壓溶作用對岩體裂隙內寬與滲透率演變之模擬技術發展

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摘要

對於高放射性廢棄物最終處置場的設計，世界各國主要採用深地層處置概念以防止放射性核種外洩造成生物與環境危害。然而，處置母岩本身與受力產生之裂隙，為放射性核種外釋的主要通道。由於地層中的裂隙可能受到壓溶作用與自由面溶解的影響，使得裂隙內寬(Aperture)與滲透率發生變化，進而影響核種傳輸特性。因此，瞭解裂隙內寬與滲透率受到外在條件影響而隨時間發生之變化，有助於評估放射性核種外釋可能性，進而確保放射性廢棄物處置場之安全性。本研究藉多重物理量耦合分析軟體 COMSOL Multiphysics®建置二維水力-力學機制模型，將水-力數值模擬結果引入商業數學軟體 Matlab 中進行裂隙幾何變化計算，再將裂隙演變結果代回數值模式中進行迭代運算，以模擬花崗岩裂隙在受到壓溶作用與自由面溶解下，裂隙內寬隨時間的變化情形，並將探討在不同條件下，各參數對於裂隙內寬與滲透率變化的敏感度。初步研究顯示，透過將裂隙粗糙接觸點(Asperity)所承受之應力值帶入 Matlab 進行計算，模型得以成功於各時間點計算裂隙幾何變化情形。然而，本研究目前僅考慮裂隙受應力作用所產生的溶解，尚未考慮自由面溶解所造成的裂隙幾何變化，因此對於裂隙幾何隨時間之變化皆呈現閉合的情形。未來將同時考慮壓溶作用與自由面溶解作用之機制，以建置完整裂隙演變幾何模型，並期望能應用於現地的安全評估工作中。

關鍵字： 岩體裂隙內寬、壓溶作用、自由面溶解、滲透率、演變。

The development of simulation techniques for the evolution of fracture aperture and permeability in rock by Pressure solution

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Abstract

For the design of high-level radioactive waste disposal facilities, countries around the world primarily adopt the concept of deep geological disposal to prevent the leakage of radioactive nuclides that could harm living organisms and the environment. However, the rock mass itself and the fractures generated under stress serve as the main pathways for the release of radioactive nuclides. Fractures within the strata may be influenced by pressure dissolution and free-face dissolution, leading to changes in fracture aperture and permeability, which causes nuclide transport. Therefore, understanding how the aperture and permeability of fractures are affected by external conditions over time is crucial for assessing the potential for radioactive nuclide release and ensuring the safety of radioactive waste disposal sites. The study use COMSOL Multiphysics® to construct a two-dimensional hydro-mechanical model. The results of simulations are then incorporated into Matlab for calculations of fracture geometry changes. The evolution of fractures is iteratively fed back into the numerical model to simulate how the fracture aperture in granite changes over time under the influences of pressure dissolution and free-face dissolution. The sensitivity of various parameters affecting changes in fracture aperture and permeability under different conditions will also be explored. Preliminary research indicates that by inputting the stress values at the rough contact points (asperities) of the fractures into Matlab for calculations, the model successfully computes the geometric changes of the fractures at various time points. However, this study currently only considers the dissolution caused by stress, without accounting for geometric changes due to free-face dissolution, resulting in a closure of the fractures over time.

Keywords: Rock fracture aperture, Pressure solution, Free-face dissolution, Permeability, Evolution.