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Ability of recycling on fiber reinforced concrete

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HIGHLIGHTS

- The ability of recycling of ordinary FRC having various kinds of fiber was experimentally investigated.
- The fiber addition (ranging from 0.2% to 1.0% in vol.) makes the size of crushed concrete smaller.
- The effect of fiber type (steel and PP) on the size of produced pieces was not significant.
- The contained fiber can be removed by the crushing process easily, because the fiber is within the removal mortar.

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ABSTRACT

Fiber Reinforced Concrete (FRC) can improve not only mechanical properties but also durability due to reduced crack width. Previous researches only enhance the advantages of fiber addition. From the view point of sustainability, the treatment of FRC after the service period of concrete structures should be one of the important issues in near future. This paper presents the ability of recycling of ordinary FRC having two kinds of fiber and different fiber content. It was clarified that fiber addition makes the size of crushed concrete smaller, and the size became smaller with increasing of the fiber content. In addition, the effect of fiber type (steel and PP) on the size of produced pieces was not significant. Eventually, crushing process, which is corresponding to the process removing mortar, can remove the fiber from the recycle aggregate, because the fiber is included within only mortar.

1. Introduction

Recycling of concrete is one of the important issues for the establishment of sustainable society, and a technology to produce recycle aggregate has been developed in concrete engineering. In particular, more than 90% of crushed concrete has been used as a base course material in road construction. On the other hand, the use of recycle aggregate as aggregate of concrete is little. For instance, Japanese Industrial Standard (JIS A 5021-5023) specifies the quality of recycle aggregate. Each recycle aggregate has been classified into Class H, M, L, in terms of quality such as density, water absorption, abrasion resistance etc. It may help to use the recycle aggregate in practical applications.

Fiber Reinforced Concrete (FRC), which is strengthening by short fibers, can improve not only mechanical properties but also durability due to reduced crack width by fiber bridging effect. There are many applications enhancing the performance of FRC [1]. In particular, the use of FRC is one of the solutions to extend the life cycle.

In the decade, various kinds of fibers such as steel, polypropylene, polyvinyl alcohol fibers have been used. Although one of the advantages of FRC that can provide the reduction of crack width may give the extension of lifecycle in terms of improvement of durability. On the other hand, CO_2 emission of fiber use is significantly increased. In particular, it has been reported that CO_2 emission of FRC with synthetic fiber was higher than that with steel fiber [1]. In addition, unknown phase is the final stage after the service period. There is no knowledge on crushing of FRC. The crushed FRC can be used as a recycled aggregate or not. Because the crushing of FRC seems to be difficult and requires higher energy consumption.

Although the previous researches have only focused on the advantages of FRC application, there is no strategy on the treatment of FRC after the service period. This paper presents the ability of recycling of ordinary FRC concerning different fiber type and fiber content. The properties of crushed FRC, which is corresponding to recycled aggregate, was investigated experimentally.

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Table 1
Mix proportions of NC (base concrete).

W/C (%)	s/a (%)	G_{max} (mm)	Unit Content (kg/m^3)				
			W	C	S	G	Ad.
42	45	20	170	410	758	1022	3.08

Fig. 1. Photo of used fibers.

Table 2
Properties of used fibers.

	SF	PP
Length	30 mm	48 mm
Diameter	0.6 mm	0.7 mm
Shape	Hooked	Indented
Young's Modulus	200 kN/mm^2	1 kN/mm^2
Strength	1080 N/mm^2	500 N/mm^2

Table 3
Flesh state of concrete.

	Slump (cm)	Air (%)
NC (Base Concrete)	16.6	3.8
PP 0.2%	10.5	3.6
PP 0.5%	10.5	6.6
PP 1.0%	9.8	4.5
SF 1.0%	15.5	9.8

2. Test programs

2.1. Materials

Ordinary concrete (NC) and four kinds of FRC having different fiber type and fiber content were used in this study. Note that NC was used as a base concrete for FRC. Mix proportions of ordinary concrete are shown in Table 1. High early strength Portland cement (density: 3.14 g/cm^3) was used. Crushed stone (density: 2.98 g/cm^3) was used as a coarse aggregate, and the maximum size of the aggregate and fineness modulus were 20 mm and 6.69, respectively. River sand (density: 2.60 g/cm^3) was used as a fine aggregate. Superplasticizer was also use to obtain the better workability of concrete.

Table 4
Mechanical properties of concrete.

	Compressive Strength (MPa)	Young's Modulus (GPa)	Flexural Strength[a] (MPa)
NC (Base concrete)	55.8	39.3	5.6
PP 0.2%	44.6	34.8	4.6
PP 0.5%	44.1	32.8	5.2
PP 1.0%	43.5	33.9	6.1
SF 1.0%	49.7	36.6	6.4

[a] At the age of 70 days.

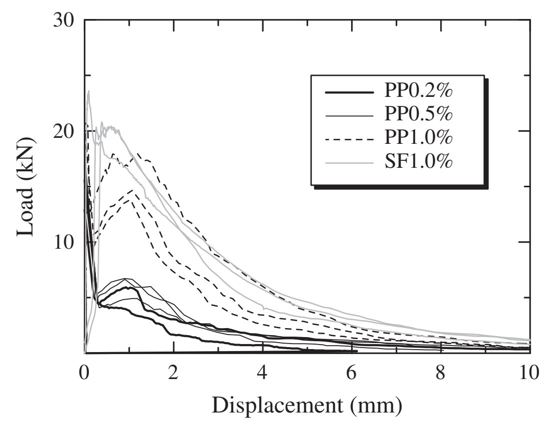

Fig. 2. Load–displacement curves of FRC in flexural tests (at the age of 70 days).

Two kinds of fibers were used in this study. One was steel fiber (namely SF) having the length of 30 mm and diameter of 0.6 mm. Note that both ends were hooked shape. The other was polypropylene fiber (namely PP) having the length of 48 mm and diameter of 0.70 mm. Each steel fiber was bound by water-soluble adhesive. The PP fiber has indented shape on the fiber surface. The Young's modulus of PP fiber is 1 kN/mm^2, which is significantly lower than that of SF. Fig. 1 represents the photo of each fiber, and properties of each fiber was tabulated in Table 2.

In this study, FRC was made by adding each fiber to base concrete, which is corresponding to ordinary concrete. The base concrete was provided as a ready mixed concrete, and each fiber were mixed in the laboratory again for one minute by pan-type mixer (capacity: 55 l). The measured slump and air content of NC and FRC are tabulated in Table 3. In the case of PP, measured slump of FRC was smaller than that of NC, because of fiber adding. On the other hand, SF1.0% case provided similar value with that of NC. The used steel fiber was bundled type, and adhesive on the fiber surface imparted better workability of FRC, eventually. Regarding the air content, a mixing after fiber adding imparted the increasing of air content. Regarding the SF1.0% case, the adhesive mentioned above helps to increase the air content like a air entraining agent.

2.2. Specimens

In this study, twenty cylindrical specimens having diameter of 150 mm and height of 300 mm were prepared for each case. The volume for crushing was totally 106 l. After the concrete casting, the specimen was demoulded at the age of 2 days, and moisture curing was conducted at the constant temperature room (20°).

Compressive strength tests for each concrete were conducted at the age of 28 days to measure the compressive strength and Young's modulus, by using the specimen with diameter of 100 mm and height of 200 mm.

Flexural strength tests at the age of 70 days were also carried out using rectangular specimens (100 mm × 100 mm × 400 mm), as a reference. Four-points flexural tests were carried out, and load and displacement at loading points were measured.

2.3. Strength of concrete

The measured compressive strength, Young's modulus at the age of 28 days and flexural strength at the age of 70 days were tabulated in Table 4. The strength of base concrete was 55.8 MPa, and fiber addition reduced the compressive strength. It is well known that the fiber addition does not contribute to increase

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