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STUDY ON THE EFFECT OF ELEVATED TEMPERATURE ON THE COMPRESSIVE STRENGTH OF CONCRETE BLENDED WITH RICE HUSK AS PARTIAL REPLACEMENT OF FINE AGGREGATE

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ABSTRACT

The utilization of pozzolanic materials such as Rice Husk (RH) as partial replacement for fine aggregate 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

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^{O}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 is 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

150mm concrete cubes specimens were considered, comprising; first, as control mix consisting of plain fine aggregate of 1:2:4 mix; Second as concrete specimen with 10% of fine aggregate were replaced by RH; third, as concrete specimens with 20% fine aggregate were replaced by RH; fourth as concrete with 30% fine aggregate were replaced by RH ; 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 fine aggregate with RH is recommended for structural elements requiring thermal stability, due to the reduction of the effect of temperature noticed on them.

Key words: *Compressive strength, Elevated Temperature, Composite Concrete, Rice Husk and fine aggregate*

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 & Hilmi, (2004). Verlory, (2009) Kaolin is the most typical examples of pozzolanic materials, which upon heating produces metakaolin (MK). The properties of Metakaolin pozzolanic material have been reported previously. The influences of constants temperature 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, & 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 fine aggregate, Rice husk (RH) 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°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,

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temperature reached inside the specimen). Rice husk is typically incorporated into concrete to replace 5% to 20%, by mass improves concrete performance by reacting with calcium hydroxide to form secondary phase, Lunding, & 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, & 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 (RH), in concrete minimises thermally induced expansion cracks Neville, (2000). This is because ordinary Portland cement/rice husk paste hydrates slowly and therefore evolved low heat making them suitable for use in concrete in the tropics, Elina, & 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 comparism 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 fine aggregate t with rice husk (RH) while in a related work on groundnut shell ash (GHA), Yusuf (2007) reported that 30% replacement of cement with fine aggregate 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

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– 30% RH has greater compressive strength than the control and have lower water permeability than the control concrete.

AIMS AND OBJECTIVES

The aim of this research work is to look at ways of producing quality concrete through effective combination of pozzolanas which can adequately reduce the effect of temperature in concrete mixes.
The specific objectives are:

a. To carry out variations in the content of fine aggregate and rice husk (RH)
b. To investigate the chemical composition of the combine mix of cement, rice husk aggregate.
c. To produce concrete cubes using synergetic mixes
d. To investigate the properties of the cracked concrete cubes with comparism with the control using concrete ultra-pulse velocity and concrete compressive tests at 7 and 28-days interval.

METHODOLOGY

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 (RH)

The rice husk (RH) used in this research work were sourced from Adamawa State, Gombe State, and Bauchi State. They were combined and sieved under controlled conditions at National Metallurgical Development Centre (NMDC) laboratory, Zaria road, Jos, in to fine aggregate where physical and chemical test were carried out as shown in Table I

Small heap of 20Kg of Rice Husk was sieve to a finer size, OPC of type I cement was used. The river sand used was of density 2.63g/cm^3. The partial replacement of fine aggregate with RH were 10%, 20% and 30% maintained in all the four different types of RH. The hydration period of 14, 21 and 28 days were used for compressive strength test.

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Table 1: Physical and Chemical Properties of RH

CONSTITUENT		(RH)
Blaine specific surface (cm^2/g)		15175
Specific Gravity g/cm^3		2.11
Main Particle Size um)		21.12
Passing Sieve 325(%)		67.0
Sio_2	94.80	
$Fe_2\ o_3$	0.56	
$A1_2o_3$	0.16	
Cao	0.11	
Mgo	0.45	
So_3	0.21	
$A1_2o_3$+Fe_2o_3	0.71	
Sio_2+$A1_2$+Fe_2o_3	96.12	
Na_2o	0.33	
Ka_2o	0.82	

Source: National Metrological Development Centre, (2019)

Preparation of Specimens

The fine aggregate were mixed with cement and coarse aggregate the compressive strength of four categories of 150mm concrete cubes specimens were considered, comprising; first, as control mix consisting of plain fine aggregate concrete of 1:2:4 mix; Second as concrete specimen with 10% of fine aggregate were replaced by RH separately; third, as concrete specimens with 20% fine aggregate were replaced by RH separately; fourth as concrete with 30% fine aggregate were replaced by RH 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.

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;

$f_{cu} = p_{max}/A$

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

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

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

RESULTS

Table 2-4 shows the Details of the Results obtained;

Table 2 : 14 days Hydration period

% REPLACEMENT OF FINE AGGREGATE

TEMPERATURE (°C)	0%	10%	20%	30%
Compressive strength (N/mm^2)				
250	10	9	8.5	8.2
500	9	8.5	8.2	8
750	8	8.2	8.0	7.5
1000	7.8	7.5	7.1	7

Table 3: 21 Days Hydration Period

% RELACEMENT FINE AGGREGATE

TEMPERATURE (°C)	0%	10%	20%	30%
Compressive strength (N/mm^2)				
250	15	13	12	11
500	14	12	11	9

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750	12	11.5	10.5	8.5
1000	11.5	10	9	7

Table 4: 28 Days Hydration Period

% RELACEMENT FINE AGGREGATE

TEMPERATURE (°C)	0%	10%	20%	30%
	Compressive strength (N/mm²)			
250	17.2	17.2	17.3	17.2
500	16	16.1	16.3	16.3
750	15	16	16	16.2
1000	13	15	15.5	16

DISCUSSION

Table 2-4 shows the compressive strength of plain concrete specimens ,concrete specimens blended with 10%, 20%, 30% (RH) 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 RH 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 RH 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

a. The difference in chemical composition of RH and normal fine aggregate with different fineness from the same batch was negligible.
b. 2 Fine RH reduces the (W/B) water to binder and improves the strength of the concrete compared to coarse original RH.

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c. The normal fine aggregate result in good strength compared to RH.

CONCLUSION

From the Results, the following conclusions were made;

a. Elevated temperature has effects on the compressive strength of concrete blended with Rice Husk
b. 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
c. The result shows that elevated temperature has greater effect on RH than fine aggregate
d. The result also shows that the thermal degradation of the specimen containing 20% of RH as replacement is less.
e. 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.

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