THERMAL BEHAVIOUR OF SELF-COMPACTING CONCRETE UNDER ELEVATED TEMPERATURE CONTAINING BOTTOM ASH AND FLY ASH

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ABSTRACT. There are many situations in which the concrete undergoes variation in temperatures which will ultimately leads to the failure of the structures. Whereas, this study of SCC developed using fly ash and bottom ash under elevated temperature is still in nascent stage. Therefore present investigation aimed to study the effect of elevated temperature of 200^{o}C, 300^{o}C & 400^{o}C on strength properties of SCC containing fly ash as partial replacement of cement @25% & 50% and bottom ash as partial replacement of sand @10%, 20% & 30% respectively at the age of 56 days. In developing SCC the water requirement increased with increase in bottom ash as partial replacement of sand. To qualify the mix to be SCC w/p ratio was increased from 0.39 to 0.44 & 0.53 for mixes with 10%, 20% and 30% replacement level of sand with bottom ash, respectively. It has been observed from the study that strength properties of SCC in terms of compressive strength and split tensile strength enhanced after exposure to elevated temperature of 200^{o}C, 300^{o}C and 400^{o}C. Increase in strength of SCC was more as compared to normal concrete mix. All the SCC mixes with higher replacement percentage of 50% cement with fly ash gained more strength as compared to corresponding mix with 25% fly ash at all elevated temperature.

Keywords: Self-compacting Concrete, Bottom Ash, Fly ash, Natural Sand.

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INTRODUCTION

A lot of uncertainties prevail concerning proportioning of self compacting concrete mixes using different types of filler when exposed to elevated temperature. With all these uncertainties and to have better understanding regarding the behavior of SCC, there is a need to develop SCC using locally available materials for its adoption. Therefore, an effort has been made to develop self compacting concrete (SCC) by making alterations in proportioning of its constituents i.e. partial replacement of cement with fly ash and partial replacement of sand with Bottom Ash and effect of exposure to elevated temperature of 200^0, 300^0 and 400^0 for 1 hour was investigated on SCC mixes and compared with the normal concrete mix.

Mix Design of SCC

Self Compacting Concrete preparation requires a special type of mix design due to its properties. The successful development of SCC must ensure a good balance between deformability and stability. Researchers have set some guidelines for mix proportioning of SCC, which include:

- Reducing the volume ratio of aggregate to cementious [12].
- Increasing the paste volume and water-cement ratio (w/c).
- Carefully controlling the maximum coarse aggregate particle size and total volume.
- Using various viscosity enhancing admixtures (VEA) [12].

Durability Properties

It is not practicable to build fire proof structures or entirely prevent outbreak of fire. It is possible however to minimize the effect of fire by a wise choice of materials and construction techniques and by planning aimed at limiting the growth of fire. This can best be achieved by designing a building as a number of separate units so as to contain the fire as long as possible.

Fire Resistance of Structural Elements

IS 456:2000 [6] describes that a structure element should be designed to possess an appropriate degree of resistance to flame penetration, heat transmission and failure. The fire resistance of structural element is expressed in terms of time in hours the built up elements of structure would offer to fire. Fire resistance of concrete element depends upon details of member size cover to reinforcement detailing and type of aggregate used in concrete.

Fire Resistance Test on Structures

IS 3809:1979 [4] deals with the determination of extent of resistance in terms of fire which the built up elements of a building structure would offer to fire. This standard describes the standard heating conditions and pressure conditions for determination of fire resistance of elements of building construction of various categories such as walls, partitions, columns, floors, roofs etc.

Temperature rise within the furnace shall be controlled so as to vary with time within the limits specified and according to the following relationship:

$$T - T_o = 345 \log_{10} (8t+1)$$

Where

T= furnace temperature at time t, expressed in degree Celsius
To= initial furnace temperature, expressed in degree Celsius
t= time, expressed in minutes

Fire Safety of Buildings

IS 1642:1989 [3] lays down the essential requirements of fire safety in buildings with respect to details of construction emphasizing that the construction should not further tend to spread the fire.
This standard describes three methods for determining fire resistance (with a mention that in the absence of any research data available in this country the data arrived by building research establishment (UK) has been adopted in the standard).

- Information as established by the research data.
- Direct applications of results of fire resistance test on an element of structure.
- On the basis of type of construction carried out.

Effect of High Temperature on SCC and Normal Concrete

The influence of a heat treatment on the pore size distribution and compressive strength of different SCC's was investigated [15]. The heat curing of the SCC lead to a change of the pore size distribution to coarser pores but no increase of total pore volume of the concrete. The change of the pore size distribution is correlated to the (w/c) eq. – ratio of the concretes. With increasing (w/c) eq – ratio the mean pore radius of the concrete is strongly influenced. Also, fire tests according to the time temperature curve of ISO 834 were carried out. It was observed that SCC showed surface spalling after 7 to 15 minutes of exposure to fire with spalling depth of approximately 20mm. The residual compressive strength determined on the interior of the test cubes ranged from 74 to 68% which was exposed to the temperature of 750^{o}C [16].

Experimental study was carried out on the high-temperature behavior of conventional vibrated high-strength concrete and self compacting high-strength concrete, subjected to a low heating rate of 0.5^{o}C/min (up to 400^{o}C) and a high heating rate. It was observed that risk of spalling for self compacting concrete was greater than that of conventional high-strength concrete [13].

EXPERIMENTAL PROGRAM

All the samples were moist cured for 28 days & then air cured for another 28 days before exposing to high temperature. The exposure of specimens to elevated temperature was done with the help of furnace (Electric) where temperature could be raised up to 1000 degree Celsius, with a provision to control temperature for a considerable period.
The various cube specimens were exposed to 200^{0}, 300^{0} & 400^{0}C and cylindrical specimens were exposed to 200^{o}C & 300^{o}C in the furnace for One hour duration and were tested after 24 hour of gradual cooling at room temperature. The results of exposed specimens were compared with the specimens cast and kept at room temperature so as to check the change in strength parameter.

Material Used

The following materials were used in the present study.

Cement

Ordinary Portland cement (43 Grade) conforming to IS 8112: 1989 [8] was used. It's Chemical & physical properties are given in Table 1.

Table 1 Physical properties of Portland cement

PHYSICAL PROPERTY	TEST RESULT	REQUIREMENT OF IS:8112-1989
Fineness(m²/kg)	274	225 (min)
Standard Consistency, %	29.5%	---
Initial Setting Time (minutes)	120	30 (min) as per IS:4031
Final Setting Time (minutes)	180	600 (max) as per IS:4031
Soundness (mm)	1.0	
Autoclave Expansion (%)	0.180	0.8 (max)
Specific Gravity	3.15	---
COMPRESSIVE STRENGTH (MPA)		
3-days	27.72	23.0 (min)
7-days	36.67	33.0 (min)
28-days	56.0	43.0(min)

Aggregates

Natural coarse river sand obtained from Pathankot conforming to Zone II as per *IS 383:1970* [5], with 4.75mm maximum size as fine aggregate and Crushed stone obtained from Anandpur sahib with 10mm maximum size as coarse aggregate were used in this study. The physical properties of the Aggregates are given in Table 2

Table 2 Physical properties of aggregates

PROPERTIES	FINE AGGREGATES (ZONE II as per IS 383)	COARSE AGGREGATES
Bulk Density (Compacted) kg/m³	1705	
Bulk Density (Loose) kg/m³	1570	1410
Specific Gravity	2.66	2.67
Water Absorption, %	1.2%	1.41%
Abrasion Value	-	23.2%
Soundness : Loss with Sodium Sulphate (5 Cycles)	-	1.4%
Estimate of Deleterious Material	-	Nil
Flakiness Index	-	27.3%
Elongation Index	-	34.7%

Fly Ash

Class F fly ash obtained from Guru Hargobind Thermal Plant, Lehra Mohabbat, Bathinda, Punjab was used. Fly ash is usually separated at the power plants & which qualify the fineness standard as per IS 3812: 2003 with retention of less than 34% on 45 micron sieve can be added as cementious material in partial replacement of cement. The physical and chemical properties of fly ash are given in the Table 3.

Table 3 Physical and Chemical properties of fly ash

PHYSICAL PROPERTIES	TEST RESULTS	REQUIREMENT (IS: 3812-2003)
Color	Grey (Blackish)	-
Specific Gravity	2.22	
Fineness-specific surface in m^2/kg by Blaine's permeability method	369.7	Min 320
Particles retained on 45 micron IS Sieve (wet sieving) in percent	31%	Max 34%
Lime reactivity –	3.4%	
Average compressive strength at 28 days in N/mm^2.	82.5%	Not less than the 80% of the strength of corresponding plain cement mortar cubes
Soundness by autoclave test – Expansion of specimen in percent	0.23 %	Max 0.8
CHEMICAL PROPERTIES (% AGE BY WEIGHT)		
Silicon dioxide (SiO_2) plus aluminium oxide (Al_2O_3) plus iron oxide (Fe_2O_3) in percent by mass.	74.88	Min 70 as per IS 1727
Silicon Dioxide (SiO_2) in percent by mass.	72.6	Min 35 as per IS 1727
Reactive silica in percent by mass.	41.48	Min 20 as per IS 1727
Magnesium Oxide (MgO) in percent by mass.	0.64	Min 5.0 as per IS 1727
Total Sulphur as sulphur trioxide (SO_3) in percent by mass.	0.31	Min 3.0 as per IS 1727
Available alkalis as sodium oxide (Na_2O) in percent by mass.	0.27	Min 1.5 as per IS 4032
Total Chlorides in percent by mass.	0.03	Max 0.05 as per IS 12423
Loss on ignition in percent by mass	1.61	Max 5.0 as per IS 1727

Coal Bottom Ash

Coal bottom ash is a waste product of thermal power plant which is dumped in landfill can be utilized in SCC as partial replacement of sand. Coal Bottom Ash obtained from Guru Hargobind Thermal Plant, Lehra Mohabbat, Bathinda (Punjab) having more than 34% retention on 45micron sieve was used. The physical properties of coal bottom ash are given in the Table 4

Table 4 Physical properties of bottom ash

PROPERTIES		OBSERVED VALUES
Bulk Density (Compacted) kg/m^3		978
Bulk Density (Loose) kg/m^3		796
Specific Gravity		1.95
Water Absorption, %		1.6%
Fineness Modulus	Bottom ash only	1.62 (confirming to Zone IV as per IS383)
	90% Coarse Sand + 10 % Bottom Ash	2.63 (confirming to Zone II as per IS383)
	80% Coarse Sand + 20 % Bottom Ash	2.31 (confirming to Zone III as per IS383)
	70% Coarse Sand + 30 % Bottom Ash	2.23 (confirming to Zone III as per IS383)

Super plasticizer

FOSROC AURAMIX 400 is polycarboxlic-ether based high performance super plasticizer intended for applications where high water reduction and long workability retention are required. Properties of super plasticizer are given in Table 5.

Table 5 Specifications of super plasticizer (for SCC)

PROPERTIES	RESULTS
Appearance	Light yellow
Volumetric mass @20°C	1.105kg/litre
Chloride content	Nil
Alkali content	Less than 1.5g Na_2O equivalent/litre

Water

Normal potable water conforming to the requirements of IS: 456-2000 [4] was used in the present study.

MIX PROPORTION OF SCC

The mix design of SCC (SCCF25B0) with 0% bottom ash having 25% fly ash in total powder content and Normal concrete mix (NCF25B0) having 25% fly ash in total powder content were taken from a project (Purab Premium Apartments) of GMADA, at SAS Nagar Punjab. In SCC fine aggregates were partially replaced by bottom ash (0 to 30% by weight at the increment of 10%), all the 5 mixes including normal concrete mix were prepared with increased percentage (@50%) of fly ash in total powder content. The compositions of all the mixes are given in Table 6 to 10. The mixes (normal & SCC) had constant coarse aggregate content, fine aggregate, cement and fly ash for particular bottom ash content. The SCC mixes were designated as SCCFxxBvv where “xx” represents fly ash percentage in the total powder content & “vv” represents the percentage of replacement of fine aggregate with bottom ash. The Normal concrete mixes were designated as NCFaaBnn where “aa” represents fly ash percentage in the total powder content & “nn” represents the percentage of replacement of fine aggregate with bottom ash.

Table 6 Composition of normal concrete mixes

MIX	CEMENT (kg/m^3)	FLY ASH (kg/m^3)	CA (kg/m^3)	SAND (kg/m^3)	S.P (kg/ m^3)	S.P (%age)	WATER (kg/ m^3)	W/P ratio
NCF25B0	280	90	1170	759	2.96	0.8	152	0.41
NCF50B0	185	185	1170	759	2.1	0.57	152	0.41

Table 7 Composition of SCC Mixes @ 0% bottom ash

MIX	CEMENT (kg/m^3)	FLY ASH (kg/m^3)	CA (kg/m^3)	SAND (kg/m^3)	BOTTOM ASH	S.P (kg/m^3)	S.P (%age)	WATER (kg/ m^3)	W/P ratio
SCC F25B0	375	125	735	899	0	4	0.8	205	0.41
SCC F50B0	250	250	735	899	0	3.5	0.7	205	0.41

Table 8 Composition of SCC Mixes @ 10% bottom ash

MIX	CEMENT (kg/m³)	FLY ASH (kg/m³)	CA (kg/m³)	SAND (kg/m³)	BOTTOM ASH	S.P (kg/m³)	S.P (%age)	WATER (kg/m³)	W/P ratio
SCCF25B10	375	125	735	809.1	89.9	4	0.8	205	0.41
SCCF50B10	250	250	735	809.1	89.9	3.5	0.7	205	0.41

Table 9 Composition of SCC Mixes @ 20% bottom ash

MIX	CEMENT (kg/m³)	FLY ASH (kg/m³)	CA (kg/m³)	SAND (kg/m³)	BOTTOM ASH	S.P (kg/m³)	S.P (%age)	WATER (kg/m³)	W/P ratio
SCCF25B20	375	125	735	719.2	179.8	4	0.8	219	0.44
SCCF50B20	250	250	735	719.2	179.8	3.5	0.7	219	0.44

Table 10 Composition of SCC Mixes @ 30% bottom ash

MIX	CEMENT (kg/m³)	FLY ASH (kg/m³)	CA (kg/m³)	SAND (kg/m³)	BOTTOM ASH	S.P (kg/m³)	S.P (%age)	WATER (kg/m³)	W/P ratio
SCCF25B30	375	125	735	629.3	269.7	4	0.8	264	0.53
SCCF50B30	250	250	735	629.3	269.7	3.5	0.7	264	0.53

Casting of Specimens

Cube of size 150x150x150 mm for compressive strength and cylinder of size 150mm dia x300mm height for split tensile strength were cast having mix proportions as given in Table 6 to 10. Weighed quantities of cement and fly ash (as per mix design) were dry mixed in a tray for about 5 minutes. A uniform color was obtained without any cluster of cement, fly ash and bottom ash particles. Required quantities of coarse and fine aggregates were then mixed in dry state. The mix of cement and fly ash was added to the mix of coarse and fine aggregate and these were mixed thoroughly until a homogeneous mix was obtained. Water was then added in three stages:

- 50% of total water to the dry mix of concrete in first stage.
- 40% of water and super plasticizer to the wet mix.
- Remaining 10% of water was sprinkled on the above mix and it was thoroughly mixed in the mixer.

The specimens were removed from moulds after 24 hours and cured in water till 28-day as per requirement of the test. After 28 days, the specimens are removed from water and kept in lab for 28-days before testing the durability properties.

Exposure to elevated temperatures

The exposure of specimens to elevated temperatures required a furnace in which the temperature could be raised to 500 degree Celsius with a provision to control the temperature for considerable period. A muffle furnace with 1200°C capacity and inbuilt thermocouple was used. After exposure to elevated temperature of 200^{0}C, 300^{0}C & 400^{0}C, the specimens were allowed to cool at room temperature for about 24 hours and the concrete cubes and cylinders were placed under water in the tank for 24 hours before testing. After taking out these specimens from water their surface were wipe out with cotton cloth and tested in compression and split tension in an automated compression testing machine of 2000 kN capacity. The average of three specimens were taken as final reading.

RESULTS AND DISCUSSION

Flow properties of SCC (Horizontal Slump Flow)

The slump flow test is suitable to evaluate the Flowability of a fresh SCC mix. Figure 1 shows the variation of slump flow diameter with various percentages of bottom ash and fly ash. The slump flow test describes the flowability of a fresh mix in unconfined conditions. EFNARC -2005 [2] suggested a slump flow value ranging 660-750mm for SF2 which is suitable for many normal applications (e.g. walls columns). At slump flow >750mm, the concrete might segregate, and at <660mm, the concrete might have insufficient flow to pass through highly congested reinforcement. All the mixes in the study conform to the above range. The slump flow diameter of all the mixes were in the range of 675-740mm. all the mixes could be designated as SCC mixes.

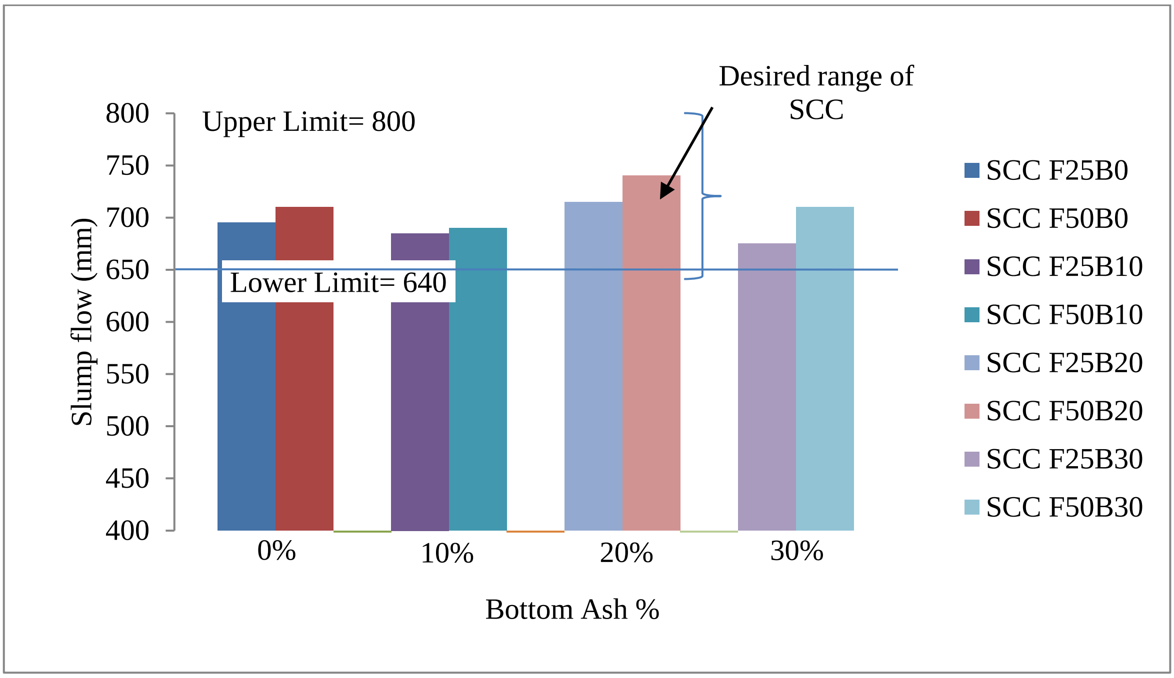

Figure 1 Slump Flow Diameter versus Bottom Ash Percentages for Various Fly Ash %age

Hardened properties of SCC

The specimens were tested for compressive strength and tensile strength at the age of 28 & 56 days and results of normal concrete mixes and SCC mixes, are presented in Table 11 to Table 13. The durability analysis under the different elevated temperature of SCC containing bottom ash as partial replacement of sand & fly ash as partial replacement of cement was carried out and compared with the corresponding strength of normal and SCC at the respective ages of testing are discussed below.

Table 11 Strength of normal concrete & SCC mixes

MIX	Compressive Strength (MPA) 28 Days	Compressive Strength (MPA) 56 Days	Cylinder Split Tensile Strength (MPA) 28 Days	Cylinder Split Tensile Strength (MPA) 56 Days
NCF25B0	50.67	57.48	4.78	5.42
NCF50B0	41.18	47.40	3.64	4.23
SCCF25B0	46.52	54.07	4.74	5.52
SCCF50B0	39.56	45.33	3.55	4.22
SCCF25B10	42.52	48.44	4.39	5.28
SCCF50B10	36.74	41.48	3.51	4.15
SCCF25B20	40.15	47.26	4.01	4.67
SCCF50B20	31.70	36.00	3.25	3.83
SCCF25B30	35.85	41.04	3.78	4.51
SCCF50B30	26.37	30.22	2.59	3.1

Thermal Behavior of SCC under Varying Elevated Temperatures

Physical Changes

Figure 2 shows the changes observed after exposure to elevated temperatures.

- No specific physical changes were noticed in specimens exposed to 200^0C and 300^0C temperature except minor change to light red color at 300^0C whereas at 200^0C exposure the concrete dehydrates the absorbed water.
- After exposures to 400^0C clear physical changes were noticed in color of concrete surface.
- Gain in strength was observed in normal concrete as well as in SCC after exposure to elevated temperature of 200^0C, 300^0C and 400^0C.
- Physical changes were similar in normal concrete as well as SCC with/without bottom ash.

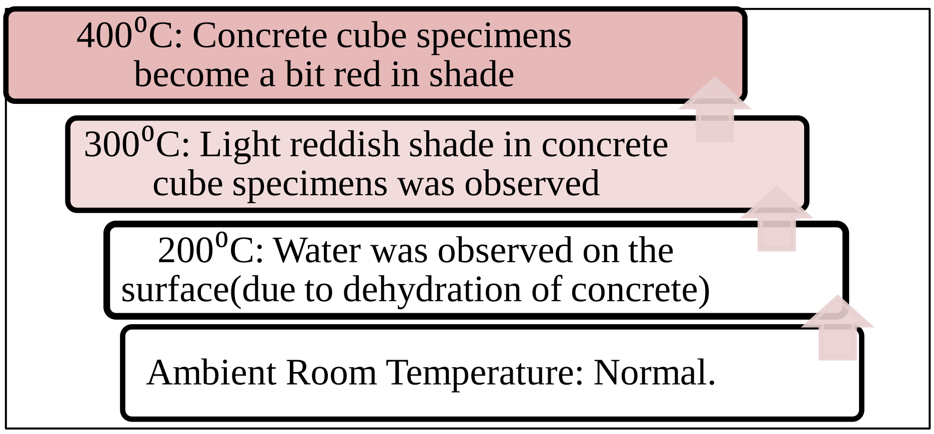

Figure 2 Observed Physical Changes During Testing

Effect of fly ash and bottom ash on the compressive strength of SCC under elevated temperature

Table 12 represents the change in compressive strength of Normal concrete mixes & SCC mixes with varying percentage of bottom ash due to exposure to elevated temperature of 200°C, 300°C and 400°C. It indicates that with 25% fly ash as total percentage of powder contents and 0% bottom ash, gain in strength of SCC (SCCF25B0) is higher than that of corresponding normal concrete mix (NCF25B0) after temperature exposure of 200°C, 300°C as well as 400°C. The strength gain in SCC reduces with increase in percentage of bottom ash in mix up to 20%. At 30% replacement of fine aggregate with bottom ash, the gain in compressive strength was observed as 1.44%, 3.97% and 4.34 % after exposure of 200°C, 300°C and 400°C respectively as compared to 0.32%, 0.32% & 4.38% gain in SCC with 20% bottom ash and 7.42%, 9.32% & 10.97% gain in SCC with 0% bottom ash after exposure of corresponding elevated temperatures.

Table 12 Residual compressive strength of normal and SCC mixes after exposure to various elevated temperatures

Mix	RESIDUAL COMPRESSIVE STRENGTH, MPA			
	Ambient temp (25°C)	200°C	300°C	400°C
NC F25B0	57.48	59.41	61.04	61.78
SCC F25B0	54.07	58.08	59.11	60.00
SCC F25B10	48.44	49.04	50.22	51.55
SCC F25B20	47.26	47.41	47.41	49.33
SCC F25B30	41.04	41.63	42.67	42.82
NCF50B0	47.40	49.33	50.82	52.74
SCCF50B0	45.33	47.7	49.04	51.41
SCCF50B10	41,48	43.11	45.48	48.74
SCCF50B20	36.00	37.04	37.93	40.44
SCCF50B30	30.22	30.52	31.55	33.48

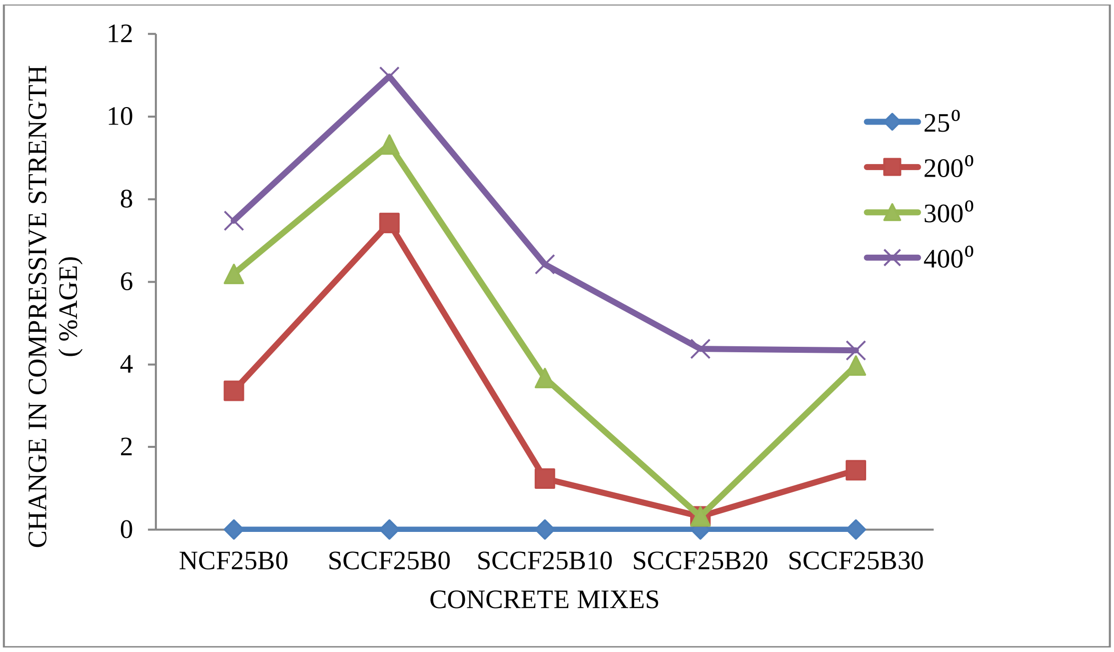

Figure 3 Percentage variation in compressive strength of normal and SCC mixes after exposure to different elevated temperatures with fly ash @25%

Figure 4 shows the change in compressive strength of Normal concrete mix (NCF50B0) & SCC mixes with varying percentage of bottom ash due to exposure to elevated temperature of 200^{o}C, 300^{o}C and 400^{o}C. It indicates that with 50% fly ash as total percentage of powder contents and 0% bottom ash, gain in strength of SCC (SCCF50B0) is higher than that of corresponding normal concrete mix (NCF50B0) after temperature exposure of 200^{o}C, 300^{o}C as well as 400^{o}C. It is also observed that in the SCC with 10% bottom ash performed better when subjected to exposure of 300^{o}C & 400^{o}C than other mixes with 50% fly ash contents, while SCC mix with 0% bottom ash gained 5.23% strength after exposure of 200^{o}C.

However, the maximum strength gain was observed at the exposure of 400^{o}C in all the mixes. Strength gain in SCC with 10% bottom ash was observed to be highest among all the mixes tested (with 50% fly ash content), while SCC mix 30% bottom ash was least affected with temperature exposure.

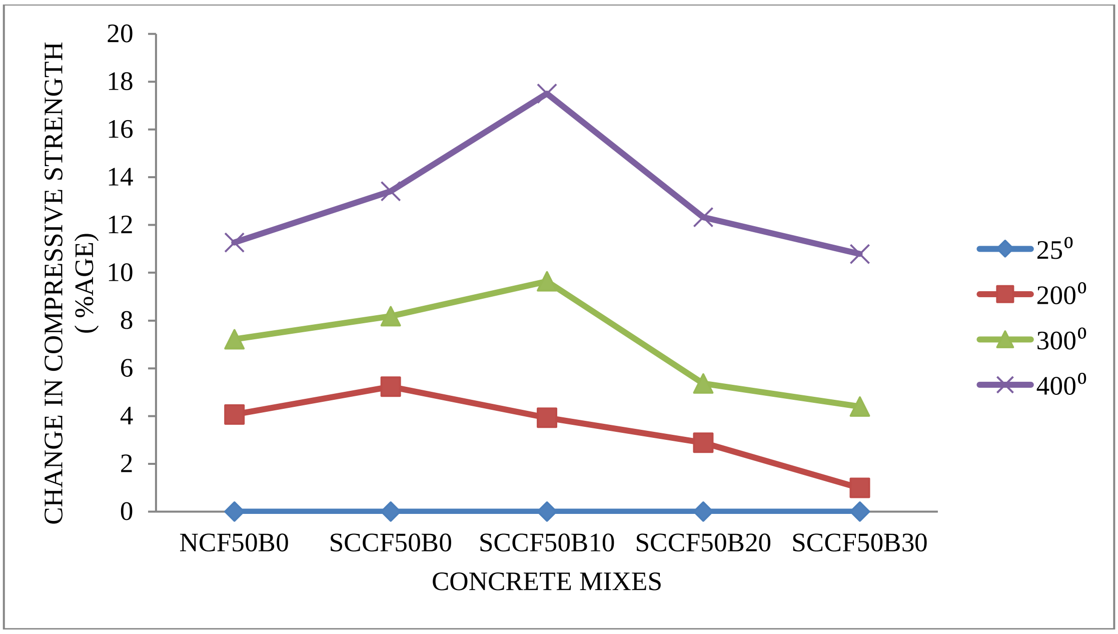

Figure 4 Variation in compressive strength of normal and SCC mixes after exposure to different elevated temperatures with fly ash@50%

It is clear from the results that there is a substantial gain in compressive strength of concrete (Normal and SCC) after exposure of elevated temperature of 200°C, 300°C & 400°C. The gain in concrete with 25% fly ash for various percentage of bottom ash was observed as 0.32 to 7.42%, 0.32 to 9.32% & 4.34 to 10.97% after exposure of 200°C, 300°C & 400°C respectively as compared to 0.99 to 5.23%, 4.4 to 9.64%, and 10.79 to 17.5% gain in mixes with 50% fly ash contents after exposure of corresponding temperatures. The strength gain after exposure was observed increasing with increase in fly ash percentage from 25% to 50%.

Strength gain due to exposure of elevated temperature observed reducing with increases in bottom ash contents from 0 to 20% in SCC mixes (25% fly ash) and then slightly increasing in SCC with 30% bottom ash, whereas among mixes with 50% fly ash; strength gain due to elevated temperature in SCC with 10% bottom ash was higher than all other corresponding mixes.

Effect of fly ash and bottom ash on the tensile strength of SCC under elevated temperature

Table 13 represents the change in split tensile strength of Normal concrete mixes and SCC mixes with varying percentage of bottom ash due to exposure to elevated temperature of 200°C, 300°C. It indicates that with 25% fly ash as total percentage of powder contents and 0% bottom ash; gain in strength of SCC (SCCF25B0) is higher than that of corresponding normal concrete mix (NCF25B0) after temperature exposure of 200°C & 300°C.

Table 13 Residual tensile strength of normal and SCC mixes after exposure to various elevated temperatures

Mix	Cylinder Split Tensile Strength, Mpa		
	Ambient temp (25°C)	200°C	300°C
NC F25B0	5.42	5.57	6.03
SCC F25B0	5.52	5.59	6.35
SCC F25B10	5.28	5.33	5.70
SCC F25B20	4.67	5.02	5.13
SCC F25B30	4.51	4.57	4.66
NCF50B0	4.23	4.44	4.98
SCCF50B0	4.22	4.58	4.85
SCCF50B10	4.15	4.46	4.85
SCCF50B20	3.83	4.13	4.27
SCCF50B30	3.1	3.31	3.43

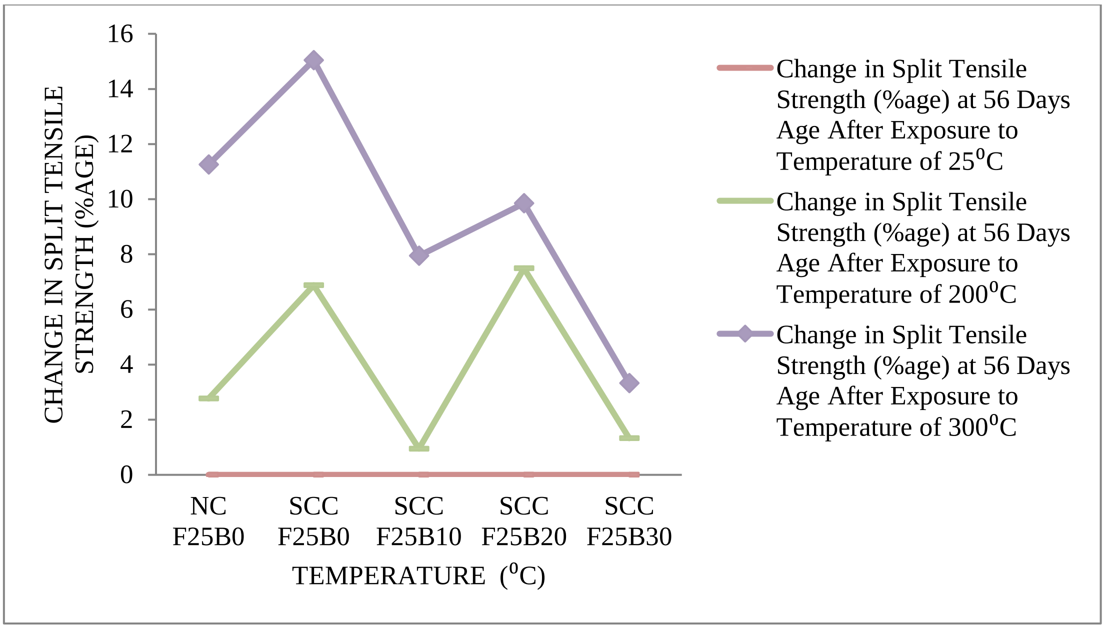

Figure 5 Variation in split tensile strength of normal and SCC mixes after exposure to different elevated temperatures with fly ash@25%

Figure 5 shows the variation in split tensile strength of various concrete mixes with 25% fly ash as total powder content after exposure of different elevated temperatures. It depicts that the strength of all the mixes increased after exposure to elevated temperature of 200□C and 300□C. However, the maximum strength gain was observed at the exposure of 300□C in all the mixes. Strength gain in SCC with 0% bottom ash was observed to be highest among all the mixes tested, while SCC mix 30% bottom ash was least affected with temperature exposure.

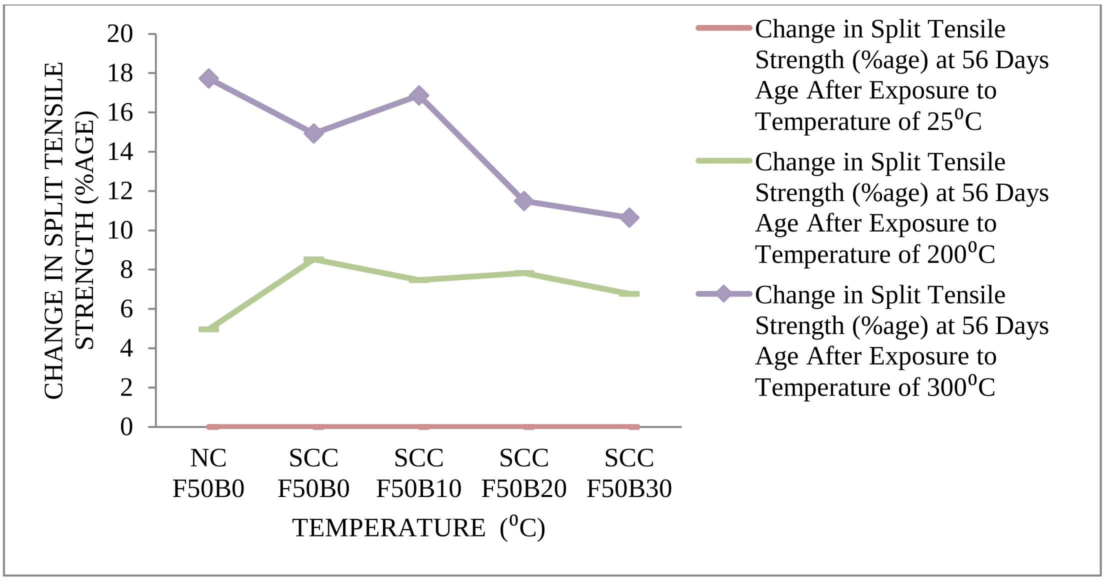

Figure 6 Variation in split tensile strength of normal and SCC mixes after exposure to different elevated temperatures with fly ash@50%

Figure 6 shows the percentage variation in split tensile strength of various concrete mixes with 50% fly ash as total powder content after exposure of different elevated temperatures. It indicates that the strength of all the mixes increase after the exposure of elevated temperature of 200□C and 300□C. However, the maximum strength gain was observed at the exposure of 400□C in all the mixes. Strength gain in SCC with 10% bottom ash was observed to be highest among all the mixes tested (with 50% fly ash content) , while SCC mix 30% bottom ash was least affected with temperature exposure.

It is clear from the results that there is a substantial gain in split tensile strength of concrete (Normal and SCC) after exposure of elevated temperature of 200□C and 300□C. The gain in split tensile strength of concrete with 25% fly ash for various percentage of bottom ash was observed as 0.95 to 7.49% & 3.33 to 15.04% after exposure of 200□C & 300□C respectively as compared to 4.96 to 8.53% and 10.65 to 17.73% gain in mixes with 50% fly ash contents after exposure of corresponding temperatures. The strength gain after exposure was observed increasing with increase in fly ash percentage from 25% to 50%.

Strength gain due to exposure of elevated temperature observed reducing with increases in bottom ash contents from 0 to 30% in SCC mixes (25% fly ash), whereas among mixes with 50% fly ash; strength gain due to elevated temperature in SCC with 10% bottom ash was higher than all other corresponding mixes.

CONCLUSIONS

On the basis of present study, the following conclusions are drawn:

- The fresh properties of the mix with 50% fly ash contents are less affected with the use of bottom ash as compared to mix with 25% fly ash.
- After exposure of 200^{0}C, 300^{0}C and 400^{0}C, the compressive and split tensile strengths of SCC as well as normal concrete mixes were observed to be increasing. This percentage increase in strength of SCC was more as compared to normal concrete mix.

- The mix with higher percentage of fly ash (50%) gained more strength after exposure to elevated temperature as compared to corresponding mix with 25% fly ash contents.
- Maximum strength gain was observed in SCC mix (SCCF50B10) with fly ash @50% as replacement of cement and 10% bottom ash as replacement of sand after exposure to elevated temperature, whereas in mixes with 25% fly ash with 0% bottom ash gained maximum strength after exposure to elevated temperature.
- The strength of SCC mix containing 30% bottom ash was least affected by exposure to elevated temperature. Thereby validate the use of bottom ash @10% as partial replacement of sand with 50% fly ash as cement replacement.
- Based on the materials used in this study, the results suggested that it is technically feasible to utilize bottom ash as a part of fine aggregate & fly ash as replacement of cement in the production of SCC. Besides environmental benefits, there could be technical and financial advantages as well.

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