International Journal of Rock Mechanics & Mining Sciences 47 (2010) 254–264

Contents lists available at ScienceDirect

International Journal of Rock Mechanics & Mining Sciences

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

Core disking and its relationship with stress magnitude for Lac du Bonnet granite

S.S. Lim *[,1], C.D. Martin

Department of Civil & Environmental Engineering, University of Alberta, Edmonton, Alberta, Canada

ARTICLE INFO

Article history:
Received 6 March 2009
Received in revised form
23 October 2009
Accepted 27 November 2009
Available online 18 January 2010

Keywords:
Core disking
Field observation
Stress magnitude
Classification

ABSTRACT

Core disking is an indicator of elevated stress magnitudes. Disked cores from boreholes drilled from underground excavations in massive unfractured granite, where the stress magnitudes are known with confidence, were used to establish a relationship between core disk thickness and the stress magnitude. Relationships were established for three disk thickness categories; (1) thin ($t/D<0.2$), (2) medium ($0.2<t/D<0.4$) and (3) thick ($0.4<t/D<2.2$) and partial disking. The data suggests that core disking initiates when the maximum principal stress normalized to the tensile strength is 6.5.

1. Introduction

There is no question that in situ stress magnitudes and directions are required for the design of deep underground excavations. Yet, in situ stress measurements are particularly difficult in deep small diameter (< 100 mm) boreholes and high-stress environments with horizontal stresses greater than the vertical stress [1]. In such situations core disking and borehole breakouts may occur. Observations of these phenomena indicate that the in situ stress magnitudes are high relative to the rock strength. However, as noted by Doe et al. [1] core disking like borehole breakouts is generally viewed as a qualitative method for estimating stress magnitudes. Nonetheless in the early stages of site investigation such observations are important and may play a critical role when evaluating the in situ stress magnitudes for a site.

Core disking has been investigated since the 1960's using either laboratory testing and/or numerical analyses [2–11]. While these studies have provided insight into the core disking mechanism there is still uncertainty as to the relationship between core disking and the stress magnitudes required to cause disking. This uncertainty arises because of the lack of core-disking field data where the in situ stress magnitudes are known with confidence. Relationships relating disking and stress magnitudes based on laboratory data are often questioned because the core diameter used in laboratory studies is usually less than 25 mm diameter, and it is well known that intact rock properties are affected by scale effects when samples are relatively small [12,13].

Disked cores from boreholes drilled from underground excavations in massive unfractured rock Lac du Bonnet granite are characterized for disk thickness, surface geometry and fracture persistence. The in situ stress magnitudes were characterized in previous studies and hence provided a unique opportunity to establish relationships between core disking in core from 75-mm-diameter boreholes and stress magnitudes. In this study we focus primarily on the relationship between the maximum stress and disk thickness, as tunnel stability is often related to the maximum stress, e.g., see Hoek and Brown [12], and when disking is encountered an obvious question is will the maximum stress magnitude be sufficient to impact tunnel stability.

2. Background

AECL's Underground Research Laboratory (URL) was constructed between 1983 and 1990 and operational experiments have been ongoing since then [14]. The majority of the geomechanics experiments were carried out on the 420 Level in a massive unfractured rock mass (Fig. 1). The characteristics of the rock mass and the properties of the intact rock are given in [15]. The in situ stress state at AECL's URL was described by Martin [16] and Read [17] used deformations ahead of a tunnel advance to develop a statistically rigorous technique to establish the in situ stress state at the 420 Level of the URL. Table 1 gives the stress

* Corresponding author. Tel.: +1 780 644 5070.
E-mail address: Seong.Lim@gov.ab.ca (S.S. Lim).
[1] Currently at Dam Safety, Infrastructure Support, Alberta Environment, Edmonton, Alberta, Canada.

1365-1609/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ijrmms.2009.11.007

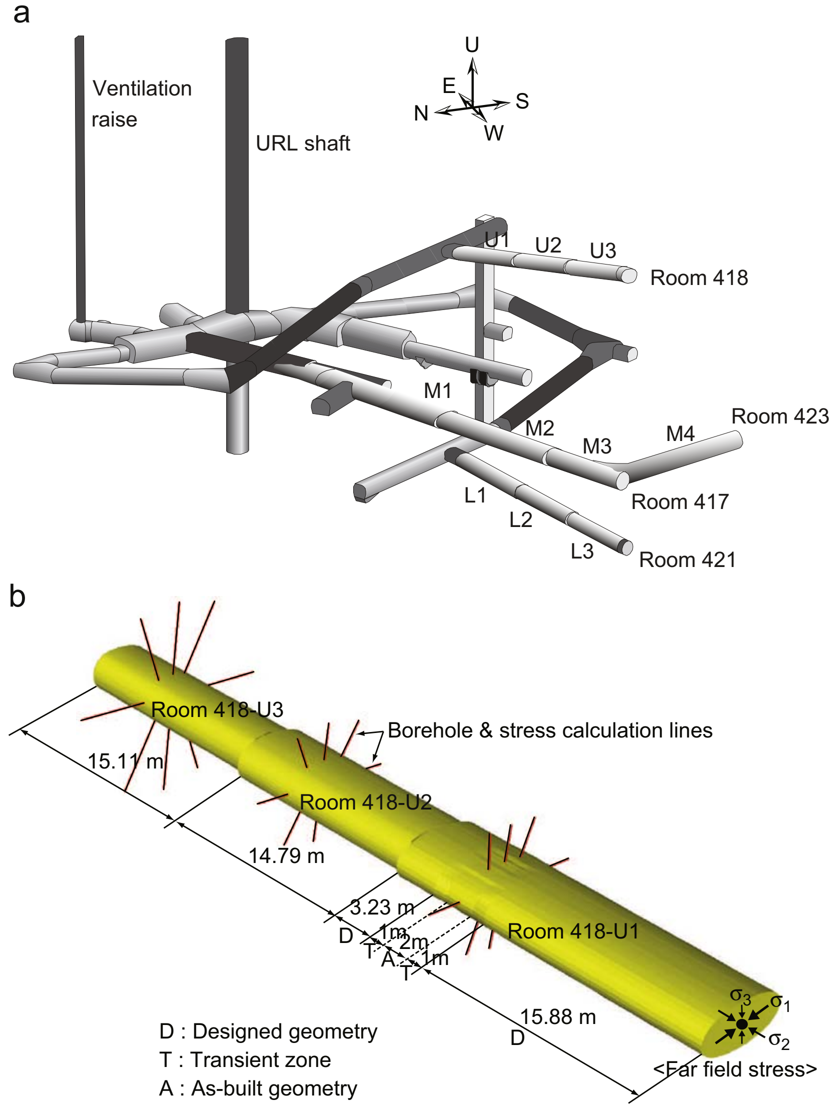

Fig. 1. General layout of the 420 Level of AECL's Underground Research Laboratory and location of MVP boreholes used in Array 418-U1, -U2 and -U3: (a) URL 420 Level and (B) Borehole in Room 418 used in Array 418-U1, -U2 and -U3.

Table 1
In situ principal stress magnitudes and orientations for the 420 Level (after Martin and Read [18]).

Stress	σ_1	σ_2	σ_3
Magnitude (MPa)	60 ± 3	45 ± 4	11 ± 4
Trend/Plunge (°)	145/11	054/08	290/77

magnitudes on the 420 Level where the excavations and experiments were conducted [18].

Between 1995 and 1997 a series of openings with different geometries were excavated on the 420 level as part of the Excavation Stability Study (ESS) [14]. According to Read [14], the excavation geometries were optimized to reduce the stress concentrations on the boundaries of the openings. By creating ovaloid shaped openings and varying orientation of the long axis of the room cross section relative to the maximum in-plane stress, the maximum tangential stress on the boundary, and hence the damage around the opening, could be controlled. To characterize the excavation damaged zone around these openings a series of radially oriented 75-mm-diameter (NQ3-size) boreholes (labelled MVP) were drilled from each opening to a nominal depth of 2.50-5.30 m [19]. The boreholes were drilled using standard triple-tube diamond-drilling coring technology typically used in underground excavation in Canada, with a nominal hole diameter of 75-mm, which produced a nominal core diameter of 45-mm. The cores from these boreholes were used for this study.

The ESS study produced two types of tunnels, those with no obvious signs of an excavation damaged zone (EDZ) and those with a visible v-shaped notch, clearly indicating the creation of an EDZ. The boreholes and core used in this study were chosen from both types of tunnels. Fig. 2 illustrates the quality and shape of the excavations and Fig. 3 shows the typical 45-mm-diameter core retrieved from the MVP boreholes. Normally the core from the 420 level is fracture free, i.e., there are no joints or discontinuities related to the geological history. Hence all the fractures observed in Fig. 3 are stress-induced fractures related to the core-drilling and retrieval process. In this paper the regularly spaced stress-induced fractures, such as those shown in Fig. 3, are termed core disking.

Extensive core disking was observed in the core from 39 out of the 54 MVP boreholes drilled in Room 417, Room 418, Room 421