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Behaviour of Concrete Encased Composite Beam under Fire

Eva Maria Regy
PG Student
Department of Civil Engineering
Mar Athanasius College of Engineering, Kothamangalam, Kerala, India

Prof. Basil Sabu
Professor
Department of Civil Engineering
Mar Athanasius College of Engineering, Kothamangalam, Kerala, India

Abstract

Fire is considered to be a major threat for buildings and its surroundings. Fire can be occurred at any stage of construction and the time or intensity cannot be predicted earlier. Concrete encased composite beams are those in which structural steel is fully covered by concrete. Concrete is considered to be a fire resistant material to an extent. So by providing concrete as cover to the structural member the fire resistance of the member can be improved. But as the temperature increases there will be spalling of concrete and steel get exposed to more fire. In order to identify the behaviour, finite element software Abaqus 6.10 is used in this study. Time temperature chart for the member is also plotted in this paper.
Keywords: Beams, Composite Structures, FEA, Fire Resistance, Temperature Curve

I. Introduction

Concrete encased composite beams are constructed by providing concrete covers on four sides of the structural steel. These types of beams are mostly used in high rise buildings. The structural steel used in this study is Indian Standard I Section of medium weight. As the beam is fully covered by concrete sections, low temperature doesn't have any effect. But as the temperature increases there may be chance for spalling of concrete and steel section will be exposed to more temperature. As the temperature increases the critical value of failure occurs in steel sections. Behaviour of this type of beams under fire cannot be studied in experimental as it is very costly. Analytical method is used to understand the behaviour under fire. Modeling and analysis are done using the software Abaqus 6.10. Sequentially coupled thermal stress analysis is used in this study. Chart presented in this study can be used for the design purpose based on fire resistance.

II. Sequentially coupled analysis of concrete encased composite beam

Sequentially coupled analysis of concrete encased composite beams is done using Abaqus. The beams were analysed by exposing two sides and bottom surface on ISO 834 standard fire. The fire curve is shown in figure 1.The time -temperature curve obtained after analysis can easily be used to determine the cover required in order to protect beams against fire. The temperature output of thermal analysis of beam is used as an input for structural analysis along with the static load. Deflection check is used as the criteria for determining fire resistance as per static analysis.

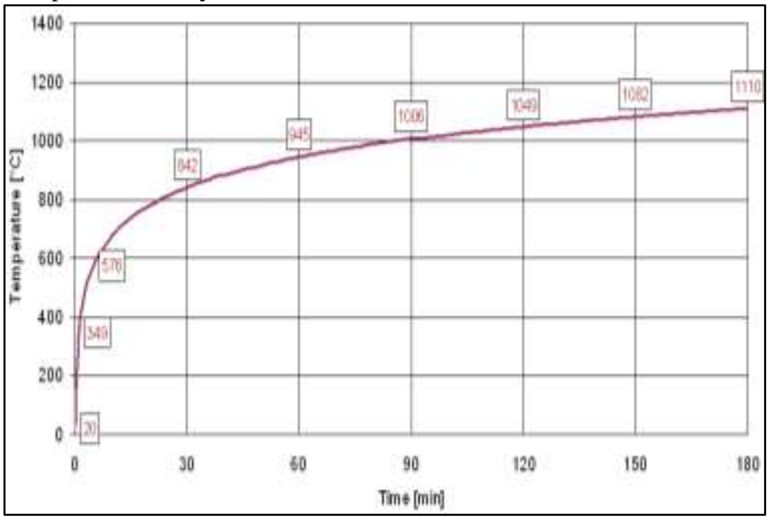

Fig. 1: ISO 834 Fire Curve

A. Failure Criteria

The output parameter of the analysis is checked against the critical failure criteria. The critical failure for concrete under ISO 834 curve is considered to be 5000C and steel is considered as 6640C. The time of failure is considered as the fire resistance of structure.

B. Finite Element Modelling

The composite beams are modelled in Abaqus with load ratio 0.3 provided in Eurocode 4 [9] as it doesn't require any additional reinforcement. Minimum cross sectional dimensions for the load level are also provided in Eurocode. The dimension of the beam created were 100 mm x 150 mm with I section having properties and dimensions of ISMB 100.The cover that is provided for the section is 25 mm. The beam is provided for a length of 3m as shown in figure 2.

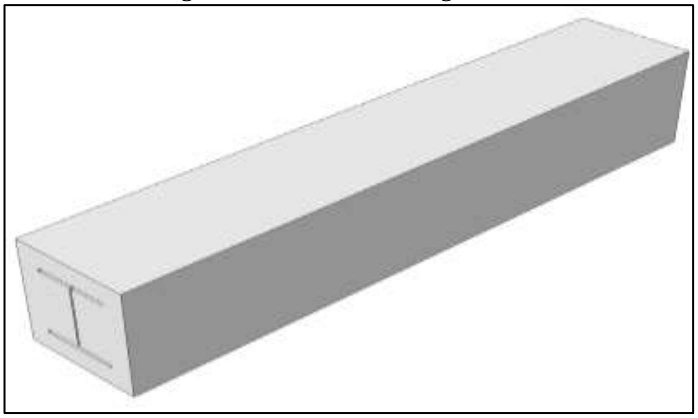

Fig. 2: Model of composite beam in abaqus

III. THERMAL ANALYSIS RESULT

Heat transfer from fire to element is by convection with film coefficient 25W/m^{2}K. At time zero, a uniform temperature of 20^{0}C is applied. The variation of temperature within the cross section in Abaqus is show in figure 2. Fire rating of the beam can be obtained from Abaqus result and it is the time at which the concrete temperature exceeds 500^{0}C and steel temperature exceeds 664^{0}C. From this analysis results the concrete reaches a temperature of 500^{0}C at time t = 35 min and due to the cover provided there is no temperature above critical value in steel sections. Time -Temperature curve for the beam 100 mm x 150 mm is shown in figure 4. From the time -temperature curve we can easily determine the cover required in order to protect beams against fire.

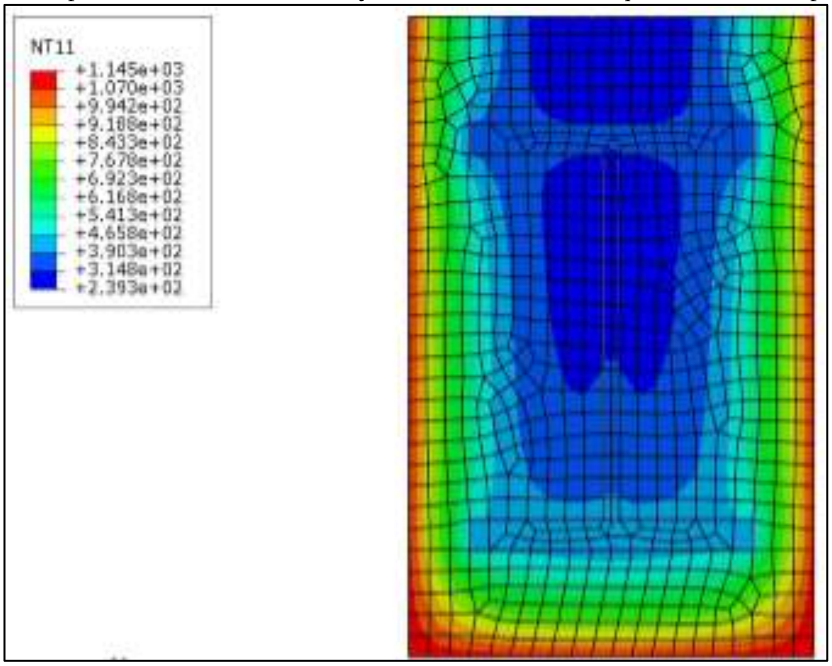

Fig. 3: Temperature profile of beam in abaqus

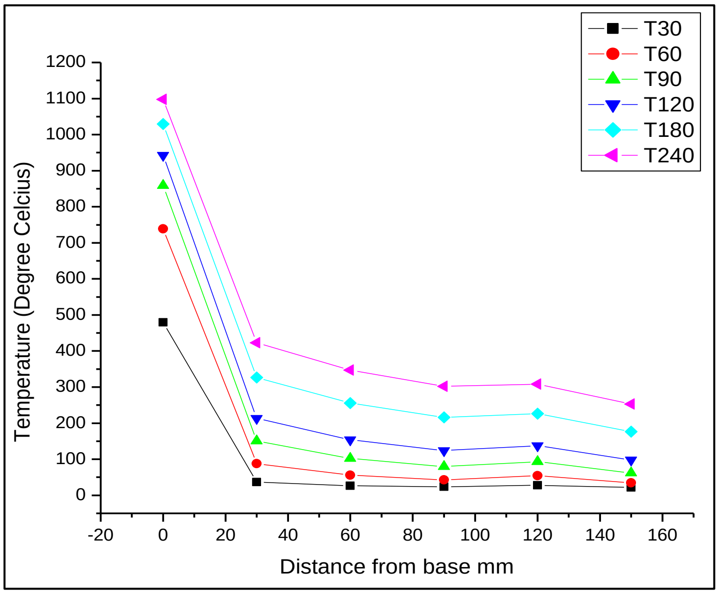

Fig. 4: Time-Temperature curve of the section

IV. STRUCTURAL ANALYSIS RESULT

In order to analyse the structural action of a composite beam a separate model is used as specified above with a length of 3m. By applying the static load and the thermal load to the beam, the beam is analyses using 3D stress analysis type. The stresses, strains and deflections can be obtained after the analysis. The fire rating is obtained based on the deflection criteria. The deflection diagram of the beam is shown in the figure 4.

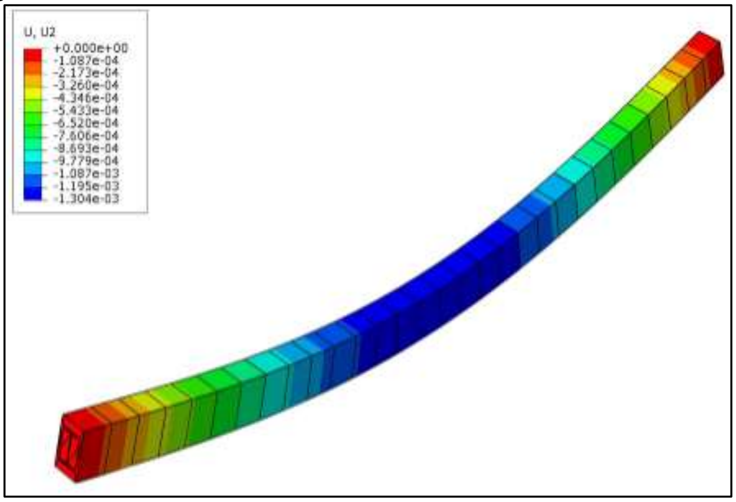

Fig. 5: Deflection diagram of the beam

While evaluating the encased beam for deflection criteria the maximum value is obtained as 1.30mm.So the deflection value is not reaching up to its limiting value. Hence we can take the fire rating as 240 min that is the total exposure time and failure doesn't occur due to fire at this time.

V. CONCLUSIONS

From the thermal analysis it is clear that as the cover increases, the resistance towards fire can be improved. The cover required for fire protection can be obtained from the time – temperature curve. From the analysis results it is clear that the steel is not reaching up to its critical temperature. But as the concrete exceeds its critical temperature the concrete gets spalled off and steel will be exposed to more temperature and it may fail due to large temperature. So the fire rating after conducting thermal analysis on 100 mm x 150 mm beam is obtained as T35. From the structural analysis it is clear that the deflection is not reaching up to its limiting value. Hence the fire rating is taken as 240 min as per deflection criteria. Fire resistance is defined as the minimum time for which the structure is able to perform without any failure when exposed to fire. So the fire rating of 100 x 150 mm is taken as 35 minutes.

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