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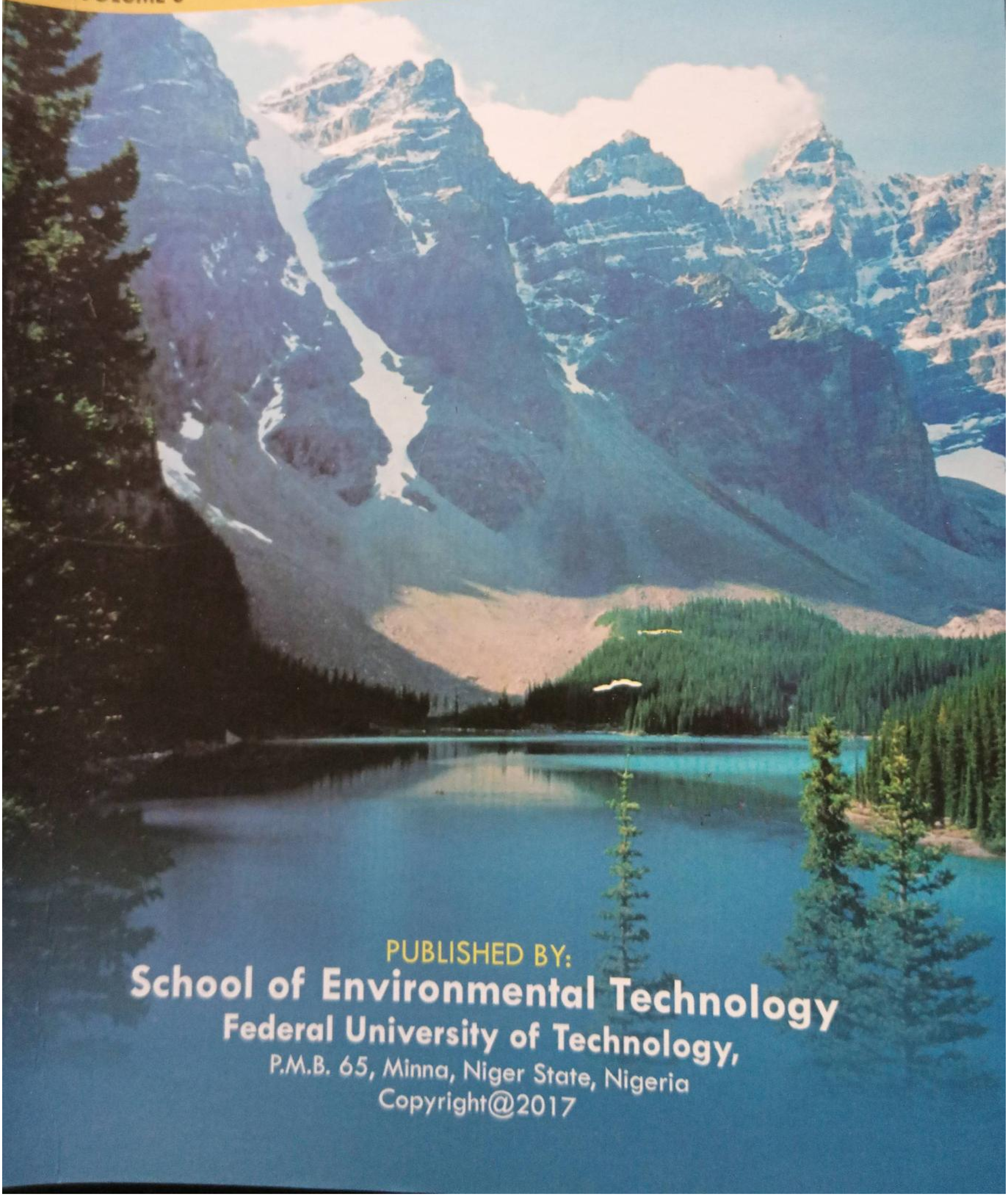

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Aim and Scope

The Environmental Technology and Science Journal (ETSJ) is devoted to the publication of papers which advance knowledge of practical and theoretical issues of the environmental technology. The aim of the journal is to provide an avenue for dissemination of academic research findings from various disciplines of the environment, engineering, pure and applied sciences, arts and social science, which have materials that emphasize on environmental issues.

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ditorial

is my honour as the Managing Editor on ehalf of the Editorial Board to present olume 8, number 1, June 2017 edition of ie Environmental Technology and Science ournal (ETSJ) to the research community ith a view to expanding the discourse and rovide a platform for robust academic ebate. As the world's population ontinues to expand, implementation of esources-efficient measures in all areas of uman activities is imperative. The built nvironment is one clear example of the npact of human activity on resources. To is end, this edition presented fifteen well-esearched articles ranging from onstruction materials, climate change sues, car park management to real estate sues, waste management, health and afety matters and transportation.

oncrete deteriorates considerably when xposed to aggressive chemicals such as cids. Incorporation of pozzolana to oncrete can ameliorate its effectiveness in hese chemicals but this has to be xperimentally established. Therefore, Aka *t al.* investigated the effect of pozzolana; rice husk ash (RHA), powdered burnt rick (PBB) and saw dust ash (SDA) on the ompressive strength of concrete in hemically aggressive environment. The esults showed that RHA and PBB concrete xhibited better strength than SDA and the ontrol specimen in $MgSO_4$ solution. The tudy concluded that RHA and PBB oncrete are highly resistant to $MgSO_4$ and an be recommended as sulphate resistant dditive in concrete production.

Climate change represents a significant environmental, social and economic threat and is now firmly recognized by the majority of the world's governments and scientists as an issue of extreme concern for the planet. The public perception of climate change on both local and global scales by residents of Minna, Niger State was interrogated by Odegbenro and Ojoye in the second paper. The findings revealed that 85.6% of the public were aware of the change in climate using change rainfall and temperature pattern as indicators. The respondents noticed that there are changes in the amount of rainfall received and increase in average daily temperature while14.4% were completely unaware of climate change issues. The study thereby recommended among others that information and communication technology be used to sensitize people on the effects of changing climate.

Olufemi *et al.* in the third paper assessed shoreline changes, land use and land cover change, geomorphological changes of the coast. The shoreline change movement showed that between 1980 and 1990, the net shoreline movement was estimated 259 meters while the net shoreline movement between 1980 and 2010 was about 347 meters. The end-point rate also indicated the rates of erosion (424.96 meters) and accretion (277.5 meters) (loss and gain), suggesting higher increase in erosion over accretion. The study advocated continuous monitoring of shoreline changes to reinforce our understanding and establishing the processes driving erosion and accretion in the coastal areas.

Creating an outdoor learning and play environment is an initiative that would incorporate green design principles targeted at meeting children's developmental needs. Children developmental needs are cognitive, physical, social and emotional. The forth paper by Ayuba and Akpama assessed the physical outdoor spaces and natural elements in elementary schools with a view to integrating these elements in elementary schools in Minna. The findings revealed that only 25% of the playgrounds of elementary schools in Minna have above average fixed components. The paper recommended that play-learning environment be integrated in elementary schools in Minna.

Parking management is increasingly becoming a major component of surface transport planning needs of public institutions like schools and hospitals, this is because the means of transportation cannot continually be in motion. Zaria metropolis harbors a number of such institutions which generates substantial vehicular traffic. Despite efforts by these institutions to provide parking facilities in the past ten years, persistent incidences of indiscriminate parking, non-usage of prescribed parking lots, double and road side parking is still very common. To this end, Oluwole *et al*. examined car par usage and management in five Federal Institutions (NITT, ABUTH, NCAT, FCE and NARICT) within Zaria Metropolis in the fifth paper. According to the authors, the major challenges faced by users of the car park facilities are long distance of the parking lots to the destination of the users within the institutions as well as poor medium of communication and direction to the available parking facilities. The implication of this study to the usage and management of car park in the study area lies in the provision of additional designated parking facilities to accommodate the increasing number of vehicles, strict enforcement through monitoring.

The sixth paper by Babatunde examined the dependability of Two-Third of Market Value (TTMV) model of deter
liquidation value

Niger State. The results
one ESV firm identifi
Model (MSM) as the ap
liquidation valuation (L
values assessed by the
between 60% and 88.20
(MV) in the state. The p
MSM to the valuation
basis of LV assessment
market is active in the sta

As cities develop and gro
is often carried out wh
existing structures be
changes in modern archite
new standards. This proc
hurriedly and with
precautionary measures re
building components tha
valuable and reusable.
renewal and renovatio
examined by Ayuba and
seventh paper in order
techniques employed in ren
parts of such existing
effective reuse or recyclin
demonstrated a lack of tech
as well as deployment
equipment during the const
The authors recommende
partnership between constr
and recycling factories
encouraged.

The shorelines are highly dy
changing. Many factors in
changes including the type
(rocky, sandy), wave a
variations, storms and human
shoreline change study is
updating the shoreline chan
management of natural resour
this, the eighth paper by A

d use land cover of the area and dforms around the coast. The study nc'uded that the shoreline is eroding at -.03 m/yr and accreting at 15 m/yr. nce, the study will be very helpful for al administrative bodies for decision king in the state and coastal nagement in the country.

d'razack *et al*. assessed the risk of iding in proximity to illegal waste dump es in Sabon Wuse, North-Central, geria in the ninth paper. The level of alth risk associated with living close to mpsites showed that a total of 878 uses are at the severe risk, while, 1,898 uses are at mild risk level. The study vocated that there should be a total arance of the existing illegal dump site d proper monitoring of the waste anagement in the town to forestall illegal mping, and adequate information to sidents and awareness on the danger of nsequences of indiscriminate dumping of fuse in undesignated dump sites.

the tenth paper, the application of mass ppraisal model in Nigeria was examined y Liman *et al*. The regression results vealed the contributory effect of the ifferent housing attributes on the house rice. Based on these results, a mass ppraisal model for residential property aluation was developed. The study iscovered that a good mass appraisal odel can bring about improvement in roperty tax administration in the study rea by reducing cost and ensuring fairness nd equity, which are very crucial in any roperty tax assessment process.

he Urban Heat Island effect is linked to he built environment and threatens human ealth during extreme heat events. Duchi nd Musa examined the spatial pattern of eat islands in Zaria urban area in the eleventh paper. The results showed the correlation between the maximum temperature and the years of analysis as 0.8433 with 84.33% linear relationship. The coefficient of determination R^2 is 0.7112 which reveals 71.12% change in maximum temperature caused by variation of time. The authors recommended the creation of shelter belt and stabilizing river embankment among other remedial measures.

Yakubu in the twelfth paper assessed safety and health performance of contractor's construction project in Nigeria using Safety and Health Assessment System in Construction (SHASSIC) method. The result of the assessment showed that the performance of the contractors was two (2) stars in ranking. Therefore, what the industry needs according to the author was an act that provides for the promotion, coordination, administration and enforcement of occupational safety and health.

The thirteenth paper by Olatunji established that an assessment index to guide Estate Surveyors and Valuers (ESV), willing to offer housing procurement service for house-seekers does not exist. The paper therefore sought to develop an Optimality Index, (OPTi), a simulation framework to assess Housing Choice Optimality (HcO), and test its application from two perspectives based on utility optimization of 5 key variables. The study revealed that indeed there were variations in HcO across households in the 6 neighbourhoods studied. The consistency of the results according to the author with well-known pattern in Abuja housing market is a proof that the simulation package could assess housing wellbeing objectively.

The effects of road quality on commercial land use pattern in Makurdi Urban, Benue State by Umoren and Mchi in the fourteenth paper indicated that interaction effects between neighbourhood and road quality was not statistically significant. The paper recommended that mix use development be encouraged and more roads to link the neighbourhoods in Makurdi urban should be developed.

Resident's wellbeing is a key factor in the quest to provide residence and neighbourhoods that are people-responsively designed, produced and situated in a conducive physical environment to bring about satisfaction, quality of life and health. The focus of the fifteenth by Johnson *et al*. attempted to find out how the physical attributes of residential units and the immediate neighbourhood impact on the wellbeing of residents. The results indicated that the neighbourhood amenities resident's wellbeing propos stage were either grossly i now completely absent. recommended that firm development control policy best professional practices ar protect occupants, main residential capacity and he residential developments s terms of well-being.

It is my hope that the issues i this edition will spur us to our environment a better reading!

R. A. Jimoh, PhD
Managing Editor

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Effect of Pozzolana on the Compressive Strength of Concrete in Chemically Aggressive Environment

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Abstract

Concrete deteriorates considerably when exposed to aggressive chemicals such as sulphates and acids. Incorporation of pozzolana to concrete can ameliorate its effectiveness in these chemicals but this has to be experimentally established. This paper therefore investigates the effect of pozzolana; (rice husk ash (RHA), powdered burnt brick (PBB) and saw dust ash (SDA)) on the compressive strength of concrete in chemically aggressive environment. This was achieved by partially replacing concrete with 10 percent (%) of each pozzolana to produce three different concrete samples. Samples of 100% concrete were equally produced to serve as the control. The quantities of cement, fine aggregate and coarse aggregate used for the production of the specimens were obtained through absolute volume method of calculation. A mix ratio of 1: 2: 4 with water-cement (w/c) ratio of 0.65 was adopted for the various specimen. 150x150x150mm twenty-seven (27) concrete cubes were produced for each pozzolana and the control specimen. The specimens were cured for 28 days in ordinary water after which they were equally and completely immersed in chemical solution of 5% H_2SO_4, 10% $MgSO_4$ and ordinary water for another 28 and 56 days. The specimens in ordinary water were used as the control during the chemical test. The percentage reduction in strengths of RHA, PBB, SDA and the control specimens in 10% $MgSO_4$ at 56 days were observed to be 2.09%, 3.26%, 23.03% and 10.06% respectively. In 5% H_2SO_4, the percentage reductions in strengths of RHA, PBB, SDA and the control at 56 days were also observed to be 25.13%, 21.27%, 52.19% and 33.61% respectively. The results show that RHA and PBB concrete exhibit better strength than SDA and the control specimen in $MgSO_4$ solution. All the specimens tested in H_2SO_4 performed poorly at 56 days. The study concludes that RHA and PBB concrete are highly resistant to $MgSO_4$ and can be recommended as sulphate resistant additive in concrete production.

Keywords: Aggressive environment, Concrete, Compressive strength, Pozzolanana.

Introduction

Concrete, a heterogeneous material is being debilitated when exposed to certain conditions. Among these conditions is aggressive chemicals (Collepardi, 2003; Dehwah, 2007). Aggressive chemicals are substances such as sea-water/soil rich in sulphates, nitrates, chlorides and carbonates that are deleterious to any material in its vicinity (Ogwu, 2001). Sadiq *et al.* (2001) and Neville and Brooks (2002) affirmed that the degree of the damage constitute by these chemicals depends mainly on the permeability of the concrete. This implies that once concrete is sufficiently permeable that water could percolate through its thickness, calcium hydroxide ($Ca\ (OH)_2$) will be leached out (Sadiq *et al.*, 2001; Neville and Brooks, 2002). The extensive leaching of $Ca\ (OH)_2$ increases porosity and consequently, concrete becomes feeble in strength and

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liable to' attack (Ogwu, 2001). According to Shetty (2005), magnesium sulphate ($MgSO_4$) is the main salt that constitutes maximum damage in concrete, and a characteristics whitish appearance is the indication of its attack. Neville and Brooks (2002) observed that calcium aluminate (C_3A) in porous concrete is more prone to sulphates attack, and the susceptibility of the attack can therefore, be reduced through the application of cement that is low in C_3A. Alternatively, Feret (1992) and Smeaton (2002) proposed for the adoption of a Pozzolana.

Pozzolana is defined as siliceous materials which in itself possesses little or no cementitious properties but in finely divided form and in the presence of moisture, chemically reacts with Ca $(OH)_2$ at ordinary temperature to form a compound possessing cementitious properties (Neville and Brooks, 2002). Zelie *et al.* (2001) accentuated that pozzolana can be incorporated as active addition or substitution to concrete due to its capacity for reacting with lime. It is essential to know that this lime principally originates during the hydration of Portland cement (Smeaton, 2002). Zelie *et al.* (2001) are of the view that the result of this reaction (pozzolanic reaction) leads to the formation of cementitious compounds (tricalcium silicate (C_3S)). Zelie *et al.* (2001) further declared that this C_3S modifies the properties of cement and the resulting concrete.

Generally, researches have been conducted by different researchers to explicate the effectiveness of pozzolana as partial replacement of cement in concrete production '(Kamang Datok, 2001; Elinwa and Mahm 2002; Sa'ad *et al.*, 2007; Dahiru Zubairu, 2008; Garba and Tahir, 20 However, the reviewed literature sh that limited studies exists on concrete that exhibits hig performance when exposed aggressive environments. Premised this gap in the literature, this resea examined the effect of three differ pozzolana (RHA, PBB and SDA) o the compressive strength of concrete i chemically aggressive environmen Hence, the pozzolana (RHA, BBP and SDA) that produces the highes compressive strength concrete i ordinary water and chemical solution of $MgSO_4$ and H_2SO_4 were establishe at 28 and 56 days curing periods.

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Reviewed Literature

Chemical Composition of Portlan cement

Based on the reviewed literature, Tab 1 shows the chemical composition Portland cement.

Table 1: Chemical Composition of Portland cement

	Normal	Rapid Hardening	Low Heat
(a) Composition in percentage			
Lime	63.1	64.5	60
Silica	20.6	20.7	22.5
Alumina	6.3	5.2	5.2
Iron Oxide	3.6	2.9	4.6
(b) Compound in percentage			
C_3S	40	50	25
C_2S	30	21	35
C_3A	11	9	6
C_2A	12	9	14

Source: Holland (2005); Kosmatka *et al.* (2002)

Chemical Composition of Common Pozzolana

From the reviewed literature, Tabl and Table 3 also indicates the chem composition of common pozzolana such as RHA and Dutch Fly Ash .

Table 2: Chemical Composition of RHA

Constituent	% Composition
Fe_2O_3	0.95
SiO_2	67.30
CaO	1.36
Al_2O_3	4.90
MgO	1.81
L.O.I	17.78

Source: Oyetola and Abdullahi (2006)

Table 3: Chemical Composition of Dutch Fly Ash

Fly ash sample (%m/m)	Average values (%m/m)	CUR No. 12
SiO_2	49.6	-
Al_2O	26.1	-
Fe_2O	6.8	-
Na_2O	0.46	-
K_2O	1.96	-
CaO	2.7	< 5.0
MgO	1.68	< 4.0
TiO_2	1.05	-
P_2O_5	0.55	-
SO_3	0.72	< 2.5
C	5.7	< 5.0

Source: Balkema (1992)

Materials and Methods

Materials

The materials that were used for this study includes: Powdered Burnt Bricks (PBB), Rice Husk Ash (RHA), Saw Dust Ash (SDA), Fine Aggregate (Sand), Coarse Aggregate (Gravel), Ordinary Portland Cement (OPC) (Dangote Brand), concentrated solutions of H_2SO_4 / $MgSO_4$ and tap water. The PBB was obtained from broken burnt bricks which were sourced from Funtua Bricks Producing Industry Funtua, Katsina State. Pieces of the broken bricks were subjected to manual crushing using pestle and mortar in the laboratory to form powdering particles. The powder was then sieved using electric vibrating table shaker. Only powdered particles that passed through the 75-micron standard BS sieve (No. 200) were collected and used for the research. The Rice Husk used was obtained from Samaru Rice Milling Factory, Zaria. It was burnt into ashes through the electric furnace in Industrial Design Centre, Zaria. Rice Husk was converted into ashes at control temperature of 650 °C for six hours (Dahiru and Zubairu, 2008). The ash obtained was then ground in grinding machine and sieved with the use of the same micrometer sieve that was used for the PBB. Also, the saw dust used for the study was obtained from local furniture making beside Samaru market in Zaria. It was sun-dried and then converted into ashes at control temperature of 650 °C for six hours (Elinwa and Mahmood, 2002). The ash obtained (SDA) was then grounded in grinding machine and sieved using the same sieve as above.

Further, the coarse aggregate used was crushed granite stones obtained from a single quarry site along Sokoto-Zaria road, opposite School of Aviation Technology Zaria. The aggregate was sieved using standard sieves and the one obtained between 10 and 20mm sieves were used for the production of the test samples. The fine aggregate (sand) used was naturally, occurring clean sharp river sand. It was sieved using standard BS 4.75mm sieve size to remove impurities and only those that passed through the sieve was used for the samples production. The magnesium sulphate ($MgSO_4$) and sulphuric acid (H_2SO_4) used for the research were obtained from Chemistry Laboratory of Ahmadu Bello University, Zaria. They were prepared into different percentage (%) concentrations through the method of chemical water addition (H_2SO_4,) and chemical water dissolution ($MgSO_4$).

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Thus, 5% H_2SO_4, 5% $MgSO_4$ and 10% $MgSO_4$ ware prepared and used for the research. These were done in accordance to ASTM C 1012 recommendation. ASTM C 1012 recommends minimum of 5% and maximum of 10% Sulphate solution to carry out sulphate attack on concrete. Ordinary tap water good for drinking was adopted throughout the design mix. The chemical analysis tests that was conducted on RHA, PBB and SDA to determine their percentage composition of iron oxide (Fe_2O_2), silicon oxide (SiO_2), magnesium oxide (MgO), aluminum oxide (Al_2O_3) and Loss on Ignition (LOI) was conducted in energy research center, Zaria. The tests were done in accordance to ASTM C 168-94 recommendations.

Physical Properties of Materials

The specific gravity of the various samples of PBB, RHA and SDA were determined in the laboratory in accordance to the requirement of ASTM C 127-93 (1993). The uncompacted bulk density of each pozzolana and fine aggregate were determined by the method recommended by BS 812: Part 2 (1990). The moisture content test of samples of RHA, PBB and SDA were also determined in accordance to BS 1377: Part 2 (1990).

Specimens Production and Compressive Strength Test

The concrete cubes produced for this study includes OPC/RHA, OPC/PBB, OPC/SDA and 100% OPC. The 100% OPC cube served as the control. 0.65 water / cement (w/c) ratio was adopted for all the specimens produced. The w/c

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ratios were obtained from the resu
the trial mix design that was
conducted before the start of the a
mix. Absolute volume method
calculation was used to determine
quantities of the materials used fo
research. Physical properties such
workability, setting time and soundn
of the mix were determined
accordance with ASTM C 143
ASTM C 451-89 and BS 4550: 19
respectively. It is essential to know t
twenty seven (27) samples of 150x 1
x150mm concrete cubes were produc
for each pozzolana as well as
control. Curing of the concrete cub
was done by complete immersion
ordinary water for 28 days. At 28 da
curing periods, three concrete cub
were removed from each pozzolana a
the control. The cubes were allowed
dry in open air for 6 hours a
thereafter, subjected to compress
strength test. The remaining concr
cubes were subsequently allowed to
and then transferred (complete
immersed) into chemical solutions
5% $MgSO_4$, 10% $MgSO_4$ and
H_2SO_4 for another 28 and 56 da
Samples of RHA, PBB, SDA
control were equally immersed
ordinary water at the start of
chemical test which served as the ba
of the comparison. The specimens
chemicals were covered with polyth
leather to prevent air interruption
could affect the concentration of
chemicals (ASTM C 1012). At 28 d
immersion, three concrete cubes w
removed from each chemical
ordinary water. The cubes were
allowed to dry in open air for 6 h
and thereafter, subjected to strength
in aggressive chemicals. This was

repeated at 56 days. The percentage reduction in strengths of the specimens n water/various chemicals were determined at each immersion period 28 and 56 days) and compared. These served as the main findings, conclusion and recommendations of the study.

Results and Discussion

The Results of the Physical Properties of Materials

The results of the physical property test conducted on the pozzolana (RHA, PBB and SDA) and the sand used for he research are shown in Table 4. From he results, PBB gives the highest specific gravity of 2.54 while SDA gives the lowest value of 2.13. The value obtained on PBB complied with BS 12:1991 which specified its range to be minimum of 2.20 and maximum of 2.80.The specific gravity of RHA and SDA are within the range of 1.9 to 2.4 recommended for pulverized fuel ash (Neville, 1996) and also similar to the values reported by Oyetola and Abdullahi (2006) and Dashan and Kamang (1999) on Acha Husk Ash (AHA) and RHA which was 2.13 for RHA and 2.12 for AHA. The specific gravity of the three materials are less than the specific gravity of Ordinary Portland Cement of 3.15 (Neville, 1996). This means that the three materials are lightweight constituents. The difference in the specific gravity of the three materials (RHA, PBB, and SDA) may be due to the dissimilarity in their biological origin. This may also be the reason to the disparity in the materials weight. Based on this findings, it can be concluded that SDA is the lightest in weight among the three materials followed by RHA. This consent with the findings of Sa'ad (2005) on different PBB samples.

Further, the compacted bulk density of RHA, PBB and SDA were found to be 670 kg/m^3, 1117kg/m^3 and 660 kg/m^3 respectively. The values obtained in RHA and SDA are close to the one reported by Oyetola and Abdullahi (2006), Nensok *et al.* (2012) and Aka *et al.* (2015). While the value obtained on PBB is also close to 1115 k/m^3 reported by Taylor (1991) and Aka *et al.* (2012). It was notable that the bulk density of RHA, PBB and SDA are less than that of OPC (1440kg/m^3) (Neville, 1996). This further confirmed that the three materials are actually lightweight materials. The compacted bulk density of sand used for the research was found to be very close to the range speculated by Jackson and Dhir (1998), which ranges from 1650 Kg/m^3 to 1850kg/m^3 specifically for all sandy soils before excavation.

Table 4: Physical Properties of RHA, PBB, SDA and Sand

S/No	Properties	Sample type and description			
		RHA	**PBB**	**SDA**	**Sand**
1	Specific Gravity	2.15	2.54	2.13	2.65
2	Compacted Bulk Density (kg/m^3)	670	1117	660	1600
3	Un-compacted Bulk Density (kg/m^3)	540	980	530	1490
4	Moisture Content (%)	1.01	1.01	1.01	

The Results of Chemical Analysis

The chemical analyses of RHA, PBB and SDA are presented in Tables 5, 6 and 7 respectively. The percentage total content of Silicon dioxide (SiO_2), Iron

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Oxide (Fe_2O_3) and Aluminum Oxide (Al_2O_3) on RHA, PBB and SDA were found to be 76.16%, 75.8% and 61.14% respectively. Both values on RHA and PBB are greater than the minimum of 70% specified in ASTM C 618-94 while that of SDA is less. ASTM C 618 - 94 stipulates that the percentage total content of SiO_2, Al_2O_3 and Fe_2O_3 in any pozzolana should not be less than 70%. The Loss on Ignition (L.O.I) obtained was 4.52 for RHA, 0.78 for PBB and 12.5 for SDA. The value obtained on RHA and PBB are less than the 12% maximum required for pozzolana (ASTM C 618 -94, 1994) while that of SDA is slightly higher. This means that SDA contain more un-burnt carbon that might have reduced its pozzolanic activities (Oyetola and Abdullahi, 2006).

The Results of Workability Test

The results of the workabilit shown in Table 8 on each spe sample indicate that the slum 100% OPC and that of replacement of each pozzolana within the range of 6-10 mm. indicate low workability (AST 143-78). Also, the result o compacting factor test on all the ranges from 0.72 to 0.74 whic indicates low workability (S 2005).The compacting factor test the pastes is closed to the range of 0.92 recommended by Shetty (200 roads and slabs concrete. It observed from the tests results mixes containing 10% replacem RHA and SDA have lower slum that of PBB and 100% OPC. Acc to Kamang (1999), this may be the high un-burnt carbon cont RHA and SDA pastes that ma two materials to absorb more water than PBB and 100% OPC pastes.

Table 5: Chemical Analysis of RHA

Constituent	SiO_2	Fe_2O_3	Al_2O_3	MgO	L.O.I
% composition	69.5	2.16	4.50	1.50	4.52

Table 6: Chemical Analysis of PBB

Constituent	SiO_2	Fe_2O_3	Al_2O_3	MgO	L.O.I
% composition	60.50	5.30	10.00	1.70	0.78

Table 7: Chemical Analysis of SDA

Constituent	SiO_2	Fe_2O_3	Al_2O_3	MgO	L.O.I
% composition	46.5	2.14	12.5	9.25	12.5

Table 8: Workability of the Pastes

S/No	Paste Sample	W/c Ratio	Degree of workability	
			Slump(mm)	Compacting fac
1	100%OPC	0.65	10	0.74
2	RHA/OPC	0.65	6	0.72
3	PBB/OPC	0.65	8	0.73
4	SDA/OPC	0.65	6	0.72

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The Results of Setting Time Test

The result of the setting time test for each pozzolana and 100% OPC pastes are presented in Table 9. From the results, it can be observed that SDA paste has the highest initial and final setting time while 100% OPC has the least. This could be due to the higher heat of hydration evolved by 100% OPC paste over SDA, RHA and PBB pastes. Literature shows that the reaction between cement and water is exothermic which can lead to the liberation of heat to the surrounding, evaporation of moisture and consequent stiffened of the pastes (Neville, 1996). Therefore, as OPC is being replaced with pozzolana, the rate of reaction may be reduced and the quantity of heat liberated into the surrounding also reduced. Hence, the late stiffening of the pastes. It is expected that with the introduction of pozzolana to cement paste, the lower the heat liberated hence, the longer the hydration period as well as the setting time period (Neville, 1996).The difference in initial and final setting times of each pozzolan paste might be due to difference in particles found in each pozzolana. The initial and final setting time of all the pastes tested were within the range recommended for OPC paste. That is, minimum of 45 minutes for initial setting and a maximum of 10 hours for final setting (BS 4550, 1992).

The Results of the Soundness Test

The results obtained on soundness tests carried out on each sample of pozzolana and 100% OPC paste are presented in Table 10. It was observed that RHA and PBB have lower expansion as compared to SDA and 100% OPC cubes. The results of all the samples tested complied with BS 812 part 121:1989 recommendation.

Table 9: Setting Time (Minutes)

S/No	Sample paste	Initial setting time(minutes)	Final setting time (minutes)
1	100%OPC	90	190
2	RHA/OPC	150	240
3	SDA/OPC	180	290
4	PBB/OPC	130	270

Table 10: Soundness (mm)

S/No	Specimen sample	Initial pointers reading before boiling (mm)	Final pointers reading after boiling (mm)	Expansion (mm)
1	100% OPC	3	3.5	0.5
2	RHA	3	3.2	0.2
3	PBB	3	3.2	0.2
4	SDA	3	3.5	0.5

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The Results of Density and Compressive Strength Tests

(A) In ordinary water

BS 8110 (1995) recommends that the strengths of lightweight structural concrete should range from 20-40 N/mm^2 at 28 days curing periods. From the study conducted, all the concrete mixes attained the minimum compressive strength at 28 days (Table 11) exception of SDA/OPC cubes that was observed to have compressive strength of 18.05 N/mm^2.

(B) In chemical solutions of $MgSO_4$

From the results that is presented in Table 12 and 13, it can be observed that there is no substantial difference in the densities of the specimens in water at 28 and 56 hydration periods. This might mean that specimens in ordinary water were adequately compacted during mixing (Neville and Brooks, 2202). Neville and Brooks (2002) accentuated that when concrete is adequately compacted, excessive water that can lead to density increase will not be able to penetration into the capillary pores of the specimens. Also, the densities of all the specimens in ordinary water at 28 and 56 days are within the range recommended for normal weigh concrete which is between 2355 to 256 kg/m^3 (Everett, 1990).

In 5% $MgSO_4$ solution, the percentage strength reduction of 100% OPC and PBB in this chemical at 28 days were observed to be lower than the percentage strength reduction of RHA and SDA. However, as hydration progressed (56 days) the percentage strength reduction of RHA was observed to be lower than the percentage strength reduction of 100% OPC, PBB and SDA. Also, the densities of the various specimens in this chemical were observed to be higher than their densities in ordinary water. In 10% $MgSO_4$, the percentage strength reduction of 100% OPC and PBB at 28 days were also observed to be lower than the percentage strength reduction of RHA and SDA. Conversely, at 56 days, the percentage strength reduction of RHA was observed to be lower than the percentage strength reduction of 100% OPC, PBB and SDA. Also, the densities of all the specimens in this chemical solution were observed to be higher than their densities in ordinary water at 56 days.

Table 11: Average Initial Compressive Strengths of Specimen Cubes in Water at 28 Days Before Chemic Test.

S/No	Specimen Sample	W/C Ratio	Average Density (kg/m^3)	Average Compressi Strength(N/mm^2)
1	100% OPC	0.60	2439.50	24.70
2	RHA/OPC	0.65	2380.45	21.10
3	PBB/OPC	0.65	2400. 00	22.70
4	SDA/OPC	0.65	2390.00	18.05

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Table 12: Average 28 and 56 Days Compressive Strengths of Specimens in 5% $MgSO_4$

Specimens	Compressive strengths (N/mm²)		Average density (Kg/m³)		Percentage strength reduction (%)
	Water (Control)	5% MgSO4	Water (Control)	5% MgSO4	
	28 Days		28 Days		
100% OPC	28.80	28.55	2449.38	2439.51	0.87
OPC/RHA	24.30	23.50	2380.45	2390.00	3.29
OPC/PBB	26.30	25.60	2409.88	2400.00	2.67
OPC/SDA	20.10	19.00	2370.78	2380.45	5.47
	56 Days		56 Days		
100% OPC	31.60	30.52	2488.89	2479.01	3.42
OPC/RHA	28.25	28.00	2390.00	2409.88	0.88
OPC/PBB	28.20	27.84	2419.75	2419.75	1.28
OPC/SDA	22.80	20.25	2400.00	2409.88	11.18

Table 13: Average 28 and 56 Days Compressive Strengths of Specimens in 10% $MgSO_4$

Specimens	Compressive strengths (N/mm²)		Average density (Kg/m³)		Percentage strength reduction (%)
	Water (Control)	10% MgSO4	Water (Control)	10% MgSO4	
	28 Days		28 Days		
100% OPC	28.80	27.55	2449.38	2459.26	4.34
OPC/RHA	24.30	22.30	2380.45	2400.00	8.23
OPC/PBB	26.30	24.30	2409.88	2400.00	7.60
OPC/SDA	20.10	17.40	2370.78	2409.88	13.43
	56 Days		56 Days		
100% OPC	31.60	28.42	2488.89	2479.01	10.06
OPC/RHA	28.25	27.66	2390.00	2409.88	2.09
OPC/PBB	28.20	27.28	2419.75	2429.63	3.26
OPC/SDA	22.80	17.55	2400.00	2429.63	23.03

Hence, increase in density of a specimen in $MgSO_4$ solution may mean that the specimen was not well compacted or being permeable to chemical denser than water and as a result, being penetrated by $MgSO_4$. This adds to the densities of the specimen due to crystal (gypsum ($CaSO_4$)) deposition on the pores of the sample. Hence, the highest increase in densities specimen may mean the least resistant to sulphate attack (Neville and Brooks, 2002; Shetty, 2005).

(C) In chemical solution of H_2SO_4

Table 14 shows the densities and compressive straights of specimens in 5% H_2SO_4 at 28 and 56 days. High strengths reduction was observed in all the specimens tested in 5% H_2SO_4 at 56 days. Severe reduction in densities were also observed in all the specimens at 28 and 56 days. Reduction in density of a specimen in H_2SO_4 may mean that H_2SO_4 was too corrosive which led to loss of mortar on the specimen and the consequent reduction in density of the specimen. Hence, the least reduction in density specimen in H_2SO_4 may mean the highest resistant to attack by the corrosive media (H_2SO_4) (Neville and Brooks, 2002; Shetty, 2005).

Table 14: Average 28 and 56 Days Compressive Strengths of Specimens in 5% H_2SO_4

Specimens	Compressive strengths (N/mm^2)		Average density (Kg/m^3)		Percentage strength reduction (%)
	Water (Control)	5% H_2SO4	Water (Control)	5% H_2SO4	
	28 Days		28 Days		
00% OPC	28.80	22.67	2449.38	2350.61	21.28
PC/RHA	24.30	20.00	2380.45	2360.49	17.70
PC/PBB	26.30	22.05	2409.88	2370.37	16.16
PC/SDA	20.10	12.78	2370.78	2360.49	36.42
	56 Days		56 Days		
0% OPC	31.60	20.98	2488.89	2350.61	33.61
C/RHA	28.25	21.15	2390.00	2370.37	25.13
C/PBB	28.20	22.20	2419.75	2360.49	21.27
C/SDA	22.80	10.90	2400.00	2360.49	52.19

onclusions

sed on the outcomes of chemical ts conducted on RHA, PBB, SDA d 100% OPC concretes, it can be ncluded that:

RHA concrete has higher strength than PBB and SDA in ordinary water and chemical solution of $MgSO_4$ specifically at 56 days curing period;

PBB concrete exhibits higher strength than SDA concrete in ordinary water and chemical solution of $MgSO_4$;

RHA and PBB can be adopted as ulphate resistant additive in oncrete production, and

)PC/RHA, OPC/ PBB and)PC/SDA concretes perform poorly 1 5% H_2SO_4.

be also be said that the density of RHA, OPC/ PBB and OPC/SDA etes increase drastically when ed to 10% $MgSO_4$ but decrease in H_2SO_4 at 56 days. The nentioned concretes are also liable to cracking and warping in 10% $MgSO_4$ / 5% H_2SO_4 at 28 days. Further, this study also shows that the cracking conditions of concretes exposed to H_2SO_4 is more severe than that of 10% $MgSO_4$.

Recommendations

Based on the findings of the study, the following recommendations were made:

RHA and PBB are recommended for production of sulphates resisting concretes;

Effects of other sulphates different from $MgSO_4$ should be carried out on RHA and PBB concretes so as to further examine their performance in sulphate environment.

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References

American Standard for Testing Metho C 143-78, Specification f Concrete Slump.
American Standard for Testing Metho C 618-94, Specification for t

Ash and Raw' or Calcined Natural Pozzolana for Use as a Mineral Admixture in Portland Cement Concrete.

nerican Standard for Testing Method C 1012: Method for Testing Sulphates Attack on OPC Concrete.

nerican Standard for Testing Method C 451-89, Specification for Setting Time of Ordinary Portland Cement.

ka, A., Nensok, M.H. and Kaase. E.T. (2015): Effect of Rice Husk Ash on the Compressive Strength of Concrete in Chemically Aggressive Environment: *Nigerian Journal of Construction Management and Technology*.12(1&2), pp. 26-30.

ka, A., Nensok, M.H. and Adamu, N. (2012): Strength Comparative Study of Concrete Produced with Different Pozzolana: *Journal of Centre for Human Settlements and Urban Development*.. 4(1), pp. 22-30.

ritish Standard Institute BS 812: 2 (1995). Specification for Bulk Density of Materials. London, United Kingdom.

ritish Standard Institute BS 1377: 2 (1990). *Method for Determination of the Specific Gravity of Aggregates*. London, United Kingdom.

ritish Standard Institute BS 812: 121 (1989). *Method for Determination of OPC Soundness*, London, United Kingdom.

ritish Standard Institute BS 4550: 3 (1992). Standard Consistency of Cement. London, United Kingdom

British Standard Institute BS 8110: 2 (1985). Recommendation for Minimum Strength of Concrete. London, United Kingdom.

Balkema, A.A. (1992). Fly Ash as Addition to Concrete, *International Journal for Institute of Material and Environmental Research*, , 8-19.

Collepardi, M.A. (2003). A State of the Art Review on Delayed Ettringite Attack on Concrete, *Cement and Concrete Composites*, 25, 401-407

Dehwah, H.A.F. (2007). Effect of Sulfate Concentration and Associated Cation Type on Concrete. Deterioration and Morphological Changes in Cement Hydrates, *Construction and Building Materials*, 21, 29-39

Dahiru, D. and Zubairu, I.K. (2008). An assessment of properties of concrete made with Rice Husk Ash as partial replacement of cement. *Journal of Engineering and Technology (JET)*. 3, . 32-40.

Elinwa, A.U. and Mahmood, Y.A. (2002). Ash from Timber Waste as cement Replacement Materials, *Cement and Concrete Composites*, 24(2), 219-222.

Everret, P.J. (1990): *Building Material* Prentice Hall, U.K, pp. 20-25..

Feret, J.J. (1992). Influence of the Finest of Pozzolana on the Strength of Lime Natural Pozzolan cement Pasts. *Cement* *and Concrete Research*,. 1189-1195.

Garba, M.M. and Tahir, M.A. (2008): Comparative Sulphate Resistance of Pozzolanic Cement Mortal, *Journal of Engineering and Technology (JET)* 3(1), 75-81.

Holland, T.C. (2005): Silica Fume Association and United States Department of Transportation. *Federal Highway Administration Technical Report FHWA-IF-05-016.* Available at: www.slicafume.org/ pdf/silicafume-users-manual (retrieved October 31, 2014), pp. 2-8

Kosmatka, S., Kerkhoff, B. and Panerese, W. (2002): *Design and Control of Concrete Mixtures* (14th edition). Skokie, Illinois: Portland cement Association.

Kamang E.E.J. and Datok, E.P. (2001). The effects of chemicals on the properties of OPC/PFA Concrete, *Nigeria Journal of Construction Technology and Management*, 4, 12-19.

Neville, A.M. (1996). Properties of Concrete. , *London,* UK: *Longman Group Ltd.* Pp. 62-67.

Neville, A.M. and Brooks, J.J. (2002). *Concrete Technology,* (2nd Edition). Delhi, India: Person Education Ltd, Pp. 8-15, 18-34.

Nensok, M.H., Aka, A. and Adamu, N. (2012): Impact of Relative Humidity and Air Temperature on the Mechanical Properties of Rice Husk Ash (RHA) Blended Cement Concrete. *International Journal of Scientific Innovations*, 4(1), pp 16-19

Ogwu, A.A. (2001). *The Effe Aggressive Chemicals o Strength of Concrete.* I Fore Sight Press Limited. 12.

Oyetota, E.B. and Abdullahi (2006). The use of Rice Ash in Low Cost Sand Block Production, N *Journal of Constr Technology and Managem (NJCTM*), 6 (1) pp 6-9.

Smeaton, A.R. (2002): Improvi Environmental Performan Pozzolana in Concrete. *Co Industry Alliance* I Available at: www.repor com/ concrete/ reports (re Sept. 12, 2005), pp 1-14.

Sa'ad, M.M. (2005). Comp Pozzolanic Activity of S Burnt Bricks. *Unpu M.Sc. Thesis.* Departm Building Ahmadu University, Zaria.

Sa'ad, M.M., Garba M.M. and (G. (2007) Comparative S of Pozzolana- Portland mortar; *Nigerian Jou Construction, Technolo Management.* 2(2),86-91

Sadiq, O.M., Akpan A.J. an A.O. (2001): Evaluation of Conc Chemically Ag Environment. *Nigerian of construction, Techno Management,* 31(2), pp Environment.

aka.femi@fut.edu.ng

hetty, M.S. (2005). *Concrete Technology Theory and Practice*. New Delhi, India: S. Chad and Company Publishers.

aylor, W.H. (1991), *Concrete Technology and Practice,* (4th Edition). New York: McGraw Hill, Pp. 33-35, 47-57.

Zelie, J., Russie, D., Vera, D., and Krestulovie, R. (2001): Reactivity of various pozzolanic materials. *Cement and Concrete Research,* 30(1), pp. 16-55.

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