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# Effect of Elevated Temperature on the Compressive Strength of Recycled Aggregate Concrete

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## Abstract

*Effect of elevated temperature on the compressive strength of concrete element with recycled aggregate was investigated. Natural aggregates were replaced with recycled aggregates during casting at 0, 25, 50, 75 & 100 percentages using water cement ratio of 0.60.The natural aggregates used were quarried granites from parent igneous rock with maximum sizes of 19mm. While the recycled aggregates were gotten from demolished old concrete building, crushed manually and sieved to also get maximum sizes of 19mm.Total of 75 concrete cubes of 150mm x 150mm sizes were cast and properly cured for 28 days. The concrete cubes were then subjected to different level of temperatures (50°c, 100°c, 200°c, 300°c, and 400°c) for a period of eight (8) hours in the electronic oven. Test results showed an average of38% reduction in strength for all percentage replacements with recycled aggregates within temperature ranges not above 200°c compare to about 25% reduction in strength of samples with 100% natural aggregates. For temperature ranges between 300°c and 400°c, an average of 55% reduction in strength was observed for samples with various percentage replacements with recycled aggregates.*

**Keywords:** Recycled aggregates, Natural aggregates, Temperature, Compressive strength, Concrete.

## Introduction

Consideration of recycled aggregates (RA) utilization in concrete production has been increasing gradually due to environmental and economic benefits. The use of alternative materials (in this case, demolished concrete rubies) can make an important contribution to the preservation of natural resources as well as substantially reducing landfill loads and protecting the environment[1-3].

Research have shown that that mechanical properties and durability characteristics of recycled aggregates concrete (RAC) depends, to a large extent, on the properties and characteristics of the recycled aggregates used[4] and the percentage replacement of natural aggregates in the new concrete[5]. Various researchers have shown that there is between 6% and 10% decrease in compressive strength of RAC compare to natural aggregates concrete (NAC)[1,3-5].

One area of RAC that has not been properly investigated is its behavior when subjected to elevated temperature. Normally, concrete is known to be a construction material with very good fire resistance properties in comparison to other construction materials, but the deterioration which occurs in the physical and mechanical properties of concrete when there is rise in temperature is because of the changes in the chemical composition of the binding paste and in the properties of aggregates used[6,7].

Generally, it is believe that high temperature causes major physical and chemical changes in concrete[2], once temperature is above $110^0$C, the dehydration becomes very significant[7]. In the research carried out by Georgali and Tsakiridis, it was discovered that Calcium Hydroxide, which is one of the most important compounds in cement paste, dissociates at around $530^0$c resulting in shrinkage of concrete[8]. The reduction in the compressive strength of concrete was significantly larger for specimen exposed to $600^0$C[9]. Arioz also observed that the weight of the concrete reduced significantly as the temperature increased[10].

All regional codes of practice specified different fire safety requirements which structural concrete members in building must satisfy. Though, the specifications depends on type of building and the level of exposure to fire, but basically, provision of adequate fire resistance measures for concrete members is an essential part of building design[11].

Response of structural concrete element to fire is highly influenced by the properties of the constituent materials, mainly the type and source of aggregates used[10]. The deformation, thermal and mechanical properties governs the extent of deformation, strength loss and stiffness deterioration expected in a concrete element when temperature rises[12].

RAC, because of its diverse characteristics, requires better understanding of its behavior under fire before recommending it for structural elements. The aim of this study, therefore, is to investigate some mechanical properties of RAC compare to NAC when subjected to moderate fire intensity.

## Materials and Methods

**Coarse Aggregates:** The rubbles were obtained from demolished old buildings within Yaba College of Technology. These buildings age ranges between 30 to 50 years and they were demolished to allow for erection of new and modern structures. Large parts of the demolished concrete were taken to the laboratory and broken into pieces manually by project students and lab workers.

The broken concrete pieces were then sieved through 20mm sieve in a mechanical shaker so that recycled aggregates passing 20mm sieve and retained on 12.5mm sieve were collected and used for the mix.

The natural coarse aggregate (NA) used was gotten from the commercial source within the city, it is made of crushed granites from igneous rock with a maximum crushing size of 19mm.

Table 1 shows some measured properties of both natural and recycled coarse aggregates.

**Fine Aggregates:** Fine aggregates used were natural river sand (Ogun River), with maximum particle size of 4.75mm, sourced commercially within the city.

**Binder and Water:** The binder used in this research is the Ordinary Portland Cement 42.5 grade conforming to specifications in BS 12:1996[13], and portable water from the laboratory was used for mixing.

**Experimental Procedure:** Natural aggregates were replaced with recycled aggregates during casting at 0, 25, 50, 75 and 100 percentages using water cement ratio of 0.60 and 1:2:4 mix ratio using the absolute volume method. Total of 75 concrete cubes of 150mm x 150mm sizes were cast, comprising of 15 concrete cubes for each of the percentage replacement. All the concrete cubes were then properly cured by immersion in water for 28 days under ambient temperature. After curing, the specimens were heated in a furnace to different level of temperatures (50°C, 100°C, 200°C, 300°C, and 400°C) for a period of eight (8) hours. Compressive strength was determined by testing cubes to destruction.

## Results and Discussion

Table-1 shows some basic properties of both natural aggregates and recycled aggregates used in this research. As expected, RA has significantly higher absorption than NA, but the specific gravity (SSD) is smaller.

The measured water absorption of RA is higher than that of NA because the porosity of old mortar which adheres to the recycled aggregates is very high.

**Table-1**
**Properties of Coarse Aggregates used**

| Properties | Natural Aggregate | Recycled Aggregate |
|---|---|---|
| Water absorption (%) | 1.35 | 4.50 |
| Specific gravity (SSD) | 2.80 | 2.35 |
| Bulk density (kg/m3) | 1475 | 1350 |

Slump for each mix of concrete with percentage replacement of RA was taken. The results, in Table-2, indicate that slump of concrete made with NA is higher while that made with RA reduces with increase in percentage replacement. The low slump on RAC is due to the high water absorption of RA. Only concrete with 25% RA gave a true slump, concrete with other percentages of RA exhibit low workability to near no slump.

**Table-2**
**Slump test result on fresh concrete mix**

| Concrete with % replacement of RA | Slump (mm) |
|---|---|
| 0 | 65 |
| 25 | 55 |
| 50 | 25 |
| 75 | 10 |
| 100 | 5 |

Table-3 and Figure-1 shows the results of compressive strength of tested concrete cubes after heating at various temperatures for 8 hours. From the results, the strength of concrete reduces as temperature and percentage replacement with RA increases.

However, the compressive strength value of RAC with 25% replacement of RA is very close to that of the control concrete.

## Conclusion

Based on the above results, it is concluded that the difference in the compressive strength of RAC and NAC after heating is marginal and with little modification of RAC properties, it should compare favorably with NAC. However, it could safely be suggested that RAC with percentage replacement above 25% of RA should be avoided when high temperature is a design consideration.

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**Table-3**
**Average Compressive Strength values of specimens after heating**

| % of RA | 0°C | 50°C | 100°C | 200°C | 300°C | 400°C |
|---|---|---|---|---|---|---|
| 0% | 32.30 | 25.71 | 14.47 | 14.22 | 13.04 | 12.96 |
| 25% | 28.22 | 20.34 | 13.58 | 13.34 | 12.89 | 12.30 |
| 50% | 25.15 | 17.04 | 13.40 | 13.32 | 12.44 | 12.22 |
| 75% | 20.32 | 16.08 | 12.51 | 12.15 | 11.95 | 11.80 |
| 100% | 18.11 | 13.33 | 12.20 | 12.09 | 11.44 | 11.35 |

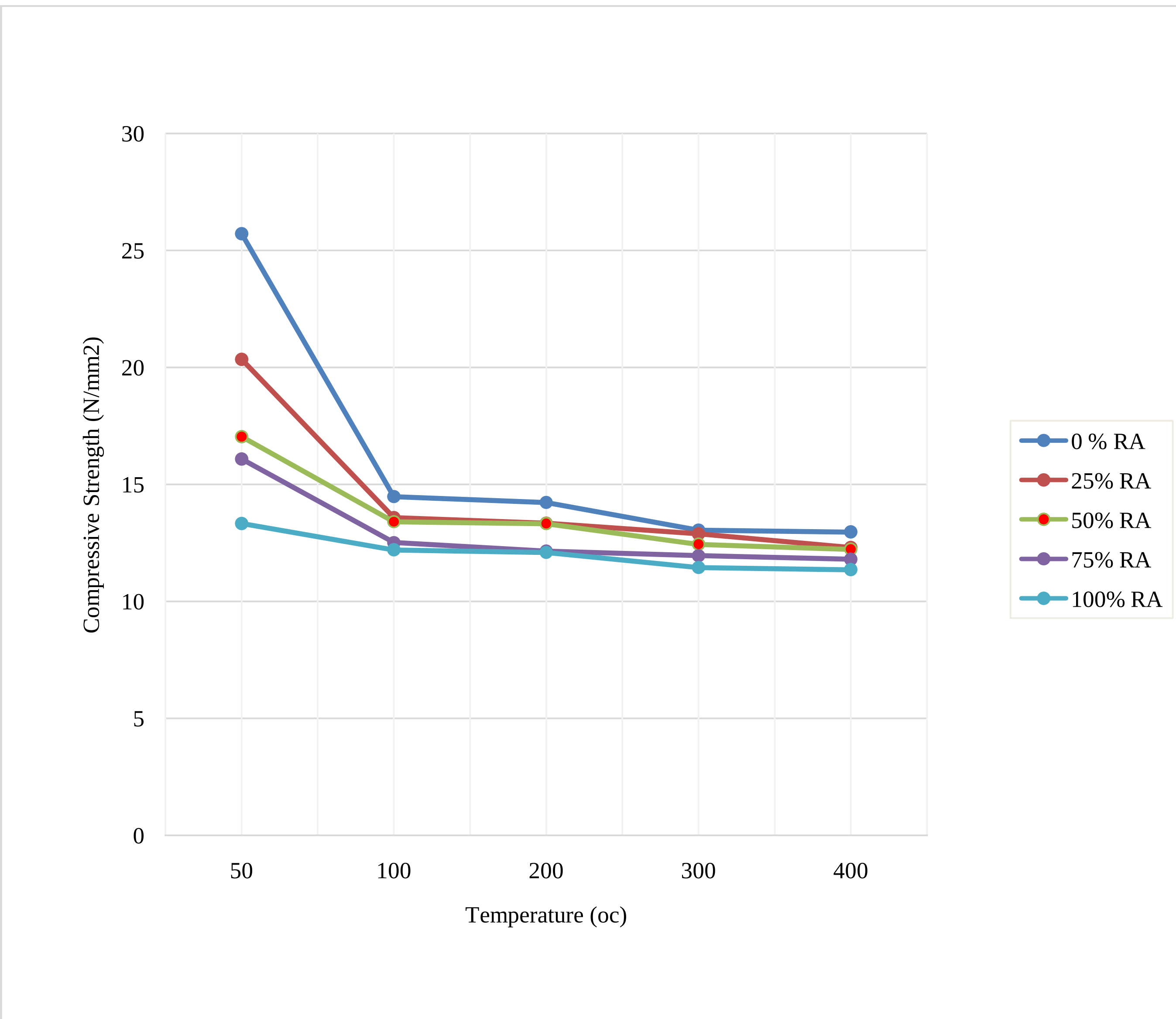


**Figure-1**
**Graph of average compressive strength against temperature**

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