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The Influence of Aggregate Types on Strength Behaviour of Geopolymer Concrete

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Abstract - **The aim of the research work is to study the influence of aggregate types on the strength behaviour of geopolymer concrete. Coarse aggregates of 20 mm from Limestone, Granite and Bush gravel were used. The combination of alkaline solution and Rice Husk Ash (RHA) formed the binding medium in ratio 4:10. The Alkaline solution was a combination of Sodium Silicate and Sodium Hydroxide in ratio 10:25. The amount of alumina and silica oxides in RHA was determined to be 81.28%. The mixing ratio of material constituents used in producing geopolymer concrete was 1:2:4. River sand was used as fine aggregates. Compressive and flexural strengths of all types of aggregates were determined at varying curing hours at constant temperature of 100°C. Results obtained showed that the compressive and flexural strength vary from 13.37 to 14.30 N/mm^2 and 2.01 to 2.18 N/mm^2 respectively. Both compressive and flexural strengths increased as the curing hours increased, but limestone gave highest strength, this may be attributed to cementing properties of limestone. Conclusively, it can be deduced that RHA is rich in Alumina and Silica oxides; thus, it is useful as source material. Geopolymer concrete showed an excellent workability and the one produced with coarse aggregates from limestone gave optimum performance.**

Keywords - **Aggregate, Behaviour, Compressive, Flexural, Geopolymer, Strength**

I. INTRODUCTION

Concrete is a versatile Engineering material consisting of cementing substance, aggregates, water and often controlled amount of entrained air. It is initially a plastic, workable mixture which can be moulded into a wide variety of shapes when wet [15]. Concrete is considerably stronger in compression than in tension, for structures required to carry only compressive loads such as massive gravity dams and heavy foundations, reinforcement is not required and the concrete is consequently called plain concrete. When the structure is to be subjected to tensile stresses, steel bars are embedded in the concrete [15]. The extent to which a given concrete resists the compressive stresses to which it is subjected depends largely on the compressive strength of the concrete which in turn depends on the quality of the concrete. Since seventy percent of concrete is made up of aggregates, its types, quality and general properties determine the quality of concrete [1]. Aggregates are usually cheaper than cement and constitute over 70% of the volume of concrete. The availability and proximity of aggregate to the construction site also affects the cost of construction [4].

The global use of concrete is increasing on daily basis. As the demand for concrete as a construction material increases, so also the demand for Portland cement. It is estimated that the production of cement will increase from about 1.5 billion tons in 1995 to 2.2 billion tons in 2010 [11]. Significant increases in cement production have been observed and are anticipated to increase due to the massive increase in infrastructure and industrialization in India, China, South America etc [20]. It is generally agreed that the production of Portland cement clinker is expensive and ecologically harmful [13]. The emissions generated by Portland cement productions are principal contributors to the Green House Gas (GHG) effect. For instance, the production of Portland cement for concrete accounts for an estimated 5 percent of global anthropogenic carbon dioxide [24]. Cement is the largest source of CO_2 emissions from decomposition of carbonates and these emissions are in two categories; namely emission from chemical reaction involved in the production of cement clinker and combustion of fossil fuels required to generate energy, which is used to heat the raw materials. The total emission of CO_2 from cement industry is put at 8% of global CO_2 emissions [3]. In view of the serious impact of carbon dioxide on the environment and the continued anticipated growth of industrialization and urbanization, there is a need to redirect the building industry away from its overwhelming reliance on Portland cement by developing alternative binder systems. The two options which have attracted attention as alternative binders are: (i) the partial replacement of cement by industrial byproducts such as fly ash, rice husk ash, cow dung ash, slag etc. (ii) the use of geopolymer binders. The first alternative has been widely researched and abundant information on the fresh and hardened properties of concrete with partial replacement of cement has led to the use of such blended cements [12], [14], [16], [17], [18], [19], [22]. The second alternative, geopolymer binder, is an emerging area of technology. [6] first proposed that an alkaline liquid could be used to react with the silicon (Si) and aluminum (Al) in a source material of geological origin or in by-product materials such as fly ash, cow dung ash, saw dust ash, rice husk ash etc to produce cementitious binders. Because the chemical reactions that take place in this case is a polymerization process and the source materials are of geological origin, he coined the term “geopolymer” to represent these binders.

[23] used two geopolymer concrete mixture proportions in laboratory studies. Numerous batches of these mixtures were manufactured during a period of four years. For each batch of geopolymer concrete made, cylindrical specimens of 100mm diameter and 200 mm long were prepared. At least three of these cylinders were tested for compressive strength at an age of seven days after casting. The unit-weight of specimens was also determined at the same time. The test data showed that the compressive strength increased with age in the order of 10 to 20%.

[8] and [9] concluded that low-calcium (ASTM Class F) fly ash is preferred as a source material than high-calcium (ASTM Class C) fly ash because the presence of calcium in high amounts may interfere with the polymerization process and alter the microstructure of the geopolymer concrete which affects its mechanical performance. The reactivity of low-calcium fly ash in geopolymer matrix has been studied by [7]. Coarse and fine aggregates used by the concrete industry are suitable to manufacture geopolymer concrete. The aggregate grading curves currently used in concrete practice are applicable in the case of geopolymer concrete [10].

[21] concluded that geopolymer concrete offers several economic benefits over Portland cement concrete. The cost of one ton of fly ash or blast furnace slag is only a small fraction of the cost of one ton of Portland cement. Given the low cost of alkaline liquids needed to make the geopolymer concrete, it is cost effective against Portland cement concrete that needs to be of a similar performance level.

The past researchers have not studied how geopolymer concrete performed when produced with coarse aggregates of different parental rocks. Hence, this research aims at studying the influence of aggregate types on strength behaviour of geopolymer concrete.

II. MATERIALS AND METHODS

A. Materials

Fine Aggregate (River Sand): The fine aggregate used was river sand retained on a 600 microns sieve acting as fillers. It was obtained from a local supplier in Ado – Ekiti.

Coarse Aggregate: The following coarse aggregates of size 20 mm were used: Limestone, Granite and Bush gravel. Limestone was obtained from a site in Okeluse, Owo, Ondo State while granite and bush gravel were sourced from a quarry site in Ikere and a local supplier in Ado – Ekiti, Ekiti State respectively.

Source Materials: The source material was Rice Husk Ash (RHA). It was obtained from a rice mill factory in Igbemo – Ekiti, Ekiti State. It was subjected to open burning in order to obtain it in ash form. Later, it was sieved with 90 micrometer in order to increase its fineness.

Alkaline Solution: A combination of sodium silicate solution and sodium hydroxide solution was used as the alkaline solution. The alkaline solution was prepared by mixing both solutions together at least 24 hours prior to use. The ratio of sodium hydroxide to sodium silicate solution used was 10:25 as suggested by [10] and [21]. The ratio of water to sodium hydroxide solids was 0.262 and that of water to sodium silicates solids was 0.559. The ratio of alkaline solution to source material used was 4:10 as suggested by [21].

B. Methods

Chemical analysis: This was conducted in accordance with [2]. It was performed on the source materials (RHA) using AAS Buck scientific 210VGP and Flame Photometer FP 902GP at Chemistry Department of Afe Babalola University, Ado-Ekiti. Nigeria. This was done to determine the amount of silicon and alumina oxides present in the source material.

Slump: This was conducted in accordance with [5]. It was performed on fresh geopolymer concrete. It was done at the Civil Engineering Department, Federal Polytechnic, Ado-Ekiti, Nigeria.

Compressive strength: This was conducted in accordance with [5]. It was done at the Civil Engineering Department of Afe Babalola University, Ado-Ekiti. Nigeria.

Flexural strength: This was conducted in accordance with [5]. It was done at the Civil Engineering Department, Federal Polytechnic, Ado-Ekiti, Nigeria.

III. RESULTS AND DISCUSSION

A. Chemical Analysis of Source Material

The amount of Alumina and Silicon oxides present in RHA was 81.28% (as shown in Table 1 and Figure 1). It was classified as source material because it is rich in Alumina and Silica oxides.

Table 1: Result of chemical analysis for source materials

Source Material	AL_2O_3 (%)	SiO_2 (%)	(AL_2O_3 + SiO_2) (%)
RHA	2.68	78.6	81.28

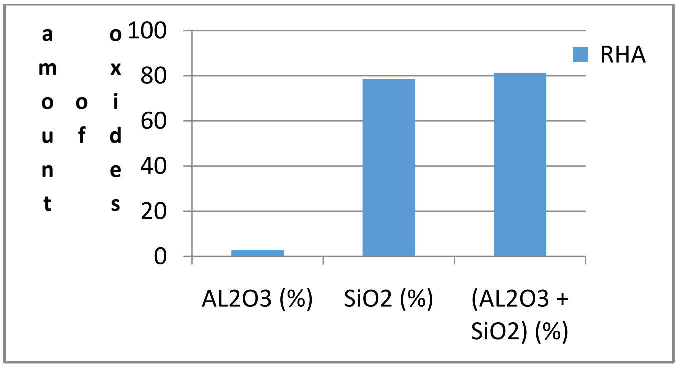

Fig. 1: The Alumina and Silica oxides composition of source material.

B. Workability of Geopolymer Concrete

This is the property of the concrete which determines its ability to be placed, compacted and finished or the measure of ease of using concrete. The geopolymer concrete produced, which can be deduced from Table 2 and figure 2 showed an excellent workability.

Table 2: Slump values of geopolymer concrete.

Source Material + Coarse Aggregates	Slump Values (mm)
RHA + Limestone	210.00
RHA + Granite	196.00
RHA + Bush Gravel	185.00

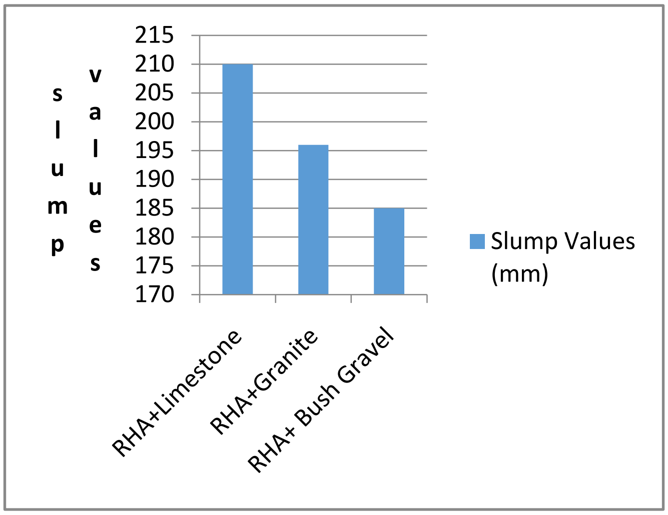

Fig. 2: Slump values for geopolymer concrete

C. Compressive Strength of Geopolymer Concrete

The RHA is the selected source material that was used to produce RHA geopolymer concrete with coarse aggregates from Limestone, Granite and Bush Gravel. The geopolymer concrete produced was subjected to curing at a constant temperature of 100^{o}C for 24 hrs, 48 hrs and 72 hrs; then their compressive strengths were determined. Effects of aggregate types on compressive strength were determined. The compressive strength increased as curing ages increased. Limestone gave highest compressive strength at each curing age, followed by granite and bush gravel in that order as shown in Table 3 and Figure 3. The performance of limestone may be attributed to its cementing properties, which enhanced good binding of the geopolymer concrete constituents.

Table 3. Compressive Strength of Geopolymer Concrete

Source Material + Coarse Aggregate	AGES OF CURING		
	24 hours	48 hours	72 hours
RHA + Limestone	8.63	10.13	14.30
RHA+ Granite	8.54	9.88	13.37
RHA+ Bush gravel	8.20	9.57	13.32

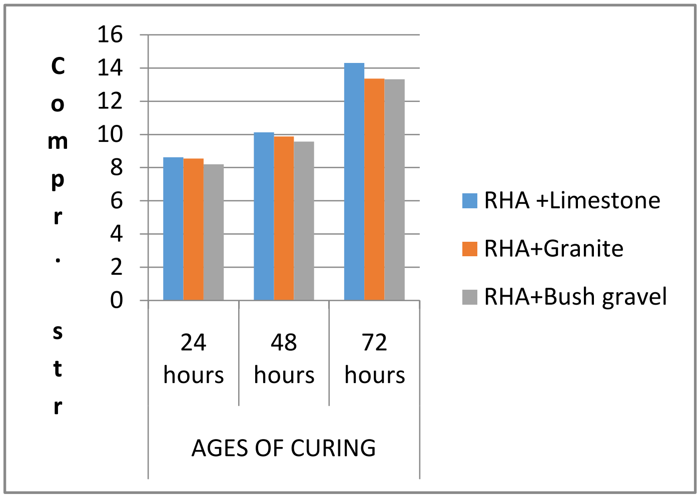

Fig. 3: Compressive Strength of Geopolymer Concrete

D. Flexural strength of geopolymer concrete

Flexural strength is a measure of tensile strength of concrete which is a fractional part of compressive strength of concrete varying between 15% - 20% [10]. The three aggregate types were used to produce geopolymer concrete and its flexural strength was determined. Limestone gave highest flexural strength at each curing age, followed by Granite and Bush gravel in that order as shown in Table 4 and Figure 4. The performance of Limestone may be attributed to its cementing properties, which enhanced good binding of the geopolymer concrete constituents.

Table 4. . Flexural Strength of Geopolymer Concrete

Source Materials + Coarse Aggregates	AGES OF CURING		
	24 hours	48 hours	72 hours
RHA+Limestone	1.30	1.52	2.18
RHA+Granite	1.28	1.48	2.08
RHA+Bush gravel	1.23	1.44	2.01

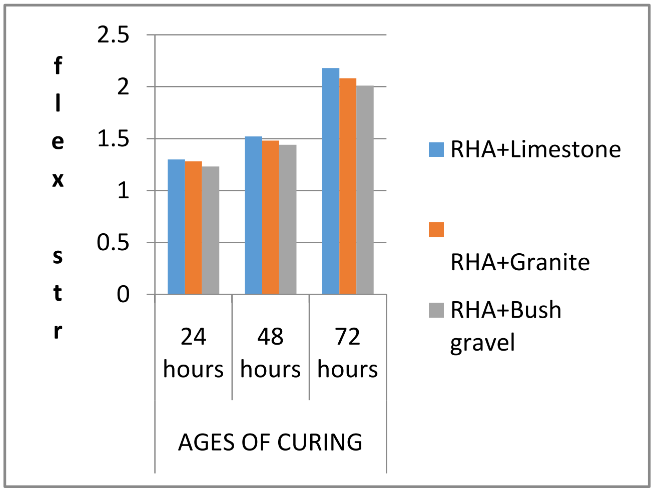

Fig. 4: Flexural Strength of Geopolymer Concrete

IV. CONCLUSION

The following conclusions were drawn based on the results obtained:

1. RHA is rich in Alumina and Silica oxides, therefore it is useful as source material
2. Geopolymer concrete showed an excellent workability
3. Geopolymer concrete produced with coarse aggregates from Limestone gave highest compressive and flexural strengths

Recommendation

The following recommendations are suggested for future research:

1. Limestone is recommended but where it is not available, granite can be used.
2. Source materials other than RHA should be used
3. Fine aggregates other than river sand should be used
4. Heat curing method was used for this research work. Other methods of curing should be used
5. Compressive and flexural strengths obtained were generally low, this may be as result of molar concentration of sodium hydroxide, curing temperature and curing age, ratio of sodium silicate and sodium hydroxide used. Higher values of the listed parameters should be used for further research.

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