Forest Chemicals Revew
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2021 Page No. 258-266
Article History: Received: 24 February 2021, Revised: 05 April 2021, Accepted: 08 May 2021, Publication: 30 June 2021

Failure Mechanism Analysis of Polypropylene Fiber Recycled Concrete Strength Evolution with Age in Natural Forest Covered Quarry

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Abstract:

Forest evaporation and turbulent exchange intensity affect the characteristics of soil and stone. The accelerated demolition and construction speed of various projects leads to the accumulation of waste concrete. It is imperative to dispose and utilize waste concrete reasonably. Based on the research results of physical and mechanical properties of artificial sand, this paper combines 100% recycled coarse aggregate with 100% artificial sand. After adding polypropylene fiber to form a new type of fiber-reinforced artificial sand recycled concrete, the mechanical properties of the concrete were studied. In the experiment, 45 standard cube test blocks and 90 standard prism test blocks were designed and made with three concrete strength grades (C25, C35 and C45) corresponding to 5 polypropylene fiber contents (0%, 0.6%, 0.9%, 1.2% and 1.5%). Through cube and prism compressive strength test and elastic modulus test, the influence of different water cement ratio and different fiber content on the basic mechanical properties of concrete is studied. The experimental results reveal the binary relationship between the cube compressive strength and prism compressive strength of recycled concrete with fiber artificial sand affected by fiber content and water cement ratio. In this paper, the conversion relationship between compressive strength and axial compressive strength is analyzed, and the stress-strain constitutive relationship of fiber reinforced artificial sand recycled concrete prism under uniaxial compression is studied.

Keywords: *Recycled Concrete, Natural Forest Covered Quarry, Recycled Coarse Aggregate, Mechanical Properties.*

I. INTRODUCTION

Our country is rich in resources, and the crisis of raw materials of concrete will not come

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out in the short term, but our country will certainly face the problem of shortage of raw materials in the future [1-2]. The development of construction industry in China is far more than that of some developed countries. The environmental pollution caused by construction waste will be more and more serious. Therefore, the government of our country has begun to study the utilization of construction waste resources [3]. The research on the development of recycled concrete is still in the laboratory stage, which is later than that of the developed countries, but the corresponding results have been achieved.

Some domestic experts and scholars have stepped up the project research on recycled concrete, such as: the construction waste block technology researched by Professor Gu Jiaxun has obtained the national patent [4-5]. Shanghai construction component products Co., Ltd. makes concrete hollow blocks from waste concrete such as foundation pit support demolished by blasting in construction site [6]. All technical indexes of the products fully meet the engineering specifications of small concrete hollow blocks in Shanghai. At present, the main application of cement concrete pavement recycling technology in our country is on-site recycling technology, that is, first crush or crush the existing pavement, and then use the crushed or crushed pavement as the base or subbase in the new pavement structure, which is widely used in highway maintenance in our country. Therefore, the mechanical properties of recycled concrete and its application in structure are of great significance.

II. EXPERIMENTAL STUDY ON MECHANICAL PROPERTIES OF RECYCLED CONCRETE WITH DIFFERENT REPLACEMENT RATIO

2.1 Research on mechanical properties of recycled concrete

Compared with natural aggregate, recycled aggregate has low strength, high water absorption and large surface roughness. These differences lead to different basic properties of recycled concrete and natural aggregate concrete. In order to have a deeper understanding of the basic mechanical properties of recycled concrete, and to promote the application of recycled concrete in the process of China's modernization construction, this chapter will study the basic mechanical properties of recycled concrete with different replacement rates in detail.

Qinling 32.5R ordinary portland cement is used as cement, 2.75 ordinary sand is used as sand, tap water is used as water, and 31.5mm continuous graded crushed stone is used as natural coarse aggregate [7]. The recycled coarse aggregate is the waste concrete from the demolished buildings in the urban construction of Xi'an city and the waste concrete from the Civil Engineering Laboratory of Xi'an University of architecture and technology. The waste concrete is first crushed by manual and jaw crusher, and then cleaned, and then graded to produce the aggregate with the maximum particle size of 31.5mm.

The test of recycled concrete is carried out in accordance with the Standard for Test Methods of Mechanical Properties of Ordinary Concrete, and the following tests are carried out

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respectively. Cubic compressive strength test, this test uses 100mm×100mm×100mm specimens, prism compressive strength test, this test uses 100mm×100mm×300mm specimens. Split tensile strength test, this test uses 100mm×100mm×100mm specimens; 100mm×100mm×400mm specimens are used for flexural strength test.

1. Cube compressive strength test

In this test, the provisions of Standard for Test Methods of Mechanical Properties of Ordinary Concrete (GBT50081-2002) shall be strictly implemented. The calculation formula is as follows [8-10]:

$$f_{cu} = \frac{F}{A} \quad (1)$$

In which: f_{cu} —— compressive strength of concrete cube specimen shall be accurate to 0.1MPa

F —— failure load of specimen, N

A —— bearing area of specimen, mm^2

Standard for Test Methods of Mechanical Properties of Ordinary Concrete (GBT50081-2002) stipulates that the cube compressive strength measured by non-standard specimens shall be multiplied by the size conversion factor, and the test value for 100×100×100mm shall be 0.95.

2. Compressive strength test of prism

The formula for calculating the axial compressive strength of concrete specimens is as follows:

$$f_c = \frac{F}{A} \quad (2)$$

In which: f_c—axial compressive strength of concrete shall be accurate to 0.1MPa

F—failure load of specimen, N

A—pressure bearing area of specimen, mm^2

The compressive strength measured by the test is multiplied by the size conversion coefficient of 0.95, because the test adopts non-standard specimens.

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Fig 1: Cubic compressive strength test

Fig 2: Compressive strength test of prism

2.2 Analysis of strength test results

1. Cube compressive strength

The aggregate of recycled concrete is different from that of natural aggregate concrete, so the influence of age growth on the strength of recycled concrete and natural aggregate concrete is different. In the mechanical properties of concrete, the compressive strength of concrete is not

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only the most important but also the most basic one. Although the experimental research on the compressive strength of recycled concrete has been carried out at home and abroad, the conclusions drawn by different researchers are quite different. A large number of relevant tests have come to a common conclusion: the 28 d compressive strength of recycled aggregate concrete with the same water cement ratio is about 15% lower than that of natural aggregate concrete, but with the increase of age, the difference between the two will gradually narrow.

Because recycled aggregate is used in recycled concrete, the strength of waste concrete is closely related to that of recycled concrete. Under the same water cement ratio, the strength of recycled concrete is affected by the strength of recycled aggregate. The higher the strength of aggregate, the higher the strength of recycled concrete. The test results show that if micro silicon powder and superplasticizer are added into the waste concrete, and the strength of the waste concrete reaches 40-60 MPa, C70-C80 high-strength concrete can be prepared from the waste concrete used to produce recycled aggregate, especially when the recycled aggregate is mixed with natural river sand, the strength is better.

2. Compressive strength of prism

Like its compressive strength, the tensile strength of recycled concrete increases with age. The difference between the tensile strength of recycled concrete and that of natural aggregate concrete also increases with the increase of age, and remains unchanged after 28 days. The research on the tensile strength of recycled concrete is relatively less both at home and abroad. Jinli has studied the splitting tensile test, and the research shows that the strength of recycled concrete is reduced by 30% ~ 40% compared with ordinary concrete. Xiao Jianzhuang and Lanyang studied the uniaxial tensile test of recycled concrete and concluded that compared with ordinary concrete, the tensile strength of recycled concrete decreased by 31%.

Through analysis, the reasons for the decrease of the above indexes may be as follows: firstly, there are defects in recycled concrete, and there are a lot of micro cracks in recycled concrete. The existing defects and cracks have a greater impact on tensile failure, but a very small impact on compressive failure. Secondly, due to the small bonding force between recycled coarse aggregate and cement mortar interface, when the specimen is under tension, the specimen is easy to crack. Although the friction coefficient between aggregate and interface is relatively large, it has little effect on the tensile strength.

III. EXPERIMENTAL STUDY ON MECHANICAL PROPERTIES OF RECYCLED POLYPROPYLENE CONCRETE

3.1 Strengthening mechanism of fiber reinforced concrete

In 1963, J. P. romualdi and B. Batson put forward the theory of fiber spacing, which is based on online elastic fracture mechanics. According to the theory of fiber spacing, micro cracks, pores and other defects of different sizes exist in the concrete. When subjected to

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external force, the cracks and pores will produce greater stress concentration, which will lead to the continuous expansion of cracks and the final failure of concrete.

If there are no defects in the cement matrix, the strength of recycled concrete can reach ten times or more of the normal strength. Therefore, if the fiber is added into the brittle matrix, the ability of the composite to prevent the initiation and expansion of cracks before and after loading will be effectively improved in the process of composite structure formation and stress failure, so as to achieve the purpose of fiber reinforced and toughened concrete. The theory of fiber spacing makes the existence of fiber can change the properties of matrix (one crack is broken), prevent the diffusion of cracks in matrix, and enhance the toughness of matrix.

The strength and elastic modulus of the composites are in accordance with the principle of elastic superposition of the components in the composites according to the law of mechanical mixing of the composites.

In recent years, polypropylene fiber has been gradually used in municipal, highway and construction engineering in our country. In these fields, the application scope is expanding, and most of the engineering application effect is good.

After a lot of experimental research and engineering experience summary, the Federal Highway strategic plan (SHRP) of the United States believes that organic fiber reinforced concrete, such as polypropylene fiber reinforced concrete, can be used as a kind of pavement high performance concrete.

3.2 Experimental study on basic mechanical properties of fiber recycled concrete

1. Failure mode of cube compressive strength

It is found that the failure mode of recycled concrete or ordinary concrete is different from that of recycled concrete.

In recycled or ordinary concrete specimens, microcracks are distributed in an irregular direction. When the microcracks propagate in the direction parallel to the stress after compression, the cracks perpendicular to the stress direction will close. When the load increases continuously, the cracks parallel to the stress direction on the surface continue to extend and develop to the inner layer. The concrete surface begins to bulge and peel off, and finally becomes a positive and inverted pyramid. For the recycled concrete mixed with fiber, the ultimate failure mode of the specimen is cracking but not breaking, and there is no obvious spalling phenomenon. The reasons are as follows: the three-dimensional distribution of the fiber in the matrix, or due to vibration, makes the fiber dominant in the vertical compression direction. When the matrix is compressed, the expansion of the transverse crack caused by tension is prevented by the fiber, and the fiber absorbs part of the energy, and the rest of the energy is released in the form of new cracks, which makes the energy distribution become uniform and universal.

2.Test results and analysis of cube compressive strength

TABLE I. Test results of cube compressive strength of C30 fiber recycled concrete

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SERIAL NUMBER	NUMBER	COMPRESSIVE STRENGTH OF CUBE (MPA)	REMARKS
1	R10Z—30	38.68	10-life recycled coarse aggregate, substitution rate 30%, adding three fibers
2	R10ZTL—30	37.02	10-life recycled coarse aggregate with substitution rate of 30%, mixed with three branches, TANK and nylon fiber
3	R10Z—50	35.17	10-life recycled coarse aggregate with a substitution rate of 50% and three fibers added
4	R10ZTL—50	30.19	10-life recycled coarse aggregate with a substitution rate of 50%, adding three branches, TANK and nylon fibers

It can be seen from table 1 that: (1) the compressive strength of r10z-30 is increased by 2% compared with r10-30, and that of r10z-50 is increased by 11.5% compared with r10-50; (2) The compressive strength of R10ZTL-30 is 3% lower than that of R10—30, and that of R10ZTL-50 is 4.3% lower than that of R10—50.

3. Splitting tensile failure mode

During the test, no cracks were found on the surface of the specimen at the initial stage of loading. With the increasing of the load, the stress will continue to increase. Cracks gradually appear on the side surface of the specimen with the increasing of the stress. Initially, the cracks appear in the center of the specimen. When the load continues to increase, the cracks gradually develop near the cushion strip. When the load continues to increase, the crack width in the middle of the specimen increases gradually, and finally the specimen is split. Although the splitting tensile failure of fiber recycled coarse aggregate concrete is similar to that of recycled coarse aggregate concrete or ordinary concrete. However, the duration from crack appearance to crack widening to failure is longer, and from the failure section of the specimen, the recycled concrete is completely broken along the splitting surface, while the fiber recycled concrete only has an obvious crack along the splitting surface, and the overall integrity is still good.

4. Test results of splitting tensile strength

TABLE II. Test results of splitting tensile strength of C30 fiber recycled concrete

SERIAL NUMBER	NUMBER	SPLITTING TENSILE STRENGTH (MPA)	REMARKS
1	R10Z—30	3.42	10-life recycled coarse aggregate, substitution rate 30%, adding three fibers

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2	R10ZTL—30	3.40	10-life recycled coarse aggregate with substitution rate of 30%, mixed with three branches, TANK and nylon fiber
3	R10Z—50	3.37	10-life recycled coarse aggregate with a substitution rate of 50% and three fibers added
4	R10ZTL—50	3.00	10-life recycled coarse aggregate with a substitution rate of 50%, adding three branches, TANK and nylon fibers

It can be seen from table 2 that: (1) the splitting tensile strength of R10Z-30 and R10ZTL-30 is 9.3% and 8.6% higher than that of R10-30 respectively （2) The splitting tensile strength of R10Z-50 and R10ZTL-50 is 15.8% and 3.1% higher than that of R10-50, respectively.

3.3 Summary of test results of basic mechanical properties

Through the above analysis, it is found that: (1) the compressive strength, splitting tensile strength and flexural strength of recycled concrete mixed with three fibers have been greatly improved; (2) The compressive strength of recycled concrete mixed with three branches and nylon fibers has little change, but the splitting tensile strength and flexural strength have been improved to some extent. (3) The compressive strength of recycled concrete mixed with three branches, nylon and TANK fibers decreases, while the flexural strength and splitting tensile strength increase slightly. In a word, due to the incorporation of fiber, the overall strength of recycled concrete is higher than that of corresponding recycled concrete, and the enhancement effect is obvious, especially the splitting tensile strength and flexural strength.

IV. CONCLUSION

Based on the recycling of waste concrete blocks, this paper discusses and analyzes the basic properties of recycled coarse aggregate with different life, as well as the basic mechanical properties and strength development rules of recycled concrete and fiber recycled concrete, providing theoretical basis and reference for vigorously popularizing and applying recycled concrete.

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