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Influence of Neem Seed Husk Ash (NSHA) on the Strength of Laterized Concrete

U.A. Aliyu[a], O.A.U. Uche[a], A. Mohammed[a], M.T. Abdulwahab[a*]

[a]Department of Civil Engineering, Bayero University Kano, Nigeria.

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Abstract

The processing of neem products from the neem tree generates a considerable amount of waste each year. The purpose of this study is to evaluate the properties of laterised concrete containing neem seed husk ash (NSHA) as an admixture. The neem seed husk was obtained from a neem oil processing company in Katsina – Nigeria, dried and burned in the open air before being calcined in an oven at 650°C to make an ash. X-ray Fluorescence (XRF) was used to analyze the chemical composition of neem seed husk ash. Grade 25 concrete was made with 0, 10, 20, 30, and 40 % by weight of fine aggregate substitution with sand. The NSHA was then added to the concrete at a ratio of 2, 4, 6, 8, and 10 % using optimal laterite content of 20 %. Workability tests were carried out for each percentage replacement of fine aggregate with laterite and percentage addition of NSHA to laterised concrete at a laterite content of 20%. At ages of 7, 14, 28, and 56 days, 100 mm x 200 mm cylinders were tested for compressive strength and splitting tensile strength. With increasing laterite and NSHA content, the slump, compressive strength and tensile strength of the concrete decrease. At 20 % laterite content and 4 % NSHA addition, the compressive and tensile strengths were 28.38 N/mm^2 – 29.10 N/mm^2 and 2.13 N/mm^2 – 2.23 N/mm^2 respectively. Therefore, laterised concrete with NSHA as an admixture can be produced by replacing fine aggregate with laterite at an optimum laterite content of 20 % and addition of NSHA at a maximum of 4 %.

1. Introduction

In recent advancements in civil engineering, many researches have been conducted to incorporate an alternative material (such as Natural fibers, corn cob ash, fly ash, rice husk ash, bagasse ash, foundry waste, e.t.c) in replacing the cement. Due to increase in global emission of CO_2 rate, the introduction of environmentally friendly alternative materials satisfying the strength criteria will be more efficient compared to the full usage of cement. The reuse of these waste products will help to save our environments from environmental pollution and saving in cost of concreting. Neem Seed Husk is a by-product obtained during industrial processing of Neem Seed to extract oil and produce fertilizer. In producing neem-based fertilizer, extraction of neem oil is done first, and the resultant cake is used in making organic based fertilizer. Some little quantity of seed husk is crushed and ground into fertilizer formulation but large quantity usually lay waste. However, neem seed husk waste constituted disposal problems in neem oil processing factories, which when disposed around, causes a severe ecological and environmental pollution which is hazardous to humanity as well as the living organism. Nuruddeen [1], established that neem seed husk ash (NSHA) is a good cementitous material and it has shown remarkable ability of improving the splitting tensile strength of concrete.

Lateritic soils are highly weathered and altered residual soils formed by the in-situ weathering and decomposition of parent rocks under tropical and subtropical climatic conditions. This weathering process primarily involves the continuous chemical alteration of minerals, the release of iron and aluminium oxides, and the removal of bases and silica in the rocks. The geotechnical properties of lateritic soils are influenced by climate, drainage, geology, the nature of the parent rock and the degree of weathering or linearization of the parent rock. Lateritic soils contribute to the general economy of the tropical and subtropical regions where they are in abundance because, they are widely utilized in civil engineering works as construction materials for roads, houses, landfill for foundations, embankment dams. As a road construction material, they form the sub-grade of most tropical road, and can also be used as sub-base and base courses for roads that carry light traffic [2].

Furthermore, studies conducted by [3], Salisu [4] revealed the suitability of laterite replacement for sand in conventional concrete and the use of industrial by-product as pozzolanas.

2. Materials and Methods
2.1 Materials

Cement, Neem seed husk ash (NSHA), laterite, water, and fine and coarse aggregates are the materials used in this study.

2.1.1 Binders

The cement used was Ordinary Portland cement (OPC) of Grade 42.5R. It was obtained from a cement dealer in Rijiyar Zaki, Kano State and was stored at room temperature in a dry environment to maintain its properties. The specific gravity of the cement was determined in accordance with BS EN 12620 [5].

2.1.2 Aggregates

The fine aggregate used was clean river sand. The sand was sun-dried and stored in a water-proof sack in the laboratory to prevent it from absorbing any moisture from the environment.

2.1.3 Water

Potable water obtained from the Civil Engineering Laboratory reservoir of Bayero University Kano was used. It was fetched in cans, weighed and subsequently used for this study.

2.1.4 Laterite

The laterite used for this study was obtained from an established borrow pit behind Janguza barracks in Tofa Local Government of Kano State, Nigeria. It was sun-dried and stored in a water-proof sack in the laboratory to prevent it from absorbing any moisture from the environment. Specific gravity, grain size analysis, and Atterberg limits tests were conducted in accordance with BS EN 12620 (2002), BS EN 12620 [6], and BS 1377: Part 2 (1990).

2.1.5 Neem Seed Husk Ash (NSHA)

The neem seed husk used for the study was obtained as an industrial by-product from neem oil processing company situated in Katsina. It was dried and burned in an open area, after which it was calcined in an oven at temperature of 600 °C to produce the ash. The chemical composition of the Neem seed husk ash (NSHA) was determined using X-Ray Fluorescence (XRF) and conducted at the National Geosciences Research Laboratory, Kaduna.

2.2 Sample Preparation and Testing

A mix design of the NSHA laterized concrete was carried out using BRE Mix Design Method (Formerly DOE Method) and using a minimum water-cement ratio of 0.6. The proportions of the constituent materials for the laterized concrete mix without NSHA and 20 % NSHA laterized concrete are as presented in Table 1 and 2 respectively.

Table 1: Mix composition of Laterised Concrete without NSHA

Mix No:	Laterite (%)	Cement (kg/m³)	Fine Agg. (kg/m³)	Coarse Agg. (kg/m³)	Water (kg/m³)	Laterite (kg/m³)
CST-00	0	350	700	1140	210	0
CST-10	10	350	630	1140	210	70
CST-20	20	350	560	1140	210	140
CST-30	30	350	490	1140	210	210
CST-40	40	350	420	1140	210	280

Table 2: Mix composition of Laterised Concrete with NSHA at 20 % optimum Laterite content

Mix No:	NSHA (%)	Cement (kg/m³)	NSHA (kg/m³)	Coarse Agg. (kg/m³)	Water (kg/m³)	Fine Agg. (kg/m³)	Laterite (kg/m³)
CST-02	2	350	7	1140	210	560	140
CST-04	4	350	14	1140	210	560	140
CST-06	6	350	21	1140	210	560	140
CST-08	8	350	28	1140	210	560	140
CST-10	10	350	35	1140	210	560	140

The consistency and the setting time tests for the NSHA paste were performed in accordance with BS EN 196-3 [8] using Vicat apparatus 0 %, 2 %, 4 %, 6 %, 8 %, 10 % NSHA addition to cement. This was done to determine the amount of water needed to prepare a hydraulic cement paste for testing and also to determine the initial and final setting times of cement paste and cement – neem seed husk ash paste. The batching and mixing of the paste is as shown in plate 1.

Plate 1: Batching and mixing of concrete

A total of 240 number cylinders were cast for both compressive and splitting tensile tests with 12 number each for the controls and 48 number each for the sand to laterite replacement and 60 numbers each for the addition of neem seed husk ash (NSHA) at optimum laterite content of 20 % respectively. The specimens were immersed in water tank (as in plate 2 and 3) for curing at an age interval of 7,14 28 and 56 days respectively.

Plate 2: Curing of concrete specimens

Plate 3: Specimens ready for testing

2.2.1 Compressive Strength Test

The compressive strength of laterised concrete using NSHA as an admixture was evaluated by crushing concrete samples made with cylinder moulds of (100 mm diameter and 200 mm long), on a universal testing machine of 2000 kN (Avery Denison Compression Testing Machine) after curing for 7, 14, 28 and 56 days. The cylinder specimens were vertically placed with their centres perfectly positioned against the platens of the testing machine. A total of 120 number concrete cylinders were cast, 12 of which were used as control specimens and 48 were the ones with laterite replacing sand at 10 %, 20 %, 30 % and 40 %; while 60 were the ones in which NSHA was added to cement at 0 %, 2 %, 4 %, 6 %, 8 %, and 10 % at optimum result of sand to laterite replacement. The compressive strength test was carried out based on BS EN 12390-3 [9] and computed using Equation (1).

$$\mathrm{Fcu} = \mathrm{P}/\mathrm{A} \qquad (1)$$

Where Fcu is the compressive strength (N/mm^2), P is the crushing load (N), and A is the section area of the cylinder (mm^2).

2.2.2 Splitting Tensile Test

This test was conducted by crushing concrete cylinder at 7, 14, 28 and 56 days using universal tensile crushing machine. The specimen was placed horizontally with drawn diametrical lines perfectly centered with platens of the testing machine. It was carried out on specimens made with sand to laterite replacement at 10 %, 20 %, 30 % and 40 %; and also, addition of 0 %, 2 %, 4 %, 6

%, 8 % and 10 % of 75 µm fineness of NSHA to cement based on BS EN 12390-6 [10]. The controls were equally 12 number with laterite and NSHA content 48 and 60 number respectively. Equation (2) was used to compute the splitting tensile strength.

$$ft = \frac{2P}{\pi DL} \tag{2}$$

Where ft is the splitting tensile strength (N/mm^2), P is the applied load (N), while L is the length of specimen cylinder (mm), and D is diameter of the cylinder.

3. Results and Discussion

3.1 Physical Properties of Materials for Concrete

The specific gravity of sand, granite and laterite as shown in Table 3 are 2.63, 2.72 and 2.66 respectively, which is within the limit for natural aggregates with value of specific gravity between 2.6 and 2.7 as reported in [11].

Table 3: Physical properties of materials for concrete

Materials	Specific Gravity	Water absorption (%)	Fineness Modulus
Cement	3.15	-	-
Fine Aggregate	2.63	7.3	2.88
Coarse Aggregate	2.72	3.05	7.1
Laterite	2.66	18.1	-
NSHA	1.97	-	-

Meanwhile, the specific gravity of NSHA is 1.97 and is less than that of the cement used which is 3.15.

3.2 Sieve Analysis of Sand and Granite

The sieve analysis of sand and granite as presented in Figure 1 showed that the fine aggregate falls in zone 2. As specified by BS EN 12620 [6], this grading is suitable for making concrete for construction and experimental work since the fine aggregate has more medium and coarse sand than finer sand, and hence will produce a well graded structural concrete.

3.3 Atterberg limits for lateritic soil

The liquid limit, the plastic limit, plasticity index and linear shrinkage for the lateritic soil are 36 %, 20 %, 16 % and 6 % respectively shown in Table 3.

Table 3: Atterberg Limits for Lateritic Soil

TESTS SUMMARY	
LIQUID LIMIT (%)	36
PLASTIC LIMIT (%)	20
PLASTICITY INDEX (%)	16
Average Linear Shrinkage (%)	6
Soil Classification	CL

Table 3 shows that the laterite is a well graded sand with clay and gravel which was classified using Unified Soil Classification System (USCS) and the soil is termed soil of low to medium (CL-ML) plasticity as the liquid limit is (36), which falls between 35 and 50. The quantity of fines in the laterite was found to be 11.92 % which is relatively low, thus the soil can be used for general engineering purposes and highway construction since the liquid limit is between the range of 35-40.

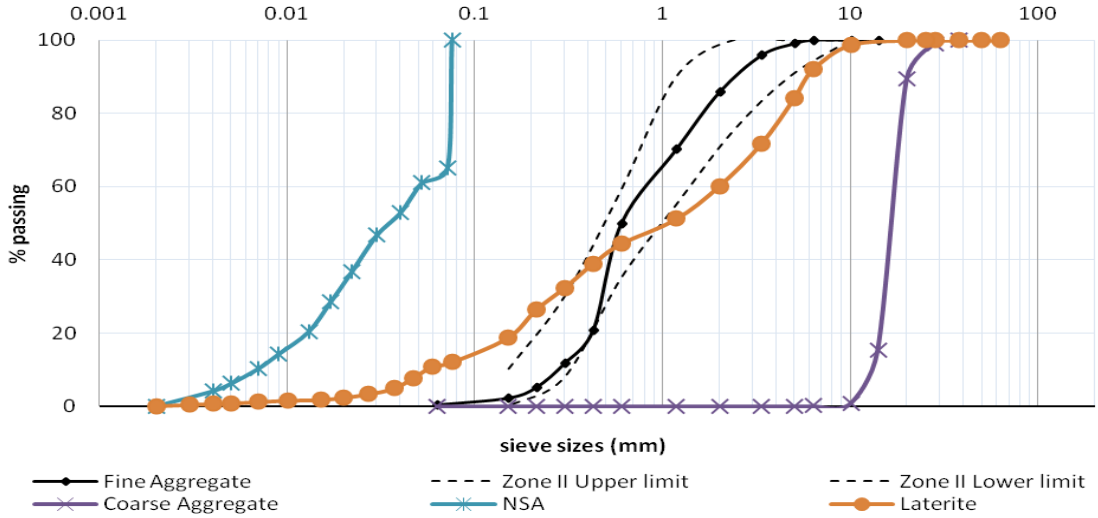

Figure 1. Particle Size Distribution of Fine Aggregate, Granite, Laterite and NSHA

3.4 Oxide Composition of Neem Seed Husk Ash and Cement

The result of chemical composition of Neem Seed Husk Ash as presented in Table 4 shows that the silica content (SiO_2) is 36.502 % composition and CaO is 26.416 % composition. The silica helps for the formation of di-calcium and tri-calcium silicates which impacts strength to the overall concrete. Excess silica and limestone in the mix increase the strength of the NSHA concrete as well as the setting time of the NSHA paste. The lime (CaO), is one of the most important ingredients of cement, it also plays a vital role toward enhancing the strength of concrete, invariably its presence in the Neem Seed Husk Ash (NSHA), increases the overall strength of the concrete as it combines with cement and form a homogeneous mixture suitable for concrete.

Table 4: Chemical Composition of Neem Seed Husk Ash and Cement

Oxide (%)	**Neem seed husk ash**	**Cement (%)**
SiO_2	36.502	14.89
Al_2O_3	4.111	4.7
Fe_2O_3	7.638	4.1
CaO	26.416	68.3
MgO	1.722	1.69
SO_3	1.061	3.67
Na_2O	0.171	0.71
K_2O	10.291	0.1
P_2O_5	4.001	-
Cl	1.221	-
TiO_2	0.392	0.22
Cr_2O_3	ND	0.01
Mn_2O_3	0.152	0.037
ZnO	0.101	-
BaO	-	0.15
SrO	0.003	-
LOI	6.213	1.4

3.5 Consistency and Setting Time of NSHA-Cement Paste

From Figure 2 and Figure 3, it can be deduced that the consistency of cement increases from 31.5 to 37, and both the initial and final setting times also increase from 110 to 153 and 165 to 245 with the addition of NSHA from 0 % to 10 %, respectively. Owing to these results, it can be concluded that NSHA acts as a retarder by slowing down the setting rate of cement paste. Retardation occurs due to the presence of C_3A because once some of it has reacted with gypsum, it does not adsorb the mixture, so more of it is left to retard the hydration of the calcium silicates, which occurs through absorption onto the calcium hydroxide nuclei [11].

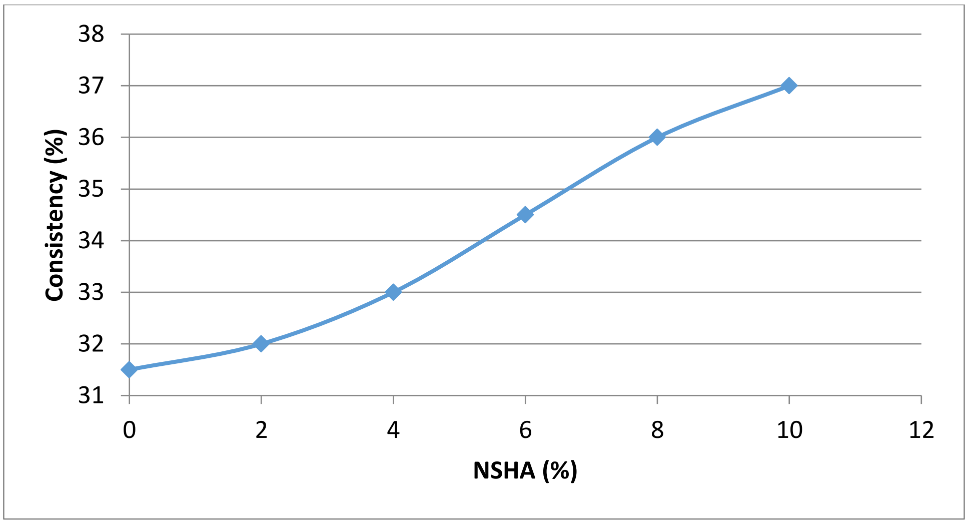

Figure 2: Consistency of NSHA-Cement Paste

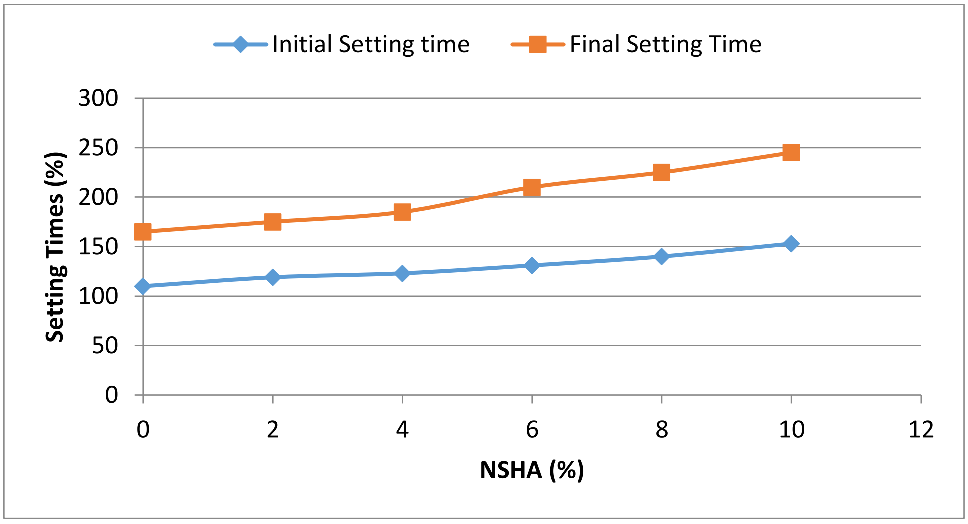

Figure 3: Initial and final setting time of NSHA-Cement Paste

3.6 Workability of Laterized Concrete and Laterized Concrete with NSHA at optimum laterite content of 20 %.

Figure 4 shows that the slump decreases with increase in laterite content, with the highest laterite content being 40% and the lowest slump being 40 mm. It can be inferred from the values that the lower the sand to laterite replacement, the higher the slump, and the higher the replacement, the lower the slump, because the laterite content tends to absorb water more than naturally fine aggregate.

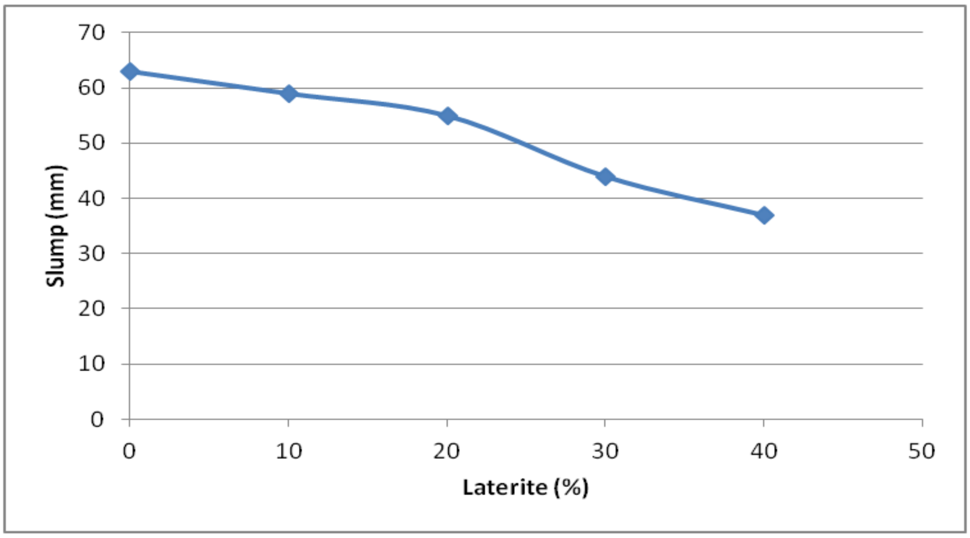

Figure 4: Slump of Laterized Concrete

3.7 Slump of Laterized Concrete with NSHA at Optimum Laterite Content (20 %)

The workability of laterized concrete with NSHA shown in Figure 5, shows that there is fall in slump from 55 mm to 37 mm as the addition of NSHA increases from 2 % to 10 % respectively. The decrease in slump is as a result of increase in the stiffness of the concrete as the percentage addition of NSHA increased as reported by [12]. This means that more water content is required to produce more workable concrete as the percentage addition of NSHA increases due to increase in silica concentration in the mix as NSHA increases. From the results obtained the water-cement ratio of 0.6 used is sufficient to produce laterized concrete at optimum laterite content of 20 % with addition of NSHA ranging from 2% to 10% respectively.

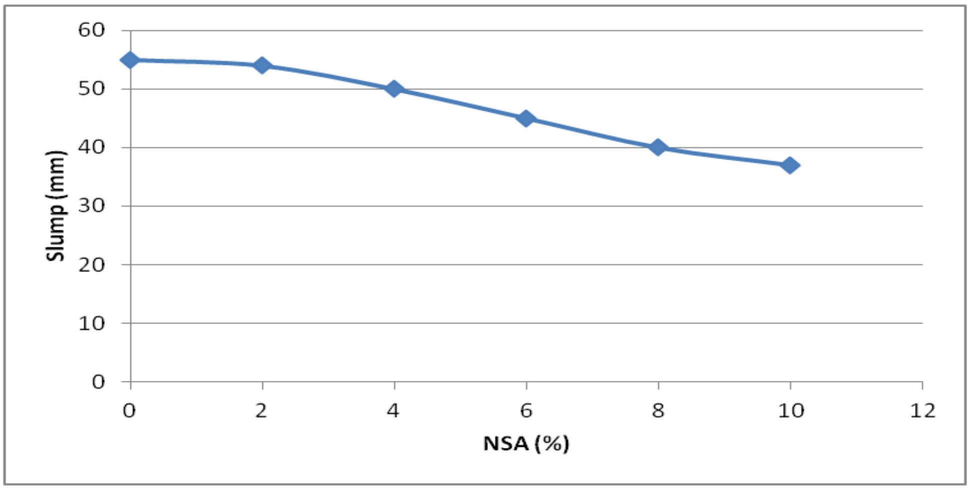

Figure 5: Slump of NSHA-Concrete at optimum laterite content of 20 %

3.8 Compressive Strength and Splitting Tensile Strength of Laterized Concrete

The compressive strength of the laterized concrete was determined to be 17.82 N/mm^2, 21.98 N/mm^2, 26.30 N/mm^2 and 29.40 N/mm^2 at 0 % replacement of fine aggregate with laterite at interval of 7 days, 14 days, 28 days and 56 days respectively. And these fall within the range of 20 N/mm^2 to 40 N/mm^2 for normal concrete as shown in Figure 6. From Figure 6, the laterized concrete's compressive strength improves as the age of curing increases. The compressive strength increases with an increase in the percentage of laterite replacing the fine aggregate (sand), but declines at 30 % and 40 % replacement. When compared to the control at 28 days, the optimal laterite content produced a strength of 26.30 N/mm^2 at 28 days of curing age. The decrease in compressive strength onward was due to higher laterite content resulting from more grain size range, because the fewer the grain size, the higher the compressive strength, which is in line with the opinion of [13], who opined that for optimum performance of laterised concrete as structural members of a building, the content of laterite replacement in the concrete should not exceed about 25 % (one-quarter of sand) in a standard mix.

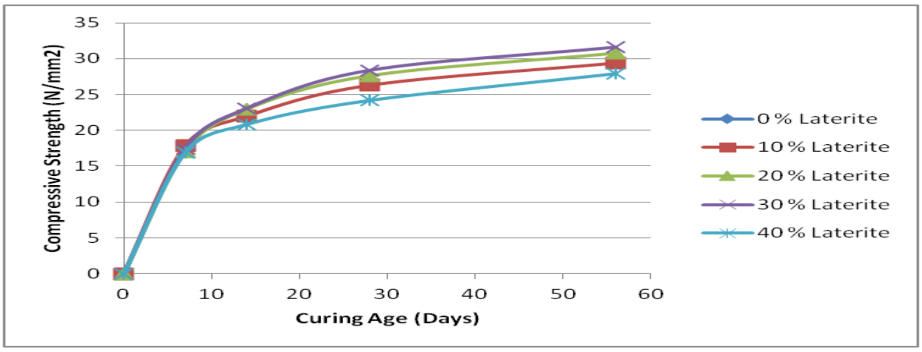

Figure 6: Compressive Strength of Laterized Concrete with curing age in days.

Similarly, the splitting tensile strength increased with an increase in curing age and lower content of laterite as presented in Figure 7. A lower value of 1.65 N/mm^2 was achieved at a 40 % laterite content, and it was also noted that the strength of the control at 28 days is 1.81 N/mm^2, and that of the 20 % replacement of fine aggregate (sand) to laterite is 2.13 N/mm^2. Furthermore, it was inferred that there is a smooth correlation between the compressive strength and splitting tensile strength of laterized concrete, as a rise in compressive strength corresponds to a rise in splitting tensile strength, which was at its highest at a level of 20 % fine aggregate replacement by laterite.

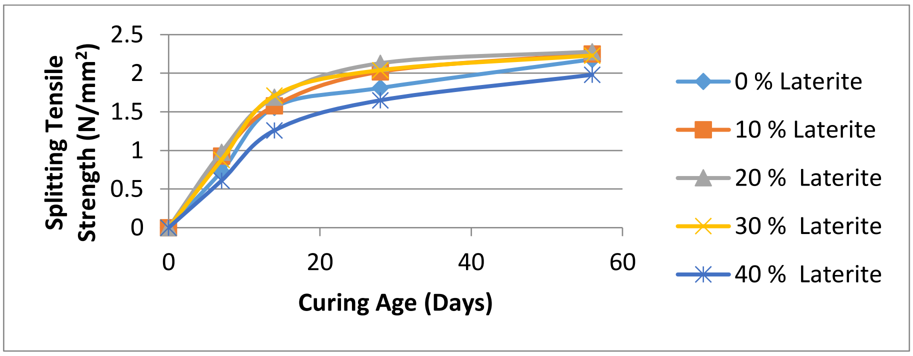

Figure 7: Splitting Tensile Strength of Laterized Concrete with curing age.

3.9 Compressive Strength and Splitting Tensile Strength of NSHA-Concrete at Optimum Laterite Content (20 %)

The compressive strength and splitting tensile strength of NSHA-Concrete as shown in Figure 8 and 9 increases with increase in days of curing and equally increase in percentage addition of NSHA at optimum laterite content of 20 %. The increase in addition of NSHA increases the compressive strength from 28.68 N/mm² at 2 % addition to a maximum of 29.10 N/mm² at 4 % addition of NSHA compared to the control of 26.30 N/mm² at 28 days strength. The compressive strength decreases with further NSHA addition and this is due to increase in stiffness of the NSHA-Concrete and ultimately water absorption of concrete [12]. This behaviour could be equally due to an increase in calcium oxide (CaO), in the mix as the percentage addition of NSHA increases at optimum laterite content of 20 % respectively.

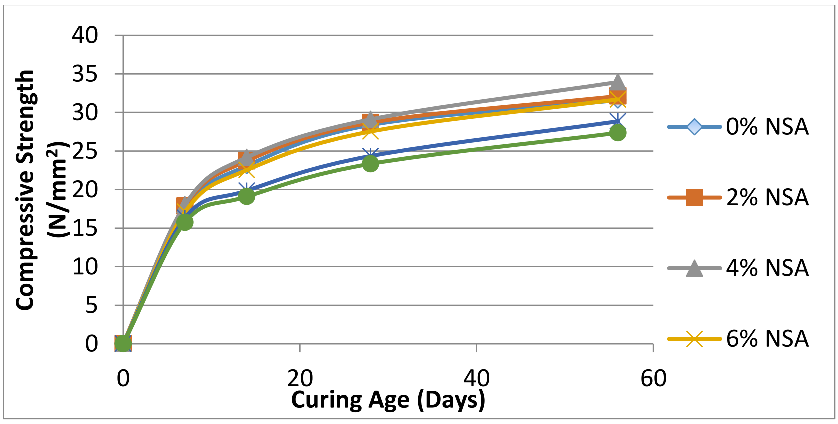

Figure 8: Compressive Strength of NSHA-Concrete with curing age at optimum Laterite Content of 20 %

The splitting tensile strength followed same trend as the compressive strength. Compared to the control of 2.13 N/mm² and 2.28 N/mm², it attained maximum value of 2.23 N/mm² and 2.46 N/mm² for 28 days and 56 days strength at 4 % addition of NSHA .Whereas, the splitting tensile strength decreased to lower values of 1.43 N/mm² and 1.64 N/mm² at 28 days and 56 days strength, at a maximum addition of 10 % NSHA.

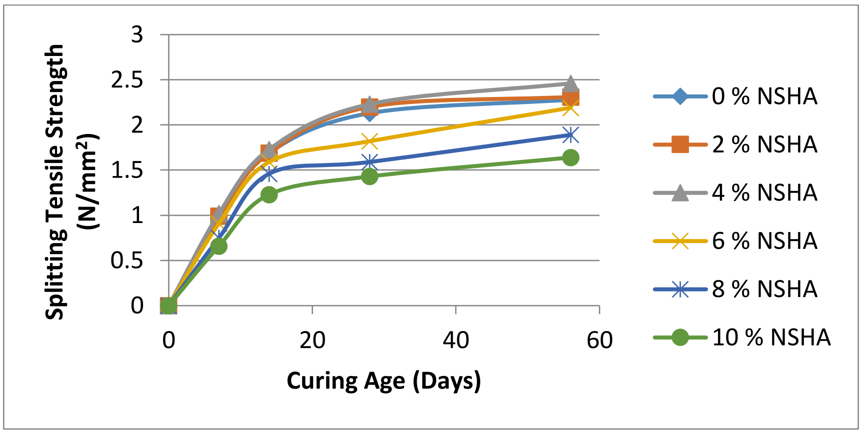

Figure 9: Splitting Tensile Strength of NSHA-Concrete with curing age at optimum Laterite Content of 20 %

4. Conclusion

The replacement of fine aggregate with laterite and addition of NSHA increased the compressive and splitting tensile strength of the concrete, as well as the consistency of the cement paste, while the workability of laterized concrete decrease with increase in NSHA content from 2 % to 10 % respectively. Furthermore, the strength of the laterized concrete increased with increase in the addition of NSHA up till 4 % and decrease in replacement of fine aggregate with laterite, resulting in compressive strengths of 29.10 N/mm^2 and 33.94 N/mm^2 at 28 days and 56 days, respectively, which are above 25 N/mm^2 and fall between the numerical values of 20 – 40 N/mm$_2$, while the splitting tensile strengths of 2.23 N/mm^2 and 2.46 N/mm^2 were obtained at 28 days and 56 days curing ages respectively.

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