Influence of temperature on behaviour of concrete

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ABSTRACT

In our world, there are many deadly factors that contribute to the devastation of livelihood and amongst them, stand as the deadliest of all, the fire. Fire has the peculiar capability of destroying and deteriorating the things that stand in it. When it comes to construction industry, fire has been a major threat to the structures over ages. Fire can bring the worst damage to any structure than any other effect could bring. Especially, it seriously affects concrete and ultimately collapses the structure. To assess the resultant effects on concrete in terms of its colour, strength parameters, concrete specimen of grades M30 and M35 are induced into a temperature from 200ºC up to 800ºC in steps and they are observed and tested aftermath of inducing. Also fire breakouts do not happen in a controlled environment like a furnace and so the specimens are subjected to open fire to simulate the conditions in an actual fire disaster structure and results are taken. The results can be used to interpret about the condition of concrete and the existing strength of it so that they can be applied to real cases where there occurred any fire breakouts and to arrive at the point whether the structure is safe for residents and the occupation can be carried along further. Along with the strength parameters, the aesthetic aspect is also concentrated and therefore the change in colour, occurrence and intensity of cracks, scaling and spalling are also observed and accounted for results. The homogeneity and quality of concrete is also checked by Ultrasonic pulse velocity method.

KEY WORDS: Cement, Concrete, UPV, Thermometer.

1. INTRODUCTION

Concrete as a material, possess very good fire resistant properties when compared with other materials in construction sector. The loss of business resulting from fires in commercial and office buildings runs into millions of pounds each year. The extent of such damage depends on a number of factors such as building material, design and use, structural performance, fire extinguishing devices and evacuation procedures. One such material which has major sharing is concrete. Concrete is a composite binding material having constituents as aggregate, finer sand and fine cement and water with designed proportion. Concrete is a composite having properties that change with time. Durability of concrete depends on many factors including its physical and chemical properties, the service environment and design life.

Fire can impart very negative effects on concrete and therefore it is necessary to study the behaviour of concrete on temperature and hence it's physical and strength parameters are analysed. In this study, concrete of grades M30 and M35 are casted and the specimens are induced to various temperatures like 200ºC, 400ºC, 600ºC and 800ºC and also in open fire and the compressive strength, split tensile strength are found out. Also it is nondestructively tested using ultrasonic pulse velocity method. These results are compared with that of normal concrete and results are analysed.

2. EXPERIMENTAL WORK

Mix design: Concrete is designed for two grades as mentioned earlier, M30 & M35 in accordance with IS 10262:2009. The materials used and the design ratio are following.

Type of Cement (Confirming to IS-12269-1987)	**OPC 53 grade**
Maximum Nominal Aggregate Size	20 mm
Minimum Cement Content	250 kg/m^3
Maximum Water Cement Ratio	0.5%
Workability	25 mm (Slump)
Exposure Condition	Normal

	M30 grade	**M35 grade**
Cement	493 kg/m^3	440 kg/m^3
Fine aggregate	1100 kg/m^3	1128 kg/m^3
Coarse aggregate	674 kg/m^3	692 kg/m^3
Water cement ratio	0.45	0.40
Water	222 ml	180 ml
Mix ratio	1: 2.21: 1.36	1:2.56: 1.57

Casting of cubes and cylinders: Cubes of dimensions 100mm x 100mm x 100mm are casted of both grades in the manner of 3cubes for a particular value of compressive strength. Similarly, cylinders of dimension 100mm diameter and 200mm height are casted in order to get split tensile strength. Concrete was filled in both in three layers and compacted separately in each layer. The specimens are de-moulded on next day and kept for curing on 28th day.

Process of inducing in high temperature: The temperature required for the testing of specimen is given by muffle furnace. A muffle furnace is a heating device functions electrically and the readings are shown by digital scale.

Figure.1. Muffle furnace

Cubes and cylinders, after cured for 28 days they are taken out of water and dried for 2 hours in sunlight and are kept inside the muffle furnace for about an hour. The temperature can be set using a knob as seen in the figure. Temperatures set are 200ºC, 400ºC, 600ºC and 800ºC and each specimen is kept inside for an hour as mentioned earlier. Then the specimen are carefully taken out of the furnace and kept in normal temperature to cool down so that tests can be carried out.

3. RESULTS

Physical property results: Colour and crack formation: The specimen that are subjected to such high temperature shows various changes in physical properties such as colour, appearance of cracks, scaling and spalling. The results are tabulated below.

Table.1. Colour and crack formation

Temperature	Colour		Cracks
Normal	Normal concrete		No
200ºC	Mild grey		Very minute
400ºC	Dark grey		Hair cracks
600ºC	Pale white		Large cracks
800ºC	White		Very large cracks

Scaling and spalling: When concrete is exposed to high temperature the smooth surface of concrete that is given as clear cover, starts to peel or flake. This is called as scaling. Similarly the portion of concrete peel off and the aggregates are also exposed sometimes. This is called as spaling. The effect of temperature causes these two effects on concrete and the results are tabulated below.

Table.2. Scaling and Spalling

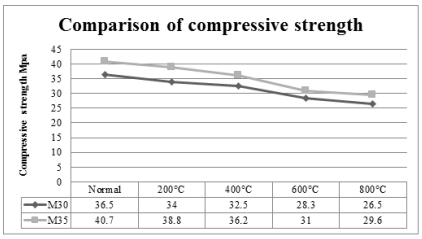
Temperature	Scaling	Spalling
Normal	No	No
200ºC	Mild	No
400ºC	Mild	Low
600ºC	High	Mild
800ºC	Very high	Moderate

Strength parameters:

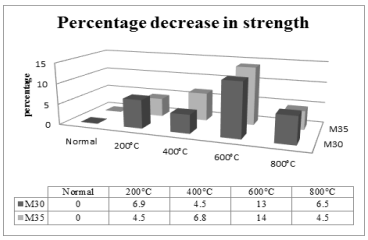
Compressive strength: When it comes to strength of specimen, firstly compressive strength are analysed. Surface area of specimen is 100mm x 100mm and the compressive strength is calculated using formula Strength = Failure load / Area.

Table.3. Compressive strength of specimen

Temperature	Compressive strength (Mpa)	
	M30	M35
Normal	36.5	40.7
200ºC	34	38.8
400ºC	32.5	36.2
600ºC	28.3	31
800ºC	26.5	29.6



Graph.1. Comparison of compressive strength at various temperature



Graph.2. Comparison of percentage decrease in strength at successive temperatures

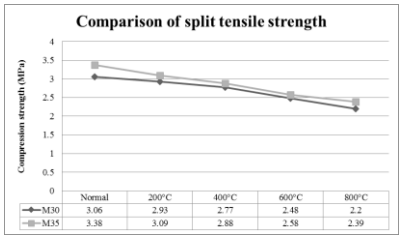
From the graph, it can be observed that the strength reduces for each 200ºC rise in temperature and ends up at nearly 30% reduction in strength at 800ºC. It can also be noted that the strength reduction graph suddenly takes a steep slope after 400ºC. This shows that the concrete undergoes drastic strength reduction beyond 400ºC.

Split tensile strength

Another important test performed is split tensile strength test which is done on a cylindrical specimen of dimension 100 mm diameter and 200 mm high. The split tensile strength is calculated using formula ($2P / \pi D L$) where D and L are diameter and length of the specimen respectively.

Table.4. Split tensile strength of specimen

Temperature	Split tensile strength (Mpa)	
	M30	M35
Normal	3.06	3.38
200ºC	2.93	3.09
400ºC	2.77	2.88
600ºC	2.48	2.58
800ºC	2.20	2.39



Graph.3. Comparision of split tensile strength

Fig.2. Open fire test

Fig.3. Physical properties

Open fire test: In real time, during fire breakout, the structure is exposed to random uncontrolled fire in which the temperature fluctuates between extremes. Such a fire behaves on concrete specimen different from that of controlled temperature in a muffle furnace. Such an open fire is induced on the specimen and the physical and strength parameters are analysed as before. This method not only shows the random fire effects and also simulates the condition when fire a breaks out in any structure. The temperature of the fire in this test was measured using infrared thermometer. Fig 2. Shows open fire test.

Fig 3. Infrared temperature measurement device. An infrared thermometer measures the temperature of an object by inferring thermal radiation from a portion of the object. The infrared rays fall on the require place and digitally shows us the result in centigrade scale as well as Fahrenheit scale. The accuracy of instrument varies around ± 2°C.

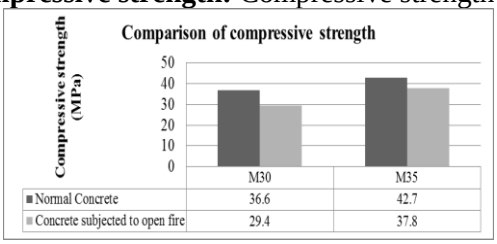
Colour: Unlike in muffle furnace, the colour of the specimen darkens to black colour that when subjected to open fire of about 1 hour. But in muffle furnace the colour turned to pale while subjected to an hour.

Cracks, scaling and spalling: In case of this open fire test, the specimen started to show cracks after half an hour in the fire. Mild cracks begun to appear after half an hour but the width of the crack got increased as the duration of fire exposure increases. Scaling phenomenon too started after half an hour in fire and it exposed the interior of concrete

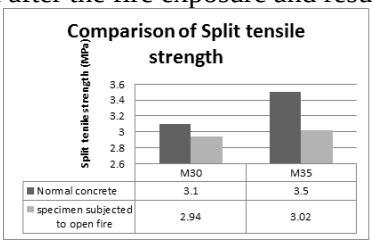
beyond its blackened outer portion. Not much spalling occurred when the concrete specimen is subjected to open fire.

Strength properties:

Compressive strength: Compressive strength is taken after the fire exposure and results obtained are as below.



Graph.4. Compressive strength



Graph.5. Split tensile strength

Fig.4.Ultrasonic pulse velocity Meter

Split tensile strength: Split tensile strength also varies but only a smaller value when compared the normal concrete and the specimen subjected to open fire.

Ultrasonic pulse velocity method: This is a nondestructive type of method used to study about the interior homogeneity of the structure by analysing the velocity through which the ultrasonic waves pass from transmitter to receiver. The test is applied on specimen of normal concrete, furnace induced concrete, open fire concrete and the results are obtained as below. Fig 4. Shows Ultrasonic pulse velocity meter. By using velocity meter to identify damage inside the concrete.

Specimen type	Velocity through the specimen (km/s)
Normal	3124
200°C	3084
400°C	3173
600°C	2861
800°C	2753
Open fire	2947

From the above results of ultrasonic pulse velocity test, it can be seen that the velocity of ultrasonic waves through the specimen varies to a certain extent. This shows that the interior condition of concrete is mildly disturbed when exposed to high temperature.

4. CONCLUSIONS

From the above investigation, the following conclusions may be drawn. Concrete loses its Compressive strength when it is exposed to high temperature more than 200 C. Especially it loses its strength by about 27% of its initial compression strength, at 800C Split tensile strength also decreases for higher temperature and loses nearly 30% of initial strength When conducted ultrasonic pulse velocity test, it is found that the interior composition of concrete also got disturbed due to this temperature rise which is shown by the decreased velocity of the waves.

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