REVIEW ON SUPPLEMETRY CEMENTITIOUS MATERIALS (SCM's) FROM AGRICULTURAL WASTE

Akash patange[1].
[1] *Student, Department of chemical engineering, Laxminarayan Institute of Technology, Nagpur, Maharashtra, India.*

ABSTRACT

In modern society the concrete is heavily used as a construction material. With the growth of urbanization and industrialization, the demand for concrete is increasing day by day. Therefore, raw materials and natural resources are required in large quantities for concrete production worldwide. At the same time considerable amount of growing waste is also a concern for solid waste management and the disposal is possessing serious environmental issues. Furthermore, the cement industry is a significant CO2 producer. To reduce the environmental impact of concrete production, supplementary cementitious materials like ash, furnace slag, and silica fume are commonly used as supplementary cement materials. These materials are industrial waste materials. The availability of these materials is expected to decrease in future due to, e.g., alternatives for traditional fuel in industries, closing of coal power plants. Also, these materials are not available everywhere e.g., in developed countries. Thus, industrial and agricultural wastes with pozzolanic behavior can be used in concrete production as SCM's. This paper reviews the possible use of agricultural wastes as a supplementary cementitious material in the production of concrete by utilizing these wastes and studying upon their engineering, physical and chemical properties.

Keyword: - *SCM, concrete, fly ash, RHA, cement.*

---

1. INTRODUCTION -

The increasing amount of waste generated across the world is a major concern for sustainable development. According to the survey done by the world bank, 2.1 billion tons of solid waste is generated worldwide in 2016 and it is expected to increase by 70% by 2050 due to increasing urbanization and rapid population growth [1]. More specifically, there is more rapid waste generation among the urban poor regions within the most developing countries due to unsustainable waste management compared to most developed countries. Over 90% of the waste in low-income countries is either disposed of in an unregulated way or openly burned. This causing serious impacts on human health and the environment. Today, concrete has become the foremost commonly used artefact within the housing industry. The other important characteristics of concrete, besides its strength, are its ability to be easily molded into any form, it is an engineered material that can meet almost any desired specification, and is also adaptable, incombustible, affordable and simply obtained. Currently, concrete is extensively used with quite 10 billion tons produced annually. The concrete production needs raw materials such as cement, aggregate and water. Its production is typically high energy expensive, costly and expels a lot of greenhouse gases like CO_2, the cement industry is alone estimated to produce 7% of the CO_2 produced worldwide [2]. Thus, researchers all over the world are finding supplementary cementitious materials to the cement. These materials will partially replace cement in concrete. Traditionally, industrial by-products such as fly ashes and slags have been used as SCM's [3]. However, their availability is being threatened because directly linked to coal-fired power plants and iron production, which are progressively being abandoned for environmental reasons. Likewise, agricultural waste is another economically reasonable ingredient that has recently drawn much attention due to population growth, social advancement, and industrial and technological developments. Agricultural wastes such as rice husk ash, wheat straw ash, and sugarcane bagasse ash are also being used as pozzolanic materials and hazel nutshell used as cement replacement material. When pozzolanic materials are added to cement, the silica (SiO_2) present in these materials reacts with free lime released during the hydration of cement. The ash produced by controlled burning of agricultural waste materials below 700 ^{0}C incinerating temperature for one hour transforms the silica content of the ash into the amorphous phase [4]. The ash produced by incineration can be pulverized to meet the required fineness and mixed with cement to produce blended cement. The scope of this work is to increase the knowledge and investigate the utilization of agricultural residues as potential supplementary cementitious materials (SCM's) with particular focus on rice husk ash (RHA) and sugarcane bagasse ash, palm oil fuel ash (POFA). In fact, since the investigation around agricultural residues as SCM's finds its primary purpose in environmental reasons, their utilization is often seen as beneficial at a regional level, close to their production. Therefore, the search for alternative binder or cement replacement materials has become a technological interest and there is an urgent need to develop newer concrete as a reliable and durable construction material.

2. OBJECTIVES-

From an ecological point of view, one has [1-6].

[1] To produce binders that consume less energy and emit less greenhouse gases, in particular carbon dioxide.

[2] To incorporate industrial by-products and recycled materials in the cementitious binder as well as in the concrete.

[3] To produce structures that would function more efficiently over time, in terms of their durability performance.

Researchers studied the pozzolanic activity and the suitability of ash as binders for partial replacement in cement obtained from the industries. Therefore, it might possible to use agricultural waste ash as cement replacement material to improve quality and reduce the cost of construction materials [6-9].

3. MATERIALS AND PROPERTIES-

Cement manufacturing is a very complex process which involves several steps. It contains concrete aggregates, concrete admixtures, supplementary cementitious materials, etc. Cement is a controlled chemical combination of calcium, silicon, aluminum, iron and other ingredients. Common materials which are used to manufacture cement are limestone, shells, and chalk or marl combined with shale, clay, slate, blast furnace slag, silica sand, and iron ore [3].

3.1 Supplementary cementitious materials-

Basically, concrete is a mixture of Portland cement, sand, coarse aggregate and water. The main cementitious materials in concrete are Portland cement. Today, most concrete mixtures contain supplementary cementitious materials that are added to make up a proportion of the cementitious materials in concrete. These materials are generally by-products Industrial processes and natural materials. Some of these materials are called as pozzolans. These materials themselves don't have any cementitious properties but when they are used with Portland cement, reacts with it to form cementitious compounds. Other materials such as slag have some cementitious properties. Supplementary cementitious materials sometimes also referred to as mineral admixtures, they should possess some specific requirements to use in cement. These materials are added to the concrete mixture as a blended cement or as a separately batched ingredient.

Some examples of these materials are shown below- 1. Fly ash 2. Ground granulated blast furnace slag (GGBS)

3. Silica fume 4. Metakaolin clay [9].

Figure 1. Fly ash

Figure 2. GGBS

Figure 3. Silica fume

Figure 4. Metakaolin clay

Fly Ash is a by-product of coal-fired furnaces at power generation plants. It is the non-combustible particulates removed from the flue gases. GGBFS is a non-metallic material that is manufactured as a by-product from a blast furnace when iron ore is reduced to pig iron. Silica Fume is a highly reactive pozzolanic material and is a by-product from the manufacture of silicon or ferro-silicon metal. Various naturally occurring materials possess some pozzolanic properties. These materials come under the standard specification, ASTM C618. The natural pozzolans are generally derived from volcanic origins. These are siliceous materials which tend to be reactive if they are cooled rapidly.

Supplementary cementitious materials are often used for improved concrete performance in its fresh and hardened state. SCM's are fundamentally used for improved workability, durability and strength. These materials allow the concrete producer to style and modify the concrete mixture to suit the specified application, Concrete mixtures with high hydraulic cement contents are vulnerable to cracking and increased heat generation. These effects are often controlled to a particular degree by using supplementary cementitious materials.

3.2 Physical and chemical properties of traditional SCM's used in industry

The main part of SCM's in concrete is to enhance long term strength, Workability and resistance to Sulphate attack. To mix these materials with Portland cement it needs to fulfil some physical demands. These supplementary materials do not possess any cementitious properties but when they mixed with Portland cement then they help to increase the strength of concrete.

The typical Fly Ash from industries which is used in concrete is when visualized, the physical and chemical properties were as follows-

1] The size of fine-grained particles of fly ash are normal sized between 1 μm to over 100 μm.

2] Only 10- 30% Of all Fly ash particles have a size of more than 45 μm.

3] The Surface area of Fly ash particle particles lies in the range of 300 to 500 m^2/kg, (In Some particles 200 m^2/kg was lowest & 700 m^2/kg was highest).

4] The density ranges from 540 to 860 kg/m^3.

5] The Specific gravity ranges from 1.3 to 2.8.

6] Depending upon the chemical & mineral constituents present in FA, the color varies from tan to dark grey.

There is difference between the chemical composition of both type of fly ashes, the silica content in class F is more than class C which is 56.8% and in class C it is only 35 %. The aluminium oxide content is 28.2 % and 18.5 % in class F and C respectively. The ferric oxide content is 5.3 % and 5.4 % respectively. These total 3 components consist 90.3% part of class f while it consists only 58.9% in case of class C [1-6].

Table 1. Chemical and physical properties of some fly ashes [1].

Chemical properties Composition %	Fly Ash, Class F	Fly Ash, Class C
Silicon dioxide (SiO_2)	56.8	35.0
Aluminium oxide (Al_2O_3)	28.2	18.5
Ferric oxide (Fe_2O_3)	5.3	5.4
$SiO_2 + Al_2O_3 + Fe_2O_3$	90.3	58.9
Calcium oxide (CaO)	3.0	27.7
Magnesium oxide (MgO)	5.2	5.5
Sulphur oxide (SO_3)	0.7	2.4

Ground granulated furnace slag which is by-product material produced by blast-furnaces used to make iron. Due to lightweight, and high iron and calcium content it is chemically similar to Portland cement. It is composed of 30 to 40 % Silicon dioxide and 40% CaO. Silicate and alumina are the main ingredients. The physical properties are as follows.

1] It contains some amount of water which can be dried in a rotating ball mill.

2]The granulated Slag size is nearly 45 μm.

3] Surface area is approximately 400 to 600 m²/kg. shows scanning electron microscopy (SEM).

Chemical Composition of ground granulated furnace slag is as shown in Table 2.2. the pure silica content is 32.6 and 31.8% in GGBS-CRC and GGBS-SG. The aluminium content is around 14.8 and 14.5 respectively. The ferric oxide and calcium oxide content in GGBS-CRC is 0.5 and 36% respectively, While in GGBs-SG it is 0.4 and 37.6%. The magnesium oxide and Sulphur oxide in CRC is 10.3 and 0.2% while, in SG is 9.4 and 0.1% [1-6].

Table 2. Chemical composition of GGBS [1].

Chemical properties Composition %	GGBS –CRC	GGBS –SG
Pure Silica content (SiO_2)	32.6	31.8
Aluminium oxide (Al_2O_3)	14.8	14.5
Ferric oxide (Fe_2O_3)	0.5	0.4
Calcium oxide (CaO)	36.0	37.6
Magnesium oxide (MgO)	10.3	9.4
Sulphur oxide (SO_3)	0.2	0.1
Sodium oxide (Na_2O)	0.4	0.3
Potassium oxide (K_2O)	0.6	0.5

3.3 Agricultural waste-

Agricultural waste is produced from various agricultural operations. It includes manure and other wastes from farms. These wastes are the residues from the manufacturing and processing of agricultural products and may contain materials that can benefit humans, although their economic value may be lower than the cost of collection, transportation, and processing. The composition of these wastes depends on the agricultural activities involved. The different types of waste can be recycled, reused according to their properties. Some of the ways for agricultural waste management used are off-site landfill, reduction, reuse, off-site incineration without energy recovery, on-site composting, off-site energy recovery, off-site energy recycling and on-site incineration with or without energy recovery. Out of the total waste generated some waste is usable for the biogas production, which can be further used as manure after composting. But, the waste such as Rice Husk Ash (RHA), Sugarcane Bagasse Ash, Bamboo Leaf Ash, Palm oil fuel ash (POFA), Wood waste ash can be used as fuel for boilers and thermal power plants. The ash generated by burning this can be further used as SCM's in concrete. The properties and composition of this ash make it suitable for the use. The chemical composition and properties of these is as follows [1]-

Rice husk ash (RHA)- In the world and Asian countries like China. India, Indonesia, Vietnam and Bangladesh. Rice is one of the major food crops. The outer part of the rice kernel is known as the rice husk. It needs to be removed from the rice groin, Although, this rice husk can be used for production of various industrial useful products such as Sodium silicate, activated carbon, Silicon carbide or Silicon India its practical utilization is limited due to economic reasons. After complete incineration of rice husk inappropriate conditions, the residue i.e., the rice husk ash. will contain 90 - 95 %. $Si0_2$. There will be 200 kg of rice husk from 1000 kg rice paddy i.e., almost 20% and after burning rice husk ~50kg of ash will be generated. The Al_2O_3 is 0.05 % and 0.06% Fe2O3 is present. Other components such as calcium oxide, magnesium oxide and potassium oxide present in very small quantities. The chemical composition of the residue is given below in table 2.3. The physical properties are as shown in table 2.4. The specific gravity is 2.05. the fineness-median particle size is 8.6 μm. The pozzolanic activity index is 99% and water absorption capacity is 104%. Some impurities such as unburnt carbon may present in ash but it can be removed by optimizing the heat rate and cooling process. RHA derives its pozzolanic properties from its internal surface area, grinding to a high degree of fineness should be avoided.

Table 3. Chemical composition of RHA [1].

Chemical Composition (%) (Minor Constituents not Given)					
SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O
93.4	0.05	0.06	0.31	0.35	1.4

Table 4. physical properties of RHA [1].

Physical properties	
Fineness—median particle size (μm)	8.6
Specific gravity	2.05
Pozzolanic activity index (%)	99
Water absorption (%)	104

Sugarcane bagasse ash- Out of the total production of the sugarcane worldwide, almost 60-70 % of total sugar is produced in countries such as Brazil, India, China and Thailand. Following every 1000 kg of planted sugarcane produced 250 kg of bagasse and 430 kg of solid waste. The sugarcane bagasse consists of roughly 50% of cellulose, 25% of hemicelluloses and 25% of lignin. Each ton of sugarcane generates approximately 26% of bagasse (at a moisture content of 50%) and 0.62% of residual ash. The residue after combustion presents a chemical composition dominates by silica (SiO_2). The presence of Al2O3, Fe2O3, and CaO in SCBA make it a good choice as a replacement binder to cement in concrete production. The chemical composition of these constituents is 6.9%, 3.7%, 4.0%, 1.1% and 2.0% respectively. The chemical composition of SCBA is similar to POFA Therefore, having similar chemical properties, SCBA can also be considered as a substitute of cement in concrete [1]-[5]. It is often used as an alternate cementitious material. the reactivity of the sugarcane bagasse ash is often improved by reducing its particle size, e.g., by milling or grinding.

Table 5. Chemical composition of sugarcane bagasse ash [1].

Chemical Composition (%) (Minor Constituents not Given)					
SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O
65.3	6.9	3.7	4.0	1.1	2.0

Table 6. physical properties of sugarcane bagasse ash [1].

Physical properties	
Fineness—median particle size (μm)	5.1
Specific gravity	1.8
Blaine fineness (m^2/kg)	900
Water absorption (%)	104

Palm oil fuel ash (POFA)- The oil palm is a tropical palm tree, which is easily cultivated in tropical countries, such as Malaysia, Indonesia, Thailand, Africa, and Latin America, 90% of the palm oil production is generated by three of the ASEAN countries. Palm oil are often grown in many parts of the tropical world. Palm oil fuel ash (POFA) may be a waste obtained within the sort of ash through the burning of solid wastes, like vegetable oil husk or fiber and palm kernel shell, like fuel in a palm oil mill boiler. The manufacturing process of palm oil fuel ash varies from the initial preparation to the incineration process. In this process, ~5% ash by weight is produced. This ash doesn't have the nutritional value to be used as fertilizer and is usually landfilled. POFA are often utilized in concrete either as aggregates, supplementary cementitious materials or as filler material [1-4], POFA has high amorphous content with silica (SiO_2) because the main constituent. POFA is extremely rich in SiO_2 compared to cement. Comparison of chemical compositions of Portland cement and palm oil fuel ash is given in table 2.7. the silicon dioxide content in POFA is much more than cement. But, calcium oxide content in cement is 63.17% and 5.23% in POFA [5].

Table 7. comparison of Chemical composition of POFA and cement [1].

Major Chemical Composition %	Cement	POFA
Silicon Dioxide (SiO_2)	19.98	66.64
Aluminium Oxide (Al_2O_3)	5.17	3.82
Iron Oxide (Fe_2O_3)	3.27	3.70
Calcium Oxide (CaO)	63.17	5.23
Magnesium Oxide (MgO)	0.79	2.29
Sulfur Trioxide (SO_3)	2.38	0.43
Loss on Ignition (LOI)	2.5	2.32

The physical properties of POFA are shown in table 2.8. There is negligible amount of insoluble materials in palm oil fuel ash. The PH of the solution is around 7.5 to 8.0 and the total solid content in the solution is 40%. The appearance of the solution is from brown to light brown colored liquid.

Table 8. physical properties of POFA [1].

Type	**Remarks**
Appearance	Brown to light brown colored liquid
Total solids (%)	40
PH solution	7.5 to 8.0
Salt content	Max. 5%
Insoluble materials	Negligible
Chlorides as NaCl	Nil

The ash should be sieved in order to remove the organic and un-combusted matter. Furthermore, the reactivity of the ash may be increased by reducing the particle size by e.g., milling.

Bamboo leaf ash- The bamboo leaf is one among the solid wastes derived from agriculture. Bamboo is the highest yielding natural resource and has the fastest growth and can be used as fiber and other significant purposes for construction materials [8]. The bamboo leaf ash is formed by the calcination process at 6000 ^{0}c. Although not tons of research have been performed on the utilization of bamboo leaf ash in concrete, it's of great interest given the massive amounts of wastes potentially available for cement production. The higher SiO_2 content in BLA can expedite the reaction of lime crystal by forming more calcium silicate hydrate. The residue after combustion presents a chemical composition dominates by silica (SiO_2). The presence of Al_2O_3, Fe_2O_3, and CaO in bamboo leaf ash make it a good choice as an replacement binder to cement in concrete production. The chemical composition of these constituents is 4.13%, 1.22% and 7.47%respectively. Thus, bamboo leaf ash can also be an alternative binder [1-4]. The moisture content in bamboo leaf ash is 0.4 and specific gravity is 2.25 [1].

Table 9. Chemical properties of bamboo leaf ash [1].

Chemical Composition (%) (Minor Constituents not Given)					
SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O
75.9	4.13	1.22	7.47	1.85	5.62

Table 10. physical properties of bamboo leaf ash [1].

Physical properties	
Moisture content	0.40
Specific gravity	2.25

4. ANALYSIS-

When the properties of ashes generated from these waste replacement or aggregate replacement are studied. The main cause is pozzolanic reactivity. The factors which affect the use of these replacement materials are control of the heat of hydration of concrete. Temperature development in Portland cement concrete (OPC) for preventing thermal cracking due to excessive heat rise. The consistency and Setting time of the blended cement. The compressive and Splitting strength of concrete. Research on cement-based composites shows that supplementary cementitious materials reduce the porosity of concrete. which, in fact, can be performed by adding supplementary cementitious materials to fill the existing voids in the cement, hence creating strength and durability. As, the percentage of water absorption is the pore Volume or porosity in hardened concrete, which is occupied by water in Saturated condition. So, water absorption is also a critical factor while Selecting replacement materials. Generally, water is one of the main components of typical concrete. The proportion of the mixing water depends very much on the combination of the aggregates, their packing effect, and the voids in a solid material. More water is necessary to maintain workability. This can be measured by using the coefficient of water absorption. Sorptivity is also an important factor. It is a measure of the capillary forces exerted by the pore structure causing Fluids to be drawn into the body of the material [1]. Particularly when the temperature development in Portland cement concrete (OPC) and the high-volume palm oil fuel ash (POFA) concrete is studied the graph is as shown in figure 1. Due to the low heat of hydration, the temperature increase in the POFA is less than in cement. In cement, the temperature rises up to 600c while in 50% POFA it rises up to 470^0c and in 6% and 70% POFA it rises up to 440^0c and 400^0c respectively.

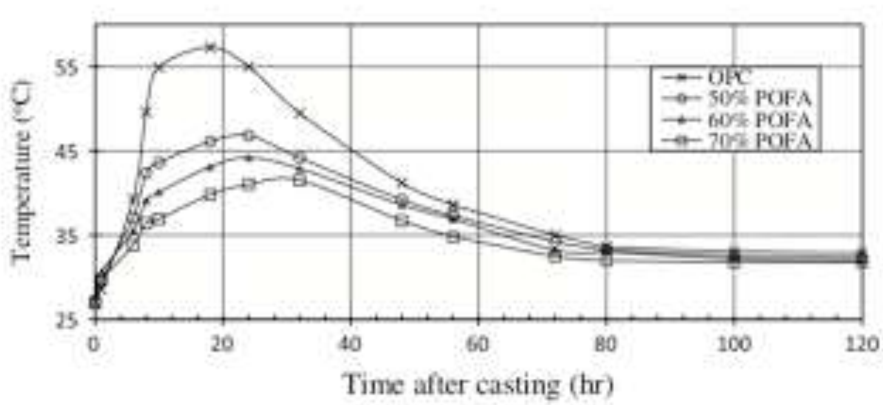

Figure 1: Temperature development in Portland cement concrete (OPC) and high-volume palm oil fuel ash (POFA) concrete [1].

POFA as partial cement replacement has a great impact on the microstructural development of the concrete. It has pozzolanic properties like Fly ash, which controls the heat of hydration, it has Low pozzolanic reactivity in earlier Stage. when water to binder ratios are studied it shown that at lower water to binder (W/b) ratio, concrete made with 30% cement replacement by POFA Show a similar range of compressive strength as concrete without POFA. In the case of RHA, which has a very high specific surface area, which has a great impact on the hydration of blended concrete. RHA has high pozzolanic reactivity. It contains other pozzolanic material Such as calcium hydroxide which is consumed during the reaction and helps to reduce porosity. The addition of RHA increases the degree of cement hydration at later Stages, which attributes internal curing ability. The macro mesoporous Structure of RHA can induce great intermolecular attraction forces and can be used as a viscosity modifying agent in concrete.

In Case of Sugarcane bagasse ash, it also has a great influence on hydration and microstructural development of blended cement. It possesses pozzolan properties. Partial replacement causes in hydration heat compared to the reference in concrete an education. The temperature rise in concrete containing sugarcane bagasse ash is shown below-

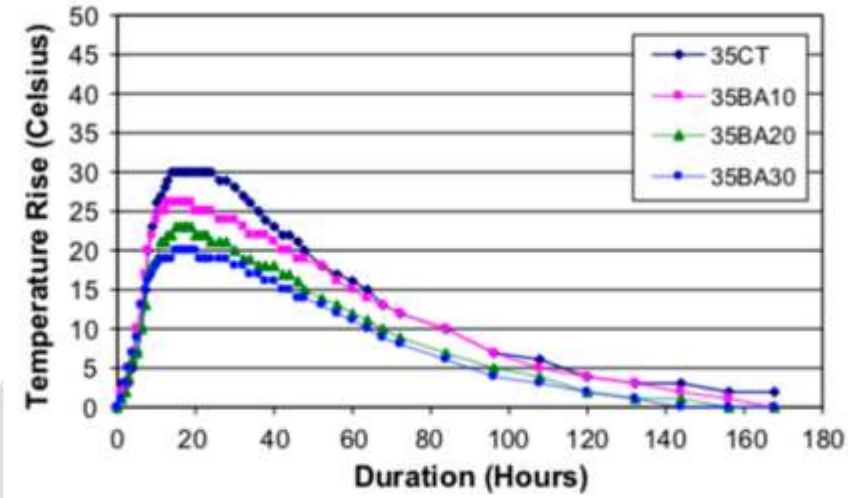

Figure 2: Temperature rise in concrete containing sugarcane bagasse ash (a number at the end indicates the percentage of sugarcane bagasse ash) [1].

Workability of concrete reduces with the increase in the amount of SCBA Content in the concrete mail in case of the mechanical properties a Study of SCBA replacement in concrete showed equal better strength than the control in concrete.

5. DISCUSSION-

Agricultural waste is widely available in developing countries and the use of that waste as a fuel is attractive from an economic point of view. The ashes produced by burning this waste are hardly of any use in industries. But, if this waste is incinerated in the appropriate conditions under controlled temperature and time, they are proven to have pozzolanic properties. This makes their use as SCM's in concrete production, which is beneficial especially in locations where other supplementary cementitious materials (SCM's) are limited. The main problem in using these materials as replacements is incomplete, current understanding of the hydration mechanism of these materials and the parameters influencing it. In addition, the long-term performance of those materials in concrete is yet to be proven. One of the main issues with the agricultural wastes is that always these got to be treated like burning at heat or grinding for having the will shape and size. However, this process requires a lot of energy and also contributes to CO_2 emission. Therefore, research must concentrate to seek out the particular advantage of reusing these waste materials in concrete. This is in addition to potential technical benefits, the use of agricultural waste as the alternative binder can lower the production cost of concrete, lower cement consumption and thus CO_2 emission.

Till the date, limited research has focused on the production and processing costs of these waste materials. In general, these wastes must be treated from their original/source condition to the stage where these are able to use in concrete as partial replacement of binders. All of this information is required so as to be ready to assess the lifecycle impact of those (potential) SCM's and possibly improve their production methods where possible. This is critical, as lower overall lifecycle costs would offer a lift for research and application of those materials in engineering practice in developing countries.

6. CONCLUSION-

Manufacture of cement is an energy-expensive process and produces a large quantity of CO_2 that aid global warming. Developing SCM's from agricultural wastes is an effective method to reduce environment pollution due to dumping of agricultural wastes and may reduce the usage of cement in the construction industry. Researchers are becoming increasingly concerned about the concept of a green economy, which is important to the environment and society. The production of cement significantly contributes to global warming due to emission of CO2. which leads to climate change. The utilization of agricultural waste can be the break-through needed which is must make the cement industry more environmentally friendly and sustainable. Many types of agricultural waste can be used as a partial replacement of cement, such as RHA, POFA, bamboo leaf ash, wood waste ash, and sugar cane bagasse ash. Each one of these materials can positively impact the concrete performance in terms of the early-age properties, late hardening, drying shrinkage, or compressive and tensile strengths. Most of these supplementary cementing materials are by-products, thus the cost of cement production can be cut down reasonably. More broadly, it is recommended that further research be undertaken on more industrial and agro-waste minerals and by-products as supplementary cementitious materials. The more these materials are added to concrete, the less cement will be used, which will eventually lead to the environmental benefits of lower emission of CO_2.

7. REFRENCES-

[1] Suvash Chandra Paul, Peter B.K. Mbewe, Sih Ying Kong and Branko Šavija (2019), Agricultural Solid Waste as Source of Supplementary Cementitious Materials in Developing Countries, MDPI, 1-20.

[2] Evi Aprianti, Payam Shafigh, Syamsul Bahri, Javad Nodeh Farahani (2015). Supplementary cementitious materials origin from agricultural wastes – A review, Construction and Building Materials, 176–187.

[3] Balagopal.V, Abdul Rahim, Viswanathan T.S. (2017). Sustainable supplementary cementitious materials derived from agro-wastes - a review, International Journal of Civil Engineering and Technology (IJCIET) Volume 8, Issue 12, December 2017, 572-582.

[4] A. K. Parande, Karthick Stalin, Ravi Kumar Thangarajan, and M. S. Karthikeyan (2011). Utilization of Agroresidual Waste in Effective Blending in Portland Cement, ISRN Civil Engineering.

[5] Haider Mohammed Owaid, Roszilah B. Hamid and Mohd Raihan Taha (2012). A Review of Sustainable Supplementary Cementitious Materials as an Alternative to All-Portland Cement Mortar and Concrete, Australian Journal of Basic and Applied Sciences.

[6] Ruben Snellings, Gilles Mertens and Jan Elsen (2012). Supplementary Cementitious Materials, Reviews in Mineralogy & Geochemistry, Vol. 74 211-278.

[7] B. Mahesh, t. Mahesh Kumar, u. Nikhil & a. Yakaswamy (2017), usage of sugarcane bagasse ash in concrete, international journal of engineering research and general science volume 5, issue 2, march-April, 2017.

[8] K. Ganesan, K. Rajagopal, K. Thangavel (2007). Evaluation of bagasse ash as supplementary cementitious material, Cement & Concrete Composites, 515–524.

[9] Use of Agricultural Wastes as Supplementary Cementitious Materials, Stockholm, 2020-09-23, 21-111.