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Analytical formulae for the elastic-plastic analysis of I-shaped steel cross-sections bent over their weak axis

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ABSTRACT

The analysis of steel cross-sections in the elastic domain is nowadays very simple, thanks to the analytical expressions given by the Theory of Elasticity. On the contrary, the evaluation of the cross-sections internal loads and stiffness terms in the elastic-plastic domain is very often complicated, and it is usually carried on by means of numerical methods.

These methods require a division of the cross-section into a mesh of strips or sub-areas. The internal loads and stiffness matrix are obtained by numerical integration of each sub-area average stress and stiffness over the whole cross-section area. This method is time consuming and, when used on the elastic-plastic of steel structures, it requires stocking of a large number of data during the successive iterations of the non-linear process.

This work presents the relationships of an analytical model for the elastic-plastic study of I-shaped steel cross sections, bent over their weak axis. The basic variables are the cross-section global deformations, from which it is possible to evaluate the internal loads and the cross-section stiffness terms, by means of simple mathematical expressions. These expressions cover all the possible combinations of deformation states in the elastic-plastic domain: yielding (in tension or compression) of one or two tips of the flanges, partial yielding of the section web, and total yielding of the section.

The model allows the yielding spreading across the sections to be taken into account as well as the effects of the strain hardening on their resistance capacity in the elastic-plastic domain. The bending - axial deformation interaction effects are considered and the steel behaviour may be limited by the deformation capacity of the material or, in other words, by its ductility. This characteristic allows to control the cross-section ultimate limit states associated to this material property.

This model represents an efficient, simple and accurate alternative to the above mentioned methods, based on the numerical integration of stresses and stiffness over the cross-section, on the elastic-plastic analysis of steel I shaped members bent over their weak axis. A different formulation, for the elastic-plastic analysis of these members bent over their strong axis, has already been published by the authors.