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EFFECTS OF MILLET HUSK ASH - NANO SILICA PARTICLES ON STRENGTH PROPERTIES OF CONCRETE

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Abstract
In construction, one of the most frequently used materials is concrete, which meets the production of about 27.3 billion tons annually by 2015. Generally concrete is comprised of cement, water and aggregates (Fine and Coarse aggregates) in a measured quantity. It is used globally in a massive amount when compared with the other building materials like steel, wood, plastic etc., an enormous consumption of concrete results in increased demand for the cement thereby increasing its production. Cementitious composite materials made from Portland cement find its far-reaching applications in construction domain. In this modern era, the industrial growth and technological development put forth the requirement for colossal infrastructure. This results in the production of cement in the huge quantities. An immense production of cement has numerous environmental effects due to the emission of hazardous pollutants like particulates and greenhouse gases. In recent times, some researchers developed the aggregates from industrial by-products and agricultural waste which is incorporated to cement-based materials to attain the sustainability. By proportionating the cement with materials having smaller sized particles can influence the physical and chemical properties ending in betterment of pore structures. It has been proven that incorporation of Nano-sized cementitious material has its impacts on the performance of the structure due to its high volume to the surface area. This study thereby is a report of attempt at utilizing Millet husk ash (MHA) as SCM in concrete. This article presents results on 28th day compressive, Flexural and tensile splitting strength of concrete mixtures for 100 mm concrete cubes, 100mm x 500mm concrete Beam and 100mm diameter x 200mm. curing of specimens was done by immersion in water for 7, 21 and days.

Keywords: Millet husk ash (MHA), Nano-Silica, Portland Cement and green gas emission

Introduction

In construction, one of the most frequently used materials is concrete, which meets the production of about 27.3 billion tons annually by 2015 (Abhilash *et al*; 2021). Generally concrete is comprised of cement, water and aggregates (Fine and Coarse aggregates) in a measured quantity. It is used globally in a massive amount when compared with the other building materials like steel, wood, plastic etc., an enormous consumption of concrete results in increased demand for the cement thereby increasing its production. However, it's low compressive–to-tensile strength, high brittleness and reduced flow ability in addition to that; its exposure to the aggressive environment increases the global concern over lifespan (Mostafa *et al*; 2021). In spite of the different grades of OPC, it is commonly used in widespread (Wang J *et al*; 2020). Cementitious composite materials made from Portland cement find its far-reaching applications in construction domain. In this modern era, the industrial growth and technological development put forth the requirement for colossal infrastructure. This results in the production of cement in the huge quantities. An immense production of cement has numerous environmental effects due to the emission of hazardous pollutants like particulates and greenhouse gases. According to the assessment, cement clinker production is considered as the major source for the emission of greenhouse gases (Wang J *et al*; 2020). One of the major effects from cement manufacturing is emission of greenhouse gases (Said *et al*; 2012) which can be immensely reduced by Carbon dioxide sequestration (Liu *et al*; 2021), Catalytic Conversion (Osazuwa &, Cheng 2020) Amine scrubbing (Wang J *et al*; 2020), and also by inculcating the supplementary materials or alkali activated cementitious materials (Shi *et al* 2021), with pozzolanic nature and there by reduces the utilization of cement partially (Said *et al*; 2012). In recent times, some researchers developed the aggregates from industrial by-products and agricultural waste which is incorporated to cement-based materials to attain the sustainability (Shi *et al* 2021). By incorporating the SCM's from agricultural waste. However, the demand for cement manufacturing rises with the advancement in infrastructure which paves the way for excessive greenhouse gas emission. The prime concern also includes strength, durability and maintenance cost of the construction material (Garg *et al*; 2020). The emerging new technique must enhance the control and cutoff the emission of greenhouse gases and energy used for the cement production and also by adding the SCM like Pozzolans for the sustainable development (Garg *et al*; 2020). The volcanic ash Silica fume bottom ash (Garg *et al*; 2020), Bagasse Ash (Praveenkumar & Sankarasubramanian 2021), Rice husk ash, Corn cab ash Nandhini K (2021) etc., are the types of conventional Pozzolans. Cementitious Material chosen for the sustainable construction practices must possess better pore structure and high strength by binding the materials. By proportionating the cement with materials having smaller sized particles can influence the physical and chemical properties ending in betterment of pore structures. It has been proven that incorporation of Nano-sized cementitious material has its impacts on the performance of the structure due to its high volume to the surface area.

Neville, (2012) define "Pozzolan as siliceous or aluminous materials which in themselves possess little or no cementitious properties but in finely divided form and in the presence of moisture will chemically react with calcium hydroxide at ordinary temperature to form a compound possessing cementitious properties". The pozzolanic reaction is expressed as shown in Equation (1.1) below:

$$pozzolan + calcium\ hydroxide + water = C - S - H \qquad (1.1)$$

In the word of Neville (2012), Pozzolan has to be in finely divided state to combine with calcium hydroxide in the presence of water to form stable calcium silicates which have cementitious properties. Neville (2012) further stated that the silica has to be in an amorphous state (or glossy) because crystalline silica has very low reactivity. These pozzolanic materials can improve the durability of the concrete /mortar as well as the strength thus reducing the rate of liberation of heat, which is beneficial for mass concrete/mortar.

Millet husk ash (MHA) is a by-product obtainable from the burning of millet husk in a large open drum. Millets are a group of small seeded species of cereal crops or grains widely grown around the world for food and fodder. They are prevalent in semi-arid tropics of Asia and Africa (Jimoh et al., 2015).

Challenges of CO_2 emissions during the production process of cement are becoming an extremely distressing issue that continues to negatively impact on the global temperature leading to melting of polar ice caps and depleting of the ozone layer (Garba, 2004). With the rapid growing construction industry, it is imperative to develop and promote sustainable design practices to address CO_2 emission issues associated with cement production processes.

The availability of agro-waste such as groundnut shell, millet husk, rice husk, sorghum husk and industrial waste product such as calcium carbide waste and indigo dye residue which when left unused can cause environmental degradation, coupled with the difficulties of evacuating these materials call for an approach of turning these perceived wastes to wealth. The conversion to useful resources in the production of mortar /concrete will thereby reduce the issues of environmental degradation that is associated with waste disposals.

Experimental Procedure

Materials

The materials that was used for this research work are binders (PC, and MHA), fine aggregates (sand), coarse aggregate, superplasticizer, nano silica, and water. The PC for this study was Dangote brand (3X) of Portland cement (CEM 42.5N) whose properties conform to the requirements of BS EN 197-1: 2016. It was purchased from a cement store in Gidan-Kwano; Minna, Niger State. The MHA which was used as (SCM) was obtained from the incineration of the husk using the locally fabricated incinerator available at the Concrete Laboratory of the Department of Building, Federal University of Technology, Minna, Niger State. The burning took place in an open air for about 24 hrs with a temperature below or equal to 700°c and then allow to cooled before harvesting and milling with grinding machine and ball milling machine. The milled MHA was sieved with 75µm in accordance to ASTM C430- 2014 before storing in an airtight polythene bag.


Figure 1: Millet husk

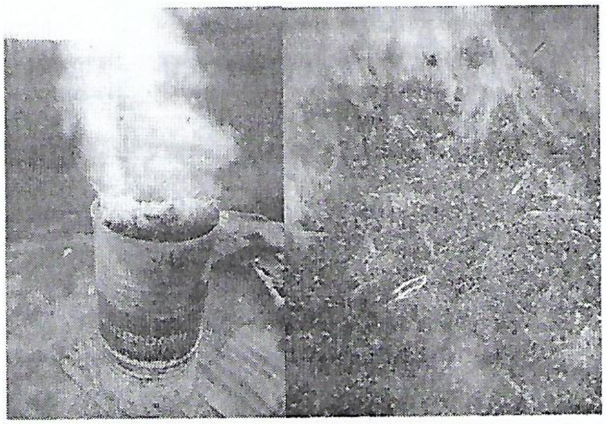
Figure 2: Open burning of the millet husk


Figure 3: Millet husk ash

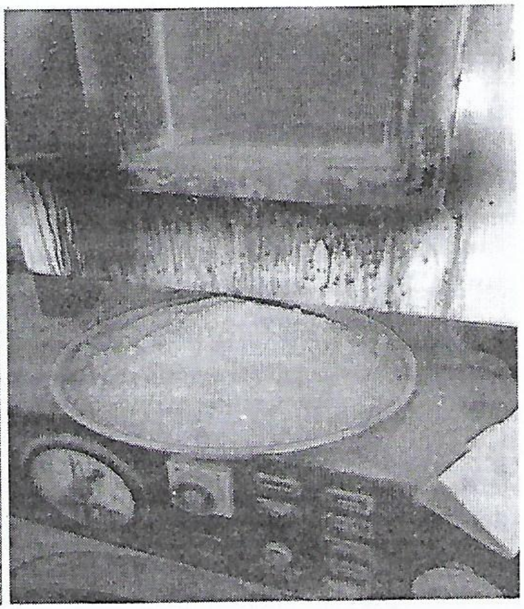
Figure 4: Millet husk ash nano silica

The nano silica used for the study was Synthesized from millet Husk using Solvo-hydrothermal method at the Laboratory of the Department of Chemistry, Federal University of Technology Minna, Niger State. The fine aggregate used for this research is natural sand with minimum particle size of 300 μm which is the requirement specification for HPC production (Shetty 2004, Neville, 2012, Nduka *et al*., 2020; Olawuyi *et al*., 2020). The physical characteristics of the sand (i.e., specific gravity (SG); fineness modulus (FM); coefficient of uniformity (Cu); coefficient of curvature (Cc); and dust content) were analysed using the sieve analysis. Crushed granite stone which passed through 13.50 mm sieve size and retained on at least 9.50 mm sieve size was used as coarse aggregate in compliance with typical HPC mixes found in the literature (Aitcin, 2004; Beushausen and Dehn, 2009; Neville, 2012; Olawuyi & Boshoff, 2018; Nduka *et al.*, 2020; Olawuyi *et al.*, 2021). The coarse aggregate was washed to remove dust impurities for less water demand by the mixture.

The water used for this study was portable water from the tap behind the convocation Square of Federal University of Technology, Minna, Niger State in accordance with the specification of BS EN 1008 (2002) was used for the mixing at 0.3 W/B (Ogunbayo *et al.* 2018). A sky 504 Masterglenium polymer-based polycarboxylic ether (PCE) superplasticizer supplied by Armorsil Manufacturing Incorporation was used as the chemical admixture (superplasticizer) and was administered at 1.5% concentration by weight of binder (b_{wob}) as used in the typical concrete mixtures. As recommended in the work of Aitcin (1998) reported in Olawuyi (2021).

Methods

Properties of Constituent Materials

The chemical compositions of binders (MHA & OPC) were conducted using X-ray Fluorescent (XRF) at the Laboratory of the Ewekoro Factory of Lafarge Plc and National Geoscience Research Laboratory, Kaduna State. About 100g of these binders were packaged in sealed polythene bags and sent after the calcination, grinding and sieving for the determination of the oxide compositions in accordance with BS EN 196-6: 2016. The particle size distribution of the aggregate's samples was determined by sieving while the specific gravity of the aggregate and binders were also determined in the Building laboratory of FUT, Minna.

Production of Concrete Specimen

The concrete were prepared using 100mm cube size for compressive strength, 100 x 500mm beam for flexural strength and 100mm diameter by 200mm height for tensile splitting. The percentage of MHA used are; 5%, 10% and 15% and for each of the percentage of MHA, 0%, 1.5%, 3% and 6% of Nano SiO2 extracted from MHA was added while CEM I serve as the control. Three cubes, beams and cylinders specimens were cast from each mix and a total of 117 cubes, 117 beams and 117 cylindrical specimens were cast and cured for 7, 21 and 28 days. Batching and mixing of concrete samples were conducted using 1:1.5: 3 and 0.5 water/cement (w/c) ratio as specified by BS EN 196-1:2016. The mix details for the concrete samples is presented in table 1.

Table 1: Mix Details for Concrete Samples

Mix ID	MHA kg/m^2	Nano-SIO2 kg/m^2	CEM I kg/m^2	F/A kg/m^2	C/A kg/m^2	Water kg/m^2	SP kg/m^2
M_0			383.20	800.94	1087.75	191.60	5.75
M_{10}			364.04	800.94	1087.75	191.60	5.75
M_{11}	19.16	5.46	358.58	800.94	1087.75	191.60	5.75
M_{12}		10.92	353.12	800.94	1087.75	191.60	5.75
M_{13}		21.84	342.20	800.94	1087.75	191.60	5.75

M_{20}			344.88	800.94	1087.75	191.60	5.75
M_{21}		5.17	339.71	800.94	1087.75	191.60	5.75
M_{22}	38.32	10.34	339.54	800.94	1087.75	191.60	5.75
M_{23}		20.68	324.20	800.94	1087.75	191.60	5.75
M_{30}			325.72	800.94	1087.75	191.60	5.75
M_{31}		4.89	320.83	800.94	1087.75	191.60	5.75
M_{32}	57.48	9.78	315.94	800.94	1087.75	191.60	5.75
M_{33}		19.56	306.16	800.94	1087.75	191.60	5.75

Fresh and Strength Properties

The preparation and curing of concrete samples were made in accordance to BS EN standards (BS EN 12350 -1 & 5, 2000 BS EN; 12390-1 BS EN & 2, 2000 BS EN; 12390 - 3, 2002) for compressive, Flexural and Tensile splitting strength. The compressive and Tensile splitting strength tests were performed on 36 samples at 0.5 N/mm^2 rate of loading using 2000kN loading capacity ELE Compressive Strength Tasting Machine while the flexural strength test was performed using the Universal Testing Machine. Both the compressive, tensile and flexural strength test were conducted at the Laboratory of the Department of Building, Federal University of Technology Minna, Niger State.

RESULTS AND DISCUSSION

Physical and Chemical Properties

Table 2 below present the result of XRF analysis of the binders (MHA & PC) powder. The result shows that The MHA is a class N Pozzolan because the sum of the main oxides (SiO_2 + Al_2O + Fe_2O_3) gives 86.46% which is above 70% minimum limit as specified in ASTMC 618 (2012) standard. The PC on the other hand major content is calcium oxide (CaO – 60.35%). This conforms to oxides composition for CEM II Portland cement found in literature (Neville, 2012; Mehta and Monteiro, 2014).

Figure 1 and Table 3 show the physical properties of the aggregate used for the study. From the result it reveals that the fine aggregate is in conformity to the medium sand classification of Shetty (2004) having a uniformity coefficient (C_u) of 2.39, coefficient of curvature (C_c) of 0.94 and fineness modulus (FM) of 2.87. The coarse aggregates used for the study have a coefficient of uniformity (C_u) of 1.3 and coefficient of curvature (C_c) of 0.93 and belong to the class of uniformly graded stone. Table 3 further explained that both the fine and coarse aggregates used for the study are good for the production of concrete. Table 4 present the specific gravity and Bulk Density of the constituent materials (PC, MHA and aggregates). The results gave the values as 3.15, 2.63, 2.79, 2.85, and 1.06 as specific gravity for PC, MHA, fine aggregate and Granite respectively while the Bulk density for for the materials are 3150, 2630, 2790, 2850 and 1060Kg/M3 for PC, MHA, fine Aggregate, coarse aggregate and superplasticizer respectively. The results reveal that the values are inconformity with the previous report in literature (Neville, (2012).

Table 2: Oxide Composition of Binder Constituents

Oxides	MHA (%)	CEM II (%)
SiO_2	78.92	25.64
Al_2O_3	2.69	5.24
Fe_2O_3	4.85	7.15
CaO	1.55	60.35
MgO	0.73	0.41
SO_3	0.66	0.11
K_2O	5.21	0.05
Na_2O	1.13	0.31
M_2O_5	2.06	0.04
P_2O_5	1.17	0.03
LOI	2.20	0.67
$SiO_2 + Al_2O_3 + Fe_2O_3$	86.46	38.03

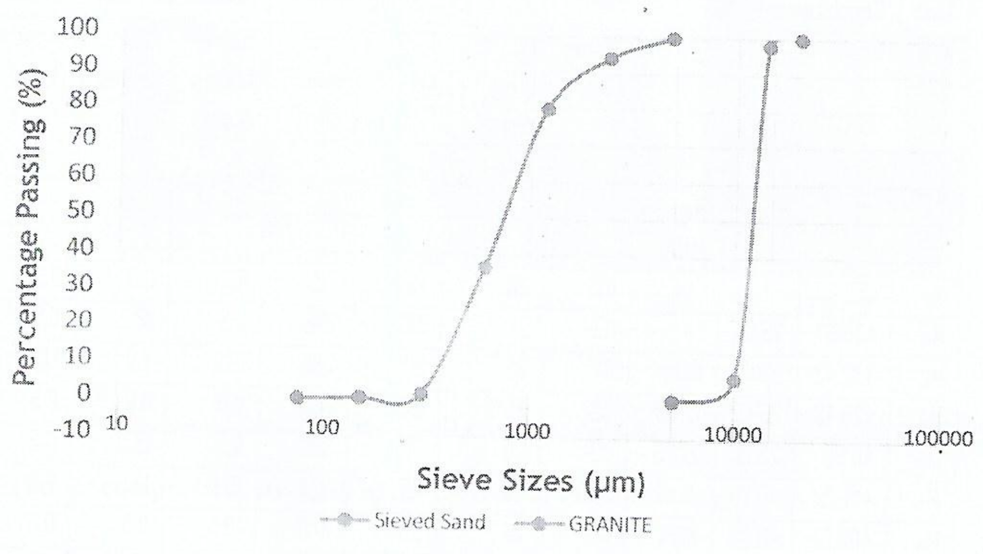

Figure 1: sieve analysis/particle size distribution of aggregates

Table 3: Summary of sieve analysis of aggregates

Item	Sand	Granite
D_{10}	360	10000
D_{30}	540	11000
D_{60}	860	13000
C_u	2.39	1.3
C_c	0.94	0.93
FM	2.87	

Table 4: Specific Gravity and Bulk Density of Constituent Materials (kg/m3)

Materials	Specific gravity	Bulk density (kg/m3)
CEM 1	3.15	3150
MHA	2.63	2630
Fine Aggregate	2.79	2790
Coarse aggregate	2.85	2850
Superplasticizer	1.06	1060

Fresh and strength properties

Fresh properties

The properties of concern in this section are consistency, setting time and soundness at varied combination proportions and the control

Table 5: consistency, setting time and soundness test of Concrete mix

Test	Consistency					Setting time		Soundness (mm)		
Mix ID	Binder wt (g)			Water (%)	Penetration depth (mm)	Initial (mins)	Final (mins)	Before boiling (L_1)	After boiling (L_2)	Expansion (L_2-L_1)
	PC	MHA	Nano-MHA							
M_0	462.50			105	28	48	135	10.5	11.0	0.5
M_{10}	439.37	23.13		112	21	190	275	11.5	12.0	0.5
M_{11}	432.43	23.13	6.94	114	23	200	285	10.0	11.0	1.0
M_{12}	425.49	23.13	13.88	118	25	210	290	11.5	11.0	0.5
M_{13}	411.62	23.13	27.75	112	26	217	300	11.5	12.0	0.5
M_{20}	416.25	46.25		122	28	220	335	10.0	12.0	2.0
M_{21}	409.31	46.25	6.94	122	31	230	340	10.5	11.0	0.5
M_{22}	402.37	46.25	13.88	125	32	239	350	11.0	12.0	1.0
M_{23}	388.50	46.25	27.75	123	35	250	390	12.0	12.5	0.5
M_{30}	393.12	69.38		124	37	260	400	11.5	12.0	0.5
M_{31}	386.18	69.38	6.94	126	36	280	450	12.5	13.0	0.5
M_{32}	379.24	69.38	13.88	128	39	298	510	10.5	11.0	0.5
M_{33}	365.37	69.38	27.75	132	42	301	520	11.0	12.0	1.0

From the result it was observed that the water demand for the control M0 was lower than other mixes. This could be as a result of hygroscopic nature of Portland cement (Olawuyi *et al*; 2021). Also, it was observed that the effect of the chemical admixture (superplasticizer) aid the setting time with M0 having initial and final setting time of 45 and 135 minutes. Also, increase in the expansion value of all the mixes obtained from soundness test was observed to be in the range of 11 mm to 12 mm but the values are within the limits (Mudashiru *et al.* 2021).

Strength properties

Compressive, flexural and tensile splitting strength are the three major strength properties of concrete considered in this study.

Compressive strength

The compressive strength of the concrete at 7, 21 and 28 days of age cured by immersion in water is presented in figure 2

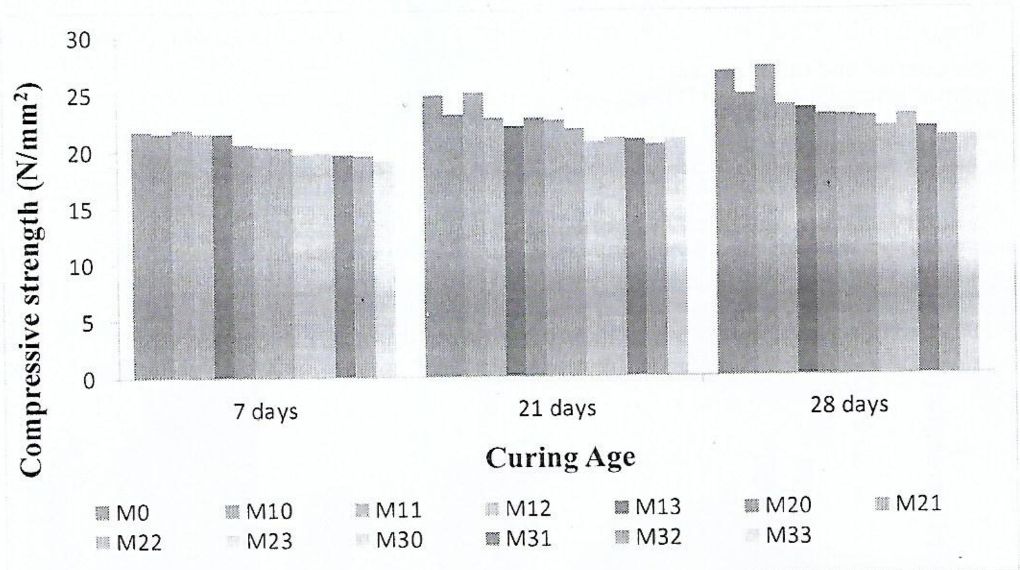

Figure 2: compressive strength of concrete at 7, 21 and 28 days

At 7 days of age the values for compressive strength for the various mixes are : M0=21.75N/mm^2 (control), 5%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{10} = 21.64 N/mm^2, M_{11}, = 21.89 N/mm^2, M_{12} = 21.58 N/mm^2 and M_{13} = 21.56 N/mm^2), 10%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{20} = 20.58 N/mm^2, M_{21}, = 20.41 N/mm^2 and M_{22} = 20.30 N/mm^2 and M_{23} = 19.72 N/mm^2) and 15%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{30} = 19.86N/mm^2, M_{31}, = 19.64N/mm^2, M_{32} = 19.52N/mm^2 and M_{33} = 19.10N/mm^2).
At 21 days, the values for compressive strength for the various mixes are : M0=24.82/mm^2 (control), 5%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{10} = 23.12 N/mm^2, M_{11}, = 25.01 N/mm^2, M_{12} = 22.82 N/mm^2 and M_{13} = 22.10 N/mm^2), 10%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{20} = 22.83 N/mm^2, M_{21}, = 22.62 N/mm^2 and M_{22} = 21.82 N/mm^2 and M_{23}

= 20.68 N/mm^2) and 15%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{30} = 21.03N/mm^2, M_{31}, = 20.92N/mm^2, M_{32} = 20.42N/mm^2 and M_{33} = 20.12N/mm^2).

At 28 days the values for compressive strength for the various mixes are : M0=26.84N/mm^2 (control), 5%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{10} = 24.82 N/mm^2, M_{11}, = 27.20 N/mm^2, M_{12} = 23.82 N/mm^2 and M_{13} = 23.60 N/mm^2), 10%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{20} = 23.02 N/mm^2, M_{21}, = 22.98 N/mm^2 and M_{22} = 22.88 N/mm^2 and M_{23} = 21.90 N/mm^2) and 15%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{30} = 22.96N/mm^2, M_{31}, = 21.84N/mm^2, M_{32} = 21.03N/mm^2 and M_{33} = 21.62N/mm^2).

From the result it clearly show that irrespective of the curing age, the percentage content of MHA, addition of Nano-MHA improve the compressive strength (Wang J *et al*; 2020). Also, from the result above increase in the Nano-MHA lead to a decrease in the compressive strength with M_{11} (5%MHA and 1.5% Nano) having the highest compressive strength of 21.89, 25.01 and 27.20N/mm2 at 7, 21 and 28 days of age when compared with the control and other mixes.

Flexural strength

The graph of the Flexural strength of the concrete at 7, 21 and 28 days of age cured in ordinary water is presented in figure 3.

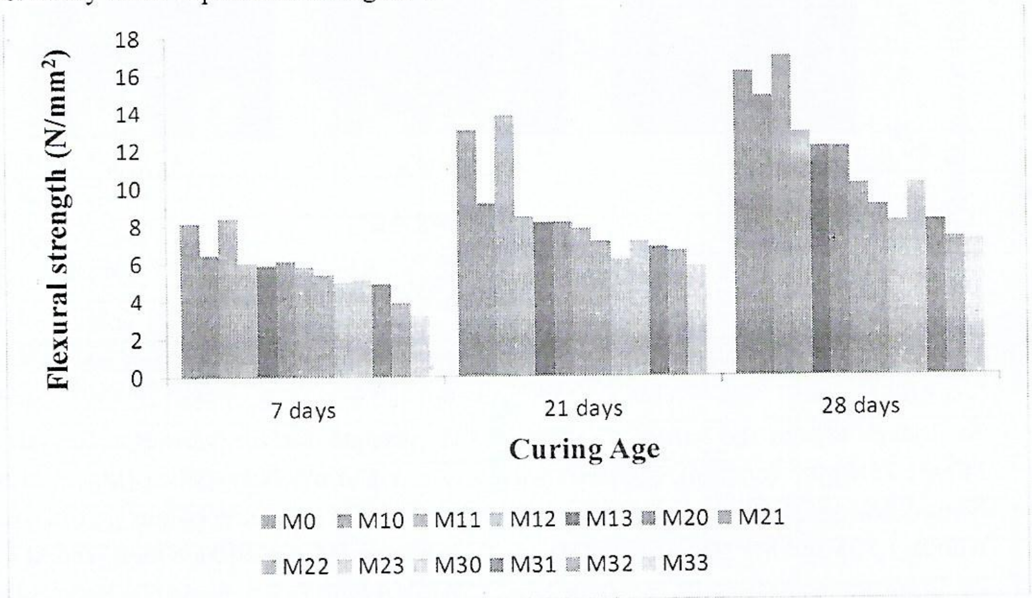

Figure 3: Flexural strength of Nano-MHA at 7, 21 and 28 days

At 7 days of age, the Flexural strength values mixes are : M0 = 8.12N/mm^2 (control), 5%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{10} = 6.42 N/mm^2, M_{11}, = 8.38 N/mm^2, M_{12} = 6.03 N/mm^2 and M_{13} = 5.89 N/mm^2), 10%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{20} = 6.12 N/mm^2, M_{21}, = 5.83 N/mm^2 ,M_{22} = 5.40 N/mm^2 and M_{23} = 5.01 N/mm^2) and

15%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{30} = 5.10N/mm^2, M_{31}, = 4.92N/mm^2, M_{32} = 3.89N/mm^2 and M_{33} = 3.20N/mm^2).

At 21 days, the values for compressive strength for the various mixes are : M0 = 13.03 N/mm^2 (control), 5%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{10} = 9.14 N/mm^2, M_{11}, = 13.80 N/mm^2, M_{12} = 8.42 N/mm^2 and M_{13} = 8.12 N/mm^2), 10%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{20} = 8.15 N/mm^2, M_{21}, = 7.82 N/mm^2, M_{22} = 7.10 N/mm^2 and M_{23} = 6.16 N/mm^2) and 15%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{30} = 7.12N/mm^2, M_{31}, = 6.80N/mm^2, M_{32} = 6.60N/mm^2 and M_{33} = 5.80N/mm^2).

At 28 days the Flexural strength values are : M0 = 16.12N/mm^2 (control), 5%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{10} = 14.80 N/mm^2, M_{11}, = 16.95 N/mm^2, M_{12} = 12.89 N/mm^2 and M_{13} = 12.12 N/mm^2), 10%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{20} = 12.10 N/mm^2, M_{21}, = 10.12 N/mm^2 ,M_{22} = 8.98 N/mm^2 and M_{23} = 8.12 N/mm^2) and 15%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{30} = 10.12N/mm^2, M_{31}, = 8.18N/mm^2, M_{32} = 7.26N/mm^2 and M_{33} = 7.12N/mm^2).

From the result it crystal clear that addition of Nanoparticle impove Flexural strength irrespective of the curing age and percentage content of MHA (Wang J *et al*; 2020). Also, from the result above increase in the Nano-MHA lead to a decrease in the Flexural strength with M_{11} (5%MHA and 1.5% Nano) having the highest Flexural strength of 8.38, 13.80 and 16.95N/mm2 at 7, 21 and 28 days of age when compared with the control and other mixes

The graph of the Modulus of Rupture (Tensile splitting strength) of the concrete at 7, 21 and 28 days of age cured in ordinary water is presented in figure 4

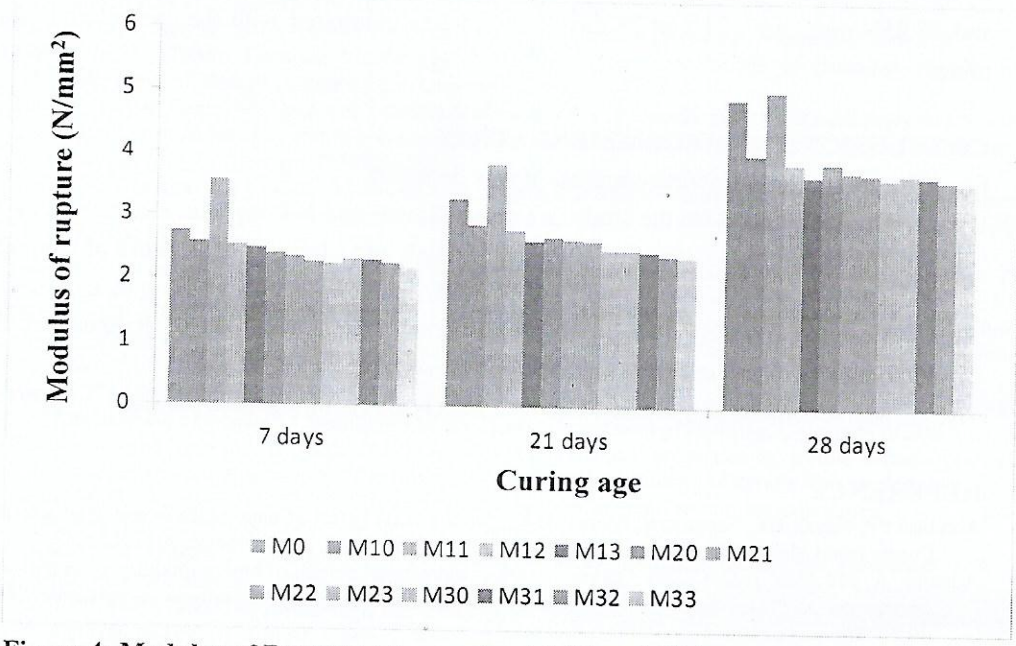

Figure 4: Modulus of Rupture of concrete at 7, 21 and 28 days

At 7 days of age, the Modulus of Rupture are : M0 = 2.74N/mm^2 (control), 5%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{10} = 2.57N/mm^2, M_{11}, = 3.56N/mm^2, M_{12} = 2.53N/mm^2 and M_{13} = 2.48N/mm^2), 10%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{20} = 2.40N/mm^2, M_{21}, = 2.36N/mm^2 ,M_{22} = 2.28N/mm^2 and M_{23} = 2.24N/mm^2) and 15%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{30} = 2.28N/mm^2, M_{31}, = 2.30N/mm^2, M_{32} = 2.25N/mm^2 and M_{33} = 2.18N/mm^2).

At 21 days, the values for Modulus of Rupture for the various mixes are : M0 = 3.28N/mm^2 (control), 5%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{10} = 3.28N/mm^2, M_{11}, = 3.84 N/mm^2, M_{12} = 2.78N/mm^2 and M_{13} = 2.62 N/mm^2), 10%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{20} = 2.68N/mm^2, M_{21}, = 2.64 N/mm^2, M_{22} = 2.62 N/mm^2 and M_{23} = 2.48 N/mm^2) and 15%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{30} = 2.48N/mm^2, M_{31}, = 2.45N/mm^2, M_{32} = 2.40N/mm^2 and M_{33} = 2.38N/mm^2).

At 28 days the Modulus of Rupture are : M0 = 4.89N/mm^2 (control), 5%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{10} = 4.01N/mm^2, M_{11}, = 5.02 N/mm^2, M_{12} = 3.88N/mm^2 and M_{13} = 2.68 N/mm^2), 10%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{20} = 2.89 N/mm^2, M_{21}, = 3.75N/mm^2 ,M_{22} = 3.72 N/mm^2 and M_{23} = 3.64 N/mm^2) and 15%MHA with 0, 1.5, 3 and 6% Nano-Silica (M_{30} = 3.72N/mm^2, M_{31}, = 3.68N/mm^2, M_{32} = 3.62/mm^2 and M_{33} = 3.58N/mm^2).

From the result it crystal clear that addition of Nanoparticle improves Modulus of Rupture irrespective of the curing age and percentage content of MHA (Wang J *et al*; 2020). Also, from the result above increase in the Nano-MHA lead to a decrease in the Flexural strength with M_{11} (5%MHA and 1.5% Nano) having the highest Flexural strength of 8.38, 13.80 and 16.95N/mm2 at 7, 21 and 28 days of age when compared with the control and other mixes

CONCLUSION AND RECOMMENDATION

From the study, the following conclusion was deduced

i. The MHA used for the study is a good Class F and N Pozzolan.
ii. The compressive strength, Flexural strength and Modulus of Rupture of Concrete containing 1.5% Nano-SIO2 and 5%MHA perform best.
iii. The compressive strength, Flexural strength and Modulus of Rupture of the concrete decreases with increase in Nano-MHA
iv. MHA content of 5% and 1.5% Nano-SIO_2 are recommended for use.

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