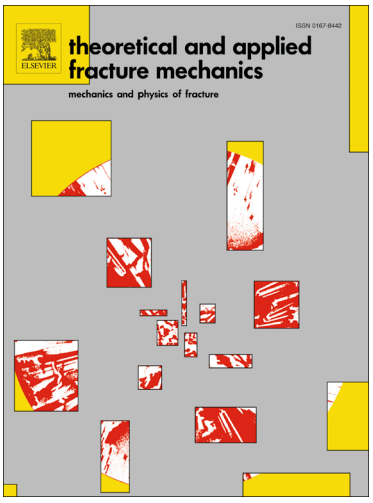

Energy-Based Forming and Anchoring Mechanism and Criterion for Zonal Disintegration

Xuguang Chen, Zhang Ning, Ma Tianchi, Niu Xiaodong, Liu Xixi, Feng Tao

PII: S0167-8442(17)30111-8
DOI: http://dx.doi.org/10.1016/j.tafmec.2017.06.006
Reference: TAFMEC 1888

To appear in: *Theoretical and Applied Fracture Mechanics*

Received Date: 6 March 2017
Revised Date: 7 June 2017
Accepted Date: 7 June 2017

Please cite this article as: X. Chen, Z. Ning, M. Tianchi, N. Xiaodong, L. Xixi, F. Tao, Energy-Based Forming and Anchoring Mechanism and Criterion for Zonal Disintegration, *Theoretical and Applied Fracture Mechanics* (2017), doi: http://dx.doi.org/10.1016/j.tafmec.2017.06.006

Energy-Based Forming and Anchoring Mechanism and Criterion for Zonal Disintegration

CHEN Xuguang[1,2], Zhang Ning[1,2], Ma Tianchi[1,2], Niu Xiaodong[1,2], Liu Xixi[1,2], Feng Tao[1,2]

(1.Shandong Provincial Key Laboratory of Ocean Engineering, Qingdao 266100, China;2. Shandong Provincial Key Laboratory of Marine Environment and Geological Engineering, Ocean University of China, 266100 Qingdao, China)

Abstract: The energy transmission and variation law during rock damage are studied. Consequently the energy-based criterion for rock damage is obtained. Based on analyzing the energy distribution law in rock mass, the geostress condition for Zonal Disintegration Phenomenon (ZDP) is studied. The criterion for ZDP in terms of strain energy is thus established. The forming mechanism for ZDP is revealed. Additionally the sensitive factors and the influences on ZDP are determined. An equivalent excavation model is proposed to investigate the releasable strain energy. Therefore, the energy-based criterion for anchoring ZDP is established with the Energy analysis of anchor bolt. Meanwhile, the number of bolts to control the ZDP formation is calculated in this paper. Finally, a model test is compared with the theoretical result and testifies the criterion.

Key words: Deep Tunnel; ZDP; Energy Criterion; Anchor Bolt

1. Introduction

In 1980, "a pattern of mining-induced fracturing" was first observed by Adams [1] in the Witwatersrand gold mine and it is known as Zonal Disintegration Phenomenon (ZDP) [2]. The zonal disintegration was afterwards observed in many deep caverns by all kinds of geophysical method and devices. For example, it was explored in the Taimyrskii deep mine in Russia by Shemyakin EI et al [3] using a resistivity meter. In China, Li [4] detected zonal disintegration in Huainan coal mine and then Tan [5] observed it in Suncun Mines by using borehole camera exploration device.

ZDP has received a wide range of scholars' attention because of its importance for excavation of deep rock masses. By the associated traditional concept, the enclosed rock mass around the shallow hole will be divided to three areas from the perimeter of the tunnel to the infinite. They are rupture, plasticity and elasticity area, in separate. This is totally different in the engineering response and morphology feature from the observed ZDP in deep caverns. Knowing the forming mechanism, and the criterion of ZDP is vital in preventing hazards and thus, protecting the deep cavern. Many different methods have been attempted to interpret it. Zhou and Qian [6-12]carried out a series of studies to study the dynamic excavation of the deep cavity, to determine the formation mechanism, the residual strength, the forming time of the fault zone and the influence of rock damage and cracks. Wang et al [13] utilized the internal variable gradient plasticity theories to investigate ZDP. Wu et al [14] adopt elastic-plastic theories to provide the correlative interpretation. Moreover, the non-traditional theory such as the Hamiltonian time-domain variation [15], and the non-Euclidean models [16] were utilized and tried to interpret the mechanism. The model tests have also been adopted to investigate the phenomenon. For example, Gu [17] put forward the mechanism of the layered fracture. Chen [18-20] have conducted a series of model tests