Investigating the effect of mineralogy and grain size on damage stress thresholds of granite and diorite

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Abstract

The deformation and failure properties of the loaded rocks are divided into different stages based on cracks' formation and growth. The different damage stress thresholds separate these stages. Considering the damage stress thresholds as a material property, geological properties of rocks can affect the damage stress thresholds. In this research, damage stress thresholds were identified for granite and diorite in the uniaxial compressive loading test with the help of the Acoustic Emission test (AE). Then fluorescence thin sections were prepared from the samples loaded to each damage stress threshold to investigate the effect of the mineralogy and the grain size. The results show that strong minerals increase the stress damage thresholds level due to the high cracking resistance. Furthermore, by decreasing the mean grain size, a better interlocking between the grains is created, and the number of grain boundaries increases. Therefore, the applied force has a higher surface to distribute. Consequently, minerals are less affected by the applied force; their crack density reduces, and crack initiation stress threshold increases

Key words: *Damage Threshold, Acoustic Emission, Crack, Granite, Diorite.*

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Extended Abstract:

1. Introduction

Among all the factors affecting the mechanical behavior of rocks, cracks are of great importance. The growth of cracks effectively controls the mechanical behavior of the rocks (Eberhardt et al., 1999a; Zhou et al., 2018). The deformation and failure properties of the loaded rocks are divided into different stages based on cracks' formation and growth including crack closure, linear elastic, stable crack propagation, and finally unstable crack propagation. The different damage stress thresholds separate these stages (Diederichs et al., 2004; Martin and Chandler, 1994). Considering the damage stress thresholds as a material property, geological properties of rocks can affect the damage stress thresholds. Eberhardt et al. (1999b) showed that in rocks with the same mineralogical composition but with different grain sizes, grain size has a limited effect on CI. Glamheden et al. (2007) stated that if two rocks have the same mineralogy, variations in grain size and grain distribution can lead to differences in the strength properties of the rock. Therefore, in this research, the effect of grain size and mineralogy on damage stress thresholds will be investigated.

2. Materials and method

Granite samples were collected from an active mine in Boroujerd complex, west of Iran, The rock is known as Jokar Granite at the market. Diorite samples were collected from active mines in Cheshmeh Ghasaban area, which is a part of the Alvand plutonic complex in the northern part of the Sanandaj-Sirjan metamorphic zone in the west of Iran. This research aims to study the effect of grain size and mineralogy on damage stress thresholds. Therefore, fluorescence thin sections were prepared from the samples and mineralogical and grain size properties of the samples were studied. Then, physical-mechanical properties and linear microcrack density (LMD) of intact rock and constituent minerals were determined. Afterward, different stresses damage threshold of a rock sample with the help of the acoustic emission (AE) measurement were identified. Three samples were loaded in uniaxial compression loading state to each damage stress threshold. Then, fluorescence thin sections were prepared from the loaded samples. Finally, microcracks were analyzed to gain a better understanding of the effect of mineralogy and grain size on damage stress thresholds.

3. Results and discussion

Based on thin section studies, it was determined that Jokar granite is a medium-grained rock (average grin size of the 1.01 mm) composed of quartz, plagioclase, k-feldspar, biotite and hornblende minerals. Thin section studies show that diorite with the mean grain size of the 0.49 mm is composed of the plagioclase, biotite, amphibole and pyroxene. The mean values of different damage stress thresholds of granite and diorite rocks were obtained through AE test and are presented in Table 1. To investigate the effect of grain size and mineralogy on damage stress thresholds, cracks were counted in intact samples and CI and CD threshold samples. The result of the LMD in rock and individual minerals were presented in Tables 2 and 3.

Table 1. Damage stress thresholds of granite and diorite rocks.

Samples	CC (MPa)	CI (MPa)	CD (MPa)	(MPa) UCS
Granite	16	54	91	114/6
Diorite	17/2	86	102	129

Table 2. Total LMD in intact state and damage stress thresholds of granite and diorite (N/mm)

Samples	Intact	CI	CD
Granite	3.50	6.40	7.60
Diorite	4.20	5.73	7.84

Table 3. LMD in constituent minerals of the granite and diorite in intact state and damage stress thresholds (N/mm)

Samples	Minerals	Intact	CI	CD
Granite	Plagioclase	4.17	5.71	7.85
	Biotite	2.66	4.48	5.12
	Quartz	2.13	2.27	3.52
	K-feldspar	2.54	3.97	4.19
Diorite	Plagioclase	3.4	4.8	6.59
	Biotite	1.48	2.85	3.76
	Amphibole	1.45	1.93	2.86
	Pyroxene	1.3	1.45	2.1

According to the results presented in Table 1, as the diorite rock has a higher uniaxial strength than granite, the damage stress thresholds in this rock is also higher. In both granite and diorite, CC thresholds are located at 14% and 13.3% of each rock's uniaxial strength, respectively. However, after passing this stage, a significant difference is observed in the CI threshold. In granite, CI is at 47.1%, and in diorite is at 66.6% of the uniaxial compressive strength. Then the CD threshold of granite is 79.4 and diorite is 79.1% of uniaxial resistance, which again shows a close percentage of uniaxial compressive strength. The significant difference between the CI threshold in granite and gabbro can be explained from two aspects, which are the strength of the constituent minerals and the grain size. High-strength minerals such as pyroxene and amphibole in diorite increase the overall strength and resistance against microcracking of the rock; therefore CI threshold of the diorite increase compared to granite. On the other hand, the smaller grain size makes the grain boundaries to be shorter. Also, smaller grain size increases the roughness of the surface contact in grain boundaries. Since, the amount of energy required to slide at weak surfaces is inversely related to the length of the weak surface (Petch, 1953), sliding at diorite grain boundaries requires more energy than granite. To verify the reasons given above, the LMD of the rock and constituent minerals were investigated (tables 2 and 3). The results show that in the intact state, CI and CD thresholds diorite minerals show lower LMD values than granite.

While the amount of LMD in diorite constituent minerals is less than granite, but total LMD in diorite rocks is higher than granite in CD threshold (Table 2). The small grain size of the diorite means that there are more grain boundaries in this rock compared to granite. The larger number of the grain boundaries in diorite created more available surface for applied energy to distribute. Therefore, minerals are less affected and fewer microcracks initiated within them. Since the grain boundaries are considered as the weakness plane (Ghasemi et al., 2019) the cracks start earlier in these planes compared to the minerals. Therefore, a large number of microcracks initiated within grain boundaries, which finally increase the total LMD of diorite compared to the granite, while diorite minerals have lower LMD than the granite.

4. Conclusion

This research aims to investigate the effect of the mineralogy and the grain size on the damage stress thresholds. The results show that strong minerals increase the stress damage thresholds level due to the high cracking resistance. Furthermore, by decreasing the mean grain size, a better interlocking between the grains is created, and the number of grain boundaries increases. Therefore, the applied force has a higher surface to distribute. Consequently, minerals are less affected by the applied force; so, their crack density reduces, and crack initiation stress threshold increases.

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