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Analytical model for the elastic-plastic analysis of deformations of isostatic I-shaped beams in simple bending

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ABSTRACT

The analysis of deformations of isostatic beams in the elastic domain is nowadays very simple, thanks to the analytical expressions given by the Theory of Elasticity. On the other hand, it is generally accepted that this type of structural elements may be submitted to plastic deformations, as long as their safety is not affected by buckling phenomena. This acceptance, for some particular situations, allows a less conservative and, therefore, cheaper design of this type of structural elements.

One difficulty that arises in the elastic-plastic analysis of these beams is the evaluation of their deformations, which may limit their safety to the serviceability limit states. Since the constitutive relationships are not linear over the whole yielded cross-sections, the expressions from the Theory of Elasticity are no longer valid.

A solution for this problem lies on the use of numerical methods. However, computer programs that allow to simulate the progressive evolution of yielding across the beam sections and along its length, and take in account the corresponding effects over its loss of stiffness and, therefore, over its deformations, are not usually available for most of designers. Furthermore, the use of these programs is frequently tedious, due to the large amount of time required to prepare the calculation data and treat the corresponding results.

This work presents an analytical model for the study of the deformations of isostatic I-shaped beams in simple bending. The analytical formulations from this model allow the evaluation of the transversal displacement and rotation of any cross-section of the beam, in the elastic or elastic-plastic domain. They also permit to follow the evolution of the limits of the yielded areas, across the beam sections and along its length, as a function of the applied loads.

This analytical model is based on analytical expressions, developed by the authors, for the elastic-plastic analysis of steel I-shaped cross-sections.

The results given by these formulations have been compared to those obtained by means of an elastic-plastic numerical analysis. A good agreement was found between these two types of results, since their relative differences was usually smaller than 1%.