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STRENGTH CHARACTERISTICS OF GROUNDNUT LEAF/STEM ASH (GLSA) CONCRETE

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Abstract

The compressive strength properties of concrete are substantial factors in the design and construction of concrete structures. Compressive strength directly affects the degree to which the concrete can be able to carry a load over time. These changes are complemented by deflections, cracks etc., in the structural elements of concrete. This research investigated the effect of groundnut leaf/stem ash (GLSA) on the compressive strength of concrete at 0%, 5 %, 10 % and 15 % replacements of cement. The effect of the water-cement ratio on properties such as the compressive strength, slump, flow and workability properties of groundnut leaf/stem ash (GLSA) mixes with OPC were evaluated to determine whether they are acceptable for use in concrete structural elements. A normal concrete mix with cement at 100 % (i.e., GLSA at 0%) with concrete grade C25 that can attain an average strength of 25 N/mm2 at 28 days was used as a control at design water-cement ratios of 0.65 and grading of (0.5-32) mm from fine to coarse aggregates was tested for: (1) compressive strength, and the (2) slump and flow Test. The results and observations showed that the concrete mixes from GLSA at 5 – 15 % ratios exhibit: pozzolanic properties and GLSA could be used as a partial replacement for cement at these percentage mix ratios compared with the control concrete; an increase in the water-cement ratio showed a significant decrease in the compressive strength and an increase in workability. Therefore, it is important that all concrete mixes exude an acceptably designed water-cement ratio for compressive strength characteristics for use in structures, water-cement ratio is a significant factor.

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Key words

- Ash,
- Concrete,
- Compressive Strength,
- Flow,
- Slump,
- Ground nut leave.

1 INTRODUCTION

The quest by governments in developing countries, especially those in the west of the Sahara in Africa, for the use of alternative, unconventional local construction material that is sustainably developed has witnessed a tremendous increase over the years. Organic waste material is available in massive quantities in rural parts of these countries. These waste materials can be useful for advances in concrete technology. The permeability of the concrete can be influenced by choosing a higher proportion of fine aggregates or by increasing the cement content. A denser concrete is also obtained when the water-cement ratio is lowered, in which case both the capillary pores and their size are decreased, thereby decreasing the pore volume available for the movement of moisture (Gram, 1983; Gram and Nimityoungskul, 1987). Concrete is a composite inert material comprised of a binder (e.g, cement), a mineral filler (aggregates) and water (Neville, 1989). Aggregates are of two types, fine and coarse. They are usually graded from sand to stone. There are two types of concrete: lightweight concrete and normal-weight concrete. The light weight concrete weighs between 1600 to 2000 kg/m^3, while normal-weight concrete has an average density of 2400 kg/m^3 (Orchard, 1976). Normal-weight concrete is often used for reinforced concrete works in suspended structural members, but can also be used as mass concrete for ground floors.

The batching of concrete can either be by weight or by volume. The batching of a design mix for high-quality jobs is usually by weight. The amount of water to be added to a batch of concrete mix is governed by the workability, strength the exposure condition of the concrete. If too much water is added, there is tendency for segregation of the aggregates during placement and the concrete does not meet the target strength after it has hardened. On the other hand, too little water in the mix will not make the chemical action of the setting of the cement incomplete. The amount of water to be added to a given batch of concrete mix is guided by a specified water-cement ratio.

Concrete can also be made impermeable to water by admixing polymers, silicons or stearates. Another method is to admix a small ball of wax in the fresh concrete. The mixture is allowed to harden. Thereafter, it is subjected to heat so that the melting wax flows into the pores of the concrete, thus sealing the system. Impregnating the concrete with sulphur, tar, asphalt or oil also constitutes a possible means of preventing the movement of moisture in the pore system of the concrete (Gram and Nimityoungskul, 1987; Guimaraes, 1990; Sivaraja *et al.*, 2010). The alkalinity of the concrete's pore water can be reduced by replacing some of the ordinary Portland cement (OPC) with various pozzolanas (Yunusa and Danladi, 2013). This is achieved when the calcium hydroxide, which is formed in connection with the cement's hydration, reacts in part with the silica present in the pozzolanas. When the free calcium hydroxide has been completely consumed, the carbonation of the matrix is also facilitated, thus entailing a marked reduction in pH value for the pore water (Cook, 1986; Suvanispan, 1988). Cements of different bands types have been found suitable as the binding material for concrete. However, cement production involved using mined soil minerals been put into processes that are not easily done by simple mechanisms. These cement materials are localized, and the necessity to import the machinery to produce cement often results in high-priced cement, which ultimately results in making the production of concrete costly. The challenge is therefore or researchers to find alternative materials that could be used to substitute for complement the cement in the production of concrete.

The deployment of viable waste materials in the production of concrete provides a satisfactory solution to some of the environmental concerns and problems associated with waste management in every country of the world. Nigeria is not an exception. Therefore, the need to study the behaviour and/or properties of sustainable waste material such as groundnut leaf/stem ash (GLSA) concrete for building construction cannot be overemphasized. The performance of the entire building structure is a function of the quality of each material that constitutes the building. As a consequence of the importation of most materials, the high cost of both local and imported building materials has made the ownership of a house beyond the reach of most Nigerians (Madedor, 1992). This has resulted in a shortage of accommodation in every urban settlement of the country with the attendant high cost of rent. Consequently, the use of locally produced building materials, including agricultural and industrial waste and products to construct houses, has to be investigated and encouraged. Assessing the use of substitutes and the economic exploitation of naturally occurring local materials and agricultural or industrial waste and products remain important areas of research in the drive towards the overall development of any nation. The current challenge facing the governments of most developing nations like Nigeria is how to provide good accommodations for the growing population at a relatively low cost.

For this research the slump, flow, and compressive strength of the basic concrete mix of grade C25 at a designed water-cement ratio of 0.60 and 0.65 were examined for:

0% GLSA, 100% Cement (0.5-32) mm fine-coarse aggregate mix concrete (Control),

5% GLSA, 95% Cement (0.5-32) mm fine-coarse aggregate mix concrete,

10% GLSA, 90% Cement (0.5-32) mm fine/coarse aggregate mix concrete,

15% GLSA, 85% Cement (0.5-32) mm fine-coarse aggregate mix concrete.

2 METHODOLOGY OF RESEARCH

The materials, experiments and laboratory works carried out to accomplish the objective of this research are as follows:

2.1 Materials

The materials used in the production of the concrete cubes used are sand, gravel, cement, groundnut leaf/stem ash and water.

2.1.1 Sand

The sand was obtained at in the environs of Gwagwalada-Abuja-FCT and transported to Julius Berger PLC (JBN PLC), Quality Assurance & ControL (QA&C) Laboratory, Mpape-Abuja, FCT, for a preliminary analysis for its suitability for use in concrete production.

2.1.2 Gravel

The coarse aggregate was obtained from Gwagwalada-Abuja-FCT and transported to JBN PLC, QA&C Laboratory, Mpape-Abuja, FCT. The aggregate was washed and allowed to dry naturally to free it from dirt and impurities according to BS 812, 1975.

2.1.3 Cement

The cement used was Dangote cement, which was obtained at Gwagwalada-Abuja-FCT. The cement obtained was ordinary Portland cement and, as such, was found to be applicable in most construction works. It was stored in a place with no direct contact with floor and walls. An analysis of the grain size of the cement was carried out to determine its suitability for the work.

2.1.4 Groundnut leaf/stem ash

Groundnut Leaf/Stem is a waste product from millet farms in the rural areas of FCT, Niger State and Kaduna State. The Groundnut Leaf/Stem obtained was sorted into sacks to avoid mixing it with materials that were already decayed or rotting from moisture or rain and was transported to the JBN PLC, QA&C Laboratory, Mpape-Abuja FCT. The burning of the Groundnut Leaf/Stem was done at a laboratory using an oven.

2.1.5 Water

The source of the water used for this work was borehole water situated in the JBN PLC, QA&C Laboratory, Mpape-Abuja, FCT. The water was potable, which therefore satisfied the required specification for making concrete as described in BS 3148 and was therefore suitable for the production of concrete.

2.2 Experimental procedures

The study commenced with the collection of groundnut leaf/stem from farms around Abuja-Niger-Kaduna-Zaria. The groundnut leaf/stem was burnt and its ashes collected. The ashes were allowed to pass through a 0.63 millimetre to sieve to achieve the same degree of fineness cement. This was followed by a preliminary investigation of the constituent material of ordinary Portland cement (OPC) and the groundnut leaf/stem ash (GLSA).

2.3 Laboratory tests

In accordance with the various codes, the following preliminary tests were conducted on the materials at room temperature and under laboratory conditions to determine their suitability for making concrete: the specific gravity test (CP100); aggregate impact value test (BS 812); silt content test (BS 11975); moisture content test; and sieve snalysis test;

2.3.1 Batching

The materials were batched by weight; the measurement was performed as usual using a head pan and a balance.

2.4 Mix design

The concrete mix was designed in accordance with the British design mix BS 8110. The method gives proportions in terms of the quantities of the materials per unit volume of concrete. The mixing was done using a rotary concrete mixer. The fine and coarse aggregates, cement, and millet husk ash were all mixed together in the concrete mixer thoroughly to achieve final degree of uniformity. The required quantity of water with a water-cement ratio of 0.75 was then added.

2.5 Slump /flow test

A slump test was carried out to determine the workability of the concrete. The slump cone was placed on a flat non-porous surface and held down by foot. The mould was then filled in three layers. Each layer was compacted. After the third layer had been tamped, the slump cone was immediately removed by raising it vertically. The height of the slump cone was determined by taking measurement from the top of the slump cone to the top of the concrete. The slump was measured as the difference between the height of the cone and the height of the slump concrete, see Figure 1. The flow test was carried out on fresh composite concrete using the various percentages of ground nut leave ash. The flow table was wetted. The flow test cone was placed on the flow table and then filled with the composite concrete in two layers; each layer was tamped 10 times. The cone was lifted up after 30 seconds. The concrete was allowed to flow. The table was then lifted up 40 mm and dropped 15 times. The diameter of spread of the fresh concrete composite on the flow table was measured as shown in Figure 2.

Fig. 1 *Slump Test*

Fig. 2 *Flow Test*

2.6 Compressive strength test

Cube moulds of the size 150mm x 150mm x 150mm were used for the casting for the compressive strength test. The concrete was placed in three layers, and each layer was tamped. The surface of the concrete was smoothened with a steel float and then covered with a sack and left for 24 hrs in the laboratory.

The concrete cubes were then unmoulded and immediately placed in moist curing tanks for 7, 21, 28 and 56 days. After each of the stated days, the cubes (Figure 3) were removed from the tank and allowed to dry in the open air for 2 hours before being subjected to a compressive strength test.

The compressive strength of the cube samples was determined in accordance with the standard procedure given in BS 2080 (BSI, 1970) as shown in Figure 4. The weights of the sample were always taken before the compressive strength test was conducted. Three cubes samples were crushed on the 3rd, 7th, 14th, 21st and 28th days respectively. The maximum load carried by the specimen before failure occurred was recorded. The compressive strength was calculated using the following formula

$$\text{Compressive strength} = F/A$$

where F = Failure load (N) and A = Cross-sectional area (mm^2).

Fig. 3 *150 x 150 x 150 mm cube samples*

Fig. 4 *Compressive Strength Test*

3. RESULTS AND DISCUSSION

3.1 Fresh concrete properties

The slump and flow tests were used to evaluate the workability and consistency of the fresh concrete.

The experiment showed that as the percentage of GLSA was increased in the mix, these was a greater decrease in the slump and flow. Hence, there was an increase in workability as shown in Table 1 and Figure 5. It was also observed that there was a change in the colour of the concrete from ash to dark ash with the increases in the percentage of ground nut leaf ash.

Tab. 1 *Slump and flow at a water-cement ratio of 0.60 for concrete grade C25*

% Replacement at water-cement ratio of 0.75 and concrete grade C25	Slump test (mm)	Flow test (mm)
100%OPC, 0% GLSA	75	430
95%OPC, 5% GLSA	65	430
90%OPC, 10% GLSA	43	390
85%OPC, 15% GLSA	43	400

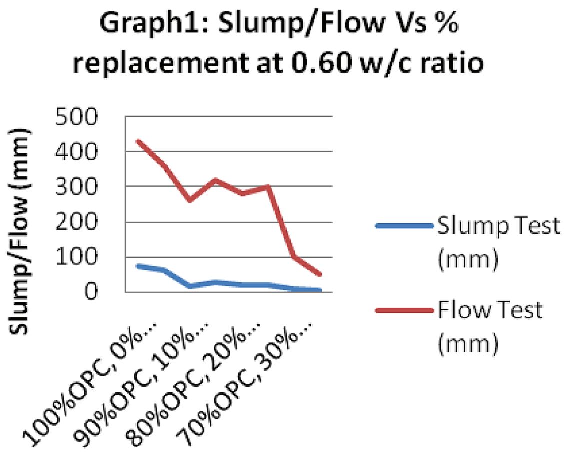

Fig. 5 *Slump and flow test*

Tab. 2 *Slumps and flow test of GLAC at a water-cement ratio of 0.65 for concrete grade C25*

% Replacement at water cement ratio of 0.65 and concrete grade C25	Slump Test (mm)	Flow Test (mm)
100%OPC, 0% GLSA	145	430
95%OPC, 5% GLSA	195	510
90%OPC, 10% GLSA	62	350
80%OPC, 20% GLSA	110	420
75%OPC, 25% GLSA	90	400

3.1 Fresh concrete properties:

The slump and flow tests were used to evaluate the workability and consistency of the fresh concrete.

The experiment showed that as the percentage of GLSA was increased in the mix, there was a greater decrease in the slump and flow. Hence, there was an increase in workability as shown in Tables 1 and 2, while Figures 5 and 6 clearly showed the trend in the slump and flow with the changes in the percentage composition of GLSA and then water-cement ratio. It was also observed that there was a change in the colour of concrete from ash to dark ash with the increased percentages of ground nut leaf ash.

Tab 3 *Compressive strength at a water-cement ratio of 0.60 for concrete grade C25*

% Replacement at water-cement ratio of 0.60 and concrete grade C25	Compressive Strength (N/mm2)			
	7 days	21 days	28 days	>56 days
100% OPC, 0% GLSA	29.8	34.4	34.2	38.2
95% OPC, 5% GLSA	28.9	35.8	35.1	36.4
90% OPC, 10% GLSA	20.9	23.8	23.8	27.6
85% OPC, 15% GLSA	16	20.2	20.4	22.2
80% OPC, 20% GLSA	14.4	17.3	18.2	17.8
75% OPC, 25% GLSA	15.6	18.9	19.6	20.8
70% OPC, 30% GLSA	Collapsed and failed during curing in the curing tank			
65% OPC, 35% GLSA				

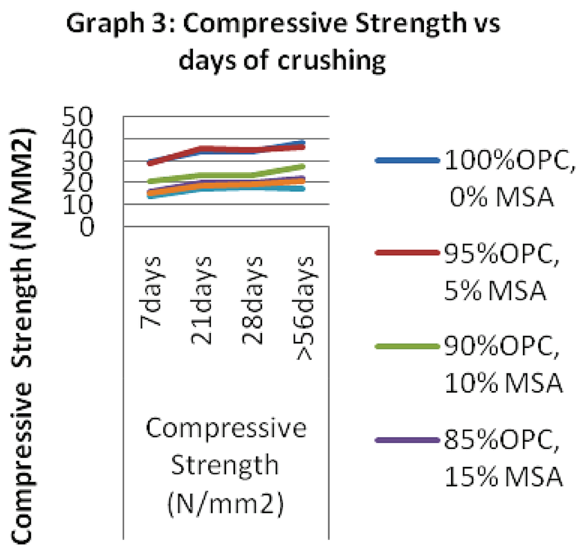

Fig. 6 *Compressive strength of groundnut leaf cement concrete composite at 0.60 water-cement ratio*

Tab. 4 *Compressive strength at water cement ratio of 0.65 for concrete grade C25*

% Replacement at water-cement ratio of 0.65 and concrete grade C25	Compressive Strength (N/mm²)			
	7 days	21 days	28 Days	>56 days
100%OPC, 0% GLSA	23.3	28.9	28.2	30.7
95%OPC, 5% GLSA	20.4	23.8	23.3	24.9
90%OPC, 10% GLSA	13.6	15.1	17.1	17.8
80%OPC, 20% GLSA	12.2	13.6	14.2	14.2
75%OPC, 25% GLSA	12.7	14.0	14.7	14.7

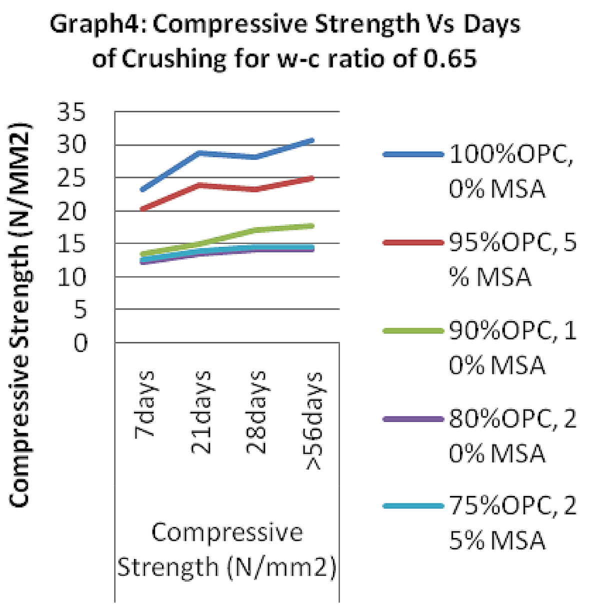

Fig. 7 *Compressive strength of groundnut leaf cement concrete composite at 0.65 water-cement ratio*

3.2 Hardened Concrete Properties

3.2.1 Compressive Strength of GLSA Concrete

The compressive strength of the concrete decreased as the percentage replacement of GLSA increased from 5 – 25 % compared with the 0% GLSA. The compressive strength dropped by 20-30 % with an increase in the water-cement ratio from 0.60 to 0.65 (see Figures 7 and 8).

The dried density and weight are presented in Tables 5 and 6. It can be observed from the graphic illustrations of the weight and dry density of the GLSA concrete shown in Figures 8 to 11 that both the dry density and weight decrease with any increase in the percentage of GLSA. These properties also decrease with an increase in the water-cement ratio and an increase in the elapsed time before crushing.

Tab. 5 *Weight and density at a water-cement ratio of 0.60 for concrete grade C25*

% Replacement at water-cement ratio of 0.60 and concrete grade C25	Crushing Days	Weight (kg)	Density (kg/m³)
0 %	7	7.961	2359
	21	7.959	2358
	28	8.090	2397
	>56	8.014	2375
	Average	8.006	2372
5 %	7	7.980	2364
	21	8.026	2378
	28	8.015	2375
	>56	7.968	2361
	Average	7.997	2370
10 %	7	7.866	2331
	21	7.889	2337
	28	7.926	2348
	>56	7.880	2335
	Average	7.890	2338
15 %	7	7.971	2362
	21	7.983	2365
	28	7.995	2369
	>56	7.991	2344
	Average	7.985	2360
20 %	7	7.833	2321
	21	7.871	2332
	28	7.890	2338
	>56	7.873	2333
	Average	7.867	2331
25 %	7	7.953	2356
	21	7.953	2356
	28	7.926	2348
	>56	7.883	2336
	Average	7.929	2349

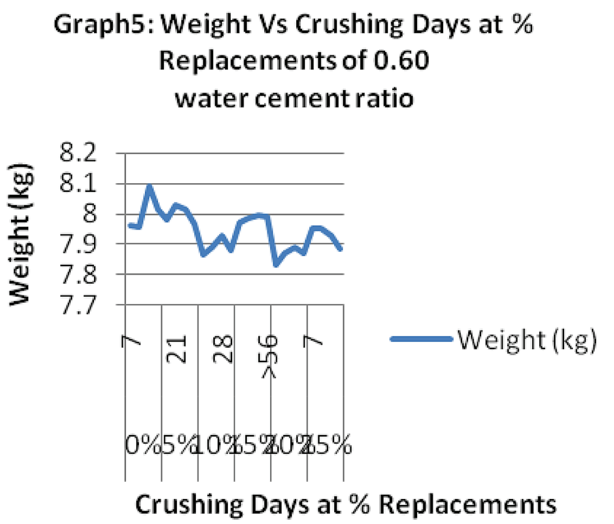

Fig. 8 *The weight of the groundnut leaf cement concrete composite at 0.60 water-cement ratio*

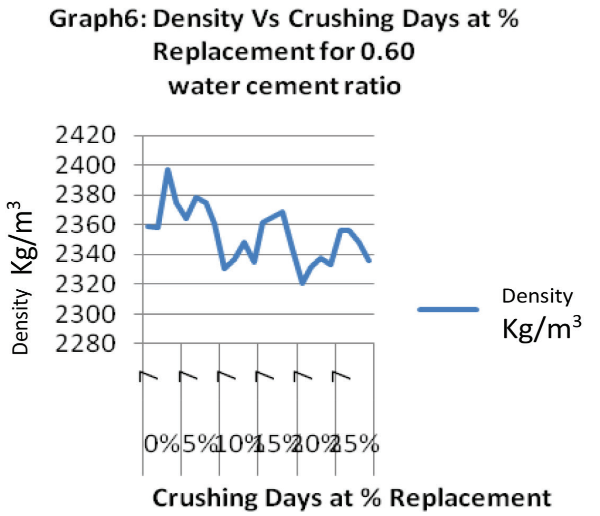

Fig. 9 *The density of ground nut leaf cement concrete composite at 0.60 water/cement ratio*

Tab. 6: *Density and weight of concrete composites at a water-cement ratio of 0.65 for concrete grade C25*

% Replacement at water-cement ratio of 0.65 and concrete grade C25	Number of days before crushing	Weight (kg)	Density (kg/m³)
0 %	7	7.889	2337
	21	7.869	2331
	28	7.916	2345
	>56	7.874	2333
	Average	7.887	2337
5 %	7	7.942	2353
	21	7.974	2363
	28	7.916	2345
	>56	7.882	2335
	Average	7.929	2349
10 %	7	7.836	2320
	21	7.827	2319
	28	7.882	2335
	>56	7.866	2331
	Average	7.853	2326
20 %	7	7.955	2357
	21	7.926	2348
	28	7.923	2348
	>56	7.959	2358
	Average	7.941	2353
25 %	7	7.790	2308
	21	7.765	2301
	28	7.806	2313
	>56	7.717	2287
	Average	7.770	2302

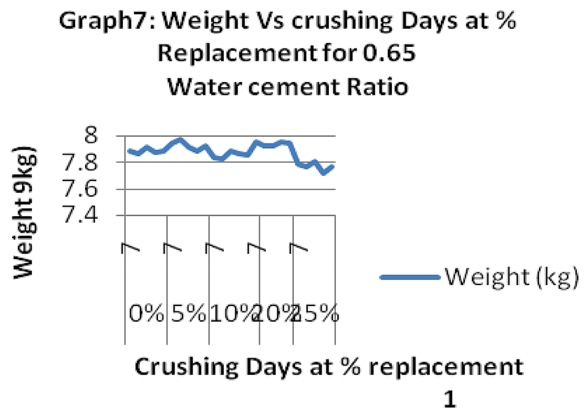

Fig. 10 *The weight of groundnut leaf cement concrete composite at 0.65 water-cement ratio*

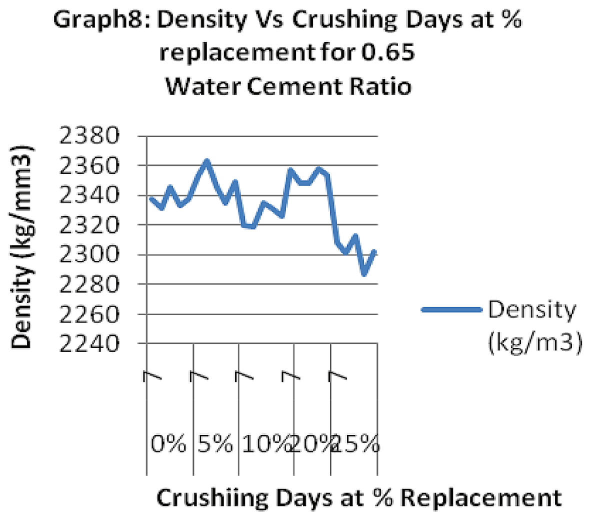

Fig. 11 *The density of groundnut leaf cement concrete composite at 0.65 water-cement ratio*

4 CONCLUSION

The results from this research show that:

(1) GLSA concrete can be used to replace of Portland cement in concrete

(2) The compressive strength of GLSA concrete shows that the mechanical property for the concrete even at 28 days is 20 N/mm2 for 25 % GLSA concrete and is influenced by the increase in the water-cement ratio. It reduced the compressive strength significantly.

(3) The density of GLSA concrete is quite comparable with normal concrete at 0 % GLSA, even with the increase in the water-cement ratio.

(4) The workability of the concrete decreases as the percentage of GLSA increases, but it is still workable with a 25 % GLSA replacement.

Further studies should be focused on:

(i) The chemical characterisation of the Millet Stem Ash

(ii) Morphology and microstructure of concrete made from GLSA concrete.

(iii) Influence of the Initial and final set time of GLSA concrete.

(iv) The shrinkage and creep test to determine the long-term suitability of GLSA concrete for structural elements in structures is still in progress.

5 RECOMMENDATIONS

All of the GLSA concrete samples evaluated for C25 and the water-cement ratio revealed that:

(1) GLSA concrete could be used for concrete at a 15 % replacement with a water-cement ratio of 0.60 and 5 % at water cement ratio of 0.65.

(2) GLSA concrete is of the same weight and density of a normal concrete at 0 % but decreases as the percentage of GLSA increases.

(3) The workability of GLSA concrete decreases as the percentage of GLSA increases; it becomes unworkable at a water-cement ratio of 0.60 but is more workable at a 0.65 water-cement ratio.

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