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# *Behavior of Concrete Under Flexural & Split Tensile Strength by Partial Replacement of Cement with Sugarcane Bagasse Ash*

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*Abstract*—**The construction industry relies a lot on cement for its operations in the development of shelter and other infrastructural facilities. It then becomes extremely difficult for majority of the people to own their own houses. In recent years, remarkable efforts have been taken in the domain of concrete engineering and technology to research and study the utilization of by-products and waste materials in the production of concrete. The successful utilization of these raw materials will result in the reduction of global warming and environmental loading, waste management cost and concrete production cost, besides enhancing the properties of concrete in both fresh and hardened state. Efforts in this direction have been focused in identifying and optimizing the benefits of different types of cement replacement materials as well as identifying alternative materials as aggregates in concrete and by better perceptive of constituent's chemistry of the concrete mix. Ordinary Portland cement is recognized as the major construction material throughout the world. Industrial wastes, such as blast furnace slag, fly ash and silica fume are being used as supplementary cement replacement materials. In addition to these, 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 (SiO2) which is present in these materials reacts with free limit released during the hydration of cement and formsadditional calcium silicate hydrate (CSH) as new hydration products, which improve the mechanical properties of concrete formulation. The ash produced by controlled burning of agro waste materials below 700$^0$C incinerating temperature for one hour transforms the silica content of the ash into amorphous phase and the reactivity of amorphous silica is directly proportional to the specific surface area of ash. The ash so produced is pulverized or ground to required fineness and mixed with cement to produce concrete and Mortar. Thus the SCBA (Sugarcane Bagasse ash) ash properties depend on burning time, temperature, cooling time and grinding conditions. India being one of the largest producers of sugarcane in the world produces 300 million tons per year and large quantity of sugarcane bagasse is available from sugar mills. Sugarcane bagasse is partly used as fuel at the sugar mill. Only a few studies have been reported on the use of SCBA as pozzolanic material in respect of cement paste. The objective of the present investigation is to evaluate SCBA as supplementary cementitious material with reference to mechanical properties of hardened concretes and Mortar and identify the optimal level of replacement.**

## I. INTRODUCTION

Ordinary Portland cement is recognized as the major construction material throughout the world. Industrial wastes, such as blast furnace slag, fly ash and silica fume are being used as supplementary cement replacement materials. In addition to these, 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 ($SiO_2$) which is present in these materials reacts with free limit released during the hydration of cement and formsadditional calcium silicate hydrate (CSH) as new hydration products, which improve the mechanical properties of concrete formulation. The ash produced by controlled burning of agro waste materials below 700$^0$C incinerating temperature for one hour transforms the silica content of the ash into amorphous phase and the reactivity of amorphous silica is directly proportional to the specific surface area of ash. The ash so produced is pulverized or ground to required fineness and mixed with cement to produce concrete and Mortar. Thus the SCBA (Sugar Cane Bagasse Ash) ash properties depend on burning time, temperature, cooling time and grinding conditions. India being one of the largest producers of sugarcane in the world produces 300 million tons per year and large quantity of sugarcane bagasse is available from sugar mills. Sugarcane bagasse is partly used as fuel at the sugar mill. Only a few studies have been reported on the use of SCBA as pozzolanic material in respect of cement paste. The objective of the present investigation is to evaluate SCBA as supplementary cementitious material with reference to mechanical properties of hardened concretes and Mortar and identify the optimal level of replacement [1].

Sugarcane baggase ash is a byproduct of sugar factories and it is produced by burning sugarcane baggase where it is formed by the extracting all sugar from sugarcane, For the use of SCBA as a partial replacement of cement in concrete and mortar, it is tested in various parts of the world. SCBA was found that it improves the properties of concrete and mortar such as compressive strength and water tightness in some percentage of replacement and fineness. The main parameter responsible for this improvement was higher silica content. The silica content may vary from ash to ash and this content is depending on the burning condition of sugarcane baggase. SCBA is a valuelessagricultural waste product but it has a pozzolanic property which can be used to replace cement in concrete and mortar, first reaction is the hydration reaction which takes place after addition of water in cement to form calcium hydroxide (CH) and calcium silicate hydrate (C-S-H). and the second reaction is pozzolanic reaction which takes place between CH from hydration reaction and SiO2 a pozzolan from SCBA and produced second phase of CSH which increase the compressive strength. Initiative are taken worldwide to control and to manage the agricultural waste to make environment good. Aim of this study was to evaluate the potential use of SCBA as partial replacement of cement in mortar and concrete. Baggase ash is recently accepted as a pozzolanic material, very few knows the effect of LOI of baggasse ash on compressive strength and sulphate resistance. The use of 20% of SCBA was beneficial. SCBA is easily available and cheap waste material of sugar industries. Sugarcane is highly produced crop grown in over 110 countries resulting in 1500 million tons of total production in the world. Sugarcane production in India is over 300 million tonnes per year. The processing of it in sugar-mill generates about 10 million tonnes of SCBA as a waste material. After characterizing SCBA its effect on rheological behavior is evaluated. One ton of sugarcane can generate approximate 26% of bagasse and 0.62% of residual ash. The residue after combustion presents a chemical composition dominated by silicon dioxide. In order to be used as a mineral admixture in mortar and concrete residual sugarcane ash must have appropriate physical and chemical properties. Portland cement is responsible for about 5 to 8% of global $CO_2$ emission this environmental problem will most likely to be increased due to exponential demand of Portland cement. The obtained results are very promising but the amount of SCBA used for this purpose constitutes 10% to 20% of binder mass.The use of SCBA in alkali activated system in 100% SCBA was inappropriate to produce geo polymer because of their low compressive strength. Sugar cane bagasse ash is generated as combustion by product of sugar cane bagasse and it is mainly composed of silica. The use of SCBA as a partial Portland cement replacement can improve the mechanical and durability properties of cementitious materials. SCBA is generally burned under uncontrolled condition. Thus the ash may contain black particles due to carbon and crystalline silica. The quality of ash can be improved by controlling temperature, rate of heating, soaking time, initially different calcination temperatures are allowed to obtain SCBA with amorphous silica and low carbon contain [2].

## II. SUGARCANE BAGASSE ASH (SCBA)

For this Research Work Sugarcane bagasse ash used was obtained from purti power plant, bela , Nagpur . Sugarcane baggase ash is a byproduct of sugar factories and it is produced by burning sugarcane baggase where it is formed by extracting all sugar from sugarcane, for the use of SCBA as a partial replacement of cement in concrete and mortar, it is tested in various part of the world. SCBA was found that it improves the properties of concrete such as compressive strength and water tightness in some percentage of replacement and fineness. The main parameter responsible for this improvement was higher silica content. The silica content may vary from ash to ash and this content is depending on the burning condition of sugarcane baggase. SCBA is a valueless agricultural waste product but it has a pozzolanic property which can be used to replace cement in concrete and mortar, first reaction is the hydration reaction which takes place after addition of water in cement to form calcium hydroxide (CH) and calcium silicate hydrate (C-S-H). The second reaction is pozzolanic reaction which takes place between CH from hydration reaction and SiO2 a pozzolona from SCBA and produced second phase of CSH which increase the compressive strength. Initiatives are taken worldwide to control and to manage the agricultural waste to prevent environment pollution. The solution is found out to burn these waste materials. Variation in burning temperature and duration of burning, size of particle, chemical composition has been studied rigorously. Aim of this study was to evaluate the potential use of SCBA as partial replacement of cement in mortar and concrete.

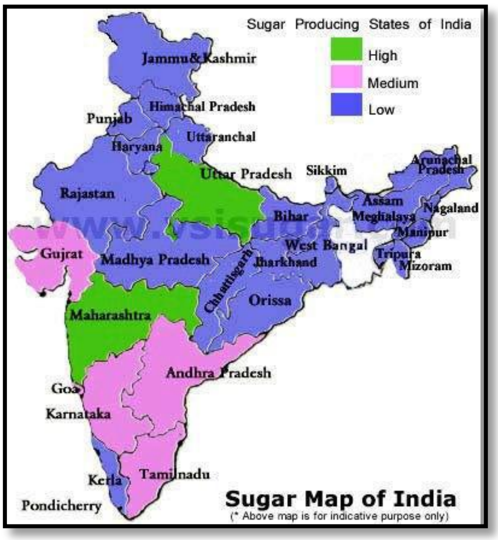


**Fig. 1. Sugar Map of India**

**Fig. 2. Raw Sugarcane Bagasse**

**Fig. 3. Sugarcane Bagasse Ash**

Agro wastes are used as construction material. Agro wastes such as rice husk ash, wheat straw ash, hazel nutshell and sugarcane bagasse ash are used as pozzolanic materials for the development of concrete and mortar. Sugarcane is major crop grown in over 110 countries and its total production is over 1500 million tons. Sugarcane production in India is over 300 million tonnes per year. The processing of it in sugar-mill generates about 10 million tonnes of SCBA as a waste material. One tonne of sugarcane can generate approximate 26% of baggasse and 0.62% of residual ash. In 2009, the total production of sugarcane in the world was estimated to be approximately 1661 million tons. After extracting sugarcane juice from sugarcane, about 40-45% fibrous residue was obtained, which is reused in the same industry as fuel in boilers for heat generation leaving behind 8 -10 % ash as waste, known as sugarcane bagasse ash (SCBA). The SCBA contains high amounts of un-burnt matter, silicon, aluminum and calcium oxides. Bagasse is often used as a primary fuel source for sugar mills; when burned in quantity, it produces sufficient heat energy to supply all the needs of a typical sugar mill. The dumping of these industrial wastes in open land poses a serious threat to the society by polluting the air and waste bodies. This also adds the no availability of land for public use. The main parameter responsible for improvement in strength of concrete and mortar was higher silica content. Bagasse ash contains amorphous silica and display good pozzolanic property [3].

## III. Material used

OPC is the widely used construction material.one of the main advantages of OPC is that it develops the strength very fast. In the modern construction activities the higher grade cement have become so popular that 33 grade of cement is almost out of market.Ordinary Portland Cement (OPC), ACC 43 grade was used for concrete. Cement may be prescribed as a material with adhesive and cohesive properties which make it capable of bonding mineral fragments into a compact whole. For constructional purpose the meaning of the term cement is restricted to the bonding material used with stones, sand, bricks, building blocks, etc. The cement in making of concrete have property of setting in addition with water by virtue of a chemical reaction with it and are therefore called hydraulic cement. Hydraulic cement consists mainly of silicates and aluminates of lime.

**Table 1: Standard Specifications for Cement**

| Sr. No. | Cement | Codes |
|---|---|---|
| 1. | Ordinary Portland Cement | |
| i | OPC 33 Grade | IS 269 : 1989 |
| ii | OPC 43 Grade | IS 8112 : 1989 |
| iii | OPC 53 Grade | IS 12269 : 1987 |
| 2. | Rapid Hardening Cement | IS 8041 : 1990 |
| 3. | Sulphate Resisting Cement | IS :12330 : 1980 |
| 4. | Portland Slag Cement | IS 455 : 1989 |
| 5. | Super Sulphated Cement | IS 6909 : 1990 |
| 6. | Low Heat Cement | IS 12600 : 1989 |
| 7. | Portland Pozzolana Cement | IS 1489 :1991 |
| 8. | Coloured Cement: White Cement | IS 8042 : 1989 |
| 9. | Hydrophobic Cement | IS 8043 : 1991 |
| 10. | Masonry Cement | IS 3466 : 1988 |
| 11. | Oil Well Cement | IS 8229 : 1986 |
| 12. | Concrete Sleeper Grade Cement | IRS-T 40 : 1985 |
| 13. | High Alumina Cement | IS 6452 : 1989 |

Sugarcane bagasse ash used was obtained from purti power plant, Bela, Nagpur. Sugarcane baggase ash is a byproduct of sugar factories and it is produced by burning sugarcane baggase where it is formed by extracting all sugar from sugarcane, for the use of SCBA as a partial replacement of cement in concrete and mortar, it is tested in various part of the world. SCBA was found that it improves the properties of concrete such as compressive strength and water tightness in some percentage of replacement and fineness. The main parameter responsible for this improvement was higher silica content.According to IS code 1226-1987 .The bagasse ash passing from a 90µ sieve and retained on 45µ the retained bagasse ash is taken in the preparation of concrete and mortar.

**Table 2: Chemical Composition of Sugar Cane Bagasse Ash**

| Sr. no | Oxides | Mass(g/100g) |
|---|---|---|
| 1 | $SiO_2$ | 53.44 |
| 2 | $Al_2O_3$ | 14.73 |
| 3 | $Fe_2O_3$ | 11.41 |
| 4 | CaO | 3.45 |
| 5 | MnO | 6.77 |
| 6 | LOI | 10.30 |

The results describe that the main composition of silicon di-oxide is present to about 50% in sugar cane bagasse ash. The other main oxides presents are aluminum oxide of 14(g/100g), iron oxides of about 11(g/100g) and CaO of about 3(g/100g).MnO was found to be about 6.7(g/100g) and loss of ignition was found to be 10.30 composition. The similar oxide have been found with that of cement. Importance of lime CaO: Deficiency of lime Decrease the strength of cement and causes cement to set quickly.

**Importance of $SiO_2$**: The excess silica increase the strength of cement but setting time of cement is decreased.

Aggregate are important constituents of concrete. They give body to the concrete reduce shrinkage and effect economy. The aggregates occupy 70-80% volume of the concrete. Their impact on various characteristics and properties of concrete is undoubtedly considerable. Cement is the only factory made standard in concrete. Water and aggregates are natural materials and can vary to an extent in many of their properties. The various aspects such as size, Texture, specific Gravity and Bulk Density, Shape, Strength, Moisture content, Cleanliness, Chemical Properties, Durability, Grading and Sieve analysis influence the properties of concrete in many respects. Aggregates are defined as inert, granular, and inorganic materials that normally consist of stone or stone-like solids. Aggregates can be used alone (in road bases and various types of fill) or can be used with cementing materials (such as Portland cement) to form composite materials or concrete. The most popular use of aggregates is to form Portland cement concrete. Approximately three-fourths of the volume of Portland cement concrete is occupied by aggregate. It is inevitable that a constituent occupying such a large percentage of the mass should have an important effect on the properties of both the fresh and hardened concrete. Aggregates can largely affect the composite properties due to its large volume fraction. Aggregate is cheaper than cement and it is, therefore, economical to put into the mix as much of the former and as little of the latter as possible. But economy is not the only reason for using aggregate; it confers considerable technical advantages on concrete, which has a higher volume stability and better durability than hydrated cement paste alone.

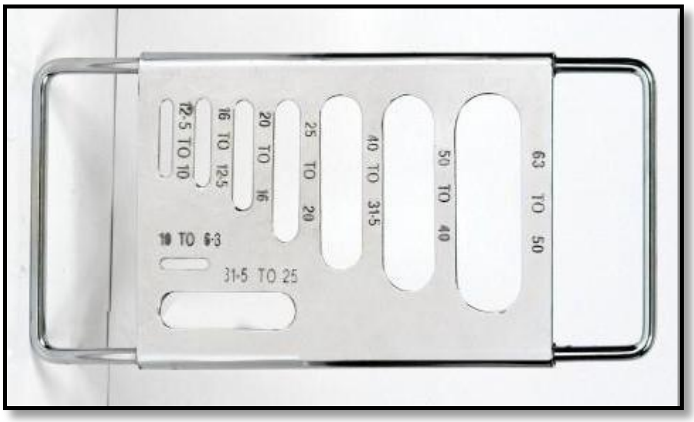


**Fig. 4. Apparatus for Flakiness index (thickness gauge)**

**Fig. 5. Apparatus for Elongation index (length gauge)**

Water used for mixing and curing should be clean and free form injurious amounts of oils, acids , alkalis, salts , sugar , organic material or other substances that may be deleterious to concrete or steel. The water can be used for making concrete if its pH lies between 6 to 8.If the pH is between 6 to 8 and water is free from organic water. Underground water is sometime found be unsuitable for making and curing concrete hence must be tested. The best coarse to find out whether a particular source of water is suitable for concrete making or not, is to make concrete with this water and compare its 7 and 28 days strength with companion cubes made with distilled water. If the compressive strength is upto 90% the source can be used for making concrete.

**Table 3: Tolerable concentrations of some impurities in mixing water**

| Impurity | Tolerable concentrations |
|---|---|
| Sodium and Potassium Carbonates and Bi-Carbonates | 1000 ppm (total).If this is exceeded, it is advisable to make tests both for setting time and 28 days strength |
| Chlorides | 10,000 ppm |
| Sulphuric Anhydride | 3000 ppm |
| Calcium Chloride | 2 percent by weight of cement in non prestressed concrete |
| Sodium iodate, Sodium Sulphate, Sodium arsenate, Sodium borate | Very low |
| Sodium sulphide | Even 100 ppm warrants testing |

**Concrete Mix Design** The mix design can be defined as the process of selecting suitable ingredients of concrete and determine their relative proportions with the view of producing concrete of certain minimum strength and durability as economically as possible. For proportioning in connection with a concrete mix, four factors are important, namely (a) Water/Cement ratio, (b) Cement Content, (c) Gradation of aggregates and (d) Consistency. Our effort in proportioning should be to use a minimum amount of paste that will lubricate the concrete mass while fresh and after hardening will bind the aggregate particles together and fill the space between them. Any excess of paste involves greater cost, greater drying shrinkage, greater susceptibility to percolation of water and therefore attack by aggressive water and weathering action. This can be achieved by minimizing the voids by proper gradation.

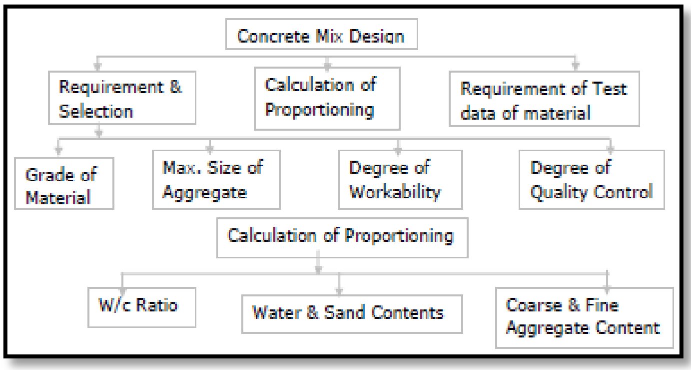


**Fig. 6. Flow Chart for Mix Design**

**Table 4. Type of Mix Proportion**

| Sr. no | Mix. | CA (%) | FA (%) | Cement (%) | SCBA (%) |
|---|---|---|---|---|---|
| 1 | B0 | 100 | 100 | 100 | 0 |
| 2 | B1 | 100 | 100 | 95 | 5 |
| 3 | B2 | 100 | 100 | 90 | 10 |
| 4 | B3 | 100 | 100 | 85 | 15 |
| 5 | B4 | 100 | 100 | 80 | 20 |
| 6 | B5 | 100 | 100 | 75 | 25 |

**Table 5. Material for Different proportion in Kg/m$^3$ for M30 Grade of Concrete (For 18 Beams & 18 Cylinders)**

| Sr. No. | Mix | Cement (Kg/M³) | SCBA (Kg/M³) | FA (Kg/M³) | CA (Kg/M³) | Water (Liters) |
|---|---|---|---|---|---|---|
| 1 | B0 | 65.90 | 0 | 100.1 | 153 | 28.33 |
| 2 | B1 | 62.6 | 3.3 | 100.1 | 153 | 28.33 |
| 3 | B2 | 59.31 | 6.59 | 100.1 | 153 | 28.33 |
| 4 | B3 | 56.03 | 9.86 | 100.1 | 153 | 28.33 |
| 5 | B4 | 52.72 | 13.18 | 100.1 | 153 | 28.33 |
| 6 | B5 | 49.42 | 16.48 | 100.1 | 153 | 28.33 |

## IV. Result and Discussion

### 1. Flexural Strength for Concrete

Out of many test applied to the concrete this is the most important which give the idea about the material's capacity to defend against Bend or Twist under load characteristics of concrete. By the single test one can judge that whether concreting has been done properly or not. According to IS 516:1959 mould of size 500×100×100 mm are commonly used. The specimens after curing are tested by 2 point load compression testing machine. The load should be applied gradually at the rate of 20 kg/cm2 per minute till the specimen fails. Load at the failure and distance between two span divided by area of specimen gives the Flexural strength of concrete.

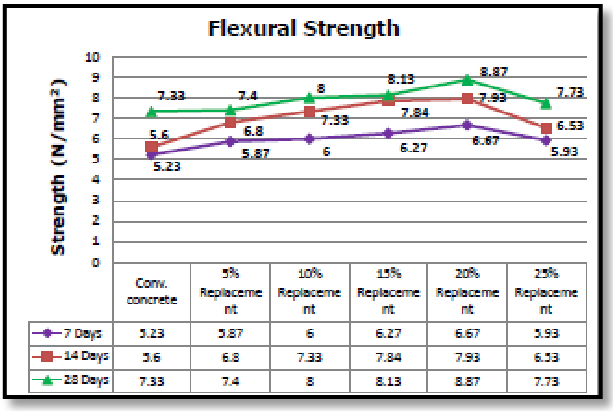


**Fig. 6. Flexural Strength of concrete (N/mm$^2$)**

### 2. Split Tensile Strength for Concrete

Out of many test applied to the concrete this is the most important which give the idea about the concrete specimen behave as an a elastic body, a uniform lateral tensile stress of flexural strength acting along the vertical plane causes the failure of the specimen is the characteristics of concrete. By the single test one can judge that whether concreting has been done properly or not. According to IS 5816:1999 mould of size 200×100 mm are commonly used. The specimens after curing are tested by compression testing machine. The load should be applied gradually at the rate of 140 kg/cm$^2$ per minute till the specimen fails. Twice time Load at the failure divided

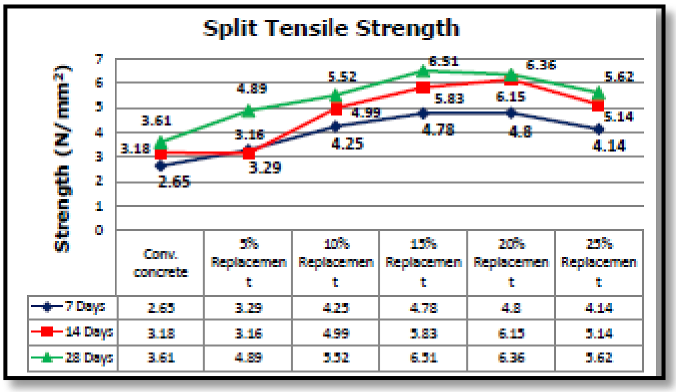


**Fig. 7. Split Tensile Strength of concrete (N/mm$^2$)**

### 3. Workability

Concrete is said to be workable when it is easily placed and compacted homogeneously i.e. without bleeding or segregation. Workability is one of the physical parameter which affects strength and Durability as well as cost of labor and appearance. Workability was measured with the help of slump cone apparatus. This apparatus is a tapered cylinder with its upper diameter as 10 cm, lower diameter 20 cm and height 30cm.

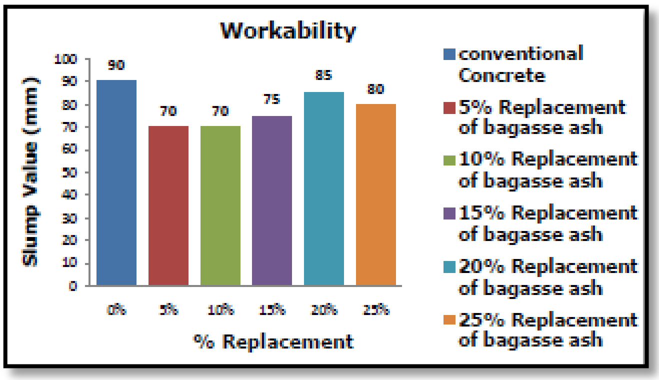


**Fig. 8. Workability**

Fig. 8 shows irrelevant behavior when 5% of cement is replaced with Sugarcane Bagasse Ash and the slump is found to have decreased suddenly and the further replacement has increased the slump. The slump Obtained for 5% and 10% replacement of Sugarcane Bagasse ash was 70 mm and increased replacement resulted in the increased slump of 75 mm and 85 mm for 15% and 20% replacement of Cement with Sugarcane Bagasse ash.

## V. Conclusion

On the basis of experimental investigation, the following conclusions can be drawn.

1. SCBA can be a good replacement for cement in concrete as well as mortar.
2. The SCBA concrete gives higher compressive strength, Flexural strength and split tensile strength than that of control concrete.
3. To improve the Flexural strength and split tensile strength of concrete, the suitable replacement of Portland cement by SCBA was 20% by weight.
4. Partial replacement of cement by SCBA increases workability of fresh concrete; therefore use of super plasticizer is not essential.
5. The Flexural strength was found to be 17.45% more at 15% replacement for 7 days of curing, 6.06% more at 10% replacement for 14 days of curing and 4.01% more at 15% replacement for 28 days of curing than conventional concrete.
6. In its purest form the bagasse ash can prove to be a potential ingredient of concrete since it can be an effective replacement to cement.
7. It is cost effective too as it mitigates the cost by 12% for 1 m$^3$ of concrete.

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