Mechanical Properties Of Heated Concrete Of M100 Grade

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Abstract:

The present study investigated the effect of elevated temperatures ranging from 50 to 250^{0}C on the compressive and splitting tensile strengths of Ultra strength concrete of M100 grade. Tests were conducted on 150 mm cubes, 150 mm diameter and 300 mm height cylindrical specimens. 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. After the heat treatment, the specimens were tested for both compressive and splitting tensile strengths. The results were analyzed and the effects of elevated temperature on these two properties were presented.

Keywords : Ultra strength concrete, split tensile strength, Silica fume, Rheobuild, compressive strength.

1. Introduction:

Fire is one of the most severe conditions when the structures are exposed for it. Mechanical properties such as compressive strength, split tensile strength and modulus of elasticity are considerably reduced during exposure, potentially resulting in undesirable structural failures. Therefore, the residual properties of concrete are still important in determining the load carrying capacity and the further use of fire damaged structures. Previous investigations have shown that concrete type, concrete strength, aggregate types, test types, maximum exposure temperature, exposure time, type and amount of mineral admixtures and type and amount of fibres affect the residual properties of concrete after exposure to high temperatures. When the concrete is subjected to elevated temperature, the incompatibility of thermal deformations within the constituents of concrete initiates cracking.

Internal stress is also caused by microstructure change due to dehydration and steam pressure build up in the pores. Forecasting and obtaining information about the physical, mechanical and transport properties of concrete is crucial for determining the usability of fire damaged structures.

Exposure to elevated temperatures causes physical changes in Ultra strength concrete including large volume changes due to thermal shrinkage and Creep related to water loss. The changes in volume will result in large internal stresses thus leading to micro cracking. Elevated temperature also generates some chemical and micro structural changes such as migration of moisture and thermal incompatibility of interface between cement paste and aggregate. All these changes will have a bearing on the strength and stiffness of concrete. Based on the limited amount of experimental data available to date, it has been found that the effects of elevated temperatures on the mechanical properties of Ultra strength concrete vary with a number of factors including the test methods, permeability of concrete, the types of aggregate used and moisture content.

1.1 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 and splitting tensile strengths of Ultra strength concrete subjected to elevated temperatures for different durations of exposure.

1.2 Research Significance

Concrete properties are changed by fire exposure. The properties such as compressive and split tensile strengths 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 and split tensile strength loss, they have limitations or lower statistical performances. A unique and comprehensive empirical model is needed to predict compressive and split tensile strength losses with high statistical values for which the database of test results is required. This study aims to fulfill the need.

1.3 Admixtures used

Silica fume (Micro silica) as a mineral admixture and Rheobuild 1100 as a chemical admixture are used.

2. Review of Literature:

1. **Klaus Holschemacher and Sven Klotz (2003) [3]** have studied about the ultra heigh strength concrete under concentrated load and found that the conventional reinforcement can be completely or partly replaced by fibres, which are also effective in the margin of the structural members. Furthermore they have found that the tensile bearing behavior is uniform

2. **Z.Wadud and S.Ahmad (2001) [4]** have carried out a parametric study on ACI method of concrete mix design. Based on their study it was concluded that the Inter particles voids, a function of the coarse aggregate grading, is an important parameter in the mix design. The ACI method has no adequate paratmeter to take this aspect into account. This leads to higher fine aggregate content, which consequently increases the surface area of aggregates when coarse aggregates of higher voids are used. The cement content is determined even before the consideration of any aggregate type, resulting in a lower cement/fine aggregate ratio. This was responsible for the failure of ACI method to gain desired strength when coarse aggregates of higher voids are used.

3. **H. Faghani Nobari and R.Ejlaly (2003) [5]** have studied about the punching shear Resistance of high strength concrete slabs and found that the use of high strength concrete improves the punching shear resistance allowing higher forces to be transferred through the slab column connection.

4. **Eugen Brihwiler and Emmanuel Denarie (2008) [6]** studied about the rehabilitation of concrete structures using Ultra-High Performance Fibre Reinforced Concrete (UHPFRC) and found that it combines efficient protection and resistance functions of UHPFRC with conventional structural concrete. It was also found that the rehabilitated structures significantly improved structural resistance and durability. The full scale realizations of the concept under realistic site conditions demonstrate the potential of applications and that the technology of UHPFRC is mature for cast in-situ and prefabrication using standard equipment for concrete manufacturing

5. **V.K.R. Kodur and L.T Phan (1996) [7]** studied about the fire performance of High Strength Concrete and found that High Strength Concrete is a high-performing material and offers a number of benefits over Normal Strength Concrete. However, it was found that there is a concern on the occurrence of spalling and lower fire endurance of High Strength Concrete (as compared to Normal Strength Concrete). The main parameters that were found influencing fire performance of High Strength Concrete at material level are: concrete strength, silica fume, concrete moisture content, concrete density, fibre reinforcement, and type of aggregate. At the structural level it was found that, tie spacing, confinement, tie configuration, load levels and size of the members play an important role in determining fire endurance.

3. 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 from the previous investigation.

3.1 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.

3.2 Silica Fume (Micro Silica)

It is a byproduct 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.

3.3 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.

3.4 Exposing the specimen to elevated temperatures An oven with a maximum temperature of 300^0C 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 250^0C 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.

Fig. 1 Cubes on Vibrating table during

Fig. 2 Cube in Oven while heating

3.5 Testing the specimens

The cubes and cylinders after heating in the oven were tested by using compression testing machine of capacity 400 tons and the values of compressive and split tensile strengths are as shown in Tables 1 and 2.

Fig. 3 Testing of Cylinder during split tensile strength test

Fig. 4 Tested Concrete cube

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 tensile and % Residual 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

4. Results and Discussions

4.1 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.5. 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]

4.2 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.6. The Split tensile strength at any temperature is expressed as the % of Split tensile strength at room temperature.

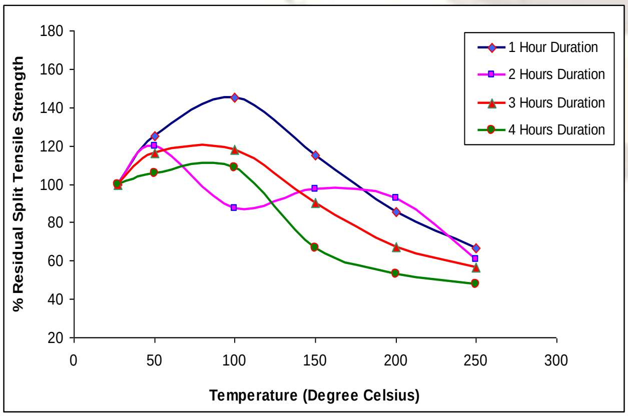

Fig. 6 Variation of % Residual Split tensile strength with temperature

4.3 Effect of temperature on residual Compressive strength

The variation of Compressive strength with the increase in temperature is studied in terms of the percentage residual compressive strength for different durations of 1, 2, 3 and 4 hours. Initially, the strength increased with temperature 50 to 100^{0}C for different durations and beyond that it was reduced. The maximum Compressive strength was noticed when the cube was heated at100^{0}C for 1 hour duration.

4.4 Effect of temperature on residual Splitting tensile strength

The variation of splitting tensile strength with the increase in temperature is studied in terms of the percentage residual Splitting tensile strength for different durations of 1, 2, 3 and 4 hours. Initially, the strength increased with temperature upto 100^{0}C for different durations and beyond that it got reduced. The maximum splitting tensile strength was noticed when the cylinder was heated at100^{0}C for 1 hour duration.

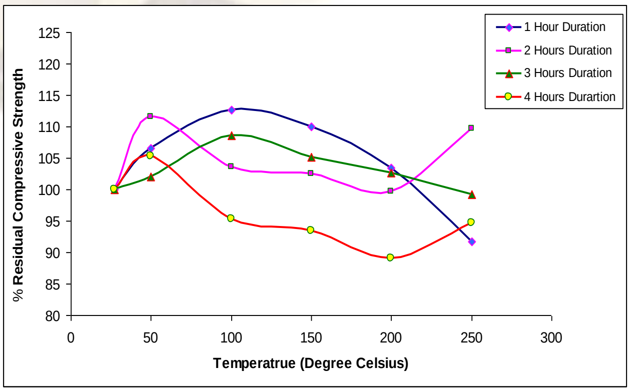

Fig. 5 Variation of % Residual Compressive strength with temperature

5. 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 50 - 100^{0}C and beyond that they got reduced rapidly with increasing the temperature
b) It was observed that major part of loss in split tensile strength is taking place in the first 1 hour exposure.
c) The compressive and Split tensile strengths are lost very much when they are heated at 250^{0}C.

References:

1. ACI 211.1-91 - Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete.
2. IS : 516-1959 - Indian Standard Methods of tests for Strength of concrete
3. Klaus Holschemacher and Sven Klotz (2003); "Ultra High Strength Concrete under Concentrated Load", Department of Civil Engineering, HTWK Leipzig.
4. Z. Wadud and S. Ahmad (2001); "ACI method of concrete mix design- A parametric study", The Eighth East Asia-Pacific Conference on Structural Engineering and Construction, Nanyang Technological University, Singapore.
5. H.Faghani Nobari and R.Ejlaly (2003); "Punching Shear Resistance of High Strength Concrete slabs", Department of Civil Engineering, Iranian Science and Technology University, Tehran.
6. Eugen Brihwiler and Emmanuel Denarie (2008), "Rehabilitation of concrete structures using Ultra-High Performance Fibre Reinforced Concrete", Department of Civil Engineering, Lausanne, Switzerland.
7. V.K.R.Kodur and L.T. Phan (1996); "Fire performance of high-strength concrete", National Institute of Standar andTechnology,Gaithersburg.