



## PERFORMANCE OF CONCRETE CONTAINING NEEM SEED HUSK ASH (NSHA) IN AGGRESSIVE ENVIRONMENT

NURUDDEEN MUHAMMAD MUSA

Civil Engineering Department, Kano University of Science and Technology, Wudil

### ARTICLE INFO

#### Keywords

Neem seed husk ash;  
Aggressive environment;  
acid resistance; weight  
loss; chloride penetration  
Correspondence author:

e-mail:

Phone:

### ABSTRACT

*Durability of concrete is its resistance to deteriorating media to which the concrete may be exposed during its service life. The understanding of the mechanisms of degradation of these materials in aggressive environment is an essential step toward the development of concrete that performs well and have increased service life. This research is aimed at assessing the performance of concrete containing cement partially replaced with 0%, 5%, 10%, 15%, 20% and 25% Neem Seed Husk Ash in aggressive environment by studying its behaviour when exposed to acidic environment and due to chloride penetration. Weight loss test shows that 5% replacement has the least weight loss, lower than the control (0% replacement), after that the weight loss increases with increase in ash replacement. Results also show that there is reduction in compressive strength when the specimens were immersed in acid. The strength reduces with increase in Neem seed husk ash replacement. Furthermore, the chloride penetration increases with increase in Neem seed husk ash replacement, with the 0% replacement having the lowest penetration and 25% replacement was having the highest penetration. Generally, specimens containing Neem seed husk ash shows a comparable performance with control specimens in aggressive environment.*

### INTRODUCTION

Concrete structures are from time to time exposed to aggressive aqueous environments by coming in contact with acidic effluents in industry and sewage in underground pipes. Failure of concrete structure due to such exposure is a wide spread phenomenon. It is also known that concrete is basically alkaline in nature and is susceptible to acidic gases in the atmosphere, especially in and around urban industrial centres (Verma et al., 2013). Therefore, the understanding of the mechanisms of degradation of cementitious matrices by these aggressive

media is an essential step toward the development of concrete that performs well in these environments and toward the increase of the service life or the safety of the structures and facilities. (Mark et.al, 2013). Basically, ordinary Portland cement concrete usually does not have good resistance and is vulnerable to acid attack because of its alkaline nature. The components of the cement paste breaks down during contact with acids. Acids attack concrete by dissolving both hydrated and unhydrated cement compounds as well as calcareous aggregate.

In most cases, the chemical reaction forms water-soluble calcium compounds, which are then leached away (Beddoe and Dorner, 2005). Some weak acids however can be tolerated, particularly if the exposure is occasional. Several concrete elements have been reported to be susceptible to the chemical attack. These elements include foundation (groundwater containing sulphuric acid due to oxidization of pyrite in backfill), industrial floors of chemical plants, basement walls of buildings near chemical plants and superstructures (due to acid rain) (Bassuoni and Nehdi, 2007; Mohamed, 2009).

Also, the influence of the environment and concrete characteristics on chloride transport into concrete has been studied by the scientific community for several years (Massazza, 1993). Concrete can be harmfully affected by chloride action due to leaching of the free calcium hydroxide which makes concrete porous and weak (Massazza, 1993). Chloride is believed to increase the risk of corrosion of the steel reinforcement. Actually the concrete itself generally provides the embedded steel with a high degree of protection against corrosion.

Neem seed husk ash (NSHA) is obtained by burning the waste husk obtained during the extraction of oil from neem seed. Neem seed itself is from Neem tree (*Azadirachta indica*) popularly known locally as Dogon yaro. Earlier researches (Ejeh et.al, 2014, Nuruddeen, 2013) shows that NSHA act as filler when incorporated in concrete and can improve its properties. The aim of this research is to assess the performance of concrete containing cement partially replaced with 0%, 5%, 10%, 15%, 20% and 25% NSHA in aggressive environment by studying its behaviour when exposed to acidic environment and due to chloride penetration.

## **MATERIALS AND METHODS**

### **MATERIALS**

#### **a. Cement**

Dangote Ordinary Portland cement was used in this study. The cement has a specific gravity of 3.14, with initial setting time of 155minutes and final setting time of 208 minutes.

#### **b. Aggregates**

River sand obtained locally in Zaria, Nigeria has been used as fine aggregate. The specific gravity of the fine aggregate was determined to be 2.55, while its particle size distribution was found to fall within the grading zone 2 of fine aggregates in accordance with BS 882:1992. Also, locally available crushed stone aggregate of maximum size 20 mm was used. The coarse aggregate has a specific gravity of 2.75.

#### **c. Neem Seed Husk Ash**

The Neem seed husk used was obtained from Neem fertiliser processing plant in Katsina, Nigeria. It was dried and burned in an open air, after which it was calcinated in an oven at temperature of 600°C to produce Neem seed husk ash.

#### **Mix Proportion**

In this study, concrete to achieve a target compressive strength of 25 N/mm<sup>2</sup> at 28 days was designed using the absolute volume mix design method. Binders were prepared by partially replacing cement with various percentages of Neem seed husk ash (NSHA). The percentages are 0%, 5%, 10%, 15%, 20% and 25% by weight, with 0% being the control specimen. For other percentages, cement and NSHA are thoroughly mixed in dry powdered form and in correct proportion. Therefore, for 5%, the cement is partially replaced with 5% NSHA etc. The binders were then mixed with the aggregates and water in accordance with the mix design proportion to form NSHA concrete.

### Experimental Work

To study the performance of concrete aggressive environment, the following tests were carried out.

1. Weight loss test
2. Compressive strength test
3. Chloride Penetration test

#### Weight loss test and compressive strength test

Weight loss test and compressive strength test were conducted on concrete containing cement partially replaced with are 0%, 5%, 10%, 15%, 20% and 25% NSHA using Concrete cube specimens of sizes 100 x 100 x 100 mm. These cubes were prepared and cured in water for 28 days, after which three cubes from each mixture were immersed in 1% hydrochloric acid solution and another three corresponding cubes were immersed in water, both for 1400 hours. In order to minimize evaporation, these specimens were kept covered throughout the testing period. The pH of the solution was controlled to 2 by checking using pH meter. The pH value of the solution was observed to be increasing with time due to decomposition of the concrete specimens in to the solution. After every 100 hours, the weights of the cubes were measured. And at the end of the 1400 hours, compressive strength test was conducted on all the cubes. The procedure adopted is similar to that used by Mohamed (2009).

Acid resistance was then evaluated by determining the weight loss (WL) and compressive strength loss (SL) of the specimens using this equation:

$$WL(\%) = \frac{w_1 - w_2}{w_1} \times 100 \quad \text{--- Eqn. (1)}$$

Where  $w_1$  and  $w_2$  are the weights of the specimens (in kilograms) before and after immersion

$$SL(\%) = \frac{f_{c1} - f_{c2}}{f_{c1}} \times 100 \quad \text{--- Eqn. (2)}$$

Where  $f_{c1}$  represents 1400 hours compressive strength of control specimens and  $f_{c2}$  is the compressive strength of the specimen after exposure to 1% hydrochloric acid (HCL) solution for 1400 hours.

#### Chloride Penetration test of NSHA concrete

Chloride penetration test was conducted on concrete containing cement partially replace with 0%, 5%, 10%, 15%, 20% and 25% NSHA. The objective of the test is to evaluate the performance of NSHA concrete in resisting the penetration of chloride ion. Three cylinders of 150 mm diameter and 300 mm length were cast for each replacement. The cylinders were cured in water for 28 days after which they were removed, dried and then immersed in 3% sodium chloride solution for additional period of 28 days. After the specified period of immersion, the specimens were removed to test for chloride penetration. The test was done by splitting the cylinder along their length. Then, the exposed cross section was sprayed with 0.2 N silver nitrate solutions. A change of white colour appeared due to the formation of silver chloride, while area not penetrated appeared as a brown precipitate due to reaction of hydroxide ions to form silver oxide. The readings were taken using vernier calliper on each cylinder along two side of a splitted specimen. Therefore, the average of three readings was taken on each side of the split cylinder. This method used is in accordance to the standard UNI 79287 (UNI 1978).

### RESULTS AND DISCUSSION

#### Weight loss

The behavior of concrete partially replaced with NSHA in hydrochloric acid was investigated. The weight of the specimens when immersed in 1% HCl acid for 1400 hours were determined and the result is shown in Table 1.

From visual examination, it was observed that the colour of concrete in the HCl solution became brownish. Also, after 1400 hours it was observed that aggregates in the concrete cubes were visible due to washing out of cement

paste. Initial pH measured was less than 2, pH increase to more than 3 as the immersion time increases due to decomposition of the concrete specimens in to the solution.

**Table 1: Results of Weights (kg) for Concrete cubes Immersed in HCl for 1400hrs. (0 – 1400hrs)**

Time (hrs)	NSHA Replacement (%)						Weights (kg)
	0%	5%	10%	15%	20%	25%	
0 (before immersion)	2590	2520	2620	2600	2550	2590	
24	2550	2510	2600	2600	2510	2500	
48	2520	2505	2590	2580	2500	2490	
72	2510	2505	2580	2570	2490	2470	
100	2500	2490	2570	2560	2490	2460	
200	2490	2480	2520	2510	2450	2450	
300	2480	2450	2510	2510	2420	2410	
400	2390	2360	2390	2410	2320	2290	
500	2325	2310	2380	2390	2290	2250	
600	2310	2300	2320	2380	2250	2200	
700	2300	2290	2310	2320	2240	2190	
800	2280	2280	2300	2310	2230	2180	
900	2250	2230	2280	2290	2200	2140	
1000	2200	2210	2220	2210	2200	2100	
1100	2190	2200	2210	2200	2100	2090	
1200	2190	2200	2210	2190	2100	2090	
1300	2190	2200	2210	2190	2100	2090	
1400	2190	2200	2210	2190	2100	2090	

Based on the result in Table 1 the rate of weight loss due to the immersion in acid is calculated using equation (1) and the result presented in Figure 1.

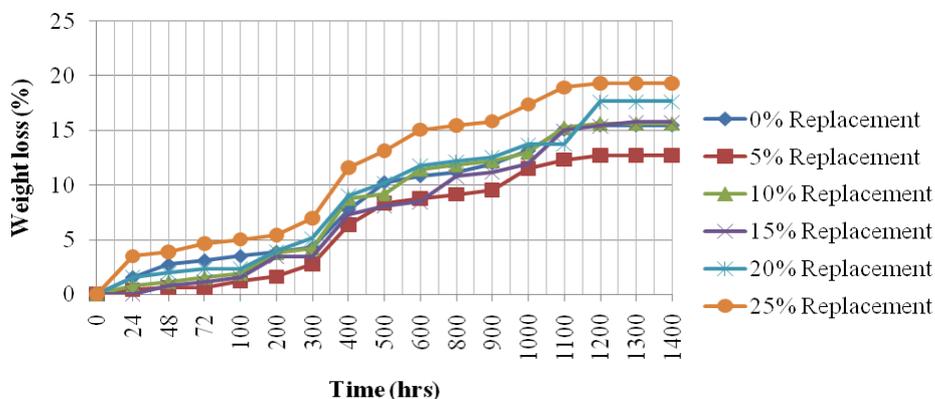


Fig. 1: Rate of weight loss of NSHA concrete immersed in HCl over time

It can be observed that the rate of weight loss follows the same pattern for all the replacements. The rate of weight loss from 1200 to 1400 hours remains constant, as no weight loss is observed. The constant weight indicates that the system has achieved equilibrium, whereby the solution has reached a saturation limit, hence dissolution of the cement matrix ceased to occur.

Generally, it can be observed that 5% replacement shows the least weight loss (12.7%), better than the 0% replacement (15.4%), thus, 5% replacement shows greater potential to resist deterioration than the control specimen, and is the optimum replacement level. After that the weight loss increases with increase in

**Compressive strength**

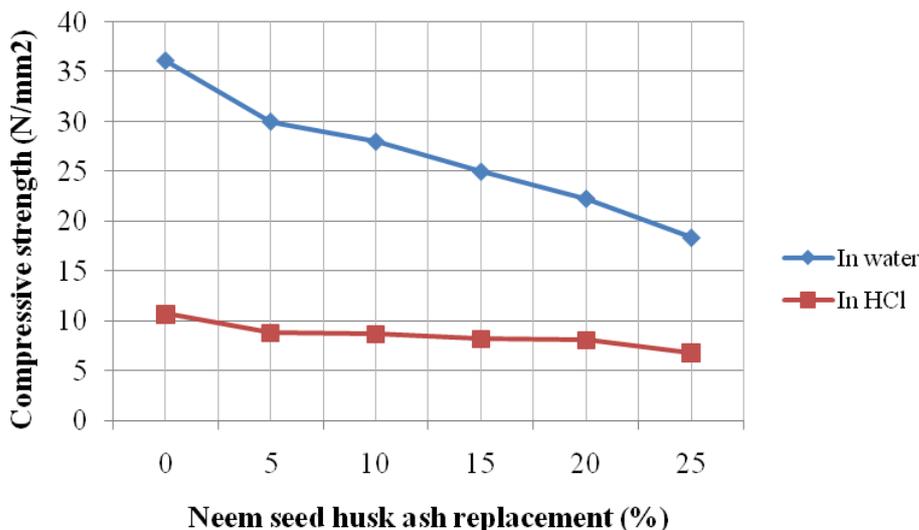
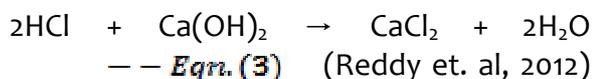


Fig. 2: NSHA Concrete compressive strength at 1400 hrs in water and in 1% HCl.

Figure 2 shows the result of the compressive strength of concrete containing cement partially replaced with NSHA at 1400 hrs in water and in 1% HCl. The specimens in water have the highest compressive strength compared with the other specimens that were immersed in acid solution. It is evident all specimens exposed to acidic environment exhibit lower ability to resist load in contrast to water cured specimens. The reduction in compressive strength can be attributed to

NSHA replacement. The weight loss is an indication of resistance to acidic attack, the higher the percentage loss the lower the resistance.

The weight loss occurs as a result of the leaching out of calcium chloride from the mortar due to reaction between calcium hydroxide in concrete with hydrochloric acid (Abdul, 1998 and Ahmed, 2008), and the reaction is higher in concrete containing NSHA. Generally, deterioration of concrete due to hydrochloric acid can be characterized by the following reactions:



the deterioration of the concrete due to acid attack on the matrix structure of the concrete as exhibited by equation (3). The control specimen (0 % replacement) has the highest compressive strength both in water and HCl. Acid resistance was then evaluated by determining the compressive strength loss (SL) of the specimens using equation 2. The result is shown in Figure 3.

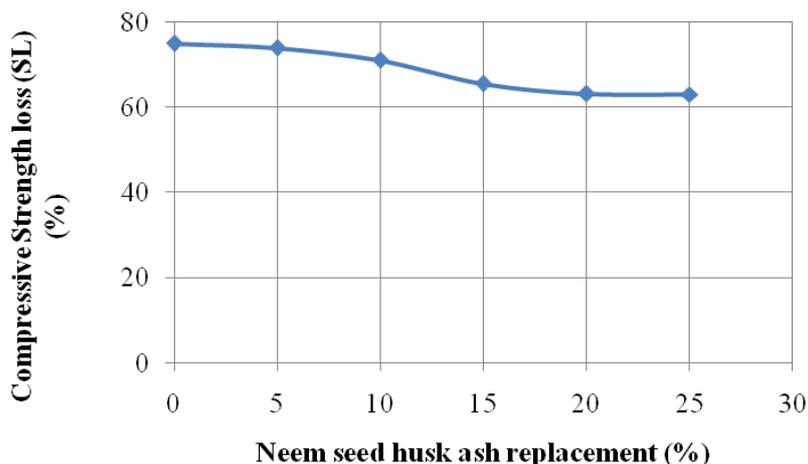


Fig. 3: Compressive strength loss against various percentage replacement of NSHA. Specimens with Neem seed husk ash replacement exhibited resistance against acid comparably with the control specimen, even though the control shows a better resistance. Among the specimens with replacements, 5% replacement exhibited the highest resistance in term of compressive loss.

**Chloride Penetration**

Figure 4 shows the result of chloride penetration test on NSHA concrete.

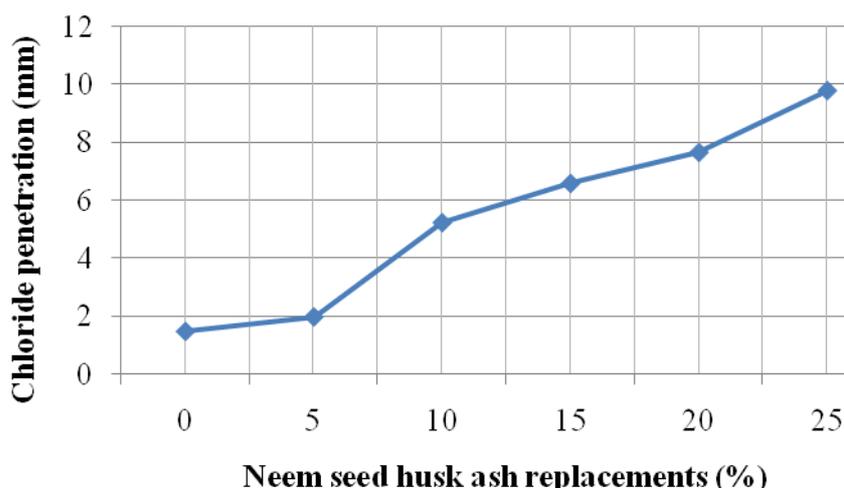


Fig. 4: chloride penetration against various percentage replacement of NSHA

The chloride penetration increases with increase in NSHA replacement as can be seen in figure 4. It was observed that the maximum chloride ingress into the control mix specimen (0% replacement) is the lowest. After that the increase is gradual in all the replacements. The penetration depths in all the specimens are below the minimum recommended concrete cover of 20mm (BS8110-1:1997).

**CONCLUSION**

Based on the test results and discussions, the following conclusion can be drawn:

1. Weight loss was observed on all the specimens when they are exposed to 1% HCl acid for 1400 hours. It was observed that 5% NSHA replacement shows the least weight loss, lower than the control (0% replacement), Thus, 5% replacement shows great potential to resist deterioration same as control specimen. After that the weight loss increases with increase in ash replacement.

2. The specimens in water have the highest compressive strength compared with other specimens, when immersed in acid solution. The control specimen (0% replacement) has the highest compressive strength both in water and HCl. The reduction in compressive strength can be attributed to the deterioration of the concrete due to acid attack on the matrix structure of the concrete. The strength reduces with increase in Neem seed husk

ash replacement. In conclusion, specimens with Neem seed husk ash replacement exhibited resistance against acid comparably with the control specimen, even though the control shows a better resistance.

3. The chloride penetration increases with increase in Neem seed husk ash replacement. With the 0% replacement was having the lowest penetration and 25 percent replacement having the highest penetration.

## REFERENCES

- Abdul, A. (1998). "A Study of Strength and Durability Performance of Concrete containing Palm Oil Fuel Ash", PhD Thesis submitted in partial fulfillment of the requirements for the award of the PhD (Civil-Structure) Faculty of Civil Engineering Universiti Teknologi Malaysia.
- Ahmed, B.(2008). "Study on Durability of High Strength Palm Oil Fuel Ash POFA Concrete", A Master Thesis submitted in partial fulfillment of the requirements for the award of the degree of Master of engineering (Civil-Structure) Faculty of Civil Engineering Universiti Teknologi Malaysia.
- Bassuonni, M.T., and Nehdi, M.L. (2007). Resistance of self-consolidating concrete to sulfuric acid attack with consecutive pH reduction, Elsevier, Cement and Concrete Research Vol. 37, pp1070-1084.
- Beddoe, R.E. and Dorner, H.W. (2005). Modelling acid attack on concrete: Part I.The essential mechanisms, Cement and Concrete Research Vol. 37, pp. 2333– 2339.
- BS 8110-1:1997, "Structural use of concrete: Part 1. Code of practice for design and construction", British Standards Institute, 389 Chiswick High Road, London, W4 4AL, <http://www.bsi-global.com/>.
- Ejeh S.P, Abubakar I, Ocholi A. and Nuruddeen M. M. (2014) 'Effect Of Neem Seed Husk Ash On Concrete Strength Properties'. Nigerian Journal of Technology. Faculty of Engineering, University of Nigeria, Nsukka. Enugu State – NIGERIA Vol 33, No.2 April 2014, PP 163 - 169
- Mark, A., Alexandra, B. and Nele-De B. (2013) "Performance of Cement-Based Materials in Aggressive Aqueous Environments" State-of-the-Art Report, RILEM TC 211-PAE
- Massazza, F.(1993). *Pozzolanoc Cements, Cement and Concrete Composite*, Vol 15,pp 185-214.
- Mohamed, A. E. I (2009), Study On The Properties Of Palm Oil Fiber, A thesis submitted in partial fulfillment of the requirements for the award of the degree of Master of engineering (Civil-Structure) Faculty of Civil Engineering Universiti Teknologi Malaysia
- Nuruddeen, M.M. (2013) 'Influence of Neem Seed Husk Ash on the Tensile Strength of Concrete'. American Journal of Engineering Research (AJER) e-ISSN : 2320-0847 p-ISSN : 2320-0936 Volume-02, Issue-12, pp- 171-174 [www.ajer.org](http://www.ajer.org)

Reddy B. M., Sudarsana H. R. and, George M.P (2012) "Effect of Hydrochloric Acid (HCl) on Blended Cement (Fly Ash based) and Silica Fume Blended Cement and their Concretes" International Journal of Science and Technology Volume 1 No. 9, September, 2012. PP 476 - 480

UNI 79287. (1978). Concrete-determination of the ion chloride penetration. UNI—Ente Nazionale Italiano Di Unificazione, Milano, piazza A. Diaz, 2.

and Stone Dust Blended Concrete in Acidic Environment Material", *Concrete Research Letters Vol. 4(1) - March 2013* PP569 - 579