Experimental Study on Impact Resistance of Synthetic Fiber Reinforced Concrete

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Keywords: Synthetic fiber; Concrete; Impact resistance

Abstract: Because ordinary concrete is easy to crack and has poor toughness, the impact test of concrete is mainly used to study the addition of synthetic polypropylene fibers and polyacrylonitrile fibers of different lengths to ordinary concrete to improve the brittle properties of concrete and improve the toughness of concrete. Statistical analysis of the initial crack strength and fracture strength of steel-polypropylene hybrid fiber reinforced concrete (SPHFRC) and steel fiber reinforced concrete (FRC) test pieces after impact shows that the average initial crack strength and fracture strength of SPHFRC are higher than those of FRC . Large; the covariance of the 2 samples of FRC and SPHFRC is much greater than 15%. The effect of synthetic fibers on the impact toughness of concrete was studied. The impact energy of fiber-single-mixed, fiber-mixed and layer-distributed steel fiber lightweight aggregate concrete was tested respectively. The test results show that the incorporation of fiber improves the impact energy of lightweight aggregate concrete, and the effect of steel fiber is the most obvious, followed by fiber blending; when the content of steel fiber is 2 %, the impact energy value is the highest 3.16 times that of concrete. The purpose of this paper is to study the influence of fiber type and content on the impact resistance of concrete, and to explore the influence of new synthetic fiber materials on the impact resistance of concrete.

1. Introduction

At present, concrete is still one of the main building materials in the world, and it has an extremely wide range of applications in many engineering fields[1]. It has the advantages of local materials, abundant raw materials, low cost, good plasticity, high strength, and good durability. But concrete also has unavoidable disadvantages, such as low tensile strength, high self-weight and prone to cracks[2]. Adding fibers to concrete can slow down or prevent the cracking of concrete, help the concrete to bear the tensile force, and effectively make up for the disadvantage of the low tensile capacity of ordinary concrete. Impact resistance mainly refers to the law of solid or structure resisting deformation or damage under the action of instantaneously changing load[3]. Therefore, using impact resistance and tensile strength to measure the toughness of lightweight aggregate concrete can more intuitively understand the reliability and stability of the structure of high-strength lightweight aggregate concrete.

Among various research methods, the method of adding fiber is to improve the performance of concrete, which is the hot spot of current concrete research, and has achieved excellent results[4]. Fiber reinforced concretes commonly used in current engineering construction are: glass fiber reinforced concrete, carbon fiber reinforced concrete, steel fiber reinforced concrete and synthetic fiber foamed concrete[5]. Such advantages have become the key development direction in the field of fiber reinforced concrete. Since the earliest asbestos cement was found to contain substances that are carcinogenic to human beings in its dust, countries around the world have imposed restrictions on the opening and use of asbestos in the last century, and the use of asbestos has been Gradually replaced by synthetic fibers. my country's research on the impact resistance of fiber reinforced concrete began in the late 1990s, when the fiber research type was mainly steel fiber and glass fiber. "Performance Test Method", which proposes a pendulum test method for the impact resistance of glass fiber reinforced cement[6]. With the increasing application of fiber reinforced concrete in engineering construction in my country, more and more scholars and institutions The performance

  DOI: 10.25236/icceme.2022.029

of fiber reinforced concrete has been studied. In addition to steel fiber, various fiber reinforced concrete such as polydiene fiber, Dura fiber and carbon fiber have been included in the research, and some research and analysis results have been obtained.

2. Experimental protocol

2.1. Test equipment and materials

The raw materials used for the preparation of synthetic fiber concrete in this test are: Portland cement, laboratory-selected sand, crushed stone, water, synthetic polypropylene fiber (PP) with a length of 40mm, and synthetic polypropylene fiber (PP) with a length of 20mm.) and polyacrylonitrile fibers. The cement used in this experiment was Tangshan Shunfa P. O42.5 grade ordinary Portland cement, the measured maximum particle size of the aggregate crushed stone used is Dmax=37.5mm, and the measured sand rate is 40%; fly ash: Class II fly ash produced by Hubei Hanchuan Power Plant, Specific surface area is 325 m2/kg; slag: ground slag produced by Wuhan Iron and Steel Company, specific surface area is 600m2/kg; silica fume: by-product of Wuhan Silicon Steel Plant (abbreviated as SF), density 2.2g/cm3, average particle size is 0.18 μm; light aggregate: grade 800 crushed stone-shaped expanded shale ceramsite from Hubei Yichang Baozhu Ceramsite Co., Ltd., and its relevant performance indicators are shown in Table 1; admixture: retarder produced by WISCO Haoyuan Admixture Factory Plastic FDN-9001; fine aggregate: medium-coarse river sand, the fineness modulus is 2.7 ~ 2.8, and the mud content is less than 1%. The research on polypropylene (fiber concrete) started earlier, and it is the largest amount of synthetic fiber concrete today. Polypropylene fibers can be divided into two types according to their shapes: polypropylene monofilament fibers and polypropylene mesh fibers, also known as polypropylene film split fibers. According to the fiber length, it can be divided into polypropylene short fibers; polypropylene long fibers are longer than fibers.

Equipment used: KQ-300VDE three-frequency CNC ultrasonic cleaner, Kunshan Ultrasonic Instrument Co., Ltd.; DF-101SZ constant temperature heating magnetic stirrer, Henan Yuhua Instrument Co., Ltd.; NN-GF362M microwave oven, Shanghai Panasonic Microwave Co., Ltd. ; SU8010 Field Emission Scanning Electron Microscope, Hitachi, Japan; D8 ADVANCE X-ray Diffractometer, Bruker, Germany; Nicolet IS50 Fourier Transform Infrared Spectrometer, Thermofisher, USA; WKO-2T Vibrating Sample Magnetometer, Beijing Wuke Optoelectronics Technology Co., Ltd.; SHZ-B water bath constant temperature oscillator, Shanghai Boxun Business Co., Ltd. Medical Equipment Factory; UV-5100 Spectrophotometer, Shanghai Yuanyan Instrument Co., Ltd.

2.2. Test proportioning and test piece making

The benchmark mix ratio of concrete and the amount and variety of fibers affect the properties of fiber-reinforced concrete to a large extent, including workability of construction, mechanical properties after hardening, and durability[7]. In this paper, based on the strength grades commonly used in engineering and the currently commonly used admixtures, the reference mix ratio, the steel fiber content (Vf= 2. 0%) and the Dura fiber content (Vp= 1. 2 kg*m^{-3}) were selected. , although the slump of the two kinds of fiber reinforced concrete is obviously reduced, it can still meet the general construction technical requirements. The concrete prepared with the data mix ratio cured under standard curing conditions for 28 d: the benchmark concrete compressive strength was 39.5 MPa, the FRC compressive strength was 46 MPa, and the SPHFRC compressive strength was 44.5 MPa. In order to ensure that the strength of the mixed concrete is consistent, the method of first dry mixing and then wet mixing is adopted, and the mixing steps are highly consistent, so as to minimize the error of test results caused by different procedures. Wet the iron plate first before mixing to ensure that the iron plate will not affect the water-cement ratio of the fresh concrete due to water absorption. The impact test used 100mm × 100mm × 100mm cube specimens, and the preparation of the specimens strictly followed the "Standards for Test Methods for Mechanical Properties of Ordinary Concrete".

3. Test research on impact resistance

3.1. Experiment method

The impact resistance of concrete can reflect the amount of energy that the concrete material can absorb before failure[8]. In this test, the drop weight test was used to test the impact resistance of concrete. The drop-weight impact tester device used in this test. The testing machine is mainly composed of a bearing platform, a drop weight, a control device, and a track. The quality and drop height of the drop weight can be manually modified. According to the China Engineering Construction Association standard "Fiber Concrete Test Method Standard", the weight of the drop weight is determined to be 9kg, and the drop height is determined to be 500mm.

The specific operation steps in the test process are as follows: (1) Take out the test piece that meets the test conditions and put it into the fixed frame in the center of the platform; (2) Place a small steel ball on the surface of the test piece, the purpose of which is to ensure the drop hammer. The hit points should be concentrated on the same position of the test piece; (3) Before starting the test, determine and adjust the quality of the drop weight and the drop height of the drop weight. Make the console switch energized, the electromagnet can be turned on to allow the drop weight to be sucked, and when the electromagnet is turned off, the drop weight can be lowered to hit the specimen, and a test is completed. (4) The judging standard of the test is to record the number of hammer blows for cracks generated by the initial failure of the specimen and the number of hammer blows when it is completely destroyed.

3.2. Test data analysis

The experiment uses a 100mm*100mm*100mm cube specimen, and the data collected and recorded in the test are as follows: ① the number of hammer blows N_1 when the concrete specimen has the first crack; ② the total number of hammer blows N_2 when the concrete is completely destroyed.

Calculate the impact energy W_1 consumed by the initial failure of the specimen and the impact energy W_2 when it is completely destroyed by formula (1). This experiment mainly compares the final failure energy meter W_2 .

$$W = mgh \times N \tag{1}$$

In the formula: M is the weight of the falling weight, which is 8kg; g is the acceleration of gravity; h is the falling distance of the weight, which is 500 mm; N is the number of times the falling weight is dropped. The ductility index β of the specimen is calculated by formula (2):

$$\beta = (N_2 - N_1) / N_2 \tag{2}$$

The hammering number N_1 when the first crack occurs, the hammering number N_2 when the first crack occurs, the absorbed energy W and the ductility index β recorded in the impact test are shown in Table 1.

Group A represents the concrete specimen without cellulose, B, C, and D represent 20mm polypropylene fiber, 40mm polypropylene fiber, and polyacrylonitrile fiber, respectively, and the numbers represent the fiber content of each m3 specimen. It can be seen from the formula W = mgh×N that the concrete absorbs impact energy, the amount of change is the number of times of resistance to falling hammers. Compared with the group A, W increased by 105.69%, 188.93%, 239.19% and 322.32% respectively with the increase of the dosage. It is concluded that the increase of fiber content can effectively improve the impact resistance of fiber reinforced concrete, and the more the increase, the more significant the effect[9]. For the observation of the ductility index, it can be compared whether the polypropylene fibers of group B and group C can improve the ductility index of concrete when the content of polypropylene fibers increases. Among them, the peaks of group B appear at about 3kg/m3 and 6kg/m3, indicating that it is not an infinite increase. Different fibers have different dosages for improving ductility.

Table 1 Impact times, impact absorbed energy and ductility index of the specimen

Number	N1	N2	W/J	β/%
A0	7	15	662.2	53.33
B1	12	28	1236.1	57.14
B3	14	36	1589.2	61.11
B6	13	39	1721.7	66.67
B9	17	45	1986.5	62.22
C1	15	33	1456.8	54.55
C3	15	45	1986.5	66.67
C6	17	53	2339.7	67.92
C9	18	61	2692.9	70.49
D1	13	21	927.1	38.10
D3	13	21	927.1	38.10
D6	15	22	971.2	31.82
D9	17	24	1059.5	29.17

4. Results and discussion

4.1. Test results

The addition of fibers can effectively improve the initial cracking times of concrete under impact load, the number of shocks when completely broken, the energy absorbed by the impact, the ductility index, and the impact toughness[10]. The specific results are as follows: the increase of fiber content will also When the number of shocks to resist initial cracking and the number of failures of concrete are increased, group B has an upward trend as a whole[11]. Compared with group A, the number of final cracking hammers increased by 71.43% and 100% respectively when the dosage is from 1kg/m3 to 9kg/m3. , 85.71%, 200%; the dosage of group C increased from 1kg/m3 to 9kg/m3 by 120%, 200%, 250%, and 306.7%, respectively; the dosage of group D increased from 1kg/m3 to 9kg/m3 Compared with group A, m3 increased by 40%, 40%, 46% and 60% respectively. Among them, the impact resistance improvement effect of group C was better, and the highest improvement reached 306.7%.

32 FRC and SPHFRC test blocks were selected for the test, and the initial crack strength and fracture strength of each test block are shown in Table 2.

Table 2 Test results of falling weight method

Sample numbering	Steel fiber reinforced concrete(FRC)			Polypropylene-steel hybrid fiber reinforced concrete(SPHFRC)		
	Initial crack strength	Breaking strength	Strong impact degree of growth	Initial crack strength	Breaking strength	Strong impact degree of growth
1	61	114	53	71	131	60
2	47	122	75	134	182	48
3	68	132	64	73	101	28
4	89	145	56	102	150	48
5	62	127	65	91	135	44
6	72	136	64	225	306	81
7	47	132	85	85	113	28
8	44	90	46	79	108	29
9	90	182	92	52	104	52
10	85	146	61	73	207	134
11	84	139	55	73	94	21
12	104	169	65	242	322	80
13	36	98	62	90	135	45
14	45	111	66	135	201	66
15	50	104	54	89	131	42
16	80	150	70	95	200	105

17	31	70	41	95	184	89
18	70	141	71	105	157	52
19	106	204	98	146	186	40
20	98	204	106	122	180	62
21	32	61	29	86	112	26
22	92	154	62	108	188	80
23	41	80	39	113	173	60
24	41	85	44	133	180	47
25	56	139	83	97	114	17
26	65	120	55	230	310	80
27	45	96	51	338	379	41
28	99	207	108	135	237	102
29	56	106	50	110	135	25
30	77	140	63	117	160	43
31	70	125	55	31	60	29
32	160	246	86	68	114	46

4.2. Statistical Analysis

Table 3 Statistical analysis

	Crack		Fracture	
	FRC	SPHFRC	FRC	SPHFRC
Minimum intensity/Time	31	31	61	60
Maximum intensity/Time	160	338	246	379
Average/Time	69	117	134	172
Standard deviation/Time	28	62	42	73
Covariance/%	40.6	53.0	31.3	42.4

The statistical results shown in Table 3 show that the minimum initial crack strengths of FRC and SPHFRC are both 31 times, the maximum values are 160 times and 338 times, respectively, the minimum value of the two fracture strengths differ only by 1 time, and the fracture strength of SPHFRC reaches 379 times. 133 times more than that of FRC. It can be seen that the maximum value of both initial crack strength and fracture strength of SPHFRC is much larger than that of FRC. The number of impact strength increases after initial cracking is 65 times for FRC and 55 times for SPHFRC.

5. Conclusions

The incorporation of fibers improves the flexural strength and impact toughness of lightweight aggregate concrete. Among them, the effect of steel fiber in improving impact toughness is the most significant. When its volume ratio is 2%, the impact energy of the specimen reaches 101 J, which is 3.16 times that of the benchmark concrete; the higher the elastic modulus of organic fiber, the lighter the improvement is. The impact resistance of aggregate concrete is better.

Fiber hybrid combines the characteristics of steel fiber and organic fiber. On the premise of not increasing cost and self-weight, its effect on improving the impact toughness of lightweight aggregate concrete is better than that of fiber alone. Among them, steel fiber, polypropylene fiber and polyacrylonitrile fiber had the best effect, and the yields were 62.4 kg/m3, 0.5 kg/m3 and 0.5 kg/m3, respectively.

The impact resistance of the layered steel fiber lightweight aggregate concrete is not as good as that of the fully covered steel fiber lightweight aggregate concrete. This is because the reduction of the fiber content reduces the strong resistance element of the matrix, which reduces the impact energy.

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