International Journal of Plasticity 27 (2011) 620–634

Contents lists available at ScienceDirect

International Journal of Plasticity

journal homepage: www.elsevier.com/locate/ijplas

A thermodynamical gradient theory for deformation and strain localization of porous media

Javier L. Mroginski, Guillermo Etse *, Sonia M. Vrech

Center for Numerical and Computational Methods in Engineering (CEMNCI), Faculty for Exact Sciences and Technology, Universidad Nacional de Tucuman, Av. Roca 1800, (4000) Tucumán, Argentina

CONICET, Argentine Council for Science and Technology Rivadavia 1917, 1033 Buenos Aires, Argentina

ARTICLE INFO

Article history:
Received 23 February 2010
Received in final revised form 13 August 2010
Available online 6 October 2010

Keywords:
Gradient theory
Porous media
Localized failure
Softening behavior

ABSTRACT

In this work, a thermodynamically consistent gradient formulation for partially saturated cohesive-frictional porous media is proposed. The constitutive model includes a classical or *local* hardening law and a softening formulation with state parameters of non-local character based on gradient theory. Internal characteristic length in softening regime accounts for the strong shear band width sensitivity of partially saturated porous media regarding both governing stress state and hydraulic conditions. In this way the variation of the transition point (TP) of brittle-ductile failure mode can be realistically described depending on current confinement condition and saturation level. After describing the thermodynamically consistent gradient theory the paper focuses on its extension to the case of partially saturated porous media and, moreover, on the formulation of the gradient-based characteristic length in terms of stress and hydraulic conditions. Then the localization indicator for discontinuous bifurcation is formulated for both drained and undrained conditions.

1. Introduction

The mechanic of porous media constitutes a discipline of great relevance in several knowledge areas like Geophysics, Biomechanics and Materials Science. Its main aim is the description of the kinematic and pore pressure of porous continua when subjected to arbitrary mechanical and/or physical actions. The definitive advantages of porous mechanics to macroscopically describe or predict complex response behavior of cohesive-frictional materials based on fundamental aspects of their microstructure while accounting for the hydraulic properties and their influence in the resulting failure mechanism were recognized by several authors in the scientific community (Bary et al., 2000; Borja, 2004; Ito, 2008). Consequently, a tendency to replace the theoretical framework of classical continuum mechanics with that of non-linear porous mechanics was observed. Firstly this process took place in case of soil mechanics, (see a.o. Ehlers et al., 2004; Coussy and Monteiro, 2007), but subsequently in the field of concrete, (see a.o. Ulm et al., 2004; Pesavento et al., 2008) and, furthermore, of biomaterials, (see a.o. Naili et al., 1989; Pierre et al., 2008).

A relevant aspect of failure processes in cohesive-frictional materials is the transition from brittle to ductile response. In the realm of classical *non-porous* smeared-crack-based continua (NPSC), the concept of discontinuous bifurcation by means of the so-called localization indication (see a.o. Etse, 1994a; Jirásek and Rolshoven, 2009) gave the mathematically foundation to distinguish between diffuse and localized or brittle failure mode. Many proposals of constitutive models based on NPSC used the discontinuous bifurcation approach to accurately evaluate failure modes under different stress conditions,

* Corresponding author at: Center for Numerical and Computational Methods in Engineering (CEMNCI), Faculty for Exact Sciences and Technology, Universidad Nacional de Tucuman, Av. Roca 1800, (4000) Tucumán, Argentina.

E-mail address: getse@herrera.unt.edu.ar (G. Etse).

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doi:10.1016/j.ijplas.2010.08.010