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Mechanical Properties of Concrete with Recycled Aggregate

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ABSTRACT

In this study, the idea of using waste product is done by recycling the concrete coarse aggregate (RCCA) as a replacement material for normal coarse aggregate. The objective of this study concentrates on mechanical properties that are compressive and flexural strength of concrete with RCCA. 50% and 100% of RCCA were used to replace the normal coarse aggregate and tested on 7, 14 and 28 days age of concrete. The strength of normal concrete as control mix has been compared with the concrete with RCCA. The result revealed that the normal concrete present the highest compressive and flexural strength and followed by concrete with 100% and 50% RCCA. As a conclusion, RCCA reduced the compressive and flexural strength of concrete but still achieve targeted strength for concrete used in construction.

1. Introduction

The concrete aggregate used in domestic construction industry had been dependent mainly on the natural aggregate such as river sand and river gravel until early 1980s, but the natural aggregate has been seriously drained out due to the massive collection of it as the construction demand has sharply increased since mid 1980s (Lee et. al, 2007). The global concrete industry will annually require 8 to 12 billion tones of natural aggregate after the year 2010, as more than three quarters of concrete volume is commonly composed of aggregate (Tu et al, 2006). Accordingly, as a substitution aggregate, the recycled aggregate from waste concrete can be used to replace the aggregate in the composition of concrete.

The heaviest materials found in construction and demolition waste are rocks, aggregates, concrete and ceramic residues. In this regard, the recycled aggregate is highly recommended to be researched in a recent atmosphere in which the environmental protection rises as a matter of national concern as the recycled aggregate can minimize the waste, and reduce the costs of waste treatment and energy used through the recycling of the produced waste. In addition, the effect of natural resource protection and pollution prevention can be expected.

The use of recycled aggregates in concrete opens a whole new range of possibilities in the reuse of materials in the building industry. This could be an important breakthrough for our society in our endeavors towards sustainable development. The trend of the utilization of recycled aggregates is the solution to the

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problem of an excess of waste material, not forgetting the parallel trend of improvement of final product quality. The utilization of waste construction materials has to be related to the application of quality guarantee systems in order to achieve suitable properties of the product. Therefore, the complete understanding of the characteristics of new material becomes so important in order to point out its real possibilities.

Even though aggregate typically accounts for 70% to 80% of the concrete volume, it is commonly thought of as inert filler having little effect on the finished concrete properties. However, previous research has shown that aggregate in fact plays a substantial role in determining workability, strength, dimensional stability, and durability of the concrete. Also, aggregates can have a significant effect on the cost of the concrete mixture. Certain aggregate parameters are known to be important for engineered-use concrete: hardness, strength, and durability. The aggregate must be clean, without absorbed chemicals, clay coatings, and other fine materials in concentrations that could alter the hydration and bond of the cement paste (Kumar and Monteiro, 2006).

Aggregate composed of recycled concrete generally has a lower specific gravity and a higher absorption than conventional gravel aggregate. New concrete made with recycled concrete aggregate typically has good workability, durability and resistance to saturated freeze-thaw action. The compressive strength varies with the compressive strength of the original concrete and the water-cement ratio of the new concrete. It has been found that concrete made with recycled concrete aggregate has at least two-thirds the compressive strength and modulus of elasticity of natural aggregate concrete (Lee et. al, 2007).

Nevertheless, the utilization of recycled aggregate for concrete is still necessary, as concrete is becoming more and more widely used around the world. Furthermore, the utilization of recycled aggregate might at least lead the concrete industry to embrace the concept of sustainable development in the near future. With an increase in our environmental consciousness, together with economic considerations, the construction industry is coming under intense scrutiny and pressures; it will be soon dealing with the problem of the depletion of the supply of natural aggregates. For that reason, this study was carried out to investigate the possibilities of recycling demolished concrete structures as aggregate in the production of new concrete.

2. Methodology

In order to investigate the mechanical properties of concrete containing recycled concrete aggregate (RCA), the laboratory work was performed focused on compressive and flexural strength test. This study covers the behavior of concrete grade 30 according to the Standard Department of Environmental (DOE), UK. The sizes of specimens for compressive strength test and flexural strength test are 150mm X 150mm X 150mm cube and 100mm X 100mm X 500mm prism, respectively. The testing was carried out at the age of 7, 14 and 28 days for specimens of concrete with normal concrete, 50% and 100% recycled concrete coarse aggregate, according to standard BS 1881 : Part 116 and ASTM C78–02.

The methodology of laboratory work was divided into four stages. First stage involved the preparation of material and samples. Material consists of Ordinary Portland Cement, water, fine, coarse and recycled concrete coarse aggregates and the quantities of materials based on 3 types of concrete samples is shown in Table 1. Then for the next stage, concrete mix was run after sieve analysis and moisture content test. A cube mould of 150mm x 150mm x 150mm in size and prism mould of 500mm x 100mm x 100mm were used for all types of concrete. For workability test, the test involved is slump test that carried out immediately after concreting done. The concrete samples were taken out from mould after 24 hours and followed by curing test according to ASTM C 192 for 7, 14 and 28 days.

The third stage is the destructive test that was conducted after completing the curing process. The compression and flexural test were done based on BS 1881: Part 116 and ASTM C 78-02, respectively. A total of 27 cubes and 27 beams were cast and being tested. For the last stage, data collection was carried and data has been processed to get the value of compressive and flexural strength for normal concrete and concrete with recycled coarse aggregate. After that, the comparison of mechanical properties of both concrete was analyzed.

Table 1: Quantity of Materials Based on 3 Types of Concrete Samples

Materials	**Quantity (kg/m^3)**		
	Normal Concrete (NC)	**Concrete with 50% RCCA (C50)**	**Concrete with 50% RCCA (C100)**
Portland Cement	359.65	359.65	359.65
Fine Aggregate	778.45	778.45	778.45
Coarse Aggregate	1031.90	515.95	-
Recycled Concrete Coarse aggregate	-	515.95	1031.90
Water	205.00	205.00	205.00

3. Result and Discussion

3.1 Moisture Content

Moisture content test was performed for fine, coarse and RCCA. The result of the moisture content is shown in Table 2. From the result, fine aggregates have higher moisture content than coarse aggregate. This is because fine aggregate have high absorption capacity and higher surface moisture. Coarse aggregates absorb very little and also hold little water on the surface. RCCA have cement particle that still adhere at the aggregate so its moisture content is higher than normal coarse aggregates.

Table 2: Moisture Content of Aggregate for Different Batch of Concrete

Aggregate	Moisture Content (%)	
	C50	C100
Fine Aggregate	5.21	4.25
Coarse Aggregate	2.62	-
RCCA	3.72	3.15

3.2 Sieve Analysis

In this study, sieve analysis was performed for fine aggregate, coarse aggregate and RCCA according to ASTM C136-05. The aggregates can be classified based on their size. For coarse aggregate and recycled coarse aggregate, it indicates that about 100% of total mass of the aggregates is passing 20mm sieve and it can be concluded that the coarse aggregates that used in this sample have a maximum size of 20mm. For fine aggregate, the sand that was used in this experiment is a fine material with the article size passing 5.00 mm sieve. Result from the data of sieve analysis for all types of aggregates was combined in a cumulative graph and shows in Figure 1.

As a conclusion, the grading of the sample aggregate used in this test is in appropriate limit which indicated that they fulfilled the grading requirement as material for structural used.

3.3 Workability

Table 3 show the result of slump test between different types of concrete. The workability of concrete can be classified by the type of slump. For the normal concrete and concrete with 50% RCCA, the type of slump is shear slump that is same as designed in concrete mix. It is different between concrete with 100 % RCCA. The reason is when using a recycled concrete coarse aggregate, it still has a particle of cement or dust adhere at the aggregate so it absorb more water than normal coarse aggregate. It is indicate that this reduction in slump is due to the higher absorption capacity of the recycled aggregates. According to the RMC Research & Education Foundation Studies report, it showed that RCCA content in concrete mixtures increases, as their workability decreases. As a conclusion, the NC and C50 concrete have a higher workability than C100 concrete.

Table 3: Slump Test of Different Types of Concrete

Concrete Types	**Height of Slump (mm)**	**Type of Slump**
NC	132	Shear
C50	106	Shear
C100	12	True

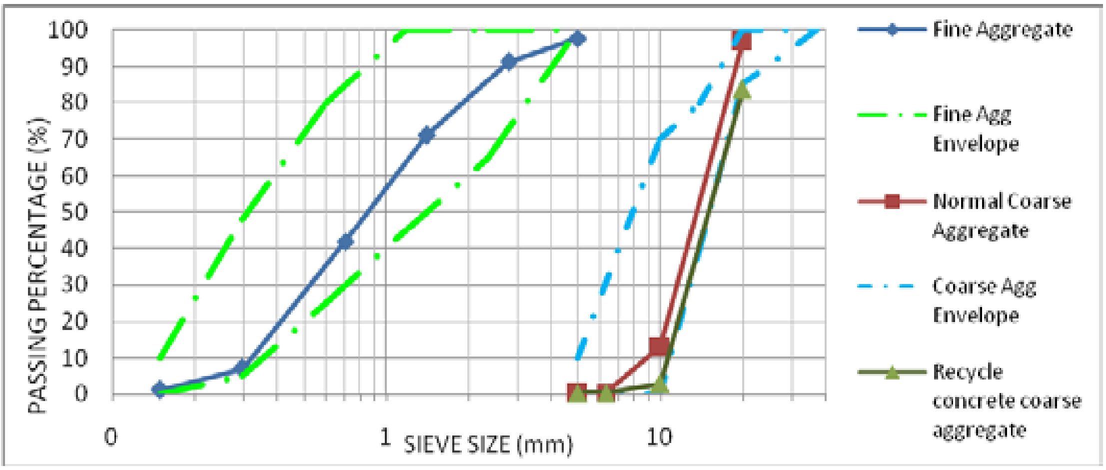

Figure 1: Sieve Analysis of Aggregate

3.4 Compressive Strength

The compressive strength of concrete specimens was determined for different types of concrete after 7, 14 and 28 days of standard curing. The load was applied at a rate of 14 N/mm^2 per minute in accordance to the BS 1881-116:1983 test method and the result were shown in Figure 2. The development of compression strength between three types of concrete after 28 days of curing process shows similar trend as age of concrete before. The normal concrete sample still emerged as the highest compression strength compared with the existence of RCCA in concrete. As expected, sample of concrete with 100% and 50% RCCA still produce lower strength from normal concrete sample with the percentage decrease about 8% and 13.4% respectively.

The compressive strength of concrete is slightly decreased due to the addition of RCCA as the replacement of normal aggregate. The replacement material did not help to improve the strength but the strength is still nearly each others. Therefore, in this study the volume of 50% and 100% RCCA as a replacement normal coarse aggregate in concrete mix decrease the compressive strength of the concrete. Nonetheless, all the three types of concrete attained the design grade of the concrete that is 30 MPa.

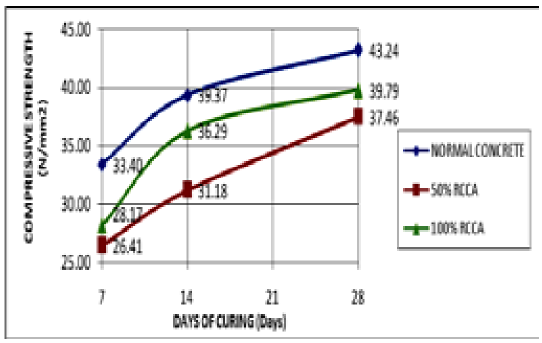

Figure 2: Compressive Strength of Different Types of Concrete

3.5 Flexural Strength

In order to determine the value of flexural strength of concrete, third-point load test were done. Figure 3 shows the result of flexural strength. After 7 days curing period, it shows that C100 concrete performed the highest flexural strength compared to the other two different types of concrete. The percentage increase in term of flexural strength from normal concrete sample to sample of C100 concrete was 26.5% and for sample of C50 concrete, the strength was decrease about 5.2 % from strength of normal concrete. As discussed before, the hydration process may influence the strength of the concrete. C100 concrete have low water content and make the concrete harden faster than other two types of concrete.

The development of compression strength between three types of concrete after 28 days of curing process shows similar trend as age of 14 days. The normal concrete sample emerged as the highest compression strength compared to the others two types of concrete. As expected, sample of C100 concrete and C50 concrete still showing decline development of flexural strength from normal concrete sample. However the percentage of difference was not too high which are 0.7 % and 3.9% for C100 and C50, respectively. Therefore, addition and replacement with RCCA influences the flexural strength.

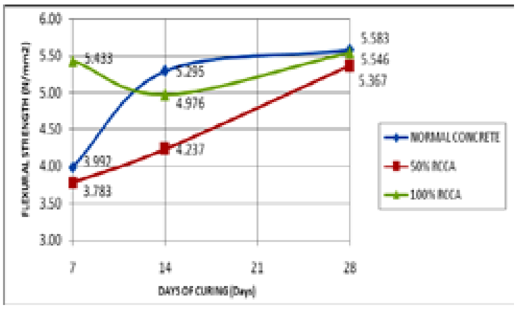

Figure 3: Flexural Strength of Different Types of Concrete

4. Conclusion

The addition of RCCA as a replacement for the normal coarse aggregate in concrete mixes produces a significant reduction in concrete compressive strength. The reason is because, RCCA have a low quality compare to the normal aggregate because during the crushing process, particle of cement still adhere at the aggregate so the aggregate not clean as a normal aggregate. Besides that, RCCA did not mixed well enough with normal aggregate and mortar in concrete mixture. This will cause segregation in the concrete. This implies on the separation on the RCCA and normal coarse aggregate from mortar and will cause the strength of concrete decrease. However, the decreasing in compressive strength still in the range of the design grade of the concrete that is 30 MPa.

The result of flexural strength showed that the strength is slightly decreased due to the addition of RCCA as the replacement of normal aggregate. It can be considered that the low of flexural strength obtained to be due to weak bonding between the cement paste and the aggregate. Bond between aggregate and cement paste is an important factor in the flexural strength of concrete.

Several studies performed recently showed application of recycled concrete coarse aggregate not improve the concrete strength but according to a comparison of concretes made by Dutch (2000) investigate that the use of 20% of recycled aggregates in concrete has no negative influence in concrete strength with respect to conventional concrete.

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