BRE Centre *for* Fire Safety Engineering

Developing A Heat Transfer Model In OpenSees For Structures In Fire

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Introduction

Heat transfer analysis of structural members subjected to fire plays an important role in structural fire design. However, an integrated fire-thermal-structural analysis may be complicated in case of using advanced fire models and non-trivial coupling strategies. To alleviate this problem, a heat transfer module using finite element method and object-oriented programming approach has been developed within a open-source framework OpenSees (The Open System for Earthquake Engineering Simulation). A fire module has also been developed to provide heat transfer analysis with appropriate fire imposed boundary conditions.

Object-Oriented Code Design

Figure 1 shows classes for the heat transfer and the fire module.
Features include:

- ❑ 2D and 3D transient nonlinear heat conduction can be modelled.
- ❑ Phase change can be taken into account for some materials at elevated temperature.
- ❑ Fire imposed boundary conditions can be specified.
- ❑ More functionality can be readily extended by providing subclasses.

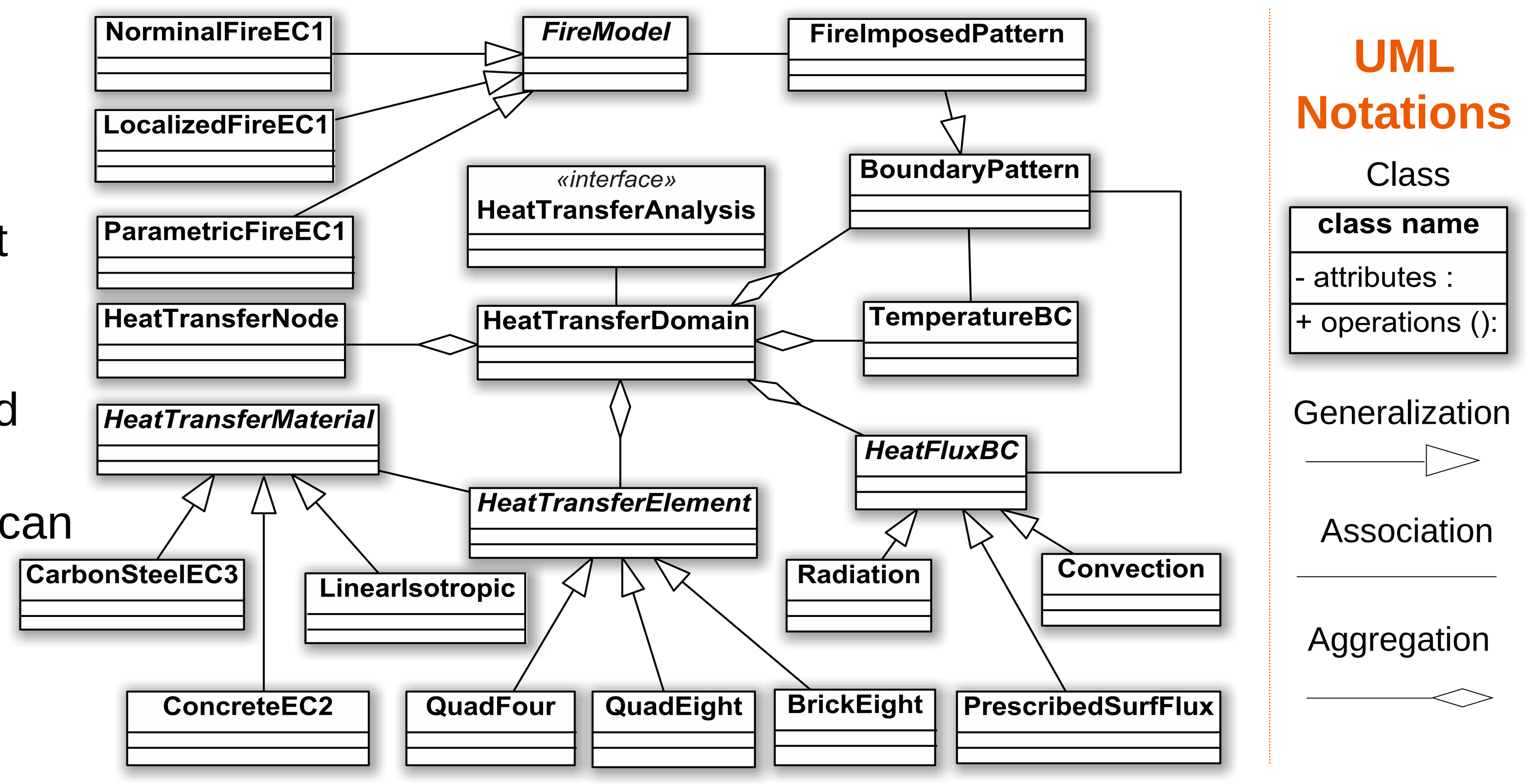

Fig.1 Class diagram for heat transfer module and fire module

Application: Concrete Slab Subjected to Non-uniform Heating

Figure 2 illustrates a concrete slab exposed to a localized fire as suggested by EC1. The height of compartment is 3.0 m with flame impinging the ceiling. Temperature at the ends of slab was fixed to 20 °C. Radiation and convection boundary conditions were considered on both top and bottom surfaces. Temperature dependent material properties as suggested by EC2 were used.

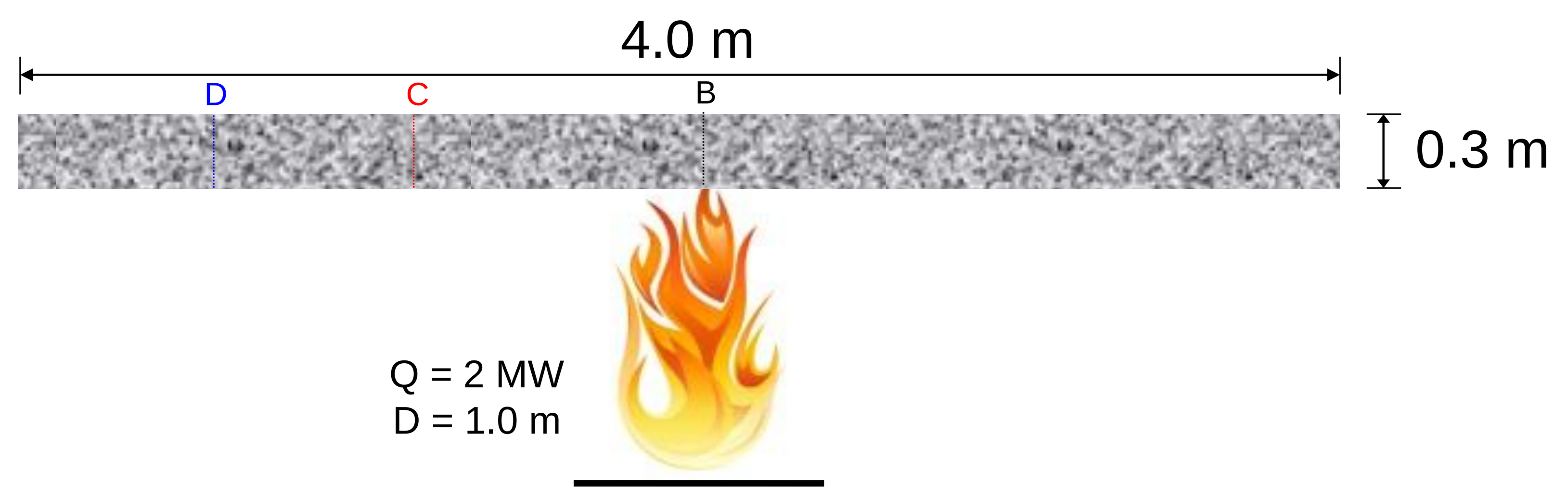

Fig.2 Non-uniformly heated concrete slab

Due to symmetry, only half of the slab was modelled with 576 four-noded elements. Figure 3 shows the temperature contours after 3hs of exposure. Temperature distribution at three locations across the thickness of the slab is given in Figure 4.

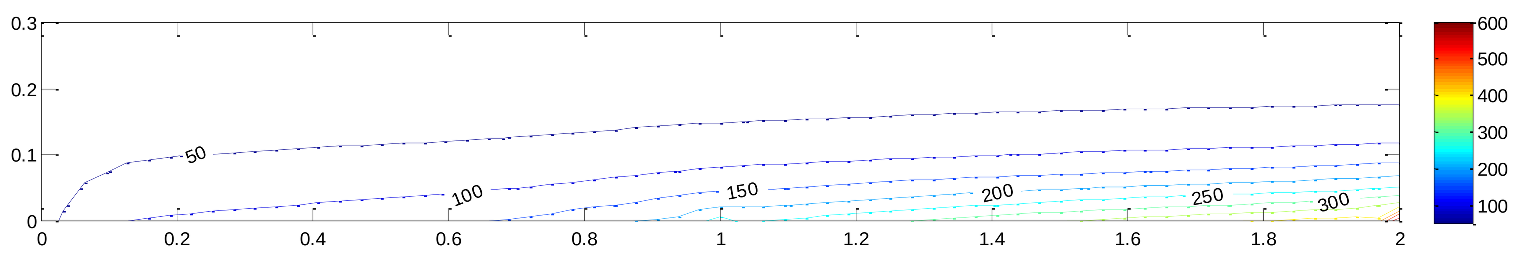

Fig.3 Temperature distribution within the slab (left-half)

As shown in Figure 5, the impact of moisture content was examined by using enthalpy method.

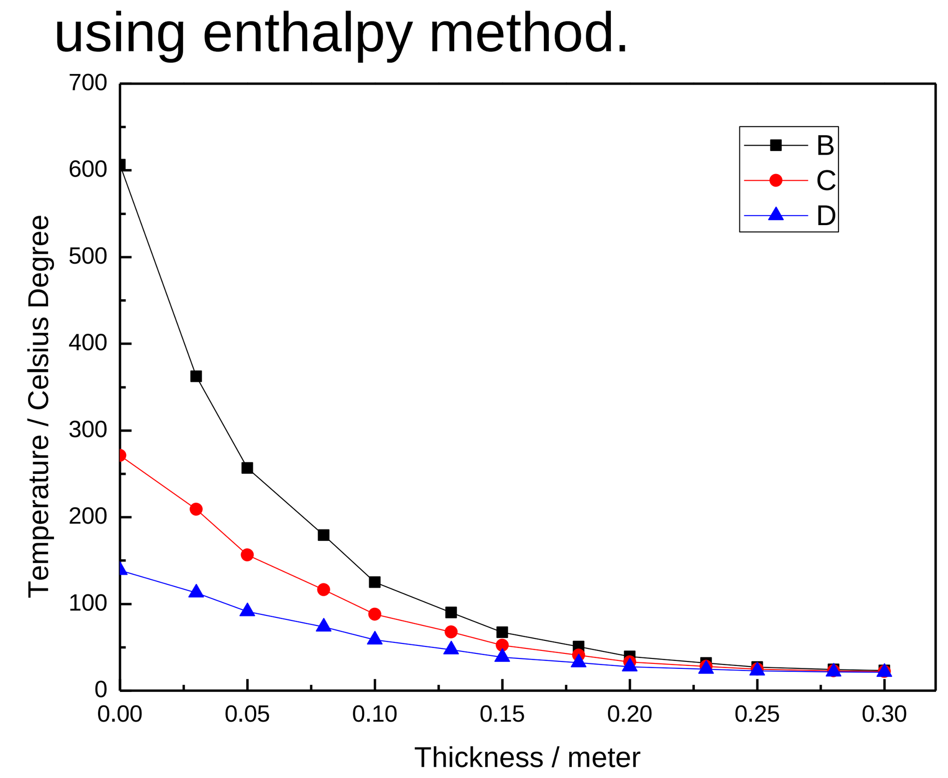

Fig.4 Temperature distribution through thickness

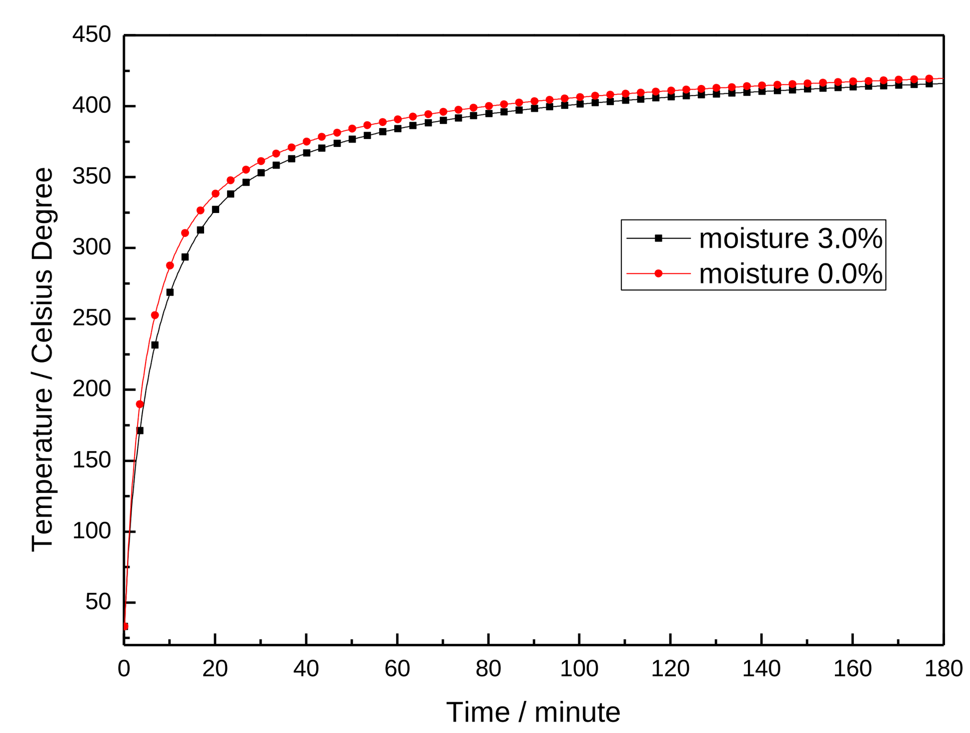

Fig.5 Temperature rise at different moisture levels

Results

❑An object-oriented finite element model has been developed which can predict temperature distribution in structures exposed to fire.

From the application:

❑Temperature distribution demonstrates a realistic pattern caused by the localized fire; temperature gradients at three locations across thickness of the slab show big differences.

❑Moisture content up to 3% has minor impact on the temperature rise.

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