NUMERICAL MODELING OF INTERNAL VOIDS IN FIRE EXPOSED STRUCTURES

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The study of steel structures at elevated temperatures needs the characterisation of the thermal action and the material thermal properties variation with temperature as well as the thermal conduction problem solution in a domain with well know boundary conditions.

Structures may have internal voids (figure 1) filled with air (hollow columns, profile sections thermally insulated, steel pipes,…). In the presence of internal voids, the internal air temperature will be determined with some simplified formulas deduced from heat transfer equations [1,2].

A finite element code has been developed for the three and two-dimensional thermal analysis, as well as an interface element for boundary conditions modelling [3-5]. The transient temperature evolution in structures submitted to fire action and the internal temperature in the voids will be calculated.

Heat conduction is assumed for heat transfer (equation 1).

A finite element formulation for heat conduction is presented, giving particular attention to the non-linear material problem.

The equation 2 makes it possible for the temperature determination inside the void.

The hypothesis used in this method is that the specific heat of the air is so small that it can be neglected [1]. Then, at any time, the fictitious temperature inside void will be considered uniform, determined by the heat convective and radiactive fluxes received from all the elements surrounding that region.

Conclusions about the importance of this modelling will be discussed.

The results of a two-dimensional case will be compared with the numerical code Safir[1]. A three dimensional internal void formulation has been developed, and the same case study has been compared.

$$\frac{\partial}{\partial x}(\lambda\frac{\partial\theta}{\partial x})+\frac{\partial}{\partial y}(\lambda\frac{\partial\theta}{\partial y})+\frac{\partial}{\partial z}(\lambda\frac{\partial\theta}{\partial z})+\dot{Q}=\rho c_p\frac{\partial\theta}{\partial t} \qquad (1)$$

$$\theta_v=\frac{\sum_{i=1}^{N_{FR}}\theta_{N_i}L_{N_i}}{\sum_{i=1}^{N_{FR}}L_{E_i}h_{E_i}}\equiv\frac{\sum_{i=1}^{N_{FR}}\theta_{N_i}L_{N_i}}{\sum_{i=1}^{N_{FR}}L_{N_i}}\ [\mathrm{K}] \qquad (2)$$

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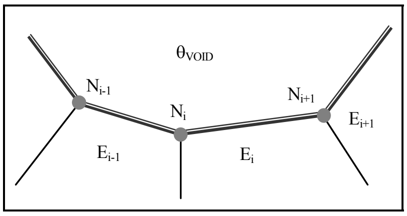

Figure 1 - Scheme of an internal void.

A steel hot-rolled profile with insulated boards will be tested. Two different situations have been considered. The first used the internal void theory and the second has considered this region as insulated. A quarter of the model has been considered due to geometry and load symmetry, (figure 2). In the figure 3 a three dimensional modelling has been presented for the same case. The results are obtained with finite element program developed, after 20 minutes of fire exposure.

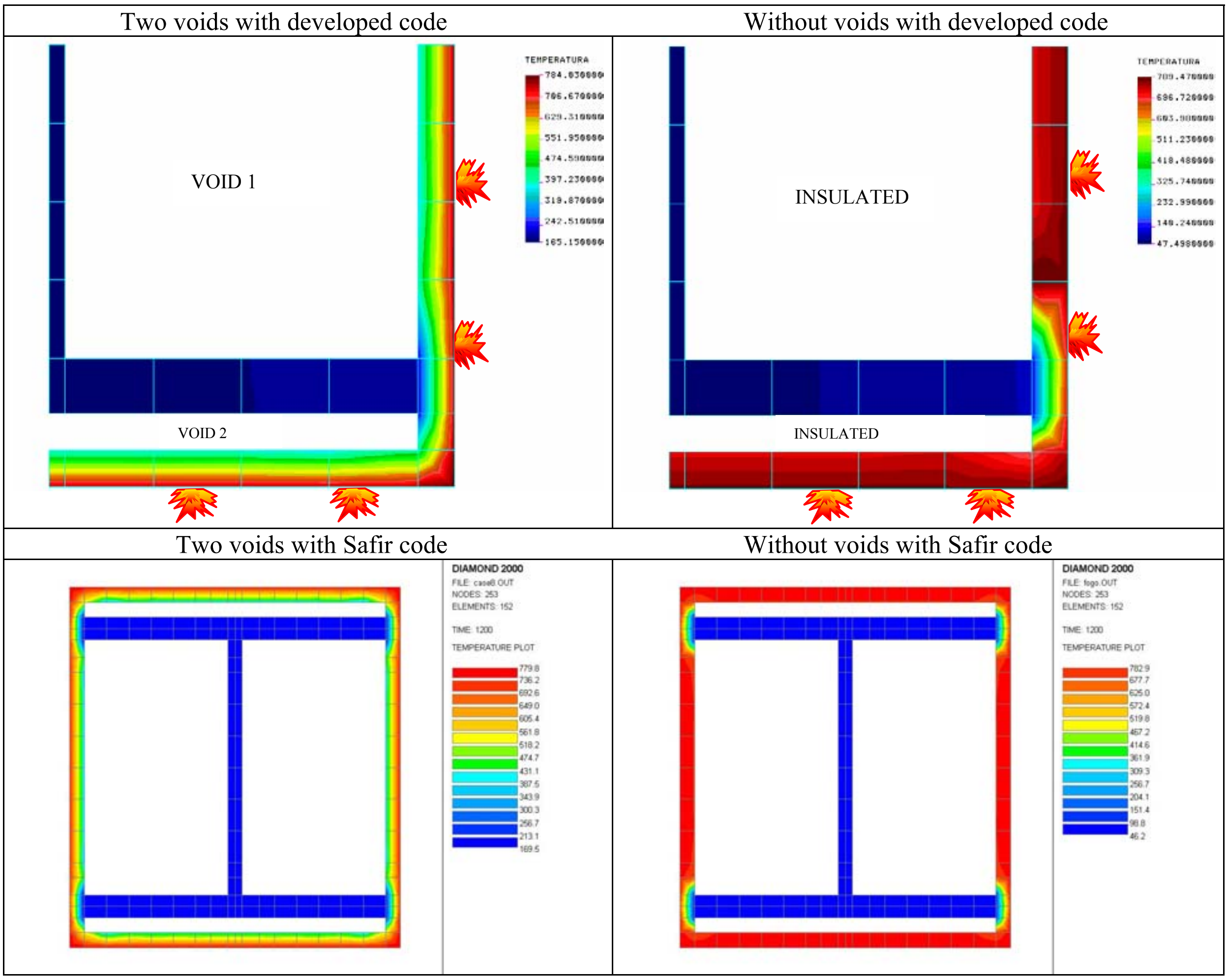

Figure 2 – Steel profile exposed to fire at four sides: two-dimensional problem.

Two voids with developed code	Without voids with developed code

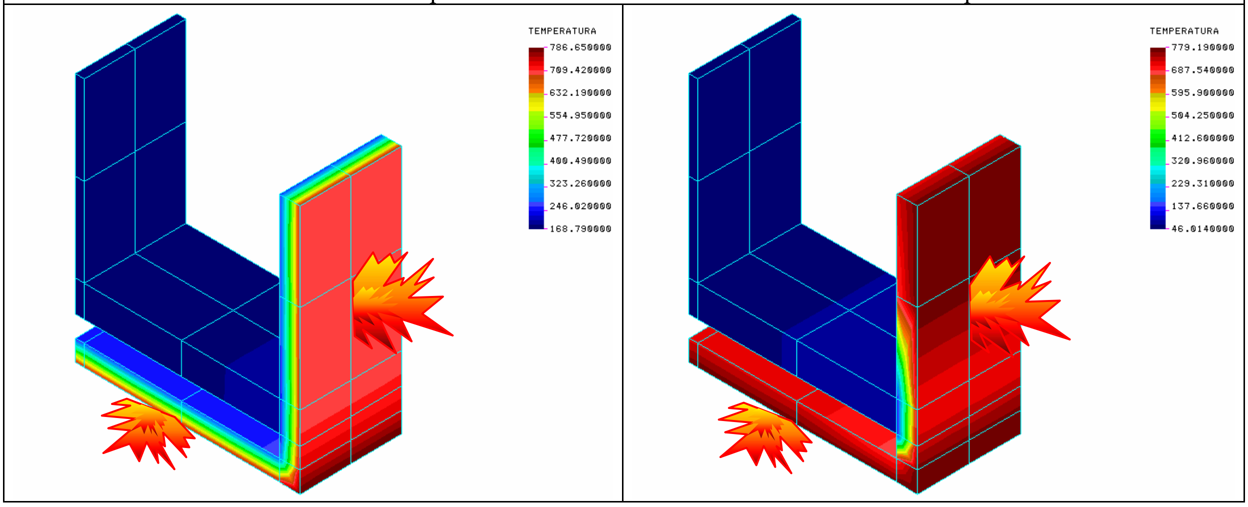

Figure 3 – Steel profile exposed to fire at four sides: three-dimensional problem.

A computational program based on the finite element method to study thermal model behaviour of steel structures exposed to high temperatures has been developed. The results obtained with the developed program have been compared with the results obtained by Safir for the two dimensional case. The three dimensional results have been obtained with the same formula implemented for higher geometric order. The modelling of internal voids is of a greater importance during the temperature evolution in a solid component in case of fire. The computing effort on meshing the internal void will be greater than the simplified formula used to model the internal void, with no advantage in temperature calculation. With this information, the designer can select the material and the profile to have an appropriate safety level or choose a thermal protection material if necessary.

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