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EFFECTS OF ELEVATED TEMPERATURE ON COMPRESSIVE STRENGTH OF SBA CONCRETE

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ABSTRACT

This paper shows the results of an experimental study on compressive strength of concrete after heating to higher temperature. So, this study aims to observe the thermal stability of concrete containing Sugarcane Bagasse Ash (SBA). In present study five mixtures were prepared at different replacement levels of SBA (0 to 20% @ increment of 5%) with cement and subjected to different temperature levels (150^0C, 300^0C and 600^0C) from room temperature. Sixty cubes were casted (with three cubes for each testing condition) and cured for 28days. Then after, these cubes were transferred to muffle furnace for two and half hour duration to observe the effect of heating. The results indicate that the concrete strength decreases with increasing temperature, and decrease in the strength of reference concrete (0% SBA) is almost similar to SBA concrete. Therefore, it can be concluded that the replacement of cement with SBA cannot change the strength properties of concrete during heating.

KEYWORDS: Compressive Strength, Concrete, Elevated Temperature, Sugarcane Bagasse Ash, Workability

INTRODUCTION

The basic objectives of the sustainable development are the preservation of natural resources, reduction of environmental pollution and appropriate utilization of waste materials. In case of concrete construction, these objectives can be fulfilled by partial replacement of cement with agrowaste ashes like sugarcane bagasse ash, rice husk ash etc. and industrial waste like copper slag, steel slag, fly ash etc. Intergovernmental panel on climate change (IPCC) stated that the largest driver of global warming is CO_2 emission from combustion of fossil fuels, cement production and deforestation. The cement industry is a large contributor of global CO_2 emission because cement is used almost in every country and manufactured in more than 80 countries. China has largest share of total emission (33%) followed by United States (6%), India (5%), Japan (5%) and Korea (4%). (Worrell *et al* 2001). One ton of cement is released an equal amount of carbon-dioxide into the atmosphere. The widely used cement is Ordinary Portland Cement which is popularly known as OPC. For production of OPC, clay and limestone mixed with other materials needs to be heated at higher temperature to obtain clinker. In this production CO_2 emission come from both industrial process and fuel combustion. To mitigate this type of problem and to make a sustainable concrete, it is necessary to reduce the production of cement. SBA shows adequate chemical and physical properties for its use as pozzolana. So it is an appropriate substitute for cement which can reduce the use of cement in concrete and solve environmental issues related to cement production up to some extent.

Sugarcane is one of the major crops grown in over 110 countries. According to Food and Agriculture Organization (FAO), India is the second largest producer of sugarcane in the world. It produces 340 million tons of sugarcane every year. The fibrous matter that remains after crushing and juice extraction of sugarcane is known as bagasse. Nowadays, this bagasse is to reutilize as a biomass fuel in boilers for vapor and power generation in sugar mills. When this bagasse is burned under controlled temperature, it results into ash. The resulting ash contain high levels SiO_2 and AL_2O_3, enabling its use as a supplementary cementitious material (SCM). The use of SBA as SCM not only reduce the production of cement which is responsible for high energy consumption and carbon emission, but also can improve the compressive strength of cement based materials like concrete and mortar (Janjaturaphan and Wanson 2010). This improved compressive strength depends on both physical and chemical effects of the SBA. The physical effect also called filler effect which relates to shape, size and texture of the SBA particles and the chemical effects relate to the ability of SBA to participate in the pozzolanic reaction with calcium hydroxide by providing reactive silicious compounds (Srinivasan and Sathiya 2010).

Many structures become damaged when exposed to higher temperature. In case of reinforced concrete structures, the importance of fire resistance was recognized as early as 1854, in the first patent filed for reinforced concrete by Wilkinson (Rao et al). Fire resistance of concrete depends upon many factors like the size and shape of structures, type of admixtures, cement and aggregates used. Aggregates have very high resistance against the fire but cooling of the heated aggregates may results to formation of internal pressure. This internal pressure may cause of changes the volume of aggregates. Apart from it, hydrated Portland cement contains a significant amount of free calcium hydroxide and will decompose into calcium oxide due to loss of water at 400–450^0 C (Metin Husem 2005). This calcium oxide changes into calcium hydroxide again, when kept under moist environment. These chemicals changes are responsible for expansion of cement paste. Some of the deformation of concrete is due to this expansion. The concrete may crumble due to such changes in volume of concrete's constituents. In terms of the rate of strength loss, in spite of conflicting data, there is general agreement between the researchers on the relative residual strength above 400^0 C (Behnood and Ghandehari 2009). It is feared therefore that addition of SBA into concrete might changes the strength properties of concrete at higher temperature.

Furthermore, most research data related to mechanical and durability properties of SBA concrete. The studies dealing with thermal properties of SBA concrete are not enough. It is therefore mainly for these reasons that the present study has been investigated the strength properties of SBA concrete in response to elevated temperatures.

MATERIALS USED

Cement

In present investigation Ordinary Portland Cement (OPC) of 43 grade conformed to IS: 12269:1987 was used. The physical properties of the cement obtained on conducting appropriate tests. Cement was carefully stored to protect from moisture. The properties of cement are given in Table 1.

Table 1: Properties of OPC 43 Grade Cement

Sr. No.	Properties	Values Obtained	Values Specified by IS: 8112-1989
1	Specific gravity	3.15	-
2	Standard consistency	31	-
3	Initial setting time	135	30 Minute (Minimum)
4	Final setting time	220	600 Minute (Maximum)
5	Compressive strength 3 Days 7 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

Fine Aggregates

Natural sand was used as fine aggregates, collected from Chakki River (Pathankot). The physical properties of fine aggregate are used in this study, conformed to IS: 383-1970. Specific gravity of fine aggregates was determined as 2.71 and confirmed to grading zone II. It was brown in color with coarser shape of particles. The sieves analysis of fine aggregates is given in Table 2.

Coarse Aggregates

Crushed gravel was used in present study, collected from Pathankot quarry. It was a mixture of two stone sizes of 10 mm and 20 mm, with equal proportions. These were washed to remove dirt, dust and then dried to surface dry condition. The required properties of aggregates, was determined on conducting some tests, conformed to IS: 383-1970. Specific gravity of coarse aggregates was determined as 2.65 and it was grey in color.

Water

Water is an important constituent of concrete as it is responsible for chemical reaction with cement. Due to its importance, mixing and curing water should not contain undesirable organic substances or inorganic constituents in excessive proportions. In this project clean potable water was used for both mixing and curing of concrete. It was free from organic matter, silt, oil, sugar, chloride and acidic material as per IS: 456-2000.

Table 2: Sieve Analysis of Fine Aggregates (Total Weight of Sample= 500gm)

Is-Sieve Designation	Weight Retained on Sieve (Gm)	Percentage Weight Retained on Sieve	Cumulative Percentage Weight Retained on Sieve	Percentage Passing	Percentage Passing for Grading Zone-2 as Per Is: 383-1970
10 mm	Nil	Nil	Nil	100	100
4.74 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

Sugarcane Bagasse Ash

Sugarcane bagasse ash is produced when bagasse is reutilized as a biomass fuel in boilers for vapor and power generation in sugar mills. When this bagasse is burned under controlled temperature, it results into ash. Bagasse ash was collected from the boiler of a sugar mill situated at village Budhewal, which falls at a distance of about 4 kms from Jandaili on Ludhiana-Chandigarh road. The collection of the ash was carried out during the boiler cleaning operation throughout three months.

LABORATORY TESTING PROGRAM

Mix Design and Specimen Preparation

In this study, five concrete mixes were prepared each with 0.55 water/cement ratio. First mix was designated as control mix (D1), designed as per IS 10262:2009. Then remaining four mixes were prepared by replacing cement with SBA (0 to 20% @ increment of 5%). Water content, cement content and coarse aggregates were constant in all five mixes. The remaining detail of mix design per cubic meter of concrete was shown in Table 3. Concrete cubes of sizes 100mm x 100mm x 100mm were cast for each mix. Three samples were used for each testing condition, and total numbers of cube specimens were 60.

Workability of Concrete

Slump test was employed to assess the workability characteristics of fresh concrete. The results show that workability of concrete mixtures decreased with the increase in levels of cement with SBA.

Compressive Strength of Concrete

All the cube samples were cured for 28 days prior to heating. The hardened concrete cubes were then dried at room temperature for two hours and then transferred to the muffle furnace. They were heated from room temperature to 150^0C, 300^0C and 600^0C for two and half hour to achieve a uniform temperature distribution across them. After that furnace was turned off and samples were cooled to room temperature. All cooled specimens subjected to compression test under digital Universal Testing Machine (UTM) of 9000kN capacity as per IS 516-1959. A loading rate of 5kN/s was used during testing.

Table 3: Mix Proportions of Concrete Mixes

Mix	CBA (%)	Cement (Kg/m3)	SBA (Kg/m3)	Fine Aggregates (Kg/m3)	Coarse Aggregates (Kg/m3)	Water (L/m3)
D1	0	358.47	0	731.70	1108.08	197.16
D2	10	340.55	17.92	731.70	1108.08	197.16
D3	20	322.62	35.85	731.70	1108.08	197.16
D4	30	304.70	53.77	731.70	1108.08	197.16
D5	40	286.78	71.69	731.70	1108.08	197.16

RESULTS AND DISCUSSIONS

Workability

Workability of concrete mixtures decreased with the increase in percentage replacement of cement with SBA. The slump values decreased from 110 mm to 96 mm when 20% of cement was replaced by SBA as given in Table 4 and illustrated by Figure 1. The reasons behind this reduction in slump values are the porous structure, higher water absorption and rough texture of SBA particles.

Table 4: Slump Values of Concrete

Mix	SBA (%)	Slump (mm)
D1	0	110
D2	5	110
D3	10	107
D4	15	100
D5	20	96

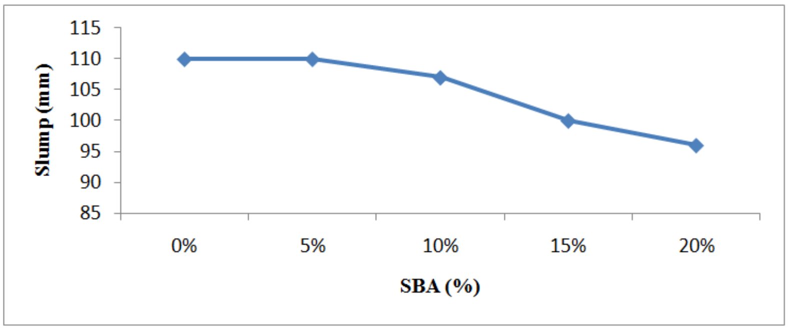

Figure 1: Slump Values of Concrete Mixtures

Compressive Strength

The residual compressive strength of all concretes mixtures at Room Temperature (R.T) and after heating to150 ^{0}C, 300 ^{0}C and 600 ^{0}C is given in Table 5 and illustrated by Figure 2. The percentage loss in strength is given in Table 6 and relative compressive strength is presented by Figure 3. These Tables and Figures clearly show that the compressive strength of all concrete mixtures decreases at elevated temperature. According to the results obtained from present investigation, the strength of concrete with 0% SBA after heated to150 ^{0}C, 300 ^{0}C and 600 ^{0}C was 88.9%, 81.9%, and 40.3% of its unheated strength respectively. Almost similarly trend was observed in SBA concrete mixtures also. The concrete containing 0, 20 and 5% SBA exhibited greatest loss in strength, about 11.1%, 19.4% and 66.4% of its unheated strength when heated to150^{0}C, 300^{0}C, 600^{0}C respectively. After the evaporation of physically and chemically bound water, a pressure is build-up which results into the extensive inner cracking. This inner cracking is the main reason for reduction in strength of all concrete mixtures. 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.

Table 5: Compressive Strength of Concrete Mixtures at Different Temperature Range

Mix	Compressive Strength (N/Mm^2)			
	Room Temperature (R.T)	150^{0}	300^{0}	600^{0}
D1	29.85	26.54	24.45	12.03
D2	30.84	28.49	25.46	10.37
D3	31.24	28.56	25.70	11.02
D4	30.77	26.95	25.30	10.44
D5	29.68	26.42	23.84	10.15

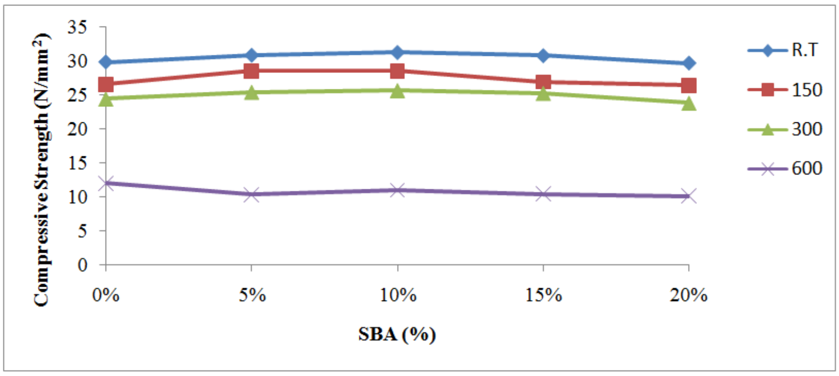

Figure 2: Compressive Strength of Concrete Mixes at Different Temperature Range

Table 6: Percentage Loss in Compressive Strength of Concrete Mixtures at Different Temperature Range

Mix	Percentage Loss in Compressive Strength		
	R.T - 150^0	R.T - 300^0	R.T - 600^0
D1	11.1	18.1	59.7
D2	7.6	17.4	66.4
D3	8.6	17.7	64.7
D4	12.4	17.8	66.1
D5	11.0	19.4	65.8

Figure 3: Relative Strength of Concrete Mixes at Different Temperature Range

CONCLUSIONS

The compressive strength of concrete with or without SBA decreases with increasing temperature. So, it can be concluded that the replacement of cement with SBA cannot change the strength properties of concrete during heating.

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