TEMPERATURE DISTRIBUTION OF FIRE EXPOSED CONCRETE SLAB

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Abstract- It is known that nonlinear temperature variation over a cross section of long-span slabs can cause longitudinal stresses and that in some cases such kind of stresses may reach or even exceed those induced by the live loads and that temperature cracking may occur in the structure component. Calculating the change of temperature field in reinforced concrete under fire is very important for the analysis of deformation and fire resistance performance in high rise building construction. However, the mechanism of such phenomenon is not very clear yet. Therefore, to predict the stresses caused by temperature distribution is important for the correct design of the structures. The purpose of the present study is to present the 2D nonlinear transient analysis over cross sections of a concrete slab. The relative factors considered include the slab geometry, the material properties and elevated temperature conditions. In this study, heat flow over a cross section of concrete slab is obtained using finite element computer programming package. This finite element analysis can be used to generate the thermal loads. A two-dimensional heat transfer model is proposed to predict the temperature distribution across the slab. A prediction for variance of concrete temperature is obtained.

I. INTRODUCTION

It is known that all structures within economic lifetime must have a specific safety in response to collapse by becoming out of service under loading. It is also known that the structures have to maintain these characteristics during probable fires. In the circumstances, it is necessary to take into account the fire effects in design, construction and using stages of reinforced concrete structures like other structures.

The first step of fire design is to choose or evaluate the temperature-time curve which represents the fire. After determined the environment temperature change according to time, in the second step it is possible to determine the temperature distributions of structural element which used in structural analyses. For this reason there are many methods in technical literatures. These methods can be listed in order tabulated data methods which are developed based on tests and experiences, simplified methods and numerical methods which provide to be carried out thermal analyses by computers (Burnaz and Durmus, 2007).

2. MATERIAL PROPERTIES

2.0 THERMAL PROPERTIES OF CONCRETE

An important design consideration for concrete includes the effects of fire. The behavior of concrete slabs subjected to fire conditions is complex. In a fully developed fire, to prevent fire spread to the upper floors, the slab has to carry and withstand the applied loads and prevent collapse during and after the fire. The effect of fire, which is not generally considered in typical structural design practice, involves the thermal conductivity, specific heat and high thermal expansion of the concrete.

2.1 THERMAL CONDUCTIVITY

Thermal conductivity is the capability of a material to conduct heat, and is defined as the ratio of heat flux to the temperature gradient. It represents the uniform flow of heat through concrete of unit thickness over a unit area subjected to a unit temperature difference between the two opposite faces [6].

2.2 MODULUS OF ELASTICITY

The modulus of elasticity of the concrete in Fig.3.6 decreases with an increment in temperature. The reduction of the modulus of elasticity is due to the rupture of bonds in the microstructure of the cement paste when the temperature increases and is the result of the onset of rapid short-term creep.

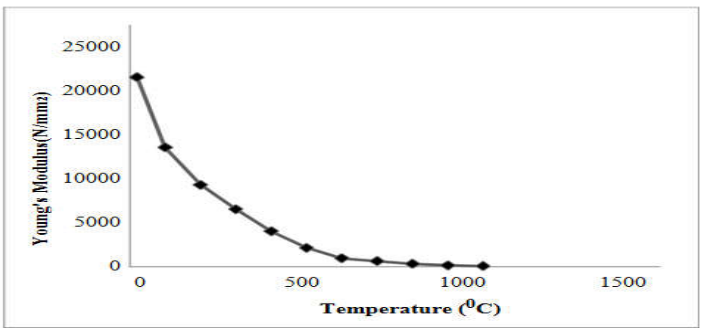

Fig.1. Modulus of elasticity of concrete at elevated temperatures, EC2

3. FINITE ELEMENT ANALYSIS

3.0 MODEL MESH OF SLAB

The 2D cross-section of the slab was meshed into 20 elements along depth as well as along width. The meshing of the slab was shown in the Fig.2

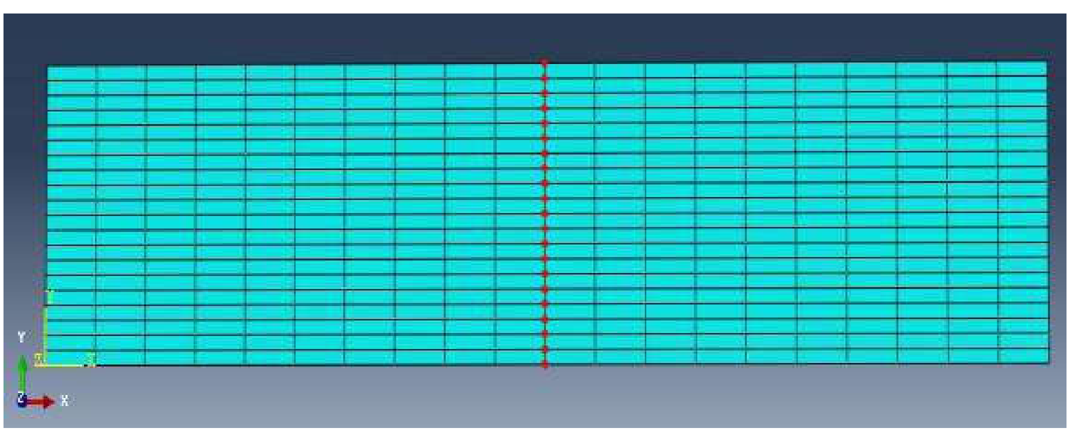

Fig.2. Meshing of beam

Table.1 Dimensions of the model slab

Dimensions	
Height	h = 150 mm
Width	b = 80 mm

Table.2 Boundary conditions for model slab

S.no	Sides	Boundary Condition
1	Top	T= 25^{o}
2	Bottom	T= ISO 834
3	Left side	Insulated
4	Right side	Insulated

3.1 MODEL MESH FOR THE BEAM

The 2D cross-section of the beam was meshed into 15 elements along depth and 8 elements along width. The meshing of the beam was shown in the Fig.3.

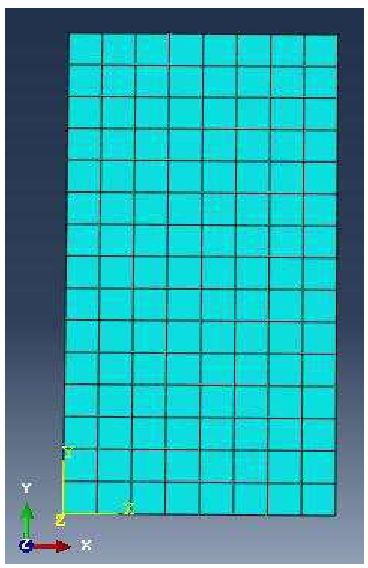

Fig.3. Meshing of the beam

Table.3. Dimensions of the model beam

Dimensions	
Height	h = 150 mm
Width	b = 80 mm

Table.4 Boundary conditions for model beam

S.no	Sides	Boundary Condition
1	Top	Insulated
2	Bottom	T=ISO 834
3	Left side	T=ISO 834
4	Right side	T=ISO 834

4. RESULTS & DISCUSSIONS

4.0 TRANSIENT HEAT TRANSFER ANALYSIS – PARAMETRIC STUDY

In this study, a slab of meter width was considered from infinite width. Therefore, we considered the sides of the slab ware insulated and the bottom surface was exposed to the temperature. The temperature distribution of 2D finite element model of slab across cross-section was found out by changing various parameters. Those are,

- Varying thickness of slab from 100mm to 500mm.
- Fire of varying temperatures from 100 °C to 400 °C.
- Varying exposure time of 30min to 240 min

4.1 Slab of thickness h =100 mm

A slab of meter width and thickness of 100mm was considered. The slab was divided into 10 layers along the depth of the slab. The temperature of slab at each point of interface of the layer was found with varying exposed temperature and exposed time.

4.2 Exposed temperature of 100 °C

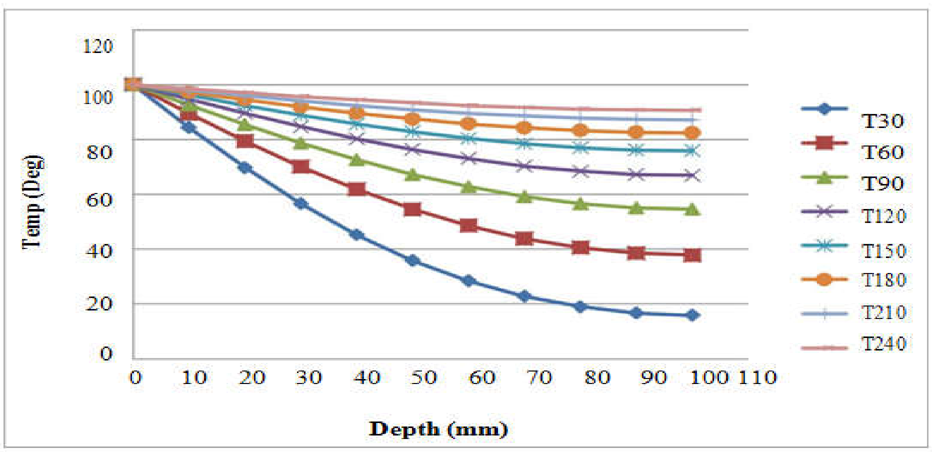

Fig.5 Temperature profiles for a slab (h=100mm &T=100°C)

4.3 Exposed temperature of 150 °C

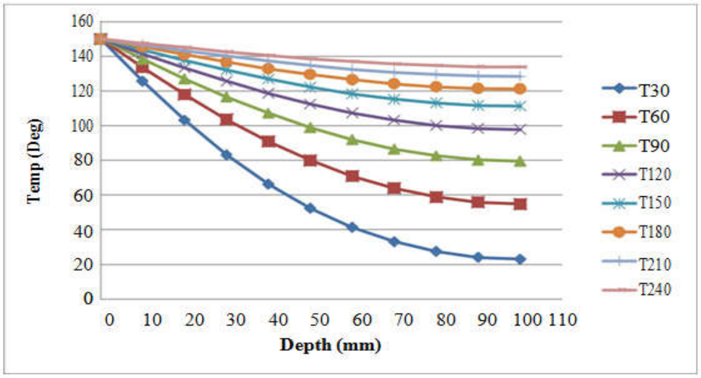

Fig.6 Temperature profiles for a slab (h=100mm &T=150°C)

DISCUSSIONS

From the results obtained from FEA software (ABAQUS), we observed that the distribution through the cross-section of slab was nonlinear. From EN1992-1-2, the thermal property, conductivity of concrete decreases with increase of temperature. Due to this decrease in conductivity, the temperature of elements of slab decreases with increase of exposed temperature.

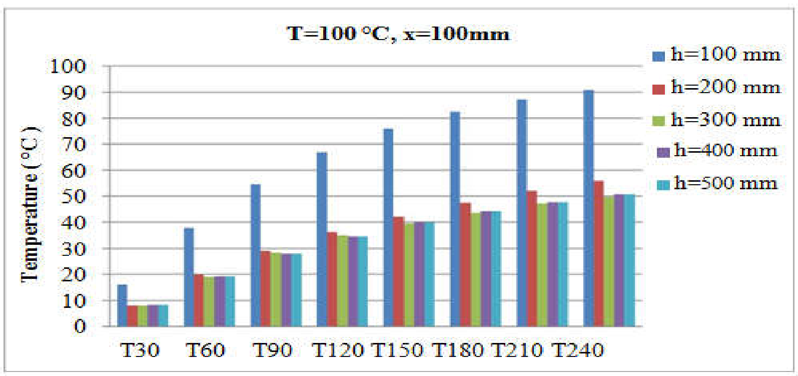

Fig.7. Comparison of temperature with slab thickness (T=100 °C, x=100mm)

When a slab of 100mm thick is considered and it is subjected to 100°C, the element at 100mm from exposed surface is reached around 90°C after 4hrs of exposure. Similarly, for 200mm thick slab, element at 100mm from exposed surface is reached around 56°C. As the depth of the slab increases beyond 200mm, the temperature of the elements at respective points is constant.

5. CONCLUSION

5.1 GENERAL

The concrete slab with different thicknesses was modeled and nonlinear heat transfer analysis was carried out using general purpose FEA software ABAQUS. Based on the results obtained, the following conclusions can made.

5.2.1 CONCLUSION

- It is observed that the distribution of temperature through the depth of the slab is non-linear irrespective of exposed temperature and exposed time.

- As the exposed time increases, the differential temperature in the slab near to exposed surface decreases. But, still it is more than far end of slab.
- As exposed temperature increases, the differential temperature in the slab near to exposed surface of slab increases.
- The results obtained from this study clearly suggest that the effect of fire is more on the region near to exposed surface.
- As the depth of slab increases, there is no significant effect of fire on the region far to the exposed surface of slab.

REFERENCES

[1]. **ABAQUS 6.11** (General Purpose Finite Element Analysis Software) Documentation.

[2]. **ASTM Standards (1988).** "Standard Test Methods for Fire Tests of Building Construction and Materials, in Annual Book of ASTM Standards." 04, Designation: E 119-88, ASTM, 922–942.

[3]. **Bailey C (2002).** "Holistic Behaviour of Concrete Buildings in Fire." Structures & Buildings, 152, 3, 199-212.

[4]. **British Standards Institution.** "Design of concrete structures, Part 1.1 General rules and rules for buildings. London: British Standard Institute" 2004. ENV1992-1-1.

[5]. **British Standards Institution.** "Design of the steel structures, Part 1.1 General rules and rules for buildings. London: British Standard Institute" 2002. ENV1993-1-1.

[6]. **ISO (1975) Fire Resistance Tests.** "Elements of Building Construction, ISO 834, International Organization for Standardization." Geneva.

[7]. **Omer Arioz** "Effects of elevated temperatures on properties of concrete".

[8]. **D. J. Naus** "The Effect of Elevated Temperature on Concrete Materials and Structures".

[9]. **Xiao-ying Zhang, Chun-cheng Gong (2009**) "Numerical Simulation of 3-D Temperature in Reinforced Concrete Structure under Fire".

[10]. **B.M. Luccioni, M.I. Figueroa, R.F. Danesi (2003)** "Thermo-mechanic model for concrete exposed to elevated Temperatures".

[11]. **Schneider U (1988).** "Concrete at High Temperatures – A General Review." Fire Safety Journal, 13, 1, 55-68.**C Sangluaia, M K Haridharan, Dr. C Natarajan.**

[12]. "Behaviour of Reinforced Concrete Slab Subjected to Fire." International journal computational engineering research, 3,1,195-206.