OBJECTIVES OF LARGE-SCALE IN SITU TESTING

- EXAMINE M-H-T INTERACTIONS
- GAIN EXPERIENCE IN EVALUATING ROCK BOUNDARY CONDITIONS AND INSTALLATION AND PERFORMANCE OF INSTRUMENTS AND LARGE VOLUMES OF SEALING MATERIALS
- EVALUATE MATHEMATICAL MODELS AGAINST OBSERVED BEHAVIOUR
<table>
<thead>
<tr>
<th>STRAP PHASE</th>
<th>ISSUES ADDRESSED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1</td>
<td></td>
</tr>
</tbody>
</table>
| (1980 to 1985) | * Borehole drilling  
|              |   * Buffer swelling  
|              |   * Buffer K & α  
|              |   * Clay longevity  
|              | * Hygro-thermo-mechanical properties of buffer & backfill  
|              | * Buffer/backfill/rock interactions  |
| Phase 2     |                  |
| (1985 to 1988) | * Borehole sealing  
|              |   * Shaft & tunnel plugs  
|              |   * Isothermal water uptake by clay barriers  
|              |   * Bentonite extrusion  
|              | * Water uptake by bentonite  
|              | * Hydro-mechanical interactions between clay/concrete/rock  |
| Phase 3     |                  |
| (1988 to 1992) | Grouting:  
|              |   * fracture zones  
|              |   * moderately fractured rock  
|              |   * excavation disturbed zones  
|              | * Clay & cement grouts:  
|              |   * rheology  
|              |   * sealing properties  
|              |   * longevity  
|              | * Water flow in grouted rock  
|              | * Grout penetration  
|              | * Rock movement  
|              | * Cement longevity  
|              | * Limits of sealing by grouting  
|              | * Morphology of injected grouts  
|              | * Effects of heat on grouted rock  |
## In Situ Hydraulic Conductivity Test Results

### URL Shaft

<table>
<thead>
<tr>
<th>Property</th>
<th>GH1</th>
<th>GH2</th>
<th>HC9</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
</tr>
<tr>
<td>Transmissivity (m²/s)</td>
<td>3.2*10⁻⁷</td>
<td>1.0*10⁻⁸</td>
<td>4.2*10⁻⁷</td>
</tr>
<tr>
<td>Equivalent single fracture aperture (µm)</td>
<td>83.4</td>
<td>26.3</td>
<td>91.2</td>
</tr>
<tr>
<td>Hydraulic conductivity (m/s)</td>
<td>4.0*10⁻⁸</td>
<td>1.2*10⁻⁹</td>
<td>7.0*10⁻⁸</td>
</tr>
</tbody>
</table>

Notes: 1. Hydraulic conductivity is calculated using the total thicknesses of the fracture zone observed in the drillhole logs.
"SHOT-CLAY", WHAT IS IT?

A Pneumatically Placed Bentonite or Bentonite/Aggregate Material

Purposes:

- To fill cracks or voids not occupied by blocks
- To create a dense, level base for block placement
- Create tight contact with walls, roof
- can be trimmed as required
- To create a uniform, relatively low permeability wetting surface
"SHOT - CLAY" EXPERIENCE

Trial:
Clay - Aggregate mixtures placed using shotcreting technology.

Results:
Various mixtures of bentonite and aggregate were successfully placed

Materials: 25% to 70% Bentonite

- Bulk Densities: 1.6 to 1.8 Mg/m³
- Dry Densities: 1.3 to 1.5 Mg/m³
- Clay Densities: 0.5 to >0.8 Mg/m³

AECL, Tunnel Sealing Experiment 9/9/96
“SHOT - CLAY”

Material Properties Expected

Hydraulic Conductivity:

<table>
<thead>
<tr>
<th>Material</th>
<th>Hydraulic Conductivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shot-Clay</td>
<td>$5 \times 10^{-12}$ to $1 \times 10^{-10}$ m/s</td>
</tr>
<tr>
<td>Bulk Seal</td>
<td>$1 \times 10^{-12}$ to $1 \times 10^{-13}$ m/s</td>
</tr>
</tbody>
</table>

Swelling Pressure:

<table>
<thead>
<tr>
<th>Material</th>
<th>Swelling Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shot-Clay Kunigel VI</td>
<td>$&lt; 200$ kPa</td>
</tr>
<tr>
<td>Wyoming Material</td>
<td>$&lt; 600$ kPa</td>
</tr>
<tr>
<td>Bulk Seal Kunigel VI</td>
<td>$&gt; 600$ kPa</td>
</tr>
<tr>
<td>Wyoming Material</td>
<td>$&gt; 6000$ kPa</td>
</tr>
</tbody>
</table>
GRANULAR BACKFILL

- CEC STUDY (1) HAS DEMONSTRATED PREPARATION OF A GRANULAR BACKFILL OF HIGH DENSITY PELLETS MIXED WITH CLAY POWDER

- EMBLACED DENSITY OF 1.7 Mg/m³ ACHIEVED, WITH k OF $10^{-11}$ m/s

(1) G. Volckaert et al. (1995)
W & D 95/66/C072052/FB/mvo/P-27
Bulwark

Upper tunnel backfill (20% bentonite, 80% sand)

Lower tunnel backfill (10% bentonite, 90% sand)

Concrete cap

Boxing out filled with bentonite/ sand backfill

Concrete slab

Heater holes

The Buffer Mass Test
OBJECTIVES OF BUFFER-CONTAINER EXPERIMENT

EVALUATE

◆ THERMAL CONDUCTIVITY AND TEMPERATURE DISTRIBUTIONS

◆ SWELLING CRACKING AND SELF-HEALING OF BUFFER

◆ MODELS AGAINST OBSERVATIONS
Buffer/Container Experiment

Dimensions in mm:
- 1240
- 5750
- 4600
- 5000

Parts:
- Restraint Columns
- Cell Cap
- Concrete Slab
- Backfill
- Sand
- Heater
- Buffer

AECL
INSTRUMENTATION IN BUFFER-CONTAINER EXPERIMENT

- THERMOCOUPLES
- THERMISTORS
- EARTH PRESSURE CELLS
- PSYCHROMETERS
- THERMAL NEEDLES
- PIEZOMETERS
Temperatures Along Buffer Centre And On Heater Surface

Start Of Heating
$t = 0$

$t = 0.1 \text{ yr.}$

$t = 1 \text{ yr.}$

$t = 2.5 \text{ yrs.}$
Buffer

Sand

Heater

> 23%

Increasing $w$

18% (As-placed $w$)

Decreasing $w$

< 11%

Moisture Content Distribution In The Buffer/Container Experiment After 30 Months
Interpretation of water content changes measured by psychrometers and thermal needles in the Buffer/Container Experiment

Water content change (%)

-4 -3 -2 -1 0 1 2 3 4

Day 0  Day 50  Day 100  Day 200  Day 400  Day 525

0m  1m  2m  3m  4m  5m

[Diagram showing water content changes over different depths and days]
Comparison of water content distributions in the Buffer/Container Experiment

(a) End-of-test water content distribution at Day 897.
(b) Best interpretation of water content distribution measured by psychrometers and thermal needles at Day 525.
Range Observed For Fresh Materials

Specimens Recovered from BC-EX

EFFECTIVE CLAY DRY DENSITY, (Mg/m^3)
EFFECTIVE CLAY DRY DENSITY, (Mg/m$^3$)

SWELLING PRESSURE, (kPa)

- Best-Fit Line For Intact Specimens
- Range Observed For Intact Specimens
- Cracked/Slotted Specimens
- BCEX Specimens
EDZ SEALING REQUIREMENTS

- SITE AND DESIGN DEPENDENT; OVERALL SYSTEM PERFORMANCE WILL DETERMINE THE SPECIFIC SEAL SYSTEM PERFORMANCE REQUIREMENT

- EXTENT OF EXCAVATION DAMAGE CAN BE REDUCED BY
  - CONTROLLED BLASTING
  - OPTIMIZING EXCAVATION SHAPE AND ORIENTATION

- SIGNIFICANCE OF THE EDZ CAN BE REDUCED BY
  - SEALING THE EDZ TO ITS PRACTICAL LIMIT
  - USING IN-ROOM EMPLACEMENT TO ENSURE CONTAMINANTS GO THROUGH BACKFILL

- IT IS POSSIBLE THAT EVEN IF PERFORMANCE ASSESSMENT SUGGESTS NO ADVERSE EFFECTS FROM AN UNSEALED EDZ, A DECISION MAY BE MADE TO SEAL IT
THE TUNNEL SEALING EXPERIMENT

Keyed Concrete Bulkhead

Water Distribution Header Embedded in Sand

Keyed Highly-Compacted Clay-block Bulkhead

Steel Support

Heater

Pump

Room Profile Shaped to Accommodate Stress Field
Use of compacted bentonite plugs has been demonstrated for sealing of exploration boreholes.
Copper Tube with Bentonite for Borehole Sealing