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# PARTIALLY ENCASED SECTION: STRENGTH AND STIFFNESS UNDER FIRE CONDITIONS

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## 1. INTRODUCTION

Fire resistance of partially encased sections (HEB and IPE) depends on the temperature evolution during fire exposure. Eurocode 4, part 1.2 [1], proposes the assessment of the cross section using the method of the four components (flanges, web, reinforcement and concrete) to determine the resistance and stiffness under fire. This study aims to assess the balanced summation model of Eurocode (informative annex G) with respect to the plastic resistance to axial compression and the effective flexural stiffness of the cross section with respect to the weak axis. New formulae will be proposed to evaluate fire resistance, based on new simple formulas to determine the flange average temperature, the residual height and average temperature of the web, the residual cross section and average temperature of concrete, the reduced stiffness and strength of reinforcement. The advance calculation method was used to validate new and safe formulae, based on the analysis of the cross section totally engulfed in fire (fire in four sides).

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## 2. MATERIAL AND METHODS

A new simple calculation method is proposed alternatively to the existing formulae of the annex G of Eurocode EN1994-1-2 [1], based on the thermal results of an advance calculation method (ANSYS). Current empirical coefficients leads to unsafe strength and stiffness of partially encased sections for certain fire resistance periods. This method of analysis considers the geometry and parameters represented in figure 1. A set of 24 partially encased section (section factors) were used to validate the results and grouped into two section series (HEB and IPE). To determine the average temperature and the reduction of strength and stiffness in flanges and reinforcement, the criterion of the arithmetic mean value was used over the corresponding nodes. To determine the residual resistant section of the concrete, the criterion of 500 °C isothermal was considered [5]. To determine the reduction of the web height, the criterion of 400 °C isothermal was used [6].

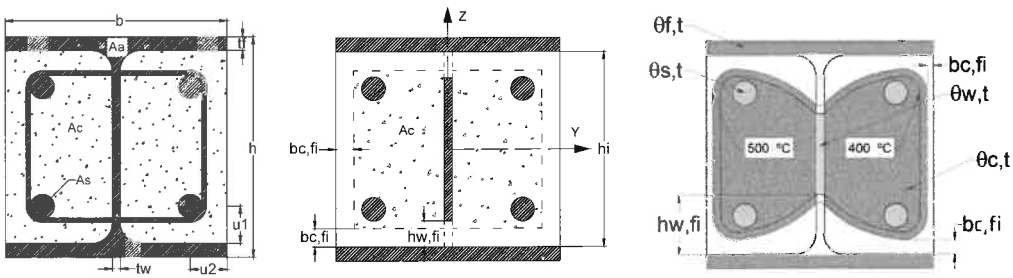


Figure 1: Partially encased section with concrete: a) section parameters; b) residual cross section in fire design; c) average temperature of each component.

## 3. RESULTS

Based on the numerical temperature field determined for each standard fire rating (R30, 60, 90, 120), each criteria was applied to the corresponding component to compare the results of different formulae. Figure 2 presents the average flange temperature for different sections factors using: the actual linear approximation of Eurocode, the numerical results and the new bilinear approximation. Figure 3 presents the results of the web height reduction for each standard fire rating. New simple formulae is proposed, using the parametric approximation based on the values of section factors and fire rating periods. Figure 4 demonstrates that the external layer of concrete to be neglected is not uniform in both directions for HEB sections.

Similar results were determined to IPE sections. New simple quadratic formulas are proposed to each cross section type, direction of reduction layer and fire rating. Figure 5 presents the results for a new proposal, based on parametric expressions, using the section factor, fire rating and concrete cover thickness as parameters.

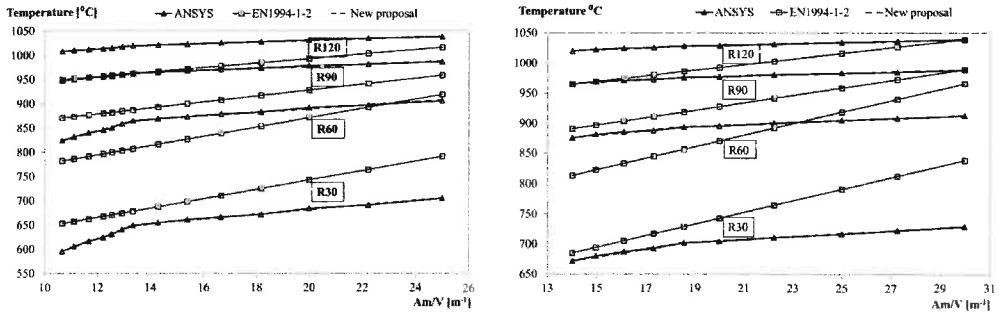


Figure 2 – Average flange temperature. Left (HEB), right (IPE).

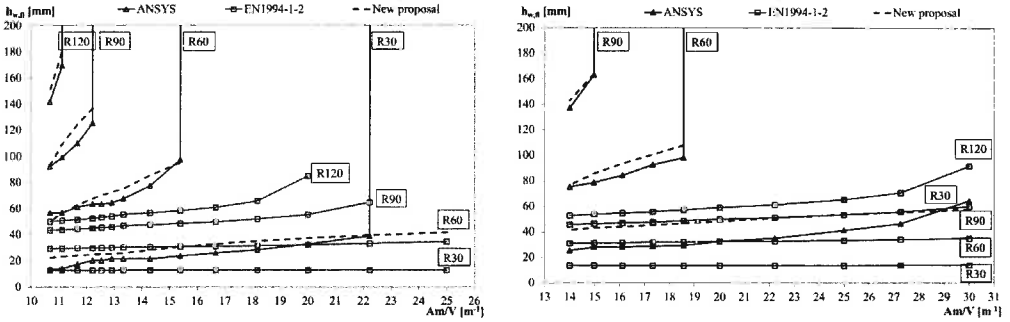


Figure 3 – Web height reduction. Left (HEB), right (IPE).

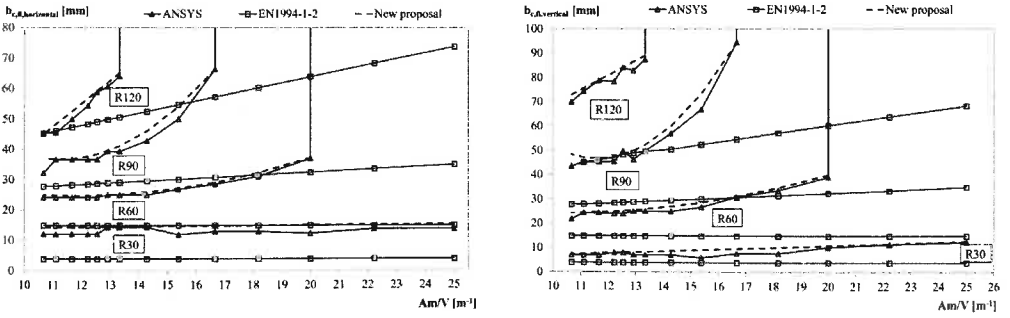


Figure 4- Reduction of the concrete cross section in HEB. Left (horizontal), right (vertical).

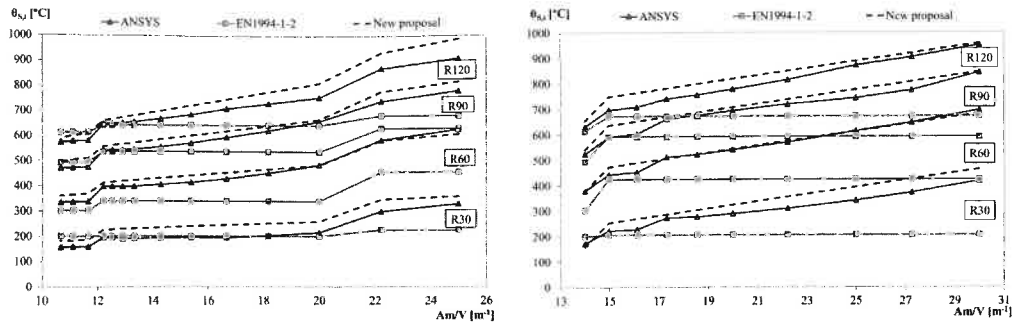


Figure 5 – Average temperature of reinforcement. Left (HEB), right (IPE).

## 4. CONCLUSIONS

The current simple calculation method of Eurocode (EN1994-1-2) highlights unsafe results and conservative results in comparison to the numerical results. The new proposals were define with a certain level of safety with respect to numerical results.

## 5. REFERENCES

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[6] Cajot louis-Guy, Gallois Louis, Debruyckere Rik, Franssen Jean-Marc, Simplified design method for slim floor beams exposed to fire, Nordic Steel Construction Conference 2012, Oslo, Norway, 5-7 September 2012.