

Recovery of high quality aggregate from concrete waste using the Pulsed Power Technology

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ABSTRACT

In Japan, a large amount of waste concrete are generated now. Therefore, the development of new recycling technology of waste concrete scraps is paramount importance. In this work, the pulsed power discharges inside of waste concrete scraps immersed in water were used to reproduce the coarse aggregate. This research collected the recycled coarse aggregate from waste concrete. As the result, it is found that the coarse aggregates reproduced by electrical pulsed discharge energy of 640kJ have the enough qualities of the bone-dry density and the water absorption rate to satisfy JIS (Japan Industrial Standard) regulation class H(A5021). The concretes consisted of the recycled coarse aggregate also have the enough compressed strength and Young's module to utilize as the construction material. In addition, the amount of generation powder is few when the concrete is crushed by pulsed power technology. The recycled fine aggregates made by electrical pulsed discharges energy of 640kJ have the qualities to satisfy JIS regulation class L(A5023).

Keywords: aggregate, concrete, pulsed power, recycle

1 INTRODUCTION

In Japan, the most of waste concrete scraps have been reused as roadbed materials and the recycling ratio of waste concrete scraps has been kept over 98 % from 2006. However, it is expected that the demands of waste concrete scraps as roadbed materials would decrease even though the waste concrete scraps increase with the pulling down buildings in next decade. A large amount of old structures are so increasing that they need to be renewed or repaired. And, the large amount of aggregate for the structure is necessary to renewal. These facts mean that the recycling of waste concrete scraps would be in the negative situation. So, it is desirable to collect the high quality recycled aggregate from waste concrete. Recently, renewal recycles technologies for concrete have been developed in Japan. The mechanical grinding method is developed as the technique, which can collect high-quality recycled aggregate. However, the recycled aggregate is damaged. In addition, the large amount of powder is generated by grinding action. Moreover, the mechanical grinding method has the two problems. At first, the recycling cost of

aggregate is very high. Secondary, the recycle operation system is complex, and the size of recycle operation system is very huge. Therefore, the development of new recycling technology of waste concrete scraps is paramount importance in Japan.

So, this research uses the "Pulse Power Technology [1]" for recycling aggregate. We proposed the application of pulsed power to recovery of the high quality recycled aggregate from concrete waste[2]. The pulse power technology can generate the huge energy at moment, and that can be controlled. In this method, pulsed electric discharges are generated inside of concrete underwater. This technology crushes the concrete by the dielectric breakdown of gas and solid[3]. The recycled coarse aggregate is collected, and that is conducted the quality evaluation test. In addition, the concretes consisted of the recycled coarse aggregate. The amount of powder was calculated. In addition, the recycle percentage of recycled coarse aggregate was calculated. So, this technology called pulsed discharge method after all.

2 BREAKDOWN PHENOMENON OF CONCRETE BY PULSED POWER

The concrete is crushed by dielectric breakdown of the gas. The gas in the concrete is made to plasma when pulsed electrical discharges are generated inside of concrete, because the dielectric breakdown level of the gas is lower than liquid and solid. Therefore, the crack occurs in mortar. The shock wave is generated by the volume expansion of making to plasma at same time. The shock wave spreads in concrete. The shock wave is divided into reflected wave and the penetration wave at the boundary of the coarse aggregate and the mortar. The tensile stress is generated by the penetration wave and the reflected wave. The mortar is delaminated from aggregate by tensile stress (Figure 1).

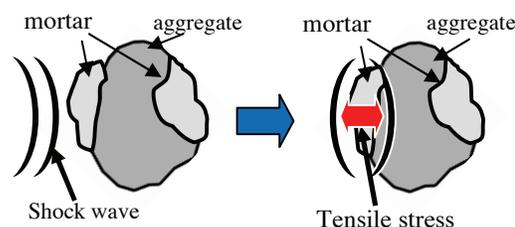


Figure 1 Breakdown phenomenon of concrete

3 CONCRETE CRUSHING EXPERIMENT

This research used the pulsed power generation device for crushing the concrete that is called Marx bank generator [4]. The ten capacitors are connected in parallel at charging and the electrical pulse is discharged in serial. The discharge energy of this pulse power generation device is decided depending on the capacitor and the charge voltage. Figure 2 shows the illustration of crushing the concrete. When the pulsed power technology is applied to recovery of the aggregate, concrete is placed under water, and pulsed power is discharged from high voltage electrode. Figure 3 shows the discharging the pulse power to concrete. As pulsed discharges were frequently applied into the concrete, concrete was broken gradually (Figure 4). The low voltage electrode is hemisphere of 30cm in the diameter, and that is mesh of 5mm corner. The concrete was crushed to 5mm or less, and dropped down in the bottom of the water tank. The recycled coarse aggregate is stayed on the low voltage electrode when the concrete is crushed. The concrete of about 5kg can be crushed by this device at once in laboratory.

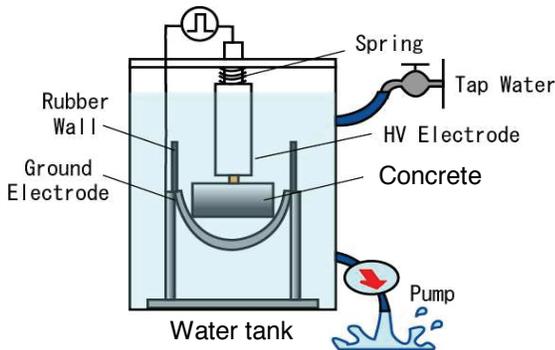


Figure 2 Illustration of crushing the concrete

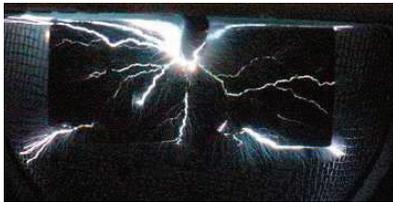


Figure 3 Pulsed discharge in concrete



Figure 4 Reproduction of coarse aggregate

The concrete shown in Figure 5 was used in this research. The size of the concrete test piece is 15cm×15cm×6cm. The recycled aggregate is collected from this concrete test piece. The coarse aggregate for the test piece is Gabbros from Yamaga, Kumamoto, and the fine aggregate is mountain sand from Nankann, Kumamoto. Table 1 shows the physical description of these aggregates.



Figure 5 Concrete

Table 1 Physical description of aggregate

	Bone-dry density (g/cm ³)	Absorption (%)	Fineness modulus
Coarse aggregate	2.98	0.49	6.68
Fine aggregate	2.56	1.27	2.74

4 QUANTITY EVALUATION OF RECYCLED COARSE AGGREGATE

In this research, the one shot of electrical pulse discharge condition is set to 6.4kJ. Pulsed power was discharged 100times. The total consumption energy was set to 640kJ. The aggregate of the size of 5mm or more was assumed to be a recycled coarse aggregate after 640kJ. Quality evaluation test of recycled coarse aggregate was conducted after 640kJ was consumed. The quality evaluation tests are Density test, Absorption test, Sieve test.

4.1 Recycled Coarse Aggregate

The concrete was divided into two to adjust a concrete test piece to about 5kg. The recycled coarse aggregate was collected from four concretes. The weight of these concrete test pieces are shown in Table 2.

Table 2 Concrete test pieces

Concrete test piece	1	2	3	4
Weight(g)	5294.2	5098.8	4835.2	4918.2

The recycled coarse aggregate was collected from these concrete test pieces. The weights of recycled coarse aggregate are shown in Table 3.

Table 3 Sample of recycled coarse aggregate

Recycled coarse aggregate	1	2	3	4
Weight(g)	2308.5	2650.0	2337.5	2964.5

4.2 Density test and Absorption test

Density test and Water absorption test of recycled aggregate were conducted. Figure 6 shows the result of density test, and Figure 7 shows the result of water absorption test. The JIS regulation class H [5] of quality of the recycled aggregate is shown in these figures.

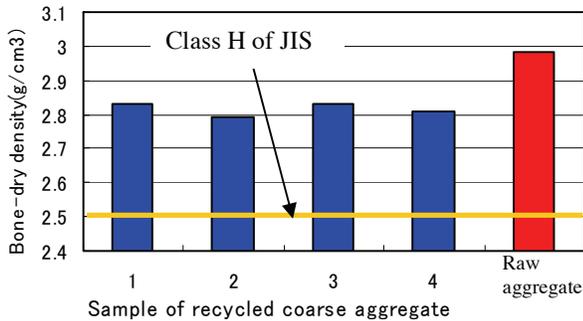


Figure 6 Bone-dry density

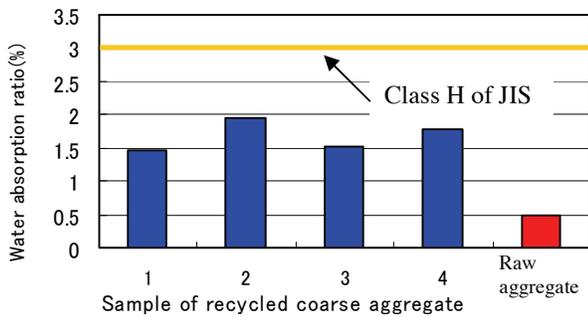


Figure 7 Water absorption ratio

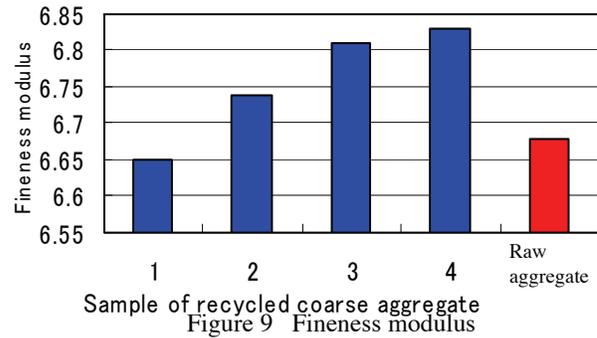
It is found that the quality of recycled coarse aggregates by 640kJ pulsed discharge have the enough qualities of the bone-dry density and the water absorption rate to satisfy JIS regulation class H. Figure 8 shows the recycled coarse aggregate. Mortar has delaminated from aggregate, and the coarse aggregate doesn't damage. So, the pulsed discharge method can collect the recycled coarse aggregate like the shape of the coarse aggregate.



Figure 8 Recycled coarse aggregate

4.3 Sieve test

Sieve test of recycled aggregate were conducted. Figure 9 shows the Fineness modulus of sample of recycled coarse aggregate.



The fineness modulus of the recycled coarse aggregate almostly became the same with the coarse aggregate. But, fineness modulus of sample No.1 became smaller than the raw coarse aggregates. Therefore, an excessive pulsed discharge breaks the coarse aggregate

5 THE CONCRETES CONSISTED OF RECYCLED COARSE AGGREGATE

It is found to be able to collect a high-quality recycled coarse aggregate by pulsed discharge method. Then, this research made the concrete that used the recycled coarse aggregate. Compressive strengths were measured at the 28days. In addition, the Young's modulus was measured. Figure 10 shows the Compressive strengths of concrete. The concretes considered of raw coarse aggregate on the same day.

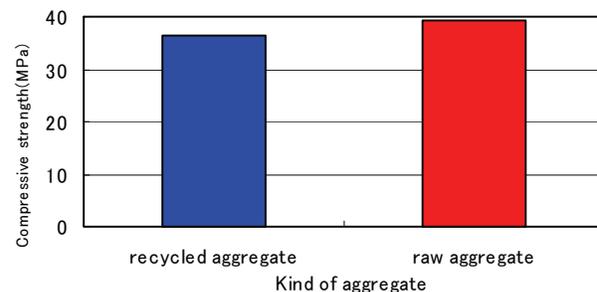


Figure 10 Compressive strength

It is found that the concrete that made by recycled coarse aggregate have almostly same compressive strength of making by raw aggregate. Figure 11 shows the Young's modulus.

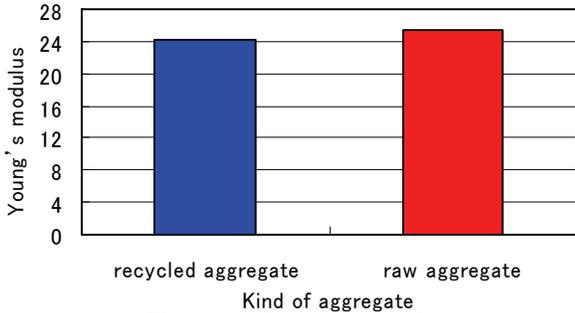


Figure 11 Young's modulus

The concrete that made by recycled aggregate has almostly same Young's modulus of making by raw aggregate. So, it is found that the coarse aggregates that reproduced by pulsed discharge be able to use to concrete.

6 RESIDUE

The mortar and the aggregate that crushed to 5mm or less are dropped down in the bottom of the water tank by pulsed discharge. These are residues. In this research, the residue was classified into the recycled fine aggregate and the powder.

6.1 Recycled fine aggregate

The recycled fine aggregate is aggregate of the size from 5 to 0.15mm in residue. Density test and Water absorption test of recycled fine aggregate were conducted. As a result, it was found that the fine aggregates collected by pulsed discharge have qualities of the bone-dry density and the water absorption rate to satisfy JIS regulation class L. A large amount of mortar was contained in the recycled fine aggregate. So, the recycled fine aggregate has low density and high absorption ratio.

6.2 Powders

The powder is crushed to 0.15mm or less. The amount of powder is serious problem at recycle process of aggregate. Then, the amount of power is calculated. Table 4 shows the amount of powder and recycles percentage of recycled coarse aggregate and recycled fine aggregate.

Table 4 Recycle percentage

	Pulsed method	Heating method
Recycled coarse aggregate (%)	50.9	34
Recycled fine aggregate (%)	37.5	14
Powders	11.6	52

The amount of generation powder is few by pulsed discharge method. In addition, recycle percentages of recycled coarse aggregate is high. These features are the advantages of the pulsed discharge method.

7 AUTOMATIC RECYCLE MACHINE

The quality of recycled aggregate is important solution of recycling aggregate. The recycle speed is also important solution. So, it is necessary to collect a high-quality recycled coarse aggregate quickly. At the pulsed discharge method is a reproduction speed of 1 ton per one hour. Because, the pulsed discharge method conducted the crushing experiment of concrete by manual in laboratory. For solving this problem, we made the automatic recycle machine(Figure 12).



Figure 12 Automatic recycle machine

The recycle speed will be increased to 10 ton per one hour using this machine. So, the reproduction speed being examined with this machine now.

This research aims the practical use of the aggregate reproduction technology by the Pulse Power Technology.

8 ACKNOWLEDGEMENT

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