International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 04 Issue: 06 | June -2017 www.irjet.net p-ISSN: 2395-0072

Estimation of Strength Properties of Binary and Ternary Blend Concrete by Experimental and Analytical Tools

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Abstract - *In this work residual compressive strength and tensile strengths of ternary and binary blend concrete when subjected to elevated temperatures of 32⁰C 200 400 and 600⁰C were investigated. Three mixes in which one was control mix having no admixtures and two mixes were binary blend concrete having 20% RHA and 10% Metakaolin were prepared. One more mix of ternary blend concrete consisting of 20%RHA and 10%Metakaolin. M Sand was used in all these mixes as fine aggregate. Multiple linear regression analysis was also carried out. Non-Destructive testing methods VIZ Rebound Hammer and Ultrasonic Pulse Velocity tests were also conducted to study the deviation in the results. Results of these experimental and analytical investigations reveal that use of M Sand dramatically improve the target strength (Predicted by using IS Code). Binary blend concrete containing 10% Metakaolin as cement replacement material outperforms all other admixture combinations at all the temperatures considered. Experiments also indicate that binary blend containing 20% RHA as cement replacement material is not suitable when concrete is exposed to elevated temperatures.*

***Key Words*: Rice Husk Ash, Metakaolin, Regression, Non-Destructive Tests**

1. INTRODUCTION

Concrete is the most required material in modern creation. It has versatile property like easy mouldability, excessive compressive strength. The concrete became major construction material due to all those properties. These characters of concrete have made it most popular creative element for all kinds of civil engineering works. It has been followed in architectural structures which require high degree of performance and aesthetic appearances. It is received with the aid of mixing cement, water, and aggregates in required mix proportion. The hardening is caused by chemical action among water and cement. Further huge quantity of residue is getting generated from industries as a byproduct. Some of such byproducts are Fly Ash (Pulverized fuel Ash, PFA), Ground Granulated Blast Furnace Slag (GGBFS), Metakaolin, Silica Fume (Micro Silica), Me and Rice Husk Ash (RHA) are cementitious in nature and may be supplemented to cement that is fairly nice from the point of economy, power efficiency, durability, and usual ecological and environmental benefits.

2. MATERIAL AND METHODOLOGY

2.1 Materials

The OPC 43 Grade cement of Ultra-Tech has been used in the experimental work. Manufactured sand of specific gravity 2.6, Coarse aggregates used in the project work are of 20 mm down size and have specific gravity of 3. Conplast SP430 is a chloride free super plasticizing admixture which is brown in color and dispersible in water. Rice husk ash of density is 0.78 g/cc and specific gravity of 2.1 used. Metakaolin of specific gravity of 2.5.The properties of Cement, Metakaolin and RHA are represented in Table 1, 2 and 3 respectively.

Table -1: Physical Properties of Cement

Property	Value	Standard values (IS 8112 : 1989)
Specific gravity	3.15	Not specified
Fineness (%)	268m²/kg	225m²/kg
Normal or Standard consistency (%)	36	Not specified
Initial setting time (minutes)	155	30 (min)
Final setting time (minutes)	265	600 (max)
Soundness (Le chatelier method) (mm)	4	10 (max)

Table -2: Properties of Metakaolin

Chemical composition	Metakaolin %
Silica (SiO_2)	54.3
Alumina Al_2O_3	38.3
Calcium oxide CaO	0.39
Ferric oxide Calcium oxide (Fe_2O_3)	4.28
Magnesium oxide (MgO)	0.08
Potassium oxide (K_2O)	0.50
Sulphuric anhydride (SO_4)	0.22
LOI	0.68
Specific gravity	2.5
Physical Form	Powder
Colour	Off white

Table -3: Properties of RHA

Grain Size	0-2 mm
Color	Grey
Moisture (%)	Max 1 %
Bulk Density	180-230 kg/m3
Form	Amorphous

2.2 Mix Proportioning

In the present investigation four different mixes were prepared. The strength was targeted as 38.25N/mm².The mix design was done using IS 10262:2009 and the mix proportion of 1:1.46:2.88 and w/c 0.42 is used. To find out the effect of Metakaolin and RHA different mixes were prepared Mix proportions for mixes were adopted are as shown in Table 4.

Table -4: Mix Proportioning per m³ of Concrete

Mix ID	CEMENT kg/m³	MK (10%) kg/m³	RHA (20%) kg/m³	COARSE AGGREGATE kg/m³	FINE AGGREGATE(M SAND) kg/m³	W/C RATIO
#CM	410.6	0	0	1182.8	601.25	0.42
#RHA	328.48	0	82.12	1182.8	601.25	0.42
#MK	369.54	41.06	0	1182.8	601.25	0.42
#RM	287.42	41.06	82.12	1182.8	601.25	0.42

2.3 Mixing Procedure

First cement, M-Sand and Coarse aggregates were dry mixed. Admixtures were added to the batch in dry state as per the mixes. Then small quantity of water was added to make concrete paste and remaining quantity of water was added with super plasticizer. Mixing is done till paste become uniform.

2.4 Casting And Curing

The casting of specimens was done as soon as mixing was over. The concrete was filled in three layers in the cubes mold as well as in the cylinder mold. To remove the entrapped air in the concrete proper compaction was carried out. Second day, molds were de-molded and specimens were taken out for curing. The curing of specimens was done by normal water curing for 28 days. Next day these specimens were heated at higher temperature and brought back to normal temperature by air cooling

2.5 Testing

Concrete cubes of 15 cm * 15 cm *15 cm were casted and Concrete cylinders of 150 mm Ø and 300 mm height were casted and they are tested on Compression testing machine. Non-destructive tests using Rebound hammer and Ultra-sonic pulse velocity machine were conducted before crushing.

3. EXPERIMENTAL RESULTS AND DISSCUTION

3.1 Compressive strength

Compressive strength test results for all four mixes at different temperatures are presented in Table 5. Figure 1 shows the variation in compressive strength of different mixes at different temperatures. From Fig. 1 shows Variation of Compressive strength at different temperatures, it is observed that in case of binary mix containing 10% of Metakaolin, the performance is more satisfactory when compared with all other mixes including the control mix.

Table -5: Compressive strength of all mixes at different temperatures

MIX ID	Temperature	Compressive strength
#CM	32	48.50
	200	48.85
	400	52.50
	600	44.00
#RHA	32	41.48
	200	33.79
	400	43.70
	600	25.93
#MK	32	51.70
	200	53.00
	400	55.00
	600	44.74
#RM	32	42.00
	200	35.00
	400	37.33
	600	21.07

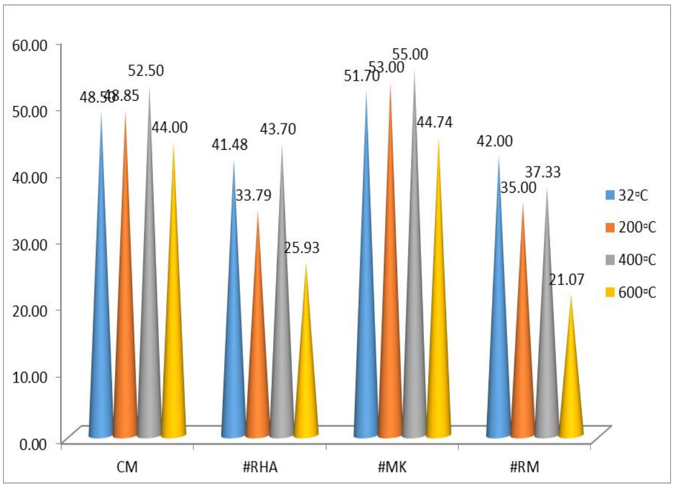

Fig 1: Variation of Compressive strength(MPa) at different temperature

3.2 Spilt Tensile strength

Split Tensile strength test results for all four mixes at different temperatures are presented in Table 6. Figure 2 shows the variation in tensile strength of different mixes at different temperatures. From Fig. 2 shows Variation of Tensile strength at different temperatures, it is observed that in case of binary mix containing 30% of GGBS, the performance is more satisfactory when compared with all other mixes including the control mix.

Table -6: Split Tensile strength of all mixes at different temperatures

MIX ID	Temperature	Split Tensile strength
#CM	32	4.70
	200	4.02
	400	3.91
	600	1.75
#RHA	32	4.19
	200	4.00
	400	3.04
	600	1.34
#MK	32	4.70
	200	4.10
	400	3.93
	600	1.84
#RM	32	4.19
	200	3.91
	400	2.98
	600	1.46

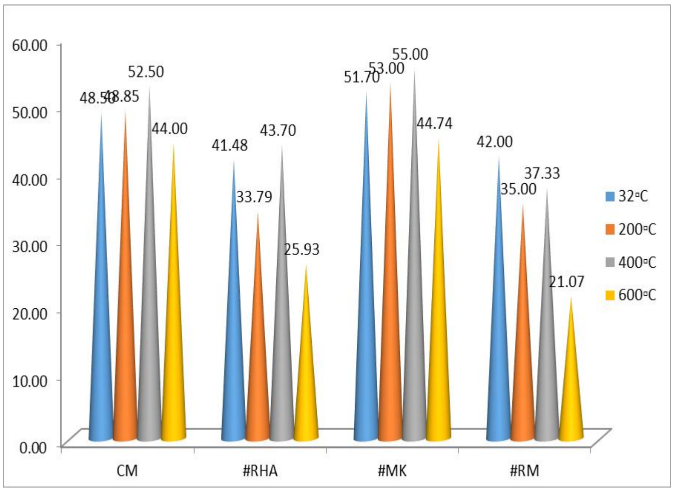

Fig 2: Variation of Split Tensile strength(MPa) at different temperature

3.3 Non-Destructive Test

The Rebound Hammer test is conducted as per IS 13311-part 2,1992. The rebound number is noted down by pressing it on the surface and compressive strength in N/mm^2 is calibrated using Schmidt chart.

Ultra Sonic Pulse Velocity test is a qualitative Non-destructive test. The test is conducted as per IS 13311-part 2,1992 and the readings are obtained in km/sec. Then we can predict the quality of concrete using chart given in IS code. The Results of Rebound Hammer and Ultrasonic Pulse Velocity conducted on concrete specimens are tabled below.

Table -7: Non Destructive Test Results

MIX ID	emperatu	ressive st	RBH	UPV	Remark
#CM	32	48.50	38.80	5.020	Excellent
	200	48.85	41.10	4.260	Good
	400	52.50	42.00	3.440	Medium
	600	44.00	35.80	2.330	Doubtful
#RHA	32	41.48	33.20	4.190	Good
	200	33.79	27.00	3.500	Good
	400	43.70	35.00	1.400	Doubtful
	600	25.93	19.40	0.390	Doubtful
#MK	32	51.70	41.30	4.990	Excellent
	200	53.00	42.70	4.100	Good
	400	55.00	43.60	3.510	Good
	600	44.74	35.20	1.720	Doubtful
#RM	32	42.00	33.60	3.680	Good
	200	35.00	28.30	3.800	Good
	400	37.33	29.90	1.730	Doubtful
	600	21.07	16.90	0.365	Doubtful

4. REGRESSION ANALYSIS

For statistical analyses, multivariable linear regression analysis (MRA) was employed. The purpose of MRA is to simultaneously identify two or more independent variables that explain variations in the dependent variable. The general MRA equation is given below, with the dependent variable being a linear function of more than one independent variable. For prediction of the compressive strength of admixture concrete before production, compressive strength is considered as a dependent variable, while the proportions of cement, RHA, Metakaolin and Temperature are independent variables. The generalized equation obtained is given below

$$f_{ck} = 54.308 + 0.001187 * C - 0.1784 * RHA + 0.001 * MK - 0.01635 * T$$

Where f_{ck} = Compressive Strength (MPa)

C = Cement (kg)

RHA= Rice Husk Ash (kg)

MK = Metakaolin (kg)

T = Temperature (^{0} C

Table -8: Predicted strengths of all mixes at different temperatures

Observations	Cement	RHA	MK	Temp	Compressive strength	Predicted Compressive Strength	Residual
1	410.6	0	0	32	48.5	54.47	-5.97
2	328.48	82.12	0	32	41.48	39.72	1.76
3	369.54	0	41.06	32	51.7	54.46	-2.76
4	287.42	82.12	41.06	32	42	39.71	2.29
5	410.6	0	0	200	48.85	51.53	-2.68
6	328.48	82.12	0	200	33.79	36.78	-2.99
7	369.54	0	41.06	200	53	51.52	1.48
8	287.42	82.12	41.06	200	35	36.77	-1.77
9	410.6	0	0	400	52.5	48.26	4.24
10	328.48	82.12	0	400	43.7	33.51	10.19
11	369.54	0	41.06	400	55	48.25	6.75
12	287.42	82.12	41.06	400	37.33	33.50	3.83
13	410.6	0	0	600	44.74	44.99	-0.25
14	328.48	82.12	0	600	25.93	30.24	-4.31
15	369.54	0	41.06	600	44	44.98	-0.98
16	287.42	82.12	41.06	600	21.07	30.23	-9.16

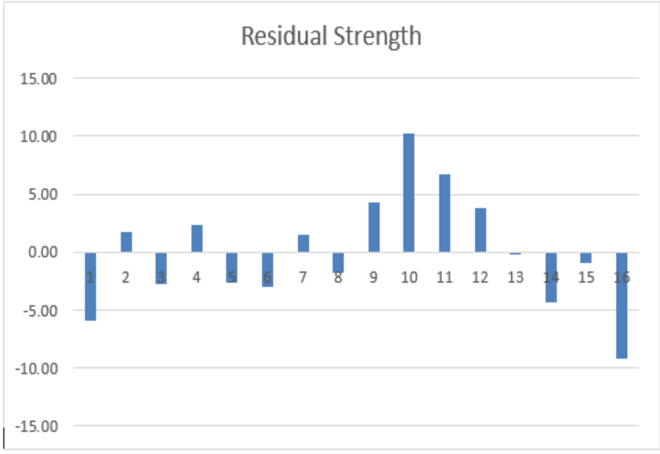

Fig 3: Variation of Residual Strength of all mixes

Fig -1: Name of the figure

5. CONCLUSIONS

The following conclusions are drawn from the study

1) At normal temperature, mix containing 10% Metakaolin has performed better than other mixes (including the control mix) both in compression and tension". Increased compressive strength is due to Metakaolin and manufactured sand.
2) When all these mixes are subjected to an elevated temperature of 200°C, 400°C, 600°C for 2 hours, compressive strength increase, but there is a decline in tensile strength. Tensile strength marginally reduces in all the mixes compared to control mix. Here also concrete containing 10% Metakaolin has performed better in compression than other mixes at 400 °C.
3) Validation of experimental data was statistically done using multivariable linear regression analysis (MRA) in EXCEL 2016 version Satisfactory values of correlation coefficient (R) and determination coefficient (R^2) were obtained.

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