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Utilization of Sugarcane Bagasse Ash as Partial Cement Replacement in Concrete

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Abstract: ***As we all are aware about the growing demand of concrete as important material being used in construction industry. Natural resources are reducing day by day, huge amount of energy being consumed and environmental degradation are involved in the production of cement has motivated researchers to investigate the suitable alternatives to partially or fully replace the cement. The research performed from more than the last two decades concerning the use of Sugarcane Bagasse Ash (SCBA) as a cement replacement to produce structural concrete is summarized in this paper. Firstly, general information about SCBA production, effect of burning temperature on the SCBA structure, physical and chemical properties of SCBA and reaction mechanism of SCBA are briefly discussed. Then, the influence of SCBA on the fresh state properties is presented and finally, the hardened state characteristics i.e. strength and rate of strength gain, modulus of elasticity, chloride ion penetration and aggressive environment effect on SCBA concrete are presented. This research examines the suitability of sugarcane bagasse ash used as partial replacement of concrete. Grade of concrete M20 is carried out in accordance with the recommendations of IS: 10262-2009. The cement was partially replaced by SCBA at 5%, 10%, 15%, 20%. The mixes then prepared were checked for the workability by slump test. It was concluded that SCBA increases the workability of the cement concrete. From the results we can conclude that optimum amount of sugarcane bagasse ash that can be replaced with cement concrete is 10% by weight without any admixtures.***

Keywords: SCBA, workability, IS: 10262-2009, slump test

1. Introduction

Overview

Ordinary Portland cement being, the most common building material used for building construction. The solid development division represents the greatest test in front of human culture, in particular ecological insurance and meeting the foundation needs of our developing populace. Structures worked in forceful regions are inclined to acidic assaults.

One among serious issues is HCl assault against solid structures because of which the structure becomes lighter and further results in the decrease of age of the structure. As we all are well aware about the fact that the water contaminated from ground, sea water is a part of the sulfate resources which assault the strong. A sharp result in resisting the attack of sulphate can be obtained by using the blended cements; sugarcane bagasse ash has pozzolanic properties and can used replacement in concrete as partial of regular intervals from 5% up to 20%.

SCBA is produced as a waste material from sugar processing units that is grinded to the very fine, less than cement to obtain a good bond between cement and S C B A.

Ordinary Portland Cement (OPC)

O P C is a managed mix of aluminates, calcium silicates and ferrate; this is mix to best powder with gypsum and so forth**.** There are 3 types of O P C on the basis of strength gained after 28:

1) OPC 33 grade:-strength at 28 days at least 33 N/mm2
2) OPC 43 grade:-strength at 28 days at least 43 N/mm2
3) OPC 53 grade:-strength at 28 days at least 53 N/mm2

The chemical reaction b/w water and cement determines the strength of Portland cement, is process of hydration. Studying the cement Chemical composition helps us in understanding the complex process of hydration.

Cement Concrete

A misleadingly stone made subsequent to solidifying of a blend of a concrete mortar, the aggregates which incorporates water or a reasonable cement/admixtures, is known as concrete cement.

Concrete cement is the blend of cement water glue and the aggregates. The role of cement water paste is to bind the different aggregate that result in the formation a hard rock like mass in the wake of solidifying has a consequence of the concoction response among water and concrete. The Aggregates are of two types, fine aggregates and coarse aggregates. Fine aggregates include sand whose size is exceeding 4.75mm while as coarse aggregate includes crushed stone, gravel, etc. of particle size exceeding 4.75mm.

The building materials are put together so as to form a workable concrete, that can be used and moulded into different shapes and structures like beams, slabs etc.

The material react chemically after few hours of mixing and then solidifies and hardness, and starts developing a greater strength with the passage of time. Cement Concrete is known for its high strength against compression, but is very poor against tensile forces. Shrinkage stresses are developed in the concrete.

Sugarcane Bagasse Ash

In India sugarcane is among the major crops grown. India is marked as 2nd largest country producing sugarcane after Brazil. In sugar industries, after the juice extraction process from the sugarcane, the residual material left over is called as Bagasse. This left over material is then used as a fuel in industries and the obtained ash is the Sugarcane Bagasse ash. It has prismatic, Spherical and fibrous shape.

From one tonne of sugarcane, 0.62% residual ash and 26% bagasse ash is produced. Great content of silica and good pozzolanic material is present in S C B A. This material is amorphous in nature and has a crystalline structure. Solid waste's by products are also consumed as pozzolanic materials, it minimizes the cement content. 519.3 killotonnes of carbon dioxide emission is reduced per year when S C B A is partially replaced in cement. For this purpose, the cost and the waste emission is reduced, resulting the energy consumption by using the solid waste materials. Health problems arise due to the disposal of these material, as they pollute the soils and underground water and. The mineral admixture to attain the maximum strength in concrete is S C B A, that includes various process. Tiles, glass materials, soil blocks and other ceramic based materials can be manufactured using it. Soft clay can be improved by this waste material, it could be used in sustainable construction technologies. Firstly, we need to study the strength of mortar, using S C B A as cement's replacement, testing of compressive strength. This testing is necessary to know whether the strength is acceptable or not if mix design standard is followed.

Scope of Study

In this research, laboratory testing of concrete includes tests to determine the flexural strength and compressive strength including S C B A as a replace of the Portland cement with different rates 0%, 5%, 10%, 15%, 20%. The specimen cube of size (150mm*150mm*150mm) for Compressive test and for Flexural test, specimen size is (700mm*150mm*150mm).After 7, 14, 28 of curing, the sample is tested.

Objectives of Study

- The main objective of this study is to replace the cement with sugarcane baggase ash in cement concrete.
- The cement in concrete mix emits a harmful carbon dioxide gas which affects the environmental conditions, so replacing the cement with bagasse ash can reduce the emission of carbon dioxide due to the presence of less cement content.
- Increase of sugarcane bagasse waste makes it difficult for dumping such a huge quantity of bagasse. So instead of dumping these wastes it would be better to use them for manufacturing of construction material.

2. Methodology

Material used for the Research

Cement

The O P C of 53 marks in one batch was used for all the work and care was taken that it should have been kept in the airtight compartments to abstain from being upset by dampness and storm dampness and moistness. The concrete expended was tried for physical prerequisites as per IS: 12269-1987 and for chemical requirements as per IS: 4032-1977.

Fine aggregate

River sand, which passes through 4.75 mm through a sieve and is stored in a 600 µm, similar to Zone II as in IS 383-1970 was used in the current study. No clay, silt or organic impurities were present in the sand. The aggregate has been tested for its physical requirements such as specific gravity, gradation, bulk modulus, and fineness modulus as per **IS: 2386-1963.**

Coarse aggregate

In the entire investigations, the coarse aggregates (squashed) of 20mm acquired from the neighborhood smasher plants were utilized. The totals were tried for various physical prerequisites includes; fine modulus, gradation, specific gravity and bulk density etc. in accordance with **IS: 2386-1963 and IS: 383-1970**.

Water

Water (palatable liquid) accessible within the campus laboratory were utilized for the mixing and curing of concrete cylinders.

Sugarcane bagasse ash

Sugarcane bagasse was brought from a local sugar processing unit in Bijnor (U.P) and burned in a closed drum (uncontrolled fire), SCBA was collected after passing through 300µm standard sieve used research. Fig 1 and 2 shows the S C B A after passing from sieved size 300µm and S C B A retained materials on sieved 300µm respectively after the process of sieving.

Density & microstructure of S C B A

The density is basically defined as the mass per unit volume. It has density approx about 1.95g/cm3. However, it can be divided into three main groups; spherical, prismatic and fibrous and S C B A sample analysis under X R D analysis, determines that bagasse ash, have substantial amount of silica particles. The physical and chemical composition of bagasse ash are listed in Tables

Chemical Composition of the Bagasse Ash

S.No	Component	Percentage	Symbol
1	Silica	63	SiO_2
2	Alumina	31.5	Al_2O_3
3	Ferric Oxide	1.79	Fe_2O_3
4	Calcium Oxide	0.48	CaO
5	Magnese Oxide	0.004	MnO
6	Magnesium Oxide	0.39	MgO
7.	Loss on Ignition	0.71	LOI

Physical Properties of SCBA

S. No	Property	Value
1	Density	$1.95 g/cm^3$
2	Specific Gravity	2.2
3	Mean particle size	0.1-0.2 µm
4	Min specific surface area	$2500 m^2/kg$
5	Particle shape	Spherical

Processing Methods

Raw bassage ash having unburnt particles, to give the good pozzolanic performance is included into various process. The steps included in the process are burning, sieving, grinding, chemical activation. Increase in Adsorption and porosity is the result of low temperature of activation. Carbon present also affects the concrete properties. Max. loss of ignition results in the decrease of Compressive strength, and increases with min. ignition loss. High-performance pozzolanic work produced by finer S C B A. Pozzolanic work reduces the alkalinity of cement pastes.

Sieving

Using sieve is used for increasing the yield stress and viscosity of paste. High carbon content will be removed by sieving through 425 µm sieve. A 300 µm sieve was also used to remove non-combustible particles. To obtain same fineness of cement passing through 90 µm sieve used. After grinding, the material passed by 45 µm Sieve, used as a cementitious material because smaller size particles increases the pozzolanic activity.

Burning

Burning process is used to elimnate the carbon content. Burnt at 700^0C, SCBA gives the max pozzolanic activity. By using burning temperature @ 550^0C for 45 min reduces the loss of ignition. Burnt @ 800^0C and 1000^0C @20min has an enough and same pozzolanic activity than kinetic diffusive model. In some experiments S C B A burnt @ 600-800^0C.Using different burning temperature, it concludes that @ 600^0C for 3h gives a min. carbon content and large specific surface area because of reduction of loss of ignition.

Grinding

The two methods used for grinding are electric propulsion and mechanical reaction. In both cases the process, gives homogeneity and enhances pozzolanic action. The 120 Minute Ground provides a 100% pozzolanic activity index. The S C B A provides superior pozzolanic performance when used as a substitute for cement mortar.

Mix Design

Concrete Mix design

Cement Replaced by of 20% of S C B A Grade of concrete – M20

Type of cement – OPC 53 grade

Type of material admixture –Sugarcane bagasse ash (SCBA)

Max. aggregate size – 20mm

Min. cement content – 320kg/m3 Max. W.C. ratio – 0.45

Workability (slump) – 100.00mm Condition of Exposure – Severe

Supervision degree –Better

Aggregate type used – Angularly crushed aggregate Max. cement – 450.00 kg/m3

Specific-gravity (Cement) - 3.17 Specific-gravity (SCBA) – 1.80

Cement replacement, 20% by S C B A Sand replacement- 0%

Target strength for mix proportion fck „ = fck + 1.65 S

fck = compressive strength @ 28 days =20 S= 4 (Table no.1 IS 10262:2009)

fck= 20 + 1.65 * 4

= 26.6 N/mm^2

Selection of w/c Ratio

Max. W.C. RATIO = 0.45 [from IS456]

Take = 0.40

Selection of W.C.

Max content of water for 20mm aggregate = 186.00 L (for slump range-20.00 to

50.00mm) Water content required for 100.00mm slump

= 186.00 + 6/100*186.00 = 186.00 + 11.10 = 197.10 ~ 197.00 L

Assuming 29%

w.c. = 197.00 – 197.00*29/100

= 140.00 (approx)

Cement Content Calculations

w.c. ratio = 0.40

Cement content = 140.00/0.40 = 350.00kg/m^3 From table No.05 of IS456 min content of cement for severe exposure conditions

= 320.00kg/m^3

350.00kg/m^3> 320.00kg/m^3

That is OK

Volume of coarse aggregates and fine aggregate (zone 1)

C. A. Volume = 0.60.

F. A.Volume = 1.00-0.60 =0.40 [IS 10262:2009].

Cementious Material Content = 350.00*1.10.

= 385.00kg/ m^3.

Water content = 140.00 kg/ m^3.

So water cement ratio 140.00/385.00 = 0.364.

SCBA@10% Of Total Cementious

Material cement content = 385-385*10/100

= 308.00 kg/m^3.

Saving of cement while using SCBA

= 350.00 – 308.00

= 42.00 Kg/ m^3

SCBA being utilized = 77 kg/m^3

Mix Proportioning

In the present project, the standard for the construction of M20 concrete is carried out in accordance with the recommendations of IS: 10262-2009 [14]. By making mixes containing S C B A, the powder amount is measured by using the weight of the powder, instead of the weight of the cement. The resultant mix proportions of all mixes are tabulated in Table.

M20 Concrete Mix Proportions

Parameters	Percentage Replacement of S C B A				
	MIX 1 (5%)	MIX2 (10%)	MIX3 (15%)	MIX 4 (20%)	CONTROL MIX
W/C Ratio	0.45	0.45	0.45	0.50	0.45
Water kg/cu.m	140	140	140	191.6	140
Cement kg/cu.m	363.85	344.70	325.55	308	383
Fine aggregates kg/cu.m	751	751	751	751	751
Coarse aggregates kg/cum	1127	1127	1127	1127	1127
Bagasse Ash kg/cu.m	19.5	38.30	57.45	77	0

3. Experimental Work

Preparation of materials
Mixing:
Hand mixing:

1) Mix the O P C with F A on a water tight none-absorbent place. Mix it continuously till the mixture is blended properly and is of uniform color. The concrete is mixed either manually or mechanically.
2) Now mix the C A with cement and F A until the uniformity is visible in the mix with coarse aggregate.
3) Add water during mixing and mix it until the concrete develops the desired consistency and the mix appears homogeneous.

Workability Test (Slump Test)

- Clean the inside surface of the mold completely and practice a layer of oil.
- After cleansing, place the mould in a easy, horizontal, firm and nonsticky area.
- The freshly blended concrete is stuffed in four layers in the mold, every approximately to 1/4th of the peak of the mould.
- The concrete to be used is compressed or tampered by given 25 strokes of tampering rod.
- After the top layer is stuck, the solid is severed the extent with a trowel.
- The mould is separated by raising it vertically.
- The difference among the stature of the shape and the maximum intense tallness of cement is estimated.
- The slump of the concrete is determined by calculating the height difference. It is determined in mm.

Workability Test (Slump Test)

Replacement of S C B A with Cement (%)	Workability (slump in cm)
Control Mix	23.10
Mix 1	24.10
Mix 2	27.90
Mix 3	25.00
Mix 4	22.40

Casting of specimen

- The mounds are cleaned and applied a layer of oil.
- The concrete is filled in layers into the moulds approx 5cm thick.
- Each layer is given atleast 35 strokes to compact the concrete with the help of tampering rod.
- The top surface smoothened and leveled with a trowel.

Curing

The 12 test samples are kept for 24 hours in air from the 1^{st} batch and after this period the mould is removed and the samples are marked. The specimen is then kept in fresh clear water until taken out for the test. The 12 testing samples are stored for 24 hours in air from the next batch and after this period the mould is removed and the specimen are marked. The specimens are then submerged in fresh water, free from dirt until taken out for test.

Precautions:

After every 7 days, the water consumed for curing should be examined and must be $27+-2^0$c. We should also ensure that the water is free from any kind of dirt.

Compression Test

Aim

To find compressive strength of 24 test specimens.

Apparatus

Compression testing machine

Specimen

24 cubes of 15 cm size mix. M20.

Procedure

1) After curing, remove the sample from the water and clean the surfaces with excess water.
2) Note the sample dimensions.
3) The bearing area of the testing machine needs to be wiped clean.
4) Place the sample in device in such a manner, the heap to be applied on the perimeters confronting the block cast.
5) On the base plate of the machine, alter the sample.
6) Rotate the turning phase delicately by using hand so it contacts the sample.
7) Without any stuns, apply the steady force on tempo of 140KG/cm2/minute constantly till the sample fails.

Note

At least three specimens should be considered for each selected age. If the result of any sample comes out more than 15 percent of the average strength, the effects of that type of assumption should be rejected. The average of these specimens provides the ability to crush of concrete.
Strong concrete requirements.

Calculations

Size of the cube = (150mm)3
Average area of the specimen =225cm

Test for Flexural Strength

This test is also called as modulus of rupture test. This test is analysed on beams with two point or three point loadings. This test actually determines the flexural strength. Flexural strength is the max. Stress at the outermost fibre on the side of compression or tension of the sample. This is determined by the slope of stress verses strain deflection curve.

Apparatus

A beam mould of size 700x150x150 mm

Test

The beam specimen are demoulded from the mould and the beam spicemen are wiped with dry cloth and are kept in between the rollers and load is now applied on it at a rate of 140 kg/cm2 per minute till the sample fails. The readings are noted down and flexural strength is finding out by below given formula
Flexural Strength = 3pl/2bd2
Where,
a = the distance between the fracture line and the nearer support
b=width of specimen (cm)
d=failure point depth (cm)

l = supported length (cm)
p = max Load (kg)

Compressive test of sample

Beam Specimen for Flexure Test

4. Results and Discussion

Compressive Strength Results

The tests were carried out as per IS: 516-1959. The 150mm size cubes were casted of various concrete mixtures for testing compressive strength. The sample cubes after de-moulding were placed in curing water tanks and after the removal of sample from the tank, the tests of compressive strength were examined at 7days,14 days and 28days and the results are represented in Table 9 and Fig 2. The test values were compared with controlled concrete.

Compressive Strength for Different Trail Mixes

Percentage of SCBA	Compressive Strength N/mm^2		
	7 Days	14 days	28 Days
Control mix	14.12	18.19	23.43
Mix 1	18.73	20.56	29.75
Mix 2	20.93	24.52	30.57
Mix 3	15.22	20.21	27.22
Mix 4	13.81	18.01	23.13

Flexural Strength Result

The test has been conducted on the samples after taken out of the curing tank such as to prevent surface drying which decreases flexural strength.

Load the sample continuously till the point of failure at a constant rate without any vibrations.

Flexural Strength for Different Trail Mixes

Percentage Replacement of S C B A	Flexural Strength N/mm^2		
	7 Days	14 days	28 Days
Control mix	7.08	8.03	9.53
Mix 1	8.25	8.98	10.35
Mix 2	9.03	10.02	10.71
Mix 3	6.55	7.50	8.98
Mix 4	5.94	6.78	7.87

As the percentage of S C B A increases the strength in compression of concrete tends to increase up to certain percentage and then start's decreasing with the increase of ash content.

The strength of 10% S C B A concrete is more than 5% S C B A concrete and strength of 5% S C B A concrete is more than normal concrete. This shows that till 10% S C B A concrete the quality increases while percentage of S C B A increases. The quality of blocks having 10% S C B A is practically equivalent to 15% S C B A. This expansion in quality in S C B A solid is because of essence of Silica in S C B A. Silica in S C B A respond with remaining CH after the arrangement of C-S-H gel, and increment the measure of C-S-H gel and results in increment the quality.

5. Conclusion

This research was successfully carried out, to the establishment of SCBA as an alternative cement replacement material in concrete. Pulverized bagasse ash is a suitable pozzolanic material for use in concrete. After the detailed investigation, the following conclusions have been drawn:

- S C B A in concrete gives the higher compressive strength, hence optimal results were found at the 10% of cement replacement with S C B A without significant loss in strength of concrete.
- Compressive strength after 28 days increases by 7.14N/mm2 as compared to normal concrete after the replacement of cement with 10% of S C B A.
- Flexural strength after 28 days increases by 1.18 N/mm2 as compared to normal concrete after the replacement of cement with 10% of S C B A.
- The usage of S C B A in concrete saves the amount of cement and also proves minimizes the environmental problem and requirement of land fill area to dispose sugarcane bagasse ash also minimizes.
- Sugarcane bagasse ash can also be used as admixtures in cement concrete as it is very rich in silica.
- The cement replacement with S C B A increases the workability, and eases the process; therefore, use of super-plasticizer is not essential.
- It is recommended that future research should be performed to assess the use of S C B A in concrete for several properties of concrete for example modulus of elasticity, flexure test, split tensile test, drying shrinkage etc.

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