PARTIAL REPLACEMENT OF CEMENT USING SUGARCANE BAGGASE ASH TO ENCHANCE THE STRENGTH OF CONCRETE

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ABSTRACT

We are aware that a lot of damage is done to environment in the manufacture of cement. It involves lot of carbon emission associated with other chemicals. The researches have shown that every one ton of cement manufacture releases half ton of carbon dioxide, so there is an immediate need to control the usage of cement. On the hand materials wastes such as Sugar Cane Bagasse Ash is difficult to dispose which in return is environmental Hazard. The Bagasse ash imparts high early strength to concrete and also reduce the permeability of concrete. The Silica present in the Bagasse ash reacts with components of cement during hydration and imparts additional properties such as chloride resistance, corrosion resistance etc. Therefore, the use of Bagasse ash in concrete not only reduces the environmental pollution but also enhances the properties of concrete and also reduces the cost. It makes the concrete more durable. This project mainly deals with the replacement of cement with Bagasse ash in fixed proportions and analysing the effect of HCl on SCBA blended concrete. The concrete mix designed by varying the 2 proportions of Bagasse ash for 10%, 15%, 20%, the cubes are been casted and cured in normal water for ages of 7, 14 and 28 days. The test result indicates that the strength of concrete increase up to 10% Sugar cane bagasse ash replacement of cement.

Keyword : - *Cement replacement, Sugar Cane Bagasse Ash (SCBA, Carbon emission, Environmental pollution, Concrete strength, Silica reaction, etc.*

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1. INTRODUCTION

Ordinary Portland cement is the most commonly used building material throughout the world and it will retain its status in near future also because of demand and expansion of construction industry all over the world. Further the greatest challenge before the concrete construction industry is to serve the two pressing needs of human society, namely the protection of environment and meeting the infrastructure requirements of our growing population Structures which are constructed in aggressive environments are liable to be subjected to acidic attack. One of such major problems is HCl attack against concrete structures due to which there will be loss of weight and reduction in strength of concrete ultimately sacrificing age of the structure. Contaminated ground water, seawater, industrial effluents are some of the sources of sulphate that attack concrete. The use of blended cements has shown a sharp result in resisting the sulphate attack on concrete, sugarcane bagasse ash which shows pozzolanic properties is being used as a partial replacement in concrete in regular 3 intervals of 10% up to 20%. SCBA is being produced from sugar manufacturing units as a waste material which will be grinded to the fineness less than cement for obtaining good bonding between cement and SCBA.

1.1 ORDINARY PORTLAND CEMENT (OPC)

Ordinary Portland cement is a controlled blend of calcium silicates, aluminates and ferrate, which is ground to a fine powder with gypsum and other materials. After 1987 OPC was divided into 3 types based on the strength obtained at 28 days.

1. OPC 33 grade: - strength not less than 33N/mm2 at 28 days
2. OPC 43 grade: - strength not less than 43N/mm2 at 28 days
3. OPC 53 grade: - strength not less than 53N/mm2 at 28 days

Portland cement gets its strength from chemical reactions between the cement and water. The process is known as hydration. This is a complex process that is best understood by first understanding the chemical composition of cement.

1.2 CHEMICAL COMPOSITION OF CEMENT

COMPOUND	FORMULA	MASS %
Calcium oxide	CaO	61-67%
Silicon dioxide	SiO_2	19-23%
Aluminium oxide	Al_2O_3	2.5-6%
Iron oxide	Fe_2O_3	0-6%
Sulphate	So_3	1.5-4.5%

1.3 CHEMICAL COMPOSITION OF CLINKER

Compound	Formula	Mass%
Tricalcium silicate	$(CaO)_3 . SiO_2$	45-75%
Dicalcium silicate	$(CaO)_2 . SiO_2$	7-32%
Tricalcium aluminate	$(CaO)_3 . Al_2O_3$	0-13%
Tetra calcium aluminoferrite	$(CaO)_3 . Al_2O_3 . Fe_2O_3$	0-18%
Gypsum	$CaSO_4 . 2H_2O$	2-10%

1.4 INTRODUCTION TO CEMENT CONCRETE

An artificially built-up stone resulting from hardening of a mixture of a cement, aggregates and water with or without a suitable admixture, is generally known as concrete. Cement concrete is a mixture of aggregates and cement water paste. The cement water paste has its role to bind the aggregates to form a strong rock like mass after hardening has a consequence of the chemical reaction between cement and water. Aggregates are classified into fine aggregate and coarse aggregate. Fine aggregate consists of sand whose particular size does not exceed 4.75mm coarse aggregate consist of gravel, crush stone etc. of practical size more than 4.75mm. When the materials are mixed together so has to form a workable concrete, it can be moulded into beams, slabs etc. A few hours after mixing the material undergo a chemical combination and have a consequence the mixture solidifies and hardness, attaining 8 greater strength with age. Concrete possesses a high compressive strength and has a poor tensile strength. It also develops shrinkage stresses.

1.5 SUGARCANE BAGASSE ASH

Bagasse is a by-product from sugar industries which is burnt to generate power required for different activities in the factory. The burning of bagasse leaves bagasse ash as a waste, which has a pozzolanic property that would potentially be used as a cement replacement material. It has been known that the worldwide total production of sugarcane is over 1500 million tons. Sugarcane consists about 30% bagasse whereas the sugar recovered is about 10%, and the bagasse leaves about 8% bagasse ash (this figure depends on the quality and type of the boiler, modern boiler releases lower amount of bagasse ash) as a waste, this disposal of bagasse ash will be of serious concern. Sugarcane bagasse ash has recently been tested in some parts of the 11 worlds for its use as a cement replacement material. The bagasse ash was found to improve some properties of the paste, mortar and concrete including compressive strength and water tightness in certain replacement percentages and fineness. The higher silica content in the bagasse ash was suggested to be the main cause for these improvements. Although the silicate content may vary from ash to ash depending on the burning conditions and other properties of the raw materials including the soil on which the sugarcane is grown, it has been reported that the silicate undergoes a pozzolanic reaction with the hydration products of the cement and results in a reduction of the free lime in the concrete.

2. METHODOLOGY

Standard Sieves

Table : Sieve analysis of Coarse Aggregate

Sr. No.	I.S Sieve No.	Weight Retained (gms)	Percentage weight retained	Cumulative Percentage Retained	Percentage Passing
1	30 mm	0	0	0	100
2	20 mm	877	17.54	17.54	82.46
3	10 mm	4085	81.70	99.24	0.76
4	4.75 mm	38	0.76	100.00	0
5	2.36 mm	0	0	100.00	0
6	1.18 mm	0	0	100.00	0
7	600 µ	0	0	100.00	0
8	300 µ	0	0	100.00	0
9	150 µ	0	0	100.00	0
Total:				716.78	

Fineness Modulus = 716.78 / 100 = 7.17

Table : Sieve analysis of Fine Aggregate

Sr. No.	I.S. Sieve No	Weight retained (gm)	Percentage weight retained	Cumulative Percentage retained	Percentage passing
1	30 mm	0	0	0	100
2	20 mm	0	0	0	100
3	10 mm	0	0	0	100
4	4.75 mm	21	2.10	2.10	97.90
5	2.36 mm	65	6.50	8.60	91.40
6	1.18 mm	180	18.00	26.06	73.94
7	600 µ	278	27.80	54.04	45.96

8	300 µ	280	28.00	82.04	17.96
9	150 µ	176	17.06	100.00	0
Total:				**246.00**	

Fineness modulus = 246 / 100 = 2.46

Confirming to zone II (I.S.: 383-1970)

Table: Physical Properties of Fine and Coarse Aggregate

		Test results	
Sr. No.	**Properties**	**Fine Aggregate**	**Coarse Aggregate**
1	Specific gravity	2.46	2.73
2	Bulk Density (kg/m3) a) Loose b) compacted	 1600 kg/m3 1750 kg/m3	 1400 kg/m3 1580 kg/m3
3	Fineness Modulus	2.46	7.17

	0%	10%	15%	20%
Slump	10mm	16mm	20mm	25mm

Table: Workability of concrete

From the test conducted are Sieve analysis on coarse aggregate and fine aggregate, the fineness modulus is 7.17 (from Table-10) for coarse aggregate. This should be between 6.5 to 8, and as Zone-II sand is used, the fineness modulus of fine aggregate is 2.54(Table-11), this should be in a range of 2.2 to 2.6 as per IS383. And we observed a varying slump value as the Percentage of Sugarcane bagasse ash increases.

Aggregate Size	20 mm
Minimum cement content	250 kg/m3(from table 5 IS 456)
W/C ratio	0.55
Work-ability	75mm (slump)
Exposure	Severe

1) Target Mean Strength of concrete

   From IS: 10262-2019, the target mean strength for the specified characteristic cube strength is

$$f1ck = f ck + 1.65 \times s$$

Then

$$f1ck = 20 + (4 \times 1.65) = 26.6 \text{ N/mm2}$$

   ('s' is standard deviation N/mm2 s =4, from table 1 IS 10262:2009)

2) Selection of Water-Cement Ratio

The free Water Cement ratio required for the target mean strength of 26.6 N/mm2 is W/C =0.55.

3) Selection of water content:

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

for 75mm slump = 186 + 3/100 * 186(for every 25mm increase in slump 3% water should be increased)

197ltrs (from table 2 IS 10262:2009)

4) Determination of Cement content:

w/c = 0.55
197/c = 0.55
c = 480kg/m3>250kg/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 for every +/- 0.05 change in w/c ratio we have to change -/+ 0.01 change in volume of coarse aggregate per unit volume of total aggregate

Coarse aggregate=0.558
Fine aggregate=0.442

6) Mix calculations:

a) Volume of concrete = 1m3
take cement content = 358kg/m3

b) Volume of cement = (mass of cement/specific gravity) *(1/1000)
= (358/3.15) *(1/1000) = 0.1218 m3

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c) Volume of water = (mass of water/specific gravity) *(1/1000)
= (197/1) *(1/1000) = 0.197 m3

d) Volume of aggregate = (a-(b+c))
= 1-(0.1218+0.197) = 0.6812 m3

e) Mass of coarse aggregate = d* volume of coarse aggregate*specific gravity of coarse aggregate
= (0.6812*0.558*2.73*1000) = 1037.69 kg

f) Mass of fine aggregate = d* volume of fine aggregate*specific gravity of fine aggregate
= (0.6812*0.442*2.46*1000) = 740.68 kg

The mix proportion then becomes:

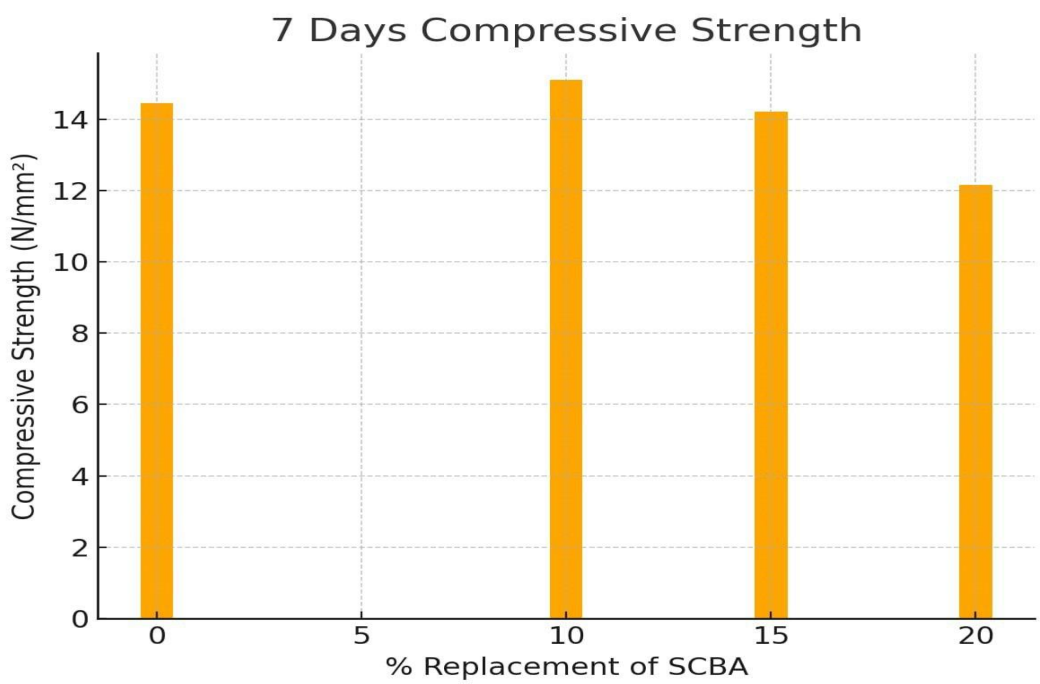
Mix proportions for M20 by weight

Water	:	Cement	:	Fine Aggregate	:	Coarse Aggregate
197	:	358.18	:	740.68	:	1037.69
0.55	:	1.0	:	2.06	:	2.89

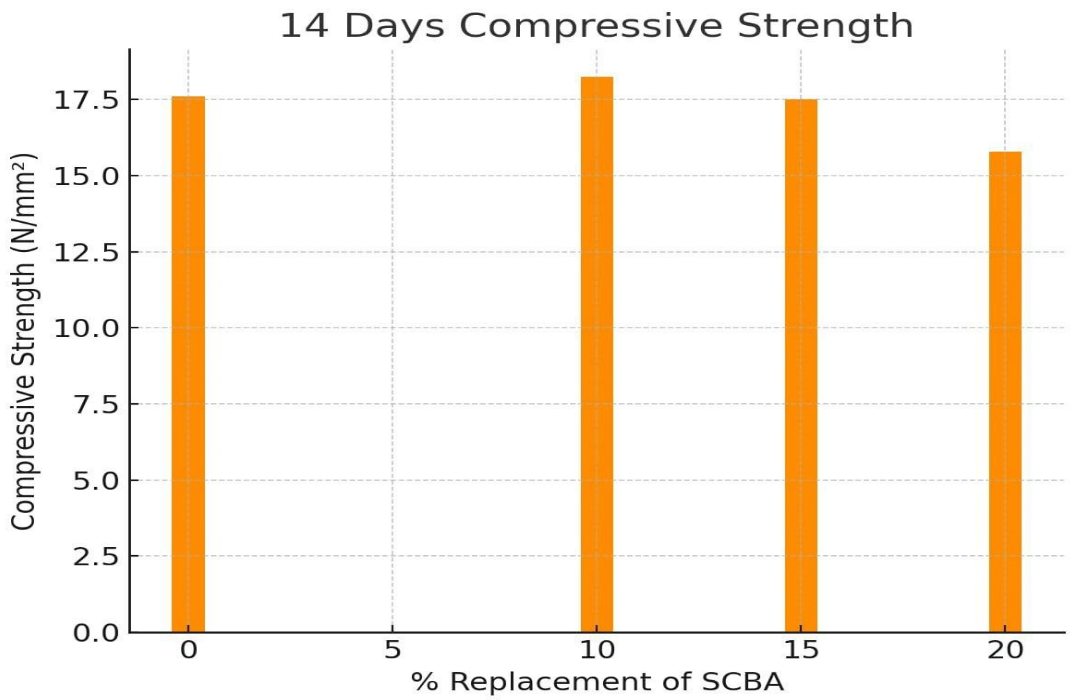
4. RESULTS

Compressive Strength Results- M20 grade at normal water
Solutions
Table: Compressive Strength Results (M20 in normal water)

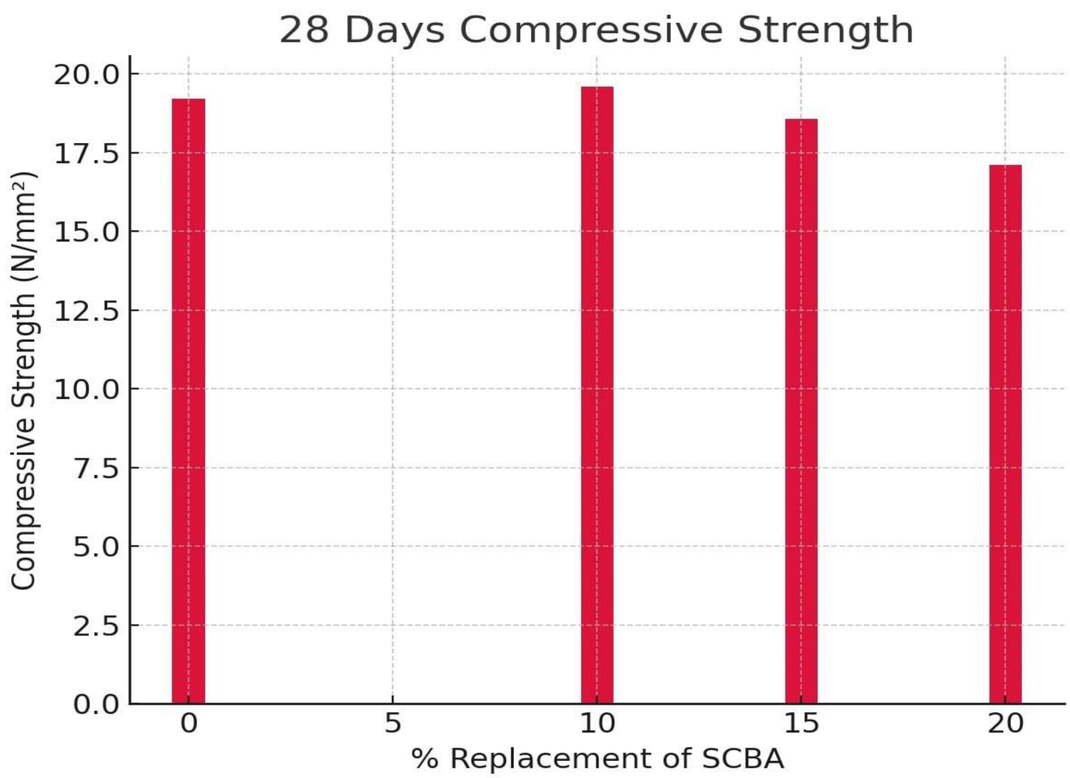
Sample Designation	% Replacement of SCBA in Cement	Compressive Strength at 7days (σcu)	Compressive Strength at 14 days (σcu)	Compressive Strength at 28 days (σcu)
C0	0	14.44	17.60	19.20
C1	10	15.10	18.25	19.60
C2	15	14.20	17.50	18.57
C3	20	12.15	15.78	17.10



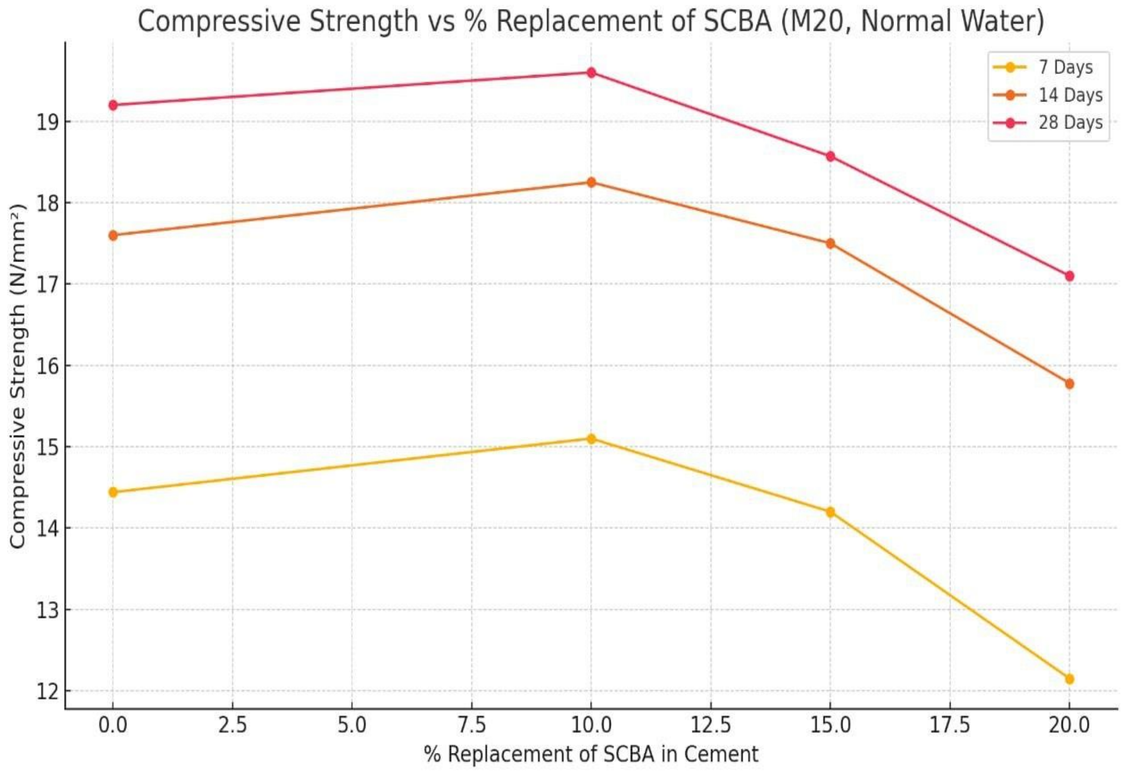
Graph: Compression test results for 7 days in normal water



Graph: Compression test results for 14 days in normal water



Graph: Compression test result for 28 days in normal water



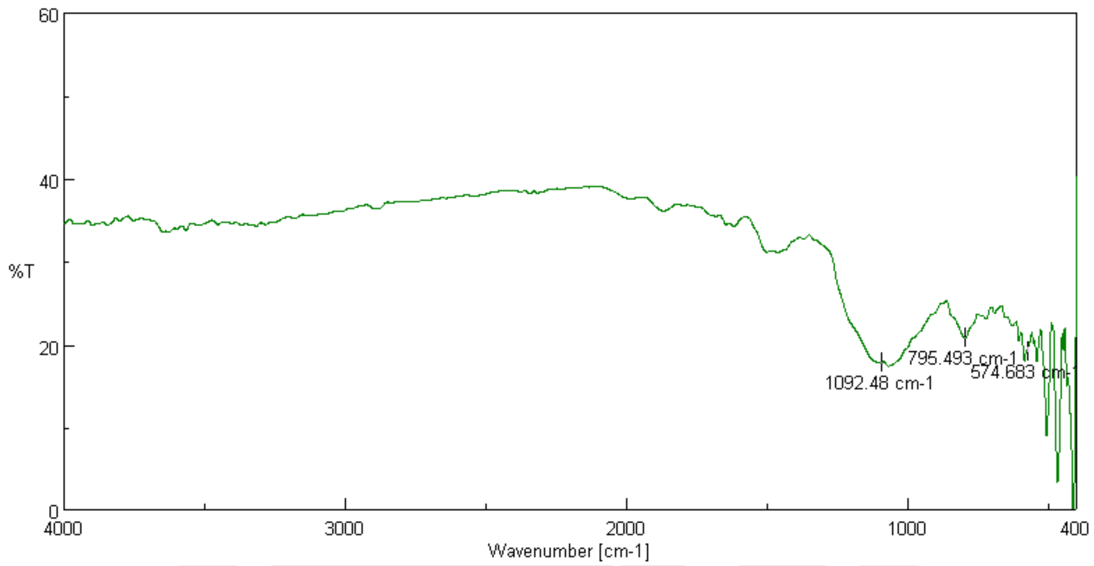
Graph: Compression test results 7, 14 &28 days in normal water

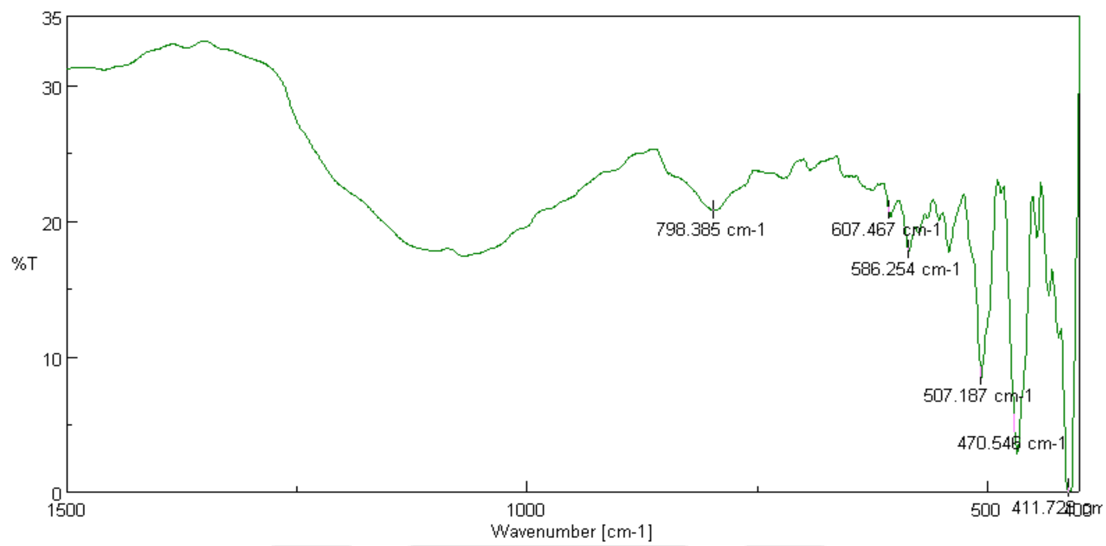
As the percentage of sugarcane bagasse ash increases the compressive strength of concrete tends to increase up to certain percentage and then start's decreasing with the increase of ash content. The strength of 10% sugarcane bagasse ash concrete is more than normal concrete. This shows that till 10% sugarcane bagasse ash concrete the strength increases while percentage of sugarcane bagasse ash increases. The strength of cubes having 10% sugar cane bagasse ash is almost equal to 15% sugar cane bagasse ash concrete. This increase in strength in Sugar cane bagasse ash concrete is due to presence of Silica in Sugar cane bagasse ash. Silica in Sugar cane bagasse ash react with residual CH after the formation of C-S-H gel, and increase the amount of C-S-H gel and results in increase the strength.

Note- C–S–H gel stands for Calcium Silicate Hydrate gel. It is the main binding product formed during the hydration of cement and plays a key role in giving concrete its strength and durability.

FTIR TEST

The FTIR test in SCBA concrete refers to Fourier Transform Infrared Spectroscopy. It is a material testing technique used to identify the chemical bonds and functional groups present in a material by analyzing how it absorbs infrared (IR) radiation.





5. CONCLUSIONS

1. SCBA concrete performed better when compared to ordinary concrete up to 10% replacement of sugar cane bagasse ash.

2. Increase of strength is mainly to presence of high amount of Silica in sugarcane bagasse ash. .

3. Compressive strength is increased for 7, 14 and 28 days when cured in normal water solutions.

4. Utilization of the waste material Sugar Cane Bagasse ash can be advantageously used as a replacement of cement in the preparation of concrete.

5. SCBA is a viable cement replacement: Sugarcane Bagasse Ash (SCBA), when used in suitable proportions, can partially replace cement in concrete without negatively affecting the strength properties.

6. The optimum replacement level of SCBA is typically around 10–15% by weight of cement. At this range, concrete often shows improved compressive strength and durability compared to conventional concrete.

7. SCBA contains silica, which reacts with calcium hydroxide (from cement hydration) to form additional calcium silicate hydrate (C-S-H), enhancing the strength and microstructure of the concrete.

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