Pressuremeter testing in Ruritania

A compilation of the results of ten tests in a variety of materials, selected to show what can be derived from careful pressuremeter testing

Reference: CIR 2001/11

Part 2 Full results and plots
A list of tests in this borehole

<table>
<thead>
<tr>
<th>Code</th>
<th>Date</th>
<th>Depth</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1T1</td>
<td>01/04/06</td>
<td>5.0m</td>
<td>Brown Clay</td>
</tr>
<tr>
<td>B1T2</td>
<td>05/04/06</td>
<td>6.1m</td>
<td>Clay and gravel</td>
</tr>
<tr>
<td>B1T3</td>
<td>05/04/06</td>
<td>8.0m</td>
<td>Clay and gravel</td>
</tr>
<tr>
<td>B1T4</td>
<td>07/04/06</td>
<td>10.0m</td>
<td>Coarse sand</td>
</tr>
<tr>
<td>B1T5</td>
<td>08/04/06</td>
<td>20.0m</td>
<td>Grey Clay</td>
</tr>
<tr>
<td>B1T6</td>
<td>10/04/06</td>
<td>25.0m</td>
<td>Grey Clay</td>
</tr>
<tr>
<td>B1T7</td>
<td>12/04/06</td>
<td>37.5m</td>
<td>Silty sand</td>
</tr>
<tr>
<td>B1T8</td>
<td>07/05/06</td>
<td>50.8m</td>
<td>Chalk (with flints)</td>
</tr>
<tr>
<td>B1T9</td>
<td>10/05/06</td>
<td>67.6m</td>
<td>Limestone</td>
</tr>
<tr>
<td>B1T10</td>
<td>11/05/06</td>
<td>80.4m</td>
<td>Phyllite</td>
</tr>
</tbody>
</table>
B1T1  01/04/06    5.0m    Brown Clay

1. Test record sheet
2. Results summary
3. Plot of expansion versus pressure – all arms
4. Plot of expansion versus pressure – arm average
5. Plot of all pressure cells versus time
6. Plot of Marsland and Randolph procedure
7. Gibson and Anderson plot, giving Cu and $P_L$ from loading curve
8. Jefferies plot, giving Cu from unloading curve
9. Plot of Reload Loop 1, with linear modulus line
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11. Plot of Reload Loop 3, with linear modulus line
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13. Ditto for Loop 2
14. And again for Loop 3
15. Plot of Shear modulus versus Shear strain for all reload loops
16. Plot of strain versus pressure, with computed curve and field data
# SITE

<table>
<thead>
<tr>
<th>SITE</th>
<th>DATE</th>
<th>DAY</th>
<th>BOREHOLE</th>
<th>TEST</th>
<th>Depth to test centre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ruritania</td>
<td>1-6-98</td>
<td>Fri</td>
<td>1</td>
<td>1</td>
<td>5-0-14</td>
</tr>
</tbody>
</table>

# MATERIAL

- **Brown Clay**
- **Site Weather:** Sunny

# Water Table

<table>
<thead>
<tr>
<th>Water Table</th>
<th>Drilling Start</th>
<th>Drilling End</th>
<th>Distance</th>
<th>Drill rate</th>
<th>Ram Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11:15</td>
<td>16:25</td>
<td>1.25</td>
<td>60 rpm</td>
<td>Low</td>
</tr>
</tbody>
</table>

# Orientation

<table>
<thead>
<tr>
<th>Water Press.</th>
<th>Probe Dia.</th>
<th>Shoe Dia.</th>
<th>Drill Bit</th>
<th>Bit Location</th>
<th>Probe Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>88 mm</td>
<td>88 mm</td>
<td>79 RBD</td>
<td>Flush</td>
<td>M6 x 60CA</td>
</tr>
</tbody>
</table>

# Strain Rate & Cycle Time

- **Strain Rate:** 1*5
- **Press. Rate:** 3 (L)
- **Cycle Time:** 5.2625
- **Gas Bottle:** 360 psi
- **Battery V:** 12.06
- **PPC Type:** PUC F
- **Mix. Press.:** 1psi

**TRANSDUCER DETAILS**

<table>
<thead>
<tr>
<th>Transducer</th>
<th>ARM 1</th>
<th>ARM 2</th>
<th>ARM 3</th>
<th>TPC</th>
<th>PPC A</th>
<th>PPC B</th>
</tr>
</thead>
<tbody>
<tr>
<td>GL Zero</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test Depth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test Start Time</th>
<th>Test End Time</th>
<th>Mix Pressure Reached</th>
<th>Disk Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>18:40</td>
<td>22:17</td>
<td>360 kPa</td>
<td></td>
</tr>
</tbody>
</table>

**TEST NOTES**

<table>
<thead>
<tr>
<th>Line No.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>47</td>
<td>Rate 4 - A bit slow</td>
</tr>
<tr>
<td>67</td>
<td>Arm 1 running - Arm 2 soon after</td>
</tr>
<tr>
<td>135</td>
<td>Arm 2 running</td>
</tr>
<tr>
<td></td>
<td>3cm on mix! Switch to up</td>
</tr>
<tr>
<td></td>
<td>Back to rate 6</td>
</tr>
<tr>
<td>167</td>
<td>Mix 3 up 10</td>
</tr>
<tr>
<td>454</td>
<td>Mix 3 up 10 - Rate 4 for slow</td>
</tr>
<tr>
<td>325</td>
<td>Mix 3 up 10 - Ditto - bigger curve</td>
</tr>
<tr>
<td>360</td>
<td>2 1/2 / min - Slip dropping away</td>
</tr>
<tr>
<td>435</td>
<td>Down - Rate 4 - Arm 2 near maximum</td>
</tr>
</tbody>
</table>

**Test Engineer:** Miguel

**Driller:** Miguel

**Membrane Correction:**

- **Membrane Compression:**
  - C0306 T2
  - C0306 T1

**Arm Cals Ref.:**

- 20-12-05

**Pressure Cals Ref.:**

- 20-12-05

**GENERAL COMMENTS:**

- **START A BIT SLOW - Work setting on sec. OK AFTER THAT.**
Site: Ruritania
Test: B1T1
Test Date: 1st April 2006
Material: Brown clay
Depth: 5.0 mtrs
Water table: ~11 mtrs

Analysis of Insitu Lateral Stress (Po):

<table>
<thead>
<tr>
<th>Method</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marsland and Randolph</td>
<td>75 kPa</td>
</tr>
<tr>
<td>Zero offset</td>
<td>0.05 mm</td>
</tr>
</tbody>
</table>

Analysis of Undrained Shear Strength (Cu):

<table>
<thead>
<tr>
<th>Method</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gibson and Anderson</td>
<td>80 kPa</td>
</tr>
<tr>
<td>Pressure at failure (P_F)</td>
<td>102 kPa</td>
</tr>
<tr>
<td>Limit Pressure (P_L)</td>
<td>505 kPa</td>
</tr>
<tr>
<td>Jefferies (unloading)</td>
<td>48 kPa</td>
</tr>
</tbody>
</table>

Analysis of Shear Modulus (G):

<table>
<thead>
<tr>
<th>Method</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Modulus (G_i)</td>
<td>17.0 MPa</td>
</tr>
</tbody>
</table>

Linear Analysis of Reload Loops (G_R):

<table>
<thead>
<tr>
<th>Loop</th>
<th>G_R MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.4</td>
</tr>
<tr>
<td>2</td>
<td>9.6</td>
</tr>
<tr>
<td>3</td>
<td>10.2</td>
</tr>
</tbody>
</table>

Non-linear Analysis of Reloading data:

<table>
<thead>
<tr>
<th>Method</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>α</td>
<td>0.87 MPa</td>
</tr>
<tr>
<td>β</td>
<td>0.597</td>
</tr>
</tbody>
</table>

Shear Modulus G_S (at 3 levels of shear strain):

<table>
<thead>
<tr>
<th>Strain (%)</th>
<th>G_S MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01%</td>
<td>36</td>
</tr>
<tr>
<td>0.1%</td>
<td>14</td>
</tr>
<tr>
<td>1%</td>
<td>5.6</td>
</tr>
</tbody>
</table>

Curve matching procedure:

<table>
<thead>
<tr>
<th>Method</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Po</td>
<td>106 kPa</td>
</tr>
<tr>
<td>O/s</td>
<td>1.13 mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Method</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu</td>
<td>49 kPa</td>
</tr>
<tr>
<td>P_L</td>
<td>462 kPa</td>
</tr>
</tbody>
</table>

Test Analysed By: PGH
Date: April 2006

Weak Rock Self-boring Pressuremeter Tests
Typical tests in a borehole

Cambridge Insitu Ltd
March 2011
RESULTS:
Cu: 48.2 kPa

Digital 3 arm weak rock self boring pressuremeter
B111
5.00 Metres
7 Apr 06
RESULTS:
Gur : 9.6MPa
Cycle mid-point:
Cavity strain : 3.109%
Total stress : 203kPa
Size of cycle:
Shear strain : 1.221%
Total stress : 118kPa
Digital 3 arm weak rock self boring pressuremeter
B1T1
5.00 Metres
7 Apr 06

RESULTS:
Gradient (beta): 0.597
Intercept (n): 1.465MPa
Shear stress constant: 0.875MPa
Digital 3 arm weak rock self boring pressuremeter B1T1
5.00 Metres
7 Apr 06
RESULTS:
Gradient (\(\beta\)) : 0.605
Intercept \((n)\) : 1.716 MPa
Shear stress constant : 1.038 MPa
Digital 3 arm weak rock self boring pressuremeter B1T1
5.00 Metres
7 Apr 06
RESULTS:
Gradient (beta): 0.611
Intercept (n): 2.028 MPa
Shear stress constant: 1.240 MPa
B1T2  05/04/06  6.1m  Clay and gravel

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<thead>
<tr>
<th>Site</th>
<th>Date</th>
<th>Day</th>
<th>Borehole</th>
<th>Test No</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>RUIRITANIA</td>
<td>5/6/06</td>
<td>THKC</td>
<td></td>
<td>2</td>
<td>6.7m</td>
</tr>
</tbody>
</table>

**Material:** Glacial Till

**Weather:** Clear
**Water Table:** 11.32
**Time Now:** 11:15
**Drilling End:** 11:15
**Orientation:** CHL

**Drilling:** 7/6H 1core
**Pocket:** 5.5-7.7m

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Distance</th>
<th>Rate</th>
<th>Core Description</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5m</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wet/Dry</td>
<td></td>
<td>Rig</td>
<td>Driller</td>
<td></td>
</tr>
</tbody>
</table>

**Press/Incrmnt:** Wall Time
**Creep Time:** Cycle Time
**Dia No.:** Inset Ref
**Engineer:** SALY

**Zero Readings:**
- Arm 1: -15.1
- Arm 2: -10.84
- Arm 3: -28.7
- Arm 4: -124.2
- Arm 5: -121.8
- Arm 6: -231.8

**Machine Diameter:**
- A: 18.4 x 12.18

**Calibrations:**
- Strain Arm Calibration Date: 10/1/11
- Total Pressure Cell Calibration Date: 10/1/11
- Membrane Stiffness Calibration Date: 10/1/11
- Mem. Compression Calibration Date: 10/1/11
- New Membrane Fitted Date: 10/1/11

**Test Comments:** Had to go in with 7/6H barrel two after hole collapse

**Test Starts at:** 11:14

<table>
<thead>
<tr>
<th>Time</th>
<th>Line No</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:42</td>
<td>B</td>
<td>HDA</td>
</tr>
<tr>
<td>11:45</td>
<td>B</td>
<td>loop 1</td>
</tr>
<tr>
<td>11:55</td>
<td>A</td>
<td>HDA</td>
</tr>
<tr>
<td>12:15</td>
<td>C</td>
<td>loop 2</td>
</tr>
<tr>
<td>12:08</td>
<td>H</td>
<td>HDA</td>
</tr>
<tr>
<td>12:11</td>
<td>235</td>
<td>loop 3</td>
</tr>
<tr>
<td>12:20</td>
<td>234</td>
<td>loop 4</td>
</tr>
<tr>
<td>12:25</td>
<td>321</td>
<td></td>
</tr>
</tbody>
</table>

**Test Ends at:** 12:33
**Max. Pressure Reached:** 40.4 kPa

**General Comments:**
- 7/6H TEC's used.
- 50% to more test fresh material caused by drilling before hitting high material.
- Tape and ropes.

Driller: Mark / Ritchie
Operator: JPB.
Site:- Ruritania                      Test :- B1T2                      Test Date :- 5th April 2006
Material :- Clay & gravel            Depth :- 6.1 mtrs                   Water table :- ~ 11m

Analysis of Insitu Lateral Stress (Po) :-

Marsland and Randolph                kPa  340
Strain zero                          mm  8.2

Analysis of Undrained Shear Strength (Cu) :-

Gibson and Anderson                  kPa  156
Pressure at failure (PF)             kPa  500
Limit Pressure (PL)                  kPa  925
Jefferies (unloading)                kPa  77

Strength of Sands Analysis (Hughes, Wroth & Windle)

Friction angle at const. vol.         deg  24  (assumed)
Angle of Friction                     deg  24.0
Angle of Dilation                     deg  0

Analysis of Shear Modulus (G) :-

Initial Modulus (Gi)                  MPa  2.3

Linear Analysis of Reload Loops (GR) :-

<table>
<thead>
<tr>
<th></th>
<th>Loop 1</th>
<th>Loop 2</th>
<th>Loop 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>GR</td>
<td>MPa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure at start</td>
<td>kPa</td>
<td>285</td>
<td>415</td>
</tr>
<tr>
<td>Depth of unload</td>
<td>kPa</td>
<td>90</td>
<td>125</td>
</tr>
</tbody>
</table>

Non-linear Analysis of Reloading data :-

<table>
<thead>
<tr>
<th></th>
<th>MPa</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>α</td>
<td>4.32</td>
<td>6.61</td>
<td>5.90</td>
</tr>
<tr>
<td>β</td>
<td>0.853</td>
<td>0.833</td>
<td>0.785</td>
</tr>
</tbody>
</table>

Shear Modulus GS (at 2 levels of shear strain) :-

<table>
<thead>
<tr>
<th></th>
<th>MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0.01%)</td>
<td>16.7</td>
</tr>
<tr>
<td>(0.1%)</td>
<td>11.9</td>
</tr>
</tbody>
</table>

Test Analysed By :- PGH
Date :- March 2011
RESULTS:
Cu: 156.0 kPa
PI: 925 kPa
Ir: 16
G: 2.4 MPa

95mm High Pressure Dilatometer
B1T2
6.10 Metres
5 Apr 06
RESULTS:
Ambient water pressure: 0.0 kPa
Residual friction angle: 24.0°
Gradient: 0.290
Friction angle: 24.0°
Dilation angle: 0.0°
Shear modulus from unload/reload cycles Loop 3: Arm ave

RESULTS:
- Gur : 16.4MPa
- Cycle mid-point:
  - Cavity strain : 3.713%
  - Total stress : 258kPa
- Size of cycle:
  - Shear strain : 0.769%
  - Total stress : 127kPa

95mm High Pressure Dilatometer
B1T2
6.10 Metres
5 Apr 06
95mm High Pressure Dilatometer
B1T2
6.10 Metres
5 Apr 06
RESULTS:
Gradient (beta) : 0.833
Intercept (n) : 7.942MPa
Shear stress constant : 6.612MPa
95mm High Pressure Dilatometer
B1T2
6. 10 Metres
5 Apr 06

CURVE FIT PARAMETERS:
Origin : 9.210mm
P0 : 220.0kPa
Cu : 77.2 kPa
Beta : 0.785
Alpha : 7.370 MPa

Total pressure (kPa)
Cavity strain (%)

Curve comparison (Whittle 1999) : Arm ave
Carter et al 1986 - Total pressure vs Cavity strain

- $U_0$ (kPa) : 0
- $P_0$ (kPa) : 195
- $C$ (kPa) : 77
- $\phi_{cv}$ (°) : 24
- $\phi_{pk}$ (°) : 24
- $G_{yield}$ (MPa) : 7.8
- Non-linearity : 0.79
- Janbu exponent : 1.28
- Poisson's Ratio : 0.50

B1T2 6.10mBGL April 05, 2006
B1T3  05/04/06  8.0m  Clay and gravel

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### Test Record Sheet

**High Pressure Dilatometer**

<table>
<thead>
<tr>
<th>Site</th>
<th>Date</th>
<th>Day</th>
<th>Borehole</th>
<th>Test No.</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Keritania</strong></td>
<td>5/4/06</td>
<td>THUL</td>
<td>1</td>
<td>3</td>
<td>8 m</td>
</tr>
</tbody>
</table>

**Material:** Glacial Till

<table>
<thead>
<tr>
<th>Weather</th>
<th>Water Table</th>
<th>Time Now</th>
<th>Drilling End</th>
<th>Orientation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunny</td>
<td>15.02</td>
<td>15:50</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Drilling:**

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Distance</th>
<th>Rate</th>
<th>Core Description</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 pm</td>
<td>2m</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Wet/Dry:**

<table>
<thead>
<tr>
<th>Wet Time</th>
<th>Creep Time</th>
<th>Cycle Time</th>
<th>Disc No.</th>
<th>Inst Ref</th>
<th>Engineer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Press/Moment:**

<table>
<thead>
<tr>
<th>Zero Readings</th>
<th>Machine Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm 1</td>
<td>Arm 2</td>
</tr>
<tr>
<td>-152.6</td>
<td>-180.3</td>
</tr>
<tr>
<td></td>
<td>-152.7</td>
</tr>
<tr>
<td></td>
<td>-171.2</td>
</tr>
<tr>
<td></td>
<td>-231.35</td>
</tr>
</tbody>
</table>

**Calibrations:**

- Strain Arm Calibration Date: 10/1/11
- Total Pressure Cell Calibration Date: 10/1/11
- Membrane Stiffness Calibration Date: 2/2/11
- Membrane Compression Calibration Date: 2/2/11
- New Membrane Fitted Date: 2/2/11

**Test Comments:**

- Test Starts at: 15:05
- Test Ends at: 16:00
- Max. Pressure Reached: 664 kPa

**Test Results:**

- Trial 1
  - 15:00: 85 Haul
  - 15:36: 78 Haul
  - 15:48: 245 Unload
  - 15:50: 266 Loop 3

**General Comments:**

- Both tests used.
- Very large and even expansion.
- Very different test curves compared to T1.
- Lower section of membrane saw no significant movement after water injection after test.

---

**Operator:** SDP

---

**Address:**

CAMBRIDGE INSTITU, Little Eversden, Cambridge CB23 1HE

**Contact:**

Tel: (01223) 262 361
Fax: (01223) 263 947

Email: Caminsitu@aol.com
Website: Cambridge-Institu.com
Site: Ruritania  
Test: B1T3  
Test Date: 5th April 2006  
Material: Clay & gravel  
Depth: 8.0 mtrs  
Water table: ~ 11m

| Analysis of Insitu Lateral Stress (Po) | Arm Av. |  |
|---------------------------------------|---------|  |
| Marsland and Randolph                 | kPa     | 340 |
| Strain zero                           | mm      | 1.4 |

| Analysis of Undrained Shear Strength (Cu) |  |
|------------------------------------------|  |
| Gibson and Anderson                      | kPa | 323 |
| Pressure at failure ($P_F$)              | kPa | 470 |
| Limit Pressure ($P_L$)                   | kPa | 1086 |
| Jefferies (unloading)                    | kPa | 105 |

| Strength of Sands Analysis (Hughes, Wroth & Windle) |  |
| Friction angle at const. vol. (deg) |  |
| Angle of Friction (deg) |  |
| Angle of Dilation (deg) |  |
| 24 (assumed) | 35.5 | 13.1 |

*Note that the curve matching technique, based on the equations of Carter et al, predicts zero dilation. This is a consequence of the much larger strain zero required to get a reasonable match.*

| Analysis of Shear Modulus (G) |  |
|-------------------------------|  |
| Initial Modulus (Gi)          | MPa | 1.0 |

<table>
<thead>
<tr>
<th>Linear Analysis of Reload Loops (G_R)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>G_R</td>
<td>Loop 1</td>
</tr>
<tr>
<td>MPa</td>
<td>16.3</td>
</tr>
<tr>
<td>Pressure at start</td>
<td>kPa</td>
</tr>
<tr>
<td>Depth of unload</td>
<td>kPa</td>
</tr>
</tbody>
</table>

Non-linear Analysis of Reloading data:

<table>
<thead>
<tr>
<th>$\alpha$</th>
<th>MPa</th>
<th>1.91</th>
<th>3.08</th>
<th>3.94</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td></td>
<td>0.649</td>
<td>0.670</td>
<td>0.649</td>
</tr>
</tbody>
</table>

Shear Modulus G_S (at 2 levels of shear strain):

| (0.01%)                              | MPa  | 48.4 | 64.5 | 99.9 |
| (0.1%)                               | MPa  | 21.6 | 30.1 | 44.5 |

Test Analysed By: PGH  
Date: March 2011
95mm High Pressure Dilatometer
B1T3
8.00 Metres
5 Apr 06

RESULTS:

G\text{t} : 1.0\text{MPa}
Pf : 469.8\text{kPa}
Po : 340.4\text{kPa}
Tf : 130.4\text{kPa}
Po + Tf : 470.8\text{kPa}
Origin : 1.375\text{mm}
RESULTS:
Cu: 323.2 kPa
PI: 1086 kPa
G: 1.2 MPa

95mm High Pressure Dilatometer
B1T3
8.00 Metres
5 Apr 06
Jefferies (1960): Arm ave

RESULTS:
Cu : 104.8 kPa

95mm High Pressure Dilatometer
B113
8.00 Metres
5 Apr 06
RESULTS:
Ambient water pressure: 0.0 kPa
Residual friction angle: 24.0°
Gradient: 0.450
Friction angle: 35.5°
Dilation angle: 13.1°
Shear modulus from unload/reload cycles Loop 1: Arm ave

RESULTS:
- Gur: 16.3 MPa
- Cycle mid-point:
  - Cavity strain: 10.209%
  - Total stress: 425 kPa
- Size of cycle:
- Shear strain: 1.036%
- Total stress: 170 kPa

95mm High Pressure Dilatometer
B1T3
8.00 Metres
5 Apr 06
RESULTS:
Gur : 23.4MPa
Cycle mid-point:
Cavity strain : 19.084%
Total stress : 561kPa
Size of cycle:
Shear strain : 0.918%
Total stress : 216kPa
95mm High Pressure Dilatometer
B1T3
8.00 Metres
5 Apr 06
RESULTS:
Gradient (β) : 0.649
Intercept (n) : 2.945MPa
Shear stress constant : 1.911MPa
95mm High Pressure Dilatometer
B1T3
8.00 Metres
5 Apr 06
RESULTS:
Gradient (beta) : 0.670
Intercept (n) : 4.607MPa
Shear stress constant : 3.085MPa
95mm High Pressure Dilatometer
B1T3
8.00 Metres
5 Apr 06
RESULTS:
Gradient (beta) : 0.649
Intercept (n) : 6.075MPa
Shear stress constant : 3.942MPa
Carter et al 1986 - Total pressure vs Cavity strain

Uo (kPa) : 0
Po (kPa) : 235
C (kPa) : 105
Phi cv (°) : 24
Phi pk (°) : 24
Gyld (MPa) : 3.5
Non-linearity : 0.65
Janbu exponent : 1.34
Poissons Ratio : 0.50
B1T4  07/04/06  10.0m  Coarse sand

1. Test record sheet
2. Results summary
3. Plot of expansion versus pressure – all arms
4. Plot of expansion versus pressure – arm average
5. Plot of all pressure cells versus time
6. Plot of Marsland and Randolph procedure
7. Hughes plot, giving peak friction angle and dilation
8. Jefferies plot, giving Cu from unloading curve
9. Plot of Reload Loop 1, with linear modulus line
10. Plot of Reload Loop 2, with linear modulus line
11. Plot of Reload Loop 3, with linear modulus line
12. Plot of Reload Loop 4, with linear modulus line
13. Bolton and Whittle plot of reloading part of Loop 1, giving nonlinearity coefficients
14. Ditto for Loop 2
15. And again for Loop 3
16. And Loop 4
17. Plot of Shear modulus versus Shear strain for all reload loops
18. Plot of measured and calculated curves, from Carter et al

Note that this last plot is included, even though the results obtained are not shown on the summary sheet. The friction angle obtained is almost identical to that from the Hughes plot.
<table>
<thead>
<tr>
<th>SITE</th>
<th>DATE</th>
<th>DAY</th>
<th>BOREHOLE</th>
<th>TEST</th>
<th>Depth to test centre</th>
</tr>
</thead>
<tbody>
<tr>
<td>RURITANIA</td>
<td>7-4-06</td>
<td>RZ1</td>
<td>1</td>
<td></td>
<td>10-12</td>
</tr>
</tbody>
</table>

**MATERIAL:** coarse sand  **Site Weather:**   

<table>
<thead>
<tr>
<th>Water Table</th>
<th>Drilling Start</th>
<th>Drilling End</th>
<th>Distance</th>
<th>Drill rate</th>
<th>Ram Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>13:08</td>
<td>13:28</td>
<td>1.07</td>
<td>OK</td>
<td></td>
</tr>
</tbody>
</table>

**Orientation:**  
Water Press. | Probe Dia. | Shoe Dia. | Drill Bit | Bit Location | Probe Ref. |
-------------|------------|-----------|-----------|--------------|------------|
             | 83 m      | 87 m      | 73 to 80 | ~ flushed   | dougal     |

**Drilling remarks:**  
Strain Rate | Press. Rate | Cycle Time | Gas Bottle | Battery V | PPC Type | Mx. Press. |
-----------|-------------|------------|------------|-----------|-----------|------------|
1/8        | 1+2        | 5          | 3300 psi   | 11.9 F    | True      | 10 m | 100 psi |

**TRANSUDER DETAILS**  

<table>
<thead>
<tr>
<th>ARM 1</th>
<th>ARM 2</th>
<th>ARM 3</th>
<th>TPC</th>
<th>PPC A</th>
<th>PPC B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**GL Zero**  
Test Depth  

<table>
<thead>
<tr>
<th>Test Start Time</th>
<th>Test End Time</th>
<th>Mx Pressure Reached</th>
<th>Disk Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>13:33</td>
<td>14:23</td>
<td>1-14-19/9</td>
<td></td>
</tr>
</tbody>
</table>

**TEST NOTES**  

<table>
<thead>
<tr>
<th>Line No.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td>Hoc (3) = Low (0)</td>
</tr>
<tr>
<td>89</td>
<td>Hoc (3) = Low (2)</td>
</tr>
<tr>
<td>162</td>
<td>Hoc (0) = Low (0)</td>
</tr>
<tr>
<td>229</td>
<td>Hoc (0) = Low (0)</td>
</tr>
<tr>
<td>293</td>
<td>Hoc (0) = Low (0)</td>
</tr>
<tr>
<td>420</td>
<td>Hoc (0) = Low (0)</td>
</tr>
<tr>
<td>523</td>
<td>Down - Rate 5 - Arms (0) + (0) ~ 5.5 mm</td>
</tr>
</tbody>
</table>

**Test Engineer:**  
Driller: Miguel  
Membrane Correction  
Membrane Compression  
Arm Cals Ref.  
Pressure Cals Ref.  

**GENERAL COMMENTS:**  
includes complete unload after loop (3) - as specified  

CAMBRIDGE INSITU, Little Eversden, Cambridge, CB3 7HE
Site: Ruritania  
Test: B1T4  
Test Date: 7th April 2006

Material: Coarse sand  
Depth: 10.0 mtrs  
Water table: ~11 mtrs

Analysis of Insitu Lateral Stress (Po):

<table>
<thead>
<tr>
<th>Marsland and Randolph</th>
<th>kPa</th>
<th>147</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero offset</td>
<td>mm</td>
<td>0.84</td>
</tr>
</tbody>
</table>

Analysis of Undrained Shear Strength (Cu):

| Pressure at failure (P_f) | kPa  | 380 |
| Jefferies (unloading)     | kPa  | 195 |

Strength of Sands Analysis (Hughes, Wroth & Windle):

| Friction angle at const. vol. | deg  | 30 | (assumed) |
| Angle of Friction             | deg  | 44.0 |
| Angle of Dilation             | deg  | 17.4 |

Analysis of Shear Modulus (G):

| Initial Modulus (Gi) | MPa  | 9.6 |

Linear Analysis of Reload Loops (G_R):

<table>
<thead>
<tr>
<th>Loop 1</th>
<th>Loop 2</th>
<th>Loop 3</th>
<th>Loop 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>G_R</td>
<td>MPa</td>
<td>26.6</td>
<td>44.9</td>
</tr>
<tr>
<td>Co-ordinate :-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strain</td>
<td>%</td>
<td>-0.1</td>
<td>1.25</td>
</tr>
<tr>
<td>Pressure</td>
<td>MPa</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Amplitude :-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strain</td>
<td>%</td>
<td>0.37</td>
<td>0.29</td>
</tr>
<tr>
<td>Pressure</td>
<td>MPa</td>
<td>0.10</td>
<td>0.13</td>
</tr>
</tbody>
</table>

Non-linear Analysis of Reloading data:

| α | MPa  | 10.4  | 17.2  | 22.3  | 28.8   |
| β |      | 0.858 | 0.852 | 0.859 | 0.845  |

Shear Modulus G_S (at 3 levels of shear strain):

| (0.01%) | MPa  | 39    | 67    | 82    | 120    |
| (0.1%)  | MPa  | 28    | 48    | 59    | 84     |
| (1%)    | MPa  | 20    | 34    | 43    | 59     |

Test Analysed By: PGH  
Date: April 2006

Weak Rock Self-boring Pressuremeter and High Pressure Dilatometer Tests  
Cambridge Insitu Ltd  
March 2011
Digital 3 arm weak rock self-boring pressuremeter
B174
10.00 Metres
7 Apr 06

RESULTS:
G: 9.6 MPa
Pf: 379.8 kPa
Po: 146.8 kPa
Tf: 233.1 kPa
Po + Tf: 379.9 kPa
Origin: 0.818 mm
Jefferies (1960): Arm ave

RESULTS:
Cu : 195.5 kPa

Digital 3 arm weak rock self boring pressuremeter
B1T4
10.00 Metres
7 Apr 06
RESULTS:
Gur : 26.6 MPa
Cycle mid-point:
Cavity strain : -0.055%
Total stress : 98 kPa
Size of cycle:
Shear strain : 0.374%
Total stress : 99 kPa
RESULTS:
Gur : 44.9MPa
Cycle mid-point:
Cavity strain : 0.633%
Total stress : 212kPa
Size of cycle:
Shear strain : 0.286%
Total stress : 129kPa

Digital 3 arm weak rock self boring pressuremeter
B114
10.00 Metres
7 Apr 06
Digital 3 arm weak rock self boring pressuremeter B1T4
10.00 Metres
7 Apr 06
RESULTS:
Gradient (beta) : 0.858
Intercept (n) : 12.155MPa
Shear stress constant : 10.433MPa
Digital 3 arm weak rock self boring pressuremeter

B1T4

10.00 Metres

7 Apr 06

RESULTS:

Gradient (beta) : 0.852

Intercept (n) : 20.162MPa

Shear stress constant : 17.178MPa
Digital 3 arm weak rock self boring pressuremeter B1T4
10.00 Metres
7 Apr 06

RESULTS:
Gradient (beta) : 0.845
Intercept (n) : 34.057MPa
Shear stress constant : 28.782MPa
Carter et al 1986 - Total pressure vs Cavity strain

Uo (kPa) : 0
Po (kPa) : 100
C (kPa) : 0
Phi cv (°) : 30
Phi pk (°) : 43
Gy dle (MPa) : 27
Non-linearity : 0.85
Janbu exponent : 0.55
Poissons Ratio : 0.33

Measured
Calculated

B1T4
10.00mBGL
April 07, 2006

Total pressure (kPa)

Cavity strain (%)
1. Test record sheet
2. Results summary
3. Plot of expansion versus pressure – all arms
4. Plot of expansion versus pressure – arm average
5. Plot of all pressure cells versus time
6. Plot of Marsland and Randolph procedure
7. Gibson and Anderson plot, giving $C_u$ and $P_l$ from loading curve
8. Jefferies plot, giving $C_u$ from unloading curve
9. Plot of Reload Loop 1, with linear modulus line
10. Plot of Reload Loop 2, with linear modulus line
11. Bolton and Whittle plot of reloading part of Loop 1, giving nonlinearity coefficients
12. Ditto for Loop 2
13. Plot of Shear modulus versus Shear strain for all reload loops
14. Plot of strain versus pressure, with computed curve and field data
15. Holding test simulation plot – matching the start of the decay
16. Ditto – matching the whole decay
<table>
<thead>
<tr>
<th>SITE</th>
<th>DATE</th>
<th>DAY</th>
<th>BORROHOLE</th>
<th>TEST</th>
<th>Depth to test centre</th>
</tr>
</thead>
<tbody>
<tr>
<td>RORITANIA</td>
<td>08/06/04</td>
<td>Mon</td>
<td>1</td>
<td>5</td>
<td>20 m</td>
</tr>
<tr>
<td>MATERIAL</td>
<td>GREY CLAY</td>
<td>Site Weather:</td>
<td>CLOUDY</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Water Table</th>
<th>Drilling Start</th>
<th>Drilling End</th>
<th>Distance</th>
<th>Drill rate</th>
<th>Ram Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>13:05</td>
<td>13:30</td>
<td>1:25</td>
<td></td>
<td></td>
<td>OK</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Orientation:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Press.</td>
</tr>
<tr>
<td>0.9</td>
</tr>
</tbody>
</table>

Drilling remarks: Poor flush on most of drill, 08/04/04.

<table>
<thead>
<tr>
<th>Strain Rate</th>
<th>Press. Rate</th>
<th>Cycle Time</th>
<th>Gas Bottle</th>
<th>Battery V</th>
<th>PPC Type</th>
<th>Mx. Press.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TRANSUCER DETAILS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARM 1</td>
</tr>
<tr>
<td>GL. Zero</td>
</tr>
<tr>
<td>Test Start Time</td>
</tr>
<tr>
<td>15:39</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TEST NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line No.</td>
</tr>
<tr>
<td>63</td>
</tr>
<tr>
<td>71</td>
</tr>
<tr>
<td>73</td>
</tr>
<tr>
<td>85</td>
</tr>
<tr>
<td>140</td>
</tr>
<tr>
<td>180</td>
</tr>
<tr>
<td>450</td>
</tr>
<tr>
<td>695</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test Engineer:</th>
<th>Driller:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GRANT</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Membrane Correction</th>
<th>Membrane Compression</th>
<th>Arm Cals Ref</th>
<th>Pressure Cals Ref</th>
</tr>
</thead>
<tbody>
<tr>
<td>h02720.5</td>
<td>h090811</td>
<td>7-8-08</td>
<td>7-8-08</td>
</tr>
</tbody>
</table>

GENERAL COMMENTS:

PPCs now working (new PPCA)
WEAK ROCK SELF-BORING PRESSUREMETER TESTS

RESULTS SUMMARY SHEET

Site: Ruritania  Test: B1T5  Test Date: 8th April 2006
Material: Grey clay  Depth: 20.0 mtrs  Water table: ~ 11 mtrs

Initial Pore Water Pressure:
<table>
<thead>
<tr>
<th>PPC A</th>
<th>PPC B</th>
</tr>
</thead>
<tbody>
<tr>
<td>775 kPa</td>
<td>805 kPa</td>
</tr>
</tbody>
</table>

Analysis of In-situ Lateral Stress (Po):
<table>
<thead>
<tr>
<th>Arm 1</th>
<th>Arm 2</th>
<th>Arm 3</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lift-off kPa</td>
<td>960</td>
<td>975</td>
<td>1010</td>
</tr>
<tr>
<td>Marsland &amp; Randolph kPa</td>
<td>1000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zero offset mm</td>
<td>-0.01</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analysis of Undrained Shear Strength (Cu):
| Gibson and Anderson kPa | 235 |
| Pressure at failure (Pf) kPa | 1090 |
| Limit Pressure (P_L) kPa | 2115 |
| Jefferies (unloading) kPa | 225 |

Analysis of Shear Modulus (G):
| Initial Modulus (Gi) MPa | 19.9 |

Linear Analysis of Reload Loop (G_R):
<table>
<thead>
<tr>
<th>Loop 1</th>
<th>Loop 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>G_R MPa</td>
<td>29.8</td>
</tr>
<tr>
<td>Co-ordinate:</td>
<td></td>
</tr>
<tr>
<td>Strain %</td>
<td>0.7</td>
</tr>
<tr>
<td>Pressure kPa</td>
<td>1070</td>
</tr>
<tr>
<td>Amplitude:</td>
<td></td>
</tr>
<tr>
<td>Strain %</td>
<td>0.87</td>
</tr>
<tr>
<td>Pressure kPa</td>
<td>260</td>
</tr>
</tbody>
</table>

Non-linear Analysis of Reloading data:
| α MPa | 4.43 | 4.26 |
| β MPa | 0.674 | 0.672 |

Shear Modulus G_S (at 3 levels of shear strain):
- (0.01%) MPa 89 87
- (0.1%) MPa 42 41
- (1%) MPa 20 19

Analysis of Holding test:
| C_H m²/yr | 18.5 | 25.3 |
| k_H x 10⁻¹⁰ m/s | 1.1 | 1.7 |

Constant flow Permeameter test:
| k_m x 10⁻¹⁰ m/s | 1.4 – 2.7 | 2.7 – 3.7 | - |

Curve matching procedure:
| Po kPa | 780 |
| O/s mm | 0.01 |
| Cu kPa | 225 |
| P_L kPa | 2090 |

Test Analysed By: PGH  Date: August 2006

Weak Rock Self-boring Pressuremeter and High Pressure Dilatometer Tests
Cambridge Insitu Ltd  March 2011
RESULTS:

\[
\begin{align*}
G & : 19.9 \text{MPa} \\
F & : 1039.3 \text{kPa} \\
P & : 1000.3 \text{kPa} \\
T & : 88.4 \text{kPa} \\
P + T & : 1088.7 \text{kPa} \\
\text{Origin} & : -0.013 \text{mm}
\end{align*}
\]
RESULTS:
Cu : 235.2kPa
Pl : 2114kPa
Ir : 42
G : 9.9MPa

Digital 3 arm weak rock self boring pressuremeter
B115
20.00 Metres
8 Apr 06
RESULTS:
Cu : 225.4 kPa

Digital 3 arm weak rock self-boring pressuremeter
BHT5
20.00 Metres
8 Apr 06
RESULTS:
Gur : 29.8MPa
Cycle mid-point:
Cavity strain : 0.668%
Total stress : 1068kPa
Size of cycle:
Shear strain : 0.869%
Total stress : 260kPa

Digital 3 arm weak rock self boring pressuremeter
B115
20.00 Metres
8 Apr 06
Digital 3 arm weak rock self boring pressuremeter
B1T5
20.00 Metres
8 Apr 06
RESULTS:
Gradient (beta) : 0.674
Intercept (n) : 6.574MPa
Shear stress constant : 4.430MPa
Digital 3 arm weak rock self boring pressuremeter
B1T5
20.00 Metres
8 Apr 06
RESULTS:
Gradient (\beta) : 0.672
Intercept (n) : 6.336MPa
Shear stress constant : 4.258MPa
Digital 3 arm weak rock self boring pressuremeter
BIT5
20.00 Metres
8 Apr 06

CURVE FIT PARAMETERS:
Cmin = -0.013mm
P0 = 780.0 kPa
Cu = 224.9 kPa
Beta = 0.672
Alpha = 4.167 MPa
Holding test simulation - matching the start of the decay

B1T5

Consolidation = 18.5 metres squared per year
Permeability = 1.1 x 10 to the -10 m/s
Holding test simulation - matching the whole decay
B1T5

Consolidation = 25.3 metres squared per year
Permeability = 1.7 x 10 to the -10 m/s
B1T6  10/04/06  25.0m  Grey Clay

1. Test record sheet
2. Results summary
3. Plot of expansion versus pressure – all arms
4. Plot of expansion versus pressure – arm average
5. Plot of all pressure cells versus time
6. Plot of Marsland and Randolph procedure
7. Gibson and Anderson plot, giving Cu and \( P_L \) from loading curve
8. Jefferies plot, giving Cu from unloading curve
9. Plot of Reload Loop 1, with linear modulus line
10. Plot of Reload Loop 2, with linear modulus line
11. Plot of Reload Loop 3, with linear modulus line
12. Plot of Reload Loop 4, with linear modulus line
13. Bolton and Whittle plot of reloading part of Loop 1, giving nonlinearity coefficients
14. Ditto for Loop 2
15. And for Loop 3
16. And Loop 4
17. Plot of Shear modulus versus Shear strain for all reload loops
18. Plot of strain versus pressure, with computed curve and field data
19. Plot of Hold 1, showing pressure and expansion
20. Plot of creep against log time, with final trend line for Hold 1
21. Plot of Hold 2, showing pressure and expansion
22. Plot of creep against log time, with final trend line for Hold 2
<table>
<thead>
<tr>
<th>SITE</th>
<th>DATE</th>
<th>DAY</th>
<th>BOREHOLE</th>
<th>TEST</th>
<th>Depth to test centre</th>
</tr>
</thead>
<tbody>
<tr>
<td>LURITANIA</td>
<td>10/6/66</td>
<td>Wed</td>
<td>1</td>
<td>6</td>
<td>25 m</td>
</tr>
</tbody>
</table>

**MATERIAL:** GREY CLAY  Site Weather: RAIN

<table>
<thead>
<tr>
<th>Water Table</th>
<th>Drilling Start</th>
<th>Drilling End</th>
<th>Distance</th>
<th>Drill Rate</th>
<th>Ram Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>09:30</td>
<td>10:30</td>
<td>1 m</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Orientation:**

<table>
<thead>
<tr>
<th>Water Press.</th>
<th>Probe Dia.</th>
<th>Shoe Dia.</th>
<th>Drill Bit</th>
<th>Bit Location</th>
<th>Probe Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8.7 mm</td>
<td>8.3 mm</td>
<td>25 mm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Drilling remarks:** SLOW TO READ 5

<table>
<thead>
<tr>
<th>Strain Rate</th>
<th>Press Rate</th>
<th>Cycle Time</th>
<th>Gas Bottle</th>
<th>Battery V</th>
<th>PPC Type</th>
<th>Mx. Press.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TRANSDUCER DETAILS**

<table>
<thead>
<tr>
<th>ARM 1</th>
<th>ARM 2</th>
<th>ARM 3</th>
<th>TPC</th>
<th>PPC A</th>
<th>PPC B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**GL Zero**

**Test Depth**

<table>
<thead>
<tr>
<th>Test Start Time</th>
<th>Test End Time</th>
<th>Mx Pressure Reached</th>
<th>Disk Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:03</td>
<td>10:43</td>
<td>2.0</td>
<td></td>
</tr>
</tbody>
</table>

**TEST NOTES**

<table>
<thead>
<tr>
<th>Line No.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>ARM 5 (D) MUNIC ~ BY 1502</td>
</tr>
<tr>
<td>0.2</td>
<td>ARM 5 (D) MUNIC ~ 1502</td>
</tr>
<tr>
<td>0.3</td>
<td>ARM 5 (D) MUNIC SLOWLY ~ BY 1502</td>
</tr>
<tr>
<td>0.4</td>
<td>ARM 5 (D) MUNIC SLOWLY ~ 1502</td>
</tr>
<tr>
<td>0.5</td>
<td>ARM 5 (D) MUNIC SLOWLY ~ 1502</td>
</tr>
<tr>
<td>0.6</td>
<td>ARM 5 (D) MUNIC SLOWLY ~ 1502</td>
</tr>
<tr>
<td>0.7</td>
<td>ARM 5 (D) MUNIC SLOWLY ~ 1502</td>
</tr>
<tr>
<td>0.8</td>
<td>ARM 5 (D) MUNIC SLOWLY ~ 1502</td>
</tr>
<tr>
<td>0.9</td>
<td>ARM 5 (D) MUNIC SLOWLY ~ 1502</td>
</tr>
<tr>
<td>0.10</td>
<td>ARM 5 (D) MUNIC SLOWLY ~ 1502</td>
</tr>
<tr>
<td>0.11</td>
<td>ARM 5 (D) MUNIC SLOWLY ~ 1502</td>
</tr>
</tbody>
</table>

**Test Engineer:** Driller:

**Membrane Correction** | **Membrane Compression** | **Arm Cals Ref** | **Pressure Cals Ref** |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.023815</td>
<td>0.028231</td>
<td>7.0</td>
<td>7.0</td>
</tr>
</tbody>
</table>

**GENERAL COMMENTS:**

CAMBRIDGE INSITU, Little Eversden, Cambridge, CB3 7HE
Telephone: (01223)262361 Fax: (01223) 263947 E-Mail: CamInsitu@AOL.COM
WEAK ROCK SELF-BORING PRESSUREMETER

RESULTS SUMMARY SHEET

Site: Ruritania
Test: B1T6
Test Date: 10th April 2006
Material: Grey clay
Depth: 25.0 mtrs
Water table: ~11 mtrs

<table>
<thead>
<tr>
<th>PPC A</th>
<th>PPC B</th>
</tr>
</thead>
<tbody>
<tr>
<td>102</td>
<td>558</td>
</tr>
</tbody>
</table>

Initial water pressure: kPa

<table>
<thead>
<tr>
<th>Marsland and Randolph</th>
<th>1000 kPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero offset</td>
<td>0.00 mm</td>
</tr>
</tbody>
</table>

Analysis of Insitu Lateral Stress (Po):

<table>
<thead>
<tr>
<th>Gibson and Anderson</th>
<th>630 kPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure at failure (P_f)</td>
<td>1446 kPa</td>
</tr>
<tr>
<td>Limit Pressure (P_L)</td>
<td>4498 kPa</td>
</tr>
<tr>
<td>Jefferies (unloading)</td>
<td>592 kPa</td>
</tr>
</tbody>
</table>

Analysis of Undrained Shear Strength (Cu):

<table>
<thead>
<tr>
<th>Gibson and Anderson</th>
<th>630 kPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure at failure (P_f)</td>
<td>1446 kPa</td>
</tr>
<tr>
<td>Limit Pressure (P_L)</td>
<td>4498 kPa</td>
</tr>
<tr>
<td>Jefferies (unloading)</td>
<td>592 kPa</td>
</tr>
</tbody>
</table>

Analysis of Shear Modulus (G):

<table>
<thead>
<tr>
<th>Initial Modulus (Gi)</th>
<th>70.1 MPa</th>
</tr>
</thead>
</table>

Linear Analysis of Reload Loops (G_R):

<table>
<thead>
<tr>
<th>Loop 1</th>
<th>Loop 2</th>
<th>Loop 3</th>
<th>Loop 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>G_R</td>
<td>MPa</td>
<td>MPa</td>
<td>MPa</td>
</tr>
<tr>
<td>79.4</td>
<td>64.7</td>
<td>75.2</td>
<td>66.8</td>
</tr>
</tbody>
</table>

Co-ordinate:

<table>
<thead>
<tr>
<th>Strain</th>
<th>%</th>
<th>%</th>
<th>%</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure kPa</td>
<td>2000</td>
<td>2330</td>
<td>1980</td>
<td>1370</td>
</tr>
</tbody>
</table>

Amplitude:

<table>
<thead>
<tr>
<th>Strain</th>
<th>%</th>
<th>%</th>
<th>%</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure kPa</td>
<td>680</td>
<td>720</td>
<td>590</td>
<td>660</td>
</tr>
</tbody>
</table>

Non-linear Analysis of Reloading data:

\[ \alpha = 13.7 \text{ MPa} \]
\[ \beta = 0.701 \]

Shear Modulus G_s (at 3 levels of shear strain):

\[
\begin{align*}
(0.01\%) & \quad \text{MPa} \quad 218 \quad 217 \quad 238 \quad 222 \\
(0.1\%) & \quad \text{MPa} \quad 112 \quad 109 \quad 111 \quad 101 \\
(1\%) & \quad \text{MPa} \quad 57 \quad 55 \quad 52 \quad 46
\end{align*}
\]

Creep:

<table>
<thead>
<tr>
<th>Hold 1</th>
<th>Hold 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure of hold</td>
<td>MPa</td>
</tr>
<tr>
<td>Time of hold</td>
<td>mins</td>
</tr>
<tr>
<td>Rate ( \varepsilon_s ) (=de/dlogt)</td>
<td>%</td>
</tr>
</tbody>
</table>

Test Analysed By: PGH
Date: August 2006

Weak Rock Self-boring Pressuremeter and High Pressure Dilatometer Tests
Cambridge Insitu Ltd
March 2011
RESULTS:
Cu: 630.1 kPa
PI: 4498 kPa
Ir: 95
G: 59.7 MPa

Digital 3 arm weak rock self boring pressuremeter
B116
25.00 Metres
10 Apr 06
RESULTS:
- Gur: 79.4 MPa
- Cycle mid-point:
  - Cavity strain: 2.092%
- Total stress: 2002 kPa
- Size of cycle:
  - Shear strain: 0.850%
- Total stress: 679 kPa

Radial Displacement (mm)

Total pressure (kPa)

Digital 3 arm weak rock self-boring pressure meter
B116
25.00 Metres
10 Apr 06
RESULTS:
Gur: 75.2 MPa
Cycle mid-point:
Cavity strain: 10.050%
Total stress: 1981 kPa
Size of cycle:
Shear strain: 0.784%
Total stress: 592 kPa
Digital 3 arm weak rock self boring pressuremeter
B1T6
25.00 Metres
10 Apr 06
RESULTS:
Gradient (beta) : 0.709
Intercept (n) : 21.061MPa
Shear stress constant : 14.938MPa

\[ \ln(\text{Radial stress}) = \ln(\text{shear strain}) \times 0.709 + 21.061 \]

Source data - Loop 1

- Total pressure (MPa)
- Radial Displacement (mm)
Digital 3 arm weak rock self boring pressuremeter
B1T6
25.00 Metres
10 Apr 06
RESULTS:
Gradient (beta) : 0.701
Intercept (n) : 19.727MPa
Shear stress constant : 13.829MPa
Digital 3 arm weak rock self boring pressuremeter
B1T6
25.00 Metres
10 Apr 06
RESULTS:
Gradient (beta) : 0.668
Intercept (n)     : 16.743MPa
Shear stress constant : 11.189MPa
Digital 3 arm weak rock self boring pressuremeter
B1T6
25.00 Metres
10 Apr 06

RESULTS:
Gradient (b) : 0.658
Intercept (n) : 14.479MPa
Shear stress constant : 9.525MPa
Hold 1
at 2325 kPa

Rate = 0.80 % per time log cycle

Ruritania B1T6  25m
April 10, 2006
Hold 1
at 2325 kPa

Rate = 0.80 % per time log cycle

Ruritania B1T6  25m
April 10, 2006
Hold 2
at 2685 kPa

Rate = 5.20 % per time log cycle

Ruritania B1T6  25m
April 10, 2006
Hold 2
at 2685 kPa

Rate = 5.20 % per time log cycle

Ruritania B1T6  25m
April 10, 2006
1. Test record sheet
2. Results summary
3. Plot of expansion versus pressure – all arms
4. Plot of expansion versus pressure – arm average
5. Plot of expansion versus pressure – arm pairs
6. Plot of expansion versus pressure – odd and even arms
7. Plot of all pressure cells versus time
8. Plot of Marsland & Randolph procedure
9. Hughes plot, giving peak friction angle and dilation
10. Jefferies plot, giving Cu from unloading curve
11. Plot of Reload Loop 1, with linear modulus line
12. Plot of Reload Loop 2, with linear modulus line
13. Plot of Reload Loop 3, with linear modulus line
14. Plot of Reload Loop 4 with linear modulus line
15. Plot of Reload Loop 5 with linear modulus line
16. Bolton and Whittle plot of reloading part of Loop 1, giving nonlinearity coefficients
17. Ditto for Loop 2
18. And again for Loop 3
19. And Loop 4
20. And Loop 5
21. Plot of Shear modulus versus Shear strain for all reload loops
22. Plot of measured and calculated curves, from Carter et al
23. Ditto, using different parameters to get a similar match

This is one of the problems with this procedure.
<table>
<thead>
<tr>
<th>Site</th>
<th>Date</th>
<th>Day</th>
<th>Borehole</th>
<th>Test</th>
<th>Depth to Test Centre (below ground level)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RULINTAKA</td>
<td>12-4-06</td>
<td>TUE</td>
<td>1</td>
<td>7</td>
<td>32.5 m</td>
</tr>
</tbody>
</table>

**Weather:** OK  **Material:** SILTY SAND

<table>
<thead>
<tr>
<th>Water table</th>
<th>Drilling Start</th>
<th>Drilling End</th>
<th>Distance</th>
<th>Drill Rate</th>
<th>Ram Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>~11m</td>
<td>15:13</td>
<td>16:03</td>
<td>1</td>
<td>slow</td>
<td>11000</td>
</tr>
</tbody>
</table>

**Ground level:** ORIENTATION:

<table>
<thead>
<tr>
<th>Water Press</th>
<th>Inst.OD</th>
<th>Shoe OD</th>
<th>Cutter Type</th>
<th>Cutter Position</th>
<th>Probe Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>87mm</td>
<td>89mm</td>
<td>Large</td>
<td>20mm out</td>
<td>Molly</td>
</tr>
</tbody>
</table>

**Drilling Remarks:** UP = DOWN TOWARDS END

<table>
<thead>
<tr>
<th>Strain Rate</th>
<th>Press. Rate</th>
<th>Cycle Time</th>
<th>Gas Bottle</th>
<th>Battery</th>
<th>PPC Type</th>
<th>Max Pressure Cap.</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual</td>
<td>6 secs</td>
<td>9.4 MPa</td>
<td>12.5 MPa</td>
<td>TPC</td>
<td></td>
<td>10 MPa</td>
<td></td>
</tr>
</tbody>
</table>

**Arm 1**

<table>
<thead>
<tr>
<th>Line</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>Hold</td>
</tr>
<tr>
<td>82</td>
<td>Hold</td>
</tr>
<tr>
<td>127</td>
<td>Hold</td>
</tr>
<tr>
<td>161</td>
<td>Hold</td>
</tr>
<tr>
<td>201</td>
<td>close</td>
</tr>
<tr>
<td>271</td>
<td>close</td>
</tr>
</tbody>
</table>

**Test starts:** 16:06

**Test ends:** 16:46  **Max Press:** 9.4 MPa

**Calibrated Data details:**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>C2005 T91</td>
<td>C2005 T32</td>
<td>12-7-05</td>
<td>12-7-05</td>
</tr>
</tbody>
</table>

**TEST REMARKS:**

NICE TEST EXTRA WORK AT HIGH PRESSURE - CHANGE OF GAS BOTTLE.

UNUSUAL TO GO TO MAXIMUM PRESSURE AT MAXIMUM EXPANSION.

Driller: [Signature]

Tester: [Signature]
### Analysis of Insitu Lateral Stress (Po) -

Marsland and Randolph (Iterative Analysis)  
Arm Av. MPa 1.70

### Analysis of Undrained Shear Strength (Cu) -

Jefferies (unloading) MPa 1.85  
Pressure at failure (Pf) MPa 4.2

### Strength of Sands Analysis (Hughes, Wroth & Windle)

Friction angle at const. vol. deg 32 (assumed)  
Angle of Friction deg 47.3  
Angle of Dilation deg 19.6

### Analysis of Shear Modulus (G) -

Initial Modulus (Gi) MPa 130

### Reload loops -

<table>
<thead>
<tr>
<th>Linear analysis</th>
<th>Loop 1</th>
<th>Loop 2</th>
<th>Loop 3</th>
<th>Loop 4</th>
<th>Loop 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reload Modulus (Gr) MPa</td>
<td>313</td>
<td>354</td>
<td>394</td>
<td>396</td>
<td>454</td>
</tr>
<tr>
<td>Pressure at start MPa</td>
<td>1.50</td>
<td>2.51</td>
<td>3.51</td>
<td>4.73</td>
<td>6.97</td>
</tr>
<tr>
<td>Depth of unload MPa</td>
<td>0.60</td>
<td>0.98</td>
<td>1.02</td>
<td>1.25</td>
<td>1.47</td>
</tr>
</tbody>
</table>

### Non-linear analysis

| Non-linearity coeff. (β) | 0.916 | 0.839 | 0.809 | 0.787 | 0.754 |
| Shear stress coeff. (α) MPa | 157   | 117   | 105   | 100   | 89.5  |

### Secant shear modulus (Gs)

<table>
<thead>
<tr>
<th>0.01% shear strain</th>
<th>0.1% shear strain</th>
<th>1% shear strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPa</td>
<td>MPa</td>
<td>MPa</td>
</tr>
<tr>
<td>0.01% “</td>
<td>0.1% “</td>
<td>1% “</td>
</tr>
<tr>
<td>340</td>
<td>280</td>
<td>231</td>
</tr>
<tr>
<td>515</td>
<td>355</td>
<td>245</td>
</tr>
<tr>
<td>612</td>
<td>394</td>
<td>254</td>
</tr>
<tr>
<td>710</td>
<td>435</td>
<td>266</td>
</tr>
<tr>
<td>863</td>
<td>490</td>
<td>278</td>
</tr>
</tbody>
</table>

Values at 1% are unlikely to be reached because the material will have failed by then.
RESULTS:
Ambient water pressure : 315.0 kPa
Residual friction angle : 32.0°
Gradient : 0.566
Friction angle : 47.3°
Dilation angle : 19.6°

Digital 6 arm weak rock self boring pressuremeter
B117
37.50 Metres
12 Apr 06
RESULTS:

Gur : 364.1 MPa
Cycle mid-point:
Cavity strain : 0.251%
Total stress : 2005 kPa
Size of cycle:
Shear strain : 0.269%
Total stress : 954 kPa

Digital 6 arm weak rock self boring pressuremeter
B117
37.50 Metres
12 Apr 06
RESULTS:
- Gur: 394.3 MPa
- Cycle mid-point: 666.6%
- Cavity strain: 0.666%
- Total stress: 3009 kPa
- Size of cycle:
- Shear strain: 0.247%
- Total stress: 977 kPa

Digital 6 arm weak rock self-boring pressuremeter
B117
37.50 Metres
12 Apr 06
RESULTS:
Gur : 396.1 MPa
Cycle mid-point:
Cavity strain : 1.220%
Total stress : 4081 kPa
Size of cycle:
Shear strain : 0.302%
Total stress : 1200 kPa

Digital 6 arm weak rock self boring pressuremeter
B117
37.50 Metres
12 Apr 06
Digital 6 arm weak rock self-boring pressuremeter
B177
37.50 Metres
12 Apr 06
RESULTS:
Gradient (\(\beta\)) : 0.839
Intercept (\(\eta\)) : 139.231 MPa
Shear stress constant : 116.803 MPa
Digital 6 arm weak rock self boring pressuremeter
B177
37.50 Metres
12 Apr 06
RESULTS:
Gradient (beta) : 0.787
Intercept (n) : 126.870MPa
Shear stress constant : 99.894MPa
Digital 6 arm weak rock self-boring pressuremeter
B1T7
37.50 Metres
12 Apr 06
RESULTS:
Gradient (beta): 0.754
Intercept (n): 118.799 MPa
Shear stress constant: 89.619 MPa
Variation of stiffness with strain, undrained analysis - Arm ave

**POWER LAW PARAMETERS:**

<table>
<thead>
<tr>
<th>Cycle No.</th>
<th>Constant (MPa)</th>
<th>Gradient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>156.966</td>
<td>0.916</td>
</tr>
<tr>
<td>2</td>
<td>116.803</td>
<td>0.839</td>
</tr>
<tr>
<td>3</td>
<td>105.373</td>
<td>0.809</td>
</tr>
<tr>
<td>4</td>
<td>99.894</td>
<td>0.787</td>
</tr>
<tr>
<td>5</td>
<td>89.519</td>
<td>0.754</td>
</tr>
</tbody>
</table>

Digital 6 arm weak rock self boring pressuremeter
B117
37.50 Metres
12 Apr 06

Log plane shear strain
Carter et al 1986 - Total pressure vs Cavity strain

Measured
Calculated

Uo (kPa) : 315
Po (kPa) : 1410
C (kPa) : 0
Phi cv (°) : 32
Phi pk (°) : 47
Gyield (MPa) : 274
Non-linearity : 0.75
Janbu exponent : 0.20
Poissons Ratio : 0.20
Carter et al 1986 - Total pressure vs Cavity strain

Measured
Calculated

Uo (kPa) : 315
Po (kPa) : 1000
C (kPa) : 1200
Phi cv (°) : 32
Phi pk (°) : 45
Gyieid (MPa) : 206
Non-linearity : 0.75
Janbu exponent : 0.20
Poissons Ratio : 0.20

B1T7
37.50mBGL
April 12, 2006
Weak Rock Self-boring Pressuremeter and High Pressure Dilatometer Tests
Cambridge Insitu Ltd                                                                                      March 2011

B1T8  07/05/06  50.8m  Chalk (with flints)

1. Test record sheet
2. Results summary
3. Plot of expansion versus pressure – all arms
4. Plot of expansion versus pressure – arm average
5. Plot of expansion versus pressure – arm pairs
6. Plot of expansion versus pressure – odd and even arms
7. Plot of Marsland & Randolph procedure
8. Plot of cavity strain versus pressure, using the strain zero from the previous plot
9. Gibson and Anderson plot, giving $C_u$ and $P_L$ from loading curve
10. Jefferies plot, giving $C_u$ from unloading curve
11. Hughes plot, giving peak friction angle and dilation
12. Plot of Reload Loop 1, with linear modulus line
13. Plot of Reload Loop 2, with linear modulus line
14. Plot of Reload Loop 3, with linear modulus line
15. Bolton and Whittle plot of reloading part of Loop 1, giving nonlinearity coefficients
16. Ditto for Loop 2
17. And again for Loop 3
18. Plot of Shear modulus versus Shear strain for all reload loops
19. Hughes plot, showing zero dilation at large strain

*Note that although the material is basically frictional, when it fails it does so at constant volume.*
TEST RECORD SHEET - HIGH PRESSURE DILATOMETER

SITE: RURITANIA
Date: 7-5-06
Day: Thu
Borehole: 1
Test No: 8
Depth: 50.8

Material: CHALK (+ FLINTS)

Weather: ~ 11°C

Drilling: CORING TCH
Pocket: 48.7 - 51.7 m

Diameter: 3.25

Wet/Dry: Mud
Rig: TS
Driller: N. Everatt
Core Quality: Size

Pres/Incmt: 10 secs
Wait Time: 10 secs
Creep Time: D. C.
Cycle Time: 10 secs
Disc No.: Operator: Engineer: D. C.

ZERO READINGS:
Arm 1: -25.18
Arm 2: -17.94
Arm 3: -14.43
Arm 4: -19.98
Arm 5: -23.43
Arm 6: -25.9
Machine Diameter: A: 16.2
B: -19.2
T/Press.: 12.12
Battery: 12.12

Calibrations:
Strain Arm Calibration date: 29/04/06
Test No: 85
Total Pressure Cell Calibration date: 
Test No: 
Membrane Stiffness Calibration date: 
Test No: 83.573
Membrane Compression Calibration date: 
Test No: 
New Membrane fitted date: 

Test Comments:
Time: Line No. | Start Test at:
---|---
81 | HOCO ~ 6 MPa
111 | L=O (O)
160 | HOCO ~ 10 MPa
190 | L=O (O)
244 | HOCO ~ 13 MPa
down | 294 | L=O (O)
322 |

Test Ends at: 15:17
Max. Pressure reached: 14.7 MPa

General Comments: FAILING NICELY.
Analysis of Insitu Lateral Stress (Po) :-

<table>
<thead>
<tr>
<th>Marsland and Randolph</th>
<th>Arm Av.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MPa 3.7</td>
</tr>
<tr>
<td>Strain zero</td>
<td>mm 2.1</td>
</tr>
</tbody>
</table>

Analysis of Undrained Shear Strength (Cu) :-

| Gibson and Anderson   | MPa 4.27 |
| Pressure at failure (P_f) | MPa 5.50 |
| Limit Pressure (P_L)   | MPa 26.2 |
| Jefferies (unloading)  | MPa 3.68 |

Strength of Sands Analysis (Hughes, Wroth & Windle)

| Friction angle at const. vol. | deg 25 (assumed) |
| Angle of Friction             | deg 37.2 |
| Angle of Dilation             | deg 14.2 |

Analysis of Shear Modulus (G) :-

| Initial Modulus (Gi) | MPa 330 |

Linear Analysis of Reload Loops (G_R) :-

<table>
<thead>
<tr>
<th>G_R</th>
<th>Loop 1</th>
<th>Loop 2</th>
<th>Loop 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPa</td>
<td>1.02</td>
<td>1.07</td>
<td>1.03</td>
</tr>
<tr>
<td>Pressure at start</td>
<td>MPa 5.91</td>
<td>10.4</td>
<td>13.4</td>
</tr>
<tr>
<td>Depth of unload</td>
<td>MPa 1.96</td>
<td>3.58</td>
<td>4.74</td>
</tr>
</tbody>
</table>

Non-linear Analysis of Reloading data :-

| α | MPa 323 | 367 | 366 |
| β | 0.843 | 0.842 | 0.838 |

Shear Modulus G_S (at 2 levels of shear strain) :-

| (0.01%) | GPa 1.37 | 1.57 | 1.63 |
| (0.1%)  | GPa 0.96 | 1.09 | 1.12 |

Test Analysed By :- PGH
Date :- Sept 2009
95mm High Pressure Dilatometer
B1T8
50.80 Metres
7 May 06
RESULTS:
Gi : 330.0MPa
Pf : 5496.6kPa
Po : 3700.9kPa
Tf : 1800.0kPa
Po + Tf : 5600.9kPa
Origin : 2.056mm
RESULTS:

- $C_u = 4269.2 \text{kPa}$
- $P_l = 26226 \text{kPa}$
- $\gamma = 72$
- $G = 307.3 \text{MPa}$
RESULTS:
Gur : 1020.7MPa
Cycle mid-point:
Cavity strain : 0.418%
Total stress : 4920kPa
Size of cycle:
Shear strain : 0.192%
Total stress : 1965kPa

95mm High Pressure Dilatometer
B118
50.80 Metres
7 May 06
RESULTS:
- Gur : 1031.1 MPa
- Cycle mid-point:
  - Cavity strain : 3.103%
  - Total stress : 10945 kPa
- Size of cycle:
  - Shear strain : 0.459%
  - Total stress : 4711 kPa

95mm High Pressure Dilatometer
B118
50.80 Metres
7 May 06
95mm High Pressure Dilatometer
B1T8
50.80 Metres
7 May 06
RESULTS:
Gradient (beta): 0.842
Intercept (n): 435.554MPa
Shear stress constant: 366.775MPa
RESULTS:
Ambient water pressure: 350.0 kPa
Residual friction angle: 25.0°
Gradient: 0.297
Friction angle: 25.0°
Dilation angle: 0.0°
B1T9  10/05/06  67.6m  Limestone

1. Test record sheet
2. Results summary
3. Plot of expansion versus pressure – all arms
4. Plot of expansion versus pressure – arm average
5. Plot of expansion versus pressure – arm pairs
6. Plot of expansion versus pressure – odd and even arms
7. Plot of Marsland & Randolph procedure
8. Plot of cavity strain versus pressure
9. Plot of Gibson & Anderson procedure, giving Cu and $P_L$
10. Jefferies plot, giving Cu from unloading curve
11. Plot of Reload Loop 1, with linear modulus line
12. Plot of Reload Loop 2, with linear modulus line
13. Plot of Reload Loop 3, with linear modulus line
14. Plot of Reload Loop 4 with linear modulus line
15. Plot of Reload Loop 5 with linear modulus line
16. Hughes plot, giving peak friction angle
17. Plot of Shear Stress versus Normal Stress, showing Friction Angle, obtained from the Manassero procedure
18. Plot of measured and calculated curves, from Carter et al
<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>BLACK LIMESTONE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather</td>
<td>Humid</td>
</tr>
<tr>
<td>Water Table</td>
<td></td>
</tr>
<tr>
<td>Time Now</td>
<td>12:00</td>
</tr>
<tr>
<td>Drilling</td>
<td></td>
</tr>
<tr>
<td>Core Length</td>
<td>To 69m</td>
</tr>
<tr>
<td>Diameter</td>
<td>5</td>
</tr>
<tr>
<td>Distance</td>
<td></td>
</tr>
<tr>
<td>Rate</td>
<td></td>
</tr>
<tr>
<td>Core Description</td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td></td>
</tr>
<tr>
<td>Wet/Dry Rig</td>
<td></td>
</tr>
<tr>
<td>Driller</td>
<td></td>
</tr>
<tr>
<td>Core Quality</td>
<td></td>
</tr>
<tr>
<td>Size</td>
<td></td>
</tr>
<tr>
<td>Pres/Incrunt</td>
<td></td>
</tr>
<tr>
<td>Wait Time</td>
<td></td>
</tr>
<tr>
<td>Creep Time</td>
<td></td>
</tr>
<tr>
<td>Cycle Time</td>
<td></td>
</tr>
<tr>
<td>Disc No.</td>
<td></td>
</tr>
<tr>
<td>Operator</td>
<td></td>
</tr>
<tr>
<td>Engineer</td>
<td></td>
</tr>
<tr>
<td>ZERO READINGS</td>
<td></td>
</tr>
<tr>
<td>Arm 1</td>
<td></td>
</tr>
<tr>
<td>Arm 2</td>
<td></td>
</tr>
<tr>
<td>Arm 3</td>
<td></td>
</tr>
<tr>
<td>Arm 4</td>
<td></td>
</tr>
<tr>
<td>Arm 5</td>
<td></td>
</tr>
<tr>
<td>Arm 6</td>
<td></td>
</tr>
<tr>
<td>T/Press.</td>
<td></td>
</tr>
<tr>
<td>Battery</td>
<td></td>
</tr>
<tr>
<td>Calibration</td>
<td></td>
</tr>
<tr>
<td>Strain Arm Calibration date:</td>
<td>6-7-10</td>
</tr>
<tr>
<td>Total Pressure Cell Calibration date:</td>
<td></td>
</tr>
<tr>
<td>Membrane Stiffness Calibration date:</td>
<td>7-3-10</td>
</tr>
<tr>
<td>Membrane Compression Calibration date:</td>
<td></td>
</tr>
<tr>
<td>New Membrane fitted date:</td>
<td></td>
</tr>
<tr>
<td>Test Comments</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>Start Test at:</td>
</tr>
<tr>
<td>18</td>
<td>12:30</td>
</tr>
<tr>
<td>20</td>
<td>Hole connection blow off</td>
</tr>
<tr>
<td>30</td>
<td>Hold = Low (4)</td>
</tr>
<tr>
<td>30</td>
<td>Hold = Low (3)</td>
</tr>
<tr>
<td>112</td>
<td>Hold = Low (6)</td>
</tr>
<tr>
<td>811</td>
<td>Arm (5) sudden jump</td>
</tr>
<tr>
<td>315</td>
<td>Down</td>
</tr>
<tr>
<td>340</td>
<td>Hold = Low (6)</td>
</tr>
<tr>
<td>Test Ends at</td>
<td>13:42</td>
</tr>
<tr>
<td>Max. Pressure reached:</td>
<td>13.75 MPa</td>
</tr>
<tr>
<td>General Comments:</td>
<td>ONLY ARMS (6) FAILED AT FIRST</td>
</tr>
</tbody>
</table>

CAMBRIDGE INSTITUTION, Little Eversden, Cambridge, England CB3 7HE
Telephone: 01223 262 361 Fax: 01223 263 947
Site: Ruritania  Test: B1T9  Test Date: 10th May 2006
Material: Limestone  Depth: 67.6 mtrs  Water table: ~11 mtrs

Analysis of In situ Lateral Stress (Po) and Cohesion (C):

<table>
<thead>
<tr>
<th></th>
<th>Po</th>
<th>C</th>
<th>Po + C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marsland and Randolph</td>
<td>5.00</td>
<td>1.85</td>
<td>4.95</td>
</tr>
<tr>
<td>Carter et al</td>
<td>3.10</td>
<td>1.85</td>
<td>4.95</td>
</tr>
<tr>
<td>Borehole diameter</td>
<td>101.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analysis of Undrained Shear Strength (Cu):

<table>
<thead>
<tr>
<th></th>
<th>MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure at failure (P_F)</td>
<td>8.01</td>
</tr>
<tr>
<td>Jefferies (unloading)</td>
<td>2.65</td>
</tr>
<tr>
<td>Gibson &amp; Anderson (loading)</td>
<td>4.58</td>
</tr>
<tr>
<td>Limit pressure (P_L)</td>
<td>36.4</td>
</tr>
</tbody>
</table>

Strength of Sands Analysis:

<table>
<thead>
<tr>
<th></th>
<th>φ_cv</th>
<th>φ_pk</th>
<th>dilation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hughes, Wroth &amp; Windle</td>
<td>(43)</td>
<td>45</td>
<td>2.8</td>
</tr>
<tr>
<td>Carter et al</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
</tbody>
</table>

Analysis of Shear Modulus (G):

<table>
<thead>
<tr>
<th></th>
<th>GPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Modulus (Gi)</td>
<td>1.92</td>
</tr>
<tr>
<td>Yield Modulus (Carter et al)</td>
<td>2.15</td>
</tr>
</tbody>
</table>

Linear Analysis of Reload Loops (G_R):

<table>
<thead>
<tr>
<th></th>
<th>Loop 1</th>
<th>Loop 2</th>
<th>Loop 3</th>
<th>Loop 4</th>
<th>Loop 5 (on unloading)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G_R</td>
<td>GPa</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure at start</td>
<td>MPa</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth of unload</td>
<td>MPa</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Test Analysed By: PGH  Date: July 2010

Note that the results of the Carter et al curve matching have been included, because of the good agreement with more traditional methods. φ_cv has been estimated from the Manassero plot.
95mm High Pressure Dilatometer
B1T9
67.60 Metres
10 May 06

RESULTS:
Gi : 1922.9MPa
Pf : 8006.3kPa
Po : 5003.4kPa
Tf : 2994.7kPa
Po + Tf : 7998.1kPa
Origin : 3.348mm
RESULTS:
C_u: 4582.2kPa
P_I: 36362kPa
\( \psi_r \): 345
C_G: 1582.2MPa
RESULTS:
Gur : 229.0MPa
Cycle mid-point:
Cavity strain : -0.307%
Total stress : 1123kPa
Size of cycle:
Shear strain : 0.223%
Total stress : 512kPa

95mm High Pressure Dilatometer
B1T9
67.60 Metres
10 May 06
RESULTS:
Gur : 4047.3MPa
Cycle mid-point:
Cavity strain : 0.346%
Total stress : 9077kPa
Size of cycle:
Shear strain : 0.068%
Total stress : 2748kPa
Shear stress vs Normal stress

Friction Angle: 43.0 Deg
Dilation Angle: 0.0 Deg

B1T9  67.60m BGL
May 10, 2006
Carter et al 1986 - Total pressure vs Cavity strain

Uo (kPa) : 650
Po (kPa) : 3100
C (kPa) : 1850
Phi cv (°) : 43
Phi pk (°) : 45
Gyeld (MPa) : 2151
Non-linearity : 1.00
Janbu exponent : 1.23
Poissons Ratio : 0.50

B1T9
67.60mBGL
May 10, 2006
B1T10  11/05/06  80.4m  Phyllite

1. Test record sheet
2. Results summary
3. Plot of expansion versus pressure – all arms
4. Plot of expansion versus pressure – arm average
5. Plot of expansion versus pressure – arm pairs
6. Plot of expansion versus pressure – odd and even arms
7. Plot showing the initial modulus line
8. Plot of Reload Loop 1, with linear modulus line
9. Plot of Reload Loop 2, with linear modulus line
10. Plot of Reload Loop 3, with linear modulus line

Note that as the material does not fail, this is all that can be determined.
**Test Record Sheet**

**High Pressure Dilatometer**

### Materials
- **Phyllite**

### Weather
- **Wet**

### Weather Table
- **Time Now:** 05:41
- **Drilling End:** 10/5/06
- **Drilling End Time:** 17:30

### Drilling
- **Drill Diameter:** 16H
- **Core Pocket:**

### Depth
- **Depth:** 80.4m

### Zero Readings

<table>
<thead>
<tr>
<th>Arm 1</th>
<th>Arm 2</th>
<th>Arm 3</th>
<th>Arm 4</th>
<th>Arm 5</th>
<th>Arm 6</th>
<th>TPRESS</th>
<th>Battery</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1587 1</td>
<td>-1634</td>
<td>999</td>
<td>-1253.6</td>
<td>-1718.4</td>
<td>-2316.5</td>
<td>A: 45.2</td>
<td>12.73v</td>
</tr>
</tbody>
</table>

### Calibrations
- **Strain Arm Calibration Date:** 19/11/10
- **Total Pressure Cell Calibration Date:** 19/11/10
- **Membrane Stiffness Calibration Date:** 19/11/10
- **Membrane Compression Calibration Date:** 19/11/10
- **Membrane Filled Date:** 19/11/10

### Test Comments
- **Test Starts at:** 05:11

### Time

<table>
<thead>
<tr>
<th>Time</th>
<th>Line No</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1:36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1:55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2:02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2:17</td>
<td>2:31</td>
<td></td>
</tr>
<tr>
<td>3:10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4:25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7:17</td>
<td>7:51</td>
<td></td>
</tr>
<tr>
<td>14:00</td>
<td>14:28</td>
<td></td>
</tr>
<tr>
<td>14:51</td>
<td>15:28</td>
<td></td>
</tr>
</tbody>
</table>

### Pressure
- **Max Pressure Reached:** 7,0037 kPa

### General Comments
- **Driller:** Hayre
- **Operator:** SDB

---

**Cambridge Insitu, Little Eversden, Cambridge CB23 1NE**
**Tel:** (01223) 262 361 **Fax:** (01223) 263 947
**Email:** caminsitu@aol.com **Website:** Cambridge-Insitu.com
Site:- Ruritania                                             Test :- B1T10                                           Test Date :- 11th May 2006
Material :- Phyllite                                        Depth (m) :- 80.4                                            Water table (m) :- ~11m

Analysis of Shear Modulus (G) :-
Initial Modulus (Gi)                                       GPa          10.5

Linear Analysis of Reload Loops (G_R) :-

<table>
<thead>
<tr>
<th>G_R</th>
<th>Loop 1</th>
<th>Loop 2</th>
<th>Loop 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPa</td>
<td>MPa</td>
<td>MPa</td>
<td>MPa</td>
</tr>
<tr>
<td></td>
<td>5.22</td>
<td>7.24</td>
<td>9.31</td>
</tr>
<tr>
<td></td>
<td>7.66</td>
<td>11.75</td>
<td>15.90</td>
</tr>
<tr>
<td></td>
<td>3.42</td>
<td>5.39</td>
<td>8.01</td>
</tr>
</tbody>
</table>

Reload loops lie on main curve. Linear response after Loop 3.

Test Analysed By :- PGH
Date :- February 2011
RESULTS:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gur</td>
<td>5218.6 MPa</td>
</tr>
<tr>
<td>Cycle mid-point</td>
<td></td>
</tr>
<tr>
<td>Cavity strain</td>
<td></td>
</tr>
<tr>
<td>Total stress</td>
<td>5948 kPa</td>
</tr>
<tr>
<td>Size of cycle</td>
<td></td>
</tr>
<tr>
<td>Shear strain</td>
<td>0.066%</td>
</tr>
<tr>
<td>Total stress</td>
<td>3421 kPa</td>
</tr>
</tbody>
</table>

95mm High Pressure Dilatometer
B1110
80.40 Metres
11 May 06