Ultimate and Nominal Strength Capacity Evaluation of Composite Sections with Arbitrary Shapes at Elevated Temperatures

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Abstract

This paper presents a new computational method for ultimate and nominal strength analysis of composite steel-concrete cross-sections with arbitrary shape subjected to elevated temperatures. A strain-driven algorithm, coupled with a bracketing approach by means of combining Bisection and Newton method has been developed. The solution of the nonlinear equilibrium equations is controlled at the strains level enforcing in the same time the elasto-plastic equilibrium for a prescribed axial force and bending-moments ratio. The ultimate (maximum) strength capacity is formulated as a problem of unconstrained mathematical optimization whereas the proposed approach evaluates the nominal strength capacity by means of using a strain-driven algorithm coupled with a bracketing approach. Since the Jacobian's of the resulted nonlinear system of equations is non-singular global convergence may be achieved and the convergence stability is not sensitive to the initial/starting values of the iterative process and to the strain softening exhibited by the concrete in compression. The developed procedure has been used to predict the bending moment capacity diagrams of a composite cross-section with arbitrary shape. The comparisons made prove the effectiveness and the reliability of the proposed method of analysis and also for the cases analyzed here significant higher ultimate strength than nominal strength capacities of cross-section has been identified.

Keywords: Fire analysis; composite steel-concrete; strength capacity; bi-axial bending.

1 Introduction

The ultimate strength capacity of a cross-section subjected to bi-axial bending moments and axial force is defined as maximum values of the bending moments under constant axial force associated to a specific deformed state when further increase in deformation results in reduced response. On the other hand, the nominal strength capacity of the cross-section is reached when in the most compressed concrete fibre or tensioned steel the predefined nominal ultimate values of the strains are attained. In general, conventional (nominal) strength capacity occurs prior to maximum (ultimate) strength capacity when considering material standard laws without strain-softening branches. However it is important to note that when strain-softening effect exhibited either by the concrete in compression or the steel susceptible to local buckling the ultimate strength capacity of the composite cross-sections occurs prior to conventional failure and such a behavior is influenced by the prescribed (nominal) ultimate strain value. During the last decades several attempts may be found in the literature for the *nominal (conventional) strength analysis* of various concrete and composite steel–concrete sections under uniaxial and biaxial moments and axial loads subjected to elevated temperatures [1, 2]. These approaches are based upon the solution of the nonlinear equilibrium equations consisting of an iterative sequence of linear predictions and nonlinear corrections to obtain either the strain distribution or the location and inclination of the neutral axis, which determines the ultimate load, where one or two components of the section