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Behaviour of Concrete Properties When Sugarcane Bagasse Ash is Mixed and Elevated to Temperatures

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ABSTRACT

The concrete cubes are casted with varying percentage of sugarcane bagasse ash i.e. 0%, 5%, 10%, 15%, 20%, 25% and exposed to different elevated temperatures 2000, 4000, 6000, 8000 for a time of 1 hour, hear we had studied the behavior of ordinary port land cement regarding its properties, and regarding the reactions that may occur when sugarcane bagasse ash is mixed. The peak stress ratios for both air-cooled and water-quenched specimens heated to 50 °C for 1h duration were 1.148 and 1.110 respectively. As the temperature increased, the stiffness of the specimens reduced. Air-cooled specimens performed slightly better than water-quenched specimens and concrete and test to be conducted for material used in preparation of concrete cubes, 150mm*150mm*150mm size concrete cubes are casted. Total of 180 cubes had been casted for both the grades. In the 180 cubes, 90 are for M35 & 90 are for M40. For the 90 cubes of M35 and M40.

KEY WORDS: ***Sugarcane bagasse, compressive strength, drying shrinkage and creep, workability.***

INTRODUCTION

Cement, both in mortar and concrete is the most important element of the infrastructure and can be a durable construction material. Cement industry is the second largest Co2 emitting industry behind the power generation. Which is one of the important green house gas as the global warming. Concrete, basically composed of two components (i.e. paste, aggregates) paste contains cement and water and sometimes other cementations and chemical admixture. Whereas aggregates are relatively inert filler material which occupy 70% to 80% of concrete and can therefore be expected to have influence on its properties, depend on the proportions of this material, strength and durability varies. Cement which is used as main binding material in concrete is most expensive and environmental unfriendly material. Therefore requirement for economical and more environmental friendly cementing material have extended interest in other cementing material that can be used as partial replacement of the ordinary Portland cement. Such as Cementations material is 1. Ground Granulated Blast furnace slag, 2.Fly ash, 3.Silica fume, 4.Sugarcane bagasse ash

Sugar cane bagasse ash, a byproduct of sugar factory found after burning of sugarcane bagasse, which in turn is found after the extraction of all economical sugar from sugarcane. Quality of concrete due to a rise of temperature is influenced by degradation, through changes included in basic process of cement hydration and hardening of binding systems in the cement paste of concrete. To achieve high performance concrete SCBA , is mixed as a substitute of cement , as SCBA mainly contains silica , it may acts as pozzolonic material and fineness of silica results in increasing durability and good performance under elevated temperatures . (Mr. V.S Ramachandran.)

Mr. G. Siva Kumar et al. (2013) had studied on "Preparation of Bio-cement using Sugarcane bagasse ash and its Hydration behavior". In this study they had used

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as partial Replacement in ordinary Portland Cement (OPC) by 10% weight. Compressive strength of the sample was carried out and reported that the cementations material in sugar cane bagasse ash is responsible for early hydration. The pozzolonic activity of bagasse ash results in formation of more amount of C-S-H gel which results in enhances the strength, and hence bagasse ash is a potential replacement material for cement.

Compressive Strength and Microstructure of Sugar Cane Bagasse Ash Concrete This study presents the results of an experimental research study on the effectiveness of Sugar Cane Bagasse Ash (SCBA) as a cement replacement material in concrete production. The ordinary Portland cement was replaced with 0, 5, 10, 15, 20, 25 and 30%, respectively bagasse ash, the effect of Sugar cane Bagasse Ash on workability, compressive strength and microstructure of Interfacial Transition Zone (ITZ) of concrete was examined. The results showed that inclusion of Sugar cane Bagasse Ash in concrete up to 20% level significantly enhanced the compressive strength of concrete at all ages; the highest compressive strength was obtained at 5% SCBA replacement level. The ITZ thickness was greatly reduced with increasing the bagasse ash replacement level up to 15%, beyond that the ITZ thickness was slightly increased, however the thickness was still narrower than the normal concrete, it was observed that at 15% bagasse ash replacement level, the interfacial transition zone was homogeneous and there was no gap between the coarse aggregate and the paste matrix

STRENGTH DEVELOPMENT

In general, pozzolanic reactions initiate after the cement hydration begins when Ca(OH),becomes available. Thus, with the replacement of cement by mineral admixture, early rate of hydration of cement concrete is retarded. The effect of pozzolanic reactions is generally manifested at late ages by increased strength and reduced permeability. The physical effect of adding fine particles of mineral admixtures results in more efficient dispersion of the flocculated structure of Portland cement particles and may increase early hydration to some extent, particularly with fine aggregate replaced by the mineral admixtures in a concrete mix.

SETTING TIME

Addition of mineral admixtures to Portland cement generally results in set retardation. This is especially true for low calcium fly ashes with high carbon content. The high calcium fly ashes, which are generally low in carbon and high in reactive components, sometimes exhibit opposite behavior. Not all high calcium fly ashes cause quick setting.

The addition of SF to concrete in the absence of a water reducer or super plasticizer is reported to cause delay in setting time, compared to non SF concrete of equal strength, especially when the SF content was high. From the previous research addition of 5% to 10% SF to either super plasticized or none super plasticized concrete with W/(C + SF) ratio of 0.4 did not exhibit any significant increase in setting time

RESISTANCE TO HIGH TEMPERATURES

There are two distinct situations to be considered when concrete is subjected to elevated temperatures. In one case, the heating is done under open conditions with the contained moisture in concrete free to evaporate, while in the other case, the heating is done under sealed conditions with the contained moisture prevented from escaping. In mass concrete structures, the inner concrete during heating at high temperatures will have its moisture converted into steam and thus subjected to steam pressures in addition to other forces.

To guard against the risk of spelling, short steel fibers are incorporated into concrete at 2% to 3% by volume especially in high risk structures such as pre stressed concrete pressure vessels, launching pads of space vehicles and runways for jet aircraft, concrete floors of boilers and chimneys, and highly stressed slender members. Damage of concrete, when subjected to elevated temperatures, is caused by the dense structure of high strength concrete itself, even without the

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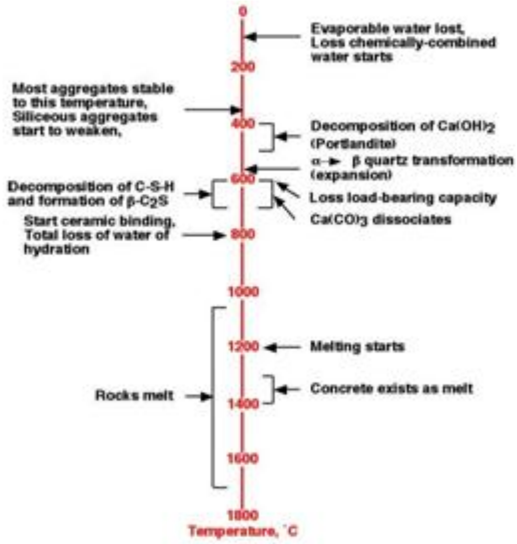
addition of mineral admixtures, and is more intense when the contained moisture in concrete is restrained during heating.

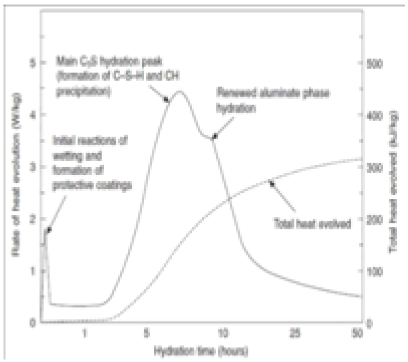


Physiochemical processes in Portland cement concrete during heating.

HYDRATION OF CEMENT

When water and Portland cement are mixed, the constituent compounds of the cement and the water undergo a chemical reaction resulting in hardening of the concrete. This chemical reaction of the cement and the water is called hydration, and it results in new compounds called hydration products. Both C3S and C2S react with water to produce an amorphous calcium silicate hydrate known as C– S–H gel which is the main glue, which binds the sand and coarse aggregate particles together in concrete

Each of the compounds found in the cement react with water, but the rate at which they react is different. C3S and C3A are the most reactive compounds, whereas C2S reacts much more slowly. Approximately half of the C3S present in typical cement will be hydrated by 3 days and 80% by 28 days, in contrast, the hydration of C2S does not normally proceed to a significant extent until approximately 14 days. Gypsum is added to lower the rate of hydration of C3A. After a rapid initial reaction C3S will pass through a dormant stage which has a practical significance because it allows concrete to be placed and compacted before setting and hardening commences.



Heat of Hydration in Cement

MATERIALS

In making of any type of concrete, selection and type of materials used is very important as all the properties depend on them. The required strength or target strength of concrete can be obtained by careful selection of ingredients, correct grading of ingredients, accurate water measurements and adopting a good workmanship in mixing, transporting, placing, compacting, finishing and curing of concrete in the construction work. The properties of material used for making the concrete mix are determined in laboratory as per relevant codes of practice.

The following materials used are listed below:

- Cement
- Fine aggregate
- Coarse aggregate
- Sugarcane bagasse ash
- Water

CEMENT

Ordinary Portland cement of 53-grade from a single batch was used for the entire work and care has been taken that it has to been stored in airtight containers to prevent it from being affected by the atmospheric and monsoon moisture and humidity. The cement procured was tested for physical requirements in accordance with IS: 12269-1987 and for chemical requirements in accordance with IS: 4032-1977, Properties of cement are tabulated in below table.

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S No	Property	Value	Code Requirements
1	Normal consistency	29mm	30-35mm
2	Fineness of cement	6.69%	≥10 %
3	Setting times		
	Initial (Minutes)	50	<≠30
	Final (Minutes)	180	>≠600
4	Specific Gravity	3.15	3.1-3.18
	Compressive Strength		
5	3 Days	28.68 Mpa	27Mpa (Min)
	7 Days	40.34 Mpa	
	28 Days	54.62 Mpa	53Mpa(Min)

Properties of Cement

FINE AGGREGATE

The river sand, passing through 4.75 mm sieve and retained on 600 μm sieve, conforming to Zone II as per IS 383-1970 was used as fine aggregate in the present study. The sand is free from clay, silt and organic impurities. The aggregate was tested for its physical requirements such as gradation, fineness modulus, specific gravity and bulk modulus in accordance with IS:2386-1963. Properties of fine aggregate are in Table

S No	Property	Value	Code Requirements
1	Specific Gravity	2.60	2.5-2.8
2	Bulk density gm/cc	1.543(loose state) 1.663(dry State)	1.45-1.65
3	Fineness Modulus	2.54	2.2-2.6
	Initial (Minutes)	50	<≠30
	Final (Minutes)	180	>≠600
4	Zone	II	I – IV

Properties of Fine Aggregate.

COURSE AGGREGATE

Throughout the investigations, a crushed coarse aggregate of 20mm procured from the local crushing plants was used. The aggregate was tested for its physical requirements such as gradation, fineness modulus, specific gravity and bulk density etc. in accordance with IS: 2386-1963 and IS: 383-1970. Properties of coarse aggregate stated in table

S No	Property	Value	Range of Values
1	Bulking Density (gm /cc)	1.468[loose State] 1.611[dry State]	
2	Specific Gravity (G) 20mm	2.71	2.6
3	Water absorption (%)	0.2	05-1.0
4	Fineness Modulus	7.17	6.5-8
5	Aggregate impact Value (%)	25.21	<30
6	Aggregate Crushing Value (%)	25.22	<30
7	Flakiness Index	12.35	<35
8.	Elongation Index	15.05	

Properties of Coarse Aggregates

COMPRESSION TEST

The compression testing machine is used for testing the cube specimens is of standard made. The capacity of the testing machine is 2000 KN. The machine has a facility to control the rate of loading with a control valve .The plates are cleaned and oil level is checked, and kept ready in all respects for testing. After the required period of curing, the cube specimens are removed from the curing tubs and cleaned to wipe off the surface water. It is placed on the machine such that the load is applied centrally. The smooth surfaces of the specimen are placed on the bearing surfaces. The top plate is bought in contact with the specimen by rotating the handle. The oil pressure valve is closed and the machine is switched on. A uniform rate of loading 140 kg/sq.cm/min is maintained.

METHODOLOGY

EXPERIMENTAL PROCEDURE

After completion of mix Design for conventional concrete and test to be conducted for material used in preparation of concrete cubes, 150mm*150mm*150mm size concrete cubes are casted. Total of 180 cubes had been casted for both the grades. In the 180 cubes, 90 are for M35 & 90 are for M40. For the 90 cubes of M35 grade, 15 cubes are casted with cement, sand and aggregate i.e 0%. 15 cubes are casted with cement, sand, aggregate and sugarcane bagasse ash; where as this 5% of cement is replaced with sugar cane bagasse ashi.e 5%. 15 cubes are casted with 10% cement replaced with sugar cane

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bagasse ash, sand, aggregate and remaining cement ie 10%. This replacement of cement with sugar cane bagasse ash is continued for 15%, 20%, 25%, each 15 cubes are casted, mixing sand and aggregate. This replacement of Sugarcane bagasse ash to cement in concrete is also done for M40 grade concrete in same percentage (0%, 5%, 10%, 15%, 20%, 25%) i.e For the 90 cubes of M40 grade, 15 cubes are casted with cement, sand and aggregate i.e 0%. 15 cubes are casted with cement, sand, aggregate and sugarcane bagasse ash, where as this 5% of cement is replaced with sugar cane bagasse ash i.e 5%. 15 cubes are casted with 10% cement replaced with sugar cane bagasse ash, sand , aggregate and remaining cement ie 10%. This replacement of cement with sugar cane bagasse ash is continued for 15%, 20%, 25%, each 15 cubes are casted, mixing sand and aggregate. Table 12 had shown the cubes to be casted in tabular form depending up on percentage and temperature.

	Room Temperature	200^{0}	400^{0}	600^{0}	800^{0}	Total Cubes
0%	3	3	3	3	3	15
5%	3	3	3	3	3	15
10%	3	3	3	3	3	15
15%	3	3	3	3	3	15
20%	3	3	3	3	3	15
25%	3	3	3	3	3	15
				Total Cubes		90

Total number of cubes to be casted for M35

	Room Temperature	200^{0}	400^{0}	600^{0}	800^{0}	Total Cubes
0%	3	3	3	3	3	15
5%	3	3	3	3	3	15
10%	3	3	3	3	3	15
15%	3	3	3	3	3	15
20%	3	3	3	3	3	15
25%	3	3	3	3	3	15
				Total Cubes		90

Total number of cubes to be casted for M40

The next day of casting, concrete cubes in the mould are removed and cubes are kept in water for 28 days from the day of casting. After completion of 28 days cubes are removed from water and dry till surface water gets off, weights of the cubes are recorded. Furnace is set for 2000C, 3 cubes of 0%- M35 and M40 each, 3 cubes of 5%-M35 and M40 each, 3 cubes of 10%- M35 and M40 each, 3 cubes of 15%- M35 and M40 each, 3 cubes of 20%- M35 and M40 each and 3 cubes of 25%-M35 and M40 each, are kept in furnace, 2000 is exposed to that cubes for 60min (i.e 1 hour) of time and removed. These heated cubes are immediately cooled by immersing them in water, and removed after temperature of cubes is cooled down to room temperature. Again weights of

Cubes exposed to 2000c.

Furnace showing 2000c.

Cube under Compression Testing Machine after exposed to 2000c

Cubes are recorded and then Strength of cubes are recorded, using compression testing machine. This procedure is done for 4000c , 6000c, 8000c. For room temperature directly the cubes after removing them

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from water, weights and strength are recorded. The results are there is increase in compressive strength of cubes when cubes are exposed to 2000c than at room temperature. Table 15 and Table 16 shows you the results of Cubes obtained at 2000c. From Table 23 we can observe the increased values.

Cubes after 8000c Temperature Exposure

Cubes after 8000c Temperature Exposure.

Cracks formed after cubes exposed to 8000c.

Cracks formed after cubes exposed to 8000c after cooled in water

Failure of cube that is exposed to 8000c in compression testing machine

At 4000c, there is a decrease in strength than at 2000c, this shows that at 4000c effect of temperature on cubes had started and strength decreased is around 10%, from Table 23 it can be observed and Table 17 and Table 18 show the values obtained at 4000c.

At 6000c, there is a decrease in strength of around 20% than strength obtained at 2000c. Table 19 and Table 20 show you the compressive strength obtained at 6000c. At an average the results obtained at 6000c is equal to results obtained at room temperature.

At 8000c, there is sudden decrease of strength; around 40% of strength is reduced at 8000c, than strength obtained at 2000c. The strength obtained is 30% less than strength obtained at room temperature. Using table

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23 we can observe this behavior, table 21 and table 22 shows the strength obtained for 8000c.

At 8000c cracks on the surface of concrete cubes after exposure is observed showing the effect of temperature on the internal structure of concrete. The surface of cube also changes its color from grey to white.

At over all view the strength obtained at 10% sugarcane bagasse ash replacement is highest, and the strength increase from 0% to 5% replacement of SCBA with cement and 5% to 10% replacement of SCBA with cement,. at 15% the strength is decreased and continues to decrease even percentage of SCBA increases.

MIX DESIGN

CONVENTIONAL CONCRETE MIX DESIGNE PROCEDURE:

1) Data for Mix Design

The following basic data are required to be specified for design of a concrete mix:

Characteristic compressive strength (that is, below which only a specified proportion of test results are allowed to fall) of concrete at 28 days (σ_{ck}),

- Degree of workability desired.
- Limitations on the water-cement ratio and the minimum cement content to ensure adequate durability (IS: 456.1978)
- Type and maximum size of aggregate to be used, and Standard deviation (s) of compressive strength of concrete

Target Strength for mix Design – In order that not more than the specified proportion of test results are likely to fall below the characteristic strength, the concrete mix has to be designed for a somewhat higher target average compressive strength (σ_{ck}). The margin over the characteristic strength depends upon the quality control (expressed by the standard deviation) and the accepted proportion of results of strength tests below the characteristic strength (σ_{ck}), given by the relation:

$$\sigma_{ck}^{1} = \sigma_{ck} + t \times s$$

Where

σ_{ck}^{1}= target average compressive strength at 28 days,

σ_{ck} = characteristic compressive strength at 28 days,

s = standard deviation, and

t = a statistic, depending upon the accepted proportion of low results and the number of tests; for large number of tests, the value of c is given in Table.

NOTE –According to IS : 456-1978* and IS:1343-1980, the characteristic strength is defined as that value below which not more than 5 percent (1 in 20) results are expected to fall. In such case, the above equation will reduce to:

$$\sigma_{ck}^{1} = \sigma_{ck} + t \times s$$

CALCULATION OF CEMENT CONTENT:

The cement content per unit volume of concrete may be calculated from the free water-cement ratio and the quantity of water per unit volume of concrete. The cement content so calculated shall be checked against the minimum cement content for the requirements of durability and the greater of the two values adopted.

CALCULATION OF AGGREGATE CONTENT:

With the quantities of water and cement per unit volume of concrete and the ratio of fine to total aggregate already determined, the total aggregate content per unit volume of concrete may be calculated from the following equations:

$$V = [W + (C/S_c) + 1/p \; x(f_a/S_{fa})] x(1/1000)$$

$$V = [W + (C/S_c) + 1/(1-p) \; x(c_a/S_{ca})] x(1/1000)$$

Where,

V- Absolute Volume of Concrete, m^3.

W- Mass of total water, Kg/m^3

C- Mass of Cement, Kg/m^3.

S_c – Specific Gravity of Cement.

P – Ratio of fine aggregate to total aggregate by Absolute Volume.

F_a , c_a - Total masses of fine aggregate and coarse aggregate, Kg/m^3.

S_{fa} ,S_{ca} –specific gravity of saturated surface-dry sand and coarse aggregate

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1. Target Mean Strength of concrete

From IS: 10262-2009, the target mean strength for the specified characteristic cube strength is

$f^1 = fck + 1.65 \times s$

Then $f^1 = 35 + (5 \times 1.65) = 43.25$ N/mm^2

(s" is standard deviation N/mm2 s =5, from table 1 IS 10262:2009)

2. Selection of Water-Cement Ratio

The free Water Cement ratio required for the target mean strength of 43.25 N/mm^2 is W/C =0.40.

3. Selection of water content:

for 20mm aggregate = 186 ltrs (25 to 50mm slump)

for 75mm slump = 186 + 3/100 * 186 (for every 25mm increase in slump 3% water should be increased) =191.58ltrs (from table 2 IS 10262:2009).

4. Determination of Cement content:

w/c = 0.40 192/c = 0.40

C= 480kg/m3>320kg/m3 hence ok

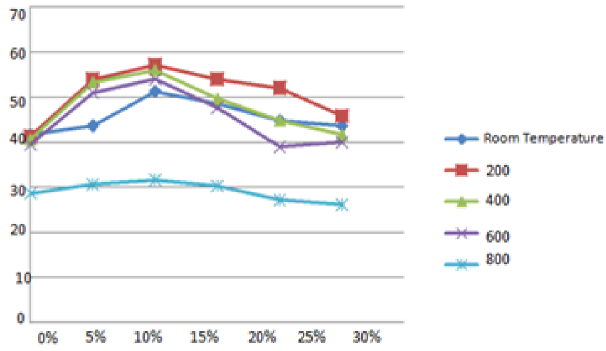
5. Proportion of volume of coarse aggregate and fine aggregate content:

Fine aggregate = Zone 2

Volume of coarse aggregate per unit volume of total aggregate for different zones of fine aggregate = 0.62 (from table 3 IS 10262:2009) When w/c = 0.50 = 0.62

	Room Temperature	200^0	400^0	600^0	800^0
0%	44.16	50.33	49	47	31
5%	45	51.33	5.667	49	33
10%	51.66	55.5	54.33	53.33	34
15%	50.33	53	50	48.5	32
20%	47.5	51.833	48	46.833	30.33
25%	36.83	47.167	47.5	45	29.667

Strength of cubes exposed to different temperature, M35, M40 Grade



Percentage

M35

	200	400	600	800
0%	0.014	0.037	0.048	0.059
5%	0.012	0.017	0.022	0.043
10%	0.01	0.012	0.019	0.035
15%	0.009	0.011	0.016	0.025
20%	0.009	0.009	0.014	0.016
25%	0.006	0.007	0.012	0.015

M40

	200	400	600	800
0%	0.01	0.022	0.026	0.038
5%	0.008	0.02	0.024	0.034
10%	0.004	0.016	0.022	0.028
15%	0.004	0.014	0.017	0.022
20%	0.002	0.011	0.016	0.02
25%	0.002	0.008	0.012	0.015

Comparison of Weight, Difference between before heating and after heating:

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Weight difference for cubes before heating and after heating an Immediate cooling with water for M35 and M40 grade concrete.

Increase of weight after exposure to elevated temperature is due to development of cracks when the cube is suddenly immersed in water for cooling. This cooling leads to formation of crack due to Thermal shock and water Penetration into the cracks leads to increase of weight of cube after exposed to elevated temperature, Due to the fine particles present in the Sugarcane bagasse ash, they react with the residual chemical and also fill the pores that formed while hydration of cement. It increases strength.

Due to filling of pores the concrete gains more strength than normal and results in opposing crack formation, and Resulting in reduction of weight difference that formed between weights of cubes before and after heating. The decrease of strength cement while increase of percentage of sugar cane bagasse ash is due to increase of fineness.

CONCLUSIONS

The test is done on concrete cubes casted with varying percentage of sugarcane bagasse ash i.e 0%, 5%, 10%, 15%, 20%, 25% and exposed to different elevated temperatures 2000, 4000, 6000, 8000 for a time of 1 hour. Replacement of Sugarcane bagasse to cement results in increase in strength of concrete than the conventional concrete. The same behavior is observed even the cubes are exposed to elevated temperature.

Increase of strength is mainly to presence of high amount of Silica in sugarcane bagasse ash. The increase of strength while percentage of Sugar cane bagasse ash increase is up to certain extent i.e 10% and then decreases even, increase in percentage of sugarcane bagasse ash i.e 15%, 20%, 25%. The strength of normal concrete is obtained when 20% of sugar cane bagasse ash is replaced with cement.

There is a decrease in strength when the cube exposed to elevated temperature is cooled by immediate immersing in water after 1 hour heating. This decrease in strength is due to thermal shock while immersing in water. The reason of development of strength in cubes is due to development of more amount of C-S-H gel matrix. Which increase the bonding between aggregates and matrix results in increase of Strength

The alumina present in the SCBA react with chemicals that forms C-S-H gel and form C-A-S-H gel and fill the pores that are formed in hydration of cement and increases the strength of concrete cube.

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