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Experimental Study on Bagasse Ash in Concrete by Partially Replacement with Cement

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Abstract:- The utilization of industrial and agricultural waste produced by industrial processes has been the focus of waste reduction research for economical, environmental, and technical reasons. Sugar-cane bagasse is a fibrous waste-product of the sugar refining industry, along with ethanol vapor. This waste product (Sugar-cane Bagasse ash) is already causing serious environmental pollution, which calls for urgent ways of handling the waste. Bagasse ash mainly contains aluminum ion and silica. In this paper, Bagasse ash has been chemically and physically characterized, and partially replaced in the ratio of 0%, 5%, 15% and 25% by weight of cement in concrete. Fresh concrete tests like compaction factor test and slump cone test were undertaken was well as hardened concrete tests like compressive strength, split tensile strength, flexural strength and modulus of elasticity at the age of seven and 28 days was obtained. The result shows that the strength of concrete increased as percentage of bagasse ash replacement increased.

Keywords – bagasse ash, concrete, Fibrous waste product.

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1. INTRODUCTION

Ordinary Portland cement is recognized as a major construction material throughout the world. Portland cement is the conventional building material that actually is responsible for about 5% - 8% of global CO2 emissions. This environmental problem will most likely be increased due to exponential demand of Portland cement. Researchers all over the world today are focusing on ways of utilizing either industrial or agricultural waste, as a source of raw materials for industry. This waste, utilization would not only be economical, but may also result in foreign exchange earnings and environmental pollution control. Several researchers and even the Portland cement industry are investigating alternatives to produce green building materials. Industrial wastes, such as blast furnace slag, fly ash and silica fumes are being used as supplementary cement replacement materials. Currently, there has been an attempt to utilize the large amount of bagasse ash, the residue from an in-line sugar industry and the bagasse-biomass fuel in electric generation industry. When this waste is burned under controlled conditions, it also gives ash having amorphous silica, which has pozzolanic properties. A few studies have been carried out on the ashes obtained directly from the industries to study pozzolanic activity and their suitability as binders, partially replacing cement.

Despite variety use of bagasse, for production of wood, papers, animal food, compost and thermal insulation,

statistics show that about one million tone extra of bagasse ash remains in the country. Sugarcane consists about 30% bagasse whereas the sugar recovered is about 10%, and the bagasse leaves about 8% bagasse ash
as a waste. As the sugar production is increased, the quantity of bagasse ash produced will also be large and the disposal will be a problem. Sugarcane bagasse[1] ash has recently been tested in some parts of the world for its use as a cement replacement material. The bagasse ash was found to improve some properties of the paste, mortar and concrete including compressive strength and water tightness in certain replacement percentages and fineness. The higher silica content in the bagasse ash was suggested to be the main cause for these improvements. Concrete is used in such large amounts because it is, simply, a remarkably good building material not just for basic road construction but also for rather more glamorous projects. Concrete production is responsible for so much CO2 because making Portland cement not only require significant amounts of energy to reach reaction temperatures of up to 1500oC, but also because the key reaction itself is the breakdown of calcium carbonate into calcium oxide and CO2. Of those 800kg of CO2 around 530kg is released by the limestone decomposition reaction itself. Concrete is the world's most utilized construction material.
With the ever increasing demand and consumption of cement and in the backdrop of waste management, scientists and researchers all over the world are always in quest for developing alternate binders that are friends to environment and contribute towards sustainable management. Also from other point of view the utilization of industrial and agricultural waste produced by industrial processes has been the focus of waste reduction research for economical, environmental and technical reasons . Sugarcane Bagasse, an industrial waste used as fuel in the same sugar cane mill that leaves 8 – 10 ash containing unburned matter, silica and alumina. But because crystallization of minerals occurs at high temperatures, these ashes are not so reactive. Sugar Bagasse for this study was brought from Sudanese Sugar Company (Three samples were brought from Asalaia, Sinnar, and Guneid Sugar companies).

After the determination of parameters such as carbon content, chemical composition, presence of crystalline matter, Pozzolanic reactivity of sugarcane Bagasse ash (SCBA) was evaluated by conducting strength development tests on SCBA – blended OPC[2] concrete to verify the hydration reaction of SCBA. Sugarcane is one of the major crops grown in over 110 countries and its total production is over 1500 million tons . After the extraction of all economical sugar from sugarcane, about 40 – 45% fibrous residues is obtained by further of un-burnt matter, silicon, aluminum and calcium oxides . A few studies have been carried out on the ashes obtained directly from the industries to study Pozzolanic activity and their suitability as binders, partially replacing cement .

Crystallization of minerals occurred at temperatures higher than 800 C . It has been reported that at burning temperatures up to 700 C silica was in amorphous form and silica crystals grew with time of incineration . The suitable burning condition was identified as 800 C for 3 hours. At this condition brownish white color indicated complete burning, and amorphous nature of the ash was ascertained by X-ray diffraction analysis. SCBA so formed was not fine enough to be blended with cement; therefore to achieve fineness comparable to OPC, the ash obtained after burning was grounded in a ball mill and subsequently screened through 63μ sieve.

The present study was carried out on SCBA obtained by controlled combustion of sugarcane bagasse, which was procured from the Maharashtra in India. Sugarcane production in India is over 300 million tons/year leaving about 10 million tons of as unutilized and, hence, wastes material. This paper analyses the effect of SCBA in concrete by partial replacement of cement at the ratio of 0%, 10%, 15%, 20%, 25% and 30% by weight. The main ingredients consist of Portland cement, SCBA[3], crusheds and, coarse aggregate and water. After mixing, concrete specimens were casted and subsequently all test specimens were cured in water at 7, 28, 56 and 90 Days

2.SCOPE OF WORK

Laboratory tests on cement, fine aggregate, coarse aggregate, bagasse ash, water. Whatever may be the type of concrete being used, it is important to mix design of the concrete. The same is the case with the industrial waste based concrete or bagasse ash replacement. The major work involved is getting the appropriate mix proportions. In the present work, the concrete mixes with partial replacement of cement with bagasse ash were developed using OPC 53 grade cement. A simple mix design procedure is adopted to arrive at the mix proportions.

After getting some trail mix, cubes of dimensions 150 mm *150 mm *150 mm, cylinder of dimensions 150mm*300 mm and beams of dimensions 100mm*100mm*150mm was casted and cured in the curing tank. Compressive strength, Split tensile strength and Flexural strength of concrete were conducted to know the strength properties of the mixes. Initially, a sample mix design was followed and modifications were made accordingly while arriving at the trail mixes to get optimized mix which satisfies both fresh, hardened properties and the economy[4]. Finally, a simple mix design is proposed.

3. MATERIALS AND METHODS

Cement:

The most common cement is used is ordinary Portland cement. Out of the total production, ordinary Portland cement accounts for about 80-90 percent. Many tests were conducted to cement some of them are consistency tests, setting tests, soundness tests, etc.

Fine Aggregate:

Locally available free of debris and nearly riverbed sand is used as fine aggregate. The sand particles should also pack to give minimum void ratio[5], higher voids content leads to requirement of more mixing water. In the present study the sand conforms to zone II as per the Indian standards. The specific gravity of sand is 2.68. Those fractions from 4.75 mm to 150 micron are termed as fine aggregate, and the bulk density of fine aggregate (loose state) is 1393.16kg/m3 and rodded state is 1606.84kg/m3.

Coarse Aggregate:

The crushed aggregates used were 20mm nominal maximum size and are tested as per Indian standards and results are within the permissible limit. The specific gravity of coarse aggregate is 2.83; the bulk density of coarse aggregate (loose state) is 1692.31kg/m3 and rodded state is 1940.17kg/m3.

Water:

Water available in the college campus conforming to the requirements of water for concreting and curing as per IS: 456-2000.

Sugarcane Bagasse Ash:

The sugarcane bagasse consists of approximately 50% of cellulose, 25% of hemicellulose 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 silicon dioxide (SiO_2)[6]. In spite of being a material of hard degradation and that presents few nutrients, the ash is used on the farms as a fertilizer in the sugarcane harvests.

4.MIXING AND CASTING

The fresh concrete was mixed using flow pan mixer of 150Kg capacity till uniform through consistency was achieved, prior to the mixing; the materials were spread in layers in the bottom of the pan, coarse aggregate first, followed by cement and finally the fine aggregate. The constituents of the mixes were mixed dry for one minute in order to homogenize the batched mix; subsequently water was added and mixed for a further three minutes. The concrete was cast into the moulds in three layers, and 36 blows were given to each layer, using 16mm diameter bar, to remove any entrapped air. For each mix the required numbers of cubes (total of 150 cubes) were casted. The moulds were covered by sacking for 24hours at room temperature. The specimens were de-molded after at least 24 hours and immersed into the curing tank . Before the molding of the samples specimens workability tests were done to observe the effect of Sugarcane Bagasse[7] on fresh concrete properties.

The workability tests adopted for this investigation were the Slump test and compacting factor test. The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible, is termed the concrete mix design. The proportioning of ingredients of concrete is governed by the required performance of concrete in two states, namely the plastic and the hardened states. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability, therefore, becomes of vital importance. The compressive strength of hardened concrete which is generally considered to be an index of its other properties, depending upon many factors, e.g. w/c ratio quality and quantity of cement, water, aggregate, batching, placing, compaction and curing. The cost of concrete is made up of the cost of material, plant and labour. The variation[8] in the cost of material arise from the fact that the cement is several times costly than the aggregates, thus the aim is to produce as lean a mix as possible. The actual cost of concrete is related to the cost of materials required for producing a minimum mean strength called characteristic strength that is specified by the designer of the structure. This depends on the quality control measures, but there is no doubt that the quality control adds to the cost of concrete. The cost of labour depends on the workability of mix.

5. Experimental work

In this experimental work, a total of 180 numbers of concrete specimens were casted. The specimens considered in this study consisted of 36 numbers of 150mm side cubes, 108 numbers of 150mm diameter and 300mm long cylinders, and 36 numbers of 750mm x 150mm x 150mm size prisms. The mix design of concrete was done according to Indian Standard guidelines6-9 for M 20 grade for the granite stone aggregates and the water cement ratio are 0.48. Based upon the quantities of ingredient of the mixes, the quantities of SCBA for 0, 5, 10,
15, 20 and 25% replacement by weight were estimated. The ingredients of concrete were thoroughly mixed in mixer machine till uniform thoroughly consistency was achieved. Before casting, machine oil was smeared on the inner surfaces of the cast iron mould. Concrete was poured into the mould and compacted thoroughly using table vibrator. The top surface was finished by means of a trowel. The specimens were removed from the mould after 24h and then cured under water for a period of 7 and 28 days. The specimens were taken out from the curing tank just prior to the test. The tests for compressive, split tensile strength were conducted using a 2000kN compression testing machine, the modulus of elasticity the test conducted using a compression testing machine and compressometer (strain measurements). For modulus of rupture was conducted using 1000kN universal testing machine[9]. These tests were conducted as per the relevant Indian Standard specifications.

In this experimental work, a total of56 numbers of concrete specimens were casted. The standard size of cube
150mm×150mm×150mm is used. The mix design of concrete was done according to Indian Standard guidelines [6] for M 20, M 30 and M40 grade. Based upon the quantities of ingredient of the mixes, the quantities of SCBA for 0, 10, 15, 20, 25 and 30% replacement by weight were estimated. The ingredients of concrete were thoroughly mixed in mixer machine till uniform thoroughly consistency was achieved. Before casting, machine oil was smeared on the inner surfaces of the cast iron mould. Concrete was poured into the mould and compacted thoroughly using table vibrator. The top surface was finished by means of a trowel. The specimens were removed from the mould after 24h and then cured under water for a period of 7, 28, 56 and 90 days. The specimens were taken out from the curing tank just prior to the test. The compressive test was conducted using a 2000kNcapacity compression testing machine. This test was conducted as per the relevant Indian Standard specifications

5.1 Experimental results

The strength results obtained from the experimental investigations are showed in tables. All the values are the average of the three trails in each case in the testing program of this study. The results are discussed as follows.
workability. A high-quality concrete is one which has acceptable[10] workability (around 6.5 cm slump height) in the fresh condition and develops sufficient strength. Basically, the bigger the measured height of slump, the better the workability will be, indicating that the concrete flows easily but at the same time is free from segregation. Maximum strength of concrete is related to the workability and can only be obtained if the concrete has adequate degree of workability[15] because of self compacting ability.

This may be due to the increasing in the surface area of sugarcane ash after adding SCBA that needs less water to wetting the cement particles. The strength test results obtained for concrete cube, cylinder and prism specimens with partial replacement of SCBA. The results show that the SCBA concrete had significantly higher compressive strength compare to that of the concrete without SCBA. It is found that the cement could be advantageously replaced with SCBA up to maximum limit of 15%. Although, the optimal level of SCBA content was achieved with 15.0% replacement. Partial replacement of cement by SCBA increases workability of fresh concrete; therefore use of super plasticizer is not essential. Based on the study, following conclusions can draw. The compressive strengths of SCBA mixes at the age of 7 days was gradually decreases its strength when compared with normal mix. It was observed that the compressive strength of SCBA 5% and SCBA 10% at the age of 28 days has reached its target mean strength; however the compressive strength was increased by 2.04% and 6.55% when compared with normal mix. It was observed that the compressive strength of SCBA 15%, SCBA 20% and SCBA 25% at the age of 28 days has decreases its compressive strength by 6.15%, 16.92% and34.13% respectively when compared with the normal mix. The split tensile strength of mixes SCBA 5% and SCBA 10% at the age of 28 days has increases its strengths by 4.42% and 9.5% respectively when compared with the normal mix. The split tensile strength of mix SCBA 15%, SCBA 20%, SCBA 25% at the age of 28 days has decreases it strengths by 11.8%, 24.8% and 32.7% when compared with the normal mix.

6. Compressive Strength Development:

This was due to the combined effect of relative fineness and
the Pozzolanic activity of SCBA and also may be due to the existing of crystalline silica. According to Bui strengthening capability of a mineral admixture not only depends on the Pozzolanic reactivity, but also on the relative fineness of the filler material. At 90 day stage compressive strength for S4 10% replacement was shown clear developing strength about 0.96% of OPC while the other samples (S2 & S3) were shown 85% strength development than OPC. Decrease in compressive strength values with increase in the substitution ratio indicated that filler effect was predominant only up to 10% ash substitution. The increase in compressive strength values in the S4 is due to the combined effect of both physical and chemical processes. Physical action was caused by the high specific surface area of SCBA and chemical action was the Pozzolanic reaction between calcium hydroxide (CH)[11] and silica (SiO_2). Also the hydration of silica itself in the alkaline environment may have been responsible for increase in compressive strength. But hydration reaction in S2 and S3 specimen was slow; possible because of low reactivity of SiO_2 and also, the reduction in CaO contents may have caused the reduction in ultimate strength development[14].

6.1 Flexural Strength graph vs Age

The flexural strength values obtained by testing standard cubes made with different SCBA mixes of 0-25%. The normal mix has strength above 30Mpa in compression as well as in flexure which is required strength. It was observed that the Flexural strength of SCBA 5% at the age of 7 days has decreased by 3% when compared with normal mix. It was observed that the Flexural strength of SCBA 5% at the age of 28 days has increased by a 4.42% when compared with normal mix. It was observed that the Flexural strength of SCBA5% at the age of 90 days has increased by 4.32% when compared with normal mix. It was observed that the Flexural strength of SCBA 10% at the age of 7 days has decreased by 3% when compared with normal mix. It was observed that the
Flexural strength of SCBA 10% at the age of 28 days has increased by 9.5% when compared with normal mix, It was observed that the Flexural strength[12] of SCBA 10% at the age of 90 days has increased by 10.72% when compared with normal mix. It was observed that the Flexural strength of SCBA 15% at the age of 7 days has decreased by 28.7% when compared with normal mix. It was observed that the Flexural strength of SCBA 15% at the age of 28 days has decreased by 2.4% when compared with normal mix. It was observed that the Flexural
strength of SCBA 15% at the age of 90 days has decreased by 6.4% when compared with normal mix. It was observed that the Flexural strength of SCBA 20% at the age of 7 days has decreased by 31.5% when compared with normal mix. It was observed that the Flexural strength of SCBA 20% at the age of 28 days has decreased by 16.1% when compared with normal mix. It was observed that the Flexural strength of SCBA 20% at the age of 90 days has decreased by

14.88 % when compared with normal mix. It was observed that the Flexural strength of SCBA 25% at the age of 7 days has decreased by 34.32% when compared with normal mix. It was observed that the Flexural strength of SCBA 25% at the age of 28 days has decreased by 29.35% when compared with normal mix[13]. It was observed that the Flexural strength of SCBA 25% at the age of 90 days has decreased by 26% when compared with normal mix.

7. CONCLUSION

The experimental result shows that the increase in the strength of concrete with use of sugar cane bagasse ash.

Therefore, with the use of sugar cane bagasse ash in partially replacement of cement in concrete, we can increase the strength of concrete with reducing the consumption of cement. Also it is best use of sugar cane bagasse ash instead of land filling and make environment clean. This was due to the combined effect of relative fineness and the Pozzolanic activity of SCBA and also may be due to the existing of crystalline silica. According to Bui strengthening capability of a mineral admixture not only depends on the Pozzolanic reactivity, but also on the relative fineness of the filler material. At 90 day stage compressive strength for S4 10% replacement was shown clear developing strength about 0.96% of OPC while the other samples (S2 & S3) were shown 85% strength development than OPC. Decrease in compressive strength values with increase in the substitution ratio indicated that filler effect was predominant only up to 10% ash substitution. The increase in compressive strength values in the S4 is due to the combined effect of both physical and chemical processes. Physical action was caused by the high specific surface area of SCBA (6) and chemical action was the Pozzolanic reaction between calcium hydroxide (CH) and silica (SiO2). Also the hydration of silica itself in the alkaline environment may have been responsible for increase in compressive strength. But hydration reaction in S2 and S3 specimen was slow; possible because of low reactivity of SiO2 and also, the reduction in CaO contents may have caused the reduction in ultimate strength development.

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