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A Review on: Behavior of Concrete Members under Elevated Temperature

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ABSTRACT

The review is based on experimental studies made on different concrete members who are exposed to different elevated temperature.The members may be in the different shapes such as cubes, beams, cylinder or slab in nature. The members exposed to elevated temperature are of high strength, normal strength which is curried under different curing methods. Frequently, the grade of concrete, strength of concrete, method of curing, type of ingredients of concrete, water cement ratio are the parameters which are influence by elevated temperature. Beyond the temperature of 500°C, the mechanical properties of concrete are affected more.

Keyword:Coefficient of thermal expansion, Flexural strength,Spalling,Temperature,Weight loss.

I. INTRODUCTION

Any building can be affected by fire accidents. As a structure cannot be left as it is, but the properties of such a building should be studied and make a fire affected structure to be functional to reuse. So it is the main challenging job for the researcher to make a structure functional after the damage due to fire. It is significantly important to build a structure which will protect the property as effectively.This specialized field involves expertise in many areas like concrete technology, material science and testing, structural engineering, repair materials and techniques etc.With the increase in fire accidents in structures, assessment, repair and rehabilitation of fire damaged structures has become a topical interest.As fire has been known since ancient times as one of mankind's greatest enemies we intend to draw attention to fire, as well as to its impact on structural elements. During design, in several cases the fact is ignored that a building may also be exposed, to the effect of high temperature, when the properties and the bearing capacity of materials also change. Therefore it is very important to get acquainted with the behaviour of the different materials under high temperature, as a consequence of which a building may also collapse.Fire is one of the natural hazards that attack the building constructions. Subjecting concrete to a higher temperature (e. g., due to accidental fire etc.) leads to severe deterioration and it undergoes a number of transformations and reactions, thereby causing progressive breakdown of cement gel structure, reduced durability, increased tendency of drying shrinkage, structural cracking and associated aggregate color changes.

Effect of high temperature on properties of concrete:

1. Compressive strength

2. Modulus of elasticity and shear modulus
3. Poisson's ratio
4. Stress - strain relationship
5. Spalling
6. Thermal properties
7. Coefficient of thermal expansion
8. Thermal conductivity
9. Thermal diffusivity
10. Specific heat
11. The Effect of temperature on steel
12. Bond strength
13. Anchorage capacity
14. Reinforced concrete

II. LITERATURE REVIEW

B. Bose et al (2016), carried out an investigation to study the causes, effects and remedy of distortion in concrete due to fire hazard, also some cost effective solutions to produce fire resistance concrete is conversed through this research. Spalling starts to occur when temperature reaches to 250°C, from 250 to 420°C some spalling occurs. After reaching to 300°C, concrete starts to reduce its strength. Within 550 to 600°C cement base materials experience creep and lose their load bearing capacity. At 600°C and higher, concrete loses its ability to function at its full structural capacity. Steel reinforcement bars need to be protected from exposure to temperature in excess of 250-300°C. This is due to the fact, that steel with low carbon contents are known to exhibit 'blue brittleness' between 200 and 300°C. Concrete and steel exhibit similar thermal expansion at temperature up to 400°C. This paper summarized several reason of structural failure and degradation of concrete structure, also the actual effect of fire on concrete and different technologies to improve fire resistance capacity of concrete members is summarized.

Belkacem Toumi (2010), done an experimental study on the identification and quantification of surface cracking of concrete heated to different temperatures ranging from 105 to 1250ºC.The mechanical properties of concrete were largely affected by temperatures beyond 500°C and were very weak when temperatures exceeded 1000°C. The surface cracks' density, initial surface absorption and total porosity by boiling methods gave a rapid indication on concrete durability.Information on the density and the distribution ofcracks is useful in determining the minimum exposure temperature. The crack density increases powerfully with temperature beyond 500ºC. The value of crack density at 1050ºC is 45 times greater than the reference, and at 1250ºC the value of crack density is 106 times greater than the crack density of unheated concrete. The compressive strength loss of HSC drops with temperature starting from 250°C. The retained compressive strength at 500°C is 90% compared to the unfired strength, while after 750°C the strength is 40%.The compressive strength value drops sharply to 0.4% after 1250°C compared to that of unfired specimens. The obtained results show that by using a high resolution flat bed scanner, this technique may be inexpensively used to assess the surface cracks' density and furthermore in investigations to evaluate the maximum temperatures at which concrete was subjected and the damaged layer of concrete to be removed for eventual repairs.The mechanical properties of concrete (as compressive strength) are largely affected by temperatures beyond 500°C. In the case of a real fire, where temperatures exceed 1000 °C, the remaining compressive strength values are very feeble and concrete structures need special attention in the repairing case if not totally demolished.

Mr. C Sangluaia (2013), studied the behaviour of reinforced concrete slab exposed to fire. Two stages of analysis is carried out using Finite Element package ABAQUS to find thermal response of structural members namely thermal analysis and structural analysis.RCC models are taken to study the thermal response of building subjected to fire. Non-linear analysis is carried out with full temperature on different boundary condition. Similarly non-linear analysis is carried out on different bars and different thickness. It is modelled in three dimensional for temperature-time curve ISO-834. ABAQUS/CAE 6.11 has been used for the analysis of thermal and structural behaviour of concrete structures for different temperature. Thermal analysis is done based on steady state condition in three dimensional members.

Specification of Slab for studying temperature distribution

Span	4.5 m
Width X Depth	925mm X 150mm
Temperature	ISO-834 Curve
Concrete Grade	M30

An accurate finite element model has been developed by using ABAQUS to study the behavior of reinforced concrete slab when subjected to fire. Based on the comparisons between the results obtained from the finite element models and available BRE slab experimental results, it was observed that they are in good agreement. The mid-span deflection with duration of heating is accurately predicted by the finite element model and a maximum discrepancy of 6% was observed when comparing the finite element model with experimental studies.Temperature distribution was studied for different layers of the slab along the depth of the slab when temperature changes according to time and it was found that temperature decreases along the depth of the slabRole of width of slab, role of rebar and role of slab thickness were also observed in this paper and it was found that:

- For simply supported slab, displacement increases when width of slab increases.
- Displacement decreases when percentage of steel in RCC slab increases.
- Displacement decreases when thickness increases.

D. Reshmasri (2014), carryout an investigation to study heat propagation in a portion of a column member subjected to heat of 1000°C acting for duration of two hours is evaluated using MSC Nastran. The temperature variation across the thickness of concrete is studied considering the variation of thermal conductivity with temperature and porosity. The propagation of heat and the corresponding distress to concrete is determined from surface to the central core of the column along the shorter dimension.a column member of dimensions 500mm×300mm is considered to be subjected to fire on one of its larger faces. A sample square portion of 500mm×500mm to a depth of 150mm is considered for this purpose. Within this area, the central portion of

200mm×200mm is subjected to an increased temperature of 1000oC on the exterior face for a period of two hours. For the purpose of study, the area is divided into nine parts such that the central portion is of dimensions 200mm×200mm. The model consists of total number of nine solids. A temperature loading of 1000oC is applied on the external face of the exterior central solid. The default initial temperature of all other faces of the model other than the temperature exposed portion is taken as 27oC. The temperature variation across the thickness is studied considering the variation of thermal conductivity with respect to temperature and porosity. The gradient of temperature variation is very flat and irregular in concrete unlike for metals, as concrete is a heterogeneous material. In the study, the variation of thermal conductivity with changes in temperature values has been considered. Similarly, the variation of thermal conductivity due to porosity has also been taken into consideration based on the available information. Magnitudes of temperature at different locations in concrete have been recorded at every ten minute intervals for two hours. Based on the FEM output, it is observed that the heat does not percolate till the core of concrete until one hour twenty minutes from the beginning of fire attack. From then on variation of temperature inside concrete core is found to increase rapidly

Haluk M. (2012), in his research, total 36 concrete samples are prepared and shaped including 10x10x50 cm sizes. They were mixed with fly ash having 5%,10%,15% in 27 samples and 9 units were selected 5% (3samples), 10% (3samples), 15% (3 samples) to predict the differences. Firstly, forms for 1/3 of the distance for pouring concrete were prepared. Then, concrete pouring process was finished with time intervals of 2hours, 12 hours and 24 hours. In accordance with standard No. 3285 of Turkish tensile strength test was applied at eliminated load while leaning. At the end of experiments it was renowned that the increasing of time difference strength has decreased, as well as the increase of fly ash rate of proportion was also a negative impact on strength. The reason is thought that the proportion of fly ash predicts its real properties after 90 days.

Saraswathy V.(2003) , studied various activation techniques, such as physical, thermal and chemical were adopted. By adopting these methods of activation, hydration of fly ash blended cement was accelerated and thereby improved the corrosion-resistance and strength of concrete. Concrete specimens prepared with 10%, 20%, 30% and 40% of activated fly ash replacement levels were evaluated for their compressive strength at 7, 14, 28 and 90days and the results were compared with ordinary Portland cement concrete (without fly ash). Electrical resistivity and ultrasonic pulse velocity measurements were also carried out to understand the quality of concrete. All the studies confirmed that up to a critical level of 20– 30% replacement; activated fly ash cement improved both the corrosion-resistance and strength of concrete. Chemical activation of fly ash yielded better results than the other methods of activation investigated in this study.

Mathew G. (2012), in his research the physical and mechanical properties of laterized concrete with fly ash and ground granulated blast furnace slag (GGBFS) as mineral admixtures have been studied after the concrete was exposed to elevated temperatures. Concrete made with laterite aggregate, a marginal material, can be used for fire protection applications. Specimens were heated to 200 °C, 400 °C and 600 °C using an electrical furnace. The rate of increase in temperature of the furnace was kept in line with the standard temperature rise – time curve. Specimens were cooled to room temperature by air cooling and water cooling and were tested at ambient temperature. It has been observed that the available equations to predict the compressive and flexural strength of concrete does not apply to laterized concrete, particularly at temperatures above 400 °C. It could be concluded that, Laterized concrete with mineral admixtures (fly ash and GGBFS) is a promising economical and sustainable material. It shows better physical and mechanical properties at elevated temperatures as against conventional concrete and has resistance against the development of thermal cracks up to an exposure temperature of 800 °C.

Bruce Ellingwood (1991), describe the results of a research program to study the behavior of reinforced concrete beams exposed to severe fires. Using normal-weight concrete, information is presented from fire tests of six full-scale beams continuous over one support. Four beams were exposed to the standard ASTM El 19 fire, and two to a short-duration high-intensity (SDHI). All six beams urbanized significant shear cracks near the continuous support somewhat early in the fire, but finally failed from extreme flexural cracking and bend. Mathematical models for predicting thermal and structural response of concrete beams exposed to natural fires, as well as the ASTM standard exposure, were also developed. These models predicted the experimental behavior with enough accuracy for purposes of limit-states design.

Anand N. and Prince A. G. (2011), in these experimental studies on the performance of concrete when exposed to higher temperature are studied. Shape of specimen (cube, cylinder, beam etc), size of specimen, magnitude of temperature load applied on the specimen, time duration maintained for heating, reference on time-temperature curve, rate of heating, rate of cooling, time taken for hot test after curing period, time taken for load test after heating, heat test on stressed/unstressed member, type of cooling adopted on heated specimen are the parameters that affects the test results. To understand the behavior of concrete under elevated temperature, it is necessary that several factors be taken into account for each experiment i.e. Strength of concrete, type of cement, type of aggregate, water cement ratio, density of concrete, percentage of reinforcement, cover to the reinforcement etc are some of the important factors that affect the performance of concrete at elevated temperature.

Solanki Jayraj V. (2013), from his investigation, fly ash and hypo sludge is obtained as waste product from the thermal and paper industries. Investigations were carried out to explore the possibility of using fly ash and hypo sludge as a replacement of cement in concrete mixtures. This paper presents the results of study undertaken to investigate the feasibility of using fly ash and hypo sludge as cement in concrete. The effects of replacing cement by fly ash and hypo sludge on the flexural strength of beams (500 mmx100 mmx100 mm) are evaluated in this study. Two test groups were constituted with the replacement percentages of 0%, 10%, 20%and 30%.The results showed the effect of fly ash and hypo sludge on concrete beams has a considerable amount of increase of the flexural strength characteristics. To investigate the utilization of Hypo Sludge as Supplementary Cementitious Materials (SCM) and influence of these hypo sludge on the Strength on concretes made with different Cement replacement levels and also compare with fly ash concrete and ordinary concrete.

Zhao J.(2002) , in this paper, the influence of fly ash from a fluidized-bed coal gasifier on the desulfurization performance of iron oxide sorbent made by a kind of waste material containing iron oxide was systematically evaluated in the temperature range of 400 °C to 550 °C in a fixed-bed reactor. The results showed that fly ash could interact with the sorbent and adversely influence the sulphur capacity and sulfidation rate of the sorbent. The interaction was promoted with increasing sulfidation temperature and quantity of fly ash. But below 450 °C, the interaction becomes negligible.

V.K.R. Kodur, carry out a research to results comparing the fire resistance of highstrength and normal-strength concrete columns and offers guidelines for improving the fire resistance of high-strength concrete structural members. Spalling results in the rapid loss of the surface layers of the concrete during a fire.The extremely high water vapour pressure, generated during exposure to fire, cannot escape because of the high density (and low permeability) of HSC. This pressure often reaches the saturation vapour pressure, which at 300°C is about 8 MPa. The fire performance of HSC, is influenced by the following factors:

1. Fire intensity
2. Dimensions and shape of specimens
3. Lateral Reinforcement
4. Type of aggregate
5. Loadingconditions
6. Original compressive strength of the concrete
7. Moisture content of the concrete

This research paper concludes that, the attractive properties of high-strength concrete must be weighed against concerns about its fire resistance and its susceptibility to spalling at elevated temperatures. To enhance the fire performance of concrete use normal-weight aggregate to minimize spalling, add polypropylene fibres to the mix to reduce spalling, Add steel fibres to enhance tensile strength and reduce spalling, employ both closer tie spacing and cross ties to improve fire resistance, Install bent ties (at 135° back into the concrete core) instead of straight ties.

III. CONCLUSION

The conclusions from above review are as follows:

1. The Flexural strength of beam decreased as the elevated temperature goes on increasing.
2. Beam shows flexural cracks in the pure bending region at temperature of 100°C and 300°C and shear flexure cracks in the shear region at temperature of 600°C and 900°C.
3. Weight loss of beam increases at temperature 100°C, 300°C, 600°C & 900°C, which shows strength of beam, goes on decreasing.
4. The mechanical properties of concrete (as compressive strength) are largely affected by temperatures beyond 500°C.
5. Concrete undergoes significant physicochemical changes at elevated temperatures. These changes cause properties to weaken at elevated temperatures and bring in additional complexities, such as spalling in HSC.

6. By using light weight aggregate in concrete, thermal diffusivity of a concrete member can be reduced.
7. By introduction of steel fibres in order to perform concrete better during fire, elastic modulus and tensile strength of concrete can be increased.
8. Spalling of HSC can be minimizing through addition of polypropylene fibres.
9. Additional examinations are needed in order to document material properties for design purposes and for the evaluation of residual strength of structural elements exposed to fire.
10. There is need to carry out a wide investigation to find out the effect of the variation in the testing procedures.
11. The fire intensity, fire size and heat output, and rate of heating influence the degree of spalling and fire endurance duration of HSC members.
12. Concrete strength, silica fume, concrete moisture content, concrete density, fibre reinforcement, and type of aggregate are the main parameters that influence fire performance of HSC.
13. For simply supported slab under fire effect, displacement increases when width of slab increases also displacement decreases when percentage of steel in RCC slab increases
14. The mid-span deflection with duration of heating is accurately predicted by the finite element model and a maximum discrepancy of 6% was observed when comparing the finite element model with experimental studies.
15. Sudden cooling concrete cause additional strength loss for RC beam.
16. Ultimate load capacity of rigid beam specimen decreases when subjected to elevated temperature.

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