11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

Direct evaluation of the load-carrying capacity of steel-reinforced concrete beams by limit analysis

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Key Words: *Fe-based Limit Analysis, Reinforced Concrete, Failure Mode, Peak Load.*

Steel reinforced concrete (RC) structural elements can exhibit, when loaded up to failure, considerable ductility injected by the presence of reinforcement bars (re-bars). The typical failure mode of properly designed so-called under-reinforced elements subjected to bending, in fact, initiates by yielding of the steel re-bars followed, with the load increasing, by crushing of concrete in compression zone. This is, actually, a failure mode regarded as ductile and normally assured by a reinforcement ratio significantly below the balanced ratio. Obviously, in these cases steel re-bars play a significant role in determining the post-elastic behaviour of the RC element as a whole.

In this contribution, a numerical methodology, founded on the limit analysis theory and already successfully applied by the authors to predict the limit state solution of RC elements (see [1], [2]), is rephrased to take into account both the plastic behaviour of concrete as well as that of the yielded re-bars. To this aim, the numerical methodology is here implemented within a *FE-layered formulation*, where concrete is governed by the *Menétrey–Willam-type yield criterion* and steel bars are handled by a *von Mises-type criterion*, so enabling the prediction of possible steel bars yielding at incipient collapse. In order to validate the effectiveness and reliability of the promoted approach, a comparison is made between numerical predictions and experimental findings on large-scale beams tested in laboratory [3].

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