FIRE ANALYSIS OF SIMPLY SUPPORTED REINFORCED CONCRETE BEAM

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Abstract: This paper presents analysis of simply supported reinforced concrete beam exposed to standard fire. Eurocode standard provides recommendations for analysis of reinforced concrete structure under fire. The thermal and structural responses of structure are calculated using commercially available software ANSYS. An advance calculation methodology must be implemented to estimate the behavior of structure and to understand thermal and mechanical properties of material during fire. These include transient thermal as well as structural analysis of structure. Finite element software ANSYS is capable to conducting thermal analysis as per defined material properties. It is important to study effect at elevated temperature on structure to understanding the behavior pattern and decrease the losses caused fire hazards.

Keywords: fire load, heat expansion, fire resisting materials, thermal analysis, ANSYS

1. INTRODUCTION:

Experimental research provides a comprehensive understanding of the behavior of structures that have been exposed to fire. Special experiment setup and equipment are needed to perform test at elevated temperature. Furnaces and correct implementation are necessary to provide standard fire exposure and to capture thermal and structural response at elevated temperature. Test consuming time, money, and energy, the need for more suitable method namely finite element method. ANSYS is a finite element software that can simulate mechanical and thermal properties of concrete and steel. Capture thermal-structural response of structure at ambient or elevated temperature [5]. As per Eurocode EN 1992-1-2 norm’s structure can be analyzed at three level with increasing complexity as follows: 1) Member analysis 2) Part of structure 3) Global structural analysis [2].

Eurocode EN-1992-1-1 (2004) and EN-1993-1-2 (2002) gives all parameter for both concrete and steel. EN1991-1-2 (2002) described thermal and mechanical measures for structural examination in the in the event of a fire. [1][2]. An advance calculation method include transient heat transfer, convection, radiation and conduction effect taking into account as well as mechanical analysis to understand material degradation at high temperatures which resulted solution An advanced calculating technique includes taking into consideration transient heat transfer, convection, radiation, and conduction effects, as well as mechanical analysis to understand material degradation at high temperatures, resulting in a solution with a significant nonlinearity [6]. Using ANSYS software analysis of adopted beam under standard fire ISO 834 is presented and result are discussed.
2. OBJECTIVES:

1) To analyzed structural performance of beam at elevated temperature.
2) To evaluate vertical displacement of beam at mid span.
3) To obtain temperature distribution in reinforcement bars in standard fire exposure.
4) To better understand the behavior of structures at high temperatures in order to reduce fire losses.
5) To understand thermal effect on properties of material.
6) To incorporate fire safety into the structural frame system design.

3. THERMAL PROPERTIES OF MATERIAL

Because of evaporation of moisture and physical-chemical changes, concrete that contains initial moisture loses weight as the temperature rises. In certain aggregates, calcium-hydroxide decomposes to calcium-oxide, and quartz transforms. The key thermal properties of concrete to be examined are thermal conductivity, thermal expansion coefficient, and specific heat capacity. These properties are based on Eurocode. [3][4].

The thermal conductivity and specific heat capacity of steel variations is given in EN 1993 -1-2 and used in the model. Steel density is 7800 kg/m3 [8].

![Figure 1: Thermal conductivity](image1)

![Figure 2: Thermal Expansion Coefficient](image2)
4. NUMERICAL EXAMPLE

Analysis of simply supported reinforce concrete beam at the elevated temperature is done using ANSYS Workbench 16.0. The length of beam 5m with cross section 300mm X 600mm is adopted. The design takes this into consideration self-weight and external load of 10 KN/m, and an imposed concentrated load of 50 KN at the middle of the beam span. Figure 1 shows the static system and the beam reinforcement was used.
For the thermal analysis, concrete and reinforcing steel are discretized using 8-node 3D SOLID 70 ELEMENT and 2 node line element LINK 33 respectively with single degree of freedom and transformed to solid65 8 node element or the structural analysis. In tension solid 65 is capable to crack and also capable in compression to plastic deformation. To apply thermal load in term of convection and radiation surface element SURF152 is used. Adopted mesh element size is 1.25 cm. To apply thermal load in relation to convection and radiation coefficient $\alpha_c=25 \text{ Wm}^{-2}\text{°C}$. The beam reinforcement bars is represented as a uniaxial line element link 33 that may transmit heat between its nodes. The reinforcement and concrete section are assumed to have a perfect bond.

According to Eurocode the beam subjected thermal load in terms of convection as well as radiation. Every 30 seconds, the thermal response of the beam is computed, and the results are then transmitted to the structural analysis as a thermal load, which is separated into two steps. The first step is structural analysis in which external permanent load and imposed load is considered. In second step thermal load is considered.

5. VERIFICATION OF THE PRESENTED NUMERICAL METHOD

Experimental test: Experimental testing was conducted to verify the accurateness and capacity of the proposed numerical approach for structural analysis of reinforced concrete beam exposed to fire. For comparison, Kumar and Kumar's test was utilized. A series of RC beams were casted in Kumar's experiments to investigate their structural behavior under fire for varying periods of time. Length, width and depth of beam 3950 mm, 200 mm and 300 mm respectively, with a 3200 mm span between supports. Figure 6 shows the experimental design.

![Experimental Test setup](image)

The fire is applied to the beams for 1, 1.5, 2, and 2.5 hours, respectively. The top surface of the beam is kept at a constant temperature of 20°C, while the bottom surface and two sides are exposed to standard fire exposure ISO 834. Four point loading test were perform on these beams. During the experiments, two loading platens were used to control the deflection of RC beams. Because the beam sample with 2.5 hours under fire could not be tested due to spalling of concrete after cooling, only four beam specimens experimental details are available. [7].

6. RESULT:

Figure 7 shows the thermal response of an arbitrary beam cross section. The results are verified by comparing the profiles to the results presented in Annex A in [1].
When the design beam exposed under fire the temperature in reinforcement at up corner (UC) and down corner (DC) bars is significantly higher than the down middle (DM) bar as shown in fig. 8 due to heat transmission.
Figure 9 displays the vertical displacement-time curve of the mid-span. The first displacement is caused by external load acting on the beam prior to thermal load. Figures 10-14 show the stress distribution, total mechanical strain, plastic strain, and thermal strain in time, as well as a stress-strain diagram, for reinforcing bars in the beam. As the temperature in the beam rises, mechanical properties begin to deteriorate as a result, the stress in the corner bars is reduced and redistribution to the bars in the centre bar. The proportionate limit in the down middle (DM) bar is exceeded and plastic deformations begin at about 3000 Sec. (50 Min.) of fire due to concrete heating and cracking in tension, as well as total beam stiffness loss. Plastic strain occurs at corner bars, eventually causing the beam to collapse.

7. CONCLUSION

1) The distribution of reinforcement bars with given properties to the material was successfully simulated.

2) Temperature of reinforcement is rises higher than the surrounded concrete surface.

3) Advance calculation method of evaluation the fire resistance of reinforced concrete beam needs application of finite element method which is capable for transient heat and structural analysis. In this paper the result obtain using ANSYS 16.0.

4) Additional experimental studies, including a parametric investigation, are required to evaluate the important and relevance of a number of concrete thermal and mechanical property factors.

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