Evaluation of High Grade Recycled Coarse Aggregate Concrete Quality Using Non-Destructive Testing Technique

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Evaluation of High Grade Recycled Coarse Aggregate Concrete Quality Using Non-Destructive Testing Technique

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Abstract. A large amount of waste concrete generates an environmental problem due to demolition of old concrete structures. To solve this problem, it is necessary to collect recycled aggregate from waste concrete. The conventional recycling technique of recycled aggregate from waste concrete does not indicate a significant quality to be re-used for making a new concrete. We proposed new techniques to produce high grade recycled aggregate by heating-grinding (H-G) method and heating-grinding-acid (H-G-A) method. To ensure the quality of the concrete made from recycled coarse aggregate concrete, the non-destructive evaluation was conducted in this research. High grade recycled aggregate concrete were prepared in advanced using two methods mentioned earlier. Then, new concrete specimens were produced using those types of recycled aggregate concrete. After 28 days curing time, rebound hammer test and ultrasonic pulse velocity test were performed on recycled coarse aggregate concrete to examine the surface hardness and ultrasonic wave velocity of the concrete. Almost similar quality to natural coarse aggregate in terms of density, water absorption, sieve analysis achieved by both H-G recycled coarse aggregate and H-G-A recycled coarse aggregate. However, the surface hardness and ultrasonic wave velocity of H-G-A recycled coarse aggregate concrete is better than those of H-G recycled coarse aggregate concrete. That acid solvent enables to dismantle the cement paste from aggregate surface more effectively, so this types of recycled aggregate shows a better performance than the other one. Continued delamination reduces pores in the interfacial transition zone resulting better bonding mechanism between new cement paste and recycled aggregate surface.

Introduction

The issue of waste concrete recycling has become more important in the world nowadays since construction wastes are increasing rapidly with the growth of the construction industry. After being produced, concrete is used to construct a concrete structure and provided to its user. When the service period of the structure is finished, the structure is demolished and disposed. Great disposal of concrete waste leads to environmental problem. In addition, significant exploitation of natural resources for concrete production is highly prohibited in some parts in the world. Thus, there is an urgent need to establish a recycling technology that reutilizes aggregate from concrete waste as a new material for fabrication of concrete in regard to environmental protection and optimized exploitation of resources. However, the conventional method of recycling does not meet the demand of recycled agregat to re-utilized for making a new concrete. This recycling process only produces smaller part from concrete lumps [1]. It only can be applied as road bed materials due to low quality of recycled aggregate. The surface of recycled aggregate is still attached by the old cement paste leading to low density and high water absorption of this aggregate.

To solve this problem, a new recycling technique has been developing in our laboratory using combination of thermal-mechanical-chemical techniques. Heating exposure up to 100°C – 200 °C weakens bonding between cement past and aggregate [2]. It should be noted that heating up to 500 °C does not affect the structure of the aggregate in concrete. After heating, the hot concrete lumps are then grinded to obtain the size of recycled aggregate. In addition, the recycled aggregate is soaked in acid solution to clean the residu of attached cement paste.

Before the recycled agregate manufactures will be used in, it needs to have the correct physical and mechanical properties. A series of research to examine the recycled agregate has been conducted. The high physical quality of recycled aggregate was obtained. Moreover, the new concrete produced by this type of recycled aggregate has an almost similar compressive strength to concrete made from normal agregate [3].

A non-destructive testing (NDT) was conducted in this research to gain more information about the properties of recycled coarse aggregate concrete produced by heating-grinding (H-G) method and heating-grinding-acid (H-G-A) method. A series of hammer test was applied to examine the surface hardness and ultrasonic pulse velocity test was employed to obtain the wave velocity of the recycled aggregate concrete. The results of these NDT are useful to evaluate the quality of the concrete.

Related Work

The use of recycled aggregate in producing new concrete is often associated with mechanical properties degradation of concrete. It is widely recognized that compressive strength in recycled aggregate concrete is lower than that of normal concrete with the same water-to-cement ratio. Concrete made from recycled aggregate has compressive strength - as much as 26% lower - than that of concrete made by natural aggregate [4]. An amount of attached cement paste reduces the interface adhesion between the recycled aggregate and the new cement paste; thus decreasing the mechanic strength of the concrete.

In Japan a new technology using pulsed power for concrete waste recycling has been developed. A promising result has been achieved because a greater amount of cement paste can be removed from aggregate without damaging the aggregate [5]. The attempt to reduce cement paste from aggregate surface also was studied using three pre-soaking treatment approaches; namely HCL, H_2SO_4 and H_3PO_4 [6].

The quality of concrete is often judged from its mechanical properties using concrete sample which need to be broken to obtain the properties. Non-destructive testing is potential to examine the inside the concrete such as layer and porosity. The study of fracture process in recycled aggregate concrete using acoustic emission has been published [7]. Concrete test hammers on concrete evaluate surface hardness as a function of resiliency, i.e., the ability of a hammer to rebound or spring back. Table 1 show the relationship between the average rebound number and the quality of concrete [8].

Table 1. Relationship between the average rebound number and the quality of concrete [8]

Average Rebound Number	Quality of Concrete
>40	Very good hard layer
30-40	Good layer
20-30	Fair
<20	Poor concrete
0	Delaminated

The pulse velocity method is appropriate for investigating of homogeneity of concrete, and, therefore, for relative assessment of quality of concrete. Heterogeneities in a concrete member will cause variations in the pulse velocity. The diffraction of a wave pulse around an internal air void will cause an increase in the time of propagation for an assumed path through the void center. Thus, the apparent velocity will decrease [8]. Table 2 indicates the relationship between velocity and concrete quality.

Table 2. Relationship between velocity and concrete quality [8]

UPV value in km/sec (V)	Concrete quality
V greater than 4.0	Very good
V between 3.5 and 4.0	Good, but may be porous
V between 3.0 and 3.5	Poor
V between 2.5 and 3.0	Very poor
V between 2.0 and 2.5	Very poor and low integrity
V less than 2.0 and reading fluctuating	No integrity, large voids suspected

Experiment

Material. There were several steps in producing recycled coarse aggregate. First, concrete lumps were heated up to 100^0C for 24 hours. Second is mechanical grinding by 500 cycles using Los Angeles machine. These processes were objected to produce heating-grinding (H-G) recycled coarse aggregate. The addition treatment; which was soaked in acid solution (H_2SO_4) in 24 hours, was aimed to produce heating-grinding-acid (H-G-A) recycled coarse aggregate.

Then new concrete was made using two types of recycled coarse aggregate. For analysis consideration, normal fresh coarse aggregate concrete were also produced taken from the same query as material for recycling. Water cement ratio was 48%. Specimens were silinder concrete. Mixture proportion is shown in Table 3.

Table 3. Mixture proportion of concrete in1 m^3

Concrete type	Concrete ingredients (kg)			
	Cement	Water	Sand	Gravel
Normal coarse aggregate concrete	427	205	675	1013
H-G recycled coarse aggregate concrete	427	205	667	1001
H-G-A recycled coarse aggregate concrete	427	205	671	1007

Method. Rebound numbers were obtained by pushing hammer into the two flat surfaces of the silinder. The position of hammer was perpendicular to the surface of specimen. A rigid floor was used to ensure no sway occurring during the test. Five points reading were taken in each surface of silinder. Meanwhile, in ultrasonic pulse velocity measurement, the transmitter sensor was attached in one surface and receiver sensor was attached in other surface of specimen. Grease was used as a couplant to ensure good signal transmission between sensor and concrete. The velocity then can be read from the display.

Result and Discussion

Physical Properties of Recycled Aggregate. According to visual examination, in margin part of recycled coarse aggregate surfaces is still attached by cement paste. However, H-G-A recycled coarse aggregate surfaces are much more cleaner than H-G recycled coarse aggregate surfaces. For further investigation, the quality examination of recycled aggregate includes density, water absorption, fineness modulus, and sieve analysis are examined. Almost similar properties are obtained compare to normal coarse aggregate, indicating the improvement quality of the recycled aggregate. Table 4 and Fig 1. show the properties of recycled coarse aggregate along with normal coarse aggregate as comparison.

Table 4. Properties of recycled coarse aggregate

Physical properties	Normal	H-G	H-G-A
Density	2,61	2,56	2,59
Water absorption(%)	1,23	2,62	2,43
Fineness Modulus	7,10	7,05	7,03

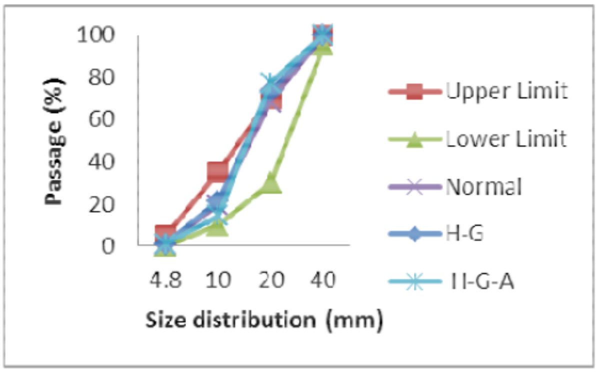

Fig. 1. Sieve analysis

Rebound Hammer Test. Concrete made of normal coarse aggregate possess the highest average rebound number. It is followed by the average rebound number of H-G-A recycled coarse aggregate concrete and that of H-G recycled coarse aggregate concrete respectively. Using H-G-A recycled coarse aggregate in concrete results better surface hardness than that of H-G recycled coarse aggregate. However, all the number falls in range of 30-40 meaning all the concrete is having good layer. Table 5 shows the average rebound number of the concrete.

Table 5. Average rebound number

Concrete type	Average Rebound Number
Normal concrete	37
H-G-A concrete	35
H-G concrete	34

Ultrasonic Pulse Velocity Test. Among the concrete types, the wave velocity of normal concrete is the greatest due to to good adhesive between cement paste and aggregate surface. H-G-A concrete shows better wave velocity around 5.5% than that of H-G concrete. According to Table 3 both recycled aggregate concrete indicate good quality. However, H-G-A concrete consists less porosity than that of H-G concrete. That acid solvent enables to dismantle the cement paste from aggregate surface more effectively, so this types of recycled aggregate shows a better performance than the other one. Continued delamination reduces pores in the interfacial transition zone resulting better bonding mechanism occurs between new cement paste and recycled coarse aggregate surface. Fig 2 illustrates the wave velocity of each concrete type.

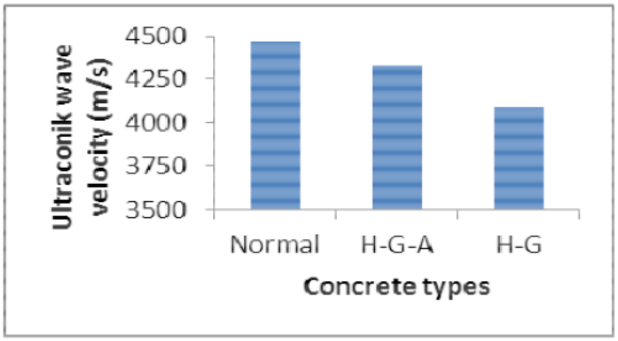

Fig. 2. Wave velocity of concrete.

Conclusion

Almost similar quality to natural coarse aggregate in terms of density, water absorption, sieve analysis achieved by both H-G recycled coarse aggregate and H-G-A recycled coarse aggregate. However, the surface hardness and ultrasonic wave velocity of H-G-A recycled coarse aggregate concrete is better that those of H-G recycled coarse aggregate concrete. That acid solvent enables to dismantle the cement paste from aggregate surface more effectively, so this types of recycled aggregate shows a better performance than the other one. Continued delamination reduces pores in the interfacial transition zone resulting better bonding mechanism occurs between new cement paste and recycled coarse aggregate surface.

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