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PROPERTIES OF MILLET HUSK ASH (MHA) CONCRETE MODIFIED WITH POLYPROPYLENE FIBRE (PPF). A STUDY ON SELF COMPACTING CONCRETE (SCC)

Mohammed A[1*] and Ayuba S[2*]
[1]Department of Civil Engineering, Bayero University Kano, Nigeria
[2]Faculty of Engineering, Federal University Wukari, Nigeria
Corresponding Author: amohammed.civ@buk.edu.ng

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Abstract:

Fiber-reinforced concrete (FRC) is a concrete comprising fibrous material which strengthens its structural integrity. It contains short discrete fiber that are uniformly distributed and randomly oriented. In addition, the character of fiber-reinforced concrete changes with varying concretes, fiber materials, geometries, distribution, orientation, and densities. This study examined the physical and chemical properties of MHA as a pozzolana and grade 40 (control) SCC obtained from series of trial mixes using 0.35 water-cement ratio. Other mixes were derived from the control mix by replacing cement with 0, 5, 0.2, 0.4, 0.6, 0.8 and 1 % by weight of PPF, respectively. The research reveals that Polypropylene Fibre (PPF) has been established to be a suitable fibre for production of self-compacting concrete. It has tensile strength between 300 – 700 N/mm^2. Similarly, the compressive strength of MHA modified SCC can be improved using up to 0.4 % PPF content. However, up to 1.0 % PPF content improves the splitting tensile and flexural strengths of Millet husk ash modified self-compacting concrete. 0.4 % PPF is recommended for optimum performance in Millet husk ash modified self-compacting concrete. However, up to 1.0 % could be used in structural members where flexure is important.

Keywords: Millet Husk Ash (MHA), Polypropylene fibre (PPF), self-compacting concrete, Mechanical properties.

Introductions

In the present time the demand for concrete infrastructure is directly proportional to the population growth. The quicker stride for construction increases the need for more production of cement with unbendable conformability on the standard specification of the quality of produced cement

The use of self-compacting concrete (SCC) has being on the increase since its inception in the 1980s because of high and the ease of production of the final product. The advantages of SCC have been extensively revealed and publicized in different research and publications as shown by Almeida *et al.* (2010); Mehdi and Ali (2016). SCC are more durable, has higher compressive and bond strength as compared to conventional concrete of similar properties (Kapoor, 2012). Also, SCC has the plus in decreasing labour cost, construction time, quality enhancement and good finished surface; these higher qualities SCC make it better than conventional concrete. Though, SCC depend largely on the use of more content of cement paste which is associated to a number of challenge comprising high cost of concrete material and the production of cement that lead to increase emissions of carbon (IV) oxide (CO_2) which has adverse effects to the environment

On the other hand, SCC is a brittle material with a low strain capacity. Reinforcement with short unsystematically distributed fibers can solve a number of of the challenges related to SCC brittleness and poor resistance to crack growth. The application of fibers, as reinforcement, can be effective in arresting cracks at both micro and macro-levels Oucief *et al.*, *(*2006). Fiber reinforced concrete is a cementitious composite material with a dispersed reinforcement in a form of fibers. Polypropylene fibers can be divided into microfibers and macrofibers depending on their length and the function that they perform in the concrete Julia and Rafał (2021). At the micro level, fibers inhibit the initiation and growth of cracks, and after the micro-cracks coalesce into macro-cracks, fibers provide mechanisms that abate their unstable propagation, provide effective. The effects of Polypropylene fibre admixed on characteristics of SCC mixes in fresh state and hardened state of SCC was studied by (Sohaib et-al., 2016). In the study, the concrete mixes were added with fibre of 0%, 1.0%, 2.0 %, and 3.0 %. The research reveals that, addition of fibres has enhanced the passing ability of SSC but on the other hand, has decreased filling ability and segregation resistance of SCC. The optimum dosage of polypropylene achieved by this research was 2% of the cement content.

Cement making industries gives approximately 8.0 % of the global CO_2 emissions (Abubakar *et al.*, 2021; Rodgers, 2018). Moreover, greater intake of Portland cement in SCC mixes consequently intensifies the heat of hydration and high autogenous shrinkage (Sabet *et al.*, 2013). Conversely, the excess usage of cement can be minimized by substituting cement with mineral additives in SCC and consequently, lessening of emission of CO_2, heat of hydration and autogenous shrinkage (Awang *et al.*, 2016).

Several extensive studies on the use of mineral additives such as rice husk ash (Habeeb and Fayyadh, 2009; Atan and Awang, 2011; Aboshio *et al.*, 2018) , fine limestone powder silica fume (Yazici, 2008; Gesoglu *et al.*, 2009; Turkel and Altuntas, 2009) among few which indicate the potential of the mineral admixture to yield the needed outcome. To this effect, the millet husk ash (MHA) an agricultural waste-based admixture has being used in this research. Investigations have shown that about 29.851 million tons of millet is made globally in 2018 and more than 7 % is produced in Nigeria (IPAD, 2021). Millet is a cereal food produced commonly in West Africa; particularly Nigeria being the second largest producer of millet in the world (Worldatlas, 2017). Largely, about 40 % of the weight of the harvested millet is removed as husk from the stalk harvested (Akande, 2002). Studies into the use of millet husk ash in concrete has shown that has ash is pozzolanic in nature (Jimoh *et al*, 2013) and can be used to substitute of cement to increase the properties of concrete (Uche *et al.*, 2012). The findings of Auta *et al.,* (2015) shows that, 10 % MHA can be used as replacement in normal concrete (NC). Similarly Jimoh *et al.,* (2013) reveals that up to 10 % MHA can be used to improve NC blended with lateritic soil. Still, scarce information can be found on the use of MHA in SCC. Hence, this research strives to comprehend the effect of addition of polypropylene fibre on the optimum MHA in SCC.

Materials and methods

Materials

The materials used in this research include: ordinary Portland cement, fine and coarse granite aggregates, Millet husk ash (MHA), polypropylene fibres, super plastisizers and water.

Ordinary Portland Cement

BUA branded ordinary Portland cement, CEM II/A-L grade 42.5N, commercially available at Rijiyar Zaki, along Gwarzo road; Kano, Nigeria was used throughout the investigations.

Fine and Coarse Granite Aggregates

The fine aggregate of clean river sand obtained from Challawa River, Kano and crushed granite rock obtained from Rimin Gado quarry site in Kano were used throughout the research.

Millet Husk Ash (MHA)

The millet husk (MH) was collected from a dump site around a farmland in Ladanai Village of Gezawa Local Government Area, Kano State, Nigeria. MH was incinerated to ash with a locally fabricated kaolin stabilized clay-bricks incinerator in the School of Technology, Kano State Polytechnic, Nigeria. The incineration was done at a temperature ranges from 600 – 700 ℃ for a period of 4 hours. The incinerator is powered by kerosene heater and designed to be operated at temperatures up to 1500℃. The incinerator has a capillary tube with gate mounted for regulation of flow of kerosene and burning temperature. The capillary tube is use to draw the kerosene from a tank into the combustion area.

Water

Potable water obtained from Civil Engineering Laboratory, Bayero University, Kano was used for mixing and curing of concretes produced for this research.

Super Plasticizer

Super plasticizer (Conplast SP430) with properties as presented in Table 1, was used. The super plasticizer is a chloride free, super plasticizing and water reducing admixture produced based on selected sulphonated naphthalene polymers to give water reductions up to 25% and reduced permeability without loss of workability (Fosroc, 2014).

Table 1: Properties of Conplast SP430 plasticiser

	Properties
Specific gravity	1.20
Chloride content	Nil
Air entrainment	Approx. 1 %
Colour	Brown
Dosage	0.5 – 2.0 Litres/100 kg of cement

Source: Fosroc, 2014

Polypropylene Fibre

Polypropylene fibre (PPF) was obtained from FAS Agro Sack Ltd, Sharada Industrial Area, Kano, Nigeria. The PPF with average cross sectional dimension of strand, 3 mm x 0.2 mm and length 30mm was used in this research.

Methods

Oxide Composition of MHA and Cement Materials

The oxide composition of MHA and cement were carried out at the Chemistry Department, Ahmadu Bello University, Zaria, Kaduna State, Nigeria using X – SUPRE8000 model X-Ray Florescence (XRF) equipment made by the Oxford Instrument Ltd. The test was re-conducted (as confirmatory test) at the Centre for Dry Land Agriculture (CDA), Bayero University, Kano using X2 RANGER model XRF equipment made by BRUKER Equipment. The tests were carried out in accordance to ASTM C114 (2018).

Specific Gravity

The specific gravity tests on MHA, PPF, fine aggregate and coarse aggregate were conducted in accordance with BS EN 12620 (2002) using Equation 1. However, the specific gravity of cement was determine using the procedure in BS EN 196 - 6 (2005) where kerosene was used as depicted in Equation 2 and 3 to avoid cement weight lost that could occur if water is used.

$$\mathrm{Gs} = \frac{(w2-w1)}{(w4-w1)-(w3-w2)} \qquad (1)$$

$$\mathrm{Gsk} = \frac{(w2p-w1p)}{(w4p-w1p)-(w3p-w2p)} \ldots \qquad (2)$$

$$\mathrm{Gsc} = \frac{(w2c-w1p)Gsk}{(w4c-w1p)-(w3c-w2c)} \qquad ..(3)$$

Particle Size Distribution

The particle size distribution of oven dried fine and coarse granite aggregates were determined using dry sieving method. 1 kg and 2 kg fine and coarse granite aggregates respectively were sieved in accordance with BS EN 12620 (2013) using the set of standard sieves. The mass retained on each sieve was measured and percentage passing each sieve was calculated as the differences between the cumulative percentage mass retained and 100. The particle size distribution test of MHA was carried out using hydrometer method in accordance with BS 1377:1 (1990). 50 g of MHA passing 75 µm sieve size, mixed with water to give 1000 ml mixture in measuring cylinder was shake thoroughly until uniform mixture is attained. The hydrometer readings (R) were recorded at time interval 0.5, 1, 2, 4, 8, 15, 30, 60, 120, 240, 480 and 1440 minutes. The percentage of MHA particle sizes (diameter) were computed using Equation 4 and 5.

$$\mathrm{D} = \frac{18\eta L}{(Gs-1)g\rho t} \quad \ldots \qquad (4)$$

$$\mathrm{P} = \frac{100R'a}{M} \ldots \qquad (5)$$

Fineness Modulus

Fineness modulus was determined for the fine and coarse aggregate in accordance with BS EN 12620 (2013) using 0.15, 0.3, 0.6, 1.18, 2.36, 4.75, 10 and 20 mm set of sieves. Fineness modulus is an index number which represents the mean particle size and was computed from particle size distribution data by dividing by 100 the sum of cumulative retained by each sieve.

Mix Design of Self-Compacting Concrete

Table 2: Material Batching for MHA-SCC with PPF

% PPF	Cement (kg/m^3)	Sand (kg/m^3)	Granite (kg/m^3)	MHA (kg/m^3)	Water (kg/m^3)	Plasticiser (l/m^3)	PPF (kg/m^3)
0	520	860	900	0	182	5.46	0
5	494	860	900	24.7	182	5.46	0
0.2	494	860	900	24.7	182	5.46	1.26
0.4	494	860	900	24.7	182	5.46	2.52
0.6	494	860	900	24.7	182	5.46	3.78
0.8	494	860	900	24.7	182	5.46	5.04
1	494	860	900	24.7	182	5.46	6.30

Properties of Harden Self Compacting Concrete

Compressive strength

The density of each cylinder before compressive strength test was determined by measuring the weight of a specimen in the air and dividing it by its volume as given in BS EN 12390-7 (2000). The compressive strength test was carried out according to BS EN 12390-3 (2002) at ages of 3, 7, 28, 56 and 90 days using ADR1500 branded ELE digital compression machine at a loading rate 0.5 kN/s. Three samples were tested per curing age for each SCC mix and average compressive strength calculated. The compressive strength of the SCC was determined using Equation 6.

$$fc = \frac{P}{A} \quad \ldots \quad (6)$$

Splitting tensile strength

The splitting tensile strength was measured in accordance to BS EN 12390-6 (2000) at the ages of 3, 7, 28, 56 and 90 days. The test was carried out for PM-Concrete respectively using ad7115/32716 model Avery Denison Universal testing machine at a loading rate 0.4kN/s. The test was carried out using 100mm diameter and 200mm length cylinders. Three samples were tested per curing age for each SCC mix and average splitting tensile strength calculated. The splitting tensile strength of the SCC was determined using Equation 7.

$$fs = \frac{2P}{\pi ld} \quad \ldots \quad (7)$$

Flexural strength

The tests were performed in accordance to BS EN 12390-5 (2000) specification for two-point loading. SCC prisms of dimensions 500 mm×100 mm × 100 mm with effective span 300 mm were cast and tested for flexural strength. The concrete prisms were tested at the ages 3, 7, 28, 56 and 90 days respectively. The test was performed using ad7115/32716 model Avery Denison made, Universal testing machine at a loading rate 0.4kN/s. Three samples were tested per curing age for each SCC mix and average flexural strength calculated. The flexural strength of the concrete prism was determined using Equation 8.

$$f = \frac{PL}{bd^2} \quad \ldots (8)$$

Water absorption test

The water absorption test was conducted in accordance with BS 1881-122 (1983) using the complete immersion test method. Concrete specimens 100 x 100 x 100 mm cubes, cured for 28 days were used for this test. The specimens were dried in the D81L201 multipurpose oven at 105 °C, then cooled for 24 hours and then completely immersed in the water for 30 min. The water absorption was evaluated in percentage as given in Equation 9.

$$\text{Water absorption} = \frac{\text{w2} - \text{w1}}{\text{w1}} \text{ X } 100\% \quad (9)$$

Results Presentation and Discussions

Chemical Properties of Binders

The chemical properties (oxide composition) of the cement and millet husk ash used in this study alongside limit of some of the oxide composition are presented in Table 3. The result satisfied the recommended limit given in BS EN 197-1 (2000) and ASTM C618 (2005) for the combined oxides of CaO and SiO_2, ratio of CaO/SiO_2 and individual oxides of SO_3, MgO and loss of ignition of ordinary Portland cement. However, the Chlorine composition (0.105 %) for the initially assessed cement slightly exceeds the recommended limit (≤ 0.1 %). The chemical composition presented in Table 3 for MHA test satisfied the recommended limit given in BS EN 197-1 (2000) and ASTM C618 (2005). This suggests that the MHA is a good pozzolanic material as also reported by Abdulwahab *et al* (2017), Jimoh *et al* (2013) and Muhammad *et al* (2018).

Table 3: Oxide Composition of Binder

Oxide	BUA CEMENT (%)		MHA (%)	
SiO_2	12.01	$CaO + SiO_2 \geq 50$ %	64.22	$SiO_2 + Al_2O_3 + Fe_2O_3 \geq 70$ %
Al_2O_3	3.03		3.71	
Fe_2O_3	4.14	$CaO/SiO_2 \geq 2$ %	3.49	
CaO	74.06		6.55	LoI ≤ 12 %
MgO	1.4	$SO_3 \leq 3.5$ %	2.81	
SO_3	2.05		1.56	
Na_2O	-	MgO ≤ 5.0 %	0.86	
K_2O	1.27	Cl ≤ 0.1 %	6.01	
P_2O_5	-		4.06	
Cl	0.1	LoI ≤ 5 %	1.05	
TiO_2	0.33		0.71	
Mn_2O_3	-		0.09	
ZnO	-		0.09	
SrO	0.49		0.06	
LoI	1.04		4.54	

Physical Properties of Concrete Ingredient

Specific gravity

The specific gravities of the concrete constituents are presented in Table 4. The specific gravity for the cement is within the recommended value of 3.10 - 3.16 for ordinary Portland cement (OPC) (ASTM C 188, 2005). MHA has a specific gravity of 2.21 which suggest that the MHA is less dense than the OPC. This further signifies that larger volume of MHA will be required to replace the equal mass of cement in SCC. This finding is similar to that of Abdulwahab *et al* (2017), Jimoh *et al* (2013) and Muhammad *et al* (2018). The specific gravities of fine and coarse aggregates also fall within the specified limit for normal weight aggregate 2.6 – 3.0 and 2.4 – 2.8 respectively as stipulated in BS 812 -103 (2003). Similarly, the specific gravity of PPF presented in the table is similar to the findings of Kosmatka *et al* (2008) and within the range (0.58 – 0.9) specified in BS EN 1346 (2012) for specific gravity of PPF for concrete purpose.

Table 4: Specific Gravities of SCC Materials

Materials	Values
Cement	3.16
MHA	2.21
Fine Aggregate	2.61
Coarse Aggregate	2.74
PPF	0.63

Fineness of cement and millet husk ash

Results of the fineness for the cement and MHA using 45 µm sieve as presented in figure 1, indicate that the fineness for cement 13 % while that of MHA is 29 % respectively. These are below the maximum specified limit 34 % given in ASTM C 618 - 9 (2005). This implies that both cement and MHA has the required fineness necessary for rapid strength development.

Particle size distribution

The particle size distribution for MHA, fine aggregate and coarse aggregate is shown in Figure 1.

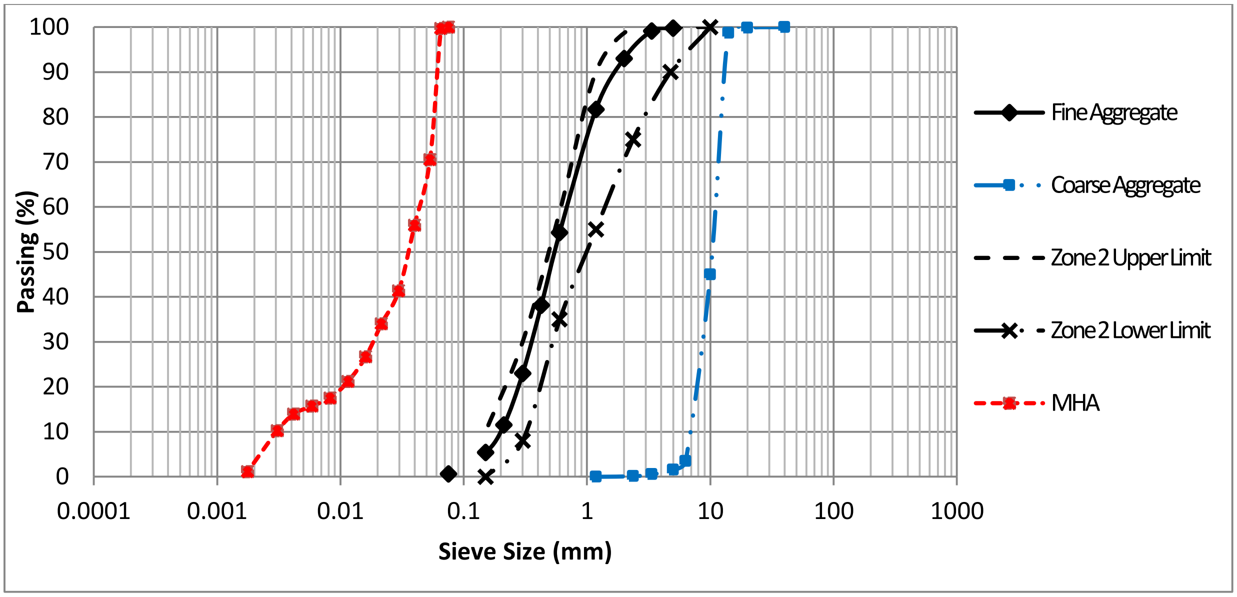

Figure 1: Particle Size Distribution of Aggregates and MHA

As indicated in the figure 1, MHA has grains sizes ranging from 75 µm to 1.76 µm and with dominant particles of 29.2 % at 53.13 µm sizes (70.5 % passing). The particle size distribution curve for the fine aggregate on the other hand shows that the fine aggregate falls in zone II class based on BS 882 (1992) grading limits for fine aggregates. The fine aggregate is in compliance with the requirement of EFNARC (2002) for suitable material for SCC. In addition, the finding of Abeer and Ikram (2013) shows that zone II fine aggregate performed better than Zone I, II and IV in SCC. The particle size distribution curve for the coarse aggregates shows that the coarse aggregate has dominant particle size of 14 mm and 10 mm having 55.77 and 41.49 % particle sizes respectively. This suggests that the coarse aggregate is within the range of the specified size limit (≤ 20 mm) for suitable material for SCC as provided in EFNARC (2002). Aggregate sizes higher than 20 mm yield SCC with poor fresh properties making it unsuitable for use in areas with congested reinforcement (EFNARC, 2002). In addition, aggregate sizes (≤ 20 mm) was also proposed in the work of Khaleel *et al*. (2011); Mohammad and Amir (2017) and Sooriyaarachchi and Lasintha (2016) for use in SCC. Also, according to Sri Durga et al (2016), lower size of aggregate yielded better fresh properties than higher size of aggregates for NCC and SCC.

Effects of PPF on compressive strength and strain of PM-Concrete

The compressive strength of PM-Concrete as shown in Figure 2, increased with curing age and decreased with increase in PPF content beyond 0.4 %. The 28 days compressive strength of PM-Concrete ranged from 37 – 47.5 N/mm^2 for PPF content 0.2 – 1.0 %, representing 85.1 – 109.2 % strength of the control sample and 84.1 – 108 % strength of the 5 % M-Concrete sample at 0 % PPF. The 28 days compressive strength of concrete with up to 0.4 % PPF content (47.75 N/mm^2) exceeded the control (0 % MHA) by about 9.2 % as observed from the figure. The increase in strength could be attributed to the ability of the PPF to resist the induced stress on the concrete matrix due to stronger bond strength between the PPF and mortar in the concrete (Priti *et al*, 2012; Mehul and Kulkarni, 2013 and Kumar *et al*, 2014).

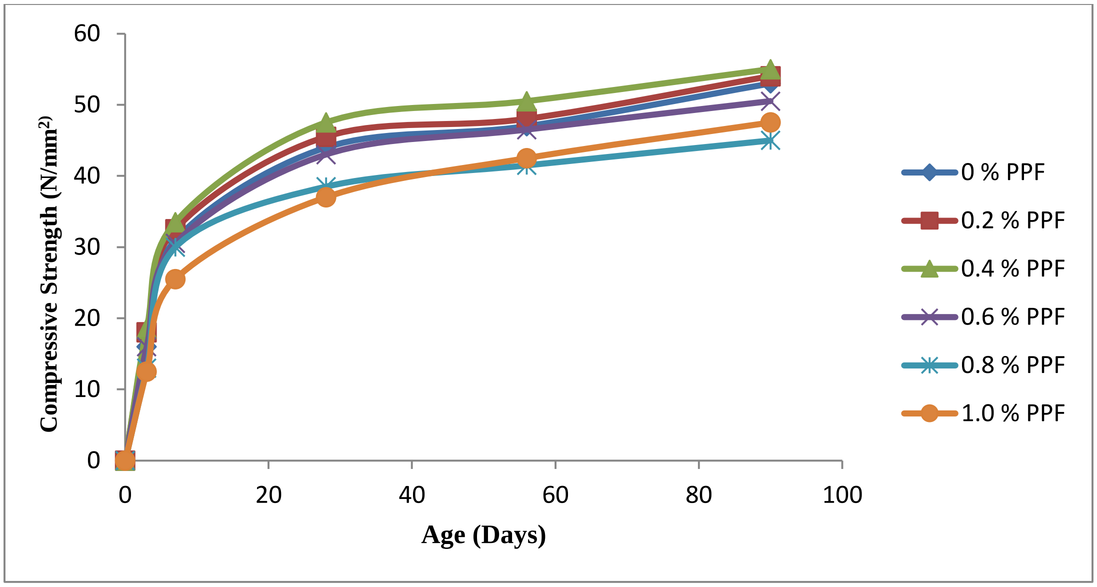

Figure 2: Effects of Curing Age on the Compressive Strength of PM-Concrete

Effects of PPF on splitting tensile strength and strain of PM-Concrete

The splitting tensile strength of PM-Concrete as showed in Figure 3, increased with increase in curing age and with increase in PPF. In addition, the splitting tensile strength of PM-Concrete was higher than control (Mo).

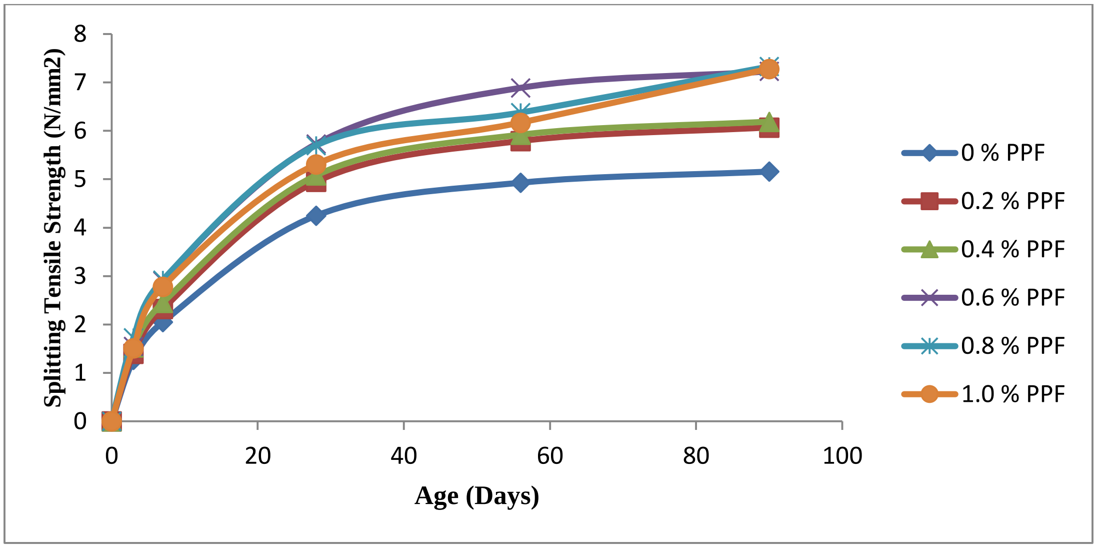

Figure 3: Effects of Curing Age on Splitting Tensile Strength of PM-Concrete

The increase in splitting tensile strength with increase in PPF content may be attributed to the effect of the crack resistance and the pull out force of PPF on the bond strength of PM-Concrete. This is in agreement with the work of Poornima *et al* (2017). It could also be safe to say that the increase in splitting tensile strength of PM-Concrete is due to additional load from tensile strength of PPF in the concrete matrix (Anthony and Abimbola, 2014).

Effects of PPF on flexural strength and strain of PM-Concrete

The flexural strength of PM-Concrete increased with increase in curing age and with increase in PPF content as shown in Figure 4. These improvements could be attributed to the effect of the tensile strength of the PPF and the pull out force of PPF on the bond strength of PM-Concrete. This finding is in agreement with the work of Priti *et al* (2012); Abdulla (2013); Mehul and Kulkarni (2013); Kumar *et al* (2014) and Poornima *et al* (2017). The increase in flexural strength could also be due to additional load absorbed by the fibres present in the concrete matrix (Anthony and Abimbola, 2014).

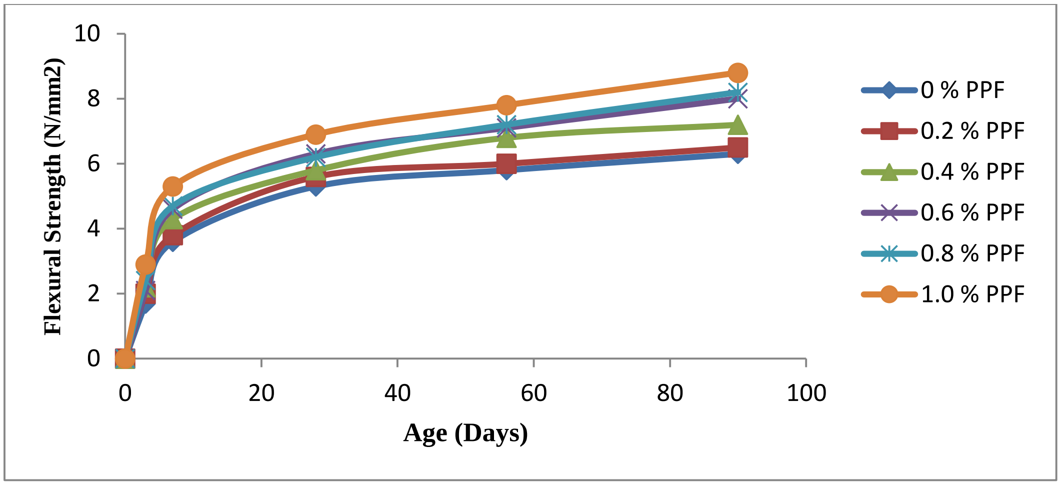

Figure 4: Effects of Curing Age on the Flexural Strength of PM-Concrete

Water on Absorption Capacity of PM-Concrete

The water absorption of PM-Concrete decreases slightly with increase in PPF content as shown in Figure 5. This could be attributed to reduction in amount of pores in the PM-Concrete that is occupied by PPF resulting in less water penetration. This idea was borrowed from the work of Nandhini and Manju (2017); Kumar and Ahmad (2019) working on fresh and durability studies of polypropylene fibre reinforced self-compacting concrete and mechanical and durability properties of self-compacting concrete reinforced with carbon fibres respectively. In addition, PPF is hydrophobic nature (Ramujee, 2013) and thus protected against wetting in cement paste. This could be a reason for the reduction in water absorption of PM-Concrete as impermeable PPF form a barrier for flowing water into the PM-Concrete. The reduction in water absorption with increase in PPF content is an indication that increase in PPF contribute to improved durability in PM-Concrete.

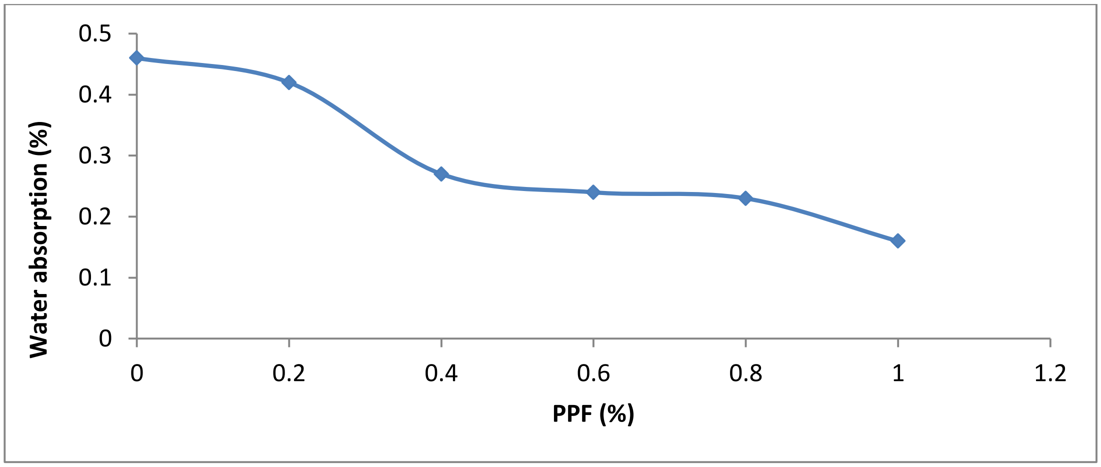

Figure 5: Water Absorption Capacity of 5 % PM-Concrete

Conclusions

Based on the study conducted on the evaluation and modelling the effects of Millet Husk Ash and Polypropylene Fibre in Self Compacting Concrete, the following conclusions are drawn.

1. Millet husk ash (MHA) is established to be a good pozzolana for production of self-compacting concrete. The summation of SiO_2, Al_2O_3 and Fe_2O_3 contents in MHA is greater than 70 % as a requirement for pozzolana as contained in BS EN 197-1 (2000) and ASTM C618 (2005).
2. Polypropylene fibre (PPF) has been established to be a suitable fibre for production of self-compacting concrete. It has tensile strength of between 300 – 700 N/mm^2 as referenced in BS EN 1346 (2012).
3. The use of 5 % MHA satisfactory produces Grade 40 self-compacting concrete with improved compressive, splitting tensile and flexural strengths.
4. The compressive strength of Millet husk ash modified self-compacting concrete can be improved using up to 0.4 % PPF content. However, up to 1.0 % PPF content improves the

splitting tensile and flexural strengths of Millet husk ash modified self-compacting concrete

5. The water absorption of Millet husk ash modified self-compacting concrete and Millet husk ash modified self-compacting concrete containing PPF decreases with increase in MHA and PPF content respectively
6. For optimum performance, 0.4 % PPF is recommended for use in Millet husk ash modified self-compacting concrete. However, up to 1.0 % could be used in structural members where flexure is important.

Reference

Abdulwahab, M. T., Uche, O. A. U. and Suleiman, G. (2017). Mechanical Properties of Millet Husk Ash Bitumen Stabilized Soil Block. Nigerian Journal of Technological Development, Vol. 14, No.*1, pp. 34 – 38.*

Aboshio , A., Shuaibu, H. G. and Abdulwahab, M. T. (2018). Properties of Rice Husk Ash Concrete with Periwinkle Shell as Coarse Aggregates. Nigerian Journal of Technological Development, Vol. 15, No. 2, pp. 33 – 38.

Akande A. B. (2002). Economic Analysis of the Relationship between Drought and Millet Production in the Arid Zone of Nigeria: A Case Study of Borno and Yobe State. Journal of Agriculture and Social Science. Vol. 2, No. 3, pp. 112- 121.

Almeida Filho, F.M., Barragán, B.E., Casas, J.R. and El Debs, A.L.H. (2010), "Hardened properties of selfcompacting concrete-A statistical approach", *Constr. Build. Mater.*, 24(9), 1608-1615.

Anthony N.E and Abimbola O.I., (2014) optimal Polypropylene fiber content for improved compressive and flexural strength of concrete. IOSR journal of mechanical and civil engineering (IOSR-JMCE), 11(3):129-135

ASTM C114-(2018), Standard Test Methods for Chemical Analysis of Hydraulic Cement, ASTM International, West Conshohocken, PA.

Atan M. N. and Awang H. (2011). The Compressive and Flexural Strengths of Self-Compacting Concrete using Raw Rice Husk Ash. Journal of Engineering, Science and Technology, Vol. 6, No. 6, pp. 720 – 732

Auta, S. M., Shiwua, A. J. and Tsodo, T. Y. (2015). Compressive strength of concrete with millet husk ash (MHA) as partial replacement of cement. Magazine of Civil Engineering, No 7. Pp. 74 – 79.

Awang H., Atan M. N., Zainul A. N. and Yusof N. (2016). A Cost-Reduction of Self - Compacting Concrete Incorporating Raw Rice Husk Ash. Journal of Engineering Science and Technology. Vol. 11, No. 1, pp. 096 – 108.

BS EN 197-1 (2000) "Cement Composition, Specifications and Conformity Criteria for Common Cements", British Standards Institution, London, UK.

BS EN 1346 (2012); 'Polypropylene split film, monofilament and multifilament(PP2) and polypropylene high tenacity multifilament(PP3) 3-4-8 and 12 strand ropes.

BS 812 -103 (2003) ''Method of Determination of particle size distribution'' BritishStandard Institution London

BS EN 12620 (2002). "Aggregates for concrete". British Standard Institution London

BS EN 196-6: (2005). "Cement density test". British Standard Institution London

BS EN 12620 (2013). "Aggregates for concrete". British Standard Institution London

BS EN 12390-7, (2000). "Testing hardened concrete: Density of hardened concrete". British Standard Institution London.

BS EN 12390-3, (2002). "Testing hardened concrete: Compressive strength of test specimens". British Standard Institution London.

BS EN 12390-6, (2000). "Testing hardened concrete: Tensile splitting strength of test specimens". British Standard Institution London.

BS EN 12390-5, (2000). "Testing hardened concrete: Flexural strength of test specimens". British Standard Institution London.

BS 1881-122 (1983) ''Method for determination of water absorption'' British Testing Method

EFNARC (2002). "Specification and guidelines for self-compacting concrete. European Federation of Producers and Applicators of Specialist Products for Structures".

Fosroc (2014). Conplast SP430. Fosroc Limited Drayton Manor Business Park Coleshill Road, Tamworth, Staffordshire B78 3XN. UK.

Gesoglu, M., Guneyisi, E. and Ozbay, E. (2009). Properties of Self Compacting Concretes made with Binary, Ternary, and Quaternary Cementitious Blends of Fly Ash, Blast Furnace Slag, And Silica Fume. Construction and Building Materials, 23(5), 1847-1854.

Habeeb, G.A. and Fayyadh, M.M. (2009). Rice husk ash concrete: the effect of RHA average particle size on mechanical properties and drying shrinkage. Australian Journal of Basic and Applied Sciences. 3(3): p. 1616-1622.

Jimoh, R. A., Banuso, O. R. and Oyeleke, F. M. (2013). Exploratory assessment of strength characteristics of millet husk ash (MHA) blended cement laterized concrete. Advances in Applied Science Research, 2013, 4(1):452-457. Retrieved from; www.pelagiaresearchlibrary.com

Julia B and Rafał B; Polypropylene fiber reinforced concrete and its application in creating architectural forms of public spaces, Case Studies in Construction Materials 14 (2021) e00549: www.elsevier.com/locate/cscm

Kapoor, Y. P. Self-Compacting Concrete; (2012); An Economical Approach. *The Masterbuilder*

Khaleel, O. R., Al-Mishhadani, S. A. and Abdulrazak, H. (2011). The Effect of Coarse Aggregate on Fresh and Hardened Properties of Self-Compacting Concrete (SCC). The Twelfth East Asia-Pacific Conference on Structural Engineering and

Construction. Procedia Engineering 14, 805–813. Retrieved from; www.sciencedirect.com.

Kosmatka, S. H., Kerkhoff, B. and William, C. (2008). “Design and Control of Concrete Mixtures”. 14th Edn., Portland Cement Association, USA.

Kumar, M. V. and Muthukannan, M. (2014). Experimental Investigation on Mechanical Properties of Hybrid Fiber Reinforced Concrete, In Proceedings of International Conference ACECIM’14, SRM University, Ramapuram, pp. 597-.602.

Kumar, A. C. and Ahmad, M. T. (2019). Mechanical and Durability Properties of Self-Compacting Concrete Reinforced with Carbon Fibers. International Journal of Recent Technology and Engineering (IJRTE). Volume-7, Issue-6, pp. 1738- 1743.

Mehdi Nazarpour and Ali Foroughi Asl (2016), Modeling the polypropylene fiber effect on compressive strength of self-compacting concrete, Computers and Concrete, *Vol. 17, No. 3 (2016) 323-336* DOI: http://dx.doi.org/10.12989/cac.2016.17.3.323

Mehul, J. P. and Kulkarni, S. M. (2013). ‘Effect of Polypropylene Fibre on The High Strength Concrete’, Journal of Information, Knowledge and Research in Civil Engineering Volume 2, Issue 2, Page 127.

Mohammed M, Aboshio A and Aliyu M. M.; Performance of Millet Husk Ash in Self Compacting Concrete, *Nigerian Journal of Technology (NIJOTECH); Vol. 40, No. 6 November, 2021, pp.1010 –1017, www.nijotech.com , ISSN: 0331-8443, ISSN: 2467-8821 http://dx.doi.org/10.4314/njt.v40i6.3*.

Mohammad, K. and Amir, S. B. (2017) ‘‘Effect of Size of Aggregate on Self Compacting Concrete of M70 Grade’’. *Journal of Mechanical and Civil Engineering (IOSR-JMCE), Volume 14, PP 82-87.*

Nandhini S. and Manju R (2017), ‘‘A study of hybride fibre reinforced self-compacting concrete’’ SSRG international Journal of civil engineering. (ICRTCETM)

Oucief, H., Habita, M.F. and Redjel, B. (2006), “Hybrid fiber reinforced self-compacting concrete: hardened properties”, *Int. J. Civ. Eng.*, 4(2), 77-85.

Priti, A. P., Atul, K. D. and Jatin, A. D. (2012). “Evaluation Of Engineering Properties for Polypropylene Fibre Reinforced Concrete”, International Journal of Advanced Engineering Technology, Vol. 3, Issue 1, pp. 42-45.

Poornima, M. R., Shreenivas, R. S., Maneeth, P. D. and Brijbhushan, S (2017). Analysis of Action of Polypropylene Fiber on M30 Concrete by Supplementing Cement with Fly Ash and GGBS. International Journal for Innovative Research in Science & Technology, Volume 4 pp. 99 -103

Ramujee, K. (2013): Strength Properties of Polypropylene Fiber Reinforced Concrete. International Journal of Innovative Research in Science, Engineering and Technology. Vol. 2. www.Ijirset.Com 3409

Rodgers, L. “Climate Change: The Massive CO2 Emitter you may not know about”. BBC News of 17th December 2018.

Sri Durga, M. V. P., Jagarlamudi.V.S. and Chennupati S. (2016). Behavior of SCC (Self Compacting Concrete and NCC (Normal Compaction Concrete) Based on Size of Aggregate. International Journal of Research Studies in Science, Engineering and Technology Volume 3, Issue 10, PP 23-37.

Sohaib Naseer, AttaUllah Shah, Mamoon Riaz, Muhammad Hassan (2016); *Effect of Polypropylene Fibers on Fresh and Hardened Properties of Self-Compacting Concrete.* 2nd International Conference on Emerging Trends in Engineering, Management and Sciences” December 28-30, 2016 (ICETEMS-2016) Peshawar, Pakistan.

Sooriyaarachchi, H.P. and Lasintha, E.D.L. (2016). Influence of Fine Aggregate Types on the Performance of Self - Compacting Concrete. Journal of the Institution of Engineers, Sri Lanka. The Institution of Engineers, Sri La. ENGINEER - Vol. XLIX, No. 01, pp. 9 – 20. Retrieved from; https://www.researchgate.net/publication/297612055

Turkel, S. and Altuntas, Y. (2009). The effect of limestone powder, fly ash and silica fume on the properties of self-compacting repair mortars. Sadhana (India), 34(2), 331-343.

Uche, O. A. U. Adamu, M. and Bahuddeen, M. A. (2012). Influence of Millet Husk Ash (MHA) on The Properties of Plain Concrete. Epistemics in Science, Engineering and Technology, Volume. 2, No.2, pp 68-73.

Worldatlas, (2017). The Leading Millet Producing Countries in the World. Updated on; April 25, 2017. Retrieved from; www.worldatlas.com/articles/the-leading-millet-producing-countries-in-the-world.html on 28th December, 2018.

Yazici, H. (2008). The effect of silica fume and high-volume Class C fly ash on mechanical properties, chloride penetration and freeze–thaw resistance of self-compacting concrete. Construction and Building Materials, 22(4), 456-462.