Behaviour of Frame Columns in Localised Fires

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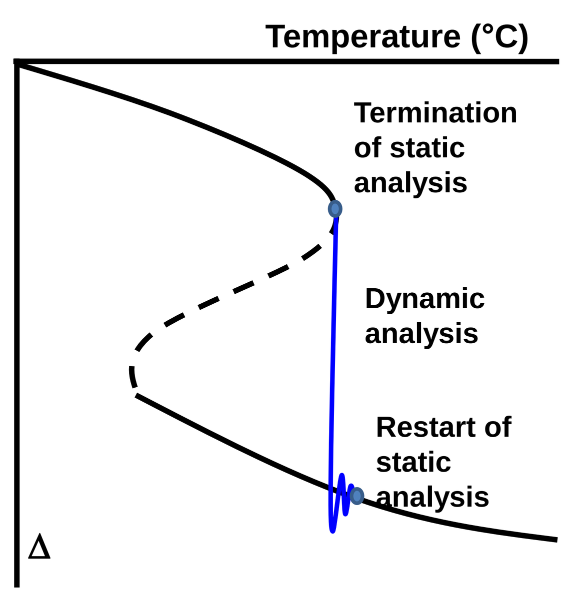
BACKGROUND

Column behaviour plays a key role in the robustness of framed structures in fire, and a key research topic in recent years has been the effect of axial restraint from superstructure on column buckling. However, most studies have concentrated on isolated columns with clearly defined boundary and loading conditions. It is well recognised that the behaviour of a column in a complete building differs from that of an isolated column, because of the effects of structural continuity. In a frame, both the critical temperature of a column and its capacity to re-stabilize after initial buckling are important aspects of preventing a progressive collapse mechanism from developing. A conventional static analysis is terminated when a local instability takes place. To evaluate frame behaviour after initial instability the analysis should be continued beyond this instability until total collapse or re-stabilisation happens

DYNAMIC PROCEDURE

The objective is to overcome the propensity of conventional static analysis to fail at the first singularity, and to enable the analysis to continue through its unstable stage.

A Static/Dynamic version of *Vulcan* has been developed, to trace the structural behaviour of single members or whole frames from initial static response, through local failure or instability, to stable post-buckling behaviour.



Explicit dynamic procedure:

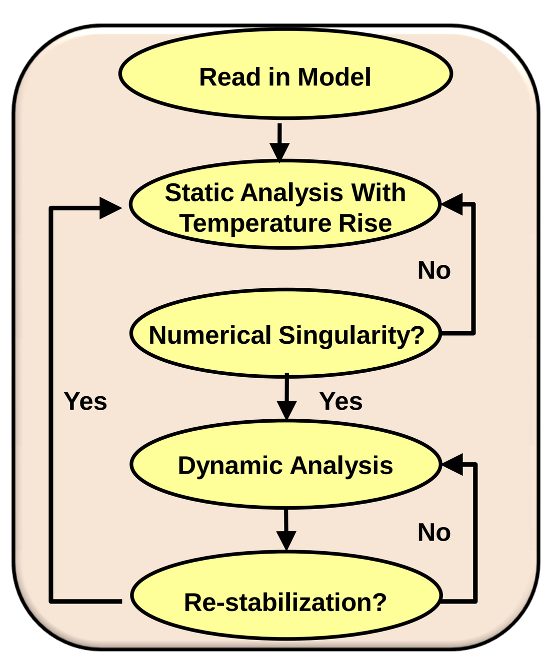
$$A = \ddot{U}_n = M_n^{-1}(P_n - I_n - D_n)$$

- A acceleration of DoF;
- M mass of DoF;
- P external force
- I internal force
- D damping

Static/Dynamic Procedure:

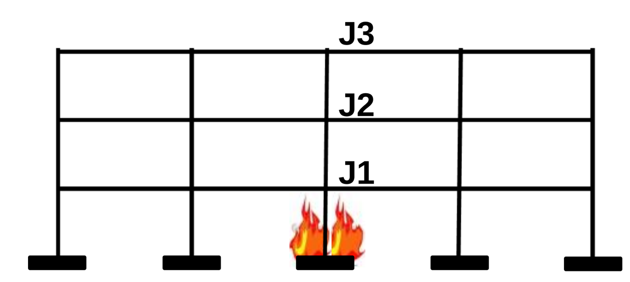
Static analysis can have advantages when the temperature is evolving and the structure is stable. Once local instability occurs, the dynamic procedure can be switched on automatically and the analysis can be carried on.

If stability of the structure is regained, the static analysis is triggered once again. The analysis will be kept going until final failure of the structure.

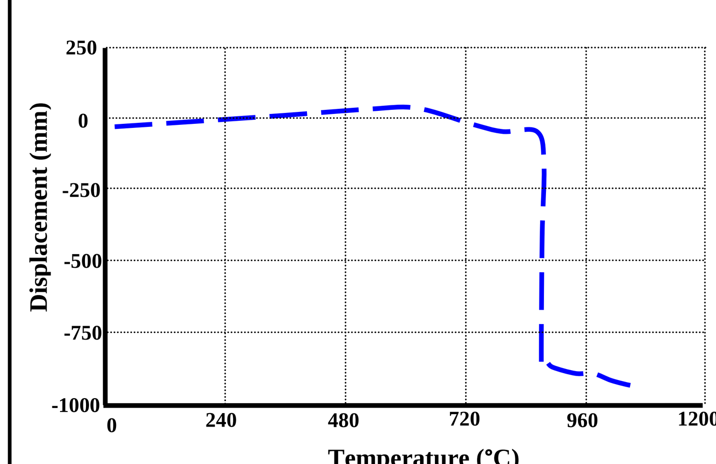


Flowchart of developed procedure

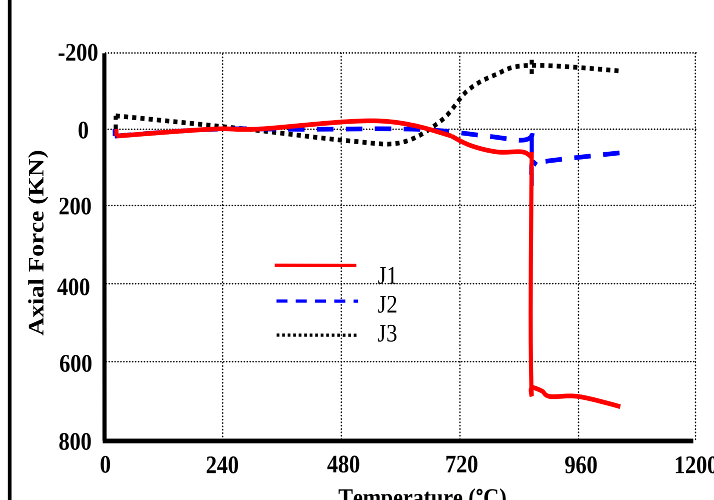
FULL FRAME ANALYSIS



A planar frame has been tested under localised fire conditions. The central column at ground floor level is assumed to be heated by an IS0834 fire curve.

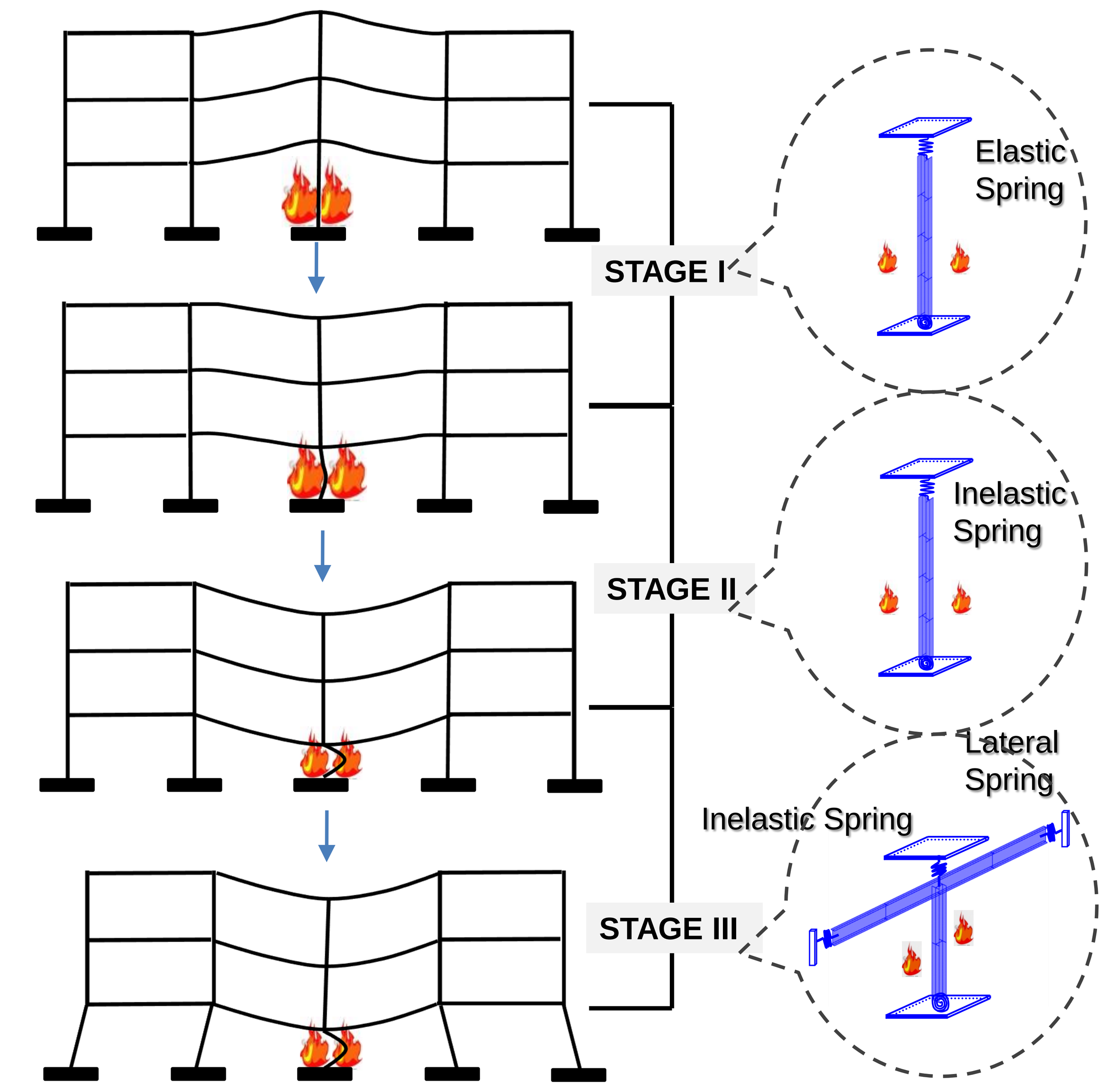


Displacement of top of heated column



Axial Force in connections

SIMPLIFIED MODEL

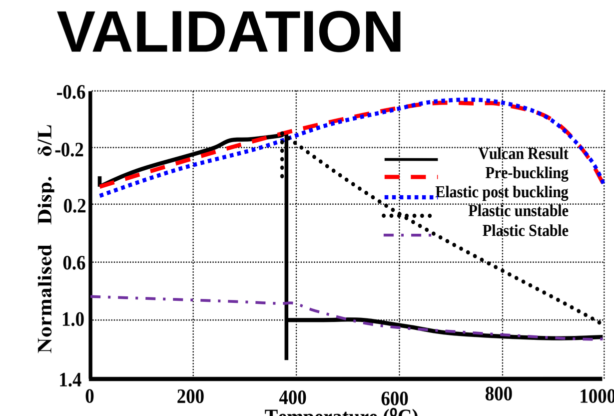


Stage I: Thermal expansion: Compressive force increasing-Column buckling;

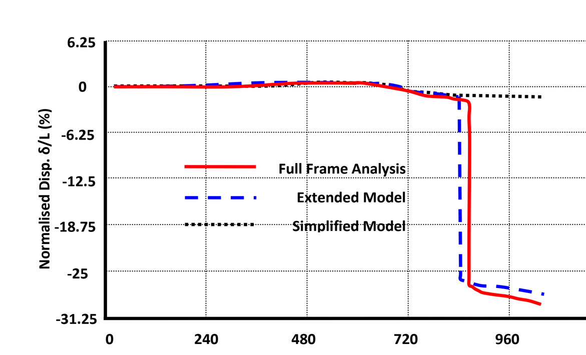
Stage II: Larger displacement: Bending moment at ends of beams increasing-- beam yielding;

Stage III: Catenary action developing: Column pull-in re-stabilization or collapse.

VALIDATION



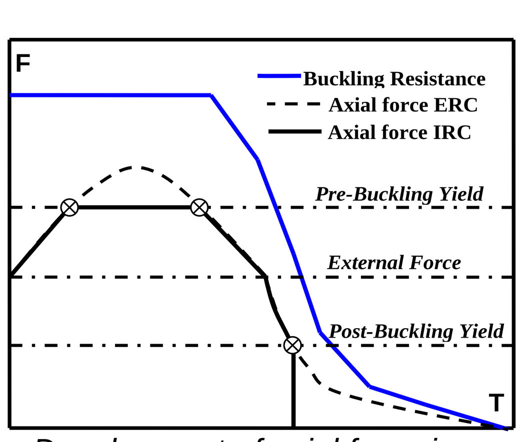
Comparison between simplified model and Spreadsheet calculation



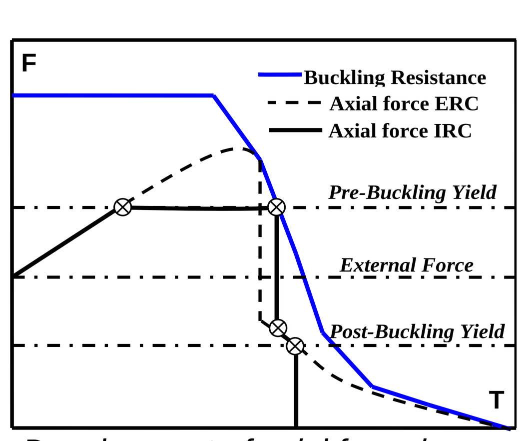
Comparison between simplified model and Full frame analysis

PRELIMINARY PARAMETRIC STUDY

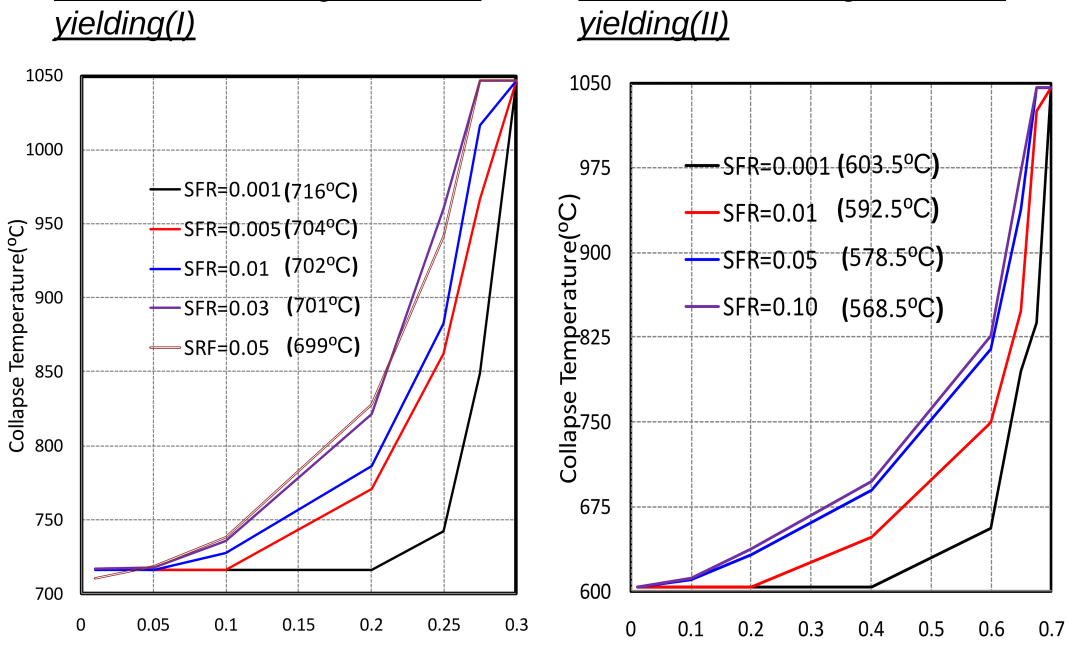
AXIAL RESTRAINT OF COLUMN



Development of axial force in column considering the beam yielding(I)



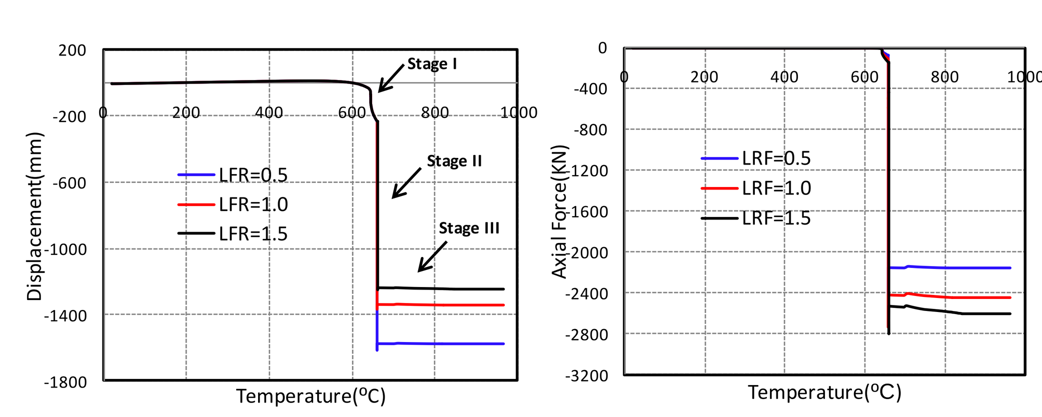
Development of axial force in column considering the beam yielding(II)



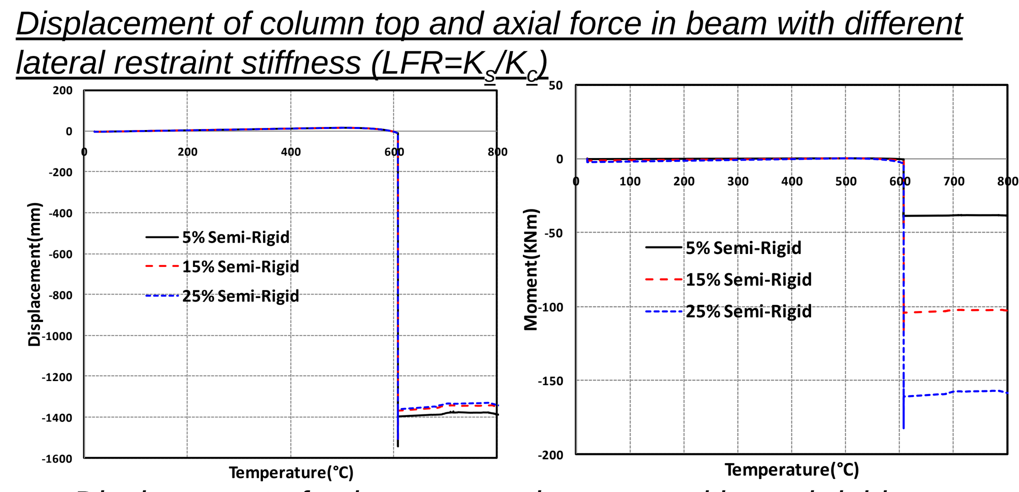
Collapse temperatures of column(Slenderness 60): left: load ratio 0.3; right: load ratio 0.7

As the strength of restraints increases, the collapse temperatures of columns increase and vary with the different stiffness ratio of restraints. With the same strength of restraints, the higher stiffness achieves higher collapse temperatures.

LATERAL RESTRAINT AND CONNECTION RIGIDITY



Displacement of column top and axial force in beam with different lateral restraint stiffness (LFR=K_l/K_c)



Displacement of column top and moment with semi-rigid connections

After the collapse of column, lateral restraint becomes the most important factor to determine whether (or when) re-stabilisation occurs. Stiffer lateral stiffness provides a lower displacement at re-stabilisation, but a smaller axial force in the beams. Different connection rotational stiffness do not change the failure temperature or re-stabilisation displacements significantly. Connections are vulnerable, and may fracture, at this stage.

CONCLUSION

A simplified model has been proposed to study the column behaviour in framed structures based on the collapse mechanism of frame under localised fire;

The collapse temperature of column is closely related to stiffness and strength of axial restraints. The column force development has been studied and the influence of stiffness and strength of axial restraint of column has been investigated;

The stiffness of lateral restraint has influence on the re-stabilization and the axial forces developing in beams, and the rigidity of connection has impact on the moment in connection rather than the re-stabilized position.

FURTHER WORK

- This method can be adopted to propose different simplified models for different frames under various fire scenarios;
- This model is based on 2D frame containing beams, columns and connections. It is also feasible to include slabs into simplified models to investigate behaviour of composite frame under fire scenarios.
- The Static/Dynamic procedure will be combined with the component-based model to trace the progressive failure of connections in fire scenarios.