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STUDY ON THE EFFECT OF ELEVATED TEMPERATURE ON THE COMPRESSIVE STRENGTH OF CONCRETE BLENDED WITH GROUNDNUT SHELL ASH AND RICE HUSK ASH AS PARTIAL REPLACEMENT OF CEMENT

Emmanuel, J. [1], Ibrahim, H.[2] and Shittu, A. N.[1]

1. Department of Building, School of Environmental Sciences, Federal Polytechnic Mubi

2 Department of Quantity Survey, School of Environmental Sciences, Federal Polytechnic Mubi

Contact: *Wajaue@gmail.com*

ABSTRACT

The utilization of pozzolanic materials such as Groundnut Shell Ash (GSA) and Rice Husk Ash (RHA) as partial replacement for ordinary Portland cement (OPC) in concrete production has received attention in recent years. Little is known about the mechanical behaviour of these new composite when exposed to elevated temperatures. In this study, the compressive strength of four categories of 150mm concrete cubes specimens were considered, comprising; first, as control mix consisting of plain OPC concrete of 1:2:4 mix; Second as concrete specimen with 10% of OPC were replaced by RHA and GSA separately; third, as concrete specimens with 20% OPC were replaced by RHA and GSA separately; fourth as concrete with 30% OPC were replaced by RHA and GSA separately; Water/binder ratio for all the mixtures was fixed at 0.60.The 150mm concrete cubes specimens were cured, dried and subjected to varying elevated temperature 250°C, 500°C, 750°C and 1000°C for exposure duration of 2 hours each. The result revealed that between temperatures of 250°C and1000°C, the concrete specimens with 20% and 30% replacement showed good thermal stability than the control mix, but recorded 25% reduction in compressive strength at elevated temperature of 1000°C. While control recorded 32% reduction in compressive strength at elevated temperature of 1000°C.It was determined that 20% replacement OPC with RHA or GSA is recommended for structural elements requiring thermal stability, due to the reduction of the effect of temperature noticed on them.

KEYWORDS: Compressive strength, Elevated Temperature, Composite Concrete, Rice Husk Ash, Groundnut Shell Ash

INTRODUCTION

Investigation into the behaviour of ordinary and high performance of concrete structures at high temperature are reaching maturity at both the scientific and technological levels, several international collaborative effort having been prompted by problems related to fire exposure in buildings and tunnels, (Abayneh, 1987). Concrete can be exposed to temperatures from ambient up to melting-in excess of 1000°C (Mehta, 1981). Throughout this temperature range, microstructural physical and chemical transformations take place which influence the material's thermal, ACI.2R, (1992). It is essential that concrete structure are designed to withstand above ambient service and accident temperature excursions without losing their function and load- bearing capacity, and that the influence of heat is understood at both the material and the structural level, (Morsy, 2008).

Occasionally, concrete structures are subjected to high temperatures (reactor vessels, thermal shock, fire, coal gasification vessels, some industrial applications, (Neville, 2000). In most cases, such elevated temperatures result in considerable damage to concrete structures and masonry walls (Punmia, 1993). Recently, high-strength concrete and high strength mortar are widely used in different parts of civil engineering structures. As they become more commonly used, the risk of being exposed to high temperatures also increases, (Rashad, 2008). Thus, better understanding of the behaviour of high-strength mortar at high temperatures gains importance for predicting the mortar properties. Additional minerals for the manufacturing of concrete generally include both natural pozzolans of volcanic origin and artificial pozzolans such as fly ash and silica fume, Olutuge, (Buari and Adeleke, 2002). Currently, other alternatives to these materials are being investigated using clay minerals (i. e., kaolinite, montmorillonite, and illite that can be thermally activated by dehydration in the temperature range of 700°C to 800°C), (Ghanan and Hilmi, 2004; Verlory, 2009). Kaolin is the most typical examples of pozzolanic materials, which upon heating produces metakaolin (MK). The properties of Metakaolinpozzolanic material have been reported previously. The influences of constantstemperature on the behaviour and stability of hydration phases have being studied (Yusuf, 2001). Metakaolin shows a high level of pozzolanic activity, similar to SF. For this reason, it is very important to quantify the heat evolution during hydration in Metakaolin/cement systems. Also, as reported by, Bentz, and Strutman, (1994) the performance of concrete incorporating Metakaaolin, at appropriate replacement levels, is similar to that of concrete containing silica fume. When used as a partial replacement for OPC, Rice husk ash (RHA) is capable of reacting with portlandite to form supplementary calcium-silicate-hydrate (C-S-H) similar in composition and structure to those obtained from Portland cement. Metakaolin has also been used for making cementitious materials called hydroceramics, i.e. ceramic-like materials synthesized from a solid aluminosilicate and alkali-rich solution at low temperature, $< 100^{\circ}$C. It has been reported that metakaolin of high lime reactivity can be produced by thermal decomposition of kaolin, a naturally occurring clay basically containing kaolinite [Al2O3-Si2O5(OH)4] mineral and trace of silica and other minerals which can be blended with high quantity of fly ash (over 45%) lime and industrial gypsum to form strong binder of low leach ability (Taylor, 1997). In the particular case of Metakaolin, it appears to have excellent potential as an active addition for producing mortars and concretes. However, this material shows a particular nature in its chemical and mineralogical composition. The hydrated phases formed during the pozolanic reaction at early curing periods, tend to be present as metastable phases. With longer curing times, the conversion of these hydrates to hydro garnet (stable phase) can be expected. This transformation will depend on different factors (for example, temperature reached inside the specimen). Groundnut shell Ash (GSA) is typically incorporated into concrete to replace 5% to 20%, by mass. GSA improves concrete performance by reacting with calcium hydroxide to form secondary phase, (Lunding, and Schwiete, 1986). Because of its white colour, high-reactivity Metakaolin does not darken concrete as S.F typically does (the white-coloured S.F is very limited in tonnage), which makes it suitable for colour-matching and other architectural applications (Shebi, 2008).

The combination of cement with other cementitious materials such as pulverized fly ash, silica fumes, millet husk ash etc. Has over the years been intensified in order to produce more economical and durable concrete for use in the construction industry (Nensok, and Adole, 2010). Various research works in recent past had checked into the utilization of agricultural wastes that are known to be pozolanas to partially substitute cement which is a major component of concrete to check strength, ingress of chemicals and durability requirements and these has proven to be more durable and strong in compression than normal concrete, (Ismail, 2001; Andrew, 1995).

The use of Ordinary Portland cement(OPC), rice husk ash(RHA), and groundnut shell ash (GSA) concrete in minimizing thermally induced expansion cracks has been identified (Neville, 2000). This is because ordinary Portland cement/rice husk ash paste hydrates slowly and therefore evolved low heat making them suitable for use in concrete in the tropics (Elina, and Ejeh, 2004; Cook, 1998) Such blended cement contains pozolanic materials which react with calcium hydroxide formed by the hydration of Portland cement to form a 100% Calcium Silicate Hydrate (C-S-H) binder phase in comparison to 75% binder phase in ordinary Portland cement. This results in the formation of a dense structure with high strength (Ismail 2001). Okpala, (1987) recommended the use of 40% partial replacement of ordinary Portland cement with rice husk ash (RHA) while in a related work on groundnut shell ash (GHA), Yusuf (2007) reported that 30% replacement of cement with groundnut shell ash gave better results in the strength of the composite concrete when compared with the normal concrete and readily reduce the detrimental effect of chemicals on concrete. Similarly, a research by Paya *et al.*, (2002) showed that at age of 28 days curing the concrete sample containing 10 – 30% GHA has greater compressive strength than the control and have lower water permeability than the control concrete. The study further recommends the use of 20%

RHA by weight to cement to check adverse effects of chemicals on concrete.

MATERIALS AND METHODS

Materials

The materials used for this research work include; Rice Husk Ash, Groundnut Shell Ash, Ordinary Portland Cement, Fine Aggregate(sand), Coarse Aggregate and Water.

Rice Husk Ash (RHA)/ Groundnut Shell Ash (GSA) production

The rice husk ash (RHA) and Groundnut shell ash (GSA) used in this research work were sourced from Adamawa State, Gombe State, and Bauchi State. They were combined and burnt under controlled conditions at National Metallurgical Development Centre (NMDC) laboratory, Zaria road, Jos, in to ashes where physical and chemical test were carried out as shown in Table 1.

Small heap of 20Kg of RiceHusk and Groundnut shell was burnt separately at maximum temperature of 650°C, the burning was controlled with total burning time of 24 hours. OPC of type I cement was used. The river sand used was of density 2.63g/cm^3. The partial replacements of cement with RHA were 10%, 20% and 30% maintained in all the four different types of RHA and GSA. The hydration period of 14, 21 and 28 days were used for compressive strength test.

Preparation of Specimens

The ashes were mixed with cement, the compressive strength of four categories of 150mm concrete cubes specimens were considered, comprising; first, as control mix consisting of plain OPC concrete of 1:2:4 mix; Second as concrete specimen with 10% of OPC were replaced by RHA and GSA separately; third, as concrete specimens with 20% OPC were replaced by RHA and GSA separately; fourth as concrete with 30% OPC were replaced by RHA and GSA separately; Water/binder ratio for all the mixtures was fixed at 0.60.The 150mm concrete cubes specimens were cured, dried and subjected to varying elevated temperature 250°C, 500°C, 750°C and 1000°C for exposure duration of 2 hours each.

The compressive and flexural strength of the sampled concrete cubes were determined at 14, 21 and 28 days curing. The total number of cube specimens was 96. The specimens were cured in water tanks prior to heating, after 14, 21 and 28 days of curing, the specimens were taken out of tanks and placed in the electric oven, with temperature capacity of 1200°C. Specimens were left in the oven for 4 hours to achieve a uniform temperature distribution across them. After that, specimens were allowed to cool in the oven for 20 hours, a total of 24 hours of heating and cooling per curing age. A loading rate of 3kN/s was used to get the residual compressive strength of concrete.

Table 1: Physical and Chemical Properties of RHA/GSA

CONSTITUENT	RHA	GSA
Blaine specific surface (cm^2/g)	15175	16196
Specific Gravity g/cm^3	2.11	2.16
Main Particle Size um)	11.12	12.34
Passing Sieve 325(%)	97.0	96.6
$Si0_2$	94.80	92.99
$Fe_2\ 0_3$	0.56	0.43
$A1_20_3$	0.16	0.18
Ca0	0.11	0.13
Mg0	0.45	1.35
$S0_3$	0.21	0.10
$A1_20_3+Fe_20_3$	0.71	0.61
$Si0_2+A1_2+Fe_20_3$	96.12	93.50
Na_20	0.33	0.02
Ka_20	0.82	0.75

Source: National Metrological Development Centre, (2014)

Compressive Strength Test

The compressive strength is the overall factor, which determines the overall quality of concrete, it is the maximum stress sustained by the specimens that is the maximum load registered on the testing machine divided by cross sectional area of the specimen, (Shetty, 1999). Three cubes specimens were tested for compressive strength at each hydration periods of 7, 14 and 28 days and at each replacement level of 0%, 10%, 20% and 30%. The mean value of the failure load for each was taken as the compressive strength. The procedure for testing and crushing of cubes were carried out in accordance to B S 1881: part 114:1983. The formulae for calculating the compressive strength were shown;

$$f_{cu} = p_{\max} / A \qquad (1)$$

Where f_{cu} is compressive strength (N/mm^2)

P_{max} is magnitude of the load (N)

A is cross sectional area of the concrete cube specimen (mm^2)

RESULTS

Table 2 shows the Details of the Results obtained;

Table 2: 14 days Hydration period

TEMPERATURE (°C)	% RELACEMENT OF RHA 0%	10%	20%	30%
	Compressive strength (N/mm^2)			
250	10.0	9.0	8.5	8.2
500	9.0	8.5	8.2	8.0
750	8.0	8.2	8.0	7.5
1000	7.8	7.5	7.1	7.0

Table 3: 21 Days Hydration Period

TEMPERATURE (°C)	% RELACEMENT RHA 0%	10%	20%	30%
	Compressive strength (N/mm^2)			
250	15.0	13.0	12.0	11.0
500	14.0	12.0	11.0	9.0
750	12.0	11.5	10.5	8.5
1000	11.5	10.0	9.0	7.0

Table 4: 28 Days Hydration Period

TEMPERATURE (°C)	% RELACEMENT RHA 0%	10%	20%	30%
	Compressive strength (N/mm^2)			
250	17.2	17.2	17.3	17.2
500	16.0	16.1	16.3	16.3
750	15.0	16.0	16.0	16.2
1000	13.0	15.0	15.5	16.0

TABLE 5: 14 days Hydration period

TEMPERATURE (°C)	% RELACEMENT OF GSA 0%	10%	20%	30%
	Compressive strength (N/mm^2)			
250	10.0	9.0	8.5	8.2
500	9.0	8.5	8.2	8.0
750	8.0	8.2	8.0	7.5
1000	7.8	7.5	7.1	7.0

Table 6: 21 Days Hydration Period

	% RELACEMENT OF GSA			
TEMPERATURE (°C)	0%	10%	20%	30%
	Compressive strength (N/mm^2)			
250	15.0	13.0	12.0	11.0
500	14.0	12.0	11.0	9.0
750	12.0	11.5	10.5	8.5
1000	11.5	10.0	9.0	7.0

Table 7: **28 Days Hydration Period**

	% RELACEMENT OF GSA			
TEMPERATURE (°C)	0%	10%	20%	30%
	Compressive strength (N/mm^2)			
250	17.2	17.2	17.3	17.2
500	16.0	16.1	16.3	16.3
750	15.0	16.0	16.0	16.2
1000	13.0	15.0	15.5	16.0

DISCUSSION

Table 2-7 shows the compressive strength of plain concrete specimens ,concrete specimens blended with 10%, 20%, 30% (RHA) and (GSA) separately combined with cement as partial replacement subjected to varying elevated temperatures of 250°C, 500°C, 750°C. The result show that the thermal degradation of the specimen containing 20% of both RHA and GSA as replacement is less. From Table 2, it can be seen that the first stage started in the temperature range 250°C-500°C, the lower the temperature the higher the compressive strength in both plain and composite concrete. In the temperature range of 500°C-1000°C, the higher the temperature the lower the compressive strength of plain concrete and the higher the compressive strength of concrete blended with 20% of both RHA and GSA with little variation in strength. The concrete specimens with 20% and 30% replacement shows good thermal stability than the control mix, but recorded 25% reduction in compressive strength at elevated temperature of 1000°C, while control recorded 32% reduction in compressive strength at elevated temperature of 1000°C

At the end of this study, the following findings were made:

1. The difference in chemical composition of RHA/GSA with different fineness from the same batch was negligible.
2. Fine RHA reduces the (W/B) water to binder and improves the strength of the concrete compared to coarse original RHA.
3. The finest GSA result in good strength compared to RHA.

CONCLUSION

From the Results, the following conclusions were made;

1. Elevated temperature has effects on the compressive strength of concrete blended with RHA/GSA
2. The Result shows that the compressive strength of plain concrete decreases as the temperature increases, while in the case of composite concrete, the compressive strength increases as the temperature increases as shown in fig 9-12
3. The result shows that elevated temperature has greater effect on GSA than RHA
4. The result also shows that the thermal degradation of the specimen containing 20% of both RHA and GSA as replacement is less.
5. The concrete specimens with 20% and 30% replacement showed good thermal stability than the control mix, but recorded 25% reduction in compressive strength at elevated temperature of 1000^{o}C. While control recorded 32% reduction in compressive strength at elevated temperature of 1000^{o}C.

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