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Experimental Studies on Sugar Cane Bagasse Ash (SCBA) as a Partial Replacement of Cement in Concrete

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Abstract: The current study presents the effect of pozzolanic material in concrete and its influence on the improvement of concrete strength characteristics. Bagasse is a fibrous waste product of the sugar refining industry made from sugar cane. Aluminium ion and silica are the major components of bagasse ash. Sugar Cane Bagasse Ash (SCBA) is used to partially replace the cement in concrete, in the range of 0%, 10% and 20%. Strength characteristics such as compressive strength, spilt tensile strength and flexural strength are evaluated and durability test is conducted. The results obtained are compared with conventional concrete.

As the SCBA is increased from 0 to 10% the 28 days compressive strength values of M15, M30 and M50 mixes increase by 5.74%, 7.32% and 7.07% respectively. The split tensile strength values of M15, M30 and M50 mixes increase by 22.6%, 18.43% and 8.41% respectively. And the flexural strength values of M15, M30 and M50 mixes increase by 5.48%, 22.4% and 18.07% respectively. Hence the replacement of cement by SCBA up to 10% can be considered without compromising the strength properties. Durability study proves that the reduction in the compressive strength and loss of weight increases with increase in SCBA.

Keywords: Concrete, Sugar Cane Bagasse Ash (SCBA), Mechanical characteristics, Durability.

1 Introduction

Concrete is second most used material after water. Cement is the important constituent of Concrete. During the production of cement, one of the greenhouse gasses namely carbon dioxide is emitted which is responsible for causing global warming [1]. Sugarcane is one of the major crops grown in over 110 countries and its total production is over 1500 million tons. In India only, sugar cane production is over 300 million tons/year that cause about 10 million tons of sugarcane bagasse ash as an unutilized waste material [2-3]. Some application of bagasse ash is as a low value material for backfill or fertilizers which is very little as compared to its quantity [4]. The sample of raw material ash consists of three different types of particles, namely, fine burnt particles, coarse fibrous unburnt and fine fibrous unburnt particles [5]. The chemical composition of this product is cellulose fibre, water, and some soil soluble material such as cube sugar, with time cube sugar is converted alcohol [6]. Replacement of cement or coarse aggregates or fine aggregates with other materials which is made to be an economical [7]. Currently, some of the agro waste such as rice husk ash, sugarcane bagasse ash, etc. has been used as an admixture. This is the one of the ways to reduce its impact on environment. In the current study, an attempt has been made to use bagasse ash as partial replacement of cement. When bagasse ash is burnt underneath controlled temperature it gives ash having high amorphous silica and alumina oxides [1].

2. Literature Survey

- Aukkadet Rekpiboon et al. (2015) [4]; In this study, strength and durability properties of concrete containing up to 50% ground bagasse ash (GBA) replacing ordinary Portland cement. The results suggest that the use GBA of up to 50% to replace OPC by weight of binder can increase the durability properties of concrete.
- K. Sampath Kumar et al. (2016) [7]; In this study currently utilize some amount of like (0%, 2%, 4%, 6%, 8%, 10%) bagasse ash, rice husk ash and stone dust are used as a replacement of cement. it has been observed that by the incorporation of SCBA, RHA, and SD as a partial replacement to cement in plain concrete, increases workability when compared to workability with reference to concrete made without admixtures. And the mix proportion of 6% replacement of cement with SCBA (2%), RHA (2%) and SD (2%) showed good properties like compressive and tensile strength.
- Lathamaheswari et al. (2017) [8]; This paper presents the attempt made in making concrete with partially replacing cement by 2.5, 5, 7.5, 10 and 12.5% of bagasse ash. Mix design is made for conventional M20 grade, conventional and ash based concrete prepared, the workability, strength and durability characteristics are

determined through proper testing and the results are compared. The optimum level of cement replacement with bagasse ash is observed to be 7.5% per-cent.

- Jose da Silva Andrade Neto et al. (2020) [14]; in this study, the effects of adding 5%, 10%, and 15% SCBA on the properties and durability (chloride migration, carbonation, and alkali aggregate reaction) of concrete were investigated, they concluded that with the increase in time lag and reduction in chloride diffusion coefficients, the addition of SCBA resulted in a higher lifetime against the penetration of chlorine ions. The larger the SCBA content, the higher the estimated lifetime, increasing by up to 95.7% for the containing 15% SCBA.

3. Materials and Methods

3.1.1 Cement: Ordinary Portland cement, 43 grade conforming to IS: 8112-1989 was used with specific gravity of 3.04

3.1.2 Aggregates: Fine aggregate, locally available river sand was used as a fine aggregate. Fine aggregate tests are carried out in accordance with IS: 383-1970. The specific gravity is found to be 2.54. With a fineness modulus of 2.04 fine aggregate is classified as zone II. Black trap coarse aggregates 20mm downsize and having specific gravity 2.85 was used.

3.1.3 Water: Portable water was used for mixing and curing of concrete cubes.

3.1.4 Sugar Cane Bagasse Ash: SCBA was collected from the Hunchal factory at Gokak Taluk, Belagavi, Karnataka. SCBA has a specific gravity of 1.86. Table 1 shows the chemical composition of SCBA.

Table 1: Chemical composition of sugar cane bagasse ash

Sl No.	Components	Mass (%)
1	Silica dioxide (SiO_2)	62.43
2	Alumina Oxide (Al_2O_3)	4.28
3	Iron Oxide (Fe_2O_3)	6.98
4	Calcium Oxide (CaO)	11.8
5	Potassium Oxide (K_2O)	3.53
6	Magnesium Oxide (MgO)	2.51
7	Sulphur Tri Oxide (SO_3)	1.48
8	Loss Of Ignition	4.73

3.2 Materials Estimation

The tests are carried out in accordance with Indian standard code. The results obtained are based on an average of three trails in each case. The concrete is prepared by replacing the cement in the concrete with SCBA (0 percent, 10% and 20%). Compressive strength, flexural strength, split tensile strength and durability tests are conducted in the hardened state. The moulds used in various tests are in accordance with IS: 516-1959. The sizes for compressive strength test 100 mm x 100 mm x 100 mm cube moulds are employed. Split tensile strength tests are performed using cylinder moulds with a diameter of 100 mm and height of 200 mm. Flexural strength tests are carried out using beam moulds of 100 mm x 100 mm x 500 mm.

The mix design for M15, M30 and M50 grade concrete is done in accordance with IS: 10262-2019. In this work, SCBA is used to partially replace cement by weight in concrete in the range of 0%, 10% and 20%. Water/cement ratio is maintained at 0.6, 0.43 and 0.292. Respectively for conventional concrete for M15, M30 and M50 grade concrete. Mix proportions are shown in Table 2.

Table 2: Mix Proportions Per Cum of Concrete.

Parameters	M15			M30			M50		
	Control Mix1	Mix2 10% SCBA	Mix3 20% SCBA	Control Mix4	Mix5 10% SCBA	Mix6 20% SCBA	Control Mix7	Mix8 10% SCBA	Mix9 20% SCBA
Cement (kg)	320	316.8	281.6	446	441.9	392.8	658	650.7	578.4
Bagasse ash (kg)	0	35.2	70.4	0	49.1	98.2	0	72.3	144.6

Fine aggregates (kg)	634	638	632	606	570	561	503	462	449
Coarse aggregates (kg)	1264	1208	1197	1178	1147	1129	1095	1038	1009
Water (kg)	192	192	192	192	192	192	192	192	192
w/c ratio	0.6	0.54	0.54	0.43	0.39	0.39	0.292	0.265	0.265

3.3 Slump test

As shown in Figure 2, a concrete slump test is a method of testing the workability of a concrete mix prepared in the laboratory or on the job site throughout the construction process. The slump test is performed in accordance with IS: 1199-1959. The values for the slump are listed in the Table 3.

Table 3: Slump cone test values

SL.NO	Grade of concrete	Type of concrete mix	Slump Value (mm)
1	M15	Mix1 (1:0:1.98:3.95:0.6)	64
2		Mix2 (1:0.11:2.01:3.08:0.54)	62
3		Mix3 (1:0.25:2.24:4.25:0.54)	63
4	M30	Mix4 (1:0:1.35:2.64:0.43)	66
5		Mix5 (1:0.11:1.28:2.59:0.39)	68
6		Mix6 (1:0.25:1.42:2.87:0.39)	67
7	M50	Mix7 (1:0:0.76:1.66:0.292)	65
8		Mix8 (1:0.11:0.71:1.59:0.265)	63
9		Mix9 (1:0.25:0.77:1.74:0.265)	62

Fig. 1: Mixing of ingredients

Fig. 2: Slump cone test.

Fig. 3: Casting of specimens.

Fig. 4: Compression test.

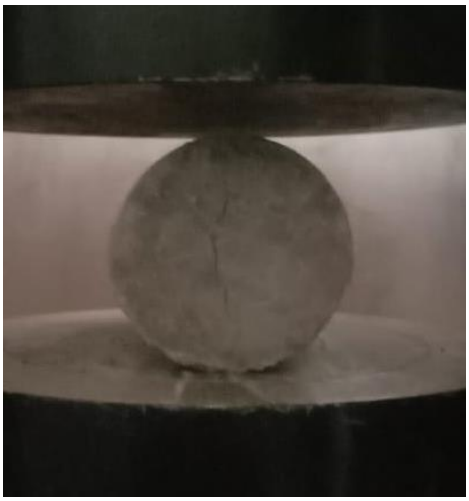

Fig. 5: Split tensile test.

Fig. 6: Flexural test.

Fig. 7: Immersion of specimens in HCL acid.

4. Results and Discussion

Experiments on hardened concrete yielded the following results:

4.1 Compressive strength of M15, M30 and M50 Grade.

- The compression strength of M15 grade is 25.76 Mpa for mix with 10% of SCBA, is 5.74% higher than the conventional concrete and 32.3% lower for mix with 20% of SCBA at 28 days strength and the 7 days strength is decreased to 7.63% and 33.33% for 10% and 20% of SCBA respectively.

- The compression strength of M30 grade is 42.61 Mpa for mix with 10% of SCBA, is 7.32% higher than the conventional concrete and 6.27% lower for mix with 20% of SCBA at 28 days strength and the 7 days strength is decreased 10.62% and 19.03% for 10% and 20% of SCBA respectively.

- The compression strength of M50 grade is 62.97 Mpa for mix with 10% of SCBA, is 7.07% higher than the conventional concrete and 3.92% lower for mix with 20% of SCBA at 28 days strength and the 7 days strength is decreased 5.56% and 10.14% for 10% and 20% of SCBA respectively.

Table 4: Compressive strength.

Sl N0	Grade of concrete	Type of concrete	Age of concrete in days	Compression strength N/mm^2
1	M15	Mix1	7	16.65
			28	24.36
2		Mix2	7	15.38
			28	25.76
3		Mix3	7	11.10
			28	16.49
4	M30	Mix4	7	21.65
			28	39.70
5		Mix5	7	19.35
			28	42.61
6		Mix6	7	17.53
			28	37.21
7	M50	Mix7	7	37.94
			28	58.81
8		Mix8	7	35.83
			28	62.97
9		Mix9	7	34.09
			28	56.50

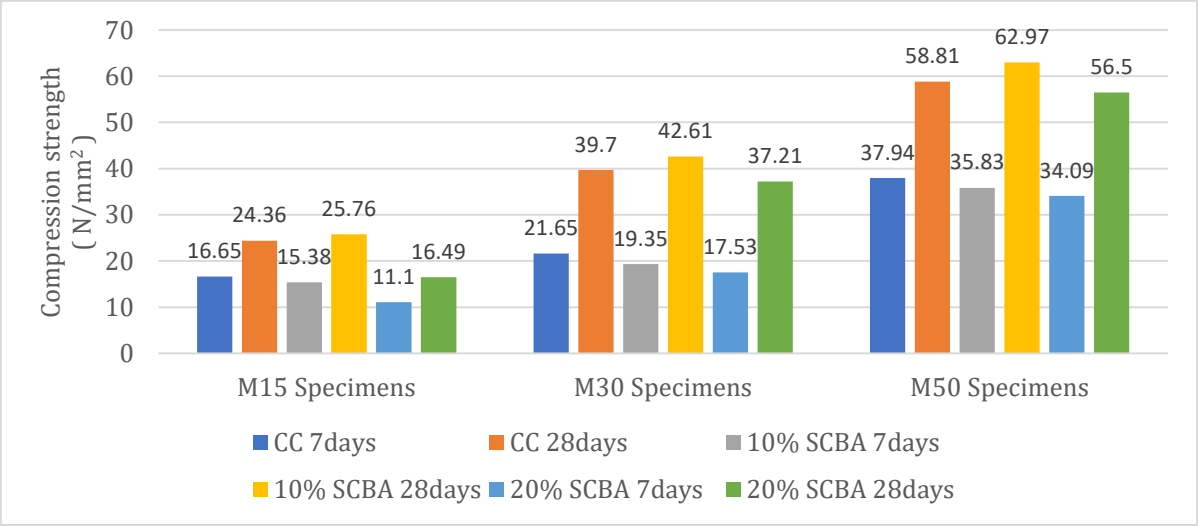

Fig. 8: Compressive strength for various percentage of SCBA for M15, M30 and M50 concrete.

CC= Conventional concrete
SCBA= Sugar cane bagasse ash

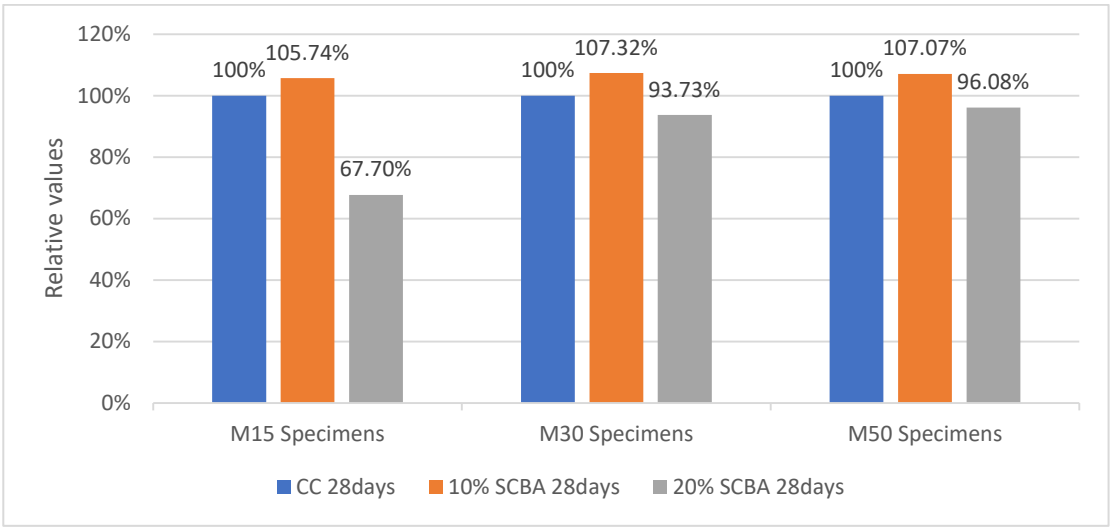

Fig. 9: Relative values for various per-cent for M15, M30 and M50 concrete.

4.2 Spilt tensile strength of M15, M30 and M50 Grade.

- The Split tensile strength of M15 grade is 1.41 Mpa for mix with 10% of SCBA, is 22.60% higher than the conventional concrete and 15.65% lower for mix with 20% of SCBA at 28 days strength and the 7 days strength is decreased 10.2% and 35.71% for 10% and 20% of SCBA respectively.

- The Split tensile strength of M30 grade is 3.02 Mpa for mix with 10% of SCBA, is 18.43% higher than the conventional concrete and 4.70% lower for mix with 20% of SCBA at 28 days strength and the 7 days strength is increased 18.6% and 11.05% for 10% and 20% of SCBA respectively.

- The Split tensile strength of M50 grade is 3.17 Mpa for mix with 10% of SCBA, is 8.6% higher than the conventional concrete and 4.79% lower for mix with 20% of SCBA at 28 days strength and the 7 days strength is increased 3.09% and 1.32% for 10% and 20% of SCBA respectively.

Table 5: Split tensile strength.

Sl No	Grade of concrete	Type of concrete	Age of concrete in days	Split tensile strength N/mm^2
1	M15	Mix1	7	0.98
			28	1.15
2		Mix2	7	0.88
			28	1.41
3		Mix3	7	0.63
			28	0.97
4	M30	Mix4	7	1.99
			28	2.55
5		Mix5	7	2.36
			28	3.02
6		Mix6	7	2.21
			28	2.43
7	M50	Mix7	7	2.26
			28	2.92
8		Mix8	7	2.33
			28	3.17
9		Mix9	7	2.29
			28	2.78

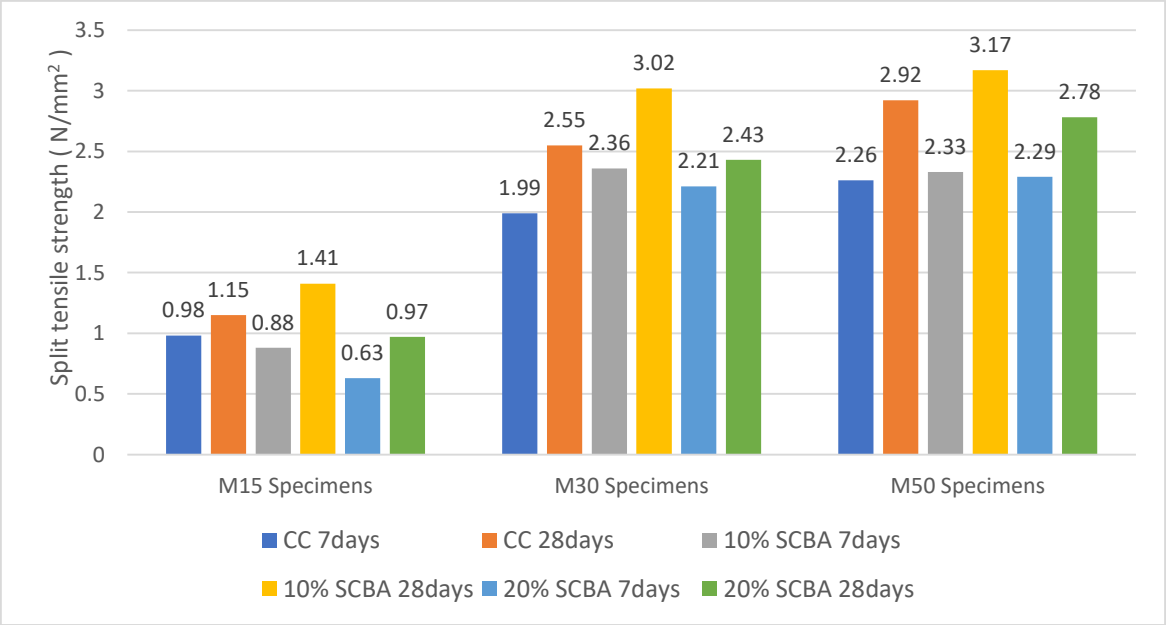

Fig. 10: Split tensile strength for various percentage of SCBA for M15, M30 and M50 concrete.

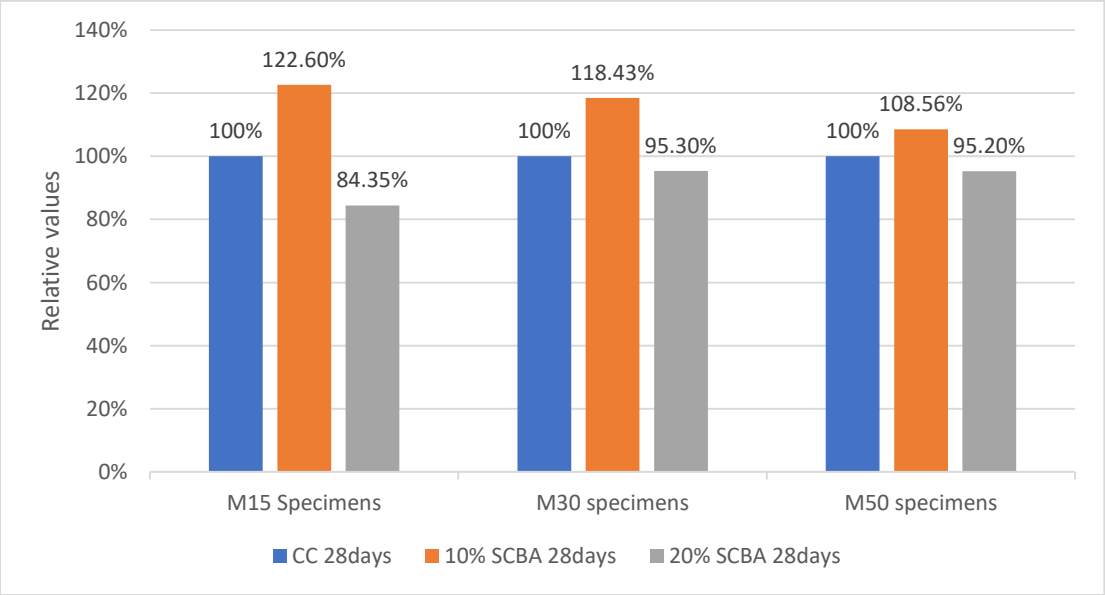

Fig. 11: Relative values for various per-cent for M15, M30 and M50 concrete.

4.3 Flexural strength of M15, M30 and M50 Grade.

- The Flexural strength of M15 grade is 3.27 Mpa for mix with 10% of SCBA, is 5.48 higher than the conventional concrete and 29.03% lower for mix with 20% of SCBA at 28 days strength and the 7 days strength is decreased 2.94% and 21.56% for 10% and 20% of SCBA respectively.
- The Flexural strength of 30 grade is 5.90 Mpa for mix with 10% of SCBA, is 22.40% higher than the conventional concrete and 4.35% lower for mix with 20% of SCBA at 28 days strength and the 7 days strength is decreased 6.02% and 17.05% for 10% and 20% of SCBA respectively.
- The Flexural strength of 50 grade is 6.73 Mpa for mix with 10% of SCBA, is 18.07% higher than the conventional concrete and 3.50% lower for mix with 20% of SCBA at 28 days strength and the 7 days strength is increased 7.29% for 10% and decreased 3.24 for 20% of SCBA respectively.

Table 6: Flexural strength.

Sl. N0	Grade of concrete	Type of concrete	Age of concrete in days	Flexural strength in N/mm^2
1	M15	Mix1	7	2.04
			28	3.10
2		Mix2	7	1.98
			28	3.27
3		Mix3	7	1.60
			28	2.20
4	M30	Mix4	7	2.99
			28	4.82
5		Mix5	7	2.81
			28	5.90
6		Mix6	7	2.48
			28	4.61
7	M50	Mix7	7	3.70
			28	5.70
8		Mix8	7	3.97
			28	6.73
9		Mix9	7	3.58
			28	5.50

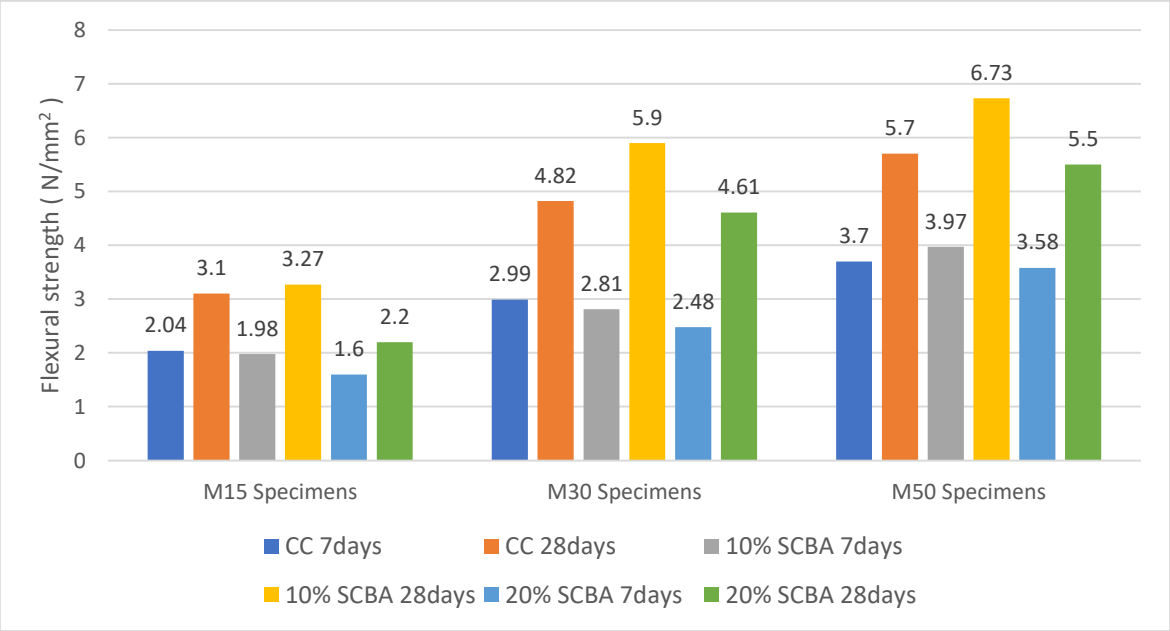

Fig. 12: Flexural strength for various percentage of SCBA for M15, M30 and M50 concrete.

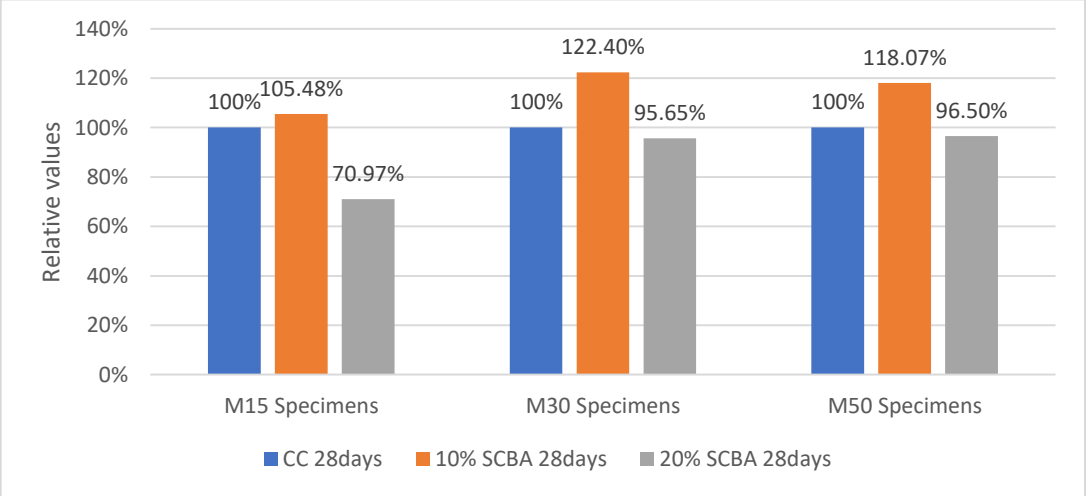

Fig. 13: Relative values for various per-cent for M15, M30 and M50 concrete.

4.4 Durability test.

In durability test first we taken water and its PH is about 6.7 checked in the PH meter in the environmental lab. And then about 500 ml of water was taken in a beaker, then drop by drop adding HCL in the beaker then checking the PH for every 15min. Then we attained the PH of 2.5 the total ml of HCL added for 500 ml sample of water was 1.2 ml. For 1 litre is about 2.4 ml per litre the bucket we used that total volume is 21 litres for 1-litre water 2.4 ml of HCL for 21 litres is about 50.4 ml. To investigate the impact of an aggressive chemical environment on compressive strength loss and weight loss in M15, M30 and M50 grades with SCBA replacing cement (0%, 10%, and 20%). The content of HCL is 0.24 per-cent. The results are tabulated in Table 7 and the graph is shown in Figure 14

Table 7: Effect of HCL on compressive strength for M15, M30 and M50.

Sl No	Grade of concrete	Type of concrete	Age of concrete in days	Initial weight Kg	Final weight Kg	% Weight reduction	Initial strength N/mm²	Final strength N/mm²	% Strength reduction
1	M15	Mix 1	7	2.40	2.37	1.25	16.75	14.65	12.5
			14	2.42	2.37	1.9	19.65	16.2	17.5
2		Mix 2	7	2.44	2.39	2.04	15.38	13.15	14.4

			14	2.50	2.45	1.99	20.80	16.91	18.6
3		Mix 3	7	2.38	2.31	2.73	11.10	8.69	21.7
			14	2.36	2.30	2.49	13.77	10.65	22.6
4	M30	Mix 4	7	2.32	2.28	1.5	21.65	19.63	9.3
			14	2.47	2..42	1.86	24.63	21.17	14
5		Mix 5	7	2.40	2.36	1.78	19.35	17.13	11.4
			14	2.37	2.31	2.19	25.02	21.32	14.7
6		Mix 6	7	2.27	2.22	2.74	17.53	15.12	13.7
			14	2.39	2.33	2.5	20.48	16.50	19.4
7	M50	Mix 7	7	2.31	2.29	0.99	37.94	35.91	5.3
			14	2.31	2.26	2.07	40.50	36.64	9.5
8		Mix 8	7	2.26	2.22	1.72	35.83	33.6	6.2
			14	2.30	2.24	2.47	41.06	36.94	10.0
9		Mix 9	7	2.21	2.16	2.12	34.09	31.68	7.0
			14	2.17	2.10	2.8	37.33	33.88	9.2

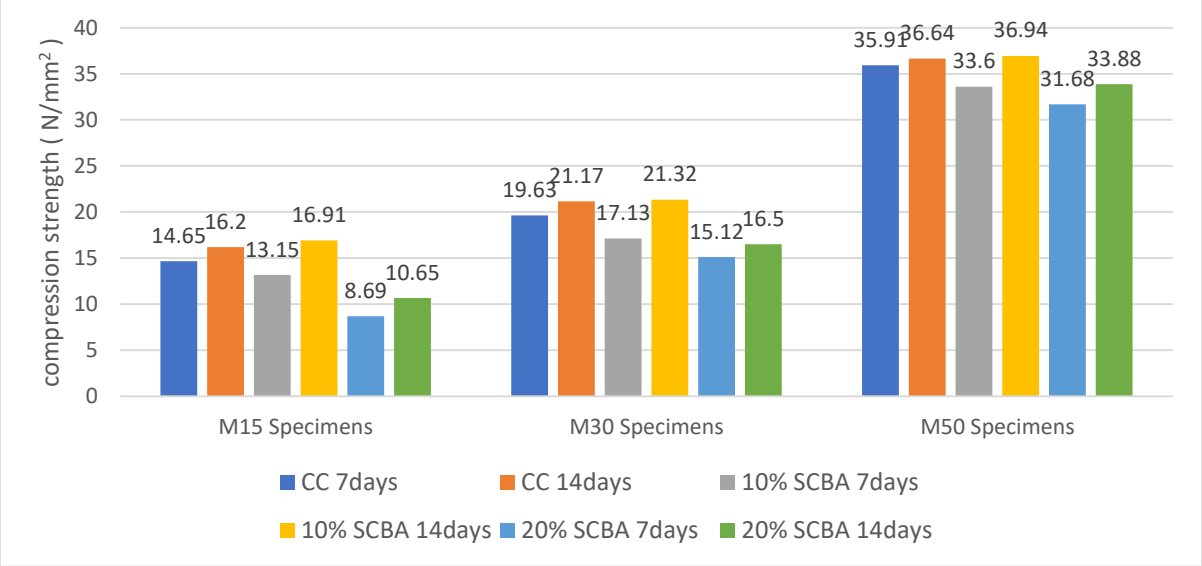

Fig. 14: Compressive strength for various percent of SCBA for M15, M30 and M50 concrete with HCL Solution.

5. Conclusions

The following conclusions are drawn from experimental studies

- The 28-day compressive strength values of M15, M30, and M50 mixes rise by 5.74 %, 7.32 %, and 7.07 %, respectively, as the SCBA is increased from 0 to 10%.
- M15, M30, and M50 mixes, split tensile strength increases by 22.6 %, 18.43 %, and 8.41 %, respectively.
- M15, M30, and M50 mixes' flexural strength increases by 5.48 percent, 22.4 percent, and 18.07 percent, respectively. As a result, up to 10% of cement can be replaced with SCBA without impairing the strength qualities.
- According to a durability study, the specimens immersed in 0.24% HCL solution shows that as SCBA usage rises, compressive strength decreases and weight loss increases.

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