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Study of Stress on Fracture Toughness Test Mode I Using Photoelastic Method

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Abstract

Stress of rocks generally can be known, but at the point of fracture initiation is often not known with certainty. To study the stress around fracture initiation, it is difficult to do using mathematical calculations so that the necessary methods of alternative solution is photoelastic method. Major principal stress can be obtained from photoelastic method. In this research, photoelastic method is conducted to study the stress on fracture toughness tests mode I (tension).

Sample testing conducted at the Laboratory of Geomechanics and Mine Equipment Institute of Technology Bandung involved the physical properties and mechanical properties test to obtain the sample characteristics as input data for numerical modeling using Rocscience 3 version 1.0, such as the natural density, uniaxial compressive strength, Young's modulus, Poisson's ratio, and tensile strength. Moreover, fracture toughness tests mode I are conducted on Modified Ring Test (MRT) and Central Straight-Through Crack (CSCBD) using photoelastic method. The stress can be calculated using colors observed in photoelastic method by following the equation of optical stress. Major principal stress obtained from photoelastic method would be compared to numerical method. From this research, it could be concluded that the results of the stress distribution obtained from numerical modeling have similar results to the stress distribution obtained from photoelastic method, although there are slightly different results, but it still tolerable.

Keywords: Stress, Photoelastic, Modified ring test, Central straight-through crack, Fracture toughness mode I

1. Introduction

Fracture toughness has been recognized as an intrinsic property of the rock material that indicates its ability to resist fracture initiation and propagation. Fracture toughness has an important contribution in designing the structure of the rock, rock excavation, and process of rock fragmentation.

In studying the stress distribution, the mathematical theory of elasticity has proven very useful to the behavior of material. This theory is not only the easiest, but has also provided very accurate prediction of the behavior on structure of rock mass. But in case of studying the stress concentration at the initiation point of fracture, mathematical difficulty increases so that the alternative solution method is necessary. The solution method that can be used is photoelastic method.

2. Theories and Experiments

2.1 Theories

Fracture mode in this research is mode I (tension), which is also called the opening mode. Fracture toughness tests mode I are conducted on Modified Ring Test (MRT) and Central Straight-Through Crack (CSCBD). Basically, the Modified Ring Test (MRT) is based on the shape of Brazilian samples with two flat loading surface is diametrically opposite. The main feature of this method is two cracks will start in a hole which is located diametrically opposite when the diametrically load increased, which cracks propagate along the loading axis until it reaches the loading surface. On the other hand, a Central Straight-Through Crack in the Brazilian Disk (CSCBD) is cut diametrally. The equipment required for CSCBD is essentially the same as that employed in conventional Brazilian disk indirect tensile strength tests. The only difference is that the specimen must be carefully set up with the crack inclination parallel to the applied load in order that the specimen is loaded in mode I.

Photoelasticity is an experimental method to determine the stress distribution in a material. The method is mostly used in cases where mathematical methods become quite cumbersome. The method is based on the property of birefringence. Photoelastic materials exhibit the property of birefringence only on the application of stress and the magnitude of the refractive indices at each point in the material is directly related to the state of stress at that point. The magnitude of the relative retardation is given by the stress optic law:

$$R = Ct(\sigma_1 - \sigma_3) \qquad (1)$$

where *R* is the induced retardation in nanometer, *C* is the stress optic coefficient (*C* value for hard glass is 4), *t* is the specimen thickness in milimeter, σ_1 is the major principal stress and σ_2 is the minor principal stress in MPa. In this research, because of only one axle stress applied, the equation (1) will be:

$$R = Ct\sigma \qquad (2)$$

2.2 Experiments

Sample testing conducted at the Laboratory of Geomechanics and Mine Equipment Institute of Technology Bandung. Testing of samples involved testing the physical properties and mechanical properties to obtain the sample characteristics, and fracture toughness mode I testing.

From physical properties test, obtained natural density of sample is 1.11 g/cm^3. From mechanical properties test, obtained the ultrasonic velocity of sample is 2513.52 m/s, UCS is 109.71 MPa, with Young's modulus (*E*) is 3049.95 MPa and Poisson’s ratio is 0.22, and tensile strength from Brazilian test is 27.16 MPa.

3. Results and Discussion

From this research, obtained results of stress distribution on Modified Ring Test (MRT) and Central Straight-Through Crack (CSCBD) using photoelastic method and numerical method, as shown in Table 3.

Table 1. Modified Ring Test (MRT) sample dimension

Dimension	Symbol	Value	Unit
Thickness	*B*	0.01	m
Width of loading surface	*b*	0.005	m
Specimen radius	r_o	0.012	m
Inner hole radius	r_i	0.00156 0.0024	m

Table 2. Central Straight-Through Crack (CSCBD) sample dimension

Dimension	Symbol	Value	Unit
Thickness	T	0.01	m
Specimen radius	R	0.012	m
Crack Length	2α	0.0096 0.012 0.0144	m

4. Conclusions

From this research, it could be concluded that the results of the stress distribution obtained from numerical modeling have similar results to the stress distribution obtained from photoelastic method, although there are slightly different results, but it still tolerable.

Table 3. stress distribution on Modified Ring Test (MRT) and Central Straight-Through Crack (CSCBD)

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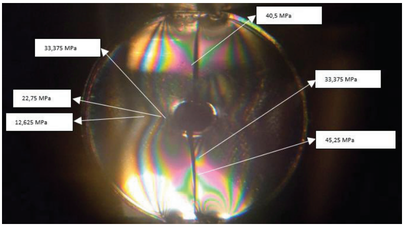
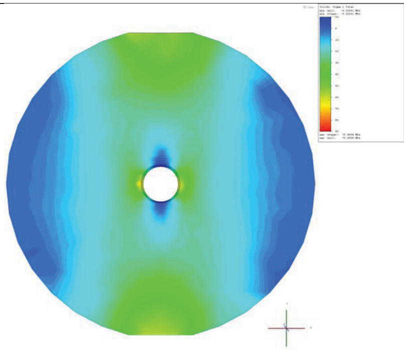
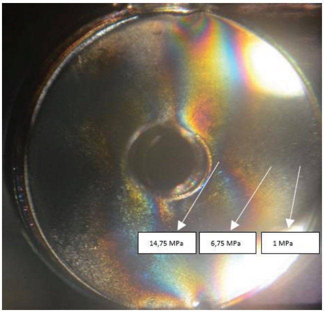
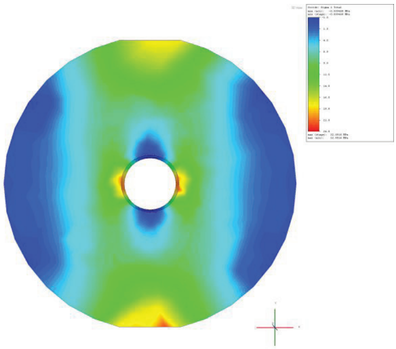
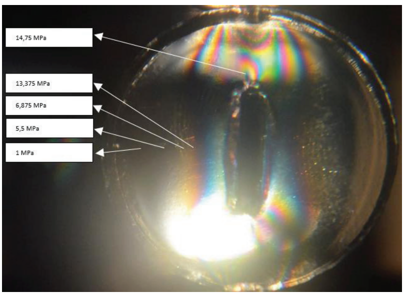
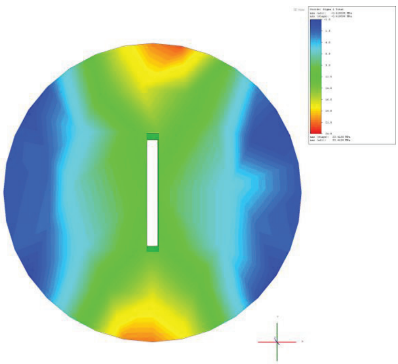
<tr><td>
</td><td></td></tr>
<tr><td>
</td><td></td></tr>
<tr><td>
</td><td></td></tr>
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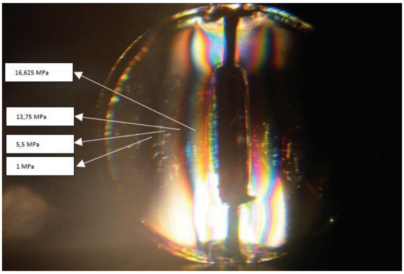

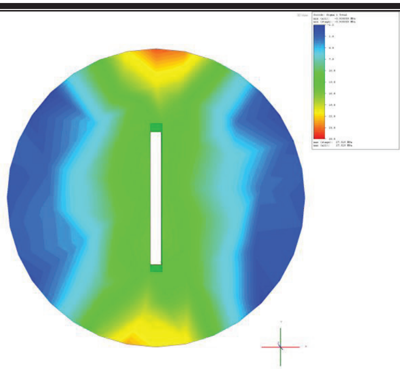

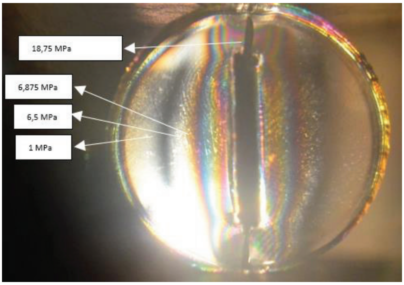

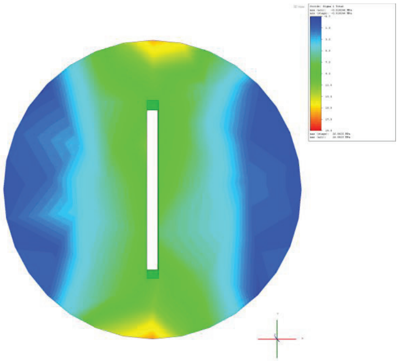

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