TIME-DEPENDENT DEFORMATION AND PROPERTIES OF QUEENSTON SHALE

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BACKGROUND INFORMATION

- Queenston shale is the cap rock located above a limestone layer in Queenston, Ontario.
- Overlays a potential long-term low and intermediate level radioactive waste depository.
- Site is geologically stable and has simple geometry.
- Important attention is provided to the time-dependent deformation (swelling) of Queenston shale.
- This shale undergoes anisotropic swelling strain: it does not have the same swelling potential in all directions (Le and Lo 1990).
- According to research by Le and Lo, swelling will occur if:
  - ➢ The initial stresses are relieved: initiating mechanism
  - ➢ Shale comes in contact with water
  - ➢ There is a concentration gradient between the pore and ambient fluid

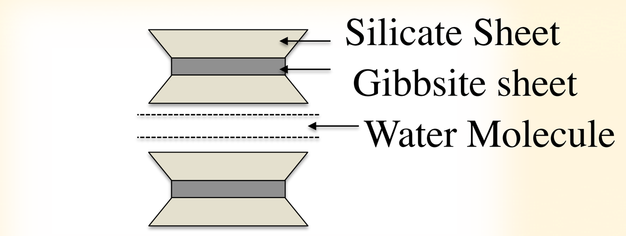


Figure 1: Schematic drawing of Montmorillonite

OBJECTIVES

Material Characterization of Queenston Shale

Physical
- Density
- Porosity
- Thermal Expansion
- Swelling
- Thermal Conductivity

Mechanical
- Elasticity Parameters
- Compressive Strength
- Indirect Tensile Strength

Chemical
- Chemical Composition
- Distribution of Minerals

METHODOLOGY - UCS

1) Strain Gauge Installation

2) Connect sample to MTS machine and external computer DAQ system

3) Set up data collection on MTS and external computer

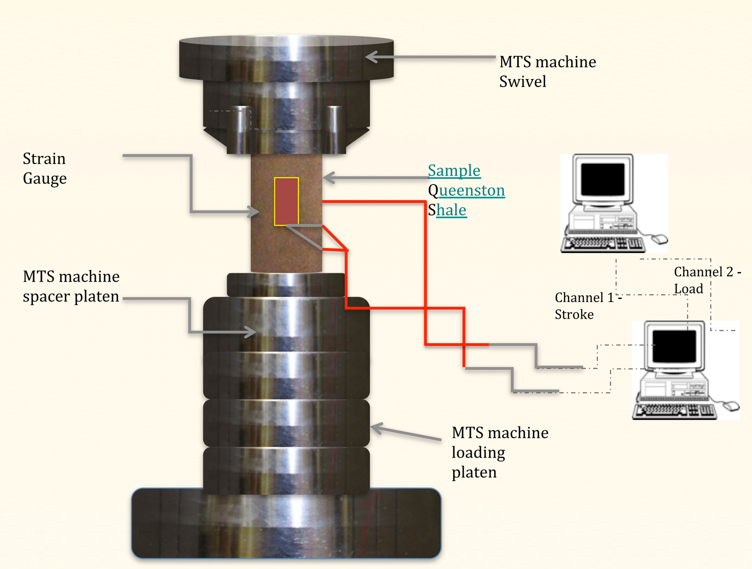


Figure 2: Schematic representation of UCS set-up

Figure 3: Set up for brazilian test

METHODOLOGY CONT.

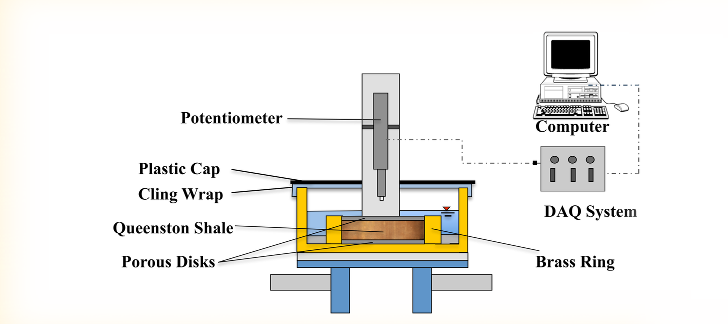


Figure 4: Schematic drawing of experiment setup for swelling test in the oedometer

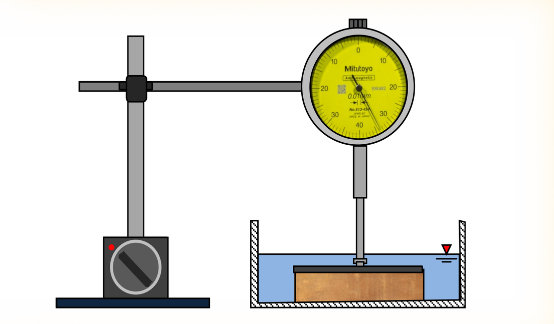


Figure 5: A schematic drawing of the free-swelling test

RESULTS - SWELLING

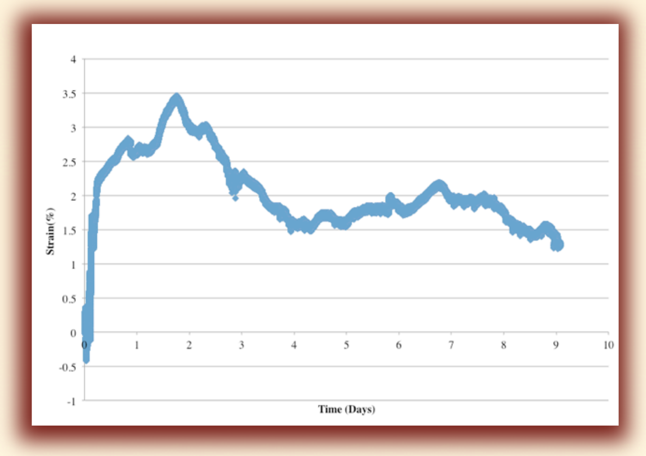


Figure 6: Swelling strain (%) versus time (days) of Queenston shale in oedometer test for 10 days (radial constrained)

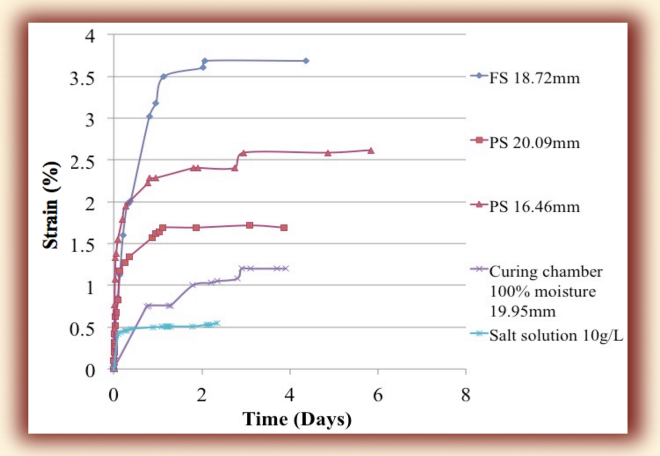


Figure 7: Free-swelling test fully submerged, partially submerged, saline solution and 100% moisture

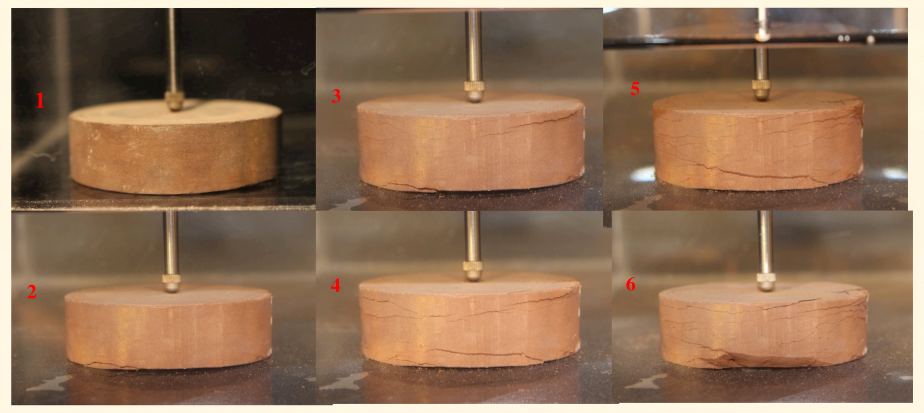


Figure 8: Disintegration of Queenston Shale in distilled water

RESULTS - BET

GAS ADSORPTION THEORY

- Consequence of surface energy.
- Atoms on the surface of a solid are not fully bound to surrounding atoms.
- They will attract other atoms to balance their charge.
- Determine surface area, porosity, pore sizes and pore distributions.

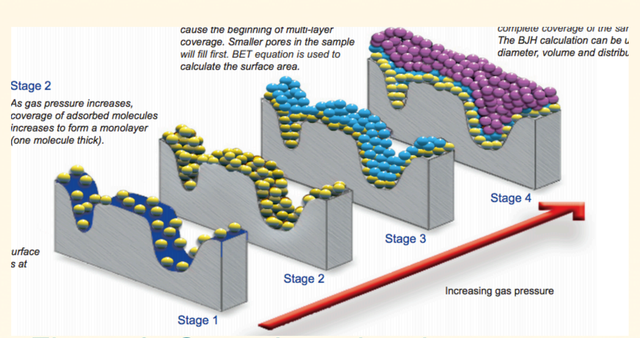


Figure 9: Gas adsorption theory

Figure 10: TriStar II analyzer

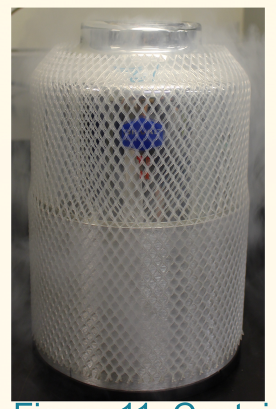


Figure 11: Container of Nitrogen

METHODOLOGY

- Place sample inside tube
- Place sample inside liquid nitrogen to keep temperature cool (-200**°C**)
- Clear tube of any air
- Pressurize sample with Liquid Nitrogen and Helium
- Measure data

Porosity $= \dfrac{\left[\left(\text{BJH Adsorption Cumulative Volume of Pores }\left(\frac{ml}{g}\right)\right)(\text{Sample Weight }(g))\right]}{\left(\frac{1}{\text{Sample Density }\left(\frac{g}{ml}\right)}\right)(\text{Sample Weight }(g))}$

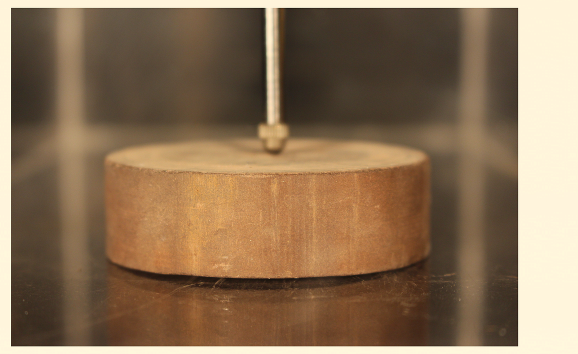
RESULTS - CHARACTERIZATION

Table 1: Summary of Basic Properties from Literature and Tests

Properties	Values from Literature	Values from Tests	
Porosity	6.60% ±0.5	BET	8.21%
		Water saturation	6.53%
Water Content	2.60%	1.69%	
Unit Weight	26.70KN/m^3	26.72 KN/m^3	
Specific Gravity	2.82	2.71	
Modulus of Elasticity	15GPa	21GPa	
Compressive Strength	44MPa	66MPa	
Poisson's Ratio	0.1-0.5	0.2	
Splitting Tensile Strength	10 MPa	4.2MPa	

Table 2: Mineral Composition of Queenston Shale from XRD test

Compound Name	Percentage (%)		
		Calcite	2.5
Quartz	41.7	Muscovite	27.7
Albite	8.6	Hematite	1.6
Microcline	3.2	Dolomite	0.4
Clinochlore (Chlorite)	14.4	Total	100.1



RESULTS – UCS & BRAZILIAN

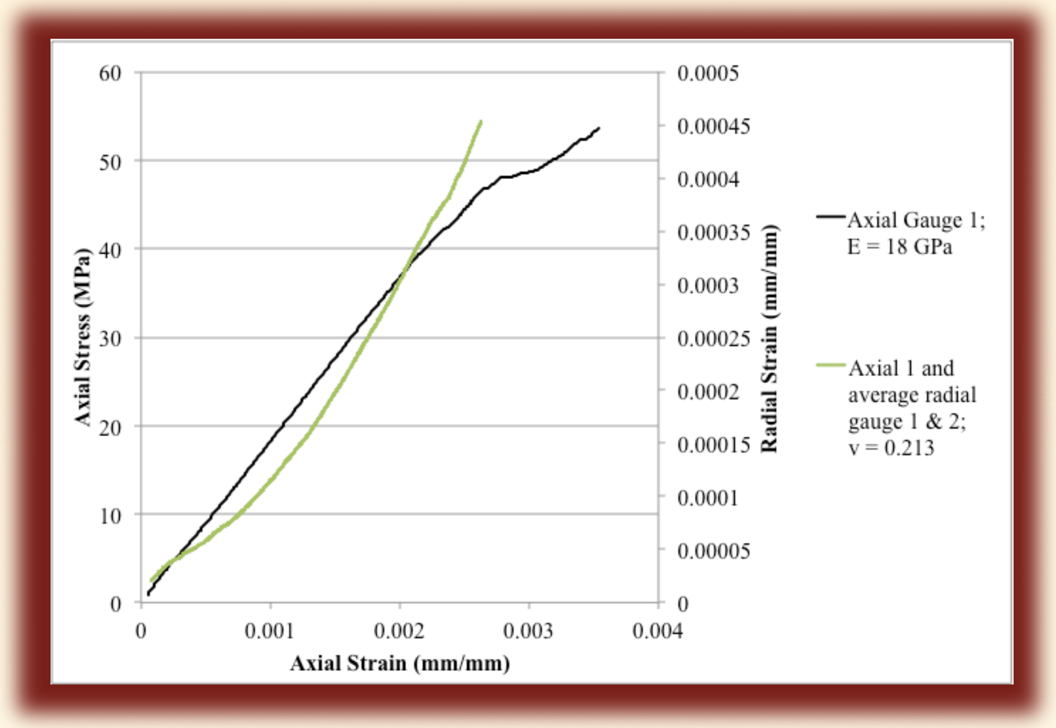


Figure 12: The loading of Queenston shale used to determine modulus of elasticity (E) and poisson's ratio (v), Test #1

Figure 13: Post-failure Test #1

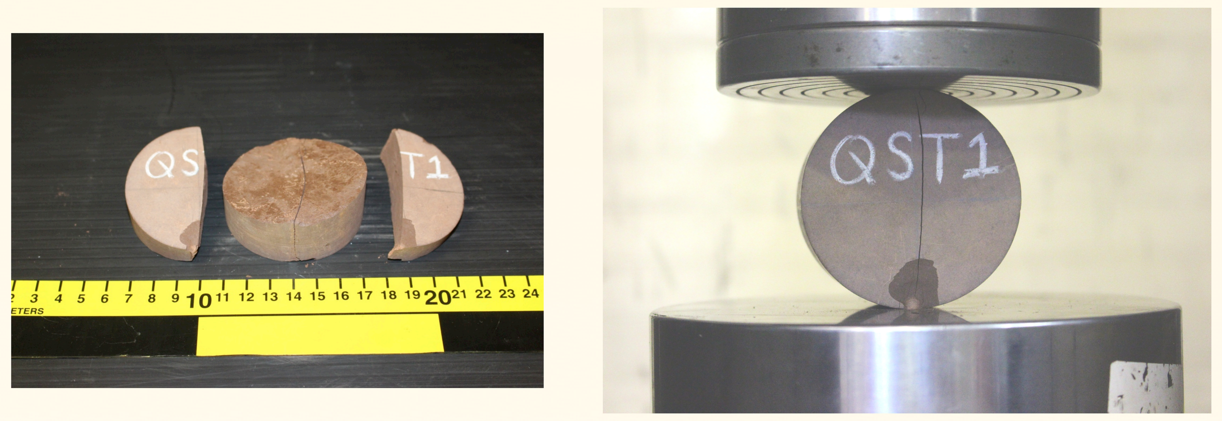


Figure 14: Post-failure Brazilian

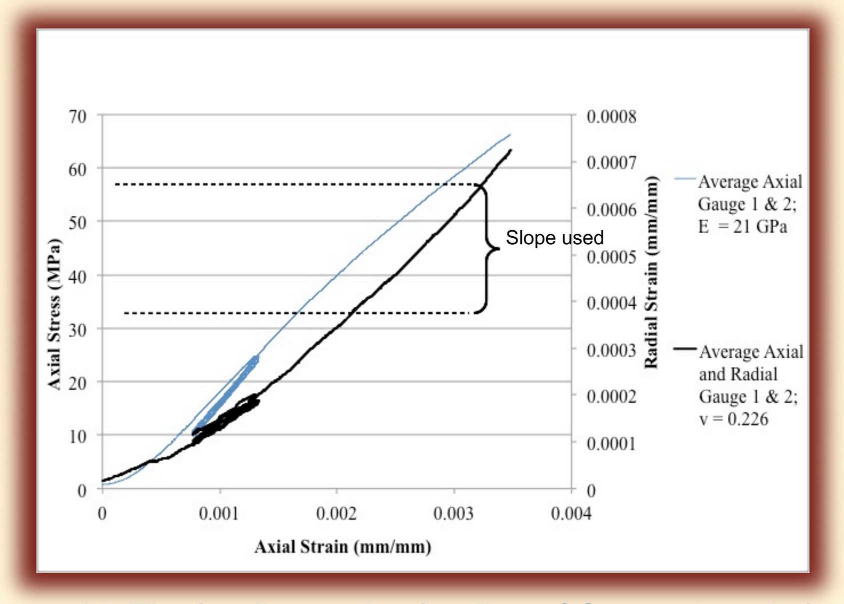


Figure 15: The loading and unloading of Queenston shale used to determine modulus of elasticity (E) and poisson's ratio (v), Test #2

Figure 16: Post-failure sample

CONCLUSION

SWELLING

- Problem with oedometer test: moisture not accessible in radial direction
- Salt water test has same initial swelling rate as fully submerged test
- The ambient fluid greatly affects the swelling potential
- Increase in pH of ambient fluid demonstrates increase in cations
- Concentration gradient between pore and ambient fluid should be monitored at the project site

STRENGTH

- Loading and unloading method increases the strength of the material
- Since swelling causes crack formation, contact with water greatly reduces the strength of Queenston shale
- The shale has a much weaker tensile strength than compressive

FUTURE DIRECTIONS

- Many variables that affect the swelling behavior of Queenston shale.
- Ambient fluid and loads from different orientations.
- Leads to measurement of swelling pressure.
- Also three-dimensional time-dependent deformations and volumetric strain
- Set up a standard experiment to investigate these relationships.

REFERENCES

1. P.Vilks and N.H. Miller. (2007). "Evaluation of Experimental Protocols for Characterizing Diffusion in Sedimentary Rocks." NWMO TR-2007-11.
2. Lo, K. Y. and Y. N. Lee (1990). "Time-dependent deformation behaviour of Queenston shale." Canadian Geotechnical Journal 27(4): 461-471.
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