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The Effect of Temperature on Mechanical Properties of M100 Concrete

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Abstract: Concrete is generally an excellent fire proofing material. As concrete is exposed to elevated temperature in accidental building fire, an operating furnace, coke oven batteries or a nuclear reactor, its mechanical properties such as Compressive strength, Split tensile strength, Modulus of rupture and Modulus of elasticity for M100 concrete may be decreased reasonably. Since M100 concrete is a relatively a new type of concrete, knowledge about the performance of M100 subjected to fire is limited in comparison with conventional concrete. The behavior of M100 concrete differs from that of Conventional concrete under the same temperature exposure. An attempt has been made in this work to study the effect of elevated temperatures on Compressive strength, Split tensile strength and Flexural strength (modulus of rupture). The cubes of 150 mm side, the beams of 500 mm x 100mm x 100mm and the cylinders of 150mm dia and 300 mm height are used for this study. They were exposed to different temperatures of 50 to 250^0 C in intervals of 50^{0}C for different durations of 1h, 2h, 3h, 4h and 5hours. After these specimens were heated, they were tested for the above mechanical properties in hot state. The effect of elevated temperature on those properties was observed.

Keywords: *Ultra strength concrete, Silica fume, Rheobuild, Modulus of rupture, Split tensile strength, Conventional concrete*.

I. INTRODUCTION

Exposed to elevated temperature causes physical changes including large volume changes dueto thermal dilations, thermal shrinkage and creep related to water loss. The volume changes can result in large internal stresses and lead to micro-cracking and fracture. Elevated temperatures also cause chemical and micro-structural changes such as water migration, increased dehydration, interfacial thermal incompatibility and the chemical decomposition of hardened cement past and aggregate. In general, all these changes decrease the stiffness of concrete and increase the irrecoverable deformation. Various investigations indicate that the strength and stiffness of concrete decrease with increasing temperature, exposure time and thermal cycles. High strength concrete is typically made with high binder contents, low water-to-binder rations. Supplementary mineral and chemical admixtures. All of these combine to form a very dense matrix that restricts the ability of moisture to escape from the concrete during a fire. As heating progresses, there is a buildup of pore pressure in the concrete that continues to increase until the internal stress becomes so great that explosive spalling results The present paper which focuses on the Flexural strength, Youngs modulus of M100 concrete and it gives the information about the behavior of M100 concrete under elevated temperatures.

II. OBJECTIVE

The objective of this work is to understand the behavior of M100 concrete when exposed to elevated temperatures. The experimentation was carried out to study the changes in Compressive strength, Split tensile strength and Flexure strength of Ultra strength concrete subjected to elevated temperatures for different durations of exposure.

III. RESEARCH SIGNIFICANCE

Concrete properties are changed by fire exposure. The mechanical properties must be accurately predicted after the fire as they are crucial for the further usage of concrete structures affected by fire. Despite the fact that certain models have already been proposed for the prediction of Compressive strength, Split tensile strength, Flexure strength as they have limitations or lower statistical performances. A unique and comprehensive empirical model is needed to predict loss with high statistical values for which the database of test results is required. This study aims to fulfill the need.

IV. LITERATURE REVIEW

1. Scott T Sherley et al performed fire tests on slab specimens with high strength concrete with and without silica fume and normal strength concrete and concluded that fire endurances of all five specimens were not significantly different.
2. Sujit Ghosh etal concluded through their research that compressive strength and Youngs modulus of 20 and 60% Flyash and 10% Silica fume concrete decreased with a rise in temperature from 21.4 to 232^{0}C for different pressures and this decrease was attributed to a gradual deterioration of the binding matrix with rise in temperature.
3. M.Saad et al concluded that concrete specimens containing 10% silica fume posses lower porosity values and the highest compressive strength values at al temperatures of thermal treatment as more CSH is formed with stronger binding forces and a sufficient thermal stability.
4. R. Ravindra rajaiah et al through their research concluded that the residual compressive and tensile strengths for high strength concrete with blended cement after heating to 800^{0}C and water quenched were 31% of initial strengths whereas the corresponding residua strengths for concrete with ordinary Portland cement was 44%
5. Potha raju et al investigated the effect of elevated temperature on the flexural strength of flyash concrete of different grades of M28, M33 and M35. Concrete specimens 100 x 100 x 50 mm with partial replacement cement by flyash were heated to 100, 200 and 250^{0}C for 1, 2 and 3h durations. The specimens were tested for flexural strength in the hot condition immediately after removing from the oven. It was concluded that flyash content upto 20% showed improved performance compared with the control specimens by retaining greater amount of its strength.
6. Geogre C Hoff et al conducted research to study the effect of elevated temperature effects on high strength concrete residual strength. They concluded that there appeared to be a slight improvement in residual strength at 200^{0}C (392^{0}F) exposure when subjected to 100^{0}C (212^{0}F) exposure. At constant temperatures of 300^{0}C (572^{0}F) there is a significant loss of strength. At temperatures 900^{0}C (1652^{0}F) and after, all concretes essentially had no structural integrity residual strengths of HSC at exposed temperatures of 300^{0}C (72^{0}F) or higher are significantly different than residual strength for NSC.

Experimental Program

Preliminary investigations were carried out to develop M100 grade concrete. The mix proportion arrived as per ACI 211.1[1] was 1:0.556:1.629 by weight with w/c ratio as 0.25. The estimated batch quantities per cubic meter of concrete were: cement, 671.81 kg; fine aggregate, 373.33 kg; coarse aggregate, 1094.4 kg and water, 167.95 litres. The optimum dosages of Mineral and Chemical admixtures were identified as 6% and 1.5% of quantity of cement respectively.

Rheobuild 1100

The basic components of RHEOBUILD 1100 are synthetic polymers which allow mixing water to be reduced considerably and concrete strength to be enhanced significantly, particularly at early ages. Rheobuild 1100 is a chloride free product. It allows the production of very flowable concrete, with a low water/cement ratio. Concrete with Rheobuild shows strengths higher than concrete without admixture having the same workability.

Silica Fume (Micro Silica)

It is a by product of producing silicon metal or ferrosilicon alloys. Because of its chemical and physical properties, it is a very reactive pozzolana. Concrete containing silica fume can have very high strength and can be very durable. Silica fume is available from suppliers of concrete admixtures and when specified, is simply added during concrete production. Placing, finishing and curing silica fume concrete require special attention on the part of the concrete contractor. Silicon metal and alloys are produced in electric furnace. The raw materials are quartz and wood chips. The smoke that results from furnace operation is collected and sold as silica rather than being land filled.

Casting and curing specimens

The test specimens were demoulded after a lapse of 24 hours from the commencement of casting and submerged in water until the time of testing.

Exposing the specimen to elevated temperatures

An oven with a maximum temperature of 300^{0}C was used for exposing the specimens to different elevated temperatures. It was provided with a thermostat to maintain constant temperatures at different ranges. The specimens were kept in the oven as shown in fig.2 for a specified duration after the temperature in the oven reached the defined temperature. The specimens were heated to different temperatures of 50, 100, 150, 200 and 250^{0}C for different durations of 1, 2, 3 and 4 hours at each temperature. The specimens were tested for their strengths with minimum delay after removing from the oven in a hot state under unstressed condition.

Table 1 : Compressive and % Residual compressive strengths of cubes after exposing to elevated temperature

Temperature (^{0}C)	Compressive Strength (N/mm^2)				% Residual Compressive strength			
	1 hour duratio	2 hours duratio	3 hours duratio	4 hours duratio	1 hour duratio	2 hours duratio	3 hours duratio	4 hours duratio
27	131.67	131.67	131.67	131.67	100.0	100.0	100.0	100.0
50	140.39	146.93	134.29	138.65	106.62	111.59	101.99	105.3
100	148.24	136.47	143.01	125.57	112.58	103.65	108.61	95.37
150	144.75	134.94	138.43	122.95	109.93	102.48	105.13	93.38
200	136.25	131.24	135.16	117.29	103.48	99.67	102.65	89.08
250	120.77	144.32	130.58	124.70	91.72	109.61	99.17	94.71

Table 2: Split and % Split tensile strengths of cylinders after exposing to elevated temperature

Temperature (^{0}C)	Split Tensile Strength (N/mm^2)				% Residual Split Tensile strength			
	1 hour duratio	2 hours duratio	3 hours duratio	4 hours duratio	1 hour duratio	2 hours duratio	3 hours duratio	4 hours duratio
27	30.79	30.79	30.79	30.79	100.00	100.00	100.00	100.00
50	38.50	36.83	35.72	32.53	125.04	119.62	116.01	105.65
100	44.62	26.83	36.28	33.36	144.92	87.14	117.83	108.35
150	35.38	29.89	27.87	20.50	114.91	97.08	90.52	66.58
200	26.41	28.50	20.71	16.40	85.77	92.56	67.26	53.26
250	20.43	18.63	17.38	14.73	66.35	60.51	56.45	47.84

Table 3: Flexure and % Residual flexure strengths of beams after exposing to elevated temperature

Temperature (^{0}C)	Flexural Strength (N/mm^2)				% Residual Flexural strength			
	1 hour duratio	2 hours duratio	3 hours duratio	4 hours duratio	1 hour duratio	2 hours duratio	3 hours duratio	4 hours duratio
27	5.34	5.34	5.34	5.34	100.00	100.00	100.00	100.00
50	5.57	6.44	6.00	5.81	104.41	120.59	112.50	108.82
100	6.32	6.87	7.22	7.02	118.38	128.68	135.29	131.62
150	7.73	8.04	7.18	6.98	144.85	150.74	134.56	130.88
200	4.79	5.65	6.00	5.77	89.71	105.88	112.50	108.09
250	4.24	4.12	3.85	3.49	79.41	77.21	72.06	65.44

Fig. 1 Cubes on Vibrating table during Compaction

Fig. 2 Cube in Oven while heating

Fig. 3 Testing of Cylinder during split tensile strength test

Fig. 4 Tested Concrete cube

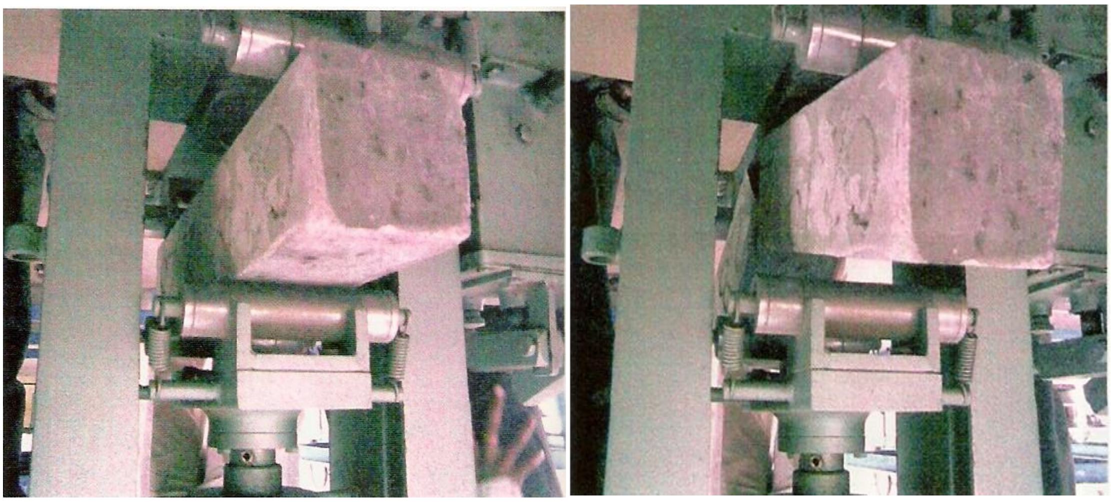

Fig.5 Testing of M100 Concrete beams for Flexure

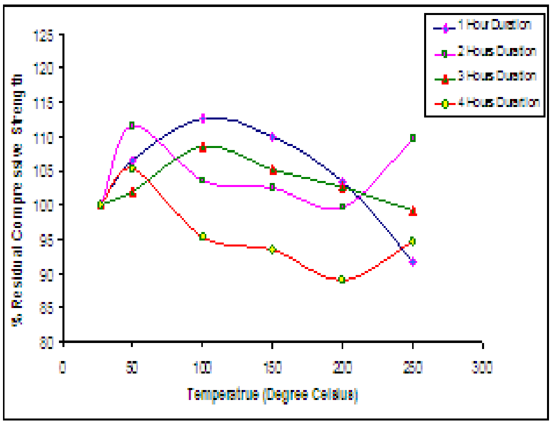

Fig.6 Variation of % Residual Compressive strength with temperature

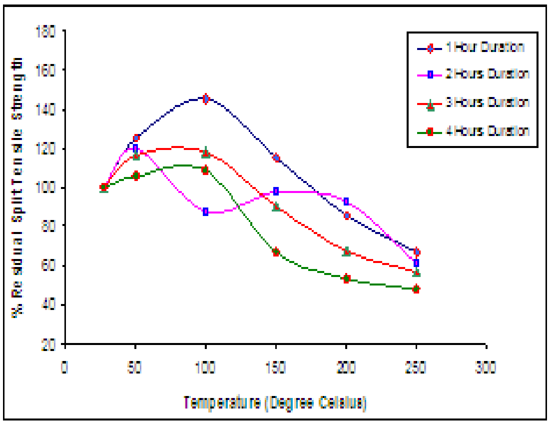

Fig. 7 Variation of % Residual Split tensile strength with temperature

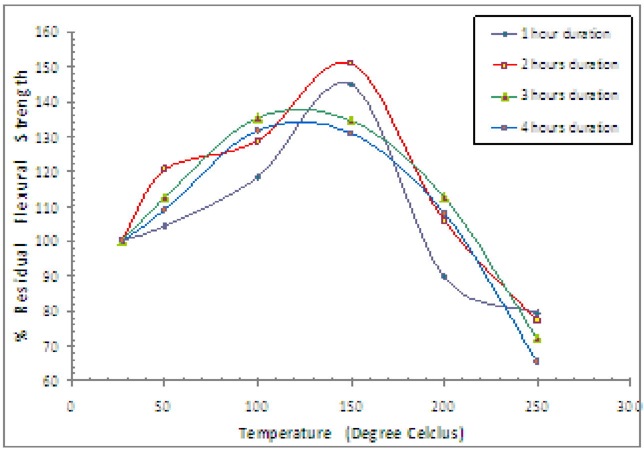

Fig. 8 Variation of % Residual Modulus of Rupture with temperature

V. RESULTS AND DISCUSSIONS

Compressive strength

The factors that influence the compressive strength of Ultra strength concrete when exposed to elevated temperatures are temperature and time of exposure. The test results are presented in Table 1. The variation of % Residual Compressive strength with temperature for different exposure durations is shown in Fig.6. The compressive strength at any temperature is expressed as the % of Compressive strength at room temperature. The heated specimens are tested in hot condition for compressive strength according to IS: 516-1959[2]

Split Tensile strength

Residual splitting tensile strength of concrete was found to be influenced by the temperature to which it was exposed and the duration of exposure. Residual splitting tensile strength of all heated specimens at any exposure time was expressed as the percentage of 28 days split tensile strength of unheated concrete specimens. The test results are presented in Table 2. The variation of % Residual Split tensile strength with temperature for different exposure durations is shown in Fig.7. The Split tensile strength at any temperature is expressed as the % of Split tensile strength at room temperature.

Modulus of Rupture

Flexural strength of M100 concrete was noticed to increase continuously upto 150^{0}C and beyond that there is rapid decrease in Modulus of rupture. The Residual Modulus of rupture is also calculated at different temperatures for 100x100x500 mm size concrete beams. The variation of modulus of rupture w.r.t to temperature is also shown in the graph from the Fig.8.

VI. CONCLUSIONS

On the basis of the experimental work with ranging temperature from 50 to 250^{0}C, the following conclusions are drawn.

a) The compressive and split tensile strengths of M100 concrete are increased initially upto a temperature of
b) 50- 100^{0}C and beyond that they got reduced rapidly with increasing the temperature
c) It was observed that major part of loss in split tensile strength is taking place in the first 1 hour exposure.
d) The compressive and Split tensile strengths are lost very much when they are heated at 250^{0}C
e) Modulus of rupture was increased gradually upto a temperature of 150^{0}C and beyond that it was observed to decrease continuously.

REFERENCES

[1]. ACI 211.1-91 - Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete.IS : 516-1959 - Indian Standard Methods of tests for Strength of concrete
[2]. M.S Shetty Text book of Concrete Technology, S. Chand & Co. Ltd.
[3]. A.M. Neville, Properties of Concrete, Longman.Said Iravani, "Mechanical properties of High Performance Concrete", ACI Mat. V.93, No.5, 1996, pp. 416-426.
[4]. Richard Gagne, Alain Boisvert and Michel Pigeon, "Effect of Super plasticizer dosage on Mechanical properties, Permeability and Freeze-Thaw durability of High strength concrete with and without silica fume", ACI Mat. Journal, Volume 93, No.2, 1996, pp.111-120.
[5]. Brandt. A.M. and Kucharska, L, "Mechanical properties and Applications of High Performance concrete", Proceedings of International Symposium on innovative world of concrete (ICI-IWC-93), pp. KN3-KN2.
[6]. Xie,J., AE Elwi and MacGregor, J.G., "Mechanical Properties of three High strength concretes containing Silica fume", ACI Material Journal, V.92, No.2, 1995, pp. 135-145.
[7]. Flyod Slate, O., Arthur Nilson H., Salvador Martinez, "Mechanical properties of High strength light weight concrete", ACI Journal, July-August 1986, pp. 603-613.
[8]. V.K.R.Kodur and L.T. Phan (1996), "Fire performance of high-strength concrete", National Institute of Standards and Technology, Gaithersburg.