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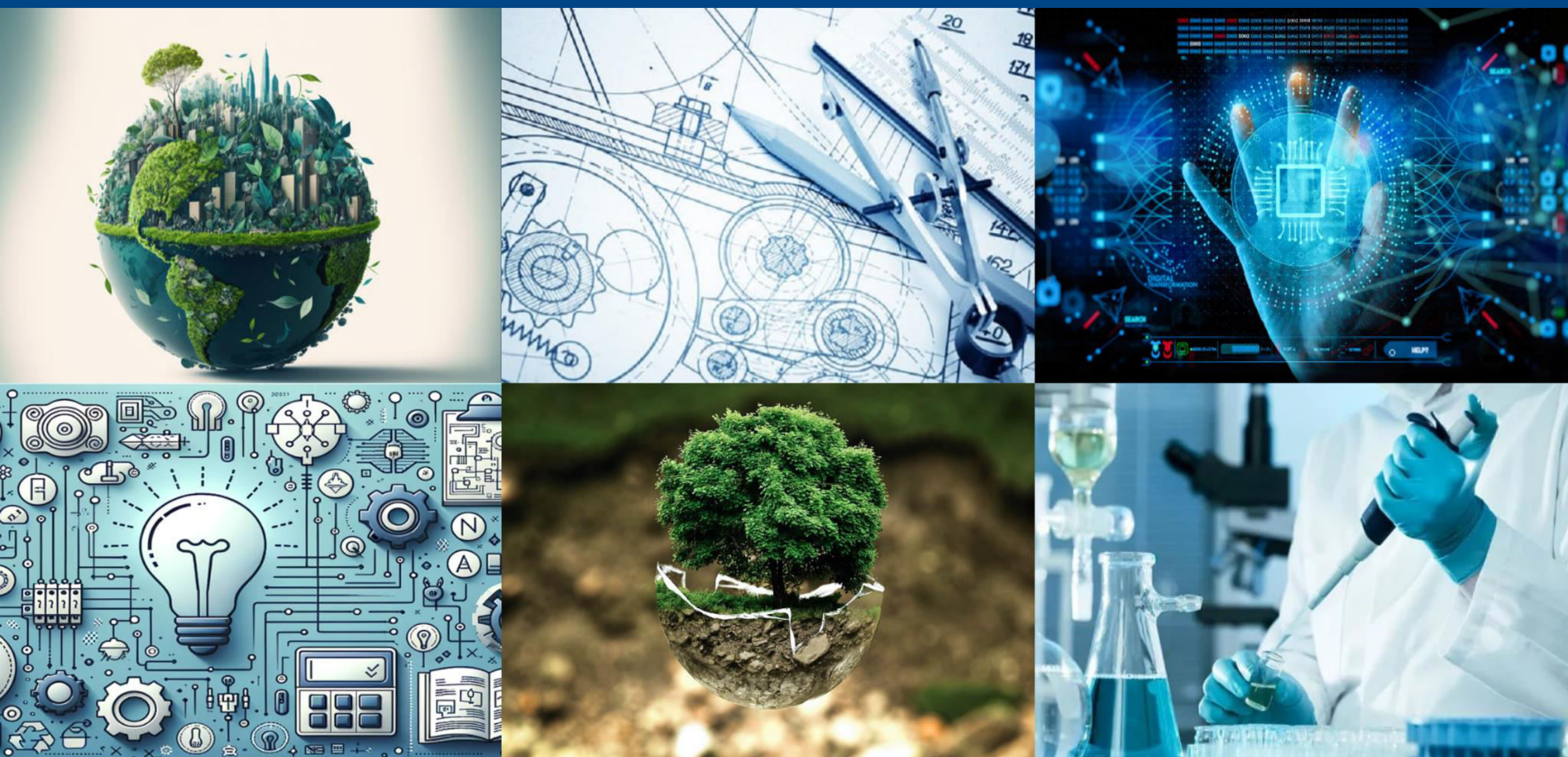

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Effect of Elevated Temperature on Mechanical Properties of Sugarcane Bagasse Ash Concrete with Post-Fire Water Curing

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ABSTRACT: Sugarcane bagasse ash concrete (SCBA) is growing tremendous and much research and modification has been done to produce sugarcane bagasse ash concrete which has the desired characteristics. SCBA concrete is one of the materials used in the heavy reinforced construction sites. The current area of research in SCBA concrete is to behavior SCBA concrete subjected to high temperature. Generation of waste sugarcane bagasse ash as by product of sugarcane industries causes environmental problems because of its improper disposal. It has some siliceous property when it heated to normal temperature. Thus, its usage in building material, construction and in other fields is essential for reduction of disposal problems. This work is carried out to produce an eco-friendly SCBA concrete. Present study demonstrates the effect of high temperature on mechanical properties of sugarcane bagasse ash concrete. Ingredients for SCBA concrete are cement, coarse aggregate, natural sand (fine aggregate), SCBA. An experimental investigation is carried out on a SCBA concrete containing bagasse ash in the range of 15% by weight for M30 grade SCBA concrete. Material was produced, tested in terms of strength. These tests are carried out on standard cube and cylinder for 28 days to determine the mechanical properties of SCBA concrete. From the obtained results it may be concluded that compressive strength of SCBA with15% is found maximum. Results obtained from compressive strength it shows relation between UPV test and compressive strength Hence it can be concluded from obtained results that SCBA concrete can use for higher temperature and it shows improvement in compressive strength after water curing.

KEYWORDS: (SCBA: sugarcane bagasse ash concrete), (FA: fine aggregate), (CA: coarse aggregate).

I. INTRODUCTION

General: Concrete with its reliable properties like easy availability of constituent materials, mouldability i.e. capacity to acquire any desired shape when it is in the fresh state, durability, and better thermal resistance, it is widely used as a major constituent in infrastructure development. Not only the buildings constructed in wood suffering from fire damage but also the buildings constructed in reinforced concrete are the examples of fire damage despite its good fire resisting properties. This is because of a change in its mechanical properties due to the change in its physical and chemical composition. According to the report of India Risk Survey 2017, out of top twelve risks from the business perception and functioning in the country, from the past three years, fire risk has been incorporated in the top five risks. Industry-wise risk of fire was observed to be greater in education, hospitality, and infrastructure. The damage extent depends on the design of the structure, fire extinguishing devices, and evacuation process. In India majority of fires caused due to electric short circuits, gas leakage, fireworks and due to other causes. Fire and Safety Association of India (FSAI) revealed the fact that India almost losses the assets of USD 100 billion and 20,000 people per year due to fire. In the Maharashtra fire incidences are 20% of the overall country, and this value is greater than any of the state in India.

Fire and Fire Classification: NFPA defines the fire as “oxidation process that Happens very fast so that light, heat, and sound are released”. Fuel heat and air are the Three components of fire and the presence of all the three is necessary. The fourth Component i.e. unrestrained chain reaction is added to explain the fire and this chain Reaction provides the heat required to maintain the fire. Fire class is a term used to Denote the type of fire, in relation to the combustible material which is being ignited.

Assessment of Fire Damage: In many cases structure needs a repair after the fire And, demolition of the entire structure as a result of fire is rare. Demolition leads to Serious financial consequences to the owner. In case of structural repair which is Referred to as retrofitting, needs a proper repair strategy. Absolute investigation of the Effect of elevated temperature on the properties of steel and concrete, permanent change In their material characterization is required for evaluating future structural Performance. Tests such as Schmidt hammer, Pull-off test, UPV are used to give an Apparent reduction in strength. While, thermo gravimetric, color, crushing strength, and Thermo-luminescence tests are used for the analysis of the temperature history of the Member.

Objectives of study: High temperature brings degradation in properties of concrete, And above-explained methods are used in the assessment of fire damaged concrete and These methods are employed on the basis of general survey (preliminary investigation).

The layout of the report: The dissertation is divided into five chapters. The content Of each chapter is summarized below.

• **Chapter 2:** Focuses on the literature review in the assessment of fire damaged Concrete by using various conventional as well as advanced methods and gives Suitable background information for this research program.
• **Chapter 3:** Describes the materials, mix proportions, heating and cooling of the Concrete specimens. This section also elaborates the main testing program and Effect of ambient cooling and quenching on the sugarcane bagasse ash concrete.
• **Chapter 4:** Presents the results of residual strength and residual UPV of heated.The established relationship between residual strength ratio and residual UPV Ratio is also justified in this section.
• **Chapter 5:** Is allocated for the conclusion and direction for future work.

II. LITERATURE REVIEW

Opening Remarks: Retrofitting of fire damaged structures is one of the most promising challenges for civil engineers and for understanding the exact level of damage, it is necessary to evaluate the residual compressive strength. There are few conventional methods likeUltrasonic Pulse Velocity method, compression strength on cores, split tensile test,rebound hammer test, and pull off test which is used widely in the retrofitting industry(Chew 1993; Chung 1985; Yang et al. 2009). But, there are few newly developed methods which are also destructive, partially destructive as well as non-destructive in nature can be used which has the capability of producing similar results as that of conventional methods. Many studies for predicting the residual strength and other physical and mechanical properties of the concrete were carried out and a correlation was developed between destructive and non-destructive test. From the available technical literature, it was noted that all these studies were conducted are especially focusing on the mature concrete. In this chapter, generic and updated information about the various conventional and new methods used in studying the properties of concrete after exposure to elevated temperature were studied. New methods include impact echo test, impact resonance test, free-free resonance test, scanning electron microscopy, mercury intrusion porosimetry, and Thermogravimetric test. Effect of elevated temperature on properties of concrete like strength, UPV, microstructure, and pore structure are explained sequentially in the present extraction.

Literature Reviewed on sugarcane bagasse ash concrete:
Mulay S. et al. (2016) has conducted study on experimental investigation of sugarcanebagasse ash concrete under sodium hydroxide solution. In this they had studied the durability properties of conventional concrete utilizing SCBA sourced from sugar factory site have been investigated. Concrete mixture with SCBA containing the range of 0% to 30% of total binder used. They had conducted different test such as compressive strength, ultrasonic pulse velocity test and also loss in weight of concrete is determine by sodium hydroxide curing. In this study they found that the partial replacement of cement improved the resistance to the alkali attack on concrete. They had found that the slower reduction in weight of concrete subjected to alkali. The compressive strength concrete at 28 days with increasing in SCBA 0% to 30% had observed the decrease in strength. He had found that the increase in strength of concrete for 15%nof SCBA at 56 days of curing.

Janjaturaphan and Wansom (2010) 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 SCBAs are higher than the minimum requirement stated for Class N pozzolana (> 70%) according to ASTM C618 (2003). Although the moisture contents for all SCBAs are higher than the maximum requirement of 3%, this possesses no serious problem to the use of SCBAs as an SCM, since it can be easily reduced by oven-drying at 105-110ºC overnight or by sun-drying, for a more energy - efficient and economical means.

Literature Reviewed effect of high temprature on concrete:

Hwang et al. (2018) carried out the study to monitor continuously the integrity of concrete subjected to elevated temperatures. The concrete sample was tested before, during and after the heating for the pulse velocity. Cylindrical specimen with a diameter 10 cm and length 20 cm was used in the present experimentation. By using a heat transfer heating method the sample was heated in the electric heating furnace installed on the universal testing machine. The sample was exposed to an elevated temperature for 5 hours for 100, 200, 300, 400, 500, 600 and 700°C temperature at the rate of 1°C/min. The results indicated that higher residual strain in the concrete indicates higher heating temperature which leads to the decreased elastic modulus of concrete. The decrease in ultrasonic pulse velocity of heated concrete was observed after cooling of the concrete, with the possible reason of an increase in the width of the crack and these results are in contrary with the findings of previous researchers. No reduction in the compressive strength and ultrasonic pulse velocity of the fire degraded concrete was observed up to 300° C temperature.

A. Husain et al. (2016) had conducted study on the effects of temperature on the behaviour of concrete materials and structures. In this he had provided the temperature elevated or depress from the ambient temperature. The main aim of this study was to effect of weather conditions on properties of concrete. This method used in current research particularly focuses on the study of elastic wave propagation through the medium of different acoustic independence and establishing the relationship between the parameters obtained from standard destructive tests and the impact-echo test. Material having high acoustic independence provides easy transfer of elastic wave. acoustic independence equal to zero or close to zero, in air. High temperature reduces this acoustic independence of concrete.

(Katarzyna and Hager 2015). Pulse is triggered on the concrete surface which travels easily through the concrete medium but, it was encountered at the material having low acoustic independence i.e. in air. Receiver positioned on the surface of the test specimen that receives and stores the signal in the time domain. It was observed that signals obtained from the test, are strongly reflecting the extent of damage to the concrete due to heat and hence, it is an effective non-destructive test for accessing the fire damaged concrete.

Nilmlyat P. S. (2013) conducted study on performance of concrete at elevated temperatures: utilizing a blended ordinary portland cement (OPC)/ saw dust ash (SDA) as binder. This study aimed at investigating the effect of subjecting concrete, produced with cement being partially replaced with saw dust ash (SDA) to elevated temperatures.It is also found that, at an elevated temperature of 800oC, concrete fail totally in flexure due to the effect of high heat on binding element. The flexural strength of both the control concrete (at 0% OPC replacement) and OPC/SDA blended concrete (at 10% OPC replacement) decreased as the temperature is increased. The concrete produced with OPC has better thermal conductivity than the concrete produced by blending OPC with SDA, as a result, the dislodgement of the concrete edges is relatively lower in the SDA blended cement concrete than in the OPC concrete. The result shows that, blending OPC with SDA in concrete performed better at elevated temperatures than concrete produced with only OPC. Therefore, the replacement of OPC with 10% SDA can be applied as a fire resisting bonding material in concrete.

Anand N. (2011) had conducted the effect of elevated temperature on concrete materials. In this study he found that the behaviour of Normal strength concrete, high strength concrete and self-compacting concrete were different when exposed to high temperature.

Ingham (2009)had studied the petrographic examination techniques to the assessment of fire damaged concrete and masonry structures. He investigate this technique on masonry structure.

III. METHODOLOGY OF PROPOSED SURVEY

Opening Remarks: This chapter explains the methodology followed during the course of the project in order to identify the effect of high temperature on mechanical properties of sugarcane bagasse ash concrete. The chapter also describes the methods used in the assessment of mechanical properties fire damaged concrete.

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Materials: Materials used for casting concrete specimens consists of Ordinary Portland Cement (OPC) of grade 43 with 28 days compressive strength of 43 MPa, as A binding material provided by Ultratech Cement complying with IS 8112: 2013 (Ordinary Portland Cement 43 Grade - Specifications). Natural washed and uncrushed river sand was used as fine aggregate (FA), and as a coarse aggregate (CA) natural crushed basalt was used in saturated surface dry (SSD) condition. In this study maximum nominal size of aggregates was restricted to 10 mm and it is s aasmaller than the one-fourth of the minimum thickness of the specimen and satisfying the IS 456: 2000 (Plain and Reinforced Concrete - Code of Practice) requirement. The density of materials used in this experiment like fine aggregate and coarse aggregate in SSD condition was 2500 kg/m3 and 2600 kg/m3 respectively. Most of the civil engineering projects in India are constructed in concrete with 28 days design compressive strength of 30 MPa. Hence, concrete mix design was performed for M30 grade of concrete by considering the water/cement (W/C) ratio 0.45, Cement, fine aggregate and coarse aggregate were mixed in the assistance of distilled water.

Material required for SCBA concrete: Materials for SCBA concrete are given below:
1. Cement
2. Fine aggregate (Natural sand)
3. Coarse aggregate
4. Water
5. Sugarcane bagasse ash

Mix Design Procedure of SCBA concrete: Available methods of mix design are listed below and mostly they are ased on empirical relations.
1. Trial and adjustment method of mix design.
2. British DoE mix design method (Improvement over Road Note No. 4 Method).
3. American Concrete Institute (ACI) mix design method.
4. Indian Standard (IS) method.
5. Rapid method for mix design.

Concrete mixing and moulding: For mixing concrete, pan type concrete mixer and Hand mixing were used. A measured amount of cement, sand, and coarse aggregate. Theconcrete mixer was washed with clean water for Avoiding the mixing of any foreign matter. Dry mixing of fine and coarse aggregate for 3 minutes was done before adding cement and SCBA, thereafter cement, SCBA and Water were added at the same interval (Husem 2006) and a homogeneous mix of Concrete was obtained. Concrete was poured in the mould in three layers by tamping Each layer 25 times with a steel rod and allowed it to set for the next 24 hours at room Temperature. the moulds filled with fresh concrete. After demoulding The diameter of the demoulded concrete specimens were checked with the help of Vernier caliper at 3 different sections along the length of the specimen, and uniform Diameter was recorded. No indication of flowing out of the cement slurry was observed From the vertical slit due to the presence of the adhesive tape. Subsequently, all Demoulded specimens after 24 hours were kept in water for 56 days curing at the 27°C Temperature.In this study total, 438 samples were cast for both The water-cement ratios.

Testing procedures: Concrete is widely used construction material because of its Easily available constituent materials, low thermal diffusivity, and the properties Resistant to combustion. The property of lower thermal diffusivity setups a hightemperature gradient near the concrete surface exposed to fire. Therefore, it is of great Interest to assess concrete exposed to fire in order to plan necessary strengthening action After the fire.
This test program was designed with three main objectives in mind:

1) To study the effect of post-fire water curing on compressive strength of fire. Damaged early age concrete at 3 days of water curing.
2) To develop a Non-destructive quality assessment approach for SCBA fire Damaged concrete, by establishing the correlation between Ultrasonic Pulse Velocity and the Compressive test results.

The properties of the specimens were measured by using Ultrasonic Pulse Velocity (UPV) Test and Compressive strength at the following important points of the heat cycle.
(Before and after heating):
1) Prior to heating at the age of 56 days (used as a control specimen for calculating The normalized strength and UPV ratio)

2) Immediately after cooling for calculating the residual strength
3) After post-fire curing to understand the effect of post-fire curing on SCBA Damaged concrete.

Ultrasonic pulse velocity test: Ultrasonic Pulse Velocity is a type of nondestructive test used for assessing the quality of concrete and it is based on the vibration method. After the fire it is necessary to judge the strength of concrete. In spite of that sometimes it is also necessary to study the parameters like overall quality and uniformity, etc. The methods like the load-carrying capacity of the test, core test are the most reliable tests but they are cumbersome and furthermore, they create structural damage by disturbing the structural integrity. Use of the UPV test not only provides an estimate of relative strength but also helps in identifying the locations where the destructive tests are needed. The objectives of using UPV are listed as below:

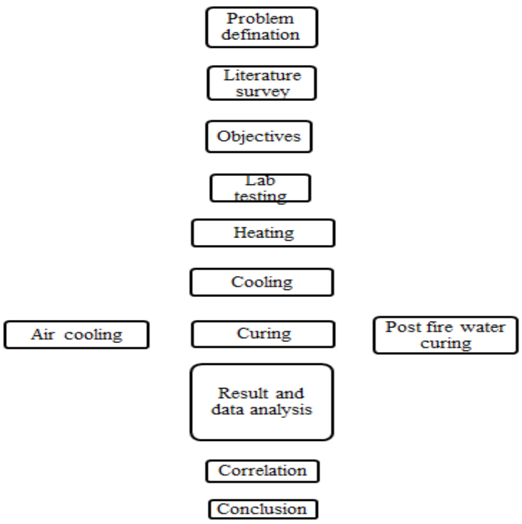
1. To study the homogeneity of the concrete
2. Existence of voids cracks, and other discontinuities
3. Microstructural changes
4. Checking the quality of the concrete in connection to the standard requirement

The method consists of measuring the time of travel of an ultrasonic pulse passing through the concrete being tested according to IS 13311 (Part 1):1992 (Non -Destructive Testing of Concrete – Methods of Test). Comparatively higher velocity is obtained when concrete quality is good in terms of density, uniformity, homogeneity, etc. The UPV test setup consists of,

1. Electric pulse 2. generator Transducer 3. Amplifier 4. Electronic time device.

Compressive strength: After performing the UPV test on the concrete specimens, Subsequently, compression test was performed on the same concrete samples. A Compression test is a widely preferred method because of its reliable results but it's a Form of destructive test. The compressive strength of the material is defined as the Internal resistance offered to failure under the action of compressive forces. Compressive strength of the concrete represents the characteristics of concrete.Before placing the sample in the universal testing machine sample was checked for Irregularities, bearing surfaces of the machine were wiped off to remove loose sand and Other material. The uniaxial compressive test was performed on the Universal Testing Machine (UTM) of 1000 kN capacity with a minimum loading rate of 0.20 kN/s i.e. 0.1 MPa/s for evaluating the residual compressive strength of air-cooled and quenched Concrete specimens. The experimental test setup of UTM is shown in figure 3.6. Before Initiating the test it was ensured that the load is adjusted to indicate zero for avoiding

Methodology flow chart :



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IV. RESULT AND DISCUSSION

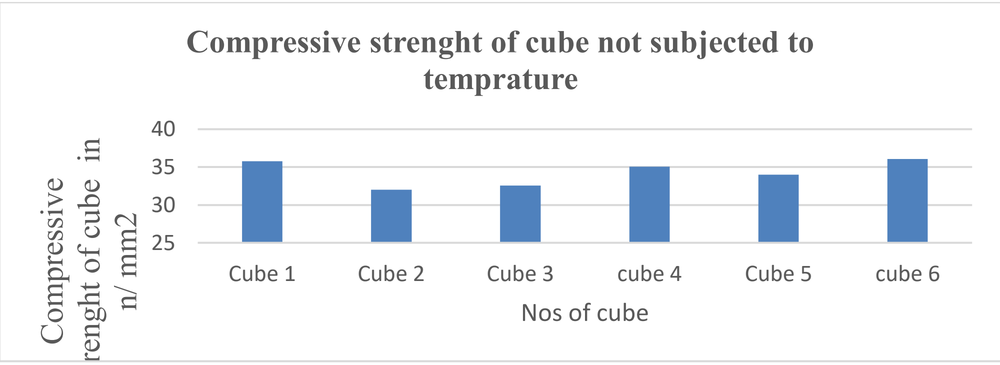
General: The result of the experimental investigation on sugar cane bagasse ash Concrete where Sugar cane bagasse ash has been used as partial replacement of cement In concrete mix. On replacing cement with 15% percentage of SCBA the compressive Strength are studied after cubes exposed to different elevated temperatures for 1 hour And then gradually cooled in air and provided a 3 days post fire water curing.

Test on hard concrete: Keeping in mind the gap in the research area, the To study The behaviour of replacement of SCBA in concrete at elevated temperature the result Which are increasing durability and good performance under elevated temperature.For this purpose different test on harden concrete were conducted at the age of 56 days Like compressive strength on 150 x 150 x 150 mm size cube, splitting tensile strength On 51 mm X 102 mm cylinder,. As per codal provision total 60 number of specimen Were tested and results are tabulated as below.

Compressive strength Test: The test was carried out as per IS 516: 1959 code. Compressive strength tests were performed on cube samples using compression testing Machine. Three samples per batch were tested with the average strength values reported In Table No.4.1. The test was carried out for 28 days water curing at 27°C. The average Strength for 28 days were calculated from breaking load obtained from compression Testing machine for SCBA with percentage of 15%.

Table: Compressive Strength result for cube not heated

M30				
Concrete cube not subjected elevated temperature				
Sr. No.	Cube No.	Average breaking load	Ultimate compressive strength after 28 days (N/mm^2)	Average compressive strength (N/mm^2)
1	01	805	35.77	34.24
2	02	720	32	
3	03	733	32.57	
4	04	789	35.06	
5	05	765	34	
6	06	812	36.08	



Graph: Compressive Strength result for cube not heated

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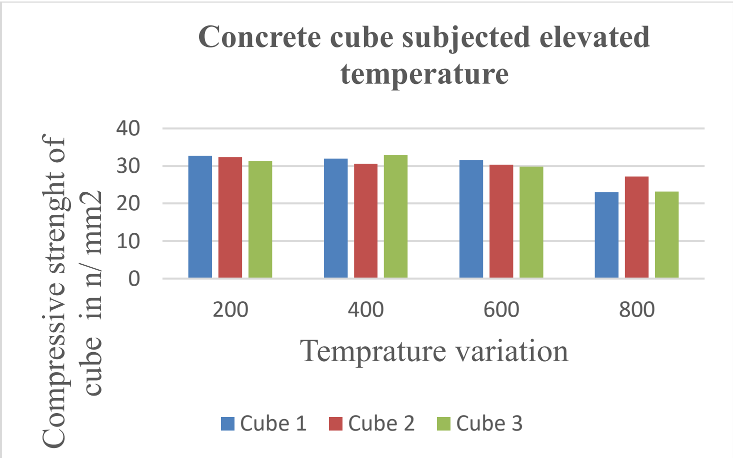
M30				
Concrete cube subjected elevated temperature				
Temp.	Cube No.	Average breaking load	Ultimate compressive strength after 28 days (N/mm^2)	Average compressive strength (N/mm^2)
200	01	736	32.71	34.24
200	02	729	32.4	
200	03	712	31.4	
400	01	720	32	31.86
400	02	689	30.62	
400	03	742	32.97	
600	01	711	31.6	30.67
600	02	683	30.35	
600	03	672	29.86	
24.47				
800	01	519	23.06	24.47
800	02	612	27.2	
800	03	521	23.15	

Table: Compressive Strength result for cube subjected to elevate



Graph: Compressive Strength result for cube subjected to elevated temperature

V. CONCLUSION

1. The performance of concrete with 15% replacement of cement with SCBA hasshown better to that of conventional concrete at higher temperature.
2. The reason for development of strength is due to development of more C-S-H gel.
3. Increase of strength is mainly to presence of high amount of silica and alumina in sugarcane bagasse ash.

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4. Effect on C-S-H gel results in decrease of strength after 6000 C.
5. There is no more strength different up 6000 C temperature means the SCBA concrete will be a perfect replacement for cement up to 15% in high temperature region.
6. Due to post fire water curing for 3 days there is increase of strength up to certain limit which create new opportunity to investigate properties for SCBA concrete for more days of water curing.
7. Post fire water curing increases the strength after fire damage and fill the cracks which generated due to high temperature reaction which will going to fill after curing.
8. In the UPV result there is increase in strength of SCBA concrete.
9. SCBA concrete has performed better when it is compared with normal concrete.

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