Effects of Calcium Nitrate in Sugar Cane Bagasse Ash and Partial Replacement of Fine Aggregate by Stone Dust

V. M. Southararajan, S. Sivasankar, A. Krishna Rao

***Abstract:** This research work has been focused on the early age setting properties of Sugar cane bagasse ash (SCBA) substituted concrete and also monitored the rate of strength gain for different mixes. The waste by-product materials SCBA were replaced 0 to 30% by weight of binding materials in Portland cement with 0 to 3% of calcium nitrate type of accelerator had shown a consistent increase in the rate of setting. It can also be noted that the rate of hardening is higher with addition of 1% accelerator with 20% SCBA accelerates the pozzolanic reactions leading to additional gel formation of C-S-H and C-A-H that leads to the early age of hardening. The test results showed the better improvement in early stage of compressive strength for M25 grade of concrete attained at 3 days up to 34.15 MPa. The preliminary results were enough encouraging that these waste by-products materials were used to produce the quality of structural concrete without affecting their durability and lifespan.*

***Keywords:** Accelerator, Setting properties, Sugar cane bagasse ash, Strength gain, Ultrasonic pulse velocity.*

I. INTRODUCTION

The burning and produces a considerable amount of sugar cane bagasse ash is the waste by-products of organic materials which is more suitable for building materials and thus resulting to improve the properties of conventional concrete. The manufacturing of cement industries produces approximately one ton of cement is nearly polluted one ton of carbon-di-oxide. This issue can be considerably reduced due to usage of sugar cane ash in cement though there is a possible chance to make a quality of concrete thereby the usage of sugar cane bagasse ash is a pozzolanic material in concrete can be acknowledged in construction industries and thus resulting to consider decreasing the CO_2 emission and protect the environment safely. Previously this type of waste can be used for land filling or construction site works because production of sugar huge amount generated in worldwide and these types of waste materials is facing the bigger issue on how to dispose the waste materials in huge quantity for every year and this type of challenging is major constrain in worldwide. Therefore, the usage of SCBA in concrete is to resolve the significant issue and make economic structures in construction industries very safely. This research work has focused on the setting process of cementitious material act as binding materials during the hydration process and concentrated the mechanical properties of concrete at different curing days. It is well defined that the prediction of strength characteristics in concrete, the test results were compared and make a correlation curve of compressive strength for ultrasonic pulse velocity is based on the stiffening of the binding materials [1]. It was concluded that usage of ash in concrete with low water-binding materials ratio for different mixes in concrete produces the rapid strength gain in concrete properties [2]. This method is to monitor the various cementitious materials to act as a pozzolanic reaction at an early age and changing the fluid form to rigid bodies during the chemical reactions between binding material and capillary water. The term setting in concrete have been described the onset of good rigidity in the various stage were involved in cement pastes, cement/binder mortar and fresh concrete and also linear relationship has compared between the degree of heat of hydration and concrete strength. The NDT method used for various specimens to monitor the pulse for hardened smooth surface of concrete consisting of low water-binder material ratio 0.4 to 0.6 was analyzed and identified the setting rate was higher at lower w/b ratio content in the cementitious systems [3-5]. Therefore, few research works have been focused on the mechanical properties of concrete containing low calcium fly ash in concrete and maintained how to increase the rate of hardening with the help of curing techniques. Also, it was noted that the NDT techniques by UPV method to attain the maximum strength as well as higher pulse based on the curing methods. However, the test results also compared between the pulse and compressive strength of concrete was an exponential relationship in the coefficient of regressions [6]. Furthermore, the mortar studies were carried out for different mixes by using the UPV techniques. Also, the study was extended the usage of steel fibers in concrete and fixes the aspect ratio depending up on the flexural rigidity in bending stress test results [7-8].

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Limited work has focused on the durability studies on sugar cane bagasse ash up to 5% (without preheating) is more suitable binding materials in building materials and increases the strength for different mixes and compared all the lab test values are satisfied as per code. Similarly, a few research works have been concentrating the fineness particle by using the grinding in a ball mill after that heating the particle in hot air oven up to 600 to 10000C and used in concrete. Therefore, it was strongly recommended for various research works to use the SCBA ash waste materials replaced in Portland cement in concrete and various works have been studied systematically on their behaviour impact effect on the concrete [9-10]. Also, this author has concluded that the research work on SCBA ash replaced in OPC at different percentage 0 to 30% (by weight of binder content) for different grade of concrete mixture proportions was considered and made a statement about SCBA ash up to 15% was considerable and suitable [11].

II. RESEARCH SIGNIFICANCE

This research work has been shot out the significance issue on the waste by-product materials of SCBA thereby this study to be carried out the setting properties of SCBA ash as more suitable binding materials to act as pozzolanic materials (cementitious material) replaced in Portland cement and also to evaluate the influence of calcium nitrate (liquid ingredients) to act as a rapid setting on the high early strength of concrete for different mixes.

III. MATERIALS AND TEST METHODS

A.Cement

A 53-grade type of OPC was used for different mixes and the experimental laboratory test results (as given in Table I) as conforming to IS 12269-1987 [12].

Table- I: Test results on OPC

Consistency test of cement		34%
Initial Setting Time		95 minutes
Final Setting Time		265 minutes
Compressive Strength of CM (1:3)	7 days	21 N/mm^2
	28 days	47 N/mm^2
Specific-gravity		3.15

B. Fine Aggregate (FA)

Natural sand passing through standard sieve size 4.75 mm and test results for fineness modulus of river sand was conformed to zone- II as per guidelines are given IS 383-2016 [13] and specific gravity value 2.35.

C. Coarse Aggregate (CA)

The two combination of average particle sizes of coarse aggregate (60:40) 60% of 20 mm and 40% of 12.5 mm were used. The test result was calculated the fineness modulus 7.25 for 20 mm size and 6.90 for 12.5 mm aggregate.

D. Quarry Dust (QD)

Quarry dust conforming to zone II as per IS 383-2016 [13] was used for preparing the quarry dust concrete with a specific gravity value of 2.31 and the loose and bulk density 1450 kg/m3 and 1720 kg/m3 respectively.

E. Sugar cane bagasse ash (SCBA)

The SCBA used for the study was collected from Begumpet sugar cane industry located in Hyderabad. The original ash was grinding in a small mill to reduce its particle sizes and burnt up to 6000C in the Oven curing until the particles passes through 90 µm (IS sieve size) reaches about 85%.

F. Chemical admixture (CD)

The hydration of binder paste contains around 30% of very fine pores, known as gel pores. The gel pores must remain filled with capillary water. The addition of chemical admixture was found to be essential to avoid the hardness of the fresh concrete in low water-binder materials ratio. In the present study CONPLAST 430 super plasticizers (Sp) was used up to 1.5% by weight of binding materials along with different dosage level of calcium nitrate was added from 0% to 3% by weight of binding materials and act as a Accelerator (Acl) for various mixes. The normal potable water used for preparing the concrete specimen which is free from chloride and sulphates content.

IV. EXPERIMENTALPROCEDURE

A. Setting properties of cementitious materials

In the different setting properties of cementitious materials have been discussed in these studies, the setting of the cement paste from fluid state to solid state is called setting. It depends on the solidifying action of loss of plasticity is to be delayed, the ordinary Portland cement without any admixture as result of normal setting occurred. However, it required for working principle of various dosage level of SCBA ash and accelerator very much affected the setting phenomena which decreases the setting time of cement that is best test result showed at addition of 20% SCBA replaced with cement and higher dosage level of accelerator, the values are 20 minutes and 48 minutes for initial and final setting of binder respectively. Further, this research work to fix the optimum binder content based on the time properties there by upto 20% of SCBA with different percentage of accelerator dosage was studied systematically.

B. Test methods on compressive and split tensile strength

This study is focused on three stages and strives to produce the quality of structural concrete, the mix details are represented in Table II. The proper selection of binding material based on the literature review and initial trial and error method the SCBA content 10%, 20% and 30% replaced in OPC in concrete. The concrete mixture proportions were used M25 grade of concrete in accordance with IS 10262 2009 [14]. The rapid hardening required for all mixes to use the different dosage level of accelerator 1 to 3% (by weight of binding materials) was used. Overall three concrete specimens were cast and tested for each mix with different age of curing was maintained.

The compressive strength of concrete having a steel mold dimension of 150 x 150 x 150 mm and cylindrical size 300 mm height and 150 mm diameter specimen tested for split tensile strength in accordance with IS: 516 2009 [15].

Table- II: Mix details

stage of mix constituents	w/b ratio	Cement = 448.60 kg/m^3		Accelerator	Fine aggregate =752.71 (kg/m^3)		Coarse aggregate = 1064.65 (kg/m^3)
		OPC	SCBA		FA	QD	CA
		(%)					
Stage 1	0.44	90	10	1, 2 & 3	50	50	100
Stage 2		80	20		50	50	100
Stage 3		70	30		50	50	100

C. Sorptivity

The sorptivity test was performed for various mixes, all the samples were kept in hot air oven at 105°C for 24 hours followed by cooled down the specimen for 24 hours to maintain the constant moisture level. After that the four sides were sealed by tape/bitumen/paint and remaining sides are open. This type of coating method was maintaining the water flow and avoids the evaporation. Before keeping the sample were taken for initial dry weight followed by bottom surface contact with water at predefined interval time the water absorption was calculated with a balance of 0.1gm readability. The coefficient of sorptivity can be calculated by the following equation number (1).

The average cumulative water-absorption (inflow surface per unit area) increases elapsed time by square root (t)

$$I = S\,x\,t^{\frac{1}{2}}$$

$$S = \frac{I}{t^{\frac{1}{2}}} - - - - -equation\ number\ (1)$$

$$where\ S = sorptivity\ (mm)\ t\ is\ the\ elapsed\ time\ (minutes)$$

$$I = \frac{\Delta w}{AD}$$

$w1 = oven\ dry\ weight\ of\ cylinder(grams)$

$w2 = weight\ of\ cylinder\ after\ 30\ minutes\ for\ capillary\ suction\ of\ water\ (grams)$

$A = surface\ are\ of\ the\ specimen\ through\ how\ much\ water\ penetrated$

$D = density\ of\ the\ water$

D. Ultrasonic pulse velocity

The ultrasonic pulse velocity method is used to monitor the quality of mortar/concrete in accordance with IS: 13311-1992 (part1) [16]. The method consists of measuring the time of travel of an ultrasonic pulse passing through the concrete being tested. Comparatively higher velocity is obtained when the quality of concrete is good in terms of higher density, uniformity; homogeneity and considerably extend their lifetime.

After sufficient curing in water tank for all specimen were tested with respect to date wise for that dry specimen with smooth surface of the both side and fixed the length of specimen was 0.15 meter in UPV machine and recorded the values by using the ultrasonic pulse velocity for various mixes and the same specimen tested for the compressive strength at different age of curing.

V. RESULTS AND DISCUSSION

A. Setting properties of binding materials

It can be observed from the test result for various level of setting behavior of the cementitious materials which are presented in the Table III and graphically represented in the Figure 1. The setting time was decreased based on the higher dosage level of the accelerator. The fresh cement paste with various cementations materials prepared and tested with different level of duration with respect to time for all the fresh cement or supplementary paste to improve the heat of hydration limit with respect to time duration.

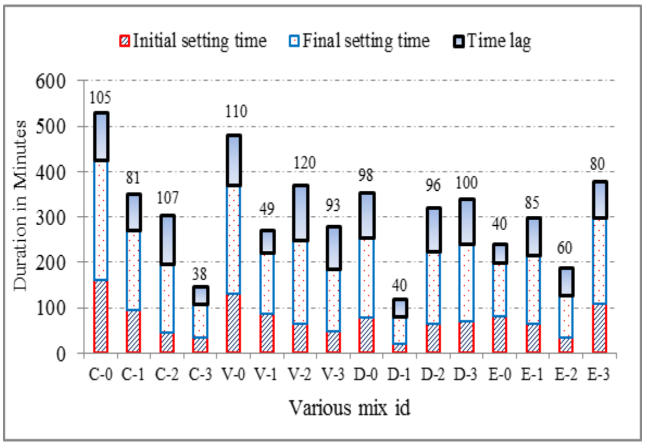


Fig. 1. Setting properties of time for various binding materials

Table- III: Setting properties of binding materials

Name	Mix details			Initial	Final	Time lag
	Cement	SCBA	Acl			
	(%)			minutes		
C-0	100	0	0	160	265	105
C-1		0	1	95	176	81
C-2		0	2	45	152	107
C-3		0	3	35	73	38
V-0	90	10	0	130	240	110
V-1		10	1	87	136	49
V-2		10	2	65	185	120
V-3		10	3	47	140	93
D-0	80	20	0	79	177	98
D-1		20	1	20	60	40
D-2		20	2	64	160	96
D-3		20	3	70	170	100
E-0	70	30	0	80	120	40
E-1		30	1	65	150	85
E-2		30	2	34	94	60
E-3		30	3	110	190	80

B. Compressive strength

The laboratory test results based on the compressive strength of concrete for various mixes are represented in Table IV and provided in Figure 2. It can be concluded that the Ordinary Portland cement (OPC) with one percent accelerator showed highest result for 28 days compressive strength 41.50 MPa as reported for C-1 and the rate of strength gain varies between 65 to 75%. The higher rate of strength gain was noted in 10% SCBA with addition of 1% accelerator (V-1 mix) and the compressive strength was 40.26 MPa at 28 days. Therefore, the effect of accelerator dosage level was optimized up to 1% based on the various test results.

Table- IV: Strength of concrete at different curing days

Mix ID	Compressive strength of concrete (MPa)			Strength gain (%) with respect to 28 days	
	3-days	14-days	28-days	3-days	14-days
C-0	21.32	27.1	35.1	39.45	22.79
C-1	29.2	35.3	41.5	29.64	14.94
C-2	28.75	34.5	40.3	28.66	14.39
C-3	34.15	35	41.2	17.11	15.05
V-0	24.2	31.3	37	34.59	15.41
V-1	26.7	33.7	40.26	33.68	16.29
V-2	25.1	26.1	28.75	12.70	9.22
V-3	20.31	22.7	27.5	26.15	17.45
D-0	24.01	29.99	38.9	38.28	22.90
D-1	27.78	37.3	41.2	32.57	9.47
D-2	24.45	29.2	39.92	38.75	26.85
D-3	21.2	24.51	34.83	39.13	29.63

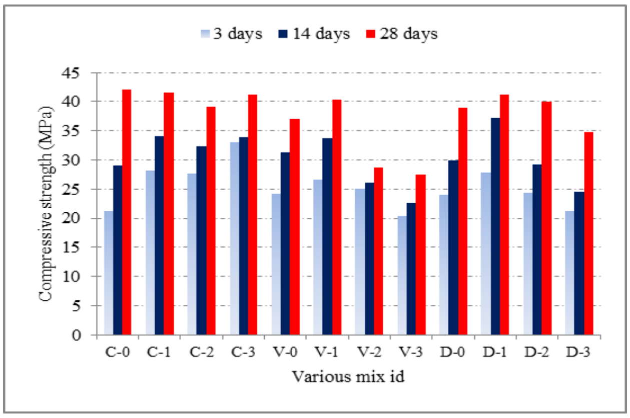


Fig. 2. Various mixes verses Compressive strength

The rate of strength gain was increased up to 80 to 84% with 20% SCBA by cement and a similar increased trend was observed that 20% SCBA with 1% accelerator (D-1 mix) for maximum strength obtained is 41.20 MPa, the rate of strength gain 85 to 86% (as shown in Figure 3) with further increase in accelerator dosage up to 3% (D-3 mix) the strength was 34.83 MPa and the rate of strength gain was less than that of conventional concrete. However, the strength was decreased at higher dosage level of accelerator for various mixes.

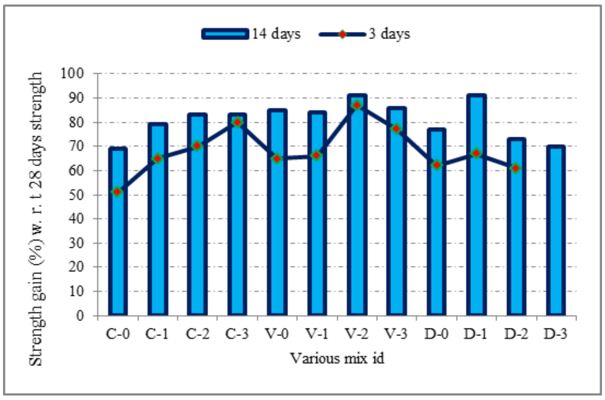
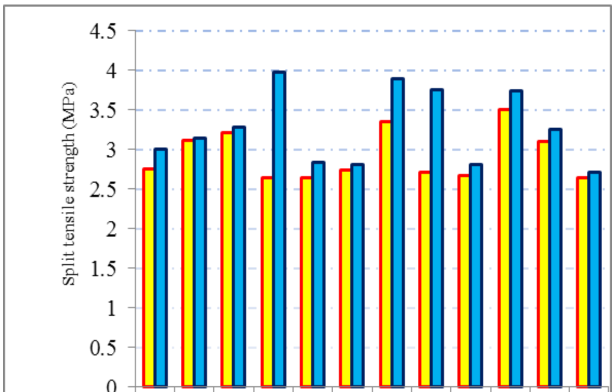


Fig. 3. The rate of strength gain of concrete at different curing days

C. Split tensile strength

This test method was identified the influence of SCBA for different percentage replaced in OPC and produced the quality of structural-concrete thus resulting shows the excellent improvement in the indirect tensile stress in concrete and test values for various mixes at different age of curing in concrete as shown in Figure 4. It was noted that the higher split tensile strength was increased 29.57% at 28 days (3.01 to 3.98 MPa) than compared to controlled concrete. Further, the decreasing trend was observed while increasing the SCBA content in OPC.

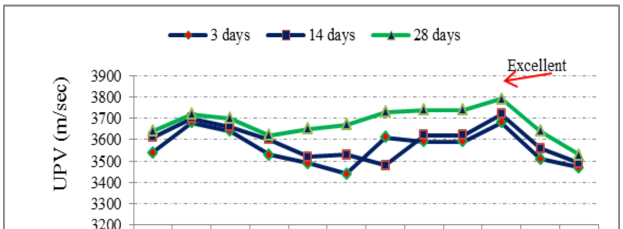


	C-0	C-1	C-2	C-3	V-0	V-1	V-2	V-3	D-0	D-1	D-2	D-3
3 days	2.75	3.12	3.21	2.65	2.65	2.74	3.35	2.71	2.67	3.5	3.1	2.64
28 days	3.01	3.15	3.28	3.98	2.84	2.81	3.9	3.75	2.81	3.74	3.25	2.71

Fig. 4. Split tensile strength of concrete at different curing days

D. Ultrasonic pulse velocity measurements

The effect of calcium nitrate is good corrosion resistance in concrete and to improve the rate of hardening, it was noted that the effect of accelerator was lesser in Portland cement when compared to SCBA mixed, the reason would be found due to delay of the hydration process from initial stages. The ultrasonic pulse velocity test results for the values are found to be showing the reasonable increase within range of 3440 to 4740 m/sec for all mixes. It is indicating that the quality of concrete uniformity agreement of cementitious materials in term of pulse velocity shows the higher values than conventional concrete. However, the UPV value was considerably decreased by increasing the SCBA content in OPC and also higher dosage level of accelerator present in the concrete mixes as shown in Figure 5. This study was concluded based on the test result, the optimum 1% of accelerator with 20% of SCBA content proved the drastic improvement in hardened concrete (D-1 mix), when compared to all mixes.



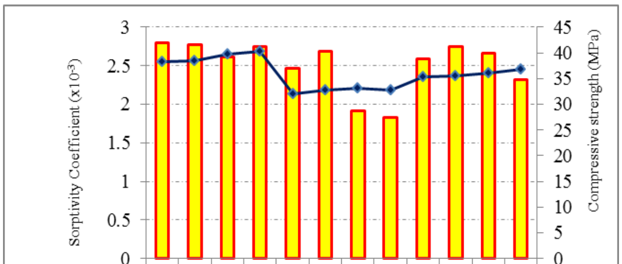
	C-0	C-1	C-2	C-3	V-0	V-1	V-2	V-3	D-0	D-1	D-2	D-3
3 days	3540	3680	3640	3530	3490	3440	3610	3590	3590	3680	3510	3470
14 days	3610	3700	3660	3600	3520	3530	3480	3620	3620	3720	3560	3490
28 days	3640	3720	3700	3620	3650	3670	3730	3740	3740	3790	3640	3530

Various mix id

Fig. 5. The UPV values for various mixes of concrete

E. Sorptivity

The sorptivity test results are shown in Figure 6. It can be seen that the sorptivity coefficient increases with increase in percentage of sugar cane bagasse ash and decreases with increase in compressive strength of concrete and also less water absorption work out in optimum level of SCBA content present in the concrete. The unburnt preheating SCBA ash contains coarser particles more pores during the hydration process hence it absorbs more water. From the experimental test results was found to be 2.18 mm/min0.5 for 10% replacement of SCBA and 2.37 mm/min0.5 for 20% replacement of SCBA in OPC concrete mix. Further, the best performance was noticed in the case of 10% of SCBA replaced in OPC produced the M25 grade concrete.



	C-0	C-1	C-2	C-3	V-0	V-1	V-2	V-3	D-0	D-1	D-2	D-3
28 days	42	41.5	39.2	41.2	37	40.3	28.8	27.5	38.9	41.2	39.9	34.8
Sorptivity	2.55	2.57	2.65	2.69	2.14	2.18	2.21	2.19	2.35	2.37	2.41	2.45

Fig. 6. Sorptivity test for various mixes

VI. CONCLUSION

The setting properties of cementitious systems can be easily assessed by using the setting properties of the cementitious materials. It can be easily noted from the experimental test results that the rate of strength gain during the progress of hydration, there is a substantial amount of heat generated while addition of sugar cane bagasse ash along with calcium nitrate accelerator. The test result containing 80% OPC with 20 % of SCBA along with 1% of accelerator showed a remarkable improvement in terms of hardening, the UPV values exhibited up to 3680 m/sec at 3 days curing. Indeed, that the delay the setting properties will take place of dormant period i.e. the heat of hydration was decreased. Further, addition of accelerator (chemical admixture) hence the setting time was increased and develops the more stiffness in SCBA materials. The effect of 1% accelerator was found to be increased the setting properties for all mixes of the concrete at different curing days. Also, it was found that the loss of consistency due to rapid hardening while higher dosage level of accelerator. The limitation of SCBA content was fixed up to 20% further addition in OPC may be rate of setting time was delayed than conventional concrete.

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