Assessment of Sugarcane Bagasse Ash Concrete on Mechanical and Durability Properties

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Abstract:
The aim of this research is to determine the mechanical and durability properties of sugarcane bagasse ash (SCBA) as a partial replacement to Ordinary Portland Cement (OPC) in concrete. The SCBA was partially replaced at the percentage of 5%, 10%, 15% and 20% by weight of cement for mean target strength of 27MPa. A slump range of 130–150mm was maintained constant throughout the experiment procedures. A total of 120 cubes and 30rectangular beams were tested and the results were compared with control concrete. To evaluate the behaviour of SCBA on concrete, different tests were conducted on the concrete specimens namely, compressive strength, flexural strength, water absorption, water penetration, carbonation and ultrasonic pulse velocity. The results demonstrated that at 7, 28, 56, 90 and 120 days of curing, compressive strength increased by 2.6%,2.4%,1.9%,1.8% and 1.7% for 5%,10%,15% and 20% replacement level. The water absorption increased by 255%, 390%, 438% and 488% for 5%, 10%, 15% and 20% replacement level. The other tests showed decreased flexural strength and ultrasonic pulse velocity and increased water penetration and carbonation depth. The study inferred that 10% replacement of OPC by SCBA exhibited positive performances and can be considered a suitable cementitious material in the construction industry.

Keywords: Ordinary Portland Cement (OPC), sugarcane bagasse ash (SCBA), Concrete, Fly Ash;

1. Introduction

Presently, concrete is the most widely used man-made construction materials in the World. Their recognition is due to their availability, capacity to resist water and adaptability in various shapes and dimensions[1]. Concrete is often manufactured with four primary components which are cement, coarse aggregates, fine aggregates and water [2]. Cement, which is considered a key element, is the second most-consumed substance on earth after water [3]. As per[4], the global cement consumption is expected to reach 4.42 billion tons by 2021. However, this value is predicted to increase to 5 billion tons by 2050[5]. Cement production has a pernicious effect on both humans and the environment. Its production process plays an integral part in the greenhouse effect and is responsible for almost 10% of the worldwide carbon dioxide emission[6]. Therefore, to minimise the carbon dioxide gas emissions, many researchers have focused on alternative materials that can replace cement as the main binding component in concrete.

To minimise the cement utilisation in concrete, proposals have been made to use agricultural waste materials as a partial substitution to cement. Many studies have demonstrated that agricultural wastes can indeed be used as an alternate cementitious material. The focus on this waste has been proposed due to their availability and pozzolaniccharacteristics[7-5]. Agricultural wastes such as rice husk ash and sugarcane bagasse ash are considered mineral admixtures with good pozzolanicproperties[15,16]. The effect of pozzolanic materials enhances the concrete properties in terms of materials rheology, strength development and contribute to the final product's long-term durability. These characteristics of pozzolans depend mostly on the type of ashes, the source, the processing stages and the temperatures at which these wastes are burnt that SCBA can be used as a suitable cementitious material in the construction industry. Moreover, waste utilisation could contribute to foreign exchange gain and help mitigate solutions for a sound, clean and pollution-free environment[18]. Sugarcane is one of the main crops grown in over 110 countries, and its total production is around 1500 million tons[19]. Brazil and India are the World’s leading sugarcane producing countries, with Brazil producing over 719 million tons of sugarcane, which is represented as one-third of the World’s total sugarcane production [20]. India produced 300 million tonnes of sugarcane per year and generated about 10 million tons of sugarcane bagasse ash [21]. In Mauritius, the bagasse obtained from sugarcane is used for electricity production mainly during the sugarcane harvest period, and the amount of bagasse used for the co-generation of electricity in 2015 was 1,98,450Ton [22]. To be in line with the recycling of industrial and agricultural wastage, the sugarcane bagasse ash is considered a potential material for the replacement of cement and contributes to reducing the disposal problems. It is an ideal product, as sugarcane is one of the most substantial agricultural plants that grow in hot regions. During the harvest period, sugarcane is crushed in sugar factories, and its juice is extracted, the remaining fibrous matter obtained is known as the bagasse. Currently, the bagasse is used as a biomass fuel in boilers for power generation in sugar factories. Burning of bagasse is conducted under controlled temperatures, and the residue obtained is known as bagasse ash. However, bagasse ash has been considered a waste and is generally disposed in landfills, spilt over farms, or dumped in ash ponds. This composition differs according to geographical location, crop type, underground water, nature of soil etc. [23]. The formation of large quantities of amorphous silica is generally associated with the calcination of SCBA at temperature ranging between 600^0C and 700^0C, and is the reason for its high pozzolanic activity. Consequently, SCBA reacts with the portlandite produced during the cement hydration process and results in calcium-silicate-hydrate (C-S-H) formation, which increases the mechanical properties of concrete [32]. Past studies have shown that the pozzolanic properties in SCBA can be beneficial for concrete production, as the minerals present contributes to strength enhancement and durability safeguard. In Mauritius, the sugar factories that generate electricity have earmarked large land areas to dispose of these unwanted wastes. The region surrounding the land disposal cannot be developed due to the hazardous nature of these materials. This increases the electrical conductivity which may retard plant establishment growth and also affect the soil and groundwater quality. The dumping of these wastes in the open lands could contaminate air and water bodies and have an irreversible impact on the environment and human life [34]. It has been stated that people who are exposed to bagasse dust particles have a high probability to develop lung diseases known as Bagassosis [35]. Many studies on SCBA as a substitution material for cement have been conducted in the past.Most of the authors have concentrated their effort on the mechanical properties of concrete however, experiments on durability have not been studied in depth from records, numerous researchers have experimented the utilisation of SCBA as a replacement to cement in concrete.

The present study was carried out on SCBA obtained by controlled combustion of sugarcane bagasse, which was procured from the Tamilnadu in India. Sugarcane production in India is over 300 million tons/year leaving about 10 million tons of as unutilized and, hence, wastes material. This paper analyses the effect of SCBA in concrete by partial replacement of cement at the ratio of 0%, 10%, 15%, 20%, 25% and 30% by weight. The main ingredients consist of Portland cement, SCBA[3], crusheds and, coarse aggregate and water. After mixing, concrete specimens were casted and subsequently all test specimens were cured in water at 7, 28, 56 and 90 Days.

1.1 Chemical Composition of SCBA

Sugarcane bagasse ash collected for experimental work was tested for the chemical compound atKSS Export, Coimbatore. Chemical compound result of bagasse ash is follow:

Table 1.Chemical Composition of Sugarcane Bagasse Ash

Chemical Compound	Abbreviation	Percentage
Silica	SiO_2	68.42
Aluminium Oxides	Al_2O_3	5.812
Ferric Oxide	Fe_2O_3	0.218
Calcium Oxide	CaO	2.56
Phosphorous Oxide	P_2O_5	1.28
Magnesium Oxide	MgO	0.572
Sulphide Oxide	SO_3	4.33
Loss on Ignition	LOI	15.90

1.2 Scope of Work

Laboratory tests on cement, fine aggregate, coarse aggregate, bagasse ash, water. Whatever may be the type of concrete being used, it is important to mix design of the concrete. The same is the case with the industrial waste based concrete or bagasse ash replacement. The major work involved is getting the appropriate mix proportions. In the present work, the concrete mixes with partial replacement of cement with bagasse ash were developed using OPC 53 grade cement. A simple mix design procedure is adopted to arrive at the mix proportions.

After getting some trail mix, cubes of dimensions 150x150x150mm, cylinder of dimensions 150x300 mm and beams of dimensions 100x100x150mm was casted and cured in the curing tank. Compressive strength, Split tensile strength Water Absorption Test, Water Penetration Test and Flexural strength of concrete were conducted to know the strength properties of the mixes. Initially, a sample mix design was followed and modifications were made accordingly while arriving at the trail mixes to get optimized mix which satisfies both fresh, hardened properties and the economy[4]. Finally, a simple mix design is proposed.

2. Materials and Methods

2.1. Materials

In the present experimental investigation, cement was partially replaced by sugarcane bagasse ash at different ratios and characteristics on hardened concrete samples were casted. The materials used in this research are as follows:

2.1.1. Cement

Ordinary Portland Cement (OPC) conforming to EN 197-1:2000 CEM I 42.5 N was used in this experiment. The chemical constituents and physical properties of OPC were obtained from the supplier's certificate of analysis and are illustrated in Table 2. Fig. 2 shows the processed SCBA and the raw SCBA.

2.1.2 M-Sand: M-Sand is nothing but crushing of hard stone aggregates to the size of natural sand. The finest particles are removed by washing with water.

Table 2- Constituents of Manufacturing Sand(M-Sand)

Element	Weight in %
Carbon(C)	1.74
Oxygen(O)	48.09
Sodium(Na)	2.69
Magnesium(Mg)	2.45
Aluminium(Al)	8.13
Silica(Si)	18.45
Potassium (K)	2.84
Calcium(Ca)	3.68
Titanium(Ti)	1.86
Iron (Fe)	10.06

2.1.3 Total: Pulverized rock stones got from nearby quarries were utilized as coarse total. The most extreme size of coarse total utilized was 20 mm. The properties of coarse total were controlled by leading tests according to Seems to be: 2386 (Part – III).

2.1.4 Super Plasticizer: Conplast SP 430 confirming to IS9103(1999) was used as super plasticizer. It is used to improve the workability properties.

2.1.5. Sugarcane Bagasse Ash (SCBA)

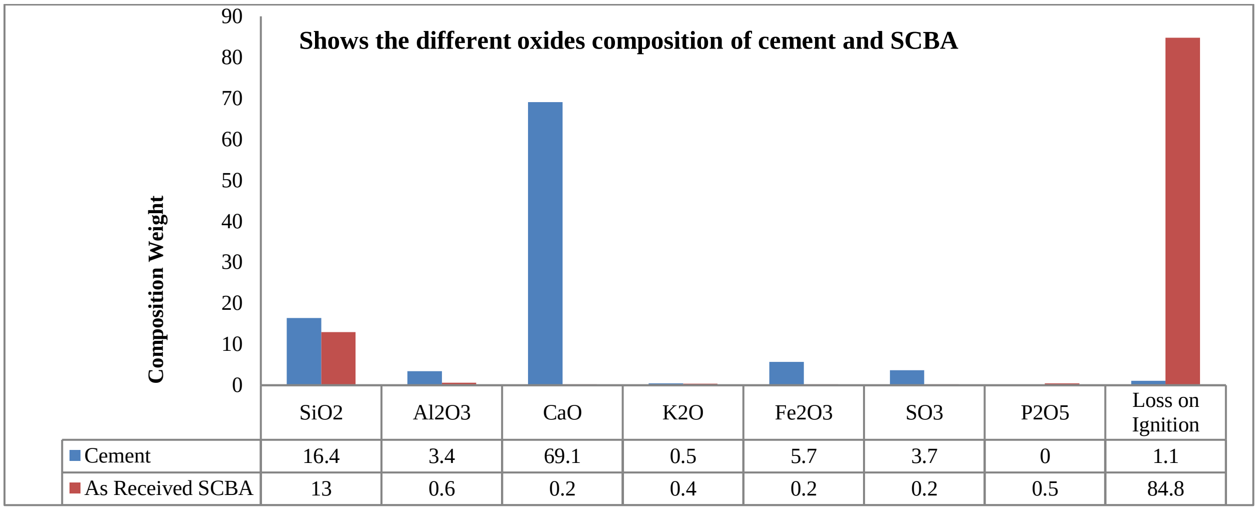
The sugarcane bagasse ash was collected from KSS Exports, Coimbatore, Tamilnadu, India. The SCBA was obtained from the burning of sugar cane bagasse. In this research, the black colour bagasse ash was burnt in a private laboratory's oven at a temperature of 240^0C for 12h. The material obtained was light brown in colour, and much finer than the raw SCBA, as part of the remaining sugarcane fibres have been converted into ashes.

Fig.1 Sugarcane Bagasse Ash (SCBA) Process

The treated SCBAwas then sieved as per BS 812 Part 103.1: 1985 with sieve size 75 mm. All materials passing through the 75mm size was collected for use in this experiment. The SCBA was used as a replacement for cement, and its properties are shown in Table 3.

Table 3. Shows the different oxides composition of cement and SCBA

S.No	Costitution	Cement	As Received SCBA
1.	SiO_2	16.4	13.0
2.	Al_2O_3	3.4	0.6
3.	CaO	69.1	0.2
4.	K_2O	0.5	0.4
5.	Fe_2O_3	5.7	0.2
6.	SO_3	3.7	0.2
7.	P_2O_5	-	0.5
8.	Loss on Ignition	1.1	84.8



	SiO2	Al2O3	CaO	K2O	Fe2O3	SO3	P2O5	Loss on Ignition
■ Cement	16.4	3.4	69.1	0.5	5.7	3.7	0	1.1
■ As Received SCBA	13	0.6	0.2	0.4	0.2	0.2	0.5	84.8

Fig.2 Shows the different oxides composition of cement and SCBA

The graph represented in Fig. 2 shows the different oxides composition of cement and SCBA. The process for retrieving the SCBA from raw sugarcane bagasse ash in laboratory condition is illustrated in Fig. 2.

2.1.6. Natural coarse aggregates

The natural coarse aggregates (NCA) were obtained from our local plant and consisted of crushed basaltic rocks. The coarse aggregates were separated into two different gradings, which are 14x20 mm and 6 x10 mm.

2.1.7. Natural Fine Aggregates

The natural fine aggregates (NFA) were supplied from the same local plant as natural coarse aggregates.

2.1.8. Water

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2.1.9. Admixture

The admixture of type Super plasticizer received from a Private Concern, Chennai was added to the concrete to improve workability and retain the required slump over an extended period. The admixture was added with a proportion of 1% by weight of binder in each batch as per the product specification and requirements.

2.2. Concrete Mix Design

In this research,120 cubes samples and 30 rectangular beams for all test were casted. The mix containing 100% of Ordinary Portland Cement (OPC) was defined as B1. The substitution of cement with SCBA was experimented using 5%, 10%, 15% and 20% of treated SCBA in each batch. The concrete mix design was carried out according to Teychenne et al. [26], which consisted of mix design calculations, tables and charts. The concrete was designed for a target mean strength of 27 MPa at 7,16,28,56,90 and 120 days with a constant slump range of 130x150 mm. Table 4 shows the mix proportion of 1m^3 of concrete on Saturated Surface Dry condition (SSD). The concrete was mixed according to BS 1881: Part 125: 1986 with a drum mixer of wet mix capacity of 260L in the laboratory. The OPC and SCBA were mixed and used as one binder for batches No. 2, 3, 4 and 5. During the mixing process, half of the coarse aggregates were added to the drum mixer, followed by fine aggregates and finally, the remaining half coarse aggregates was added. The aggregates were mixed in the drum for 20s. The mixing was continued and half of the water content was added during the next 15s. The whole batch was mixed for a total of 2.5 min and then stopped and the content in the mixer was covered and left for another 10min. The binder (OPC and SCBA) was added to the mixer's wet batch, and all the materials were mixed for another 30s. The remaining water was added over the following 30s and mixing was continued for 2.5min. Moreover, particular consideration was given to the high absorption value of SCBA and the final water required in the mixing process of the concrete was adjusted according to the desired workability range (slump values). After the mixing was completed, the concrete was off-loaded onto a clean non-adsorbent surface and mixed thoroughly using a hand tool to ensure uniformity before sampling.

3. EXPERIMENTAL INVESTIGATIONS

In present study, M25grade concrete was designed as per IS: 10262-2009.

3.1 Workability

Tests performed on the fresh concrete give an idea about the workability of concrete mix. Hence in order to determine the workability slump cone test is performed. Freshlymixed concrete were tested for workability by slump value. In this investigation, M25 mix concrete is considered to perform the test by weight basis by partially replacing 5%, 10%, 15% and 20% in the weight of cement.

Table 4: Workability Properties of Concrete mix

Mix Combinations	Slump(in mm)	Compaction Factor
Control Mix	105	0.95
CM +5%	126	0.96
CM+10%	138	0.96
CM+15%	143	0.98
CM+20%	154	0.98

3.2 Compressive Strength

In this investigation, M25mix concrete is considered to perform the test by partially replacing 0%, 5%, 10%, 15% and 20% in the weight of cement. A 150x150mm concrete cube was used as test specimen to determine the compressive strength of concrete. The ingredients of concrete were thoroughly mixed till uniform consistency was achieved. The cubes were properly compacted. All the concrete cubes were de-moulded within 24 hours after casting. The de-moulded test specimens were properly cured in water available in the laboratory at age of 7, 16, 28and 56 days. Compression test was conducted with 2000KN capacity on universal testing machine. The load was applied uniformly until the failure of the specimen occurs. The specimen was placed horizontally between the loading surface of the compression testing machine and the load was applied within shock until the failure of the specimen occurred.

Table 5: Mix Proportions of Different Combination

				Quantities in Kg/m^3				
Mix Combination	SCBA in %	Binder	Superplastizicer	Water	Cement	SCBA	M-Sand	Aggregate
Control Mix	0	0.4	1% of its total weight	136.5	342.00	0	728	1230
CM +5%	5	0.4	1% of its total weight	123.54	308.10	34.15	728	1230
CM+10%	10	0.4	1% of its total weight	112.50	275.50	70.20	728	1230
CM+15%	15	0.4	1% of its total weight	96.10	240.00	105.40	728	1230

CM+20%	20	0.4	1% of its total weight	83.50	206.50	140.3	728	1230

3.3 Split Tensile Strength

In the investigation, M25 mix concrete is considered to perform the test by weight basis by replacing 0%, 5%, 10%, 15% and 20%in weight of cement. The casting cylinders having mathematical dimensions of 150mm x150mm length were used as test specimen to determine the split tensile strength of concrete. The various ingredients of concrete were mixed thoroughly until uniform consistency was achieved the cylinders were compacted properly. All the cylinders were de-moulded within 24 hours after casting .the de-moulded test specimens were properly cured in water which is available in the laboratory for an age of 7,16,28 and 56 days .The split tensile strength was conducted as per IS:5816-1976. the specimen was placed horizontally between the loading surfaces of the compression testing machine and the load was applied without any sudden impact until the failure of the specimen occurred.

3.4 Water Absorption Test

The water absorption test was conducted on 150 mm x 150 mm x 150 mm cubes samples which were water cured for 28 and 56 days and tested as per BS 1881: Part 122: 1983. Cores samples of diameter 50 mm were drilled, and were placed in an oven for 72 h. After the drying process, the samples were removed and placed in a dry airtight vessel to cool.

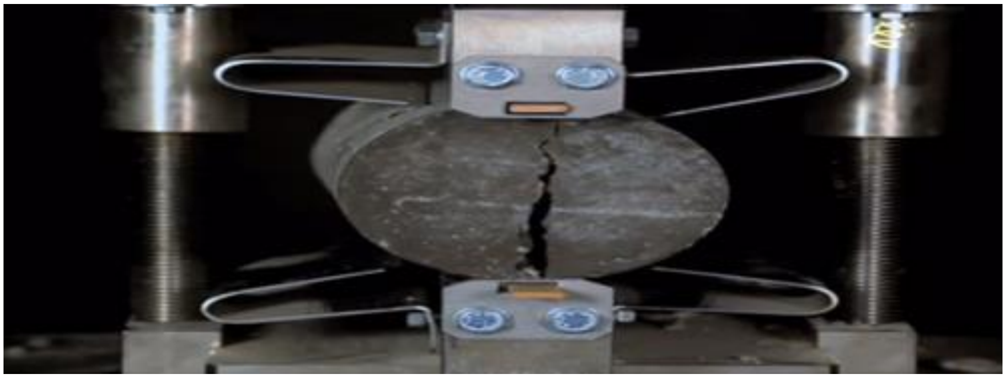

Fig.7 : Water Absorption Test for SCBA

Each core was weighed and immediately immersed in a water tank for 30 min with 25 mm of water over the top of the specimen. After 30 min the cores were removed and dried with a cloth rapidly and weighed. The measured absorption of each specimen was calculated as the increase in mass resulting from immersion denoted as a percentage of the dry sample's mass Fig. 7.

3.5 Water Penetration Test

The water penetration test was conducted on 150 mm x 150 mm x 150 mm cubes and cured in water for 28 and 56 days, as per BS EN 12390: Part 8: 2009. The specimens were placed in an apparatus and a water pressure of 500 KPa were applied for 72 h. After 72 h, the specimens were removed and cleaned to remove excess water.

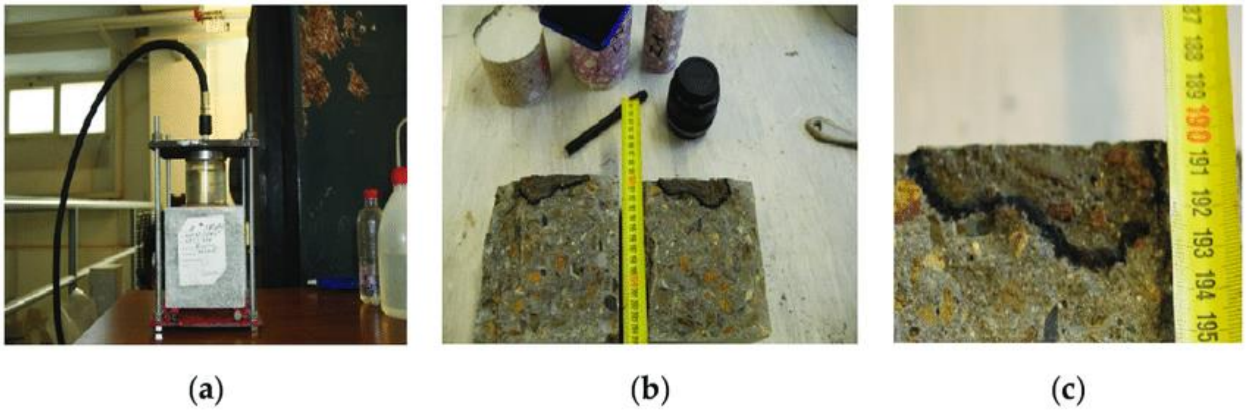

Fig.8 Apparatus and a water pressure for Water Penetration Test

The sample was split into half perpendicular to the face exposed, and the watermark was recorded. The maximum depth of water penetration on the concrete cube was measured Fig. 8.

3.6 Carbonation Test

The carbonation test was performed to analyse the reaction of hydrated cement minerals with carbon dioxide (CO_2) in the presence of moisture. This was conducted by evaluating the depth of the carbonated zone in the concrete sample. This test was performed in compliance with BS EN 14630:2006 at 180 and 365 days on cylindrical cores of diameter 50 mm which were split into half. A solution of phenolphthalein indicator containing approximately 1g phenolphthalein was dissolved in 70 mL ethyl alcohol and diluted with distilled water up to 100 ml.

Figure 9 : Carbonation Test for SCBA

The solution was poured into a container fitted with a nozzle. The drilled cores were then sprayed with phenolphthalein solution on the dust-free surface. The depth was recorded within 30 s of spraying, starting from the edge of the sample to the pink/red purple colour Fig. 9.

4. RESULTS AND DISCUSSIONS

4.1 Workability

The performance of conventional concrete mix and SCBA replaced concrete mix under plastic stage were measured by means of slump cone and compaction factor. Table 2 shows the workability properties of various mixes. This was clearly noticed that the SCBA replaced concrete mix provided better workability than the conventional one. Work ability properties of different concrete values were in accordable one.

Table-6: Slump values for partial replacement of SCBA as cement for M25grade concrete

Sl. No	**%of Cement replaced with SCBA**	**Slump Value**	**Compaction Factor**
1.	**0%**	76	0.95
2.	**5%**	78	0.96
3.	**10%**	80	0.96
4.	**15%**	81	0.98
5.	**20%**	82	0.98

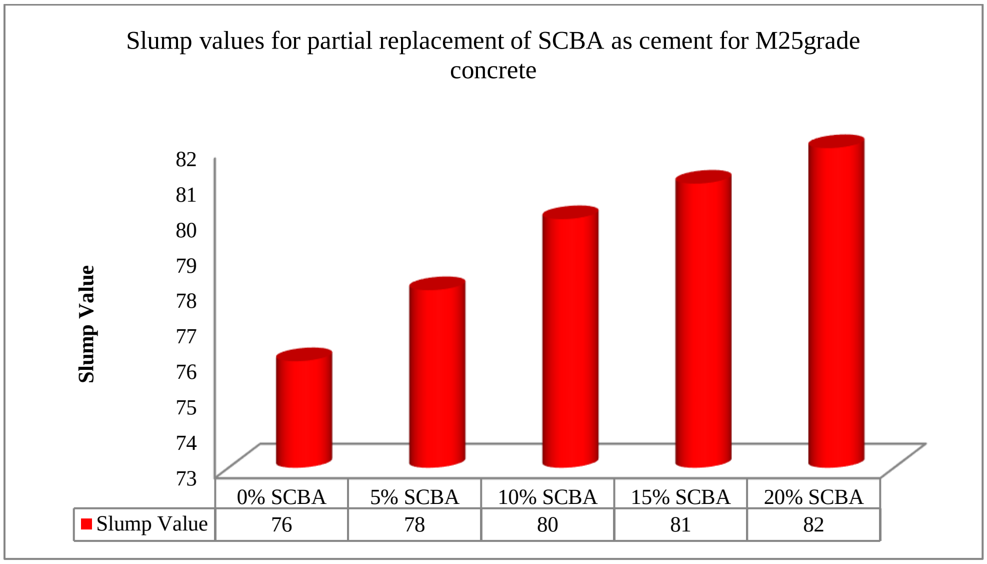

Fig.9 Slump values for partial replacement of SCBA as cement for M25grade concrete

Lowest workability was acquired by the conventional mix. Workability of concrete increases by increasing the percentage of replacement of SCBA in concrete.

4.2 Compressive Strength Test

The compressive strength test of concrete was achieved in 7,16,28 and 56days of various proportions and presented below. The specimens were cast and tested as per IS: 516-1959.

Table-7: Compressive Strength values for partial replacement of SCBA as cement for M_{25}grade concrete.

			7 Days				16 Days				28 Days				56 Days			
S.no	Type of Design	Cubeno	Weight of each cube(KG)	Readingondialgauge (KN)	Compressive Strength(N/mm^2)	Averagecompressive Strength(N/mm^2)	Weigh to feachcube(KG)	Reading ondialgauge(KN)	Compressive Strength(N/mm^2)	Averagecompressive Strength(N/mm^2)	Weight of each cube(KG)	Reading ondialgauge(KN)	Compressive Strength(N/mm^2)	Averagecompressive Strength(N/mm^2)	Weight of each cube(KG)	Reading ondialgauge(KN)	Compressive Strength(N/mm^2)	Averagecompressive Strength(N/mm^2)
1	Nominal concretemix	1	9.32	641	29.43	28.68	8.980	641	29.09	28.34	8.880	641	28.99	28.25	9.380	641	29.490	28.75
		2	9.27	511	23.65		8.930	511	23.31		8.830	511	23.21		9.330	511	23.710	
		3	9.12	721	32.98		8.780	721	32.64		8.680	721	32.54		9.180	721	33.040	
2	5% Replacement of cement	1	8.74	591	27.21	26.46	8.400	591	26.87	26.12	8.300	591	26.77	26.02	8.800	591	27.270	26.52
		2	8.67	531	24.53		8.330	531	24.19		8.230	531	24.09		8.730	531	24.590	
		3	8.70	601	27.65		8.360	601	27.31		8.260	601	27.21		8.760	601	27.710	
3	10% Replacement of cement	1	8.81	371	17.42	18.01	8.470	371	17.08	17.67	8.370	371	16.98	17.57	8.870	371	17.480	18.07
		2	8.69	371	17.42		8.350	371	17.08		8.250	371	16.98		8.750	371	17.480	
		3	8.73	411	19.20		8.390	411	18.86		8.290	411	18.76		8.790	411	19.260	
4	15% Replacement of cement	1	8.66	321	15.20	16.98	8.320	321	14.86	16.64	8.220	321	14.76	16.54	8.720	321	15.260	17.04
		2	8.44	401	18.76		8.100	401	18.42		8.000	401	18.32		8.500	401	18.820	
		3	8.53	361	16.98		8.190	361	16.64		8.090	361	16.54		8.590	361	17.040	
5	20% Replacement of cement	1	8.28	211	10.32	11.95	7.940	211	9.98	11.61	7.840	211	9.88	11.51	8.340	211	10.380	12.01
		2	8.38	281	13.43		8.040	281	13.09		7.940	281	12.99		8.440	281	13.490	
		3	8.21	251	12.10		7.870	251	11.76		7.770	251	11.66		8.270	251	12.160	

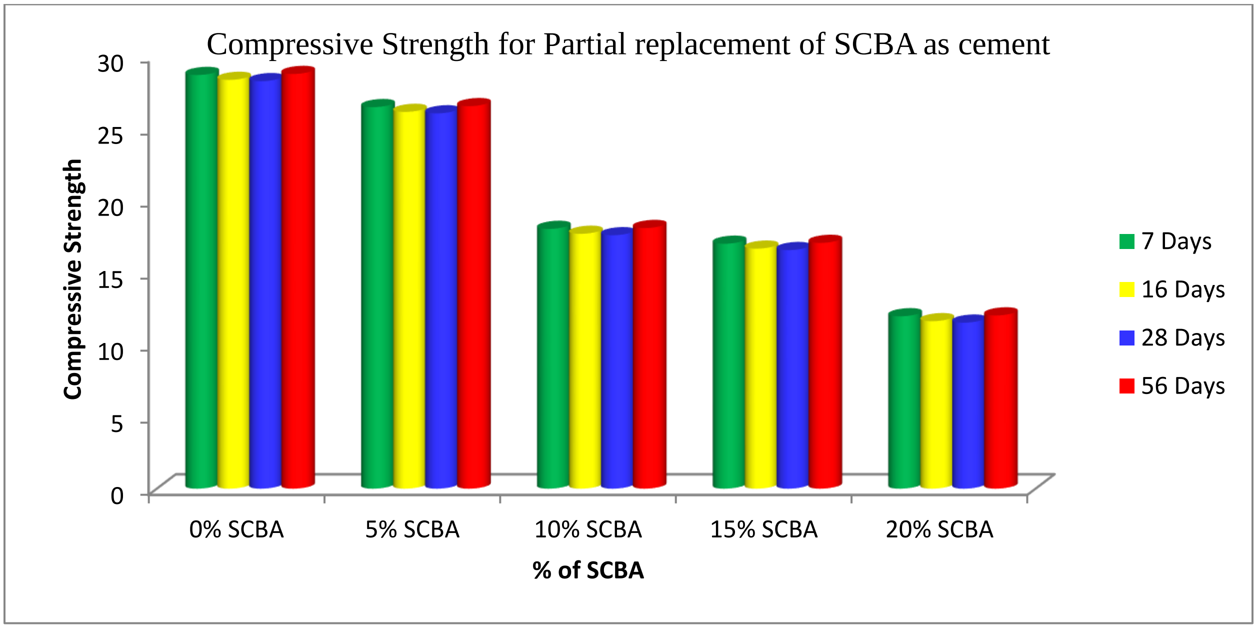

Fig.14 Compressive Strength for Partial replacement of SCBA as cement

From the above compressive strength results, it is observed that Rubber based concrete shave achieve dad ecreased in strength for partial replacement of coarse and fine aggregate for 28 days when compared to conventional concrete.

4.3 Tensile Strength Test Value

The Tensile strength test of concrete with 7, 16, 28 and 56 days curing period for various proportions and presented below. The specimens were cast and tested as per IS:516-1959

Table-4: Tensile Strength values for partial replacement of SCB Aascement for M25 gradeconcrete.

			7 Days				16 Days			
S.no	**TypeofDesign**	**Cubeno**	**Weight ofeachCylinder(KG)**	**Readingondial gauge(KN)**	**SplitTensileStrength(N/mm2)**	**AverageSplitTensileStrength(N/mm2)**	**Weight ofeachCylinder(KG)**	**Readingondialgauge(KN)**	**SplitTensileStrength(N/mm2)**	**AverageSplitTensileStrength(N/mm2)**
1	Nominalconcretemix	1	12.750	144	2.03	1.94	12.750	144	2.03	
		2	12.900	139	1.96		12.900	139	1.96	
		3	12.360	130	1.83		12.360	130	1.83	
2	5% Replacementofcement	1	12.760	135	1.91	1.89	12.760	135	1.91	
		2	12.610	135	1.91		12.610	135	1.91	
		3	12.720	130	1.84		12.720	130	1.84	
3	10% Replacementofcement	1	11.950	120	1.7	1.68	11.950	120	1.7	
		2	12.05	120	1.7		12.05	120	1.7	
		3	11.900	115	1.63		11.900	115	1.63	
4	15% replacementofcement	1	11.650	110	1.56	1.51	11.650	110	1.56	
		2	11.400	100	1.41		11.400	100	1.41	
		3	11.500	110	1.56		11.500	110	1.56	
5	20% Replacementofcement	1	11.250	90	1.27	1.31	11.250	90	1.27	
		2	11.380	100	1.41		11.380	100	1.41	
		3	11.180	90	1.27		11.180	90	1.27	

			28 Days				56 Days			
S.no	**TypeofDesign**	**Cubeno**	**Weight ofeachCylinder(KG)**	**Readingondial gauge(KN)**	**SplitTensileStrength(N/mm2)**	**AverageSplitTensileStrength(N/mm2)**	**Weight ofeachCylinder(KG)**	**Readingondialgauge(KN)**	**SplitTensileStrength(N/mm2)**	**AverageSplitTensileStrength(N/mm2)**
1	Nominalconcretemix	1	12.750	144	2.03	1.94	12.750	144	2.03	
		2	12.900	139	1.96		12.900	139	1.96	
		3	12.360	130	1.83		12.360	130	1.83	
2	5% Replacementofcement	1	12.760	135	1.91	1.89	12.760	135	1.91	
		2	12.610	135	1.91		12.610	135	1.91	
		3	12.720	130	1.84		12.720	130	1.84	
3	10% Replacementofcement	1	11.950	120	1.7	1.68	11.950	120	1.7	
		2	12.05	120	1.7		12.05	120	1.7	
		3	11.900	115	1.63		11.900	115	1.63	
4	15% replacementofcement	1	11.650	110	1.56	1.51	11.650	110	1.56	
		2	11.400	100	1.41		11.400	100	1.41	
		3	11.500	110	1.56		11.500	110	1.56	
5	20% Replacementofcement	1	11.250	90	1.27	1.31	11.250	90	1.27	
		2	11.380	100	1.41		12.750	144	2.03	
		3	11.180	90	1.27		12.900	139	1.96	

4.4 Water Absorption Test

The results of water absorption of concrete are demonstrated in Fig. 14. It showed an increasing trend of water absorption with addition of SCBA in the mix. Moreover, it was observed that with increasing time, the water absorption rate decreased. It was observed that the water absorption increased with increasing amount of SCBA materials and decreased with increasing curing period. The increase at early days was between 389–476 % when compared to the control mix. This could be explained by the fact that SCBA has a high absorption value due to the presence of pores in SCBA[12]. Nevertheless, this increasing trend was seen to decrease at 56 days of curing period. The variation was noted to be ranging from 255 to 488 % with respect to the control mix value. This was attributed to the dense and compact structure of the concrete samples that decreased the water absorption [13]. Similar results were obtained from Zareei et al. [16]Chindaprasirt et al. [17] and Le et al. [18], which ascribed the high absorption rate due to the increased amount of voids in the samples thus producing a more porous specimen.

4.5 Water Penetration Test

The water penetration of the concrete mix was presented in Fig. 15. The chart showed the increasing pattern of the SCBA concrete samples. Moreover, as per the results recorded, the trend was similar to that of water absorption (decrease in water penetration with time). At 28 days, the graph showed increasing water penetration as compared to control mix values. This was attributed to the high porosity nature of the SCBA and voids availability to be filled with water. Nonetheless, this trend was observed to drop with ageing period. The abate was between 23.8–112.7 % for 28 days of curing for 5 %, 10 %, 15 % and 20 % of SCBA replacement level. This increase in water penetration could be well explained by the high porosity nature of SCBA material, which fill-up all Fig.14. Water Absorption of OPC-SCBA concrete. Fig.13. Relationship between Flexural and Compressive strength of OPC-SCBA concrete at 28 days.

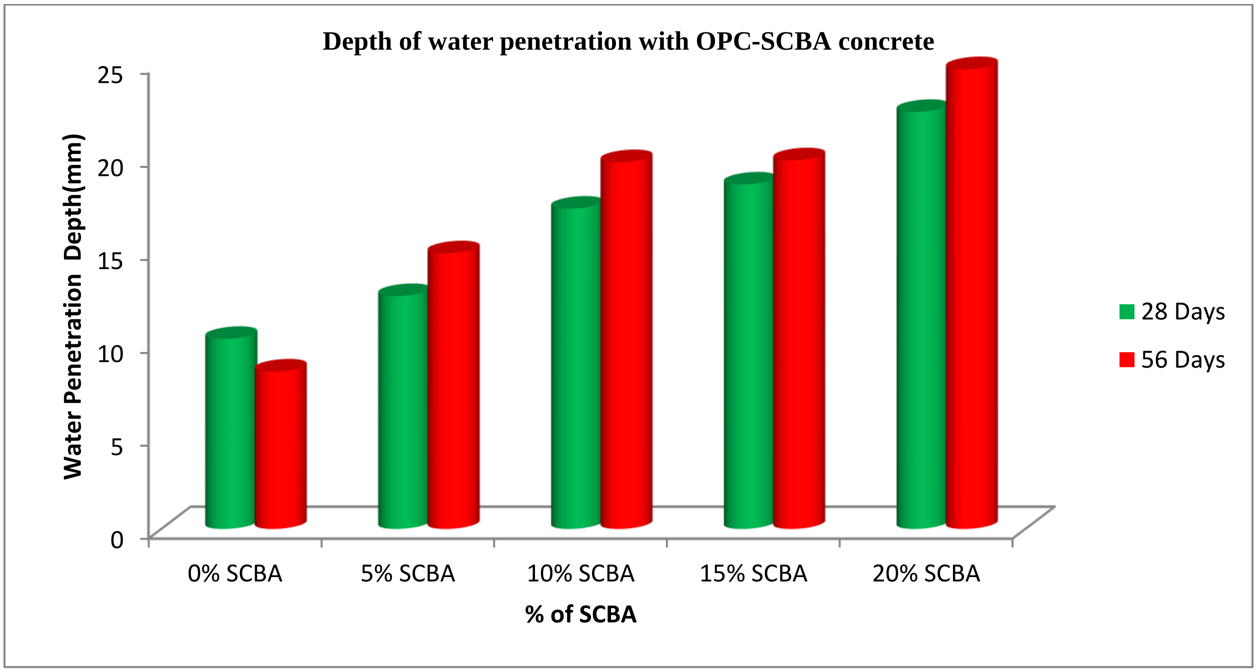

Fig. 15. Depth of water penetration with OPC-SCBA concrete.

Fig. 16.Measurement of water penetration in concrete sample.

the pores with water. Furthermore, at 56 days a diminution of 33.3–133.3 % was noted compared to the control mix. The difference between 28 days and 56 days was not much significant and showed that with time, the concrete was much denser and compact, therefore limiting the penetration of water [24]. The trend was comparable to that for water absorption properties and was mainly due to voids in the samples. Fig. 12 shows the measurement of penetration depth in the concrete sample.

4.6 Carbonation Test

The evolution over time for carbonation depth for each concrete mixture is shown in Fig. 17. The carbonation process in the OPC-SCBA blended samples showed an enhancing trend compared to the control concrete specimens. The results demonstrated that the carbonation of the concrete samples increased with the curing period. At 90 days of curing, the carbonation depth tendency from the upper surface layer was increased by increasing SCBA content. However, it was noted that at 5% of SCBA replacement, the value was the same as compared to the control concrete, whereas for 10% and 15%, the percentage was 100% and that of 20% SCBA replacement, the increase was 300%. The high porosity of SCBA and slow pozzolanic reaction allowed the penetration of moisture easily into the samples with increasing SCBA content. The reaction of hydrated cement component with humidity content took place and the surface layer was carbonated. Fig. 18 depicts the measurement of the carbonation depth in the concrete sample. With increasing age from 90 days to 180 days, the carbonation depth was almost thrice in depth values. The trend also showed the same increasing pattern as that for 90 days which meant that the carbonation depth increased with increasing SCBA content. At 5% SCBA substitution, the value remained the same as that of the control concrete. However, at 10% and 15% of SCBA replacement, the depths have increased by 50%.

Fig. 17.Measurement of Carbonation Depth in the concrete sample.

It was also observed that the carbonation depth was greater than that for 90 days. The addition of SCBA in the mix resulted in decreased capillary pores due to C-S-H formation, which decreased both the permeability and carbonation rate [22].

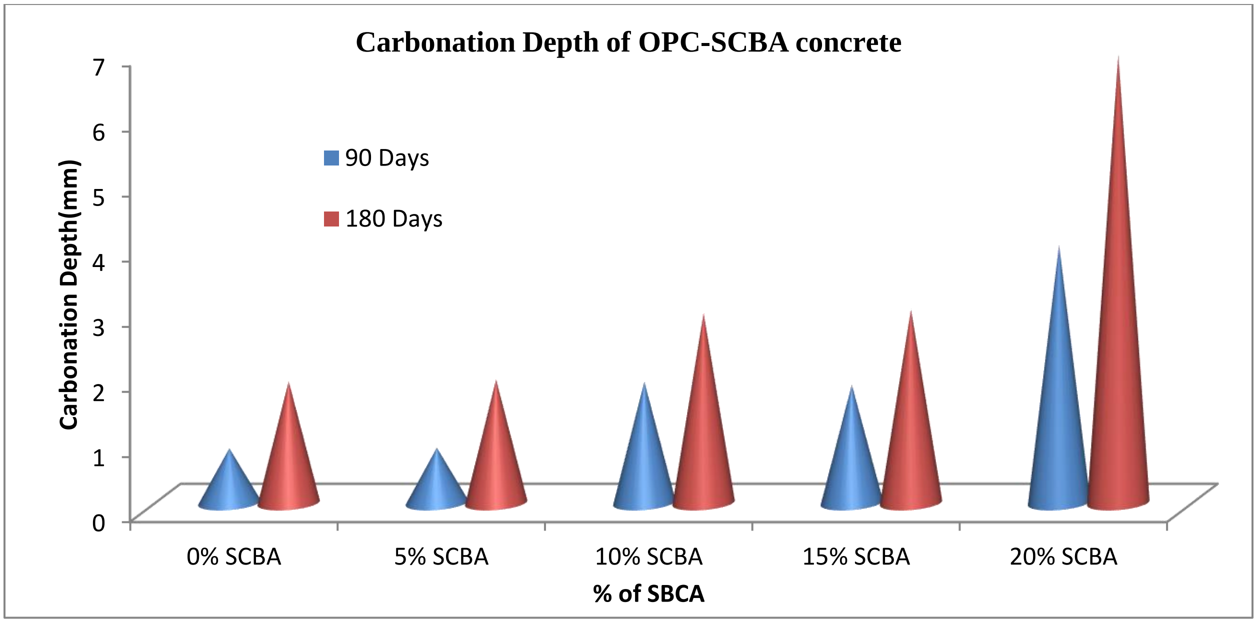

Fig. 18. Carbonation Depth of OPC-SCBA concrete.

5. Conclusion

Based on the experimental results and their plots and subsequent discussion on the results the following conclusions are drawn: Workability of concrete increases by increasing the percentage of replacement of SCBA in concrete. The compressive strength of concrete increased at 5% replacement of cement with SCBA. Further increase in percentage of SCBA results in decrease in compressive strength. The tensile strength of concrete decreasing with addition of SCBA. The presence of pores enhanced the absorbent properties of the concrete, thus increasing the water absorption values. The increase was between 389–476% for 28 days and 255–488% for 56 days. However, with increasing curing period, a decrease in the absorption paradigm was noted. It was inferred that with increasing time period, the concrete matrix was denser and more compact, thus slowing the absorption rate. The water penetration increased with increasing SCBA content. The water penetration at 28 days for 5% and 20% were measured at 13.0mm and 22.3mm respectively, which were high compared to control concrete (10.3mm). This increase in water penetration was suggested to be due to the high-water absorption nature of SCBA at an early age. However, these values decreased with increasing curing time and was due to the concrete matrix compactness. The carbonation test exhibited an increasing carbonation rate with increasing SCBA content. At 90 days and 180 of curing, the carbonation depth for 5% (1mm) was similar to the control concrete value but gradually increased to 7 mm for 20% replacement level. The high porosity and the weak intergranular bonding of SCBA particles ease moisture permeation into the concrete specimens.

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