Abrasion And Water Absorption Properties Of Polypropylene Fibre-Reinforced Recycle Aggregated Concrete

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Abstract

In this study, re-use of recycle aggregates obtained from polypropylene fiber-reinforced welded concretes in concrete is researched. Eight kinds of polypropylene fibers were used in the study. Polypropylene fibers were used within the admixture at three different rates. The amount of cement in the admixture is 300 kg/m^3. Water-cement rate is 0,52. Cylinder samples in 150 mm diameter and 300 mm height were used for the tests. Samples were crushed in jaw crusher in the end of 120 days. Fibrous recycle aggregates at the size of 0-4 mm, 7-15 mm and 16-22.4 mm were acquired in the end of crushing. A new concrete admixture was acquired by using fiber-reinforced recycle aggregates. Recycle aggregates at the sizes of 7-15 mm and 16-22.4 mm were added to new admixture. 0-4 mm natural sand was used as fine aggregate. The fine aggregate obtained from recycle was not used in the new admixture. It was observed in the pretests carried out that recycle fine sand increase the amount of water and cement in the admixture. The amount of cement in new admixture is 350 kg/m^3. Water-cement rate is 0,56. Cubic samples were prepared from new admixture at the size of 70x70x115 mm. upward wear and water absorption tests were conducted on the samples in the end of 28 days. Welded concrete was compared with abrasion and water absorption values. Abrasion and water-absorption values have increased compared to welded concrete.

Keywords: Polypropylene fiber, recycled aggregate, abrasion, water absorption.

1. Introduction

Concrete is a building material widely-used in construction sector. Particularly, several buildings are demolished with urban transformation and new ones are built in the place of them. Therefore, the production of concrete increase day by day. Cement and aggregate are the most important components forming concrete. Approximately about 75% of concrete is comprised of aggregate. And the raw material of cement is also natural aggregate. Continuously consumption of natural aggregate in the nature causes ecological imbalance. This will result in serious environmental problems. Besides this, construction wastes coming out of the buildings demolished are also another environmental problem. Half of the construction wastes are the wastes of concrete [1-3]. Construction wastes are most frequently used as filling material and in the foundations of roads [4-8]. Many researchers have done studies on recycled aggregate and concrete made of recycle aggregate with the purpose of decreasing the consumption of aggregate in the nature and benefitting from concrete wastes [5,8-21]. In addition to this, fibers are also used in concrete to improve weak features of concrete. These are steel, glass, polypropylene and carbon fibers. The effects of fibers on concrete change according to the type, kind, form, and size of fiber and according to the features of other materials forming concrete [22-27]. Fibers are generally preferred in site and road concretes. It is stated that fiber-reinforced concretes are effective, safe and low-cost solutions for roads, and especially in tunnels [28]. There have been numerous researches on abrasion and water absorption characteristics of polypropylene fiber-reinforced concretes [29-36].

As the use of fiber-reinforced concrete is increased day by day, recycle of fiber-reinforced concretes is quite significant. But there are not many studies on how to benefit from fibrous concretes in the end of its life time. In a study carried out, the features of aggregates obtained from steel and polypropylene fiber-reinforced concretes are experimentally researched. It is specified that type and rate of fiber do not affect the value of water absorption in particles the sieve size of which is 20 mm. In the particles with 10 mm sieve size, it is deducted that water absorption is reduced with increasing rate of fiber [37]. In this study, re-use of recycle aggregates acquired from polypropylene fiber-reinforced welded concretes is researched. Water absorption and abrasion values of fiber-reinforced and fiber additive-free welded concretes and water absorption and abrasion values of recycle aggregate concretes acquired from this concrete are compared.

2. Test Programs

2.1. Materials and Specimens

Fiber-reinforced and fiber additive-free welded concretes are primarily produced in the experimental study. Eight different polypropylene fiber are used in fiber-reinforced concrete admixtures (Figure 1). Technical characteristics of polypropylene fibers are given in. each kind of fibers are added in welded concrete admixtures at three different rates. Fiber rates are 600-1200 and 1800 g/m^3. 0-4mm, 7-15mm and 16-22,4mm broken stones aggregate are used in the production of fiber-reinforced and fiber additive-free welded concrete. The type of cement in all admixtures is CEM I 42.5 R. Welded concrete admixture rates is given in Table 2.

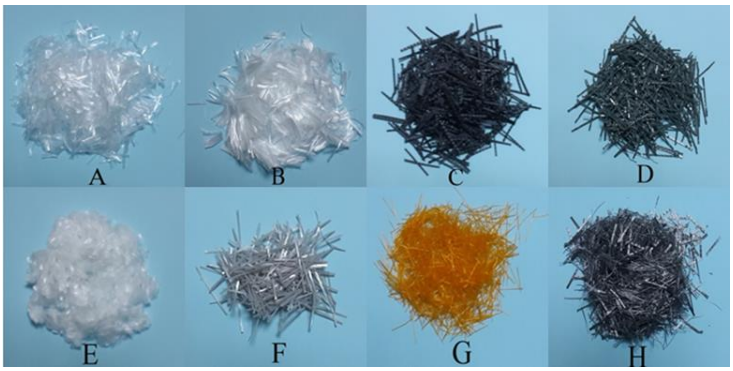


Fig. 1: Polypropylene fibers

2.2. Crushing welded concrete and features of recycle aggregate

Welded concretes are left in external environment conditions for about 200 days. Afterwards, it was crushed in jaw crusher (Figure 2). The breaking is carried out according to the sized of aggregate used in production of welded concrete. Recycle aggregates at 0-4mm, 7-15mm and 16-22,4mm size are acquired (Figure 3,4).



Fig 2. Jaw crusher

Table 1. Characteristics of Polypropylene Fibres

Fiber	Tensile Strength (MPa)	Unit Weight (g/cm^3)	Fusing Point (˚C)	Elasticity Module (MPa)	Water Absorption (%)
A	450-600	0.91	160-590	3500	0.01/0.02
B	400-500	0.91	160-590	3500	0.01/0.02
C	400-800	1.36	253	11300	0.04
D	400-800	1.36	253	11300	0.04
E	600-700	0.91	150-160	3500	0.01/0.02
F	620	0.90	160-590	9500	-
G	400-800	1.36	250	11237	0.4
H	600	0.90	230	3800	0.01/0.02
Fiber	**Length (mm)**	**Width (mm)**	**Thickness (mm)**	**Fragility**	**Shape**
A	12	0.48	0.30	25	Circular
B	19	0.48	0.30	37.5	Circular
C	30	1.20	0.30	100	Ribbed
D	30	1.20	0.45	25	Clip Hook
E	30	0.48	0.30	62.5	Circular
F	40	0.433	0.433	0.92	Straight
G	18	0.3	0.50	36	Circular
H	20	0.6/1.3	0.18/0.22	33/46	Straight

Table 2. Ratios and amounts of materials used within the source concretes.

Ingredients		**CN**	**Mixtures with Fibre, g/m^3**		
			600	**1200**	**1800**
Sand (0-4 mm)	(kg/m^3)	1127	1127	1127	1127
Crushed Stone (7-15 mm)	(kg/m^3)	451	451	451	451
Crushed Stone (16-22,4 mm)	(kg/m^3)	301	301	301	301
Water	(kg/m^3)	156	156	156	156
Cement	(kg/m^3)	300	300	300	300
Polypropylene Fiber	g/m³	-	600	1200	1800
Admixture	%	0,6	0,8	0,9	1,1
Water-cement ratio	**W/C**	**0.52**	**0,52**	**0,52**	**0,52**
Unit weight	**(kg/m^3)**	**2335**	**2335**	**2335**	**2335**

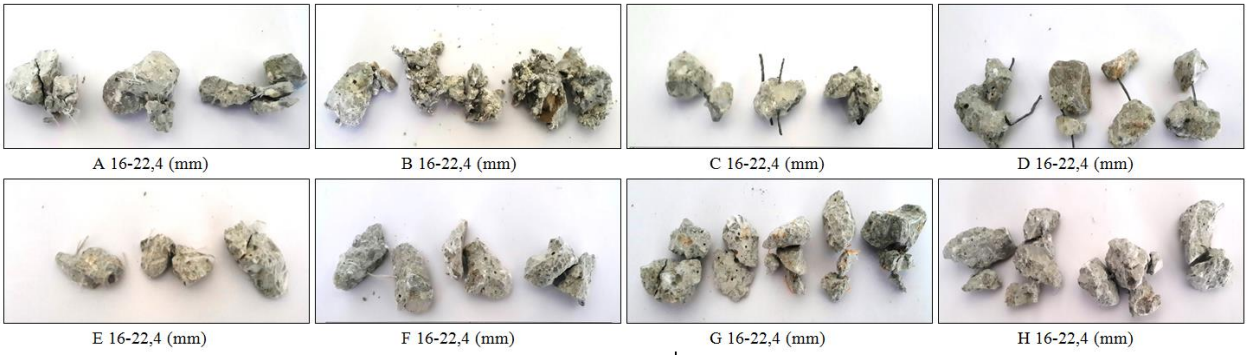


Fig 3. Recycling aggregates



Fig 4. Recycling aggregates

3. Re-use of recycle aggregates in concrete

As the amount of fine material in fine aggregate (0-4mm) acquired in the end of crushing is not adequate, it is not used in new concrete admixtures. 0-4mm natural sand is used rather than recycle fine aggregate. Recycle aggregates at 7-15 mm and 16-22.4 mm dimensions are added to new admixture as coarse aggregate. The amount of aggregate in 1 m^3 concrete is 1794 kg/m^3. 37% of the amount of total aggregate in concrete is comprised of recycle coarse aggregate. As each fiber type are used in welded concrete admixtures at three different rates (600-1200 and 1800 g/m^3), three different recycle aggregates are acquired from each fiber type. The aggregates obtained from each fiber types are used in new admixtures by being mixed. For instance, 600-1200 and 1800 g/m^3 fiber-reinforced recycle aggregates acquired from A fibrous admixture is mixed within itself. Rate of admixture of recycle aggregate concrete is given in Table 3. Fiber-reinforced welded concretes are shown with A,B,C,D,E,F,G,H; fiber additive-free welded concretes with CN, aggregate concrete obtained from fiber additive-free welded concrete with RC, aggregate concrete obtained from fiber-reinforced welded concrete with PRC.

Table 3. Admixture rates of recycle aggregate concrete

Ingredients		**RC**	**PRC, g/m^3**
Sand (0-4 mm)	(kg/m^3)	1130	1130
Recycling aggregates (7-15 mm)	(kg/m^3)	410	410
Recycling aggregates (16-22,4 mm)	(kg/m^3)	254	254
Water	(kg/m^3)	196	196
Cement	(kg/m^3)	350	350
Polypropylene Fiber	g/m^3	-	600+1200+1800
Admixture	%	0,5	0,5
Water-cement ratio	**W/C**	**0.56**	**0,56**
Unit weight	**(kg/m^3)**	**2340**	**2340**

4. Upward abrasion and findings

Specimens at 70x70x115mm sizes are prepared for upward abrasion test. The specimens are abraded in abrasion device 75/minute and in a manner that flow will be 2.5 liters in a minute with F80 aluminum oxide emery powder (Figure 5). The distance of abrasion is measured from two points on the abraded surface and average abrasion sizes are calculated with calibration adjustment (Figure 6). Abrasion test of the specimens are carried out in the end of 28 days.

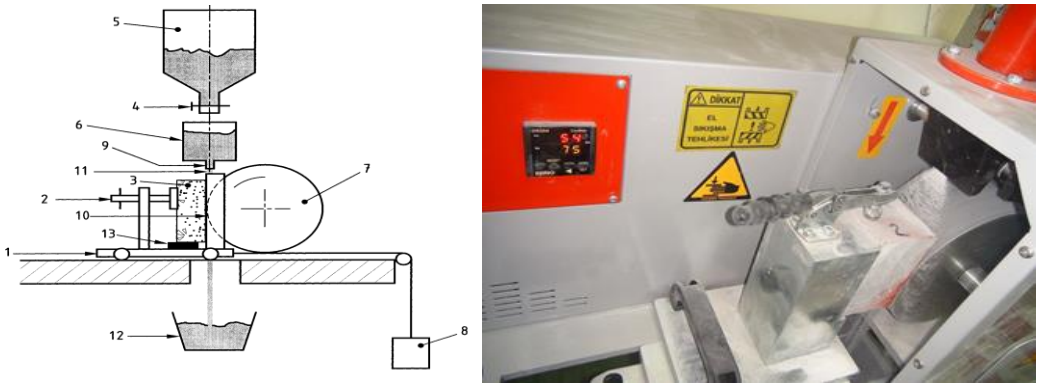


Figure 5. Abrasion test device

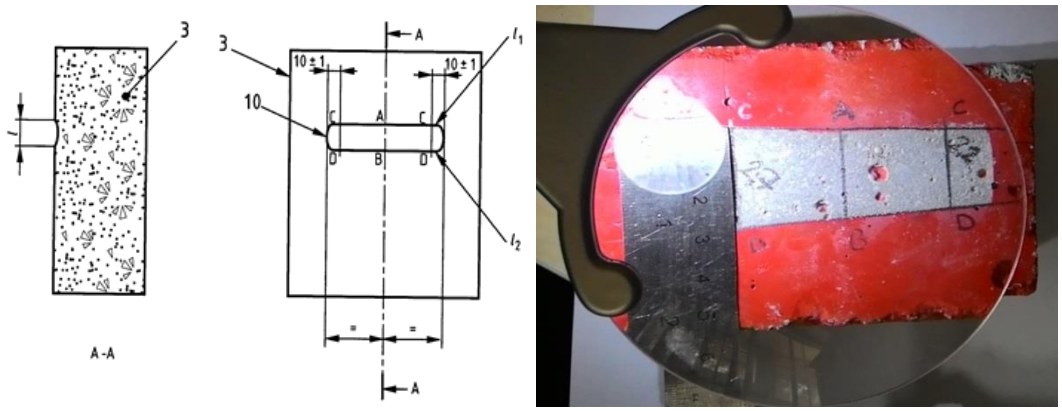


Figure 6. Measuring points for abrasion depth value

To measure abrasion width, a rectangle is drawn on the surface subjected to abrasion. Abrasion width is measured from two end edges (C,D) of the rectangle drawn. Center line is drawn from center edge (AB). The average of the width measured from 2 points calculated.

$$A_{d,ort} = \frac{A_{d,CD} + A_{d,CD}}{2}$$

$A_{d,ort}$: Mean width of the hollows measured in two edges (mm),
$A_{d,CD}$: The dimension of the hollow measured in the abraded first edge (mm),
$A_{d,AB}$: Center affirmation line of the rectangle, which is abraded,
$A_{d,CD}$: The size of the hollow measured in abraded last edge (mm),

When the value of upward abrasion is investigated; abrasion value of polypropylene fiber-reinforced concretes is generally measured as bigger than abrasion value of fiber additive-free concrete. Only the abrasion values of C6, D6, D12, E12 and H12 admixtures are measured as lower than the abrasion value of fiber additive-free welded concrete (CN) specimen. The biggest abrasion value is measured in C6 admixture. Polypropylene fiber admixture has increase the upward abrasion value of concrete. Abrasion value of fiber additive-free recycle aggregate concrete (RC) is measured as higher than the abrasion value of welded concrete. While the abrasion value of CN concrete is 21,5mm, abrasion value of RC concrete is measured as 25mm. Abrasion value of PRC concrete is measured as higher than the abrasion values of almost all admixtures. It is only measured as lower than abrasion value of C6 admixture. The highest abrasion values are measured in A and F fiber-reinforced recycle aggregate concretes as 26,5mm. Abrasion values of A,B,C,D and F fibrous PRC concrete are measured higher than abrasion values of RC concrete. Abrasion value of E and H fibrous PRC concrete is measured as equal with the abrasion value of RC concrete (Figure 7).

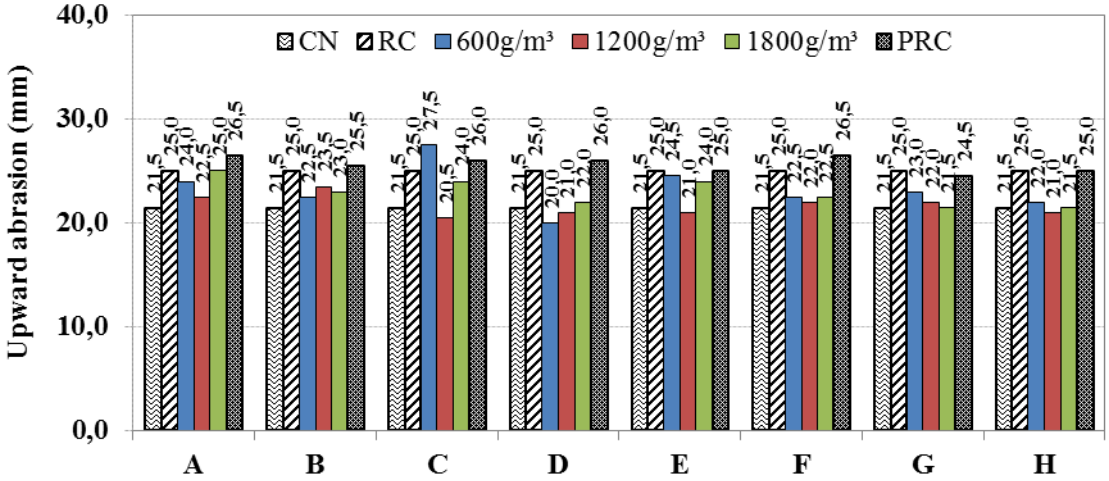


Figure 7. Upward abrasion

5. Water absorption test and Findings

Specimens smaller than 5.0 kg are prepared for total water absorption test. The dimensions of specimen are taken as 70x70x115 mm. The specimens prepared are left in a vessel filled with water at 20±5 ^{0}C temperature until reach to constant mass (M_1). Water layer is adjusted in a manner that it will be 20 mm over the specimens. Specimens are left in water at least for 3 days and weighed in each 24 hours. The specimens taking out of the water are dried with a cloth wet and unwatered. After that, the weighing is carried out. When the difference of mass between two weighings carried out successively is lower than 0.1%, it is accepted that constant saturated mass is reached. The specimens accepted as reach to saturated mass are placed on drying oven in a manner that there will be at least 15 mm between them and dried at 105±5 ^{0}C temperature until constant dried mass (M_2) is reached. The specimens are left in drying oven at least for 3 days and weighted in each 24 hours. When the difference of mass between two weighings carried out successively is lower than 0.1%, it is accepted that constant mass is reached. Water absorption value (W_a) of each specimen is calculated (Figure 8). Water absorption test of the specimens are carried out in the end of 28 days.

$$W_a = \frac{M_1 - M_2}{M_2} \%$$

W_a : Water absorption value (%),

M_1 : First mass of test specimen (g),

M_2 : last mass of test specimen (g),

Water absorption values of fiber-reinforced concretes have increased in general. Only water absorption value of D fiber-reinforced concrete is calculated as lower than water absorption of fiber additive-free concrete (CN). While water absorption value of CN concrete is 3,4%, water absorption value of RC concrete is 4,21%. Water absorption value of RC concrete is measured as higher than water absorption value of CN concrete. Only the water absorption value of E12 concrete is bigger than water absorption value of CN concrete. Water absorption value of E fibrous PRC concrete is measured as lower than water absorption value of fibrous welded concretes. Water absorption values of other PRC concretes are higher than water absorption values of all admixtures. The higest water absorption value is in D fibrous PRC concrete with 5,71%.

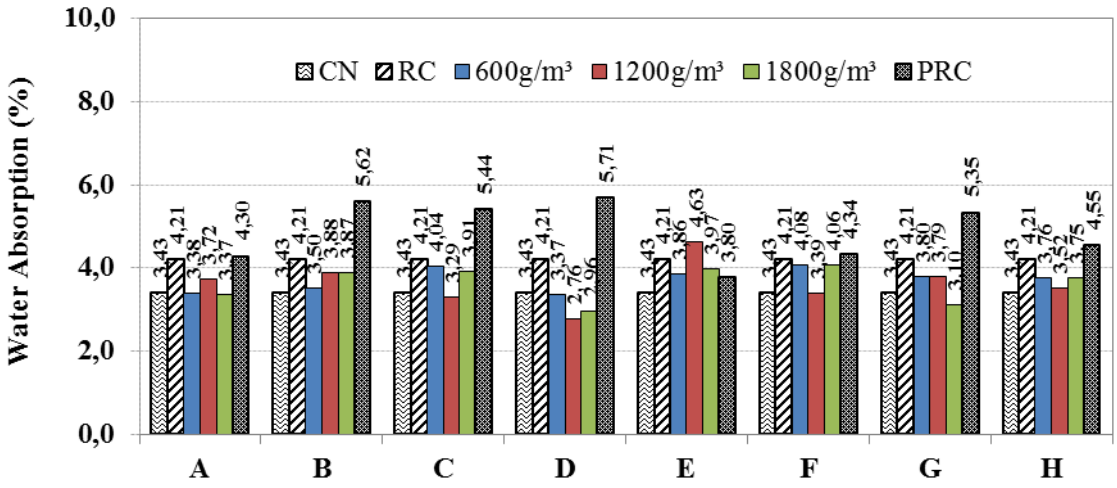


Fig 8. Water absorption

6. CONCLUSIONS

Fiber additive has increased the abrasion value of concrete. Recycled fiber-reinforced ve fiber additive-free coarse aggregate addition at 37% rate of total aggregate in concrete has increased the abrasion value of concrete. Fiber-reinforced recycle aggregates result in increase of abrasion value further. While abrasion value of CN concrete is 21,5 mm, abrasion value in PRC concrete has increased up to 4mm and become 26,5 mm. The fiber additive cause closing up of the air gaps in concrete. These gaps are further increased with recycle aggregate addition. Fibers gather by rendering service as a bridge between aggregates. When the aggregates gathered together are used in concrete, those cannot place in exactly in the fresh concrete as they are linked to one another with fibers and gaps come out. These gaps cause increase in abrasion lost during abrasion test. Fiber additives have increased the water absorption values of concretes. Water absorption value of RC concrete has increased about 24% more than water absorption value of CN concrete.

Water absorption value of PRC concrete has increased 12% (E fibrous recycle aggregate concrete) and 68% (D fibrous recycle aggregate concrete) compared to CN concrete. Water absorption value of PRC concrete has decreased at about 10% only in E fibrous recycle aggregate concrete compared to water absorption value of RC concrete. It has increased in other admixtures. water absorption value of D fibrous recycle aggregate PRC concrete has increased more than 36% of water absorption value of RC concrete. Addition of recycled fiber-reinforced and fiber additive-free coarse aggregate in concrete at rate of 37% of total amount of aggregate has increased the water absorption value of concrete.

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