Mechanical Property Tests for Waste Tires Steel Fiber Reinforced Concrete

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Abstract. In order to research the application possible of waste fiber steel fiber reinforced concrete in road engineering, the effect of fiber types and strength grade of base concrete on cube compressive strength, splitting strength, flexural-tensile strength and other mechanical properties of waste tires steel fiber and conventional steel fiber reinforced concrete were determined. The results show that: the waste tires steel fiber has a significant enhancement effect on the strength of concrete, and it can be used as green road material as the waste tire powder. The strength of waste steel fiber reinforced concrete is lower than that of conventional steel fiber. To achieve the same strength, the amount of waste tires steel fiber required to be about 40% higher than conventional steel fiber. In addition, the effect of strength grade of base concrete on the growth ratio of flexural tensile strength of waste tires steel fiber reinforced concrete is weak, and the influence on growth ratio of the compressive strength and splitting strength can be neglected.

Keywords: Cement concrete · Steel fiber · Waste tires · Mechanical property

1 Introduction

With the development of the automobile industry, the recycling of waste tires has received more and more attention. Waste tires are mainly composed of rubber, carbon black and metal, etc., with a high resource recycling value, but inappropriate storage, regeneration, disposal and other processes will cause environmental and safety issues, affecting people's health [1, 2]. Therefore, how to rationally and effectively use and disposal of waste tires, to prevent environmental pollution has become a problem people must face.

At present, the old tires are mainly used for refurbishing new tires. Waste tires are mainly used for recycled rubber and the production of rubber powder, while the metal wire part is no better use of channels [3, 4]. As the tire wire is mostly cold drawn or tempered steel wire, tensile strength up to 1800 MPa, with excellent tensile, bending performance [5]. With the development of steel fiber reinforced concrete [6–10] and the development of tire recycling process, the use of waste tires to produce steel fiber, and

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then the production of waste tire steel fiber reinforced concrete is possible. In this paper, the mechanical properties such as compressive strength, splitting strength and flexural tensile strength of waste tire steel fiber reinforced concrete were studied in order to provide reference to recycle waste tire.

2 Raw Material

2.1 Steel Fiber

In order to compare the difference between the steel fiber and the conventional steel fiber, the paper uses two kinds of steel fiber raw materials, namely Zhitai waste tire steel fiber and Zhitai conventional milling steel fiber with end hook. The performance of the two fiber's indicators is shown in Table 1. Among them, the waste tire steel fiber is mainly obtained by the following process: pull-cut off-shaping.

Table 1. Parameters of steel fiber

Type	Tensile strength/MPa	Bending performance	Equivalent diameter/mm	Length/mm	Process	Shape	Remarks
Waste tires steel fibe	1260	Qualified	1.0	35.34	Cutting	With indentation	Uniform, neatly cut, little surface with a small amount of rubber adhesion
Conventional steel fiber	990	Qualified	1.0	36.02	Milling	With end hook	Uniform, neatly cut, the surface glossy

2.2 Cement

P.O 42.5 cement used in this test was produced in Shanxi Weidun. The physical mechanical performance indicators are shown in Table 2 and meet Chinese specification "General Portland cement" GB175-2007 requirements.

Table 2. Performance indicators of Cement

Finess/(m^2/kg)	Setting time/min		Compression strength/MPa		Flexural tensile strength/MPa		Stability (boiling method)
	Initial	Final	3d	28d	3d	28d	
350	180	275	35.6	49.8	6.1	8.9	Confirmed

2.3 Coarse Aggregate

The coarse aggregate is made of limestone and has a particle size of 5 mm to 20 mm and the gradation is shown in Table 3.

Table 3. Coarse aggregate gradation

Mesh diameter/mm	Cieve quality/g	Cieve percentage/%	Cumulative sieve percentage/%
19	125	0.8	0.8
16	930	6.2	7
13.2	2870	19.1	26.1
9.5	5320	35.5	61.6
4.75	5360	35.7	97.3
0	400	2.7	100

2.4 Fine Aggregate

The source of the fine aggregate is Duling River. Its gradation is shown in Table 4.

Table 4. Fine aggregate gradation

Mesh diameter/mm	Sieve quality/g	Sieve percentage/%	Cumulative sieve percentage/%
4.75	9	1.8	1.8
2.36	47	9.3	11.1
1.18	57	11.3	22.5
0.6	141	28	50.5
0.3	151	30	80.5
0.15	57	11.3	91.7
0	41	8.2	100

2.5 Water

Water used in this test is Taiyuan municipal tap water.

3 Experimental and Analysis on Mechanical Properties of Steel Fiber Reinforced Concrete

In order to characterize the mechanical properties of waste fiber steel fiber reinforced concrete, C30 and C40 base concrete were used to prepare conventional steel fiber reinforced concrete and waste fiber steel fiber reinforced concrete with different volume ratio. Then, the cube compressive strength, splitting strength and flexural tensile strength was compared.

3.1 Test Methods

Concrete mix design reference to Chinese specification “highway cement concrete pavement construction technical rules” JTG /T F30-2015. The mix of C30, C40 concrete is shown in Table 5. Among them, the amount of water-reducing agent is meet the requirement of 30–55 mm slump.

Table 5. Concrete mix

Strength grade	Water/kg	Cement/kg	Sand/kg	Stone/kg	Water reducing agent/kg
C30	195	380	833	981	5.3
C40	195	460	783	998	5.8

After several tests, we found that to achieve the equal strength, the volume ratio of waste tire steel fiber was higher than conventional steel fiber. According to the test results, the volume ratio of the two kinds of steel fiber is shown in Table 6.

Table 6. Steel fiber volume ratio

Type	Volume ratio/%				
conventional steel fiber	0.5	1.0	1.5	2.0	2.5
waste tires steel fiber	1.2	1.8	2.4	3.0	3.6

The test of cube compressive strength, splitting strength and flexural tensile strength of steel fiber concrete is referenced to Chinese specification "highway cement and cement concrete test procedures" JTG E50-2005.

3.2 Test Results and Analysis

Cube Compressive Strength. When the concrete strength grade is C30 and C40, the effect of fiber volume ratio on the cube compressive strength of two kinds of steel fiber reinforced concrete is shown in Fig. 1.

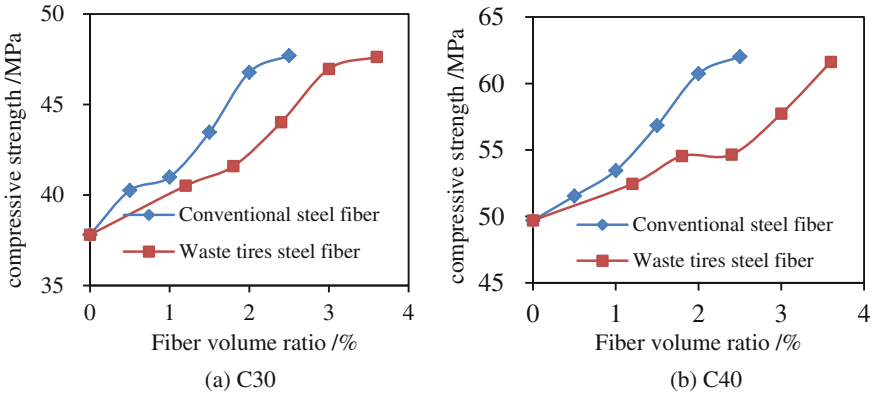

Fig. 1. The relationship between fiber volume ratio and cube compressive strength

When the fiber volume ratio is the same, the compressive strength of the conventional steel fiber reinforced concrete is obviously higher than that of the waste tire steel fiber. With the increase of the volume ratio of steel fiber, the compressive strength of the two kinds of steel fiber reinforced concrete is increasing, the growth ratio shown in Fig. 2.

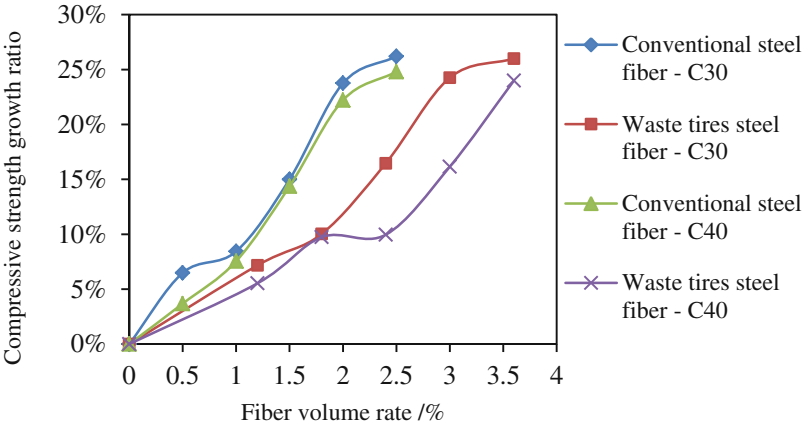

Fig. 2. Growth curve of cube compressive strength

When the steel fiber type is same, the strength growth ratio of C30 and C40 concrete is similar, that is, the strength grade of the concrete has little effect on the strength growth ratio. When the type is different, the compressive strength growth ratio of conventional steel fiber reinforced concrete is higher than that of waste tire steel fiber reinforced concrete. As the waste tire steel fiber processing technology, shape characteristics and other factors, to achieve the same growth ratio, the volume ratio of conventional steel fiber is about 38.7% higher.

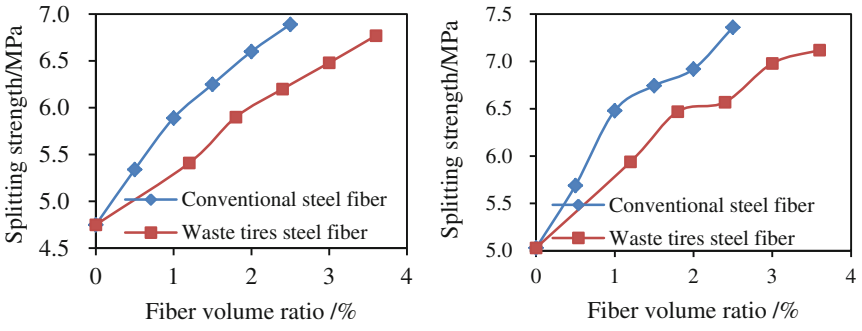

Fig. 3. The relationship between fiber volume ratio and splitting strength

Splitting Strength. When the strength grade of the base concrete is C30 and C40, the effect of the fiber volume ratio on the splitting strength of the two kinds of steel fiber concrete is shown in Fig. 3. When the fiber volume ratio is the same, the splitting strength of conventional steel fiber concrete is higher than that of waste tire steel fiber.

With the increase of the fiber volume ratio, the splitting strength of the two kinds of steel fiber reinforced concrete is increasing, as shown in Fig. 4. To the C30 concrete, the splitting strength of the two kinds of steel fiber concrete increases uniformly with the volume ratio. Compared with C30 concrete, when the strength grade is 40 MPa, the splitting strength growth ratio decreased when the steel fiber volume ratio is greater than 2%. The strength grade of concrete has little effect on the growth ratio of splitting strength, and the growth ratio of conventional steel fiber reinforced concrete is higher than that of waste tire steel fiber concrete. To achieve the same growth ratio, the amount of waste tire steel fiber is about 42.9% higher than that of conventional steel fiber.

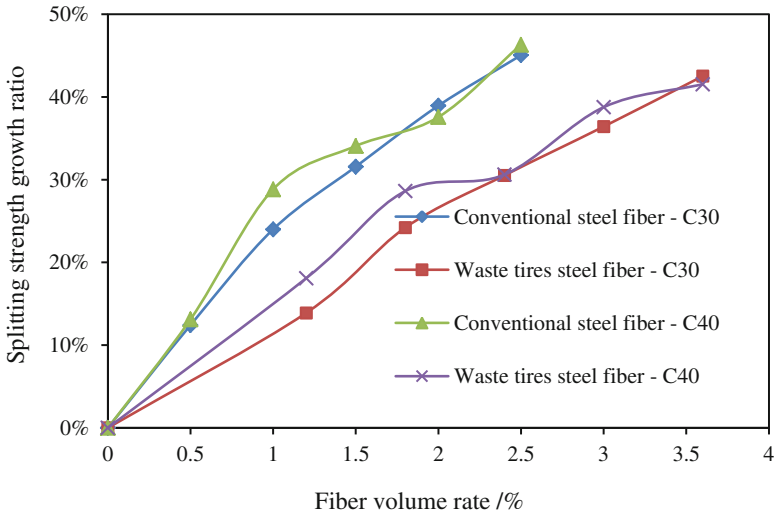

Fig. 4. The growth curve of splitting strength

Flexural Tensile Strength. The flexural tensile strength of conventional steel fiber reinforced concrete is higher than that of waste tire steel fiber, as shown in Fig. 5, when the fiber volume is the same. With the increase of the steel fiber volume ratio, the flexural tensile strength of the two kinds of steel fiber reinforced concrete is increasing, as shown in Fig. 6. The fiber volume ratio of waste tire steel fiber is about 44.6% higher than that of conventional steel fiber to achieve the same strength. The strength grade of the concrete and the steel fiber type has a great influence on the growth ratio of the flexural tensile strength. The difference is that the effect of the steel fiber type is more significant than the strength grade.

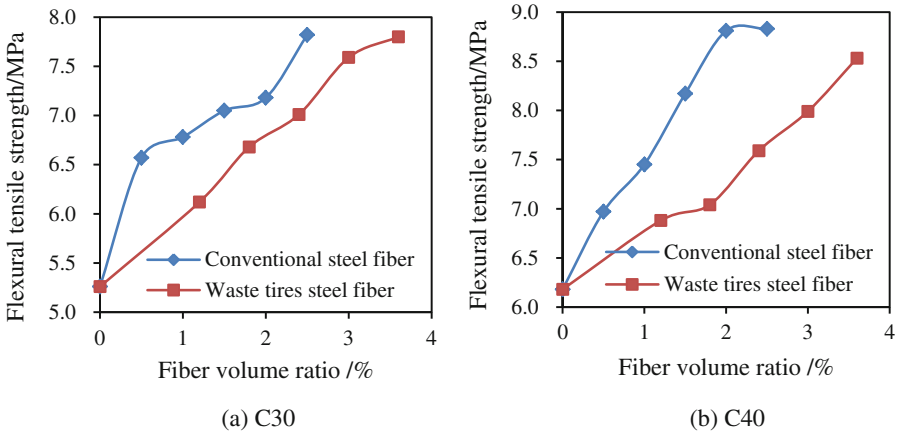

Fig. 5. The relationship between fiber volume ratio and flexural tensile strength

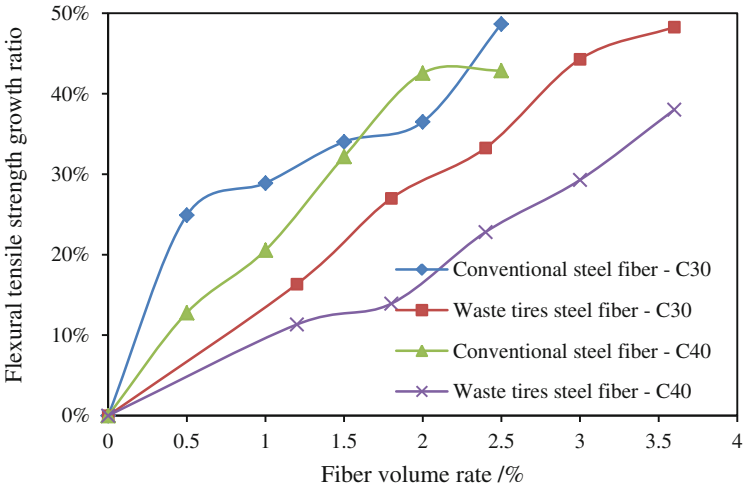

Fig. 6. The growth curve of flexural tensile strength

4 Conclusions

In order to characterize the mechanical properties of waste fiber steel fiber reinforced concrete, C30 and C40 concrete with two kinds of steel fiber (conventional steel fiber and waste fiber steel fiber), five kinds of volume ratio were prepared, and the cube compressive strength, splitting strength and flexural tensile strength was measured.

The waste tires steel fiber has a significant enhancement effect on the strength of concrete, and it can be used as green road material as the waste tire powder.

The strength of waste steel fiber reinforced concrete is lower than that of conventional steel fiber. To achieve the same strength, the amount of waste tires steel fiber required to be about 40% higher than conventional steel fiber.

The effect of strength grade of base concrete on the growth ratio of flexural tensile strength of waste tires steel fiber reinforced concrete is weak, and the influence on growth ratio of the compressive strength and splitting strength can be neglected.

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