EFFECT OF VARIOUS TEMPERATURES ON THE STRENGTH OF CONCRETE

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Abstract — This work was carried out to assess the effect of high temperatures on compressive strength of concrete. Effect of fire on concrete is a relatively less explored area because of the lesser use of RCC structures in Europe/USA as compared to steel structures. Concrete does not burn, it cannot be 'set on fire' like other materials in a building and it does not emit any toxic fumes when affected by fires. It will also not produce smoke or drip molten particles, unlike some plastics and metals, so it does not add to the fire load. For this reason concrete is said to have a high degree of fire resistance and in the majority of applications, concrete can be described as virtually 'Fire Proof '.This excellent performance is due in the main to concrete's constitute materials. (I.e. Cement and Aggregate) which when chemically combined with concrete, form a material that is essentially inert and importantly for fire safety design has a relatively poor thermal conductivity. It is this slow rate of heat transfer (conductivity) that enables concrete to act as an effective fire shield not only between adjacent spaces, but also to protect itself from fire damage. The rate of increase of temperature through the cross section of concrete element is relatively slow and so internal zones do not reach the same high temperature as surface exposed to flames. When concrete is exposed to the high temperatures of a fire, a number of physical and chemical changes can take place.

Keywords-Elevated Temperature, Mix Proportion

I. INTRODUCTION

Any engineering advancement is for betterment of human life. Shelter is considered as one of the basic needs for human beings. The buildings constructed should give protection from heat, cold, rain, and also from disasters like fire, floods and earthquakes. Fire is considered as one of the disastrous event which causes loss or damage to human life and property. When there is an accidental fire in a structure, the duration of fire will be less but the intensity of heat produced will be more, this heat causes damage to the structures. In addition to accidental fire there are some special structures which are subjected to high temperatures, like take-off areas of jet aircraft, rocket launching pads, nuclear reactors, chimneys, metallurgical or chemical industries, glass, cement industry, coke ovens, storage tanks for hot crude oil and hot water, where the localized areas of concrete are subjected to high temperatures, The material used for construction should be capable of resisting high temperatures and it should also give minimum time for the inmates to escape.

II. STRUCTURAL FIRE PROTECTION MEASURES MUST FULFILL THREE AIMS

1) Personal protection to preserve life and health
2) Protection of property to preserve goods and other belongings both in residential or commercial units that have caught fire, and in neighboring properties. To this must be added substantial preservation of the building structures;
3) Environmental protection to minimize the adverse effects on the environment through smoke and toxic gases as well as from contaminated water used for extinguishing fires.

III. LITERATURE REVIEW

Khoury Gabriel A.

He did research work on effect of elevated temperatures on concrete. As per them, basic creep studies at constant temperatures indicated a marked increase in creep above 550–600°C for cement paste and lightweight concrete which suggested that the structural, though not necessarily the refractory, usefulness of Portland cement-based concretes in general would be limited to temperatures below 550–600°C.

Chakrabarti S. C.

Conducted an extensive test program for assessing the residual strength of concrete after fire. The authors proclaimed that the concrete actually gained some strength between 100 to 300°C in the presence of siliceous & carbonaceous aggregates. Some other researchers too have reported this phenomenon which has more detractors than supporters. As per the authors, concrete didn't lose much of its strength up to 500°C & in fact regained 90% of lost strength up to this temperature after about a year. The theory of fire affected concrete regaining some of its strength with time is not an established one. Concrete cubes heated beyond 800°C for 4 hours started crumbling after 2-3 days

Rafat Siddique, Deepinder Kaur (2011)

Normal strength (NSC) and high-performance concretes (HPC) are being used extensively in the construction of structures that might be subjected to elevated temperatures. The behavior of concrete structures at elevated temperatures is of significant importance in predicting the safety of structures in response to certain accidents or particular service conditions. This paper deals with the mechanical properties of concrete made with ground granulated blast furnace slag (GGBFS) subjected to temperatures up to 350℃. For this purpose, normal concrete having compressive strength of 34 MPa was designed using GGBFS as partial replacement of cement. Cylindrical specimens (150·300 mm) were made and subjected to temperatures of 100, 200 and 350℃. Measurements were taken for mass loss, compressive strength, splitting tensile strength,

and modulus of elasticity. This investigation developed some important data on the properties of Concrete exposed to elevated temperatures up to 350℃.

Phan Long T.

performed experiments on high-strength concrete (HSC) and normal strength concrete (NSC) at elevated temperature in order to study the phenomenon of explosive spelling associated with HSC & suggest further research needs. The differences were found to be most pronounced in the temperature range of 200°C to 400°C. High strength concrete is a material often used in the construction of high rise buildings.

Ravindrarajah R.

Summarized and discussed the degradation of the strengths and stiffness of high-strength concrete in relation to the binder material type. The results showed that the binder material type had a significant influence on the performance of high-strength concrete particularly at temperatures below 800°C. The influence of the binder material type was significantly decreased at temperature of 1000°C. The strengths and stiffness of high strength concrete were reduced with the increase in temperature without any threshold temperature level.

P. Jyotsna Devi, Dr. K. Srinivasa Rao (2014)

The present study aims at investigating the performance of steel fiber reinforced concrete at high temperatures. It also aims at comparing the flexural and split tensile strengths of normal (M30) and high strength concrete (M60) when mixed with 1% volume fractions of steel fibers. To study flexural strengths prisms of size 100x100x500mm were casted and to study splitting tensile strength cylinders of 150mm diameter and 300mm length were casted. The samples are cured for 7, 28 and 91 days. After specified period of curing, the specimens were air dried and then exposed to 100, 200, 300, 400 and 500oC (apart from 27oC), for duration of one hour and then allowed to cool. The prisms are tested in Universal Testing machine for flexure and cylinders are tested for split in compression testing machine. The use of fibers in high strength concrete is of good advantage than using in normal Strength concrete. By adding steel fibers fracture resistance of concrete can be increased.

Khaled Mohammed Nassar, Prof. Samir Shihada (2011)

Fire has become one of the greatest threats to buildings. Concrete is a primary construction material and its properties of concrete to high temperatures have gained a great deal of attention. Concrete structures when subjected to fire presented in general good behavior. The low thermal conductivity of the concrete associated to its great capacity of thermal insulation of the steel bars is the responsible for this good behavior. However, there is a fundamental problem caused by high temperatures that is the separation of concrete masses from the body of the concrete element "spalling phenomenon ". Spalling of concrete leads to a decrease in the cross section area of the concrete column and thereby decrease the resistances to axial loads, as well as the reinforcement steel bars become exposed directly to high temperatures. With the increase of incidents caused by major fires in buildings; research and Developmental efforts are being carried out in this area and other related disciplines. This research is to investigate the behavior of the reinforced concrete columns at high temperatures. Several samples of reinforced concrete columns with Polypropylene (PP) fibers were used. Three mixes of concrete are prepared using different contents of Polypropylene ;(0.0 kg/m³, 0.5 kg/m³ and 0.75 kg/m³). Reinforced concrete columns dimensions are (100 mm x100 mm x300 mm). The samples are heated for 2, 4 and 6 hours at 400 C°, 600 C° and 800°C and tested for compressive strength. Also, the behavior of reinforcement steel bars at high temperatures is investigated. Reinforcement steel bars are embedded into the concrete samples with 2 cm and 3 cm concrete covers, after heating at 800°C for 6 hours. The reinforcement steel bars are then extracted and tested for yield stress and maximum elongation ratio. The analysis of results obtained from the experimental program showed that, the best amount of PP to be used is 0.75 kg/m³, where the residual compressive strength is 20% higher than of that when no PP fibers are used at 400 C for 6 hours. Moreover, a 3 cm of concrete cover is in useful improving fire resistance for concrete structures and providing a good protection for the reinforcement steel bars, where it is 5 % higher than the column samples with 2 cm concrete cover at 6 hours and 600 C°.

Rahul Subhash Patil (2014)

The present work is aimed to study the effect of elevated temperature ranging from 200oC to 600oC on the compressive strength on M20 grade concrete with percentage of polypropylene fiber (0.22%) & steel fiber (0.5%) by volume of concrete. Tests were conducted on 150mm side cube concrete specimens. The specimens were heated to different temperatures of 200oC, 400oC, and 600oC for 6 hour durations. After the heat treatment the specimens were cooled by wet and dry cooling condition and then they were tested for compressive. The results were analyzed and presented with comparison of compressive strength of specimens with & without fibers for different cooling conditions. The concrete containing fiber exhibited better performance than without fiber for high temperature. Strength loss was more significant on specimens cooled in water.

Mr. Ran Vijay Singh and Prof. Prashant Awsarmal (2015)

The use of natural and chemical admixtures like Met kaolin, silica fume, fly ash, finely ground pumice, Palm Oil Fuel Ash, Rice Husk Ash as replacement of cement would be caused the decrease in the compressive strength, modulus of elasticity, tensile strength, ultrasonic pulse velocity and color change of the concretes at elevated temperatures. The use of different w/c ratios and different types of aggregates would be exhibited reduction of mechanical properties of concrete at elevated temperatures particularly above 600^0C. Different curing methods irrespective of types of concretes made with different admixtures might be caused the reduction in the mechanical properties at elevated temperatures.

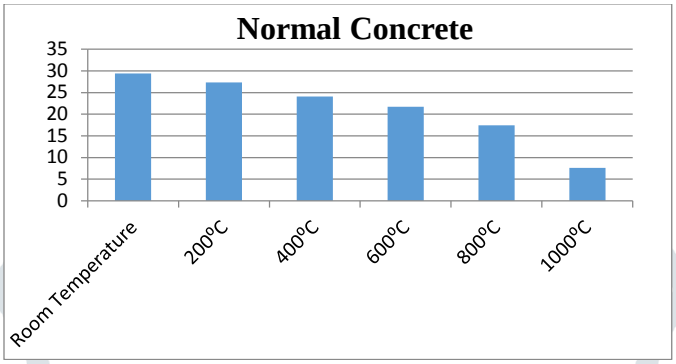
IV. MIX DESIGN FOR M25 BY INDIAN STANDARD AS PER IS 10262:2009

Cement	Water	Fine Aggregate	Coarse Aggregate
413	185	682	1022.39
1	0.45	1.65	2.47

V. TEST RESULT & DISCUSSION

COMPRESSIVE STRENGTH (N/mm²)

Temperature℃	Normal Concrete
Room Temp	29.41
200^{0}C	27.32
400^{0}C	24.1
600^{0}C	21.69
800^{0}C	17.41
1000^{0}C	7.6
1200^{0}C	0



VI. CONCLUSION

Based on the limited study carried out in this particular study, The Following conclusions may be drawn out,

1. After elevated temperatures test and analysis it may be found that with the increasing temperature the compressive strength of concrete gets reduced.
2. As temperature and exposure time increases the effect of fire on concrete increases.
3. Effect of fire can be observed on the surface of concrete in the form of deep cracks.
4. Between 400-600°C temperature Strength may loss.
5. Above 600^{0}C temperature concrete may not functioning at its full structural Capacity.
6. At 600°C temperature whitish colour and at 800°C temperature dark brown colour may appear on the surface of cubes.
7. At 1000°C temperature hair cracks may develop on specimen.

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