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Capturing 3D effects and non-linear response in concrete frame elements by means of high order cross-section models

Jesus Miguel Bairan
Associate professor
Universitat Politècncia de Catalunya
School of Civil Engineering

Abstract

Frame elements are useful in practical assessment of large structures, as they allow for fast model building and result interpretation, compared to more complex solid models. In these elements, non-linear response is possible by means of uniaxial fibre discretization of the cross-section in smeared inelastic models or by lumped inelastic models through localized plastic-hinges. Nevertheless, as the hypothesis of plane-sections is inherited from basic beam theories, only some strain fields are considered, i.e. longitudinal axial strains in Navier-Bernoulli theory and also in-plain shear strains in Timoshenko theory, while the other strain components are neglected. For elastic and isotropic materials, this assumption is satisfactory; however, this is not the case in many common situations. Cracked reinforced concrete elements exhibit induced anisotropy, nonlinear relationship between longitudinal and transversal strains. Particularly, crack-induced anisotropic response of concrete is essential in activating some resisting mechanisms in reinforced concrete, like shear and torsion, which cannot be captured with traditional frame elements.

In this lecture, a theory is presented in which cross-section based on Navier-Bernoulli formulations are enriched by means of warping and distortion fields, internally computed in the cross-section model. The warping-distortion field allows for considering multiaxial strain tensor and thus multiaxial constitutive models in sectional analysis or frame models. This theory allows for the correct estimation of strains and stress distribution under combined loading of cracked concrete elements and other materials showing anisotropic behaviour, like CFRP, under combined loading. The effects of different confining materials is naturally considered through out-of-plane compatibility of the cross section. After the 3D formulation, two simplified models are presented, for accounting for dynamic loading and the assessment of existing and repaired infrastructures. Case studies will be discussed showing the advantages and possible improvements of the formulations and possible future applications.