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Research Paper

Design of test method for mechanical properties of recycled coarse aggregate concrete

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Abstract: *In this paper, the preparation process, size, quantity and code of recycled coarse aggregate specimen are introduced in detail based on the test content and the performance of raw materials. Finally, the experimental methods of compressive strength, splitting tensile strength, flexural strength and mechanical properties of recycled coarse aggregate concrete are designed.*
Key words: *recycled coarse aggregate concrete; Mechanical properties; Test method*

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In this paper, the performance of the ordinary recycled concrete prepared by the traditional process and the high-performance recycled concrete prepared by the improved recycled aggregate production process are compared, so the test scheme is also divided into two parts. The first part is the production of recycled aggregate by traditional process. For this part of recycled concrete, the basic mechanical properties such as compressive strength, splitting resistance and tensile strength are mainly measured. The test results verify the existing domestic research results and provide reference for the performance research of improved high-performance concrete. The second part focuses on improving the production equipment of recycled aggregate, increasing the basic physical properties of high-performance recycled aggregate produced by mechanical grinding and washing, and the compressive strength performance of high-performance recycled concrete. Finally, whether the compressive strength, flexural strength and other mechanical properties of HPC are changed after high temperature fire is studied.

1. Test work content

(1) Refer to a large number of domestic and foreign literature, design feasible test scheme;
(2) through research, test and other means to improve the test program, to determine the mix ratio of concrete;
(3) Prepare raw materials, contact the laboratory and determine the test time;
(4) Using the traditional process to produce ordinary recycled coarse aggregate;
(5) Add grinding, washing and other processes on the basis of the traditional process, and subdivide the recycled aggregate;
(6) The physical properties of ordinary recycled coarse aggregate and high performance recycled aggregate were compared;
(7) Make matrix concrete test blocks, ordinary recycled concrete test blocks and high-performance recycled concrete test blocks, and maintain them according to the standard method;
(8) The above three types of test blocks to carry out compressive and splitting tensile tests;
(9) High temperature heating treatment of high-performance recycled concrete, heating through 200°C, 400°C, 600°C, 800°C four stages;
(10) Compressive and flexural mechanical tests are carried out on high-performance recycled concrete test blocks after high temperature.

2. Performance of raw materials

(1) Cement

The cement used in this study is 32.5R ordinary Portland cement produced by Henan Anyang Hubo Cement Company, whose apparent density is 3100kg/ m^3. The chemical composition and physical properties of cement are shown in Table 1 and 2 below.

Table 1 Chemical composition of cement (%)

Name of the material	CaO	SiO2	Al2O3	MgO	Fe2O3	other
Percentage content	60.86	21.76	4.61	4.55	3.97	4.25

Table 2 Physical properties of cement

The project name	Setting time(min)		Flexural strength(Mpa)		The compressive strength(Mpa)	
	Initial setting	Final set	3d	28d	3d	28d
The national standard	≥45	≤390	≥2.5	≥5.5	≥11	≥32.5
The measured values	112	195	3.7	8.1	18.5	40.8

(2) natural aggregate

Natural fine aggregate is common yellow sand, fineness modulus is 2.85; Natural coarse aggregate is continuously graded gravel with a maximum particle size of 31.5mm. All natural aggregates come from the building materials market of Anyang Development Zone, as shown in Table 3 below.

Table 3 Physical properties of natural aggregate

The name of the aggregate	Grain size (mm)	The apparent density (kg/ m^3)	Loose packing density (kg/ m^3)	Bibulous rate (%)	Crush indicators (%)
Natural coarse aggregate	5~31.5	2797	1459	0.76	4.55
Natural fine aggregate	≤5	2576	1387	2.75	–

(3) Reclaimed coarse aggregate

The abandoned concrete used in this test comes from an office building demolished for urban reconstruction in the old city of Anyang, which was built in the early 1990s. The ordinary recycled coarse aggregate processed by the traditional process is shown in Table 4 below.

Table 4 Physical properties of common recycled coarse aggregate

The name of the aggregate	Grain size (mm)	The apparent density (kg/ m^3)	Loose packing density (kg/ m^3)	Bibulous rate (%)	Crush indicators (%)
Recycled coarse aggregate	5~31.5	2476	1288	6.45	16.73

(4) water

Concrete mixing, maintenance water for anyang city tap water.

(5) Fly ash

The fly ash used in this test comes from Anyang Thermal power plant, with vitreous content of 85.2%, water requirement of 94.8% and specific surface area of 542 m^2 / kg.

(6) high efficiency water reducing agent

The high efficiency water reducing agent is naphthalene FDN-SR, the water reducing rate is 15% ~ 20%.

3. Preparation of specimens

3.1 The manufacturing process of specimens

The manufacturing process of matrix concrete and ordinary recycled concrete strictly follows "Performance Test Method of Ordinary Concrete Mixture". During the specimen production, the amount of raw materials was measured according to the requirements of the mix ratio design. Coarse aggregate and sand were mixed into the mixer and mixed evenly. After that, an appropriate amount of water (about 1/3) was added to continue mixing, and cement was added to mix evenly, and the remaining water (about 2/3) was added to mix evenly.

The secondary mixing process can improve the performance of recycled concrete, so this test intends to use this method in the mixing of high-performance recycled concrete.

Take out the mixed concrete from the mixer, load it into the standard specimen mold, and then put it on the concrete vibration table, vibrate and tamp it and wipe its surface flat. The specimen was placed in the standard curing room for 24 hours, then demoulded and coded. Then curing was carried out under standard curing conditions (temperature 20°C±2°C, humidity above 95%) until the test.

3.2 Size, quantity and coding of specimens

In this project, the compressive and splitting tensile tests of matrix concrete, ordinary recycled concrete and high-performance recycled concrete, as well as the compressive strength and flexural strength of high-performance recycled concrete after high temperature fire are completed. The size, quantity and coding meanings of the specimens are shown in Table 5, Table 6 and Table 7.

Table 5 Size of specimen

Test type	Specimen size（mm×mm×mm）	Specimen size
Compression test	150×150×150	The cube
Split tensile test	150×150×150	The cube
Compression test after fire	150×150×150	The cube
Flexural resistance test after fire	150×150×600	prism

Table 6 Code and quantity of matrix concrete and ordinary recycled aggregate specimens

Specimen number of coarse aggregate	replacement ratio (%)	water-cement ratio	sand ratio (%)	Sproduction quantity
NC-1	0	0.40	34	15
NC-2	0	0.45	35	15
NC-3	0	0.50	36	15
NC-4	0	0.55	37	15
RC-25-1	25	0.40	34	15
RC-25-2	25	0.45	35	15
RC-25-3	25	0.50	36	15
RC-25-4	25	0.55	37	15
RC-50-1	50	0.40	34	15
RC-50-2	50	0.45	35	15
RC-50-3	50	0.50	36	15
RC-50-4	50	0.55	37	15
RC-75-1	75	0.40	34	15
RC-75-2	75	0.45	35	15
RC-75-3	75	0.50	36	15
RC-75-4	75	0.55	37	15
RC-100-1	100	0.40	34	15
RC-100-2	100	0.45	35	15
RC-100-3	100	0.50	36	15
RC-100-4	100	0.55	37	15
RC-50-3-I	50	0.50	20	3
RC-50-3-II	50	0.50	25	3
RC-50-3-III	50	0.50	30	3
RC-50-3-IV	50	0.50	35	3
RC-50-3-V	50	0.50	40	3
RC-50-3-VI	50	0.50	45	3

Table 7 Code and quantity of high-performance recycled concrete specimens

Specimen number of coarse aggregate	replacement ratio (%)	water-cement ratio	sand ratio (%)	Sproduction quantity
NC-0	0	0.45	35	36（12）
HRC-25	25	0.45	35	36（12）
HRC-50	50	0.45	35	36（12）
HRC-75	75	0.45	35	36（12）
HRC-100	100	0.45	35	36（12）
NC-1	0	0.45	35	12
NC-2	0	0.45	35	12
NC-3	0	0.45	35	12
HRC-25-1	25	0.45	35	12
HRC-25-2	25	0.45	35	12
HRC-25-3	25	0.45	35	12
HRC-50-1	50	0.45	35	12
HRC-50-2	50	0.45	35	12
HRC-50-3	50	0.45	35	12
HRC-75-1	75	0.45	35	12
HRC-75-2	75	0.45	35	12
HRC-75-3	75	0.45	35	12
HRC-100-1	100	0.45	35	12
HRC-100-2	100	0.45	35	12
HRC-100-3	100	0.45	35	12
NC-Ⅰ	0	0.36	35	6
HRC-25-Ⅰ	25	0.36	35	6
HRC-50-Ⅰ	50	0.36	35	6
	75	0.36	35	

HRC-75- Ⅰ	100	0.36	35	6
HRC-100- Ⅰ				6

Note :(12) the number of specimens used for flexural test is 12, and the size of the specimen is 150mm×150mm×600mm; Other specimens were all 150mm×150mm×150mm in size.

4 Test method

The compressive strength, splitting tensile strength and flexural strength of concrete specimens were measured according to the relevant requirements of "Test Method for Mechanical Properties of Ordinary Concrete".

4.1 Determination method of compressive strength

(1) Test method

Take out the concrete specimen from the curing room, and wipe the surface of the specimen and the upper and lower pressure plates of the pressure testing machine clean. When installing specimens, pay attention to the adjustment of the position of the specimen, so that the center point of the specimen pressure surface and the center of the pressure plate of the pressure testing machine are positive, so that the specimen pressure is uniform. The loading speed is continuous and uniform, controlled at 0.4mpa per second. When the concrete specimen is rapidly deformed and close to failure, stop adjusting the throttle of the testing machine until the final failure. Record the failure load and complete the concrete compressive strength test.

(2) Determination of compressive strength

The determination formula of concrete cube compressive strength is calculated according to Formula 1:

$$f_{cc} = \frac{F}{A}$$

4.2 Determination of splitting tensile strength

(1) Test method

Take out the concrete specimen from the curing room, and wipe the surface of the specimen and the upper and lower pressure plates of the testing machine clean. In the installation of the specimen, pay attention to the adjustment of the position of the specimen, so that the center point of the splitting pressure surface of the specimen and the center of the pressure plate of the pressure testing machine. Between the upper and lower pressure plate and the specimen, the pad and the pad are aligned with the center line of the upper and lower surface of the specimen and perpendicular to the top surface. Continuous and uniform loading, the loading rate is controlled at 0.04mpa per second. When the concrete specimen is close to failure, stop adjusting the throttle of the testing machine until the final failure. The failure load was recorded and the splitting tensile strength test of concrete was completed.

(2) Determination of splitting tensile strength

The determination formula of concrete splitting tensile strength is calculated according to Formula 2:

$$f_{ts} = \frac{2F}{\pi A} = 0.637\frac{F}{A}$$

4.3 Determination method of flexural strength

The loading speed of the flexural strength test is controlled at 0.04mpa per second, and the strength value is calculated according to Formula 3:

$$f_f = \frac{Fl}{bh^2}$$

4.4 High temperature treatment method of high performance recycled aggregate concrete

Drx-36 high temperature furnace made in Shanghai is used in this experiment. The test design experienced temperatures of 20°C, 200°C, 400°C, 600°C, and 800°C. According to the predetermined processing temperature and batch batch test blocks into high temperature furnace, carefully observe the appearance of test blocks before and after high temperature. The heating mechanism of this test is as follows: firstly, the temperature is heated rapidly to the predetermined maximum temperature at a rate of 20°C/min, and then the furnace is opened at a constant temperature of 2.0h. The concrete test block is gradually cooled to room temperature, and then the compressive and flexural strength tests are carried out on the specimens. The compressive strength and flexural strength of concrete are determined in strict accordance with the "Standard for mechanical Properties test of Ordinary Concrete".

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