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Analysis of the Pore Structure of Compacted Salt Material Based on the Measurement of Hydraulic Properties

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Abstract

This study presents an experimental analysis on the hydraulic properties – porosity, absolute permeability, capillary pressure, effective gas and brine permeabilities – of artificially-compacted sodium chloride granulates as the model backfill material in hazardous waste repositories placed in rock salt. The hydraulic properties are measured by standard core analysis techniques on the compacted plugs. A modified procedure is applied for the evaluation of restored-state capillary pressure data including deformation effect.

The porosity-permeability correlation classifies the model saliferous backfill material as a coarse-grained rock type. However the tortuosity values with 3-4, derived from the Klinkenberg slip factor for gases, exceed by far the tortuosity of coarse-grained sediments of 1.5-2. From this observation and measured capillary-pressure functions, a grain boundary-matrix interconnected 3-D flow network model is derived.

The laboratory experiments show transient effects in gas flow through the partially-saturated compacted backfill material. The transient change of the end-point values of effective permeabilities in the long term experiments can only be explained by a saturation redistribution in the boundary-matrix network of pore structure. With this grain boundary model the transient effects on effective gas and brine permeabilities can be interpreted. The ductile mechanical behavior of the composite salt core is characterized by a steady-state creep rate, determined from the experiments. Drainage relative permeability functions for long term safety analysis in repositories are correlated from end-point measurements with the Corey-Brooks, van Genuchten-Mualem models.

1. Introduction

Radioactive wastes produced from power plants, research institutes, industry and medicine have to be stored in a final repository to seal them off from the biosphere. The geological repositories are currently a preferred solution for disposal and there have been many investigations made on salt, granite, clay, sedimentary, basalt, and tuff formations as a geological barrier. Among these possibilities many countries have focussed on the salt and granite rocks because of sealing properties and tightness[1-7].

Salt formations had been considered as suitable repository media because they were assumed impervious to fluids[1]. This assumption was probably motivated by the satisfactory performance of existing hydrocarbon storage as well as by the self-healing capacity of salt due to viscoplastic deformation of the grains, causing the closure of cracks and pores. However, laboratory and field investigations[8-11] performed in the early 90s show that rock salt may have a very low but measurable permeability (in the range of 10^{-15} to 10^{-21} m^2) under two conditions: (a) mechanical damage near excavated openings due to deviatoric stresses creating micro-cracks and/or opening discontinuities, (b) in the presence of impurities (usually anhydrite) that may become preferential pathways for fluid flow. The first effect explains why the zone surrounding an underground storage in rock salt modifies the hydraulic properties. Within this so-called disturbed rock zone (DRZ) around underground facilities, rock salt dilates and its pore volume increases. As a consequence, its pore pressure decreases, resulting in a reduction in liquid saturation and an increase in permeability of the rock salt. Therefore, it is important to investigate the mechanical and transport properties of rock salt for the long term safety assessment of stor-