EFFECT OF COCONUT SHELL ASH ON THE SULHATE RESISTING CAPABILITIES OF CONCRETE

Kassar Terungwa*, Momoh Emmanuel**
*(Civil Engineering Department, University of Agriculture, Makurdi
Email: terrychenko@gmail.com)
** (Civil Engineering Department, University of Agriculture, Makurdi
Momohemmanuel85@yahoo.com)

ABSTRACT

The foundations of concrete structures like buildings, bridges, embankments etc. are embedded in the soil. These structures come in contact with naturally occurring sulphate in soil, rocks and groundwater. Also groundwater containing sulphates is often high in magnesium and other sulphates and these attacks has often been in terms of reaction between calcium hydroxide in cement paste and dissolved compounds such as Na_2SO_4 or $MgSO_4$, in the attacking solution. These compounds react with concrete to form ettringite in the hardened cement paste. This formation generates stresses in the cement paste and, as a result cracks develop in the concrete which may have adverse effect on the concrete strength and durability. Thus the need to find alternative binding materials that can be used in partial replacement of cement to resist this sulphate attack to concrete thereby prolonging its service time in use. Coconut shells were collected and burnt in the open air (uncontrolled combustion) to produce coconut shell ash (CSA), which in turn was used as a pozzolan in partial replacement of cement in concrete production. Concrete cubes were produced using various replacement levels of 0, 5, 10, 15, 20, 25 and 30 percent of OPC (Ordinary Portland Cement) with CSA (Coconut Shell Ash). A total of 126 cubes were produced and cured by immersing half (63cubes) in a normal water curing medium and the other half in sulphate solution made by dissolving 5% of $MgSO_4$ and Na_2SO_4 by weight of water respectively, in the curing tank for 7, 14 and 28 days respectively. Properties such as compressive strength, density, setting times and water absorption were determined for both curing media. The results showed that the reduction in compressive strength decreased from 2.26% at 0% replacement to 1.01% at 30% replacement at 28 days curing thus confirming the theory that incorporating CSA in concrete will help to reduce the attack caused by sulphate compounds available in the soil.

KEYWORDS- *Coconut Shell Ash (CSA), Curing, Ordinary Portland Cement (OPC), Pozzolan, Sulphate attack*

1. INTRODUCTION

The increased reliance of the construction industries on cement for the production and development of shelter and infrastructure has increased considerably over the years and as a result, it has become extremely difficult for majority of the people to own their own houses or many collapse structures in attempt to reduce cost [1], [2]. The increasing cost of construction materials such as cement, reinforcement bars and other construction materials has led to increased cost of construction[3]. Also, it has been suggested by many researchers that leaving waste materials unattended to can impact the environment directly and cause environmental problem and hence the reuse of waste material has been emphasized[4]. Waste can be used to produce new products or can be used as pozzolans so that natural resources are used more efficiently and the environment is protected from waste deposits. Apart from the issue of increased cost, there is also the risk of pollution associated with cement production, which has necessitated a search for an alternative binder which can be used sorely or in partial replacement of cement in concrete production. [4], [5]. A lot of researchers have shown that a variety of agricultural waste such as coconut shell, palm kernel shell, rice husk, can be converted to ash with considerable amount of amorphous silica which can replace cement in the production of concrete with the minimum desirable strength. [3], [6], [1].

Beside the strength criteria of concrete there is also the case of durability of these concrete and its proneness to chemical attack, especially sulphate attack. This is as a result of the presence of free lime ($Ca(OH)_2$) in the concrete after cement has undergone hydration.[7], [8]. It is reported that under sulphate environment, cement paste undergoes deterioration that results from expansion, spalling and softening which impairs on strength and durability properties of cement paste.[8], [9], [10].

Generally the addition of pozzolans to freshly mixed mortar reduces cement proneness to chemical attack by reducing the amount of free lime available and also improving the permeability of concrete.[8].

In this particular research, the effectiveness of coconut shell ash in improving the proneness of concrete to sulphate attack. The objectives of the research work are highlighted below;

- Casting 126 concrete cubes with dimensions 150mm x 150mm x150mm
- Blending the cement in the concrete with coconut shell ash in percentages (0%, 5%, 10%, 15%, 20%, 25% and 30%)
- Curing cubes in normal curing conditions and acidic curing condition (Na_2SO_4 and $MgSO_4$) for 7, 14 and 28 days
- Ascertaining the reduction in strength as a result of the acidic curing condition

2. MATERIALS AND METHODS

2.1 Materials

The Materials for this research work were all obtained within Makurdi Metropolis of benue state, Nigeria. They include the following;

2.1.1 Cement

The cement used for the research was ordinary Portland cement (Grade 42R satisfying BS 12:1996) produced by Dangote Cement Company, Nigeria**.**

2.1.2 Aggregates

Coarse and fine aggregate used were river gravel and sand respectively and were sourced from the river Benue in Makurdi, Nigeria. The fine aggregate was partially replaced with CSA (coconut shell ash).

2.1.3 Coconut Shell Ash

This was ash obtained from the burning of the coconut shell. The coconut shells were burnt in open air which was used for the research work as pozzolan for partial replacement of cement in the production of concrete.

2.1.4 Water

Fresh water (satisfying ASTM C1602) used for specimen casting was obtained from the university water works. The storage tank beside the Civil Engineering laboratory served as access point to the water used for the research.

2.2 Methodology of Tests

The various tests carried out were conducted at the Department of Civil Engineering Laboratory, University of Agriculture Makurdi (UAM). The tests include:

2.2.1 Sieve Analysis

2.2.1.1 Sieve Analysis for fine aggregate

The grading of the aggregate which defines the proportion of its particles in different sizes, can be seen as continuous. Majority of the fine aggregate particles are smaller than 10mm with the largest fraction being 0.85mm and the smallest fraction being 0.075mm. The proportions of the fine aggregate particles, falls within the limits specified by BS 882 for natural sand (0-5mm).

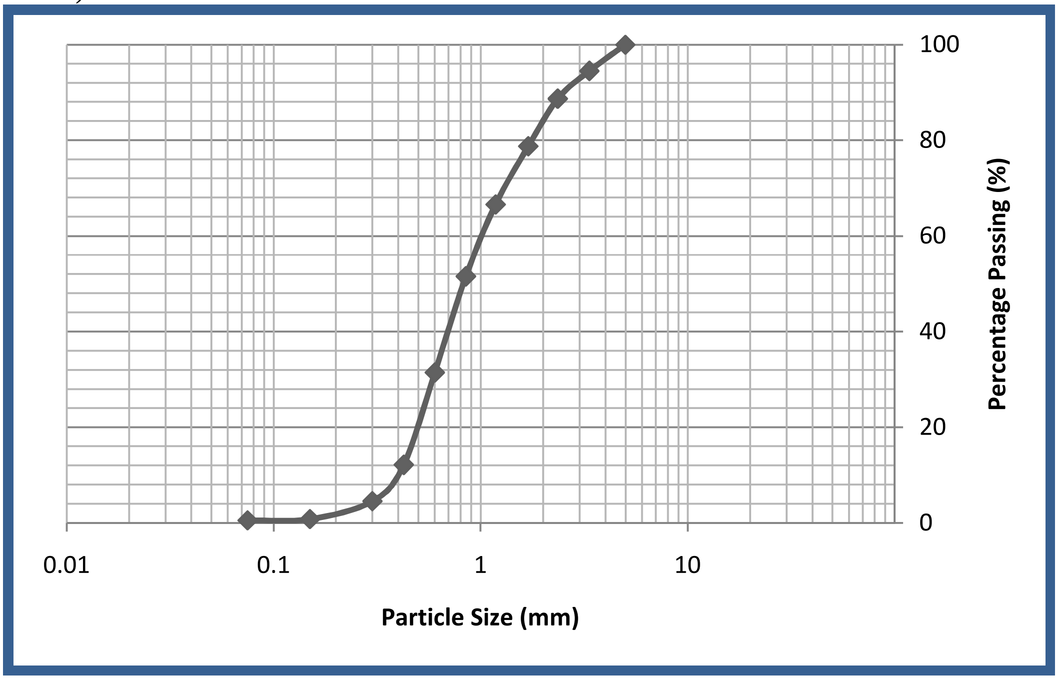

Fig.1: particles size distribution of sand

The particle size distribution is plotted as shown in Fig. 1. The graph shows that the gradation of sand is within zone grading No. 2. And it is suitable for concrete works. The gradation of particles falls within the fine aggregates specified gradation limits in (BS882:1992) [11]

2.2.1.2 Sieve Analysis Test for Coarse Aggregate.

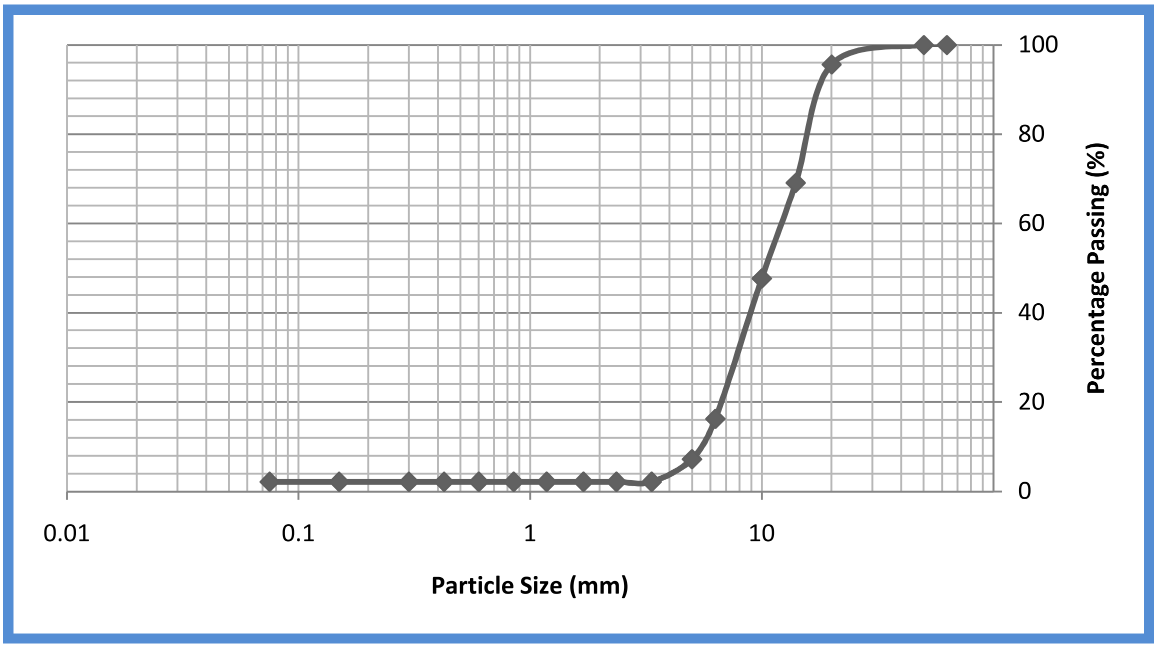

Fig.2: particle size analysis of the coarse aggregate

The result shows that, the gravel is in 20-14 and 14-10 mm fraction. The largest fraction is 14.00mm in size and the smallest fraction is 10.00mm in size. This results shows a similar trend as [11]

2.2.1.2 Sieve Analysis Test for CSA.

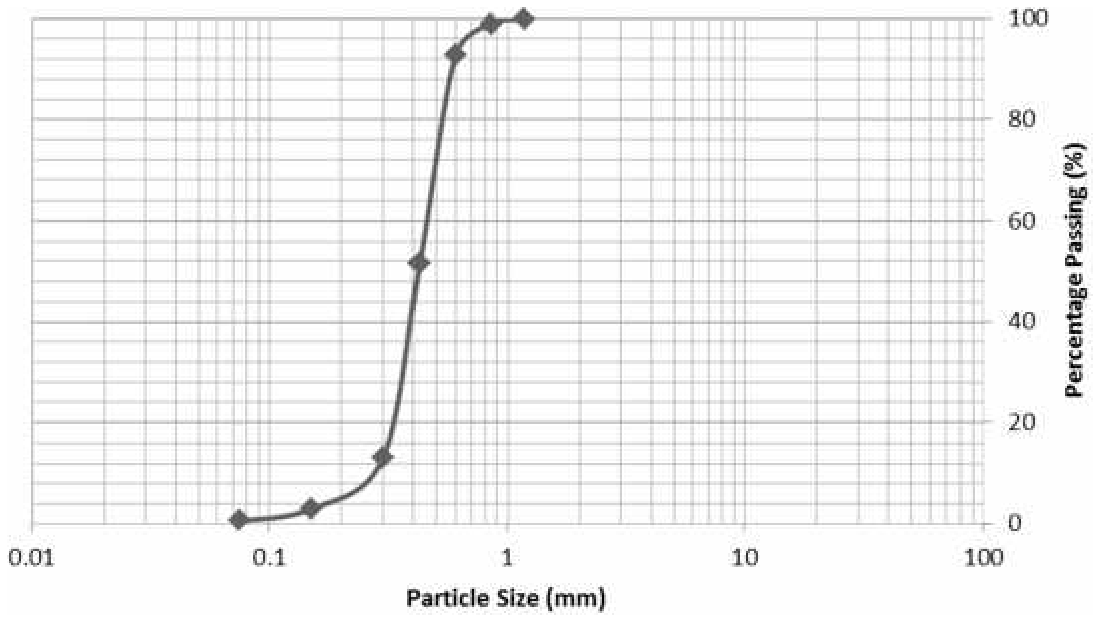

Fig.3: particles size analysis of coconut shell ash

Fig. 3 shows the proportion of the particles of different sizes in the Coconut Shell Ash (CSA). The CSA has Grain Fineness Number (GFN) particles than the fine aggregate when compared together. The ash contains more fine particles smaller than 0.60mm. The result shows that, the fineness of the CSA is up to 61.6% retention on a 0.30mm sieve. The property of the CSA had an effect on the water/cement ratio because it increased the porosity of the composite material.

2.2.2 Setting Times OPC/CSA Blended Pastes

Table 1: Setting Time of Ordinary Portland Cement/Coconut Shell Ash (OPC/CSA) paste

% replacement	*Initial setting time (mins.)*	*Final setting time (mins)*
0	74	96
5	142	239
10	262	345
15	273	384
20	295	458
25	327	476
30	346	492

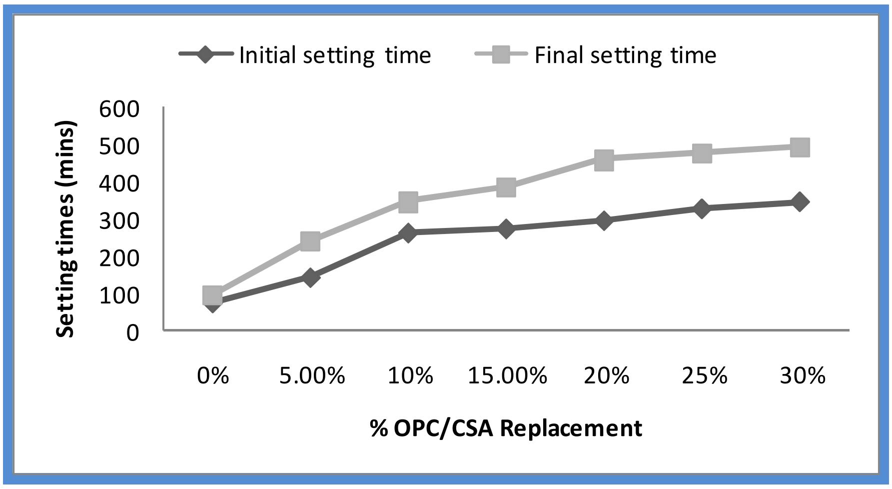

Fig. 4: Depicts the setting times of various percentage replacements of OPC with CSA.

Table 1 shows that the setting times increase with increase in the amount of coconut shell ash. The initial setting time increases from 1 hour 14 minutes at 0 percentage replacement to 5 hours 46 minutes at 30 percentage replacement. While the final setting time increases from 1 hour 36 minutes to 8 hours 12 minutes. However, BS 12 (1978) recommends initials and final setting times to be not more than 45 minute and 10 hours respectively for which the CSA/OPC pastes passes in final setting time.

2.2.3 Water Absorption Test Result

Fig. 5 shows the water absorption of OPC/CSA blended concrete at various percentage replacements after 28days curing age. The percentage water absorption at 0% replacement is 3.16% while that at 30% replacement is 3.68%. It can be seen from the Fig. 5 that there is a gradual increase in the water absorption property in the blended concrete with increasing CSA content. This shows a similar trend in pozzolans as reported by [12]

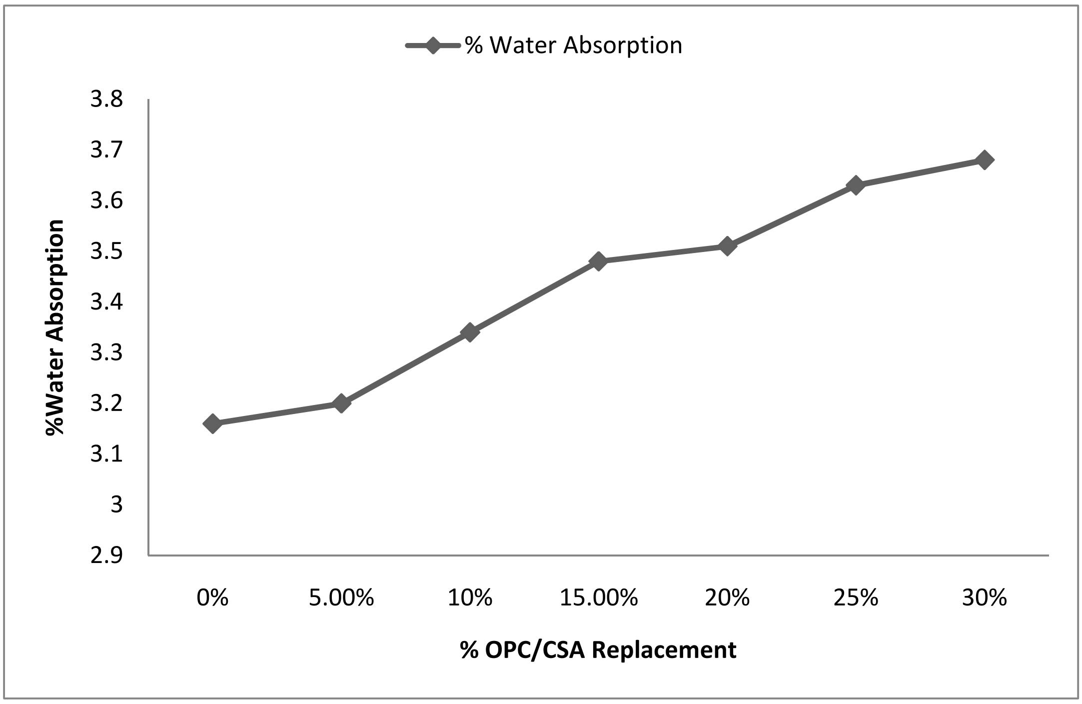

Fig.5: variation of water absorption against OPC/CSA % replacement

2.2.4 Compressive Strength Test Result

Table 2: Reduction in the Compressive Strength of OPC/CSA Blended Concrete Cubes Cured in Normal and Sulphate Solution Media at 28days Curing age.

% Replacement	*Average Strength in Normal Curing Tank (N/mm^2)*	*Average Strength in Acidic Solution Curing Tank (N/mm^2)*	*% Reduction in Strength*
0	29.63	28.60	2.26
5	26.30	25.71	2.24
10	24.96	24.44	2.08
15	23.11	22.74	1.60
20	19.63	19.26	1.88
25	16.37	16.15	1.34
30	13.85	13.71	1.01

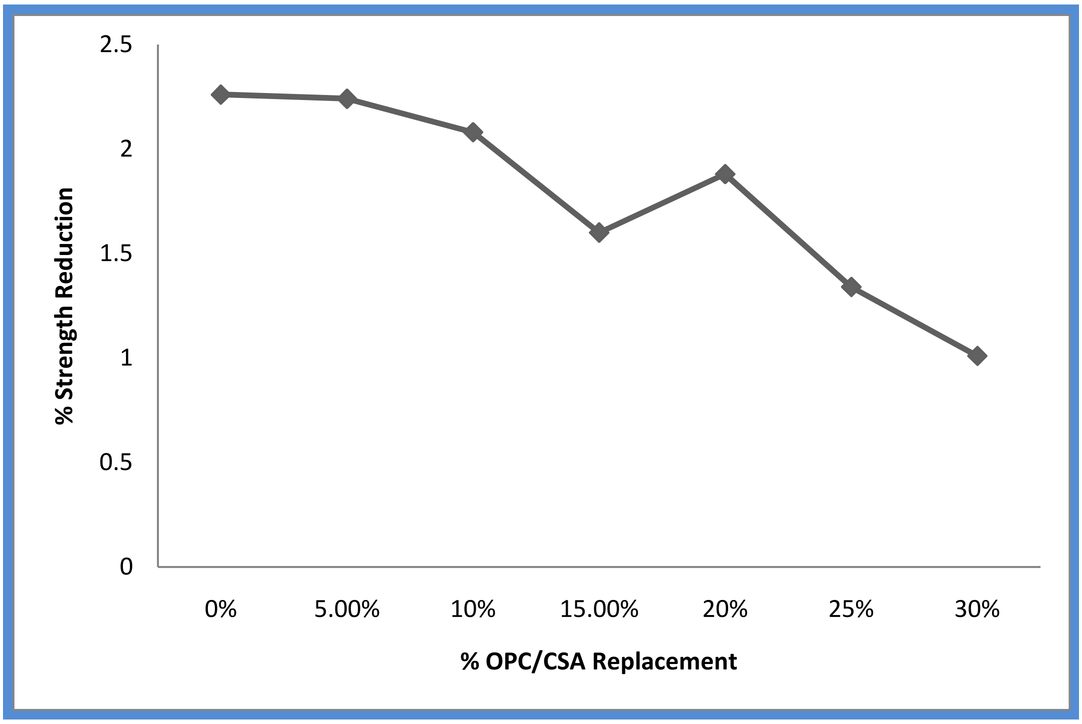

Fig.6: Percentage reduction in the compressive strength of OPC/CSA concrete in sulphate solution curing medium

Table 2 shows the percentage reduction in the compressive strength of OPC/CSA blended concrete cubes cured in normal water tank and sulphate solution tank after 28days of curing. The reduction in the compressive strength decreases with increasing percentage replacement of OPC with CSA as expected which can be seen in Fig. 6. Though, the strength at 0% replacement in normal curing tank is 29.63N/mm^2 while its corresponding strength in the sulphate solution curing tank is 28.96N/mm^2 resulting in a 2.26% strength reduction. While at 30% replacement, the cube strength in normal curing tank is 13.85N/mm^2 and its corresponding strength in the sulphate solution is 13.71N/mm^2 giving a 1.01% strength reduction. The above analysis was expected since the increase in CSA content will decrease the effect of sulphate compound in the hydrated OPC/CSA blended concrete by reducing the amount of free lm available in the hydrated cement as suggested by [8]

3. CONCLUSION

Based on the results obtained from the experiment, the following conclusions can be inferred that;

- the compressive strength of the cubes at 28 days curing indicates that 10% and 15% replacement levels meet the requirement of BS EN 206-1: 2000 for class C20/25 and C20/22
- there is an increase in water absorption of the concrete blend increases as the pozzolanic content in the mix increases owing to the increased surface area of the ash.
- There is a decrease in strength reduction as the percentage of ash in the mix increases i.e from 2.26% at 0% CSA/OPC replacement to 1.01% at 30% CSA/OPC replacement.
- The coconut shell ash inhibits the effect of sulphate attack in the concrete

REFERENCE

[1]. Alabadan, B., et al., *Partial replacement of ordinary Portland cement (OPC) with bambara groundnut shell ash (BGSA) in concrete*. Leonardo Electronic Journal of Practices and Technologies, 2005. **6**: p. 43-48.

[2]. Olanipekun, E., K. Olusola, and O. Ata, *A comparative study of concrete properties using coconut shell and palm kernel shell as coarse aggregates*. Building and environment, 2006. **41**(3): p. 297-301.

[3]. Aho, M. and J. Utsev, *Compressive Strength of Hollow Sandcrete Blocks Made with Rice Husk Ash as a Partial Replacement to Cement*. Nigerian Journal of Technology, 2008. **27**(2): p. 71-78.

[4]. Shirule, P., A. Rahman, and R.D. Gupta, *Partial replacement of cement with marble dust powder*. International Journal of Advanced Engineering Research and Studies, 2012. **1**(3): p. 175-177.

[5]. Habeeb, G.A. and H.B. Mahmud, *Study on properties of rice husk ash and its use as cement replacement material*. Materials research, 2010. **13**(2): p. 185-190.

[6]. Utsev, J. and J. Taku, *Coconut shell ash as partial replacement of ordinary Portland cement in concrete production.* International journal of scientific & technology research, 2012. **1**(8): p. 86-89.

[7]. Zhang, M.-H. and V.M. Malhotra, *High-performance concrete incorporating rice husk ash as a supplementary cementing material.* ACI materials journal, 1996. **93**: p. 629-636.

8.] Chindaprasirt, P., et al., *Sulfate resistance of blended cements containing fly ash and rice husk ash.* Construction and Building Materials, 2007. **21**(6): p. 1356-1361.

[9]. Lauer, K., *Classification of concrete damage caused by chemical attack.* Materials and structures, 1990. **23**(3): p. 223-229.

[10]. Collepardi, M., *A state-of-the-art review on delayed ettringite attack on concrete.* Cement and Concrete Composites, 2003. **25**(4-5): p. 401-407.

[11]. Neville, A.M., *Properties of concrete*. Vol. 4. 1995: Longman London.

[12]. Fapohunda, C., B. Akinbile, and A. Shittu, *Structure and properties of mortar and concrete with rice husk ash as partial replacement of ordinary Portland cement–A review.* International Journal of Sustainable Built Environment, 2017.