International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-9 Issue-3, February 2020

A Comprehensive Exploration on Sustainable Supplementary Cementitious Materials Derived from Agro-Wastes

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Abstract*: Concrete is one of the most popular construction materials in the present world. Cement is the binding material used in concrete and its production requires large quantity of natural raw materials and generates enormous volume of greenhouse gases like CO_2. In developing and under developed countries, the primary sector forms the crucial part of the economy. The management of waste generated from agricultural sector is becoming a major concern due to their negative impact on the environment. Under this scenario, several researchers have developed supplementary cementitious materials (SCMs) from these by products that can be used as a cement replacing material in concrete. Many of these materials have shown great performance and they enhanced the fresh and hardened properties of concrete. This paper is aimed at reviewing the performance of various SCMs from agricultural waste materials. Reviewing such materials helps to identify and develop new materials

Keywords: Supplementary Cementitious Material, Pozzolanic Material, Agricultural Waste, Concrete.

I. INTRODUCTION

Among the various fast booming industries in the world, construction industry is a major one and it has got a very important and unavoidable role in the social and economic prosperity of a country. Concrete is a very popular construction material and cement is the binding material used in concrete. Cement, aggregates and water forms the components of the concrete. The demand for concrete has been increasing in an alarming rate due to the rise in world population and uncontrolled urbanization. The components of concrete are derived from nature and the increase in concrete consumption led to depletion of natural resources associated with concrete production thereby causing severe environmental pollution. The global annual production of concrete exceeds 10 billion tonnes [1] and its production is highly expensive in terms of energy and cost. In addition to this, it generated greenhouse gases like carbon dioxide. In order to produce 1 tonne of cement, 1.7 tonnes of raw materils and 4 GJ of energy are essential [2]. In other words, the cement industry alone contributes to 7% of the CO_2 produced worldwide.[3]. Many researchers across the globe are now continuously trying to develop some efficient supplementary cementitious materials (SCMs) that can be added to concrete as a cement replacing material. Several such SCMs have shown high pozzolanic reactivity and could replace cement upto %. The pozzolanic activity enhances the overall quality of concrete by reducing heat of hydration, improving the resistance against chemical agents, and increasing the fresh and hardened properties. Many SCMs have been derived from industrial by products like flyash and recently some limited studies have focused on agricultural wastes also (Rice husk ash, Sugarcane bagasse ash etc.). Dumping of these wastes into the landfill causes various environmental issues like groundwater pollution, soil and air contamination and hazardous effects on plant and animal life. Thus, developing SCMs from agricultural by-products can be considered as an effort to protect the environment. The main aim of this paper is to review the usefulness of SCMs derived from the agricultural by- products and its impact on various properties of concrete.

II. SUPPLEMENTARY CEMENTITIOUS MATERIALS FROM AGRICULTURAL SECTOR

As mentioned earlier, most of the developing countries depend largely on agriculture and wide range of waste products are generated from this sector. Table 1 shows the data of total production of various crops as per Food and Agricultural Organisation of United Nations (FAO). Different geographical areas support different types of vegetation and researchers all over the world have analysed the effectiveness of different by-products from agriculture as a construction material. Extensive studies have been carried out on various Supplementary Cementitious Materials (SCMs) derived from agricultural by-products like Rice Husk Ash [4-8], Sugar Bagasse ash [9-14],Palm oil fuel Ash(POFA) [15-18],Cassava Waste ash [19-22] etc that can contribute to properties of fresh and hardened concrete through pozzolanic reaction.

Revised Manuscript Received on February 05, 2020.
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Table 1: Crop Production data as per FAO 2014

Crop	Production (Mt)[a]	Area (Mha)[a]
Sugar cane	1884	27
Maize	1038	185
Rice, paddy	741	163
Wheat	729	220
Potatoes	382	19
Cassava	268	24
Barley	144	49
Oranges	71	4
Coconuts	61	12
Groundnut, with shell	44	27
Sunflower seed	41	25
Maize, green	10	1
Cashew nuts	4	6
Almonds,	3	2
Sheanut	0.55	0.46

[a] data obtained from FAO 2014

III. METHODOLOGY

Considering the various SCMs used as a cement replacing materials, a general methodology of its application in concrete can be explained. The ash obtained by the combustion of agricultural by-products are initially sieved. Then chemical and microstructural analysis may be carried out. After that, the efficiency of these SCMs may be analysed by considering its impact when added to concrete on various fresh and hardened properties of concrete.

The microstructural analysis is generally carried out by using various techniques like Scanning Electron Microscope (SEM), Energy Dispersive Spectroscopy (EDS), X-ray diffraction (XRD) etc. The mechanical performance is generally checked by carrying out compressive strength test, split tensile strength test and flexural test. In addition to this, Non-destructive methods like ultra-sonic pulse velocity methods are also applied. Durability performance may be evaluated considering the parameters like Acid attack resistance, water absorption, water penetration, sulphates and chlorides attack resistance and permeability.

IV. RESULT ANALYSIS

The detailed review on various SCMs derived from agricultural by products has been carried out. The review includes the details about the development and performance evaluation of these SCMs. The result analysis of various experiments carried out by various researchers across the globe have been mentioned. The data for each material is shown under separate headings

A.RICE HUSK ASH

Rice or paddy can be considered one of the most important crops of India as well as the world. The annual worldwide production of rice exceeds 741 tonnes. Rice husk (RH) is the external covering of the rice grain and is a by-product obtained during the processing of paddy. Rice husk ash (RHA) is obtained by incinerating rice husk and it contribute nearly 20% of the weight of the rice husk [23]. RHA is an excellent SCM due to the presence of reactive silica [24]. The percentage of amorphous silica content in RHA depends on the duration and temperature of incineration. As per the studies carried out by Mehta, RHA with amorphous silica may be obtained by heating rice husk at 500 oC for longer durations [25].

Table 2: Physical Properties of RHA

Physical Properties	Specific Gravity (g/cm)	Mean Particle size (µm)	Fineness: Passing 45 µm (%)
Mehta [25]	2.06	-	99
Zhang and Mohan [27]	2.06	-	99
Bui et al [28]	2.1	7.4	-

Della et al. carried out experimental works on RH and concluded that 95 % silica content in RHA can be obtained by burning RH at 700 oC for 6 hours. Wet milling process can be applied to grind the ash to increase the surface area and surface area obtained was in the range of 54-81 Kg/m2 [26]. The physical and chemical characteristics of RHA as per various researchers are shown in table 2 and tables 3 respectively [25,27-28]

Table 3: Chemical Properties of RHA

Chemical Components	Mehta [25]	Zhang and Mohan [27]	Bui et al [28]
(SiO_2)	87.2	87.3	86.98
(Al_2O_3)	0.15	0.1	0.84
(Fe_2O_3)	0.16	0.16	0.73
(CaO)	0.55	0.55	1.4
(MgO)	0.35	0.3	0.57
(SO_3)	0.24	0.24	0.11
(Na_2O)	1.12	1.12	2.46
(K_2O)	3.68	3.68	-
(LOI)	8.55	8.5	5.14

Many studies have taken place to understand the efficiency of RHA as a SCM in concrete.

[6,29,30]. As per the research carried out by Iam and Makul, adddion of RHA to self-compacting concrete resulted in the reduction of flowability, porosity, unit weight, water absorption, compressive strength, ultrasonic pulse velocity and cost [31].

Studies carried out by Ramaswamy and Biswas revealed that the addition of RHA upto a certain optimum percentage enhances the mechanical characteristics of concrete.[32]. Detailed microstructural studies including X-ray diffraction (XRD) analysis and mechanical property evaluation were conducted by Xu et al. Highly reactive RHA with amorphous silica was obtained at 600 oC [33] Tashima et al. studied the characteristics of RHA blended cement concrete and concluded that the addition of RHA improves the strength and decrease the water absorption of concrete [24]. Preparation of high strength RHA blended concrete have been studied by numerous researchers [34-37]. Resistance to water and chloride ion penetration also improved with RHA addition [34,38]. Rahmat et al. assessed the mechanical and durability of RHA concrete and found that even though the addition of RHA improved the later age strength and homogeneity of concrete, it contributed very little to the early age strength development of concrete. The optimum replacement percentage was found to be 20%. From the Microstructural analysis of RHA blended concrete, it was understood that the RHA filled the pores of the concrete matrix. Also, the durability was assessed by exposing the specimens to aggressive environment containing 5% NaCl with wet cycling for a period of eleven months.[29]

B. WOOD ASH (WA)

Wood ash is obtained by the combustion of wood and wood products like wood chips, barks and saw dust. Since wood is considered a fuel in many of the developing and under developed countries, burning of wood generated enormous quantity of WA as the residue. Several researchers carried out investigations to know the feasibility of WA usage as a SCM in concrete. [39-44]. From the results obtained from various tests, it was concluded that WA can be used as a promising SCM in concrete and the optimum percentage of WA addition was found to be in the range of 10-12%. Raheem and Adenuga replaced cement by WA upto 25 % and found that the the compressive strength increased upto 10%. However, the strength marginally decreased beyond 10% WA content. Dawood, Eethar Thanon carried out researches on the WA and silica fume addition to mortar. As per the research findings, the addition of WA to mortar reduces the density of the mortar and this could be attributed to the low specific gravity of WA. As far as the flowability was concerned, the WA ash mortar performed better than the mix containing silica fume. [44]. Augustine and Yakubu studied the effect of ash derived from saw dust on the fresh and hardened properties of concrete. Addition of saw dust ash negatively influenced the slump. The slump reduced by 50% with increase in ash content by 30%. Similar to slump, at 28 days of curing, the compressive strength also decreased by 62% with increase in ash content by 30%.[40]. Naik et al. conducted detailed studies on the physical properties of WA from five separate sources and came to the conclusion that the WA samples had unit weight in the range of 162-1376 Kg/m^3. The specific gravity was in the range of 2.26-2.60. [45]

C. CORN COB ASH

Corn cob is the agricultural waste obtained from corn and the ash derived from corn cob have been studied to understand its potential to be used as a SCM. [46-48] Adesanya and Raheem investigated the workability and compressive strength characteristics of corn cob ash (CCA) blended cement concrete. Addition of CCA had a negative influence on setting time, strength and workability. Slump and compacting factor decreased with increase in CCA content. Both initial and final setting time increased with increase in CCA addition. The rate of pozzolanic reaction was also found to be slow. At early curing ages, the compressive strength was seen to be lesser than that of normal concrete but improved significantly at prolonged curing periods. The optimum CCA replacement percentage was found to be 8%. Also, the authors suggested that when CCA is used as a SCM, to get maximum strength gain, a curing period of 120 days are required [46]. Adesanya and Raheem also studied the durability of CCA blended cement concrete. Resistance to permeability and chemical attack were studied. The water absorption decreased with CCA addition. Three mixes were considered for the study. The optimum percentage of CCA addition for 1:1½:3 and 1:2:4 mix proportions were found to be 10%. Also, for 1:3:6 mix, the optimum percentage was found to be 15%. Resistance against chemical attack was studied by considering various parameters like weight loss and permeability of specimens exposed to dilute sulphuric acid and hydrochloric acid. The optimum percentage was concluded to be 15%. [47]. Studies carried out on the thermal conductivity of CCA concrete revealed that the addition of CCA decreased the thermal conductivity of concrete [48].

D. WHEAT STRAW ASH (WSA)

Wheat plant is cultivated all over the world and the common species of wheat plant is Triticum aestivum. As per FAO 2014, the production of wheat is nearly 730 Mega tones. Wheat is considered as an annual plant and the length of the stalk varies between 35-100 cm. Wheat straw ash which is derived from, wheat straw contains considerable amount of SiO_2 (nearly 73 %) that makes it a good pozzolanic material in concrete. Wheat straws contain various proportions of elements like C, H, O, N, Si, Fe, Ca, Al, Na, Mg, P K, Cu and Mn [49,50]. Biricik, Hasan, et al. studied the pozzolanic properties of WSA and focused on morphological properties, chemical properties, and optimum burning temperature to obtain WSA with good efficiency. The optimum temperatures for burning was determined as 570°C and 670°C for 5 hours. But when comparing these two temperatures, pozzolanic properties for WSA obtained at 670 °C were better than that obtained at 570 °C.

It was also suggested that the volume of the material can be lessened by a pre-burning step and that will save burning energy and prevent smoke formation. Details of the physical properties are shown in table 4. [50]

Table 4: Physical Properties of WSA [50]

Properties	Specific gravity	Specific surface Blaine (cm^2/g)
K5	2.31	4850
K6	2.41	5520

K5 -ash production at 570°C

K6- ash production at 670°C

Al-Akhras et al. researched on the effect of WSA on mechanical properties of autoclaved mortar. Two different varieties of fine aggregates were used for preparing the mortar mixes ie, crushed limestone aggregate, and a mixture containing 50% natural silica and 50% wadi (local sand).From the experiments conducted, it was concluded that, except for the compressive strength of the sample containing silica-wadi mixture, the compressive, flexural and tensile strength of the specimens increased steadily when the percentage of WSA increased. From SEM analysis it was inferred that, when compared to reference samples, the autoclaved specimens that contain 7.3% WSA contained more amount of hydration products (C-S-H) [51].

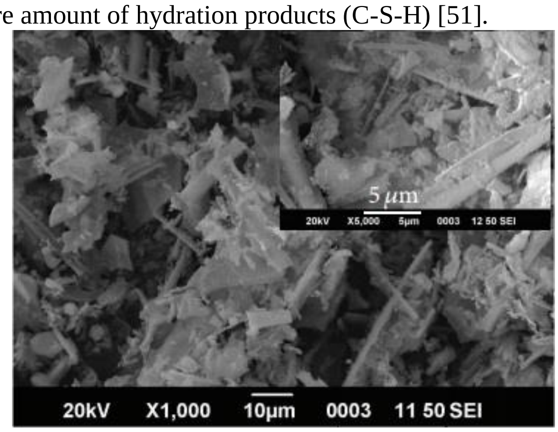

Figure 1(a): SEM image of WSA Sample [49]

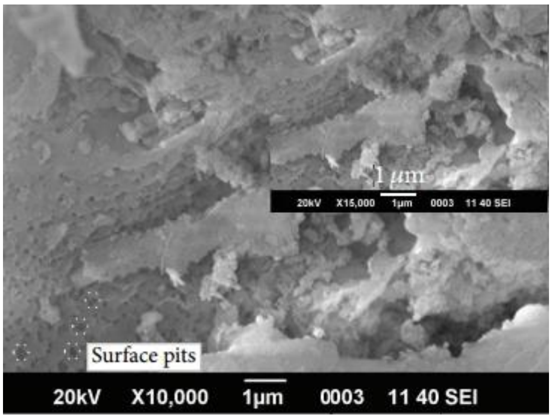

Figure 1(b): SEM image of WSA Sample [49]

Khushnood, Rao Arsalan, et al. investigated experimentally the application of WSA and Bentonite (a type of absorbent clay made by breakdown of volcanic ash) in Self-Compacting Cementitious System. Different parameters of concrete both in fresh and hardened state like water demand, super plasticizer demand, flow behaviour mechanical properties including compressive strength and flexural strength, water absorption, resistance to acid attack, porosity, microstructural and mineralogical investigations were carried out. It was reported that the mechanical properties were more or equal to the reference sample. WSA formulation seemed to be highly efficient in consuming free lime available in the matrix. The porosity also reduced considerably with time and this helped to develop the resistance of Self compacting formulation against acid attack and water absorption. The SEM analysis results are shown in figure 1(a) and figure 1(b) [49]

As per the available literature, Al-Akhras et al., has contributed a greater number of researches on wheat straw ash [51-54]. Al-Akhras (2012) carried out studies on the impact of WSA on alkali aggregate reaction. In order to study alkali aggregate reaction, 1N NaOH solution was used and the concrete specimens were submerged in it for 40 min to accelerate the reaction. Expansion of concrete samples and decrease in compressive strength were considered the factors to judge the intensity of deterioration. From the results, it was concluded that the resistance of concrete with WSA towards alkali aggregate reaction were superior than that of control concrete and the durability increased with increase in replacement percentage from 5% to 15 %. [52]. Al-Akhras et al. (2008) investigated on the impact of WSA on the efficiency of concrete against thermal cycling. The efficiency against thermal cycling were measured by considering the electrical resistivity, compressive strength and by visual inspection of various cracks developed on the concrete specimens. An electric furnace was used to provide thermal cycling over a range of 30-150°C for a period of 24 hours. From the results obtained, it was concluded that, the efficiency of WSA concrete against thermal cycling was better than that of plain concrete. And the efficiency rose when the percentage content of WSA was increased to 15%. Thermal cycling initiated and developed several cracks in concrete. The number of cracks and maximum width of cracks increased with increase in number of thermal cycles. It was also inferred that WSA concrete with W/C ratio 0.5 showed better resistance to thermal cycling when compared to WSA Concrete with W/C ratio 0.7. Similarly, air entrainment of WSA concrete also showed positive results on the resistance against thermal cycles [53].

Table 5: Initial Stetting times of concrete with different percentage of WSA[51]

WSA replacement (%)	0	10	20	30
Initial setting time (min)	150	232	245	265

Al-Akhras et al. (2011) studied the impact of WSA on resistance of concrete against deterioration caused due to freeze and thaw with different w/b ratio. It was reported that the durability of concrete samples with WSA to freeze and thaw was seen to be better than that of the reference sample and the durability increased when WSA replacement percentage increased from 5 % to 15 %.

The main reasons behind this increased durability were the pozzolanic activity and filler effect of WSA. Test results suggested that the impact of w/b was more reflected in concrete with WSA than that of control concrete. Improved durability was shown by WSA concrete with w/b ratio of 0.5 where the relative dynamic modulus came up to 87 % after 300 cycles of freeze and thaw. As the w/b reduced, the number of capillary pores also reduced and this in turn reduced the amount of water available in the pores. Thus, the hydraulic and internal pressure induced upon freezing of capillary water got lesser when compared with samples with higher w/b ratio. [54]

E. BARLEY STRAW ASH (BSA)

Barley (Hordeum vulgare) is a prominent cereal crop of the world and the total production of barley is nearly 144 Megatones. [Table 1]. The rate of production of barley has been growing in the recent few decades at an annual rate of nearly 1-2%. The main reasons for this increase include advancement in genetic breeding techniques in terms of more productive cultivars, better insect and disease control, improved and better fertilization schemes and finally improvements in agricultural production technology [55]. Obviously, the growth of barley production increases the by-product generation and the effective use of these by-products are getting importance. However only limited number of works have been carried out on the efficiency of BSA as an effective pozzolanic material in concrete

Cobreros, Carlos, et al. studied the pozzolanic activity of BSA and it was compared with properties of various natural and artificial pozzolanic materials. Micro X-Ray Fluorescence (XRF) technique was implemented to understand the chemical composition of BSA and found that the silica content was nearly 21% which can be considered a lower value when compared with other agro based pozzolanic materials like wheat straw ash. Also, the percentage of Potassium chloride was higher and its presence can bring negative impacts on the pozzolanic activity of BSA. Thus, when compared with other conventional pozzolanic materials, BSA showed less pozzolanic activity. In addition to this, lime pozzolana compressive strength development tests were carried out at 7 days and 28 days. When compared with 7-day compressive strength of the specimens, there were no development in compressive strength at 28 days of curing. [56]. Bajare, Diana, et al. suggested that the pozzolanic activity of BSA is slower and replacing cement with BSA would reduce the compressive strength of the sample. BSA addition of 20 % as cement replacement showed 73.3-75.8% compressive strength in comparison to reference sample and 40% replacement, showed 55.9-60.5% compressive strength at 28 days of curing. [57]

F. GROUNDNUT HUSK ASH (GHA) / GROUNDNUT SHELL ASH (GSA)

The total groundnut production across the globe is nearly 44 Megatonnes. Ground nut shell or ground nut husk is the outer covering of ground nut and is a by-product. Ground nut shell ash has been developed by researchers and have proved its pozzolanic properties. Mara Wazumtu and Egbe-Ngu Ntui Ogork assessed the application of GSA as an admixture in cement paste and concrete. GSA was prepared by burning of groundnut shell at 600 ºC in an incinerator for 2 hours. The obtained ash was allowed to cool and subjected to grinding before sieving through 75 µm sieve. Replacing cement by GHA up to 4% led to increase in compressive strength and resistance to sulphuric acid exposure. Also, GSA resulted in a decrease in workability, rate of setting, and water absorption of blended concrete [58]. DR. F. A. Olutoge et al., studied the strength and durability performance of GSA concrete in sulphate environments and concluded that replacement up to 10% would be acceptable to be considered for the construction of masonry structures and mass foundations exposed to sulphate environments. However, addition of GSA had a negative impact on the workability [59]. The impact of particle size of GHA on its pozzolanic properties were studied by Ogork, Egbe-Ngu Ntui, and Okorie Austine Uche. GHA was prepared from groundnut husk by controlled burning at 600 ºC for 2 hours. The compressive and flexural strength of GHA mortar increased with finer GHA particle size distribution. However, chemical analysis showed that the the sum of SiO_2, Al_2O_3 and Fe_2O_3 content was nearly 26.06% which did not satisfy the minimum value of 70% as given in ASTM C618, 2008[60]. Egbe-Ngu Ntui Ogork et al., carried out investigations on microstructural and durability characteristics of GHA concrete. Due to low pozzolanic activity, the SEM analysis of GHA concrete samples at 28 days and 90 days showed a less compact microstructure compared to OPC concrete. Durability performance was assessed by considering the resistance of GHA concrete samples against sulphuric and nitric acid exposure. Even though the presence of GHA improved the resistance of concrete against sulphuric acid, the GHA concrete was more susceptible to the impact of nitric acid [61].

G. BAMBOO LEAF ASH

Bamboo leaf ash (BLA) is obtained by burning Bamboo leaf at controlled temperatures. Researches carried out on BLA reveals its capability to be used as a SCM. [62-65]. Dwivedi et al. prepared BLA by burning bamboo leaf at 600 oC in open atmosphere for 2 hours. Experimental results showed that the BLA blended concrete with 20% BLA and normal concrete showed comparable results [62]. Ernesto Villar-Cociña et al., prepared BLA by calcining bamboo leaf at 600oC for 2 hours in an electric furnace. Physical, chemical, morphological, microstructural and pozzolanic properties were thoroughly studied. Test results confirmed the high pozzolanic reactivity of BLA. Also, chemical composition obtained through XRF showed silica concentrations in the range of 80% [65]. Moisés Fríasa et al carried out an elaborate technical study on Brazilian bamboo leaf ash and its behaviour when added as a SCM. From the study, it was concluded that BLA formed contained 78.7 % SiO2. Presence of amorphous silica was confirmed by XRD analysis. The reactivity of BLA was analysed using pozzolanic activity method and found that BLA was more reactive than commercial silica fume. The water content to obtain required consistency increased with the addition of BLA. Also, the mixes with 10% and 20% BLA satisfied the physical and mechanical requirements mentioned in EN 197-1 standards [63].

Asha et al., studied the durability performance of BLA blended cement concrete by considering various parameters like acid resistance and chloride resistance. Considering the durability performance, the optimum percentage of BLA was found to be 10%. It was also inferred that BLA can be used as SCM in circumstances where durability is the main concern and not high strength [64].

H. OLIVE WASTE ASH

Olive oil is used all over the world and Olive waste is a by-product of Olive oil production industry. Olive waste ash (OWA) is obtained by burning olive waste. Haraf Alkheder et al., attempted to utilize OWA as a partial substitute for OPC in cement paste. The ash was obtained by burning olive waste in an oven for 6 hours and was sieved through 75-micron sieve for using in the mix. Adding OWA to cement paste resulted in a decrease in its consistency, rate of initial and final setting times, compressive and flexural strengths. However, the soundness test showed that the expansion decreases with increase in OWA content [66].

Table 6: Chemical Composition of OWA [66]

Compound	Percentage (%)
K_2O	31.6
Fe_2O_3	2.5
Al_2O_3	3.1
CaO	30
SiO_2	21
Na_2O	0.4
P_2O_5	6.1
MgO	5.3
SO_3	-

Nabil M. Al-Akhras et al., assessed the performance of OWA blended cement concrete exposed to elevated temperatures. The performance of OWA concrete with OWA content up to 22% under high temperatures were proved to be better than that of normal concrete. Also, the air entrained OWA concrete performed better than non-air entrained OWA concrete under elevated temperatures [67]. Nabil M. Al-Akhras also carried out investigations on the performance of OWA blended concrete against alkali aggregate reaction. Results of the tests showed that the resistance of OWA concrete against alkali aggregate reaction deterioration was found to be better than that of control mix and the optimum percentage of OWA to be added was found to be 22% [68]

I. PALM OIL FUEL ASH

Palm oil fuel ash (POFA) is derived from various by-products obtained from palm oil industry like palm oil fibers and shells. Sooraj V.M evaluated the effectiveness of POFA as a SCM in concrete. Compressive strength, split tensile strength and flexural strength of POFA blended cement concrete were found to be lower than that of control mix concrete. [15] Joo-HwaTay carried out the feasibility study of the application of POFA as a construction material. The specific gravity and loose bulk density of the ash was found to be 1.84 and 493 Kg/m^3 respectively. Also, the ash had a pH value of 9.5. From the micro structural analysis, the specific surface area of the ash was 30% less than cement and the mean diameter of the ash was found to be more than twice the diameter of the cement. The compressive strength of POFA blended concrete was more than that of ordinary concrete at 10 % replacement levels. Also, there could see an increase in setting time with increase in POFA content in the concrete mix [69].

J. PAW PAW LEAF ASH

L. O. Ettu et al., carried out a detailed study on the strength characteristics of paw paw leaf ash (PPLA) blended cement composites. Even though the strength of PPLA blended concrete was lower than that of control mix during initial days of curing, at 90 days of curing, for 5-10% replacement percentage, the strength of PPLA blended concrete was better than that of control mix concrete [70]. L. O. Ettu et al., worked on the strength aspect of ternary blended cement concrete containing corn cob ash and paw paw leaf ash. Experimental results showed that the ternary blended cement concrete containing equal proportions of CCA and PPLA had strength values in between those of OPC-CCA and OPC-PPLA cement concretes for all percentage replacements of OPC at all curing ages [71].

V. CONCLUSION

Development of SCMs from agricultural by-products which are dumped as landfill, can be considered as an efficient way to reduce the negative impact caused to the environment. The various SCMS reviewed in this paper, derived from agricultural by-products have shown pozzolanic reactivity and have shown positive influence on properties of fresh and hardened concrete. It is suggested that a greater number of researches have to be carried out on available agro materials because there is limited data on the impact of many SCMs on various parameters of concrete like creep, shrinkage crack formation, carbonation, corrosion initiation and passivity. Thus it can be concluded that there is a wide research scope in the field of agro based SCMs and it is very important to keep in mind that, every step of research in this field will encourage the reuse of agricultural waste and may decrease cement usage that will aid the protection of the environment.

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