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Research article

Numerical investigating on the effect of anisotropy ratio, layering angle, and crack length in stress intensity factor in phyllite rock

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Keywords

Anisotropic rock
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Layering angle
Crack length
Numerical modeling

English Extended Abstract

Summary

Geomechanical properties of some sedimentary and metamorphic rocks are important because they are anisotropic. These properties affect on stability of rock construction. In this research, the changes in the stress intensity factor in anisotropic rock have been investigated based on the changes in the crack angle with the loading axis and anisotropy ratio. In this research, the finite element method and ABAQUS software are used because of their ability to simulate anisotropic rock. The CCNBD disc sample was used according to the standards of ISRM. It concluded that the stress intensity factor is dependent on the anisotropy ratio, layering angle, and crack length and pure tension (mode one) does not necessarily occur at a zero-crack angle with the loading axis ($\beta=0$), and this angle is completely affected by the layering angles (Ψ).

Introduction

Investigating the behavior of rock under load and determining its mechanical properties are important to designing rock structures. The importance increases when the rock is anisotropic. In the design two mechanical properties; the first rock strength and the second deformation should be considered. The anisotropy rocks require the simultaneous investigation of the resistance behavior and the failure mechanism [1]. A rock is called anisotropic when the value of mechanical properties is different in two different directions. Fracture toughness is the critical stress intensity factor of a sharp crack where propagation of the crack suddenly becomes rapid and unlimited [2].

For materials that have linear elastic behavior, this property is usually expressed in terms of a quantity called the critical value of the stress intensity factor. This parameter is indicated by the symbol K [3] In this research, the main question is to investigate the changes in the stress intensity factor in anisotropic rocks by changing the angle of the crack with the loading axis, anisotropy ratio, crack length, and layering angle.

Methodology and Approaches

For investigation of research question numerical method was considered. The software used Abaqus finite element(FEM) [4]. Abaqus is a set of powerful engineering simulation programs based on the FEM and can solve a wide range of problems from a relatively simple linear analysis to very complex nonlinear analysis. The rock sample was an anisotropic Phyllite belonging to the abutment of the Azad Dam in Kurdistan and the mechanical properties of the sample were taken from Abadat (2013) [5]. CCNBD disk numerical models (D=54 mm and t=30

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Vol. 13, No. 36, Fall 2023, Pages 91-100

Journal of Analytical and Numerical Methods in Mining Engineering

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mm) of Phyllite according to the standard of the International Society of Rock Mechanics (ISRM) with anisotropy ratio (E/E'=1.8 and E/E'=4) in different layering angles (ψ=0-30°-45°-60°-75°-90°) and in different crack angles with loading extension (β) and in different crack lengths (a=12-24-36 mm) were built and executed by Abaqus. After execution, the Abacus determined the stress intensity factor of each model, and data were collected and analyzed.

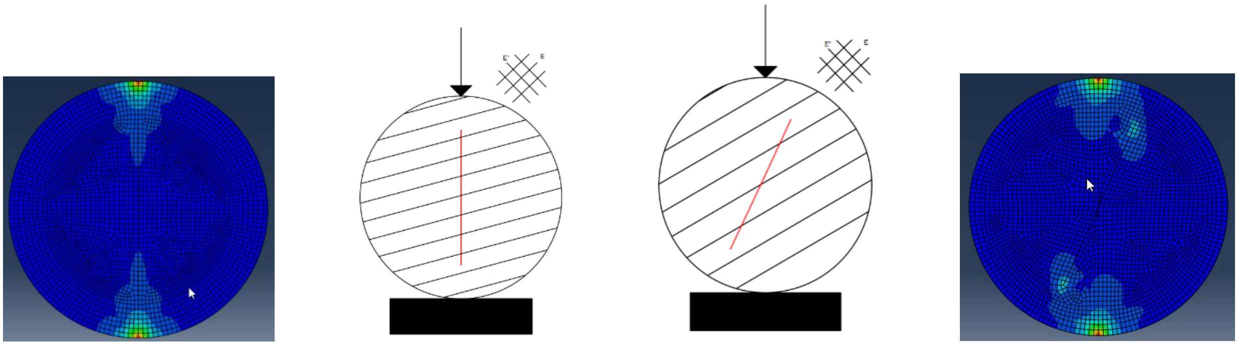

Fig. 1 : Geometry and stress intensity factor contour for a) in tensile mode and b) and shear mode.

Results and Conclusions

Sensitivity analysis by variation of four parameters which were anisotropy ratio, different layering angles, different crack angles with loading extension, and different crack lengths was carried out. 180 models were built and executed by Abacus software. Three parameters were kept constant the last was changed and the stress intensity factor was evaluated. Figures 2, 3, and 4 show the effect of the anisotropy ratio variation on the angle of the crack with the loading axis in the pure tensile (mode one), pure shear (mode two), and mixed-mode in the crack length of 12 mm respectively.

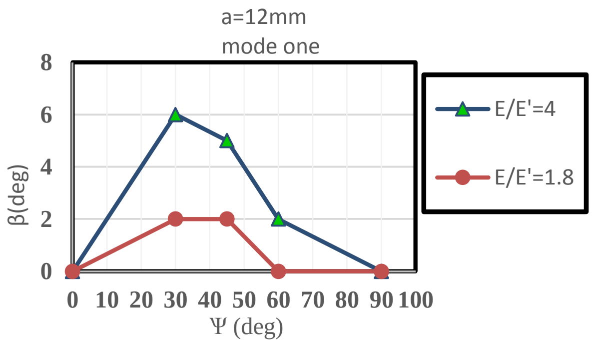

Fig. 2: The effect of anisotropy ratio on the angle of crack with loading axis in pure tensile (mode one) in crack length equal to 12 mm.

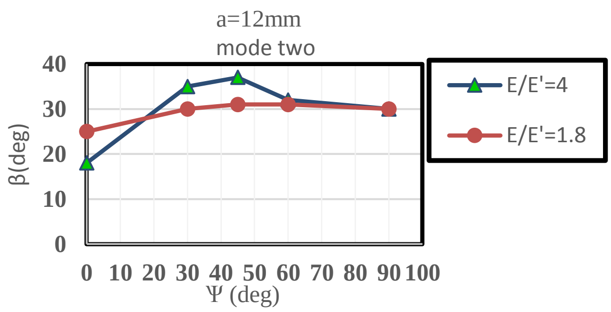

Fig. 3: The effect of anisotropy ratio on the angle of crack with loading axis in pure share(mode two) in crack length equal to 12 mm.

Vol. 13, No. 36, Fall 2023, Pages 91-100

Journal of Analytical and Numerical Methods in Mining Engineering

Journal home page: http://anm.yazd.ac.ir/

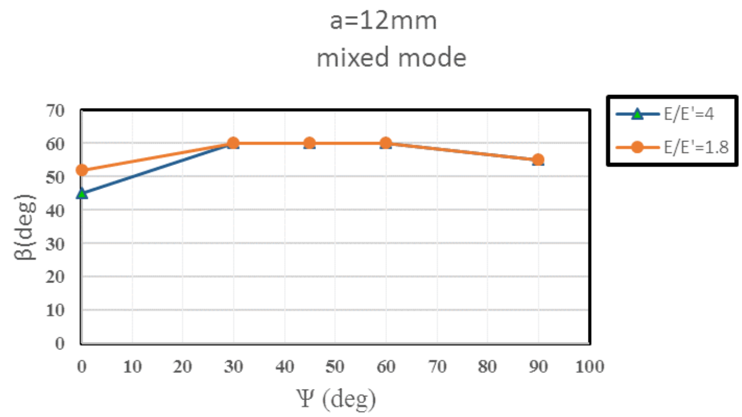

Fig. 4: The effect of anisotropy ratio on the angle of crack with loading axis in a mixed mode in crack length equal to 12 mm.

1- Variations of layer angle (ψ), crack angle with loading axis (β), crack length(a), and change of anisotropy ratio have a noticeable effect on the values of the stress intensity factor.

2- In different crack lengths and in different anisotropy ratios, for a constant layering angle, the stress intensity factor of tensile mode is maximum at β=0 and minimum at β=90° and the stress intensity factor of shear mode is minimum at β=0 and β=90̊ and maximum at β between 30̊-40̊.

3- Mode one(pure tensile) in different angles of layering does not necessarily occur at a zero-degree angle with the loading axis (β=0) and this angle is completely affected by the angles of layering (Ψ).

4- According to the results in different layering angles and in different anisotropy ratios, the β angle is different, so that the pure tensile in the layering angle of 30° and the anisotropy ratio equal to 4 occur in β =6°. However, this value is equal to 2° for the anisotropy ratio equal to 1.8

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