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Quality Improvement of Recycled Aggregates from Waste Concrete by the heating and grinding

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To examine the grinding effect through preheating of waste concrete as a way of retrieving coarse aggregates from waste concrete, the removal rates of cement mortar and paste of both recycled aggregates and heated and grinded ones were investigated. As the preheating temperature increased, the removal rate of cement mortar from waste concrete was raised, and this kind of removal hardly affected the abrasion rate and specific gravity of aggregates. On the other hand, when it was treated over 400℃ of preheating temperature, the absorptance was reduced to less than 2.17, and cement mortar was effectively separated from waste concrete. It could meet the Korean Standards on recycled aggregates for concrete, and it is expected to expand the scope of utilization by making it possible to retrieve the aggregates which have the properties close to natural aggregates.
Keywords: waste concrete, recycled aggregate, recycling

Introduction

The amount of construction waste in Korea is 62,221 ton/day as of 1999. Because this kind of construction waste is generated around densely populated cities and the suburbs, it is inevitable to transport it long distances to landfills or interim treatment facilities. Owing to complicated factors like the lack of an adequate management system in construction sites, the lack of a proper understanding of disposal, a short-sighted attitude of treatment companies which seek profit-making, etc., the wastes which have to be carried in to or treated in landfills or interim treatment facilities are illegally thrown away in mountain areas around cities and in secluded places, which causes serious social problems. Furthermore, the aggregates which have been considered just as a kind of abundant natural resources, show a rapid increase in demand by the excessive boom of construction, but the supply cannot meet the demand, which is expected to cause serious unbalance of supply and demand in 5～10 years from now on. Under these circumstances, great importance has been attached to the terms, the conservation and the effective use of resources, and interest in recycling and resource conservation from daily life to each kind of industrial field is getting deeper In 1995, 35.0% of waste concrete and 48.5% of waste asphalt concrete were shown to be recycled, which means the recycling of construction waste is being facilitated centering on big construction companies. However, the existing technology of producing recycled aggregates is just to use crushers and cement paste is not fully removed from the aggregates enough to be used as structure aggregates. Thus, if recycled aggregates manufactured by this method are used, concrete becomes to have lower durability and cannot be applied to structure concrete. On this account, the recycled aggregates produced are used as roadbed materials or mostly disposed without being used as materials for structural concrete.

To overcome this deterioration in the quality of recycled aggregates, some researches in the retrieval of recycled aggregates by heating and grinding method that a lump of waste concrete is heated for the dehydration and weakening of cement paste and grinded to the extent that the aggregates are not crushed, and then, mortar and cement paste attached to aggregates are selectively removed, were published in Japan. This method is based on the fact that the heating under 500℃ has little effect on the quality of aggregate, while the quality is lowered if aggregates are heated over 500 ℃ because of the dehydration of contained clay minerals and the transition of SiO_2. This study aimed to retrieve coarse aggregates which have better quality by investigating the characteristics of cement mortar removal according to the treatment conditions like preheating temperature, grinding time, etc., regarding domestic aggregates treated by construction waste treatment companies.

Methods and Materials

Samples

In this experiment, the recycled aggregates produced by Company I, a domestic construction waste treatment company were used as samples. In Company I, the generated construction waste is crushed into the size of 200mm particle in a primary jaw crusher, moved into a water tank, a high-pressure nozzle for jetting water and crushed again into the size 50mm with a secondary jaw crusher after impure suspension and aggregates are washed at high pressure. As a result, the aggregates with the size under 25mm and 9mm are produced with a cone crusher.

In this study, the samples whose size is under 25mm were used.

After it was divided into -25/+20mm, -20/+15mm, -15/+10mm, -10/+5mm, -5.0/+2.5mm, -2.5mm using KS sieves, and dried at 105 ± 5 ℃. the amount of cement mortar attached to waste concrete of each sample, specific gravity, absorptance, and abrasion loss were measured, and the separation experiment of aggregates and cement mortar by a ball mill was made.

Procedures

Analysis of Cement Mortar Content in Waste Concrete

Each sample was added 2kg to 2L of 6M HCl in a plastic container and soaked for 1 day. To facilitate the separation of cement mortar and aggregates, it was stirred regularly. After one day of soaking, it was divided using a 4mesh(4.75mm) of KS standard sieve. Things over and under sieve were regarded as aggregates and cement mortar, respectively. things over sieve was washed with water, dried at 105±5℃, and weighed. The content of cement mortar attached to waste concrete was found from initial weight and that of things over 4mesh after soaked in acid.

Experiment of heating and grinding

Each sample with different particle size was not heated or heated in an electric furnace from 200 ℃ to 500°C at 100°C intervals for one hour, grinded (height:45cm, diameter:20cm) using steel balls(diameter:1.5cm, weight:30g) at the ball/sample ratio(w/w) of 1.5 for a fixed period of time, divided using a 4.75mm KS sieve. And the weight of things over sieve was found. The separation rate of cement mortar was found using the initial weight and that of things over 4.75mm after grinding. After measuring the weight of things over 4.75mm, the remaining amount of cement mortar was found in the same way as that of the analysis of cement

Measure of the specific gravity, absoptance, and abrasion loss of aggregates

The specific gravity and absorptivity of aggregates were experimented according to the KS F 2503 and the abrasion loss of aggregates followed the KS F 2508.

Results and Discussion

Fig. 1 shows the particle size distribution of recycled aggregates from Company I. Particles 20-25mm, 15-20mm, 10-15mm and 5-10mm were 20.2%, 21.6%, 38.8%, and 18.3%, respectively, forming 98.8% of the total. The particle under the size of 5mm was 1.1%. The experiment after that was made in the particles with the size of 5～25mm which occupy 98.8% of the total.

Fig. 2 shows the amounts of cement mortar of -25/+20mm, -20/+15mm, -15/+10mm and -10/+5mm whose average, highest and lowest values were displayed after 7 times of measurement. The average values of 20-25mm, 15-20mm, 10-15mm and 5-10mm were 17.4%, 23.5%, 35.5%, and 57.6%, respectively, which means that the amount of mortar increased as the particle size decreased. The deviation by the particle size was not large as about 3～4%.

Table 1 shows the absolute dry gravity and specific gravity of saturated surface dry aggregate, absorptance, and abrasion loss of recycled aggregates by the particle size. The absolute dry specific gravity shows little difference by the particle size as 2.63-2.67, while the absorptance and abrasion loss were greatly raised as the particle size was reduced. These absorptance and abrasion loss showed the same tendency as that of the amount of cement mortar attached to aggregates by the particle size. Therefore, it is thought that the deterioration in the physical properties of recycled aggregates like absorptance was affected by the cement mortar and paste attached to the aggregates of waste concrete. The KS for Fig. 2. Mortar amount in raw recycled aggregates of each

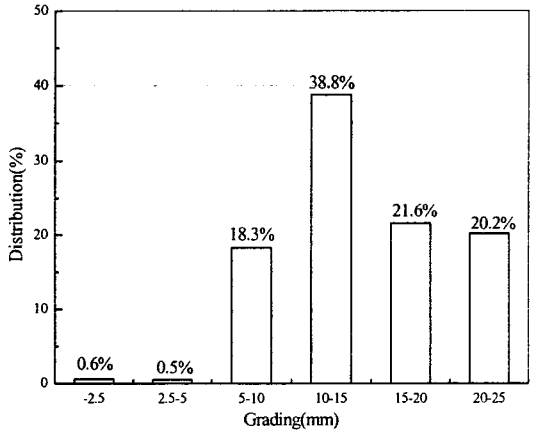
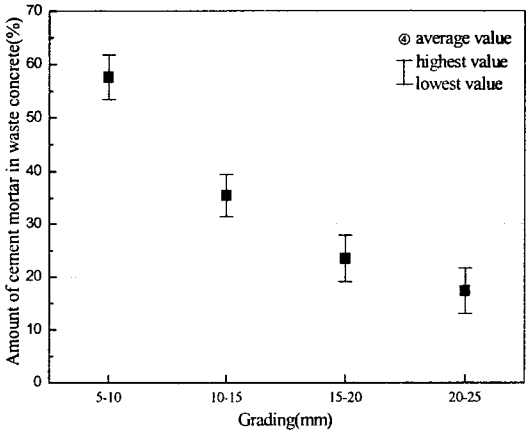


Fig. 1 Grading of recycled aggregates



Grading.

mortar content in waste concrete in the above

Table 1. Physical properties of recycled aggregates

grading (mm)	Absolute dry specific gravity	Specific gravity of saturated surface dry aggregate	Absorptance(%)	Abrasion loss(%)
5-10	2.64	2.83	7.08	45.2
10-15	2.63	2.75	4.62	32.2
15-20	2.66	2.75	3.58	28.8
20-25	2.67	2.74	2.43	15.2

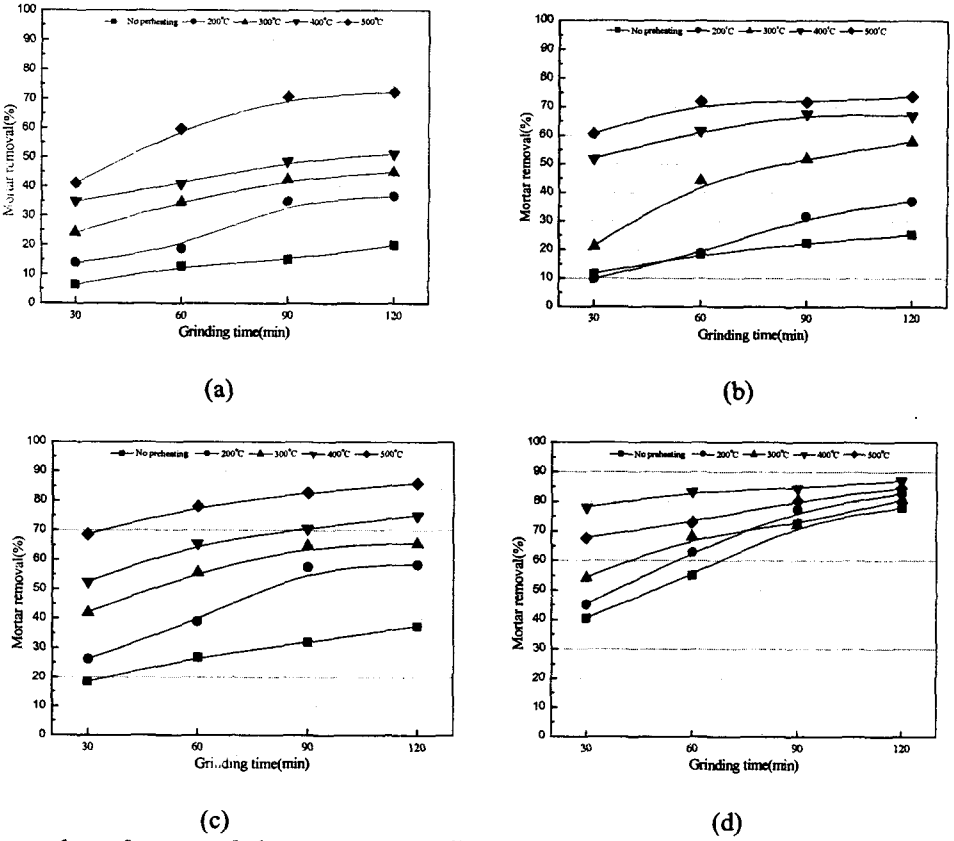


Fig. 3. Mortar removal rate from recycled aggregates according to preheating temp. and grinding time. ball/aggregate ratio(w/w) is 1.5 and heating time is one hour at each temp.(a) 20-25mm (b) 15-20mm (c) 10-15mm (d) 5-10mm

the absorptance, specific gravity and abrasion loss coarse for concrete are : less than 3.0, more than 2.2 and less than 40%, respectively. The particle with the size of 5-20mm doesn't satisfy the standards for absorptance and abrasion loss.

Fig. 3 displays the separation rate of cement mortar from recycled aggregates when the aggregates with each particle size were grinded after heated from 200 ℃ to500℃ at 100℃ intervals. It could be found that as the preheating temperature increased, does the separation rate. This tendency was clear in the particle with the size of 10-25mm, and relatively slight in that of 5-10mm. while the samples which didn't go through preheating had less than 40% of separation rate in size 10-25mm after 2 hours of grinding, those with preheating at 500℃ had more than 70% of separation rate in size 10-25mm and more than 85% in size 5-15mm. In case of grinding time, the higher the preheating temperature and the smaller the particle size, the shorter period of time had the separation. More than 90 minutes of grinding time was found to be adequate for this experiment, and the preheating temperature around 400℃ is thought to be proper, considering the weakening of aggregates like the dehydration of clay minerals.

Fig. 4 displays the amount of residual mortar (more than 4.75mm) of both raw sample and heated and grinded ones. It can be found that it's possible to reduce the amount to less than 6.0% at 500℃ in aggregates with the size of 10～25mm. The sample with the size of 5-10mm showed the amount of 20～29% according to the preheating temperature, but it's the result of considering the one with the size of less than 4.75mm as cement mortar in this experiment. If the products over 1.18mm are compared, the amount at the preheating temperature over 400°C is reduced to less than 10%. Fig. 5 shows the values of specific gravity, absorptance

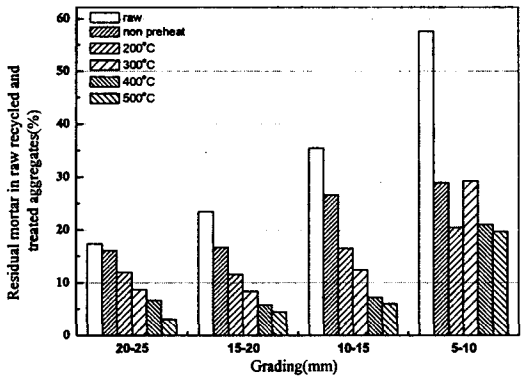
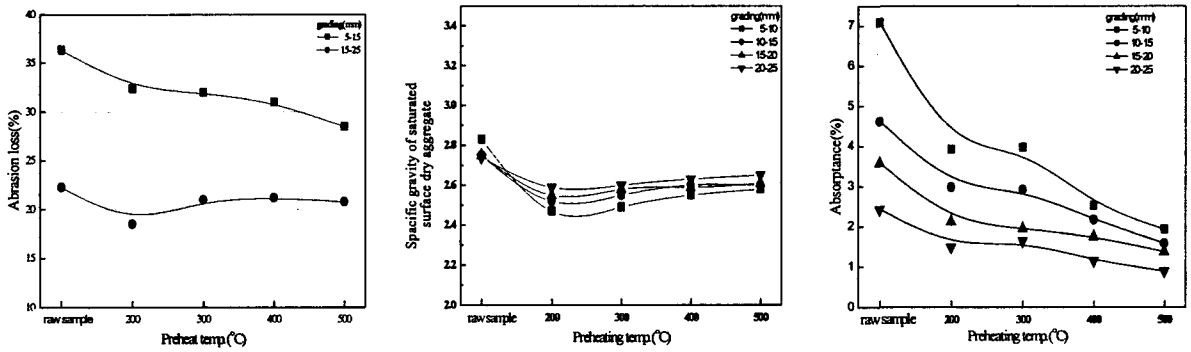


Fig. 4.Residual cement mortar in recycled aggregate heated at various temp.and grinded



(a) (b) (c)

Fig. 5. Physical properties of recycled aggregates heated at various temp. and grinded . ball/aggregate ratio is 1.5 and heating time and grinding time is 1hr at each temp. (a) abrasion loss (b) specific gravity of saturated surface dry aggregate (c) absorptance

and abrasion loss of aggregates with each particle size after 1hour of heating at 100°C invervals from 200°C to 500°C and 1 hour of grinding at the ball/aggregate(w/w) ratio of 1.5. For the purpose of camparison, the spectific gravity, absoptance and abrasion loss of the raw samples were displayed together. Though the abrasion loss of both raw samples and heated and grinded ones show the tendency of decreasing with the increase of the preheating temperature as shown in Fig. 4, it can be said it doesn't have a great meaning, considering that the KS for the abrasion loss of recycled aggregates for concrete is under 40%. The KS for specific gravity is over 2.2., those of raw recycled aggregates by the particle size are more than 2.2, and don't show any distinguished change by heating and grinding conditions. On the other hand, the absorptance of the heated and grinded samples was remarkably reduced. In aggregates with the size 5~10mm, while the raw recycled aggregates had 7.08 of absorptance, that of the one after heated at 500℃ was reduced to 1.93. Though the differences between the absorptance of raw recycled aggregates and heated and grinded samples are reduced with the increase in the size of aggregate, it is thought to be mostly caused by the fact that the smaller the particle size of aggregates, the more the amount of cement mortar attached to raw recycled aggregates. If the preheating temperature is adjusted to over 400℃, it can meet the KS for the absorptance of first-class coarse recycled aggregates for concrete (less than 3 of absorptance).

Table 2 shows the result of chemical analysis of the grinded from raw sample and the heated at each temperature and grinded ones. Each sample didn't show any large difference in its components. The SiO_2 had the content of more than 60%, occupying most part, and found to be a main ingredient of CaO, Al_2O_3, Fe_2O_3, and the like. It's estimated that high percentage of SiO_2 contained in the grinded is due to the grinding of fine aggregates, and that the speed of rotation, the change in the kind of a medium, etc. should be considered to retrieve fine aggregates.

Conclusion

As a way of retrieving coarse aggregates from wasteconcrete, the removal rate of cement mortar and paste by the grinding treatment through preheating was examined. As the result of dividing the recycled aggregates from company I into four kinds by particle size and of measuring absorptance, abrasion loss and specific gravity, the absorptance and abrasion loss, according to the particle size, didn't meet the KS for recycled aggregate

Table 2. Composition of mortar separated from recycled aggregate after heated at various temp.and grinded(unit:wt.%)

sample	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	MgO	CaO	Na_2O	K_2O	MnO	P_2O_5	LOI	total
No preheating	60.74	7.34	0.20	2.03	1.25	13.02	1.16	2.54	0.04	0.07	12.40	100.78
200℃	62.90	7.52	0.20	2.14	1.25	12.97	1.11	2.63	0.04	0.06	8.81	99.63
300℃	63.14	7.65	0.20	2.01	1.21	12.62	1.30	2.73	0.04	0.07	7.95	98.91
400℃	62.80	7.40	0.20	2.03	1.30	14.23	1.08	2.54	0.04	0.06	8.04	99.71
500℃	63.07	7.78	0.20	2.02	1.23	13.64	1.17	2.70	0.04	0.06	7.01	98.90

for concrete of less than 40% of abrasion loss and less than 3.0 of absorptance. as the result of examining the removal rate of cement mortar by the preheating temperature up to 500 ℃ , considering the transition of SiO_2 and the dehydration of clay minerals, etc., it showed the tendency that the higher the preheating temperature, the higher the removal rate of cement mortar from waste concrete. This removal of cement mortar hardly affected the abrasion rateand specific gravitity of aggregates. On the other hand, the absorptance was reduced to less than 2.17 at more than 400 ℃ of preheating temperature, which proves that cement mortar was effectively separated from waste concrete. When it was grinded after heating at 500℃, the remaining amount of mortar could be reduced to less than 6% in particles with the size of 10~25mm and it could satisfy the KS for recycled aggregates for concrete (less than 40% of abrasion loss, less than 3.0 of absorptance and more than 2.2 of specific gravity)

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