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PII: S0022-5096(18)30243-6
DOI: 10.1016/j.jmps.2018.06.017
Reference: MPS 3374

To appear in: *Journal of the Mechanics and Physics of Solids*

Received date: 23 March 2018
Revised date: 8 June 2018
Accepted date: 22 June 2018

Please cite this article as: Lun-Yang Zhao, Jian-Fu Shao, Qi-Zhi Zhu, Analysis of localized cracking in quasi-brittle materials with a micro-mechanics based friction-damage approach, *Journal of the Mechanics and Physics of Solids* (2018), doi: 10.1016/j.jmps.2018.06.017

Analysis of localized cracking in quasi-brittle materials with a micro-mechanics based friction-damage approach

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Abstract

This paper is devoted to the study of transition from diffuse damage to localized cracking in quasi-brittle materials. A micro-mechanics based friction-damage model is first formulated with a rigorous homogenization procedure. The plastic deformation is related to the frictional sliding along diffuse micro-cracks while the damage is induced by the growth of micro-cracks. The localized cracking is considered as a consequence of coalescence of diffuse micro-cracks. The onset of localized crack is then defined by introducing a critical value of diffuse damage density parameter. The orientation of localized crack is determined from the Mohr's maximization postulate. After the onset of a localized crack, the energy dissipation of material is entirely related to the frictional sliding and propagation of the localized crack. In this context, a localized friction damage model is developed in the framework of thermodynamics to describe the frictional sliding of the localized crack which acts as the driving force for its propagation. As an example, analytical results of localized crack angle are determined for some specific loading paths including plane stress, plane strain and conventional triaxial compression. Moreover, analytical solutions of complete stress-strain curves with the transition from diffuse damage to localized cracking are also obtained for conventional triaxial compression tests and compared with experimental data.

Keywords: plastic damage, localized cracking, friction-damage coupling, micro-mechanics, quasi-brittle materials

1. Introduction

In quasi brittle materials such as concrete, rocks and ceramics, the nucleation, propagation and coalescence of micro-cracks are the main physical process of inelastic deformation and failure. The macroscopic failure is generally induced by the onset of localized cracks which are originated from the coalescence of diffuse micro-cracks. Unlike shear bands in ductile materials like soils, the localized cracks or fractures in rock-like materials are generally surfaces of very small thickness but with strong displacement discontinuities. After the localization, the macroscopic stress-strain relations of cracked material are essentially governed by the behavior of localized cracks. The objective of the present study is to develop a micro-mechanics based approach to describe the plastic damage of quasi-brittle materials before localization, the onset condition of localized cracking, and the mechanical behavior of cracked material after localization.

The concept of localized failure in quasi brittle materials was first introduced in the landmark papers of Ngo and Scordelis (1967) and of Rashid (1968). After that, a great diversity of approaches have been developed to deal with this

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