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Improving of recycled aggregate quality by thermal-mechanical-chemical process

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Abstract

To save natural resources and promote the sustainable development of construction industry, the use recycled coarse aggregate (RCA) from waste concrete has been encouraged recently. However, it is widely accepted that RCA concrete has lower performance about 15% to 20% than that of natural aggregate concrete. The adhered mortar on RCA surfaces causes lower quality of RCA produced through conventional recycling process. Therefore, it is necessary to provide higher quality of RCA from waste concrete by detaching old mortar as much as possible; so that the quality of RCA concrete can be improved as well. This research proposes a thermal-mechanical-chemical process to produce better properties of RCA from waste concrete. Then, new concrete was produced by utilizing the RCA. Results indicate that the physical properties of RCA are close to natural aggregate and meet the requirement of Indonesian Standard for concrete aggregate. Furthermore, the mechanical performance of RCA concrete produced by the proposed method has better mechanical properties to that of conventional RCA. It is about 3-8% lower than the mechanical properties of natural coarse aggregate concrete.

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Keywords: Recycled aggregate; mechanical properties; thermal-mechanical-chemical process.

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1. Introduction

Construction wastes are increasing as the growth of the construction industry; therefore, the issue of waste concrete recycling has become more important in the world nowadays. After the service period is over, the concrete construction might be demolished and disposed. It causes the problem of accumulation of waste concrete in the near future and leads to environmental problem. In addition, significant exploitation of natural resources for concrete production is highly prohibited in some parts in the world. Thus, in favor of the reducing of waste concrete and pointing at sustaining environment, the utilizing of recycled aggregate from waste concrete has been encouraged, recently.

However, the conventional method of recycling does not meet the demand of recycled aggregate 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 [2,3].

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 residue of attached cement paste. Before the recycled aggregate manufactures will be used in, it needs to have the correct physical and mechanical properties. A series of research to examine the recycled aggregate will be discussed in this paper.

2. Related Works

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. Therefore, the utilization of recycled aggregate in producing new concrete is often associated with physical and mechanical deterioration of concrete as well as its durability. Concrete manufactured from recycled aggregate has compressive strength as much as 26% lower than that of concrete made by natural aggregate [3]. This can be understood because generally the recycled aggregate produced by conventional method, the aggregate is still attached by cement paste; therefore, the adhesion of interface between recycled aggregate and cement paste on new concrete reduce. As a result, the mechanics strength of concrete also decreases.

In attempt of producing higher quality recycled aggregate from waste concrete, a pulsed power (PP) technique was implemented [4]. The high quality recycled coarse aggregate (RCA) produced by PP has been conducted. Density and absorption test results of the aggregate meet the requirement for H (high) class set by Japanese Industrial Standard for recycled aggregate. Other research has concentrated on mechanical properties of concrete made using the pulsed power recycled coarse aggregate (PP-RCA). It is clarified that the concrete made by high grade PP-RCA has sufficient compressive strength and Young's modulus to be utilized as construction material [5] and furthermore, analysing of kind of recycled aggregate concrete under acoustic emission testing show the similar behaviour to that of normal concrete aggregate [6].

3. Experiment

3.1. Material

There were several steps in producing recycled coarse aggregate. First, concrete lumps were heated up to 100 °C 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 objected 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 was also produced taken from the same quarry as material for recycling. Water cement ratio was 48%. Specimens were cylinder concrete. Mixture proportion is shown in Table 3.

Table 1. Mixture proportion of concrete in 1 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

3.2. Method

After demoulding, they were placed in a water until the time of testing. Curing was performed in accordance with the ASTM C511 standard. The compressive strength tests were carried out in accordance with ASTM C39 -86 at 28 days. The splitting tensile strength tests were performed according to ASTM C496-87 at 28 days. Meanwhile, flexural strength was determined according to ASTM C597. Each testing of concrete consisted of five samples. Specimens were cylinder concrete in size of 150 mm in diameter and 300 mm in height for compressive and tensile testing. While the specimen for flexural testing were concrete prisms in size of 150 mm x 1500 mm x 500 mm. All experiments were conducted in Material and Structural Engineering Laboratory, Civil Engineering Department, Mataram University.

4. Result and Discussion

4.1. Physical Properties of Recycled Aggregate.

According to visual examination as shown in Fig. 1, in margin part of recycled coarse aggregate surfaces is still attached by cement paste. However, H-G-A recycled coarse aggregate surfaces are much 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 2 and Fig. 2 show the physical properties of recycled coarse aggregate along with normal coarse aggregate as comparison.

(a) (b)

Fig. 1. Recycled Aggregate (a) H-G; (b) H-G-A.

Table 2. 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

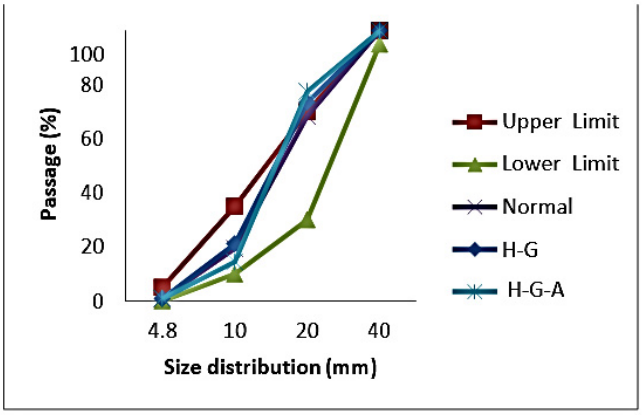

Fig. 2. Sieve analysis

4.2. Mechanical Properties

Mechanical properties of recycled aggregate concrete along with those of normal concrete are written in Table 3. Generally, the mechanical properties of normal concrete aggregate (NCA) are slightly higher than those of both types of recycled concrete aggregate (RCA). Different impact on mechanical properties of two types of RCA is caused by their different quality. H-G-A RCA possesses better mechanical properties than those of H-G RCA. The continued treatment process by soaking in acid solution enables to improve the mechanical properties of H-G-A concrete. However, that mechanical properties improvement is not in significant different so H-G RCA can be potential as well as H-G-A RCA in utilization.

Table 3. Mechanical properties of concrete

Average of mechanical properties (MPa)	Normal aggregate concrete	H-G-A concrete	H-G concrete
Compressive strength	41.77	39.79	39.32
Modulus of elasticity	30280	29643	29472
Splitting tensile strength	4.57	4.49	4.31
Flexure strength	6.29	5.73	5.58

5. Conclusion

Both H-G and H-G-A coarse aggregate almost have similar quality to natural coarse aggregate in terms of density, water absorption, and sieve analysis. However, the Compressive Strength, Modulus of Elasticity, Splitting-Tensile Strength, and Flexure Strength of H-G recycled coarse aggregate concrete is less than those of H-G-A recycled coarse aggregate concrete. The acid solvent treatment of H-G-A enables to remove the cement paste from aggregate surface more effectively than that of H-G, therefore the H-G-A recycled aggregate gives better performances than those of H-G. Continued delamination process increases bonding mechanism between new cement paste and recycled coarse aggregate surface. However, that mechanical properties of both RCA concrete are not in significant different so that they can be potential as construction material in near future.

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