PARTIAL REPLACEMENT OF CEMENT WITH SUGARCANE BAGASSE ASH AND COAL BOTTOM DUST

A thesis submitted
in Partial Fulfillment of the Requirements
for the Degree of

Master of Technology

In

(STRUCTURAL ENGINEERING)

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LUCKNOW (INDIA)
October, 2019

CERTIFICATE

Certified that **Jitendra Kumar yadav** (University Roll No. 1170444004) has carried out the research work presented in this thesis entitled, **"Partial Replacement of Cement With Sugarcane Bagasse Ash And Coal Bottom Dust",** for the award of **Master of Technology (Structural Engineering)** from Babu Banarasi Das University, Lucknow under my supervision. The thesis embodies results of original work, and studies are carried out by the student himself and the contents of the thesis do not form the basis for the award of any other degree to the candidate or to anybody else from this or any other university.

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DECLARATION

I hereby certify that the work which has been presented in this thesis entitled **"Partial Replacement Of Cement With Sugarcane Bagasse Ash And Coal Bottom Dust",** in partial fulfillment of award of degree of **Master of Technology (Structural Engineering)** submitted in civil department, Babu Banarasi Das University, Lucknow is an authentic record of my own work carried under the supervision of **Mr. Faheem Ahmad Khan** BBD University, Lucknow, India.

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ACKNOWLEDGEMENT

It is indeed a great pleasure to express my sincere thanks to my Supervisor **Mr. Faheem Ahmad Khan, Assistant Professor, Civil Engineering Department**, **Babu Banarasi Das University, Lucknow** for his continuous support in this dissertation. He was always there to listen and to give advice to me. He showed me different ways to approach a research problem and the need to be persistent to accomplish any goal. He had confidence in me when I doubted myself, and brought out the good ideas in me. He was always there to meet and talk about my ideas, to proofread and mark up my work, and to ask me good questions to help me think through my problems. Without his encouragement and constant guidance, I could not have finished this thesis.

Besides my supervisor, I would like to thank for her timely co-operations and guidance for this project work. He has always been for me. I would also like to extend my deep sense of gratitude towards **Anupam Mehrotra**, **Associate Professor** and **Head of the Department, Civil Engineering, Babu Banarasi Das University, Lucknow** for his valuable suggestions.

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ABSTRACT

The recent construction boom has led to a dramatic increase in the price of natural sand and stone aggregates. Additionally various government agencies have put restrictions on sand and stone quarrying to conserve this diminishing natural resource. This has prompted many engineers to look for alternate materials that are cheaper while possessing similar characteristics. One such alternative is the use of stone dust a byproduct of crushers as replacement of stone dust and ceramic waste as a replacement of coarse aggregate. These materials are easily available at very low cost as compared to natural fine and coarse aggregates.

This study was conducted to analyze the compressive and flexural strength of concrete when natural sand was replaced with stone dust at 20%, 40 %, 60%, 80 % and 100% along with 20 % stone aggregate replacement with ceramic waste. For conducting the study 36 cubes (150mm x 150mm x150mm) were tested. To increase the workability of concrete Lyconicsulphate plasticizer was used as an admixture. The plasticizer was used as 2% by weight of cement. The percentage of ceramic waste is kept 20% for all specimens.

It is found that at 40 % replacements of natural sand with stone dust along with 20% replacement of stone aggregate with ceramic waste, the compressive strength is maximum, which is 22 MPa for M20 grade (within the permissible limit). The maximum flexural strength reached at 40 % stone dust replacing natural sand with 20 % ceramic waste replacing stone aggregate. It is also founds that it is not feasible using ceramic waste alone as a replacement of coarse aggregate because it decreases the compressive and flexural strength of concrete below the permissible limit.

The study concludes that the stone dust with 20 % of ceramic waste as a coarse aggregate can be used effectively as an alternative to natural sand for nominal concreting upto 40 % for M20 grade of concrete.

TABLE OF CONTENTS

List Of Table

LIST OF FIGURE

LIST OF GRAPH

ABBREVIATION AND SYMBOLS

SCBA	Sugarcane bagasse ash
CBA	Coal bottom ash
cm	Centimeter
g	Gram
g/cm^3	Gram per cubic centimeter
BIS	Bureau of Indian Standards
Kg	Kilogram
kg/m^3	Kilogram per cubic meter
kN/s	Kilo newton per second
L	Liter
L/m^3	Liter per cubic meter
m	Meter
m^2/kg	Square meter per kilogram
mm	Millimeter
N/mm^2	Newton per square millimeter
µm	Micrometer
°F	Degrees Fahrenheit
°C	Degree Celsius
%	Percent

CHAPTER I

INTRODUCTION

1. GENERAL

The Concrete is the most consumed building material in the world due to its excellent mechanical properties and durability. Throughout the world, the concrete industry produces more than 10 billion tons of concrete per year (Meyer 2006). At present, the concrete industry is cursed by the shortage of aggregates and the environmental pollution of cement production. The cement industry has a significant contribution to global warming because the combustion of fuel in the cement kiln and the electricity used to grind the clinker emit a large amount of CO_2. The cement industry is responsible for around 5% of global CO_2 emissions (Worrell et al 2001). In addition, the natural resources of the aggregates are being gradually depleted due to the development of infrastructure throughout the world. The prohibition of mining in some areas further increases the problem of the availability of natural aggregates. Therefore, it becomes very essential and more meaningful to find substitutes for both cement and natural aggregates. In addition, the continuous growth of agricultural and industrial waste is the main cause of many environmental concerns and burdens that can be reduced by using these wastes in concrete construction.

Agricultural waste is the waste produced from various agricultural products. Sugarcane bagasse, wheat husk and wheat straw, peanut husk and paddy rice husk are agricultural waste. Most developing countries produce about 400 million tons of agricultural waste per year. Today, some of the waste such as rice husk, bagasse, nutshell, etc. they are used partly as fuel for power generation. This use results in ash causing the elimination problem. In addition, the chemical composition of the ash has diverted these wastes to useful materials that can be used in concrete construction. In addition to the aforementioned agricultural waste ash, some researchers identified that sugarcane bagasse ash can also be used as a pozzolona in concrete.

Sugarcane is one of the main crops grown in more than 110 countries. According to the Food and Agriculture Organization (FAO), India is the second largest producer of sugarcane in the world. It produces 340 million tons of sugar cane every year. The fibrous matter that remains after the crushing and extraction of sugar cane juice is known as bagasse. When this bagasse is burned at a controlled temperature, it results in ash. The resulting Sugar Cane Bagasse Ash (SCBA) contains high levels of SiO_2 and AL_2O_3, which can help allow its use as supplementary cementing material (SCM). The use of SCBA as SCM not only reduces cement production that is responsible for high energy consumption and carbon emissions, but can also improve the compressive strength of cement-based materials such as concrete and mortar (Janjaturaphan and Wanson 2010). This improved compressive strength depends on the physical and chemical effects of the SCBA. The physical effect is also known as the filler effect that is related to the shape, size and texture of the SCBA particles while the chemical effects are related to the ability of the SCBA to participate in the pozzolanic reaction with calcium hydroxide by providing compounds reactive siliceous (Srinivasan and Sathiya 2010).

In recent decades, there has been a rapid increase in the production of waste and by-products from various industries. This obviously causes many environmental problems and increases the potential to pollute the natural resources of life such as water, air and soil. Therefore, the proper disposal of these wastes and by-products is a serious burden for all countries. The safe disposal of such industrial waste is very expensive. In addition, there is a lack of disposal sites that can properly handle such wastes without causing harmful effects on the environment. Therefore, researchers around the world are focusing on ways to use these wastes, where they reduce their harmful effects. The concrete industry is one of the places where the beneficial use of this waste could have a good future. The important study has been published for the use of many industrial wastes, such as fly ash, blast furnace slag, copper slag, steel slag and silica fume in the manufacture of concrete. Undoubtedly, a large amount of such waste is used in the production of concrete, but coal ash (a waste of thermal coal plants) is still not used in any way.

Carbon bottom ash (CBA) is produced in furnaces of thermal coal plants. It is an incombustible material produced after the combustion of coals, mainly formed by thicker molten ash particles. This unused ash should be disposed of dry or wet in an open area near the plant or mixed with water and pumped into bodies of water that cause contamination. To overcome this type of problem, it is necessary to use bottom ash. The bottom ash forms up to 25% of the total ash, while the fly ash forms the remaining 75%. In India, more than 70% of electricity is generated through the combustion of fossil fuels, of which almost 61% is produced by coal-fed plants (Aggarwal et al 2007). Coal-fired power plants burn approximately 407 million tons of coal for power generation and produce approximately 131 million tons of coal ash annually (Singh and Siddique 2014). In addition, it has also been observed that the CBA is well graduated and most of its grain sizes are similar to the sizes of river sand grains. This grain size of CBA is within the limit established by the specification of the Office of India (BIS) (Kadam and Patil 2013). These physical properties of CBA make it attractive for use as fine aggregates in concrete production.

Sometimes concrete structures are exposed to fire. Fire decreases the durability and strength of such concrete structures. Meanwhile, the resistance capacity of ordinary concrete against fire is only very complicated because concrete is a composite material with components that have different thermal properties. The fire resistance of concrete depends on many factors, such as the size and shape of the structures, the type of mixtures, the cement and the aggregates used. The aggregates have a very high resistance against fire, but the cooling of the heated aggregates can result in the formation of internal pressure. This internal pressure can cause changes in the volume of aggregates. In addition, the hydrated cement contains a significant amount of free calcium hydroxide and will decompose into calcium oxide due to the loss of water at 400-4500 C (Metin Husem 2005). This calcium oxide is transformed back into calcium hydroxide, when it is kept in a humid environment. These chemical changes are responsible for the contraction of the cement paste. Part of the deformation of the concrete is due to this contraction. Due to such changes in the volume of aggregate and cement paste, the concrete can be chipped. In fact, normal concrete can withstand up to 100-1200 C without significant loss of compressive strength. Therefore, it is feared that the replacement of any concrete ingredient with other materials (agricultural or industrial waste) may change the properties of the concrete at a higher temperature.

Several investigators have investigated the individual effect on the strength properties of concrete when replacing cement with SCBA or fine aggregates with CBA. The information available on the performance of fresh and hardened concrete through the combination of SCBA and CBA is rare. The main objective of this study is to investigate the workability and compressive strength of concrete by using SCBA and CBA as a combination. In addition, this study also examines the effect of elevated temperature on the thermal stability of all concrete mixtures.

Taking into account the above, the present study has been planned with the following objectives:

i) Study the characteristic compressive strength of concrete using sugar cane bagasse ash (as a partial replacement for cement) and coal ash (as a partial replacement for fine aggregates).

ii) Study the viability characteristic of concrete using bagasse ash from sugarcane and coal ash.

iii) Study the effect of high temperature on the compressive strength of concrete using bagasse ash from sugarcane and coal ash.

CHAPTER II

LITERATURE REVIEW

Worell et al. (2001)[1] investigated the carbon dioxide emissions of the global cement industries. The results showed that the cement industry contributes approximately 5% to the global anthropogenic CO2 emissions from calcination of lime stone and the combustion of fuels in a kiln. China has the largest share in total emissions (33%), followed by the United States (6%), India (5%), Japan (5%) and Korea (4%).

Husem (2006)[2] studied the variation of the resistance to compression and bending of the ordinary micro concrete and high performance at high temperatures. In the experiment, concrete samples were exposed to high temperatures (200, 400, 600, 800 and 1000 ° C) and cooled differently (in air and water). The compressive and flexural strengths of these concrete samples were compared with each other and then compared with the samples that had not been heated. The results indicated that concrete strength decreases with increasing temperature and that the decrease in strength of ordinary concrete is greater than in high performance concrete. The type of cooling also affects the resistance to compression and residual bending.

Aggarwal et al. (2007)[3] studied the effect of coal ash as a replacement for fine aggregates in concrete. In the experiment, various aspects such as workability, compressive strength, tensile strength by bending and by division were studied. Five mixing ratios were made replacing sand with CBA by weight. First it was the control mix (without CBA), and the other four mixes contained CBA. The proportions of fine aggregate were replaced varying from 20% to 50%. The concrete cubes of 150 mm were molded to obtain resistance to compression, the cylinders of 150 × 300 mm to divide the tensile strength and the bundles of 101.4 × 101.4 × 508 mm for the resistance to bending. The tests were conducted at 7, 28, 56, 90 days in accordance with the provisions of the BIS: 516-1959. The results indicated that the compressive strength, the tensile strength by division and the flexural strength of the CBA concrete specimens were lower than the control concrete samples at all ages. The difference in strength between the CBA concrete samples and the control concrete samples became less clear after 28 days. The results also showed that the workability of the concrete decreased with the increase in the CBA content due to the increase in water demand.

Souza et al. (2007)[4] studied the effects of the addition of various proportions of SCBA on the properties of mortar and concrete. The ash was partially replaced (0%, 10%, 20% and 30%) with cement at a constant w / c ratio of 0.5. The study was carried out in the following way: workability with the flow table test, compression resistance at ages 1, 7, 14, 21 and 56 days, total water and capillary absorption after 28 days of curing, pore size distribution at the age of 28 days, gas permeability at ages 1, 7, 14, 21 and 28 days and pore size distribution. The results revealed that SCBA can be replaced up to 20% and capillary water sorption increased with the addition of SCBA.

Ganesan et al. (2007)[5] studied the effect of SCBA as a supplementary cementing material on concrete properties. Seven different proportions of concrete mixtures (SCBA ranging from 5% to 30% by weight of cement), including the control mixture, were prepared with a water binder ratio of 0.53. The compressive strength of cement concrete bins mixed with bagasse ash was determined after 7, 14, 28 and 90 days, the tensile strength test was performed on SCBA mixed concrete cylinders after 28 days. It was concluded that up to 20% OPC can be replaced by a well-burned SCBA without any adverse effect on the desirable properties of the concrete.

Bishr (2008)[6] studied the effect of elevated temperature on the compressive strength of concrete made with silica fume (as a partial replacement of cement). Six mixing proportions were made. First it was the control mix (no silica fume), and the other five mixes contained silica fume. The cement was replaced by silica fume by weight. The proportions of cement replaced ranged between 0% and 15%. The 100 mm cubes were melted and cured for 28 days. Three cubes of each mixing ratio were placed at elevated temperature, that is, 20,150,300,500,700 and 900 ° C for four hours in the electric furnace. The values of the compressive strength were measured for the various mixtures at elevated temperatures. The results showed that the compressive strength of the concrete with or without silica fume decreases with increasing temperature, the maximum value in the ratio between the resistance to compression at high temperature and the room temperature is observed around 300 ° C. This maximum value could be attributed to the evaporation of free water within the concrete.

Cordeoro et al. (2008)[7] studied the pozzolanic and fill effects of a residual SCBA on mortars. Initially, the influence of the SCBA particle size on the packing density was examined. After that, the pozzolanic activity of the SCBA and the compressive strength of the mortars were also observed. In addition, the behavior of SCBA was also analyzed by comparing insoluble material of the same packing density. The results showed that there was a direct relationship between the compressive strength of the mortar containing SCBA and the Blaine fineness of the ash. In addition, the compressive strength of the SCBA-containing mortar is inversely proportional to the particle size of SCBA. According to the results, the best SCBA produced by vibratory crushing provided the highest packing density of the mortar. This density generated a greater resistance to compression and pozzolanic activity. Therefore, it was concluded that the SCBA showed good physical and chemical properties so it is suitable for use as a mineral additive.

Andrade et al. (2009)[8] studied the effect of CBA as a partial replacement of fine aggregate in the properties of fresh concrete. In the study, the concrete mixtures were prepared by means of two forms of addition of CBA that is the replacement of equivalent volume, correcting the quantities of bottom ash according to the moisture content and the non-equivalent volume replacement, without replacement of CBA according to the moisture content of the aggregate. The CBA was replaced up to 100%. The compressive strength of the concrete was investigated at the curing ages of 3, 28 and 90. It was concluded that the compressive strength decreases when the natural sand is replaced by coal ash.

Behnood and Ghandehari (2009)[9] studied the comparison of tensile strength by compression and by division of high strength concrete with and without polypropylene (PP) fibers heated at high temperatures. The mixtures were prepared with 0%, 6% and 10% silica fume replacement cement and polypropylene fibers with a content of 0, 1, 2 and 3 kg / m3. The samples were heated at 100, 200, 300, 400, 500 and 600 ° C for three hours. A loss of strength was observed for the entire concrete mix after exposure to 600 °C. The relative compression strengths of the concretes containing PP fibers were higher than those of the concrete without PP fibers. The breaking tensile strength of concrete was more sensitive to high temperatures than the compressive strength. The presence of PP fibers was more effective for the compressive strength than the tensile strength by division above 200 °C. Based on the results of the test, it can be concluded that the addition of 2 kg fibers / m^3 of PP can significantly promote the residual mechanical properties of high strength concrete during heating.

Chusilp et al. (2009)[10] investigated the physical properties of SCBA concrete such as compressive strength, water permeability and heat evolution. SCBA was obtained from a sugar factory. It was ground with the help of the ball mill until the particles retained in a sieve no. 325 were less than 5% by weight. The OPC was replaced with SCBA at different replacement levels (10, 20 and 30%) with a constant ratio w/c (0.50). The results of the experiment showed that, at the age of 28 days, the concrete samples containing 10-30% ground bagasse ash by weight of binder had higher compressive strengths than the control concrete (concrete without bagasse ash), while the water permeability was lower than the concrete control. Concrete containing 20% ground bagasse ash had the highest compressive strength in 113% of the control concrete. The water permeability of the concrete decreased as the fractional substitution of ground bagasse ash increased. It was also observed that, for heat evolution, the maximum temperature increase of the concrete containing ground bagasse ash was lower than that of the control concrete and the maximum temperature increase of the concrete was reduced 13, 23 and 33% in comparison with the control concrete when the cement was replaced by ground bagasse ash at 10, 20 and 30% by weight of binder, respectively.

Cordeiro et al. (2010)[11] described the characterization of the SCBA produced by controlled combustion and ultrafine grinding. Initially, the optimal combustion conditions of the bagasse were examined, which helped to find the maximum pozzolanic activity. The results showed that an amorphous SCBA can be produced with a high specific surface area and a reduced ignition loss with combustion at 600 °C in the muffle furnace. After observing an optimal combustion, they investigated the milling process of SCBA. The results also indicated that milling in a vibratory mill for 120 min allowed the production of an ash with a pozzolanic activity index of 100% that can be replaced with cement up to 20%.

Janjaturaphan and Wansom (2010)[12] studied the pozzolanic activity of SCBA. The study found that the total amounts of SiO_2, Al_2O_3 and Fe_2O_3 for all SCBA's are higher than the minimum requirement for Class N pozzolans (> 70%) according to ASTM C618 (2003). Although the moisture content for all SCBAs is higher than the 3% maximum requirement, this presents no serious problem for the use of SCBA as SCM, since it can be easily reduced by oven drying at 105-110 °C overnight or by the sun drying, for a more energy efficient and economical means.

Fairbairn et al. (2010)[13] studied the effect of SCBA as a partial replacement of cement in concrete. SCBA was replaced with cement in the proportion of 0%, 10%, 15% and 20%. All specimens were cured for 7, 28, 90 and 180 days. Based on the results of their tests, it was concluded that an optimal combination of 10% SCBA with OPC could be used for reinforced concrete.

Srinivasan and Sathiya (2010)[14] studied the effect of SCBA as a partial replacement of cement in concrete. The study was carried out in SCBA obtained by controlled combustion of sugarcane bagasse that was acquired in Tamilnadu province in India. The SCBA was partially replaced with cement in the proportion of 0%, 5%, 10%, 15% and 25% by weight. In the experimental work, a total of 180 numbers of concrete specimens were fused. The samples considered in this study consisted of 36 numbers of lateral cubes of 150 mm, 108 numbers of cylinders of 150 mm in diameter and 300 mm in length, and 36 numbers of prisms of 750 mm x 150 mm x 150 mm. The samples were removed from the mold after 24 hours and then cured under water for a period of 7 and 28 days. The study examined compressive strength, split tensile strength, flexural strength, Young's modulus and concrete density. It was concluded that SCBA in mixed concrete had significantly higher compressive strength, tensile strength and flexural strength than concrete without SCBA. It was also found that the cement could advantageously be replaced with SCBA up to the maximum limit of 10%.

Paula et al. (2010)[15] evaluated the effects of the partial replacement of OPC by SCBA in mortars. Firstly, they burned SCBA on stove at 600°C and then at 700°C. The second burn was lasted for 3 hrs. After this burn, it was cooled naturally and then ground by using ball mill at different grinding time at different grind times (0, 30, 60, 120, 180, 300, 420, 540 and 660 min). The SCBA was replaced with cement at different replacement levels i.e. 0%, 10%, 20% and 30% in mortar proportion (1:3). The results showed that the addition of SCBA retards the setting time of mortars by 10 minutes. It was also observed that SCBA in blended mortar had significantly higher strength up-to

10% of replacement.

Ismail et al. (2011)[16] examined the residual compressive strength of concrete containing palm oil fuel ash (POFA) after exposure to elevated temperatures and subsequent cooling. Specimens from OPC and POFA concrete mixes were prepared and subjected to various temperature levels such as 100, 300, 500 and 800°C. The POFA concrete contains 20% partial replacement of cement by weight. Furthermore, two cooling systems which include cooling at room temperature by the natural breeze and water-spray were involved. Compressive strength test was conducted on control specimens as well as concrete specimens revived through the two cooling systems. It was concluded from the study that the residual performance was found to be higher in POFA concrete than in the normal concrete. In addition, water-cooling was realized to aggravate strength reduction in both normal and POFA concretes when compared with air-cooling.

Krishna et al. (2011)[17] studied the effect of elevated temperature on the strength of cured concrete differently. The study investigated the effect of sustained elevated temperature on compressive strength, loss of strength, weight loss and curing method. In the experiment, ordinary Portland cement (OPC), pozzolan Portland cement (PPC), OPC with 10% replacement by micro silica were used. The experiments were carried out in an M40 grade concrete mixing ratio of 1: 1.61: 1.95, designated as mixture A: 1: 1.59: 1.95, designated as mixture B: and 1: 1.595: 1.95, designated as mixture C: it contains OPC-43, PPC-43 and OPC with 10% micro lice respectively as cementing materials with a ratio a w/c=0.43. After carrying out the workability tests, this homogenous concrete mass was poured into the molds of cubes of 150 x 150 x 150 mm size and they were compacted in a vibrating table. They were cured for 28 days using two different curing techniques, such as conventional wet curing (curing tank) and by applying a curing compound that forms a membrane. After 28 days of curing, the samples were transferred to the muffle furnace where they were heated at 150 ° C, 300 ° C and 450 ° C for 1 hour. After 1 hour, they were cooled with air at room temperature. The results revealed that the samples of the concrete mixtures: A, B and C suffered an increasing loss in their compressive strength when exposed to sustained high temperatures. The loss of strength is comparable in mixtures A and B, while it is more in mixture C when cured by conventional curing with water.

Fairbairn et al. (2012)[18] observed the feasibility of possible scenarios of reducing CO_2 emissions for cement manufacturing through the implementation of Clean Development Mechanisms (CDM) associated with the partial replacement of cement by sugarcane bagasse ash (SCBA) . The main reason for this study was to explore the thermal, chemical and mechanical behavior of concrete containing 5 to 20%. This study revealed that there is an improvement in the performance of all properties analyzed. In addition, the CO_2 emissions of two hypothetical scenarios of the implementation of the CDM Project were evaluated. The analysis of the experimental results indicated that there are emission reductions in both scenarios.

Lavanya et al. (2012)[19] studied the effect of SCBA as a partial replacement of cement in concrete. The SCBA was partially replaced with cement in the proportion of 0%, 5%, 10%, 15% and 30% for three different cement-water ratios, ie 0.35, 0.40 and 0.45. For each water and cement ratio, 3 cubes were replaced and their average compressive strength was tabulated for 7, 14 and 28 days. According to the results obtained, it can be concluded that: the SCBA can increase the total resistance of the concrete when it is used up to a cement replacement level of 15% with a w/c ratio of 0.35. SCBA is a valuable pozzolanic material and can potentially be used as a partial replacement of cement.

Otuoze et al. (2012)[20] studied the effect of SCBA as a partial replacement of cement in concrete. In this study, SCBA collected was burned in an incinerator at a controlled temperature of 600 °C. A total of one hundred and eight (108) samples in total, each measuring 100 mm x 100 mm x 100 mm, were melted and cured for 7, 14, 21 and 28 days during 0, 5, 10, 15, 20, 25, 30, 35 and 40% SCBA mixed with OPC. The results showed that the SCBA is a good pozzolan for concrete cementing and the partial blends with OPC could give a good resistance development and other engineering properties in concrete. An optimal mix of 10% SCBA with OPC for reinforced concrete could be used. Higher mixes of 15% and up to 35% SCBA with OPC are acceptable for flat or massive concrete.

Rukzon and Chindaprasirt (2012)[21] studied the effect of SCBA as a partial replacement of cement in high strength concrete. In the study, the cement was partially replaced with 10%, 20% and 30% SCBA. For all the mixtures, 100 mm diameter and 200 mm height of cylindrical samples were molded for the compression strength test.

They were tested at the ages of 7, 28 and 90 days. The results showed that the SCBA improves the strength of the concrete. Concrete containing up to 30% SCBA exhibited better compressive strength than conventional concrete.

Bajare et al. (2013)[22] studied the efficiency for the partial replacement of cement with CBA and if it is possible to use CBA as micro filler as fly ash with pozzolanic properties in concrete production. This ash was crushed for 4, 15, 30 and 45 minutes to discover how the milling period has an impact on CBA pozzolanic activity. 20% and 40% cement in the concrete mix was replaced by ground coal bottom ash. Three different reference mixtures were prepared. In one of the reference mixtures 100% cement was used as binder and in two mixtures the cement was partially replaced by inert filler - dolomite flour - 20 and 40% of the cement mass respectively. Four different mixtures were prepared with coal ash: two of them with ground coal ash for 4 minutes and another two with ground coal ash for 15 minutes, replacing it with 20 and 40% of the cement. The samples were cured for 7 minutes. , 14 and 28 days. The study concluded that CBA can efficiently replace cement up to 20% of its total amount without reducing the compressive strength of concrete, and dolomite flour is more useful as a micro filler than CBA.

Kadam and Patil (2013)[23] studied the effect of CBA as sand replacement on concrete properties with different water cement ratio. In the study, the natural sand was replaced by coal ash at 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100% by weight. The results showed that the compressive strength was increased to 20% replacement and the divided tensile strength and flexural strength increased up to 30% replacement.

Malkit and Siddique (2013)[24] studied the effect of coal ash as a partial replacement for sand. Several concrete properties such as density, compressive strength, flexural strength, divided tensile strength and durability were investigated in this paper from the review of the published research work. The study noted that the density, compression strength, tensile strength and flexural strength of concrete decrease when natural sand is replaced by coal ash due to the porosity and higher water demand of particulate matter.

Malkit and Siddique (2014)[25] investigated the strength properties and microstructural properties of concrete containing coal ash as a partial replacement for fine aggregate.

The cubes of 150 mm in size were melted to examine the compressive strength and the tensile strength by division of the concrete mixes. Cylinders of size 150 mm x 300 mm and 100 mm x 200 mm were molded to measure the modulus of elasticity of the concrete. The compressive strength and the tensile strength by division of the concrete samples were measured at 7 days, 28 days, 90 days and 180 days of age of curing respectively. The modulus of elasticity of the concrete was calculated at the age of curing of 28 days, 90 days and 180 days. The fixed ratio of water and cement of 0.45 was applied in all concrete mixtures. At an early age, the compressive strength was marginally reduced in the inclusion of CBA in the concrete. However, the 28-day compressive strength of the concrete was not significantly affected by replacing the river sand with coal ash because the pozzolanic activity of the coal bottom ash is slow up to 14 days and begins after 28 days of curing. The separation of the tensile strength of concrete improved in all ages of curing in the use of CBA as a fine aggregate in the partial or total replacement of river sand. The modulus of elasticity of the concrete mixture containing CBA as a fine aggregate in the partial or total replacement of the river sand was lower than that of the control concrete.

Muangtong et al. (2013)[26] examined the effects of fine SCBA on the workability and compressive strength of mortars. Initially, the clinker was designed. After that, it was replaced with SCBA with different replacement levels in the range of 0, 20 and 40%, while the plaster was added constantly. For cement mortars, sand, cement, SCBA and water were mixed and molded in cubic molds (50 mm x 50 mm x 50 mm) for the compressive strength and fluidity of the cement mortar tests. The results revealed that the replacement of the clinker with 20% SCBA was appropriate for laboratory scale production and a w / c ratio of 0.735 is adequate for the workability of the resulting cement.

Jaymin Kumar A. Patel, Dr. D. B. Raijiwala(2015)[27] replaced the cement by 0 and 5% SCBA. Cubes of 150X150X150 mm were molded into concrete M25 and the samples were tested for the seventh day, day 14, day 28 and day 56 of curing in the compression test machine. The results show that the compressive strength of concrete can be increased by reducing the cement consumption, which indicates the best use of SCBA instead of pouring and cleaning the environment.

CHAPTER III

MATERIALS AND METHODS

3.1 GENERAL

This chapter briefly explains the materials used and the methods adopted to carry out the study of the workability and compressive strength of concrete containing SCBA and CBA.

3.2 MATERIAL USED

3.2.1 Cement

The cement is a folder that unites the other materials. It has cohesive and adhesive properties in the presence of water. It is obtained by burning the mixture of calcareous and clayey materials. This mixture is suitably impinged and melted in the oven at about 1450 ° C and a product called clinker is obtained. The clinker cools and the cold clinker is mixed with a small percentage of gypsum, then ground to obtain cement. The cements used in the construction can be characterized as hydraulic or non-hydraulic, depending on the capacity of the cement to be established in the presence of water. Hydraulic cements such as OPC adhere and become adhesive due to a chemical reaction between the dry ingredients and the water. The chemical reaction results in mineral hydrates that are not very soluble in water, so they are quite durable in water and are safe from chemical attacks. The different types of cement classified by BIS are OPC, Portland Pozzolana cement (PPC), Portland cement quick hardening, portland slag cement, hydrophobic Portland cement, portland cement of low heat and Portland cement resistant to sulfate. The OPC is the one commonly used in concrete construction. It is more suitable than other cements, for use in general concrete construction where there is no exposure to sulphates in soil or groundwater. It is classified into three grades, namely, 33 degrees, 43 degrees and 53 degrees. This classification depends on the compressive strength of the cement at 28 days. The physical properties of the cement were determined in accordance with the BIS specification and are provided in Chapter IV.

3.2.2 Aggregates

Aggregates are the essential constituents of concrete. The aggregates occupy almost 85 percent of the volume of concrete. Therefore, its effect on various properties such as resistance to compression, contraction, creep, etc. It is undoubtedly considerable. Without the study of aggregates in depth and range, the study of concrete is incomplete. Almost all natural aggregates materials originate from bedrock rocks that are classified into three categories, namely, igneous rocks, sedimentary rocks and metamorphic rocks.

The aggregates can be classified according to their size and weight. On the basis of their weight, the aggregates are classified into aggregates of normal weight, light weight and heavy weight. But, to know more about the concrete, it is very essential that one knows more about the classification according to their sizes. Therefore, depending on their size, the aggregates can also be classified according to the size of the aggregates as coarse aggregates and fine aggregates.

3.2.3 Coarse aggregates

Aggregates most of which is retained on 4.75-mm BIS Sieve are known as coarse aggregates. The various types of coarse aggregates described as:

i) Uncrushed gravel or stone which results from natural disintegration of rock.
ii) Crushed gravel or stone when it results from crushing of gravel or hard stone.
iii) Partially crushed gravel or stone when it is a product of the blending of above two.

The shape of coarse aggregates is an important characteristic since it affects the workability and strength properties of concrete. The shape of aggregates is very much influenced by the type of crusher and the reduction ratio i.e. the ratio of size of material into crusher and the size of finished product. The coarse aggregates can be classified on the basis of their shape as rounded, irregular or partly rounded, angular and flaky. Regarding the shape characteristics of different types of aggregate, angular shape tends to improve the strength because of interlocking characteristics, while the rounded shape improves the workability characteristics because of lower internal friction. Furthermore, the graded coarse aggregate is described by its nominal size i.e. 40 mm, 20 mm, 16 mm and 10 mm. Crushed stone aggregates of nominal size 20 mm and 10 mm in the proportion of 50:50 were used throughout the experimental study. The aggregates were washed to remove dust, dirt and were dried to surface dry condition. The properties of coarse aggregates such as specific gravity, water absorption and fineness modulus were determined and are given in Chapter IV.

3.2.4 Fine aggregates

Aggregates most of which passes 4.75-mm BIS Sieve are known as fine aggregates.

i) **Natural sand** - Fine aggregates resulting from the natural disintegration of rock and which has been deposited by streams or glacial agencies.

ii) **Crushed stone sand** - Fine aggregates produced by crushing hard stone.

iii) **Crushed gravel sand -** Fine aggregates produced by crushing natural gravel.

According to size, fine aggregates can be described as coarse, medium or fine aggregates. Depending on the distribution of the particle size, the fine aggregates are divided into four classification zones according to BIS: 383-1970. Classification zones become finer from Classification Area I to Classification Area IV. The sand that fits zone II was used in this study. The properties of fine aggregates such as specific gravity, modulus of fineness and water absorption were determined and presented in Chapter IV.

3.2.5 Sugarcane bagasse ash

Bagasse ash from sugarcane is produced when the bagasse is reused as biomass fuel in the boilers. When this bagasse is burned at a controlled temperature, it results in ash. The ashes obtained from the boiler of a sugar mill were used in this study shown in Figure 3.1. The sugar mill is located in the Khambarkheda Village of Kheri District of Uttar Pradesh. The collection of the ash was carried out during the boiler cleaning operation. The chemical properties of SCBA are given in Chapter IV.

Figure 3.1: Sugarcane bagasse ash

3.2.6 Coal bottom ash

The coal bottom ash is the waste product of the coal power plant. It is an incombustible material produced after the burning of coal in the furnace of coal-fired power plants. The

CBA obtained from the Feroze Gandhi Unchahar thermal power plant was used in this study shown in Figure 3.2. The thermal plant is located in Unchahar, in the district of Raebareli, in the Indian state of Uttar Pradesh. The physical properties of CBA are given in Chapter IV.

The coal bottom ash is the waste product of the coal power plant. It is an incombustible material produced after the burning of coal in the furnace of coal-fired power plants.
The CBA obtained from the Feroze Gandhi Unchahar thermal power plant was used in this study shown in Figure

Figure 3.2: Coal bottom ash

3.2.7 Water

Water is an important component of concrete because it is responsible for the chemical reaction with cement. Due to its importance, the mixture and the curing water must not contain undesirable organic substances or inorganic constituents in excessive proportions. In this project, clean drinking water was used to mix and cure the concrete. It was free of organic matter, silt, oil, sugar, chloride and acid material according to BIS: 456-2000.

3.3 METHODS

The procedure of methods used for testing concrete, cement, coarse aggregates and fine aggregates are given below:

3.3.1 Methods of concrete mix design

The The process of selecting the right concrete ingredients and determining their relative amounts in order to produce a concrete with the required strength, durability and manageability in the most economical way possible is called concrete mixing design. In the present study, the design of the mixture was carried out using the BIS mix design method, which is based on BIS: 10262- 2009.

The basic steps involved in the design of the concrete mix can be summarized as follows:

i) Depending on the level of quality control, the target average resistance is estimated from the characteristic intensity specified.
ii) The water cement ratio is selected for the average resistance of the target and verified for the durability requirements.
iii) The water content is determined for the required workability.
iv) The cement content can be determined from the proportion of water and cement and the water content obtained in steps (ii) and (iii), respectively, and verified for water requirements.
v) The relative proportion of fine and coarse aggregates is selected from the characteristic of coarse and fine aggregates.
vi) The proportions of the test mixture are determined.
vii) Test mixtures are tested to verify the compressive strength and appropriate adjustments are made to arrive at the final composition of the mixture.

3.3.2 Specific gravity

The specific gravity is a dimensionless defined as the ratio of the density (mass of a unit volume) of a substance to the density (mass of the same unit volume) of a reference substance. The reference substance is water for liquids or air for gases. The specific gravity of the solid is the ratio of its weight in air to the difference between its weight in air and its weight after immersed in water.

3.3.3 Standard consistency of cement as per BIS: 4031 (Part 4) - 1988

The standard consistency of a cement paste is defined as that consistency which will permit a vicat plunger having 10 mm diameter and 50 mm length to penetrate to a depth of 33-35 mm from the top of the mould.

i) Weigh approximately 400 g of cement and mix it with a weighed quantity of water. The time of gauging should be between 3 to 5 minutes.

ii) Fill the vicat mould with paste and level it with a trowel.

iii) Lower the plunger gently till it touches the cement surface.

iv) Release the plunger allowing it to sink into the paste.

v) Note the reading on the gauge.

vi) Repeat the above procedure taking fresh samples of cement and different quantities of water until the reading on the gauge is 5 mm to 7 mm. The water content for the cube is the standard consistency of cement.

3.3.4 Determination of Initial and Final Setting time as per BIS: 4031 (Part 5) - 1988

i) Take 400 g of cement and prepare a neat cement paste with 0.85P of water by weight of cement where P is standard consistency of cement as found earlier.

ii) Gauge time is kept between 3 to 5 minutes.

iii) Fill the vicat mould with cement and smoothen the surface of the paste making it level with the top of the mould. The cement block thus prepared is known as test block.

iv) For initial setting time place the test block confined in the mould and resting on non-porous plate under the rod bearing needle, lower the needle gently in contact with the surface of the test block.

v) In the beginning the needle completely pierces the test block. Repeat this procedure until the needle fails to pierce the block for about 5 mm measured from the bottom of the mould.

vi) The period elapsing between the times when water is added to the time at which the needle fails to pierce the test block by about 5 mm is the initial setting time.

vii) For determining the final setting time, replace the needle of vicat apparatus by the needle with an annular attachment.

viii) The cement is considered finally set when upon applying the final setting needle gently to the surface of the block; the needle makes an impression thereon, while the attachment fails to do so. The period elapsing between the time when water is added to the cement and the time at which the needle makes an impression on the surface of the test block while the attachment fails to do so shall be the final setting time.

3.3.5 Compressive strength of cement as per BIS: 4031 (Part 6) - 1988

Compressive strength of cement is determined from cubes of 70.6 mm X 70.6 mm X 70.6 mm in size, made of cement mortar with one part of cement and three parts of standard sand. The quantity of materials for each cube taken as follows:-

Cement	:	200 g
Standard sand	:	600 g
Water	:	(P/4+3.0) percent weight of cement and sand

Where P is the percentage of water required to produce a paste of standard consistency determined as found in 3.3.3.

Procedure:

i) Gauge a mixture of cement and standard sand in the proportion of 1:3 by weight using (P/4+3.0) percent of water required to produce a paste of standard consistency.
ii) Fill the cube moulds by compacting it for two minutes on a vibrating machine.
iii) Smooth the top surface of the cubes with flat side of trowel.
iv) Immediately upon completion of moulding, place the cube moulds in an atmosphere of $27^{o}C \pm 2°C$.
v) After 24 hours, remove the specimen from the moulds and keep them in water for curing till testing.
vi) Test the cubes at 3, 7 and 28 days age in the compression testing machine.
vii) Report the average compressive strength in N/mm^2.

3.3.6 Sieve analysis for coarse and fine aggregates as per BIS: 2386 (Part 1) - 1963

i) The sample was dried on a hot plate or in an oven at a temperature of 110ºC (230ºF).
ii) The air dry sample was weighed and sieved successfully on the appropriate sieves starting with the large.
iii) Each sieve was shaken separately over a clean tray until not more than a trace passes, but in any case for a period of not less than two minutes. The shaking was done with a varied motion, left to right, backward and forward, circular clockwise and anti-clockwise, and with frequent jarring, so that the material is kept moving over the sieve surface in frequently changing directions.

iv) Lumps of fine materials, if present, was broken by gentle pressure with fingers against the side of the sieve. Light brushing with a soft brush on the underside of the sieve was used to clear the sieve openings.

v) On completion of sieving, the material retained on each sieve, together with any material cleaned from the mesh, was weighed.

3.3.7 Workability of concrete as per BIS: 1199-1959

Workability is that property of freshly mixed concrete or mortar which determines the ease and homogeneity with which it can be mixed, placed, consolidated, and finished. The strength and durability of hardened concrete, in addition to labour costs, depend on concrete having appropriate workability. Workability test methods have been classified in terms of the type of flow produced during the test. Commonly used test methods are:-

i) Slump Test
ii) Compressive Strength Test
iii) Flow Table Test

In present study, workability was found by slump test. The test is an empirical test that measures the workability of fresh concrete. The test is popular due to the simplicity of apparatus used and simple procedure. The apparatus consist of slump cone, scale for measurement and temping rod.

The basic steps involved in the slump test can be summarized as follows:

i) The mould for the slump test is a frustum of a cone, 300 mm (12 in) of height. The base is 200 mm (8 in) in diameter and it has a smaller opening at the top of 100 mm (4 in).

a)

b)

c)

d)

Figure 3.3: Procedure of slump test

ii) The base is placed on a smooth surface and the container is filled with concrete in three layers, whose workability is to be tested.

iii) Each layer is tamped 25 times with a standard 16 mm (5/8 in) diameter steel rod, rounded at the end as shown in Figure 3.3(a).

iv) When the mold is completely filled with concrete, the top surface is struck off (leveled with mould top opening) by means of rolling motion of the trowel x shown in Figure 3.3(b).

v) The mould must be firmly held against its base during the entire operation so that it could not move due to the pouring of concrete and this can be done by means of handles or foot - rests brazed to the mould.

vi) Immediately after filling is completed and the concrete is leveled, the cone is slowly and carefully lifted vertically, an unsupported concrete will now slump as shown in Figure 3.3(c).

vii) The decrease in the height of the center of the slumped concrete is called slump.

viii) The slump is measured by placing the scale just besides the slump concrete as shown in Figure 3.3(d).

The decrease in height of concrete to that of mould is noted with scale.

3.3.8 Compressive strength of concrete as per BIS: 516-1959

The quantities of cement, coarse aggregates (20 mm and 10 mm), fine aggregates, bagasse ash, coal bottom ash and water for each batch were weighed separately. Firstly, the cement and bagasse ash were mixed dry then after fine aggregates and coal bottom ash were mixed uniformly in dry form. The coarse aggregates were mixed to get uniform distribution throughout the batch. Water was added to the mix and then mixed thoroughly for 3 to 4 minutes in mechanical mixer.

(b)

Figure 3.4: Casting of cube specimens

Compressive strength of concrete was determined from cubes of 150 mm X 150 mm X 150 mm in size. Cube moulds were cleaned and oil was applied. Then the concrete was filled into the cube moulds and get vibrated to ensure proper compaction as shown in Figure 3.4(a). The surface of the concrete was finished with the top of the mould using trowel. The finished specimens were left to harden in air for 24 hours as shown in Figure 3.4(b). The specimens were removed from the moulds after 24 hours of casting as shown in Figure 3.5(a). These were placed in the water tank, filled with potable water in the laboratory.

Specimens were taken out from the curing tank at the ages of 7, 14, and 28 days. Surface water was wiped off and specimens were immediately tested after removal from the curing tank. The compressive strength of concrete cubes was found on Universal Testing Machine (UTM) as shown in Figure 3.5(b). A loading rate of 5kN/s was applied for the compressive strength test.

(a) **(b)**

Figure 3.5: Demoulding and Testing of cube specimens

3.3.9 Compressive strength of concrete at elevated temperature

Compressive strength of concrete was also determined at different temperature ranges. The cubes of 10 cm X 10 cm X 10 cm in size were used for this purpose. All the cubes were cured for 28 days prior to heating. The hardened concrete cubes were then transferred to the muffle furnace as shown in Figure 3.6(a). They were heated from room temperature to 150°C, 300°C and 600°C for two and half hour to achieve a uniform temperature distribution across them as shown in Figure 3.6(b). After that furnace was turned off and samples were cooled to room temperature. All cooled specimens subjected to compression test under UTM.

(b)

Figure 3.6: Heating of cube specimens into muffle furnace

CHAPTER IV

RESULTS AND DISCUSSION

The present chapter deals with the results of tests conducted on materials used in research work. The performance of various mixes containing different percentage of SCBA and CBA is discussed. All the tests were conducted in accordance with the methods described in Chapter III.

4.1 PROPERTIES OF MATERIALS

The aim of studying various properties of material used is to check the conformance with codal requirements and to enable an engineer to design a concrete mix for a particular strength. The following materials were used in the present study.

4.1.1 Properties of cement

In present investigation OPC of 43 grades was used. The physical properties of the cement were obtained on conducting some appropriate tests are listed in Table 4.1 and the corresponding standard for that parameter as per BIS: 8112-2013 is also listed in Table 4.1.

Table 4.1: Properties of OPC 43 grade cement

Sr. No.	Characteristics	Value Obtained experimentally	Values specified by BIS: 8112-2013
1.	Specific Gravity	3.15	-
2.	Standard consistency	31%	-
3.	Initial Setting time	45 minutes	30 minutes (minimum)
4.	Final Setting time	220 minutes	600 minutes (maximum)
5.	Compressive Strength 7 days 14 days 28 days	 25.54 N/mm^2 36.12 N/mm^2 49.53 N/mm^2	 23 N/mm^2 33 N/mm^2 43 N/mm^2

The values are conforming to specifications given in BIS: 8112-2013.

4.1.2 Properties of aggregates

4.1.3 Properties of coarse aggregates

The coarse aggregates used in present investigation, were a mixture of two locally available crushed stone of 10 mm and 20 mm size in 50:50 proportions. The aggregates were washed to remove dirt, dust and then dried to surface dry condition. Specific gravity and other properties of coarse aggregates are given in Table 4.2. The sieve analysis of coarse aggregates was done and the results of sieve analysis are shown in Table 4.3 & Table 4.4. After proportioning of coarse aggregates, sieve analysis was also performed which is given in Table 4.5 respectively.

Table 4.2: Properties of coarse aggregates

Colour	Grey
Shape	Angular
Maximum Size	20 mm
Specific Gravity	2.65
Water Absorption (%)	0.61
Fineness modulus	6.57

Table 4.3: Sieve analysis of coarse aggregates (10 mm size)

Total weight of sample = 2000 g

BIS- Sieve Designation	Weight Retained on sieve (g)	Cumulative weight retained (g)	Cumulative %age weight retained	%age passing
80 mm	Nil	Nil	Nil	100
40 mm	Nil	Nil	Nil	100
20 mm	Nil	Nil	Nil	100
12.5 mm	14	14	0.70	99.30
10 mm	614	628	31.40	68.60
4.75 mm	1240	1868	93.40	6.60
2.36 mm	105	1973	98.65	1.35

Table 4.4: Sieve analysis of coarse aggregates (20 mm size)

Total weight of sample = 2000 g

BIS- Sieve Designation	Weight Retained on sieve (g)	Cumulative weight retained (g)	Cumulative %age weight retained	%age passing
80 mm	Nil	Nil	Nil	100
40 mm	Nil	Nil	Nil	100
20 mm	Nil	Nil	Nil	100
10 mm	1904	1904	95.20	4.80
4.75 mm	96	200	100	0

Table 4.5: Sieve analysis of proportioned of coarse aggregates

BIS- Sieve Designation	50:50 Proportion (10mm: 20mm) Weight Retained	Cumulative weight retained (g)	Cumulative % age weight Retained	% age passing	BIS: 383-1970 Requirements
80 mm	Nil	Nil	Nil	100	100
40 mm	Nil	Nil	Nil	100	100
20 mm	Nil	Nil	Nil	100	95-100
10 mm	1262	1262	63.10	36.90	25-55
4.75 mm	629	1891	94.55	5.45	0-10

Coarse aggregates are conforming to Table 2 of BIS: 383-1970

4.1.4 Properties of fine aggregates

Natural sand was used as fine aggregates, collected from Sharda River (Kheri). The specific gravity, water absorption and fineness modulus of fine aggregates was determined as 2.71, 1.21 and 2.67 respectively. It was brown in colour with coarser shape of particles. The sieves analysis of fine aggregates is given in Table 4.6.

Table 4.6: Sieve analysis of fine aggregates

Total weight of sample = 500 g

BIS-Sieve Designation	Weight Retained on Sieve (g)	Percentage Weight Retained on sieve	Cumulative Percentage Weight Retained on sieve	Percentage passing	Percentage passing for Grading Zone- II as per BIS: 383-1970
10 mm	Nil	Nil	Nil	100	100
4.75 mm	42	8.40	8.40	91.60	90-100
2.36 mm	24	4.80	13.20	86.80	75-100
1.18 mm	70	14.00	27.20	72.80	55-90
600 micron	106	21.20	48.40	51.60	35-55
300 micron	121	24.20	72.60	27.40	8-30
150 micron	125	25.00	97.60	2.40	0-10

Fine aggregates are conforming to grading zone II as per BIS-383:1970

4.1.5 Properties of sugarcane bagasse ash

The ash was obtained from the boiler of a sugar mill situated at village Khambarkheda, which falls at a distance of approx 15 kms from Lakhimpur, a city in Kheri District of Uttar Pradesh. The ash was grinded before it was used as a cement replacement material. After grinding, the fraction of particles retained on 45µm sieve was 15%. The chemical properties of SCBA are given in Table 4.7.

Table 4.7: Chemical properties of SCBA

(Source: Bajaj Hindustan Sugar Ltd., Khambarkheda, Kheri.)

Sr. No.	Chemical component	% of Chemical component
1.	SiO_2	78.34%
2.	Fe_2O_3	3.61%
3.	Al_2O_3	8.55%
4.	CaO	2.15%
5.	Na_2O	0.12%
6.	K_2O	3.46%
7.	Ignition loss	0.42%

4.1.6 Properties of Coal bottom ash

The ash was obtained from Feroze Gandhi Thermal Power Plant Unchahar, [U.P.]. The physical properties of CBA are given in Table 4.8.

Table 4.8: Physical properties of CBA

Colour	Grayish or Shiny Black
Particles shape and texture	Spherical, irregular and porous
Specific Gravity	1.78
Water Absorption	9.64%

4.2 TESTING OF CONCRETE

In this study, the specimens were tested after 7, 14 and 28 days of curing to study the effect of SCBA and CBA in concrete while all the cubes were tested after 28 days of curing to study the effect of different temperature ranges on compressive strength of all mixes. The 24 mixes were prepared other than control mix. The cement was replaced with different replacement levels of SCBA (0%, 5%, 10%, 15% & 20%) while fine aggregates was replaced with different ranges of CBA (0%, 10%, 20%, 30% & 40%). The water/cement (w/c) ratio in all the mixes was kept 0.55. The cubes considered in this study consisted of 225 numbers of 150mm side cubes and same numbers of 100mm side cubes. The ratio of different materials used in each mix and mix designation are given below in Table 4.9.

Table 4.9: Designation of concrete mix

Mix	CBA (%)	SCBA (%)	Cement (%)
D1	0	0	0
D2		5	95
D3		10	90
D4		15	85
D5		20	80
D6		0	0
D7		5	95

D8	10	10	90
D9		15	85
D10		20	80
D11	20	0	0
D12		5	95
D13		10	90
D14		15	85
D15		20	80
D16	30	0	0
D17		5	95
D18		10	90
D19		15	85
D20		20	80
D21	40	0	0
D22		5	95
D23		10	90
D24		15	85
D25		20	80

4.2.1 Mix design of concrete by BIS recommendations

The present investigation includes design of concrete mix for M20 grade of concrete. The guideline given in codes BIS: 10262-2009 and BIS: 456-2000 has been adopted for mix design of concrete.

4.2.2 Stipulation for proportioning

a) Grade designation : M-20

b) Type of cement : OPC 43 grade conforming to BIS 8112

c) Maximum nominal size of aggregate : 20 mm

d) Minimum cement content : 300 kg/m^3

e) Maximum water-cement ratio : 0.55

f) Workability : 50 mm (slump)

g) Degree of supervision : Good

h) Type of aggregate : Crushed angular aggregate

i) Maximum cement content : 450 kg/m^3

4.2.3 Test data for materials

Cement used : OPC 43 grade conforming to BIS: 8112

Specific gravity of cement : 3.15

Specific gravity of Coarse aggregate : 2.65

Fine aggregate Water absorption : 2.71

Coarse aggregate : 0.61%

Fine aggregate : 1.21 %

Free (surface) moisture

Coarse aggregate : Nil

Fine aggregate Sieve analysis : Nil

Coarse aggregate : Conforming to Table 2 of BIS: 383-1970

Table 4.10: Sieve analysis of coarse aggregates

BIS- Sieve Designation	50:50 Proportion (10 mm: 20mm) Weight Retained	Cumulative weight retained (g)	Cumulative %age weight Retained	% age passing	BIS: 383-1970 Requirements
80 mm	Nil	Nil	Nil	100	100
40 mm	Nil	Nil	Nil	100	100
20 mm	Nil	Nil	Nil	100	95-100
10 mm	1262	1262	63.10	36.90	25-55
4.75 mm	629	1891	94.55	5.45	0-10

1. Fine aggregates : Conforming to grading Zone II of Table 4 of BIS 383-1970.

4.2.4 Target strength for mix proportioning

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

Where,

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

f_{ck} = Characteristic compressive strength at 28 days,

and s = Standard deviation
From Table 4.11, standard deviation for M20 is 4 N/mm^2 Therefore, target strength = 20+ 1.65 x 4 = 26.6 N/mm^2

Table 4.11: Assumed Standard Deviation (Source: Table 1 of BIS: 10262:2009)

Grade of Concrete	Assumed Standard Deviation in N/mm^2
M 10	3.5
M 15	3.5
M 20	4.0
M 25	4.0
M 30	5.0
M 35	5.0
M 40	5.0
M 45	5.0
M 50	5.0

4.2.5 Selection of water-cement ratio

From Table 4.12, maximum water cement ratio: 0.55

Table 4.12: 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 (Source: Table 5 of BIS 456)

Sr. No.	Exposure	Plain Concrete			Reinforced Concrete		
		Minimum Cement Content (kg/m^3)	Maximum Free w/c Ratio	Minimum Grade of Concrete	Minimum Cement Content (kg/m^3)	Maximum Free w/c Ratio	Minimum Grade of Concrete
1.	Mild	220	0.60	--	300	0.55	M 20
2.	Moderate	240	0.60	M 15	300	0.50	M 25
3.	Severe	250	0.50	M 20	320	0.45	M 30
4.	Very Severe	260	0.45	M 20	340	0.45	M 35
5.	Extreme	280	0.40	M 25	360	0.40	M 40

Based on experience, adopt water-cement ratio as 0.55 Maximum water cement ratio is 0.55, Hence O.K.

4.2.6 Selection of water content

From Table 4.13, maximum water content is 186 liter (for 25 to 50 mm slump range) for 20 mm aggregate.

Table 4.13: Maximum water content per cubic metre of concrete for nominal maximum size of aggregate.

(Source: Table 2 of BIS: 10262-2009)

Sr. No.	Maximum Size Of Aggregates (mm)	Maximum Water Content (Kg)
I.	10	208
II.	20	186
III.	40	165

Based on experience, adopt 186 litres.

4.2.7 Calculation of cement content

Water-cement ratio = 0.55

Cement content = 186\0.55 = 338.18 kg/m^3

From Table 4.12, minimum cement content for 'mild' exposure condition is 300 kg/m^3

338.18 kg/m^3 > 300 kg/m^3. Hence, O.K.

4.2.8 Proportion of volume of coarse aggregate and fine aggregate content

From Table 4.14, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone II) for water-cement ratio of 0.50 is 0.62.

Table 4.14: Volume of coarse aggregate per unit volume of total aggregate for different zone of fine aggregate.

(Source: Table 3 of BIS: 10262-2009)

Sl NO.	**Nominal Maximum Size Aggregate**	**Volume Of Coarse Aggregate per unit Volume of total Aggregate for Different Zones of Fine Aggregate**			
	Mm	Zone IV	Zone III	Zone II	Zone I
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

In present investigation water cement ratio is 0.55. Therefore, volume of coarse aggregate has to be decreased to increase the content of fine aggregate. As water cement ratio is higher by 0.05, the proportion of volume of coarse aggregate is decreased by 0.01 (at the rate of -\+ 0.01 for every +\- 0.05 change in water cement ratio). Therefore, corrected proportion of volume of coarse aggregates for water cement ratio of 0.55 is 0.61.

4.2.9 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 : $\frac{Mass\ of\ Cement}{Specific\ Gravity\ of\ Cement}\ X\ \frac{1}{1000}$

c) Volume of water : $\frac{186}{1}\ X\ \frac{1}{1000}$ =0.186

d) Volume of all in aggregate : [a-(b+c)]

: [1-(0.107 + 0.186)] = 0.707 m3

e) Mass of coarse aggregate : d × Volume of coarse aggregate × Specific gravity of coarse aggregate × 1000

: 0.707 x 0.61 x 2.65 x 1000

= 1142.87 kg

f) Mass of fine aggregate : d × Volume of fine aggregate × Specific gravity of fine aggregate × 1000

: 0.707 x 0.39 x 2.71 x 1000

= 747.23 kg

Table 4.15: Proportion of different materials

Water	Cement	Fine aggregates	Coarse aggregates
186 liters	338.18 kg	747.23 kg	1142.87 kg
0.55	1	2.21	3.38

4.2.10 Preparation of trial mixes

Based on the concrete mix design by BIS method, four trials mixes were prepared. Two trials mixes were prepared with water cement ratio of 0.55 and other two mixes were prepared with water cement ratio of 0.50. The nine cubes were cast for each mix and were tested at 3, 7 and 28 days. The mix proportions for various constituents have been summarized in Table 4.16

Table 4.16: Quantities per cubic meter for trial mixes (M20)

Mix No.	Water Cement Ratio	Water (L)	Cement (kg)	Sand (kg)	Coarse Aggregates (kg)	Average cube strength at 7 days (N/mm^2)	Average cube strength at 14 days (N/mm^2)	Average cube strength at 28 days (N/mm^2)	Slump (mm)
MR1	0.55	186	338.18	747.23	1142.87	18.01	23.65	28.40	20
MR2	0.55	197.16	358.47	728.30	1113.77	17.72	23.57	27.73	60
MR3	0.50	186	372.00	716.74	1143.52	19.72	25.40	31.90	25
MR4	0.50	197.16	394.32	698.20	1113.95	18.23	23.74	29.85	55

The mix M_{R2} was chosen as the control mix because its average cube strength was very close to the target mean strength of concrete among all mixes. Furthermore, this mix also had good workability characteristics. Based on mix M_{R2} the mix proportions of concrete mixes are given in Table 4.17.

Table 4.17: Mix proportions of different concrete mixes

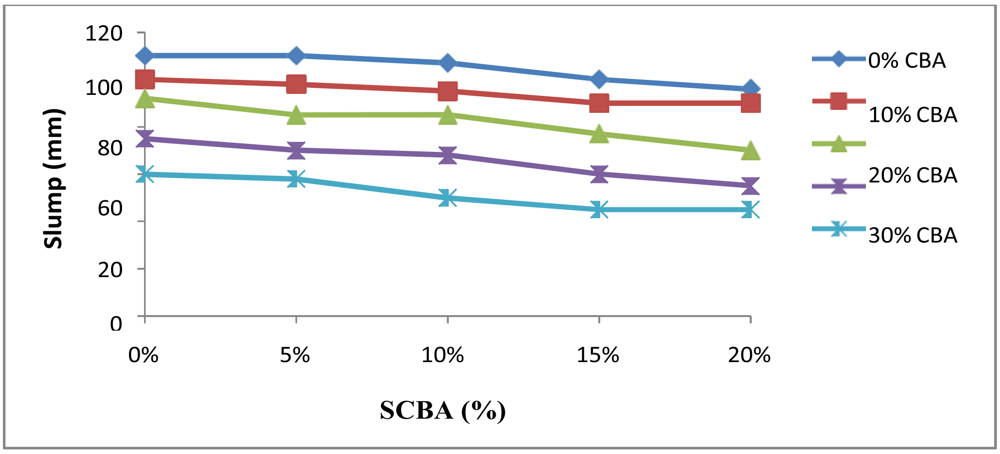
Mix	SCBA (%)	CBA (%)	Cement (Kg/m^3)	SCBA (Kg/m^3)	Fine Aggregates (Kg/m^3)	CBA (Kg/m^3)	Coarse Aggregates (Kg/m^3)	Water (L/m^3)
D1	0	0	358.47	0	728.20	0	1113.77	197.16
D2	5	0	340.55	17.92	728.20	0	1113.77	197.16
D3	10	0	322.62	35.85	728.20	0	1113.77	197.16
D4	15	0	304.70	53.77	728.20	0	1113.77	197.16
D5	20	0	286.78	71.69	728.20	0	1113.77	197.16
D6	0	10	358.47	0	655.38	72.82	1113.77	197.16
D7	5	10	340.55	17.92	655.38	72.82	1113.77	197.16
D8	10	10	322.62	35.85	655.38	72.82	1113.77	197.16
D9	15	10	304.70	53.77	655.38	72.82	1113.77	197.16
D10	20	10	286.78	71.69	655.38	72.82	1113.77	197.16
D11	0	20	358.47	0	582.56	145.64	1113.77	197.16
D12	5	20	340.55	17.92	582.56	145.64	1113.77	197.16
D13	10	20	322.62	35.85	582.56	145.64	1113.77	197.16
D14	15	20	304.70	53.77	582.56	145.64	1113.77	197.16
D15	20	20	286.78	71.69	582.56	145.64	1113.77	197.16
D16	0	30	358.47	0	509.74	218.46	1113.77	197.16
D17	5	30	340.55	17.92	509.74	218.46	1113.77	197.16
D18	10	30	322.62	35.85	509.74	218.46	1113.77	197.16
D19	15	30	304.70	53.77	509.74	218.46	1113.77	197.16
D20	20	30	286.78	71.69	509.74	218.46	1113.77	197.16
D21	0	40	358.47	0	436.92	291.28	1113.77	197.16
D22	5	40	340.55	17.92	436.92	291.28	1113.77	197.16
D23	10	40	322.62	35.85	436.92	291.28	1113.77	197.16
D24	15	40	304.70	53.77	436.92	291.28	1113.77	197.16
D25	20	40	286.78	71.69	436.92	291.28	1113.77	197.16

4.3 WORKABILITY OF CONCRETE

In fresh condition, workability characteristics for high quality concrete should be acceptable (90-100mm slump height). The desired strength of concrete can only be obtained if fresh concrete has adequate slump value. In present study, workability of each mix was measured in terms of slump. The slump values of each mix are given in Table 4.18 and presented by Figure 4.1. From results, it can be concluded that the concrete mixes decreased with the increase in content of SCBA and CBA. The slump values decreased from 110 mm to 45 mm when 40% of fine aggregates were replaced by CBA and 20% of cement by SCBA. It can be due to the porous structure of CBA's particles which cause the higher water absorption. Due to higher water absorption of particles, concrete rapidly absorbed water which reduced the free water content of mix. In addition, rough and angular shape of SCBA's particles increased the inter particle friction which further decreased the slump values of concrete.

Table 4.18: Test results for workability of concrete

Mix	SCBA (%)	CBA (%)	Slump(mm)
D1	0	0	20
D2	5		20
D3	10		18
D4	15		16
D5	20		14
D6	0	10	60
D7	5		58
D8	10		55.5
D9	15		54
D10	20		53.5
D11	0	20	25
D12	5		23.5
D13	10		22
D14	15		21
D15	20		20
D16	0	30	55
D17	5		53
D18	10		52
D19	15		50.5
D20	20		48
D21	0	40	24
D22	5		22
D23	10		21.5
D24	15		20
D25	20		18



Graph 4.1: Slump values of concrete with different replacement levels of SCBA and CBA

4.4 COMPRESSIVE STRENGTH OF CONCRETE

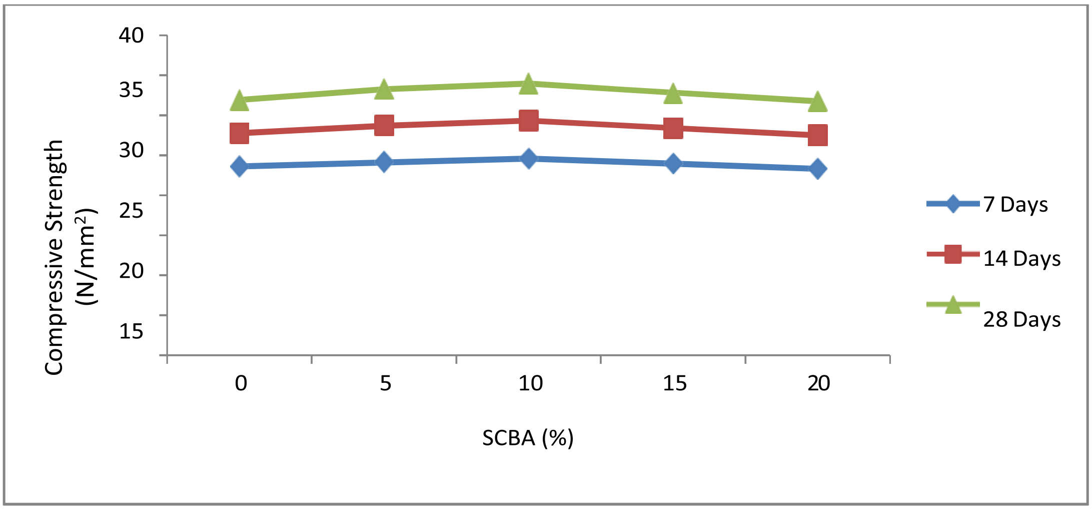
The compressive strength of all concrete mixes was measured at the age of 14, 28 and 60 days. The results of average compressive strength and the percentage loss or gain in compressive strength are given in Table 4.19 and Table 4.20 respectively. The effect of both waste materials on compressive strength at curing ages of 14, 28 and 60 days is illustrated by Figure 4.2 to Figure 4.11. It is evident from Table values that with increasing the SCBA content (up to 15%) the improvement in compressive strength of concrete mixes is continuous. At the curing age of 14 days, the concrete containing 5%, 10% and 15% SCBA as cement, gained 2.5%, 4.2% and 1.6% of strength while at 20% replacement level concrete loosed 1.2% of strength. It was also concluded that the gain in compressive strength of SCBA concrete mixes at curing age of 60 days was more than that of 14 and 28 days of curing. After 60 days of curing, compressive strength of SCBA concrete mixes exceeded by 4.3%, 6.5% and 2.7% while decreased by 0.5% as compared to control concrete mix when cement was replaced up-to 5%, 10%, 15% and 20% respectively. Nevertheless, the replacement of 15% of SCBA still improves the compressive strength of concrete as compared to the control concrete but for much better results, the 10% of SCBA seems to be the optimum. This improvement in strength may be due to finer particle size of SCBA which gives filler effect. In addition, high silica content as well as high pozzolanic reaction between calcium hydroxide and reactive silica in SCBA also improves the strength characteristics of concrete. On the other hand, there was a significant loss in compressive strength of concrete when fine aggregates replaced with CBA. The incorporation of bottom ash produced relatively low strength concrete as compared to reference concrete due to its porous structure and higher water absorption. The compressive strength decreases at every replacement level of CBA with fine aggregates. There was no improvement in strength at any curing period. As shown in Table 4.19, the compressive strength of concrete containing 10%, 20%, 30%, and 40% CBA as fine aggregates loosed 2.3%, 5.1%, 6.9%, and 9.3% as compared to control concrete when cured to 14 days. The same trend was observed for curing period of 28 and 60 days. It can be seen that the loss in compressive strength was minor up to 10% of CBA but beyond 10%, there was large reduction in compressive strength. From the above, it can be concluded that as combination we can replace cement with SCBA up to 15% and fine aggregates with CBA up to 10% without any loss in strength of concrete. But, to obtain much better result in strength characteristics as compared to reference concrete, the combination of 10% SCBA and 10% CBA is recommended.

Table 4.19: Test results for average compressive strength of concrete

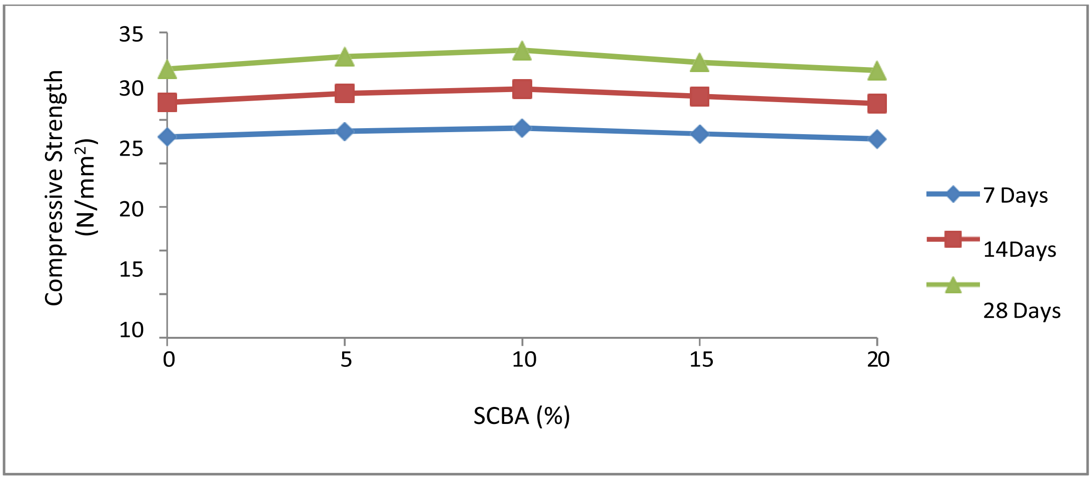
Mix	SCBA (%)	CBA (%)	Average compressive strength (N/mm^2) of concrete for different curing days		
			7 days	14 days	28 days
D1	0	0	23.57	27.73	31.88
D2	5		24.16	28.69	33.25
D3	10		24.56	29.31	33.95
D4	15		23.95	28.37	32.74
D5	20		23.29	27.48	31.72
D6	0	10	23.03	26.98	30.80
D7	5		23.66	28.04	32.24
D8	10		24.06	28.51	32.96
D9	15		23.36	27.67	31.59
D10	20		22.77	26.84	30.64
D11	0	20	22.37	26.17	29.99
D12	5		23.00	27.26	31.43
D13	10		23.41	27.81	32.07
D14	15		22.79	26.93	31.02
D15	20		22.18	26.26	30.06
D16	0	30	21.94	25.76	29.30
D17	5		22.58	26.81	30.67
D18	10		23.03	27.31	31.47
D19	15		22.42	26.54	30.25
D20	20		21.90	25.71	29.48
D21	0	40	21.38	25.04	28.72
D22	5		22.23	26.18	30.19
D23	10		22.49	26.54	30.96
D24	15		22.04	25.82	29.71
D25	20		21.43	24.98	28.63

Table 4.20: Percentage loss (-) or gain (+) in compressive strength of concrete

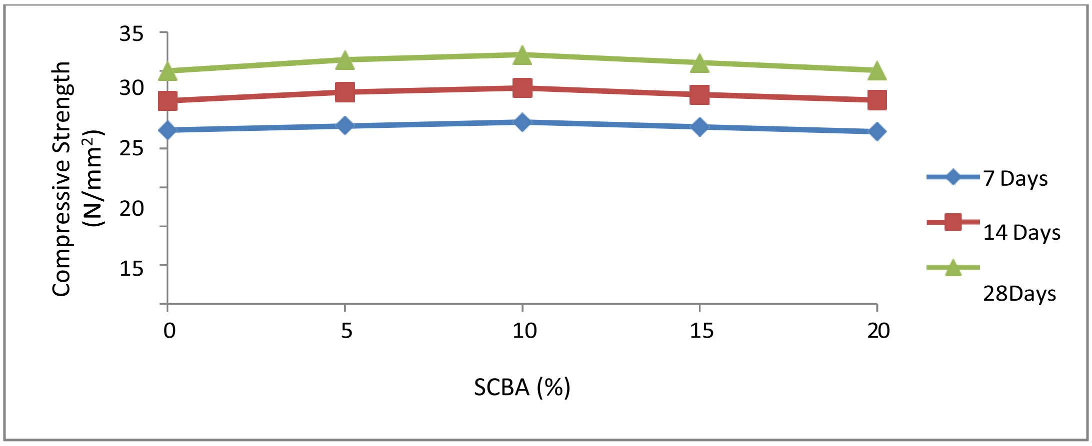
Mix	SCBA (%)	CBA (%)	Percentage loss (-) or gain (+) in compressive strength for different curing days		
			7 days	14 days	28 days
D1	0	0	0	0	0
D2	5		+2.5	+3.5	+4.3
D3	10		+4.2	+5.7	+6.5
D4	15		+1.6	+2.3	+2.7
D5	20		-1.2	-0.9	-0.5
D6	0	10	-2.3	-2.7	-3.4
D7	5		+0.4	+1.1	+1.1
D8	10		+2.1	+2.8	+3.4
D9	15		-0.9	-0.2	-0.9
D10	20		-3.4	-3.2	-3.9
D11	0	20	-5.1	-5.7	-5.9
D12	5		-2.4	-1.7	-1.4
D13	10		-0.7	+0.1	+0.6
D14	15		-3.4	-2.9	-2.7
D15	20		-5.9	-5.3	-5.7
D16	0	30	-6.9	-7.1	-8.1
D17	5		-4.2	-3.3	-3.8
D18	10		-2.3	-1.5	-1.3
D19	15		-4.9	-4.3	-5.1
D20	20		-7.1	-7.3	-7.5
D21	0	40	-9.3	-9.7	-9.9
D22	5		-5.7	-5.6	-6.8
D23	10		-4.6	-4.1	-2.9
D24	15		-6.5	-6.9	-6.8
D25	20		-9.1	-9.9	-10.2



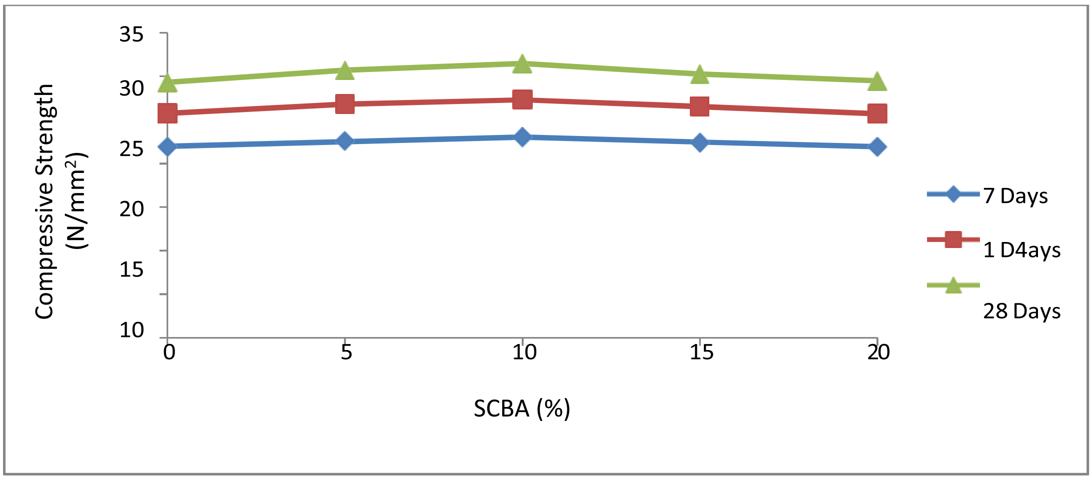
Graph 4.2: Compressive strength of concrete with different replacement levels of cement with SCBA for 0% CBA



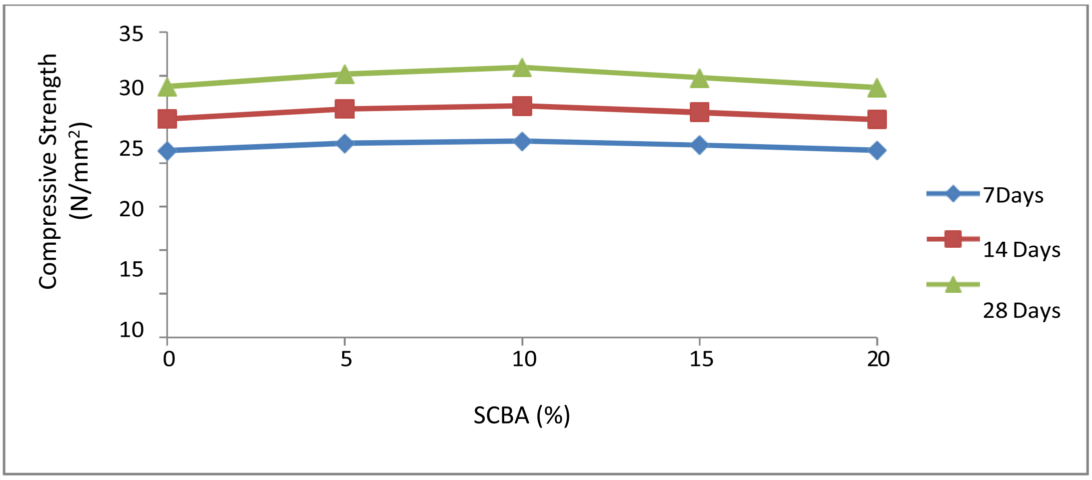
Graph 4.3: Compressive strength of concrete with different replacement levels of cement with SCBA for 10% CBA



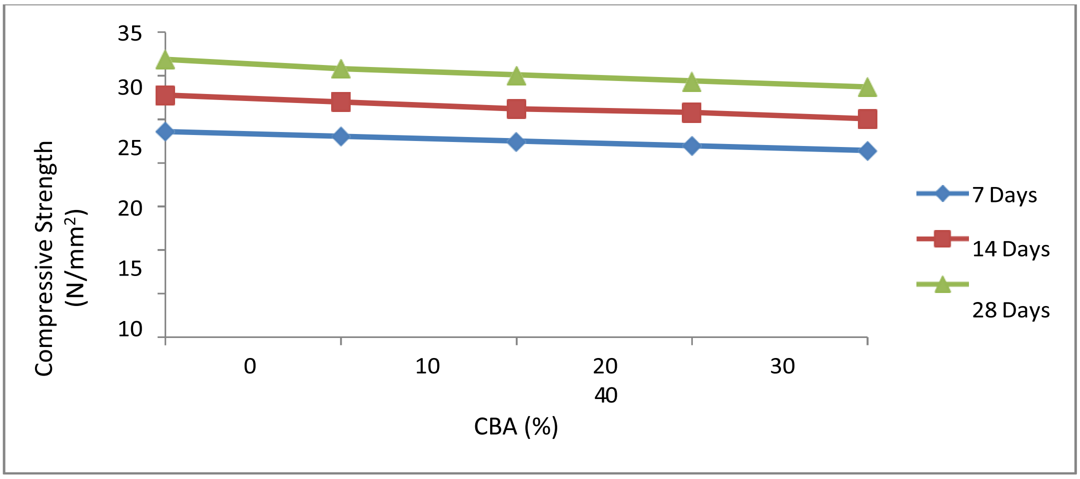
Graph 4.4: Compressive strength of concrete with different replacement levels of cement with SCBA for 20% CBA



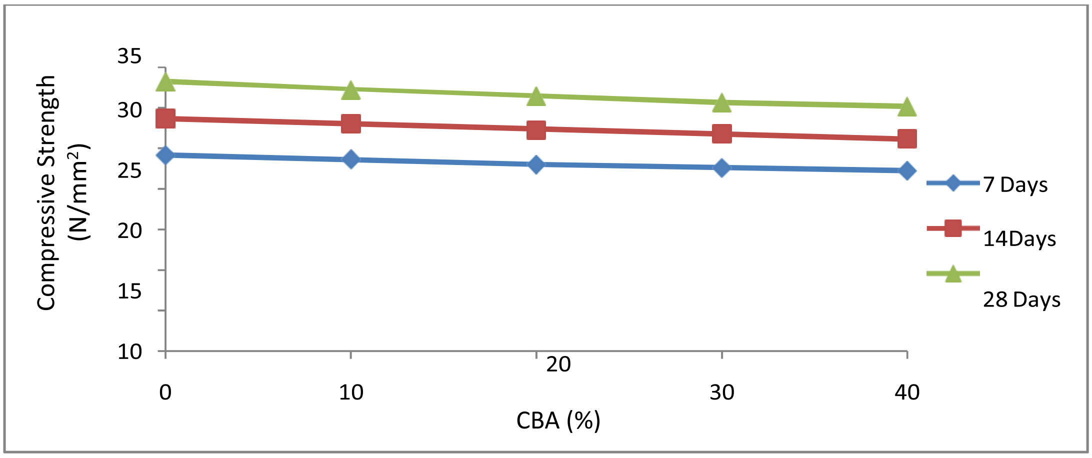
Graph 4.5: Compressive strength of concrete with different replacement levels of cement with SCBA for 30% CBA



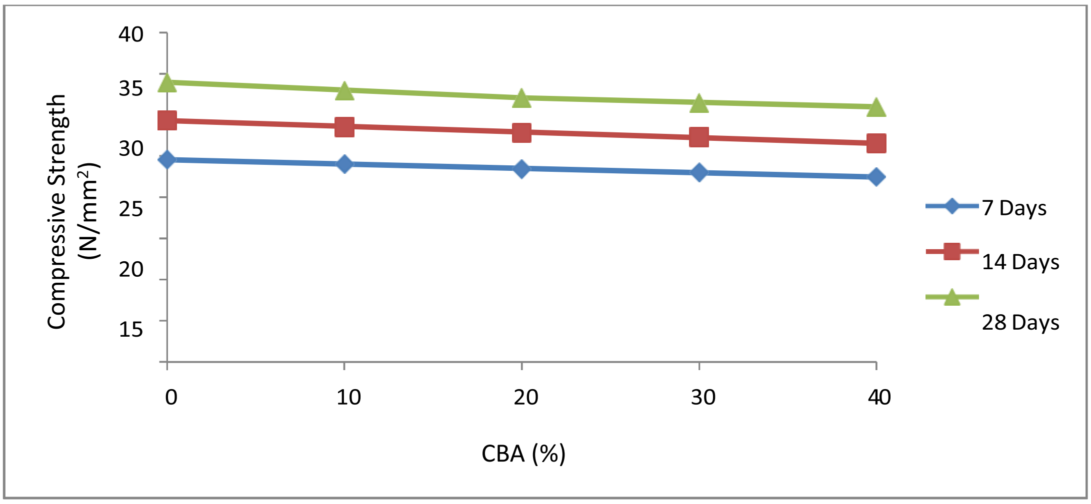
Graph 4.6: Compressive strength of concrete with different replacement levels of cement with SCBA for 40% CBA



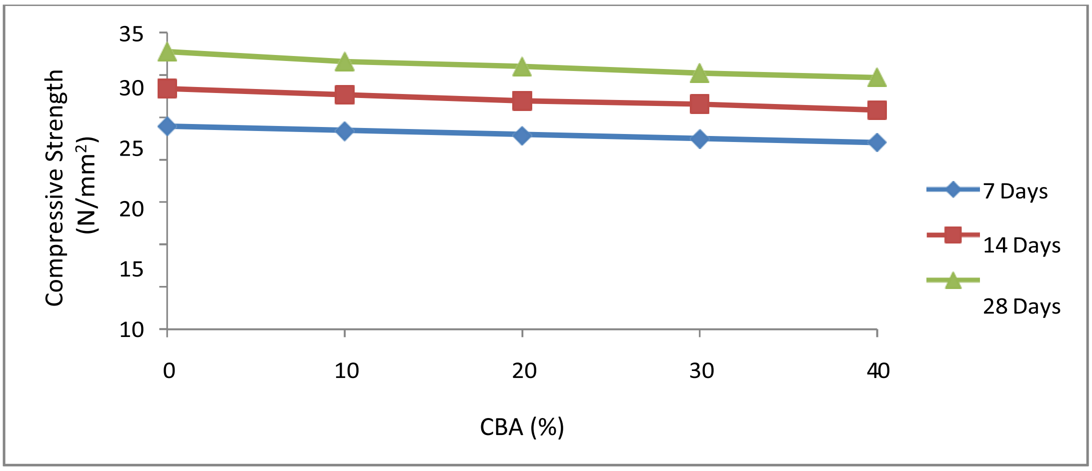
Graph 4.7: Compressive strength of concrete with different replacement levels of fine aggregates with CBA for 0% SCBA



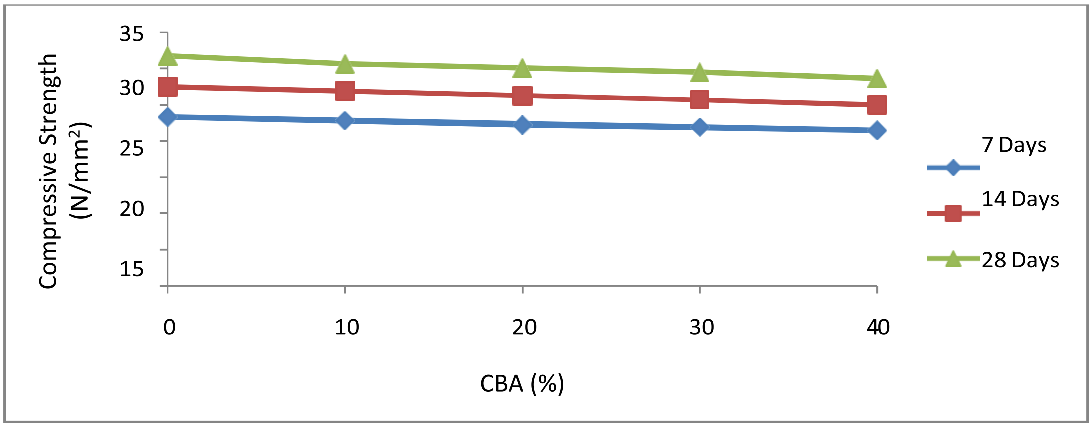
Graph 4.8: Compressive strength of concrete with different replacement levels of fine aggregates with CBA for 5% SCBA



Graph 4.9: Compressive strength of concrete with different replacement levels of fine aggregates with CBA for 10% SCBA



Graph 4.10: Compressive strength of concrete with different replacement levels of fine aggregates with CBA for 15% SCBA



Graph 4.11: Compressive strength of concrete with different replacement levels of fine aggregates with CBA for 20% SCBA

4.5 COMPRESSIVE STRENGTH OF CONCRETE AT ELEVATED TEMPERATURE

The residual compressive strength and percentage loss in compressive strength of all concretes mixes at room temperature and after heating to 150°C, 300°C and 600°C is given in Table 4.21 and Table 4.22 respectively. The combined effect of temperature elevation and both waste materials on compressive strength at curing age of 28 days is illustrated by Figure.

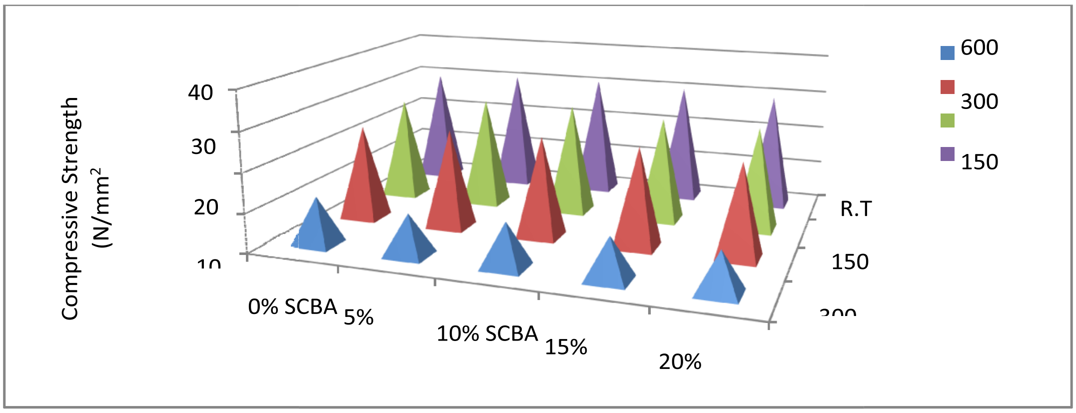
These Tables and Figures clearly show that the compressive strength of all concrete mixes decreases at elevated temperature. According to the results obtained from present investigation, the strength of concrete with 0% replacement of SCBA and CBA after heated to150°C, 300°C and 600°C was 88.9%, 81.9%, and 40.3% of its unheated strength respectively. Almost similarly trend was observed in SCBA and CBA concrete mixes also. The concrete containing 10% SCBA and 30% CBA exhibited greatest loss in strength, about 12.9% of its unheated strength when heated to 150°C while concrete containing 5% SCBA and 0% CBA exhibited minimum loss in strength, about 7.6% of its unheated strength when heated to 150°C. Similarly, concrete containing 5% SCBA and 10% CBA exhibited greatest loss in strength, about 22.1% of its unheated strength when heated to 300°C while concrete containing 10% SCBA and 10% CBA exhibited minimum loss in strength, about 17.1% of its unheated strength when heated to 300°C. The large reduction in compressive strength was observed when the specimens were heated to 600°C. The mix contains 5% SCBA and 0% CBA exhibit large reduction in compressive strength among all mixes while mix contains 0% SCBA and 30% CBA exhibit minimum reduction in compressive strength. The main cause of this reduction in strength is extensive inner cracking. After the evaporation of physically and chemically bound water, a pressure is build-up which results into this extensive inner cracking. Apart from it, the cement paste contracts and aggregate expands due to loss of water at higher temperature which leads to loss of the bond between paste and aggregates. So, it can be concluded that the contribution of SCBA and CBA cannot change the strength properties of concrete during heating.

Table 4.21: Residual compressive strength of concrete mixes at different temperature range

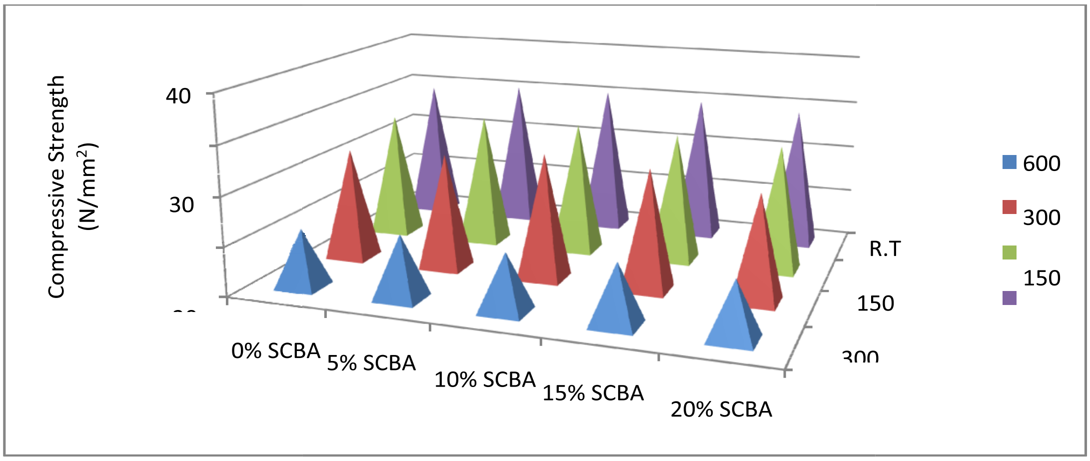
Mix	SCBA (%)	CBA (%)	Residual compressive strength (N/mm^2) at different temperature ranges			
			Room Temperature	150°C	300°C	600°C
D1	0	0	29.85	26.54	24.45	12.03
D2	5		30.84	28.49	25.46	10.37
D3	10		31.24	28.56	25.70	11.02
D4	15		30.77	26.95	25.30	10.44
D5	20		29.68	26.42	23.84	10.15
D6	0	10	29.14	26.15	23.11	11.86
D7	5		30.56	27.35	23.80	12.80
D8	10		30.92	27.38	25.63	11.57
D9	15		30.03	26.69	24.53	12.07
D10	20		28.99	25.97	22.64	11.34
D11	0	20	28.41	25.71	23.21	10.85
D12	5		29.49	26.57	23.97	10.37
D13	10		30.14	27.34	24.84	11.02
D14	15		29.31	26.95	25.31	10.44
D15	20		28.38	25.35	22.73	11.75
D16	0	30	27.82	24.26	21.73	12.19
D17	5		29.22	25.60	23.05	11.86
D18	10		29.51	25.68	23.43	10.96
D19	15		28.72	25.32	23.48	11.62
D20	20		27.77	24.65	22.66	10.41
D21	0	40	27.04	24.15	21.74	11.74
D22	5		28.54	25.14	22.83	10.96
D23	10		28.46	25.16	23.39	10.78
D24	15		28.12	25.39	21.40	11.77
D25	20		26.98	24.28	22.47	11.09

Table 4.22: Percentage loss in compressive strength at different temperature range

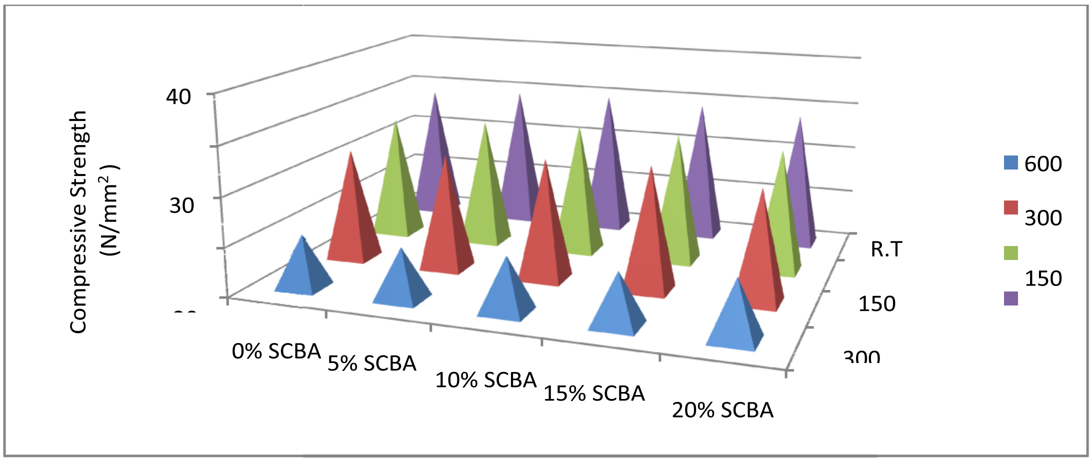
Mix	SCBA (%)	CBA (%)	Percentage loss (-) in compressive strength with increase in temperature		
			Room Temperature to 150°C	Room Temperature to 300°C	Room Temperature to 600°C
D1	0	0	11.1	18.1	59.7
D2	5		7.6	17.4	66.4
D3	10		8.6	17.7	64.7
D4	15		12.4	17.8	66.1
D5	20		11.0	19.4	65.8
D6	0	10	10.3	20.7	59.3
D7	5		10.5	22.1	58.1
D8	10		11.4	17.1	62.6
D9	15		11.9	18.3	59.8
D10	20		10.4	21.9	60.9
D11	0	20	9.5	18.3	61.8
D12	5		9.9	18.7	64.8
D13	10		9.3	17.6	63.4
D14	15		8.1	20.6	64.4
D15	20		10.7	19.9	58.6
D16	0	30	12.8	21.9	56.2
D17	5		12.4	21.1	59.4
D18	10		12.9	20.6	62.9
D19	15		11.8	18.2	59.5
D20	20		11.2	18.4	62.5
D21	0	40	10.7	19.6	56.6
D22	5		11.9	20.0	61.6
D23	10		11.6	17.8	62.1
D24	15		9.7	20.1	58.1
D25	20		10.0	19.0	58.9



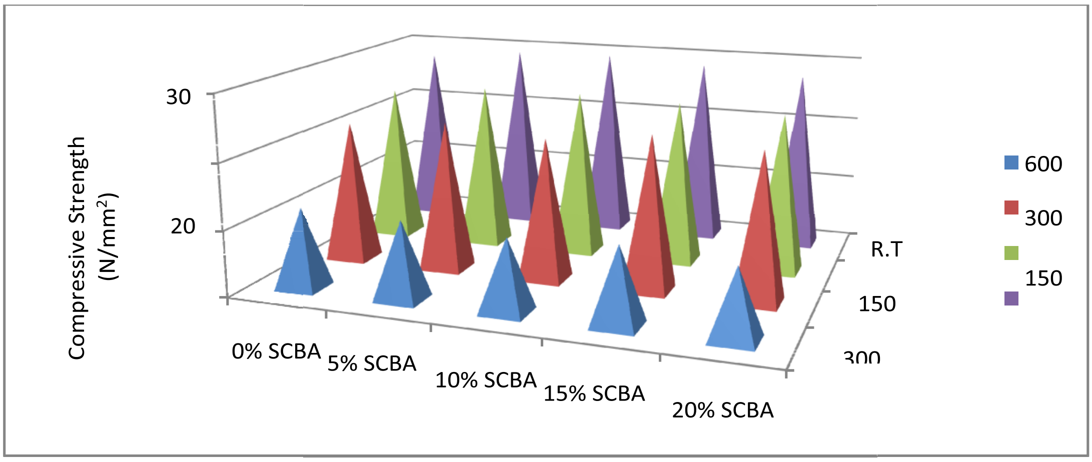
Graph 4.12: Compressive strength of concrete at different temperature ranges with different replacement levels of cement with SCBA and 0% CBA



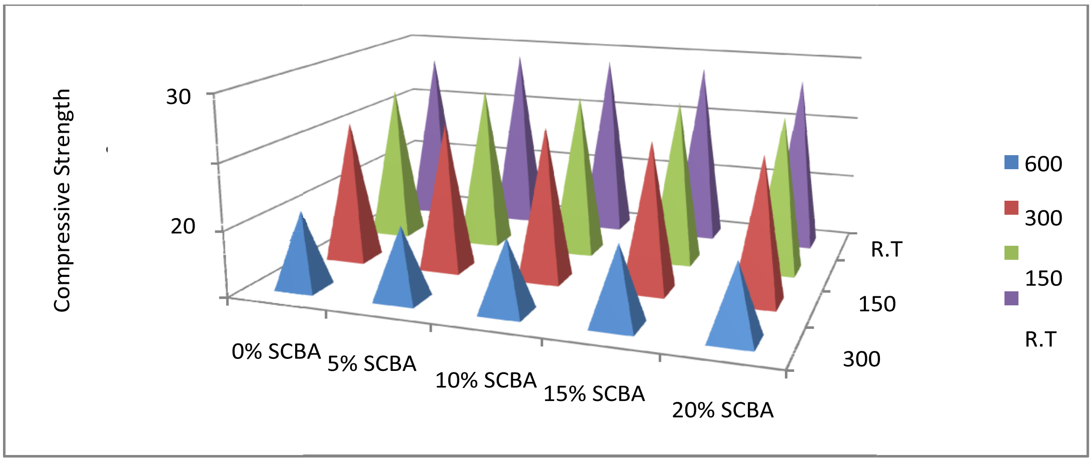
Graph 4.13: Compressive strength of concrete at different temperature ranges with different replacement levels of cement with SCBA and 10% CBA



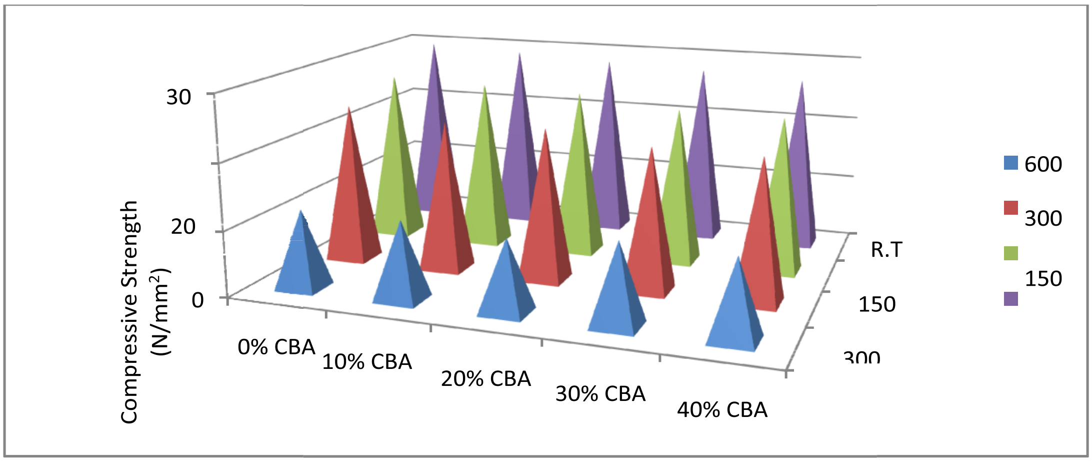
Graph 4.14: Compressive strength of concrete at different temperature ranges with different replacement levels of cement with SCBA and 20% CBA



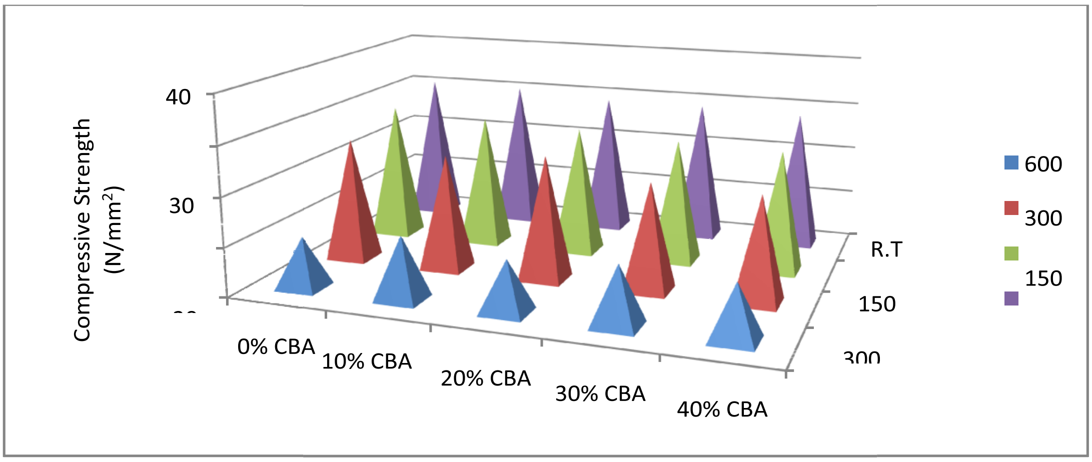
Graph 4.15: Compressive strength of concrete at different temperature ranges with different replacement levels of cement with SCBA and 30% CBA



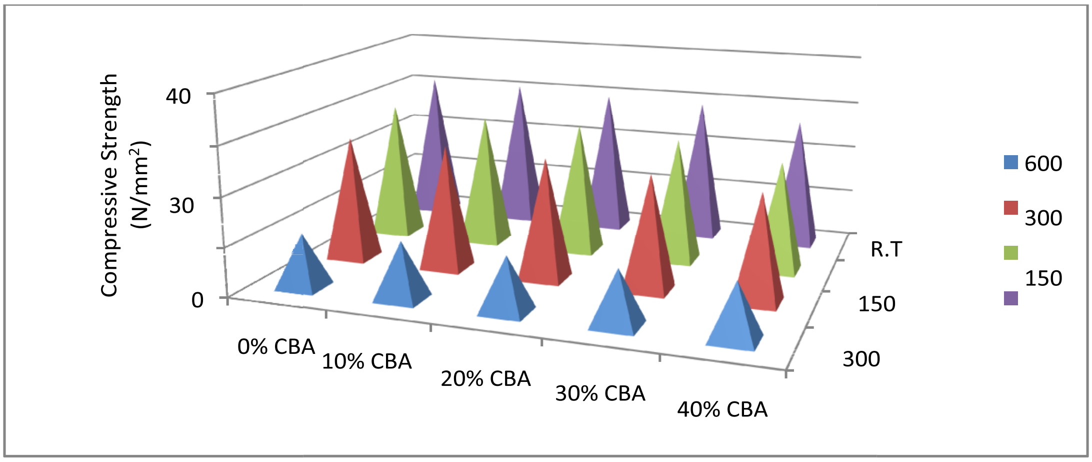
Graph 4.16: Compressive strength of concrete at different temperature ranges with different replacement levels of cement with SCBA and 40% CBA.



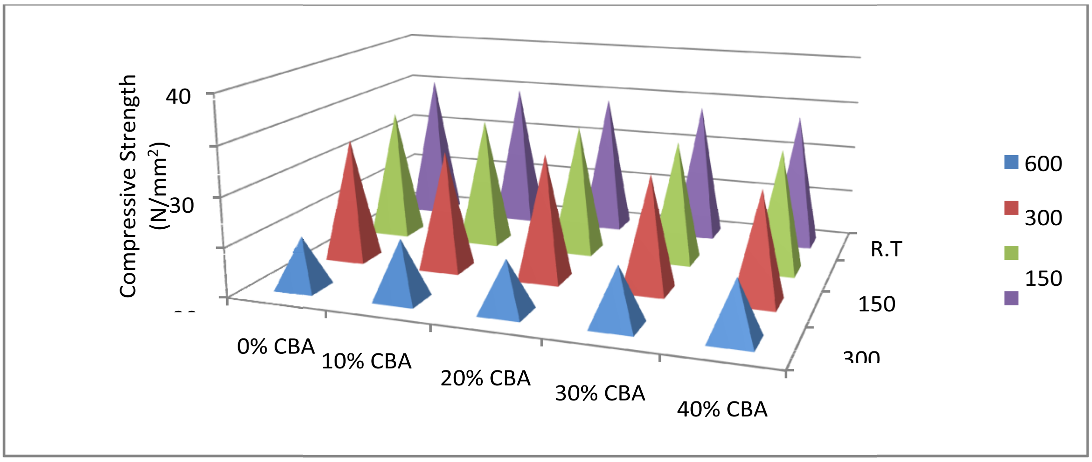
Graph 4.17: Compressive strength of concrete at different temperature ranges with different replacement levels of fine aggregates with CBA and 0% SCBA



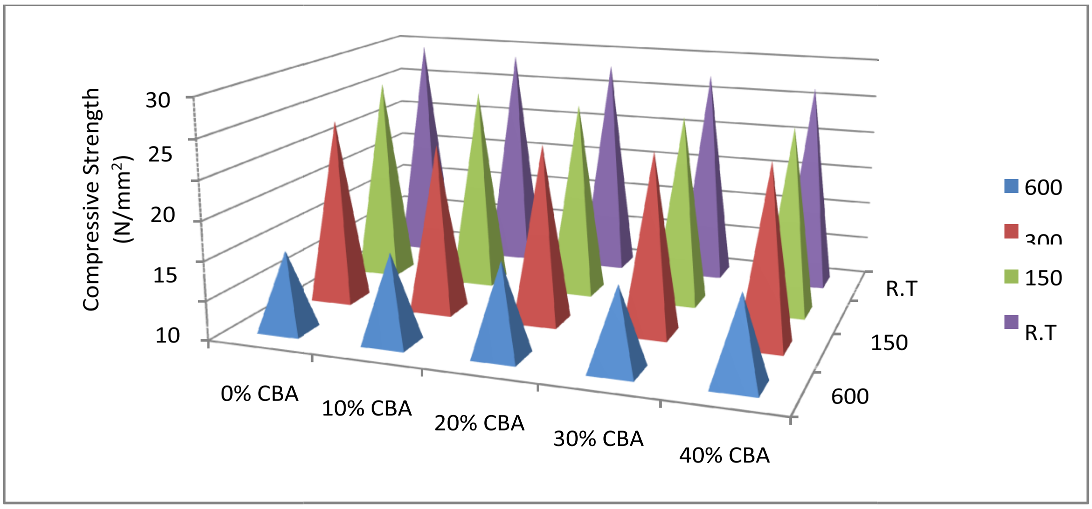
Graph 4.18: Compressive strength of concrete at different temperature ranges with different replacement levels of fine aggregates with CBA and 5% SCBA.



Graph 4.19: Compressive strength of concrete at different temperature ranges with different replacement levels of fine aggregates with CBA and 10% SCBA



Graph 4.20: Compressive strength of concrete at different temperature ranges with different replacement levels of fine aggregates with CBA and 15% SCBA



Graph 4.21: Compressive strength of concrete at different temperature ranges with different replacement levels of fine aggregates with CBA and 20% SCBA

4.6 COST ANALYSIS

Cost analysis of concrete requires the cost of its ingredients multiplied with their respective quantity. The cost of concrete's ingredients includes transportation charges and manufacturing charges. As we know that the transportation price depends on the distance between manufacturing place and delivery destination. So, in present study the cost analysis of concrete has been done without considering the transportation expenditure (Table 4.23 to Table 4.25). The cost analysis indicates that the cost of concrete decreases as the content of SCBA and CBA increases. The D25 mix reduces 14.24 percent cost of concrete but at same time the strength of concrete also decreases. Furthermore, the D8 mix reduces 6.99 percent cost of concrete which is recommended for higher strength and acceptable workability. Therefore, this analysis spreads the awareness towards the use of these waste materials in concrete which provides economic benefits for concrete industries.

Table 4.23: Cost of concrete's ingredients

(without considering transportation expenditure)

Sr.No	Ingredients	Cost (Rs/Kg)
1	Cement	7.0
2	Fine Aggregates	0.05
3	Coarse Aggregates	0.20

Table 4.24: Cost of Waste Materials

(without considering transportation expenditure)

Sr. No	Waste Materials	Grinding Charges	Total Cost (Rs/Kg)
1	SCBA	1.70	1.70
2	CBA	-	0

CHAPTER V
CONCLUSION

In the present study, the workability characteristics, strength characteristics and thermal stability of concrete containing SCBA and CBA has been investigated. Twenty five concrete mixes were prepared each with 0.55 w/c ratio by replacing the cement with SCBA (0 to 20% @ increment of 5%) and fine aggregates with coal bottom ash (0 to 40% @ increment of 10%). To investigate the effect of SCBA and CBA on compressive strength, cubes of 15 cm X 15 cm X 15 cm in size were prepared by varying percentage of SCBA and CBA. Same numbers of cubes of 10 cm X 10 cm X 10 cm in size were also prepared to study the effect of elevated temperature on compressive strength of each mix. The statistical analysis was also applied on results of compressive strength test of 150mm cubes specimen. From the experimental investigations, it can be concluded that:

i) The workability of concrete decreases as SCBA and CBA content increases. The slump value decreased from 110 mm to 45 mm with the inclusion of 40% CBA and 20% SCBA.
ii) The compressive strength of concrete increases as SCBA content increases for all curing ages. The maximum improvement in compressive strength is at 10% of SCBA but beyond 10% replacement of SCBA, strength starts reducing. There is a significant reduction in compressive strength at 20% replacement of SCBA.
iii) The addition of CBA decreases the compressive strength of concrete for all curing ages.
iv) As combination, cement can be replaced with SCBA up to 15% while fine aggregates can be replaced with CBA up to 10% without any loss in strength of concrete. The combination of 10% SCBA and 10% CBA is recommended to obtain higher strength and acceptable workability.
v) The contribution of SCBA and CBA doesn't change the strength properties of concrete during heating. All concrete mixes reduce their strength when heated at higher temperature.
vi) The loss in strength is minor up to 150°C. The strength reduces between 7.1-12.9%

whereas at 300°C, the reduction in strength is 22%.

vii) The serious deterioration has been found at 600°C. The concrete loses almost half of its original strength.

viii) On the basis of cost analysis, it is recommended to use these waste materials in concrete which provides potential environmental as well as economic benefits for concrete industries.

Future scope of work:

A complete investigation on bagasse ash concrete is required to evaluate its benefit in terms of durability involving carbonation, chloride penetration or diffusion coefficient. Bagasse ash use in making low strength products such as bricks and blocks may be studied. Strength relationship with bagasse ash reactivity and reaction products needs to be established. A detailed investigation involving toughness and microstructural behavior of bagasse ash concrete exposed to elevated temperature need to be carried out.

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TESTING REPORT

REPORT NO. :AEC/09/2019

DUPLICATE COPY

ISSUED TO	MR. JITENDRA KUMAR YADAV	DATE OF ISSUE	26/09/2019
PROJECT NAME	PARTIAL REPLACEMENT OF CEMENT WITH SUGARCANE BAGASSE ASH AND COAL BOTTOM DUST		
UNDER THE GUIDANCE OF MR. MOHD. AFAQUE KHAN			

BASIC TEST RESULT

S.NO.	TEST NAME	RESULT	REMARK
1.	FINESS TEST OF CEMENT (OPC 43)	6% RETAINED ON SIEVE NO. 9	OK
2.	FINE AGGREGATE SIEVE ANALYSIS	SAND ZONE 3 CONFORMING	OK
3.	COARSE AGGREGATE SIEVE ANALYSIS	20mm SIZE OF AGGREGATE	OK

PHYSICAL PROPERTIES TEST OF OPC

S.NO.	CHARACTERISTICS	TEST RESULT	STANDARD RESULT (AS PER IS CODE)	REMARK
1.	INITIAL SETTING TIME	45 MIN	NOT LESS THAN 30 MIN	OK
2.	FINAL SETTING TIME	220 MIN	NOT MORE THAN 600 MIN	OK
3.	FINESS MODULUS(OPC 43)	6%	10%	OK
4.	COMPRESSIVE STRENGTH (OPC 43)	49 N/mm²	NOT LESS THAN 43 N/mm²	OK

CHARACTERISTICS

S.NO.	TEST NAME	SP. GRAVITY	%WATER ABSORPTION	REMARK
1.	COARSE AGGREGATE (25 MM)	2.637	0.61%	OK
2.	FINE AGGREGATE (ZONE 3)	2.62	1.21%	OK
3.	CEMENT (OPC 43)	3.15	-	OK

MAIN TEST

COMPRESSIVE STRENGTH OF CONCRETE (M20)ADDED 0%SUGAR CANE BAGGASS AND COAL BOTTOM DUST

SL. NO.	SETTING TIME	LOAD (N)	AREA (mm^2)	STRENTGH (N/mm^2)	STANDARD RESULT (AS PER IS CODE)	REMARK
1.	7 DAYS	405.225x1000	22500	14.50	13.5 N/mm^2	OK
2.	14 DAYS	532.125x1000	22500	18.65	18 N/mm^2	OK
3.	28 DAYS	639.00x1000	22500	20.40	20 N/mm^2	OK

COMPRESSIVE STRENGTH OF CONCRETE (M20)ADDED 5%SUGAR CANE BAGGASS AND COAL BOTTOM DUST

SL. NO.	SETTING TIME	LOAD (N)	AREA (mm^2)	STRENTGH (N/mm^2)	STANDARD RESULT (AS PER IS CODE)	REMARK
1.	7 DAYS	405.225x1000	22500	18.01	13.5 N/mm^2	OK
2.	14 DAYS	532.125x1000	22500	23.65	18 N/mm^2	OK
3.	28 DAYS	639.00x1000	22500	28.40	20 N/mm^2	OK

COMPRESSIVE STRENGTH OF CONCRETE (M20) ADDED 10%SUGAR CANE BAGGASS AND COAL BOTTOM DUST

SL. NO.	SETTING TIME	LOAD (N)	AREA (mm^2)	STRENTGH (N/mm^2)	STANDARD RESULT (AS PER IS CODE)	REMARK
1.	7 DAYS	398.7 x1000	22500	17.72	13.5 N/mm^2	OK
2.	14 DAYS	530.325x1000	22500	23.57	18 N/mm^2	OK
3.	28 DAYS	623.925x1000	22500	27.73	20 N/mm^2	OK

COMPRESSIVE STRENGTH OF CONCRETE (M20) ADDED 15% SUGAR CANE BAGGASS AND COAL BOTTOM DUST

SL. NO.	SETTING TIME	LOAD (N)	AREA (mm^2)	STRENTGH (N/mm^2)	STANDARD RESULT (AS PER IS CODE)	REMARK
1.	7 DAYS	443.70X1000	22500	19.72	13.5 N/mm^2	OK
2.	14 DAYS	571.50x1000	22500	25.40	18 N/mm^2	OK
3.	28 DAYS	717.75x1000	22500	31.90	20 N/mm^2	OK

COMPRESSIVE STRENGTH OF CONCRETE (M20) ADDED 20% SUGAR CANE BAGGASS AND COAL BOTTOM DUST

SL. NO.	SETTING TIME	LOAD (N)	AREA (mm^2)	STRENTGH (N/mm^2)	STANDARD RESULT (AS PER IS CODE)	REMARK
1.	7 DAYS	410.175x1000	22500	18.23	13.5 N/mm^2	OK
2.	14 DAYS	534.150x1000	22500	23.74	18 N/mm^2	OK
3.	28 DAYS	671.625x1000	22500	29.85	20 N/mm^2	OK

Aiecro Engineering Works & Consultants LLP, Authorised Signatory

FOR AIECRO ENGINEERING WORKS & CONSULTANTS

AIECRO ENGINEERING WORKS
& CONSULTANTS

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CERTIFICATE OF COMPLAINCE

This is to certify that MR. JITENDRA KUMAR YADAV has performed the following Tests in our respective laboratory with all means under the supervision of our Technical Incharge to study the partial replacement of cement with Sugarcane Bagasse Ash and Coal Bottom Dust.

- Basic Test (Feb-March 2019)
  - Physical Properties Test of OPC
  - Characteristics Test
- Main Test (May to July 2019)
  - Compressive Strength Of Concrete (M20) Added Variable Percentage (%) Of Sugar Cane Baggasse And Coal Bottom Dust.

These Variable Percentage (%) mentioned are 0, 5, 10, 15 & 20.

The Test Results of the above mentioned Tests are listed in the Testing Report

(Report No. : AEC/09/2019) attached to this Certificate.

Aiecro Engineering Works & Consultants LLP
Authorised Signatory

Date : 26/09/2019

Er. Mudassir Ahmad Khalid

(Quality Manager)

1) This certificate refers only to the particular sample submitted for testing.
2) The test result reported in this certificate are valid under the stated conditions of measurements.
3) Sample will be destroyed after one months of the date of issue of test report unless otherwise specified.
4) The test results is for the information of client and cannot be used for any legal purpose or produced in any court of law.

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Ref. No. : M/31/L1/2019

Date : 03/10/2019

TEST REPORT

Name of Student	Jitendra Kumar Yadav
Name of College	Babu Banarsi Das University Lucknow
Project	Partial Replacement of Cement With Sugercane Bagasse and Coal Bottom Dust Under the Guidance Of Mr. Mohd. Afaque Khan
Descriptions of Sample	Aggregate , Sand, Ultratech (OPC Grade 43), Sugercane Bagasse, Coal Bottpm Dust
Date of Testing	03/10/2019

TABLE INDICATING CONCRETE MIX PROPORTIONING AND SLUMP VALUE

Mix	W/C Ratio	Cement (kg/m³)	Sand (kg/m³)	Coarse Aggregate (kg/m³)	Water (kg/m³)	Slump Value after 25 min (mm)
1.	0.55	338.18	747.23	1142.87	186.00	20
2.	0.55	358.47	728.30	1113.77	197.16	60
3.	0.50	372.00	716.94	1143.52	186.00	25
4.	0.50	394.32	698.20	1113.95	197.16	55

(TESTED BY)
MONA KUSHWAH
ASSISTANT ENGINEER
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(CHECKED BY)
AKHILESH PRATAPP SINGH
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(ARUN SOIL LAB PVT. LTD.)

3/10/19
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IJSRD
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in recognition of the publication of the paper entitled

Review Paper on Sugar Bagasse and Coal Bottom Dust Mixed Concrete

published in e-journal

Volume 7, Issue 2, in April 2019

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