節理粗糙度係數與裂縫滲透率的相關性

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報告者：葉哲瑋

指導教授：董家鈞 老師

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摘要

本文使用一種新的建模方法來研究開放裂縫中的流體輸運，該方法依賴於從裂縫掃描表面獲得的數據，並考慮了兩個正交方向的表面變化和速度拉普拉斯運算子以及整體流動旋轉。模型預測通過使用 COMSOL™ 多物理場中可用的過程獲得的不可壓縮流動建模結果進行了驗證。該模型檢查了節理粗糙度係數（JRC）與裂縫滲透率之間的關係。提出了一種利用 JRC 和碎形維度（fractal dimension）再現裂縫的新方法。JRC 滲透率相關性在完全匹配的表面、在其平面內發生平移的表面和獨立表面上進行分析，以凸顯破裂面相對位移在流體輸運分析中的重要性。確定兩個平移表面可被視為獨立的平移閾值。結果表明，對於 0.1 mm 的孔徑尺寸，即使是 62.5 微米的平移對滲透率也有顯著影響，並且由於表面平移，滲透率先降低後增加；立方定律（Cubic law）一致的低估了中高 JRC（>10）對小孔徑（< 0.1 毫米）和獨立表面的滲透率。還討論了樣本量和接觸面積比的影響。所提出的模型是開發計算效率高、相當準確的模型的第一步，用於對應力斷裂網路的流體輸運特性進行統計分析。

關鍵字：滲透率、斷裂、節理粗糙度係數（JRC）、立方定律、尺度效應、碎形維度、統計分析

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Presenter：Che-Wei Yeh

Advisor：Prof. Jia-Jyun Dong

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Correlation of joint roughness coefficient and permeability of a fracture

S.M. Rezaei Niya*, A.P.S. Selvadurai

Department of Civil Engineering and Applied Mechanics, McGill University, 817 Sherbrooke West, Montreal, QC, Canada H3A 0C3

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ABSTRACT

This paper uses a new modeling approach to study fluid transport in an open fracture, which relies on data derived from scanned surfaces of fractures and considers surface variations and velocity Laplacians in two orthogonal directions and the bulk flow rotation. The model predictions are verified against the results for incompressible flow modeling obtained using the procedures available in COMSOL™ multiphysics. The model examines the relationship between the joint roughness coefficient (JRC) and permeability of a fracture. A new method is presented to reproduce the surfaces of the fracture using both JRC and the fractal dimension. The JRC-permeability correlation is analyzed in exactly mated surfaces, surfaces that have undergone translations in their plane and independent surfaces to highlight the importance of the relative displacement of fracture surfaces in fluid transport analysis. A shifting threshold from which two translated surfaces can be considered independent is determined. It is shown that even a 62.5-micron translation for an aperture size of 0.1 mm has a noticeable effect on the permeability, which first decreases and then increases because of surface translation; the cubic law consistently underestimates the permeability for small apertures (< 0.1 mm) and moderate to high JRCs (> 10) for independent surfaces. The effect of sample size and contact area ratios are also discussed. The presented model is a first step towards developing a computationally efficient, reasonably accurate model for statistical analysis of the fluid transport properties of a network of stressed fractures.