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# An approximation method for critical temperatures of steel members and horizontal displacements of columns

## Introduction

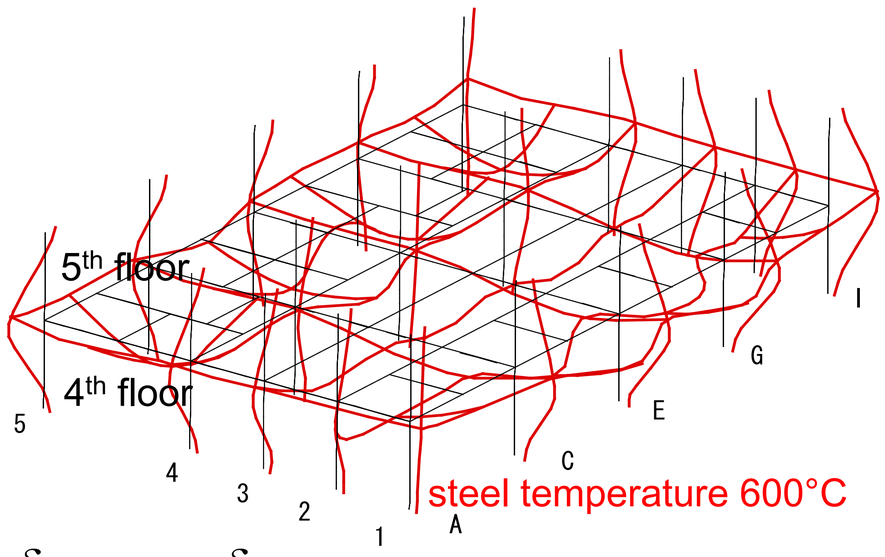
It is important in structural fire safety design not only to ensure the load-bearing capacity of structures, but also to prevent the fire spreading, especially to upstairs compartments. For the performance of exterior elements, the horizontal displacement of the tops of the outer columns is an important aspect.

The purpose is to discuss a manual approximation method for both the horizontal displacement at the columns and the critical temperatures of steel members in steel structures.

## FE analysis of a frame

This is a FE analysis using Bernoulli-Euler beam elements, which is capable of modelling the three-dimensional behaviour of frames in fire, and includes geometrical and material non-linearities.

The structure is assumed to be an office building with 8 storeys, composed of Class 1 or Class 2 steel members. Fire is assumed to develop over the whole 4th floor. A uniform temperature is applied to the steel members exposed to fire.




## Horizontal displacements of columns

Horizontal displacements at the top of the columns can be calculated by *Eq.* (3) based on elastic thermal stress theory.

$$\delta_2 = C_2\left(\delta_1 + \varepsilon_{b2}^{th}\cdot\ell_{b2}\right),\quad \delta_1 = \varepsilon_{b1}^{th}\frac{k_{b1}\cdot\ell_{b1} - C_2\cdot k_{c2}\cdot\ell_{b2}}{k_{b1}+k_{c1}+C_2\cdot k_{c2}} \qquad (3)$$

$$C_i = \frac{k_{bi}}{k_{bi}+k_{ci}},\quad k_{ci} = \frac{24E_{ci}I_{ci}}{\ell_c^{\,3}},\quad k_{bi} = \frac{E_{bi}A_{bi}}{\ell_{bi}}$$

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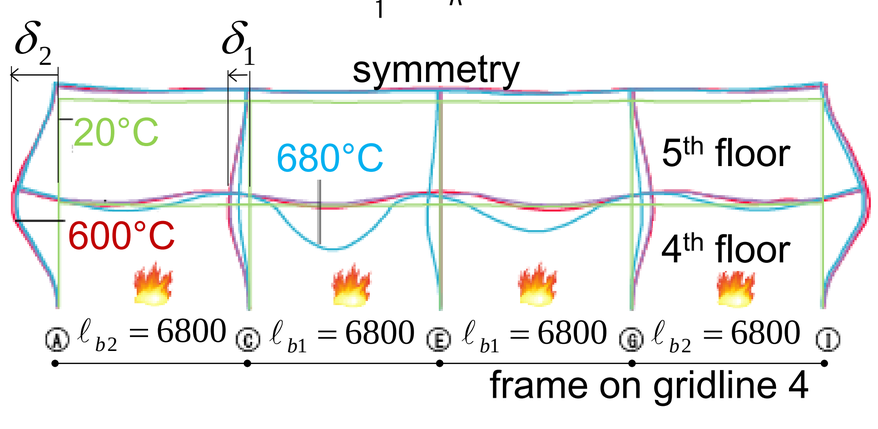
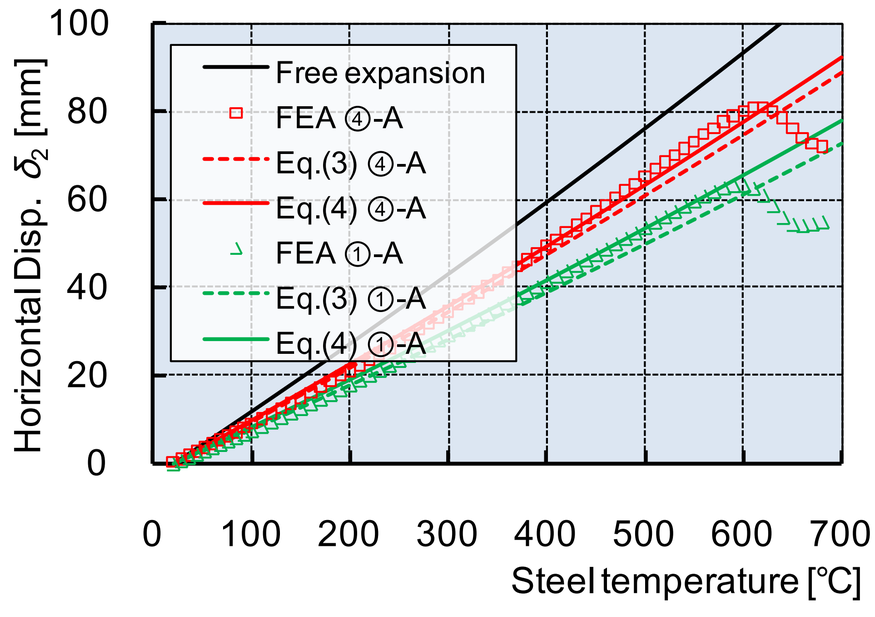
$$\delta_2 = C_2\left(\delta_1 + \varepsilon_{b2}^{th}\cdot\ell_{b2}\right),\quad \delta_1 = \frac{k_{b1}}{k_{b1}+k_{c1}+k_{c2}}\varepsilon_{b1}^{th}\cdot\ell_{b1} \qquad (4)$$

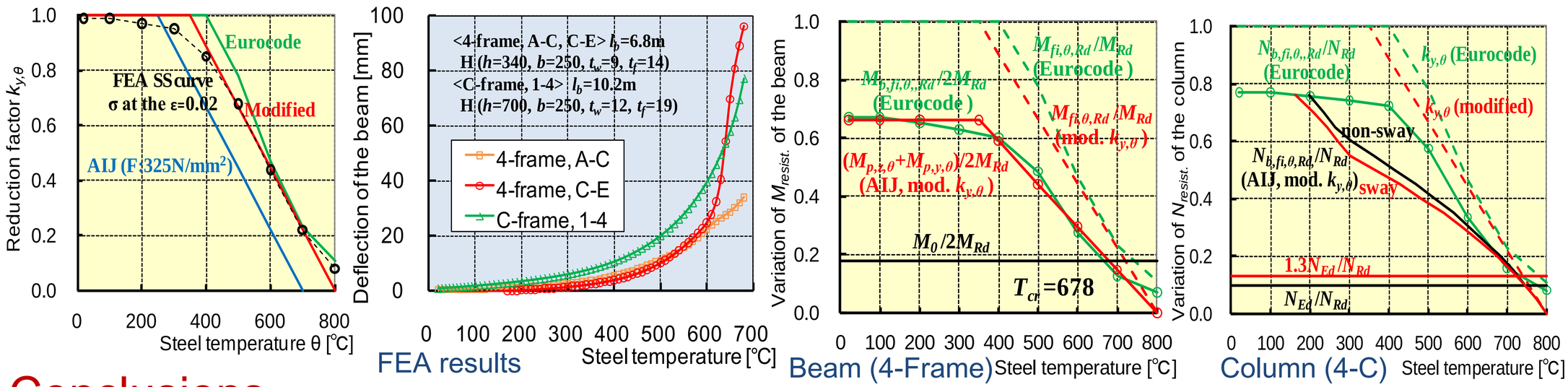
$$\delta_n = C_n\left(\sum_{i=1}^{n-1}\delta_i + \varepsilon_{bn}^{th}\cdot\ell_{bn}\right),\quad \delta_k = \frac{k_{bk}}{k_{bk}+\sum_{i=k}^{n}k_{ci}}\varepsilon_{bk}^{th}\cdot\ell_{bk} \qquad (5)$$




## Critical temperatures

Figures show the comparison between the computational result, AIJ values and Eurocode 3 values for the critical temperature.




## Conclusions

In this case study, the manual approximation result from *Eq.* (4) for the horizontal displacements of the columns agrees well with the FE analysis results. The design resistance of the beam according to AIJ is similar to the design buckling resistance moment of Eurocode 3, and both approximately agree with FE analysis results.