International Journal of Sustainable Construction Engineering & Technology (ISSN: 2180-3242)
Vol 9, No 2, 2018

A Study of Neem Seed Husk Ash as Partial Replacement for Cement in Concrete

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Received 23 February 2017; Revised 3 November 2018; Accepted 31 December 2018

DOI: https://10.30880/ijscet.2018.09.02.006

Abstract

The production of neem products from neem tree generates large quantity of waste annually. There is need to reduce environmental pollution resulting from neem seed covering. Therefore, the use of Neem Seed Husk Ash (NSHA) as partial substitution for cement in concrete was investigated. Neem seed husk was obtained from Bishop Smith Memorial College, Ilorin, Nigeria; sun – dried for 3 days and then calcined at 650^{o} C. The calcined neem seed husk was ground and sieved using 200 µm sieve to obtain NSHA. Pozzolanicity test was conducted on NSHA to determine its chemical composition. Concrete was produced with 5, 10, 15, 20 and 25% by weight of NSHA substitution for ordinary Portland cement. Workability tests (slump and compacting factor) were performed on fresh concrete while compressive strength test was conducted on 150 mm cubes at ages 3, 7, 14, 21, 28, 56, 90 and 180 days for the hardened concrete. NSHA mainly comprises Al_2O_3, SiO_2 and Fe_2O_3 with a combined percentage of 75.35%. The slump and compacting factors of NSHA concrete ranged from 5.50 mm to 10.00 mm and 0.91 to 0.95, respectively. The compressive strength at 180 days decreased from 26.9 N/mm^2 to 19.4 N/mm^2 as the NSHA content increased from 5% to 25%. Only 5% NSHA substitution is adequate to enjoy maximum benefit of strength gain.

Keywords: *Neem Seed Husk Ash, Slump, Compacting factor, Compressive Strength*

1.0 Introduction

The present society has shown increasing interest in the use of new materials in place of traditional products. The use of locally sourced materials, such as palm kernel shell for aggregates [21]; lateritic interlocking block in place of sandcrete block [22] and fan palm as reinforcement [5] were considered as possible alternatives. However, the non acceptability of these materials by the end users [20] poses another problem. Hence, the need to focus on cement which is one the most widely used construction materials.

The search for alternative binders or cement replacement materials has continued in the last three decades. From the economical, technological and ecological points of view, cement replacement materials play an undisputed role in the construction industry. Small amounts of inert fillers have always been acceptable as cement replacement. If the fillers have pozzolanic properties, they impart not only technical advantages to the resulting concrete but also enable larger quantities of cement replacement to be achieved [1].

In the quest for alternative binder or cement replacement material, ashes from agricultural residues generally regarded as waste and found to possess pozzolanic properties have been used to replace cement. Some of these wastes are; rice husk ash [11, 14, 18, 21, 25]; corn cob ash [1, 2, 3]; oil palm residue ash [19]; saw dust ash [15, 28]; groundnut husk Ash [12] and bagasse ash [26]. Their uses are receiving more attentions since they result in enhanced properties of the blended cement concrete. However, there is paucity of literature on the use of neem seed husk.

Neem seed comes from Neem tree (*Azadirachta indica*). Neem seed husk is a by-product obtained during industrial processing of neem seed to extract oil and produce fertilizer [29]. In producing neem based fertilizer, extraction of neem oil is done first, and the resultant cake (which consists of ground seed and husk) is used in making organic based fertilizer. Little quantity of neem seed husk is crushed and ground into fertilizer formulation while the remaining large quantity usually lay as waste. This study investigates the use of Neem Seed Husk Ash (NSHA) as partial replacement for cement in concrete.

2.0 Materials

The neem seed husk used was obtained from Bishop Smith Memorial College, Ilorin, Nigeria. The ordinary Portland cement, fine and coarse aggregates (sand and granite) used were also sourced locally. The neem seed husk was sun – dried for 3 days and then calcined at 650^{o} C. The calcinated neem seed husk was ground and sieved using 200 μm sieve to obtain Neem Seed Husk Ash (NSHA). Figure 1 shows the Neem Pod, Seed and Husk.

3.0 Methodology

The pozzolanicity test on NSHA was carried out to determine the presence and percentage composition of chemical compounds such as SiO_2, Al_2O_3, Fe_2O_3, SO_3, MgO and CaO using X-ray flourescence spectometer (Model QX 1279).

The grading of NSHA and aggregates (fine and coarse) were done in accordance with the procedure in BS 1377 (1990)[10].

Mix ratio of 1:2:4 (cement and NSHA: sand: granite), with water/binder ratio of 0.70 was used in the production of concrete. The cement replacement with NSHA was at 5%, 10%, 15%, 20% and 25% by weight of cement. Concrete without NSHA serves as the control. Batching of the concrete was by weight. The mixing was done manually.

Slump and compacting factor tests were carried out to check the effect of NSHA on the workability of fresh concrete. The tests were carried out in accordance with the requirements of BS 1881: Part 102 (1983) [8] for slump test and BS 1881: Part 103 (1983) [9] for compacting factor test.

For compressive strength measurement, 150mm cube concrete specimens were produced. The specimens were cast in three layers, each layer being tamped with 35 strokes of the tamping rod spread uniformly over the cross section of the mould. The top of each mould was smoothened and leveled and the outside surfaces cleaned. The moulds and their contents were kept in the curing room at temperature of 27 $\pm$ 5^{0}C and relative humidity not less than 90% for 24hours. All specimens were demoulded after 24hours and cured in water at 27 $\pm$ 5^{0}C. The compressive strength of the cubic specimens were determined at curing ages 3, 7, 14, 21, 28, 56, 90 and 180 days; using compression machine with maximum capacity of 1500 *kN* (Model 50- C34AC and Serial no 02094910). The strength value was the average of three specimens.

(a) Neem Pod

(b) Neem Seed

(c) Neem Husk

Figure 1: Neem Pod, Seed and Husk

4.0 Results and Discussion

The results of the various tests performed are discussed in the subsequent sections.

4.1 Pozzolanicity

Table 1 showed the chemical composition of Neem Seed Husk Ash (NSHA). The chemical constituents include Alumina (Al_2O_3), Silica (SiO_2) and Ferric Oxide (Fe_2O_3) amongst others. The major chemical compound in NSHA is silica (SiO_2) with an average value of 69.14 %. It has a combined percentage of SiO_2, Al_2O_3 and Fe_2O_3 of 75.34%. Thus, the requirement of ASTM C 618 (2001) [4] for a combined $SiO_2 + Al_2O_3 + Fe_2O_3$ of more than 70% was satisfied. Hence, NSHA is a suitable material for use as a pozzolan.

4.2 Grading of NSHA and Aggregates

The grading curves for NSHA and aggregates (fine and coarse) are shown in Figures 2 and 3, respectively. It could be observed from Figure 2 that the NSHA curve falls within the sand zone of the particle size distribution curve stretching from the fine to the coarse division. The material falls within zone 2 of the grading curve according to [13].

For the aggregates, it could be observed from Figure 3 that the coefficient of uniformity (C_u) and coefficient of curvature (C_c) for the fine aggregate are 8.0 and 1.53, respectively. Thus, the sand can be said to be well graded according to [27]. Similarly, the C_u and C_c for the coarse aggregate as obtained from Figure 2 are 3.37 and 1.92, respectively. Hence, the granite is uniformly graded.

4.3 Workability

The results of the slump and compacting factor of NSHA cement concrete shown in Table 2. It could be observed from the table that as the percentage of NSHA increased from 0 to 25%, the slump decreased from 10 to 5.5 mm. Similarly, the compacting factor decreased from 0.96 for the control to 0.93 for 25% NSHA replacement. This decrease is as a result of increase in the stiffness of the concrete as the percentage of NSHA substitution increased. This implies that more water is required to make the concrete workable as the percentage NSHA substitution increases. This finding is in line with that of [2]. The high demand for water is due to the high silica concentration in NSHA. Nevertheless, water-binder ratio of 0.70 was adequate to produce workable mix with true slump for all percentages of NSHA considered.

Table 1: Chemical Composition of Neem Seed Husk Ash (NSHA)

Constituents	Sample 1	Sample 2	Sample 3	Average
SiO_2	69.14	69.13	69.16	69.14
Al_2O_3	2.94	2.96	2.94	2.95
Fe_2O_3	3.25	3.24	3.27	3.25
CaO	2.75	2.77	2.76	2.76
MgO	0.54	0.56	0.55	0.55
SO_3	0.42	0.43	0.41	0.42
Na_2O	0.15	0.14	0.17	0.15
K_2O	15.01	15.02	15.04	15.02
TiO_2	0.24	0.26	0.24	0.25
P_2O_5	1.01	1.01	1.01	1.01
Mn_2O_3	0.04	0.04	0.05	0.04
$SiO_2 + Al_2O_3 + Fe_2O_3$	75.33	75.33	75.37	75.34

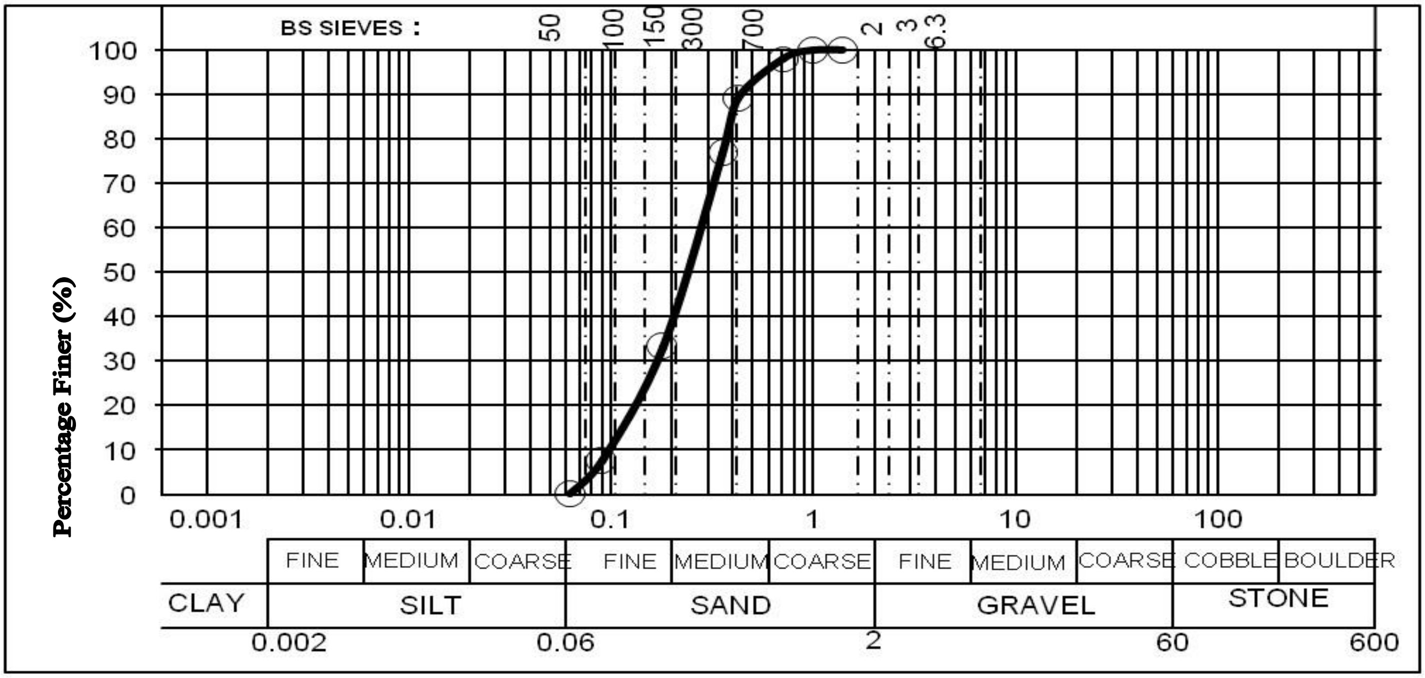

Figure 2: Grading Curve of NSHA

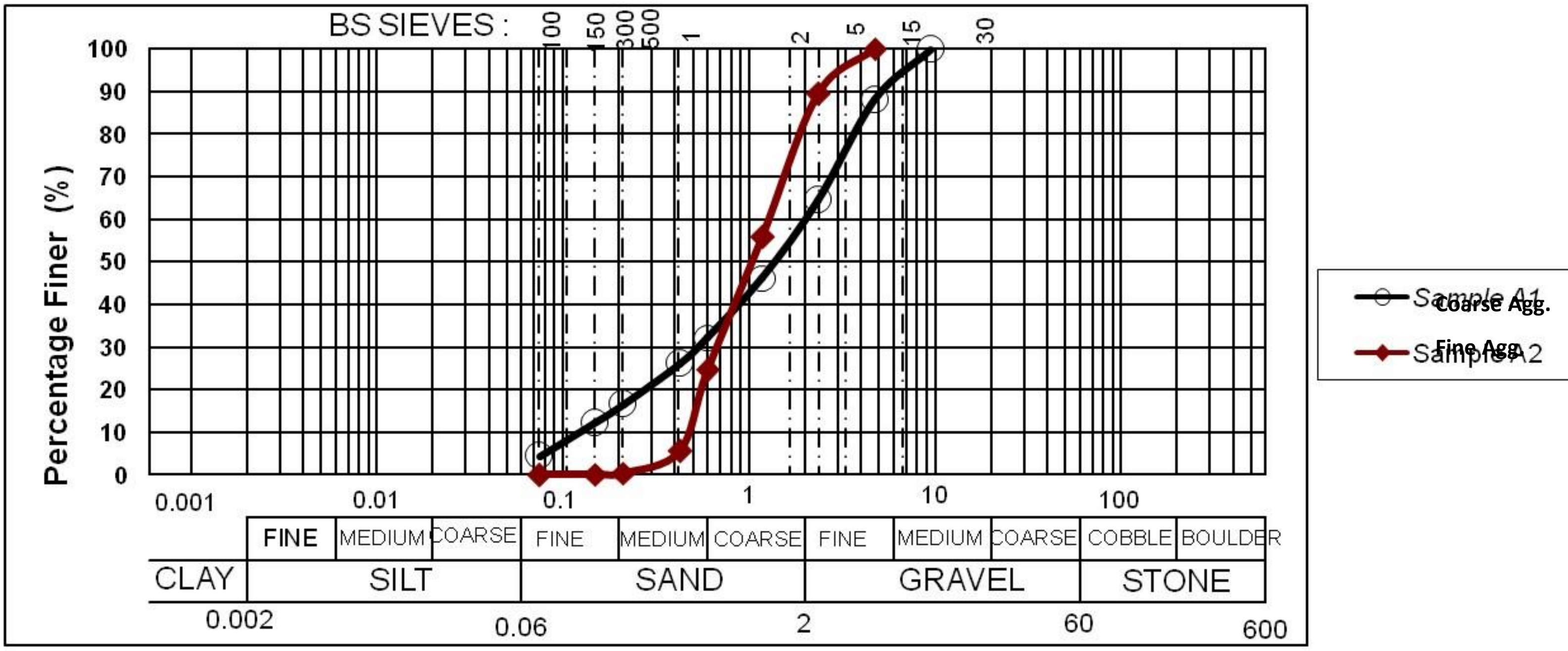

Figure 3: Grading Curves of Fine and Coarse Aggregate

Table 2: Slump and Compacting Factor of NSHA Cement Concrete

NSHA (%)	Slump (mm)	Compacting Factor
0	10.0	0.96
5	9.82	0.95
10	9.40	0.92
15	8.20	0.91
20	6.20	0.91
25	5.50	0.93

4.4 Compressive Strength

The effect of curing ages on the compressive strength of NSHA concrete is presented in Figure 4. The figure indicated that compressive strength generally increased with increase in curing age and decreased as the percentage content of NSHA increases.

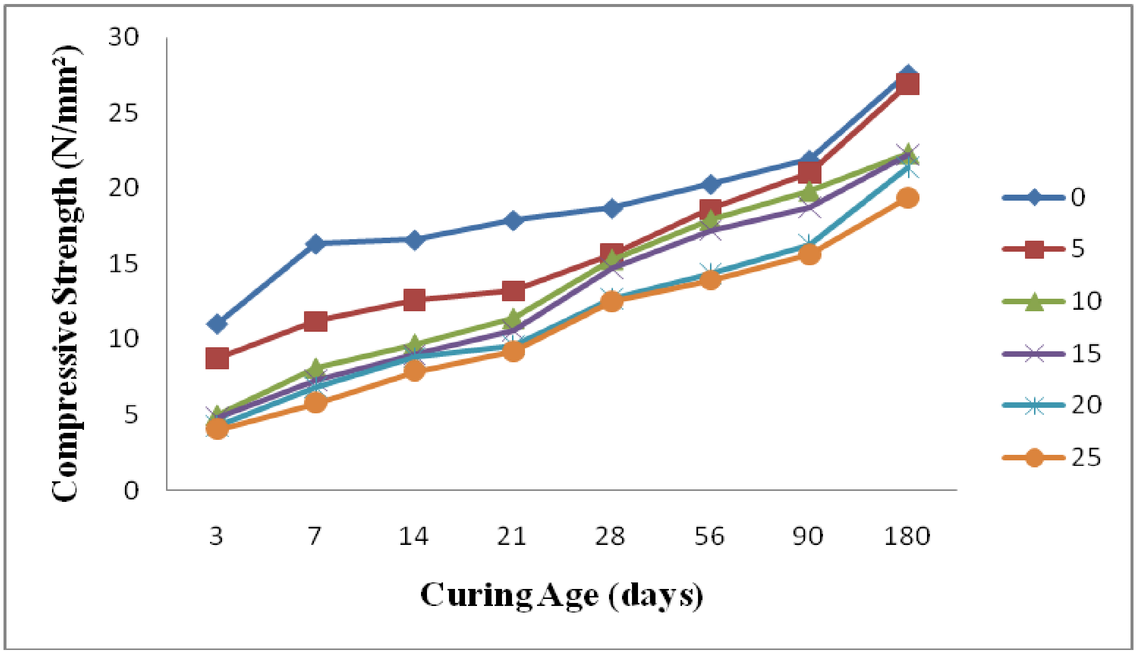

Figure 4: Effect of NSHA on Compressive Strength of Concrete

The result at 3 days indicated that the control had a compressive strength of 11.05 N/mm^2 while NSHA concrete witnessed a decrease in strength from 8.72 to 4.01 N/mm^2 for 5% to 25% NSHA replacement, respectively. Similar trends were observed at 7 and 14 days as shown in Figure 2. These results indicated that concrete containing NSHA gain strength slowly at early curing age. This is in line with previous findings that concrete containing pozzolanic materials gained strength slowly at early curing ages [2, 6, 16].

At 28 Days, there was continuous increase in compressive strength for all the classes of concrete with values raging from 18.7 N/mm^2 for the control, to 12.5 N/mm^2 for 25% NSHA replacement. The control still has the highest compressive strength at this age.

The result at 56 days showed that there is higher percentage increase in compressive strength by NSHA concrete over that of the control. This is an indication that pozzolanic activity had commenced. The percentage increase with respect to the 28 day strength for control was 8.6%, while it was 19.2%, 17.0%, 16.2%, 13.3% and 12.9% for 5%, 10%, 15%, 20% and 25% NSHA replacements, respectively. This increase in compressive strength can be attributed to the reaction of NSHA with calcium hydroxide liberated during the hydration of cement.

At 90 days, there was significant improvement in strength development beyond 56 days as shown in Figure 2. The percentage increase in strength from 28 to 90 days was between 24.8% and 34.0%. Higher percentage increases in strength than at 56 days were observed confirming the continuous pozzolanic reaction in the NSHA concrete. The general increase in strength of the concrete specimens was attributed to the cement that continues to hydrate as curing age increases. However, the significant increase in strength of NSHA concrete is due to the pozzolanic reaction of NSHA. The strength gain can be attributed to the cementing products formed as a result of hydration of cement and those formed when lime reacts with the pozzolan incorporated [1, 6, 17].

The result at 180 days showed that the strength development of NSHA cement concrete continued to be higher than that of the control indicating the long-term strength development of concrete incorporating pozzolan. The 5% NSHA replacement had a compressive strength of 26.9 N/mm^2 which is very close (97%) to that of the control (27.6 N/mm^2). This is an indication that with further curing, the compressive strength of the control is likely to be surpassed. Also, it is only the 5% NSHA replacement that has closer value to the control. Thus, it could be concluded that only 5% NSHA substitution is adequate to enjoy maximum benefit of strength gain. However, since all the specimens meet the minimum compressive strength of 6 N/mm^2 after 28 days of curing recommended by [7] for masonry cement, NSHA cement concrete could be used for general concrete works where strength is of less importance such as in mass concrete, floor screed, partition walls and mortar.

The influence of percentage NSHA replacement and curing age on the Compressive strength was statistically analyzed using Analysis of Variance (ANOVA). The analysis was aimed at determining which of the factors considered have significant effect on the Compressive strength of NSHA concrete. The result as shown in Table 3 indicated that both factors had significant effects on the measured compressive strength. The coefficient of determination (R^2) obtained from the analysis was 0.98 (98%) for the Compressive strength. This implies that there is a strong statistical relationship between the independent variables (% NSHA replacement and curing age) and the dependent variables (Compressive strength). The independent variables were estimated to account for 98% of variance in the Compressive strength of NSHA concrete at 5% confidence level. Thus, as the curing age increased, the compressive strength increases. Conversely, as the percentage replacement of NSHA increased, the compressive strength decreases.

Table 3: Univariate Analysis of Variance for Compressive strength

Source	**Type III Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Corrected Model	1632.814[a]	12	136.068	144.476	.0002
Intercept	9482.909	1	9482.909	10068.880	.0001
NSHA %	333.350	5	66.670	70.790	.0001
Curing Days	1299.464	7	185.638	197.109	.0002
Error	32.963	35	.942		
Total	11148.686	48			
Corrected Total	1665.777	47			

R^2 = 0.980 (Adjusted R^2 = .973)

5.0 Conclusion

From the results of various tests performed, it could be concluded that:

(i) NSHA is a suitable material for use as a pozzolan, since it satisfied the requirement for such by having a combined (SiO_2 +Al_2O_3 +Fe_2O_3) of more than 70%.
(ii) The compressive strength of NSHA cement concrete generally increases with curing period and decreases with increased amount of NSHA content.
(iii) Only 5% NSHA substitution is adequate to enjoy maximum benefit of strength gain.

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