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Effect Of Elevated Temperature On Mechanical Properties Of High Strength Self Compacting Concrete

By

R.VASUSMITHA* **Dr.P.Srinivasa Rao ****

**Research Scholar, J.N.T.U. College of Engineering. Hyderabad, A.P. India.*
***Professor and Head, Dept of Civil Engineering, J.N.T.U. College of Engineering. Hyderabad, A.P. India*

ABSTRACT - High-strength concrete is a material often used in the construction of high rise buildings. In the case of unexpected fire, the building concrete elements such as columns, slab and walls will be subjected to extreme temperatures. In order to assess the performance of high-rise concrete members it is important to understand the changes in the concrete properties due to extreme temperature exposure. The elimination of vibration for compacting concrete during placing through the use of Self compacting concrete leads to substantial advantages related to better Homogeneity, Enhancement of working environment and improvement in the productivity by increasing the speed of construction.

This paper mainly concentrates on studying mechanical properties High Strength Self Compacting concrete subjected to Elevated Temperature of 200, 400 and 600^{o}C with exposure duration of 4,8,12 Hours of Grade M80 Mix. The resulting concrete is characterized in the fresh state by methods used for Self compacted concrete, such as Slump flow, V-funnel and L-Box tests respectively

Key words: High Strength concrete, Self compacting Concrete, Quartz powder , Quartz sand , Crushed basalt, Split tensile strength, Pulse velocity, Compressive strength.

I – INTRODUCTION

Concrete is a material often used in the construction of high rise buildings and in case of unexpected fire, the concrete properties are changes after fire. Hence, it is important to understand the change in the concrete properties due to extreme temperature exposures. As the concrete used for special purpose, the risk of exposing it to high temperature also increases. To be able to predict the response of structure after exposure to high temperature, it is essential that the strength properties of concrete subjected to high temperatures be clearly understood. High temperature can cause the development of cracks. These cracks like any other cracks propagation may eventually cause loss of structural integrity and shorting of service life. The influence of elevated temperatures on mechanical properties of concrete is of very much important for fire resistance studies and also for understanding the behavior of containment vessels, chimneys, nuclear reactor pressure vessels during service and ultimate conditions structures like storage tanks for crude oil, hot water , coal gasification, liquefaction vessels used in petrochemical industries, foundation for blast furnace and coke industries, furnace walls industrial chimney, air craft runway etc., will be subjected to elevated temperatures. So that the variation of compressive strength, performance are some of the important parameters to be investigated when concrete structures are subjected to temperatures.

Self Compacting Concrete is defined as a category of high performance concrete that has excellent deformability in the fresh state and high resistance to segregation, and can be placed and compacted under its self weight without applying vibration.

II – LITERATURE REVIEW

Effect of transient high temperature of high strength concrete by Castillo, C and Durrant AJ (1990) (1) Castillo.C et. al carried out investigations to study the effect of transient high temperature on compressive strength and load deformation properties of high strength concrete under both in loaded and pre loaded conditions and to compare the behavior with that of normal strength concrete. Based on the results obtained on this study, it was concluded that when exposed to temperature in the range of 100^{o} C to 300^{o} C, high strength concrete showed a 15 to 20 % loss of compressive strength. After an initial loss of strength, the HSC recover its strength between 300^{o}C to 400^{o}C reaching a maximum value of 8 to 13 % above the room temperature.

Elevated temperature effects on high residual strength by George C. Hoff et al (2000) (2) George C. Hoff et al conducted research to study the effect of elevated temperature on residual strength of High Strength Concrete. Twelve HSC concrete mixtures were made including three types of concrete: normal density (MND) concrete where 45 % by volume of the coarse aggregate was structural light weight aggregate with the remaining 55 % by volume being normal weight aggregate and two types aggregate were used. Each concrete made with a specific type of aggregate was made with and without the incorporation of polypropylene fibers. It was concluded that in residual strength at 200^{o} C exposure when subjected to 100^{o}C exposure. At constant temperatures of 300^{o} C there is a significant loss of strength. Residual strengths of HSC at exposed temperatures of 300^{o}C or higher are significantly different than residual strength for NSC.

Mechanical properties of PENLY reactor envelope at temperatures up to 200^{o} C by Janotka, Nurnbergurora T (1990), Thermo (3) Janotka, et al carried out experimental investigation to study the effects of high temperatures of up to 200^{o} C on the phase composition, pore structure development and physico-mechanical properties of concrete at the PENLY nuclear plant in France. It was reported that the decrease in mechanical properties of the specimens and shrinkage / expansion development of PENLY concrete was influenced by the degradation through changes induced in basic processes of cement hydration at achieved temperature levels. The damage of bound water from hydration air voids evoking pore structure coarsening.

Effects of test Conditions and Mixture proportions on Behavior of High Strength concrete Exposed to High Temperatures by Long T.Phan and Nicholas Carino J. (2002) (4) : Mechanical properties of high strength concrete exposed to elevated temperatures were measured by heating 100x200mm cylinders at 50^0 C / min to temperature up to 600^0 C. Heating was carried out with and without a sustained stress, and properties were measured at elevated temperatures as well as after cooling to room temperature. Four mixtures with water-cementitioius materials and compressive strength ranging from 51 to 98 MPa were used. Two of the mixtures contained silica fume. The values of w/cm or the presence of silica fume affected the results. The influence of these variables on the tendency for explosive spelling was also examined by the authors. Results indicate that losses in relative strength due to high temperature exposure were affected by the test condition and w/cm, but there were significant interactions among the main factors that resulted in complex behaviors. The presence of silica fume does not appear to have a significant effect. Measurements of temperature histories in the cylinders revealed complex behaviors that are believed to be linked to heat-induced transformations and transport of free and chemically combined water.

Effect of Elevated temperature on compressive strength on HSC made with OPC & PPC by Srinivasa Rao K., Potha Raju M. and Raju P.S.N. (2006) (5): The authors made an attempt to study the effects of elevated temperatures ranging from 50^0 C and 250^0 C on the compressive strength of HSC made with both ordinary Portland cement (OPC) and Portland pozzolana cement (PPC). The residual compressive strengths were evaluated at different ages. The results showed that at later ages HSC made with Portland pozzolana cement performed better by retaining more residual compressive strength compared to concrete made with ordinary Portland cement.

Malhotra (1956), Zoldners (1960), Davis (1967), Abrams (1971), Faiyadh (1989), Khoury (1992), and Noumowe et. al. (1994) (6) had reported the effects of high temperature exposure on the properties of concrete. Several mechanisms have been identified for the deterioration of concrete due to high temperatures. These include decomposition of the calcium hydroxide into lime and water, expansion of lime on re-hydration, destruction of gel structure, phase transformation in some types of aggregate, and development of micro-cracks due to thermal incompatibility between cement paste matrix and aggregate phase. High strength concrete compared to medium strength concrete is more brittle; contains less water; and the solid particles are more compact. Hence, the effects of high temperature on high strength concrete will be different to those with the medium strength concrete.

Sri Ravindrarajah et. al. (1998) (7) through their research concluded that the residual compressive and tensile strengths for high strength concrete with blended cement after heating to 800 C and water quenched were 31 % of its initial strengths whereas the corresponding residual strengths for concrete with ordinary Portland cement was 44%.

III – EXPERIMENTAL PROGRAMME

To study the Effect of Elevated Temperature on High Strength Self Compacting Concrete and total No. of 30 Cubes of Size 100 x 100 mm and 30 Cylinder Specimens of size 100 x 200 mm were tested

- The test specimens were subjected to temperatures ranging from 200 to 600 ^oC for exposure duration of 4,8,12 hours, their behavior was compared to that observed room temperature.
- To study the Effect of Elevated Temperature on Compressive strength, Split Tensile Strength , Weight loss of Specimens and Pulse velocity to observe the crack pattern with respect to Room Temperature

Materials Used

A. Cement

Ordinary Portland cement of 53 grades available in local market is used in the investigation. The cement used has been tested for various proportions as per IS 4031 – 1988 and found to be confirming to various specifications of IS 12269-1987. The specific gravity was 3.15 and fineness was 2800 cm^2/gm

B. Coarse Aggregate

Basalt originates from "hot spot" volcanoes, massive basalt flows and mid oceanic ridges. Basalt is a dark-colored, fine-grained, igneous rock composed mainly of plagioclase and pyroxene minerals. In present investigation Crushed basalt metal of Size 2 to 5 mm is used as Coarse Aggregate with Specific gravity of 3.10 and is obtained from local source.

C. Quartz Powder and Quartz Sand

Quartz has a hardness of 7 on Mohs scale and a density of 2.65 g/cm^3. Quartz is a common constituent of granite, sandstone, limestone, and many other igneous, sedimentary, and metamorphic rocks. It has a hexagonal crystal structure and is made of trigonal crystallized silica. In present investigations the size of quartz sand is 0.3 to 0.8 mm and Quartz powder is in order of 0 -10 µm. Quartz sand is used a fine aggregate with Specific gravity of 2.65 and Quartz powder is used as a cementitioius material with Specific gravity of 2.63. These are obtained from local source.

D. Viscosity Modifying Agent

A Viscosity modified admixture for Rheodynamic Concrete which is colorless free flowing liquid and having Specific of gravity 1.01+0.01 @ 250C and pH value as 8+1 and Chloride Content nil was used as Viscosity Modifying Agent.

E. Admixture

The Modified Polycarboxylated Ether based Super Plasticizer which is Brown Color and free flowing liquid and having Relative density 1.08+0.01 and pH value greater than 6 and Chloride Content nil was used was Super Plasticizer. Flow tests were carried out on pastes containing different water to powder ratios or different superplasticizer dosages with a flow cone as in conventional self-compacting concrete. Superplasticizer dosage of about 1.8% was determined in powder mass as the optimum dosage to above Mix.

F. Micro Silica

Commercially available Micro silica from Elkem Metallurgy, India Ltd. Mumbai having Specific gravity of 2.1 is used. Micro Silica (very fine non-crystalline silicon dioxide) is a by-product of the

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manufacture of silicon, ferrosilicon or the like, from quartz and carbon in electric arc furnace. The Specific surface area was 20000 cm^2/gm

IV – EXPERIMENTAL INVESTIGATION

A. Mix proportion

As there is no standard procedure available for designing the mix proportions for Self Compacting Concrete proportion based on the Experimental trail was adopted. Water to cementitioius material by weight was kept at about 0.215 for M 80 grade of concrete. The Mix proportion for M80 grade SCC is reported in Table No.1

S.No	Material	Weight (Kg)
1	Crushed basalt-2 to 5mm (Z)	1022
2	Quartz Sand (0.3 to 0.8mm) (QS)	437
3	Quartz Powder (0 to 10 µm) (QP)	202
4	Micro Silica (M)	142
5	Cement (R)	472
6	Water (W)	175 lt
7	Super Plasticizer (1.8 % of (M+R+QP)	14688 ml
8	VMA (0.1 % of (M+R+QP)	816 ml
9	W /(M + R + QP)	0.215

Table 1.0: Quantities of Materials Required Per 1 Cum Of High Strength Self Compacting Concrete

B.Preparation of specimen & Testing Procedure

For the temperatures of 200 ^{o}C and above, an electrically heated muffle furnace designed for a maximum temperature of 1200 was used. The furnace was heated by means of exposed heating elements laid on the refractory walls of the inside chamber, which was approximately 400 by 400 by 800mm in dimension. The test specimens of size 100 x 100 mm cubes and 100 x 200 mm cylinders were stacked with sufficient space between two adjacent specimens to obtain a uniform heating in each specimen. The test specimens were heated in batches due to limited capacity of the furnace. Extreme care was taken when handling the heated concrete specimens. The test Setup, testing and Specimens after Impact test are shown in (Fig.1).

Fig .1 Tested Specimens

C. Tests on Fresh Concrete

Conventional workability tests devised for conventionally vibrated concrete mixes are not adequate of SCC as they are not sensitive to detect all the characteristics of SCC mix. Many different methods have been developed to characterize the properties of SCC. As no single method has been found till date that characterizes all the relevant workability aspects, the mix was tested by more than one test method for the different workability parameters. The following test methods were used to characterize the workability properties of SCC for the final acceptance of the SCC mix proportion. Deformability and Viscosity of fresh concrete is evaluated through the measurement of slump flow time and diameter, L-Box ratio test and V-funnel flow time are shown (Fig.2)

D. Slump Flow Test

The slump flow test is used to assess the horizontal free flow and the filling ability of SCC in the absence of obstructions. It is recommended to maintain slump flow value as 650 to 800 mm.

E. T 50cm Slump Flow Test

This test is used along with slump flow test to assess the flowability of SCC.

F. V-Funnel

This test is used to determine the filling ability, flow-ability and segregation resistance of SCC

G. L-Box

This test assesses the flow of the concrete in presence of reinforcement obstructions.

The summary of test results of workability parameters of High Strength Self compacting Concrete are reported in Table 2.0.

Test method	Mix	Permissible limits as per EFNARC Guidelines	
		Max	Min
V-Funnel	8 sec	6 sec	12 sec
V-Funnel at T_5 min	12 sec	11 sec	15 sec
Abrams slump flow	720 mm	650 mm	800 mm
T 50cm slump flow	3 sec	2 sec	5 sec
L- Box	0.9	0.82	1
	1 sec	1 sec	2 sec
	2 sec	2 sec	3 sec

Table No 2.0 Workability properties

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Fig .2 Workability Tests on High Strength Self Compacting Concrete

V – RESULTS AND DISCUSSIONS

A. Workability

As it is observed from Table No.2, the basic requirements of high flowability and segregation resistance as specified by guidelines on Self Compacting Concrete by EFNARC (8) are satisfied.

B. Effect of Temperature with respect to Exposure Time on High Strength self compacting concrete

The results of elevated temperature on HSSCC were provided in Tables from 3.0 to 10.0 and Fig. 3.0 to 10.0

It is observed from Table No.3, that, Compressive Strength of High Strength Self Compacting Concrete Specimens 28 days at Room Temperature varied from 84.69 to 82.57 N/mm^2, for 200^0 C varied from 80.59 to 76.62 at 4 hrs, 76.59 to 73.62 at 8 hrs, 74.55 to 71.68 at 12 hrs, for 400^{0}C varied from 71.68 to 68.02 at 4 hrs, 67.02 to 66.02 at 8 hrs, 64.65 to 61.95 at 12 hrs, for 600^{0}C at 4, 8, 12 hrs concrete specimen were crushed

It is observed from Table No.4, that, Percentage decrease in Compressive Strength of High Strength Self Compacting Concrete Specimens at 28 days with respect to Room Temperature for 200^0 C varied from 4.84 to 7.21 at 4 hrs, 8.56 to 10.84 at 8 hrs, 11.97 to 13.19 at 12 hrs, for 400^{0}C varied from 14.36 to 16.62 at 4 hrs, 17.86 to 19.04 at 8 hrs, 20.66 to 23.97 at 12 hrs, for 600^{0}C at 4, 8, 12 hrs concrete specimen were crushed

It is observed from Table No.5, that, Percentage weight loss of High Strength Self Compacting Concrete Cube Specimens at 28 days with respect to Room Temperature for 200^0 C varied from 0.79 to 1.60 at 4 hrs, 1.96 to 2.43 at 8 hrs, 3.07 to 3.57 at 12 hrs, for 400^{0}C varied from 3.92 to 5.05 at 4 hrs, 5.51 to 5.81 at 8 hrs, 6.98 to 7.96 at 12 hrs, for 600^{0}C at 4, 8, 12 hrs concrete specimen were crushed

It is observed from Table No.6, that, Pulse Velocity (m/sec) of High Strength Self Compacting Concrete Cube Specimens at 28 days for Room Temperature varied from 4370 to 4430, for 200^0 C varied from 4270 to 4390 at 4 hrs, 4200 to 4230 at 8 hrs, 4120 to 4200 at 12 hrs, for 400^{0}C varied from 3900 to 4090 at 4 hrs, 3500 to 3800 at 8 hrs, 3290 to 3470 at 12 hrs, for 600^{0}C at 4, 8, 12 hrs concrete specimen were crushed

It is observed from Table No.7, that, Split Tensile strength of High Strength Self Compacting Concrete Specimens at 28 days at Room Temperature varied from 7.32 to 7.77, for 200^0 C varied from 7.25 to 7.48 at 4 hrs, 6.99 to 7.32 at 8 hrs, 6.87 to 7.08 at 12 hrs, for 400^{0}C varied from 6.81 to 6.99 at 4 hrs, 6.69 to 6.87 at 8 hrs, 6.24 to 6.51 at 12 hrs, for 600^{0}C at 4, 8, 12 hrs concrete specimen were crushed

It is observed from Table No.8, that, Percentage decrease in Split Tensile Strength of High Strength Self Compacting Concrete Specimens at 28 days with respect to Room Temperature for 200^0 C varied from 2.96 to 4.01 at 4 hrs, 4.51 to 6.08 at 8 hrs, 6.15 to 8.66 at 12 hrs, for 400^{0}C varied from 9.10 to 10.61 at 4 hrs, 11.61 to 13.89 at 8 hrs, 14.75 to 18.15 at 12 hrs, for 600^{0}C at 4, 8, 12 hrs concrete specimen were crushed

It is observed from Table No.9, that, Percentage weight loss of High Strength Self Compacting Concrete Cylinder Specimens at 28 days with respect to Room Temperature for 200^0 C varied from 0.65 to 1.27 at 4 hrs, 1.53 to 1.97 at 8 hrs, 2.43 to 3.04 at 12 hrs, for 400^{0}C varied from 3.37 to 4.02 at 4 hrs, 4.37 to 5.31 at 8 hrs, 6.07 to 6.81 at 12 hrs, for 600^{0}C at 4, 8, 12 hrs concrete specimen were crushed

It is observed from Table No.10, that, Pulse Velocity (m/sec) of High Strength Self Compacting Concrete Cylinder specimens at 28 days at Room Temperature varied from 4730 to 4600, for 200^0 C varied from 4650 to 4550 at 4 hrs, 4530 to 4500 at 8 hrs, 4450 to 4350 at 12 hrs, for 400^{0}C varied from 4300 to 4200 at 4 hrs,4030 to 3850 at 8 hrs, 3280 to 3060 at 12 hrs, for 600^{0}C at 4, 8, 12 hrs concrete specimen were crushed

S.No	Room Temperature	Temperature (200^{0}C) Exposure Time (Hours)			Temperature (400^{0}C) Exposure Time (Hours)			Temperature (600^{0}C) Exposure Time (Hours)		
		4h	8h	12h	4h	8h	12h	4h	8h	12h
1	84.69	80.59	76.59	74.55	71.68	67.02	64.65	0	0	0
2	83.59	77.68	74.68	72.58	68.68	66.58	63.52	0	0	0
3	82.57	76.62	73.62	71.68	68.02	66.02	61.95	0	0	0

Table 3.0.Compressive Strength of HSSCC Specimen with (w/b= 0.215) at 28 days at Room Temperature, 200^0 C, 400^{0}C and 600^{0}C at 4, 8, 12 hours duration

S.No	Temperature (200^{0}C) Exposure Time (Hours)			Temperature (400^{0}C) Exposure Time (Hours)			Temperature (600^{0}C) Exposure Time (Hours)		
	4h	8h	12h	4h	8h	12h	4h	8h	12h
1	4.84	8.56	11.97	14.36	17.86	20.66	0	0	0
2	6.07	9.66	12.17	15.84	18.35	22.01	0	0	0
3	7.21	10.84	13.19	16.62	19.04	23.97	0	0	0

Table 4.0 Percentage Decrease of Compressive Strength of HSCCC Specimen with (w/b=0.215) at 200^0 C, 400^{0}C and 600^{0}C at 4, 8, 12 hours duration with respect to 28 days strength

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S.No	Temperature (200^0C) Exposure Time (Hours)			Temperature (400^0C) Exposure Time (Hours)			Temperature (600^0C) Exposure Time (Hours)		
	4h	**8h**	**12h**	**4h**	**8h**	**12h**	**4h**	**8h**	**12h**
1	0.79	1.96	3.07	3.92	5.51	6.98	0	0	0
2	1.18	2.29	3.29	4.56	5.81	7.31	0	0	0
3	1.60	2.43	3.57	5.05	5.76	7.96	0	0	0

Table 5.0 Percentage Weight Loss of HSSCC Cube Specimen with (w/b=0.215) at 200^0 C, 400^0C and 600^0C at 4, 8, 12 hours duration with respect to 28 days

S.No	Room Temperature	Temperature (200^0C) Exposure Time (Hours)			Temperature (400^0C) Exposure Time (Hours)			Temperature (600^0C) Exposure Time (Hours)		
		4h	**8h**	**12h**	**4h**	**8h**	**12h**	**4h**	**8h**	**12h**
1	4370	4270	4200	4120	3900	3500	3290	0	0	0
2	4400	4290	4220	4150	4050	3690	3390	0	0	0
3	4430	4390	4230	4200	4090	3800	3470	0	0	0

Table 6.0 Pulse Velocity (m/sec) of HSSCC Cube Specimen with (w/b=0.215) at 28 days at Room Temperature, 200^0 C, 400^0C and 600^0C at 4, 8, 12 hours duration

S.No	Room Temperature	Temperature (200^0C) Exposure Time (Hours)			Temperature (400^0C) Exposure Time (Hours)			Temperature (600^0C) Exposure Time (Hours)		
		4h	**8h**	**12h**	**4h**	**8h**	**12h**	**4h**	**8h**	**12h**
1	7.32	7.25	6.99	6.87	6.81	6.69	6.24	0	0	0
2	7.74	7.43	7.22	7.07	6.95	6.82	6.49	0	0	0
3	7.77	7.48	7.32	7.08	6.99	6.87	6.51	0	0	0

Table 7.0 Split Tensile Strength of HSSCC Specimen with (w/b=0.215) at 28 days at Room Temperature, 200^0 C, 400^0C and 600^0C at 4, 8, 12 hours duration

S.No	Temperature (200^0C) Exposure Time (Hours)			Temperature (400^0C) Exposure Time (Hours)			Temperature (600^0C) Exposure Time (Hours)		
	4h	**8h**	**12h**	**4h**	**8h**	**12h**	**4h**	**8h**	**12h**
1	2.96	4.51	6.15	9.10	11.61	14.75	0	0	0
2	3.73	5.43	8.88	10.04	12.58	16.47	0	0	0
3	4.01	6.08	8.66	10.61	13.89	18.15	0	0	0

Table 8.0 Percentage decrease of Split Tensile Strength of HSSCC Specimen with (w/b=0.215) at 200^0 C, 400^0C and 600^0C at 4, 8, 12 hours duration with respect to 28 days strength

S.No	Temperature (200^0C) Exposure Time (Hours)			Temperature (400^0C) Exposure Time (Hours)			Temperature (600^0C) Exposure Time (Hours)		
	4h	**8h**	**12h**	**4h**	**8h**	**12h**	**4h**	**8h**	**12h**
1	0.65	1.53	2.43	3.37	4.37	6.07	0	0	0
2	0.87	1.61	2.84	3.82	4.64	6.46	0	0	0
3	1.27	1.97	3.04	4.02	5.31	6.81	0	0	0

Table 9.0 Percentage Weight Loss of HSSCC Cylinder Specimen with (w/b=0.215) at 200^0 C, 400^0C and 600^0C at 4, 8, 12 hours duration with respect to 28 days

S.No	Room Temperature	Temperature (200^0C) Exposure Time (Hours)			Temperature (400^0C) Exposure Time (Hours)			Temperature (600^0C) Exposure Time (Hours)		
		4h	**8h**	**12h**	**4h**	**8h**	**12h**	**4h**	**8h**	**12h**
1	4730	4650	4530	4450	4300	4030	3280	0	0	0
2	4650	4600	4510	4400	4240	3900	3160	0	0	0
3	4600	4550	4500	4350	4200	3850	3060	0	0	0

Table 10.0 Pulse Velocity (m/sec) of HSSCC Cylinder Specimen with (w/b=0.215) at Room Temperature ,200^0 C, 400^0C and 600^0C at 4, 8, 12 hours duration at 28 days strength

Conclusions

[1] The loss of Compressive Strength and Split Tensile strength were nearly 14 % and 9 % at 200 ^{o}C and 400 ^{o}C for 12 hrs and 24 % and 18 % at 200 ^{o}C and 400 ^{o}C for 12 hrs.

[2] The percentage weight loss of Cube Specimens and Cylinder Specimens were nearly 4 % and 8 % at 200 ^{o}C and 400 ^{o}C for 12 hrs and 3 % and 7 % at 200 ^{o}C and 400 ^{o}C for 12 hrs.

[3] The Pulse Velocity of Cube Specimens and Cylinder Specimens were nearly 4200 m/sec and 3470 m/sec at 200 ^{o}C and 400 ^{o}C for 12 hrs and 4350 m/sec and 3060 m/sec at 200 ^{o}C and 400 ^{o}C for 12 hrs.

[4] The specimens when exposed to 600^o C for 4, 8, 12 hours duration, all the specimens got totally powdered at this temperature.

[5] Ultrasonic pulse velocity measurement can be used to estimate the temperature-related damage in concrete.

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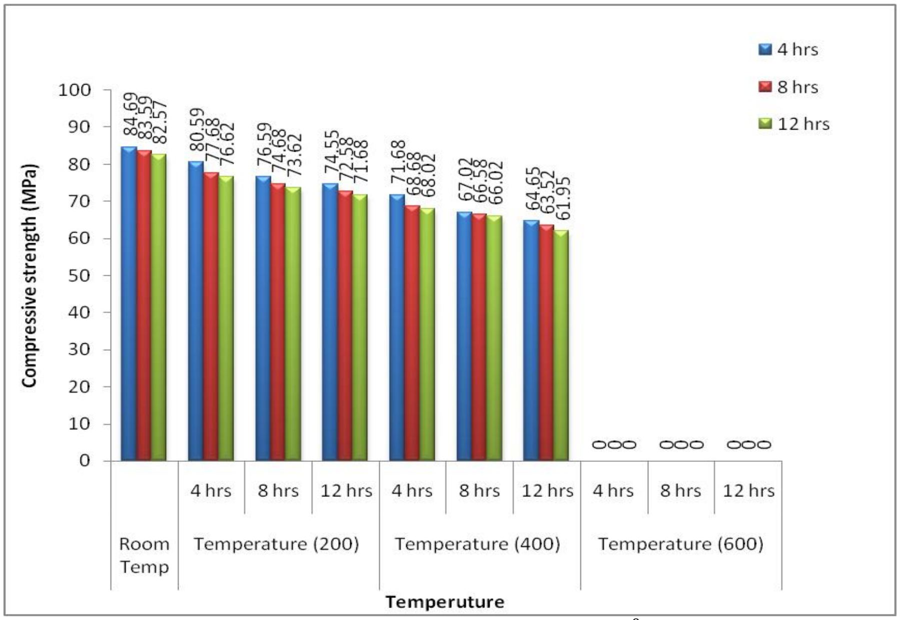

Fig. 3.0.Variation of Compressive Strength at Room Temperature, 200, 400, 600^{0} C for exposure duration of 4, 8, 12 hrs at 28 days

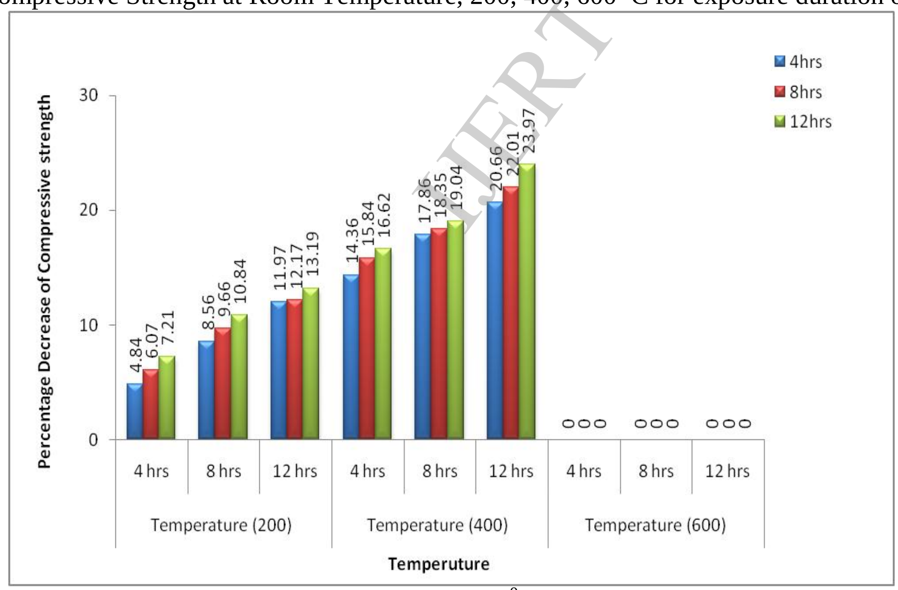

Fig. 4.0.Percentage decrease in Compressive Strength at 200, 400, 600^{0} C for exposure duration of 4, 8, 12 hrs with respect to Room Temperature at 28 days

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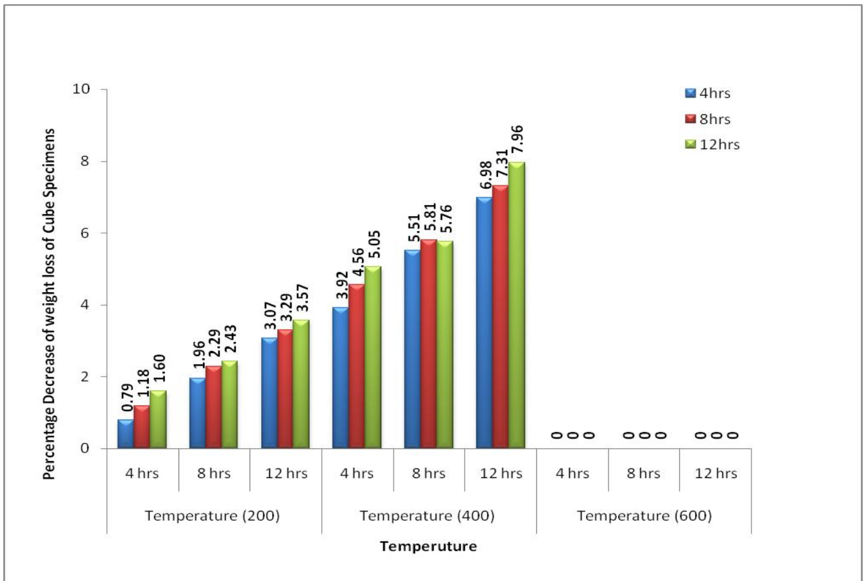

Fig. 5.0.Percentage weight loss of cube specimens at 200, 400, 600^0 C for exposure duration of 4, 8, 12 hrs with respect to Room Temperature at 28 days

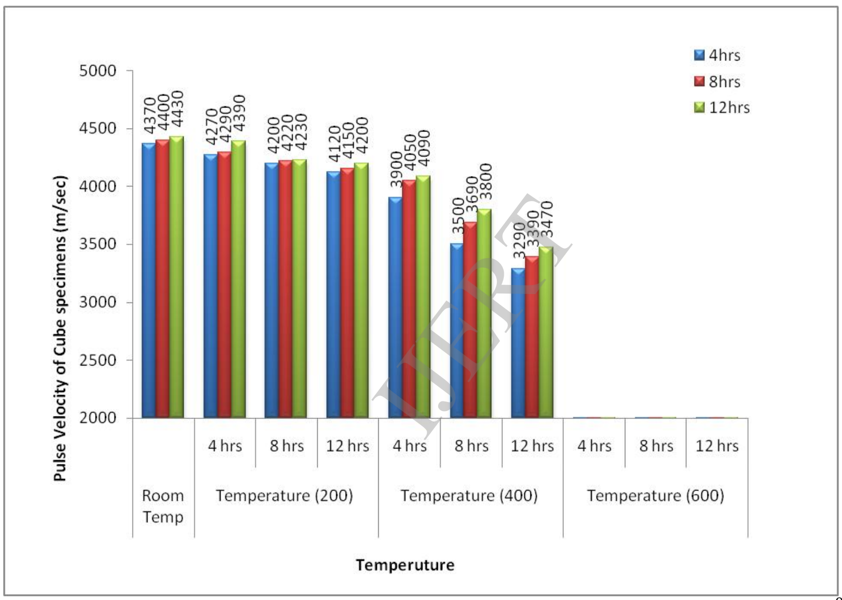

Fig. 6.0. Variation of Pulse Velocity (m/sec) of Cube Specimens at Room Temperature, 200, 400, 600^0 C for exposure duration of 4, 8, 12 hrs at 28 days

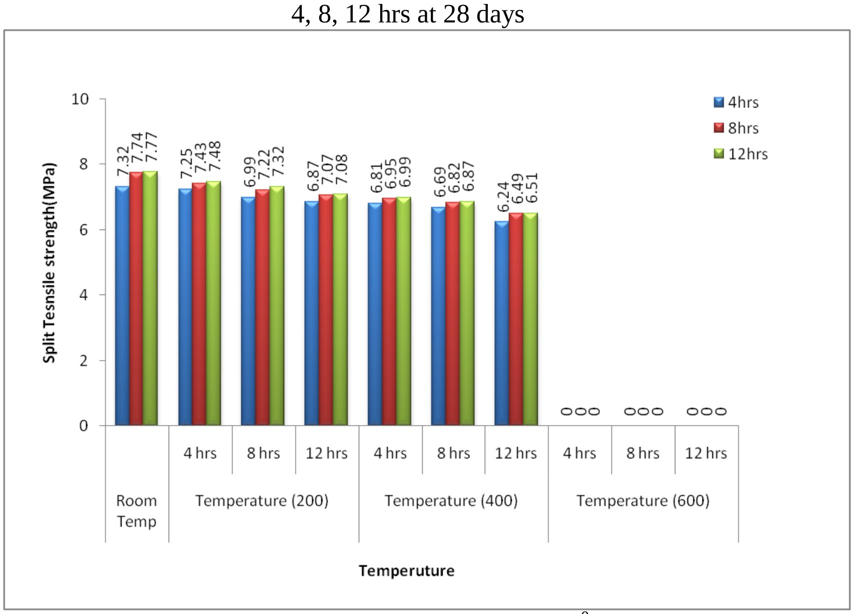

Fig. 7.0. Variation of Split Tensile Strength at Room Temperature, 200, 400, 600^0 C for exposure duration of 4, 8, 12 hrs at 28 days

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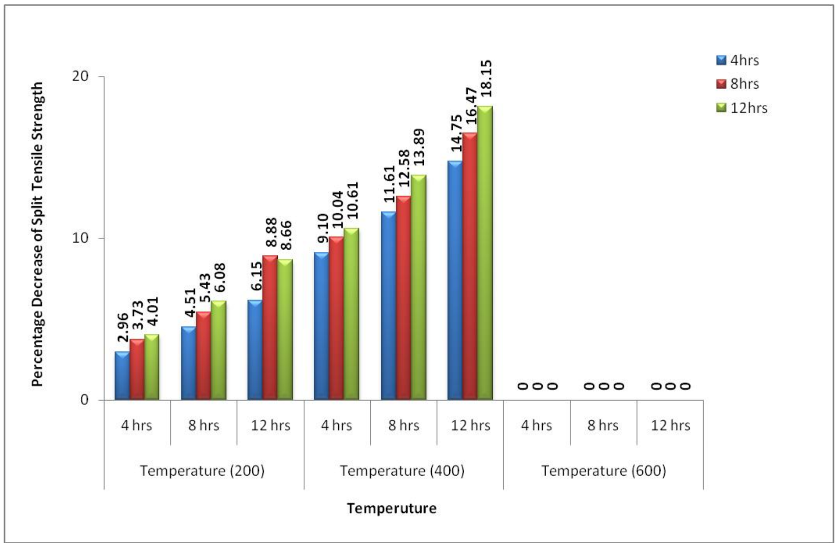

Fig. 8.0.Percentage decrease in Split Tensile Strength at 200, 400, 600^0 C for exposure duration of 4, 8, 12 hrs with respect to Room Temperature at 28 days

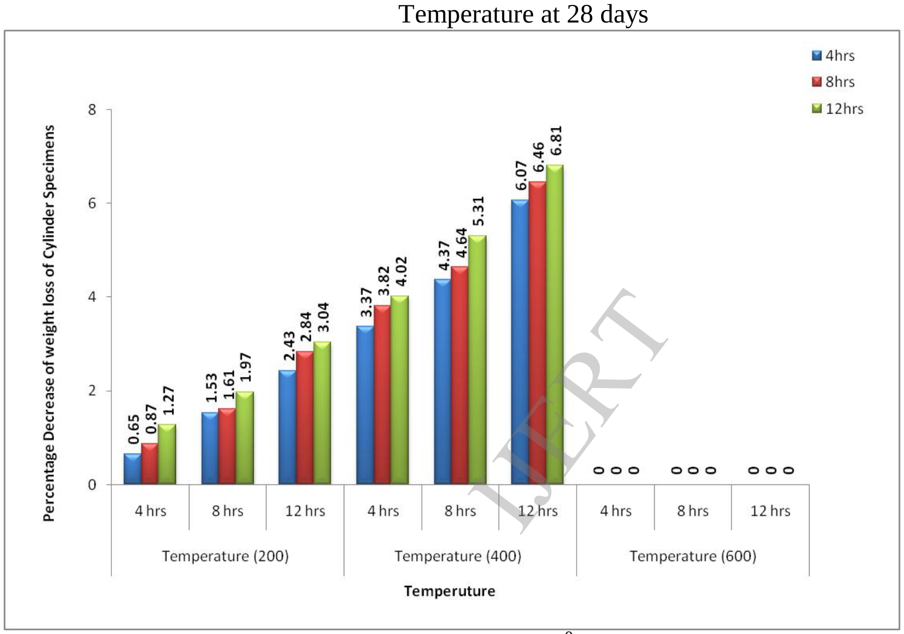

Fig. 9.0.Percentage weight loss of cylinder specimens at 200, 400, 600^0 C for exposure duration of 4, 8, 12 hrs with respect to Room Temperature at 28 days

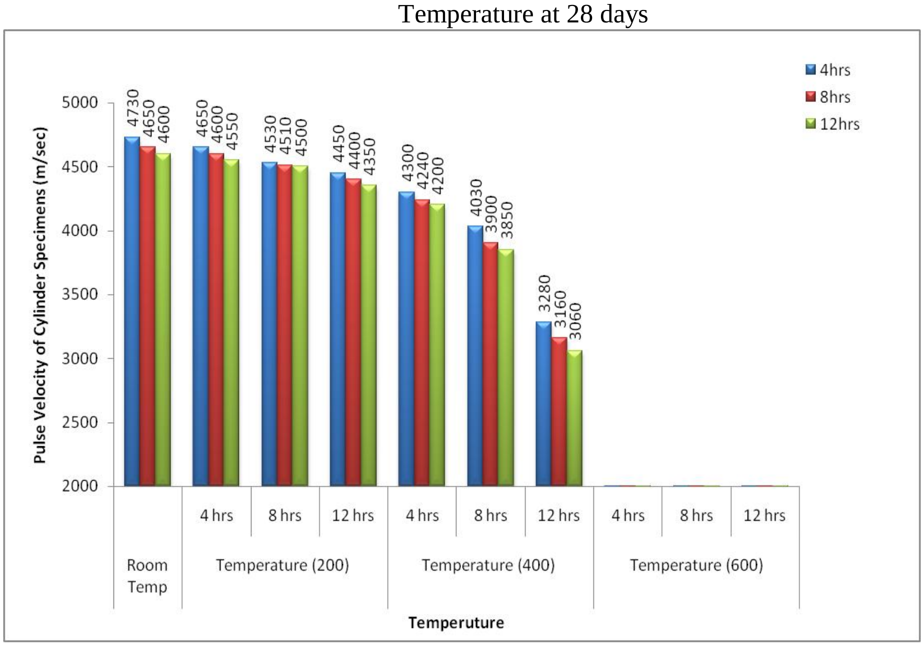

Fig. 10.0. Variation of Pulse Velocity (m/sec) of Cylinder Specimens at Room Temperature, 200, 400, 600^0 C for exposure duration of 4, 8, 12 hrs at 28 days

ABOUT THE AUTOHRS

R. Vasusmitha is currently working as Senior Manager (Designs) in M/s Afcons Infrastructure limited, Mumbai. She has about 15 years of Industrial experience in various fields of Marine structures, Bridges, Industrial Buildings etc., Graduated and Post Graduated from J.N.T.U College of Engineering, Hyderabad in Civil Engineering. Research Scholar under esteemed guidance of Dr.P.Srinivasa Rao, Head of Department, Civil Engineering J.N.T.U Hyderabad.

Dr P. Srinivasa Rao is currently working as Professor in the Department of Civil Engineering, J.N.T University College of Engineering, Kukatpally, Hyderabad. He has about 25 years of experience in Teaching and Research. He is presently Head of Department, Civil Engineering J.N.T.U Hyderabad. He has guided many PhD's and involved in R& D activities. Apart from general Structural Engineering, the Special Concretes like Self Compacting Concrete, SFR-SCC, and HPC are the fields of his special interest.