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Experimental Determination of Crack Initiation and Crack Damage of Two Granites

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Abstract

Mineralogical composition and microstructural features influence rock strength and their failure mechanisms. Crack initiation (CI) and crack damage (CD) are important processes of the failure mechanisms of rocks. Since CI is the lower limit of the long term strength of rocks at low confinement, this study is mainly concerned with triaxial tests and the determination of CI and CD using different methods. A triaxial cell has been designed to examine spalling behavior of magmatic rocks under low confinement, at minor principal stresses up to 2.5 MPa. Two granites with different grain sizes were tested. Methods to determine CI and CD include the calculation of circumferential, volumetric and crack volumetric strain. In addition, acoustic emission monitoring provides the onset of CI and CD. Uniaxial compressive tests including primary wave velocity measurements as well as acoustic emission were used to supplement the dataset. The wave velocities also give an indirect determination of CI and CD as the initiation of cracks reduces the speed of the waves. This study aims to compare the different methods determining CI and CD and to connect the results with mineralogical and microstructural features. Orientated thin sections were prepared to identify the mineralogical composition. Furthermore, the growing influence of confining pressure from 0.1 to 2.5 MPa on rock strength was analyzed.

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Keywords: Crack initiation; Crack damage; Mineralogical composition; Acoustic emission; Primary wave velocity

1. Introduction

Laboratory experiments of rocks were conducted to determine geomechanical properties like peak strength. A widely accepted model for the failure mechanism of rocks during the loading process includes four main stages:

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(1) crack closure, (2) crack initiation, (3) crack damage and (4) peak strength. CI detected from laboratory experiments is of special interest because it coincides with the in-situ rock spalling strength [1]. This means a reduction of the peak strength by 0.4 ± 0.1 of the unconfined compressive strength [1]. The phenomenon spalling describes the development of thin spall slabs near excavation boundaries that can form notch geometries [2]. Spalling might be violent or non-violent [2]. For economic and safety reasons it is important to determine the rock spalling strength reliably. The aim of this paper is to compare different methods determining CI and CD and to depict the influence of confinement on the peak strength. Two new methods including AE or wave velocity measurements are presented. This research focused on triaxial tests conducted under low confinement as this is the region where spalling occurs and little published data is available under these conditions. At higher confinement the stress envelope makes a transition to the CD defined envelope [3].

Nomenclature

CC	crack closure	AE	acoustic emission
CI	crack initiation	PPL	plane-polarized light
CD	crack damage	XPL	cross-polarized light

2. Rocks investigated

The experiments were conducted on two granites with different grain sizes and varying properties. The subsequent photos give an impression of these granites (Fig. 1). The abbreviation for Granite Othello is GO and for Granite St. Tirso is GT.

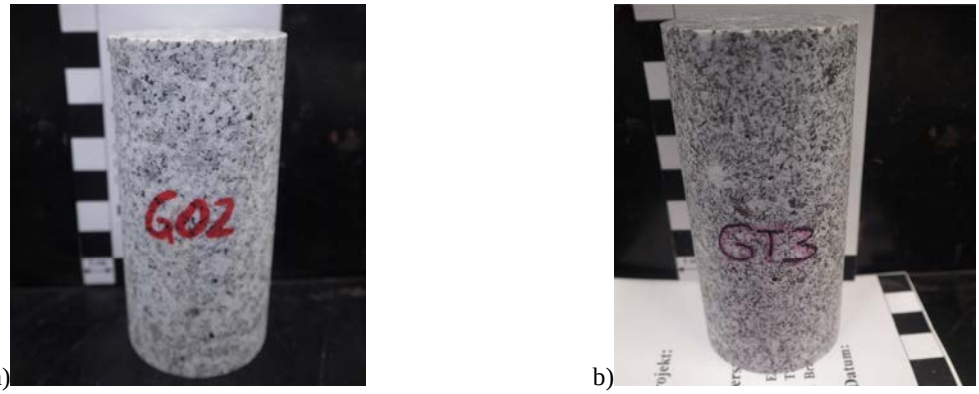

Fig. 1. (a) Cylindrical specimen of Granite Othello and (b) of Granite St. Tirso.

Table 1 summarizes the basic geomechanical properties of the two granites based on triaxial tests. Nineteen triaxial tests on GO samples and 24 on GT samples were conducted with varying confining pressure between 0.1 and 2.5 MPa. Moreover, 6 triaxial tests of each GO and GT were performed with saturated specimens.

Table 1. Geotechnical properties of GO and GT.

granite	$\rho_{geom.}$ [g/cm³]	v_p [km/s]	σ_1-$\sigma_3$at failure [MPa]	$\varepsilon_{failure}$ [mm/mm]	Young's Modulus [GPa]	ν [-]
GO	2.66 ± 0.01	4.00 ± 0.24	188.5 ± 18.4	0.01410 ± 0.00117	21.2 ± 0.9	0.11 ± 0.02
GT	2.72 ± 0.01	5.40 ± 0.14	184.2 ± 22.1	0.01267 ± 0.00134	21.9 ± 0.9	0.12 ± 0.02

Total sample number n = 55, mean values ± SD