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A Review of use of sugarcane bagasse ash in concrete

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***Abstract*—** The use of waste product such as sugarcane bagasse ash (SCBA) in concrete serves as a way to decrease the volume of waste landfills and to reduce the use of naturally mined materials. Therefore, minimizing the adverse effect that the construction industry has on the environment. This manuscript summarizes the current state of practice with regard to the use of waste product sugarcane bagasse ash as supplementary cementitious material(SCM) in Portland cement concrete(PCC). This waste product has the potential to be employed alongside traditional SCM. This document will serve as a guide for the use of nontraditional waste SCM, to highlight areas likely requiring further research. The beneficial use of waste material SCBA as SCM is very less in recent years, however current research indicates that these materials typically provide a benefit when using as SCM in concrete.

Keywords*— *cement, durability properties, mechanical properties, sugarcane bagasse ash, waste.

I. INTRODUCTION

Concrete consists of cement, aggregates, water, and and chemical admixtures. When all these materials are mixed, cement particles in contact with water undergo a hardening reaction that bonds the aggregates together. Concrete is the world's most consumed construction material because it holds good mechanical and durability properties, pleaceability, workability and it is relatively inexpensive. However, cement production involves significant CO_2 emissions, which is known as the greenhouse gas mostly important for the global warming. Each tone of cement produces approximately one tone of CO_2 and the cement industry is responsible for about 5% of global anthropogenic CO_2 emissions. Cement is manufactured in more than 80 countries and the most commonly used cement is Ordinary Portland Cement (referenced as OPC). For its production, limestone mixed with clays and small quantities of other materials needs to be heated up to 1450^{0}C. As a result of this process, clinker (about 95% in mass) is obtained. The clinker is then ground and mixed to gypsum (about 5% in mass). In the cement production green house gas (GHG) emissions come from both industrial process and fuel combustion. During the industrial process CO_2 is emitted due to the heating of limestone to obtain calcium oxide (CaO), which is the main oxide in the OPC. To reduce emissions, several recommendations can be followed in the cement industry. Conciderig the industrial process an alternative is the replacement of clinker by mineral additions that can also act as cementitious materials such as blast furnace slag and pozzolonas. The main pozzolonas currently used in cement industry are fly ash, a by-product of coal-fired power plants, and silica fume, a by- product of metallurgical processes. Other pozzolonas have also been used in a reduced scale, such as metakaolin and agro industrial ashes such as rice husk and sugarcane bagasse ash.[1]

This paper provide a review of sugarcane bagasse ash utilized as SCM, their physical and chemical characteristics, effect on mechanical and durability properties as well as information with regard to production and utilization. The newness of this document is that it provides a clear and concise summary of state of the art published research using sugarcane bagasse ash as SCM, which is waste material.

II. BACKGROUND

Supplementary cementitious material generally falls into one of two categories which are self-cementing and pozzolonic. Self-cementing material react in a similar way as that of Portland cement whereby resulting mixture hardens during an irreversible hydraulic reaction when combined with water. A pozzolon is a cementitious material, primarily siliceous in composition, which on its own does not have cementitious properties in the presence of water. When a pozzolon exposed to water and calcium it hydrates and exhibits cementitious properties.[2].

Table.I Summary of SCM types

Material	Type of SCM
Portland cement	Self-cementing
Class C fly ash	Self-cementing
Ground granulated blast furnace slag	Self-cementing
Class F fly ash	Artificial pozzolan
Rice husk ash	Artificial pozzolan
Silica fume	Artificial pozzolan
Biomass combustion ash	Artificial pozzolan
Sugarcane bagasse ash	Artificial pozzolan

Pozzolans can be further classified as artificial pozzolan and natural pozzolan. Natural pozzolan include volcanic ash diatomaceous earth, chert and shell. The use of natural pozzolon is a typical cost preventive specifically for use in concrete as compound of SCM. Artificial pozzolan consist of fly ash, ground granulated blast furnace slag, rice husk ash, silica fume, biomass combustion ash, sugarcane bagasse ash. Table.I presents SCM types.

III. PORTLAND CEMENT CHEMISTRY

Ordinary Portland cement is composed of a number of chemical oxides that can be unmanageable when written in conventional notation, therefore it can be often uses alternate nomenclature presented in table.II.

Table.II Notation for common oxides.

Notation	Chemical formula	Chemical name
C	CaO	Calcium Oxide(Lime)
S	SiO_2	Silicon Dioxide(Silica)
A	Al_2O_3	Aluminum Oxide(Alumina)
H	H_2O	Water
F	Fe_2O_3	Iron Oxide
T	TiO_2	Titanium Dioxide (Titania)
M	MgO	Magnesium Oxide (Magnesia)
K	K_2O	Potassium Oxide
N	Na_2O	Sodium Oxide

Ordinary portland cement consist of four oxides which are tricalcium silicate- C_2S, dicalcium silicate-C_2S, tricalcium alliminate-C_3A and tetracalcium aluminoferite-C_4AF, the exact composition of which may vary. Table.III provide the composition of chemical oxide for sugarcane bagasse ash.

Table.II Chemical composition of SCBA

Chemical composition	SCBA[3]
CaO	7.77
SiO_2	72.95
Al_2O_3	1.68
Fe_2O_3	1.89
MgO	1.98
K_2O	9.28

IV. SUGARCANE BAGASSE ASH

Sugarcane bagasse ash (SCBA) is obtained in huge quantities from sugar industries. After crushing of sugarcane in sugar mills and extraction of juice from processed cane by milling, the discarded fibrous matter is called bagasse. Bagasse is used as fuel in the cogeneration boiler to generate steam for the production of sugar as well as electricity. Bagasse is burnt at around 500°C in a controlled process to use its maximum fuel value. The residue after burning, namely bagasse ash is collected using a bag-house filter. Bagasse ash is directly disposed to the nearest land as slurry.

Plants ingest orthosilicic acid from ground water. When bagasse is burnt in the boiler of cogeneration plant under controlled conditions, reactive amorphous silica is formed due to the combustion process and is present in the residual ashes. This amorphous silica content makes bagasse ash a useful cement replacement material in concrete.

Use of supplementary cementitious materials significantly enhances the microstructure of concrete and helps to attain less permeable concrete. Pore structure, pore connectivity, and interfacial transition zone (ITZ) of concrete influence to a great extent the mechanical and durability properties of concrete. When pozzolanic materials are used, reactive silica present in these materials react with calcium hydroxide and produce additional C–S–H gel. Permeability of concrete is considerably reduced because of pore refinement as well as additional C–S–H formation.[4]

V. PROPERTIES OF CONCRETE WITH SUGARCANE BAGASSE ASH

Nuntachai Chusilp, Chai Jaturapitakkul, Kraiwood Kiattikomol.

Author investigated Utilization of bagasse ash as a pozzolanic material in concrete. Cement replaced by sugarcane bagasse ash at 10%, 20% and 30%. Concrete with up to 20% bagasse ash have greater compressive strength and lower water permeability as compared with control concrete both at 28 days and 90 days. The maximum temperature rise of concrete containing 10-30% bagasse ash was lower than the control concrete.[5]

G.C. Cordeiro, R.D. Toledo Filho, E.M.R. Fairbairn.

Author investigated Effect of calcination temperature on the pozzolanic activity of sugar cane bagasse ash. Bagasse ash sample were burnt in an aired electric oven at 350^0C for 3h and at different temperature ranging from 400^0C to 800^0C for another 3h. Sugarcane bagasse ash produced with air calicination at 600^0C for 3h (3 hour after 350^0C) present amorphous silica, low carbon content and high specific surface area. The sample produced with these characteristics presents considerable pozzolonic activity according to both mechanical and chemical method of evolution.[6]

Tayyeb Akram, Shazim Ali Memon, Humayun Obaid

Author investigated Production of low cost self-compacting concrete using bagasse ash. Bagasse ash used as viscosity modifying agent in self-compacting concrete. The compressive strength developed by self-compacting concrete mixes with bagasse ash at 28 days were comparable to the control concrete. Cost analysis showed that the cost of ingredients of specific self-compacting concrete mix is 35.63% less than that of control concrete.[7]

Guilherme Chagas Cordeiro, Romildo Dias Toledo Filho, Luis Marcelo Tavares, Eduardo de Moraes Rego Fairbairn.

Author investigated Ultrafine grinding of sugar cane bagasse ash for application as pozzolanic admixture in concrete. Effective application of Sugarcane bagasse ash in mortar and concrete require first the controlled use of grinding and classification process to allow it to achieve the fineness and homogeneity. It was observed that although different size distributions were produced by the different mills, the pozzolonic activity of ground ash was directly correlated to its fineness characterized by Blaine specific area. From a low pozzolonic activity of less than 50% of the as received ash, values above 100% could be reached after prolonged grinding times. Incorporation of an ultrafine ground ash in a high performance concrete in a partial replacement of Portland cement (10%, 15%, 20%) resulted in no measurable change in mechanical behavior but improved rheology and resistance to penetration of chloride ions.[8]

R.Srinivasan, K. Sathiya.

Author investigated Experimental study on bagasse ash in concrete. Cement replaced by Sugarcane bagasse ash at 0%, 5%, 10%, 15%, 20%, and 25%.From the test result it was found that the workability of sugarcane bagasse ash concrete improved. Compressive strength, split tensile strength and flexural strength increase up to 10% replacement, then it starts decreasing.[9]

Noorul Amin, Sultan Alam.

Author investigated Activation of bagasse ash in cement using different techniques. Bagasse ash activated mechanically by grinding to 250, 360 and 420m^2/kg Blaine surface areas and chemically by mixing bagasse ash with two alkalis namely potassium hydroxide and sodium hydroxide at different concentration. Test result shows that increase in fineness of bagasse ash resulted in increased strength. Alkali activation of bagasse ash led to increased strength but it is less than control mortar. Test result shows that for high ultimate strength mechanical activation is more beneficial than chemical activation.[10]

N. Amin, M. T. Shah, K. Ali, S. Alam.

Author investigated Chemical activation of bagasse ash in cement mortar. Cement replaced by SCBA at 5%, 10%, 15%, 20%, 25%, and 30%. Industrial grade $CaCl2.2H_2O$ was used as a chemical activator. Aqueous solution of calcium chloride was prepared in different percentage ranging from 1 to 6. If bagasse ash is 10% and cement is 90% then an aqueous solution of $CaCl2.2H_2O$ was used instead of water in the same ratio. The addition of $CaCl2.2H_2O$ increased the strength of the blended cement and 4% $CaCl2.2H_2O$ was found to be optimum dosage to obtain high compressive strength and 20% bagasse ash was the maximum possible amount of cement replacement.[11]

Veera Horsakulthai, Santi Phiuvanna, Watcharase Kaenbud.

Author investigated Investigation on the corrosion resistance of bagasse-rice husk-wood ash blended cement concrete by impressed voltage. OPC partially replaced by bagasse ash and rice husk wood ash at 10%, 20% and 40%. From test result it was found that with 20% replacement there is highest gain of compressive strength. Use of bagasse ash and rice husk wood ash reduces chloride penetration. Initial current and the weight loss of embedded steel reduced by using bagasse ash and rice husk wood ash. Time of initial crack increased by using bagasse ash and rice husk wood ash.[12]

Sumrerng Rukzon, Prinya Chindaprasirt.

Author investigated Utilization of bagasse ash in high-strength concrete. Cement replaced by 10%, 20%, and 30% by sugarcane bagasse ash. Incorporation of bagasse ash up to 30% increases the resistance to chloride penetration, for 10% replacement produces the concrete with good strength and low porosity.[13]

Kawee Montakarntiwong, Nuntachai Chusilp, Weerachart Tangchirapat, Chai Jaturapitakkul.

Author investigated Strength and heat evolution of concrete containing bagasse ash from thermal power plants in sugar industry. OPC replaced by bagasse ash at 20%, 30% and 40%. Compressive strength found much lower than control concrete. Concrete with low loss of ignition bagasse ash had a slightly higher compressive strength than the concrete with high loss of ignition bagasse ash.[14]

A. Bahurudeen, A.V. Marckson, Arun Kishore, Manu Santhanam.

Author investigated Development of sugarcane bagasse ash based Portland pozzolana cement and evaluation of compatibility with superplasticizers. Sugarcane bagasse ash concrete is produced at three level of replacement 10%, 15%, and 20%. Effect of superplasticizer in sugarcane bagasse ash concrete was studied. Polycarboxylic ether based superplasticizer was found compatible as compared with sulphonated naphthalene based superplasticizer in sugarcane bagasse ash concrete.[15]

T. S. Abdulkadir, D. O. Oyejobi, A. A. Lawal.

Author investigated Evaluation of sugarcane bagasse ash as a replacement for cement in concrete works. Sugarcane bagasse ash burned at 700^0C. Burned ash sieved through 45 micron sieve. Ordinary Portland cement replaced by sugarcane bagasse ash at 10%, 20%, and 30%. Result of chemical test shows that sugarcane bagasse ash has pozzolonic properties having met ASTM 595. The test result shows decrease in density and compressive strength with increase in replacement level.[16]

A. Bahurudeen and Manu Santhanam.

Author investigated Performance evaluation of sugarcane bagasse ash-based cement for durable concrete. Durability performance was investigated by different methods. The methods used were rapid chloride penetration test (RCPT), and Torrent air permeability test. The result shows that use of sugarcane bagasse ash in concrete significantly enhance its durability performance.[4]

A. Bahurudeen, Deepak Kanraj, V. Gokul Dev, Manu Santhanam.

Author investigated Performance evaluation of sugarcane bagasse ash blended cement in Concrete. Sugarcane bagasse ash is used to replace cement at 5%, 10%, 15%, 20% and

25%. Concrete of the same grade can be produced with up to 25% replacement of cement by sugarcane bagasse ash. Total heat of hydration found to be lesser as compare with cement concrete. Drying shrinkage of sugarcane bagasse ash concrete is similar to that of OPC concrete. Sugarcane bagasse ash concrete is more durable as compare with control concrete. Resistance of sugarcane bagasse ash concrete against chloride and gas penetration significantly increased as compare with control concrete.[3]

A. Bahurudeen, Manu Santhanam.

Author investigated Influence of different processing methods on the pozzolanic performance of sugarcane bagasse ash. Burnt sugarcane bagasse ash at 700^0C showed maximum pozzolonic activity. Grinding of these burnt samples to cement fineness resulted increase in pozzolonic activity.[17]

Aukkadet Rerkpiboon, Weerachart Tangchirapat, Chai Jaturapitakkul.

Author investigated Strength, chloride resistance, and expansion of concretes containing ground bagasse ash. Ground bagasse ash is used to replace ordinary Portland cement up to 50%. By use of ground bagasse ash setting time slightly affected. Concrete with 50% ground bagasse ash have compressive strength up to 90% of control concrete. Increase durability properties of concrete especially chloride ion penetration. The rapid chloride ion penetration in terms of charge passed was at very low level.[18]

Elisabeth Arif, Malcolm W. Clark, Neal Lake.

Author investigated Sugar cane bagasse ash from a high efficiency co-generation boiler applications in cement and mortar production. The sugarcane bagasse ash from high efficiency (high temperature) co-generation boiler does not contain significant amorphous silica. The high combustion temperatures appear to deactivate the silica. Compressive strength testing of the cement paste also suggests that at 5% cement replacement level, the SCBA is potentially pozzolonic. Despite an apparent lack of pozzolonic activity all SCBA additions improved sulphuric acid resistance.[19]

Rahimah Embong, Nasir Shafi, Andri Kusbiantoro, Muhd Fadhil Nuruddin.

Author investigated Effectiveness of low-concentration acid and solar drying as pre-treatment features for producing pozzolonic sugarcane bagasse ash. Pretreatment is divided in three stages viz. obtaining pretreatment variables, obtaining optimum burning variables and substantiation of pozzolonic feature. Pretreatment involved soaking of bagasse in different concentration of hydrochloric acid solution for different interval of time after which it was dried in dedicated solar drying chamber. Treated bagasse then undergoes burning process with various temperature and durations. The produced ash was characterized by determining different oxide composition, particle size analysis, mineralogical characteristics and microstructure. The ash obtained was found to be amorphous, chemically stable and ultrafine. Pozzolonic reactivity test also revealed that the ash possessed quite high pozzolonic reactivity index and suitable to be used as cement replacement material.[20]

Marcela M.N.S. De Soares, Dayana C.S. Garcia, Roberto B. Figueiredo, Maria Teresa P. Aguilar, Paulo R. Cetlin.

Author investigated Comparing the pozzolanic behavior of sugar cane bagasse ash to amorphous and crystalline SiO2. Pozzolonic behavior of sugarcane bagasse ash by comparing it to amorphous and crystalline silica studied. Test result suggests sugarcane bagasse ash should be used as a replacement for inert constituents in cement composite rather than pozzolonic addition.[21]

Parisa Setayesh Gar, Narayana Suresh, Vivek Bindiganavile.

Author investigated Sugar cane bagasse ash as a pozzolanic admixture in concrete for resistance to sustained elevated temperatures. Cement replaced by sugarcane bagasse ash at 0%, 5%, 10%, 15%, 20% & 25%. Concrete exposed to 300^0C, 400^0C and 500^0C for 2h in each case. Residual strength of above concrete are compared with the reference concrete at room temperature. Compressive strength is maximum for 10% replacement of cement by sugarcane bagasse ash. Compressive strength is equal to reference mix for 15% replacement then it falls down. Flexural strength is lower for sugarcane bagasse ash concrete as compared with reference mix.[22]

G.C. Cordeiro, R.D. Toledo Filho, L.M. Tavares, E.M.R. Fairbairn.

Author investigated Experimental characrtrization of binanry and ternary blended cement concrete containing uitrafine residual rice husk and sugarcane bagasse ash. Binary concrete- rice husk ash and sugar cane bagasse ash were used to replace cement by 20%. Ternary concrete- cement, rice husk ash and sugar cane bagasse ash used at 0.6, 0.2, 0.2 proportion. The joint influence of both ashes allowed reaching a high level of cement replacement due to positive effect in rheology and kept constant or increased compressive strength. Slight increase in yield stress and small reduction in plastic viscosity. Ternary concrete presented lower chloride ion penetration.[23]

Rattapon Somna, Chai Jaturapitakkul, Amde M. Amde

Author investigated Effect of ground fly ash and ground bagasse ash on the durability of recycled aggregate concrete. Coarse aggregate are totally replaced by recycled aggregate. Ordinary Portland cement is replaced by ground fly ash and ground bagasse ash at 20%, 35% and 50%. Compressive strength of OPC replacement by ground fly ash at 20% and OPC replacement by ground bagasse ash at 20% is same as that of recycled coarse aggregate concrete. Both ground fly ash & ground bagasse ash reduce water permeability. Both ground fly ash & ground bagasse ash improve chloride penetration resistance. The expansion of recycled aggregate concrete by sulphate attact could be reduced.[24]

Deepak Verma, Prakash Chandra Gope, Mohit Kumar Maheshwari, Ravinder Kumar Sharma.

Author investigated Mechanical properties and morphological study of fly-ash–bagasse composites. Fly ash, bagasse ash fiber composite materials were developed. The density decreases by mixing bagasse fiber. Bagasse fiber exhibit better tensile strength. Compressive strength for fly ash and bagasse fiber composite decreases. Flexural strength for fly ash and bagasse fiber composite also decreases. The image from scanning Electron Microscope Demonstrated that the fly ash and bagasse fiber uniformly distributed over the matrix.[25]

Chaiyanunt Rattanashotinunt, Pongsiri Thairit, Weerachart Tangchirapat, Chai Jaturapitakkul.

Author investigated Use of calcium carbide residue and bagasse ash mixtures as a new cementitious material in concrete. Calcium carbide residue and bagasse ash is used as a cementitous material. Result shows that by using above binder OPC consumption can be reduced up to 70%. Mechanical properties of above binder are similar to conventional concrete.[26]

V.G. Jimenez-Quero, F.M. Leon-Martinez, P. Montes-Garcia, C. Gaona-Tiburcio, J.G. Chacon-Nava.

Author investigated Influence of sugar-cane bagasse ash and fly ash on the rheological behavior of cement pastes and mortars. In binary system cement and fly ash or bagasse ash used. In ternary system cement, fly ash, and bagasse ash used. Sugarcane bagasse ash produces more viscous and plastic binary paste.[27]

VI. CONCLUSION

The use of sugarcane bagasse ash as Portland cement replacement or as supplementary cementitious material has the potential to use in construction industry as well as it will prevent the adverse impact on the environment if properly incorporated in concrete. The SCM with SCBA improves some of mechanical and durability properties but there is need to find different chemical activator in sugarcane bagasse ash concrete.

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