AN EXPERIMENTAL INVESTIGATION ON STRENGTH AND CHLORIDE ION PERMEABILITY CHARACTERISTICS OF CONCRETE BY PARTIAL REPLACEMENT OF SUGAR CANE BAGASSE ASH WITH FINE AGGREGATE

Mohammed ShakeebUlla Khan¹ and Dr. Vijaya G. S²

¹Asst. Prof., Department of Civil Engineering, Sampoorna Institute of Technology & Research
Belakere, Channapatna tq. Ramnagram district - 562160
²Asst. Prof Department of Civil Engineering, Govt. Sri Krishnarajendra Silver Jubilee Technological Institute,
Bangalore INDIA

Abstract- Today researches all over the world are focusing on ways of utilizing either industrial or agricultural wastes as a source of raw materials for the construction industry. These wastes utilization would not only be economical, but may also help to create a sustainable and pollution free environment. Sugar-cane bagasse is one such fibrous waste-product of the sugar refining industry, along with ethanol vapor. Bagasse ash mainly contains aluminum ion and silica. In the present work the agricultural waste product like Sugar Cane Bagasse Ash (SCBA) is used as alternate filler material to sand. This will result in saving sand. The bagasse ash used for the project work is obtained from Pandavapura Sahakara Sakkare Karkhane (PSSK), Pandavapura. In this experiment study to conducted to examine the potential of Bagasse ash as a fine aggregate replacing material. The different concrete mixes are prepared with the Bagasse Ash of 0%, 5%, 10%, 15%, 20%, 25% and 30% replacement by weight of fine aggregate in concrete for M30 grade concrete with water to cement ratio of 0.44. The properties of these mixes are assessed both at the fresh and hardened state. Fresh concrete tests like slump cone test are undertaken along with hardened concrete tests like compressive strength, split tensile strength flexure strength test and rapid chloride ion permeability test (RCPT) as per codal provisions. The results of the present study depicts that up to 20% replacement of the fine aggregate by SCBA achieved a higher mechanical strength and lower chloride ion permeability at 28 days of curing. The result shows that bagasse ash can be a suitable replaced to fine aggregate.

Keywords-- Sugar Cane Bagasse Ash (SCBA), Compressive Strength, Flexural Strength, Split Tensile Strength, Rapid Chloride Ion Permeability Test (RCPT)

I. INTRODUCTION

Huge quantity of concrete is consumed by the construction industry all over the world. Concrete is a widely used construction material consisting of cementing material, fine aggregate, coarse aggregate and required quantity of water, where the fine aggregate is usually natural sand. Natural sand takes millions of years to form and it is not replenish able.

Currently India has taken a major initiative on developing the infrastructures such as express highways, power projects and industrial structures etc., to meet the requirements of globalization. In the construction of buildings and other structures, it plays the rightful role and a large quantum of concrete is being utilized. Natural sand, which is one of the constituents used in the production of conventional concrete, has become highly expensive and also scarce. Also, good quality of natural sand has to be transported from long distance, which adds to the cost of construction, and also because of increasing pressure from local bodies, to protect the environment, either replacement or substitution for natural sand is warranted during this decade and for future.

DOI: 10.21884/IJMTER.2017.4280.B8LIA
The increase in the cost of natural sand is due to dwindling natural resources coupled with the restrictions imposed by several state governments on sand quarrying, as well as the concern to prevent further environmental degradation. These problems have led to the search for alternative materials for fine aggregates that are eco-friendly besides being inexpensive.

**Sugarcane Bagasse:** Sugar production from sugarcane involves shredding of fresh sugarcane, then mixing with water, and crushing using heavy rollers to extract the juice. The fibrous material left over after the juice extraction is called “bagasse”. The burning of bagasse in cogeneration boiler produces sufficient heat energy for all the needs of a typical sugar mill, with a quantity of energy to spare. The surplus energy produced in the cogeneration process is supplied to local households or factories in collaboration with the state electricity board. It is called as co-generation because bagasse is used as fuel and the steam produced by this heating is used in the production of electricity as well as for heating in juice treatment and clarification processes. Sugarcane bagasse ash, a waste industrial byproduct is one such material identified for use as a replacement of natural sand. Sugarcane bagasse ash (SCBA) generated from sugar mills is fibrous waste-product usually delivered to landfills for disposal. Using of sugarcane bagasse ash in concrete is an interesting possibility for economy and conservation of natural resources.

### II. LITERATURE REVIEW

Review of the literature was organized under the heading of Bagasse ash in concrete, properties and reactivity of bagasse ash, determination of compressive strength in bagasse ash, characterization of bagasse ash and use of bagasse ash as sand replacement.

**Asokan Pappua et al., 2007** [1] have stated that the inclusion of industrial waste-based newer building construction materials developed using agro-industrial wastes have ample scope will reduce to an extent the costs of building materials. **Ganesan et al., 2007** [2] the utilization of waste materials in concrete such as Agro wastes like rice husk ash, wheat straw ash, hazel nutshell and sugarcane bagasse ash are used as pozzolanic materials for the development of blended cements. **Noor-ul-Amin 2010** [3] Bagasse ash has been utilized in the high strength which not only improves the early strength but also increases the compactness of the concrete and enhanced the high early strength and resistance to chloride diffusion and the water permeability. **K. Ganesan et al., 2007** [4] have showed in their investigation that Up to 20% of ordinary Portland cement can be optimally replaced with well-burnt bagasse ash without any adverse effect on the desirable properties of concrete. **Shafana, R. Venkatasubramani** [5] Have stated that fine aggregate upto 10% can be effectively replaced with sugarcane bagasse ash without any considerable loss of workability and strength. **V. S. Aigbodion, S. B. Hassan, T. Ause and G.B. Nyior** [6] have shown that Bagasse ash have similar compound with the XRD analysis. The ash can withstand a temperature of up to 1600°C with a density of 1.95g/cm³. Due to these properties, it is clear that presence of oxides and carbon in the ash will make it suitable for refectory and ceramic products such as insulation, membrane filters and structural ceramics. **Shivakumar S A, Karthik M N, Sidramappa S I**[7] have used SCBA in concrete and shoed that As the replacement of SCBA increased, the binding of ingredients of concrete was relatively less and the water requirement increased, this may be because of high carbon content. **AlmirSales Sofia AraújoLima** [8] have used SCBA in Mortars and concretes with SBA as sand replacement which shows better mechanical results than the reference samples. SCBA can be used as a partial substitute of sand in concretes made with cement slag-modified Portland cement. **Prashant O Modania , M R Vyawahareb** [9], have conducted the workability, compressive strength, Sorptivity test at 28days and concluded that the loss of workability, with 10% and 20% bagasse ash increases compressive strength and increase in percentage of bagasse ash which indicate more permeable concrete that is due to porous nature of SCBA. **R.Srinivasan K.Sathiya[10]** have shown that the SCBA in blended concrete had significantly higher
compressive strength, tensile strength, and flexural strength compare to that of the concrete without SCBA and density of concrete decreases with increase in SCBA content.

### III. EXPERIMENTAL WORK

In this experimental investigation an attempt has been made to study the effect of mechanical strength characteristics of concrete containing various percentages of waste tyre rubber particles into it.

#### A. Materials Used

**3.1 Cement:** Ordinary Portland Cement-53 grade was used having a specific gravity of 3.15 and it satisfies the requirements of IS: 12269-1987 specifications. The physical properties of cement are given in Table 1.

| Sl. No. | Particulars | Results | Requirements as per IS: 12269-1987 |
|---------|-------------|---------|-----------------------------------|
| 1       | Standard Consistency | 29%     | -                                 |
| 2       | Setting Time (a) Initial Setting Time | 160 minutes | 30 Minutes (min)                 |
|         | Setting Time (b) Final Setting Time | 310 Minutes | 600 Minutes (max)               |
| 3       | Soundness | 0.8mm | 10mm                              |
| 4       | Specific Gravity | 3.15  | 3.15                              |
| 5       | Compressive strength of mortar cubes for a. 7 days d. 28 days | 38.19N/mm² 54.83N/mm² | Should not be less than 37 N/mm² Should not be less than 53 N/mm² |

**3.2 Fine aggregates:** Manufactured sand was used as fine aggregate. The sand used was having a specific gravity of 2.522 and confirmed to grading zone-II as per IS: 383-1970 specification. The physical properties of fine aggregates are given in Table 2.

| Sl. No. | Properties | Test Results |
|---------|------------|--------------|
| 1       | Specific Gravity | 2.522        |
| 2       | Fineness Modulus | 3.491 %     |
| 3       | Silt Content | 2.439 %      |
| 4       | Surface Moisture | Nill         |
| 5       | Water Absorption | 0.73         |

**3.3 Coarse aggregates:** The coarse aggregates used in the experimentation were 12.5 mm and down size aggregate and tested as per IS: 383-1970 and 2386-1963 (I, II and III) specifications. The aggregates used were having specific gravity of 2.51.

| Sl. No. | Properties | Test Results |
|---------|------------|--------------|
| 1       | Specific Gravity | 2.51         |
| 2       | Nominal Size | 10 to 12 mm  |
| 3       | Surface Moisture | Nill        |
| 4       | Water Absorption | 0.13        |

**3.4 Water:** Ordinary potable water free from organic content, turbidity and salts was used for mixing and for curing throughout the investigation.

**3.5 Superplastizers:** MASTER GLENIUM® SKY 8233 is a high range, retarding super plasticizer for high performance concrete mixes.
3.6 Bagasse Ash: Bagasse is a fibrous residue obtained from sugar cane during extraction of sugar juice at sugarcane mills. The average length of bagasse fibers is 80 mm and their average thickness is 0.2 mm. 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 dominated by silicon dioxide (SiO₂). 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. Figure 1 shows the picture of bagasse ash sample used in the study and this Bagasse ash was collected from Pandavapura Sahakara Sakkare Karkhane (PSSK), Pandavapura.

![Figure 1. Bagasse Ash sample](image)

### Table 4. Properties of Bagasse Ash

| Sl. No | Test                        | Results |
|-------|-----------------------------|---------|
| 1     | Specific Gravity            | 2.14    |
| 2     | Water absorption, %         | 0.4%    |

### Table 5. Chemical properties of SCBA (Srinivasan and Sathiya 2010)

| Chemical Composition | SCBA in % |
|----------------------|-----------|
| Silicon dioxide      | 62.43     |
| Aluminum             | 4.38      |
| Ferric Oxide         | 6.98      |
| Calcium Oxide        | 11.8      |
| Magnesium            | 2.51      |
| Sulfur trioxide      | 1.48      |
| Potassium Oxide      | 3.53      |

B. Mix Design, Casting And Curing

In the present study nine different mixes of Sugar Cane Bagasse Ash (SCBA) concrete were prepared with varying percentage of 5%, 15%, 20%, 25% and 30% by weight of sand in concrete. The mix proportion (Cement: Fine aggregate: Course aggregate 1: 2.34: 2.066: 0.45) for M 30 grade of concrete was obtained. The super plastizers dosage was 7% for different percentage of Sugar Cane Bagasse Ash. The materials are taken in order and added in the required quantities and thoroughly mixed. Slump cone test was used for the determination of slump values to check the workability of concrete with or without Sugar Cane Bagasse Ash.

### IV. TEST PROGRAM

4.1 Compressive Strength Test:

The cubes having dimensions of 150mmx150mmx150mm are casted to perform this test after the water curing period of 28 days to determine its strength performance in accordance with codal specification as given in IS : 516 - 1959 (Reaffirmed 1999) Edition 1.2 (1991-07).
4.2 Split Tensile Strength:
Concrete cylinders of size 15cm (dia.) x 30cm (height) are casted. The test is carried out by placing a cylindrical specimen horizontally between the loading surface of a compression testing machine and the load is applied until the failure of the cylinder, along the vertical diameter in accordance with codal specification as given in IS : 516 - 1959 (Reaffirmed 1999) Edition 1.2 (1991-07).

4.3 Flexural Strength Tests:
Beams of size 100x100x500mm are tested using a flexure testing machine. The specimen is simply supported on the two rollers of the machine which are 400mm apart, with a bearing of 50mm from each support in accordance with codal specification as given in IS : 516 - 1959 (Reaffirmed 1999) Edition 1.2 (1991-07).

4.4 Rapid Chloride ion Penetration Test (RCPT):
This test is conducted for the determination of resistance to penetration of chloride ions in concrete. The RCPT method is a fastest method and used in quality control purposes.
In the present study, the cylinders having dimensions150 mm dia. x 300mm height are casted and then cored to a disc of 100 ± 2mm diameter with 50±3mm thick are used for chloride ion penetrability test with technical reference as ASTM C 1202-2003.

V. RESULTS AND DISCUSSION

5.1 Workability
The slump flow test results indicate that, with increase in percentage of SCBA the workability has reduced as shown in figure.2, this may be due to fineness of SCBA. As the percentage increase in SCBA replaced by sand the workability reduces because of its fineness of SCBA hence would also affect the workability characteristics. And also to maintain the required slump flow, the amount of water needed will more compare to conventional concrete due to the porous nature of the bagasse particles and have a larger surface area and average size leading to enhanced absorption of water.

![Figure 2 Results of Slump Cone Test](image1.png)  ![Figure 3 Compressive Strength of cubes for 28 days](image2.png)
5.2 Compressive Strength

There is increase in compressive strength with increase in percentage of SCBA upto 20% replacement of fine aggregate by SCBA as shown in figure. 3. Beyond 20% replacement of fine aggregate by SCBA, the compressive strength reduces. The increase in compressive strength is due to reduction of voids in concrete and also because of the cohesive property of SCBA. At 20% replacement of fine aggregate by SCBA the percentage increase in compressive strength is 4.18% with respect to the conventional concrete and the maximum compressive strength at 20% replacement is found to be 38.86N/mm². Further addition of SCBA reduces the strength due to more porosity of material as it has more water required to get proper slump.

5.3 Split Tensile strength

There is increase in Split Tensile strength with increase in percentage of SCBA upto 20% replacement of fine aggregate by SCBA as shown in figure. 4. Beyond 20% replacement of fine aggregate by SCBA, the Split Tensile strength reduces. The increase in compressive strength is due to reduction of voids in concrete and also because of the cohesive property of SCBA. At 20% replacement of fine aggregate by SCBA the percentage increase in Split Tensile strength is 1.13% with respect to the conventional concrete and the maximum Split Tensile strength at 20% replacement is found to be 4.42 N/mm². Further addition of SCBA reduces the strength due to more porosity of material as it has more water required to get proper slump.

5.4 Flexural Strength

There is increase in Flexural strength with increase in percentage of SCBA upto 20% replacement of fine aggregate by SCBA as shown in figure. 5. Beyond 20% replacement of fine aggregate by SCBA, the Flexural strength reduces. The increase in Flexural strength is due to reduction of voids in concrete and also because of the cohesive property of SCBA. At 20% replacement of fine aggregate by SCBA the percentage increase in Flexural strength is 0.90% with respect to the conventional concrete and the maximum Flexural strength at 20% replacement is found to be 3.52N/mm². Further addition of SCBA reduces the strength due to more porosity of material as it has more water required to get proper slump.

5.5 Rapid Chloride ion Penetration Test (RCPT):

From the RCPT test results as shown in figure. 6, it is found that the total (Coulombs) charge passed through SCBA concrete specimens is reducing with increase in percentage of SCBA up to 20%. we can see that SCBA is finer than sand, it fills the voids in concrete and thus reduces permeability up to 20% replacement Beyond 20% replacement as the bonding strength reduces the permeability of concrete increases due to more porosity of material as it has more water required to get proper slump.

![Graph 1: Split Tensile Strength vs % replacement of Baggase Ash](figure4)

![Graph 2: Flexural Strength vs % replacement of Baggase Ash](figure5)

Figure 4 Split Tensile strength of cylinder for 28 days  
Figure 5 Flexural strength of cylinder for 28 days
VI. CONCLUSIONS

Based on the experimental results the following conclusion can be drawn

- Use of sugar cane Bagasse ash reduces the workability.
- From test results it is found that the SCBA could be advantageously replaced with sand up to maximum limit of 20% as there is increase in compression, tensile and flexure strength.
- By the 20% replacement of sand by SCBA the permeability also reduces.
- It can be concluded that 20% SCBA is the optimum percentage, which improves mechanical properties as well as permeability characteristics of concrete.

REFERENCES

[1] AsokanPappua, MohiniSaxenaa, Shyam R and Asolekarb “Solid wastes generation in India and their recycling potential in building”, Materials Building and Environment 42 pg. 2311–2320, 2007
[2] Ganesan, K., Rajagopal, K., and K., Thangavel. “Evaluation of bagasse ash as supplementary cementitious material”. Cem. Conc. Comp., 2007: 515-524.
[3] Noor-Ul-Amin “Chemical activation of Bagasse ash in cementitious systemand its impact on strength development”, J.Chem.Soc.Pak., vol 32, no 4, pg. 481-484.2010.
[4] Ganesan, K., Rajagopal, K., and K., Thangavel. “Evaluation of bagasse ash as supplementary cementitious material”. Cem. Conc. Comp., 2007: 515-524.
[5] T. Shafana, R. Venkatasubramani “A study on the Mechanical Properties of Concrete with partial replacement of Fine aggregate with Sugarcane bagasse ash” International Journal of Advanced Structures and Geotechnical Engineering ISSN 2319-5347, Vol. 03, No. 01, January 2014
[6] V. S. Aigbodion, S. B. Hassan, T. Ause and G.B. Nyior “Potential Utilization of Solid Waste (Bagasse Ash)” Journal of Minerals & Materials Characterization & Engineering. Vol. 9, No.1, pp.67-77, 2010
[7] Shivakumar S A, Karthik M N, Sidramappa S I “STUDIES ON MECHANICAL PROPERTIES OF CONCRETE USING SUGARCANE BAGASSE ASH (SCBA)” IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684, p-ISSN: 2320-334X PP 33-37
[8] AlmirSales Sofia AraújoLima “Use of Brazilian sugarcane bagasse ash in concrete as sand replacement” Elsevier Volume 30, Issue 6, June 2010, Pages 1114-112
[9] Prashant O Modania, M R Vyawahareb, “Utilization of Bagasse Ash as a Partial Replacement of Fine Aggregate in Concrete” Procedia Engineering 51 25 – 29,2015
[10] R.Srinivasan K.Sathiya, “Experimental Study on Bagasse Ash in Concrete” International Journal for Service Learning in Engineering, Vol. 5, No. 2, pp. 60-66, Fall 2010
[11] IS 383-1970 “Specifications for Coarse and Fine Aggregates from Natural Sources for Concrete,” Bureau of Indian Standards, New Delhi, Ninth Reprint, 2006.
[12] IS 10262-2009 “Concrete Mix Proportioning-Guidelines,” Bureau of Indian Standards, New Delhi, First Revision, 2009.
[13] IS: 516 - 1959 (Reaffirmed 1999) Edition 1.2 (1991-07) “Methods of Tests for strength of concrete,” Bureau of Indian Standards, New Delhi, Eighteenth Reprint, 2006.
[14] IS 456-2000 “Plain and Reinforced Concrete- Code of Practice,” Bureau of Indian Standards, New Delhi, Fifth Reprint, 2002.
[15] IS 2386 (Part I) – 1963 “Methods of test for aggregates for concrete,” Bureau of Indian Standards, New Delhi, Eleventh Reprint, 1997.
[16] IS 2386 (Part III) – 1963 “Methods of test for aggregates for concrete,” Bureau of Indian Standards, New Delhi, Eleventh Reprint, 1997.