STUDY OF THE MECHANICAL AND DURABILITY PROPERTIES OF CONCRETE BY PARTIAL REPLACEMENT OF CEMENT BY SUGARCANE BAGGASE ASH

A PROJECT

Submitted in partial fulfillment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

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Under the supervision of

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CERTIFICATE

This is to certify that the work which is being presented in the project title **"**Study of the Mechanical and Durability Properties of Concrete by Partial Replacement of Cement by Sugarcane Bagasse Ash**"** in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology and submitted in Civil Engineering Department, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by "Vaibhav Gupta (121631) and Aayush Mittal (121685)" during a period from July 2015 to June 2016 under the supervision of "Mr. Abhilash Shukla" Assistant Professor, Civil Engineering Department, Jaypee University of Information Technology, Waknaghat.

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Abbreviations & Symbols	Description
SCBA	Sugar Cane Bagasse Ash
BA	Bagasse Ash
CA	Coarse Aggregate
FA	Fine Aggregate
HCl	Hydrochloric Acid
OPC	Ordinary Portland Cement
$CaCl_2$	Calcium Chloride
PAI	Pozzolanic Activity Index
PC	Portland Cement
XRF	X-ray Fluorescence
XRD	X-ray diffraction

ABSTRACT

Sugarcane is one of the major crops grown in over 110 countries and its total production is over 1500 million tons. In India sugarcane production is over 300 million tons per year that cause about 10 million tons of sugarcane bagasse ash as an un-utilized and waste material. After the extraction of all economical sugar from sugarcane, about 40-45% fibrous residue is obtained, which is reused in the same industry as fuel in boilers for power generation leaving behind 8-10 % ash as waste, known as sugarcane Bagasse ash (SCBA).

The natural, bio-degradable features and chemical constituents of the sugarcane Bagasse (SCB) have been attracting attention as a highly potential and versatile ingredient in composite materials. Eco-friendly and low cost considerations have set the momentum for material science researchers to identify green materials that give low pollutant indexes.

The study of cement replacement by sugarcane Bagasse ash (SCBA) in industrial scale aiming to reduce the CO_2 emissions into the atmosphere.

The utilization of waste materials in concrete manufacture provides a satisfactory solution to some of the environmental concerns and problems associated with waste management. Agro wastes such as rice husk ash, wheat straw ash, hazel nutshell and sugarcane bagasse ash are used as pozzolanic materials for the development of blended cements.

Under this project PPC is partially replaced with finely ground Bagasse ash to make concrete. Cement is replaced with 0%, 5%, 10%, 15% and 20% of SCBA respectively and mechanical properties of concrete like Compressive Strength, Split Tensile Strength and flexural strength are determined at the age of 7 days, 14 days and 28 days. Also durability studies of concrete are performed with exposure to acid attack and sulphate attack

CHAPTER 1
INTRODUCTION

1.1General

Cement is the third most energy intensive material after steel and aluminium which is produced in large quantities. Cement industry consumes raw materials rich in silica, alumina, iron and calcium. Therefore this industry has been actively involved in finding ways to use waste products in the manufacturing of cement both as secondary fuel and raw material. Sugar manufacturing is the major agro industry in India. Initiatives are emerging worldwide to control and regulate the management of sub-products, residuals, and industrial waste in order to preserve the environment from the point of view of environmental contamination as well as the preservation and care of natural areas. Industrial wastes, such as blast furnace slag, fly ash and silica fume are being used as supplementary cement replacement materials. Currently, there has been an attempt to utilize the large amount of Bagasse ash, the residue from an in-line sugar industry and the Bagasse-biomass fuel in electric generation industry. When this waste is burnt under controlled conditions, it also gives ash having amorphous silica, which has pozzolanic properties. Therefore it is possible to use sugarcane bagasse ash (SCBA) as cement replacement material to improve quality and reduce the cost of construction materials such as mortar, concrete pavers and concrete roof tiles.

1.2 Purpose

Sugarcane is one of the major crops grown in over 110 countries and its total production is over 1500 million tons. In India only, sugarcane production is over 300 million tons/year that cause about 10 million tons of sugarcane bagasse ash as an un-utilized and waste material. After the extraction of all economical sugar from sugarcane, about 40-45% fibrous residue is obtained, which is reused in the same industry as fuel in boilers for power generation leaving behind 8 -10 % ash as waste, known as sugarcane bagasse ash (SCBA). The SCBA contains high amounts of un-burnt matter, silicon, aluminium and calcium oxides. SCBA can be utilized to replace cement in making concrete in order to reduce the cost of making concrete as well as making less contribution to carbon emissions from cement industry.

The use of blending materials in concrete reduces the heat of hydration and increases the life of structure.

1.3 How will Bagasse ash prove useful to construction industry?

As the advancements in the field of structural engineering are taking place more and more building are being constructed and higher is the demand for aggressive environment resisting concrete will emerge. Also the requirement for the cement in future will exploit the natural resources and the environment as construction industry has the maximum impact on the environment from the production of cement to production of concrete etc.

In order to counter the impact on the environment blended Portland cement concrete can be a viable solution as according to the present study Sugarcane Bagasse which is a sugar industry waste which requires large areas for the disposal can be used to replace cement in concrete making which enhances the compressive strength properties as well as split tensile properties of SCBA replaced concrete.

1.4 Materials used

1.4.1 Cement

Portland Pozzolona cement (PPC), 53 grade cement from Ambuja.

PPC was used for casting all the Specimens. Different types of cement have different water requirements to produce pastes of standard consistence. Different types of cement also will produce concrete have a different rates of strength development. The choice of brand and type of cement is the most important to produce a good quality of concrete. The type of cement affects the rate of hydration, so that the strengths at early ages can be considerably influenced by the particular cement used. It is also important to ensure compatibility of the chemical and mineral admixtures with cement.

1.4.2 Fine Aggregate

Locally available river sand conforming to Grading zone II of IS: 383 –1970. Clean and dry river sand available locally will be used. Sand passing through IS 4.75mm Sieve will be used for casting all the specimens.

1.4.3 Coarse Aggregate

- We collected the aggregates from the civil department of the college campus.
- As per the assumptions taken in mix design, we have collected 20mm maximum size aggregates by the help of sieve analysis.

Table 1.1 Sieve Analysis of Aggregate

Sieve size	% Retained on each sieve		Cumulative % Retained		Cumulative % passing	
	20 mm CA (50%)	10 mm CA (50%)	20 mm CA	10 mm CA	20 mm CA	10 mm CA
20 mm	0	0	0	0	100	100
10 mm	22.24	22.24	22.24	22.24	77.76	77.76
4.75 mm	61.88	61.88	84.12	84.12	15.88	15.88

1.4.4 Bagasse Ash

Sugarcane is one of the major crops grown in over 110 countries and its total production is over 1500 million tons. In India production is over 300 million tons/year that cause around 10 million tons of bagasse ash as an un-utilized and waste material. After the extraction of all economical sugar from, about 40-45 percent fibrous residue is obtained, which is reused in the same industry as fuel in boilers for heat or power generation leaving behind 8 -10 percent ash as waste, known as bagasse ash (SCBA).

1.4.5 Advantages of Using Bagasse Ash

Primarily the ash disposal problem from sugar industry is reduced since it is usually disposed off in open land area. The recent average results of the chemical analyses of the sugarcane bagasse ash from Novel sugar factory, Pilibhit revealed that sugarcane bagasse combustion products (ash) resemble pozzolana in chemical nature. Therefore, it should be considered as an important mineral resource in India. It might be successfully used as an engineering material for a wide variety of applications. The chemical investigations on the bagasse ash carried in this study indicated that it has had more or less the same chemical composition of other artificial pozzolanic material, like fly ash or any other conventional pozzolana.

1.4.6 Water

Casting and curing of specimens were done with the potable water that is available in the college premises.

1.5 Objectives of the study

- To study the chemical properties of sugarcane bagasse ash for checking the feasibility to use it as a potential mineral admixture in concrete.
- Compressive strength, split tensile strength and flexural strength properties of concrete are tested.
- Determine the optimum replacement content for the SCBA with cement in concrete mixture.
- Durability studies are done to determine the capability of SCBA in concrete to resist aggressive environment.

CHAPTER 2
LITERATURE REVIEW

2.1 Evaluation of SCBA as a replacement for cement in concrete works

T. S. Abdulkadir et. Al[1] studied the suitability of SCBA as a partial replacement for cement in concrete productions. Chemical test was conducted on SCBA to evaluate its percentage composition. It was then used to replace OPC by weight in ratio of 0%, 10%, 20% and 30%.The cubes were tested at 7, 14, 21 and 28days of curing ages for density and compressive strength. The results of chemical test showed that SCBA has pozzolanic properties having met ASTM- 595 (1985) with total sum of silica, alumina and ferric composition of 80.55%. The results showed a decrease in concrete density with increase in % replacement of SCBA. Pozzolanic activity index (PAI) of 83.2%, 75% and 64.5% were obtained. This showed that only 10% and 20% replacement of cement by weight of SCBA satisfied ASTM-595(1985) specification for PAI. It was concluded that SCBA is a low weight material and 10% replacement of SCBA has the highest PAI. Also, 10% and 20% replacement of SCBA with compressive strengths of 22.3N/mm^2 and 20.1N/mm^2 are recommended for reinforced concrete.

Conclusion

The compressive strength of the concrete cubes for all the mix ratios increases with curing age and decreases as the SCBA content increases. From the density result, the SCBA concrete can be classified as normal weight concrete. It was clearly shown that SCBA is a pozzolanic material that has the potential to be used as partial cement replacement material and can contribute to the environmental sustainability. SCBA is a pozzolana and can be recommended for use as partial replacement of cement in concrete production at a percentage up to 20%. For environmental sustainability, SCB can be utilized for the production of lightweight, durable and cheap concrete.

2.2 An experimental study on the compressive strength of concrete by partial replacement of cement with SCBA

Lavanya M.R et.al[2] studied the feasibility of using sugarcane Bagasse Ash (SBA), a finely ground waste product from the sugarcane industry, as partial replacement for cement in conventional concrete is examined. The tests were conducted as per Bureau of Indian Standards (BIS) codes to evaluate the suitability of SBA for partial replacements up to 30% of cement with varying water cement (w/c) ratio. The physical properties of SBA were studied. Compressive strengths (7, 14 and 28 days) were determined. The results showed that the addition of sugarcane bagasse ash improves the strengths in all cases. The maximum strength increase happens at 15% with 0.35 w/c ratio.

Conclusion

Bagasse ash can increase the overall strength of the concrete when used up to a 15% cement replacement level with w/c ratio of 0.35.Bagasse ash is a valuable pozzolanic material and it can potentially be used as a partial replacement for cement. This could reduce the environmental problems and minimize the requirement of land fill area to dispose SBA.

2.3 Experimental study on BA in concrete

R. Srinivasan and K. Sathiya[3] studied about “Experimental Study on Sugarcane Bagasse Ash in Concrete” which was published in 2010 in journal “International Journal for Service Learning in Engineering”.

In this paper, Bagasse ash has been chemically and physically characterized, and partially replaced in the ratio of 0%, 5%, 15% and 25% by weight of cement in concrete. Fresh concrete tests like compaction factor test and slump cone test were undertaken was well as hardened concrete tests like compressive strength, split tensile strength, flexural strength and modulus of elasticity at the age of seven and 28 days was obtained. The result shows that the strength of concrete increased as percentage of bagasse ash replacement increased. The results show that the SCBA in blended concrete had significantly higher compressive strength, tensile strength, and flexural strength compare to that of the concrete without SCBA.

Conclusion

It is found that the cement could be advantageously replaced with SCBA up to maximum limit of 10%. Although, the optimal level of SCBA content was achieved with 1.0% replacement. Partial replacement of cement by SCBA increases workability of fresh concrete; therefore use of super plasticizer is not substantial. The density of concrete decreases with increase in SCBA content, low weight concrete produced in the society with waste materials (SCBA).

2.4 Partial replacement of cement in concrete with SCBA and its behavior in HCl Solution

K Meeravali et.al[4] studied that blended cement concrete is one of the best solutions to this durability criterion. The adoption of blended cements has shown a sharp increment in results of compressive strength in standard conditions and in aggressive conditions. Sugarcane bagasse ash (SCBA) is chosen for this study which has been confirmed as a blending material possessing pozzolanic properties which even reduces the cost of construction and environmental pollution caused due to cement manufacture and disposal of SCBA. In this paper cement is replaced by sugarcane bagasse up to 25% in regular intervals of 5%. To analyze the behavior of SCBA concrete in HCl the casted specimens are cured in 5% HCl solution for 7, 28 and 60 days. The water binder ratio adopted is 0.4. The use of blending materials in concrete reduces the heat of hydration and increases the life of structure. When calcium hydroxide reacts with hydrochloric acid gives out ettringite (and $CaCl_2$) possessing a crystal type of structure which makes the concrete porous and allows the external chloride ions to penetrate into concrete leading in the loss of weight and strength of concrete. In this paper an attempt is made to prove that SCBA helps to restrict this attack of HCl on concrete.

Conclusion

The following conclusions can be drawn that indicates the behavior of Sugarcane bagasse ash replaced concrete:

1. 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.

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

3. Compressive strength is decreased for concrete cured in 5% HCL solution when compared to the concrete cured in normal water.

4. Compressive strength is increased for 7, 28 and 60 days when cured in normal water, but compressive strength is reduced very slight acid attack after immersion of 28 & 60 days in acid solutions.

5. Compressive strength is reduced if the curing duration is increased more than 60 days in 5% HCL solution.

6. Concrete is affected when concrete is exposed to HCL solution for longer duration.

7. Utilization of the waste material Sugar Cane Bagasse ash can advantageously be used as a replacement of cement in the preparation of concrete when it is exposed to 5% HCL solution only.

2.5 Cement replacement by SCBA: CO_2 emissions reduction and potential for carbon credits

Eduardo M.R. Fairbairn et.al[5] in this paper presents a study of cement replacement by sugarcane bagasse ash (SCBA) in industrial scale aiming to reduce the CO_2 emissions into the atmosphere. SCBA is a by-product of the sugar/ethanol agro-industry abundantly available in some regions of the world and has cementitious properties indicating that it can be used together with cement. Since one of the key variables to estimate the CO_2 emissions is the average distance between sugarcane/ethanol factories and the cement plants, a genetic algorithm was developed to solve this optimization problem. The results indicated that SCBA blended cement reduces CO_2 emissions.

Conclusion

It can be summarized Sugar cane bagasse ash (SCBA) is a pozzolan that can partially replace clinker in cement production and reduces emissions of CO_2 into the atmosphere. SCBA is an agro-industrial residue available in several countries, and it was proved by previous comprehensive studies that its use generally improves the behavior of the cementitious construction materials. The increasing of blend in cement production using SCBA, for the simulation carried out in this study, fulfill the conditions to be candidate for CDM (Clean Development Mechanism) projects, respecting the constraints of the UNFCCC (United Nations Framework Convention on Climate Change) approved and consolidated methodologies. Hence there is potential for the issuance of Certified Emission Reduction credits.

2.6 Compressive strength and microstructure of SCBA concrete

Asma Abdul Elhameed Hussein, Nasir Shafiq, Muhd. Fadhil Nuruddin and Fareed Ahmed Memon (2013)[6] studied 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.

2.7 Utilization of BA as a partial replacement of Fine aggregates in concrete

Prashant O Modani and M R Vyawahare (2013)[7] in this paper used untreated bagasse ash has been partially replaced in the ratio of 0%, 10%, 20%, 30% and 40% by volume of fine aggregate in concrete. Fresh concrete tests like compaction factor test and slump cone test were undertaken along with hardened concrete tests like compressive strength, split tensile strength and sorptivity. The result shows that bagasse ash can be a suitable replacement to fine aggregate.

Conclusion

On the basis of experimental investigation carried out, the following conclusions can be drawn.

i) The fraction of fine aggregates i.e. 10% to 20% can be effectively replaced with a bagasse ash (untreated) without a considerable loss of workability and strength properties.

ii) The compressive strength results represent that, the strength of the mixes with 10% and 20% bagasse ash increases at later days (28 days) as compared to7 days that may be due to pozzolanic properties of bagasse ash.

iii) The Sorptivity test result shows that the sorptivity coefficient increases with increase in percentage of bagasse ash which indicate more permeable concrete that is due to porous nature of SCBA and the impurities in it.

iv) In its purest form the bagasse ash can prove to be a potential ingredient of concrete since it can be an effective replacement to cement and fine aggregate.

2.8 Experimental study on BA in concrete

T.Subramani and M.Prabhakaran (2015)[8] investigated in this study by using M35 grade concrete with partial replacement of coarse aggregate by furnace slag by 50% to 60% and by 70%.This paper presents the result of an experimental investigation caring out to find the sustainability of furnace slag in concrete and compressive strength, split tensile strength, flexural strength is attained at the age of 7days and 28 days. Durability study on acid attack was also studied and percentage of weight loss is compared with normal concrete. Test result indicates that use of furnace slag in concrete has improved the performance of concrete in strength as well as durability aspect. The cost optimization is found out by comparing one m^3 of conventional concrete and slag concrete resulting high strength of slag with coarse aggregate replacement.

Conclusion

Bagasse ash belongs to zone IV as per IS code. Water requirement increased as the percentage of BA increased. Unit weight of the mixture produced decreased as the percentage of BA increased. The compressive strength results represent that the strength of the mixes with 10% and 20% and 30%bagasse ash increased at later days (28 days) as compared to 7 days that may be due to pozzolanic properties of bagasse ash. The greatest compressive strength split tensile strength and flexural strength was achieved when the mixture contained 10% of fine aggregate replacement of BA with the water cement ratio of 0.43. Hence we concluded that the fine aggregate up to 20% can be effectively replaced with sugarcane bagasse ash without considerable loss of workability and strength.

2.9 Utilization of BA in high-strength concrete

Sumrerng Rukzon and Prinya Chindaprasirt (2012)[9] presented the use of bagasse ash (BA) as a pozzolanic material for producing high-strength concrete.

Portland cement type I (PC) is partially replaced with finely ground bagasse ash. The concrete mixtures, in part, are replaced with 10%, 20% and 30% of BA respectively. In addition, the compressive strength, the porosity, the coefficient of water absorption, the rapid chloride penetration and the chloride diffusion of concretes are determined. The test results indicate that the incorporation of BA up to 30% replacement level increases the resistance to chloride penetration. Besides, the use of 10% of BA produced concretes with good strength and low porosity. Reasonably, the substitution of 30% BA is acceptable for producing high-strength concrete.

Conclusion

The results indicate that the concretes containing up to 30% of BA exhibit the compressive strength in the range of 65.6–68.6 MPa (at 28 days), which is higher than that of the control concrete (101–105%). In conclusion, the incorporation of BA significantly improves the resistance to chloride penetration of concrete by increasing pozzolanic reaction, by enhancing the precipitation sites of hydration products and by reducing $Ca(OH)_2$ of concrete.

2.10 Evaluation of BA as supplementary cementitious material

K. Ganesan, K. Rajagopal and K. Thangavel (2007)[11] studied the effects of BA content as partial replacement of cement on physical and mechanical properties of hardened concrete are reported. The properties of concrete investigated include compressive strength, splitting tensile strength, water absorption, permeability characteristics, chloride diffusion and resistance to chloride ion penetration. The test results indicate that BA is an effective mineral admixture, with 20% as optimal replacement ratio of cement.

Conclusion

From the present investigation, the following conclusion can be drawn. Up to 20% of ordinary Portland cement can be optimally replaced with well-burnt bagasse ash without any adverse effect on the desirable properties of concrete.

The specific advantages of such replacement are:

(i) Development of high early strength.

(ii) A reduction in water permeability and

(iii) Appreciable resistance to chloride permeation and diffusion.

2.11 Durability Studies on Concrete and Comparison with Partial Replacement of Cement with Rice Husk Ash and Sugarcane Bagasse Ash in Concrete

B.SomeswaraRao , N.Vidya Sagar Lal and G.Naveen(2015)[10] describes the feasibility of using the Rice Husk Ash (RHA) and Sugarcane Bagasse Ash (SCBA) waste in concrete production as a partial replacement of cement. This present work deals with the effect on strength and mechanical properties of concrete using RHA and SCBA instead of cement. The cement has been replaced by rice husk ash, accordingly in the range of 0%, 5%, 10%, 15%, and 20% by weight. Concrete mixtures with RHA, were produced, tested and compared in terms of compressive strengths with the Conventional concrete. These tests were carried out to evaluate the mechanical properties for the test results of 7, 28, 60, 90 days for compressive strengths in normal water and in $MgSO_4$ solution of 1%, 3% and 5%. Also the durability aspect for rice husk ash concrete for sulphate attack was tested. Similarly the above tests were also performed for SCBA. The result indicates that the RHA and SCBA improve concrete durability. Finally the test results for RHA and SCBA were compared. Key words: Rice Husk Ash, Sugarcane Bagasse Ash, Concrete, M35 grade concrete, cubes, cylinders, $MgSO_4$, durability.

Conclusion

When the compressive strengths of concrete with 0%, 5%, 10%, 15% and 20% weight replacement of cement with RHA and SCBA cured in Normal Water and in 1%, 3%, 5% $MgSO_4$ solution for 28 days.

(i)The target mean strength has been increased for the partial replacement of up to 10% by weight.Whereas the compressive strengths at 15 and 20 % replacement of RHA and SCBA are lower.

(ii)Due to slow Pozzolonic action the rice husk ash (RHA) concrete achieves significant improvement in its mechanical properties at later stages of curing but still it reduces for 15 and 20 % replacement.

(iii)Due to slow pozzolanic reaction the Sugar Cane Bagasse Ash (SCBA) concrete achieves significant improvement in its mechanical properties at later ages.

(iv)In concretes can be replaced with 20% SCBA without sacrificing strength at later ages.

(v)Both RHA and SCBA concrete is resistant against sulphate attack up to 3%, but further increase up to 5% of $MgSO_4$ the decrease in compressive strengths can be observed.

(vi)The workability of RHA concretes have decreased in compared with ordinary concrete. It is inferred that reduction in workability is due to large surface area of RHA and SCBA.

CHAPTER 3
PLANNING OF LABORATORY WORK

3.1 Flow of Work

1 • Obtained SCBA from sugar factory in Pilibhit,Uttar Pradesh.

2 • Incinerated the SCBA at high temperature approx 250 degree celsius to reduce carbon content.

3 • Characterstics of SCBA for using it as a admixture is determined using XRD studies.

4 • SCBA contains enough silica content to be used as pozzolanic material.

5 • Grade for the concrete is fixed M25 and replacement content of SCBA at intervals of 5% is decided.

6 • Mix design is performed for required grade using IS 10262-2009.

7 • Cement,sand and aggregate are mixed in proportions found out by mix design for making concrete.

8 • Cubes, cylinders and beams are casted for testing mechanical properties of concrete.

9 • After curing in water for 7, 14 and 28 days specimes are tested for respective mechanical properties.

10 • Optimum replacement content for the SCBA is found out by plotting the graph between comprerssive strength and % replacement of SCBA.

11 • In second phase M25 concrete is tested for durability in acidic and sulphate exposure to cube specimens.

12 • Change in weight of the specimens is noted after specified time.

13 • Conclusions are derived on the basis of the results obtained after durability study.

14 • Summary is reported for the present project and explanations are given for the trends.

3.2 Incineration of procured Bagasse Ash in Open Field

Bagasse is the matted cellulose fiber residue from sugar cane that has been processed in a sugar mill. Previously, bagasse was burned as a means of solid waste disposal. However, as the cost of fuel oil, natural gas, and electricity has increased, bagasse has come to be regarded as a fuel rather than refuse. Bagasse is a fuel of varying composition, consistency, and heating value. These characteristics depend on the climate, type of soil upon which the cane is grown, variety of cane, harvesting method, amount of cane washing, and the efficiency of the milling plant.

After this it is converted into high carbon and very low density ash when it was further burnt by the project team under field conditions in open air.

Approximate time taken for incineration: 1 hour

Approximate temperature reached during incineration: 250 degree Celsius

Procedure Adopted

1. A tray full of mill burnt ash was taken.
2. Aviation fuel was used to burn it continuously an hour.
3. A grayish-black residual ash was obtained after burning.

In order to determine the benefit of replacing cement using sugarcane Bagasse ash following tests need to be done.

Figure 3.1 Open Field Incineration of Sugarcane Bagasse Ash procured from sugar mill

Figure 3.2 Sugarcane Ash burning in open producing flames

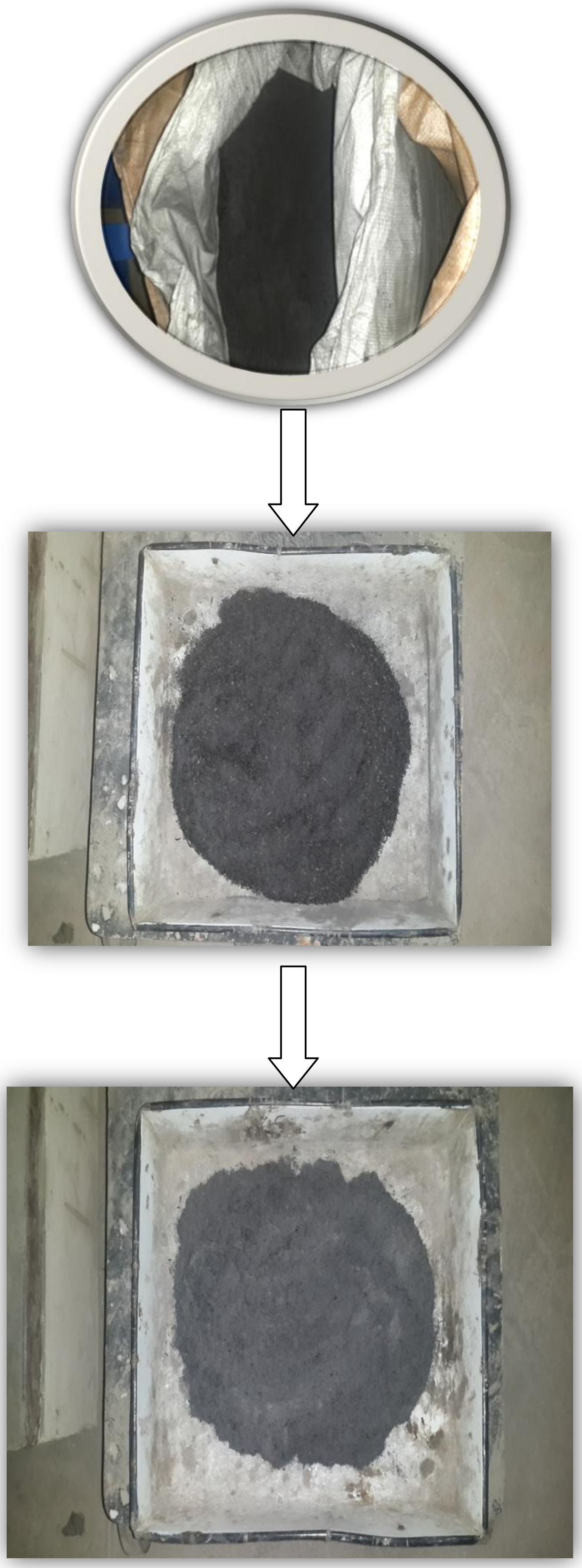

Figure 3.3 Sugarcane Bagasse Ash Before and after Incineration

3.3 Testing of the mechanical properties

The aim of our project is to use the SCBA as a replacement of cement and study its mechanical properties.

Our objective is to add the SCBA as replacement of cement to the concrete and to study the properties of hardened concrete with the variation in SCBA content. SCBA content is varied at intervals of 5% up to 15% only. Strength parameters are tested at 7, 14 and 28 days respectively.

The strength properties being studied in our project are as follows:

1. Compressive Strength

2. Split tensile Strength

3. Flexural strength

These properties are then compared to the control concrete (without replacement with SCBA).

Table 3.1 List of Tests Performed

	Name of Experiment
1	Specific Gravity of SCBA using Le- chatelier Flask
2	Workability using compaction factor apparatus
3	Compression Strength test
4	Splitting-tensile test
5	Flexural Strength test using centre-point loading

3.3.1 To determine the specific gravity of SCBA

Material Required

Le-Chatelier Flask	250 ml, the neck graduated 0-1 ml and 15-24 ml
Kerosene	Kerosene
Funnel	Glass, narrow mouth
Wash Bottle	Plastic, 250 ml capacity
Pipette	Glass, 5 ml capacity
Thermometer	Glass, 0-50^{O}C
Spatula	150 mm blade length

Theoretical Background

Specific gravity of solid particles is defined as the ratio of the mass of a given volume of solids to the mass of an equal volume of water. The specific gravity depends upon the mixing the quantity by which it is made.

The difference between the first and final readings represents the volume of liquid displaced by the mass of cement used in test.

The density is calculated as per the below mentioned formula to the second place of decimal.

$$Density = \frac{mass\ of\ cement, g}{Displaced\ volume, cm^3}$$

Procedure

1. Fill up the flask with kerosene up to the mark below the bulb.
2. Take 64 gram of cement.
3. Pours the cement gradually into the flask through the funnel.
4. As the kerosene rise the lowest point of graduation, cement is cautiously poured.
5. As the first gradation if achieved, stop the cement to be poured.
6. Volume of the cement is noted down.

7. Weight of the cement used is calculated.

Figure 3.4 Le-Chatelier's Flask For determining Specific Gravity

3.3.2 Compaction factor test

Material Required

Compacting factor apparatus as per IS: 1199-1959, two trowels, hand scoop, tamping rod, platform weighing machine, graduated cylinder of 1000 ml capacity.

Theoretical background

Concrete is said to be workable if it can be easily mixed and easily placed, compacted and finished, Etc., the ease with which concrete mix flows to the remote corner of the form work.

It is based upon the definition that workability is the amount of work necessary to achieve full compaction of concrete. Compacting factor test work's on a principal of determining the degree of compaction achieved by a standard amount of work by allowing the concrete to fall through a standard height.

Table 3.2 Consistency measurements by various methods (as per ACI committee 211)

Workability description	Workability measurement		Vee-Bee time (seconds)
	Slump (mm)	Compacting factor	
Extremely dry	-	-	32-18
Very stiff	-	0.70	18-10
Stiff	0-25	0.75	10-5
Stiff plastic	25-50	0.85	5-3
Plastic	75-100	0.90	3-0
Flowing	150-175	0.95	-

Procedure

1. Weigh the empty cylinder accurately and note down the mass say W1 kg.
2. Prepare the sample of concrete with given proportion and W/C ratio.
3. Fill the sample of concrete in upper hopper gently and carefully with hand scoop without compacting.
4. Open the trap door so that the concrete falls into the lower hopper.
5. Immediately after the concrete has come to rest, open the trap door of the lower hopper and allow concrete to fall into the cylinder.
6. Remove the excess concrete remaining above the level of the top of the cylinder.
7. Find the weight of partially compacted concrete thus filled in the cylinder say W2 kg.
8. Refill the cylinder with the same sample of concrete and layers approximately 5 cm, vibrating each layer heavily so as to expel all the air and to obtain full compaction.
9. Clean the outside of cylinder and weigh it again say W kg.
10. Calculate the compaction factor using the formula.

3.3.3 Test to determine the compressive strength of normal mix concrete of a given grade

Material Required

1. Compressive testing machine
2. Moulds
3. Tampering rod
4. Equipment to mix

Theoretical background

The compressive strength of concrete is the most useful and important properties of concrete. In most of the structural applications concrete is employed primarily to resist compressive stresses. Cubes or cylinders are casted and tested for the determinations of the compressive strength of harden concrete.

Procedure

1. Calculate the quantities of cement, coarse aggregate, fine aggregate, and water required for making 6 cubes of desired grade of concrete.
2. Place the concrete mix in cube and vibrate it. After vibration, level the top surface of cube by removing excess concrete.
3. Put the cube $27 \pm 2^{o}C$ for 24 hrs.
4. Remove the concrete cubes from the mould and put them in water for curing.
5. Put them in compression testing machine after 7 days and 28 days of curing.
6. Compare the theoretical and observed values.

Figure 3.5 Compression Testing Machine (CTM)

3.3.4 To determine the split tensile strength of concrete of given mix proportions

Material Required

1. Compression testing machine, of sufficient capacity and with an arrangement for applying the load at the specified rate. The bearing faces of both plates shall provide a minimum loading area of 12 mm x the length of the cylinder so that the load is applied over the entire length of the specimen; two packing strips of plywood conforming to IS: 303-1970 for each specimen. The strip shall be 12 mm wide and 3 mm thick and used once only.
2. Cylinder moulds of 100 mm diameter and 200 mm height
3. Weighing machine
4. Mixer
5. Tamping rods.

Theoretical Background

The magnitude of tensile stress developed due to the application of compressive load is given by

$$S = \frac{2P}{\pi d l}$$

Where P =applied load

d = diameter of cylindrical specimen

l = Length of cylindrical specimen

Diameter should be larger than four times the maximum size of course aggregate or 150 mm whichever is greater. The length of the specimen should not be less than the diameter and should not be more than twice the diameter.

Procedure

1. Take the concrete mix used for workability tests.
2. Fill the cylinder mould with four layers, each of approximately 75 mm and tamp each layer more than 35 times with evenly distributed strokes.
3. Remove the surplus concrete from the top of the moulds with the help of the trowels.
4. Cover the moulds with wet mats and put the identification marks after about 3 to 4 hours.

5. Remove the specimen from the moulds after 24 hours and immerse them in water for the final curing. The test is usually conducted at the ages of 7 and 28 days. The age shall be calculated from the time addition of water to the dry ingredients.

   Test at least 3 specimens for each age of test as follows:

   - Draw diametrical lines on two ends of the specimen so that they are in the same axial plane.
   - Determine the diameter of the specimen lying in the plane of pre-marked lies measured near the ends and the middle of the specimen. The length of the specimen also shall be taken to the nearest 0.2 mm by averaging the two lengths measured in the plane containing the pre-marked lines.
   - Center one of the plywood strips along the center of the lower plate place the specimen on the plywood strip and align it so that the lines marked on the end of the specimen are vertical and centered over the plywood strip. The second plywood strip is placed lengthwise on the cylinder centered on the lines marked on the lines marked on the ends of the cylinder. The assembly is positioned to ensure that the lines marked in the ends of the specimen are vertical and the projection of the plane passing through these two lines intersects the center of the plate.
   - Apply the load without shock and increase it continuously at a rate of produce a splitting tensile stress of approximately1.4 to 2.1 N/mm^2/min., until no greater load can be sustained. Record the maximum load applied to the specimen.
   - Note the appearance of concrete and any unusual feature in the type of failure.
   - Compute the splitting strength of the specimen to the nearest 0.05 N/mm^2.

3.3.5 Method of Test for Flexural Strength of Concrete (Using Simple Beam with Center-Point Loading)

Flexural strength is one measure of the tensile strength of concrete. It is a measure of an unreinforced concrete beam or slab to resist failure in bending. It is measured by loading 100x100mm concrete beams with a span length at least three times the depth. The flexural strength is expressed as Modulus of Rupture (MR) in psi (MPa) and is determined by standard test methods ASTM C 78 (third-point loading) or ASTM C 293 (center-point loading).

Flexural Strength of Concrete Flexural MR is about 10 to 20 percent of compressive strength depending on the type, size and volume of coarse aggregate used. However, the best correlation for specific materials is obtained by laboratory tests for given materials and mix design. The MR determined by third-point loading is lower than the MR determined by centre-point loading, sometimes by as much as 15%.

$$F = \frac{P \times L}{b \times d^2}$$

P= max load (N)

l= length of beam (mm)

b= width of beam (mm)

d= depth of beam (mm)

Figure 3.6 Casting the beam from mould (50x10x10 cm)

Figure 3.7 Universal Testing Machine

3.4 Mix Design of Concrete

Guidelines for proportioning concrete mixes as per the requirements using the concrete making materials including other supplementary materials identified for this purpose are as follows:

The following data arc required for mix

Proportioning of a particular grade of concrete:

Where

- Grade designation
- Type of cement
- Maximum nominal size of aggregate
- Minimum cement content
- Maximum water-cement ratio
- Workability
- Exposure conditions as per Table 4 and Table 5 of IS-456
- Maximum temperature of concrete at the time of placing
- Method of transporting and placing
- Early age strength requirements, if required
- Type of aggregate
- Maximum cement content
- Whether an admixture shall or shall not be used and the type of admixture and the condition of use.

Step I: Target Strength for Mix Proportioning

$$f'_{ck} = f_{ck} + 1.65 \times s$$

When adequate past records for a similar grade exist and justify to the designer a value of standard deviation different from that shown in Table I, it shall be permissible to use that value.

Where‘s’ is the assumed standard deviation taken from table 1 IS 10262:2009

Table 3.3 Assumed standard deviation

Table 1 Assumed Standard Deviation

(*Clauses* 3.2.1.2, A-3 *and* B-3)

Sl No. (1)	Grade of Concrete (2)	Assumed Standard Deviation N/mm² (3)
i)	M 10	3.5
ii)	M 15	
iii)	M 20	4.0
iv)	M 25	
v)	M 30	5.0
vi)	M 35	
vii)	M 40	
viii)	M 45	
ix)	M 50	
x)	M 55	

NOTE — The above values correspond to the site control having proper storage of cement; weigh batching of all materials; controlled addition of water; regular checking of all materials, aggregate grading and moisture content; and periodical checking of workability and strength. Where there is deviation from the above, values given in the above table shall be increased by 1 N/mm².

Step II: Water/cement ratio selection

Different cements, supplementary cementitious materials and aggregates of different maximum size, grading, surface texture, shape and other characteristics may produce concretes of different compressive strength for the same free water-cement ratio.

Otherwise, the water-cement ratio given in Table 5 of IS 456 for respective environment exposure conditions may be used as starting point.

The free water-cement ratio selected previously should be checked against the limiting water/cement ratio for the requirements of durability and the lower of the two values adopted.

Table 3.4 Minimum cement content, water/cement Ratio IS 456:2009

Table 5 Minimum Cement Content, Maximum Water-Cement Ratio and Minimum Grade of Concrete for Different Exposures with Normal Weight Aggregates of 20 mm Nominal Maximum Size

(*Clauses* 6.1.2, 8.2.4.1 *and* 9.1.2)

Sl No.	Exposure	Plain Concrete			Reinforced Concrete		
		Minimum Cement Content kg/m³	Maximum Free Water-Cement Ratio	Minimum Grade of Concrete	Minimum Cement Content kg/m³	Maximum Free Water-Cement Ratio	Minimum Grade of Concrete
1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Mild	220	0.60	–	300	0.55	M 20
iii)	Moderate	240	0.60	M 15	300	0.50	M 25
iii)	Severe	250	0.50	M 20	320	0.45	M 30
iv)	Very severe	260	0.45	M 20	340	0.45	M 35
v)	Extreme	280	0.40	M 25	360	0.40	M 40

NOTES

1 Cement content prescribed in this table is irrespective of the grades of cement and it is inclusive of additions mentioned in 5.2. The additions such as fly ash or ground granulated blast furnace slag may be taken into account in the concrete composition with respect to the cement content and water-cement ratio if the suitability is established and as long as the maximum amounts taken into account do not exceed the limit of pozzolona and slag specified in IS 1489 (Part 1) and IS 455 respectively.

2 Minimum grade for plain concrete under mild exposure condition is not specified.

Step III: Maximum water content requirement

The quantity of maximum mixing water per unit volume of concrete may be determined from Table 2(IS 10262:2009). The water content in Table 2 is for angular coarse aggregate and for 25 to 50 mm slump range.

Table 3.5 Maximum water content per Cubic metre of Concrete

Table 2 Maximum Water Content per Cubic Metre of Concrete for Nominal Maximum Size of Aggregate

(*Clauses* 4.2, A-5 *and* B-5)

Sl No.	Nominal Maximum Size of Aggregate mm	Maximum Water Content [1)] kg
(1)	(2)	(3)
i)	10	208
ii)	20	186
iii)	40	165

NOTE — These quantities of mixing water are for use in computing cementitious material contents for trial batches.

[1)] Water}content corresponding to saturated surface dry aggregate.

Step IV: Calculation of Cementitious Material Content

The cement and supplementary cementitious material 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 cementitious material content so calculated shall be checked against the minimum content for the requirements of durability and greater of the two values adopted. The maximum cement content shall be in accordance with IS 456.

Step V: Estimation of Coarse Aggregate Proportion

Aggregates of essentially the same nominal maximum size, type and grading will produce concrete of satisfactory workability when a given volume of

Coarse aggregate per unit volume of total aggregate is used. Approximate values for this aggregate volume are given in Table 3 for a water-cement ratio of 0.5,

which may be suitably adjusted for other water cement ratios.

Table 3.6 Volume of Coarse Aggregate per Unit Volume of Total Aggregate

Table 3 Volume of Coarse Aggregate per Unit Volume of Total Aggregate for Different Zones of Fine Aggregate

(*Clauses* 4.4, A-7 *and* B-7)

Sl No.	Nominal Maximum Size of Aggregate mm	Volume of Coarse Aggregate[1] per Unit Volume of Total Aggregate for Different Zones of Fine Aggregate			
		Zone IV	Zone III	Zone II	Zone I
(1)	(2)	(3)	(4)	(5)	(6)
i)	10	0.50	0.48	0.46	0.44
ii)	20	0.66	0.64	0.62	0.60
iii)	40	0.75	0.73	0.71	0.69

[1] Volumes are based on aggregates in saturated surface dry condition.

Step VI: Estimation of Fine aggregates proportion

Coarse and fine aggregate content are determined by finding out the absolute volume of cementitious material, water and the other chemical admixtures by dividing their mass by their respective specific gravity, multiplying by 1/1000 and subtracting the result of their summation from unit volume. The values so obtained are divided into coarse and fine aggregate fractions by volume in accordance with coarse aggregate proportion already determined before. The C.A and F.A content are then determined by multiplying with their respective specific gravities and multiply by 1000.

3.4.1 Ratio of Mix Design

Table 3.7 Ratio for M-25 Grade of Concrete

Cement	Coarse Aggregate	Fine Aggregate	Water
465 Kg	1133 Kg	694.5 Kg	186 Kg
1	2.44	1.5	0.4

3.5 Durability of Concrete

A durable concrete is one that performs satisfactorily in the working environment during its anticipated exposure conditions during service .The materials and mix proportions specified and used should be such as to maintain its integrity and ,if applicable , to protect embedded metal from corrosion. One of the main characteristics influencing the durability of concrete is its permeability to the ingress of water, oxygen, carbon-dioxide, chloride, sulphate and other potentially deleterious substances. Factors Influencing Durability

- The environment
- The cover to embedded steel
- The type and quality of constituent materials
- The cement content and w/c ratio of concrete
- Workmanship, to obtain full compaction and efficient curing
- The shape and size of the member

3.5.1 Sulphate Attack on Concrete

Most soils contain some sulphate in the form of calcium, sodium, potassium and magnesium. They occur in soil or ground water. Of all the sulphates magnesium sulphate causes maximum damage to concrete. A Characteristic whitish appearance is the indication of sulphate atack.Because of solubility of calcium sulphate is low; ground waters contain more of other sulphates and less of calcium sulphate. Ammonium sulphate is frequently present in agricultural soil and water from the use of fertilizers or from sewage and industrial effluents. The term sulphate attack denote an increase in the volume of cement paste in concrete or mortar due to the chemical action between the products of hydration of cement and solution containing sulphates.

Figure 3.8 Cubes put for durability study (Sulphate attack)

3.5.2 Acid Attack

Concrete is not fully resistant to acids. Most acid solutions will rapidly or slowly disintegrate Portland cement concrete depending upon the type and concentration of acid. Certain acids such as oxalic acid and phosphoric acids are harmless. The most vulnerable part of the cement hydrate is $Ca(OH)_2$ but C-S-H gel can also be attacked. Siliceous aggregates are more resistant than calcareous aggregates.Concrete can be attacked by liquids with pH value less than 6.5. But the attack is severe only at a pH value below 5.5. At a pH value below 4.5 the attack is very severe.

Figure 3.9 Cubes exposed to Hydrochloric Acid (5% Solution)

3.5.3 How to perform the durability test on concrete?

1. Cubes containing the mix of M25 Grade coded as C0, C5, C10, and C15 by replacing (0%, 5%, 10%, and 15%) of cement by SCBA were casted.
2. The cubes were demoulded after 1 day of casting and then kept for moist curing in hot water in the curing tank for the duration of 7, 14 and 28 days.
3. After curing in water cubes are put into respective solutions of 5% H_2SO_4 and 5% HCl for curing, at room temperature with a normal humidity.
4. The cubes are taken out from curing after 21 days.
5. The surface of specimen was cleaned and weights were measured.
6. The loss in mass and strength of specimen due to acid attack and sulphate attack will be determined after completion of 21 days time period.

Figure 3.10 Condition of cubes after 21 days exposure to 5% H_2SO_4 solution

Figure 3.11 Condition of cubes after 21 days exposure to 5% HCl solution

Figure 3.12 Student Vaibhav Gupta displaying Cubes exposed to Sulphate attack

Figure 3.13 Student Aayush Mittal displaying cubes exposed to Sulphate attack

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Properties of Sugarcane Bagasse Ash

The calculated specific gravity of SCBA by using Le-chatelier's apparatus is equal to 2.6.

Properties of Sugarcane Bagasse Ash obtained from Novel Sugar works, Pilibhit, Uttar Pradesh are as follows:

These chemical properties were tested at SOPHISTICATED ANALYTICAL INSTRUMENT LABORATORY, IIT BOMBAY.

Chemical properties of Bagasse Ash

According to **ASTM C618** Specification for coal fly ash and raw or calcined natural pozzolan use as mineral admixture in concrete, it specifies if the chemical composition of natural pozzolan has in total $\mathbf{SiO_2 + Al_2O_3 + Fe_2O_3}$ content more than 70% of composition. The material qualifies to be used as mineral admixture in Portland cement concrete as Class F pozzolan which has pozzolanic properties.

Table 4.1 Chemical properties of SCBA obtained by XRF

Oxide	**SCBA (%)**
CaO	**2.71**
$\mathbf{SiO_2}$	**53.35**
$\mathbf{Al_2O_3}$	**16.77**
$\mathbf{Fe_2O_3}$	**1.85**
K_2O	4.60
MnO	0.07
P_2O_5	2.37
SO_3	0.232
SrO	0.04
TiO_2	0.66
BaO	0.09
MgO	3.26
Na_2O	0.60
$\mathbf{Fe_2O_3+SiO_2+Al_2O_3}$	71.97

Particle size distribution

From the Particle size distribution curve obtained from the graph plotted between Percentage finer and particle diameter (microns) most of the particles lie between 10 microns to 100 microns for the sugarcane Bagasse sample used for the present study.

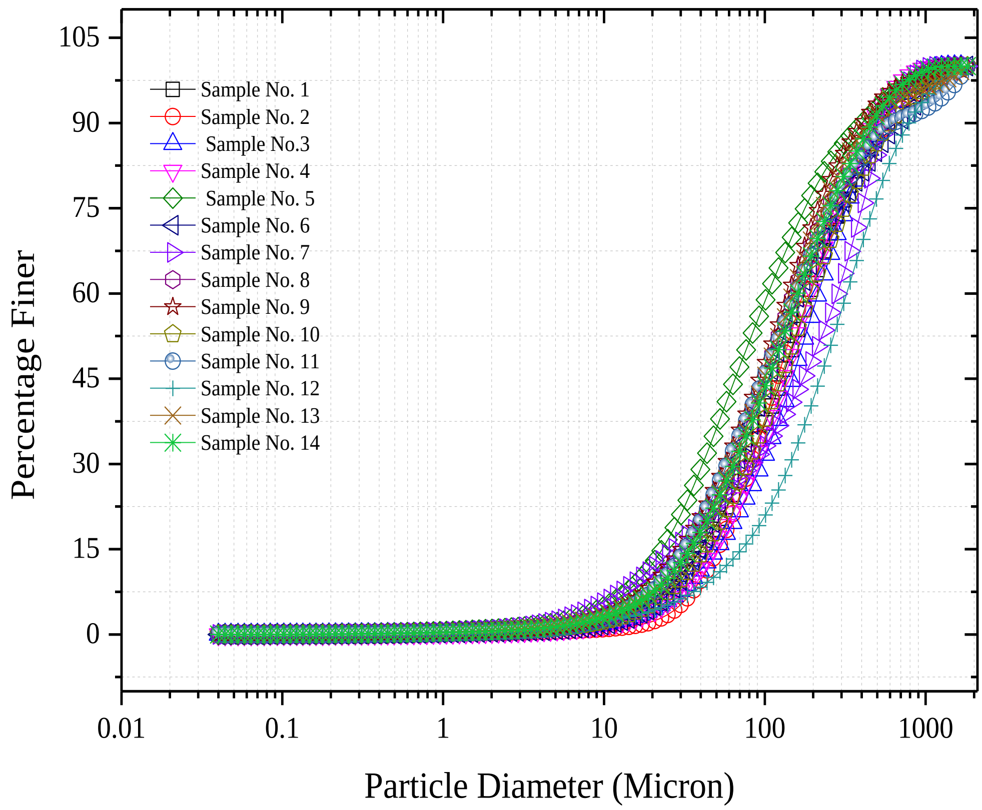

Figure 4.1 Particle size distribution of SCBA

XRD studies for Crystal structure

X-ray powder **diffraction** (**XRD**) is a rapid analytical technique primarily used for phase identification of a crystalline material and can provide information on unit cell dimensions. The analyzed material is finely ground, homogenized, and average bulk composition is determined.

XRD studies show three prominent peaks in the graph namely cristobalite, tridymite and quartz and there is very less noise in the graph which shows maximum portion of the material is amorphous in nature hence can be utilized as mineral admixture for making concrete.

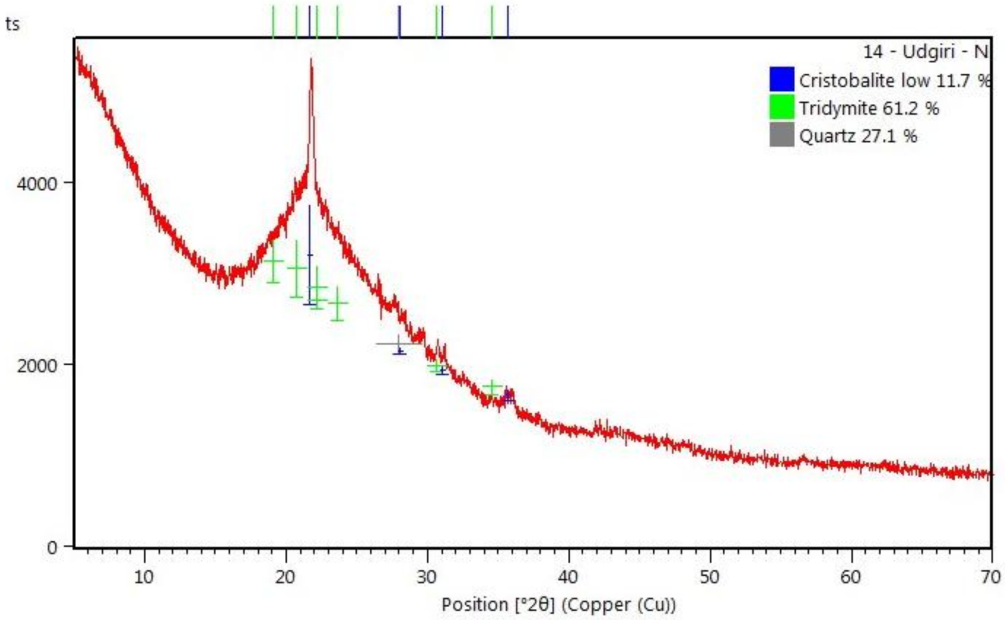

Figure 4.2 XRD analysis of SCBA

4.2Workability of concrete

Workability found out by using compaction factor apparatus after mixing of concrete for particular replacement content are as follows.

Table 4.2 Compaction Factor for different replacements of SCBA

Concrete code	Compaction Factor	Slump(in cm)
C0	0.83	75
C5	0.85	80
C10	0.86	82
C15	0.88	85

A slight increase in workability is observed due to replacement of cement particles by finer size particles of SCBA.As the replacement content increases workability also increases.

4.3 Compressive Strength Observations and Results

Compressive strength for the casted cube specimens were tested after moist curing was done for the time period of 7, 14 and 28 days respectively. The dimension of the cube specimen used for testing was 100mmX100mmX100mm. The procedure for the compressive strength testing was strictly followed by the provisions of IS 516:1959.Data for the testing is compiled in the form of tables which are then plotted at different replacement content of SCBA for 7 days, 14 days and 28 days respectively. After this a comparison chart describing the compressive strength at different duration is obtained which is used to get optimum replacement content.

Figure 4.3 Compression testing of casted Cube (100mmx100mmx100mm)

Figure 4.4 Cracks at failure in Compression testing of Cube (100mmx100mmx100mm)

Table 4.3 Compressive Strength Observations (7 days)

Compressive Strength test on Cube 10x10x10 cm (After 7 Days)		
Sample	Max Load(kN)	Compressive Strength (MPa)
0% replacement	115	11.5
5% replacement	110.0	11.0
10% replacement	125.0	12.5
15% replacement	95	9.5

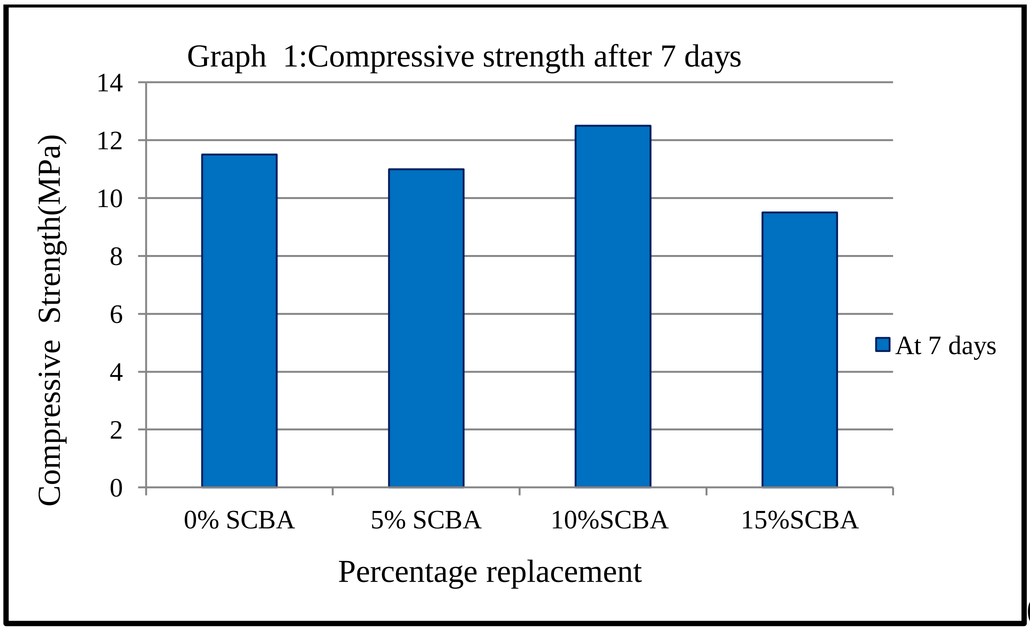

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Table 4.4 Compressive Strength Observations (14 days)

Compressive Strength test on Cube 10x10x10 cm (After 14 Days)		
Sample	Max Load(kN)	Compressive Strength (MPa)
0% replacement	200	20
5% replacement	195	19.5
10% replacement	205	20.5
15% replacement	185	18.5

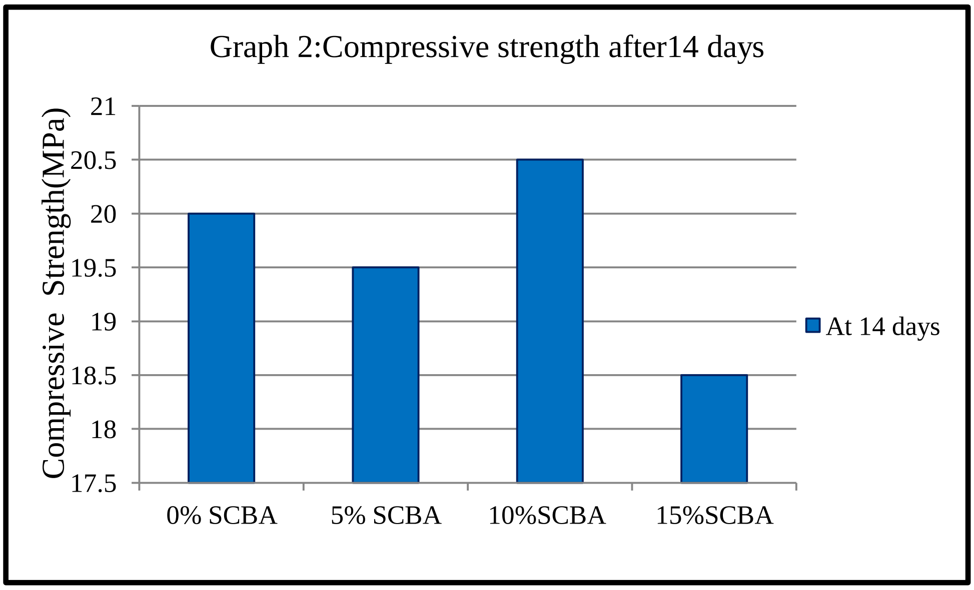
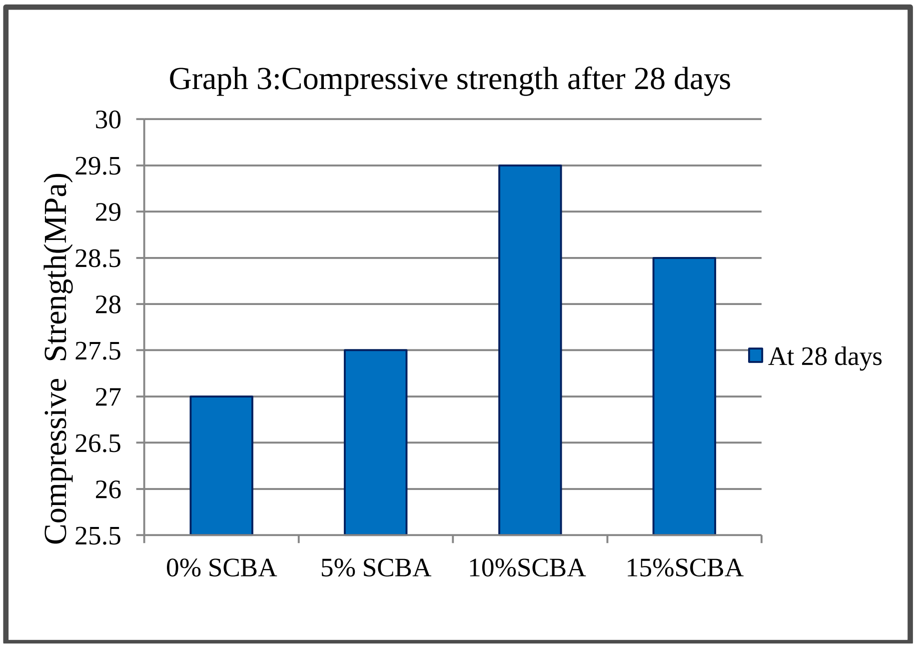
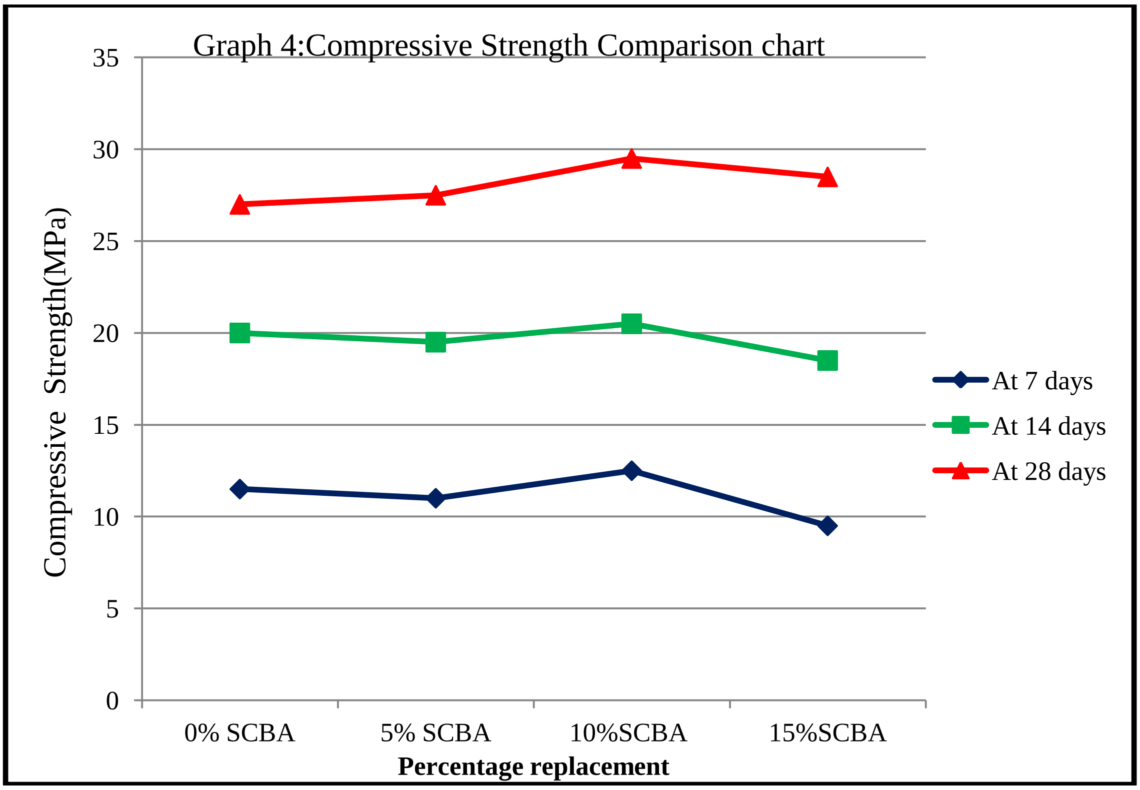


Table 4.5 Compressive Strength Observations (28 days)

Compressive Strength test on Cube 10x10x10 cm (After 28 Days)		
Sample	Max Load(kN)	Compressive Strength (MPa)
0% replacement	270	27
5% replacement	275	27.5
10% replacement	295	29.5
15% replacement	285	28.5





4.4 Split-Tensile test Observations and results

Split tensile strength for the casted cylinder specimens were tested after moist curing was done for the time period of 7, 14 and 28 days respectively. The dimensions for the cylinder used for testing was height: diameter :: 200mm:100mm. The procedure for the conducting split tensile strength testing was strictly followed by the provisions of IS 516:1959.Data for the testing is compiled in the form of tables which are then plotted at different replacement content of SCBA for 7 days, 14 days and 28 days respectively.

Table 4.6 Split-Tensile Strength Observations (7 days)

Split-Tensile Strength test on Cylinder height: dia=20cm:10cm(After 7 Days)		
Sample	Max Load(kN)	Split-Tensile Strength (MPa)
0% replacement	21	0.67
5% replacement	25	0.79
10% replacement	27	0.85
15% replacement	26	0.810

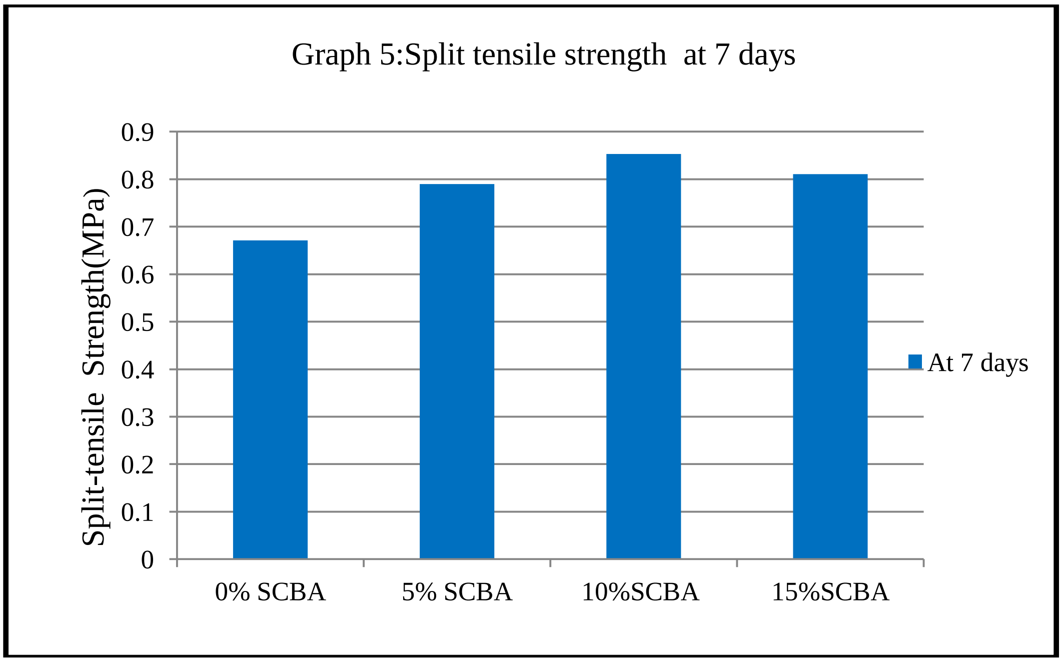


Table 4.7 Split-Tensile Strength Observations (14 days)

Split-Tensile Strength test on Cylinder height: dia=20cm:10cm(After 14 Days)		
Sample	Max Load(kN)	Split-Tensile Strength (MPa)
0% replacement	26	0.836
5% replacement	30	0.95
10% replacement	32	1.026
15% replacement	30	0.94

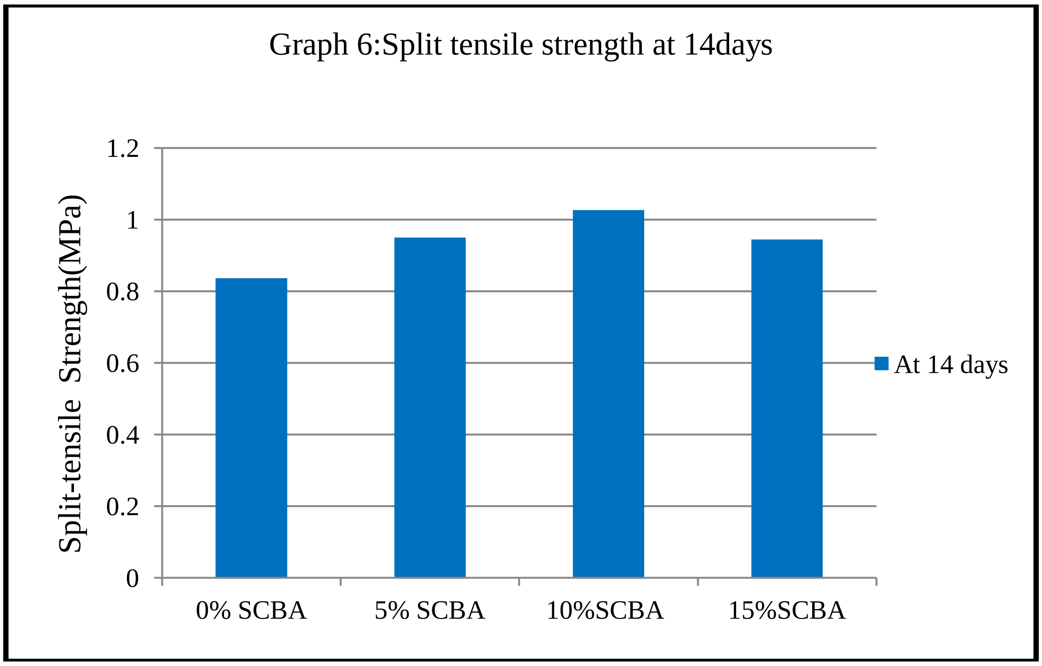
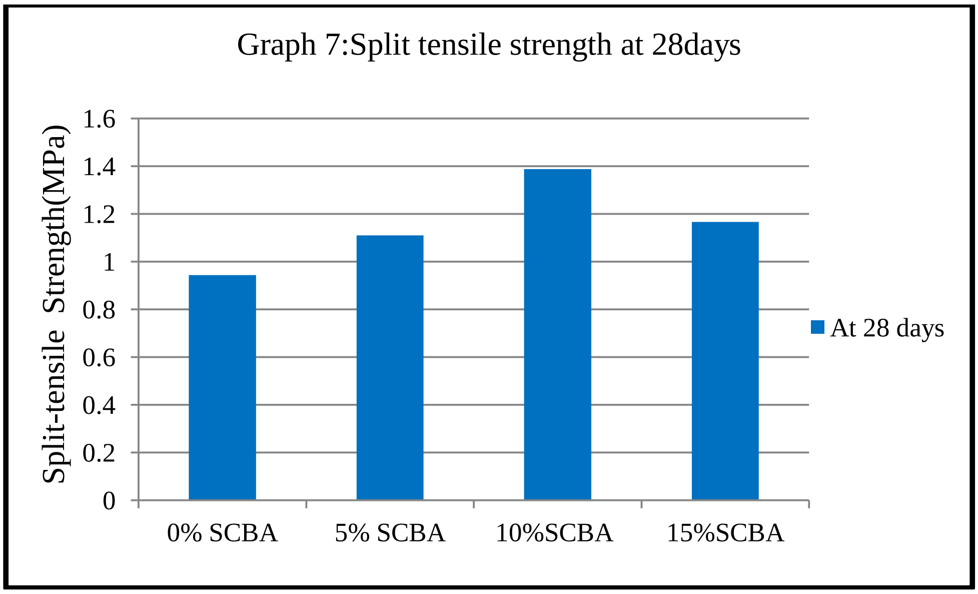
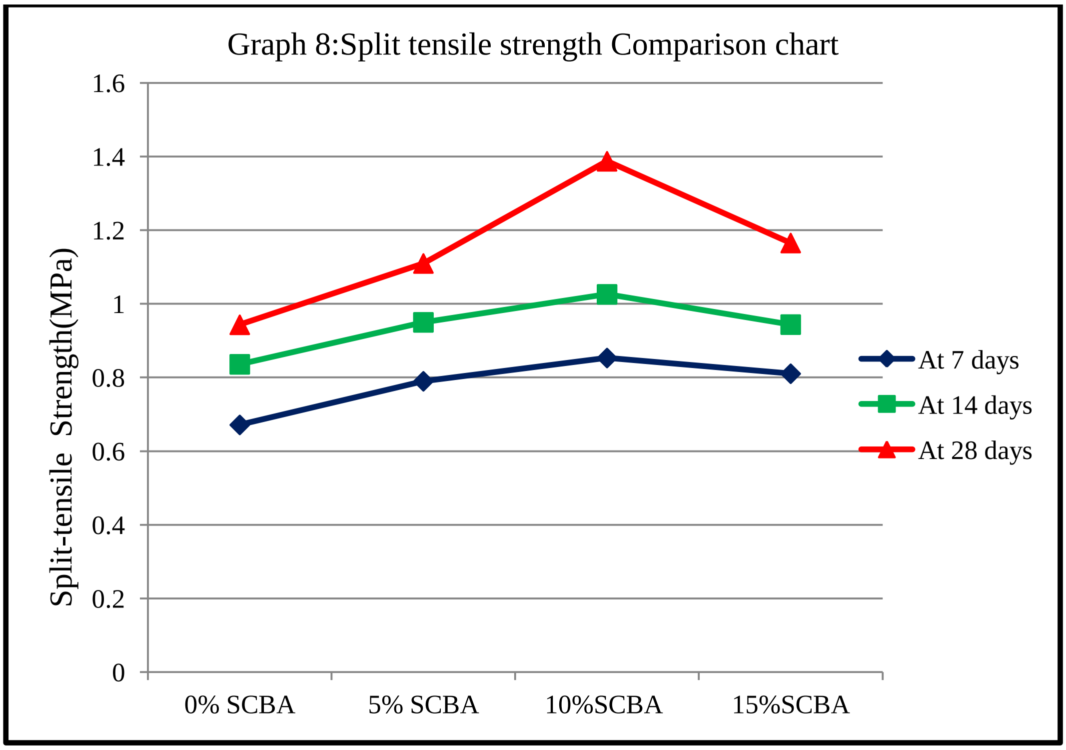


Table 4.8 Split-Tensile Strength Observations (28 days)

Split-Tensile Strength test on Cylinder height: dia=20cm:10cm(After 28 Days)		
Sample	Max Load(kN)	Split-Tensile Strength (MPa)
0% replacement	30	0.94
5% replacement	35	1.11
10% replacement	44	1.38
15% replacement	37	1.16





4.5 Flexural Strength (Centre point loading test) Observations and results

Flexure strength for the casted cylinder specimens were tested after moist curing was done for the time period of 7, 14 and 28 days respectively. The dimensions for the beam used for testing of size 500mmX100mmX100mm. The procedure for the conducting flexural strength testing was strictly followed by the provisions of IS 516:1959.Data for the testing is compiled in the form of tables which are then plotted at different replacement content of SCBA for 7 days, 14 days and 28 days respectively.

Table 4.9 Flexure Strength Observations (7 days)

Flexural Strength test on Beam size 50x10x10cm (After 7 Days)		
Sample	Max Load(kN)	Flexural Strength (MPa)
0% replacement	10.8	5.4
5% replacement	10.1	5.05
10% replacement	10.28	5.14
15% replacement	9.96	4.98

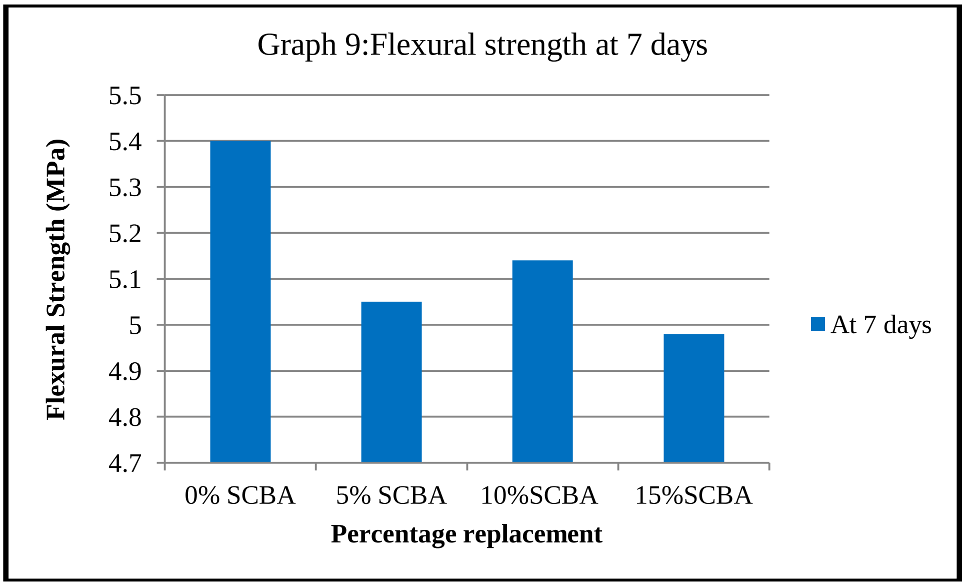


Table 4.10 Flexure Strength Observations (14 days)

Flexural Strength test on Beam size 50x10x10cm (After 14 Days)		
Sample	Max Load(kN)	Flexural Strength (MPa)
0% replacement	11.04	5.52
5% replacement	11.6	5.8
10% replacement	11.36	5.68
15% replacement	10.74	5.37

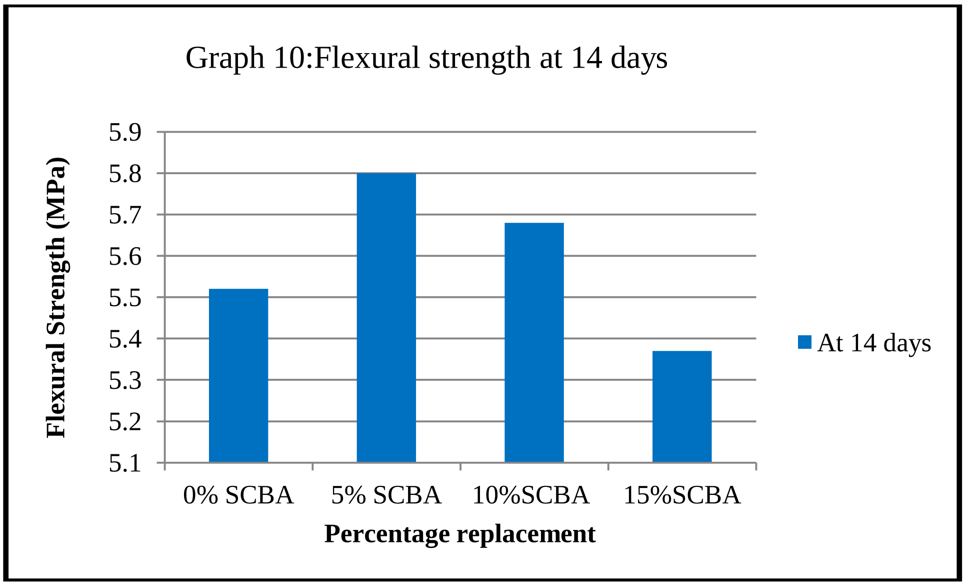
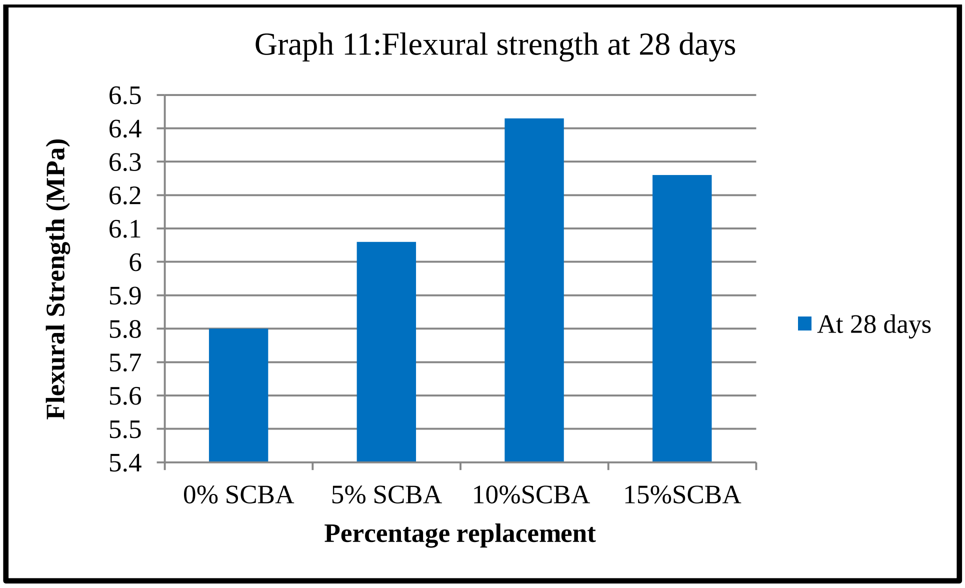
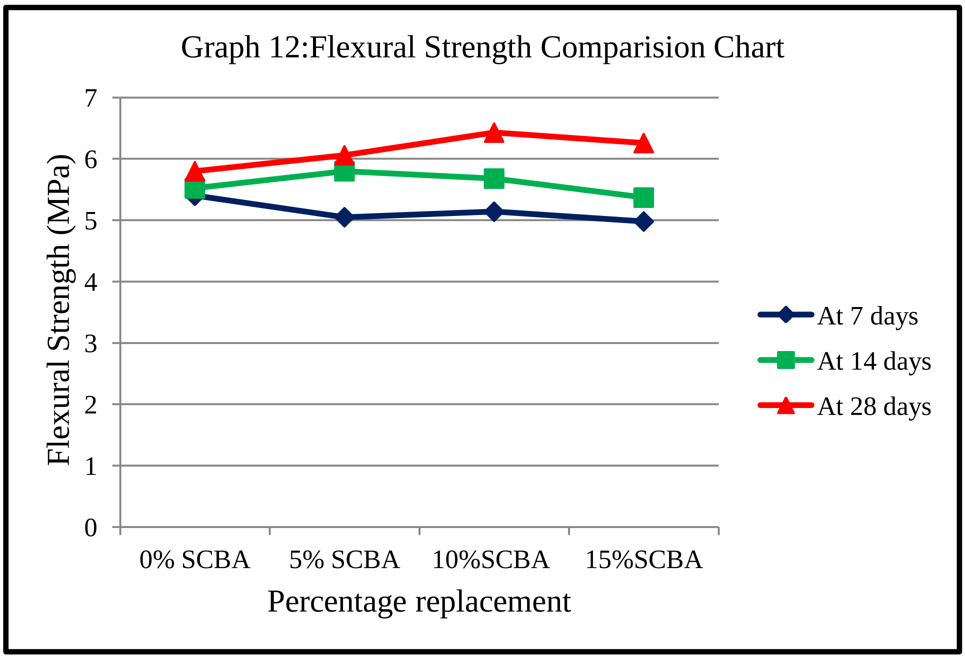


Table 4.11 Flexure Strength Observations (28 days)

Flexural Strength test on Beam size 50x10x10cm (After 28 Days)		
Sample	Max Load(kN)	Flexural Strength (MPa)
0% replacement	11.6	5.8
5% replacement	12.12	6.06
10% replacement	12.86	6.43
15% replacement	12.52	6.26


Graph 11:Flexural strength at 28 days
Flexural Strength (MPa)
6.5
6.4
6.3
6.2
6.1
6
5.9
5.8
5.7
5.6
5.5
5.4
0% SCBA
5% SCBA
10%SCBA
15%SCBA
Percentage replacement
At 28 days


Graph 12:Flexural Strength Comparision Chart
Flexural Strength (MPa)
7
6
5
4
3
2
1
0
0% SCBA
5% SCBA
10%SCBA
15%SCBA
Percentage replacement
At 7 days
At 14 days
At 28 days

4.6 Results obtained from durability studies of concrete at different replacement content

According to the results obtained from the present study and information from the literature, the above mentioned replacement range of 5% to 15% was selected for the study of durability aspects.

The solution for the required concentration was prepared for acid attack and sulphate attack respectively. A solution of 5% HCl and 5% H_2SO_4 were prepared for testing the cubes (100x100x100mm).

After 7, 14, 28 water curing cubes were immersed in respective solution for acid attack and sulphate attack. Then specimens were kept for 21 days curing for durability studies. Compressive strength was found out after taking out from the solution.

Table 4.12 For 0 % replacement Sulphate attack

Age of Specimen	Identification Mark	Wt. of cube before curing (kg)	Wt. of cube after curing in water (kg)	Wt. of cube after 21 days of exposure (kg)	Max. Load (kN)	Max. Mean Load (kN)
7 Days	0SCBA (7I)	2.32	2.34	2.41	222.5	215.25
	0SCBA (7II)	2.00	2.09	2.18	208	
14 Days	0SCBA (14I)	2.20	2.21	2.27	275	285
	0SCBA (14II)	2.30	2.31	2.36	295	
28 days	0SCBA (28I)	2.34	2.36	2.4	300.2	305.1
	0SCBA (28II)	2.29	2.29	2.33	310	

Table 4.13 For 5% replacement Sulphate attack

Age of Specimen	Identification Mark	Wt. of cube before curing (kg)	Wt. of cube after curing in water (kg)	Wt. of cube after 21 days of exposure (kg)	Max. Load (kN)	Max. Mean Load (kN)
7 Days	5SCBA (7I)	2.31	2.31	2.36	263.8	223.6
	5SCBA (7II)	2.37	2.37	2.41	183.4	
14 Days	5SCBA (14I)	2.25	2.22	2.30	189.7	244.85
	5SCBA (14II)	2.31	2.30	2.34	300	
28 days	5SCBA (28I)	2.36	2.36	2.39	310.7	257.85
	5SCBA (28II)	2.26	2.25	2.31	205	

Table 4.14 For 10 % replacement Sulphate attack

Age of Specimen	Identification Mark	Wt. of cube before curing (kg)	Wt. of cube after curing in water (kg)	Wt. of cube after 21 days of exposure (kg)	Max. Load (kN)	Max. Mean Load (kN)
7 Days	10SCBA (7I)	2.36	2.38	2.42	257	228.5
	10SCBA (7II)	2.22	2.24	2.28	200	
14 Days	10SCBA (14I)	2.19	2.18	2.25	269	264.5
	10SCBA (14II)	2.20	2.22	2.23	260	
28 days	10SCBA (28I)	2.35	2.36	2.42	336.6	356.7
	10SCBA (28II)	2.30	2.32	2.36	376.8	

Table 4.15 For 15 % replacement Sulphate attack

Age of Specimen	Identification Mark	Wt. of cube before curing (kg)	Wt. of cube after curing in water (kg)	Wt. of cube after 21 days of exposure (kg)	Max. Load (kN)	Max. Mean Load (kN)
7 Days	15SCBA(7I)	2.32	2.34	2.38	223	219
	15SCBA (7II)	2.29	2.30	2.36	215	
14 Days	15SCBA (14I)	2.35	2.36	2.42	260	253
	5SCBA (14II)	2.25	2.25	2.30	246	
28 days	15SCBA (28I)	2.36	2.37	2.40	283	279.5
	15SCBA (28II)	2.40	2.41	2.42	276	

Table 4.16 For 0 % replacement Acid attack

Age of Specimen	Identification Mark	Wt. of cube before curing (kg)	Wt. of cube after curing in water (kg)	Wt. of cube after 21 days of exposure (kg)	Max. Load (kN)	Max. Mean Load (kN)
7 Days	0SCBA (7III)	2.20	2.22	2.25	246.1	238
	0SCBA (7IV)	2.23	2.25	2.28	230	
14 Days	0SCBA (14III)	2.17	2.17	2.20	263	255.5
	0SCBA (14IV)	2.18	2.20	2.24	248	
28 days	0SCBA (28III)	2.16	2.19	2.21	260	261.5
	0SCBA (28IV)	2.20	2.21	2.24	263	

Table 4.17 For 5% replacement Acid attack

Age of Specimen	Identification Mark	Wt. of cube before curing (kg)	Wt. of cube after curing in water (kg)	Wt. of cube after 21 days of exposure (kg)	Max. Load (kN)	Max. Mean Load (kN)
7 Days	5SCBA (7III)	2.32	2.32	2.33	178	181.5
	5SCBA (7IV)	2.30	2.30	2.32	185	
14 Days	5SCBA (14III)	2.27	2.28	2.29	205	204
	5SCBA (14IV)	2.26	2.26	2.26	203	
28 days	5SCBA (28III)	2.28	2.28	2.28	252	261
	5SCBA (28IV)	2.27	2.28	2.28	270	

Table 4.18 10 % replacement Acid attack

Age of Specimen	Identification Mark	Wt. of cube before curing (kg)	Wt. of cube after curing in water (kg)	Wt. of cube after 21 days of exposure (kg)	Max. Load (kN)	Max. Mean Load (kN)
7 Days	10SCBA (7III)	2.33	2.36	2.36	248.7	242.35
	10SCBA (7IV)	2.30	2.32	2.35	236	
14 Days	10SCBA (14III)	2.29	2.30	2.32	250	252
	10SCBA (14IV)	2.28	2.30	2.33	254	
28 days	10SCBA (28III)	2.40	2.41	2.42	275	279
	10SCBA (28IV)	2.38	2.39	2.41	283	

Table 4.19 For 15 % replacement Acid attack

Age of Specimen	Identification Mark	Wt. of cube before curing (kg)	Wt. of cube after curing in water (kg)	Wt. of cube after 21 days of exposure (kg)	Max. Load (kN)	Max. Mean Load (kN)
7 Days	15SCBA (7III)	2.25	2.26	2.26	175	179
	15SCBA (7IV)	2.23	2.24	2.25	183	
14 Days	15SCBA (14III)	2.24	2.25	2.26	192	190
	15SCBA (14IV)	2.22	2.23	2.24	188	
28 days	15SCBA (28III)	2.28	2.28	2.30	249	257
	15SCBA (28IV)	2.27	2.28	2.31	265	

4.7 Comparison of difference in weights and compressive strength between normal control concrete and concrete with exposure to sulphate environment

Table 4.20

Specimen Age: 7 Days in water and 21 days exposure to Sulphate attack

Percentage of SCBA		Weight (kg)	Compressive Strength (MPa)
0%	Normally Cured	2.215	11.5
	H_2SO_4 Exposed	2.295	11.6
	Difference	0.080	0.1
5%	Normally Cured	2.340	11
	H_2SO_4 Exposed	2.385	10.36
	Difference	0.045	0.64
10%	Normally Cured	2.310	12.5
	H_2SO_4 Exposed	2.350	12.3
	Difference	0.040	0.20
15%	Normally Cured	2.320	9.5
	H_2SO_4 Exposed	2.370	10.4
	Difference	0.050	0.9

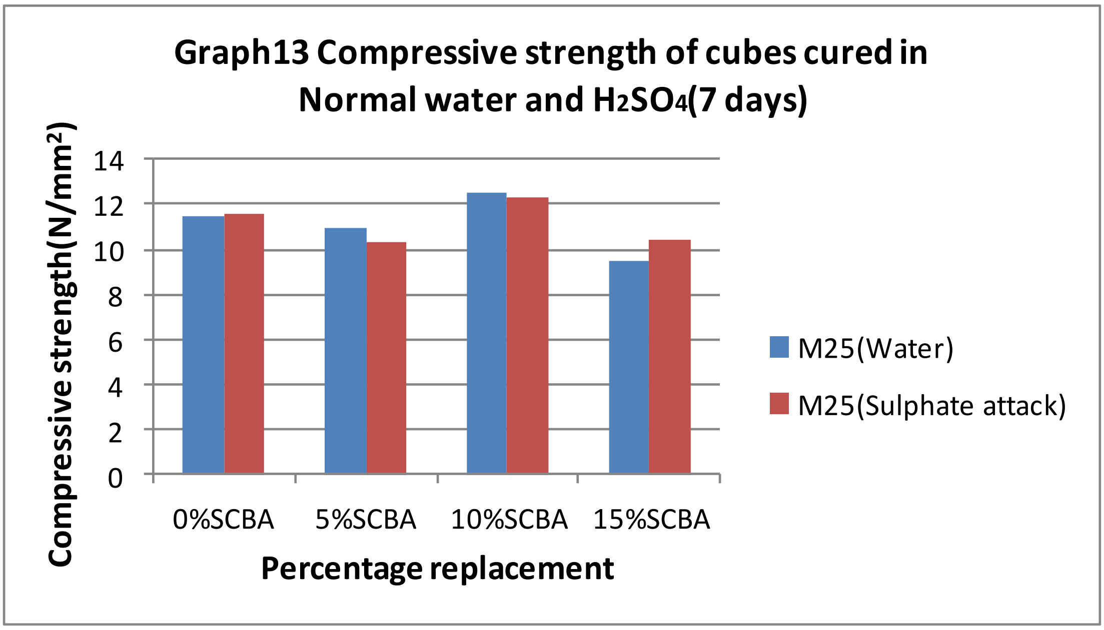


Table 4.21

Specimen Age: 14 Days in water and 21 days exposure to Sulphate attack

Percentage of SCBA		Weight (kg)	Compressive Strength (MPa)
0%	Normally Cured	2.260	20
	H_2SO_4 Exposed	2.315	18.5
	Difference	0.055	1.5
5%	Normally Cured	2.260	19.5
	H_2SO_4 Exposed	2.320	14.6
	Difference	0.060	4.9
10%	Normally Cured	2.200	20.5
	H_2SO_4 Exposed	2.240	18.4
	Difference	0.040	2.1
15%	Normally Cured	2.305	18.5
	H_2SO_4 Exposed	2.360	15.3
	Difference	0.055	3.2

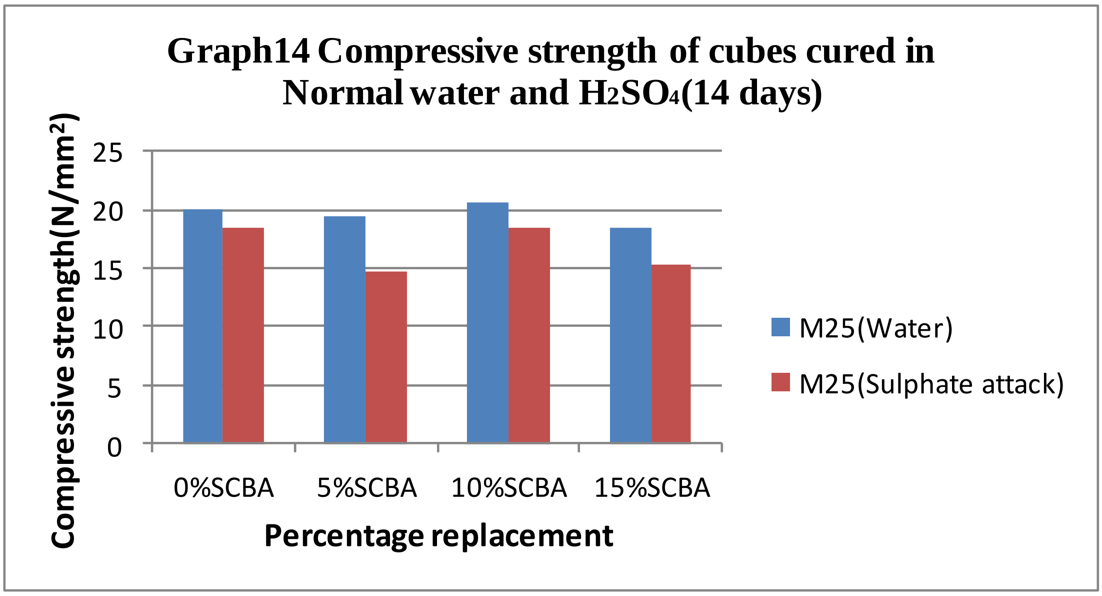
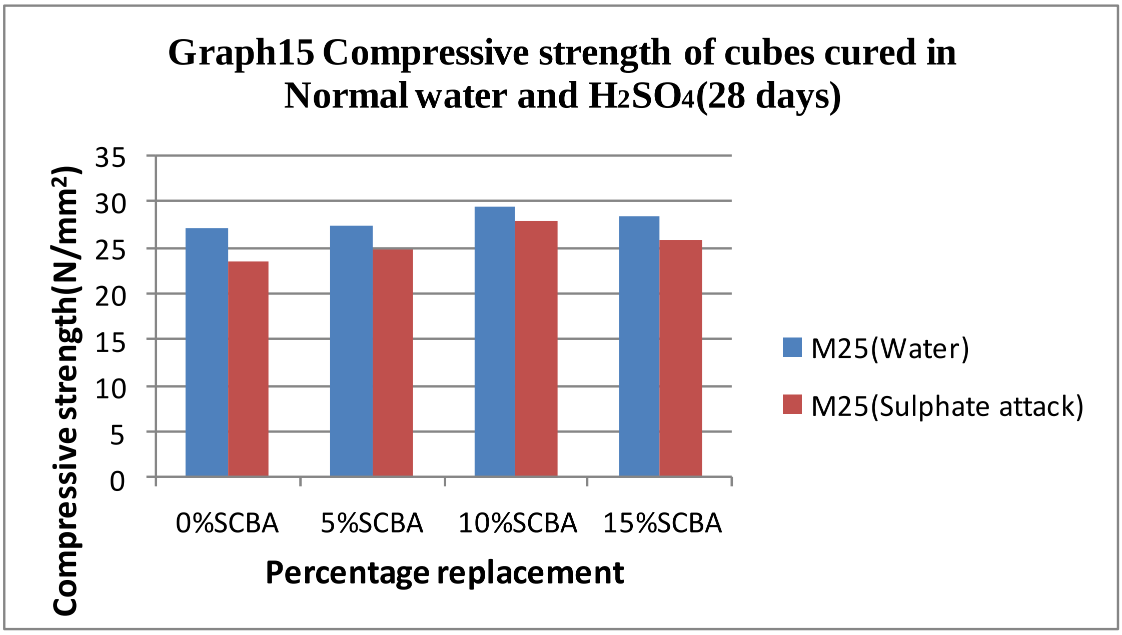


Table 4.22

Specimen Age: 28Days in water and 21 days exposure to Sulphate attack

Percentage of SCBA		Weight (kg)	Compressive Strength (MPa)
0%	Normally Cured	2.325	27
	H_2SO_4 Exposed	2.365	23.5
	Difference	0.040	3.5
5%	Normally Cured	2.305	27.50
	H_2SO_4 Exposed	2.350	24.80
	Difference	0.045	2.70
10%	Normally Cured	2.340	29.5
	H_2SO_4 Exposed	2.390	27.9
	Difference	0.050	1.60
15%	Normally Cured	2.390	28.50
	H_2SO_4 Exposed	2.410	25.95
	Difference	0.020	2.55



4.8 Comparison of difference in weights and compressive strength between normal control concrete and concrete with exposure to acidic environment

Table 23 Specimen Age: 7 Days in water and 21 days exposure to Acid attack

Percentage of SCBA		Weight (kg)	Compressive Strength (MPa)
0%	Normally Cured	2.235	11.5
	HCl Exposed	2.265	13.8
	Difference	0.030	2.3
5%	Normally Cured	2.310	11
	HCl Exposed	2.325	11.15
	Difference	0.015	0.15
10%	Normally Cured	2.340	12.5
	HCl Exposed	2.355	12
	Difference	0.015	0.5
15%	Normally Cured	2.250	9.5
	HCl Exposed	2.255	10.9
	Difference	0.005	1.4

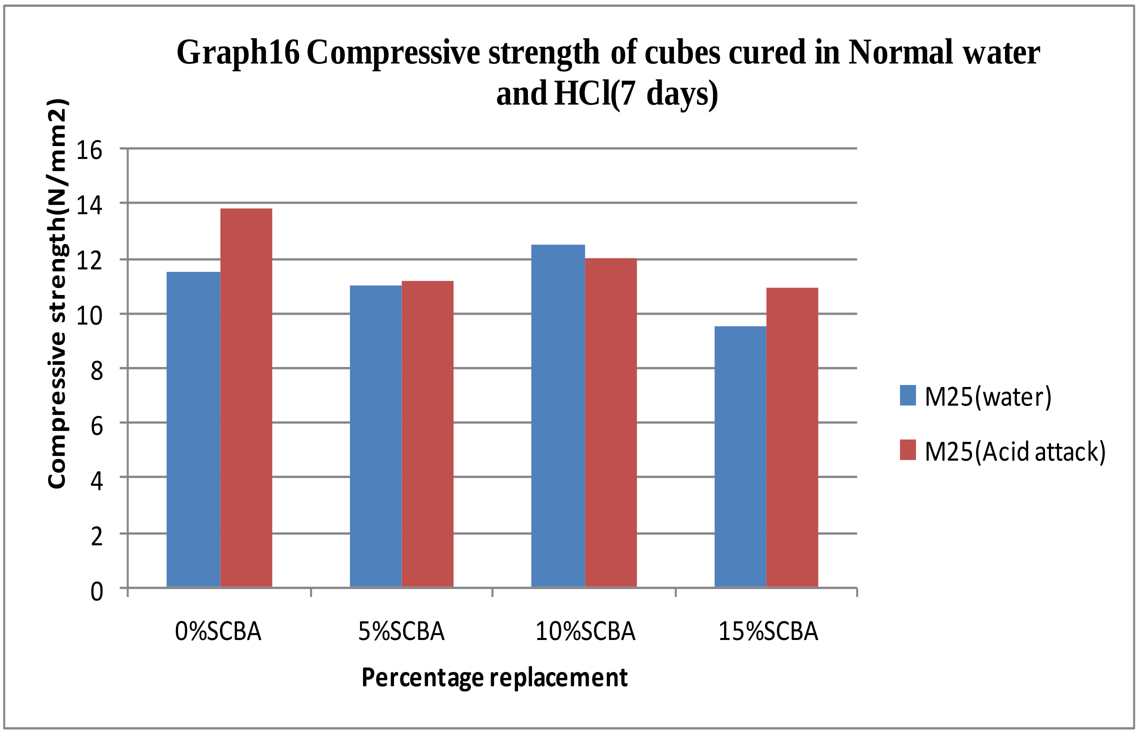


Table 24 Specimen Age: 14 Days in water and 21 days exposure to Acid attack

Percentage of SCBA		Weight (kg)	Compressive Strength (MPa)
0%	Normally Cured	2.185	20
	HCl Exposed	2.220	15.55
	Difference	0.035	4.45
5%	Normally Cured	2.270	19.5
	HCl Exposed	2.275	17.8
	Difference	0.005	1.70
10%	Normally Cured	2.300	20.5
	HCl Exposed	2.325	20.2
	Difference	0.025	0.30
15%	Normally Cured	2.240	18.5
	HCl Exposed	2.250	15.6
	Difference	0.010	2.9

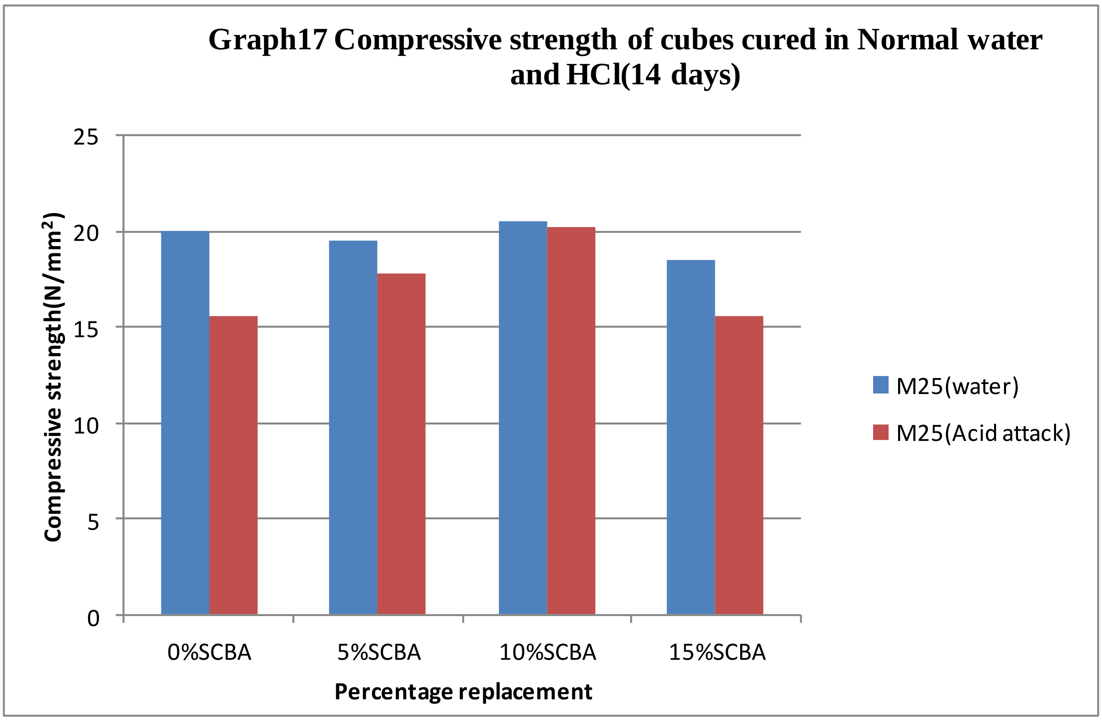
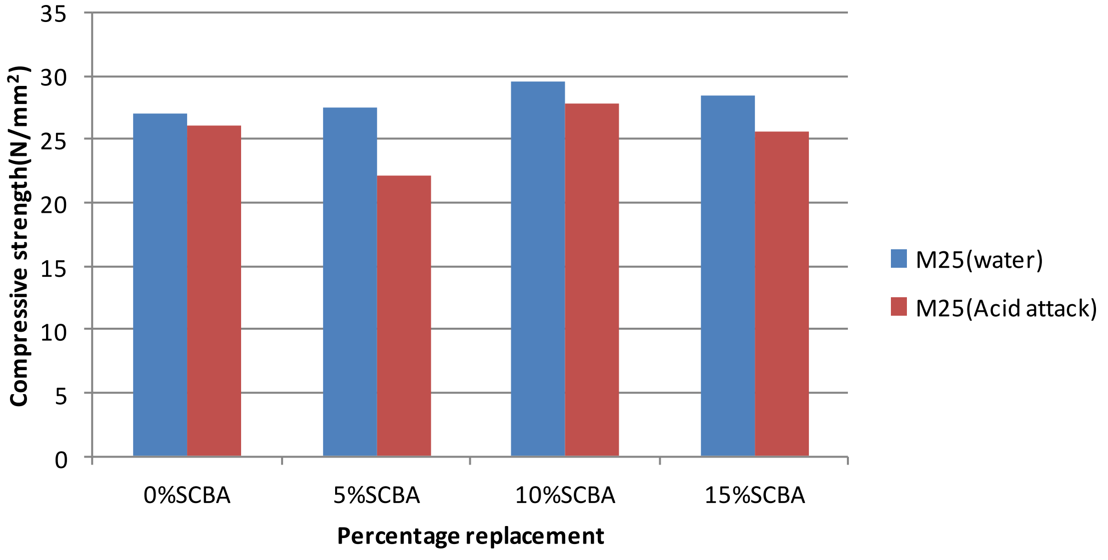


Table 25 Specimen Age: 28 Days in water and 21 days exposure to Acid attack

Percentage of SCBA		Weight (kg)	Compressive Strength (MPa)
0%	Normally Cured	2.200	27
	HCl Exposed	2.225	26.15
	Difference	0.025	0.85
5%	Normally Cured	2.280	27.50
	HCl Exposed	2.280	22.10
	Difference	0	5.40
10%	Normally Cured	2.400	29.5
	HCl Exposed	2.415	27.9
	Difference	0.015	1.6
15%	Normally Cured	2.280	28.5
	HCl Exposed	2.350	25.7
	Difference	0.070	2.8

Graph18 Compressive strength of cubes cured in Normal water and HCl(28 days)



4.9 Discussion

4.9.1 Effect on Compressive strength after addition of SCBA in concrete

- The compressive strength of Normal M-25 concrete after the duration of 28 days was found to be 27Mpa after testing the casted cube.
- The compressive strength of M-25 concrete with addition of 5% SCBA, 10%SCBA and 15% SCBA at the end of 28 days is observed as 27.5MPa, 29.5MPa, 28.5MPa respectively.
- The **Optimum Replacement Content for SCBA** with **9.25%** increase in compressive strength as compared to ordinary concrete was found at **10% SCBA replacement.**
- Increase in strength is attributed to pore refinement of the concrete which is a result of replacing of cement particles by SCBA particles of smaller size.
- Better interfacial transition zone (ITZ) has resulted in increased strength.

4.9.2 Effect on split-tensile strength after addition of SCBA in concrete

- The split-tensile strength of Normal M-25 concrete after the duration of 28 days was found to be 0.95Mpa after testing the casted cylinder.
- The split-tensile strength of M-25 concrete with addition of 5%SCBA, 10%SCBA and 15%SCBA at the end of 28 days is observed as 1.11MPa, 1.38MPa and 1.16MPa respectively.
- There was an increase of **47.05%** splitting-tensile strength at 10% replacement as compared to ordinary concrete.

4.9.3 Effect on flexural strength after addition of SCBA in concrete

- The flexural strength of Normal M-25 concrete after the duration of 28 days was found to be 5.8Mpa after testing the casted beam.
- The flexural strength of M-25 concrete with addition of 5%SCBA, 10%SCBA and 15%SCBA at the end of 28 days is observed as 6.06MPa, 6.430MPa and 6.26MPa respectively.
- There was an increase of **10.86%** flexural strength at 10% replacement as compared to ordinary concrete.

4.9.4 Durability studies

From the above graphs and observations following inference can be derived:

- Compressive strength is decreased for concrete cured in 5% HCl and 5% H_2SO_4 when compared to concrete cured in normal water.
- Utilization of waste material Sugarcane Bagasse can be advantageously used as replacement of cement in making concrete when it is exposed to acidic and sulphate attack.
- There is a significant reduction in compressive strength after 10% replacement for both acid attack and sulphate attack.
- Initially there is increase in compressive strength significantly and comparable values are obtained in case of optimum case of 10%SCBA replacement.
- Weight and volume increase in the specimens is registered in both the cases.
- Reason for the increase in weight can be attributed to formation of ettringite in case of sulphate attack.
- Also blended cement concrete reduces permeability and reduces the chances of aggregates to react with the chloride and sulphates.

Chapter 5
Conclusion

The mechanical and durability properties concluded as per the present study conducted by us:

- Chemical properties found out from laboratory at IIT BOMBAY indicate that **SiO_2+ Al_2O_3+Fe_2O_3** content was more than 70% total composition which renders material suitable mineral admixture for concrete.
- The optimum replacement content was found out to be at 10% replacement level which resulted in maximum gain in compressive strength after which compressive strength tend to decrease.
- A significant increase in the split tensile strength was observed as high as 40-50% as compared to the control concrete with zero replacement with SCBA.
- Similarly at the optimum replacement content flexural strength property of concrete was observed to increase by almost 10-12% as compared to the control concrete with zero replacement with SCBA.
- When the durability studies of the SCBA replaced concretes tested in the acid attack and sulphate attack curing environment, the results show slight decrease in strengths but not very steep decline as compared to normal control concrete. Thus use of blended cement concrete performed better in the aggressive environment in comparison with control concrete (0% SCBA).

CHAPTER 6
Recommendation

Overall the use of the SCBA as replacement in concrete is beneficial to the environment as it reduces disposal and air pollution and addition to concrete saves an ample quantity of cement which as a result reduces the air pollution caused by burning of limestone and gases released due to the burning of the same.

From the present investigation, the following recommendation can be made. The optimum replacement content is suggested to exist at 10% replacement level of SCBA with the cement in making of concrete. Up to 15% of Portland pozzolana cement can be optimally replaced with well-burnt Bagasse ash without any adverse effect on the desirable properties of concrete.

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APPENDIX-I
Mix design calculations for M25 grade concrete

Stipulations for Proportioning

1) Grade designation : M 25

2) Type of cement : PPC 53 Grade

3) Maximum nominal size of aggregate : 20 mm

4) Minimum cement content : 240 kg/m^3

5) Maximum water-cement ratio : 0.4

6) Exposure condition : Moderate

7) Degree of supervision : Good

8) Type of aggregate : Crushed angular aggregate

TEST DATA FOR MATERIALS

1) Cement used : PPC 53 Grade

2) Specific gravity of cement : 3.15

3) Specific gravity of SCBA : 2.6

4) Specific gravity of:

   i. Coarse aggregate : 2.74

   ii. Fine aggregate : 2.74

1. For 0% Replacement

Target strength for mix proportioning

$$f'_{ck} = f_{ck} + 1.65s$$

Where,

$f'_{ck} =$ target average compressive strength at 28 days,

$f_{ck} =$ Characteristics compressive strength at 28 days, and

S= standard deviation.

$$f'_{ck} = f_{ck} + 1.65s$$

$$f'_{ck} = 25 + (1.65 \times 4)$$

$$=31.6 \text{ N/mm}^2$$

Selection of water content

Maximum water content for 20 mm aggregate=186 kg/m^3 (for 25 to 50 mm slump range)

Calculation of cement content

Cement Content=186÷ 0.4

=465 kg/m^3

Proportion of volume of coarse aggregate and fine aggregate content

From Table 3 of IS:10262:2009, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone I) for water-cement ratio of 0.50 =0.60.
In the present case water-cement ratio is 0.40. Therefore. Volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by 0.10. The proportion of volume of coarse aggregate is increased by 0.02.

Therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.40 = 0.62

Volume of coarse aggregate =0.62 m^3

Volume of fine aggregate=1-0.62=0.38 m^3

Mix calculations

The mix calculations per unit volume of concrete shall be as follows:

a)Volume of Concrete=1 m^3

b)Volume of Cement=$\frac{Mass\ of\ Cement}{Specific\ Gravity\ of\ Cement} \times \frac{1}{1000}$

$= \frac{465}{3.15} \times \frac{1}{1000}$

= 0.147 m^3

c)Volume of Water=$\frac{Mass\ of\ Water}{Specific\ Gravity\ of\ Water} \times \frac{1}{1000}$

$=\frac{186}{1} \times \frac{1}{1000}$

=0.186 m^3

d)Volume of all in Aggregate=1-(0.147+0.186)

=0.667 m^3

e)Mass of Coarse Aggregate=0.667×0.62×2.74×1000=1133 kg

f) Mass of Fine Aggregate=0.667×0.38×2.74×1000=694.5 kg

Ratio			
Cement	CA	FA	Water
465	1133	695.5	186
1	2.44	1.5	0.4

2. For 5% Replacement:

Target strength for mix proportioning

$$f'_{ck} = f_{ck} + 1.65s$$

Where,

$f'_{ck} =$ target average compressive strength at 28 days,

$f_{ck} =$ characteristics compressive strength at 28 days, and

S= standard deviation.

$$f'_{ck} = f_{ck} + 1.65s$$

$$f'_{ck} = 25 + (1.65 \times 4)$$

$$=31.6 \text{ N/mm}^2$$

Selection of water content

Maximum water content for 20 mm aggregate=186 kg/m^3 (for 25 to 50 mm slump range)

Calculation of cement and SCBA content

Cement Content=186÷ 0.4

=465 kg/m^3

SCBA Content=5% of Cement Content

=0.05×465

=23.25 kg/m^3

Proportion of volume of coarse aggregate and fine aggregate content

From Table 3 of IS:10262:2009, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone I) for water-cement ratio of 0.50 =0.60.
In the present case water-cement ratio is 0.40. Therefore. Volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement

ratio is lower by 0.10. The proportion of volume of coarse aggregate is increased by 0.02.

Therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.40 = 0.62

Volume of coarse aggregate =0.62 m^3

Volume of fine aggregate=1-0.62=0.38 m^3

Mix calculations

The mix calculations per unit volume of concrete shall be as follows:

a)Volume of Concrete=1 m^3

b)Volume of Cement=$\frac{Mass\ of\ Cement}{Specific\ Gravity\ of\ Cement} \times \frac{1}{1000}$

$= \frac{441.75}{3.15} \times \frac{1}{1000}$

$= 0.140\ m^3$

c) Volume of SCBA=$\frac{Mass\ of\ SCBA}{Specific\ Gravity\ of\ SCBA} \times \frac{1}{1000}$

$=\frac{23.25}{2.6} \times \frac{1}{1000}$

$=0.0089\ m^3$

d) Volume of Water=$\frac{Mass\ of\ Water}{Specific\ Gravity\ of\ Water} \times \frac{1}{1000}$

$=\frac{186}{1} \times \frac{1}{1000}$

$=0.186\ m^3$

e)Volume of all in Aggregate=1-(0.140+0.0089+0.186)

$=0.665\ m^3$

f)Mass of Coarse Aggregate=0.665×0.62×2.74×1000=1129.7 kg

g) Mass of Fine Aggregate=0.665×0.38×2.74×1000=692.4 kg

Ratio			
Cement	CA	FA	Water
465	1129.7	692.4	186
1	2.43	1.49	0.4

3. For 10% Replacement

Target strength for mix proportioning

$$f'_{ck} = f_{ck} + 1.65s$$

Where,

$f'_{ck} =$ target average compressive strength at 28 days,

$f_{ck} =$ Characteristics compressive strength at 28 days, and

S= standard deviation.

$$f'_{ck} = f_{ck} + 1.65s$$

$$f'_{ck} = 25 + (1.65 \times 4)$$

$=31.6$ N/mm^2

Selection of water content

Maximum water content for 20 mm aggregate=186 kg/m^3 (for 25 to 50 mm slump range)

Calculation of cement and SCBA content

Cement Content=186÷ 0.4

=465 kg/m^3

SCBA Content=10% of Cement Content

=0.10×465

=46.5 kg/m^3

Proportion of volume of coarse aggregate and fine aggregate content

From Table 3 of IS:10262:2009, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone I) for water-cement ratio of 0.50 =0.60.
In the present case water-cement ratio is 0.40. Therefore. Volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by 0.10. The proportion of volume of coarse aggregate is increased by 0.02.

Therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.40 = 0.62

Volume of coarse aggregate =0.62 m^3

Volume of fine aggregate=1-0.62=0.38 m^3

Mix calculations

The mix calculations per unit volume of concrete shall be as follows:

a)Volume of Concrete=1 m^3

b)Volume of Cement=$\frac{Mass\ of\ Cement}{Specific\ Gravity\ of\ Cement} \times \frac{1}{1000}$

$= \frac{418.5}{3.15} \times \frac{1}{1000}$

= 0.133 m^3

c) Volume of SCBA=$\frac{Mass\ of\ SCBA}{Specific\ Gravity\ of\ SCBA} \times \frac{1}{1000}$

$=\frac{46.5}{2.6} \times \frac{1}{1000}$

=0.018 m^3

d) Volume of Water=$\frac{Mass\ of\ Water}{Specific\ Gravity\ of\ Water} \times \frac{1}{1000}$

$=\frac{186}{1} \times \frac{1}{1000}$

=0.186 m^3

e)Volume of all in Aggregate=1-(0.133+0.018+0.186)

=0.663 m^3

f)Mass of Coarse Aggregate=0.663×0.62×2.74×1000=1126.3 kg

g) Mass of Fine Aggregate=0.663×0.38×2.74×1000=690.315 kg

Ratio			
Cement	CA	FA	Water
465	1126.3	690.32	186
1	2.42	1.5	0.4

4. For 15% Replacement

Target strength for mix proportioning

$$f'_{ck} = f_{ck} + 1.65s$$

Where,

$f'_{ck} =$ target average compressive strength at 28 days,

$f_{ck} =$ Characteristics compressive strength at 28 days, and

S= standard deviation.

$$f'_{ck} = f_{ck} + 1.65s$$

$$f'_{ck} = 25 + (1.65 \times 4)$$

=31.6 N/mm^2

Selection of water content

Maximum water content for 20 mm aggregate=186 kg/m^3 (for 25 to 50 mm slump range)

Calculation of cement and SCBA content

Cement Content=186÷ 0.4

=465 kg/m^3

SCBA Content=15% of Cement Content

$=0.15\times465$

$=69.75\ kg/m^3$

Proportion of volume of coarse aggregate and fine aggregate content

From Table 3 of IS:10262:2009, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone I) for water-cement ratio of 0.50 =0.60.
In the present case water-cement ratio is 0.40. Therefore. Volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by 0.10. The proportion of volume of coarse aggregate is increased by 0.02.

Therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.40 = 0.62

Volume of coarse aggregate $=0.62\ m^3$

Volume of fine aggregate$=1-0.62=0.38\ m^3$

Mix calculations

The mix calculations per unit volume of concrete shall be as follows:

a)Volume of Concrete$=1\ m^3$

b)Volume of Cement$=\frac{Mass\ of\ Cement}{Specific\ Gravity\ of\ Cement}\times\frac{1}{1000}$

$=\frac{395.25}{3.15}\times\frac{1}{1000}$

$= 0.125\ m^3$

c) Volume of SCBA$=\frac{Mass\ of\ SCBA}{Specific\ Gravity\ of\ SCBA}\times\frac{1}{1000}$

$=\frac{69.75}{2.6}\times\frac{1}{1000}$

$=0.0268\ m^3$

d) Volume of Water$=\frac{Mass\ of\ Water}{Specific\ Gravity\ of\ Water}\times\frac{1}{1000}$

$=\frac{186}{1} \times \frac{1}{1000}$

$=0.186\ m^3$

e)Volume of all in Aggregate=1-(0.125+0.0268+0.186)

$=0.6622\ m^3$

f)Mass of Coarse Aggregate=0.6622×0.62×2.74×1000=1124.95 kg

g) Mass of Fine Aggregate=0.6622×0.38×2.74×1000=689.5 kg

Ratio			
Cement	CA	FA	Water
465	1125	689.5	186
1	2.42	1.48	0.4

5. Calculation of volume of moulds

Moulds	Diameter(d)/width(b) (cm)	Height(h) (cm)	Length(l) (cm)	Formula for Volume	Volume(m^3)
Cube	10	10	10	l×b×h	0.001
Cylinder	10	20	-	$\pi d^2 h/4$	0.00157
Beam	10	10	50	l×b×h	0.005