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EVALUATING THE STRENGTH PROPERTY OF CONCRETE BY PARTIALLY REPLACING CEMENT WITH MANGO SEED ASH

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ABSTRACT

This study aims to investigate the compressive strength of concrete produced with partial replacement of cement with mango seed ash (MSA). The oxide composition analysis of MSA indicates that the Ash is pozzolanic in nature and contains about fifty-eight (58.26%) percent of SiCO2. Consistency, setting times, compressive, Slump, Compacting Factor test were carried out on both the fresh and hard concrete. Mix ratio 1:2:4 was used in preparing each of the samples from which nine concrete cubes were cast at each replacement levels of; 0%, 5%, 10%, 15%, 20%, 25%, and 30%. Compressive strength test performed on the cubes at 7days, 14days, and 28days curing periods showed that the strength of the test cubes decreases with an increase in MSA content. The 28days compressive strength of cement-MSA concrete cubes was observed to have attained its highest compressive strength of 23.70N/mm2 at 5% replacement level. The compressive strength result obtained from the partial replacement of cement with MSA is less than that of the control specimen due to weak bonds, light weight and elemental chemical composition of MSA, which was less than that of cement. Some of the advantages to be derived from this partial replacement are; to promote waste management at little cost, to bring about the low capital cost per tonne production compared to cement, to reduce pollution caused by these waste, to promote conservation of lime stone deposit and reduction in CO2 emission.

1. INTRODUCTION

Promoting the replacement of natural raw materials with Agro-wastes often provides the opportunity to mitigate against the ever-increasing rate of waste management problems. If this is put into practice, even in small amounts, there are possibilities that high production rates will translate into significant consumption of the waste materials especially if the industries are willing to use them [1]. Hence, the utilization of agro-waste materials as partial replacement serves as an advantage when used technically or economically for a wide range of applications which include the production of concretes and mortars.

The use of concrete as a construction material cannot be overemphasized; it is always a valuable product in construction industries. It is very strong in compression but weak in tension and it offers stability and flexibility in a building structure. Concrete consist of cement, sand, aggregate and water, cement is regarded as the most important of them all because it acts as a binder in the mixture and it must be sufficient in a mix ratio. The increase in the price of construction materials especially cement has made people seek alternative construction materials or at least partially replace them with cheaper materials.
In recent years, growing consciousness about the global environment and increasing energy security has lead to increasing demand for renewable energy resources, among these resources are forestry and agricultural waste [2]. According to Manasse [3], in third world countries, the most common and readily available material that can be used to partially replace cement without economic implications is an agro-based waste.
Some advantages to being derived from the use of agro-waste are the partial replacement of cement as presented by Dashan and Kamang [4] are low cost per tonne production compare to cement, promotion of waste management at little cost, reduce pollution by these wastes and increased economy base of farmers when such waste are sold, thereby encouraging more production. Chandra and Berntsson [5] stated that utilization of waste material in the construction provides both practical

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and economic advantages, while Ramezanianpour et al. [6] underlined the potential of using agricultural waste as it contributes to resources conservation and environmental protection.
Since global warming is known as the most crucial environmental issue at present and sustainability is becoming an important issue of economic and political debates, the next developments in the concrete industry will not be the concrete produced with expensive materials and special methods but concrete produce with low cost and highly durable concrete materials containing largest possible amounts of industrial by-product and agro-waste that are suitable for supplementary use of Portland cement, virgin aggregate, and drinking water [7].
Besides, huge energy is required for the burning of clinker during the production of cement, for these, a large amount of CO2 is produced and released into the atmosphere. Worldwide, the cement industry is responsible for about 1.4 billion tons in 1995, which caused the emission of as much CO2 gas as 300 million automobiles - statistically for almost 7% of the total world production of CO2 [8]. Hence environmental pollution and global warming are increasing continuously and, natural resources and energies are being reduced day by day. On the other hand, the huge amount of biogenic wastes (mango pod) are being produced in the developing countries, Nigeria is the best example. In fact, despite their technical and financial benefits, till now there is no potential example of using these ashes, they are only used for landfill purposes.

2. METHODOLOGY

2.1 Materials

The materials used for this study are cement, sand, wash river gravel (coarse aggregate), water and mango seed ash (MSA). The methods used in this study are as follows;

2.1.1 Specific Gravity Test

The ratio of the weight of a given material to the weight of an equal volume of water is termed specific gravity. The specific gravity bottle (pycnometer) was weighed empty and the weight recorded as W1. An amount of the sample was poured into the empty specific gravity bottle and weighed and the weight recorded as W2 (empty bottle + water). Distilled water was then added to the specific gravity bottle with its content (i.e bottle + sample + water), weighed and the weight recorded as W3. The Specific gravity bottle was then emptied of its content, rinsed, and filled with distilled water which was weighed and the weight then be recorded as W4, then the specific gravity was calculated using Equation (1) below:

$$G_s = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)} \tag{1}$$

The above experiment was repeated for a sample of MSA, gravel and sand, and the results were calculated as stated above

2.1.2. Sieve Analysis

This test aims to determine the particle size distribution of the aggregate under investigation. Various sieves with sizes 20 mm, 14 mm, 20 mm, 6.3 mm, 5.0 mm, 3.35 mm, 2.36 mm, 1.70 mm, 1.18 mm, 850 μm, 600 μm, 425 μm, 300 μm, 150 μm, 75 μm, and the pan was arranged in descending order. The materials were then weighed and poured into the arranged sieves, and were thoroughly shaken manually with the topmost sieve covered until no passing of the aggregates is observed to differentiate samples of the aggregates into fractions. The fraction or quantity of aggregate that is retained on each sieve and the pan was weighed and recorded against each sieve sizes, then the percentage retained, passing, and the fineness modulus for each sample was determined.

2.1.3 Slump Test

The concrete slump test is an empirical test that measures the workability of fresh concrete. The mould used for the slump test is the frustum of a cone, 305mm (12 inches) high. The base of diameter 203mm (8inches) was placed on a smooth surface with the smaller opening of diameter 102mm (4 inches) at the top. The inside of the cone was moistened to reduce friction that may influence slump variations. The cone was filled with concrete in three layers. Each layer was tamped 25 times with a standard 16mm (5/8 inches) diameter steel rod with a rounded end. After filling the three layers, the top surface of the cone was struck off and levelled with the steel rod, the area around the base of the cone after levelling was cleaned. Immediately after filling, the cone was slowly lifted, and the unsupported concrete will slump. The decrease in the height of the center of the slumped concrete is called a slump and is measured to the nearest 5mm (1/4 in.) [9].

2.1.4 Compressive Strength Test

The compressive strength of the cubes was to be determined after the removal of the cubes from the curing tank and air-dried. Using a mechanically operated ELE crushing machine of 1500KN capacity, the cubes were placed on the crushing machine to make contact with the top and bottom surface of the cube. The load at failure was recorded as the crushing load of the cube. Then the compressive strength test was evaluated. The average value of the cube's compressive strength was recorded as the compressive strength of the concrete.

2.1.5 Compacting Factor Test

The apparatus and materials used for this experiment were compacting factor apparatus, scoop and two floats. The upper hopper was filled with concrete, levelled to the brim, without compacting the concrete. Two minutes after completing the mixing of concrete the upper hopper was filled and the door at the bottom was released to allow the concrete to fall into the second smaller hopper. The second was released at the bottom of the second hopper and the concrete was allowed to fall into the cylinder. The excess concrete was cut off by simultaneously cut by work floats slide across the top of the mould. The weight of concrete in the cylinder was determined to the nearest 10g, which was "partially compacted weight". The corresponding weight of fully compacted concrete was determined by refilling the cylinder with concrete in four layers, even tamped, as it will be done on the site.

2.1.6 Consistency and Setting Time Test For Cement Paste

The standard consistency test was carried out to determine the water-cement ratio at which the plunger penetrates the paste to a point 5-7mm above the bottom of the mould. The initial setting time is the time elapsed between when water was added to the paste and when the needle penetrates not deeper than 5mm above the bottom of the mould, whereas the final setting takes place when the needle makes an impression on the surface of the paste but the annular cutting edge fail to.

2.2 Experimental design

The concrete grade that was adopted for this investigation was the M-25 grade of concrete.

3. RESULTS AND DISCUSSION

The particle size distributions of fine and coarse aggregates used for the study are shown in Figures 1 and 2. The maximum size of gravel used as coarse aggregate as obtained from the sieve analysis result was 20 mm. The result of the sieve analysis of sand and gravel revealed that the sand is medium-fine grading sand and the gravel is well-graded coarse aggregate.

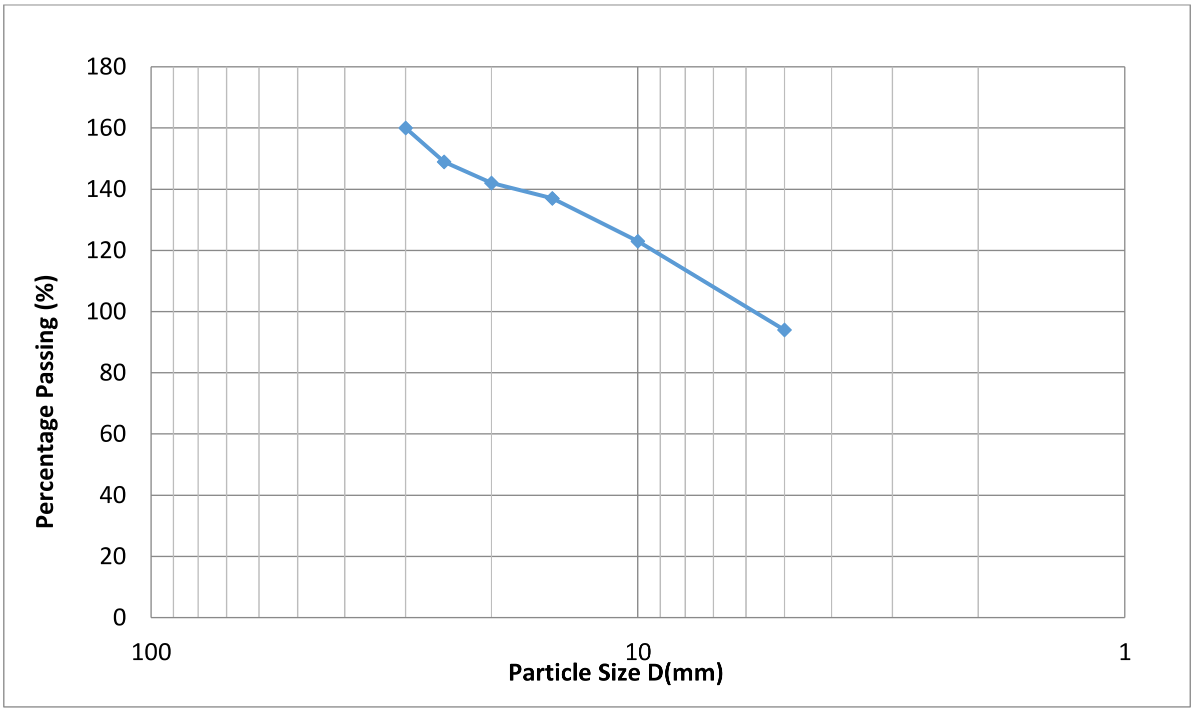

Fig 1. Particle Size Distribution of Fine Aggregate

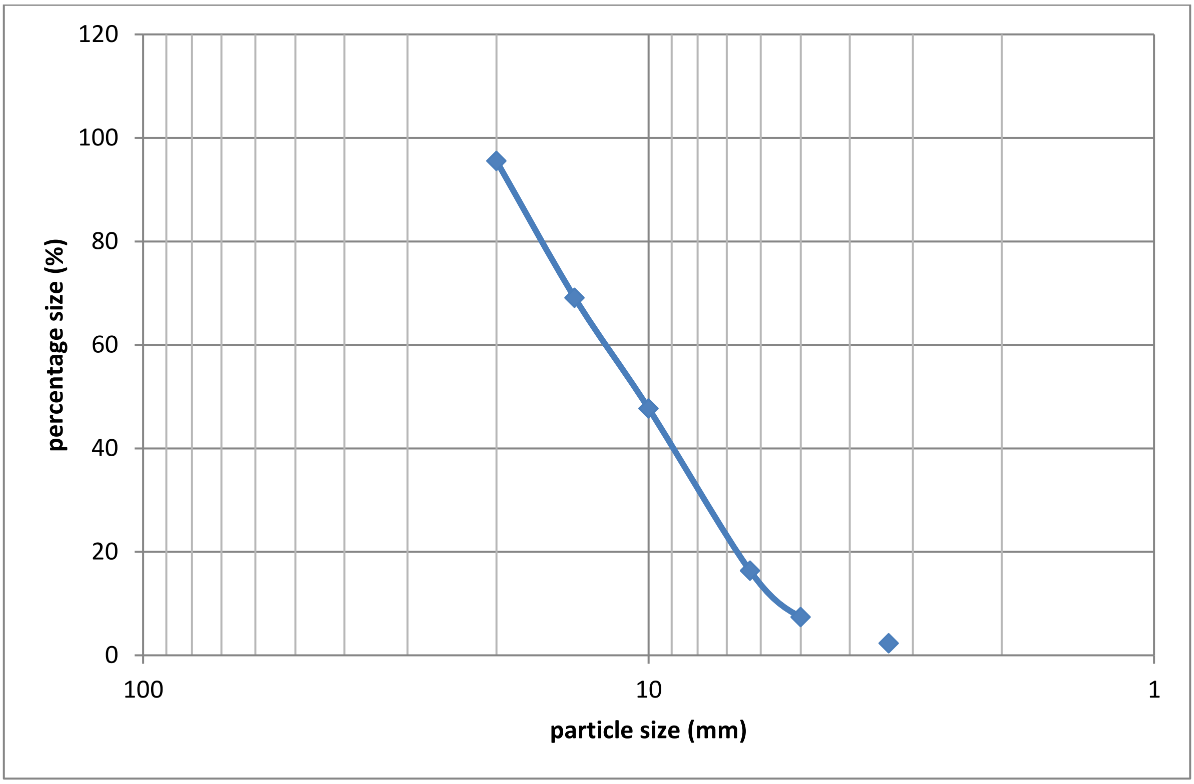

Fig 2. Particle Size Distribution of Coarse Aggregate

3.1 Results of Specific Gravity Test

Table 1 shows the result of specific gravity test for cement, MSA, sand and gravel. The specific gravity of MSA was found to be 2.04. This value is far less than 3.15 for Portland cement. The specific gravity result is though close to the 2.12 reported by [4] for acha husk ash. The specific gravity of sand and gravel were found to be 2.63 and 2.69 respectively.

Table 1: Specific Gravity Test

Material	Specific Gravity
CEMENT	3.15
MSA	2.04
SAND	2.63
GRAVEL	2.69
WATER	1.00

3.2 Result of Chemical Composition of MSA

Oxide composition analysis of MSA shown in Table 2 confirms the status of MSA as a pozzolanic material with low calcium oxide composition and high Silicon dioxide (SiO2) compositions with values 4.67 and 58.2 % respectively. Based on the oxide composition analysis, the use of MSA can be used to replace cement on the bases of the SiO2 and CaO contents.

Table 2: Elemental Oxide composition of Mango Seed Ash (MSA)

Element	Concentration %
Na_2O	0.166
MgO	2.546
Al_20_3	9.534
SiO_2	58.29
P_2O_5	6.790
SO_3	1.915
Cl	0.279
K_2O	9.864
CaO	4.678
TiO_2	2.054
Cr_2O_3	0.000
Mn_2O_3	0.178
Fe_2O_3	3.711
ZnO	0.069
SrO	0.036

3.3 Result of Setting Time of Cement and MSA

Figure 3 shows the setting time of both cement and MSA. The initial and final setting time of cement was 63 min and 109 min respectively which falls within the range of 45minutes to 10 hours as specified by BS 12 requirement. It was found that the initial and final time of cement and MSA increases with an increase in MSA content. The exothermic reaction between cement and water result in libration of heat and evaporation of water and eventually hardening of the paste. The rate of reaction and quantity of heat liberated decreases with the introduction of MSA leading to late stiffening of the paste the increase in setting time implies that MSA is a good admixture known as decelerating agents, which is in turn used to decrease the rate of both sets, and late strength development. Studies have shown that the introduction of Agro-waste as partial replacement for cement is likely to increase the setting time with increased in the content. Naji et al [10] cited studies where the setting time of cement paste with Agro-waste content increase. According to Dakroury et al [11], this trend could be as a result of the slower pace of hydration when Agro-waste content is present in the cement paste.

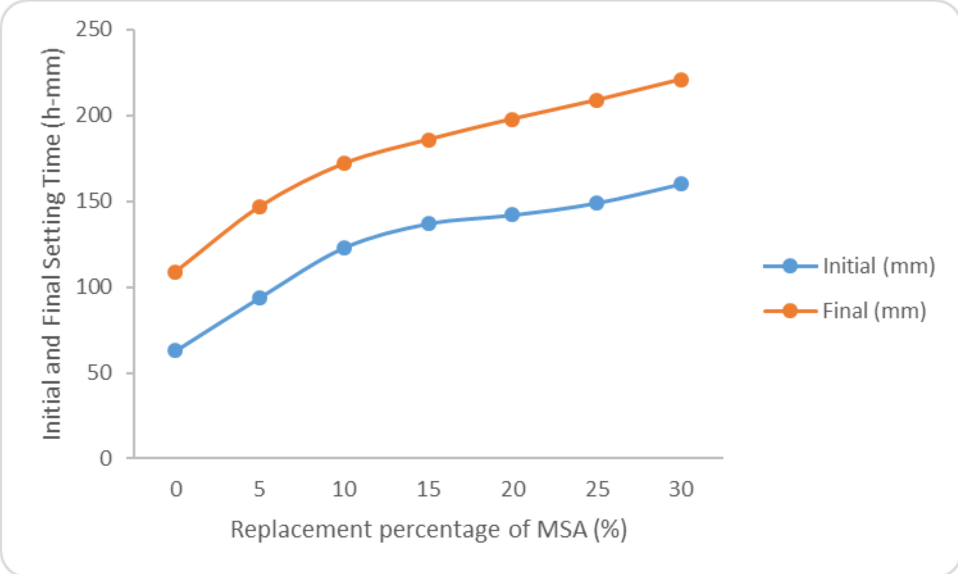

Fig 3. Initial and Final setting Time of MSA for Different Replacement percentages (%)

3.4 Result of Slump Test

The result of the slump test is shown in table 4. The test result shows that mixes with greater MSA content require greater water content to achieve reasonable workability. The slumps observed were medium (35 to 75mm) according to BS 1881. The implication is that concrete produced by partial replacement of cement with MSA can be used for rigid pavement within the slump value. The water/cement ratio is likely to increase with the addition of MSA, this may be due to more water required for effective hydration arising from MSA addition. There was no definitive trend in the slump value in this research which is contrary to the research conducted by Oseni and Audu [12]. They used millet stem ash (MSA) as a partial replacement for cement where the slump value decreased with increase percentage replacement. However, the used of ash from bakery as a partial replacement for cement had the same trend for slump test as established in this research [13].

Table 3: Slump Value of Cement and MSA

s/no	Percentage of cement (%)	Percentage of MSA (%)	Slump (mm)
1	100	0	49
2	95	5	55
3	90	10	51
4	85	15	53
5	80	20	56
6	75	25	53
7	70	30	55

3.5 Result of Compressive Strength Test

Figure 4 shows the result for the compressive strength of concrete with MSA and Portland concrete at 7, 14, and 28 days. The result shows that the cubes containing 0% MSA had the highest compressive strength. The strength decreases with more MSA content. Silica in Ordinary Portland Cement contains about 29-30% of cement mixture while silica makes up about 58.3% in MSA. The 58.3% will be inadequate to react with the calcium hydroxide produced by the hydration of cement. This implies that MSA contains excess silica content. Although with the silica content, there was a significant increase in strength from 7 – 28 days curing period as indicated by Muhammad et al [14]. In addition to the silica content of MSA, the presence of CaO could lead to the decrease in strength of concrete [15]. There is a possibility that the reaction of OPC, silca and CaO could affect the binding characteristics of concrete thus leading to a reduction in strength [16].

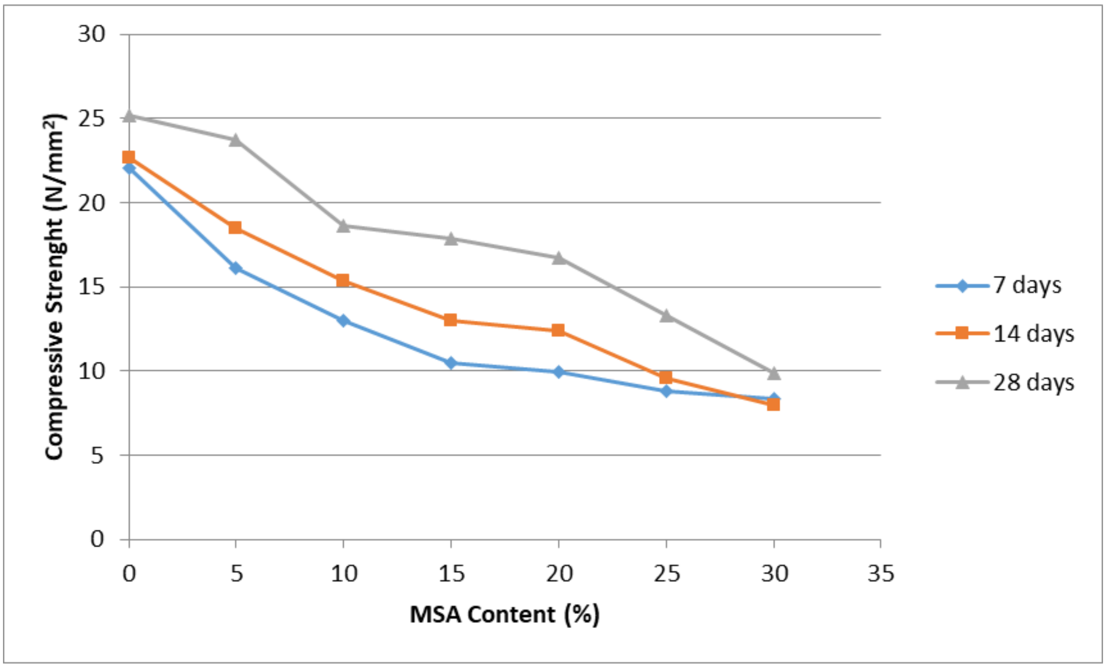

Fig 4. Compressive Strength of Concrete Specimen at 7, 14 and 28days

4. CONCLUSIONS

The study focuses on investigating the compressive strength of concrete produced by partially replacing cement with mango seed ash (MSA). The oxide composition analysis of mango seed ash revealed that MSA is a pozzolanic material with about fifty-eight (58.3 %) SiCO2 content. The setting time of MSA concrete increased with an increase in MSA content as a partial replacement for cement. The setting time increased from 63 minutes to 109 minutes at 0 % MSA and from 151minutes to 221 minutes at 30 %. The value of the slump test for Cement and MSA ranged from 49 – 56 mm. The experimental investigation on the compressive strength of concrete showed that the use of MSA as a partial replacement of cement in concrete production yields compressive strength values which were lower than the values obtained with the use of only cement, although the results show that cement can be partially replaced with MSA at 5 % replacement for efficient yield. Due to the outcome of this study, chemical additives like lime are recommended to strengthen the weak bonds that exist between the mix of MSA and cement.

REFERENCES

[1]. Daniel, V. R., João, A. L. and Marcio, R. M. (2011). Potential Use of Natural Red Mud as Pozzolan for Portland Cement. Materials Research Journal, 14(1): 60-66.

[2]. Festus, A., Habeeb, A. and Oladipupo, S. (2012). Investigation of the strength properties of palm kernel ash. Engineering, technology and applied science research. 2 (6): 315-319.

[3]. Dashan I. and Kamang E. (1999). Some characteristics of AHA/OPC concrete. Nigeria journal of construction technology and management. 2(1): 22-29.

[4]. Chandra Z. and Berntsson L. (2002). light weight aggregate. Concrete science, technology and application. 6 (8): 32-41.

[5]. Ramezanianpour, A., Mahdikhani, M. and Ahmadibeni G. (2009). The effect of rice husk ash on mechanical properties and durability of sustainable concrete, International journal of civil engineering, 7(2): 83-91.

[6]. Mehta, K. P. (2002). Greening of Concrete Industry for Sustainable Development. Concrete International. 24(6): 86-73.

[7]. Manasse, J. (2010). A Review of Partial Replacement of Cement with Some Agro Wastes. Nigeria Journal of Technology. 29 (2): 12-20.

[8]. Malhotra V. (1998). A Global Review with Emphasis on Durability and Innovative Concrete, Journal of America Concrete Institute, 30: 120-130.

[9]. Neville, A. M. (1995). Properties of Concrete 4th edition. Pitman Publishing Company Ltd, New York.

[10]. Naji Givi, A., Rashid, S. A., Aziz, F. A., Mohd Salleh, M. A. (2010) Contribution of Rice Husk Ash to the Properties of Mortar and Concrete: A Review. Journal of American Science, 6(3):157-165.

[11]. Dakroury, A. E., and Gasser, M. S. (2008). Rice husk ash (RHA) as cement admixture for immobilization of liquid radioactive waste at different temperatures. Journal of Nuclear Materials. 381(3): 271–277.

[12]. Oseni, O. W. and Audu, T. M. (2016) The Effects of Percentage Compositon of Millet Stem Ash (MSA) and Water Cement Ratio on The Properties Composite Concrete, International Journal of Civil Engineering and Technology, 7(1): 427-440.
[13]. Raheem, A. A. and Adenuge, O. (2013). Wood Ash from Bakery as Partial Replacement for cement in Concrete. International Journal of Sustainable Construction Engineering & Technology, 4(1):75-81.
[14]. Muhammad, S. S., Nor, H. O., Shahiron, S. (2019). Performance of Concrete containing mussel shell (Perna Viridis) ash under effect of sodium chloride-curing. IOP Conf. Ser. Mater. Sci. Eng., 601: 1-14.
[15]. Sun, J. and Chen, Z. (2018) Influences of limestone powder on the resistance of concretes to the chloride ion penetration and sulfate attack Powder Technology, 338: 725–733.
[16]. Lee, S. T., Hooton, R. D., Ho-Seop, J., Du-Hee, P. and Chang, S. C. (2008). Effect of limestone filler on the deterioration of mortars and pastes exposed to sulfate solutions at ambient temperature Cement and Concrete Research, 38: 68–76.

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