Numerical Analysis of Structures in Fire Using OpenSees

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Introduction

OpenSees is an open-source object-oriented software developed at UC Berekeley. The OpenSees framework is being extended to deal with the frame structures in fire conditions by a team at the University of Edinburgh. The work involves adding new classes and modifying existing classes in the OpenSees.

Modification in OpenSees

➢New class <*Beam2dTemperatureLoad*> is added to store the temperature distribution along the section consisting of temperature and coordinate (Fig. 1)

➢New class <Steel01Temperature> is added to define the temperature dependent material properties according to Eurocode 3 (Fig. 2)

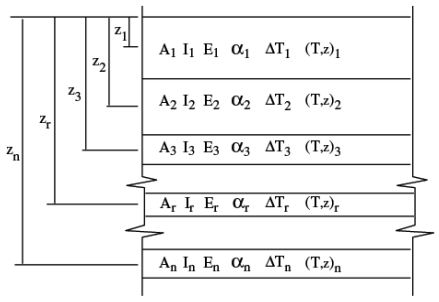


Fig.1 Temperature distribution through the fibre section

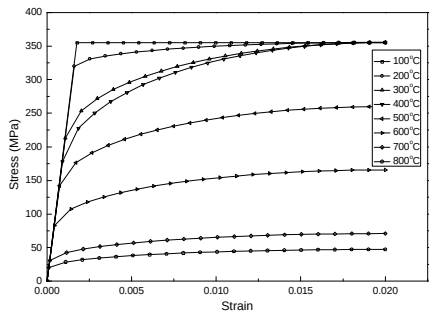


Fig.2 Temperature dependent material properties according to Eurocode3

➢Modified beam element class with updated interfaces to temperature data.

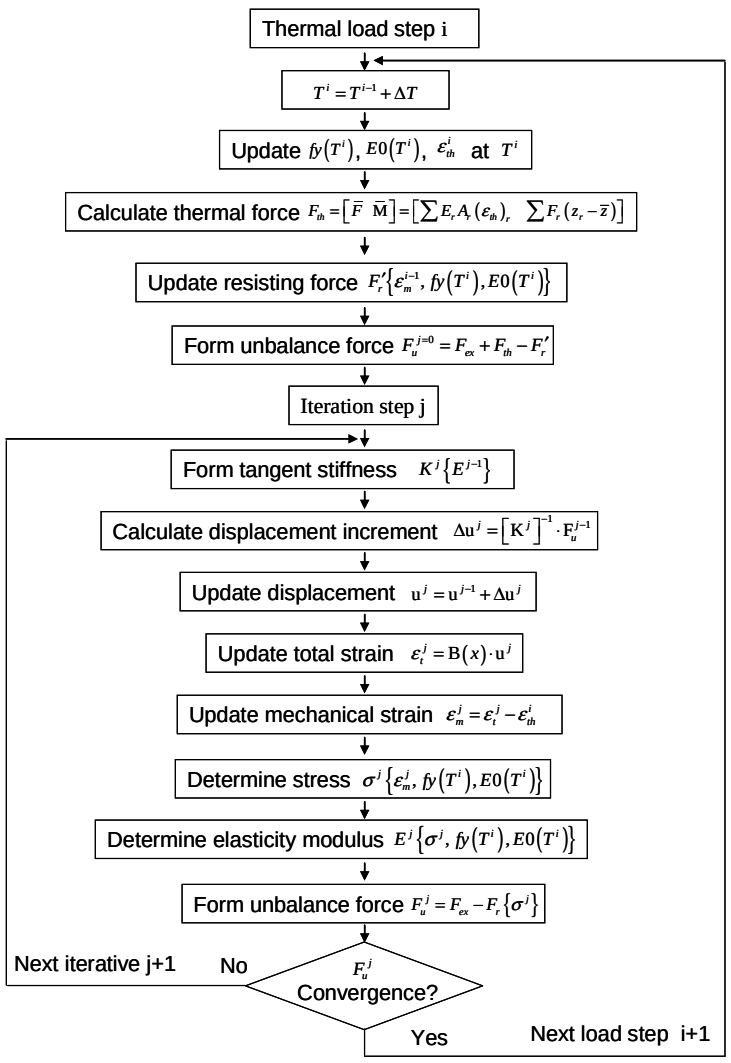


Fig.3 Flowchart of thermo-mechanical analysis in OpenSees

Validation

Two benchmark problems were solved to check the performance of the updated thermo-mechanical analysis in OpenSees. The results from OpenSees agreed well with those from ABAQUS and test (Fig. 5 and Fig. 6).

➢Case 1 Single beam

The beam was subjected to uniformly distributed load and thermal gradient linearly distributing through the height of section

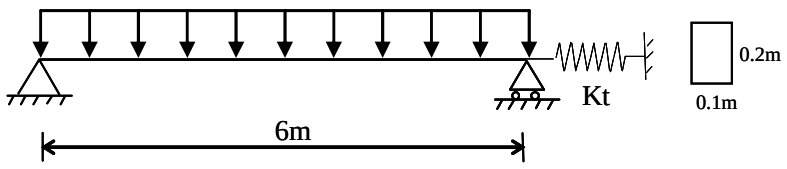
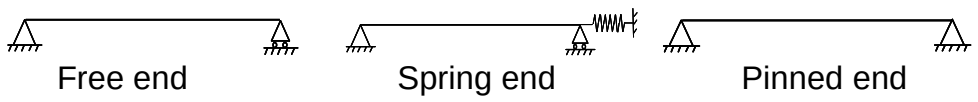


Fig.4 Schematic of the single beam with translational restraint

Three boundary conditions could be obtained by varying Kt



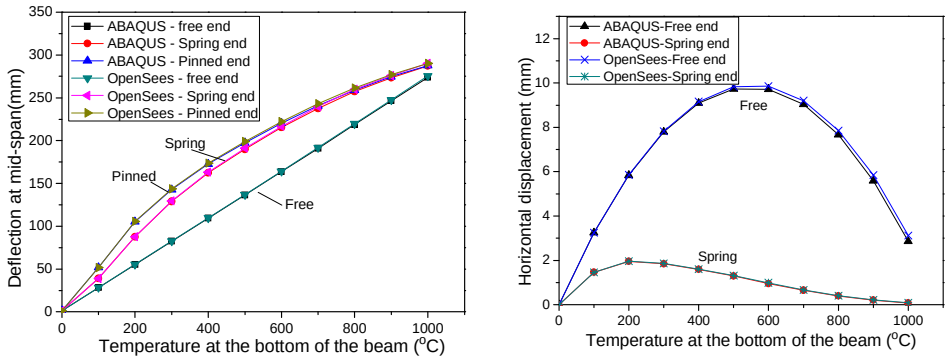
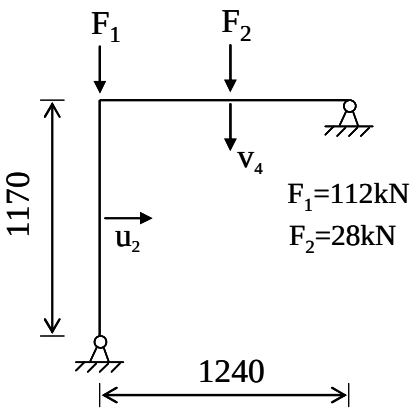


Fig.5 Comparison of displacement between OpenSees and ABAQUS

➢Case 2 Steel frame uniformly heated

Test results were from reference Rubert 1986.



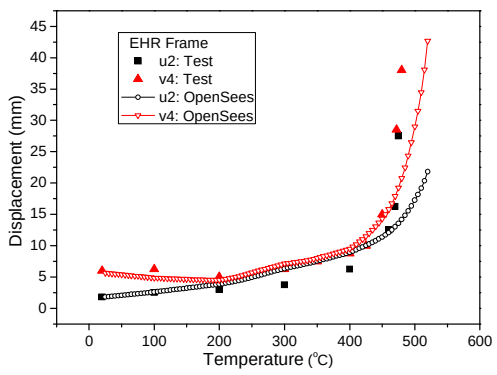


Fig.6 Comparison of displacement between OpenSees and test

Conclusion

➢The extended OpenSees framework (still under development) seems to be able to adequately deal with the thermo-mechanical analysis of structures under fire conditions.

➢Further work is being done to develop 3D beam element and shell element for thermo-mechanical analysis.

Reference: Rubert, A. “Structural steel and plane frame assemblies under fire action”, Fire Safety Journal, 10, 173-184, 1986