A MIXTURE CONTINUUM APPROACH FOR THREE-DIMENSIONAL ANALYSIS OF REINFORCED CONCRETE MEMBERS USING EMBEDDED CRACK FINITE ELEMENTS

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Key Words: *finite elements, fracture mechanics, strong discontinuities, mixture theory, embedded cracks.*

ABSTRACT

As well known, modeling reinforced concrete behavior requires an approach able to describe the formation and propagation of multiple cracks in non-homogenous solids composed of concrete and steel bars.

Embedded strong discontinuity finite elements have recently acquired important contributions, mainly related to the increase in robustness and stability. The development of an effective technique to track multiple discontinuity paths in two and three dimensional solids, based on an analogous thermal problem, also stands out [1, 2]. With these advances, this finite element class currently shows the necessary maturity to represent the complex crack growth process in reinforced concrete

In this context, as an alternative to the explicit representation of the rebars, the mixture theory [3] is a suitable option for modeling reinforcement at a macroscopic level, so that the steel bars can be embedded in the solid elements, permitting the use of coarser meshes. Using this theory, the effects of the fibers (steel bars) can be added to the matrix (concrete) behavior. For long fibers, as in the case of steel reinforcement bars, a parallel model is employed, assuming that all constituents share the same strain field. Thus, the composite stress field can be obtained by the sum of stresses supplied by the constitutive model of

each constituent, weighted according to volumetric fraction. These constitutive models are taken from available phenomenological models based on standard continuum theories. The Continuum of Strong Discontinuity Approach (CSDA) is used to model material failure of the composite. This methodology, which combines CSDA with the mixture theory, was first proposed by Linero [4] for two-dimensional analyses of reinforced concrete members with two orthogonal bundles of fibers.

The present work extends this methodology to three-dimensional problems with an unlimited number of fiber bundles in different directions, using the following strategies:

- Macroscopic representation of reinforced concrete by means of the mixture theory;
- Standard constitutive laws to describe each constituent behavior (concrete and steel), as well their interactions (bond-slip and dowel action);
- Continuum Strong Discontinuities Approach to describe material failure of the resulting composite material;
- Finite elements with embedded discontinuities to simulate crack propagation with a fixed mesh;
- Global 3D tracking algorithm to capture multiple crack surfaces;
- Implicit-explicit integration scheme to improve robustness and stability of non-linear computations.

Three-dimensional numerical studies of existing experimental tests are conducted to evaluate the performance of the proposed methodology for failure mechanism and ultimate load capacity prediction.

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