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Nonlinear failure prediction of concrete composite columns by a mixed finite element formulation

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ABSTRACT

This study focuses on developing a mixed frame finite element formulation of reinforced concrete and FRP composite columns in order to give more accuracy not only to predict the global behavior of the structural system but also to predict the local damage in the cross-section. A hypo-elastic constitutive law of concrete is presented under the basis of a three-dimensional stress state in order to model the compressive behavior of confined concrete wrapped with FRP jackets. To predict the nonlinear load path-dependent confinement model of FRP-confined concrete, the strength enhancement of concrete was determined by the failure surface of concrete in a tri-axial stress state, and its corresponding peak strain was computed by the strain-enhancement factor proposed in this study. The behavior of FRP jacket was modeled using the two-dimensional classical lamination theory. The flexural behavior of concrete and composite members was defined using a nonlinear fiber cross-sectional approach. The results obtained by developed mixed finite element formulation were verified with the experiments of concrete composite columns and also were compared with a displacement-based finite element formulation. It is shown that the proposed formulation gives e more accurate results in the global behavior of the column system as well as in the local damage in the column sections.

1. Introduction

The accuracy of the nonlinear model for the analysis of concrete structures becomes more important not only in the performance-based design and assessment of existing concrete structures in zones of severe earthquake region but also in the development of appropriate retrofit strategies. In this context an alternative modeling strategy can be pursued for the study of the global, regional and local response of retrofitted concrete structures under strong ground motions. Since the inelastic behavior of reinforced concrete frames often concentrates at the ends of beams and columns, earlier approaches were by means of nonlinear springs located at the member ends [1,2]. A more accurate description of the inelastic behavior of reinforced concrete members was possible with distributed nonlinearity models with classical plasticity theory in terms of stress and strain resultants or explicitly derived by discretization of the cross section into fibers [3–5]. In these models, elements with distributed nonlinearity were formulated with the displacement-based finite element method using cubic Hermitian polynomials to approximate the deformations along the element. However, the shape function of beam element in the inelastic state is assumed as same as that in the elastic state. In addition to, the stiffness formulation (or the displacement-based method) leads to violations of the equilibrium assumptions in the level of element.

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