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Durability Studies of Hybrid Reinforced Self Compacting Concrete with Partial Replacement of Sugarcane Bagasse Ash

[I]Manjupriya.R, [II]Suresh.M, [III]Sivaraj.M
[I]PG Student, [II]Assistant Professor, [III]Prof & Principal,
[I,II,III]Dept. of Civil Engineering, N.S.N College of Engg. and Tech., Karur, Tamil Nadu, India

Abstract
This project deals with the durability properties of hybrid reinforced self compacting concrete with partial replacement of sugarcane bagasse ash. Cement is partially replaced by sugarcane Bagasse Ash (SCBA).Self-compacting concrete (SCC) offers several economical and technical benefits; the use of steel fibers extends its possibilities. This study is to compare the properties of SCC and hybrid reinforced self-compacting concrete (HRSCC) with high volume of mineral addition. Self-compacting concrete (SCC) mixes are produced by replacing the cement with 5%, 10%, 15% & 20% of sugarcane bagasse ash and with addition of polypropylene synthetic fiber of 0.05% and 0.10% to the SCC concrete. The water-powder (w/p) ratio used in this investigation is 0.32. Super plasticizer used in this study is Glenium B233 and its dosage is 2% to obtain the required SCC mix. Fresh concrete Specimens such as cubes, cylinders and prisms were casted and tested for various mix proportions to study the mechanical properties such as compressive strength, split tensile strength and flexural strength & durability studies such as sulphate attack, carbonation, chloride diffusion, porosity, saturated water absorption, sorptivity are proposed at different ages of required days. The use of two or more types of fibers in a suitable combination may potentially not only improve the overall properties of self-compacting concrete, but may also result in performance synergy.

Keywords
Self Compacting Concrete, Sugarcane Bagasse ash, Fly ash, Glenium B233, Polypropylene fiber

I. Introduction

Self compacting concrete (SCC), which flows under its own weight and does not require any external vibration for compaction, has revolutionized concrete placement. SCC, was first introduced in the late 1980's by Japanese researchers, is highly workable concrete that can flow under its own weight through restricted sections without segregation and bleeding. Such concrete should have a relatively low yield value to ensure high flow ability, a moderate and must maintain its homogeneity during transportation, placing and curing to ensure adequate structural performance and long term durability. In SCC, the aggregates contribute 60–70% of the total volume. Proper choice of aggregates has significant influence on the fresh and hardened properties of concrete. Aggregate characteristics such as shape, texture and grading influence workability, finish ability, bleeding, pump ability, segregation of fresh concrete and strength, stiffness, shrinkage, creep, density, permeability, and durability of hardened concrete. It leads to a better quality concrete and an efficient construction process. The successful development of SCC must ensure a good balance between deformability and stability. The advantages of SCC are: Improved quality of concrete and reduction of onsite repairs; Faster construction times; Lower overall costs; Facilitation of introduction of automation into concrete construction; Improvement of health and safety is also achieved through elimination of handling of vibrators;

Self-curing or internal curing is a technique that can be used to provide additional moisture in concrete for more effective hydration of cement and reduced self-desiccation. There are two major methods available for internal curing of concrete. The first method uses saturated porous lightweight aggregate (LWA) in order to supply an internal source of water, which can replace the water consumed by chemical shrinkage during cement hydration. The second method uses poly-ethylene glycol (PEG) or super absorbent polymers which reduces the evaporation of water from the surface of concrete and also helps in water retention. In the present study the first method is being adopted.

II. Literature Review

Strength and durability performance of SCC over a wide range of concrete strength with varying dosages of fly ash were through micro-structure related properties of concrete such as permeability, water absorption, chloride diffusion and chemical attack. The weight loss significantly decreased with increasing in fly ash dosage for sulphate attack, chloride ion permeability [1]. In this study the strength and durability performance of SCC over a wide range of concrete strength with varying dosages of fly ash. The durability properties were investigated through micro-structure related properties of concrete such as permeability, waterabsorption, chloride diffusion and chemical attack. The experimental investigations was carried out for the specimen with different mixes incorporated various dosages of fly ash percentages of 0,10,30,50,70,85%.SCC of lower strength grades (20-30M Pa) can be produced at a replacement of about 70-85% while at (60-90MPa) can be produced at a replacement of about 30-50%.The weight loss significantly decreased with increasing in fly ash dosage for sulphateattack,chloride ion permeability than normal concrete. [2]. The various durability indicators for the specific filler additives in the mix design incorporated in ash.The durability properties were investigated properties of concrete such as sorptivity, poro sity,waterabsorption,chloride diffusion and chemical attack. The experimental investigations was carried out for the specimen with different mixes incorporated various dosages of silica fume in this paper.SCC exhibit better durability potential compared to NVC. The replacement of silica fume reduces the open porosity and capillary absorption and chloride iron permeability than NVC. [3]. In this project, the potential durability of SCC and VC with similar compressive strength is achieved by the general indicators of durability and additional properties such as mercury porosity, waterporosity,chloridediffusion,corbonation,oxygen permeability were examined.The experimental investigation was carried out for the various mixes of SCC and VC were made with the same raw materials with identically proportion.SCC has a compressive strength better than VC.The results oh chloride diffusion and water absorption were equivalent for SCC and VC.The oxygen permeability for SCC is better than VC.The SCC and VC perform similar resistance to deterioration by aggressive agent. [4]. SCC usually show improved durability as compared to normal vibrated concrete with same w/c ratio.The durability properties such as water absorption,carbonation resistance and chloride induced corrosion resistance.Eight mixtures of different w/c ratio is used for experimental investigations from 0.62-0.42.SCC shows better results in durability properties for the w/c ratio as 0.42. [5]. In this paper the sulphate resistance and internal fundamental frequency was measured and compared with normal concrete.The objective of the research was to compare the performance of SCC under the influence of a solution of a sodium sulphate.The significant decrease of weight was observed for SCC when exposed to 18 g/l of sodium sulphatein distilled water.So the limestone filler is added to the mix.If the content of sulphates is not known,SCC is not suitable to use with large amount of limestone powder. [6]. Sugar cane bagasse ash (SCBA) is generated as a combustion by-product from boilers of sugar and alcohol factories. Composed mainly of silica, this by-product can be used as a mineral admixture in mortar and concrete. Several studies have shown that the use of SCBA as partial Portland cement replacement can improve some properties of cementitious materials. However, it is not yet clear if these improvements are associated to physical or chemical effects. This work investigates the pozzolanic and filler effects of a residual SCBA in mortars. Initially, the influence of particle size of SCBA on the packing density, pozzolanic activity of SCBA and compressive strength of mortars was analyzed. In addition, the behavior of SCBA was compared to that of an insoluble material of the same packing density. The results indicate that SCBA may be classified as a pozzolanic material, but that its activity depends significantly on its particle size and fineness.[7]. A comprehensive set of experimental data were generated regarding the effects of collated fibrillated polypropylene fibers at relatively low volume fractions (below 0.3%) on the compressive, flexural and impact properties of concrete materials with different binder compositions. Statistical analysis of results produced reliable conclusions on the mechanical properties of polypropylene fiber reinforced, concrete and also on the interaction of fibers and pozzolanic admixtures in deciding these properties. Polypropylene fibers were observed to have no statistically significant effects on compressive or flexural strength of concrete, while flexural toughness and impact resistance showed an increase in the presence of polypropylene fibers. Positive interactions were also detected between fibers and pozzolans.

III. Materials

1. Cementitious Materials

Ordinary Portland cement of 53 grade conforming to IS: 12269-1987 [9] is used. The specific gravity of cement is found to be 3.15. The class 'F' fly ash obtained from Mettur thermal power plant is used as a mineral admixture. The specific gravity of fly ash is 2.27. The chemical properties of the cementitious materials are shown in Table 3.1.

Table 3.1 : Chemical properties of cementitious materials

Chemical Composition	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O
Cement (%)	19.4	5.28	6.0	62.3	1.16	2.21	0.23	0.97
Fly ash (%)	50.68	26.9	11.24	5.24	1.82	1.72	0.5	0.81

2. Fine aggregate and coarse aggregate

Locally available river sand is used as natural fine aggregate. River sand was conforming to aggregate grading zone III. Natural crushed coarse aggregate of size 12 mm is used in this study. It is tested as per IS: 383-1970 [10]. The properties of fine & coarse aggregate are presented in Table 3.2.

3. Sugar cane Bagasse Ash

The bagasse ash was then ground until the particles passing the 63μm sieve size reach about 85% and the specific surface area about 4716 cm^2/gm. Ordinary Portland cement and Portland Pozzolana cement were replaced by sugarcane bagasse ash at different percentage ratios.

4. Polypropylene Fiber

Polypropylene fibers were first suggested as an admixture to concrete in 1965 for the construction of blast resistant buildings for the US Corps of Engineers. The fiber has subsequently been improved further and at present it is used either as short discontinuous fibrillated material for production of fiber reinforced concrete or a continuous mat for production of thin sheet components. Since then the use of these fibers has increased tremendously in construction of structures because addition of fibers in concrete improves the toughness, flexural strength, tensile strength and impact strength as well as failure mode of concrete. Polypropylene twine is cheap, abundantly available, and like all manmade fibers of a consistent quality.

Table 3.2 : Properties of Aggregates

S. No	Properties	Fine Aggregate	Coarse Aggregate
1.	Specific Gravity	2.61	2.73
2.	Bulk Density (kg/m^3)	1635	1571
3.	Fineness Modulus	2.18	6.36
4.	Water Absorption (%)	0.52	0.45

5. Chemical Admixtures

Superplastcizer or high range water reducing admixtures are an essential component of SCC. Glenium B233 (polycarboxylate ether based) superplastcizer was used to attain good workability in SCC and their dosage is 0.5% of cementitious material. Glenium Stream 2 admixture was used as viscosity modifying admixture to attain good flowability in SCC and their dosage is 0.2% of cementitious material.

6. Water

Mixing water used in the study satisfied the quality standards of drinking water and it was taken from NSN college campus.

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IV. Methodology

A. Mix Design & Curing

In this present investigation self compacting concrete were designed based on EFNARC [12] guidelines. Totally 11 mix proportions are arrived including control mix and it shown in Table 4.1. Coarse and fine aggregate contents are initially fixed so that self compactability is achieved by adjusting the water/ powder ratio and super plasticizer dosage. From the hardened properties results, durability properties such as sulphate attack, water absorption, porosity and sorptivity were performed.

Table 4.1 : Mix proportion for various SCC mixes

S.No	Material	Replacement kg/m³				
		Control mix 0%	5% SCBA	10% SCBA	15% SCBA	20% SCBA
1.	Cement	437.19	415.34	393.49	371.62	349.76
2.	Sugarcane-Bagasse ash	-	21.85	43.7	65.57	87.43
3.	Fine aggregate	826.05	826.05	826.05	826.05	826.05
4.	Coarse aggregate	812.91	812.91	812.91	812.91	812.91
6.	Fly ash	122.58	122.58	122.58	122.58	122.58
7.	Water	178.44	178.44	178.44	178.44	178.44
8.	Super plasticizer	3.91	3.91	3.91	3.91	3.91

B. Durability Tests of SCC

1. Sulphate Attack

Concrete cube specimens 100mm x 100mm x 100mm are casted for sulphate attack. The casted specimens are kept at curing condition upto 28 days. The specimens were immersed in a solution of 3% of sodium sulphate in distilled water as shown in Fig 4.1. The solutions were renewed at regular interval for accurate results. At the days of age, at 7, 28 and 56 days of exposure, the specimens were weighed and strength loss is calculated. The test results are shown in Table 5.2.

Fig.4.1 Sulphate attack

2. Water Absorption

Concrete specimens of 100 mm dia and 50 mm thickness are casted for water absorption. The casted specimens are kept at curing condition upto 28 days. The specimens were completely immersed in water as shown in Fig 4.2. At the days of age at 7, 28 and 56 days the specimens were weighed to measure the percentage increase in water absorption. The water absorption percentages of the specimens are tabulated in Table 5.3.

Fig.4.2 Water absorption

3. Porosity

Concrete specimens of 100 mm dia and 50 mm thickness are casted to determine the porous nature of the concrete. The casted specimens are kept at curing condition upto 28 days. The porosity is the fraction of the bulk volume of the material occupied by voids. The volume of voids is obtained from the volume of water absorbed by an oven dried specimen. The effective porosity is found by using the given relation,

$$\text{Effective Porosity} = \frac{Ws-Wd}{Ws-Wsub} X\ 100$$

Where,
Ws = weight of specimen at fully saturated condition
Wd = weight of oven dried specimen, Wsub = submerged weight of specimen in water.
The calculated porosity values are showed in Table 5.4.

4. Sorptivity

Concrete specimens of 100 mm dia and 50 mm thickness cylinders are casted for sorptivity test. . The casted specimens are kept at curing condition upto 28 days. It is the material property to absorb transmits water by capillarity. The specimens were placed in a tray such that their bottom surface up to a height of 5 mm is in contact with water which should allow free movement of water through the bottom surface. The sides of the specimens were sealed with an adhesive coating from the bottom surface as shown in Fig 4.3. Specimens were removed from the tray weighed at regular intervals. The sorptivity is measured from the relation,

$S = I/ t^{½}$

Where; S = sorptivity in mm,
t = elapsed time in mint.
I = $\Delta w/Ad$,
A= surface area of the specimen through which water penetrated.
d= density of water
The sorptivity values of each specimen are shown in Table 5.5.

Fig.4.3 : Sorptivity

V. Results and Discussion

A. Hardened properties of SCSCC

Hardened concrete properties obtained from the tests such as compressive strength, split tensile strength and flexural strength for 7 days and 28 days as per IS516:1959 [11] are given in Table 9. These values are tabulated for the various replacement of fine aggregate by SCBA.From the hardened properties of SCC, 15% replacement of cement by SCBA shows increase in compressive strength, tensile strength and flexural strength than the conventional and other SCC mixes as shown in Table 5.1.

Table 5.1 : Hardened Properties of SCC with SCBA

S.No	Mix ID	Compressive strength (MPa)		Split tensile strength (MPa)		Flexure strength (MPa)	
		7 Days	28 Days	7 Days	28 Days	7 Days	28 Days
1.	CM_{WC}	38.00	44.10	2.96	3.98	5.65	6.63
2.	CM_{SC}	35.56	41.25	1.85	2.31	5.04	5.52
3.	$SCBA_5$	28.50	43.90	1.92	3.41	5.55	6.02
4.	$SCBA_{10}$	32.06	44.26	2.12	3.65	5.67	6.65
5.	**$SCBA_{15}$**	**34.40**	**50.90**	**2.89**	**4.42**	**5.83**	**7.87**
6.	$SCBA_{20}$	34.36	50.00	2.60	3.98	5.30	7.33

B. Durability properties

1. Sulphate attack

Table 5.2 Results for sulphate attack

Sample No	Mix ID	Weight Loss (%)			Strength Loss (%)		
		7 days	28 days	56 days	7 days	28 days	56 days
1.	CMsc	0.85	1.51	2.67	3.91	5.12	6.09
2.	$SCBA_{15}$	0.85	1.52	2.68	3.92	5.13	6.10

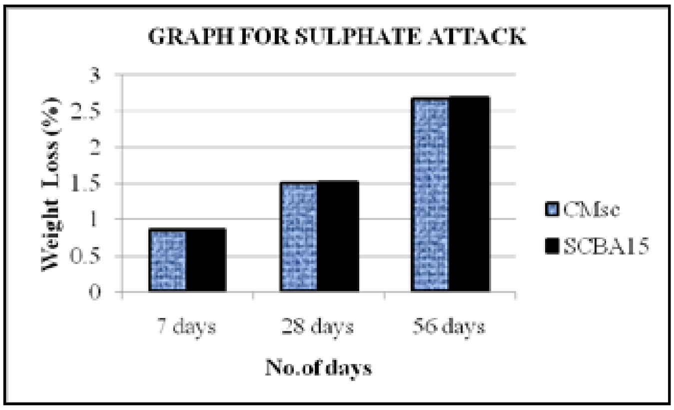

Fig.5.1 : Weight loss

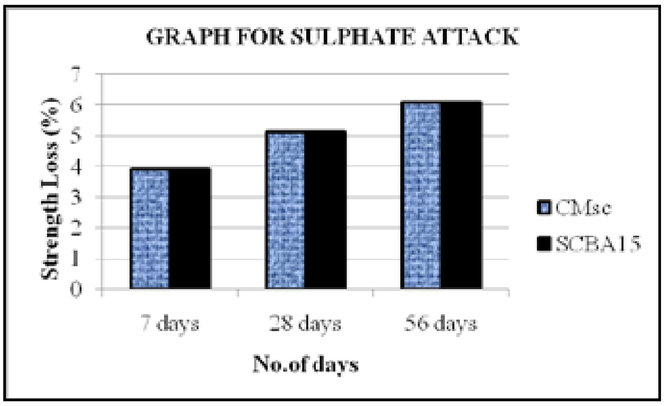

Fig.5.2 Strength loss

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The percentage of weight loss due to sulphate attack for CMsc and $SCBA_{15}$ are 0.85% and 0.89% for 7 days, 1.51 and 1.53% for 28 days and 2.67% and 2.69% for 56 days and strength loss as 3.91% and 3.97% for 7 days, as 5.12% and 5.23% for 28 days, as 6.09% and 6.21% for 56 days and was obtained. Table 5.2 and Fig 5.1 and Fig 5.2 clearly shows the variation. The results shows that SCC with SCBA mixes is similar to the control mixes.

2. Water absorption:

Table.5.3 Results for water absorption

Sample No	Mix ID	Water absorption (%)		
		7 days	28 days	56 days
1.	CMsc	1.55	1.52	1.51
2.	$SCBA_{15}$	1.56	1.53	1.52

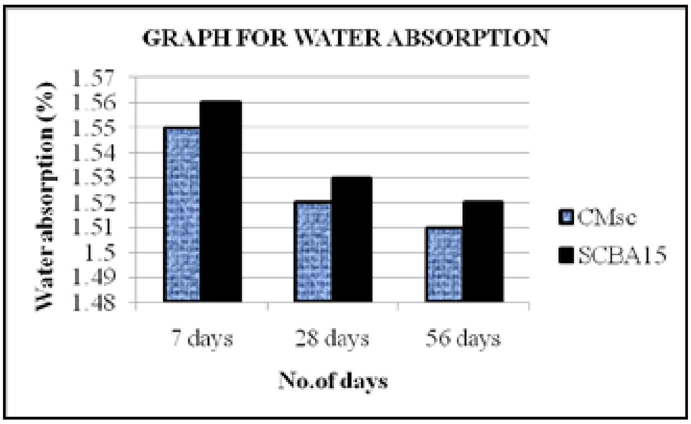

Fig. 5.3 : Water Absorption

The percentage of water absorbed in water absorption test for CMsc and $SCBA_{15}$ are 1.55% and 1.59% for 7 days, 1.52% and 1.57% for 28 days, 1.51% and 1.56% for 56 days was found. The test results is shown in Table 5.3 shown in Fig.5.3. From the fig 5.5 it can be understood that SCBA mix attained similar absorption compared to control mix.

3. Porosity

Table.5.4 : Results for porosity

Sample No	Mix ID	Effective Porosity (□)		
		7 days	28 days	56 days
1.	CMsc	6.88	7.01	7.1
2.	$SCBA_{15}$	6.89	7.03	7.14

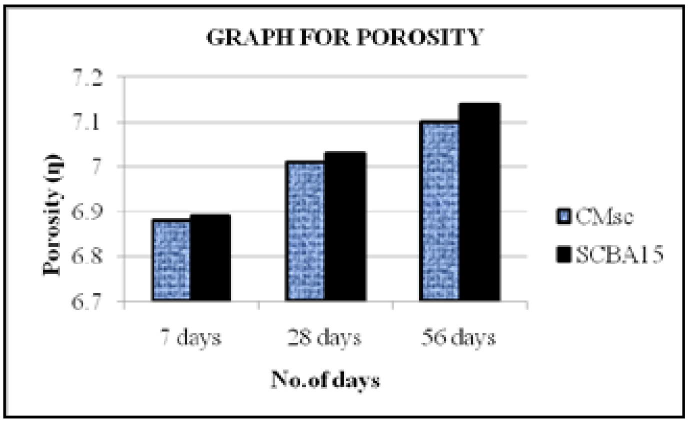

Fig.5.4 : Porosity

Porosity of SCC with SCBA is given in Table 5.4. The effective porosity (□) for CMsc and $SCBA_{15}$ 6.88% and 6.98% for 7 days, 7.01% and 7.09% for 28 days, 7.1% and 7.16% for 56 days was obtained. Fig 5.4 clearly illustrates that the porosity values of SCBA mix is similar to control SCC mix.

4. Sorptivity

Table.5.5 : Results for Sorptivity

Sample No	Mix ID	Sorptivity(10^{-5} ($mm/min^{0.5}$))		
		28 days	28 days	28 days
1.	CMsc	3.12	3.2	3.22
2.	$SCBA_{15}$	3.12	3.2	3.22

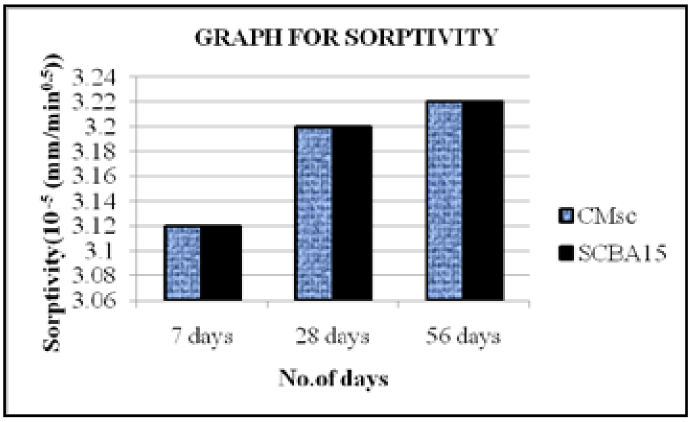

Fig.5.5 : Sorptivity

Table 5.5 gives the Sorptivity of SCC with SCBA. The sorptivity for CMsc and $SCBA_{15}$ are 3.12 and 3.12 for 7 days, 3.2 and 3.2 for 28 days, 3.22 and 3.22 for 56 days was found. Fig 5.5 shows that the sorptivity values of control mix and SCBA mix were remained same values. It indicates that less water is capillarised compared to SCBA mix.

VI. Conclusion

The following conclusions are drawn from the study on self compacting concrete with Sugarcane bagasse ash .

1. Bagasse ash is the by-product material which is used as the cement substitute material. It reduces the level of CO2 emissions by the cement industries and also save a great deal of core materials in cement manufacture
2. As the percentage (%) of partially replacement of bagasse ash in cement increases it normal consistency and its setting

time

3. In addition of polypropylene fiber, the crack formation had been arrested and mechanical and flexural properties of concrete achieve 30% higher than conventional concrete at lower volume fraction of fibre (0.25%).
4. The hybrid fiber reinforced concrete at the volume fraction of 1% enhances compressive strength by 34%, split tensile strength by 15% and flexural strength by 10% compared to conventional concrete.

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