The International Journal Of Engineering And Science (IJES)
||Volume||2 ||Issue|| 4 ||Pages|| 51-56||2013||
ISSN(e): 2319 – 1813 ISSN(p): 2319 – 1805

Strength of Binary Blended Cement Composites Containing Saw Dust Ash

[1,]L. O. Ettu, [2,]O. M. Ibearugbulem , [3,]U. C. Anya, [4,]C. T. G. Awodiji, and [5,]F. C. Njoku
[1,2,3,4,5,]*Department of Civil Engineering, Federal University of Technology, Owerri, Nigeria*

Abstract
This work investigated the strength characteristics of binary blended cement composites made with Ordinary Portland Cement (OPC) and Saw Dust Ash (SDA). 105 concrete cubes and 105 sandcrete cubes of 150mm x 150mm x 150mm were produced at percentage OPC replacement with SDAof 5%, 10%, 15%, 20%, and 25% and crushed to obtain their compressive strengths at 3, 7, 14, 21, 28, 50, and 90 days of curing. The 3-21 day compressive strength values of OPC-SDAbinary blended cement concrete were found to be much lower than the control values; the 28-50 day strengths were comparable to the control values; while the 50-90 day strengths were higher than the control values especially at 5-10% replacements of OPC with SDA, ranging from 25.00N/mm^2 for 10% replacement of OPC to 26.60N/mm^2 for 5% replacement of OPC compared with the control value of 23.60N/mm^2. This same trend was observed for OPC-SDAbinary blended cement sandcrete. The variation in density was not significant. Mathematical models were developed for predicting compressive strengths of OPC-SDAbinary blended cement composites using polynomial regression analysis. The model values of compressive strengths obtained from the various model equations were found to be either exactly the same as those of the equivalent laboratory values or very close to them, especially at ages 28-90 days, with percentage differences ranging from 0 to 0.06. Thus, OPC-SDAbinary blended cement composites would be good for civil engineering works and the developed model equations can be easily used to estimate their strengths for various curing ages and percentage OPC replacement with SDA.

Key Words: *Blended cement, binary, composites, compressive strength, concrete, curing method, mix ratio, pozzolan, sandcrete.*

Date of Submission: 8 April 2013 Date Of Publication: 25, April.2013

I. INTRODUCTION

Many persons have been rendered homeless by the scarcity of building due to the high cost of Ordinary Portland cement in Nigeria and many other parts of Africa. Thus, attempts should continuously be made to reduce the cost of production of Portland cementand enhance the quality of cement. Suitable low-cost,sustainablematerials could be used as partial replacement of Portland cement to achieve this purpose. Industrial and agricultural by-products regarded as wastes in technologically disadvantaged communities have been used in this regard. Researchers have continued to intensify work on substitute materials for cement in making cement composites such as concrete and sandcrete (Olugbenga et al., 2007). Blended cements are currently used in many parts of the world (Bakar, Putrajaya, and Abdulaziz, 2010). During hydration of Portland cement, lime or calcium hydroxide [$Ca(OH)_2$] is obtained as one of the hydration products and itgreatly contributes toward the deterioration of concrete. When a pozzolanic material is blended with Portland cement it reacts with the lime to produce additional calcium-silicate-hydrate (C-S-H), which is the main cementing component. Thus the pozzolanic material reduces the quantity of lime and increases the quantity of C-S-H. Therefore, the cementing quality is enhanced if a good pozzolanic material is blended in suitable quantity with Portland cement (Padney et al., 2003).

The incorporation of agricultural by-product pozzolans has been studied with positive results in the manufacture and application of blended cements (Malhotra and Mehta, 2004). Ezeh and Ibearugbulem (2009) found good prospect in partially replacing cement with periwinkle shell ash in river stone aggregate concrete. Adewuyi and Ola (2005) successfully applied waterworks sludge as partial replacement for cement in concrete production. Elinwa and Awari (2001) investigated the potentials of groundnut husk ash concrete by partially replacing Ordinary Portland Cement with groundnut husk ash. Many other researchers have confirmed rice husk ash a pozzolanic material that can be used to partially replace OPC in making cement composites (Cordeiro, Filho, and Fairbairn, 2009;

Habeeb and Fayyadh, 2009; Rukzon, Chindaprasirt, and Mahachai, 2009.). Martirena, Middendorf, and Budelman (1998) found that sugar industry solid wastes such as sugar cane straw ash has pozzolanic activity derived from its high content of amorphous silica. Hernandez et al. (1998) also obtained results that confirmed the possibility of using sugar industry wastes as pozzolans. Singh, Singh, and Rai (2000) further found that bagasse ash could improve the later hydration properties of cement. Middendorf et al. (2003) found that solid waste of sugar cane could be mixed with clay in compounding blended cement. Adesanya (1996) investigated the properties of blended cement mortar, concrete, and stabilized earth made from OPC and Corn Cob Ash and recommended that corn cob ash can serve as replacement for OPC in the production of cement composites. Adesanya (2000) further studied the characteristics of lateritic bricks and blocks stabilized with corn cob fillers and obtained results that confirm the usability of corn cob ash as laterite stabilizer for block making. Nimityongskul and Daladar (1995) highlighted the potentialities of coconut husk ash, corn cob ash, and peanut shell ash as good pozzolans. Dwivedia et al. (2006)investigated the pozzolanicity of bamboo leaf ash and found that the compressive strength values of OPC-bamboo leaf ash blended cement concrete were lower until at 28 days of hydration when the compressive strength value of the blended cement was close to that of the control. A number of researchers have also found good prospects in using blended cements made with sawdust ash (Mehta, 1997;Elinwa and Mahmood, 2002; Elinwa and Ejeh, 2004; Elinwa, Ejeh, and Akpabio, 2005; Elinwa, Ejeh, and Mamuda, 2008; andElinwa and Abdulkadir, 2011).However, studies by Chandrasekar et al. (2003) suggest that soil chemistry as well as climatic and geographical conditions could affect the physical and chemical properties and consequently the pozzolanicityof agricultural and plant by-products.

Intensified local economic ventures in many Nigerian communities have led to increased agricultural and plant wastes such as saw dust. Large quantities of saw dust are generated every day in saw mills and timber markets scattered all over Southern Nigeria. There is therefore a need to further specifically investigate the suitability of using Nigerian saw dust ash as possible cement replacement in making cement composites. Its utilization as pozzolanic material would both reduce the problem of solid waste management (Elinwa and Ejeh, 2004) and add commercial value to the otherwise waste product.

II. METHODOLOGY

Saw dust was obtained from timber milling factories in Owerri, Imo State, Nigeria, air-dried, and calcined into ashes in a locally fabricated combustion chamber at temperatures generally below 650^{o}C. The ash was sieved and large particles retained on the 600µm sieve were discarded while those passing the sieve were used for this work. No grinding or any special treatment to improve the ash quality and enhance its pozzolanicity was applied because the researchers wanted to utilize simple processes that can be easily replicated by local community dwellers. The resultant saw dust ash (SDA) had a bulk density of 800 Kg/m^3, specific gravity of 2.00, and fineness modulus of 1.87. Other materials used for the work are Ibeto brand of Ordinary Portland Cement (OPC) with a bulk density of 1650 Kg/m^3 and specific gravity of 3.13; river sand free from debris and organic materials with a bulk density of 1580 Kg/m^3, specific gravity of 2.70, and fineness modulus of 2.84; Crushed granite of 20 mm nominal size free from impurities with a bulk density of 1510 Kg/m^3, specific gravity of 2.94, and fineness modulus of 3.65; and water free from organic impurities.

A simple form of pozzolanicity test was carried out for the SDA. It consists of mixing a given mass of the ash with a given volume of Calcium hydroxide solution [$Ca(OH)_2$] of known concentration and titrating samples of the mixture against hydrochloric acid solution of known concentration at time intervals of 30, 60, 90, and 120 minutes using phenolphthalein as indicator at normal temperature. The titre value was observed to reduce with time, confirming the ash as a pozzolan that fixed more and more of the calcium hydroxide, thereby reducing the alkalinity of the mixture. The chemical analysis of the ash showed it satisfied the ASTM requirement that the sum of SiO_2, Al_2O_3, and Fe_2O_3 should be not less than 70% for pozzolans.

A standard mix ratio of 1:2:4 (blended cement: sand: granite) was used for concrete and 1:6 (blended cement: sand) for sandcrete. Batching was by weight and a constant water/cement ratio of 0.6 was used. Mixing was done manually on a smooth concrete pavement. The SDA was first thoroughly blended with OPC at the required proportion and the homogenous blend was then mixed with the fine aggregate-coarse aggregate mix, also at the required proportions. Water was then added gradually and the entire concrete heap was mixed thoroughly to ensure homogeneity. The workability of the fresh concrete was measured by slump test, and the wet density was also determined. One hundred and five (105) concrete cubes and one hundred and five (105) sandcrete cubes of 150mm x 150mm x 150mm were produced at percentage OPC replacement with SDA of 5%, 10%, 15%, 20%, and 25%. Twenty one concrete cubes and twenty one sandcrete cubes with 100% OPC were also produced to serve as controls.

This gives a total of 126 concrete cubes and 126 sandcrete cubes. All the concrete cubes were cured by immersion while the sandcrete cubes were cured by water sprinkling twice daily in a shed. Three concrete cubes and three sandcrete cubes for each percentage replacement of OPC with SDA and the control were tested for saturated surface dry bulk density and crushed to obtain their compressive strengths at 3, 7, 14, 21, 28, 50, and 90 days of curing. Average values of concrete and sandcrete compressive strengths and densities for the various curing ages and percentages of OPC replacement with SDA were obtained and presented in tables and graphs. Mathematical models were developed in form of equations through polynomial regression analysis of the data showing the variation of concrete and sandcrete compressive strengths with curing age and percentage replacement of OPC with SDA. Suitable analytical tools in Microsoft Excel were used to plot appropriate polynomial curves, generate the corresponding mathematical equations, and obtain model values of compressive strengths for comparison with corresponding laboratory values.

III. RESULTS AND DISCUSSION

The particle size analysis showed that the SDA was much coarser than OPC, the reason being that it was not ground to finer particles. The implication of this is that whatever compressive strength values obtained using it can still be improved upon when the ash is ground to finer particles. The pozzolanicity test confirmed sawdust ash as a pozzolan since it fixed some quantities of lime over time, thereby reducing the alkalinity of the mixture as reflected in the smaller titre value over time compared to the blank titre. The compressive strengths of the binary blended cement concrete and sandcrete produced with OPC and SDA are shown in tables 1 and 2 respectively. It can be seen from table 1 that the compressive strength values of binary blended cement concrete consistently decrease with increase in percentage replacement of OPC with SDA. The 3-14 day compressive strength values are much lower than the control values for all percentage replacements of OPC with SDA. The 3-day strengths range from 3.20N/mm^2 at 25% replacement of OPC to 4.90N/mm^2 at 5% replacement of OPC compared with the control value of 7.9 N/mm^2. The 7-day strengths range from 6.50N/mm^2 at 25% replacement of OPC to 9.30N/mm^2 at 5% replacement of OPC compared with the control value of 14N/mm^2. The 14-day strengths range from 11.50N/mm^2 at 25% replacement of OPC to 17.10N/mm^2 at 5% replacement of OPC compared with the control value of 21.50N/mm^2.

Table 1. Compressive strength of blended OPC-SDA cement concrete

Age (days)	Compressive Strength (N/mm^2) for					
	0 % SDA	5 % SDA	10 % SDA	15 % SDA	20 % SDA	25 % SDA
3	7.90	4.90	4.20	4.00	3.60	3.20
7	14.00	9.30	8.70	7.00	6.80	6.50
14	21.50	17.10	16.30	14.90	12.80	11.50
21	22.10	20.20	19.50	16.30	15.70	13.00
28	23.00	22.20	20.00	19.00	17.90	16.00
50	23.50	24.40	23.00	21.70	19.30	18.50
90	23.60	26.60	25.00	23.70	22.00	21.50

Table 2. Compressive strength of blended OPC-SDA cement sandcrete

Age (days)	Compressive Strength (N/mm^2) for					
	0 % SDA	5 % SDA	10 % SDA	15 % SDA	20 % SDA	25 % SDA
3	2.70	1.80	1.80	1.70	1.50	1.40
7	5.00	2.80	2.80	2.60	2.40	2.10
14	7.10	4.20	3.80	3.40	3.00	2.70
21	8.00	5.00	4.60	4.10	3.70	3.00
28	9.30	7.30	6.00	5.30	4.70	3.90
50	9.70	9.00	8.10	7.40	6.90	6.10
90	10.30	11.20	10.50	10.00	9.40	8.30

However, the 90-day strength at 5-15% replacement of OPC with SDA is higher than that of the control, ranging from 23.70 N/mm^2 for 15% replacement of OPC to 26.60N/mm^2 for 5% replacement of OPC compared with the control value of 23.60N/mm^2. This same trend of blended cement concrete strength variation with age and percentage replacement of OPC with SDA relative to the control values is noticeable for blended cement sandcrete as shown in table 2. The 3-14 day low strength values compared to the control can be attributed to the low rate of pozzolanic reaction at those ages. The silica from the pozzolans reacts with lime produced as by-product of hydration of OPC to form additional calcium-silicate-hydrate (C-S-H) that increases the binder efficiency and the corresponding strength values at later days of curing.

The density results suggests that although the saturated surface dry bulk densities of OPC- SDAbinary blended cement concrete and sandcrete reduce slightly with both curing age and percentage replacement of OPC with SDA, the variations are of no significance for engineering purposes as they all still fall within the range for normal weight composites. As should be expected, the results show that the strength of 100% OPC concrete (the control) increases steeply with age until about 14 days. The strength still increases steadily but less steeply between 14 and 28 days, after which the strength increases much more slowly such that the strength at 90 days is not much greater than the strength at 50 days.

The variation in strength with age for the binary blended OPC-SDA cement concrete is different from the control, especially at high percentages of OPC replacement with SDA. The results show that the variation for 5% OPC replacement with SDA is not much different from that of the control, although, unlike the control, the binary blended cement concrete continues to attain much higher strength values up to 90 days. The variation for 10% and 15% OPC replacement with SDA is significantly different from that of the control. The binary blended cement concrete strength picks up more slowly up to 21 days, after which it begins to increase rapidly until 90 days and beyond. At 20% and 25% OPC replacement with SDA the strength picks up even more gradually during the early ages up to 21 days than at 10-15% replacement levels. However the increase in strength continues more steeply at the later ages of 50 days and above.

3.1 MATHEMATICAL MODELS FOR PREDICTING COMPRESSIVE STRENGTH OF OPC-SDA CEMENT COMPOSITES

The mathematical equations for predicting compressive strength of OPC-SDAbinary blended cement concrete and sandcrete obtained from the results of polynomial regression analysis are presented in this section.

3.2 Variation of OPC-SDA concrete strength with percentage SDA

$$Y_3 = 0.00006667X^4 - 0.00434074X^3 + 0.09911111X^2 - 0.99441799X + 7.89920635 \text{ ---- } (1)$$

Where Y_3 is the 3-day compressive strength in N/mm^2 of the binary blended OPC-SDA concrete and X is the percentage replacement of OPC with SDA.

$$Y_7 = 0.00012000X^4 - 0.00697778X^3 + 0.14566667X^2 - 1.45174603X + 13.95238095 \text{ ---- } (2)$$

$$Y_{14} = -0.00000667X^5 + 0.00060667X^4 - 0.01963333X^3 + 0.27283333X^2 - 1.82500000X + 21.50000000 \text{ ---- } (3)$$

$$Y_{21} = -0.00003333X^4 + 0.00157778X^3 - 0.02483333X^2 - 0.20253968X + 22.02619048 \text{ -- } (4)$$

$$Y_{28} = -0.00011000X^4 + 0.00543333X^3 - 0.08275000X^2 + 0.11023810X + 23.01785714 \text{ -- } (5)$$

$$Y_{50} = 0.00001000X^4 + 0.00067778X^3 - 0.04541667X^2 + 0.35317460X + 23.52976190 \text{ -- } (6)$$

$$Y_{90} = -0.00011000X^4 + 0.00749259X^3 - 0.17197222X^2 + 1.24867725X + 23.63134921 \text{ -- } (7)$$

Model values of OPC-SDA concrete strength from equations (1) to (7) together with their equivalent laboratory values are shown in table 3.

3.3 Variation of OPC-SDA sandcrete strength with percentage SDA

$$Y_3 = -0.00000213X^5 + 0.00017333X^4 - 0.00520000X^3 + 0.06966667X^2 - 0.41866667X + 2.70000000 \text{ ---- } (8)$$

$$Y_7 = 0.00007667X^4 - 0.00464074X^3 + 0.09536111X^2 - 0.79656085X + 4.98849206 \text{ ---- } (9)$$

$$Y_{14} = -0.00000640X^5 + 0.00048667X^4 - 0.01393333X^3 + 0.18583333X^2 - 1.21766667X + 7.10000000 \text{ ---- } (10)$$

$$Y_{21} = -0.00000933X^5 + 0.00066000X^4 - 0.01756667X^3 + 0.21750000X^2 - 1.32500000X + 8.00000000 \text{ ---- } (11)$$

$$Y_{28} = 0.00000160X^5 - 0.00010667X^4 + 0.00206667X^3 - 0.00133333X^2 - 0.43266667X + 9.30000000 \quad (12)$$

$$Y_{50} = -0.00000027X^5 - 0.00001333X^4 + 0.00110000X^3 - 0.01766667X^2 - 0.07733333X + 9.70000000 \quad (13)$$

$$Y_{90} = 0.00000533X^5 - 0.00040667X^4 + 0.01126667X^3 - 0.13983333X^2 + 0.64500000X + 10.30000000 \quad (14)$$

Model values of OPC-SDA sandcrete strength from equations (8) to (14) together with their equivalent laboratory values are shown in table 4.

Table 3: Model and laboratory values of OPC-SDA concrete strength

Age (days)	Compressive Strength in N/mm^2 for					
	0 % SDA	**5 % SDA**	**10 % SDA**	**15 % SDA**	**20 % SDA**	**25 % SDA**
L3	7.9	4.9	4.2	4	3.6	3.2
M3	7.9	4.9	4.2	4.0	3.6	3.2
L7	14	9.3	8.7	7	6.8	6.5
M7	14.0	9.5	8.2	7.5	6.6	6.5
L14	21.5	17.1	16.3	14.9	12.8	11.5
M14	21.5	17.1	16.3	14.9	12.8	11.5
L21	22.1	20.2	19.5	16.3	15.7	13
M 21	22.0	20.6	18.8	17.0	15.3	13.1
L28	23	22.2	20	19	17.9	16
M 28	23.0	22.1	20.2	18.8	18.0	16.0
L50	23.5	24.4	23	21.7	19.3	18.5
M50	23.5	24.3	23.3	21.4	19.4	18.5
L90	23.6	26.6	25	23.7	22	21.5
M90	23.6	26.4	25.3	23.4	22.2	21.5
L3 = Laboratory value at 3 days; M3 = Model value at 3 days.						

Table 4. Model and laboratory values of OPC-SDA sandcrete strength

Age (days)	Compressive Strength in N/mm^2 for					
	0 % SDA	**5 % SDA**	**10 % SDA**	**15 % SDA**	**20 % SDA**	**25 % SDA**
L3	2.7	1.8	1.8	1.7	1.5	1.4
M3	2.7	1.8	1.8	1.7	1.5	1.4
L7	5	2.8	2.8	2.6	2.4	2.1
M7	5.0	2.9	2.7	2.7	2.3	2.1
L14	7.1	4.2	3.8	3.4	3	2.7
M14	7.1	4.2	3.8	3.4	3.0	2.7
L21	8	5	4.6	4.1	3.7	3
M 21	8.0	5.0	4.6	4.1	3.7	3.0
L28	9.3	7.3	6	5.3	4.7	3.9
M 28	9.3	7.3	6.0	5.3	4.7	3.9
L50	9.7	9	8.1	7.4	6.9	6.1
M50	9.7	9.0	8.1	7.4	6.9	6.1
L90	10.3	11.2	10.5	10	9.4	8.3
M90	10.3	11.2	10.5	10.0	9.4	8.3
L3 = Laboratory value at 3 days; M3 = Model value at 3 days.						

It can be seen from tables 3 and 4 that the model values of compressive strengths obtained from the various model equations 1 to 14 are either exactly the same as those of the equivalent laboratory values or very close to them, especially at ages 28-150 days, with percentage differences ranging from 0 to 0.06. Therefore, the respective model equations are all suitable for determining the compressive strength values of OPC-SDA binary blended concrete and sandcrete for various curing ages and percentage replacement of OPC with SDA.

IV. CONCLUSIONS

The strength of OPC-SDA binary blended cement concrete with 5 to 10% replacementof OPC with SDA gets comparable to that of the control at 21 days of curing. The strength of the binary blended cement concrete at 5 to 15% replacement is higher than that of the control at 90 days of curing. This clearly shows that OPC-SDA binary blended cement concrete can be used for high strength requirements at curing ages greater than 28 days. There is similarity in the pattern of variation of OPC-SDA binary blended cement sandcrete strength with that of OPC-SDA binary blended cement concrete for different percentage replacements of OPC with SDA at 3 to 90 days of curing. Just as for concrete, OPC-SDA binary blended cement sandcrete has very low strength compared to the control at early ages up to 21 days. The strength improves greatly thereafter and increases to become greater than that of the control at ages above 50 days. This also shows that binary blended cement sandcrete could be used in civil engineering works where early strength is not a major requirement.The mathematical models/equations developed for predicting compressive strength of OPC-SDA binary blended cement composites can be used as guide in determining appropriate percentage replacement and minimum curing age to use for required strength values since the model values of compressive strengths obtained from the equations are either exactly the same as those of the equivalent laboratory values or very close to them, especially at ages 28-150 days.

REFERENCES

[1] Adewuyi, A.P., & Ola, B. F. (2005). Application of waterworks sludge as partial replacement for cement in concrete production. *Science Focus Journal*, 10(1): 123-130.

[2] Adesanya, D. A. (1996). Evaluation of blended cement mortar, concrete and stabilized earth made from OPC and Corn Cob Ash. *Construction and Building Materials*, 10(6): 451-456.

[3] Adesanya, D. A. (2000). The characteristics of lateritic bricks and blocks stabilized with corn cob fillers. *The Professional Builder*, June/July: 47-55.

[4] Bakar, B. H. A., Putrajaya, R. C., &Abdulaziz, H. (2010).Malaysian Saw dust ash –Improving the Durability and Corrosion Resistance of Concrete: *Pre-review. Concrete Research Letters*, 1 (1): 6-13,March 2010.

[5] Chandrasekhar, S., Pramada, S. K. G., &Raghavan, P. N. (2003). Review Processing,Properties And Applications of Reactive Silica From Rice Husk-An Overview. *Journal Of Materials Science*, 38: 3159-3168.

[6] Cordeiro, G. C., Filho, R. D. T., & Fairbairn, E. D. R. (2009). Use of ultrafine saw dust ash with high-carbon content as pozzolan in high performance concrete. *Materials and Structures*, 42: 983–992. DOI 10.1617/s11527-008-9437-z.

[7] Dwivedia, V. N., Singh, N. P., Das, S. S., & Singh, N. B. (2006). A new pozzolanic material for cement industry: Bamboo leaf ash. *International Journal of Physical Sciences*, 1 (3): 106-111.

[8] Elinwa, A. U., &Abdulkadir, S. (2011). Characterizing Sawdust-ash for Use as an Inhibitor for Reinforcement Corrosion. *New Clues in Sciences*, 1: 1-10.

[9] Elinwa, A. U., &Awari, A. (2001).Groundnut husk ash concrete.*Nigerian Journal of Engineering Management*, 2 (1), 8 - 15.

[10] Elinwa, A. U., &Ejeh, S. P. (2004). Effects of the incorporation of sawdust waste incineration fly ash in cement pastes and mortars. *Journal of Asian Architecture and Building Engineering*, 3(1): 1-7.

[11] Elinwa, A. U., Ejeh, S. P., &Akpabio, I. O. (2005). Using metakaolin to improve sawdust-ash concrete. *Concrete International*, 27 (11), 49 - 52.

[12] Elinwa, A. U., Ejeh, S. P., &Mamuda, M. A. (2008). Assessing of the fresh concrete properties of self-compacting concrete containing sawdust ash. *Construction and Building Materials Journal*, 22: 1178 - 1182.

[13] Elinwa, A. U., &Mahmood, Y. A. (2002). Ash from timber waste as cement replacement material. *Cement and Concrete Composites*, 24(2): 219 – 222.

[14] Ezeh, J. C., &Ibearugbulem, O. M. (2009a). Suitability of Calcined Periwinkle Shell as Partial Replacement for Cement in River stone Aggregate Concrete. *Global Journal of Engineering and Technology*, 2(4): 577-584.

[15] Habeeb, G. A., &Fayyadh, M. M. (2009).Saw dust ash Concrete: the Effect of SDA Average Particle Size on Mechanical Properties and Drying Shrinkage.*Australian Journal of Basic and Applied Sciences*, 3(3): 1616-1622.

[16] Hernandez, J. F., Middendorf, B., Martirena, M. G., &Budelmaun, H. (1998). Use of wastes of the sugar industry as pozzolana in lime pozzolana binders: Study of the reaction. *Cem.Concr. Res*., 28 (11): 1528-1536.

[17] Malhotra, V. M., & Mehta, P. K. (2004).*Pozzolanic and Cementitious Materials*. London: Taylor & Francis.Martirena, J. F., Middendorf, B., &Budelman, H. (1998). Use of wastes of the sugar industry aspozzolan in lime-pozzolan binders: study of the reaction. *Cem.Concr.Res*., 28: 1525– 1536.

[18] Mehta, P. K. (1997). Properties of blended cements made with sawdust ash. *ACI Journal Proceedings*, 74:440-442.

[19] Middendorf, B., Mickley, J., Martirena, J. F., & Ray, R. L. (2003). Masonry wall materials prepared by using agriculture waste, lime and burnt clay. In: D. Throop, R.E. Klingner (Eds.), *Masonry: Opportunities for the 21st Century*. ASTM STP 1432: 274- 283.West Conshohocken, PA. Nimityongskul, P., &Daladar, T. U. (1995). Use of coconut husk ash, corn cob ash and peanut shell ash as cement replacement. *Journal of Ferrocement*, 25(1): 35-44.

[20] Olugbenga, A. (2007). Effects of Varying Curing Age and Water/Cement Ratio on the Elastic Properties of Laterized Concrete.*Civil Engineering Dimension*, 9 (2): 85 – 89.

[21] Padney, S. P., Singh, A. K., Sharma, R. L., &Tiwari, A. K. (2003). Studies on high-performance blended/multiblended cements and their durability characteristics. *Cement and Concrete Research*, 33: 1433-1436.

[22] Rukzon, S., Chindaprasirt, P., &Mahachai, R. (2009).Effect of grinding on chemical and physical properties of saw dust ash. *International Journal of Minerals, Metallurgy and Materials*, 16 (2): 242-247.

[23] Singh, N. B., Singh, V. D. &Rai., R. (2000). Hydration of bagasse ash-blended Portland cement. *Cem.Concr. Res*. 30: 1485-1488.