An Experimental Study on Strength Properties of Concrete by Partially Replacing Cement with Sugarcane Baggase Ash

M. Sambasiva Rao
Associate Professor,
Department of Civil Engineering
Sri Vasavi Engineering ollege,
Pedatadepalli

T. Yeswanth Sai
Assistant Professor,
Department of Civil Engineering
Sri Vasavi Engineering College,
Pedatadepalli

L. Vyshnavi Sai
Assistant Professor,
Department of Civil Engineering
Sri Vasavi Engineering College,
Pedatadepalli

GVLN Murthy
Assistant Professor,
Department of Civil Engineering
Sri Vasavi Engineering College,
Pedatadepalli

Abstract - **With increasing demand and consumption of cement, researchers and scientist are in search of developing alternate binders that are eco-friendly and contribute towards waste management. The utilization of industrial and agricultural waste produced by industrial processes has been the focus on waste reduction. One of the agro waste sugar cane bagasse ash (SCBA) which is a fibrous waste product obtained from sugar mills as byproduct. Juice is extracted from sugar cane then ash produced by burning bagasse in uncontrolled condition and at very high temperature.**

In this paper SCBA has been chemically and physically characterized and partially replaced in the ratio of 0%, 10%, 15%, and 20% by weight of cement in concrete. The properties for fresh concrete are tested like slump cone test and for hardened concrete compressive strength at the age of 7,28,56 and 90 days. The test result indicate that the strength of concrete increase up to 15% SCBA replacement with cement.

Keywords: Bagasse Ash, concrete, Compressive strength

INTRODUCTION

Ordinary Portland cement is the most extensively used construction material in the world. Since the early 1980's, there has been an enormous demand for the mineral admixture and in future this demand is expected to increase even more. Also in this modern age every structure has its own intended purpose and hence to meet this purpose modification in traditional cement concrete has become essential. This situation has led to the extensive research on concrete resulting in mineral admixture to be partly used as cement replacement to increase workability in most structural application. If some of raw material having similar composition can be replaced by weight of cement in concrete then cost could be reduced without affecting its quality. For this reason sugarcane bagasse ash (SCBA) is one of
the main byproduct can be used as mineral admixture due to its high content in silica (Sio2). 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.

Sugar cane bagasse ash in the present study is obtained from Jeypore sugars ltd from chagallu, west Godav ari district, Andhra Pradesh. This study investigates the strength performance of concrete using partial blends of Ordinary Portland cement 53 grade (kcp) cement, fine aggregate conforming to zone-III.

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% and 20%, by weight. The main ingredients consist of Portland cement, SCBA, crushed and coarse aggregate and water. After mixing, concrete specimens were casted and subsequently all test specimens were cured in water at 3, 7, 28 and 56 Days.

I. EXPERIMENTAL INVESTIGATION:

The standard size of cube 150mm×150mm×150mm is used. The mix design of concrete was done according to Indian Standard guidelines. Based upon the quantities of ingredient of the mixes, the quantities of SCBA for 0, 10, 15, and 20 replacements 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

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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, split tensile strength for 56 days. The specimens were taken out from the curing tank just prior to the test. This test was conducted as per the relevant Indian Standard specifications.

A. Material Details:

The materials used in this investigation are Cement: The OPC Cement of 53 grade was used with fineness 6%and standardconsistency28%. Fine Aggregate:Basalt stone crushed sand is used as fine aggregate. The sand particles should also pack to give minimum void ratio, 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 2.64 and fineness modulus is 3.35. Those fractions from 4.75 mm to 50 micron are termed as fine aggregate, and the bulk density of fine aggregate is 1593.16kg/m^3. Coarse Aggregates: The crushed aggregates used were 10mm and 20mm nominal size and are tested as per Indian standard and results are within the permissible limit. The specific gravity and bulk density of 10 mm and 20mm aggregate are 2.78 and 2.83 and 1687 kg/ m3 and 1792.31kg/m3respectively.And fineness modulus is 6.260and 6.734. Water: Water available in the site campus conforming to the requirements of water for concreting and curing as per IS: 456-2009. Sugarcane Bagasse Ash: The sugarcane bagasse consists of approximately 50% of cellulose, 25% of hemicelluloses 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 bagasse was backed in the graphite crucible air tight, and place inside electric control furnace and burnt at temperature of 1200^{0} c for 5 hours to obtain a black color ash which is the bagasse ash which was used in research particle size analysis.

The particle size of the distributions of bagasse ash were determined using the (ASF) specifications. 100 g each of the dried ash was taken and introduced into a set of sieves arranged in descending order of fineness and shaken for 15 minutes which is the recommended shaking time to achieve complete classification. The weight retained on each sieve was taken and expressed as % gas of the total sample weight few studies has been reported on the bagasse ash

Sl. No	Particular	53grade OPC
1	Normal consistency	35%
2	Specific gravity	3.00
3	Setting time (in min)	47 sec
	(a) Initial setting time	90min
	(b) Final setting time	220 min
4	Fineness	8%

(BA) as partial replacement material in respects of cement motors. In this study, the effects of BA content as partial replacement of cement on physical and mechanical properties of hardened concrete or reported. The properties of concrete investigated include compressive strength etc. The test results indicate that BA is an effective mineral admixture with 20% as partial replacement ratio of cement.

B.MIX CONSTITUENTS

C_1 (100%cement) + F.A+ C.A
C_2 (90% cement+10% SCBA) + F.A+C.A
C_3 (85% cement+15% SCBA) +F.A+C.A
C_4 (80% cement+20% SCBA) +F.A+C.A
F.A – fine aggregate, C.A – coarse aggregate
SCBA – sugar cane bagasse ash

Total 12 cubes of four different mix proportions were casted and four were casted at 3 days, four cubes at 7 days, four cubes at 28 days.

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II. DESIGN OF MIX FOR M_{20} GRADE CONCRETE

1. Concrete Mix Design: The grade of cement OPC 53(kcp) cement used in this investigation is M_{20} without use of sugar cane bagasse ash. The mix design is based on strength criteria and durability criteria used for moderate environment. The ratios by weight cement, fine aggregate and coarse aggregate are obtained using the equations given in IS: 10262-1982 are given below. These proportions are maintained strictly same throughout the casting process to obtain a uniform standard and workable concrete mix. Cubes are tested for compressive test after 3 days, 7 days and 28 days curing.

2. Factors Affecting The Chioce Of Mix Proportions:

1. Compressive strength
2. Workability
3. Durability
4. Maximum nominal size of aggregate
5. Grading and Type Of Aggregate
6. Quality Control.

3. Factors To Be Considered For Mix Design:

- The grade designation giving the characteristic strength requirement of concrete.
- The type of cement influences the rate of development of compressive strength of concrete.

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- Maximum nominal size of aggregates to be used in concrete may be as large as possible within the limits prescribed by IS 456:2000.
- The cement content is to be limited from shrinkage, cracking and creep.
- The workability of concrete for satisfactory placing and compaction is related to the size and shape of section, quantity and spacing of reinforcement and technique used for transportation, placing and compaction.

4. DETAILS OF MIX DESIGN (DURABILITY CRITERIA) AS PER IS: 10262-1982:

1. Design specifications:

Characteristic compressive strength at 28days (f_{ck}) $=20 N/mm^2$ (M_{20})
Maximum size of aggregate = 20mm
Degree of workability (assumed) = 0.90
Degree of quality control (assumed) = Good
Assumed type of exposure = Mild

a) *Test data for materials:*

Cement used = OPC 53 grade
Specific gravity of cement = 3.00
Specific gravity of coarse aggregate = 2.83
Specific gravity of fine aggregate =2.6(Zone-III)
Standard deviation for M_{20} grade and good degree of control (s) = 4.6 N/mm^2 (S is taken as greater of two values given in IS: 456- 2000 and IS: 10262-1982)
Target average compressive strength at 28 days,

$F_{ck} = f_{ck} + t_{cs}$
$= 20 + (1.65 \times 4.6) = 27.59\ N/mm^2$

F_{Ck} = characteristic compressive strength

b) *Selection of water-cement ratio:*

For mild exposure form durability point of view maximum water- cement ratio is 0.55. Hence water- cement ratio is adopted in this investigations is 0.48.

c) *Estimation of air content:*

For 20mm size coarse aggregate percentage of entrapped air = 2.0%

d) *Selection of water and sand content:*

Approximate sand and water content per cubic meter. For water cement ratio = 0.6; compaction factor = 0.9 up to M_{35} and 20mm max. Size coarse aggregate.

Water content including surface water per cubic meter concrete= 186kg
Sand as the % total aggregate by absolute volume = 35 %

Increase in water content for increase in value of compaction factor by 0.1=3% Adjusted water content = 186 +186 x (3/100)

= 191.58 kg/m^3

Required sand content as % of total aggregate by absolute volume is =35-0.9 =34.1%

e) *Calculation of cement content:*

Water cement ratio =0.48
Water content = 191.58 kg/m^3
Cement content, C = (water content) / (w/c ratio) =191.58 / 0.48
=399.125kg/m^3>300(min. cement content)

f) *Calculation of coarse and fine aggregate content:*

For 20mm max. Size of aggregate entrapped air % of volume of concrete= 2%
Fine aggregate content:
Volume $V = [W+(C/S_C) + (1/P) \times (f_a/s_{fa})] \times (1/1000)$
Where,
V=absolute volume= (1-0.02) = 0.98
W=water content = 191.58 kg/m^3
C =cement content = 399.125 kg/m^3
S_C =specific gravity of cement = 3.00
P = ratio of F.A to total aggregate by absolute volume
=sand content required / total absolute volume
=34.1 / 100
=0.341
f_a = fine aggregate , kg/m^3
s_{fa} = specific gravity of fine aggregate = 2.53
$V=[W+(C/S_C)+(1/P)X(f_a/s_{fa})]X(1/1000)$
$0.98=[191.58+(399.125/3.00)+(1/0.341)x(f_a/2.53)]X(1/1000)$
=516.13kg/m^3

Weight of coarse aggregate:

$V=[W+(C/S_C)+((1/(1-P)) \times (c_a/s_{fa})] \times (1/1000)]$

Where, V = absolute volume= (1-0.02) = 0.98
W = water content = 191.58 kg/m^3
C = cement content = 399.125 kg/m^3
S_C = specific gravity of cement = 3.00
P = ratio of F.A to total aggregate by absolute volume
=sand content required / total absolute volume
=34.1 / 100 = 0.341
c_a=coarse aggregate, kg/m^3
s_{ca} =specific gravity of coarse aggregate = 2.5 $V=[W+(C/S_C+((1/ (1-P)) \times (c_a/s_{fa})] \times (1/1000)]$
$0.98=[191.5+(399.125/3.00)+(1/(10.341)X(c_a/2.82)X(1/1000)]$
=1218.17658 kg/m^3

g) *Determination of mix proportion:*

Water: cement: fine aggregate: coarse aggregate
191.58: 399.125: 565.469: 1218.176
0.48: 1: 1.5: 3.00

Hence the final mix proportions are
0.48: 1: 1.5: 3.00

COMPOSITION OF MIXES FROM C_1 TO C_4

a) For mix $C_{1:}$ 0.48: 1: 1.5: 3.00

The mix is nominal mix with 1 part of cement, 1.5 parts of fine aggregate and 3.00 parts of coarse aggregate in full proportions.

Materials for cubes:

Quantity of cement added = 11.2kg
Quantity of fine aggregate added = 16.8 kg
Quantity of coarse aggregate added = 33.6 kg
For 4 cubes, Quantity of water added = 3840ml
Water cement ratio w/c = 0.48

b) For mix C_2 :0.48:(0.9% cement + 0.1%SCBA):1.5:3.00

The mix is nominal mix with cement is replaced by 0.1% of bagasse ash, 1.5 parts of fine aggregate and 3.00 parts of coarse aggregate.

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Materials for cubes:
Quantity of cement added = 10.08 kg Quantity of fine aggregate added = 16.8 kg
Quantity of coarse aggregate added = 33.6 kg
Quantity of bagasse ash added = 1.12 kg
For 4 cubes, Quantity of water added = 3840ml
Water cement ratio w/c = 0.48

c) For mix C_3:0.45 :(0.85%cement + 0.15% SCBA):1.5:3.00

The mix is nominal mix with cement is replaced by 0.15% of bagasse ash, 1.5 parts of fine aggregate and 3.00 parts of coarse aggregate.

Materials for cubes:
Quantity of cement added = 9.52kg
Quantity of fine aggregate added = 16.8 kg
Quantity of coarse aggregate added = 33.6 kg
Quantity of bagasse ash added = 1.68 kg
For 4 cubes, Quantity of water added = 3840ml
Water cement ratio w/c = 0.48

d)For mix C_4:0.45 :(0.80%cement + 0.20% SCBA):1.5:3.00

The mix is nominal mix with cement is replaced by 0.20% of bagasse ash, 1.5 parts of fine aggregate and 3.00 parts of coarse aggregate.

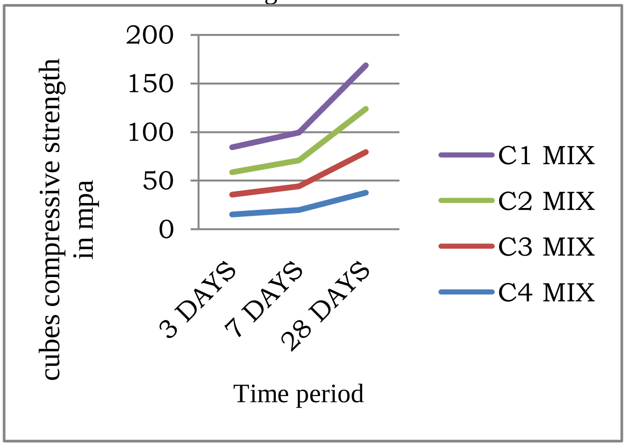
Materials for cubes:
Quantity of cement added = 8.96kg
Quantity of fine aggregate added = 16.8 kg Quantity of coarse aggregate added = 33.6 kg
Quantity of bagasse ash added = 2.24 kg For 4 cubes, Quantity of water added = 3840ml
Water cement ratio w/c = 0.48

5. TESTS ON HARD CONCRETE AND RESULTS

Strength results including graphs hardened propertie s of trail mixes sugar cane bagasse ash as an admixture:

Mix no	Hardened concrete properties		
	cubes compressive strength		
	3 days n/mm^2	7 days n/mm^2	28 days n/mm^2
c_1	25.78	28.89	44.89
c_2	23.11	26.67	44.44
c_3	20.44	24.22	41.56
c_4	15.11	19.78	37.78

Graph showing the result of the cube: Compressive strength at different stages for different mixes:



A) Strength Variations Of Mixes (C_1toc_4) After 3 Days:

- The strength of mix C_1 at 3 days is 25.78 N/mm^2
- The mix C_2 (0.45 :(0.9+0.1):1.5:3.00) gave a strength of 23.11 N/mm^2 which is 89.64 % of the strengths of C_1.
- The mix C_3 (0.45 :(0.85+0.1):1.5:3.00) gave a strength of 20.44 N/mm^2 which is79.29% of the strengths of C_1.
- The mix C_4 (0.45 :(0.80+0.20):1.5:3.00) gave a strength of 15.11 N/mm^2 which is58.61% of the strengths of C_1

B) Strength Variations Of Mixes (C_1toc_4) After 7 Days:

- The strength of mix C_1 at 7 days is 28.89 N/mm^2
- The mix C_2 (0.45 :(0.9+0.1):1.5:3.00) gave a strength of 26.67 N/mm^2 which is 92.31% of the strengths of C_1.
- The mix C_3 (0.45 :(0.85+0.15):1.5:3.00) gave a strength of 24.22 N/mm^2 which is 83.83% of the strengths of C_1.
- The mix C_4 (0.45 :(0.80+0.20):1.5:3.00) gave a strength of 19.78N/mm^2 which is 68.47% of the strengths of C_1.

C) Strength Variations Of Mixes (C_1toc_4) After 28 Days:

- The strength of mix C_1 at 7 days is 44.89 N/mm^2
- The mix C_2 (0.45 : (0.9+0.1):1.5:3.00) gave a strength of 44.44 N/mm^2 which is 98.99% of the strengths of C_1.
- The mix C_3 (0.45 : (0.85+0.15):1.5:3.00) gave a strength of 41.56N/mm^2 which is 92.58% of the strengths of C_1.
- The mix C_4 (0.45:(0.80+0.20):1.5:3.00) gave a strength of 37.78N/mm^2 which is 84.16 % of the strengths of C_1.

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