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PROPERTIES OF CONCRETE MADE WITH RECYCLED COARSE AGGREGATES FROM OLD CONCRETE CUBES

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Sustainability in the construction industry is a global concern, and one way of handling this is the idea of recycling old concrete rubbles in the production of fresh concrete. Recycled aggregate concrete is normally classified as light weight concrete and recommended for use in production of low-grade non-structural elements. This study examined the properties of crushed old concrete cubes as replacement for natural aggregate. Five specimens 150x150mm concrete cubes with varying percentages of coarse recycled aggregate of 0 %(control), 25, 50, 75 and 100% were prepared. All the mixes were proportioned using the absolute volume method with a targeted compressive strength of 30N/mm^2 and varying w/c ratio. The result shows that with up to 75% replacement of natural aggregate with recycled aggregate, the 28 days compressive strength of concrete is in close proximity with that of normal concrete. While the strength of exclusive recycled aggregate concrete is about 15% lesser than that of exclusive natural aggregate. The result of this research confirms that crushed old concrete cubes can be safely used in the production of high grade concrete.

Keywords: Natural aggregate, Water absorption, Compressive strength, Slump, Workability, Absolute volume.

1 INTRODUCTION

One of the aftermaths of rapid industrial growth all over the world is the depletion of natural aggregates, which is the major concrete material, and generation of large amount of waste from construction and demolition activities. To overcome this problem, sustainable concrete construction is one of the strategies being considered by the construction industry. One way of achieving this is to introduce recycled aggregate from these construction and demolition wastes into the production of fresh concrete, Khalaf et al (2004) and Zaidi et al (2009).

Though, the reuse of recycled aggregate (RA) is not, presently a common practice in many countries because there is no depletion of natural aggregates yet. But time will come when the sources of natural aggregates will reduce and shortage of its supply will pose serious challenge to the industry. Many significant researches have been carried out which generally confirmed that the mechanical properties of recycled aggregates concrete (RAC) depends largely on the properties of the recycled aggregate used to produce the new concrete, (Chen et al 2003, Topcu and Sengel 2004 and Limbachiya et

al 2004). Generally, construction and demolition (C&D) wastes often contains foreign matters in the form of metals, wood, hardboard, paper, plastics and some organic materials which may indirectly affect the performance of RAC, Limbachiya et al (2004). In line with the level of contaminants, RA can be broadly divided into three categories as shown in Table 1.

Table 1. Categorization of recycle aggregates.

Recycled Aggregate Source	Aggregate Characteristics
Demolition of existing concrete structure	High level of contamination, Unknown constituent materials, and Irregular consistency
Rejected concrete from ready-mix plants and left over from in-situ cast concrete	Low contamination, Regular consistency, Known constituent materials, but High un-hydrated cement paste content
Old laboratory cast specimen	Low contamination, Regular consistency, Known constituent materials, and Known concrete grade

Some parts of recycled aggregate from C&D activities are mortar from the concrete and plastering that can have shape like aggregate and which might be responsible for the low strength of concrete produced from such aggregates. RA from C&D is readily available and in large quantity in many countries and hence many researchers used it directly in their works. It was found that the workability of fresh RAC decreases with an increase in RA percentage due to water absorption of mortal adhere to recycled aggregate, Topcu and Sengel (2004) and Rahal (2007). While Rao et al (2007) reported that RAC with 100% replacement of RA will have a decrease of about 13% in flexural strength compared to natural aggregate concrete (NAC), Zaidi et al (2009) found that the compressive strength of RAC is within the same range compared to NAC. Yet, RAC is normally classified as light weight concrete and recommended for use in production of low-grade concrete. In order to promote wider applications of RAC, there is need for better understanding of the causes of strength reduction in RAC. This research therefore focused on the use of old laboratory cast specimens as the source of RA with the aim of determining the role of contaminations in the properties of RAC.

2 MATERIALS AND EXPERIMENTAL PROCEDURE

2.1 Materials

Portland cement conforming to BS 12 (1996) was used throughout the experiment. Natural river sand, sourced from Ogun River in the Southwest region of Nigeria, was used as fine aggregates. The fine aggregates have maximum size of 2.36mm in conformity with the requirements in BS 882 (1992). The natural aggregates (NA) used were natural quarry granites of 20mm maximum size. The recycle aggregates used were obtained by manually crushing old concrete cubes laboratory specimens using hammer (F igure 1), the crushed concrete was then sieved through 25mm and 4.75mm sieve in a mechanical shaker. Recycled aggregate passing 25mm and retained on

4.75mm sieve was collected and served as the recycled aggregates. Sieved recycled aggregate was later rinsed with clean water in order to remove dust fractions. There are research results indicating that difference in compressive and bending strength of concrete produced with rinsed and non-rinsed recycled aggregates can reach up to 10%, Ajdukiewicz and Kliszczewicz (2002). By rinsing, impurities from recycled aggregate surface will be removed and this can lead to strengthening aggregate –cement paste matrix. After this rinsing exercise, the RA was left to dry under the sun before used for concrete. While Table 2 shows the basic properties of natural and recycled aggregates.

Figure 1. Manual crushing of old concrete cubes.

Table 2. Properties of natural and recycled aggregates.

Property	Natural Aggregate	Recycled Aggregate
Water absorbability (%)	3.0	5.4
Crushing ratio (%)	16.0	21.0
Mass loss (%)	4.2	4.8

2.2 Experimental Procedure

Five specimens of 150mmx150mm concrete cubes with variable amount of coarse recycled aggregate (0%, 25%, 50%, 75% and 100%) were prepared. All the mixes were proportioned using the absolute volume method with a targeted compressive strength of 30N/mm^2. Due to the high rate of water absorption of the recycled aggregates, the determination of the amount of mixing water was done experimentally in order to maintain consistency in mixing and achieve reasonable workability. Table 3 shows the compositions of concrete mixes.

Table 3. Concrete mix compositions.

Mix Type	Cement (kg)	Water (m3)	w/c Ratio	Sand (kg)	Natural Aggregate (kg)	Recycled Aggregate (kg)
NAC	386	0.174	0.45	573	764	-
RAC1	378	0.178	0.47	566	566	190
RAC2	376	0.184	0.49	557	372	372
RAC3	374	0.191	0.51	547	182	548

RAC4	371	0.200	0.55	535	-	764

In Table 3, the followings are the proportioning:

- NAC – concrete mix with exclusively natural aggregates (control)
- RAC1 – concrete mix with replacement of natural aggregate with 25% of recycled aggregates
- RAC2 - concrete mix with replacement of natural aggregate with 50% of recycled aggregates
- RAC3 - concrete mix with replacement of natural aggregate with 75% of recycled aggregates
- RAC4 - concrete mix with exclusively recycled aggregates

3 RESULTS AND DISCUSSION

Table 4 shows the basic properties of the fresh concrete.

Table 4. Properties of fresh concrete mix.

Property	**NAC**	**RAC1**	**RAC2**	**RAC3**	**RAC4**
w/c ratio	0.45	0.47	0.49	0.51	0.55
Slump (mm)	65	55	25	10	0
Density (kg/m3)	2472	2440	2419	2388	2350

From Table 4, the result showed that increase in the percentage of recycled aggregate decreased the density of the concrete mix. The reason for this is likely to be the higher porosity characteristic of recycled aggregate in comparison to natural aggregate. The workability of the mixes also decreased as RA percentage increases as shown by the slumps and no slump recorded for the exclusively RAC. This must be due to the high water absorption of adhered mortar on the RA. Compressive strength tests on standard 150mm cube concrete cubes were carried out at ages up to 90 days after initial curing in water at room temperature. The influence of RA on compressive strength of concrete is plotted in Figure 2.

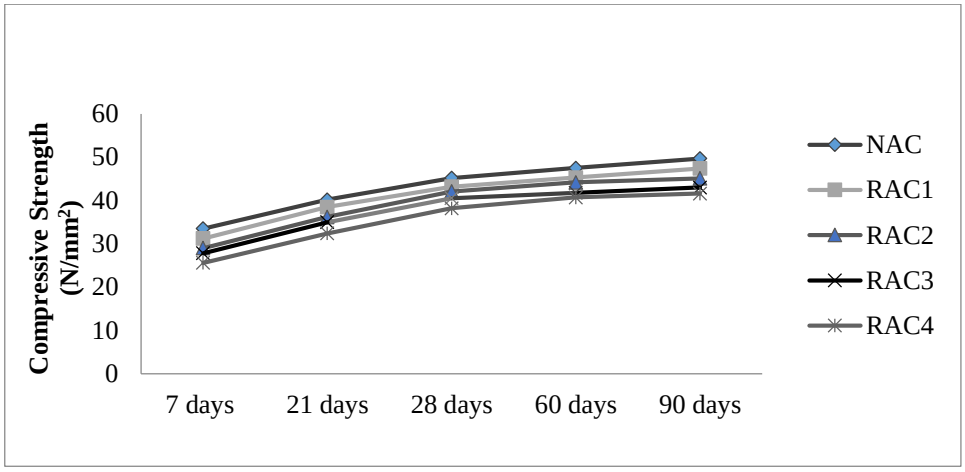

Figure 2. Graph of concrete strength versus age.

The results show that percentage replacement of RA up to 50% has no significance effect on concrete strength. But thereafter, a gradual reduction with increasing RA content occurred.

Water absorption was carried out on the samples on the basis of mass difference when saturated with water and when oven dried to 100^0c. The results, as reflected in figure 3, shows that water absorption of concrete increases with the increase in RA content. This is possibly caused by the remains of old mortar which adhere to the recycled aggregate, thus increasing concrete porosity and consequently increase in water absorption.

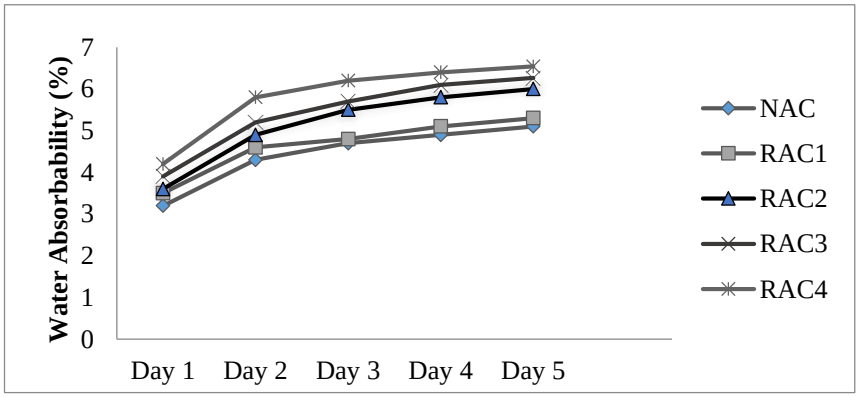

Figure 3. Graph of concrete water absorbability.

4 CONCLUSION

The results of this study shows that crushed old concrete cubes possess less contamination and can be safely used in the production of high grade concrete with little adjustment in w/c ratio. It is very interesting to know that the difference in 28 days compressive strength of exclusively NAC and exclusively RAC is just about 15%,

which implies that the high reduction in strength recorded by past researchers using construction and demolition rubbles as RA must have been due to high contaminations from the rubbles.

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