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Experimental study on compressive properties of steel fibre concrete

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Abstract. The uniaxial compression tests were carry out in 5 groups steel fibre concrete specimens for 3 kinds of curing age, and the effect of steel fibre incorporation rate and curing age was studied on the compressive properties of concrete. The results show that the compressive strength of steel fibre reinforced concrete increases with the increase of the ratio of steel fibre. When the steel fibre incorporation rate is constant, the compressive strength of the steel fibre has a small increase with the growth of the curing age. The addition of steel fibre can effectively improve the crack resistance and toughness of concrete. With the addition of steel fibre, plastic deformation ability of concrete is enhanced, and the ultimate destruction form of concrete is the shear failure with obvious oblique cross section.

1. Introduction

Steel fibre concrete is a new type of high quality composite material [1-2]. Steel fibre concrete has more superior mechanical properties than ordinary concrete in the enhancement and cracking resistance [3-4]. The strength of steel fibre with different content was increased to concrete, and the optimal rate of steel fibre admixture was determined. After the steel fibre is added to the concrete base, The strength of concrete is not only closely related to this element, but also related to the mixed strength of cement, coarse aggregate and other components, and the performance of steel fibre added to change the concrete [5-6]. This test can minimize the influence of the above factors by controlling the variable method and using the same raw material and match ratio. In addition, the length of the maintenance period also has a certain impact on the performance of concrete [7-8]. The maintenance condition of concrete can obviously improve its durability, but the concrete maintenance strength is insufficient in the actual construction process. Therefore, the development of compressive strength of steel fibre doped concrete under 7d, 28d age and long period 365d was studied [9].

2. Test profile

2.1. Test design

2.1.1. Steel fibre type. Shear steel fibre. According to the principle of cold hardening, the strength of steel fibre was increased. The reasonable shape structure of steel fibre improved the adhesion force and tensile force in concrete by effectively. The main performance indicators of steel fibres are shown in Table 1.



Table 1. Steel fibre performance indicators.

Length(mm) shape	Equivalent diameter(mm)	Length radius ratio	Tensile strength (MPa)	Section
40	0.6	67	≥ 600	rectangle

2.1.2. *Steel fibre incorporation rate* are 0, 0.5 %, 1.0 %, 1.5 %, 2.0 %, respectively.

2.1.3. *Test size.* The compressive strength test uses a standard concrete cube test block of 150mm $\times$ 150mm $\times$ 150mm.

2.2. Test raw materials

2.2.1. *Cement.* Using 32.5 composite Portland cement, the performance of cement is shown in Table 2.

2.2.2. *Sand.* The performance of sand using natural medium coarse river sand is shown in Table 3.

Table 2. Physical and mechanical properties of cement.

Cement grade	Fineness%	Standard consistency	water consumption%	Stability	Condensation time(min) Pressure strength/MPa			
					Initial	Condensation	3d	28d
32.5	2.1	26.7	qualified		184	293	18.9	45

Table 3. physical properties of sand.

Dry water absorption rate (%)	Apparent density (kg·m ⁻³)	Accumulation density (kg·m ⁻³)	Accumulation density	Mud content (%)
3.8	2.5	1.63	2.79	2.5

2.2.3. *Aggregate.* Using gravel with a particle size of 5mm to 20mm, with a mud content of 1 %.

2.2.4. *Additives.* High efficiency water reducer using powdered naphthalene.

2.2.5. *Water.* Use tap water as mixing water.

2.3. Concrete ratio design

The ratio of matrix concrete is: cement: sand: gravel: additive: water = 1:2.16: 1.17:0.01: 0.45. Five sets of concrete are prepared according to the design ratio, the insertion rates of fibres are: 0, 0.5 %, 1.0 %, 1.5 %, 2.0 %, Each doped steel fibre concrete pouring 9 specimens. As with ordinary concrete, the strength of steel fibre concrete increases with the decrease of water ash ratio, but reducing the

water ash ratio will increase the cost of concrete. So choosing a reasonable water-ash ratio is very important[10]. In order to ensure the reliability of the test, According to the determination method of compressive strength of ordinary concrete, water ash ratio of the test is determined to be W/C=0.45.

2.4. Sample preparation

Sample preparation: in order for the steel fibre to be evenly distributed in the concrete, the cement, sand and stone are first stirred evenly, then add steel fibre to stir, finally, add water for wet mixing.

Stir time is not less than 3 min. After the specimen is formed 24h, the test block was demoulded. Afterwards, they were placed in standard maintenance rooms to maintain 7d, 28d, and 365d respectively.

3. Concrete compressive strength tests

3.1. Test process

In order to study the development law of the effect of steel fibre admixture and long period maintenance on the compressive strength of steel fibre concrete, a total of 45 test blocks were measured. For 5 groups of different steel fibre admixture, 9 test blocks in each group were subjected to uniaxial compression test without side limit. Test work for 7d, 28d and 365d, respectively. Record the maximum load and damage pattern of the test block during loading.

3.2. Data reduction

Measurement of 5 sets of specimens per phase, each set of 3 specimens. The test is a uniaxial compression test without side limit. Pressure strength of steel fibre concrete cube test block calculated as:

$$f_{CP} = F/A \quad (1)$$

Here f_{CP} ----- the steel fibre concrete cube compressive strength (MPa);

F----- maximum load(N)

A---- the sample bearing area(mm²).

Through the compressive strength test for all three stages of the specimen, the uniaxial compressive strength value is listed in Table 4.

3.3. Experimental data analysis

The data in Table 4 are analyzed and the fold-line diagram of compressive strength and the increase in the compressive strength (compared to the concrete) with three different ages and different steel fibre admixtures of steel fibres are shown in Fig. 1 and Fig. 2.

Table 4. Physical and mechanical properties of cement.

Number	Steel fibre admixture(%)	Pressure strength(MPa)		
		7d	28d	365
1	0	39.2	40.10	41.78
2	0.5	41.83	44.25	46.21
3	1.0	43.52	47.69	49.33
4	1.5	49.43	53.75	57.18
5	2.0	50.47	54.61	55.70

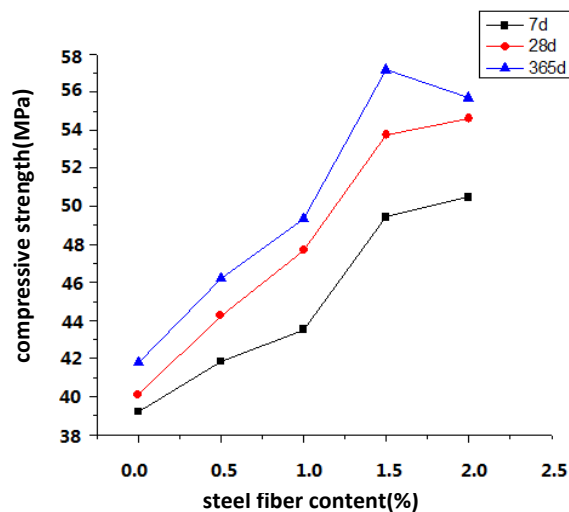


Fig.1 Relationship of steel fibre content and compressive strength

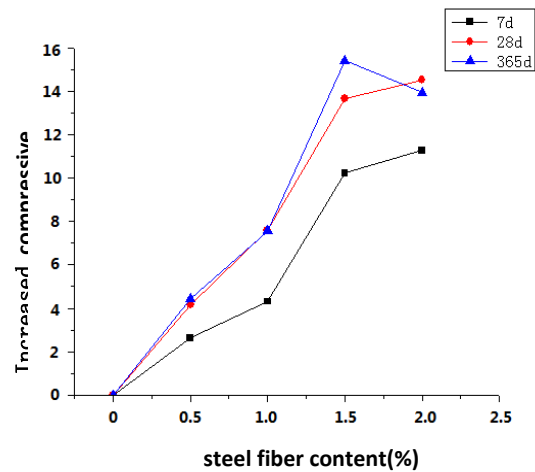


Fig.2 Relationship of steel fibre content and increased compressive strength

It can be seen from figures 1 and 2, when the amount of steel fibre added changed from 1.5 % to 2.0 %, the folding charts maintained during the 7d and 28d ages were relatively flat, and the overall compressive strength increased slightly. The folding chart of 365d age maintenance began to decline because the steel fibre and aggregate under 365d maintenance had been fully bite. When the mixing rate of steel fibre is too large, the uneven distribution of steel fibre in the test block weakens the enhancement effect of steel fibre on concrete. Taking into account economic factors, the optimal rate of incorporation of steel fibre was selected by 1.5 %.

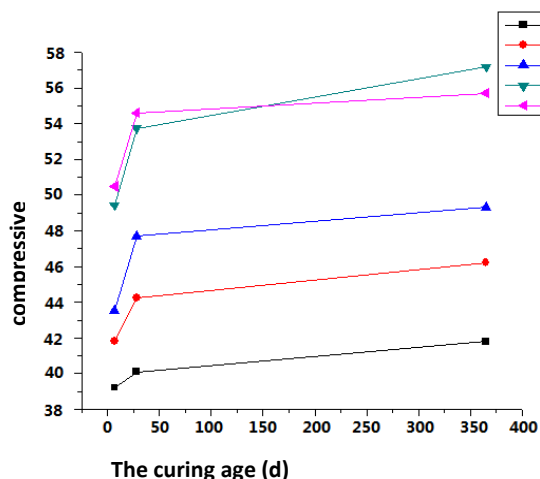


Fig.3 Relationship of strength in different and the curing age

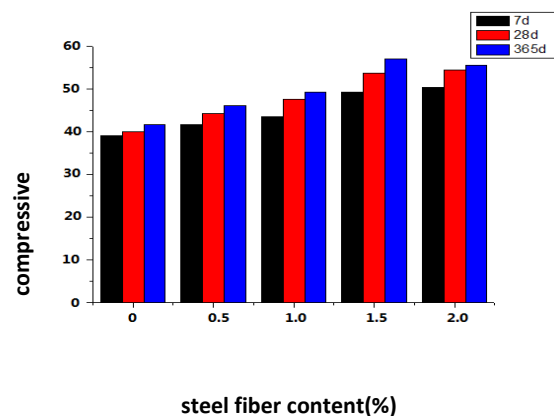


Fig.4 Change of the strength of steel fibre content content with the curing age

For the analysis of the variation of the compressive strength of each doped steel fibre concrete with the maintenance age as which fig. 3 and fig. 4.

As can be seen from figures 3 and 4, the increase in the age of conservation has led to an increase in the compressive strength of each doped steel fibre concrete. When the age of concrete maintenance increases from 7d to 28d and 28d to 365d, the amount of steel fibre admixture is 0 %, which means that the compressive strength of concrete increases by 2.3 % and 4.2 %; The compressive strength of

steel fibre concrete with a content of 0.5 % increased by 5.8 % and 4.4 % ; The amount of doped was 1.0 % increase of 9.6 % and 3.4 %; The amount of admixture of 1.5 % increased by 8.7 % and 6.4 % ; The amount of admixture of 2.0 % increased by 8.2 % and 2.0 % . When the age of maintenance changes from 7d to 28d, the compressive strength of steel fibre concrete increases significantly, and the change of 28d to 365d is relatively gentle, but the compressive strength is still increasing. According to the regulations: The standard value of cube compressive strength refers to 95 % compressive strength value measured by the standard test method at the 28d age with a cube specimen with a side length of 150 mm produced and maintained according to the standard method[13]. In this experiment, the compressive strength of 365 d age was used as the final strength of concrete.

The compressive strength of each doped steel fibre concrete has 96.0 %, 95.8 %, 96.7 %, 94.0 %, and 98.0 % respectively under the 28d maintenance age. The results of this test also prove the accuracy of the above specifications again. Although the compressive strength of concrete during the 365d maintenance age has increased, the overall increase is not high. In actual production activities, it is very rare to use one year of maintenance time to further improve the compressive strength of concrete.

3.4. Damage analysis of pressed test block

The failure patterns of concrete are observed during the test. Fig. 5(a) and 5(b) are the peak load images of steel fibre concrete with 1.0 % steel fibre content and the damage patterns of the test blocks after continuous loading; Fig. 5(c) is a diagram of the internal failure of steel fibre concrete.

It was observed that when the concrete test block was pressed, the side of the test block gradually expanded and then partially began to fall off. When the peak stress was reached, the test block quickly broke through the cracks. The integrity of the test block was poor, and the properties of brittle destruction appeared. When the steel fibre is mixed into the concrete, the test block gradually produces small cracks during the compression process. After reaching the peak stress, the test block does not quickly break but appears the oblique cracks shown in Figure 5(a). There is no shedding phenomenon on the side. After the loading, the test block is destroyed, and then a macroscopic crack is generated. The local surface layer falls off as which Fig.5(b). The integrity of the test block is good, and the plastic damage property is present. Fig.5(c) is the internal destruction form of the concrete, showing a four-cornered cone shape with a distinct oblique shear surface inside, in which the bite of steel fibres and aggregates is clearly visible.

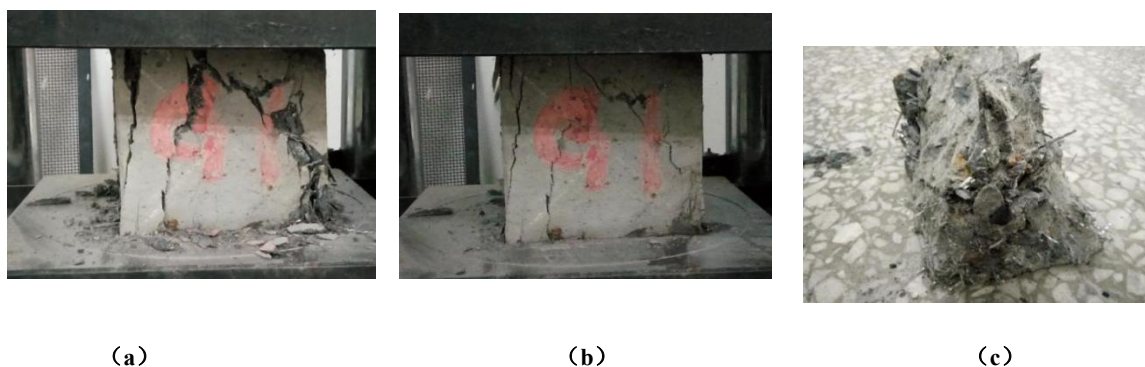


Fig.5 Failure pattern of compressive strength of steel fibre reinforced concrete block

4. Conclusions

Based on the comparison test of the above five groups of steel fibre concrete specimens with different amounts of content under different maintenance ages, the following conclusions are obtained:

For concrete test blocks using shear steel fibres, when the rate of steel fibre admixture is 0 % to 2 %, the compressive strength of steel fibre concrete gradually increases with the increase of the

admittance, especially when the compressive strength increases by 1.0 % to 1.5 %. The increase in intensity of 1.5 % to 2 % was slow. Therefore, the optimal admixture rate of steel fibre is 1.5 %.

Concrete with constant steel fibre content was maintained in the standard maintenance room of 7d, 28d, and 365d, and its compressive strength increased the most before 28d. Although the compressive strength under the long-term maintenance of 365d was improved, the increase was not obvious. The concrete has the same properties.

The addition of steel fibre can effectively improve the crack resistance and toughness of concrete. Steel fibre concrete (CFRC) acts as a constraint to the lateral deformation of steel fibre under the ring effect of the test machine bearing plate, which makes the final failure form of steel fibre concrete have obvious shear damage with oblique section.

Acknowledgments

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