OS02 - 05

INFLUENCE ON REPLACEMENT OF RECYCLED AGGREGATE FOR STRENGTH AND DURABILITY OF CONCRETE

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ABSTRACT

In recent years, returned concrete from the construction site is increasing in japan. There is also a shortage of coarse aggregates. Therefore, the use of recycled aggregate as a substitute for coarse aggregate has attracted attention in the construction industry. However, the production of high quality recycled aggregate is expensive and low quality recycled aggregate has been limited for its use. Previous studies have reported that attached mortar becomes dense by carbonation. Therefore, in this study, we focused on carbonated recycled aggregate. It is also conceivable to suppress drying shrinkage, strength reduction and freeze-thawing of recycled aggregate concrete by replacing modified aggregate with ordinary aggregate. Then, the replacement rate of recycled aggregate in concrete was changed, and strength and durability test conducted. As a result, carbonated recycled aggregate has improved density and water absorption. It also improved strength and durability compared to concrete using recycled aggregate that is not carbonated. In particular, the strength of the concrete using recycled aggregate decreased when the replacement rate of the recycled aggregate over 50%. Whereas the strength of the concrete using the carbonated aggregate was not decrease.

Keywords: *recycled aggregate, environmental impact reduction, compressive strength, drying shrinkage*

1. INTRODUCTION

In recent years, returned concrete from the construction site is increasing in japan. The amount is 1.5 to 2 million m^3 in one year. It is high disposing cost and also has environmental impact. Recently, the use of recycled aggregate has attracted attention as due to lack of coarse aggregate.

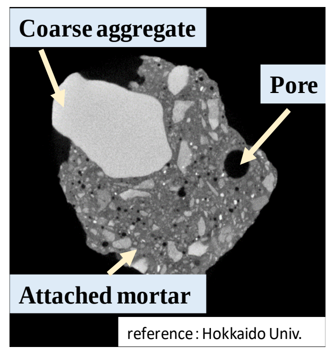

Fig. 1. Low quality recycled aggregate

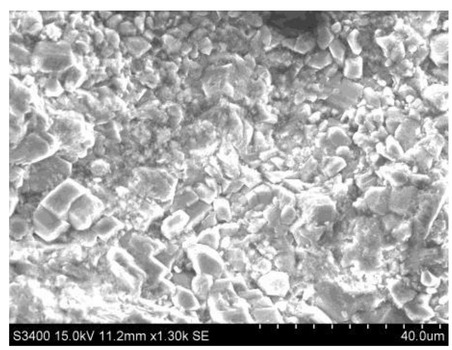

Fig. 2. Products after improving in pore (Calcium carbonate)

Recycled aggregate is classified into high quality, medium quality and low quality according to absolute drying density and water absorption rate. The cost and energy will be high for manufacturing good quality recycled aggregate. On the other hand, low quality recycled aggregate is more attached mortar than high quality recycled aggregate (**Fig.1**). And the concrete using low quality recycled aggregate has lower strength and durability than the concrete using high quality recycled aggregate. Previous studies have shown that the strength and drying shrinkage of recycled concrete improved by carbonating low quality recycled aggregate. Carbonation of concrete is considered to cause corrosion of reinforcing bars in reinforced concrete. But focusing only on concrete, it is known that by carbonation, the volume of mortar increases by 12%, and its strength increases as it becomes dense. The observation of the carbonated aggregate using a SEM. Production of calcium carbonate was confirmed as shown in **Fig2**. Therefore, improvement of low quality recycled aggregate can be expected by using this technology. In addition, it is conceivable to mix with ordinary aggregate in order to reduce the influence of low quality recycled aggregate. In this study, it is known that concrete using recycled aggregate is inferior in strength, drying shrinkage and freezing-thawing resistance. So compressive strength, drying shrinkage and freezing-thawing resistance were examined by changing replacement rate of recycled aggregate in concrete. We also studied the strength and durability of concrete using carbonated recycled aggregate and no carbonated recycled aggregate.

2. OUTLINE OF EXPERIMENT

2.1 Outline of recycled aggregate and recycled concrete

The mix proportion of the returned concrete is shown in **Table 1**. The returned concrete with different strength was crushed after 20 days. The recycled aggregate was produced as shown in **Table2**. 18RG and 24RG are no carbonated recycled aggregate. 18 RGC and 24RGC was carbonated 1 week in accelerated carbonation chamber having a temperature of 20 degree celsius, a humidity of 60% and a carbon dioxide concentration of 5%. 18RGO and 24RGO was left outside for 20 days for carbonation. Recycled aggregates concrete is shown in **Table 3**. The replacement rate of recycled aggregate was 0, 15, 30, 50, 75, 100%. The water cement ratio was 50% and sand-total aggregate was 46%. The target slump was 10 ± 2.5 cm and the target air volume was 4.5 ± 1.5%

2.2 Absolute drying density and water absorption rate

The quality of recycled aggregate is classified by absolute drying density of aggregate and water absorption rate. Therefore, in this study, absolute drying density and water absorption rate of recycled aggregate before and after carbonation were calculated according to (JIS A 1110).

2.3 Crushing value test

In order to confirm whether carbonated recycled

Table 1. Mix proportion of returned concrete

Strength of returned concrete(N/mm^2)	W/C(%)	s/a(%)	Unit mass(kg/m^3)					
			C	W	S1	S2	G	Ad
24	57.0	45.4	277	158	594	250	1029	3.1
18	66.5	46.0	242	161	610	255	1029	2.7

Table 2. Types of Aggregate Properties

Sample name	Surface dry density (g/cm^3)	Absolute dry density (g/cm^3)	Water absorption rate (%)
24RG	2.43	2.29	5.72
24RGO	2.44	2.32	5.11
24RGC	2.45	2.33	4.79
18RG	2.42	2.29	5.78
18RGO	2.44	2.32	5.24
18RGC	2.44	2.32	4.87

Table 3. Kind of concrete

Symbol	Replacement rate of recycle aggregate (%)	W/C(%)	s/a(%)	Unit mass (kg/m^3) Water	Slump(cm) Carbonation Yes	Slump(cm) Carbonation No	air(%) Carbonation Yes	air(%) Carbonation No
24RG	0	50	46	160	-	8.5	-	5.2
	15				9.5	11	4.6	4.9
	30				10	10.5	5.7	5
	50				10	10	4.9	5.6
	75				9.5	10	4	4.3
	100				10	11.5	5.3	5.6
18RG	0				-	7.5	-	5.6
	30				9.5	7	4.6	5.4
	50				10	11	3.5	4.2
	75				9	10	5.8	5.8
	100				9.5	12.5	3.6	4.9

aggregate became stronger, crushing value test of aggregate was carried out.

2.4 Compressive strength test

Demolding on the next day after casting recycled aggregate concrete. Compressive strength test (JIS A 1108) was carried out after curing in water on 20 degree celsius at 28 days.

2.5 Drying shrinkage

A concrete prism specimen of 100 mm × 100 mm × 400 mm was demolded at one day after casting. After that, they were cured for 7 days in water at 20 degree celsius. Length change rate was measured 1, 2, 3, 4, 6, 8, 10, 13 weeks after curing.

2.6 Scaling test (ASTM C672)

Concrete prism specimen of 220 mm × 220 mm × 55 mm was demolded at one day after casting. Curing in water on 20 degree celsius at 14 days.

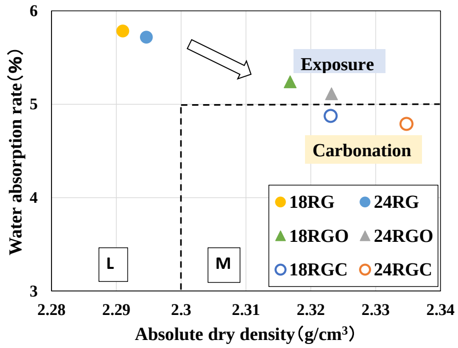

Fig. 3. absolute dry density and water absorption rate

Then it was placed in a room at a temperature of 20 degree celsius and a humidity of 60% for 14 days. After curing, water was poured into the surface of specimen to a depth of 6 mm. After that, it was frozen in a freezer at -20 degree celsius for17 hours. Then, the specimen was melted for 7 hours in a room having a temperature of 20 degree celsius and a humidity of 60%. After 50 cycles, pieces of scaling were taken and the scaling amount per unit area was calculated.

3. RESULTS AND DISCUSSION

3.1 Absolute drying density and water absorption rate

Relationship between absolute dry density and water absorption rate is shown in **Fig.3**. After carbonating, absolute drying density and water absorption rate improved. And quality upgraded from low quality to medium quality. There was no difference on the difference recycled aggregate. Therefore, even if recycled aggregate is produced from returned concrete with different strength, it can be expected to obtain the same quality. Also, as exposure carbonation could not be improved compared to accelerated carbonation. It is necessary to consider exposure time and exposure place.

3.2 Crushing value test

Crushing value test results are shown in **Fig.4**. Crushing value decreased by carbonation. Therefore, improvement rates before carbonation and after carbonation were calculated (**Fig.5**). Carbonated recycled aggregate was improved. On the other hand, the exposed carbonated recycled aggregate had a small improvement.

3.3 Compressive strength test

The results of the 18RG series are shown in **Fig.6**. Compressive strength was not improved by carbonation at any replacement rate. The results of the 24RG series are shown in **Fig.7**. When the replacement rate of recycled aggregate over 50%, the strength decrease. In addition, when the replacement rate of the exposed carbonated

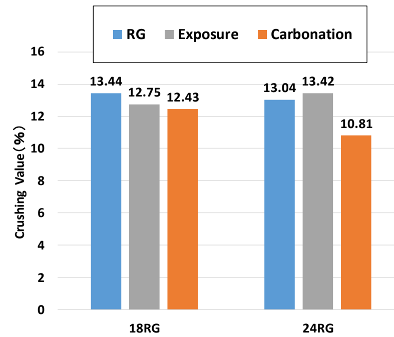

Fig. 4. Crushing value test

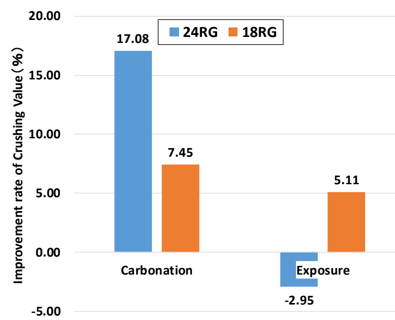

Fig. 5. Improvement rate of Crushing value

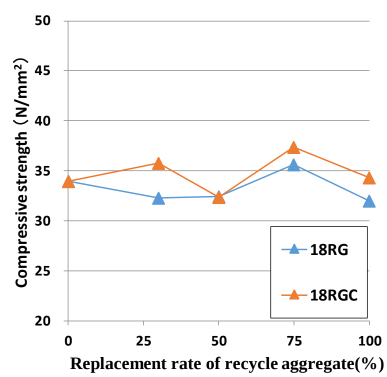

Fig. 6. Compressive strength (18RG series)

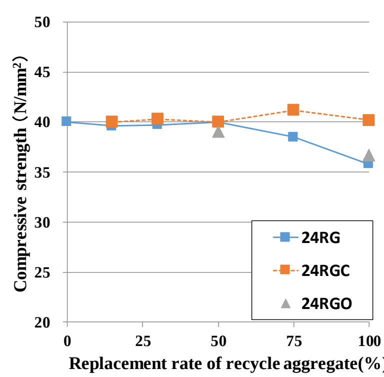

Fig. 7. Compressive strength (24RG series)

recycled aggregate over 50%, the strength decreased. However, the concrete using carbonated recycled aggregate did not decrease the strength. It is thought that the transition zone of recycled aggregate was reformed by carbonation.

3.4 Drying shrinkage

The results of the 18RG series are shown in **Fig.8.** Shrinkage decreased slightly in carbonation. There was no difference in shrinkage depending on the replacement rate. The results of the 24RG series are shown in **Fig.9**. When the replacement rate of recycled aggregate was 50%, shrinkage was the smallest result. In addition, reduction of shrinkage due to carbonation was small.

3.5 Scaling test

The results of the scaling test are shown in **Fig.10**. At the replacement rate of 50%, the amount of scaling was half by carbonation. The scaling amount improved even when the replacement rate was 100%. Therefore, it was found that the resistance to freezing and thawing improves by carbonation of the recycled aggregate.

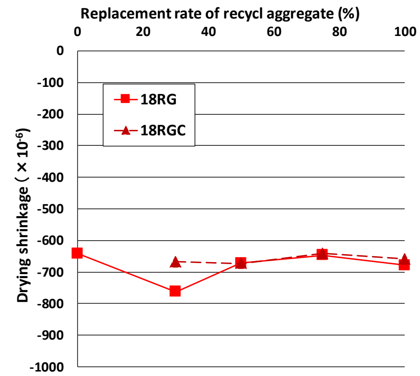

Fig. 8. Length change test(18RG)

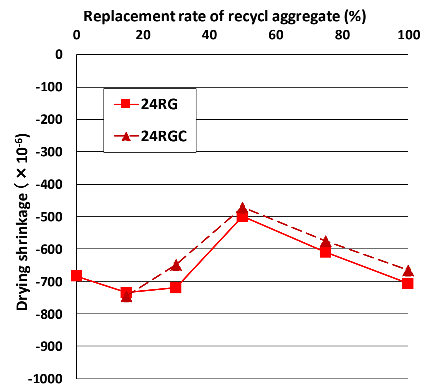

Fig. 9. Length change test(24RG)

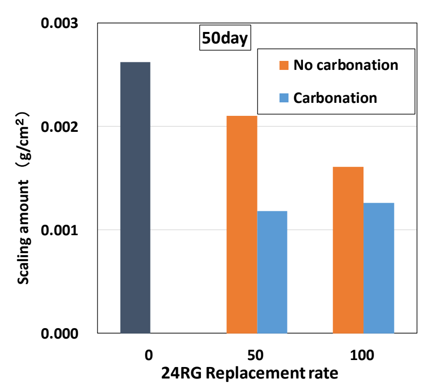

Fig. 10. Scaling test

5. CONCLUSIONS

The summarized results obtained in this research as follows

(1) Carbonation improves absolute dry density and water absorption rate. Low quality recycled aggregate improves

(2) Concrete using recycled aggregate has a different replacement rate that decreases strength depending on the strength of returned concrete.

(3) Concrete using recycled aggregate that replacement rate that decreases in strength depends on the strength of the returned concrete

(4) Depending on the type of returned concrete, the replacement rate at which drying shrinkage increases is different. Drying shrinkage was decrease by carbonation.

(5) The amount of scaling was decrease by carbonation. Therefore, it was found that the resistance to freezing and thawing is improved by carbonation.

In the future, it is necessary to study recycled aggregate made from concrete with different water cement ratio and cement type.

REFERENCES

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PHOTOS AND INFORMATION

Hiroki Mizuno received the B.E. (2016), degrees in civil engineering From Shibaura Institute of Technology Department of Architecture and Civil Engineering Shibaura Institute of Technology in Japan