EXPERIMENTAL INVESTICATION OF CONCRETE WITH PARTIAL REPLACEMENT OF FINE AGGREGATE WITH SUGARCANE ASH

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***Abstract*: The construction industry is the largest consumer of natural resources which led to depletion of good quality natural sand (fine aggregate). This situation led us to explore alternative materials and 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 a 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. This project work examined the possibility of using sugarcane bagasse ash as replacement of fine aggregate in concrete. The effects of replacing fine aggregates by SCBA on the compressive strength of cubes, split tensile strength of cylinders and flexural strength of prisms and RCC beams under monotonic loading were evaluated in this study. Five test groups were constituted with the replacement percentages of 0%, 5%, 10%, 15%, and 20%. The experiment was carried out by adopting M30 grade of concrete and Fe415 grade of steel. The results showed the effect of SCBA on concrete elements has a considerable amount of increase in the compressive, split tensile and flexural strength characteristics. The chemical and physical properties of SCBA were also studied.**

***Keywords*: SCBA - Sugarcane bagasse ash.**

1. INTRODUCTION

1.1 GENERAL

The global consumption of natural sand is very high, due to the extensive use of concrete. In general, the demand of natural sand is quite high in developing countries to satisfy the rapid infrastructural growth. In this situation developing country like India is facing shortage in good quality natural sand. Particularly in India, natural sand deposits are being depleted and causing serious threat to environment as well as the society. In the past decade variable cost of natural sand used as fine aggregate in concrete increased the cost of construction. In this situation research began for inexpensive and easily available alternative material to natural sand. Large amounts of industrial waste or by-products accumulate every year in the developing countries. For the production of cement and concrete, very high amount of energy is needed. Harmful effects of concrete can be reduced by producing good and durable concrete by using Industrial byproducts. Sugarcane bagasse ash is one of the materials that is considered as a waste material which could have a promising future in construction industry as a partial or full substitute of either cement or aggregates. Moreover, industrial waste and by-products can be used as substitute materials in concrete and construction, which in itself is a better alternative to dumping such wastes, as it will protect the environment and alleviate the exhaustion of perishable natural resources. This research study examines the possibility of using sugarcane bagasse ash as a partial natural sand replacement.

1.2 OBJECTIVE

- Checking the availability of bagasse ash in the country.
- Determining the chemical composition and physical properties of the bagasse ash.
- Evaluating the performance of concrete made of bagasse ash as a fine aggregate replacement material by conducting some laboratory tests on the fresh, hardened state and durability properties.
- Determining the quantity of bagasse ash that can be used successfully.

1.3 MATERIAL USED

Concrete is a mixture of cement, fine aggregate, coarse aggregate and water with or without a suitable admixture in required proportion. The properties of each of these materials should be studied for mix design of concrete. The materials can be used only if it meets specifications in the code.

1.3.1 CEMENT

Portland-Pozzolana cement used for casting all the specimens should be confirming to IS 1489 (Part 1) : 1991. Different types of cement have different water requirements toproduce pastes of standard consistence. Different types of cement also will produce have a different rates of strength development. The choice of brand and type of cement is the most important to produce a good quality of concrete. The type of cements affects the rate of hydration, so that the strengths at early ages can be considerably influenced by the mineral admixtures with cement.

The physical properties of cement

1) Setting time
2) Soundness
3) Fineness
4) Strength

1.3.2 COARSE AGGREGATE

Coarse aggregate passing through 20 mm sieve and retained on 12.5 mm sieve as given in IS 383 – 1970 was used for all the specimens. In addition to cement paste- aggregate ratio, aggregate type has a great influence on concrete dimensional stability.

1.3.3 FINE AGGREGATE

Clean and dry river sand available locally will be used. Sand passing through IS 4.75 mm sieve will be used for casting all the specimens.

1.3.4 SUGARCANE BAGASSE ASH

Sugarcane bagasse ash was collected from M/s Kothari Sugars and Chemical (P) Ltd., Kattur, Tiruchirappalli District of Tamil Nadu.The chemical properties of the random ash samples were analysed.

Table 1.1 Properties of sugarcane bagasse ash

Property	**Values**
Fineness modulus	1.42
Specific gravity	1.63

CHEMICAL PROPERTISE

Table 1.2 Chemical properties of sugarcane bagasse ash

Compound	**Percent by weight %**
Calcium Oxide (CaO)	4.68
Silicon di Oxide (SiO_2)	77.86
Aluminum Oxide (Al_2O_3)	2.85
Magnesium Oxide (MgO)	3.61
Phosphorus (P_2O_5)	0.23
Ferric Oxide (Fe_2O_3)	4.76
Potassium Oxide (K_2O)	3.19
Sodium Oxide (Na_2O)	0.53
Loss on ignition (LOI)	1.86

Availability of sugarcane bagasse ash in India

Sugarcane is one of the major crops grown in over 110 countries and its total production is over 1500 million tons. In India sugarcane production is over 300 million tons/year that causes about 10 million tons of sugarcane bagasse ash as an un-utilized and waste material. Average bagasse production is about 30 percent of the sugarcane crushed and about 90 percent of bagasse produced is used as fuel. The sugar production is undertaken practically throughout the country and there are well-established factories in 18 out of 28 States. The major sugar producing states in the country are Maharashtra, Uttar Pradesh, Tamil Nadu, Karnataka, Gujarat and Andhra Pradesh considering total sugar production and area under sugarcane.

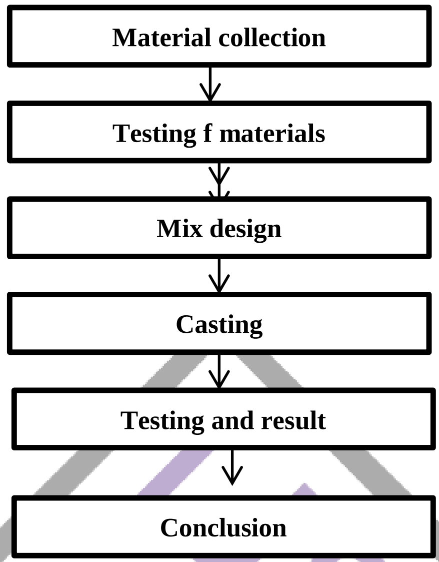
Advantage

- **Reduces land pollution:** Primarily the ash disposal problem from sugar industry is reduced since it is usually disposed off in open land area.
- **Economy:** Due to the non-availability of fine aggregate, the prices of natural sand which is used as fine aggregate have increased by 300% in the past few months. Hence the overall cost involved in the construction is reduced.
- **Future demand:** The partial replacement will also help in meeting the increasing demand for fine aggregate in future.

1.3.5 WATER

Casting and curing of specimens were done using potable water that is available in the college premises. Water shall be free from deleterious materials. In cause of doubt, the suitability of water for making concrete shall be ascertained by the compressive strength and initial setting time test specified in IS 456 – 2000.

2. METHODOLOGY



3. TEST OF MATERIALS

3.1 MATERIAL TESTING

To investigate the properties of the materials that were used for casting the specimens, various laboratory tests were performed; following the IS codes 2386:1963 and IS 383:1970.

3.2.1 CEMENT

Portland-pozzolana cement can be produced either by grinding together Portland cement clinkerand pozzolana with addition of gypsum or calcium sulphate, or by intimately and uniformly blending Portland cement and fine, pozzolana. Portland-pozzolana cement produces less heat of hydration and offers greater resistance to the attack of aggressive waters than normal Portland cement. Moreover, it reduces the leaching of calcium hydroxide liberated during the setting and hydration of cement. It is particularly useful in marine and hydraulic construction and other mass concrete structures. Portland-pozzolana cement can generally be used wherever 33 grade ordinary Portland cement is usable under normal conditions. However, it should be appreciated that all pozzolanas need not necessarily contribute to strength at early ages.

3.2.2 Fineness of Cement Test

100gm of cement taken and sieved in a standard IS no 90µ. The air which get lump is broken down and the material was sieved continuously for 15 minutes using sieve shaker. The weight of residue left on the sieve is noted.

3.2.3 Initial setting time test

Lower the needle (c) gently and bring it in contact with the surface of the test block quickly release. Allow it to penetrate into the block. But after some times when the paste starts losing its plasticity needle may penetrate only to a depth of 33-35mm from the top.

The period elapsing between the times when water is added when the water is added to the test block to a depth equal to 33-35mm form the top is takenas initial setting time.

Initial setting time of the cement used = 30 Minutes

3.2.4 Final setting time of cement test

Replace the needle (c) of the Vicat apparatus (F). The cement shall be considered as finally set when , upon , lowering the attachment gently cover the surface of the test block, the center needle makes an impression, while the circular cutting edge of the attachment fails to do so . In other words the paste more than 0.5mm. Replace the needle of the vicat apparatus by a circular attachment. The cement shall be considered as finally set when , upon lowering the attachment gently cover the surface of the test block , the center needle makes an impression , while the circular edge of the attachment fails to do so.

Final setting time of cement = 540 min

3.3 PROPERTIES OF CEMENT

Table 3.1 Property of cement

S.no	Property of cement	Values
1	Fineness	7.5
2	Grade	53
3	Specific gravity	3.15
4	Initial setting time	28 min
5	Final setting time	600 min

3.4 FINE AGGREGATE

The following experiment were conducted to fine out properties of fine aggregate as per IS-2386, **Table**

3.4.1 Specific gravity test

The specific gravity of aggregate is made use of in design calculation of concrete mixes. Specific gravity of aggregate is also required calculating the compaction factor in connection with the workability measurement. The specific gravity is determined by pycnometer method.

Specific gravity of sand =dry weight of sand / weight of equal volume of water.

Table 3.2 Property of fine aggregate

Property	Values
Fineness modulus	2.79
Specific gravity	2.64

3.5 COARSE AGGREGATE

3.5.1 Water absorption test

The coarse aggregate for the work should be river gravel or stone. The maximum size of aggregate is generally limited to 20mm. aggregate of 10 to 20mm is desirable for structures having congested reinforcement. Well graded cubical or rounded aggregates are desirable aggregates should be of uniform in size for this project 20mm size aggregate were used.

3.5.2Specific gravity test for coarse aggregate

The specific gravity of aggregate is made use in design calculation of concrete mixes. Within the specific gravity of each constituent known, its weight can be converted into solid volume and hence a theoretical yield of concrete per unit volume can be calculated. Similarly specific gravity of aggregate is required to be considered when we deal with light and heavy weight concrete.

Table 3.3 Property of coarse aggregate

Properties	Values
Specific gravity	2.60
Fineness modulus	5.96

3.5.3 Sugarcane bagasse ash

Sugarcane bagasse ash was collected from M/s Kothari Sugars and Chemical (P) Ltd., Kattur, Tiruchirappalli District of Tamil Nadu.The chemical properties of the random ash samples were analysed.

Table 3.4 Sugarcane bagasse ash

Property	Values
Fineness modulus	1.42
Specific gravity	1.63

4. MIX DESIGN

1. Stipulations of proportioning

Grade designation - M30
Grade of cement - PPC 53 grade
Maximum nominal size of aggregate - 20 mm
Minimum cement content - 320 kg/m^3
Maximum cement content - 450 kg/m^3
Maximum W/C ratio - 0.45
Workability - 75 mm (slump)
Exposure condition - severe
Method of placing - hand placed

2. Test data for materials

Cement used - PPC 53 grade
Specific gravity of cement - 3.15
Specific gravity of water - 1
Specific gravity of fine aggregate - 2.64
Specific gravity of coarse aggregate- - 2.60

3. Target mean strength

$F_{ck'}$ = F_{ck}+1.65S
$F_{ck'}$ - arget average compressive strength at 28 days
F_{ck} - characteristic compressive strength at 28 days
S – Standard deviation = 5(Table 1 of IS 10262:2009)
Fck' = 30+1.65x5
= 38.25 N/mm^2

4. Selection of W/C ratio

From table 5 of IS 456:2000 maximum W/C ratio = 0.45
Adopt W/C ratio = 0.43

5. Selection of water content

From table 2 of IS 10262:2009 maximum water content for 20mm aggregate =186 litres
Increase by 3% for every additional 25mm slump
Estimated water content for 100 mm slump = 186 + (3 x186/100)
= 191.6 litre

6. Calculation of cement content

W/C ratio = 0.43
Cement content = 191.6/0.43
= 445.6kg/m^3

From table 5 of IS 456:2000, minimum cement content for severe exposure condition
= 320 kg/m^3

445.6 kg/m^3>320 kg/m^3
Hence o.k.

7. Proportion of volume of coarse aggregate and fine aggregate content

From table 3 of IS 10262:2009, volume of coarse aggregate corresponding to 20mm size aggregate, fine aggregate of zoneII and for W/C ratio of 0.5 is 0.62
In the present case W/C ratio=0.43
Volume of coarse aggregate is required to be increased to decrease fine aggregate content. As W/C ratio is lower by 0.1,the proportion of volume of coarse aggregate is increased by 0.02(at the rate of ±0.01 for every ±0.05 change in W/C ratio)
Corrected proportion of volume of coarse aggregate for W/C ratio of 0.43 = 0.64
Volume of fine aggregate = 1-0.64
= 0.36

8. Mix calculations

Mix calculations per unit volume of concrete is as follows:

a) Volume of concrete = $1 m^3$

b) Volume of cement = (mass of cement/specific gravity of cement)x(1/1000)
= (445.6/3.15)x(1/1000)
= $0.141 m^3$

c) Volume of water = (mass of water/specific gravity of water)x(1/1000)
= (191.6 /1)x(1/1000)
= $0.192 m^3$

d) Volume of all in aggregate = 1-(0.141+0.192)
= $0.667 m^3$

e) Mass of coarse aggregate = (e) x volume of coarse aggregate x specific gravity of coarse aggregate x 1000
= 0.667 x 0.64 x2.6x1000
= 1110 kg

f) Mass of fine aggregate = (e) x volume of fine aggregate x specific gravity of fine aggregate x 1000
= 0.667 x 0.36 x2.64x1000
= 634 kg

9. Mix proportion

Cement = $445.6 kg/m^3$
Water = $192 kg/m^3$
Fine aggregate = $634 kg/m^3$
Coarse aggregate = $1110 kg/m^3$
Water-cement ratio = 0.43

10. Mix ratio

Cement	Fine aggregate	Coarse aggregate	Water
1	1.42	2.5	0.43

5. EXPERIMENTAL INVESTIGATION
5.1 GENERAL

After arriving the mix design, the concrete is tested for workability parameters by performing the slump test, followed by casting of concrete in moulds for further investigations.

5.1 TEST ON FRESH CONCRETE

The workability of fresh concrete is a composite property which includes the diverse requirements of stability, mobility, compactability, placeability and finishability. There are different methods for measuring the workability. Each of them measures only a particular aspect of it and there is really no unique test which measures workability of concrete in its totality. For determining the fresh properties, slump test was performed as envisaged by BIS 1199-1959.

5.1.1 Slump test

A high-quality concrete is one which has acceptable workability (around 6.5 cm slump height) in the fresh condition and develops sufficient strength. Basically, the bigger the measured height ofslump, the better the workability will be, indicating that the concrete flows easily but at the sametime is free from segregation. Maximum strength of concrete is related to the workability and canonly be obtained if the concrete has adequate degree of workability because of self compacting ability.The slump value also determines the robustness of the mix, segreation, bleeding in the mix.

Table 5.1 Slump test

Mix proportions	Slump value (mm)
0BA	78
5BA	70
10BA	65
15BA	60
20BA	53

5.1.2 Compressive strength test

The compressive strength for concrete with replacement of natural sand with bagasse ash of 0%, 5%, 10%, 15% and 20% at the age of 7 and 28 days was found. The compressive strength continued to increase as the curing period increased. The control mix had a compressive strength of 33.33 MPa at 28 days. Addition of increasing amounts of SCBA generally decreased the strength at a given age due to the greater porosity of the material as indicated by the higher water requirement. The greatest compressive strength was achieved when the mixture contained 10% of fine aggregate replacement of SCBA with the water cement ratio 0.43. Improvement stemmed from the void-filling ability of the smaller particles and was more pronounced at lower w/c ratios.

Table 5.2 Compressive Strength

Mix	Compressive Strength (MPa)		
	7 days	14 days	28 days
0BA	14.22	21.56	33.33
5BA	13.33	20.13	32.44
10BA	12	18.92	33.78
15BA	11.56	17.56	28.5
20BA	10.22	16.37	28

5.1.2 Split tensile strength

The split tension test result is shown in Table 7.3 and Fig 7.3. It was observed that the development of tensile strength of mixes decreases as the replacement of SCBA increases but with 10 % of SCBA gives higher strength compared to the control mix.

Table 5.3 Split Tensile Strength

Mix	Split Tensile Strength(MPa)		
	7 days	14 days	28 days
0BA	2.6	3	3.96
5BA	2.55	2.94	4.1
10BA	2.5	2.8	3.89
15BA	2.33	2.67	3.82
20BA	2.12	2.48	3.75

5.1.3 Flexural strength test

A beam specimen is casted to test the flexural strength of the concrete. After casting the test specimen it is cured for 7 days,14 and 28 days and tested for maximum load. The result is given the the variation in flexural strength for different replacement with respect to controlled concrete for 7 days,14 and 28 days respectively.The failure of the specimen. The bagasse ash concrete gains flexural strength with the age that is comparable but less than that of the controlled concrete with the increasing SCBA content. It is believed to be due to the poor interlocking between the aggregates, as bagasse ash particles are spherical in nature. The 10 % bagasse ash is considered optimum to get flexural strength greater than the control mix.

Table 5.3 Flexural Strength

Mix	Flexural Strength (MPa)		
	7 days	14 days	28 days
0BA	3.5	3.7	4
5BA	3.4	3.63	4.1
10BA	3.35	3.40	3.9
15BA	3.25	3.51	3.85
20BA	2.9	3.46	3.75

CONCLUSION

The results show that the SCBA as partial replacement of fine aggregates in concrete upto 10% had significantly higher strength compared to that of the concrete without SCBA. It was shown that 20% of SCBA decreases the compressive strength to a value which is near to the control concrete. This may be due to the fact that the quantity of SCBA present in the mix is higher than the amount required to combine with the liberated lime during the process of hydration thus leading to excess silica leaching out and causing deficiency in strength. Also, it may be due to the defects generated in dispersion of SCBA that causes weak zones. It was found that the natural sand could be advantageously replaced with SCBA up to maximum limit of 10%.

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