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Agricultural Waste Ash in the Domain of Sustainable Concrete: A Review

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***Abstract*---**The agricultural industry is a major global key. After the processing of agricultural products, an abundant amount of agricultural waste is generated and most of them are used as a combustion fuel in the industries that results in the final product agricultural waste ashes (AWA). The most commonly available AWA are rice husk ash (RHA), neem seed husk ash (NHA), palm oil fuel ash (PFA), sugarcane bagasse ash (SBA), corn cob ash (CCA), bamboo leaf ash (BLA), coconut shell ash (CSA) and wood waste ash (WA). These AWA when not properly utilized pollutes air, water, and soil. Effective utilization of these AWA in the production of sustainable and eco-friendly products leads to the reduction of environmental pollution. The production of concrete involves huge amounts of natural resources or raw materials. The production of concrete is not an environmentally friendly process. This paper reviews the use of AWA as pozzolan in producing sustainable concrete. After the review, it is noticed that the reactive silica (SiO2) and alumina (Al2O3) present in the AWA help in the enhancement of the performance of concrete and reduce the production cost of concrete.

***Keywords*---**agricultural industry, agricultural waste, global key, green concrete, sustainable concrete.

Introduction

The agricultural industry is a major global key. After the processing of agricultural products, an abundant amount of agricultural waste is generated and most of them are used as a combustion fuel in the industries that results in the final product agricultural waste ashes (AWA). The most commonly available AWA

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are RHA, PFA, SBA, CCA, BLA, CSA, NHA, and WA (Mohammad et al., 2022; Akeem et al., 2020). Most commonly these AWA are disposed in the surrounding landfills that leads to the loss of fertility and utilization potential of land. Furthermore, these landfills become a source of water, soil, and air pollution. The incineration of agricultural waste creates environmental problems. The undesirable effect of agricultural waste does include global warming, deterioration of soil fertility, smog that results in health hazards, and increasing particulate matter in the environment. Agricultural waste when burnt increases the levels of SOX, NOX, NH3, CO, CO2, non-methane hydrocarbon, volatile and semi-volatile organic compounds. Burning of 98.4 Mt of agricultural waste results in the emission of nearly 141.14 Mt of CO2, 8.57 Mt of CO, 0.037 Mt of SOX, 0.65 Mt of non-methane hydrocarbon, 1.46 Mt of non-methane volatile compounds, 0.23 Mt of NOx, and 0.12 Mt of NH3. Agricultural waste management is required to reuse them in a better way and to maintain the quality of the environment (Niveta et al., 2013; Bhuvaneshwari et al., 2019). Considering the impact of AWA, effective utilization of these materials will reduce environmental burden and also helps in producing sustainable products. In the recent past, several researchers have made extensive research on the effective utilization of these AWA as a partial substitute in producing sustainable construction materials. Agricultural waste management involves the following functions (USDA 1992):

- Production: It depends upon the production quantity of parent crop and processing techniques.
- Collection: The collection of agricultural waste involves the method of collection, supporting human resources, structural and equipment facilities.
- Storage: The storage of agricultural waste involves holding, estimation of quantity, type and storage volume, site and observation of the periodic cultivation of crops.
- Treatment: To reduce the toxic and pollution materials in the agricultural waste, effective physical, biological and chemical treatment is necessary.
- Transfer: Effective utilization of agricultural waste needs a proper transportation system from the collection landfills to the utilization site.
- Utilization: The process involves the conversion of agricultural waste into sustainable products.

The production of concrete involves the utilization of natural resources that creates a negative impact on the environment. Furthermore, every 1.0 t production of cement produces 0.8 t of CO2 (Flower et al., 2007). The extensive use of conventional aggregates resulted in the reduction of natural resources and also involves environmental issues (Blankendaal et al., 2014). To overcome these issues, the effective utilization of agricultural waste materials in producing concrete has become a major research interest. Agricultural waste materials are low in cost, abundantly available, and have excellent reactive nature (Li., 2011). Effectively utilization of these materials in producing green or sustainable concrete will result in the effective or green method of disposal of AWA. The choice of agricultural waste materials for specific purposes and suitable treatment techniques helps in the effective utilization. However, the quality of agricultural waste materials depends upon the parent source.

During the growth of plants, high amounts of silicates are absorbed from the soil and this SiO2 content makes agricultural waste more pozzolanic therefore AWA is suitable as supplementary cementing materials (SCM) in producing sustainable construction materials. A pozzolanic material is defined by its reactive siliceous and aluminous content (Biricik et al., 1999; Malhotra & Mehta, 1996). The pozzolanic nature of AWA depends mainly on the burning temperature, grinding conditions, burning time, and cooling. The efficiency of the inclusion of AWA in concrete depends upon the relation between the specific surface area and reactivity. The construction industry uses these AWA as pozzolanic materials in producing additional or secondary calcium hydrates and calcium silicates. The advantages like the enhancement of mechanical, fresh properties, and durability properties of construction materials by the use of AWA made them a viable choice as pozzolanic materials (Scrivener et al., 2018). Furthermore, the AWA are widely available, economical, eco-friendly, conserving natural resources, contribute to saving energy and reduce the production cost of concrete. In the recent past, the use of sustainable or green concrete is increased in the construction industry spurred by international and national regulations for reducing the carbon footprint. Furthermore, the construction industry is nowadays accepting sustainable construction practices for LEED certifications (Leadership in Energy and Environmental Design) (Liew et al., 2017).

Activation techniques for pozzolanic materials

The activation or initial processing of pozzolanic materials is necessary to prevent low and slow reactive nature, development of initial strength, and to accelerate the pozzolanic nature. The pozzolanic activation helps in enhancing the properties of concrete (Shi et al., 2000). The activation techniques are mechanical, chemical, temperature/curing and SCM controlled activation. A brief note on the activation processes is given below:

- Mechanical activation: This process involves the grinding of AWA to fine particles for increasing their fineness and specific surface area (Sajedi et al., 2011).
- Chemical activation: This process uses chemical substances for activating the pozzolanic nature of AWA. The popularly used chemical activators in sustainable concrete are TiO2, K2SO4, Ca(OH)2, Na2CO3, NaOH, Na2SO4, CaCl2, H2SO4, HCl, calcium formate, sodium silicate, and sodium sulphate. During the grinding process of AWA, chemical activators are mixed with AWA (Sajedi et al., 2011 & Shi et al., 2001).
- Temperature/Curing activation: In this process, the concrete with AWA is cured with temperature for a desired duration of age that helps in the enhancement of properties of concrete. The curing medium may be water, air, or both (Mirzahosseini & Riding, 2014).
- Temperature activation: This process uses elevated temperatures or above ambient temperatures for accelerating the reactive nature of concrete constituents. The most commonly used temperature activation media are water and air (Mirzahosseini & Riding, 2014).
- SCM-Controlled activation: In this process, the activation is made by using cement or SCM for activating the pozzolanic nature of AWA (Mirzahosseini & Riding, 2014).

Agricultural waste ashes in concrete
Rice husk ash

Rice husk an outer cover of rice grains is a widely available and cheap material that is commonly used as a combustion fuel in industrial operations. The inner surface of rice husk has less quality amorphous silica, while the external surface has more quantity of amorphous silica. Porous SiO2 remains as waste material in the combustion process of rice husk, resulting in a good quality of reactive silica (Jamil et al., 2013 & Jauberthie et al., 2000). The reactive nature of RHA mainly depends upon the surface area, structure of granules, and combustion process. The use of RHA in producing concrete or cement-based materials helps in the development of secondary calcium silicate hydrate and portlandite. This helps in the enhancement of concrete properties (Hotza et al., 2002). RHA reduces the moisture evaporation and heat of hydration that results in the delay of the formation of the cement matrix. The gain in the strength of concrete and the rate of reaction mainly depends on the fineness of RHA. The fineness of RHA also influences the workability, water to binder ratio, creep, and shrinkage of concrete (Begum et al., 2014 & Goncalves & Bergmann, 2007).

Maize ash/Corn cob ash

The waste produced from maize/corn is known as corn cob. The CCA is rich in silicate and alumina content that results with lime to form a dense cement matrix (Adesanya & Raheem, 2009). The replacement of CCA in concrete improves the durability property of concrete by the enhancement of water resistance capacity. Furthermore, the inclusion of CCA in concrete helps in the enhancement of compressive strength, chemical attack resistance, chloride resistance and reduces the cement permeability. The CCA contains the oxides (SiO2 and Al2O3) combination of nearly 70% to 75% with SiO2 content of about 65%. This signifies that the CCA is an excellent SCM in producing sustainable concrete (Adesanya, 1996).

Wood waste ash

The pozzolanic activity index of WA is found to be nearly 75.9% (Elinwa & Mahmood, 2002). X-ray diffraction (XRD) confirms that the WA contains an appreciable amount of reactive silica, which made WA an excellent reactive pozzolan. The pozzolanic reactive nature of WA improved the concrete strength with the age of curing (Chowdhury et al., 2015 & Siddique, 2012). From the literature survey conducted on the use of WA in concrete, it is noticed that extensive research is to be conducted on the durability properties of concrete with WA for considering the WA as a pozzolanic material.

Bamboo leaf ash

Bamboo is the fastest growing and high-yielding crop. Burning of the bamboo leaf at 600oC for about 2 hours of time produces BLA with nearly 80% of SiO2, confirming the pozzolanic nature of BLA (Dwivedi et al., 2006 & Singh et al., 2007). The inclusion of BLA in concrete showed the improvement in the hydration process and gain of strength (Chusilp et al., 2009). Extensive research is still required to declare BLA as a promising pozzolanic material.

Sugarcane bagasse ash

Sugarcane bagasse is a waste or left-over produced during the production process of raw sugar from the sugarcane crop. This waste when burnt at 600oC, results in SBA with high surface area, low carbon content, and high amounts of amorphous silica (Chusilp et al., 2009; Montakarntiwong et al., 2013; Rukzon & Chindaprasirt, 2012; Cordeiro et al., 2009). A significant decrease in the heat of hydration is observed with the addition of SBA. The 20% substitution of SBA with cement in concrete reduced the chloride penetration capacity by more than 50%, without affecting the strength of concrete. The high contents of alumina and silica in SBA accelerate the hardening process of concrete (Amin, 2011 & Ganesan et al., 2007).

Palm oil fuel ash

The palm tree is widely cultivated in the countries like Latin America, Africa, Thailand, Indonesia, and Malaysia (Oil Palm Market Monitor, FAO). PFA is obtained after the combustion of palm waste such as palm kernel shells, palm fruit fibre, and palm oil husk (Tangchirapat et al., 2007). The grinding of PFA improves the fineness and specific gravity tends to improve the reactive nature with cement in concrete (Tangchirapat et al., 2009). From the literature survey, it is observed that the PFA is moderately rich in amorphous silica (59.6% to 66.9%). The combustion of palm waste influences the percentage of carbon content in PFA. The loss of ignition of palm waste is 8.25%, which is higher than the quantified limit in ASTM C618 (ASTMC 618, 2001). The quality of PFA depends upon the parent source, the efficiency of the burning process. The high levels of substitution of PFA in concrete decrease the formation of Ca(OH)2 and helps in improving the sulfate resistance. The fine PFA has more pozzolanic reaction than coarse PFA. The use of ultrafine PFA reduces the water demand of concrete (Chindaprasirt et al., 2007). The use of PFA in concrete confirms its pozzolanic nature by increasing the strength of concrete at later ages (Jaturapitakkul et al., 2011).

Coconut shell ash

Coconut shell is a waste generated by the coconut millers after every period of coconut harvesting or plantations. This coconut shell waste is used as combustion fuel in the industries. A temperature of about 700oC for 3 hours of duration is required to produce CSA (Joshua et al., 2018). After the incineration process of the coconut shell, CSA is produced as a final product that contains reactive silica. The oxides (Fe2O3, Al2O3, and SiO2) composition of CSA is about 80.64% out of which 66.32% is silica. The loss of ignition is 48. No loss of compressive strength of concrete is observed with the substitution of CSA (Joshua et al., 2018 & Oluwafemi et al., 2019).

Neem seed husk ash

Neem seed husk is a waste produced after the removal of oil from neem seeds. This waste after undergoing the incineration process results in the production of NHA. The oxides (Fe2O3, Al2O3, and SiO2) composition of NHA is 75.34%, out of which 69.14% is SiO2 (Raheem & Ibiwoye, 2018). This confirms the pozzolanic nature of NHA. Limited research is available on the use of NHA in producing sustainable concrete and hence the research gap is to be filled by establishing the properties of concrete with NHA (Ibiwoye, 2018).

Discussion

About 500 Mt of agricultural waste is generated annually in India. This agricultural waste is to be disposed of in an efficient and effective way. Due to the cheap and abundant availability of agricultural waste, these are used as combustion fuel in the industries that result in the production of AWA (NPMCR & Jeff et al., 2017). The disposal of AWA is a serious problem and if left freely or dumped in the landfills creates air, water, and soil pollution (Lohan et al., 2018). The main factors responsible for the pozzolanic nature of AWA are namely loss of ignition and the content of oxides (SiO_2 and Al_2O_3). The particle size, density, and specific gravity of the AWA are lesser than the cement. The acceptance of AWA as a pozzolanic material mainly depends on their amorphous SiO_2 content. The minimum SiO_2 content required to satisfy the pozzolanic nature of AWA is 35% and the sum of Al_2O_3, Fe_2O_3, and SiO_2 percent by mass should not be less than 70%. The suitability of AWA or pozzolanic material can also be verified as per IS 3812:1981 (IS 3812: 1981). The physical and chemical properties of AWA are shown in Tables 1 and 2.

Table 1
Physical properties of AWA

Material	Density (%)	Density (kg/m³)	Specific gravity (%)	Specific gravity	Particle size (%)	Particle size (μm)
Cement	100	3140	100	3.12	100	25
SBA	2.87-71.33	90-2240	57.69-67.50	1.8-2.22	20.4-65.6	5.1-16.4
RHA	4.78-15.6	150-490	66.02-67.50	2.06-2.16	15.2-180	3.8-45
CCA	9.55-10.51	300-330	78.13-112.50	2.5-3.6	116-180	29-45
BLA	71.65	2250	72.11-88.46	2.25-2.76	232.4	58.1
PFA	9.55-11.15	300-350	59.38-75	1.9-2.4	42	10.5
WA	15.6-24.2	490-760	68.26-79.48	2.13-2.48	300	75-45

Table 2
Chemical oxides composition of AWA (% by mass)

Material	Loss on Ignition	Al_2O_3	SiO_2
OPC	0.193-1.3	3.7-9.87	19-22.13
SBA	0.9-10.5	3.6-6.74	62.43-87.4
RHA	0.51-8.5	0.15-1.21	86.81-95.04
CCA	-	5.97-9.14	65.39-67.33
BLA	8.04	1.22-4.13	75.9-80.4

PFA	2.3-18.22	2.6-24.6	34.3-66.91
WA	1.47-58.1	4.09-28	8.1-73.01
NHA	9.03-48	2.10-2.95	25.00-69.14

It is noticed that by the use of AWA in producing concrete, the water demand, setting time, and requirement of air-entraining agents increases. The durability properties of concrete with AWA are also needed to be investigated on a case-to-case basis. Based on the microscopic analysis, the pozzolanic reaction model is as follows: (i) At the surface of particles or interaction transition zone, there will be the movement of ions from the aqueous phase to the reaction phase. (ii) Precipitation of $Ca\ (OH)_2$ occurs. (iii) Reaction between the glassy phase of AWA and $Ca\ (OH)_2$ occurs that results in the formation of Stratlingite (C_2ASH_8) and calcium silicate hydrate. From the literature survey conducted on the use of AWA as a partial substitute to cement in producing concrete or cement-based building materials have many advantages such as chloride penetration resistance, reduces water permeability, improved durability, density, and strength of concrete. Therefore, for a clean and sustainable environment, the AWA can be effectively used as SCM in producing sustainable concrete or cement-based materials or low-cost housing materials. Behaviours of some AWA in concrete such as WA, CSA, and NHA are still not understood and a detailed investigation is required on various properties of concrete. IS 456: 2000 recommends the use of SCM's as a partial substitute to cement in producing concrete (is 456: 2000). The advantages observed by using AWA in concrete are as follows:

- Increased strength properties.
- Increased durability properties.
- Increased resistance towards chemical attack.
- Improved colour, density, finish, and appearance.
- Reduced permeability.

There is a need to develop both industrial and economic policy planning for the effective utilization of AWA such as:

- Formation of standards/references on the use of AWA in cement and concrete and also on the quality assessment.
- Identification of scientific methods to process and produce AWA by considering the local available conditions.
- Creating awareness on the effective usage of AWA in producing sustainable materials, cement, concrete, cement-based products, and low-cost building materials.

The economic and technical aspects related to the production and applications of AWA are to be addressed scientifically.

Conclusion

- The study explores different AWA that have suitable pozzolanic activity for substitution in concrete.

- The quality of AWA depends upon their combustion conditions, physical and chemical properties.
- The main constituent of AWA is the reactive silica that helps in the enhancement of the properties of concrete.
- Effective utilization of AWA as a partial substitute to cement reduces environmental pollution and also reduces the consumption of natural resources that are involved in producing cement or concrete.
- Use of AWA in producing sustainable concrete improves the chloride penetration resistance, reduces water permeability, and improves durability, density, and strength of concrete.
- Furthermore, the cost of concrete or cement-based materials or low-cost housing materials will be reduced by the inclusion of freely or cheaply available AWA.
- From the literature survey, it is observed that most of the studies are on the mechanical properties of concrete with AWA. There is a need to study the durability properties of concrete with AWA for establishing the references.
- Behaviors of some AWA in concrete such as WA, CSA, and NHA are still not understood and a detailed investigation is required on various properties of concrete.
- Extensive research studies are required on the use of agricultural waste as a partial substitute to fine aggregate in concrete for conforming to the mechanical and durability properties of concrete.
- Specifications/regulations are to be developed for technological processing and utilization of agricultural waste in concrete.
- In conclusion, there should be an enhancement in the research studies and the existing knowledge on the use of AWA in concrete that will be a valuable solution and contribution for developing sustainable construction practices.

References

Adesanya, D. A. (1996). Evaluation of blended cement mortar, concrete and stabilized earth made from ordinary Portland cement and corn cob ash. Const. Build. Mater. 10(6):451-456.

Adesanya, D. A., Raheem, A. A. (2009). Development of corn cob ash blended cement. Const. Build. Mater. 23:347-352.

Akeem, A., Raheem, Bolanle D. Ikotun. (2020). Incorporation of agricultural residues as partial substitution for cement in concrete and mortar – A review. J. Build. Engg. 31:1-10.

Amin, N. (2011). Use of bagasse ash in concrete and its impact on the strength and chloride resistivity. J Mater. Civil Engg. ASCE. 23(5):717-720.

ASTMC 618 (2001). Standard specification for coal fly ash and raw or calcined natural pozzolan for use as a mineral admixture for concrete. Annual Book of ASTM Standards.

Begum, R., Habib, A., Mostafa, S. (2014). Effects of rice husk ash on the non autoclaved aerated concrete. Int. J of Engg. Inn. & Res. 3(1):116-121.

Bhuvaneshwari, S., Hiroshan Hettiarachchi, Jay Meegoda, N. (2019). Crop Residue Burning in India: Policy Challenges and Potential Solutions. Int. J. Environ. Res. Public Health. 16.

Biricik, H., Akoz, F., Berktay, I., Tulgar, A. N. (1999). Study of pozzolanic properties of wheat straw ash. Cem. Conc. Res. 29(5):637-643.

Blankendaal, T., Schuur, P., Voordijik, H. (2014). Reducing the environmental impact of concrete and asphalt: a scenario approach. J. Clean. Prod. 66:27-36.

Chindaprasirt, P., Jaturapitakkul, C., Sinsiri, T. (2007). Effect of fly ash fineness on microstructure of blended cement paste. Const. Build. Mater. 21(7):1534-1541.

Chowdhury, S., Maniar, A., Suganya, O. M. (2015). Strength development in concrete with wood ash blended cement and use of soft computing models to predict strength parameters. J. of Adv. Res. 6:907-913.

Chusilp, N., Jaturapitakkul, C., Kiattkomol, K. (2009). Utilization of bagasse ash as a pozzolanic material in concrete. Const. Build. Mater. 23:3352-3358.

Cordeiro, G., C., Toledo, R. D. F., Fairbairn, E. M. R. (2009). Effect of calcinations temperature on the pozzolanic activity of sugar cane bagasse ash. Const. Build. Mater. 23:3301-3303.

D.A.Adesanya, A.A.Raheem. (2010). A study of the permeability and acid attack of corn cob ash blended cements. Const. Build. Mater. 24:403-409.

Dwivedi, V. N., Singh, N. P., Das, S. S., Singh, N. B. (2006). A new pozzolanic material for cement industry: Bamboo leaf ash. Int. J. Phy. Sci. 1(3):106-111.

Elinwa, A. U., Mahmood, Y. A. (2002). Ash from timber waste as cement replacement material. Cem. Conc. Comp. 24:219-222.

Flower, D., J., M., Sanjayan, J., G. (2007). Greenhouse gas emissions due to concrete manufacture. Int.J. LCA. 12(5):282-288.

Ganesan, K., Rajagopal, K., Thangavel. K. (2007). Evaluation of bagasse ash as supplementary cementitious material. Cem. Conc. Comp. 29(6):515-524.

Goncalves, M. R., Bergmann, C. P. (2007). Thermal insulators made with rice husk ashes: production and correlation between properties and microstructure. Const. Build. Mater. 21:2059-2065.

Hotza, D., Della, V. P., Kuhn, I. (2002). Rice husk ash as an alternative source for active silica production. Mater. Letters. 57:818-821.

Ibiwoye, E. O. (2020). Production and Determination of Characteristics of Neem Seed Husk Ash Blended Cement. Unpublished PhD Thesis. Department of Civil Engineering, Ladoke Akintola University of Technology. Nigeria.

IS 3812: 1981. Specification for fly ash for use as pozzolana and admixture. Bureau of Indian Standard. New Delhi.

IS 456: 2000. Plain and reinforced concrete-Code of practice. Bureau of Indian Standard. New Delhi.

Jamil, M., Kaish, A. B. M. A., Raman, S.N., Zain, M. F. M. (2013). Pozzolanic contribution of rice husk ash in cemetitious system. Const. Build. Mater. 47:588-593.

Jaturapitakkul, C., Tangpagasit, J., Songmue, S., Kiattikomal, K. (2011). Filler effect and pozzolanic reaction of ground palm oil fuel ash. Const. Build. Mater. 25:4287-4293.

Jauberthie, R., Rendell, F., Tamba, S., Cisse, I. (2000). Origin of the pozzolanic effect of rice husks. Const. Build. Mater. 14:419-423.

Jeff, S., Prasad, M., Agamuthu, P. (2017). Asia Waste Management Outlook. UNEP Asian Waste Management Outlook. United Nations Environment Programme: Nairobi, Kenya.

Joshua, O., Olusola, K. O., Busari, A. A., Omuh, I. O., Ogunde, A. O., Amusan, I. M., Ezenduka, C. J. (2018). Data on the pozzolanic activity in coconut shell ash (CSA) for use in sustainable construction, Data in Brief. 18:1142-1145.

Li, Z. (2011). Advanced Concrete Technology. John Wiley & Sons.

Liew, K. M., Sojobi, A. O., Zhang, L. O. (2017). Green concrete: Prospects and challenges. Const. Build. Mater. 156:1063-1095.

Lohan, S. K., Jat, H. S., Yadav, A. K., Siddu, H. S., Jat, M. L., Choudhary, M., Jyotsna kiran, P., Sharma, P. C. (2018). Burning issues of paddy residue management in north-west states of India. Renew. Sustain. Energy. Rev. 81:693-706.

Malhotra, V. M., Mehta, P.K. (1996). Pozzolanic and Cementitious Materials. CRC Press.

Mirzahosseini, M., Riding, K. A. (2014). Effect of curing temperature and glass type on the pozzolanic reactivity of glass powder. Cem. Conc. Res. 58:103-111.

Mohammad, I., AlBiajawi, Rahimah Embong, Khairunisa Muthusamy. (2022). An overview of the utilization and method for improving pozzolanic performance of agricultural and industrial wastes in concrete. Materials Today: Proceedings. 48(4):778-783

Montakarntiwong, K., Chusilp, N., Tangchirapat, W., Jaturapitakkul, C. (2013). Strength and heat evolution of concrete containing bagasse ash from thermal power plants in sugar industry. Mater. Des. 49:414-420.

Niveta Jain, Arti Bhatia, Himanshu Pathak. (2013). Emission of Air Pollutants from Crop Residue Burning in India. Aerosol and Air Quality Research. 14:422-430.

NPMCR. Available online: http://agricoop.nic.in/sites/default/files/npmcr_1.pdf

Oil Palm Market Monitor. FAO.

Oluwafemi, I. J., Laseinde, T. O., Akinwamide, J. (2019). Data showing the effects of geotechnical properties of lateritic soil with coconut shell powder in Ado Ekiti, south western Nigeria. Data in Brief. 24:1-16.

Raheem, A. A., Ibiwoye, E. O. (2018). A study of neem seed husk ash as partial replacement for cement in concrete. Int. J. Sus. Const. Engg. & Tech. 9(2):55-65.

Rukzon, S., Chindaprasirt. P. (2012). Utilization of bagasse ash in high-strength concrete: Technical Report. Mater. Des. 34:45-50.

Sajedi, F., Razak, H. A. (2011). Effects of thermal and mechanical activation methods on compressive strength of ordinary Portland cement – slag mortar. Mater. Des. 32(2):984-995.

Scrivener, K. L., John, V. M., Gartner, E. M. (2018). Eco-efficient cements; Potential economically viable solutions for a low CO2 cement-based materials industry. Cem. Conc. Res. 114:2-26.

Shi, C., Day, R. L. (2000). Pozzolanic reaction in the presence of chemical activators: Part I. Reaction kinetics. Cem. Conc. Res. 30(1):51-58.

Shi, C., Day, R. L. (2001). Comparison of different methods for enhancing reactivity of pozzolans. Cem. Concr. Res. 31(5):813-818.

Siddique, R. (2012). Utilization of wood ash in concrete manufacturing. Res. Cons. Recy. 67: 27-33.

Singh, N. B., Das, S. S., Singh, N. P., Dwivedi, V. N. (2007). Hydration of bamboo leaf ash blended Portland cement. Int. J Engg. Mater. Sci. 14(1):69-76.

Tangchirapat, W., Jaturapitakkul, C., Chindaprasirt. P. (2009). Use of palm oil fuel ash as a supplementary cementitious material for producing high-strength concrete. Cons. Build. Mater. 23:2641-2646.

Tangchirapat, W., Saeting, T., Jaturapitakkul, C., Kiattikomal, K., Siripanichgorn, A. (2007). Use of waste ash from palm oil industry in concrete. Waste Management. 27:81-88.

USDA (1992). Agricultural waste management field handbook. Part 651 of National Engineering Handbook, USA. Department of Agriculture (Washington). Soil Conservation Service, Washington, DC.