Geomechanical Characterisation and Long-term Emplacement room Stability Analysis, Ontario Power Generation's proposed Deep Geologic Repository, Tiverton, Ontario

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Introduction

The Nuclear Waste Management Organization (NWMO) is conducting geoscientific investigations as part of an on-going Environmental Assessment for development of a Deep Geologic Repository for Ontario Power Generation's Low and Intermediate Level Radioactive Waste at the Bruce nuclear site, located near Tiverton, Ontario. The Bruce nuclear site is situated on the eastern flank of the Michigan Basin and is underlain by an 840 m thick Paleozoic sequence of near horizontally bedded dolostones, limestones, shales, evaporites and minor sandstones of Cambrian to Devonian age. As envisioned, the DGR would be excavated within the Cobourg Formation, a nominal 28 m thick argillaceous limestone formation at a depth of 680 m below ground surface. An important and unique aspect of the DGR is the assessment of long-term stability of the host and enclosing bedrock formations. This paper describes the geoscientific program as it relates to the derivation of geomechanical properties and characteristics, and numerical simulations performed to understand long-term formation stability and barrier integrity.

Geomechanical Characterisation

As part of the Geoscientific Site Characterisation Plan (GSCP) for the DGR, initiated in fall 2006, six deep boreholes have been drilled and cored through the sedimentary sequence (Intera, 2006; 2008). As described in the GSCP an extensive geomechanics investigation program was undertaken to study the strength, deformation and petrophysical properties of rock. The program was also designed to explore the time dependent behaviour of the rock mass hosting and enclosing the repository, and formation specific constraints on stress orientation and magnitude through the sequence using wellbore stability observations.

The Cobourg Formation beneath the Bruce nuclear site is a massive and competent unit with very high RQD and sub-vertical/vertical fracture spacing that exceeds ten meters. Table 1 summarized the results of over 50 laboratory tests in terms of their mean and standard deviation values and the estimated horizontal in-situ stresses for the Cobourg Formation.

Parameter	Mean	Std. Deviation
Peak Uniaxial Compressive Strength (UCS)	114MPa	24MPa
Crack Initiation Stress	0.40UCS	0.10UCS
Crack Damage Stress	0.86UCS	0.23UCS
Modulus of Elasticity	39GPa	8.5 GPa
Poisson's Ratio	0.30	0.08
Long-term UCS Peak Strength	124MPa	25MPa
Maximum Horizontal Stress (σ_H) Ratio	$1.5<\sigma_H/\sigma_v<2.0$	
Minimum Horizontal Stress (σ_h) Ratio	$1.0<\sigma_h/\sigma_v<1.2$	

Table 1 Cobourg Formation: Best Estimate Geomechanical Parameters

These data and studies have provided a basis to proceed with numerical simulations of emplacement room stability under various loading scenarios (i.e. glacial, seismic, gas pressure). One of the challenges in the stability analysis was the estimation of the long-term strength of the rock. Martin and Chandler (1994) have shown that the crack damage and the crack initiation stress values are inherent properties of the rock. The laboratory test results reveal that the crack initiation stresses for the Cobourg argillaceous limestone were very consistent at about 40% of the peak Uniaxial Compression Strength (Figure 1). Because the crack initiation stress marks the onset of axial crack growth and is the lowest bound threshold of rock strength, it was conservatively selected as the long-term strength used in the assessment of underground stability for a very long time frame. Special designed Long-term strength-degradation tests were conducted on Cobourg rock samples to verify this limit.

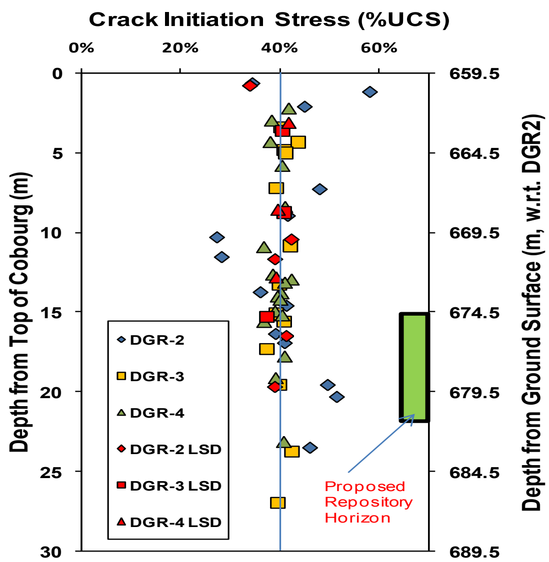

Figure 1 Crack Initiation Stress of Cobourg Formation

Numerical Simulation: Long-term Emplacement Room Stability

A comprehensive suite of short-term and long-term stability analyses for the emplacement caverns was performed employing UDEC and Phase^2 codes for discrete and continuum media. These numerical simulations are to test the repository design and the integrity of the barrier shale overlying the Cobourg Formation considering different loads and conditions including, in-situ stresses, long-term strength degradation, pore pressure, gas generation, seismic loading and sequential glacial episodes. Based on the interim analysis results, the caverns will be stable during construction and operation, requiring standard support. They will gradually degrade over next 60,000 years until the long-term strength is reached and when the next glacial cycle is expected to occur. Each cycle of glacial loading will create an additional increment of damage and pillar degradation until the complete loss of pillar load-bearing capacity predicted after several glacial periods. Damage and failure will propagate throughout the pillars and 8 to10 metres into the roof. The fractured rock mass will eventually degrade and accumulate inside the emplacement caverns. The accumulated rubble will bulk completely filling the cavern. Further collapse will be prevented and the cavern will stabilize without damaging the barrier shale cap rock above the limestone host rock formation.

References

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