Experimental Investigation on Strength Properties of Binary and Ternary Blend Concrete Containing Silica-Fume and Rice Husk Ash Subjected to Elevated Temperature

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***Abstract*—Residual compressive strength and tensile strength of ternary and binary blend concrete when subjected to elevated temperatures of 200°C, 400°C and 600°C were investigated. Four concrete mixes in which one was control mix having no admixture , two binary blend concrete having 20%Rice Husk Ash and 10% Silica Fume, and one ternary blend concrete consisting both 20% Rice husk Ash and 10% Silica Fume were prepared for analysis. Manufactured sand was used in all these mixes as fine aggregate. Non-Destructive tests namely Rebound Hammer test and Ultrasonic Pulse Velocity tests were also carried out to observe the deviations between the test results of destructive and non-destructive tests. From results it is seen that binary concrete containing Silica fume as admixture gave good strength than binary concrete containing Rice Husk Ash. When concrete were subjected to elevated temperature the strength increased up to 400°C and beyond 400°C it decreased considerably in all mixes. Correlation coefficient between Rebound Hammer and compression test is R^2=0.8. Ultra-Sonic Pulse Velocity value decreased with increase in temperature irrespective of type of mix.**

***IndexTerms*—Compressive Strength, Tensile strength, Elevated temperature, Non-destructive test, Silica-Fume, Rice Husk Ash.**

I. INTRODUCTION

In order to decrease the consumption of cement, many researches is being carried out to use industrial by-products as supplementary cementitious materials to produce cement without compromising on the quality and strength, at the same time to have economic and ecofriendly concrete. Supplementary cementing materials are commonly used because they improve strength, durability and reduce porosity and improve interface with aggregate [1]. In the present work Silica Fume (SF) and Rice Husk Ash (RHA) are used as partial replacement to cement to produce binary and ternary blend concrete. Manufactured Sand (M-Sand) is used as fine aggregate. From previous researches carried out, it was seen that, about 30% by weight of cement can be replaced by Rice husk ash without any adverse effect on strength and permeability properties of concrete [2]. The combination of 10% Rice husk ash and 10% Silica fume gave better compressive strength and this combination is optimum for achieving maximum synergic effect [3]. The presence of Silica fume in concrete did not affect the relative strength of specimens which were subjected to elevated temperature but it controlled the spalling significantly [4]. By having 100% replacement of natural sand by M-sand the compressive strength increases up to 7.03% [5]. Benefits of using silica fume on fresh properties of concrete are increase in cohesiveness of concrete and therefore less segregation. Because of high surface area of silica fume particles and low water content of silica fume concrete there will be less bleeding, these results in efficient finishing and more durable concrete. Effects of using silica fume on hardened properties are enhanced mechanical properties such as compressive strength and modulus of elasticity. It also reduces permeability which leads to more durable and resistant to chloride and sulfate attack. The rice husk ash contains about 85-95% of amorphous silica, it is highly porous and lightweight, with high external surface area ranging from 50-1000 m2/g. It is a very fine material; its particle size range from 5 to 10 micron. The amorphous silica present in rice husk ash reacts with calcium hydroxide (Ca (OH) 2) which is formed during the hydration of concrete and secondary calcium-silicate-hydrate (C-S-H) is formed. C-S-H acts as a strengthening constituent. The reduction of calcium hydroxide during the reaction with RHA increases resistance to acid attack and also provides resistance to chloride ion penetration.

II. MATERIALS USED

A. Cement

Ordinary Portland cement of grade 43 confirming to IS 8112-1989 of brand Ultratech, with specific gravity of 3.15 was used for all concrete mixes

B. Fine Aggregate

Manufactured sand was used as fine aggregate in this work. It was acquired from Gurumatti quarry, Belagavi. It confirmed to Zone –II. Specific gravity and fineness modulus of M-sand was 2.6 and 3.26 respectively.

C. Coarse Aggregate

Locally available 20 mm down size aggregate with specific gravity 2.96 was used in this present experimental work.

D. Water

Clean potable water available in college was used for preparing concrete mixes and curing of specimens.

E. Silica Fume

Silica fume from the company CORNICHE INDIA PVT.LTD was used as admixture in this present work with specific gravity of 2.2.

F. Rice Husk Ash

Rice husk ash was obtained from Raichur industrial area, Karnataka. It had very fine texture and was grey in color having. Bulk density of Rice Husk Ash (RHA) was 180-230 kg/m^3, and maximum moisture percentage of 1%.

G. Superplasticizer

MasterRheobuild SP11 superplasticizer by BASF chemical company was used to obtain desired workability of concrete. It was dark brown free flowing liquid having relative density of 1.18±0.02 at 25°C and chloride ion content < 0.2% as test data provided by BASF chemicals. The percentage addition of superplasticizer was adjusted while mixing the concrete to get desired workability.

Figure 1 Silica Fume

Figure 2 Rice Husk Ash

III. Methodology

A. Mix Design

Mix design was carried out for M30 grade concrete with reference to IS 10262-2009. Total four mixes were prepared first is control mix/ reference mix without any admixture, second mix Mix-2 contained 20%RHA by weight of cement, Mix-3 contained 10%SF by weight of cement with 70%OPC, these two mixes (MIX-2 & Mix-3) formed binary concrete, and the fourth mix Mix-4 had both 10%SF and 20%RHA forming ternary blend concrete. Table 1 gives quantity of materials used for preparation of mixes.

B. Casting of Specimens

Specimens of all the four mixes were casted and were tested for compression and split tensile strength. For compression strength test, cubes of standard size 150mm x 150mm x 150mm, similarly for split tensile test cylinders of size 150mm x 300mm were casted, after 24hr they were demolded and were subjected to curing for 28 days.

C. Subjecting Specimens to Elevated Temperature

After 28 days of curing, the specimens were removed from curing tank and were allowed for surface drying. The specimens were taken to the furnace and were subjected to elevated temperature of 200, 400 and 600°C for duration of 2hrs. After 2hrs the specimens were removed and were allowed to cool down before testing. Figure 4 shows placing of specimens in furnace for elevated temperature.

D. Testing of Specimens

Specimens subjected to four different temperatures (normal 32°C, 200, 400 and 600°C) of all four mixes (control mix, Mix-2, Mix-3 and Mix-4) were tested for compression strength and split-tensile strength as per IS 516-1959 and IS 5816-1999 respectively. Non-destructive tests namely Rebound Hammer and Ultrasonic Pulse Velocity (UPV) were conducted on the specimens in parallel with compression and tensile strength test. Figure 5 shows the performance of non-destructive tests before they are tested for compressive and split tensile strength.

Table 1 Quantity of materials used in mixes

Materials	**Mix ID**			
	Control mix	**80%OPC+20%RHA (MIX 1)**	**70%OPC+10%SF (MIX 2)**	**50%OPC+10%SF+20%RHA (MIX 3)**
Cement (Kg/m3)	410.6	328.48	369.54	287.42
RHA (Kg/m3)	0	82.12	0	82.12
Silica Fume (Kg/m3)	0	0	41.06	41.06
M-sand (Kg/m3)	601.25	601.25	601.25	601.25
Coarse Agg (Kg/m3)	1182.8	1182.8	1182.8	1182.8
Water	172.44	172.44	172.44	172.44
W/C ratio	0.42	0.42	0.42	0.42
Superplasticizer	2%	2%	2%	3%

Figure 3 Specimens Casted

Figure 4 Placing specimens in furnace

Figure 5 Rebound hammer and UPV tests conducted on specimens

Figure 6 Compression and Split tensile tests

IV. EXPERIMENTAL TEST RESULTS

A. Compressive Strength

Average compressive strength of all four mixes (CM, Mix-2, Mix-3 and Mix-4) at normal temperature, 200, 400 and 600°C are given in Table 2.

Table 2 Average compressive strength of all mixes at different temperatures

MIX ID	%RHA	%SF	Temp	Comp. Strg(MPa)
CM	0	0	Normal	48.52
			200°C	48.89
			400°C	52.7
			600°C	44.7
MIX-2	20	0	Normal	41.5
			200°C	33.2
			400°C	43.71

			600°C	25.93
MIX-3	0	10	Normal	50.67
			200°C	48.75
			400°C	54.52
			600°C	45.04
Mix-4	20	10	Normal	43.9
			200°C	42.6
			400°C	44.3
			600°C	28.6

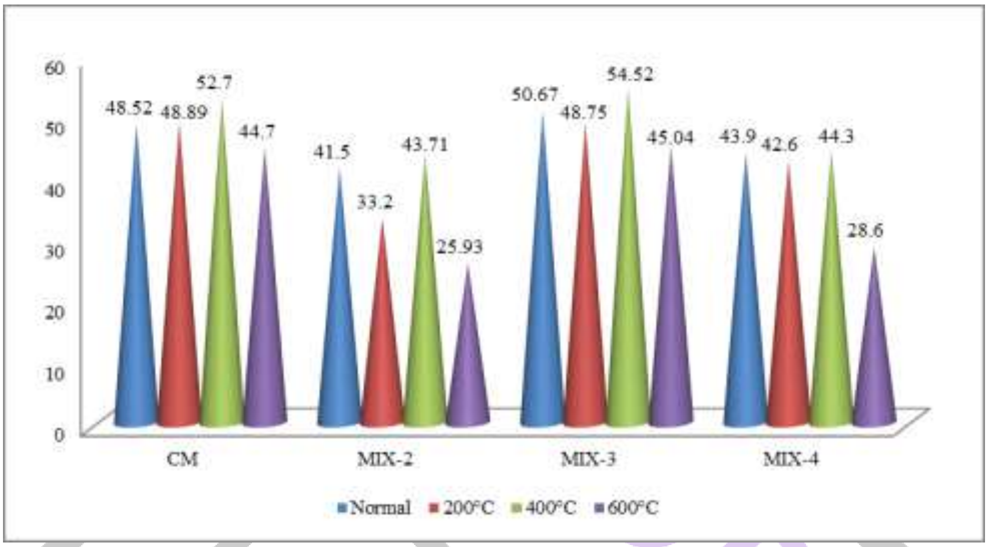

Figure 7 variation of compressive strength of all mixes at different temperatures considered

B. Tensile Strength

Average Tensile strength of all four mixes (CM, Mix-2, Mix-3 and Mix-4) at normal temperature, 200, 400 and 600°C are given in Table 3.

Table 3 average tensile strength of all mixes

MIX ID	%RHA	%SF	Temp	Tensile. Strg(MPa)
CM	0	0	Normal	4.705
			200°C	4.03
			400°C	3.96
			600°C	1.755
MIX-2	20	0	Normal	4.175
			200°C	3.96
			400°C	3.04
			600°C	1.345
MIX-3	0	10	Normal	5.27
			200°C	4.525
			400°C	4.1
			600°C	2.44
Mix-4	20	10	Normal	4.205
			200°C	3.345
			400°C	2.405
			600°C	1.2

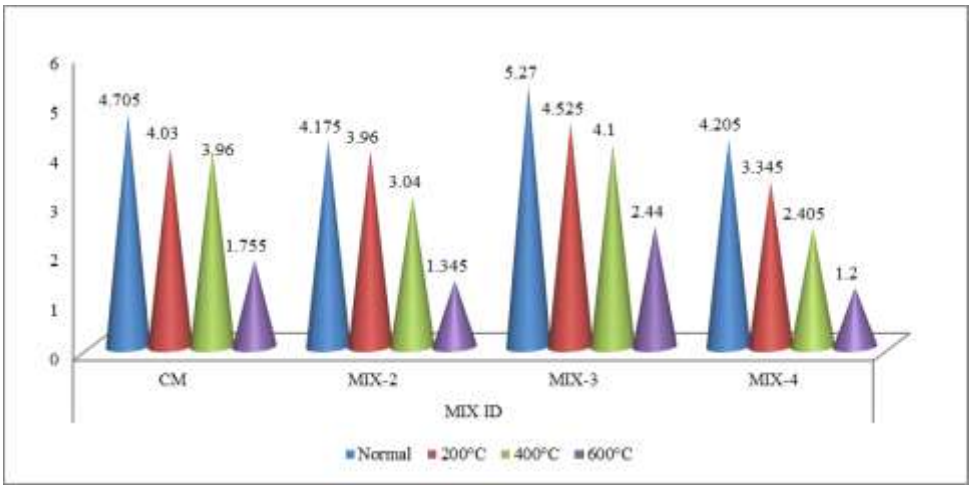

Figure 8 variation of tensile strength of all mixes at different temperatures considered

C. Rebound Hammer

Rebound hammer test was performed on all the cube specimens when they were placed in compression testing machine, before they are tested for compression strength. Compressive strength based on the rebound number was obtained referring to the graph provided by the company. Results of rebound hammer of all the cube specimens irrespective of the composition and their corresponding compressive strength obtained from compression testing are given in following Table 10. Correlation between rebound hammer values and compressive strength values by destructive testing is obtained from linear regression graph as shown in Figure 7. R^2 value is found to be 0.8067 and its equation is **y=0.6199*x + 23.708** where y is compressive strength, x is Rebound hammer values.

Table 4 Compressive Strength and Rebound Hammer values

Compressive strength by CTM (N/mm2)	Rebound Hammer values	Compressive strength by CTM (N/mm2)	Rebound Hammer values
47.56	38.8	28	14
48.44	40	49.78	40.4
49.56	40.4	50.67	42.4
48	40	51.56	44
48.89	40.2	39.56	28
49.78	42	56.89	52.2
52.44	44.2	49.78	40.4
52.67	46	48	40
52.89	46	50.67	44
47.78	38.6	64.89	62
38.22	26	40	28
48	38.2	30.67	24
37.78	24.4	53.78	46.4
41.78	30	43.69	32.2
44.89	34.4	44.44	34.2
26.67	12	43.56	32.2
38.22	26	43.56	32.2
34.67	20	50.67	44
41.78	30	33.33	18.8
43.56	3.2	45.33	18
45.78	36	40.89	28
27.56	12.4	46.67	36.8
		27.56	12
		35.11	22

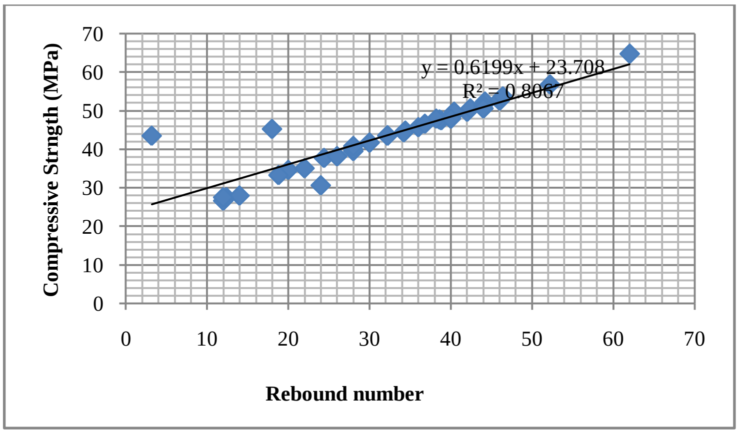

Figure 9 Correlation between rebound number and compressive strength

D. Ultrasonic Pulse Velocity(UPV)

The basic principle behind assessing quality of concrete based on pulse velocity is, if the material is homogeneous and dense without any cracks or voids in it, then higher velocity is obtained because the path of the ultrasonic wave is not disturbed and it takes less time to traverse. If imperfections are presents the path length will be longer, consequently lower velocity will be obtained. UPV test is also used to assess the residual strength of concrete subjected to elevated temperature. In the present work UPV test was conducted on specimens subjected to normal temperature as well as elevated temperature of 200°C, 400°C, and 600°C before they are tested for compression and split-tensile tests. Average ultrasonic pulse velocity value of cubes and cylinder specimens for respective concrete mixes are given in following tables. Variation of UPV values with temperature are shown in respective graphs.

Table 5Ultrasonic Pulse Velocity values of cube specimens of all the mixes

	UPV (m/s) of Cubes			
Temp	CM	MIX-2	MIX-3	MIX-4
Normal	5.03	4.19	4.59	4.072
200°C	4.26	3.36	4.18	3.623
400°C	3.44	1.4	3.6	1.532
600°C	2.33	0.388	1.53	0.169

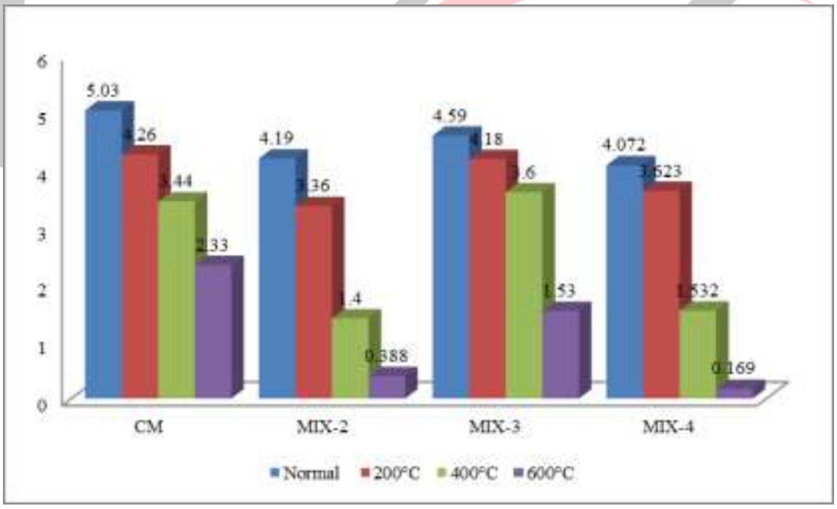

Figure 10 variation of Ultrasonic Pulse Velocity with temperature

Table 6 Ultrasonic Pulse Velocity values of cylinder specimens of different mixes

	UPV (m/s) of Cylinders			
Temp	CM	MIX-2	MIX-3	MIX-4
Normal	3.41	3.03	3.38	3.38
200°C	2.87	2.39	3.05	2.02
400°C	1.43	1.24	1.87	0.38
600°C	0	0	0	0

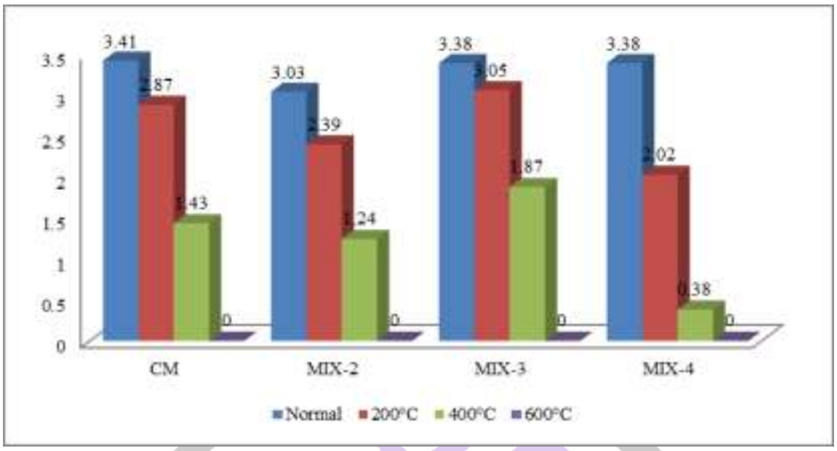

Figure 11 variation of Ultrasonic Pulse Velocity with temperature

V. CONCLUSIONS

The binary blend concrete where 10% OPC is replaced by Silica Fume gave good compressive as well as tensile strength than binary blend with Rice husk Ash. Compressive strength of all mixes increased up to 400°C and beyond 400°C it drastically reduced. Tensile strength reduced with the rise in temperature irrespective of the concrete mix at all temperatures, this shows that RHA and SF have no significant effect on concrete at elevated temperature. Rice Husk Ash in combination with Silica fume in ternary blend concrete gave satisfactory result than binary blend concrete were only RHA is used. The coefficient of determination R^2obtained for Rebound values and Compressive strength is 0.806 which less than 1. Therefore Rebound Hammer test gives only indicative value it cannot be used as substitute for Compressive strength test. Ultrasonic Pulse Velocity decreased when concrete were subjected to higher temperature because, at higher temperature the concrete become porous.

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