strength and flexural toughness tests of multiscale COPPER-plated steel fiber lightweight concrete were carried out, and the influence of light aggregate substitution rate and fiber scale on concrete properties was analyzed by using light aggregate instead of ordinary aggregate. The results show that its mechanical properties are mainly determined by fiber scale and lightweight aggregate substitution rate. The longer the fiber scale and the smaller the lightweight aggregate substitution rate, the better the mechanical properties.

Keywords

Copper-plated Steel Fiber; Lightweight Concrete; Mechanical Properties.

1. Introduction

Reinforced concrete bearing heavy, durable and fire resistance, easy to form and other characteristics, so that reinforced concrete structure is widely used in the domestic construction industry, but reinforced concrete since the heavy, brittle high defects also limited the scope of use of concrete, concrete work often bear two parts of the load: (1) the external load, (2) the weight of its own, most of the damage forms are caused by its own weight is too large, such as long-span frame, bridge and other structures, the external load is generally small, far from leading to the collapse of the structure, but its own weight is far more than the external load, therefore, The main reason for the damage of concrete structure is the damage caused by the structure self-gravity. To reduce the occurrence of similar phenomena, we must start from its defects, reduce the material weight, improve its strength.

FLAC can obviously improve the above shortcomings, lightweight aggregate can effectively improve the shortcomings of the structure, adding fiber can also improve the characteristics of ordinary concrete easy to crack, in summary, fiber lightweight concrete conforms to the development status quo and becomes an indispensable material.

With the rapid development of concrete, the performance requirements of FLAC in the construction industry are also increasing. However, the research on FLAC is relatively weak. The preparation process of FLAC is relatively complex, the amount of fiber added is difficult to control, and the thickness and length of fiber are the main factors affecting FLAC performance. The properties of concrete were investigated by using copper-plated steel fiber (CPSF), and the effects of different scales and different lightweight aggregate substitution rates on the properties of concrete were analyzed.

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2. Experiment

2.1. Raw Material

Test cement: Tangshan Jidong P.O42.5 type ordinary Portland cement.

Water reducer: Juqi brand polycarboxylic acid superplasticizer, water reduction rate of 20%.

Fine aggregate: high quality river sand, medium sand, fineness modulus 2.76.

Coarse aggregate: gravel is used as small particle size stone, and the gradation state of gravel is continuous gradation, and the nominal particle size is 5~10mm.

Copper coated steel fiber:

Table 1. Parameter index of fiber

Type	Length /mm	Diameter /mm	Aspect ratio	Density/kg/m^3
Copper coated steel fiber	6, 13, 17	0.22	27, 59, 77	7800

(a) (b) (c)

a-6mmCopper coated steel fiber; b-13mmCopper coated steel fiber; c-17mmCopper coated steel fiber

Fig 1. Copper coated steel fiber

2.2. Concrete Mix Ratio

Taking copper-plated steel fiber scale and ceramsite content as parameters, 13 groups of concrete with different content were designed and tested. The proportions of each group are shown in Table 2.

Table 2. Mix ratio of copper-plated steel fiber lightweight concrete(kg/m^3)

Serial number	Ceramsite	Cement	Water	Water reducing agent	Sand	Stone	Silica fume	Fly ash	CPSF
OPC	0	357	200	2.55	813	878	51	102	0
0CPSF6	0	357	200	2.55	813	878	51	102	40
0CPSF13	0	357	200	2.55	813	878	51	102	40
0CPSF17	0	357	200	2.55	813	878	51	102	40
30CPSF6	159.58	357	200	2.55	813	612.5	51	102	40
50CPSF6	266.0	357	200	2.55	813	612.5	51	102	40
70CPSF6	372.4	357	200	2.55	813	612.5	51	102	40

30CPSF13	159.58	357	200	2.55	813	612.5	51	102	40
50CPSF13	266.0	357	200	2.55	813	612.5	51	102	40
70CPSF13	372.4	357	200	2.55	813	612.5	51	102	40
30CPSF17	159.58	357	200	2.55	813	612.5	51	102	40
50CPSF17	266.0	357	200	2.55	813	612.5	51	102	40
70CPSF17	372.4	357	200	2.55	813	612.5	51	102	40

Note: CPSF in the above expression means copper-plated steel fiber; The number before the letter indicates the replacement rate of light aggregate in %; The back represents the length of the fiber in mm.

2.3. Mixing Process

The following mixing process was adopted in this test according to CECS 38:2004 specification of Technical Regulations for Fiber reinforced Concrete Structures and combined with the actual situation: Firstly, the cementified material and copper coated steel fiber were added for dry mixing: The mixing time of silica fume, cement, fly ash and copper-plated steel fiber is 1min. The silica fume particles are much smaller than cement, which can be attached to the fiber surface and contribute to the fiber dispersion. Moreover, the friction caused by the impact of cement and fly ash particles can promote the fiber dispersion. Then put pulverized coal ash pottery, stones, sand for mixing, for 1min, some fiber with strong cohesion is not easy to disperse under the impact of small particles, and sand stones are used for secondary impact. Then add water and water reducing agent and stir for 2min.

3. Analysis of Test Methods and Results

3.1. Cube Compressive Strength

Table 3. Compressive strength of the cube

Type	f_{cu}/MPa
OPC	36.4
0CPSF6	59.9
0CPSF13	55.7
0CPSF17	57.2
30CPSF6	52.7
50CPSF6	48.5
70CPSF6	45.1
30CPSF13	42.3
50CPSF13	47.5
70CPSF13	52.7
30CPSF17	50.5
50CPSF17	54.6
70CPSF17	48.2

In the cube compressive strength test of copper-plated steel fiber lightweight concrete, the test piece adopts the cube of 100mm×100mm×100mm to carry out the test, and uses the ruler to test the side length of the cube specimen, the measurement size is accurate to 1mm, and the cross section area of the bearing surface is calculated. Place the center of the test piece in the middle of the press, and start the press until the upper and lower pressure plates of the press completely contact with the surface of the test piece to stop; Open the press and load evenly at the rate of 0.5 ~ 0.8mpa per second until time failure, and record the failure. The experimental results of cube compressive strength of each specimen are shown in Table 3.

According to the data in Table 3, Compared with 30CPSF6, 50CPSF6 and 70CPSF6, 0CPSF6 f_{cu} increased by 12%, 19% and 24% respectively. Compared with 30CPSF13, 50CPSF13 and 70CPSF13, 0CPSF13 f_{cu} increased by 24%, 14% and 5% respectively. Compared with 30CPSF17, 50CPSF17 and 70CPSF17, 0CPSF17 f_{cu} increased by 11%, 4% and 15%, respectively. It can be seen that: CPSF f_{cu} is generally higher than ordinary concrete mixed with CPSF lightweight aggregate concrete, which is due to the strength of the lightweight aggregate is small, relative to ordinary aggregate decreased after mixed with lightweight aggregate concrete f_{cu}, with the increase of lightweight aggregate replacement rate of ordinary aggregate volume reduced f_{cu} should into decline, but 13 mm CPSF lightweight aggregate combination instead for the upward trend, the reason is: The rough outer surface of the ceramsite increases the bond of the cement paste, and the porous structure of the ceramsite itself can retain water, so that the cement inside the structure is fully hydrated to achieve the enhanced effect, so there will be light aggregate content and f_{cu} is proportional to the situation. When the lightweight aggregate content is 0, the maximum value of 0CPSF6 f_{cu} is 59.9mpa; when the lightweight aggregate content is 30%, the maximum value of 30CPSF6 f_{cu} is 52.7mpa; when the lightweight aggregate content is 50%, the maximum value of 50CPSF17 f_{cu} is 54.6mpa; when the lightweight aggregate content is 70%, the maximum value of 70CPSF13 f_{cu} is 52.7mpa.

3.2. Split Tensile Test

Table 4. Splitting tensile strength of the cube

Type	f_{ts} /MPa
OPC	2.6
0CPSF6	4.6
0CPSF13	4.3
0CPSF17	4.5
30CPSF6	3.6
50CPSF6	3.3
70CPSF6	3.5
30CPSF13	4.0
50CPSF13	3.8
70CPSF13	4.0
30CPSF17	3.6
50CPSF17	3.3
70CPSF17	3.4

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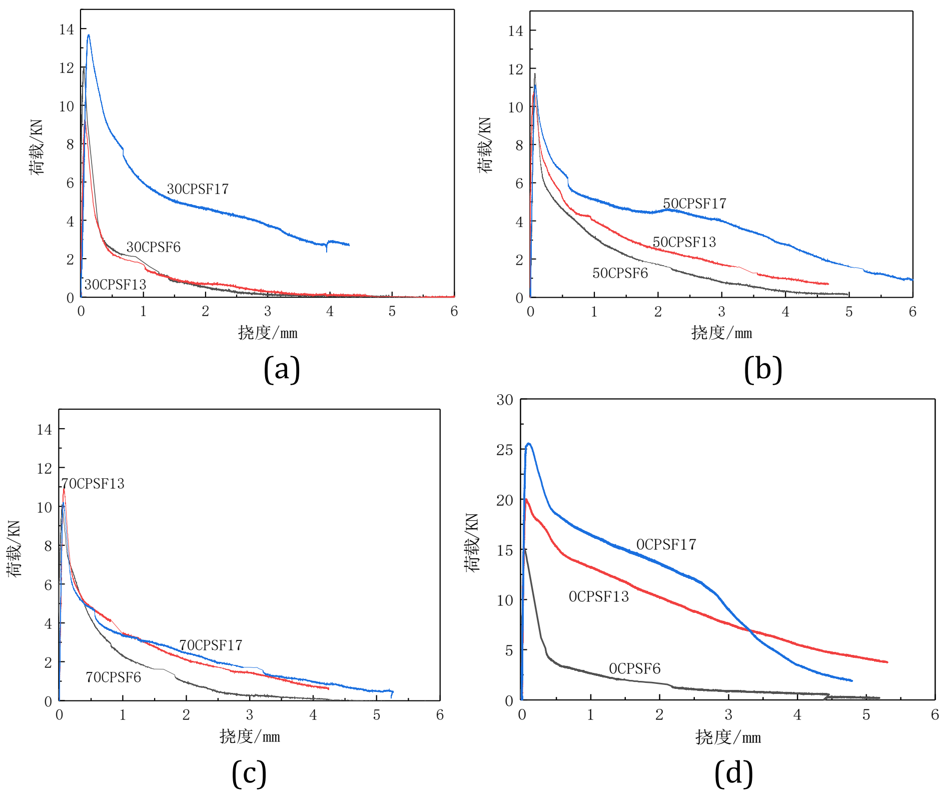
In the splitting tensile test experiment of copper-plated steel fiber lightweight concrete, the specimens were tested with cubes of 100mm×100mm×100mm. After curing, the surface of the specimens was wiped clean, and the splitting position was drawn at the section. Put the specimen in the middle of the circular arc pad and the pad; The press was opened and uniformly loaded at a rate of 0.05-0.08Mpa per second until the specimen was damaged and the failure load of the structure was recorded. The test results of split tensile strength are shown in Table 4. According to the data in Table 4, the f_{ts} of ordinary fiber concrete is significantly higher than that of lightweight aggregate concrete. For CPSF fiber reinforced concrete: When the fiber scale is fixed, it is found that the substitution rate of light aggregate has no obvious effect on the f_{ts} after changing the amount of light aggregate. However, when the light aggregate is fixed, it can be seen that the f_{ts} of CPSF concrete increases first and then decreases with the increase of fiber scale. Cause this could be due to CPSF concrete in the splitting tensile test CPSF belongs to pull out, and a long CPSF can keep sufficient assurance and matrix bond length, fiber is not easy to pull out, inhibit the specimen cracking effect, but CPSF too long can reduce the number of fibrous roots, reduce and substrate bonded area, affect the f_{ts} of concrete performance.

3.3. Bending Strength and Toughness Test

In this paper, 100×100×400 fiber reinforced concrete specimens were selected for three-point loading, and the span of the two supports was 300mm. The test steps were as follows: using a ruler to test the side length of the cube specimen, the measurement size was accurate in 1mm; The distance between the two supports should be 3 times of the side length of the cross-section h, the distance between the indenter and the nearest support frame is H, and the distance between the two indenters is and h; When the press is opened, the displacement control is used to uniformly load the press at a rate of 0.15±0.02mm/min per second. The test results are shown in Figure 2 and Table 5.



a-30%CPSF; b-50%CPSF; c-70%CPSF; d-0%CPSF

Fig 2. Load-displacement curve of CPSF fiber reinforced concrete

Table 5. Toughness index of copper-plated steel fiber reinforced concrete

Fiber type	F_{er} /KN	F_{max} /KN	f_f /MPa	δ_{er} /mm	f_e /MPa	I_5	I_{10}	I_{20}
0CPSF6	14.9	15.2	4.5	0.025	1.07	3.75	6.83	11.55
0CPSF13	19.1	20.0	5.7	0.044	4.08	4.14	7.78	14.51
0CPSF17	25.3	25.6	7.6	0.059	5.09	3.96	7.34	12.97
30CPSF6	11.2	12.0	3.3	0.026	2.9	2.1	4.9	7.06
30CPSF13	8.78	9.3	2.6	0.059	2.0	3.3	4.9	6.8
30CPSF17	13.3	13.7	4.0	0.097	0.9	4.3	7.4	12.3
50CPSF6	10.8	11.7	3.3	0.052	1.27	2.81	4.37	7.2
50CPSF13	10.5	10.7	3.1	0.040	1.09	2.97	4.8	7.9
50CPSF17	10.7	11.1	3.2	0.063	0.76	3.9	6.8	11.6
70CPSF6	8.80	10.1	2.6	0.023	2.14	2.18	3.87	6.31
70CPSF13	10.4	10.8	3.1	0.059	1.15	4.11	6.6	10.7
70CPSF17	10.1	10.2	3.0	0.053	0.96	4.0	6.51	10.7

As can be seen from Fig. 2, the load-deflection curve shows a straight upward trend before the initial crack load, and the displacement almost has no deformation. When the initial crack load is reached, the displacement basically remains within 0.1mm. After the peak load, the images of 0CPSF6, 30CPSF6, 50CPSF6, and 70CPSF6 have obvious sharp drops. The longer the fiber in the period of the leveling off, compared with that of 6 mm fiber concrete specimen with a relatively low compared with other dimensions of fiber reinforced concrete ductility, this can be explained by the addition of copper coated steel fiber can improve the toughness of concrete, when specimens reach before the initial crack, concrete bear loads together with CPSF fiber displacement deformation is relatively small, after the specimen with initial crack, Since the tensile strength of CPSF fiber is much greater than that of concrete, all its load is borne by the bonding force between matrix and copper-plated steel fiber. After that, the matrix will be in the state of fiber pulling out, and short fiber is easier to pull out than long fiber. Therefore, the longer the fiber is, the better the ductility of the specimen will be, and the flatter the curve will be. In addition, it can be seen from the area of the curve that the bending toughness index (I_5, I_{10}, I_{20}) of the long fiber is basically better than that of the short fiber.

It can be seen from Table 5 that the f_f of 0CPSF17 is 7.6mpa, which is increased by 40.7% and 25% compared with 0CPSF6 and 0CPSF13 respectively. The f_f of 30CPSF17 is increased by 17.5% and 35% compared with 30CPSF6 and 30CPSF13 respectively. Compared with 50CPSF13 and 50CPSF17, 50CPSF6 increased by 6.0% and 34% respectively, and 70CPSF6 increased by 1.6% and 3.0% compared with 70CPSF13 and 70CPSF17. In addition, except for ordinary concrete, the initial crack load and peak load of 30% lightweight aggregate replacement rate group were relatively higher than other groups. This shows that when the light aggregate content is 30%, the coal ash ceramsite and stones form a compact and uniform continuous skeleton in the concrete, which improves the flexural performance of concrete. In terms of f_e, the strength of 0CPSF17 is significantly higher than that of 0CPSF6 and 0CPSF13. After adding lightweight aggregate, it is found that the f_e of 6mm fiber lightweight aggregate is higher than that of other sizes of fiber concrete, which shows that: In ordinary fiber concrete, the fiber size is directly proportional to the f_e, while the fiber size is inversely proportional to the f_e when light aggregate is added. In addition, the data show that when the fiber size is 6mm and 17mm, the smaller the light aggregate content is, the greater the initial cracking load and equivalent flexural f_e will be. It can be seen from the data in the table: The flexural toughness index (I_5) of 30CPSF17 is the best when the mid-span deflection is 3 times of the initial crack deflection, the flexural toughness index (I_{10}) of 0CPSF13 is the best when the deflection is 5.5 times of the initial crack deflection, and the flexural toughness index (I_{20}) of 0CPSF13 is the best when the deflection is 10.5 times of the initial crack deflection, which can be interpreted as: Low lightweight aggregate content and long fiber can improve the toughness of concrete more obviously.

4. Conclusion

The mechanical properties of fiber reinforced concrete under different combinations were tested, and the experimental phenomena of the specimens after test failure were analyzed, and the conclusions were drawn as follows: The f_{cu}, f_{ts}, f_f of CPSF fiber lightweight concrete are mainly determined by fiber scale and the replacement rate of light aggregate. The f_{cu}, f_{ts}, f_f of 17mmCPSF fiber concrete with the same amount of light aggregate are better than those of 6mm and 13mm fiber concrete. When the CPSF scale is the same, the f_{cu}, f_{ts} of ordinary fiber reinforced concrete are generally higher than that of light aggregate fiber reinforced concrete, and are inversely proportional to the amount of light aggregate. In the flexural toughness test, the displacement of the initial crack load is controlled within 0.1mm. The smaller the replacement rate of lightweight aggregate, the greater the peak load, and the longer the fiber, the better the ductility and flexural toughness index (I_5, I_{10}, I_{20}) of the specimen.

References

[1] NEHDIM L. Fibers Thergy in Finber-reinforced Self-Consolidating Concrete[J]. ACI Materials journal, 2004, 101(6);508-517.

[2] Saber F, Mahdi N. Mechanical properties and durability of high-strength concrete containing macro-polymeric and polypropylene fibers with nano-silica and silica fume[J]. Construction and Building Materials, 2017, 132(3):122-134.

[3] Ghasemzadeh M., Shemshad S. Experimental Study Effect of Silica Fume and Hybrid Fiber on Mechanical Properties Lightweight Concrete[J]. Iran J Sci Technol Trans Civ Eng, 2019,43(01):263–271.

[4] Wu F, Liu C, Diao Z. Improvement of Mechanical Properties in Polypropylene- and Glass-Fibre-Reinforced Peach Shell Lightweight Concrete. Advances in Materials Science & Engineering. February, 2018, 45(7):1-11.

[5] Li J, Niu J, Wan C. Comparison of flexural property between high performance polypropylene fiber reinforced lightweight aggregate concrete and steel fiber reinforced lightweight aggregate concrete[J]. Construction & Building Materials, 2017, 157(2):729-736.

[6] Nicolas A, Mehrdad M. Mechanical properties of hybrid fiber reinforced lightweight aggregate concrete made with natural pumice[J]. Construction and Building Materials, 2010, 25(05):89-96.