International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 05 | May-2018 www.irjet.net p-ISSN: 2395-0072

Finite Element Analysis of RC Beam Exposed to Fire

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Abstract - *Concrete is considered as a fire resistant material which means that it does not conduct heat to a large extent like a metallic object does and does not produce much deformation due to increase in the temperature surrounding it or within it. Concrete do undergo certain deformation after a limit of temperature exposure time. These defects includes loss and strength, palling of concrete, total failure of the structure, change in material properties of concrete constituents etc. Therefore it is necessary to study the effect of high temperature on concrete structure to understand its behavior pattern and reduce the losses due to fire hazards. It can be studied by finite element analysis and in this paper Ansys 17 is used to simulate a fire exposure condition on an RC beam of certain dimensions and other properties. The method with which the temperature propagates within the beam is being analyzed here and the pattern of propagation is studied.*

Key Words: *ANSYS, Finite element model, Reinforced concrete beams, Fire resistance, Temperature gradient etc …*

1. INTRODUCTION

Fire can be indeed considered as a most severe condition a concrete structure can be subjected to in its service life. It is a very unpredictable situation where the concrete can behave in any way depending upon the intensity of the fire load as well as a service and dead loads existing on the structure .This can cause critical damages to both the structure as well as human life and property to such an extent that retrofitting becomes very much difficult. Fire attack can occur on any type of building regardless of the economic value of the place. Therefore it is inevitable for engineers across the world to study the condition of RC beams exposed to high temperature and understand the method of propagation of fire within the beam so that required mitigatory measures can be taken.

2. METHODOLOGY

The working methodology for this study includes the following elements:

1) Simulation of the experimental work done by Wu et al (1993), beams to study the complex distribution of temperature within the beam.

2) 3D models of RC beams used for the fire test are created in the ANSYS finite element modeling software, version 17.

3) The propagation of the temperature inside the RC beam, including the effect inside the rebar, is obtained and reported as a function of time.

2.1 Thermal Properties of Concrete

Thermal conductivity, specific heat capacity ,thermal expansion coefficient are some of the major thermal properties of concrete that need to be analyzed and can be adopted from the data given in the euro code.

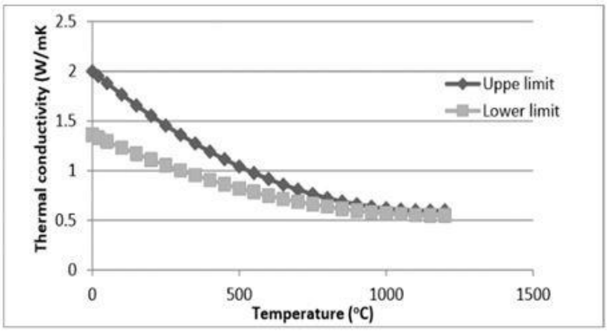


Chart -1: Thermal Conductivity

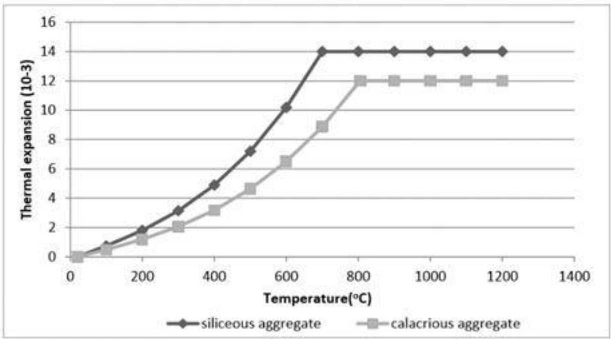


Chart -2: Thermal Expansion Coefficient

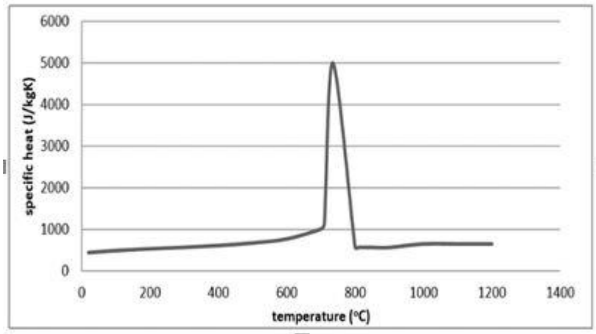


Chart -3: Specific heat capacity

2.2 Thermal Properties of Steel

The temperature-dependent variations of thermal conductivity and specific heat capacity of steel as specified in

EN 1993-1-2 are adopted in the present FE model. The density of steel is 7800 kg/m3

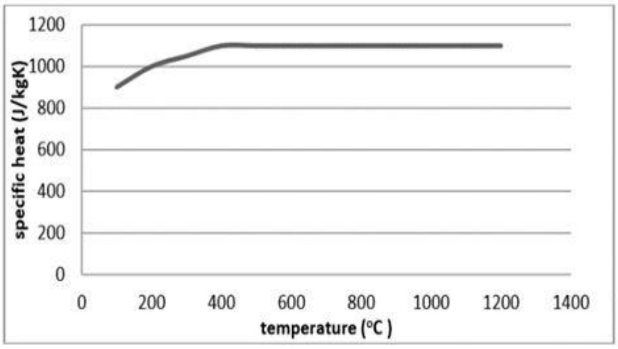


Chart -4: Specific heat capacity

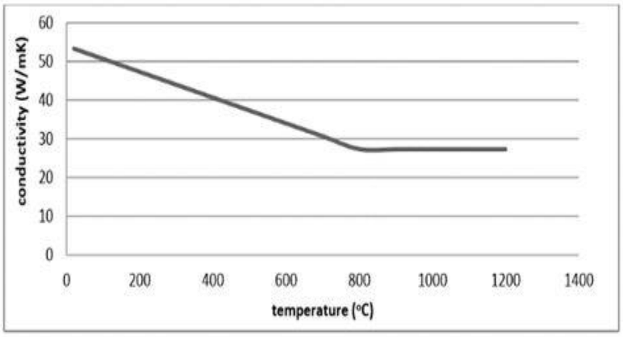


Chart -5: Thermal Conductivity

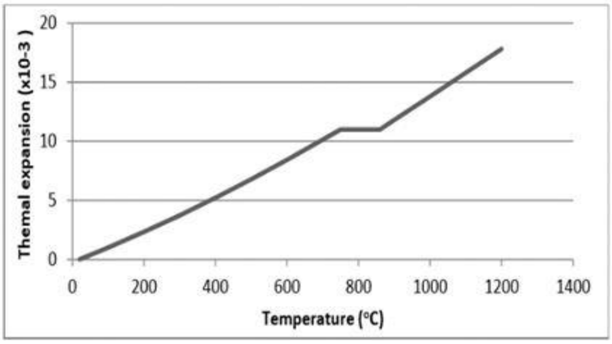


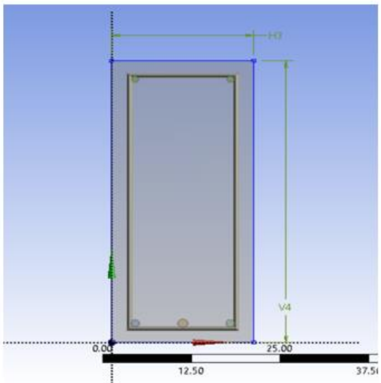
Chart -2: Thermal Expansion Coefficient

Table -1: Properties of Beam Tested by Wu et al

Geometrical properties	
Span, L	5.1 m
Width, b	200 mm
Depth, h	400 mm
Concrete properties	
Compressive strength (ambient temperature)	24.2 N/mm^2
Elastic modulus (ambient temperature)	25000 N/mm^2
Concrete model (thermal and mechanical)	Siliceous aggregate
Bottom and top cover	25 mm
Side cover	38mm
Reinforcing steel properties	
Yield strength (ambient temperature)	240 N/mm
Elastic modulus (ambient temperature)	2e10^{5}N/mm^2
Reinforcing bars at the top	2 # 10mm dia
Number of bars at the bottom	2 #12mm dia 1#14mm dia
Loads	
Superimposed dead load	300kg/m2
Fire exposure	ISO -834 standard fire

The stress–strain relationships of structural steel both in tension and compression can be adopted from the stress strain relations from the Euro code.

The constitutive model of concrete is adopted from the stress strain relation of concrete under both compression and tension which is given in the Euro code. Solid 65 and link 185 is used here.



Reinforcing bars at the top	2 number of 10mm dia bars
Number of bars at the bottom	2 number of 12mm dia bars , one 14mm dia bar

Fig -1: **Details of the beam (200mmx400mmx5400mm)**

The required beam with the earlier mentioned dimensions and physical properties are modelled .Convection coefficient of 25kW/m3 on the exposed face and 9kW/m3 in the unexposed face are provided (Fig 2). The ISO fire curve (Fig.3) was also input with respect to time on the externally loaded beam. Reinforcement bars of the required dimension as mentioned above was provided. Stirrups at 300mm spacing was provided.

It is a three step process were initially the fire scenario analysis is done followed by heat analysis will be carried out where heat propagation is analyzed. Finally the mechanical analysis is done where over all response of the beam to temperature as well as the external load is carried out.

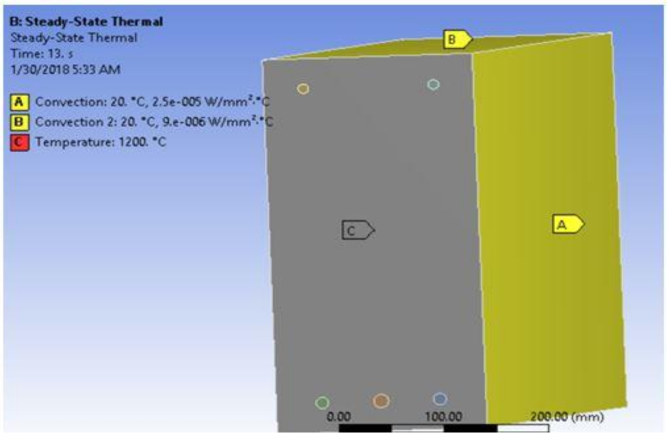


Fig -2: Input of coefficient of thermal expansion

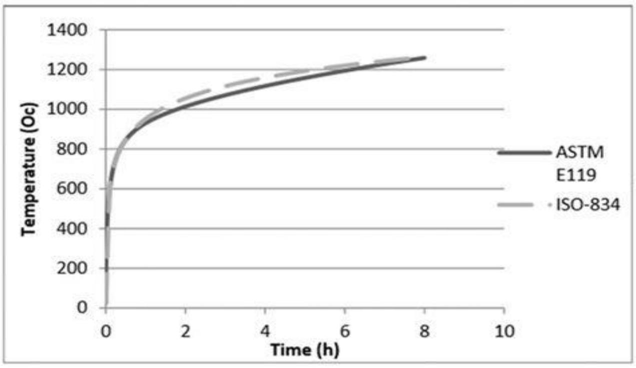


Fig -3: Fire Curves

3. RESULT

Using ISO fire curve the temperature gradient through the reinforced concrete beam was found out. Temperature was found to be maximum at the outer surfaces and progressed inwards with time .This simulation was done in ANSYS 17. At 3600 sec of fire exposure (max temperature of 600◦C) the reinforcement starts conducting heat. Once the temperature in the reinforcement starts increasing it increment with a great pace with fire exposure and causes the structure to fail.

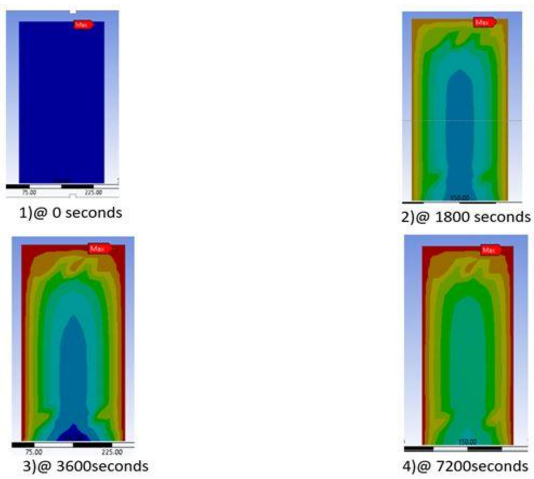


Fig -4: Temperature at various time interval

4. CONCLUSIONS

1) With the given data temperature distribution within the RC beam was successfully simulated.

2) At 3600 sec of fire exposure (max temperature of 600◦C) the reinforcement starts conducting heat.

3) The reinforcement temperature rises a step higher than that of the surrounding concrete surface.

4) The given relationships, for thermal and mechanical properties at elevated temperatures will successfully facilitate modelling the concrete under fire exposure.

5) The additional experimental tests including a parametric study is needed to check the importance and role of several parameters of thermal and mechanical properties of concrete.

6) Fire effect within a beam due to short circuiting can be also found out apart from external fire.

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