Appendix E:
Tailings Properties
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<th>Test Certificate Type</th>
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<tr>
<td>EG</td>
<td>TC 1 – CSL Test Certificates</td>
</tr>
<tr>
<td>EH</td>
<td>TS2 – CSL Test Certificates</td>
</tr>
<tr>
<td>EI</td>
<td>TC2 – CSL Test Certificates</td>
</tr>
<tr>
<td>EJ</td>
<td>Interpreted CPTu</td>
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<tr>
<td>EK</td>
<td>Oedometer Test Certificates</td>
</tr>
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<td>EL</td>
<td>Bender Element Test Certificates</td>
</tr>
<tr>
<td>EM</td>
<td>CSD Triaxial Test Certificates</td>
</tr>
<tr>
<td>EN</td>
<td>Cyclic Direct Simple Shear (CDSS) Certificates</td>
</tr>
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<td>Golder Stress Path Test Results</td>
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<td>EP</td>
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<td>Test Procedures</td>
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<tr>
<td>ER</td>
<td>Stress Path Triaxial Test Video Footage</td>
</tr>
</tbody>
</table>
E1. Introduction

The tailings retained within the NTSF are predominantly silt-sized soils which were discharged as a slurry that subsequently consolidated. These tailings have accumulated with flat beach slopes such that the tailings are near horizontally bedded.

The CPTu investigations of the tailings undertaken in 2017 remain relevant and have not been duplicated by the ITRB; rather, the original data has been retrieved, and then evaluated. The earlier 2013 CPTu data has been assessed at a high level as it reflects conditions five or more years ago.

Appendix C documents the insitu testing and sampling of tailings, undertaken on behalf of the ITRB in 2018, together with previous investigations completed in 2013 and 2017.

In terms of property measurement, the ITRB has undertaken substantial laboratory testing as, comparatively, the earlier campaigns carried out little work on this aspect.

This appendix presents the following work:

- Documentation of the laboratory testing, followed by detailed analysis of that data to determine the tailings properties. These properties have been used to simulate the laboratory tests (using the same NorSand model as the deformation analysis) to confirm that the derived properties are consistent with the tailings stress-strain behaviour.

- A detailed evaluation (“interpretation”) of the CPTu data using the measured properties of the NTSF tailings. This work leads to the insitu state parameter that controls soil behaviour (and liquefaction in particular).

Both the calibrated parameters and the insitu state parameter have been carried forward into the numerical analyses documented in Appendix H.
E2. ITRB Laboratory Testing

E2.1 Overview

The ITRB’s investigations and subsequent testing focused on determining the properties and other aspects of:

- the insitu tailings that remained within the impoundment near the slump, and
- the tailings from the slump run-out where the properties may have changed during the slump due to considerable dynamic mixing, as apparent on the video records.

In order to fast track critical state testing of the tailings, two bulk samples were collected from the tailings runout on the slump. Sample HA401; a low plasticity, clayey silt, was considered to represent the bulk of the tailings that had liquefied, while sample, HA402, possibly representing the coarsest phase of the tailings, was taken by carefully scraping the surface of a number of randomly selected sand boils.

The insitu tailings in the vicinity of the slump provide an insight on the condition of the tailings relevant to how the slump initiated.

Within the constraints of the post-failure exclusion zone, bulk samples of insitu tailings and nominally undisturbed piston samples were taken from drillholes located as close as practicable to the slump. Table E2-1 provides details of the materials comprising the bulk samples collected from Lexan tubes. Three samples were collected in June 2018, while a further two were collected from stored Lexans in December 2018.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Sample Date</th>
<th>Visual Description</th>
<th>Investigation ID</th>
<th>Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC1</td>
<td>June 19-23, 2018</td>
<td>Clayey SILT</td>
<td>CE407</td>
<td>21.0 – 22.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>30.0 – 31.5</td>
</tr>
<tr>
<td>TC2</td>
<td>December 17, 2018</td>
<td>Clayey SILT</td>
<td>CE413</td>
<td>15.0 – 16.5</td>
</tr>
<tr>
<td>TC3</td>
<td>December 17, 2018</td>
<td>Clayey SILT</td>
<td>CE413</td>
<td>27.0 – 28.5</td>
</tr>
<tr>
<td>TS1</td>
<td>June 19-26, 2018</td>
<td>Sandy SILT, trace clay</td>
<td>CE407</td>
<td>27.9 – 28.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>14.6 – 15.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15.6 – 15.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>17.7 – 18.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>22.1 – 22.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>29.7 – 30.0</td>
</tr>
<tr>
<td>TS2</td>
<td>June 24-26, 2018</td>
<td>Sandy SILT trace clay</td>
<td>CE408</td>
<td>21.0 – 22.5</td>
</tr>
</tbody>
</table>

Initial testing was focused on determining the critical state locus with further testing to evaluate resistance to cyclic loading (earthquake or similar) and evaluation of the stress path indicated by numerical analyses.

Initial testing was carried out on bulk samples, with four samples being tested at Golder Associates (Golder) Perth laboratory. The focus of the critical state and associated advanced laboratory testing has been on the following samples:
- HA401  Slumped Clayey SILT  (predominant run-out tailings)
- HA402  Slumped Sandy SILT  (sander run-out tailings)
- TC1   ‘Insitu’ Clayey SILT   (predominant insitu tailings)
- TS2   ‘Insitu’ Sandy Clayey SILT  (sander insitu tailings)

Four bulk samples (HA401, HA402, TC1 and TS2) were shipped to Golder’s Perth laboratory by air freight, while the remaining bulk sample (TS1), piston samples and disturbed samples were shipped to Trilab’s Brisbane laboratory.

Subsequently, sample HA401 was split and sent to Trilab, sample TS1 was sent to Golder’s Perth laboratory and sample TC2 was shipped to KCB’s Vancouver laboratory.

The following tests were undertaken to characterise the tailings:

- Atterberg Limits
- Particle size distribution by hydrometer
- Particle size distribution by X-Ray sedimentation
- Specific gravity
- X-Ray Diffraction (XRD) – semi quantitative
- Scanning Electron Microscopy (SEM)

The following ‘advanced’ laboratory tests were undertaken on the tailings:

- Isotropically consolidated undrained (CIU) triaxial;
- Isotropically consolidated drained (CID) triaxial;
- Anisotropically consolidated constant shear drained (CSD) triaxial;
- Cyclic direct simple shear test (CDSS);
- Bender element test;
- Oedometer consolidation; and
- Stress path triaxial testing.

### E2.2 Advanced Laboratory Test Methods

#### E2.2.1 Critical State Testing

The Critical State Locus (CSL) was determined by undertaking a number of CID and CIU tests on samples that had been reconstituted to a range of densities. This testing provides a reference data set and is generally not at, nor intended to be at, the insitu density of the tailings. The testing was generally undertaken in accordance with the procedures detailed in Appendix B of the *Soil Liquefaction, 2nd edition* (Jefferies & Been, 2016).

Key aspects of the testing are:

- Sample preparation involving the following steps 1) Drying in low temperature oven (50°C), 2) breaking down of aggregations, 3) thoroughly mixing, 4) sub-sampling, 5) reconstituting to a moisture content of ~10% using TSF decant water supplied by CVO and 6) curing.
- Compaction of sample into a split mould (mounted on the triaxial pedestal) to a specified density by moist tamping in eight layers, using vibration where high densities are required. Golder used 63 mm diameter specimens while TriLabs testing was undertaken on 75 mm diameter specimens.

- Accurate measurement of changes in cell volume and pore fluid.

- Computer controlled loading and data acquisition to achieve approximately 4000 readings by 20 % strain. A much higher rate of sampling was used by Golders, with the data subsequently filtered to reduce file size.

- Void ratio and moisture content determined by lightly freezing the assembled sample (including pedestal) before dis-assembly.

Constant shear drained (CSD) triaxial tests were also undertaken to support the CSL testing and assess the strength of the tailings under conditions of reducing lateral confinement, a condition that potentially existed when the tailings embankment began to move.

CSD triaxial tests were prepared in a similar manner to the CIU and CID samples for CSL testing. CSD tests were anisotropically consolidated to a specified value of K0, followed by a reduction in the mean effective stress. Servo controlled loading was used during the CSD testing.

Table E2-2 summarises the type, density and consolidation pressure of the principal CSL tests.

| Test | Density (1) | Test Type | Consolida**
<table>
<thead>
<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>HA401</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Golder 18003</td>
</tr>
<tr>
<td>1</td>
<td>VL</td>
<td>CIU</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>L</td>
<td>CIU</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>L</td>
<td>CIU</td>
<td>500</td>
</tr>
<tr>
<td>4</td>
<td>L</td>
<td>CID</td>
<td>300</td>
</tr>
<tr>
<td>5</td>
<td>L</td>
<td>CID</td>
<td>800</td>
</tr>
<tr>
<td>6</td>
<td>D</td>
<td>CID</td>
<td>50</td>
</tr>
<tr>
<td>7</td>
<td>D</td>
<td>CID</td>
<td>100</td>
</tr>
<tr>
<td>8</td>
<td>D</td>
<td>CID</td>
<td>800</td>
</tr>
<tr>
<td>9</td>
<td>D</td>
<td>CID</td>
<td>1300</td>
</tr>
<tr>
<td>10</td>
<td>L</td>
<td>CSD (3)</td>
<td>200 (2)</td>
</tr>
</tbody>
</table>

Notes:
(1) Except where noted on individual samples; VL= very loose, L = loose, D=dense.
(2) Mean effective stress.

**E2.2.2 Cyclic Direct Simple Shear (CDSS)**

The ability of the tailings to withstand earthquake induced ground motions was tested using cyclic direct simple shear (CDSS) tests. The CDSS is a plain strain test that is analogous to the vertical propagation of earthquake motion through the tailings. This type of testing is the de facto current standard, at least for silts.

The tests were all carried out on reconstituted samples, using modern GDS equipment, and a ‘large’ sample size of 100 mm diameter. Tests were mostly carried out on TC1 material; with one test completed on TS1.
The upper, loose tailings will be the most vulnerable to earthquake ground motion because of the amplification of that motion as it propagates upwards from the underlying bedrock. Consequently, sample preparation was as loose as possible within the constraint of DSS preparation. After consolidation to the test stress level these samples were found to be loose to somewhat looser than the insitu tailings.

Tailings close to the upstream construction may behave differently (and likely, stronger) than the tailings further away from the point of tailings discharge. A static bias (the ratio of horizontal shear stress to initial vertical effective stress) is applied to the specimen to replicate these conditions while an absence of static bias replicates conditions away from the upstream raise.

Cyclic loading is specified as the cyclic stress ratio (CSR) which is the ratio of cyclic shear stress to the initial vertical effective stress. Relatively low values of CSR, between 0.05 and 0.10, were adopted to replicate the expected low magnitude of ground motion (even with amplification).

The majority of tests were completed using a sinusoidal cyclic loading, however two tests were undertaken that closely replicated the two seismic events recorded on March 8, 2018, albeit with a much reduced separation between the two events.

**E2.2.3 Bender Element Tests (BE)**
The small strain shear modulus was investigated in the laboratory via the measurement of shear wave velocity. With this test miniature transducers ("bender elements") embedded in the platens at either end of a triaxial test specimen were used to measure the shear wave travel time, with shear waves being identified by polarity reversal. A single sample, TC1, was consolidated anisotropically ($K_0 = 0.6$) in steps, with shear wave velocity being measure at each step.

**E2.2.4 Oedometer Consolidation Tests (OED)**
Four oedometer consolidation tests were completed on 75 mm diameter piston samples in accordance with AS1289.6.6.1. Specimens were loaded in increments to 3200 kPa, with one unloading / reloading cycle between 400 kPa and 100 kPa.

**E2.2.5 Stress Path Triaxial Testing**
The stresses developed in the tailings during the construction of the various embankment stages and Stage 1 Buttress was extracted from the FLAC 2D analyses at various critical points.

Stress path triaxial tests were completed by preparing the samples in a loose state followed by anisotropic consolidation. The samples were then loaded to replicate the loading path at a particular point within the tailings. As the loading path can influence how the soil responds once the stress state exceeds the soil’s instability locus, a number of tests were undertaken to test various loading scenarios.

Six stress path tests were completed in Golder’s Perth laboratory and three in KCB’s Vancouver laboratory.

**E2.3 Test Results**
The results of laboratory test undertaken as part of the 2018 ITRB investigations are provided in the annexures to this Appendix, whilst summaries of the test results are provided in the following sections.
E3. Tailings Characteristics

E3.1 Overview
Tailings stratigraphy and condition can be initially assessed (at a “screening” level) by processing CPTu data using standard methods. This section describes that work, giving a context for the detailed testing that then follows.

E3.2 Stratigraphy
The CPTu measurements at CPT–N04 (2017-010) are shown on Figure E3-1, together with the standard normalised responses of friction ratio (F) and excess pore pressure (Bq). The left-hand plot on this figure shows the tip resistance, with the ‘spikes’ on the plot being caused by sand layers within the overall tailings; the induced excess pore pressure drops at the same time because sand is ‘free draining’. The friction ratio is less in sand than in silts, but this is a less sensitive indicator.

The CPTu measurements can be combined to derive a ‘normalised soil behaviour type’ or SBTn (Roberston, 1990). In the case of 2017-N04, the SBTn indicates a profile that is predominantly clays above RL 727, clays with intermittent 0.1 to 0.2 m thick sandy lenses between RL727 and RL697 with the lower 14 m of the profile reverting to silty clay. A thicker layer of interbedded sandy mixtures and clays is present from RL 723 to 727 m.

The investigations carried out for the ITRB indicate that the tailings are predominantly silt, not clay; an effect that arises with loose silts which show large excess pore pressure when sheared (eg Bq~0.5-0.6) and which the standard CPTu evaluation methods then indicate as ‘soft clay’.

Laboratory index tests in conjunction with the CPTu data, suggests an appropriate stratigraphic characterisation of the tailings should be based on the relative proportions of sand layers within the overall silt-dominated profile. Figure E3-1, shows the three strata, A, B, and C, adopted using this characterisation.

![Figure E3-1: CPT N04 showing measured and derived parameters](image-url)
E3.3 Soil Condition

The CPTu data is readily processed one step further to indicate how dense or loose the tailings are. There are two standard charts for this, which are presented for CPTu 2017-N04 on Figure E3-2 and Figure E3-3. In each case, the CPT data has been averaged into representative depth increments and annotated as to the A, B and C strata just discussed.

The plot on Figure E3-2 is based on Shuttle & Cunning (2008) and uses the state parameter (Ψ) approach. The plot uses dimensionless penetration resistance (relying on Bq) versus Friction Ratio. The green line indicates the boundary between contractive (potential for flow slide) and dilatant (limited deformation) soil behaviour. As can be seen, all of the 2017–N04 profiles classifies as potentially contractive material with the C stratum being a little weaker than the overlying tailings.

The plot on Figure E3-3 is based on Robertson (2016) and is a plot of normalized tip resistance versus friction ratio. The ‘S’ shaped line on this graph similarly denotes the boundary between contractive and dilatant behaviour. The inference from this figure remains the same, with all of the 2017–N04 profile classifying as contractive.

Plots showing the tailings conditions at all CPTu locations is provided as Annexure EJ.
Figure E3-2: CPT-N04 – Shuttle and Cunning (2008) tailings state plot

Figure E3-3: CPTu-N04 – Robertson (2016) tailings state plot
E3.4 Tailings Properties

E3.4.1 Atterberg Limits

Atterberg Limits were obtained for various insitu samples collected from drill holes CE407, CE408 and CE413 as well as for the bulk samples subjected to CSL triaxial testing. The plastic limit for HA402 could not be determined as this material is predominantly clean sand from a sand boil and is inherently non-plastic. Test certificates are provided in Annexure EB, while results are summarised in Figure E3-4.

![Figure E3-4: Plasticity chart for NTSF tailings samples](image)

E3.4.2 Specific Gravity

The specific gravity determined on fifteen samples (using AS 1289.3.5.1) ranged between 2.55 and 2.77 with a mean value of 2.69. The specific gravity of triaxial test samples for critical state locus determination was completed in accordance with ASTM D5550 using helium pycnometry and AS 1289.3.5.1. These tests are compared in Table E3-1.

<table>
<thead>
<tr>
<th>Bulk Sample</th>
<th>Specific Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AS 1289.3.5.1</td>
</tr>
<tr>
<td>HA 401</td>
<td>2.73</td>
</tr>
<tr>
<td>HA 402</td>
<td>2.63</td>
</tr>
<tr>
<td>TC1</td>
<td>2.74</td>
</tr>
<tr>
<td>TS2</td>
<td>2.69</td>
</tr>
</tbody>
</table>
**E3.4.3 Particle Size Distribution**

Particle Size Distributions (PSD) test certificates are provided in Annexure EB while the results for bulk samples are presented graphically in Figure E3-5, with HA401 and HA402 determined by X-Ray Sedimentation (shown as dashed lines) and a composite Concentrator 1 sample (Golders, 2016). PSD for all remaining tailings samples (excluding bulk samples) are presented graphically in Figure E3-6.

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**Figure E3-5: Particle size distributions for tailings triaxial samples**

**Figure E3-6: Particle size distributions for tailings samples**
Key observations regarding Figure E3-5 and Figure E3-6 are:

- The dominant NTSF tailings classify as a low plasticity Sandy SILT according to AS1726-2017.
- X-Ray Sedimentation yield similar result to hydrometer analysis, with slightly lower clay content recorded using X-Ray Sedimentation.
- HA401 PSD is very similar to the Concentrator 1 (C1) sample tested by Golder’s in 2016.
- TC1 and TS2 are very similar in grading, with TS2 containing slightly less clay than TC1.
- Although taken from a sand boil, HA402 is representative of some portions of the tailings profile; eg. CE407 30.5 m

**E3.4.4 Mineralogy**

Semi-quantitative X-Ray Diffraction (XRD) analysis was completed on samples HA401 and TC1 to determine the main mineral constituents of the NTSF tailings. XRD reports are included in Annexure EC. Representative sub-samples were removed and lightly ground such that 20% was passing 20 microns to eliminate preferred orientation. Analyses were completed by Microanalysis Australia by using cobalt radiation for the x-ray source, search match software Eva 4.3 and an up-to-date ICDD card set.

Mineral phases and concentrations for HA401 and TC1 are listed in Table E3-2. The NTSF tailings generally consists of four dominant mineral phases, i.e. Albite, Quartz, Clinochlore and Microcline. These results are consistent with an earlier mineralogical investigation of the Cadia Hill extended tailings samples (JKTech Job No. 3233,11/2003).

<table>
<thead>
<tr>
<th>Mineral Phase</th>
<th>Concentration (%)</th>
</tr>
</thead>
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<tr>
<td></td>
<td>TC1</td>
</tr>
<tr>
<td>Albite</td>
<td>46</td>
</tr>
<tr>
<td>Quartz</td>
<td>19</td>
</tr>
<tr>
<td>Clinochlore</td>
<td>9</td>
</tr>
<tr>
<td>Microcline</td>
<td>14</td>
</tr>
<tr>
<td>Illite</td>
<td>2</td>
</tr>
<tr>
<td>Calcite</td>
<td>3</td>
</tr>
<tr>
<td>Amhipbole Group</td>
<td>4</td>
</tr>
<tr>
<td>Magnetite</td>
<td>3</td>
</tr>
<tr>
<td>Gypsum</td>
<td>1</td>
</tr>
<tr>
<td>Pyrite</td>
<td>Trace</td>
</tr>
<tr>
<td>Bohemite</td>
<td>-</td>
</tr>
</tbody>
</table>

Table E3-2: NTSF Tailings XRD mineral phase concentrations
E3.4.5 Particle Shape

Run out and insitu tailings were subject to scanning electron microscopy (SEM) tests undertaken by Microanalysis Australia using a Carl Zeiss EVO50 scanning electron microscope fitted with an Oxford INCA X-Max energy dispersive spectrometer (EDS).

Tests were undertaken on bulk samples HA401 and TC1 to qualitatively investigate particle characteristics on a microscopic level such as describing particle angularity.

Particles are angular to sub-angular, with some showing a characteristic rhomboid shape, as shown in the SEM images presented in Figure E3-7 and Figure E3-8. SEM reports are included in Annexure ED.

![Figure E3-7: SEM image of NTSF insitu tailings from TC1](image1)

![Figure E3-8: SEM image of NTSF run out tailing from HA401](image2)
E3.5 Tailings Properties for Monotonic Loading

E3.5.1 Small Strain Modulus

The shear wave velocity of the insitu tailings adjacent to CPT-N04 was measured, as part of the 2017 field campaign, using a seismic dilatometer (SDMT) and the “elasticity” or small strain shear modulus, \( G_{\text{max}} \), was estimated using the following relationship:

\[
G_{\text{max}} = v_s^2 (m/s) \times \rho_{\text{bulk}} (kg/m^3)
\]

This insitu data for the small shear strain modulus is plotted against the mean effective stress at the test depth in Figure E3-9 as the blue points.

The small strain shear modulus was measured in the laboratory bender elements and this is also shown on Figure E3-9 as brown squares. Detailed results for the bender element tests are included in Annexure EL.

![Figure E3-9: Elastic shear modulus (Gmax) for NTSF tailings](image)

The elasticity of the NTSF tailings determined by these two test methods is comparable, with the insitu data being slightly stiffer. The difference in behaviour may be a result of aging or alternatively, a difference in particle arrangement or fabric; ie. the insitu tailings were deposited hydraulically while the laboratory sample was loosely tamped.

The elastic stiffness of the NTSF tailings appears normal for loose silt, when compared with data from other sites (Shuttle & Jefferies, 2016) and shown in grey on Figure E3-9.

The relationship between \( G_{\text{max}} \) and \( p' \) for NTSF silt can be expressed by a power law:

\[
G_{\text{max}} = 1.5 \times p'^{0.757} \text{ (MPa)} \quad \text{Equation 3-1}
\]
### E3.5.2 Confined compressibility

Four oedometer tests were undertaken on undisturbed samples of in situ tailings from CE407, CE408 and CE413. Samples were loaded to between 3 and 3200 kPa. The results of these tests are presented in Figure E3-10 on a plot of void ratio versus log applied pressure while key parameters for each test are summarised in Table E3-3.

The low-stress part of the curve corresponds to the re-consolidation of the sample to both its original in situ stress state as well as some densification due to disturbance during sample extrusion. Over the stress range of 100 kPa to 2000 kPa these samples exhibited a compression index of 0.05 < C_c < 0.09. The compressibility increases at stress levels greater than 2000 kPa, possibly caused by grain crushing (a behaviour seen in other soils).

Oedometer test certificates are included in Annexure EK.

![Figure E3-10: Oedometer Test Results](image)

<table>
<thead>
<tr>
<th>ID</th>
<th>Depth</th>
<th>RL</th>
<th>γ_d (t/m³)</th>
<th>&gt;75µm (%)</th>
<th>w (%)</th>
<th>e_o</th>
<th>Cr</th>
<th>C_c</th>
<th>p’c</th>
</tr>
</thead>
<tbody>
<tr>
<td>CE407</td>
<td>12.00-12.45</td>
<td>719.8</td>
<td>2.02</td>
<td>29</td>
<td>25.0</td>
<td>0.674</td>
<td>0.025</td>
<td>0.112</td>
<td>110</td>
</tr>
<tr>
<td>CE408</td>
<td>11.00-11.45</td>
<td>732.8</td>
<td>2.13</td>
<td>33</td>
<td>22.2</td>
<td>0.561</td>
<td>0.025</td>
<td>0.113</td>
<td>130</td>
</tr>
<tr>
<td>CE413</td>
<td>25.95-26.40</td>
<td>717.9</td>
<td>2.20</td>
<td>36</td>
<td>23.5</td>
<td>0.538</td>
<td>0.024</td>
<td>0.100</td>
<td>155</td>
</tr>
<tr>
<td>CE408</td>
<td>25.00-25.45</td>
<td>718.8</td>
<td>1.99</td>
<td>41</td>
<td>19.2</td>
<td>0.591</td>
<td>0.023</td>
<td>0.112</td>
<td>300</td>
</tr>
</tbody>
</table>
### E3.5.3 Critical State Locus

The CSL for each tailings sample was determined using the standard method, with triaxial tests on predominantly loose samples, tested both drained and undrained. The critical state is the end point of those tests that reach the condition of continuing deformation at constant deviator stress and constant void ratio. Dense tests generally cannot reach this condition within the deformation limits of the triaxial test equipment.

The result of triaxial tests on the TC1 tailings are presented in Figure E3-11 as a void ratio versus mean effective stress plot (e versus log $p'$). The inferred CSL is the green line on this figure. The three undrained tests all reached their critical state, which is shown as a blue dot. The loose drained tests were close to their critical state at the limits of the test equipment. The dense tests did not reach the CSL, as is usual, and were carried out to measure stress-dilatancy of the tailings.

Although a linear semi-log distribution is a reasonable representation of the CSL, close inspection of the test results suggests the now-common “curved” equation is a better fit:

$$e_c = a - b \times \left( \frac{p'}{100} \right)^c$$

where:

- $e_c$: critical state void ratio
- $p'$: mean effective stress measured in kPa, and
- $a$, $b$, $c$: soil properties defining the CSL.

![Figure E3-11: Triaxial test paths showing critical state locus for TC1](image)

Similar results were obtained for the sandier insitu tailings as well as the mixed tailings found in the run-out soils. In all cases a slightly ‘curved’ CSL was the best fit to the tests, with the properties given in Table E3-4. The CSL’s of these soils are compared on Figure E3-12.
The effect of mixing during the slump is to give the mixture a more contractive state. That is, for any given void ratio the mixed CSL (red line) lies at a lower void ratio than that for either of the ‘parent’ tailings. The implication of this is that the tailings will accelerate as they slump because of further loss of undrained strength.

Plots showing the results from triaxial tests on the bulk samples are presented in Figure E3-12, while test certificates are provided for individual samples in Annexure EE to Annexure EI.

Key points to note with respect to the CSL testing are:

- A CSL has not been reported for the sand boil material from the slump (HA402) as this material was not considered representative of the insitu materials encountered.
- The CSL for sample TS1 is based on limited testing (2 x CIU and 1 x CID) and was undertaken to confirm the similarity of samples TS1 and TS2.
- CSL testing of sample HA401 was undertaken by both Golders and Trilabs. The results presented in Annexure EE are considered to be within the accuracy of measurements.

![Figure E3-12: Comparison of CSL for NTSF tailings](csl_comparison_r1.xls)

<table>
<thead>
<tr>
<th>Bulk Sample</th>
<th>CSL Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a</td>
</tr>
<tr>
<td>TC1 – Insitu Sandy Clayey Silt</td>
<td>0.906</td>
</tr>
<tr>
<td>TS1 – Insitu Sandy SILT</td>
<td>1.302</td>
</tr>
<tr>
<td>TS2 – Insitu Sandy SILT</td>
<td>1.350</td>
</tr>
<tr>
<td>HA401 – Mixed run-out tailings</td>
<td>1.400</td>
</tr>
</tbody>
</table>
**E3.5.4 Drained Strength**

The drained strength of soils is controlled by their critical friction ratio (the property $M$ or, equivalently, $\phi_c$) and their dilatancy (controlled by the property $\chi$ and their current state parameter). Although these properties are most easily determined using drained triaxial tests on dense samples, as part of the CSL testing programme, the properties carry over into the full spectrum of soil stress-strain behaviour – drained or undrained, loose or dense.

The data from the various tests is summarised on the upper graph of Figure E3-12 which plots the stress ratio at peak strength ($\eta_{\text{max}}$) versus the dilation rate at that strength ($D_{\text{min}}$). As there is considerable similarity between the three tailings tested, a single line (shown in green) has been adopted to represent the tailings strength behaviour. This line is defined by the slope $(1-N)$ where $N$ is the volumetric coupling parameter, and the critical state friction ratio, the intercept $\phi_{CS}$, where $\phi_{CS} = \tan^{-1}(1/M)$.

The dilation that develops as soil deforms (shears) is a consequence of the available space for particles to move into – and thus controlled by the state parameter, $\psi$. The state dilatancy parameter, $\chi_{\text{tc}}$, is the slope of the trend line for minimum dilatancy (equal to dilatancy at peak stress ratio) versus the state parameter at peak stress ratio ($D_{\text{min}}$ vs $\psi$ at $D_{\text{min}}$) as shown on the lower plot of Figure E3-13. As is the usual case with silts, there is a small range of state over which to infer this property and with consequent loss of precision. As a consequence, an average representative value $\chi_{\text{tc}} = 8.0$ was adopted for the deformation modelling. The calculated values for these deformation parameters are listed in Table E3-5.

**Table E3-5: Adopted deformation parameters**

<table>
<thead>
<tr>
<th>$M_{SC}$</th>
<th>$N$</th>
<th>$\chi$</th>
<th>$\phi_{CS}$</th>
<th>$H$</th>
<th>$\nu$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>0.3</td>
<td>8.0</td>
<td>34°</td>
<td>50 -450$\psi$</td>
<td>0.2</td>
</tr>
</tbody>
</table>

The strength property determination discussed above illustrates how those properties are determined. However, these properties are used in the opposite way in subsequent analysis (as illustrated by the ‘blue arrows’ on Figure E3-13). The input is the state parameter ($\psi$), which establishes the limiting dilation, $D_{\text{min}}$. This limiting dilation in turn both controls the relative strains (for example, vertical versus horizontal) as well as the strength of the soil. Hence, the insitu state parameter must be determined to use these properties.

**E3.5.5 Stress-Strain Behaviour**

The properties determined above were used in the NorSand model to compute the stress-strain behaviour of the tailings, which was then compared to the measured stress-strain behaviour. This is slightly less than full validation because NorSand, as do other comparable models, requires a plastic hardening modulus in addition to the properties listed in Table E3-5. The approach adopted was to estimate this plastic hardening modulus and then to adjust (“iterate”) that modulus to provide a best-fit of the theory to the data.
Examples of the fits obtained are shown on Figure E3-14 and Figure E3-15. The first figure shows a moderately dense test on the predominant insitu silt (TC1), which checks that the dilatancy has been properly captured by the determined soil properties and establishes the plastic hardening modulus. The second figure shows that the same properties carry across to undrained behaviour, although as usual a reduced elastic shear modulus is needed from that determined shear wave velocity measurements in the field. In both cases the reported void ratio of the test is honoured. The plastic hardening modulus determined by this iterative fitting is linearly dependent on the state parameter, illustrated on Figure E3-16.

The iterative fitting was done for the predominant silt (TC1) and the ‘sandier interlayers’ (TS2), as the derived plastic modulus was needed for calibrating the CPT insitu. In fitting the test, the plastic hardening modulus was varied to best-fit each test. This produces some scatter around the trend, generally attributed to the effect of the detailed particle arrangement “fabric” that is not captured by void ratio. A linear trend line was fitted through the modelling results: $H = H_0 - H_o$. Values for these modulus parameters are given on Table E3-5.

Displacement modelling used the average trend for $H$ as a uniform soil type.
Figure E3-14: Calibration to a dilatant drained triaxial test on the predominant silt

Figure E3-15: Calibration to a contractive undrained triaxial test on the predominant silt
E3.6 Cyclic Strength

E3.6.1 Test Program

All cyclic direct simple shear tests (CDSS) were carried out on the predominant insitu silt (TC1) sample because the wavelength of earthquake motion is such that the thinner sand lenses will not be “seen” by the ground motion.

Seven tests were carried out for the ‘far-field’ condition upstream of the dam crest where the tailings were most likely in a geostatic stress state; i.e. minimal to no ‘static bias’. Three of these tests were at a vertical effective stress of 50 kPa and three at 300kPa. The 50kPa stress was selected to correspond to the lowest stress level of the saturated tailings, as the upper 3 -5 m of tailings appears unsaturated and would not be subject to liquefaction. The 300 kPa stress level was selected to define trends with stress, noting that strong ground motions are normally amplified during propagation from the underlying bedrock and thus it is the near surface stress levels that are of greatest initial interest.

All tests were on samples that were slightly looser than the best-estimate of the insitu $\phi$ of the tailings, with some tests being markedly looser. The cyclic stress level was chosen to simulate low-level earthquake motions (or comparable) with two tests at a markedly greater cyclic stress to ensure that the effect of loading was observed. Thus, this part of the test program provides a slightly conservative view of how the tailings might respond just upstream of the dam.

A further two tests were then added to the program to measure the response of tailings beneath the upstream raise fills where deformation modelling revealed the most highly loaded soils; i.e. with a high ‘static bias’. The test conditions were abstracted from the deformation modelling (‘Point 1’, Appendix H). The test samples were prepared loose, but densified substantially as the static shear stress was applied; a behaviour also seen in the deformation modelling. The cyclic stress level was set based on the March 8, 2018 earthquakes. In one test, a uniform cyclic stress was applied, while the computed stress-time history was applied in the other test.
The cyclic testing was then supplemented by two monotonic direct simple shear tests, carried out to illustrate the tailings response in the absence of earthquake loading from the computed stress state representing the most highly loaded tailings. One of these tests was undrained from the outset; the second was loaded drained to the stress state from the displacement modelling before being loaded undrained.

### E3.6.2 Sample Preparation

Samples were reconstituted ‘very loose’ and then consolidated to the test pressure of 50 or 300 kPa (Figure E3-17). As usual, there was marked void ratio reduction when load was first applied before a proper consolidation trend was established.

The CSL shown on Figure E3-17 is from triaxial testing of TC1 tailings converted from mean effective stress to vertical stress using an assumed $K_0=0.7$. As can be seen, the as-tested state parameters were markedly loose of the critical state, lying in the range $+0.10 < \psi < +0.16$ while the characteristic in situ state is approximately $\psi \sim +0.09$.

![Figure E3-17: Evolution of sample void ratios to tested conditions](image)

### E3.6.3 Test Conditions

The test conditions are summarised in Table E3-6 and Table E3-6 using the standard loading metrics of imposed cyclic stress ratio and static bias. One test had a ‘custom’ cyclic loading that replicated the two small earthquakes on March 8, 2018.

Certificates for the cyclic simple shear testing are included in Annexure EN.
Table E3-6: CDSS test conditions and applied loading for ‘far field’ tests

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>State</th>
<th>Test No.</th>
<th>Consol.</th>
<th>Bias</th>
<th>Void Ratio</th>
<th>Void Ratio</th>
<th>Ψo</th>
<th>CSR</th>
<th>Applied</th>
<th>Number of Cycles to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC1</td>
<td>Very Loose</td>
<td>CSS1</td>
<td>50</td>
<td>0.05</td>
<td>0.75</td>
<td>0.16</td>
<td>0.096</td>
<td>20.3</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>TC1</td>
<td>Very Loose</td>
<td>CSS2</td>
<td>50</td>
<td>0.05</td>
<td>0.75</td>
<td>0.16</td>
<td>0.054</td>
<td>495</td>
<td>495</td>
<td></td>
</tr>
<tr>
<td>TC1</td>
<td>Very Loose</td>
<td>CSS3</td>
<td>50</td>
<td>0.00</td>
<td>0.72</td>
<td>0.14</td>
<td>0.054</td>
<td>500</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>TC1</td>
<td>Very Loose</td>
<td>CSS4</td>
<td>300</td>
<td>0.00</td>
<td>0.61</td>
<td>0.10</td>
<td>0.059</td>
<td>505</td>
<td>505</td>
<td></td>
</tr>
<tr>
<td>TC1</td>
<td>Very Loose</td>
<td>CSS5</td>
<td>300</td>
<td>0.05</td>
<td>0.62</td>
<td>0.11</td>
<td>0.094</td>
<td>18.3</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>TC1</td>
<td>Very Loose</td>
<td>CSS6</td>
<td>300</td>
<td>0.05</td>
<td>0.62</td>
<td>0.11</td>
<td>0.056</td>
<td>510</td>
<td>510</td>
<td></td>
</tr>
<tr>
<td>TC1</td>
<td>Very Loose</td>
<td>CSS7</td>
<td>300</td>
<td>0.05</td>
<td>0.62</td>
<td>0.11</td>
<td>0.127</td>
<td>3.5</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

Table E3-7: CDSS and MDSS test conditions and applied loading for ‘in dam’ tests

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>State</th>
<th>Test No.</th>
<th>Consol.</th>
<th>Bias</th>
<th>Void Ratio</th>
<th>Void Ratio</th>
<th>Ψo</th>
<th>CSR</th>
<th>Applied</th>
<th>Number of Cycles to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC1</td>
<td>Very Loose</td>
<td>CSS8</td>
<td>300</td>
<td>0.30</td>
<td>0.57</td>
<td>0.060</td>
<td>0.057</td>
<td>~12</td>
<td>See text</td>
<td></td>
</tr>
<tr>
<td>TC1</td>
<td>Very Loose</td>
<td>MSS9</td>
<td>300</td>
<td>0.00</td>
<td>0.61</td>
<td>0.096</td>
<td>monotonic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TC1</td>
<td>Very Loose</td>
<td>MSS10</td>
<td>300</td>
<td>0.30</td>
<td>0.59</td>
<td>0.082</td>
<td>monotonic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TC1</td>
<td>Very Loose</td>
<td>CSS11</td>
<td>300</td>
<td>0.30</td>
<td>0.56</td>
<td>0.046</td>
<td>custom</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TC1</td>
<td>Very Loose</td>
<td>TS1</td>
<td>CSS11</td>
<td>300</td>
<td>0.30</td>
<td>0.60</td>
<td>0.080</td>
<td>custom</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**E3.6.4 Far Field Tests Results**

The measured behaviour in one of the high-load samples (test CSS-5) is shown on Figure E3-18. The shear strain induced by cyclic loading remains small until the excess pore pressure increase to about \( r_u \sim 0.8 \), which also corresponds to the sample beginning to show a “butterfly” stress-path as loading continues. This is normal behaviour, in both sands and silts, with the soil accommodating substantial excess pore pressures before cyclic softening becomes established.

Typically, the number of cycles to ‘liquefaction’ is reported in cyclic shear tests. However, for these tests two criteria have been used to define liquefaction, namely:

- a shear strain of \( >2.5\% \) regardless of whether static bias was used; and,
- an excess pore pressure ratio, \( r_u >0.9 \).

The results of applying these criteria to the test results are tabulated in Table E3-6.

It should be noted that values quoted at \( \sim500 \) cycles are an underestimate, as testing was terminated at this point and none had met the liquefaction criteria at the test limit.
Figure E3-18: CDSS5 test result on TC1
It does not matter whether the strain or excess pore pressure criterion of liquefaction is preferred as the results are similar. The trend for the number of cycles to the strain criterion versus cyclic stress ratio is presented on Figure E3-19; a logarithmic x-axis is used as cyclic loading is a fatigue-like process. There is no obvious effect of soil state nor any obvious effect of static bias; the results are also notably strong for such loose soil.

Further insight can be gained if the excess pore pressure ratio $r_u$ is considered at 5 and at 15 load cycles. This is shown on Figure E3-20. There is again little obvious effect of static bias or soil state, but what is very clear is a ‘yield’ stress ratio (or, equivalently, a strain threshold) below which there is no generation of excess pore pressure. This limit is approximately at a cyclic stress ratio of $\sim 0.045$. As threshold strains have been observed in other soils, the measured appears reasonable.

![Figure E3-19: Strain based onset of liquefaction vs severity of loading](image1)

![Figure E3-20: Excess pore pressure ratio at $N = 5$ & $15$ vs severity of loading](image2)
E3.6.5 Near Field Tests Results

The FLAC 2D deformation analysis (Appendix H), established the stress state within the tailings after completion of the Stage 1 Buttress. A zone of particularly high mobilised stress ratio (Point 1) was chosen and the stress history was output. A static bias of 0.3 was adopted and this was then used to define the start of a second set of tests to evaluate the tailings response during the March 8, 2018 seismic events.

The first cyclic test used a uniform sinusoidal cyclic loading as is standard. The results are shown on Figure E3-21 as the blue lines. Also shown on this figure is the result of a duplicate sample tested monotonically from the same initial conditions, shown as the red lines. The cyclic test actually shows greater strength than the monotonically loaded sample, which is most likely a reflection of slightly different sample preparation. The measured cyclic behaviour amounts to about 12-15 cycles of almost ‘load-unload’ behaviour during which the pore pressure increased slowly; at that point the stress path intersected the samples monotonic undrained strength and this largely controlled the response. Essentially, this test had so much ‘static bias’ that its strength was controlled by the maximum shear stress rather than the cyclic aspect.

A further test was then carried out which exploited the ability of the GDS equipment to simulate a custom waveform. The computed earthquake response of the tailings at the ‘Point 1’ location was recovered from the analysis as a time history of variation in the horizontal shear stress. After discussion with the equipment manufacturers, the variation in shear stress with time computed by FLAC 2D at Point 1 was filtered into a cyclic loading record for the simple shear equipment. Both pulses of the March 8, 2018 seismic events were included, with the time between them reduced for testing convenience whilst test conditions were maintained undrained. The test equipment was able to reasonably match the desired shear stress variation computed by FLAC 2D, illustrated on Figure E3-23.
Two of these custom cyclic tests were carried out; one on the predominant silt tailings (TC1) and one on the slightly sandier sample (TS1) representing the ‘interbedded layers’ apparent on the CPT records. Both samples were prepared loose, and both were loaded drained to the ‘static bias’ computed by FLAC 2D for Point 1 and with the consequent shear-induced densification. The results of these two tests are shown on Figure E3-23. Very little excess pore pressure was generated in either case (the vertical effective stress changes minimally) with the response being quasi-elastic unload-reload from a dominant pre-cyclic stress state established by the drained loading.

Figure E3-22: Ground motion input to CDSS test simulating earthquake motion at Point 1

Figure E3-23: Response of Point 1 tailings to 8 Mar 2018 earthquake in cyclic simple shear
E3.7 Stress-Path Testing

E3.7.1 Stress-Path

The trajectory over which the mean effective stress ($\sigma_m$) and the distortional stress (the 3D stress invariant $\sigma_q$) changes is known as the ‘stress path’ and this can influence how soil responds.

FLAC 2D deformation modelling was used to assess how stresses developed at five points within the tailings as shown on Figure E3-24. Of these five locations, ‘Point 1’ corresponds to the most plastically loaded tailings with the greatest ratio of the parameter $\eta (=\sigma_q / \sigma_m)$. The stress-paths at Point 1 and Point 5 are shown on Figure E3-24.

Soil can fail by transitioning from a drained loading path to an undrained one if the stress state exceeds the soil’s instability locus. Although the instability locus can be computed, the ITRB wished to confirm this by a physical testing and commissioned a number of stress path triaxial tests.

![Figure E3-24: Computed stress-path tested used in triaxial shear](image)

E3.7.2 Test Method and Program

Six stress path tests were completed by Golder’s Perth laboratory and two by KCB’s Vancouver laboratory.

At Golder’s Perth laboratory, two stress path triaxial tests were completed on Sandy Clayey SILT tailings represented by sample TC1, while four tests were completed on Sandy SILT represented by sample TS1. In all cases the samples were prepared by moist tamping the tailings in a manner used for the CSL testing. Following assembly and saturation, the triaxial specimens were anisotropically consolidated at a mean effective stress of $(p') \text{ of } 188\text{kPa}$ and $K_0 \sim 0.64$, corresponding to the stress at ‘Point 1’ at the end of Stage 4.

On completion of anisotropic consolidation, the samples were loaded in such a manner to replicate the construction of the embankment Stages 5 to 10 and the Stage 1 Buttress. Two loading paths were followed, a fully drained path with consolidation being permitted during each loading stage, and a partially undrained path where the load was applied in 5kPa increments under undrained conditions, followed by drainage.
Following loading up to conditions replicating those on completion of the Stage 1 Buttress, the loading path followed two trajectories as shown on Figure E3-26. In the case of Path A and B, the load applied resulted in a constant deviator stress, while in the case of Path C the deviator stress increased following the same trajectory as that during the Buttress 1 construction.

During the stress path tests the principal stress was applied by either ‘dead weights’ or by servo controlled loading. A brief description of each test and loading conditions is provided in Table E3-8.

In the case of KCB test TX05, the specimen was cyclically loaded after following the Point 1 stress path that replicated construction from Stage 4 to the end of Buttress 1. The custom double pulse wave form which used the March 8, 2018 seismic event (Figure E3-22) was used for the cyclic loading.

The various loading paths adopted for the stress path testing are shown on Figure E3-25.

**Table E3-8: Stress path triaxial test details**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Test Type</th>
<th>Description</th>
<th>K0</th>
<th>Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>TS1</td>
<td>Sa-1</td>
<td>Test A                         Fully drained construction loading path. Constant deviator stress loading.</td>
<td>0.64</td>
<td>Servo (DigiRFM)</td>
</tr>
<tr>
<td>TS1</td>
<td>Sa-2</td>
<td>Test B                         Anisotropic consolidation from p’=20kPa Partially undrained construction loading path. Constant deviator stress loading.</td>
<td>0.65</td>
<td>Servo (DigiRFM)</td>
</tr>
<tr>
<td>TS1</td>
<td>Sa-3</td>
<td>Test C1                        Fully drained construction loading path. Increasing deviator stress.</td>
<td>0.62</td>
<td>Dead Weights</td>
</tr>
<tr>
<td>TS1</td>
<td>Sa-7</td>
<td>Test C2                        Anisotropic consolidation from p’=20kPa Fully drained construction loading path. Increasing deviator stress.</td>
<td>0.62</td>
<td>Dead Weights</td>
</tr>
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<td>TC1</td>
<td>Sa-10</td>
<td>Test C3                        Partially undrained construction loading path. Increasing deviator stress.</td>
<td>0.62</td>
<td>Dead Weights</td>
</tr>
<tr>
<td>TC1</td>
<td>Sa-11</td>
<td>Test C4                        Partially undrained construction loading path. Increasing deviator stress. Last stage fully undrained with valves closed.</td>
<td>0.61</td>
<td>Dead Weights</td>
</tr>
<tr>
<td>TC2</td>
<td>TX03</td>
<td>Test C5                        Isotropically consolidated - 3 Stages. Fully drained construction loading path. Increasing deviator stress.</td>
<td>-</td>
<td>Dead Weights</td>
</tr>
<tr>
<td>TC2</td>
<td>TX04</td>
<td>Test C6                        Isotropically consolidated – 4 Stages. Fully drained construction loading path. Increasing deviator stress</td>
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<td>Dead Weight</td>
</tr>
<tr>
<td>TX05</td>
<td>Cyclic</td>
<td>Isotropically consolidated – 4 Stages. Fully drained construction loading path. Double pulse cyclic loading</td>
<td>-</td>
<td>Servo</td>
</tr>
</tbody>
</table>
E3.7.3 Test Results

Stress path plots, together with plots of axial strain versus mean effective stress are provided for samples TS1 and TC1 on Figure E3-26, while full details are provided in Annexure EO. Results for sample TC2 are included in Annexure EP.

In the case of test Sa-11, essentially instantaneous collapse of the sample (liquefaction) resulted when it was subject to a small increment of shear stress under undrained conditions. As it is difficult to appreciate the speed at which liquefaction can develop past the instability locus, a video has been prepared of this test illustrating this very rapid change and which is included in the report as Annexure ER.
Although the double pulse waveform used for the cyclic loading of sample TX05, replicated in full the two seismic events of March 8, 2018 (albeit with the time between them reduced to 2 sec), approximately 700 cycles of this double pulse waveform were applied to the sample. The results indicate an initial transient pore pressure response that was minimal and most likely a system compliance issue leading to phase-lag between mean stress increase/decrease and measured pore pressure. Only after approximately 70 cycles of this double pulse waveform was there an increase in the axial strain.

Figure E3-26: Stress path and axial strain plots for Tests A, B and C
The first cyclic loading pulse and pore pressure response are shown on Figure E3-27 and Figure E3-28 respectively. As can be seen, there is no increase in residual excess pore pressure at the end of the loading cycle.

Figure E3-27: First cyclic loading pulse

Figure E3-28: Pore pressure response to first cyclic loading pulse
E4. Insitu State Parameter

E4.1 Overview
The CPTu does not measure soil state, relative density or void ratio. These parameters have to be recovered from the CPTu data by processing the measured mechanical responses as the CPTu probe is pushed into the ground. This processing is theoretically difficult with no complete universal method; thus, the industry has always looked to calibration studies. In the case of sands, calibration studies involved controlled chamber testing. In the case of clays, calibration studies reference another test method (commonly triaxial testing of undisturbed samples or insitu vane shear).

Silts have, to date, no controlled chamber test studies nor can undisturbed samples be tested as there is always gross disturbance during extrusion and sample handling. Further, silts have largely been avoided in the literature with few cited papers. There are also few case-histories of failure in silt and those that have been published are missing basic information on soil properties.

The approach followed here has been developed over the past decade and is based on the mechanics of soil behaviour being the same in silt as in sand. Thus, the numerical methods developed and calibrated for sand can be extend to silt by allowing for the lower hydraulic conductivity of silt, which switches the penetration from drained to undrained. There is a very small window of partially drained penetration, which can be ignored for practical purposes.

The current state of the art for CPTu behaviour in silt lie in work at Somincor (Shuttle & Jefferies, 2016) and that work has been further extended for the NTSF.

The CPTu has only been calibrated for the predominant Sandy clayey SILT (TC1). Theoretically the tailings would require a ‘thin layer correction’, to accommodate for thin sandy layers, however this is beyond the current assessment. At other sites it has been found that soils within a tailings impoundment display very similar state parameters even as their gradation changes with distance from the discharge point. Thus, a reasonable assessment of the insitu state of the NTSF tailings is to focus on the predominant silt alone.

E4.2 Methodology

E4.2.1 Cavity Expansion Analogue
Although a few attempts have been made to capture the true CPTu geometry in finite element analysis, nearly all understanding is based on ‘cavity expansion’ analysis. The attraction of cavity expansion analysis is that a true 3D situation can be approximated by 1D (with soil particles just moving radially away from the CPT). Such an approximation allows relatively straightforward simulation of CPTu penetration using ‘large strain’ finite element methods. One of the programs that does this is known as the ‘CPTwidget’. It has been extensively calibrated in sands, while the initial extension to silts was undertaken by Shuttle & Cunning (2007) with further development and calibration at Somincor (Shuttle & Jefferies, 2016).

The cavity expansion methods work as an analogue to the load on the conical tip of the CPT. In the case of piezocone testing, this analogue is for the ‘u1’ location of the pore pressure sensor. However, most of the CPT industry (and as was the case at the NTSF) deploys the pore pressure sensor at the ‘u2’ location just behind the shoulder of the CPT tip, as experience is that the u2 location gives with most sensitive indication of changing soil type and properties.

The ‘CPT Widget’ has been enhanced (Release 2.5) to output an analogue of induced pore pressure at the u2 location. This enhancement was based on the common assumption that the u2 location reflects only pure shear of the soil.
E4.2.2 CPT Calibration at NTSF

The 'widget' uses NorSand and thus the soil properties determined during the laboratory testing are used directly as inputs. The widget outputs the soil-specific coefficients for evaluating CPTu data based on these properties and which are used in the equation:

\[ \psi = \frac{\ln \left( \frac{Q'}{k} \right)}{m} \quad \text{Equation 4-1} \]

where

\[ Q' = Q \cdot \left( 1 - B_q \right) + 1 \]

The computed relation for the normalised tip resistance is shown on Figure E4-1. As has been found in all other silts, there is no effect of elasticity in the computed trends; nor is there any bias with stress level. The fitted trend line through the results corresponds to the usual semi-log fit and is given by the coefficients; \( k' = 11.5 \) and \( m' = 19.0 \)

The matching computed excess pore pressure trends are shown on Figure E4-2. The computed trend has been fitted with a quadratic equation for ease of using the calibration in CPT processing; the parameters have been weighted for best-fit of the equation in the zone of interest \(+0.05 < \psi < +0.13\). The fitted trend is given by:

\[ B_q = 2.1 \cdot \psi + 35 \cdot \psi^2 \quad \text{Equation 4-2} \]

Where, \( B_q \) is that at the u2 location as used at Cadia.

![Figure E4-1: Computed CPTu resistance and fitted trend for CPTu in NTSF TC1 silt.](image-url)
E4.3 CPTu Processing

E4.3.1 In-situ state parameter profile

The derived calibrations have been used in processing the data from CPT-N04 located near the edge of the slump and these are shown on Figure E4-3. The state parameter $\psi$ computed using both Figure E4-1 and Figure E4-2 show very good correspondence.

Processed results for all CPTu completed during the 2013 and 2017 campaigns are included in Annexure EJ.

The characteristic state parameter $\psi_k$ is that for which about 90% of the stratum is denser (more dilatant), as both stochastic simulations and physical tests have shown that the looser zones control the stability of the overall soil mass. This characteristic state has been assessed by eye (as opposed to formal statistical processing), with the estimate that this characteristic state is about $\psi_k = +0.09$, possibly a little looser at depth.

E4.3.2 Undrained strengths: Peak and post-liquefaction

The peak undrained strength has been computed using the conventional ‘total stress’ method. Although vane shear test undertaken in conjunction with the 2017 CPTu campaign indicate a lower value, the coefficient adopted for the current analysis is $N_{KT}=16$; a value established at Somincor after the extensive work on silts (Shuttle & Jefferies, 2016).

The strength computed on this basis is the results shown in grey in the middle plot of Figure E4-3 and corresponds to a peak undrained strength ratio $s_u/s' = 0.18$. 
As the current laboratory calibrations are generally considered to over-estimate actual strengths developed during liquefaction failures, the post-liquefaction strength is based on the computed state parameter as well as case-history experience. The strength computed on this basis is the results shown in green in the middle plot of Figure E4-3. This corresponds to a characteristic post-liquefaction undrained strength ratio \( \frac{s_d}{\sigma_v'} = 0.09 \), perhaps reducing to \( \frac{s_d}{\sigma_v'} = 0.08 \) at depth.

**Figure E4-3: CPTu 2017 N04 state parameter, undrained strength ratios and brittleness**
E4.3.3 Brittleness

Brittleness is the proportion of undrained strength lost on liquefaction. This has been computed from the strength profiles derived from the inferred state parameter (tip resistance method) and is shown on the right hand plot of Figure E4-3. Although this indicates ~60% loss of tailings strength on liquefaction, this may be an over-estimate as the observed post-liquefaction slopes at the NTSF slump are reasonably steep and would indicated a higher post-liquefaction strength.

The average brittleness (with standard deviation) and average critical state undrained shear strength ratio (Sadrekarimi, 2013) have been calculated for CPT N03 and N04 and are plotted on Figure E4-4. Figure E4-4 supports the view that the NTSF tailings are susceptible to liquefaction as the NTSF data lies within the zone where case histories of flow liquefaction have been reported (Robertson, 2010b).

![Brittleness Index vs. Undrained Shear Strength Ratio](image)

**Figure E4-4: CPTu 2017- N04 - Robertson brittleness plot**

E4.3.4 Validation Check

As part of the 2017 CPTu campaign, ATC Williams recovered high quality undisturbed samples using specialised sampling equipment. Further, they recognised the potential for sample disturbance, and sample handling procedures were established to minimise this. These samples were used to validate the state parameter determined from CPTu testing. This validation was undertaken in the following manner:

- This sample depth for each undisturbed sample was converted to an insitu mean effective stress using: the estimated saturated unit weight of the tailings; the measured pore water pressure from CPT dissipation tests; and, a geostatic stress ratio coefficient $K_0=0.7$.
- The critical void ratio was computed for the insitu mean effective stress using the critical state parameters for both the TC1 and TS1. Both CSL were used because the CPT show that layering of sandier and predominant-silt is pervasive in the depth range of these samples and the proportion of each layer in the tube is not known.
- The state parameter was calculated based on the initial void ratio reported for each undisturbed sample and the critical void ratios calculated for each CSL.
For each undisturbed sample, the range in computed state parameters are shown on Figure E4-5 together with the state parameter derived from the CPT, screened to remove sandy layers.

The range of insitu $\psi$ estimated from the tube samples generally straddles the profile of $\psi$ computed from the CPT and provides a first-order validation of the insitu state parameter. However, as there are uncertainties in each method of estimating $\psi$, the analysis presented here is in the nature of an ‘engineering check’ rather than a formal validation.

Figure E4-5: Comparison of $\psi$ determined from CPT N04 and undisturbed samples
E5. References


Annexure EA

Figures

Figure E1  Location of CPTu
Annexure EB

Index Tests
<table>
<thead>
<tr>
<th>HOLE</th>
<th>SAMPLE</th>
<th>DEPTH (m)</th>
<th>W_L</th>
<th>W_P</th>
<th>PI</th>
<th>% FINES</th>
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# Grain Size Distribution

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<th>GRAVEL</th>
<th>SAND</th>
<th>SILT OR CLAY</th>
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<tr>
<td>coarse</td>
<td>fine</td>
<td>coarse</td>
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<td>50</td>
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**HOLE** | **DEPTH (m)** | **D85** | **D60** | **D30** | **D10** | **CC** | **CU** | **%GRAVEL** | **%SAND** | **%FINES**
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<td>0.171</td>
<td>0.068</td>
<td>0.014</td>
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<td>0.0</td>
<td>37.4</td>
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**HOLE** | **SAMPLE** | **DEPTH (m)** | **W%** | **W_L** | **W_P** | **PI** | **REMARKS / SAMPLE DESCRIPTION**
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<td>21</td>
<td>15</td>
<td>6</td>
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CU = COEFFICIENT OF UNIFORMITY = D60/D10  
PARTICLE SIZES, e.g. D85, in mm  
Tested by Wet Sieving Method (ASTM D6913 & ISO/TS 17892-4)
### Specific Gravity of Soil Solids (ASTM-D854)

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<th>De-airing Period hr</th>
<th>Test temperature °C</th>
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<th>Mass of Flask+Water+Soil (Mₐ) g</th>
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<th>Mass of Dry Soil (Mₐ) g</th>
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**Average Specific Gravity of Solids @ 20°C:** 2.73

**Specific Gravity of Solids @ 20°C = \( \frac{K \times M₀}{M₀ + Mₐ - Mₐ} \)**

---

**PROJECT#: A03353A01**
**PROJECT: NWM CVO NTSF**
**LOCATION: Australia**
**DATE: 2019-01-04**
**TESTED BY: CM**
**CHECKED BY: JG**
# ATTERBERG LIMITS TEST REPORT

Test Method: AS 1289 2.1.1, 3.1.1, 3.1.2, 3.2.1, 3.3.1, 3.4.1

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<td>20</td>
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<td>18.6</td>
<td>15.6</td>
<td>20.1</td>
<td>27.5</td>
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## NOTES/REMARKS:

The samples were tested air dried, dry sieved and in a 125-250mm mould.

Sample/s supplied by the client

* Cracking occurred  + Curling occurred
### ATTERBERG LIMITS TEST REPORT

**Test Method:** AS 1289 2.1.1, 3.1.1, 3.1.2, 3.2.1, 3.3.1, 3.4.1

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**NOTES/REMARKS:**

The samples were tested air dried, dry sieved and in a 125-250mm mould.

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* Cracking occurred  + Curling occurred

**Authorised Signatory**

C. Channon

Accredited for compliance with ISO/IEC 17025 - Testing. The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards. Tested at Trilab Brisbane Laboratory.

Reference should be made to Trilab's "Standard Terms and Conditions of Business" for further details.

Trilab Pty Ltd  ABN 25 065 630 506

**ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING**
### PARTICLE SIZE DISTRIBUTION TEST REPORT

**Test Method:** AS 1289 3.6.3, 3.5.1 & 2.1.1

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**NOTES/REMARKS:**
- Moisture Content 19.9%
- 2.36mm Soil Particle Density (t/m³) 2.70
- Sample/s supplied by the client

**ACCURATE QUALITY RESULTS FOR TOMORROW’S ENGINEERING**
**PARTICLE SIZE DISTRIBUTION TEST REPORT**

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

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**NOTES/REMARKS:**
- Moisture Content 21.1%
- Sample/s supplied by the client

**Laboratory No. 9926**

Tested at Trilab Brisbane Laboratory.

**ACCURATE QUALITY RESULTS FOR TOMORROW’S ENGINEERING**
### PARTICLE SIZE DISTRIBUTION TEST REPORT

**Test Method:** AS 1289 3.6.3, 3.5.1 & 2.1.1

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**NOTES/REMARKS:**

- Moisture Content: 17.5%
- -2.36mm Soil Particle Density (t/m³): 2.67
- Sample/s supplied by the client

---

**Accredited for compliance with ISO/IEC 17025 - Testing.**

The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Tested at Trilab Brisbane Laboratory.

**Authorised Signatory**

C. Park

**Laboratory No. 9926**

**ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING**
PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1 & 2.1.1

Client: Hatch Pty Ltd
Report No.: 18120520-G
Workorder No.: 0005334

Address: PO Box 425 SPRING HILL QLD 4004
Test Date: 18/12/18-4/1/19

Project: H356804 - Cadia NTSF Failure
Report Date: 4/1/2019

Client ID: CE413 - TC2
Depth (m): 15.00-16.50

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NOTES/REMARKS:
- Moisture Content: 20%
- -2.36mm Soil Particle Density(t/m³): 2.65

Sample/s supplied by the client

Authorised Signatory
C. Channon

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Trilab Pty Ltd  ABN 25 065 630 506

ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING
## PARTICLE SIZE DISTRIBUTION TEST REPORT

**Test Method:** AS 1289 3.6.3, 3.5.1 & 2.1.1

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<th>Sieve Size (mm)</th>
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### NOTES/REMARKS:
- **Moisture Content:** 19.2%
- **-2.36mm Soil Particle Density($t/m^3$):** 2.73
- Sample/s supplied by the client

---

Trilab Pty Ltd     ABN 25 065 630 506

Authorised Signatory

C. Channon

Laboratory No. 9926

ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING
# MOISTURE CONTENT TEST REPORT

**Test Method:** AS 1289 2.1.1

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**NOTES/REMARKS:**

Sample/s supplied by the client

---

**Accredited for compliance with ISO/IEC 17025 - Testing.**

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Tested at Trilab Brisbane Laboratory.

**Authorised Signatory**

C. Channon

**Laboratory No.** 9926

**Trilab Pty Ltd**  
ABN 25 065 630 506

**ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING**
## MOISTURE CONTENT TEST REPORT

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**Project:** Cadia NTSF Failure

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<td>19.9</td>
<td>19.8</td>
<td>20.8</td>
<td>21.1</td>
<td>20.9</td>
<td>18.4</td>
</tr>
</tbody>
</table>

### NOTES/REMARKS:

Sample/s supplied by the client

---

**Acknowledged for compliance with ISO/IEC 17025 - Testing.**

The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Tested at Trilab Brisbane Laboratory.

**Authorised Signatory**

C. Channon

**Laboratory No. 9926**

**ACCURATE QUALITY RESULTS FOR TOMORROW’S ENGINEERING**
## SOIL PARTICLE DENSITY TEST REPORT

**Test Method:** AS 1289 3.5.1

<table>
<thead>
<tr>
<th>Client</th>
<th>Hatch Pty Ltd</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Address</strong></td>
<td>PO Box 425 SPRING HILL QLD 4004</td>
</tr>
<tr>
<td><strong>Report No.</strong></td>
<td>18080190-SG</td>
</tr>
<tr>
<td><strong>Workorder No.</strong></td>
<td>0004644</td>
</tr>
<tr>
<td><strong>Report Date</strong></td>
<td>22/08/2018</td>
</tr>
<tr>
<td><strong>Project</strong></td>
<td>H356804 - Cadia NTSF Failure</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>18080190</th>
<th>18080191</th>
<th>18080193</th>
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</thead>
<tbody>
<tr>
<td>Test Date</td>
<td>16/08/2018</td>
<td>16/08/2018</td>
<td>20/08/2018</td>
</tr>
<tr>
<td>Client ID</td>
<td>CE407 - DH402 - PS2</td>
<td>CE413 - DH404 - PS1</td>
<td>CE413 - DH404 - PS3</td>
</tr>
<tr>
<td>Depth (m)</td>
<td>21.00-21.50</td>
<td>13.80-14.25</td>
<td>34.00-34.45</td>
</tr>
<tr>
<td>Soil Particle Density (t/m³) (-2.36mm)</td>
<td>2.77</td>
<td>2.70</td>
<td>2.65</td>
</tr>
<tr>
<td>Soil Particle Density (t/m³) (+2.36mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Soil Particle Density (t/m³)</td>
<td>2.77</td>
<td>2.7</td>
<td>2.65</td>
</tr>
</tbody>
</table>

NOTES/REMARKS:

Sample/s supplied by the client

**Authorised Signatory**

T. Lockhart

Accredited for compliance with ISO/IEC 17025 - Testing.

The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Trilab Pty Ltd  ABN 25 065 630 506

**Authorised Signatory**

C. Channon

**Laboratory No. 9926**

**ACCURATE QUALITY RESULTS FOR TOMORROW’S ENGINEERING**
### UNIT WEIGHT TEST REPORT

**Test Method:** AS 1289 6.4.1

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<th>Hatch Pty Ltd</th>
<th>Report No.</th>
<th>18080190-UW</th>
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<tr>
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<td>Workorder No.</td>
<td>0004644</td>
</tr>
<tr>
<td><strong>Project</strong></td>
<td>H356804 - Cadia NTSF Failure</td>
<td>Report Date</td>
<td>14/08/2018</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Test Date</th>
<th>Client ID</th>
<th>Depth (m)</th>
<th>Moisture (%)</th>
<th>Wet Density (t/m³)</th>
<th>Dry Density (t/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18080190</td>
<td>10/08/2018</td>
<td>CE407 - DH402 - PS2</td>
<td>21.00-21.50</td>
<td>17.8</td>
<td>2.11</td>
<td>1.79</td>
</tr>
<tr>
<td>18080191</td>
<td>10/08/2018</td>
<td>CE413 - DH404 - PS1</td>
<td>13.80-14.25</td>
<td>21.3</td>
<td>1.95</td>
<td>1.61</td>
</tr>
<tr>
<td>18080193</td>
<td>10/08/2018</td>
<td>CE413 - DH404 - PS3</td>
<td>34.00-34.45</td>
<td>23.2</td>
<td>1.95</td>
<td>1.59</td>
</tr>
<tr>
<td>18080197</td>
<td>10/08/2018</td>
<td>CE412 - DH405 - PT2</td>
<td>39.50-39.72</td>
<td>48.5</td>
<td>1.70</td>
<td>1.14</td>
</tr>
</tbody>
</table>

### NOTES/REMARKS:

Sample/s supplied by the client

---

Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Tested at Trilab Brisbane Laboratory.

Authorised Signatory

C. Park

Laboratory No. 9926

The results of calibrations and tests performed apply only to the specific instrument or sample at the time of test unless otherwise clearly stated.

Reference should be made to Trilab’s “Standard Terms and Conditions of Business” for further details.

Trilab Pty Ltd

ABN 25 065 630 506

ACCURATE QUALITY RESULTS FOR TOMORROW’S ENGINEERING
Annexure EC

X Ray Diffraction (XRD) Analysis
The sample was supplied by the client to Microanalysis Australia on 13th August 2018 for the above mentioned analyses. A representative sub-sample was removed and lightly ground such that 90% was passing 20 μm. Grinding to this size helps eliminate preferred orientation.

Analysis

Only crystalline material present in the sample will give peaks in the XRD scan. Amorphous (non-crystalline) material will add to the background. The search match software used was Eva 4.3. An up-to-date ICDD card set was used. The X-ray source was cobalt radiation.

No standards were used in the quantification process. The concentrations were calculated using the peak area integration method where the area of the 100% peak for each mineral phase is summed and the relative percentages of each phase calculated based on the relative contribution to the sum. This method allows for some attention to be paid to preferred orientation but is limited in considering substitution and lattice strain.

Summary

The phases are listed in order of interpreted concentration:

<table>
<thead>
<tr>
<th>Mineral phase</th>
<th>Concentration (%)</th>
<th>ICDD match probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albite (Na0.986Al1.005Si2.995O8)</td>
<td>34</td>
<td>medium</td>
</tr>
<tr>
<td>Quartz, syn (SiO2)</td>
<td>21</td>
<td>good</td>
</tr>
<tr>
<td>Clinohlore-1Milib, ferroan (Mg,Fe)6(Si,Al)4O10(OH)8</td>
<td>18</td>
<td>good</td>
</tr>
<tr>
<td>Microcline, sodian (K0.88Na0.12Al3Si3O8)</td>
<td>15</td>
<td>medium</td>
</tr>
<tr>
<td>Illite (K0.78Mg0.18FeO10.1AI2.46Si3.36O10(OH)2)</td>
<td>4</td>
<td>medium</td>
</tr>
<tr>
<td>Calcite (CaCO3)</td>
<td>3</td>
<td>good</td>
</tr>
<tr>
<td>Amphibole group, syn</td>
<td>Sodium Calcium Magnesium Aluminum Scandium Silicon Oxide Fluoride (Na1.97Ca0.98Mg4.14Sc0.86Al0.79Si7.21O22F2)</td>
<td>2</td>
</tr>
<tr>
<td>Magnetite, syn (Fe2Fe3+O4)</td>
<td>1</td>
<td>medium</td>
</tr>
<tr>
<td>Gypsum, synthetic CaSO4</td>
<td>H2O2</td>
<td>trace</td>
</tr>
<tr>
<td>Pyrite, syn (FeS2)</td>
<td>trace</td>
<td>low</td>
</tr>
<tr>
<td>Boehmite, (AlO(OH))</td>
<td>trace</td>
<td>low</td>
</tr>
</tbody>
</table>

The ICDD match probability is reported as an indication as to how well the peak positions and relative intensities for the sample matched those in the published literature (www.icdd.org) for that particular compound.
Sample preparation

The sample was supplied by the client to Microanalysis Australia on 13th August 2018 for the above mentioned analyses. A representative sub-sample was removed and lightly ground such that 90% was passing 20 µm. Grinding to this size helps eliminate preferred orientation.

Analysis

Only crystalline material present in the sample will give peaks in the XRD scan. Amorphous (non-crystalline) material will add to the background. The search match software used was Eva 4.3. An up-to-date ICDD card set was used. The X-ray source was cobalt radiation.

No standards were used in the quantification process. The concentrations were calculated using the peak area integration method where the area of the 100% peak for each mineral phase is summed and the relative percentages of each phase calculated based on the relative contribution to the sum. This method allows for some attention to be paid to preferred orientation but is limited in considering substitution and lattice strain.

Summary

The phases are listed in order of interpreted concentration:

<table>
<thead>
<tr>
<th>Mineral phase</th>
<th>Concentration (%)</th>
<th>ICDD match probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albite (Na0.98Ca0.02Al1.02Si2.98O8)</td>
<td>46</td>
<td>medium</td>
</tr>
<tr>
<td>Quartz, syn (SiO2)</td>
<td>19</td>
<td>good</td>
</tr>
<tr>
<td>Microcline (K0.96Na0.046Al1.038Si3O8)</td>
<td>14</td>
<td>medium</td>
</tr>
<tr>
<td>Clinohlore‐1M1b, ferroan ([Mg6Fe6Si2Al4O10(OH)8]</td>
<td>9</td>
<td>good</td>
</tr>
<tr>
<td>amphibole group, syn</td>
<td>Sodium Calcium Magnesium Aluminum Scandium Silicon Oxide Fluoride</td>
<td>4</td>
</tr>
<tr>
<td>(Na1.97Ca0.98Mg4.145Sc0.86Al0.79Si7.21O22F2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcite, syn (Ca(CO3))</td>
<td>3</td>
<td>good</td>
</tr>
<tr>
<td>Magnetite, syn (Fe+2Fe2+3O4)</td>
<td>2</td>
<td>good</td>
</tr>
<tr>
<td>Illite (K0.84Na0.01Ca0.02Mg0.13Al2.63Si3.24O10(OH)2</td>
<td>2</td>
<td>medium</td>
</tr>
<tr>
<td>Gypsum, syn (CaSO4)(H2O)</td>
<td>1</td>
<td>low</td>
</tr>
<tr>
<td>Pyrite, syn (FeS2)</td>
<td>trace</td>
<td>low</td>
</tr>
</tbody>
</table>

The ICDD match probability is reported as an indication as to how well the peak positions and relative intensities for the sample matched those in the published literature (www.icdd.org) for that particular compound.

Analyst: Owen Carpenter, B.Sc.(Physics)
Reported: Owen Carpenter, B.Sc.(Physics)
Approved: Ian Davies, B.Sc.(Chemistry)
Annexure ED
Scanning Electron Microscopy (SEM)
Sample preparation
The sample was supplied to Microanalysis Australia as solid particulate matter.

A sub-sample was removed and placed on top of a double sided carbon tab before being carbon coated. Non-conducting samples require coating prior to SEM analysis to prevent charging whilst being analysed by the electron beam.

Analysis
The sample was analysed using a Carl Zeiss EVO50 scanning electron microscope (SEM) fitted with an Oxford INCA X-Max energy dispersive spectrometer (EDS).

EDS is a semi-quantitative technique (at best) on well prepared, optically flat samples. Factors such as sample unevenness may adversely bias elemental concentration interpretation. EDS has a spatial resolution of ~5 µm meaning spectra from particles less than this size may contain elemental concentrations biased by their surroundings.

No calibration standards (standardless quant) were used in the EDS detector standardization prior to analysis.

Summary
All images were acquired using backscatter electrons. Image contrast is directly proportional to average atomic number i.e. the brighter the area, the higher the atomic number.

Analyst: Greta Brodie, B.Sc. (Applied Chemistry)
Reported: Greta Brodie, B.Sc. (Applied Chemistry)
Approved: Nimue Pendragon, B.Sc. (Nanotechnology)
<table>
<thead>
<tr>
<th>Sample: 18_1340_03</th>
<th>Project: 18_1340</th>
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</thead>
<tbody>
<tr>
<td>Type: Default</td>
<td>Owner: lab</td>
</tr>
<tr>
<td>ID: HA401 0-2m</td>
<td>Site: Site of Interest 1</td>
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</tbody>
</table>
Sample: 18_1340_03
Type: Default
ID: HA401 0-2m

Project: 18_1340
Owner: lab
Site: Site of Interest 5

Electron Image 1
Sample preparation
The sample was supplied to Microanalysis Australia as solid particulate matter.

A sub-sample was removed and placed on top of a double sided carbon tab before being carbon coated. Non-conducting samples require coating prior to SEM analysis to prevent charging whilst being analysed by the electron beam.

Analysis
The sample was analysed using a Carl Zeiss EVO50 scanning electron microscope (SEM) fitted with an Oxford INCA X-Max energy dispersive spectrometer (EDS).

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All images were acquired using backscatter electrons. Image contrast is directly proportional to average atomic number i.e. the brighter the area, the higher the atomic number.

Analyst: Greta Brodie, B.Sc. (Applied Chemistry)
Reported: Greta Brodie, B.Sc. (Applied Chemistry)
Approved: Nimue Pendragon, B.Sc.(Nanotechnology)
<table>
<thead>
<tr>
<th>Sample: 18_1340_02</th>
<th>Project: 18_1340</th>
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<td>Owner: lab</td>
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<tr>
<td>ID: TC1</td>
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</tr>
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Sample image with dimensions: 200μm

**Electron Image 1**
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<td>Owner: lab</td>
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<tr>
<td>ID: TC1</td>
<td>Site: Site of Interest 4</td>
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</table>
Annexure EE
HA 401 - CSL Test Certificates
HA401

**Golder (Perth) Testing**

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<th>Test ID</th>
<th>p0</th>
<th>e0</th>
<th>psi0</th>
<th>Dmin</th>
<th>eta_max</th>
<th>psi</th>
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</thead>
<tbody>
<tr>
<td>RunOut_sa4-CID</td>
<td>300.9</td>
<td>0.510</td>
<td>0.055</td>
<td>0.000</td>
<td>0.545</td>
<td>0.045</td>
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<tr>
<td>RunOut_sa5-CID</td>
<td>801.7</td>
<td>0.460</td>
<td>0.054</td>
<td>0.000</td>
<td>0.517</td>
<td>0.048</td>
</tr>
<tr>
<td>RunOut_sa6-CID</td>
<td>50.7</td>
<td>0.400</td>
<td>-0.144</td>
<td>-0.440</td>
<td>1.870</td>
<td>-0.100</td>
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<tr>
<td>RunOut_sa7-CID</td>
<td>101.2</td>
<td>0.390</td>
<td>-0.119</td>
<td>-0.280</td>
<td>1.754</td>
<td>-0.094</td>
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<tr>
<td>RunOut_sa8-CID</td>
<td>800.9</td>
<td>0.330</td>
<td>-0.076</td>
<td>-0.153</td>
<td>1.631</td>
<td>-0.048</td>
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</table>

As tested initial at critical state

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<tr>
<th>Test ID</th>
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<th>e0</th>
<th>psi0</th>
<th>pc</th>
<th>ec</th>
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</thead>
<tbody>
<tr>
<td>RunOut_sa1-CIU</td>
<td>50.1</td>
<td>0.630</td>
<td>0.085</td>
<td>10</td>
<td>0.630</td>
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<tr>
<td>RunOut_sa2-CIU</td>
<td>101.0</td>
<td>0.576</td>
<td>0.066</td>
<td>22</td>
<td>0.576</td>
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<tr>
<td>RunOut_sa3-CIU</td>
<td>501.6</td>
<td>0.486</td>
<td>0.057</td>
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<td>0.486</td>
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**Trilab (Brisbane) Testing**

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<th>e0</th>
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<td>0.499</td>
</tr>
<tr>
<td>18080184A-CIU</td>
<td>99.3</td>
<td>0.550</td>
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<tr>
<td>18080184B-CIU</td>
<td>250.3</td>
<td>0.522</td>
</tr>
<tr>
<td>18100437-CIU</td>
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<td>0.586</td>
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<tr>
<td>18100438-CIU</td>
<td>498.3</td>
<td>0.463</td>
</tr>
</tbody>
</table>

\[ Mtc = 1.50 \]

\[ N = 0.23 \]

\[ \chi_{tc} = 4.6 \]

**Figure 1**

---

**HA401**

**NTSF Failure Review**

<table>
<thead>
<tr>
<th>Job number</th>
<th>H356804</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ref</td>
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</tr>
<tr>
<td>By</td>
<td>TMY</td>
</tr>
<tr>
<td>Revision</td>
<td>A</td>
</tr>
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</table>
# Triaxial Test Report

**Isotropically Consolidated Undrained (CIU)**

<table>
<thead>
<tr>
<th>Client:</th>
<th>Hatch</th>
<th>Date:</th>
<th>23/06/2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Address:</td>
<td>61 Petrie Terrace, Brisbane</td>
<td>Project No.:</td>
<td>18101980</td>
</tr>
<tr>
<td>Project:</td>
<td>NTSF Embankment Failure ITRB</td>
<td>Sample ID:</td>
<td>HA401 0-2m</td>
</tr>
<tr>
<td>Location:</td>
<td>Cadia Mine</td>
<td>Test ID:</td>
<td>18003 - sa-1 CIU very loose 50kPa</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Initial Height (mm):</th>
<th>144.1</th>
<th>Final Liquor Content (%):</th>
<th>23.2%</th>
<th>Strain Rate (mm/min):</th>
<th>0.03</th>
<th>B Response (%):</th>
<th>99%</th>
<th>Mean Effective Consolidation Stress (kPa):</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Diameter (mm):</td>
<td>62.6</td>
<td>Final Dry Density (t/m³):</td>
<td>1.67</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Geostatic Stress Ratio $K_0$ (-):</td>
<td>0.98</td>
</tr>
<tr>
<td>Trimmings GWC (%):</td>
<td>11.3%</td>
<td>Final Void Ratio (-):</td>
<td>0.63</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial Dry Density (t/m³):</td>
<td>1.23</td>
<td>Final Liquor Solids Conc. (g/L):</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh

**Reviewed by:** R. Fanni / D. Reid

---

**Sample Before Test**

**Sample After Test**

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
Triaxial Test Report

Isotropically Consolidated Undrained (CIU)

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NTSF Embankment Failure ITRB
Location: Cadia Mine

Date: 23/06/2018
Project No.: 18101980
Sample ID: HA401 0-2m
Test ID: 18003 - sa-1 CIU very loose 50kPa

Initial Height (mm): 144.1  Final Liquor Content (%): 23.2%
Initial Diameter (mm): 62.6  Final Dry Density (t/m$^3$): 1.67
Trimmings GWC (%): 11.3%  Final Void Ratio (-): 0.63
Initial Dry Density (t/m$^3$): 1.23  Final Liquor Solids Conc. (g/L): -

Strain Rate (mm/min): 0.03  B Response (%): 99%
Mean Effective Consolidation Stress (kPa): 50
Geostatic Stress Ratio $K_0$ (-): 0.98

Preparation Notes: Sample was moist tamped to a loose condition

Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid
Isotropically Consolidated Undrained (CIU)

Client: Hatch  
Address: 61 Petrie Terrace, Brisbane  
Project: NTFS Embankment Failure ITRB  
Location: Cadia Mine  
Test ID: 18003 - sa-1 CIU very loose 50kPa

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Height (mm)</td>
<td>144.1</td>
</tr>
<tr>
<td>Final Liquor Content (%)</td>
<td>23.2%</td>
</tr>
<tr>
<td>Strain Rate (mm/min)</td>
<td>0.03</td>
</tr>
<tr>
<td>Trimmings GWC (%)</td>
<td>11.3%</td>
</tr>
<tr>
<td>Initial Diameter (mm)</td>
<td>62.6</td>
</tr>
<tr>
<td>Initial Dry Density (t/m³)</td>
<td>1.23</td>
</tr>
<tr>
<td>Final Dry Density (t/m³)</td>
<td>1.67</td>
</tr>
<tr>
<td>Final Void Ratio (-)</td>
<td>0.63</td>
</tr>
<tr>
<td>Mean Effective Consolidation Stress (kPa)</td>
<td>50</td>
</tr>
<tr>
<td>Geostatic Stress Ratio K₀ (-)</td>
<td>0.98</td>
</tr>
</tbody>
</table>

Preparation Notes: Sample was moist tamped to a loose condition

Tested by: K. Koh  
Reviewed by: R. Fanni / D. Reid
Triaxial Test Report

Isotropically Consolidated Undrained (CIU)

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Location: Cadia Mine

Date: 23/06/2018
Project No.: 18101980
Project: NTSF Embankment Failure ITRB
Sample ID: HA401 0-2m
Test ID: 18003 - sa-1 CIU very loose 50kPa

Initial Height (mm): 144.1
Initial Diameter (mm): 62.6
Initial Dry Density (t/m$^3$): 1.23
Trimmings GWC (%): 11.3%

Final Liquor Content (%): 23.2%
Final Dry Density (t/m$^3$): 1.67
Final Void (-): 0.63
Final Liquor Solids Conc. (g/L): -

Strain Rate (mm/min): 0.03
B Response (%): 99%
Mean Effective Consolidation Stress (kPa): 50
Geostatic Stress Ratio $K_0$ (-): 0.98

Preparation Notes: Sample was moist tamped to a loose condition

**Graph:**
- **X-axis:** Axial Strain (%)
- **Y-axis:** Mobilised Friction Angle (Degrees)

**Tested by:** K. Koh
**Reviewed by:** R. Fanni / D. Reid
<table>
<thead>
<tr>
<th>Sample Before Test</th>
<th>Sample After Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation Notes:</td>
<td>Sample was moist tamped to a loose condition</td>
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<tr>
<td>Tested by:</td>
<td>K. Koh</td>
</tr>
<tr>
<td>Reviewed by:</td>
<td>R. Fanni / D. Reid</td>
</tr>
</tbody>
</table>

**Isotropically Consolidated Undrained (CIU)**

**Client:** Hatch  
**Project:** NTSF Embankment Failure ITRB  
**Location:** Cadia Mine  
**Address:** 84 Guthrie Street, Osborne Park

**Date:** 20/06/2018  
**Project No.:** 18101980  
**Sample ID:** HA401 0-2m  
**Test ID:** 18003 - sa-2 CIU loose 100kPa

<table>
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<tbody>
<tr>
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<tr>
<td>Initial Diameter (mm)</td>
<td>63.6</td>
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<tr>
<td>Trimmings GWC (%)</td>
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<tr>
<td>Initial Dry Density (t/m³)</td>
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<tr>
<td>Final Liquor Content (%)</td>
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<tr>
<td>Strain Rate (mm/min)</td>
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<tr>
<td>B Response (%)</td>
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<tr>
<td>Mean Effective Consolidation Stress (kPa)</td>
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<tr>
<td>Geostatic Stress Ratio $K_0$ (-)</td>
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<tr>
<td>Final Void Ratio (-)</td>
<td>0.58</td>
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<td>Final Liquor Solids Conc. (g/L)</td>
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Isotropically Consolidated Undrained (CIU)

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NTSF Embankment Failure ITRB
Location: Cadia Mine
Date: 20/06/2018
Project No.: 18101980
Sample ID: HA401 0-2m
Test ID: 18003 - sa-2 CIU loose 100kPa

Initial Height (mm): 146.7
Initial Diameter (mm): 63.6
Trimmings GWC (%): 11.3
Initial Dry Density (t/m$^3$): 1.22

Final Liquor Content (%): 21.1%
Final Dry Density (t/m$^3$): 1.73
Final Void Ratio (-): 0.58
Final Liquor Solids Conc. (g/L): -

Strain Rate (mm/min): 0.03
B Response (%): 99%
Mean Effective Consolidation Stress (kPa): 101
Geostatic Stress Ratio $K_0$ (-): 0.97

Preparation Notes: Sample was moist tamped to a loose condition

Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
# Triaxial Test Report

**Isotropically Consolidated Undrained (CIU)**

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<td>HA401 0-2m</td>
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<td>Test ID:</td>
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- **Initial Height (mm):** 146.7
- **Final Liquor Content (%):** 21.1%
- **Strain Rate (mm/min):** 0.03
- **B Response (%):** 99%
- **Mean Effective Consolidation Stress (kPa):** 101
- **Geostatic Stress Ratio \( K_0 \):** 0.97

**Preparation Notes:** Sample was moist tamped to a loose condition

![Triaxial Stress-Strain Test](chart.png)

**Mean Effective Stress \( p' \) (kPa)** vs. **Deviator Stress \( q \) (kPa)**
## Triaxial Test Report

### Isotropically Consolidated Undrained (CIU)

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTSF Embankment Failure ITRB  
**Location:** Cadia Mine  
**Sample ID:** HA401 0-2m  
**Test ID:** 18003 - sa-2 CIU loose 100kPa

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**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh  
**Reviewed by:** R. Fanni / D. Reid

---

**Diagram:**

- **Axes:** Axial Strain (%) on the x-axis and Mobilised Friction Angle (Degrees) on the y-axis.
- **Graph:** Shows the relationship between Axial Strain (%) and Mobilised Friction Angle (Degrees) for the test.
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<td>Location:</td>
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<td>Test ID:</td>
<td>18003 - sa-3 CIU loose 500kPa</td>
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<table>
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<th>Final Liquor Content (%):</th>
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<tr>
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<td>Final Void Ratio (-):</td>
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<td>Mean Effective Consolidation Stress (kPa):</td>
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<td>Final Liquor Solids Conc. (g/L):</td>
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<td>Geostatic Stress Ratio $K_0$ (-):</td>
<td>1.00</td>
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**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh

**Reviewed by:** R. Fanni / D. Reid
# Triaxial Test Report

## Isotropically Consolidated Undrained (CIU)

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<td>Cadia Mine</td>
<td>Test ID</td>
<td>18003 - sa-3 CIU loose 500kPa</td>
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</tbody>
</table>

### Test Details

- **Initial Height (mm):** 147.2
- **Final Liquor Content (%):** 17.8%
- **Strain Rate (mm/min):** 0.03
- **Initial Diameter (mm):** 66.2
- **Final Dry Density (t/m³):** 1.84
- **B Response (%):** 99%
- **Trimmings GWC (%):** 11.3%
- **Final Void Ratio (-):** 0.49
- **Mean Effective Consolidation Stress (kPa):** 502
- **Initial Dry Density (t/m³):** 1.20
- **Final Liquor Solids Conc. (g/L):** -
- **Geostatic Stress Ratio K₀ (-):** 1.00

### Graph

- **Deviator Stress (kPa)** vs **Axial Strain (%)**
- **Shear-induced Pore Pressure (kPa)**

**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh

**Reviewed by:** R. Fanni / D. Reid

---

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Triaxial Test Report

Isotropically Consolidated Undrained (CIU)

Client: Hatch  Date: 16/06/2018
Address: 61 Petrie Terrace, Brisbane  Project No.: 18101980
Project: NTTF Embankment Failure ITRB  Sample ID: HA401 0-2m
Location: Cadia Mine  Test ID: 18003 - sa-3 CIU loose 500kPa

Initial Height (mm): 147.2  Final Liquor Content (%): 17.8%  Strain Rate (mm/min): 0.03
Initial Diameter (mm): 66.2  Final Dry Density (t/m³): 1.84  B Response (%): 99%
Trimmings GWC (%): 11.3%  Final Void Ratio (-): 0.49  Mean Effective Consolidation Stress (kPa): 502
Initial Dry Density (t/m³): 1.20  Final Liquor Solids Conc. (g/L): -  Geostatic Stress Ratio $K_0$ (-): 1.00

Preparation Notes: Sample was moist tamped to a loose condition

Tested by: K. Koh  Reviewed by: R. Fanni / D. Reid

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## Triaxial Test Report

### Isotropically Consolidated Undrained (CIU)

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project No.:** 18101980  
**Project:** NTSF Embankment Failure ITRB  
**Sample ID:** HA401 0-2m  
**Location:** Cadia Mine  
**Test ID:** 18003 - sa-3 CIU loose 500kPa

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<tr>
<td>Geostatic Stress Ratio $K_0$ (-):</td>
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**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh  
**Reviewed by:** R. Fanni / D. Reid

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**Isotropically Consolidated Drained (CID)**

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<tr>
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<td>Final Void Ratio (-):</td>
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<tr>
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<td>Sample Before Test</td>
<td>![Sample Before Test Image]</td>
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<tr>
<td>Sample After Test</td>
<td>![Sample After Test Image]</td>
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**Triaxial Test Report**

**Perth Laboratory**
84 Guthrie Street, Osborne Park

**THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL**
### Triaxial Test Report

**Isotropically Consolidated Drained (CID)**

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTSF Embankment Failure ITRB  
**Location:** Cadia Mine  
**Project No.:** 18101980  
**Sample ID:** HA401 0-2m

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**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh  
**Reviewed by:** R. Fanni / D. Reid

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![Graph showing the relationship between Deviator Stress (kPa) and Axial Strain (%)](image)
**Triaxial Test Report**

**Isotropically Consolidated Drained (CID)**

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**Graph:**

- **Deviator Stress $q$ (kPa):** 0 to 800
- **Mean Effective Stress $p'$ (kPa):** 0 to 600

**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh

**Reviewed by:** R. Fanni / D. Reid
## Triaxial Test Report

**Isotropically Consolidated Drained (CID)**

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTSDL Embankment Failure ITRB  
**Location:** Cadia Mine  
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</tbody>
</table>

**Raw Material Notes:** Sample was moist tamped to a loose condition

**Reported by:** K. Koh

**Reviewed by:** R. Fanni / D. Reid
**Isotropically Consolidated Drained (CID)**

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTSF Embankment Failure ITRB  
**Location:** Cadia Mine  
**Date:** 18/06/2018  
**Project No.:** 18101980  
**Sample ID:** HA401 0-2m  
**Test ID:** 18003 - sa-4 CID loose 300kPa

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**Graph:**
- **X-axis:** Axial Strain (%)  
- **Y-axis:** Mobilised Friction Angle (Degrees)

**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh  
**Reviewed by:** R. Fanni / D. Reid
## Triaxial Test Report

### Isotropically Consolidated Drained (CID)

| Client: | Hatch |
| Address: | 61 Petrie Terrace, Brisbane |
| Project: | NTSF Embankment Failure ITRB |
| Location: | Cadia Mine |
| Test ID: | 18003 - sa-5 CID loose 800kPa |

| Initial Height (mm): | 147.1 | Final Liquor Content (%): | 14.2% |
| Initial Diameter (mm): | 66.4 | Final Dry Density (t/m³): | 1.97 |
| Trimmings GWC (%): | 11.3% | Final Void Ratio (-): | 0.39 |
| Initial Dry Density (t/m³): | 1.19 | Final Liquor Solids Conc. (g/L): | - |

| Strain Rate (mm/min): | 0.015 | B Response (%): | 99% |
| Mean Effective Consolidation Stress (kPa): | 801 | Geostatic Stress Ratio $K_0$ (-): | 1.00 |

Sample Before Test

- Sample was moist tamped to a loose condition

Sample After Test

- 18003 - HA401
- sa-5 - CID - 800kPa
- Loose

Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
Isotropically Consolidated Drained (CID)

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NTSF Embankment Failure ITRB
Location: Cadia Mine

Date: 14/06/2018
Project No.: 18101980
Sample ID: HA401 0-2m
Test ID: 18003 - sa-5 CID loose 800kPa

Initial Height (mm): 147.1
Initial Diameter (mm): 66.4
Initial Dry Density (t/m³): 1.19
Trimmings GWC (%): 11.3%
Initial Height (mm): 147.1
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Initial Dry Density (t/m³): 1.19
Trimmings GWC (%): 11.3%

Final Liquor Content (%): 14.2%
Final Dry Density (t/m³): 1.97
Final Void Ratio (-): 0.39
Mean Effective Consolidation Stress (kPa): 801

Strain Rate (mm/min): 0.015
B Response (%): 99%
Mean Effective Consolidation Stress (kPa): 801

Geostatic Stress Ratio $K_0 (-)$: 1.00

Sample was moist tamped to a loose condition

Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid

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### Triaxial Test Report

**Isotropically Consolidated Drained (CID)**

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**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh

**Reviewed by:** R. Fanni / D. Reid

---

**Graph:**

- **Deviator Stress $q$ (kPa)** on the y-axis.
- **Mean Effective Stress $p'$ (kPa)** on the x-axis.

- The graph shows a linear relationship between deviator stress and mean effective stress.

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**Triaxial Test Report**

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**Preparation Notes:** Sample was moist tamped to a loose condition

**Axial Strain (%)**

**Volumetric Strain (%)**
Isotropically Consolidated Drained (CID)

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NTSF Embankment Failure ITRB
Location: Cadia Mine

Initial Height (mm): 147.1 Final Liquor Content (%): 14.2%
Initial Diameter (mm): 66.4 Final Dry Density (t/m$^3$): 1.97
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Initial Dry Density (t/m$^3$): 1.19 Final Liquor Solids Conc. (g/L): -

Strain Rate (mm/min): 0.015 B Response (%): 99%
Mean Effective Consolidation Stress (kPa): 801
Geostatic Stress Ratio $K_0$ (-): 1.00

Preparation Notes: Sample was moist tamped to a loose condition

Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
### Triaxial Test Report

#### Isotropically Consolidated Drained (CID)

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#### Preparation Notes:
- Sample was moist tamped

#### Tested by: K. Koh

#### Reviewed by: R. Fanni / D. Reid

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# Triaxial Test Report

## Isotropically Consolidated Drained (CID)

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**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTSE Embankment Failure ITRB  
**Location:** Cadia Mine

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**Preparation Notes:** Sample was moist tamped

**Tested by:** K. Koh  
**Reviewed by:** R. Fanni / D. Reid

---

[Graph of Deviator Stress vs. Axial Strain]
Triaxial Test Report

Isotropically Consolidated Drained (CID)

Client: Hatch  Date: 28/06/2018
Address: 61 Petrie Terrace, Brisbane  Project No.: 18101980
Project: NTSF Embankment Failure ITRB  Sample ID: HA401 0-2m
Location: Cadia Mine  Test ID: 18003 - sa-6 CID dense 50kPa

Initial Height (mm): 160.8  Final Liquor Content (%): 15.9%  Strain Rate (mm/min): 0.015
Initial Diameter (mm): 72.5  Final Dry Density (t/m³): 1.90  B Response (%): 96%
Trimmings GWC (%): 11.3%  Final Void Ratio (-): 0.43  Mean Effective Consolidation Stress (kPa): 50
Initial Dry Density (t/m³): 1.93  Final Liquor Solids Conc. (g/L): -  Geostatic Stress Ratio $K_0$ (-): 0.98

Preparation Notes: Sample was moist tamped

Tested by: K. Koh  Reviewed by: R. Fanni / D. Reid

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## Triaxial Test Report

### Isotropically Consolidated Drained (CID)

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTSF Embankment Failure ITRB  
**Location:** Cadia Mine

**Preparation Notes:** Sample was moist tamped

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### Graph

- **Volumetric Strain (%):**
  - 0% 2% 4% 6% 8% 10% 12% 14%
  - 0% 0.5% 1.0% 1.5% 2.0%

- **Axial Strain (%):**
  - 0% 2% 4% 6% 8% 10% 12% 14%

### Notes

- **Client:** Hatch
- **Address:** 61 Petrie Terrace, Brisbane
- **Project:** NTSF Embankment Failure ITRB
- **Location:** Cadia Mine
- **Preparation Notes:** Sample was moist tamped
- **Tested by:** K. Koh
- **Reviewed by:** R. Fanni / D. Reid
- **Date:** 28/06/2018
- **Test ID:** 18003 - sa-6 CID dense 50kPa
- **Sample ID:** HA401 0-2m
- **Project No.:** 18101980
- **Project:** NTsf Embankment Failure ITRB
- **Client:** Hatch
- **Date:** 28/06/2018

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### Isotropically Consolidated Drained (CID)

#### Triaxial Test Report

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTFS Embankment Failure ITRB  
**Location:** Cadi Mine  
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**Preparation Notes:** Sample was moist tamped

**Tested by:** K. Koh  
**Reviewed by:** R. Fanni / D. Reid
# Triaxial Test Report

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### Preparation Notes:
Sample was moist tamped

---

**Sample Before Test**

**Sample After Test**

**Tested by:** K. Koh

**Reviewed by:** R. Fanni / D. Reid

---

**THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL**
Isotropically Consolidated Drained (CID)

Initial Height (mm): 159.9  Final Liquor Content (%): 15.0%
Initial Diameter (mm): 72.5  Final Dry Density (t/m³): 1.94
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Mean Effective Consolidation Stress (kPa): 101  Geostatic Stress Ratio $K_0 (-)$: 0.98

Sample was moist tamped

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### Isotropically Consolidated Drained (CID)

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project No.:** 18101980  
**Project:** NT SF Embankment Failure ITRB  
**Sample ID:** HA401 0-2m  
**Location:** Cadia Mine  
**Test ID:** 18003 - sa-7 CID very dense 100kPa

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**Preparation Notes:** Sample was moist tamped

**Tested by:** K. Koh  
**Reviewed by:** R. Fanni / D. Reid
## Isotropically Consolidated Drained (CID)

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project No.:** 18101980  
**Project:** NTSF Embankment Failure ITRB  
**Sample ID:** HA401 0-2m  
**Location:** Cadia Mine  
**Test ID:** 18003 - sa-7 CID very dense 100kPa

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---

**Volumetric Strain (%)** vs. **Axial Strain (%)**

---

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**Triaxial Test Report**

**Isotropically Consolidated Drained (CID)**

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**Project No.:** 18101980  
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---

**Graph:**
- **Mobilised Friction Angle (Degrees)** vs. **Axial Strain (%)**
- The graph shows a typical triaxial test result with mobilised friction angle increasing with axial strain until a peak is reached, followed by a decrease and stabilization.

---

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### Triaxial Test Report

**Isotropically Consolidated Drained (CID)**

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<td>Sample ID:</td>
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</tr>
<tr>
<td>Test ID:</td>
<td>18003 - sa-8 CID very dense 800kPa</td>
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#### Test Parameters

| Initial Height (mm):    | 149.3                                                                 |
| Initial Diameter (mm):  | 72.6                                                                  |
| Trimmings GWC (%):      | 11.3%                                                                 |
| Initial Dry Density (t/m³): | 2.00                                                             |
| Final Liquor Content (%): | 12.5%                                                                |
| Final Dry Density (t/m³): | 2.04                                                                  |
| Final Void Ratio (-):   | 0.34                                                                  |
| Geostatic Stress Ratio K₀ (-): | 1.00                                                               |
| Strain Rate (mm/min):   | 0.015                                                                 |
| B Response (%):         | 96%                                                                   |
| Mean Effective Consolidation Stress (kPa): | 801                                                             |

#### Sample Notes

- **Preparation Notes:** Sample was moist tamped
- **Tested by:** K. Koh
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---

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Isotropically Consolidated Drained (CID)

Client: Hatch  Date: 28/06/2018
Address: 61 Petrie Terrace, Brisbane  Project No.: 18101980
Project: NTSF Embankment Failure ITRB  Sample ID: HA401 0-2m
Location: Cadia Mine  Test ID: 18003 - sa-8 CID very dense 800kPa

Initial Height (mm): 149.3  Final Liquor Content (%): 12.5%  Strain Rate (mm/min): 0.015
Initial Diameter (mm): 72.6  Final Dry Density (t/m³): 2.04  B Response (%): 96%
Trimmings GWC (%): 11.3%  Final Void Ratio (-): 0.34  Mean Effective Consolidation Stress (kPa): 801
Initial Dry Density (t/m³): 2.00  Final Liquor Solids Conc. (g/L): -  Geostatic Stress Ratio K₀ (-): 1.00

Preparation Notes: Sample was moist tamped

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## Triaxial Test Report

### Isotropically Consolidated Drained (CID)

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**Location:** Cadia Mine  
**Sample ID:** HA401 0-2m  
**Test ID:** 18003 - sa-8 CID very dense 800kPa

**Preparation Notes:** Sample was moist tamped  
**Tested by:** K. Koh  
**Reviewed by:** R. Fanni / D. Reid

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---

### Graph

- **Y-axis:** Deviator Stress q (kPa)  
- **X-axis:** Mean Effective Stress \( p' \) (kPa)

---

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Isotropically Consolidated Drained (CID)

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NTFS Embankment Failure ITRB
Location: Cadia Mine

Date: 28/06/2018
Project No.: 18101980
Sample ID: HA401 0-2m
Test ID: 18003 - sa-8 CID very dense 800kPa

Initial Height (mm): 149.3
Initial Diameter (mm): 72.6
Trimmings GWC (%): 11.3%
Initial Dry Density (t/m³): 2.00

Final Liquor Content (%): 12.5%
Final Dry Density (t/m³): 2.04
Final Void Ratio (-): 0.34
Final Liquor Solids Conc. (g/L): -

Strain Rate (mm/min): 0.015
B Response (%): 96%
Mean Effective Consolidation Stress (kPa): 801
Geostatic Stress Ratio $K_0$ (-): 1.00

Volumetric Strain (%)
Axial Strain (%)

Preparation Notes: Sample was moist tamped
Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid
### Triaxial Test Report

**Isotropically Consolidated Drained (CID)**

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- **Initial Height (mm):** 149.3
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- **Final Liquor Solids Conc. (g/L):** -
- **Geostatic Stress Ratio K₀ (-):** 1.00

![Graph](image)

**Preparation Notes:** Sample was moist tamped

**Tested by:** K. Koh

**Reviewed by:** R. Fanni / D. Reid

---

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## Triaxial Test Report

### Isotropically Consolidated Drained (CID)

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### Preparation Notes:
Sample was moist tamped

### Tested by:
K. Koh

### Reviewed by:
R. Fanni / D. Reid

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**Sample Before Test**

**Sample After Test**

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### Triaxial Test Report

**Isotropically Consolidated Drained (CID)**

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**Address:** 61 Petrie Terrace, Brisbane  
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**Location:** Cadia Mine

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**Reviewed by:** R. Fanni / D. Reid

**Tested by:** K. Koh

**Sample ID:** HA401 0-2m

**Test ID:** 18003 - sa-9 CID dense 1300kPa

**Test ID:** 18003 - sa-9 CID dense 1300kPa

**Graph:**

- **Deviator Stress (kPa):** 0, 500, 1000, 1500, 2000, 2500, 3000, 3500, 4000
- **Axial Strain (%):** 0, 5, 10, 15, 20, 25, 30, 35

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Triaxial Test Report

Isotropically Consolidated Drained (CID)

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Project: NTSF Embankment Failure ITRB  Sample ID: HA401 0-2m
Location: Cadia Mine  Test ID: 18003 - sa-9 CID dense 1300kPa

- Initial Height (mm): 125.7
- Final Liquor Content (%): 13.2%
- Strain Rate (mm/min): 0.015
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- Final Dry Density (t/m$^3$): 2.01
- B Response (%): 96%
- Trimmings GWC (%): 13.5%
- Final Void Ratio (-): 0.36
- Mean Effective Consolidation Stress (kPa): 1301
- Initial Dry Density (t/m$^3$): 1.93
- Final Liquor Solids Conc. (g/L): -
- Geostatic Stress Ratio $K_0$: 1.00
- Location: Cadia Mine
- Test ID: 18003 - sa-9 CID dense 1300kPa

Preparation Notes: Sample was moist tamped

Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid

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## Triaxial Test Report

**Isotropically Consolidated Drained (CID)**

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**Sample Preparation Notes:** Sample was moist tamped  
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**Reviewed by:** R. Fanni / D. Reid  

---

**Diagram:**

- **Volumetric Strain (%)** vs. **Axial Strain (%)**

---

**Location:** Cadia Mine  
**Address:** 61 Petrie Terrace, Brisbane  
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**Preparation Notes:** Sample was moist tamped  
**Tested by:** K. Koh  
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---

**Mobilised Friction Angle (Degrees)**

---

**Axial Strain (%)**

---

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## TRIAXIAL TEST REPORT

**Test Method: AS1289.6.4.2**

### SAMPLE & TEST DETAILS

<table>
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<th>Description</th>
<th>Tailings</th>
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<tr>
<td>Dry Density</td>
<td>1.71 t/m³</td>
</tr>
<tr>
<td>Rate of Strain</td>
<td>0.013 %/min</td>
</tr>
<tr>
<td>B Response</td>
<td>99 %</td>
</tr>
<tr>
<td>Target Void Ratio</td>
<td>0.600</td>
</tr>
<tr>
<td>Final Void Ratio</td>
<td>0.550</td>
</tr>
<tr>
<td>Freezing Void Ratio</td>
<td>0.551</td>
</tr>
</tbody>
</table>

Sample Type: Single Individual Remoulded Specimen

### TEST RESULTS

#### FAILURE DETAILS

<table>
<thead>
<tr>
<th>Effective Pressure</th>
<th>Confining Pressure</th>
<th>Back Pressure</th>
<th>Initial Pore</th>
<th>Failure Pore</th>
<th>Deviator Stress</th>
<th>Strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>101 kPa</td>
<td>600 kPa</td>
<td>499 kPa</td>
<td>499 kPa</td>
<td>51 kPa</td>
<td>171 kPa</td>
<td>103 kPa</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.660</td>
<td>68 kPa</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.07 %</td>
</tr>
</tbody>
</table>

#### FAILURE ENVELOPES

Interpretation between stages:

- Cohesion C' (kPa):
- Angle of Shear Resistance $\Phi'$ (Degrees):
- Failure Criteria: Peak Deviator Stress

Remarks:
Sample/s supplied by the client
## TRIAXIAL TEST REPORT

**Test Method:** AS1289.6.4.2

**Client:** Hatch Pty Ltd

**Report No.:** 18080184A - CU

### Mohr Circle Diagram

<table>
<thead>
<tr>
<th>Principal Stress (kPa)</th>
<th>Shear Stress (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

### Interpretation between stages:
- Cohesion C' (kPa):
- Angle of Shear Resistance Φ' (Degrees):
- Failure Criteria: Peak Deviator Stress

### Remarks:
- Sample/s supplied by the client
- Note: Graph not to scale

---

**Trilab Pty Ltd**

ABN 25 065 630 506

**Authorised Signatory**

C. Channon

**Laboratory Number**

8726

---

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ABN 25 065 630 506
Triaxial Test Report

Test Method: AS1289.6.4.2

Client: Hatch Pty Ltd
Report No.: 18080184A - CU

Remarks:
Sample/s supplied by the client

Note: Graph not to scale

Stress/Strain & Pore Pressure/Strain Diagram

Shear Stress  Pore Pressure

Strain %

Deviator Stress kPa

Pore Pressure kPa

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C. Channon

Lab Number 9926

Trilab Pty Ltd
ABN: 25 065 630 506
MIT Method - Effective Stress Path

\[ s = \frac{(\sigma'_1 + \sigma'_3)}{2} \text{ kPa} \]

Remarks:
Sample/s supplied by the client

Note: Graph not to scale

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TRIAXIAL TEST REPORT
Test Method: AS1289.6.4.2

Client: Hatch Pty Ltd
Report No.: 18080184A - CU

Cambridge Method - Effective Stress Path

\[ q = (\sigma'_1 - \sigma'_3) \text{ kPa} \]

\[ p = (\sigma'_1 + 2\sigma'_3)/3 \text{ kPa} \]

Remarks:
Sample/s supplied by the client
Note: Graph not to scale

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Laboratory Number
9926
TRIAXIAL TEST REPORT
Test Method: AS1289.6.4.2

Client: Hatch Pty Ltd
Report No.: 18080184A - CU

Void ratio v's p

\[ p = \left( \sigma'_1 + 2 \sigma'_3 \right) / 3 \text{ kPa} \]

Remarks:
Sample/s supplied by the client
Note: Graph not to scale

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Trilab Pty Ltd
ABN 25 065 630 506
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Hatch Pty Ltd
Report No.: 18080184A - CU

Friction Angle v's Axial Strain

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ABN 25 065 630 506
TRIAXIAL TEST REPORT
Test Method: AS1289.6.4.2

Client: Hatch Pty Ltd
Report No.: 18080184A - CU

CLIENT: Hatch Pty Ltd
PROJECT: H356804 - Cadia NTSF Failure
LAB SAMPLE No. 18080184 A
BOREHOLE: HA401
BEFORE TEST
DATE: 25.05.22
DEPTH: Not Supplied

Remarks:
Sample/s supplied by the client

Note: Photo not to scale

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ABN 25 065 630 506

Trilab Pty Ltd
Volume v's Time (Log Scale)

Remarks:
Sample/s supplied by the client

Note: Graph not to scale

Hatch Pty Ltd
18080184A - CU

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Trilab Pty Ltd
ABN 25 065 630 506
### TRIAXIAL TEST REPORT

**Client:** Hatch Pty Ltd  
**Report No.:** 18080184B - CU  
**Workorder No.:** 0004644  
**Address:** PO Box 425 SPRING HILL QLD 4004  
**Test Date:** 24/09/2018  
**Report Date:** 8/10/2018  

**Project:** H356804 - Cadia NTSF Failure  
**Client Id.:** HA401  
**Depth (m):** 0.00–2.00

#### SAMPLE & TEST DETAILS

| Initial Height | 152.2 mm | Initial Moisture Content | 10.0 % | Rate of Strain | 0.013 %/min |
| Initial Diameter | 76.1 mm | Final Moisture Content | 19.5 % | B Response | 99 % |
| L/D Ratio | 2.0 : 1 | Wet Density | 1.94 t/m³ | Target Void Ratio | 0.550 |
| | | Dry Density | 1.76 t/m³ | Final Void Ratio | 0.527 |
| | | | | Freezing Void Ratio | 0.522 |

Sample Type: Single Individual Remoulded Specimen

#### TEST RESULTS

<table>
<thead>
<tr>
<th>Effective Pressure</th>
<th>Confining Pressure</th>
<th>Back Pressure</th>
<th>Initial Pore</th>
<th>Failure Pore</th>
<th>Deviator Stress</th>
<th>Strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>253 kPa</td>
<td>751 kPa</td>
<td>498 kPa</td>
<td>498 kPa</td>
<td>14 kPa</td>
<td>247 kPa</td>
<td>84 kPa</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.945</td>
<td>163 kPa</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.23 %</td>
<td></td>
</tr>
</tbody>
</table>

#### FAILURE ENVELOPES

**Interpretation between stages:**
- **Cohesion C’ (kPa):**
- **Angle of Shear Resistance Φ’ (Degrees):**
- **Failure Criteria:** Peak Deviator Stress

**Remarks:** Sample/s supplied by the client

---

Trilab Pty Ltd  
ABN 25 065 630 506
TRIAXIAL TEST REPORT
Test Method: AS1289.6.4.2

Client: Hatch Pty Ltd
Report No.: 18080184B - CU

Interpretation between stages:
- Cohesion C' (kPa):
- Angle of Shear Resistance Φ' (Degrees):
- Failure Criteria: Peak Deviator Stress

Remarks:
Sample/s supplied by the client
Note: Graph not to scale

Trilab Pty Ltd
ABN 25 065 630 506

Authorized Signatory
T. Lockhart

Authorized Signatory
C. Channon

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TRIAXIAL TEST REPORT
Test Method: AS1289.6.4.2

Client: Hatch Pty Ltd
Report No.: 18080184B - CU

Stress/Strain & Pore Pressure/Strain Diagram

Shear Stress
Pore Pressure

Deviator Stress kPa
Pore Pressure kPa

Strain %

Remarks:
Sample/s supplied by the client

Note: Graph not to scale

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TRIAXIAL TEST REPORT
Test Method: AS1289.6.4.2

Client: Hatch Pty Ltd
Report No.: 18080184B - CU

MIT Method - Effective Stress Path

\[ s = \frac{\sigma'_1 + \sigma'_3}{2} \text{ kPa} \]

Remarks:
Sample/s supplied by the client

Note: Graph not to scale

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Authorised Signatory
C. Channon

Laboratory Number
9926
TRIAXIAL TEST REPORT
Test Method: AS1289.6.4.2

Client: Hatch Pty Ltd
Report No.: 18080184B - CU

Cambridge Method - Effective Stress Path

\[ q = (\sigma'_{1} - \sigma'_{3}) \text{ kPa} \]

\[ p = (\sigma'_{1} + 2\sigma'_{3})/3 \text{ kPa} \]

Remarks:
Sample/s supplied by the client

Note: Graph not to scale

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Authorised Signatory
C. Channon

Laboratory Number 9926
TRIAXIAL TEST REPORT
Test Method: AS1289.6.4.2

Client: Hatch Pty Ltd
Report No.: 18080184B - CU

Void ratio v's p
- Shearing Stage
- Consolidation Stage

\[ p = \left( \sigma_1' + 2\sigma_3' \right) / 3 \text{ kPa} \]

Remarks:
Sample/s supplied by the client

Note: Graph not to scale

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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Hatch Pty Ltd
Report No.: 18080184B - CU

Friction Angle v's Axial Strain

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Tested at Trilab Brisbane Laboratory.

Remarks:
Sample/s supplied by the client
Note: Graph not to scale
CLIENT: Hatch Pty Ltd

PROJECT: H356804 - Cadia NTSF Failure

LAB SAMPLE No.: 18080184

BOREHOLE: HA401

BEFORE TEST

DATE: 25-09-18

DEPTH: Not Supplied

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ABN 25 065 630 506
TRIAXIAL TEST REPORT
Test Method: AS1289.6.4.2

Client: Hatch Pty Ltd
Report No.: 18080184B - CU

Volume v's Time (Log Scale)

Remarks: 0
Sample/s supplied by the client
Note: Graph not to scale

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Authorised Signatory
C. Channon

Laboratory Number
9926
### TRIAXIAL TEST REPORT

**Test Method:** AS1289.6.4.2

<table>
<thead>
<tr>
<th>Client: Hatch Pty Ltd</th>
<th>Report No.:</th>
<th>18100437A - CU</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Address:</strong> PO Box 425 SPRING HILL QLD 4004</td>
<td>Workorder No.:</td>
<td>0005014</td>
</tr>
<tr>
<td><strong>Project:</strong> H356804 - Cadia NTSF Failure</td>
<td><strong>Test Date:</strong></td>
<td>16/10/2018</td>
</tr>
<tr>
<td><strong>Client Id.:</strong> HA401</td>
<td><strong>Report Date:</strong></td>
<td>24/10/2018</td>
</tr>
</tbody>
</table>

**Depth (m):** 0.00-2.00

**Description:** -

#### SAMPLE & TEST DETAILS

<table>
<thead>
<tr>
<th>Initial Height: 152.1 mm</th>
<th>Initial Moisture Content: 9.8 %</th>
<th>Rate of Strain: 0.013 %/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Diameter: 76.3 mm</td>
<td>Final Moisture Content: 22.1 %</td>
<td>B Response: 98 %</td>
</tr>
<tr>
<td>L/D Ratio: 2.0 : 1</td>
<td>Wet Density: 1.79 t/m³</td>
<td>Target Void Ratio: 0.630</td>
</tr>
<tr>
<td></td>
<td>Dry Density: 1.63 t/m³</td>
<td>Final Void Ratio: 0.586</td>
</tr>
</tbody>
</table>

**Sample Type:** Single Individual Remoulded Specimen

#### TEST RESULTS

<table>
<thead>
<tr>
<th>Effective Pressure</th>
<th>Confining Pressure</th>
<th>Back Pressure</th>
<th>Initial Pore</th>
<th>Failure Pore</th>
<th>Principal Effective Stresses</th>
<th>Deviator Stress</th>
<th>Strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>51 kPa</td>
<td>550 kPa</td>
<td>499 kPa</td>
<td>499 kPa</td>
<td>33 kPa</td>
<td>43 kPa</td>
<td>16 kPa</td>
<td>2.593</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>26 kPa</td>
</tr>
</tbody>
</table>

#### FAILURE ENVELOPES

**Interpretation between stages:**

- **Cohesion C’ (kPa):**
- **Angle of Shear Resistance Φ’ (Degrees):**
- **Failure Criteria:** Peak Deviator Stress

**Remarks:** Sample/s supplied by the client

---

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---

Authorised Signatory

C. Channon
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Hatch Pty Ltd

Report No.: 18100437A - CU

Mohr Circle Diagram

Interpretation between stages:
- Cohesion C' (kPa)
- Angle of Shear Resistance \( \Phi' \) (Degrees)
- Failure Criteria: Peak Deviator Stress

Remarks:
Sample/s supplied by the client

Note: Graph not to scale

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Trilab Pty Ltd
ABN 25 065 630 506

Page 2 of 9

Laboratory Number 9926
TRIAXIAL TEST REPORT
Test Method: AS1289.6.4.2

Client: Hatch Pty Ltd
Report No.: 18100437A - CU

Remarks:
Sample/s supplied by the client

Note: Graph not to scale

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Authorised Signatory
C. Channon

ABN 25 065 630 506
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Hatch Pty Ltd
Report No.: 18100437A - CU

MIT Method - Effective Stress Path

\[ s = \frac{(\sigma_1' + \sigma_3')}{2} \text{ kPa} \]

Remarks:
Sample/s supplied by the client

Note: Graph not to scale

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Laboratory Number 9926

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ABN 25 065 630 506
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Hatch Pty Ltd

Report No.: 18100437A - CU

Cambridge Method - Effective Stress Path

\[ q = (\sigma'_1 - \sigma'_3) \text{ kPa} \]

\[ p = (\sigma'_1 + 2\sigma'_3)/3 \text{ kPa} \]

Remarks:
Sample/s supplied by the client

Note: Graph not to scale

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TRIAXIAL TEST REPORT
Test Method: AS1289.6.4.2

Client: Hatch Pty Ltd
Report No.: 18100437A - CU

Void ratio v's p
- Saturation Stage
- Consol - 50 kPa
- Shear Stage

$p = (\sigma_1' + 2\sigma_3')/3\ \text{kPa}$

Remarks:
Sample/s supplied by the client

Note: Graph not to scale

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Laboratory Number
9926
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Hatch Pty Ltd

Report No.: 18100437A - CU

Friction Angle v's Axial Strain

Remarks:
Sample/s supplied by the client

Note: Graph not to scale

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Tested at Trilab Brisbane Laboratory.
<table>
<thead>
<tr>
<th>CLIENT:</th>
<th>Hatch Pty Ltd</th>
<th>PROJECT:</th>
<th>H356804 - Cadia NTSF Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAB SAMPLE No.</td>
<td>18100437</td>
<td>BEOREHOLE:</td>
<td>HA401</td>
</tr>
<tr>
<td>DATE:</td>
<td>17.10.16</td>
<td>DEPTH:</td>
<td>0.00-2.00</td>
</tr>
</tbody>
</table>

Remarks: Sample/s supplied by the client
Note: Photo not to scale
Volume v's Time (Log Scale)

- Consol - 50 kPa

Remarks:
Sample/s supplied by the client

Note: Graph not to scale

T. Lockhart

Authorised Signatory

C. Channon

Authorised Signatory

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# TRIAXIAL TEST REPORT

**Test Method:** AS1289.6.4.2

### SAMPLE & TEST DETAILS

<table>
<thead>
<tr>
<th>Description</th>
<th>Initial Height</th>
<th>Initial Moisture Content</th>
<th>Rate of Strain</th>
<th>B Response</th>
<th>Final Moisture Content</th>
<th>Wet Density</th>
<th>Target Void Ratio</th>
<th>Final Void Ratio</th>
<th>Freezing Void Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>152.7 mm</td>
<td>9.8 %</td>
<td>0.013 %/min</td>
<td>B</td>
<td>17.7 %</td>
<td>1.98 t/m³</td>
<td>0.470</td>
<td>0.463</td>
<td>0.484</td>
</tr>
<tr>
<td></td>
<td>76.4 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.80 t/m³</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.0 : 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sample Type: Single Individual Remoulded Specimen

### TEST RESULTS

#### FAILURE DETAILS

<table>
<thead>
<tr>
<th>Effective Pressure</th>
<th>Confining Pressure</th>
<th>Back Pressure</th>
<th>Initial Pore Pressure</th>
<th>Failure Pore Pressure</th>
<th>Failure Pore Type</th>
<th>Deviator Stress (kPa)</th>
<th>Strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>501 kPa</td>
<td>999 kPa</td>
<td>498 kPa</td>
<td>491 kPa</td>
<td>316 kPa</td>
<td>582 kPa</td>
<td>181 kPa</td>
<td>3.215</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>401 kPa</td>
<td>1.21 %</td>
</tr>
</tbody>
</table>

#### FAILURE ENVELOPES

Interpretation between stages:
- **Cohesion C’ (kPa):**
- **Angle of Shear Resistance \( \Phi \) (Degrees):**
- **Failure Criteria:** Peak Deviator Stress

### Remarks

Sample/s supplied by the client

---

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ABN 25 065 630 506

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Tested at Trilab Brisbane Laboratory.

Authorised Signatory
C. Channon

NATA Technical Competence Laboratory Number
9926

Page 1 of 9
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Hatch Pty Ltd

Report No.: 18100438A - CU

Interpretation between stages:
- Cohesion C' (kPa):
- Angle of Shear Resistance $\Phi'$ (Degrees):

Failure Criteria: Peak Deviator Stress

Remarks:
Sample/s supplied by the client

Note: Graph not to scale

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C. Channon

Laboratory Number 9926
TRIAXIAL TEST REPORT
Test Method: AS1289.6.4.2

Client: Hatch Pty Ltd
Report No.: 18100438A - CU

Stress/Strain & Pore Pressure/Strain Diagram

Shear Stress
Pore Pressure

Accredited for compliance with ISO/IEC 17025 - Testing.
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Tested at Trilab Brisbane Laboratory.

Authorised Signatory
C. Channon

Page 3 of 9
REP03901

Laboratory Number
9926
TRIAXIAL TEST REPORT
Test Method: AS1289.6.4.2

Client: Hatch Pty Ltd
Report No.: 18100438A - CU

MIT Method - Effective Stress Path

\[ s = \frac{(\sigma'_{1} + \sigma'_{3})}{2} \text{ kPa} \]

Remarks:
Sample/s supplied by the client

Note: Graph not to scale

Authorised Signatory
C. Channon

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Laboratory Number
9926
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Hatch Pty Ltd
Report No.: 18100438A - CU

Cambridge Method - Effective Stress Path

\[ q = (\sigma'_1 - \sigma'_3) \text{ kPa} \]

\[ p = (\sigma'_1 + 2\sigma'_3)/3 \text{ kPa} \]

Remarks:
Sample/s supplied by the client

Note: Graph not to scale
TRIAXIAL TEST REPORT
Test Method: AS1289.6.4.2

Client: Hatch Pty Ltd
Report No.: 18100438A - CU

Void ratio v's p

\[ p = \left( \sigma'_1 + 2\sigma'_3 \right) / 3 \] kPa

p = (\sigma'_1 + 2\sigma'_3) / 3 kPa

Remarks:
Sample/s supplied by the client

Note: Graph not to scale

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TRIAXIAL TEST REPORT
Test Method: AS1289.6.4.2

Client: Hatch Pty Ltd  
Report No.: 18100438A - CU

Friction Angle v's Axial Strain

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Trilab Pty Ltd  
ABN 25 065 630 506
TRIAXIAL TEST REPORT
Test Method: AS1289.6.4.2

Client: Hatch Pty Ltd
Report No.: 18100438A - CU

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<tr>
<th>CLIENT:</th>
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<tr>
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<td>H356804 - Cadia NTSF Failure</td>
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<tr>
<td>LAB SAMPLE No.</td>
<td>18100438</td>
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<tr>
<td>BOREHOLE:</td>
<td>HA401</td>
</tr>
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<td>BEFORE TEST</td>
<td></td>
</tr>
<tr>
<td>DATE:</td>
<td>11/10/18</td>
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<tr>
<td>DEPTH:</td>
<td>0.00-2.00</td>
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Remarks: Sample/s supplied by the client
Note: Photo not to scale

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Tested at Trilab Brisbane Laboratory.

Authorised Signatory
C. Channon

Laboratory Number: 9926
Volume v’s Time (Log Scale)

Consol - 50 kPa
Consol - 100 kPa
Consol - 200 kPa
Consol - 300 kPa
Consol - 350 kPa
Consol - 400 kPa
Consol - 500 kPa
Consol - 500 kPa

Remarks:
Sample/s supplied by the client

Note: Graph not to scale

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Tested at Trilab Brisbane Laboratory.
TRIAXIAL TEST REPORT

Client: Hatch Pty Ltd                Report No.: 18110416 - CD

Address: PO Box 425 SPRING HILL QLD 4004        Workorder No. 0005143

Project: H356804 - Cadia NTSF Failure

Client Id.: HA401                      Depth (m): 0.00-2.00

Description: -

**SAMPLE & TEST DETAILS**

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<thead>
<tr>
<th>Description</th>
<th>Value</th>
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<td>Initial Height:</td>
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<td>Initial Diameter:</td>
<td>75.1 mm</td>
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<td>L/D Ratio:</td>
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<td>Initial Moisture Content:</td>
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<td>Final Moisture Content:</td>
<td>15.8 %</td>
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<tr>
<td>Wet Density:</td>
<td>1.93 t/m³</td>
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<td>Dry Density:</td>
<td>1.78 t/m³</td>
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**TEST RESULTS**

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<tr>
<th>Effective Pressure</th>
<th>Confining Pressure</th>
<th>Back Pressure</th>
<th>Initial Pore</th>
<th>Failure Pore</th>
<th>Principal Effective Stresses</th>
<th>Deviator Stress</th>
<th>Strain</th>
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<tbody>
<tr>
<td>200 kPa</td>
<td>700 kPa</td>
<td>500 kPa</td>
<td>500 kPa</td>
<td>1 kPa</td>
<td>748 kPa</td>
<td>197 kPa</td>
<td>3.797</td>
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**FAILURE ENVELOPES**

Interpretation between stages:
- Cohesion C' (kPa):
- Angle of Shear Resistance \(\Phi'\) (Degrees):

Failure Criteria: Peak Deviator Stress

Remarks:
Sample/s supplied by the client

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Tested at Trilab Brisbane Laboratory.
CLIENT: Hatch Pty Ltd

REPORT NO.: 18110416 - CD

MOHR CIRCLE DIAGRAM

Interpretation between stages:
Cohesion C' (kPa): 
Angle of Shear Resistance Φ' (Degrees):
Failure Criteria: Peak Deviator Stress

Remarks:
Sample/s supplied by the client

Note: Graph not to scale

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Tested at Trilab Brisbane Laboratory.

Authorised Signatory
T. Lockhart

Laboratory Number
9926
TRIAXIAL TEST REPORT

Test Method: ASTM D7181

Client: Hatch Pty Ltd

Report No.: 18110416 - CD

Remarks:
Sample/s supplied by the client

Note: Graph not to scale

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Tested at Trilab Brisbane Laboratory.

Authorized Signatory
T. Lockhart

Laboratory Number
9926
TRIAXIAL TEST REPORT
Test Method: ASTM D7181

Client: Hatch Pty Ltd
Report No.: 18110416 - CD

MIT Method - Effective Stress Path

\[ t = \frac{\sigma_1' - \sigma_3'}{2} \text{ kPa} \]

\[ s = \frac{\sigma_1' + \sigma_3'}{2} \text{ kPa} \]

Remarks:
Sample/s supplied by the client

Note: Graph not to scale

Page 4 of 9

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Trilab Pty Ltd
ABN 25 065 630 506

Laboratory Number
9926
Client: Hatch Pty Ltd

Test Method: ASTM D7181

Cambridge Method - Effective Stress Path

\[ q = \left( \sigma'_1 - \sigma'_3 \right) \text{ kPa} \]

\[ p = \frac{(\sigma'_1 + 2\sigma'_3)}{3} \text{ kPa} \]

Remarks:
Sample/s supplied by the client

Note: Graph not to scale

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TRIAXIAL TEST REPORT

Test Method: ASTM D7181

Client: Hatch Pty Ltd
Report No.: 18110416 - CD

Void ratio \( v \)'s \( p \)

\[ p = \left( \sigma'_1 + 2 \sigma'_3 \right) / 3 \] kPa

Saturation Stage
Consol - 50 kPa
Consol - 100 kPa
Consol - 200 kPa
Shear Stage

Remarks:
Sample/s supplied by the client
Note: Graph not to scale

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Tested at Trilab Brisbane Laboratory.

Trilab Pty Ltd
ABN 25 065 630 506
TRIAXIAL TEST REPORT
Test Method: ASTM D7181

Client: Hatch Pty Ltd

Friction Angle v's Axial Strain

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Trilab Pty Ltd
ABN 25 065 630 506

Page 7 of 9

Authorised Signatory
T. Lockhart

Laboratory Number
9926
## TRIAXIAL TEST REPORT

**Test Method:** ASTM D7181

### Client:
Hatch Pty Ltd

### Report No.:
18110416 - CD

<table>
<thead>
<tr>
<th>CLIENT</th>
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<tbody>
<tr>
<td>PROJECT</td>
<td>H356804 - Cadia NTSF Failure</td>
</tr>
<tr>
<td>LAB SAMPLE No.</td>
<td>18110416</td>
</tr>
<tr>
<td>BOREHOLE</td>
<td>HA401</td>
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<tr>
<td>AFTER TEST</td>
<td>DATE: 01/12/04</td>
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<tr>
<td></td>
<td>DEPTH: 0.00-2.00</td>
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### Remarks:
Sample/s supplied by the client

### Note:
Photo not to scale

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Tested at Trilab Brisbane Laboratory.

Authorized Signatory
T. Lockhart

Laboratory Number
9926

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Trilab Pty Ltd
ABN 25 065 630 506
TRIAXIAL TEST REPORT
Test Method: ASTM D7181

Client: Hatch Pty Ltd

Volume v's Time (Log Scale)

- Consol - 50 kPa
- Consol - 100 kPa
- Consol - 200 kPa

Remarks:
Sample/s supplied by the client

Note: Graph not to scale

Tested at Trilab Brisbane Laboratory.

Accredited for compliance with ISO/IEC 17025 - Testing.
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Page 9 of 9

Laboratory Number

9926
Annexure EF
HA 402 – CSL Test Certificates
## Triaxial Test Report

### Isotropically Consolidated Undrained (CIU)

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTSM Embankment Failure ITRB  
**Location:** Cadia Mine  
**Date:** 5/07/2018  
**Project No.:** 18101980  
**Sample ID:** HA402 0m  
**Test ID:** 18004 - sa-1 CIU very loose 50kPa

<table>
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<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Initial Height (mm):</td>
<td>148.2</td>
</tr>
<tr>
<td>Final Liquor Content (%)</td>
<td>31.8%</td>
</tr>
<tr>
<td>Strain Rate (mm/min):</td>
<td>0.03</td>
</tr>
<tr>
<td>Initial Diameter (mm):</td>
<td>68.0</td>
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<tr>
<td>Final Dry Density (t/m³):</td>
<td>1.43</td>
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<tr>
<td>B Response (%)</td>
<td>95%</td>
</tr>
<tr>
<td>Trimnings GWC (%)</td>
<td>6.6%</td>
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<tr>
<td>Final Void Ratio (-):</td>
<td>0.84</td>
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<tr>
<td>Mean Effective Consolidation Stress (kPa):</td>
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<tr>
<td>Initial Dry Density (t/m³):</td>
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<tr>
<td>Final Liquor Solids Conc. (g/L):</td>
<td>-</td>
</tr>
<tr>
<td>Geostatic Stress Ratio $K_0$ (-):</td>
<td>0.98</td>
</tr>
</tbody>
</table>

### Preparation Notes:
- Sample was moist tamped to a loose condition

### Sample Before Test

![Sample Before Test](image1)

### Sample After Test

![Sample After Test](image2)

---

**Reviewed by:** R. Fanni / D. Reid  
**Tested by:** K. Koh

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
# Triaxial Test Report

**Isotropically Consolidated Undrained (CIU)**

<table>
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<tr>
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<th>Hatch</th>
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<th>61 Petrie Terrace, Brisbane</th>
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<tbody>
<tr>
<td>Address:</td>
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<td>Project No.:</td>
<td>18101980</td>
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<tr>
<td>Project:</td>
<td>NTSE Embankment Failure ITRB</td>
<td>Sample ID:</td>
<td>HA402 0m</td>
</tr>
<tr>
<td>Location:</td>
<td>Cadia Mine</td>
<td>Test ID:</td>
<td>18004 - sa-1 CIU very loose 50kPa</td>
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<td>0.98</td>
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</table>

**Preparation Notes:** Sample was moist tamped to a loose condition

**Graph:**
- **Deviator Stress**
- **Pore Pressure**

**Trimmings GWC (%):**

**Client:** Hatch  
**Date:** 5/07/2018

**Location:** Cadia Mine  
**Test ID:** 18004 - sa-1 CIU very loose 50kPa

**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh  
**Reviewed by:** R. Fanni / D. Reid

**THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL**
# Triaxial Test Report

## Isotropically Consolidated Undrained (CIU)

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<tbody>
<tr>
<td>Address:</td>
<td>61 Petrie Terrace, Brisbane</td>
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<tr>
<td>Project:</td>
<td>NTSF Embankment Failure ITRB</td>
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<tr>
<td>Location:</td>
<td>Cadia Mine</td>
</tr>
<tr>
<td>Date:</td>
<td>5/07/2018</td>
</tr>
<tr>
<td>Project No.:</td>
<td>18101980</td>
</tr>
<tr>
<td>Sample ID:</td>
<td>HA402 0m</td>
</tr>
<tr>
<td>Test ID:</td>
<td>18004 - sa-1 CIU very loose 50kPa</td>
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<td>-</td>
<td>Geostatic Stress Ratio ( K_0 ) (-):</td>
<td>0.98</td>
</tr>
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</table>

![Triaxial Stress-Strain Diagram](chart_image)

- **Deviator Stress** \( q \) (kPa)
- **Mean Effective Stress** \( \rho' \) (kPa)

**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh

**Reviewed by:** R. Fanni / D. Reid
### Triaxial Test Report

**Isotropically Consolidated Undrained (CIU)**

<table>
<thead>
<tr>
<th>Client:</th>
<th>Hatch</th>
<th>Date:</th>
<th>29/06/2018</th>
</tr>
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<tbody>
<tr>
<td>Address:</td>
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<td>Project No.:</td>
<td>18101980</td>
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<tr>
<td>Project:</td>
<td>NTSF Embankment Failure ITRB</td>
<td>Sample ID:</td>
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<tr>
<td>Location:</td>
<td>Cadia Mine</td>
<td>Test ID:</td>
<td>18004 - sa-2 CIU loose 100kPa</td>
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#### Initial Values

<table>
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<tr>
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<th>Value</th>
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<tbody>
<tr>
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<tr>
<td>Final Dry Density (t/m³)</td>
<td>1.46</td>
</tr>
<tr>
<td>Final Void Ratio (-)</td>
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</tr>
<tr>
<td>Mean Effective Consolidation Stress (kPa)</td>
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</tr>
<tr>
<td>Geostatic Stress Ratio K₀ (-)</td>
<td>0.98</td>
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</tbody>
</table>

#### Sample Preparation

- Sample was moist tamped to a loose condition

#### Sample Test Results

- Tested by: K. Koh
- Reviewed by: R. Fanni / D. Reid
Triaxial Test Report

Isotropically Consolidated Undrained (CIU)

Client: Hatch  Date: 29/06/2018
Address: 61 Petrie Terrace, Brisbane  Project No.: 18101980
Project: NTSF Embankment Failure ITRB  Sample ID: HA402.0m
Location: Cadia Mine  Test ID: 18004 - sa-2 CIU loose 100kPa

<table>
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</tbody>
</table>

Preparation Notes: Sample was moist tamped to a loose condition

Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid
Triaxial Test Report

Isotropically Consolidated Undrained (CIU)

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NTFS Embankment Failure ITRB
Location: Cadia Mine

Initial Height (mm): 148.8
Initial Diameter (mm): 67.8
Initial Dry Density (t/m³): 1.18
Trimmings GWC (%): 6.6%

Final Liquor Content (%): 30.6%
Final Dry Density (t/m³): 1.46
Final Void Ratio (-): 0.80
Final Liquor Solids Conc. (g/L): -

Strain Rate (mm/min): 0.03
B Response (%): 97%
Mean Effective Consolidation Stress (kPa): 101
Geostatic Stress Ratio $K_0$ (-): 0.98

Preparation Notes: Sample was moist tamped to a loose condition

Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid

Date: 29/06/2018
Project No.: 18101980
Sample ID: HA402 05
Test ID: 18004 - sa-2 CIU loose 100kPa

Location:
Address:

Initial Height (mm): 148.8
Initial Diameter (mm): 67.8
Initial Dry Density (t/m³): 1.18
Trimmings GWC (%): 6.6%

Final Liquor Content (%): 30.6%
Final Dry Density (t/m³): 1.46
Final Void Ratio (-): 0.80
Final Liquor Solids Conc. (g/L): -

Strain Rate (mm/min): 0.03
B Response (%): 97%
Mean Effective Consolidation Stress (kPa): 101
Geostatic Stress Ratio $K_0$ (-): 0.98

Preparation Notes: Sample was moist tamped to a loose condition

Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid

Date: 29/06/2018
Project No.: 18101980
Sample ID: HA402 05
Test ID: 18004 - sa-2 CIU loose 100kPa

Location:
Address:

Initial Height (mm): 148.8
Initial Diameter (mm): 67.8
Initial Dry Density (t/m³): 1.18
Trimmings GWC (%): 6.6%

Final Liquor Content (%): 30.6%
Final Dry Density (t/m³): 1.46
Final Void Ratio (-): 0.80
Final Liquor Solids Conc. (g/L): -

Strain Rate (mm/min): 0.03
B Response (%): 97%
Mean Effective Consolidation Stress (kPa): 101
Geostatic Stress Ratio $K_0$ (-): 0.98

Preparation Notes: Sample was moist tamped to a loose condition

Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid
### Triaxial Test Report

**Isotropically Consolidated Undrained (CIU)**

<table>
<thead>
<tr>
<th>Location:</th>
<th>Cadia Mine</th>
<th>Date:</th>
<th>3/07/2018</th>
</tr>
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<tr>
<td>Client:</td>
<td>Hatch</td>
<td>Project No.:</td>
<td>18101980</td>
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<tr>
<td>Address:</td>
<td>61 Petrie Terrace, Brisbane</td>
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<td>Project:</td>
<td>NTSF Embankment Failure ITRB</td>
<td>Test ID:</td>
<td>18004 - sa-3 CIU loose 500kPa</td>
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<td><strong>Strain Rate (mm/min):</strong></td>
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<td><strong>Initial Height (mm):</strong></td>
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<tr>
<td><strong>Initial Diameter (mm):</strong></td>
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<tr>
<td><strong>Trimmings GWC (%):</strong></td>
<td>6.6%</td>
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<tr>
<td><strong>Initial Dry Density (t/m³):</strong></td>
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<td><strong>Final Liquor Content (%):</strong></td>
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<td><strong>Final Dry Density (t/m³):</strong></td>
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<td><strong>Geostatic Stress Ratio K₀ (-):</strong></td>
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<td><strong>Final Liquor Solids Conc. (g/L):</strong></td>
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**Sample Before Test**

**Sample After Test**

**Tested by:** K. Koh

**Reviewed by:** R. Fanni / D. Reid

---

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
### Isotropically Consolidated Undrained (CIU)

- **Client:** Hatch
- **Address:** 61 Petrie Terrace, Brisbane
- **Project:** NTFS Embankment Failure ITRB
- **Location:** Cadia Mine
- **Date:** 3/07/2018
- **Project No.:** 18101980
- **Sample ID:** HA402 0m
- **Test ID:** 18004 - sa-3 CIU loose 500kPa

**Preparation Notes:** Sample was moist tamped to a loose condition

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#### Graph
- **Graph Title:** Shear-induced Pore Pressure vs. Axial Strain
- **Axes:**
  - X-axis: Axial Strain (%)
  - Y-axis: Deviator Stress (kPa), Pore Pressure (kPa)
  - Graph includes data points and trend lines.

####签字
- **Tested by:** K. Koh
- **Reviewed by:** R. Fanni / D. Reid

**THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL**
## Isotropically Consolidated Undrained (CIU)

**Client:** Hatch  
**Date:** 3/07/2018  
**Address:** 61 Petrie Terrace, Brisbane  
**Project No.:** 18101980  
**Project:** NTSE Embankment Failure ITRB  
**Sample ID:** HA402 0m  
**Location:** Cadia Mine  
**Test ID:** 16004 - sa-3 CIU loose 500kPa

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**Tested by:** K. Koh  
**Reviewed by:** R. Fanni / D. Reid  

---

**Graph:**

The graph shows a deviator stress ($q$) versus mean effective stress ($p'$) plot. The sample reaches a peak deviator stress of approximately 275 kPa at a mean effective stress of around 500 kPa.
### Isotropically Consolidated Undrained (CIU)

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTSF Embankment Failure ITRB  
**Sample ID:** HA402 0m  
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**Preparation Notes:** Sample was moist tamped to a loose condition

**Reviewed by:** R. Fanni / D. Reid

**Tested by:** K. Koh

---

**Graph:**
- **Mobilised Friction Angle (Degrees) vs. Axial Strain (%)**
- The graph shows the relationship between mobilised friction angle and axial strain, demonstrating the deformation behavior of the sample under CIU conditions.

---

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# Isotropically Consolidated Drained (CID)

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTSF Embankment Failure ITRB  
**Location:** Cadia Mine

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<td>1.64</td>
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<tr>
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<td>Final Dry Density (t/m³)</td>
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<td>Final Void Ratio (-)</td>
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<td>Mean Effective Consolidation Stress (kPa)</td>
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**Sample Notes:** Sample was moist tamped

**Preparation Notes:**

**Date:** 16/07/2018  
**Project No.:** 18101980  
**Sample ID:** HA402 0m  
**Test ID:** 18004 - sa-4 CID dense 100kPa

**Reviewed by:** R. Fanni / D. Reid

**Tested by:** K. Koh

**Address:** Perth Laboratory  
**Location:** 84 Guthrie Street, Osborne Park

---

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Triaxial Test Report

Isotropically Consolidated Drained (CID)

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NT$F Embankment Failure ITRB
Location: Cadia Mine

Date: 16/07/2018
Project No.: 18101980
Sample ID: HA402 0m
Test ID: 18004 - sa-4 CID dense 100kPa

Initial Height (mm): 144.4
Initial Diameter (mm): 62.6
Trimmings GWC (%): 20.0%
Initial Dry Density (t/m³): 1.64

Final Liquor Content (%): 25.1%
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Final Void Ratio (-): 0.66
Final Liquor Solids Conc. (g/L): -

Strain Rate (mm/min): 0.015
B Response (%): 97%
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Geostatic Stress Ratio $K_0$ (-): 0.98

Preparation Notes: Sample was moist tamped

Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid

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# Triaxial Test Report

**Isotropically Consolidated Drained (CID)**

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</tbody>
</table>

**Preparation Notes:** Sample was moist tamped

**Tested by:** K. Koh

**Reviewed by:** R. Fanni / D. Reid

---

**Graph:**

- **Deviator Stress q (kPa):** 0 to 450
- **Mean Effective Stress p' (kPa):** 0 to 250
## Triaxial Test Report

### Isotropically Consolidated Drained (CID)

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTSF Embankment Failure ITRB  
**Location:** Cadia Mine  
**Date:** 16/07/2018  
**Project No.:** 18101980  
**Sample ID:** HA402 0m  
**Test ID:** 18004 - sa-4 CID dense 100kPa

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**Tested by:** K. Koh  
**Reviewed by:** R. Fanni / D. Reid

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**Geostatic Stress Ratio**

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**Volumetric Strain (%)**

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**Axial Strain (%)**

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Isotropically Consolidated Drained (CID)

Initial Height (mm): 144.4  Final Liquor Content (%): 25.1%  Strain Rate (mm/min): 0.015  B Response (%): 97%
Initial Diameter (mm): 62.6  Final Dry Density (t/m$^3$): 1.58  Mean Effective Consolidation Stress (kPa): 101
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Preparation Notes: Sample was moist tamped

Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid

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**Triaxial Test Report**

Isotropically Consolidated Drained (CID)

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<table>
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<tr>
<th>Initial Height (mm):</th>
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- Sample was moist tamped

**Preparation Notes:** Sample was moist tamped

**Reviewed by:**
- R. Fanni / D. Reid
### Triaxial Test Report

#### Isotropically Consolidated Drained (CID)

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</tr>
<tr>
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<td>-</td>
</tr>
<tr>
<td>Geostatic Stress Ratio $K_0$ (-)</td>
<td>0.99</td>
</tr>
</tbody>
</table>

#### Sample Graph

```
Deviator Stress (kPa) vs. Axial Strain (%)
```

**Preparation Notes:** Sample was moist tamped

**Tested by:** K. Koh  
**Reviewed by:** R. Fanni / D. Reid

**THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL**
Isotropically Consolidated Drained (CID)

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NTSF Embankment Failure ITRB
Location: Cadia Mine

Date: 21/07/2018
Project No.: 18101980
Sample ID: HA402 0m
Test ID: 18004 - sa-5 CID dense 300kPa

Initial Height (mm): 126.8
Final Liquor Content (%): 22.2%
Strain Rate (mm/min): 0.015

Initial Diameter (mm): 62.8
Final Dry Density (t/m³): 1.66
B Response (%): 96%

Trimmings GWC (%): 20.0%
Final Void Ratio (-): 0.58
Mean Effective Consolidation Stress (kPa): 301

Initial Dry Density (t/m³): 1.72
Final Liquor Solids Conc. (g/L): -
Geostatic Stress Ratio $K_0$ (-): 0.99

Preparation Notes: Sample was moist tamped

Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid
### Triaxial Test Report

#### Isotropically Consolidated Drained (CID)

**Client:** Hatch  
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**Reviewed by:** R. Fanni / D. Reid
## Triaxial Test Report

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### Graph

- **Mobilised Friction Angle (Degrees)**
- **Axial Strain (%)**

**Preparation Notes:** Sample was moist tamped

**Tested by:** K. Koh

**Reviewed by:** R. Fanni / D. Reid

**THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL**
# Triaxial Test Report

## Isotropically Consolidated Drained (CID)

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<tr>
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<td>1.00</td>
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**Address:**
Perth Laboratory  
84 Guthrie Street, Osborne Park

**Location:**
Cadia Mine

**Sample Before Test**
Sample was moist tamped

**Sample After Test**

**Preparation Notes:**

---

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
# Triaxial Test Report

## Isotropically Consolidated Drained (CID)

### Details
- **Client:** Hatch
- **Address:** 61 Petrie Terrace, Brisbane
- **Project:** NTSF Embankment Failure ITRB
- **Location:** Cadia Mine
- **Date:** 14/07/2018
- **Project No.:** 18101980
- **Sample ID:** HA402.0m
- **Test ID:** 18004 - sa-6 CID very dense 800kPa

### Test Results
- **Initial Height (mm):** 142.7
- **Final Liquor Content (%):** 20.4%
- **Strain Rate (mm/min):** 0.015
- **B Response (%):** 96%
- **Initial Diameter (mm):** 62.8
- **Final Dry Density (t/m³):** 1.71
- **Mean Effective Consolidation Stress (kPa):** 801
- **Trimmings GWC (%):** 23.0%
- **Final Void Ratio (-):** 0.54
- **Geostatic Stress Ratio \( K_0 \):** 1.00
- **Initial Dry Density (t/m³):** 1.65
- **Final Liquor Solids Conc. (g/L):** -

### Graph

![Deviator Stress vs Axial Strain](graph.png)

**Deviator Stress (kPa) vs Axial Strain (%)**

- **Preparation Notes:** Sample was moist tamped
- **Tested by:** K. Koh
- **Reviewed by:** R. Fanni / D. Reid

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# Triaxial Test Report

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## Graph

The graph shows the relationship between Deviator Stress ($q$) and Mean Effective Stress ($p'$) in kPa. The curve indicates a linear relationship with an increasing trend as the stress values increase.

## Preparation Notes:
Sample was moist tamped

## Tested by: K. Koh

## Reviewed by: R. Fanni / D. Reid
## Triaxial Test Report

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTFS Embankment Failure ITRB  
**Location:** Cadia Mine  
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**Project No.:** 18101980  
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### Preparation Notes:
Sample was moist tamped

### Tested by:
K. Koh

### Reviewed by:
R. Fanni / D. Reid

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- **Initial Height (mm):** 142.7
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### Graph Details:
- **Volumetric Strain (%)**
- **Axial Strain (%)**

### Notes:
- **Address:** 61 Petrie Terrace, Brisbane
- **Project:** NTFS Embankment Failure ITRB
- **Location:** Cadia Mine
- **Client:** Hatch
- **Date:** 14/07/2018
- **Project No.:** 18101980
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---

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Triaxial Test Report

Isotropically Consolidated Drained (CID)

Client: Hatch  Date: 14/07/2018
Address: 61 Petrie Terrace, Brisbane  Project No.: 18101980
Project: NTSF Embankment Failure ITRB  Sample ID: HA402 0m
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Mean Effective Consolidation Stress (kPa): 801  Geostatic Stress Ratio \( K_0 (-) \): 1.00

Strain Rate (mm/min): 0.015  B Response (%): 96%

Mobilised Friction Angle (Degrees)
Axial Strain (%)
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**Preparation Notes:** Sample was moist tamped to a loose condition

**Sample Before Test**

**Sample After Test**

**Tested by:** K. Koh

**Reviewed by:** R. Fanni / D. Reid

**Address:** 61 Petrie Terrace, Brisbane

**Location:** Cadia Mine

**Client:** Hatch

**Date:** 21/07/2018

**Project No.:** 18101980

**Sample ID:** HA402 0m

**Test ID:** 18004 - sa-8 CID loose 500kPa
### Triaxial Test Report

**Isotropically Consolidated Drained (CID)**

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**Preparation Notes:** Sample was moist tamped to a loose condition

**Prepared by:**  
**Reviewed by:** R. Fanni / D. Reid

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Triaxial Test Report

Isotropically Consolidated Drained (CID)

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Initial Dry Density (t/m³): 1.26
Final liquor solids conc. (g/L): -

Preparation Notes: Sample was moist tamped to a loose condition

Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid

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**Graph:**

- **Mobilised Friction Angle (Degrees)**
- **Axial Strain (%)**

**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh

**Reviewed by:** R. Fanni / D. Reid
Annexure EG
TC 1 – CSL Test Certificates
### Golder (Perth) Testing

**As tested initial**

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<th>p0</th>
<th>e0</th>
<th>psi0</th>
<th>Dmin</th>
<th>eta_max</th>
<th>psi</th>
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<td>400.9</td>
<td>0.550</td>
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<td>0.030</td>
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<td>si-5 CID 1200 kPa</td>
<td>1201.9</td>
<td>0.490</td>
<td>0.062</td>
<td>0.000</td>
<td>1.373</td>
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<td>si-6 CID 100 kPa</td>
<td>100.7</td>
<td>0.450</td>
<td>-0.100</td>
<td>-0.360</td>
<td>1.754</td>
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<tr>
<td>si-7 CID 200 kPa</td>
<td>200.1</td>
<td>0.410</td>
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<td>-0.500</td>
<td>1.843</td>
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<td>si-8 CID 1000 kPa</td>
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<td>0.370</td>
<td>-0.069</td>
<td>-0.220</td>
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**At max dilation (=Dmin)**

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<th>psi0</th>
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<th>psi</th>
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<td>0.640</td>
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**As tested initial at critical state**

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<th>psi0</th>
<th>pc</th>
<th>ec</th>
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</thead>
<tbody>
<tr>
<td>si-1 CIU 100 kPa</td>
<td>101.1</td>
<td>0.640</td>
<td>0.100</td>
<td>12</td>
<td>0.640</td>
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<tr>
<td>si-2 CIU 200 kPa</td>
<td>200.6</td>
<td>0.600</td>
<td>0.092</td>
<td>26</td>
<td>0.600</td>
</tr>
<tr>
<td>si-3 CIU 800 kPa</td>
<td>800.2</td>
<td>0.520</td>
<td>0.075</td>
<td>224</td>
<td>0.520</td>
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</tbody>
</table>

- **Mtc**: 1.49
- **N**: 0.30
- **χ tc**: 8.0
**Isotropically Consolidated Undrained (CIU)**

**Location:** Cadia Mine  
**Test ID:** 18018 - si-1 CIU very loose 100kPa

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<tr>
<th>Initial Height (mm):</th>
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<tr>
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<td>B Response (%):</td>
<td>99%</td>
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<tr>
<td>Trimmings GWC (%):</td>
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<td>Mean Effective Consolidation Stress (kPa):</td>
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<td>Geostatic Stress Ratio $K_0$ (-):</td>
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**Sample Before Test**

Sample was moist tamped to a loose condition

**Sample After Test**

18018 TC1  
si-1-CIU-100kPa  
very loose

**Preparation Notes:**

Sample was moist tamped to a loose condition

**Tested by:** K. Koh

**Reviewed by:** R. Fanni / D. Reid
Isotropically Consolidated Undrained (CIU)

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NTSF Embankment Failure ITRB
Location: Cadia Mine

Date: 27/07/2018
Project No.: 18101980
Sample ID: TC1
Test ID: 18018 - si-1 CIU very loose 100kPa

Initial Height (mm): 147.9
Initial Diameter (mm): 69.4
Initial Dry Density (t/m³): 1.23
Trimmings GWC (%): 10.9%

Final Liquor Content (%): 23.2%
Final Dry Density (t/m³): 1.67
Final Void Ratio (-): 0.64
Final Liquor Solids Conc. (g/L): -

Strain Rate (mm/min): 0.03
B Response (%): 99%
Mean Effective Consolidation Stress (kPa): 101
Geostatic Stress Ratio $K_0$ (-): 0.97

Preparation Notes: Sample was moist tamped to a loose condition

Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid
### Isotropically Consolidated Undrained (CIU)

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTSF Embankment Failure ITRB  
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**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh  
**Reviewed by:** R. Fanni / D. Reid

---

**Graph:**

- **Y-axis:** Deviator Stress $q$ (kPa)
- **X-axis:** Mean Effective Stress $p'$ (kPa)
# Triaxial Test Report

**Isotropically Consolidated Undrained (CIU)**

**Client:** Hatch  
**Date:** 27/07/2018

**Address:** 61 Petrie Terrace, Brisbane  
**Project No.:** 18101980

**Project:** NTSF Embankment Failure ITRB  
**Sample ID:** TC1

**Location:** Cadia Mine  
**Test ID:** 18018 - si-1 CIU very loose 100kPa

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**Preparation Notes:** Sample was moist tamped to a loose condition

---

### Graph

- **Mobilised Friction Angle (Degrees)** vs **Axial Strain (%)**

---

**Tested by:** K. Koh  
**Reviewed by:** R. Fanni / D. Reid

---

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<tr>
<td>Project: NTBF Embankment Failure ITRB</td>
<td>Sample ID: TC1</td>
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<tr>
<td>Location: Cadia Mine</td>
<td>Test ID: 18018 - si-2 CIU loose 200kPa</td>
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| Initial Height (mm): 147.5 | Final Liquor Content (%): 22.0% | Strain Rate (mm/min): 0.03 |
| Initial Diameter (mm): 68.9 | Final Dry Density (t/m³): 1.71 | B Response (%): 99% |
| Trimmings GWC (%): 10.9% | Final Void Ratio (-): 0.60 | Mean Effective Consolidation Stress (kPa): 201 |
| Initial Dry Density (t/m³): 1.25 | Final Liquor Solids Conc. (g/L): - | Geostatic Stress Ratio $K_0$ (-): 0.99 |
Isotropically Consolidated Undrained (CIU)

Client: Hatch  Date: 23/07/2018
Address: 61 Petrie Terrace, Brisbane  Project No.: 18101980
Project: NTSF Embankment Failure ITRB  Sample ID: TC1
Location: Cadia Mine  Test ID: 18018 - si-2 CIU loose 200kPa

Initial Height (mm): 147.5  Final Liquor Content (%): 22.0%  Strain Rate (mm/min): 0.03
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Initial Dry Density (t/m\(^3\)): 1.25  Final Liquor Solids Conc. (g/L): -  Geostatic Stress Ratio \( K_0 \) (-): 0.99

Preparation Notes: Sample was moist tamped to a loose condition

Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid
**Isotropically Consolidated Undrained (CIU)**

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**Preparation Notes:** Sample was moist tamped to a loose condition

**Graph:**
- Deviator Stress $q$ (kPa) vs. Mean Effective Stress $p'$ (kPa)

**Tested by:** K. Koh
**Reviewed by:** R. Fanni / D. Reid
# Triaxial Test Report

## Isotropically Consolidated Undrained (CIU)

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<td>TC1</td>
</tr>
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<td>Cadia Mine</td>
<td>Test ID:</td>
<td>18018 - si-2 CIU loose 200kPa</td>
</tr>
</tbody>
</table>

- **Initial Height (mm):** 147.5
- **Final Liquor Content (%):** 22.0%
- **Strain Rate (mm/min):** 0.03
- **B Response (%):** 99%
- **Final Void Ratio (-):** 0.60
- **Mean Effective Consolidation Stress (kPa):** 201
- **Geostatic Stress Ratio $K_0$:** 0.99

**Preparation Notes:** Sample was moist tamped to a loose condition

**Diagram:**

- **Mobilised Friction Angle (Degrees) vs. Axial Strain (%)**
  - The graph shows the relationship between the mobilised friction angle and axial strain for the test sample.
  - The mobilised friction angle increases as the axial strain increases, indicating a typical behavior for CIU tests.
  - The axis ranges from 0% to 25% for Axial Strain and from 0 to 40 for Mobilised Friction Angle.

**Reviewed by:** R. Fanni / D. Reid

**Tested by:** K. Koh

*THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL*
### Triaxial Test Report

**Isotropically Consolidated Undrained (CIU)**

- **Client:** Hatch
- **Address:** 61 Petrie Terrace, Brisbane
- **Project:** NTSF Embankment Failure ITRB
- **Location:** Cadia Mine

#### Initial Test Details

<table>
<thead>
<tr>
<th>Initial Height (mm)</th>
<th>148.5</th>
<th>Final Liquor Content (%)</th>
<th>19.0%</th>
<th>Strain Rate (mm/min)</th>
<th>0.03</th>
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</thead>
<tbody>
<tr>
<td>Initial Diameter (mm)</td>
<td>69.4</td>
<td>Final Dry Density (t/m³)</td>
<td>1.80</td>
<td>B Response (%)</td>
<td>99%</td>
</tr>
<tr>
<td>Trimmings GWC (%)</td>
<td>10.9%</td>
<td>Final Void Ratio (-)</td>
<td>0.52</td>
<td>Mean Effective Consolidation Stress (kPa)</td>
<td>800</td>
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<tr>
<td>Initial Dry Density (t/m³)</td>
<td>1.22</td>
<td>Final Liquor Solids Conc. (g/L)</td>
<td>-</td>
<td>Geostatic Stress Ratio $K_0$ (-)</td>
<td>1.00</td>
</tr>
</tbody>
</table>

#### Preparation Notes:

Sample was moist tamped to a loose condition

---

**Sample Before Test**

**Sample After Test**

- **Test ID:** 18018 - si-3 CIU loose 800kPa
- **Location:** Perth Laboratory, 84 Guthrie Street, Osborne Park

---

**Reviewed by:** R. Fanni / D. Reid

**Tested by:** K. Koh

---

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## Isotropically Consolidated Undrained (CIU)

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<td>Sample was moist tamped to a loose condition</td>
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**Diagam:**
- **Deviator Stress**: 800 kPa
- **Pore Pressure**: 0 kPa

**Notes:**
- Sample was moist tamped to a loose condition.
**Triaxial Test Report**

**Isotropically Consolidated Undrained (CIU)**

Client: Hatch  
Address: 61 Petrie Terrace, Brisbane  
Project: NTFS Embankment Failure ITRB  
Location: Cadia Mine  
Date: 26/07/2018  
Project No.: 18101980  
Sample ID: TC1  
Test ID: 18018 - si-3 CIU loose 800kPa

- **Initial Height (mm):** 148.5  
- **Initial Diameter (mm):** 69.4  
- **Initial Dry Density (t/m³):** 1.22  
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- **Initial Liquor Content (%):** 19.0%  
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- **Final Diameter (mm):** 69.4  
- **Final Void Ratio (-):** 0.52  
- **Final Dry Density (t/m³):** 1.80  
- **Mean Effective Consolidation Stress (kPa):** 800  
- **Strain Rate (mm/min):** 0.03  
- **B Response (%):** 99%  
- **Mean Effective Stress p' (kPa):** 800  
- **Geostatic Stress Ratio K₀ (-):** 1.00

**Preparation Notes:** Sample was moist tamped to a loose condition

**Perth Laboratory**  
84 Guthrie Street, Osborne Park

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTFS Embankment Failure ITRB  
**Location:** Cadia Mine  
**Date:** 26/07/2018  
**Project No.:** 18101980  
**Sample ID:** TC1  
**Test ID:** 18018 - si-3 CIU loose 800kPa

**Preparation Notes:** Sample was moist tamped to a loose condition  
**Reviewed by:** R. Fanni / D. Reid  
**Tested by:** K. Koh
**Triaxial Test Report**

**Isotropically Consolidated Undrained (CIU)**

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**Graph**

- **Mobilised Friction Angle (Degrees)**
- **Axial Strain (%)**

**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh

**Reviewed by:** R. Fanni / D. Reid
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<td>Initial Diameter (mm):</td>
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<td>Final Dry Density (t/m³):</td>
<td>1.89</td>
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<td>Trimmings GWC (%):</td>
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**Preparation Notes:** Sample was moist tamped to a loose condition

**Sample Before Test**

**Sample After Test**

**Reviewed by:** R. Fanni / D. Reid

**Tested by:** K. Koh

**Address:** 84 Guthrie Street, Osborne Park

**Location:** Perth Laboratory
Triaxial Test Report

Isotropically Consolidated Drained (CID)

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NTSF Embankment Failure ITRB
Location: Cadia Mine

Date: 23/07/2018
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Initial Height (mm): 147.9 Final Liquor Content (%): 16.6%
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Strain Rate (mm/min): 0.015
B Response (%): 99%
Mean Effective Consolidation Stress (kPa): 401
Geostatic Stress Ratio $K_0$ (-): 0.99

Preparation Notes: Sample was moist tamped to a loose condition

他说

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Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid
## Triaxial Test Report

### Isotropically Consolidated Drained (CID)

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTSF Embankment Failure ITRB  
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### Graph:

A graph showing the relationship between Mean Effective Stress $\rho'$ and Deviator Stress $q$.

### Preparation Notes:

- Sample was moist tamped to a loose condition

### Tested by:

K. Koh

### Reviewed by:

R. Fanni / D. Reid
Triaxial Test Report

Isotropically Consolidated Drained (CID)

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Strain Rate (mm/min): 0.015
B Response (%): 99%
Mean Effective Consolidation Stress (kPa): 401
Geostatic Stress Ratio K₀ (-): 0.99

Preparation Notes: Sample was moist tamped to a loose condition

Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid
**Triaxial Test Report**

**Isotropically Consolidated Drained (CID)**

<table>
<thead>
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<tr>
<td>Project:</td>
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<td>Sample ID:</td>
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<td>Test ID:</td>
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<table>
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<tr>
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<tr>
<td>Trimmings GWC (%):</td>
<td>10.9%</td>
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<tr>
<td>Final Void Ratio (-):</td>
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<td>Geostatic Stress Ratio $K_0$ (-):</td>
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**Graph**

- **Mobilised Friction Angle (Degrees) vs. Axial Strain (%)**

**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh

**Reviewed by:** R. Fanni / D. Reid
### Triaxial Test Report

**Isotropically Consolidated Drained (CID)**

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<tr>
<td>Location:</td>
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<td>Test ID:</td>
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<td>Initial Height (mm):</td>
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<tr>
<td>Initial Diameter (mm):</td>
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<td>B Response (%):</td>
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<tr>
<td>Trimmings GWC (%):</td>
<td>10.9%</td>
<td>Mean Effective Consolidation Stress (kPa):</td>
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<tr>
<td>Initial Dry Density (t/m³):</td>
<td>1.23</td>
<td>Geostatic Stress Ratio $K_s$ (%):</td>
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**Preparation Notes:** Sample was moist tamped to a loose condition

---

**Sample Before Test**

18018 TC1
si-5-CID-1200kPa
loose

**Sample After Test**

18018 TC1
si-5-CID-1200kPa
loose
### Isotropically Consolidated Drained (CID)

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTSF Embankment Failure ITRB  
**Location:** Cadia Mine  
**Sample ID:** TC1  
**Project No.:** 18101980  
**Test ID:** 18018 - si-5 CID loose 1200kPa

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<tbody>
<tr>
<td>Initial Height (mm)</td>
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</tr>
<tr>
<td>Final Liquor Content (%)</td>
<td>14.4%</td>
</tr>
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<td>Strain Rate (mm/min)</td>
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<td>Trimmings GWC (%)</td>
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<tr>
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**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh  
**Reviewed by:** R. Fanni / D. Reid
Triaxial Test Report

Isotropically Consolidated Drained (CID)

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NTSF Embankment Failure ITRB
Location: Cadia Mine

Date: 23/07/2018
Project No.: 18101980
Sample ID: TC1
Test ID: 18018 - si-5 CID loose 1200kPa

Initial Height (mm): 148.1
Final Liquor Content (%): 14.4%
Strain Rate (mm/min): 0.015

Initial Diameter (mm): 69.1
Final Dry Density (t/m$^3$): 1.96
B Response (%): 99%

Trimmings GWC (%): 10.9%
Final Void Ratio (-): 0.40
Mean Effective Consolidation Stress (kPa): 1201

Initial Dry Density (t/m$^3$): 1.23
Final Liquor Solids Conc. (g/L): -
Geostatic Stress Ratio $K_0$ (-): 1.00

![Triaxial Stress-Strain Curve](chart.png)

Preparation Notes: Sample was moist tamped to a loose condition

Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid

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**Triaxial Test Report**

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**Preparation Notes:** Sample was moist tamped to a loose condition

**Axial Strain (%) vs. Volumetric Strain (%)**

**Adress:** 61 Petrie Terrace, Brisbane

**Location:** Cadia Mine

**Sample ID:** TC1

**Test ID:** 18018 - si-5 CID loose 1200kPa

**Sample was moist tamped to a loose condition**

**Reviewed by:** R. Fanni / D. Reid

**Tested by:** K. Koh
Triaxial Test Report

Isotropically Consolidated Drained (CID)

Client: Hatch  Date: 23/07/2018
Address: 61 Petrie Terrace, Brisbane  Project No.: 18101980
Project: NTSF Embankment Failure ITRB  Sample ID: TC1
Location: Cadia Mine  Test ID: 18018 - si-5 CID loose 1200kPa

Initial Height (mm): 148.1  Final Liquor Content (%): 14.4%
Initial Diameter (mm): 69.1  Final Dry Density (t/m$^3$): 1.96
Trimmings GWC (%): 10.9%  Final Void Ratio (-): 0.40
Initial Dry Density (t/m$^3$): 1.23  Final Liquor Solids Conc. (g/L): -

Strain Rate (mm/min): 0.015  B Response (%): 99%
Mean Effective Consolidation Stress (kPa): 1201
Geostatic Stress Ratio $K_0$ (-): 1.00

Preparation Notes: Sample was moist tamped to a loose condition

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL

Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid

Location: Cadia Mine

Address: 61 Petrie Terrace, Brisbane

Client: Hatch

Date: 23/07/2018
**Triaxial Test Report**

**Isotropically Consolidated Drained (CID)**

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<tr>
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<th>Final Liquor Content (%):</th>
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<td>Initial Diameter (mm):</td>
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<td>Final Dry Density (t/m³):</td>
<td>1.84</td>
<td>B Response (%):</td>
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<tr>
<td>Trimmings GWC (%):</td>
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<tr>
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<td>Final Liquor Solids Conc. (g/L):</td>
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<td>Mean Effective Consolidation Stress (kPa):</td>
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**Address:**
84 Guthrie Street, Osborne Park

**Client:**
61 Petrie Terrace, Brisbane

**Location:**
Cadia Mine

**Final Liquor Content (%):**
1.85

**Final Dry Density (t/m³):**
1.84

**Trimmings GWC (%):**
14.4%

**Initial Dry Density (t/m³):**
1.85

**Reviewed by:**
R. Fanni / D. Reid

**Tested by:**
K. Koh

**Preparation Notes:**
Sample was moist tamped

**Sample Before Test**

**Sample After Test**

**THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL**
# Triaxial Test Report

## Isotropically Consolidated Drained (CID)

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<tr>
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<td>Geostatic Stress Ratio $K_0$ (-):</td>
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<tr>
<th>Geostatic Stress Ratio $K_0$ (-):</th>
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<tr>
<td>Deviator Stress (kPa)</td>
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<tr>
<td>Axial Strain (%)</td>
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Preparation Notes: Sample was moist tamped

Tested by: K. Koh

Reviewed by: R. Fanni / D. Reid

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
**Triaxial Test Report**

**Isotropically Consolidated Drained (CID)**

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTSE Embankment Failure ITRB  
**Location:** Cadia Mine  
**Date:** 16/08/2018  
**Test ID:** 18018 - si-6 CID dense 100kPa

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<td>Initial Dry Density (t/m³)</td>
<td>1.85</td>
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<td>-</td>
<td>Geostatic Stress Ratio $K_0$ (-)</td>
<td>0.97</td>
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**Graph:**
- **Deviator Stress $q$ (kPa)**
- **Mean Effective Stress $p'$ (kPa)**

**Preparation Notes:** Sample was moist tamped  
**Tested by:** K. Koh  
**Reviewed by:** R. Fanni / D. Reid

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Triaxial Test Report

Isotropically Consolidated Drained (CID)

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NTSF Embankment Failure ITRB
Location: Cadia Mine

Preparation Notes: Sample was moist tamped

Initial Height (mm): 127.5
Initial Diameter (mm): 62.8
Trimmings GWC (%): 14.4%
Initial Dry Density (t/m³): 1.85

Final Liquor Content (%): 17.8%
Final Dry Density (t/m³): 1.84
Final Void Ratio (-): 0.49
Final Liquor Solids Conc. (g/L): -

Strain Rate (mm/min): 0.015
B Response (%): 98%
Mean Effective Consolidation Stress (kPa): 101
Geostatic Stress Ratio K₀ (-): 0.97

Date: 16/08/2018
Test ID: 18018 - si-6 CID dense 100kPa

Mobilised Friction Angle (Degrees)
Axial Strain (%)
# Triaxial Test Report

## Isotropically Consolidated Drained (CID)

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<td>Project:</td>
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<tr>
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<td>Test ID:</td>
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<table>
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<tr>
<th>Initial Height (mm):</th>
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<th>Final Liquor Content (%):</th>
<th>16.4%</th>
<th>Strain Rate (mm/min):</th>
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<th>B Response (%):</th>
<th>95%</th>
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<tbody>
<tr>
<td>Initial Diameter (mm):</td>
<td>62.9</td>
<td>Final Dry Density (t/m³):</td>
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<td>Mean Effective Consolidation Stress (kPa):</td>
<td>200</td>
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<tr>
<td>Trimmings GWC (%):</td>
<td>12.0%</td>
<td>Final Void Ratio (-):</td>
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<td>Initial Dry Density (t/m³):</td>
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<td>Final Liquor Solids Conc. (g/L):</td>
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**Sample Before Test**
- Preparation Notes: Sample was moist tamped to a dense condition

**Sample After Test**
- Tested by: K. Koh
- Reviewed by: R. Fanni

---

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Triaxial Test Report

Isotropically Consolidated Drained (CID)

Client: Hatch
Date: 16/09/2018

Address: 61 Petrie Terrace, Brisbane
Project No.: 18101980

Location: Cadia Mine
Sample ID: TC1

Project: NTSF Embankment Failure ITRB
Test ID: 18018 - si-7 CID dense 200kPa

Initial Height (mm): 127.1
Final Liquor Content (%): 16.4%
Strain Rate (mm/min): 0.015
B Response (%): 95%

Initial Diameter (mm): 62.9
Final Dry Density (t/m³): 1.89

Final Liquor Solid Conc. (g/L): -
Geostatic Stress Ratio $K_0$: 0.99

Initial Dry Density (t/m³): 1.94
Final Void Ratio (-): 0.45

Mean Effective Consolidation Stress (kPa): 200

Preparation Notes: Sample was moist tamped to a dense condition

Tested by: K. Koh
Reviewed by: R. Fanni

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Triaxial Test Report

Isotropically Consolidated Drained (CID)

Client: Hatch  Date: 16/09/2018
Address: 61 Petrie Terrace, Brisbane  Project No.: 18101980
Project: NTZF Embankment Failure ITRB  Sample ID: TC1
Location: Cadia Mine  Test ID: 18018 - si-7 CID dense 200kPa

Initial Height (mm): 127.1  Final Liquor Content (%): 16.4%  Strain Rate (mm/min): 0.015
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Preparation Notes: Sample was moist tamped to a dense condition

Tested by: K. Koh
Reviewed by: R. Fanni
Final Liquor Solids Conc. (g/L):

Geostatic Stress Ratio $K_0$ (-):

Tested by: K. Koh

Reviewed by: R. Fanni

Preparation Notes: Sample was moist tamped to a dense condition
**Triaxial Test Report**

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</tr>
<tr>
<td>Initial Dry Density (t/m³):</td>
<td>1.94</td>
<td>Final Liquor Solids Conc. (g/L):</td>
<td>-</td>
<td>Geostatic Stress Ratio K_0 (-):</td>
<td>0.99</td>
</tr>
</tbody>
</table>

**Preparation Notes:** Sample was moist tamped to a dense condition

**Tested by:** K. Koh

**Reviewed by:** R. Fanni

![Axial Strain vs. Mobilised Friction Angle Chart](chart.png)
Triaxial Test Report

Isotropically Consolidated Drained (CID)

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NTSF Embankment Failure ITRB
Location: Cadia Mine

Date: 27/08/2018
Project No.: 18101980
Sample ID: TC1
Test ID: 18018 - si-8 CID very dense 1000kPa

Mean Effective Consolidation Stress (kPa): 1002
Strain Rate (mm/min): 0.015
Geostatic Stress Ratio $K_0$ (-): 1.00

Final Void Ratio (-): 0.38
Initial Void Ratio (-): 13.9%
Strain Rate (%): 97%

Initial Height (mm): 130.2
Initial Diameter (mm): 63.0
Initial Dry Density (t/m$^3$): 1.98

Geostatic Stress Ratio $K_0$ (-): 1.00

Trimmings GWC (%): 12.0%
Final Void Ratio (-): 0.38

Final Liquor Solids Conc. (g/L): -
Final Liquor Content (%): 13.9%

Sample Before Test
Preparation Notes: Sample was moist tamped

Sample After Test
Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
## Triaxial Test Report

### Isotropically Consolidated Drained (CID)

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<td>Mean Effective Consolidation Stress (kPa):</td>
<td>1002</td>
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<td>Initial Dry Density (t/m³):</td>
<td>1.98</td>
<td>Final Liquor Solids Conc. (g/L):</td>
<td>-</td>
<td>Geostatic Stress Ratio $K_0 (-)$:</td>
<td>1.00</td>
</tr>
</tbody>
</table>

### Graph

- **X-axis:** Axial Strain (%)
- **Y-axis:** Deviator Stress (kPa)

### Preparation Notes:
Sample was moist tamped

### Tested by:
K. Koh

### Reviewed by:
R. Fanni / D. Reid

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
# Triaxial Test Report

**Isotropically Consolidated Drained (CID)**

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTFSF Embankment Failure ITRB  
**Location:** Cadia Mine  
**Date:** 27/08/2018  
**Project No.:** 18101980  
**Sample ID:** TC1  
**Test ID:** 18018 - si-8 CID very dense 1000kPa

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</tr>
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**Preparation Notes:** Sample was moist tamped

**Tested by:** K. Koh  
**Reviewed by:** R. Fanni / D. Reid

---

**Graph:**

![Graph showing the relationship between Deviator Stress $q$ (kPa) and Mean Effective Stress $\sigma'$ (kPa). The graph is a straight line indicating a linear relationship.](image-url)
**Triaxial Test Report**

**Isotropically Consolidated Drained (CID)**

<table>
<thead>
<tr>
<th>Client:</th>
<th>Hatch</th>
<th>Date:</th>
<th>27/08/2018</th>
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<tr>
<td>Address:</td>
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<td>Project No.:</td>
<td>18101980</td>
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<td>Project:</td>
<td>NTSF Embankment Failure ITRB</td>
<td>Sample ID:</td>
<td>TC1</td>
</tr>
<tr>
<td>Location:</td>
<td>Cadia Mine</td>
<td>Test ID:</td>
<td>18018 - si-8 CID very dense 1000kPa</td>
</tr>
</tbody>
</table>

**Initial Height (mm):** 130.2  **Final Liquor Content (%):** 13.9%

<table>
<thead>
<tr>
<th>Initial Diameter (mm):</th>
<th>63.0</th>
<th>Final Dry Density (t/m$^3$):</th>
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<td>Final Liquor Solids Conc. (g/L):</td>
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</table>

<table>
<thead>
<tr>
<th>Strain Rate (mm/min):</th>
<th>0.015</th>
<th>B Response (%):</th>
<th>97%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Effective Consolidation Stress (kPa):</td>
<td>1002</td>
<td>Geostatic Stress Ratio $K_0$ (-):</td>
<td>1.00</td>
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</tbody>
</table>

**Location:** Cadia Mine  
**Test ID:** 18018 - si-8 CID very dense 1000kPa

**Preparation Notes:** Sample was moist tamped

**Address:** 61 Petrie Terrace, Brisbane  
**Date:** 27/08/2018

**Client:** Hatch  
**Project No.:** 18101980

**Sample ID:** TC1

**Project:** NTSF Embankment Failure ITRB

**Sample was moist tamped**

**THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL**

**Reviewed by:** R. Fanni / D. Reid
Isotropically Consolidated Drained (CID)

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTNF Embankment Failure ITRB  
**Location:** Cadia Mine  
**Test ID:** 18018 - si-8 CID very dense 1000kPa

- **Initial Height (mm):** 130.2
- **Final Liquor Content (%):** 13.9%
- **Strain Rate (mm/min):** 0.015
- **Initial Diameter (mm):** 63.0
- **Final Dry Density (t/m³):** 1.98
- **B Response (%):** 97%
- **Trimmings GWC (%):** 12.0%
- **Final Void Ratio (-):** 0.38
- **Mean Effective Consolidation Stress (kPa):** 1002
- **Initial Dry Density (t/m³):** 1.98
- **Final Liquor Solids Conc. (g/L):** -
- **Geostatic Stress Ratio K₀ (-):** 1.00

**Preparation Notes:** Sample was moist tamped

**Axial Strain (%)** vs. **Mobilised Friction Angle (Degrees)**

---

**Tested by:** K. Koh  
**Reviewed by:** R. Fanni / D. Reid

---

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Annexure EH
TS2 – CSL Test Certificates
### Golder (Perth) Testing

<table>
<thead>
<tr>
<th>Test ID</th>
<th>As tested initial</th>
<th>At max dilation (=Dmin)</th>
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<tbody>
<tr>
<td></td>
<td>p0</td>
<td>e0</td>
</tr>
<tr>
<td>sa-4 CID 400 kPa</td>
<td>401.4</td>
<td>0.570</td>
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<tr>
<td>sa-5 CID 1200 kPa</td>
<td>1201.5</td>
<td>0.510</td>
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<td>sa-6 CID 100 kPa</td>
<td>101.0</td>
<td>0.490</td>
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<tr>
<td>sa-8 CID 1000 kPa</td>
<td>1001.9</td>
<td>0.380</td>
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</table>

<table>
<thead>
<tr>
<th>Test ID</th>
<th>As tested initial</th>
<th>at critical state</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p0</td>
<td>e0</td>
</tr>
<tr>
<td>sa-1 CIU 100 kPa</td>
<td>101.7</td>
<td>0.690</td>
</tr>
<tr>
<td>sa-2 CIU 200 kPa</td>
<td>201.2</td>
<td>0.590</td>
</tr>
<tr>
<td>sa-3 CIU 800 kPa</td>
<td>800.7</td>
<td>0.520</td>
</tr>
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</table>

- \( M_{tc} = 1.48 \)
- \( N = 0.30 \)
- \( \chi^{tc} = 8.7 \)

![Void Ratio vs Mean Effective Stress Graph](image_url)

### NTSF Failure Review

<table>
<thead>
<tr>
<th>Job number</th>
<th>Ref.</th>
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<td>H356804</td>
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**NTSF Failure Review**

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<tr>
<th>By</th>
<th>Ref.</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>TMY</td>
<td>IAG</td>
<td>19-Mar-19</td>
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**Tailings Critical State Properties Summary**

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<th>CSL</th>
<th>a</th>
<th>b</th>
<th>c</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>1.350</td>
<td>0.762</td>
<td>0.065</td>
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</tbody>
</table>

![Graph Image](image_url)
# Triaxial Test Report

## Isotropically Consolidated Undrained (CIU)

**Client:** Hatch  
**Date:** 8/08/2018

**Address:** 61 Petrie Terrace, Brisbane  
**Project No.:** 18101980

**Project:** NTFSF Embankment Failure ITRB  
**Sample ID:** TS2

**Location:** Cadia Mine  
**Test ID:** 18017 - sa-1 CIU very loose 100kPa

<table>
<thead>
<tr>
<th>Initial Height (mm):</th>
<th>146.7</th>
<th>Final Liquor Content (%):</th>
<th>25.6%</th>
<th>Strain Rate (mm/min):</th>
<th>0.03</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Diameter (mm):</td>
<td>64.7</td>
<td>Final Dry Density (t/m³):</td>
<td>1.59</td>
<td>B Response (%):</td>
<td>99%</td>
</tr>
<tr>
<td>Trimmings GWC (%):</td>
<td>11.4%</td>
<td>Final Void Ratio (-):</td>
<td>0.69</td>
<td>Mean Effective Consolidation Stress (kPa):</td>
<td>102</td>
</tr>
<tr>
<td>Initial Dry Density (t/m³):</td>
<td>1.18</td>
<td>Final Liquor Solids Conc. (g/L):</td>
<td>-</td>
<td>Geostatic Stress Ratio $K_0$ (-):</td>
<td>0.97</td>
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</table>

### Preparation Notes:
Sample was moist tamped to a loose condition

### Sample Before Test

### Sample After Test

**Tested by:** K. Koh  
**Reviewed by:** R. Fanni / D. Reid

---

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## Triaxial Test Report

### Isotropically Consolidated Undrained (CIU)

**Client:** Hatch  
**Date:** 8/08/2018  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTNF Embankment Failure ITRB  
**Sample ID:** TS2  
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**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh  
**Reviewed by:** R. Fanni / D. Reid

---

**Graph:**
- **Axial Strain (%):** 0% to 25%
- **Shear-induced Pore Pressure (kPa):** 0 to 100
- **Deviator Stress (kPa):** 0 to 100

---

**Perth Laboratory**  
84 Guthrie Street, Osborne Park

---

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# Triaxial Test Report

## Isotropically Consolidated Undrained (CIU)

### Client: Hatch

### Address: 61 Petrie Terrace, Brisbane

### Project: NTZF Embankment Failure ITRB

### Location: Cadia Mine

### Date: 8/08/2018

### Project No.: 18101980

### Sample ID: TS2

### Test ID: 18017 - sa-1 CIU very loose 100kPa

### Preparation Notes:

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### Graph:

![Triaxial Test Graph](image)

- **Deviator Stress $q$ (kPa)**
- **Mean Effective Stress $\rho'$ (kPa)**

### Tested by: K. Koh

### Reviewed by: R. Fanni / D. Reid
### Triaxial Test Report

**Isotropically Consolidated Undrained (CIU)**

**Client:** Hatch  
**Date:** 8/08/2018

**Address:** 61 Petrie Terrace, Brisbane  
**Project No.:** 18101980

**Project:** NTTF Embankment Failure ITRB  
**Sample ID:** TS2

**Location:** Cadia Mine  
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**Preparation Notes:** Sample was moist tamped to a loose condition

**Location:** Cadia Mine  
**Test ID:** 18017 - sa-1 CIU very loose 100kPa

**Client:** Hatch  
**Date:** 8/08/2018

**Address:** 61 Petrie Terrace, Brisbane  
**Project No.:** 18101980

**Project:** NTTF Embankment Failure ITRB  
**Sample ID:** TS2

**Location:** Cadia Mine  
**Test ID:** 18017 - sa-1 CIU very loose 100kPa

**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh  
**Reviewed by:** R. Fanni / D. Reid

---

**Graph:**
- **X-axis:** Axial Strain (%)
- **Y-axis:** Mobilised Friction Angle (Degrees)

---

**Client:** Hatch  
**Date:** 8/08/2018

**Address:** 61 Petrie Terrace, Brisbane  
**Project No.:** 18101980

**Project:** NTTF Embankment Failure ITRB  
**Sample ID:** TS2

**Location:** Cadia Mine  
**Test ID:** 18017 - sa-1 CIU very loose 100kPa

**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh  
**Reviewed by:** R. Fanni / D. Reid

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**Graph:**
- **X-axis:** Axial Strain (%)
- **Y-axis:** Mobilised Friction Angle (Degrees)
### Triaxial Test Report

**Isotropically Consolidated Undrained (CIU)**

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<tr>
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<td>Project No.:</td>
<td>18101980</td>
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<td>Project:</td>
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<td>Sample ID:</td>
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<tr>
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<td>Cadia Mine</td>
<td>Test ID:</td>
<td>18017 - sa-2 CIU loose 200kPa</td>
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<thead>
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<th>Sample After Test</th>
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<tr>
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<td>Sample was moist tamped to a loose condition</td>
<td>Tested by: K. Koh</td>
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<td></td>
<td>Reviewed by: R. Fanni / D. Reid</td>
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<table>
<thead>
<tr>
<th>Initial Height (mm):</th>
<th>147.1</th>
<th>Final Liquor Content (%):</th>
<th>22.1%</th>
<th>Strain Rate (mm/min):</th>
<th>0.03</th>
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<tr>
<td>Initial Diameter (mm):</td>
<td>65.4</td>
<td>Final Dry Density (t/m$^3$):</td>
<td>1.69</td>
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</tr>
<tr>
<td>Trimmings GWC (%):</td>
<td>6.6%</td>
<td>Final Void Ratio (-):</td>
<td>0.59</td>
<td>Mean Effective Consolidation Stress (kPa):</td>
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<tr>
<td>Initial Dry Density (t/m$^3$):</td>
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<td>Final Liquor Solids Conc. (g/L):</td>
<td>-</td>
<td>Geostatic Stress Ratio $K_0$ (-):</td>
<td>0.98</td>
</tr>
</tbody>
</table>

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## Triaxial Test Report

### Isotropically Consolidated Undrained (CIU)

**Client:** Hatch  
**Date:** 1/08/2018  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTSF Embankment Failure ITRB  
**Sample ID:** TS2  
**Location:** Cadia Mine  
**Test ID:** 18017 - sa-2 CIU loose 200kPa

### Test Results

- **Initial Height (mm):** 147.1  
- **Final Liquor Content (%):** 22.1%  
- **Strain Rate (mm/min):** 0.03  
- **B Response (%):** 99%  
- **Initial Dry Density (t/m³):** 1.28  
- **Final Void Ratio (-):** 0.59  
- **Mean Effective Consolidation Stress (kPa):** 201  
- **Initial Diameter (mm):** 65.4  
- **Final Dry Density (t/m³):** 1.69  
- **Final Liquor Solids Conc. (g/L):** -  
- **Geostatic Stress Ratio K₀ (-):** 0.98

### Graph

- **Shear-induced Pore Pressure (kPa)**  
- **Deviator Stress (kPa)**  
- **Axial Strain (%)**  
- **Deviator Stress**  
- **Pore Pressure**

**Preparation Notes:** Sample was moist tamped to a loose condition  
**Tested by:** K. Koh  
**Reviewed by:** R. Fanni / D. Reid
### Isotropically Consolidated Undrained (CIU)

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Address:</td>
<td>61 Petrie Terrace, Brisbane</td>
<td>Project No.:</td>
<td>18101980</td>
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<tr>
<td>Project:</td>
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<td>Sample ID:</td>
<td>TS2</td>
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<td>Location:</td>
<td>Cadia Mine</td>
<td>Test ID:</td>
<td>18017 - sa-2 CIU loose 200kPa</td>
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</tbody>
</table>

- **Initial Height (mm):** 147.1
- **Final Liquor Content (%):** 22.1
- **Strain Rate (mm/min):** 0.03
- **B Response (%):** 99%
- **Initial Diameter (mm):** 65.4
- **Final Dry Density (t/m³):** 1.69
- **Final Void Ratio (-):** 0.59
- **Mean Effective Consolidation Stress (kPa):** 201
- **Trimmings GWC (%):** 6.6
- **Initial Dry Density (t/m³):** 1.28
- **Final Liquor Solids Conc. (g/L):** -
- **Geostatic Stress Ratio \( K_0 \):** 0.98

**Preparation Notes:** Sample was moist tamped to a loose condition

**Graph:**

- **Y-axis:** Deviator Stress \( q \) (kPa)
- **X-axis:** Mean Effective Stress \( p' \) (kPa)

**Tested by:** K. Koh

**Reviewed by:** R. Fanni / D. Reid

---

**THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL**
Isotropically Consolidated Undrained (CIU)

Client: Hatch
Date: 1/08/2018
Address: 61 Petrie Terrace, Brisbane
Project: NTSF Embankment Failure ITRB
Sample ID: TS2
Location: Cadia Mine
Test ID: 18017 - sa-2 CIU loose 200kPa

Initial Height (mm): 147.1
Final Liquor Content (%): 22.1%
Strain Rate (mm/min): 0.03

Initial Diameter (mm): 65.4
Final Dry Density (t/m³): 1.69
B Response (%): 99%

Trimmings GWC (%): 6.6%
Final Void Ratio (-): 0.59
Mean Effective Consolidation Stress (kPa): 201

Initial Dry Density (t/m³): 1.28
Final Liquor Solids Conc. (g/L): -
Geostatic Stress Ratio K₀ (-): 0.98

Preparation Notes: Sample was moist tamped to a loose condition

Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
## Triaxial Test Report

### Isotropically Consolidated Undrained (CIU)

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<tr>
<td>Trimmings GWC (%):</td>
<td>6.6%</td>
<td>Final Void Ratio (-):</td>
<td>0.52</td>
<td>Mean Effective Consolidation Stress (kPa):</td>
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<tr>
<td>Initial Dry Density (t/m³):</td>
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<td>Final Liquor Solids Conc. (g/L):</td>
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<td>Sample Before Test</td>
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<tr>
<td>Sample After Test</td>
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<tr>
<td>Tested by:</td>
<td>K. Koh</td>
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<td>R. Fanni / D. Reid</td>
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THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
Triaxial Test Report

Isotropically Consolidated Undrained (CIU)

Client: Hatch  Date: 31/07/2018
Address: 61 Petrie Terrace, Brisbane  Project No.: 18101980
Project: NTSC Embankment Failure ITRB  Sample ID: TS2
Location: Cadia Mine  Test ID: 18017 - sa-3 CIU loose 800kPa

Initial Height (mm): 146.7  Final Liquor Content (%): 19.4%
Initial Diameter (mm): 65.7  Final Dry Density (t/m$^3$): 1.77
Trimmings GWC (%): 6.6%  Final Void Ratio (-): 0.52
Initial Dry Density (t/m$^3$): 1.27  Mean Effective Consolidation Stress (kPa): 800

Strain Rate (mm/min): 0.03  B Response (%): 99%
Geostatic Stress Ratio $K_0$: 1.00

Preparation Notes: Sample was moist tamped to a loose condition

Tested by: K. Koh  Reviewed by: R. Fanni / D. Reid

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
Triaxial Test Report

Isotropically Consolidated Undrained (CIU)

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NTSF Embankment Failure ITRB
Location: Cadia Mine

Date: 31/07/2018
Project No.: 18101980
Sample ID: TS2
Test ID: 18017 - sa-3 CIU loose 800kPa

Initial Height (mm): 146.7
Final Liquor Content (%): 19.4%
Strain Rate (mm/min): 0.03

Initial Diameter (mm): 65.7
Final Dry Density (t/m³): 1.77
B Response (%): 99%

Trimmings GWC (%): 6.6%
Final Void Ratio (-): 0.52
Mean Effective Consolidation Stress (kPa): 800

Initial Dry Density (t/m³): 1.27
Final Liquor Solids Conc. (g/L): -
Geostatic Stress Ratio K₀ (-): 1.00

Preparation Notes: Sample was moist tamped to a loose condition

Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
## Triaxial Test Report

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<td></td>
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<tr>
<td>Geostatic Stress Ratio K₀ (-):</td>
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**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh

**Reviewed by:** R. Fanni / D. Reid
# Triaxial Test Report

## Isotropically Consolidated Drained (CID)

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<td>Project No.:</td>
<td>18101980</td>
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<td>Location:</td>
<td>Cadia Mine</td>
<td>Sample ID:</td>
<td>TS2</td>
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<td>Project:</td>
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<td>Test ID:</td>
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<table>
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<tr>
<th>Initial Height (mm):</th>
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<tr>
<td>Initial Diameter (mm):</td>
<td>65.8</td>
<td>B Response (%):</td>
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<tr>
<td>Trimmings GWC (%):</td>
<td>8.1%</td>
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<tr>
<td>Initial Dry Density (t/m$^3$):</td>
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<tr>
<td>Final Liquor Content (%):</td>
<td>17.8%</td>
<td>Final Void Ratio ( -):</td>
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<tr>
<td>Final Dry Density (t/m$^3$):</td>
<td>1.82</td>
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<td></td>
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<tr>
<td>Final Liquor Solids Conc. (g/L):</td>
<td>-</td>
<td></td>
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<tr>
<td>Sample Before Test</td>
<td>Sample After Test</td>
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<td></td>
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**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh

**Reviewed by:** R. Fanni

D. Reid

**THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL**

**Perth Laboratory**

84 Guthrie Street, Osborne Park

---

18017 TS2
sa-4-CID-400kPa
loose

18017 TS2
sa-4-CID-400kPa
loose
# Triaxial Test Report

## Isotropically Consolidated Drained (CID)

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTSF Embankment Failure ITRB  
**Location:** Cadia Mine  
**Designation:** 18101980 - sa-4 CID loose 400kPa  

### Test Details
- **Sample ID:** TS2  
- **Test ID:** 18017 - sa-4 CID loose 400kPa  
- **Date:** 6/08/2018  
- **Preparation Notes:** Sample was moist tamped to a loose condition

### Test Results
- **Initial Height (mm):** 147.7  
- **Initial Diameter (mm):** 65.8  
- **Initial Trimmed GWC (%):** 8.1%  
- **Initial Dry Density (t/m³):** 1.25  
- **Final Liquor Content (%):** 17.8%  
- **Final Trimmed GWC (%):** 8.1%  
- **Final Void Ratio (-):** 0.48  
- **Final Liquor Solids Conc. (g/L):** -  
- **Strain Rate (mm/min):** 0.015  
- **B Response (%):** 99%  
- **Mean Effective Consolidation Stress (kPa):** 401  
- **Geostatic Stress Ratio K₀ (-):** 0.99

### Graphs
- Deviator Stress (kPa) vs. Axial Strain (%)
- Sample was plotted for deviator stress and axial strain relationship.
Triaxial Test Report

Isotropically Consolidated Drained (CID)

Client: Hatch  
Date: 6/08/2018

Address: 61 Petrie Terrace, Brisbane  
Project No.: 18101980

Location: Cadia Mine  
Sample ID: TS2

Project: NT SF Embankment Failure ITRB  
Test ID: 18017 - sa-4 CID loose 400kPa

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<tr>
<th>Initial Height (mm):</th>
<th>Final Liquor Content (%):</th>
<th>Strain Rate (mm/min):</th>
<th>B Response (%):</th>
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<tbody>
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<td>147.7</td>
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<td>99%</td>
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<th>Initial Diameter (mm):</th>
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<th>Final Void Ratio (-):</th>
<th>Mean Effective Consolidation Stress (kPa):</th>
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<td>1.82</td>
<td>0.48</td>
<td>401</td>
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<tr>
<th>Trimmings GWC (%):</th>
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<th>Geostatic Stress Ratio $K_0$:</th>
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<tr>
<td>8.1%</td>
<td>-</td>
<td>0.99</td>
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<table>
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<tr>
<th>Initial Dry Density (t/m³):</th>
<th>Final Liquor Content (%):</th>
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<tr>
<td>1.25</td>
<td>17.8%</td>
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Preparation Notes: Sample was moist tamped to a loose condition

Tested by: K. Koh
Reviewed by: R. Fanni
D. Reid
**Triaxial Test Report**

**Isotropically Consolidated Drained (CID)**

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<td>Test ID:</td>
<td>18017 - sa-4 CID loose 400kPa</td>
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**Initial Height (mm):** 147.7
**Final Liquor Content (%):** 17.8%
**Strain Rate (mm/min):** 0.015
**B Response (%):** 99%

**Initial Diameter (mm):** 65.8
**Final Dry Density (t/m³):** 1.82
**Mean Effective Consolidation Stress (kPa):** 401

**Trimmings GWC (%):** 8.1%
**Final Void Ratio (-):** 0.48
**Location:** Cadia Mine
**Initial Height (mm):** 147.7
**Final Liquor Content (%):** 17.8%
**Strain Rate (mm/min):** 0.015
**B Response (%):** 99%

**Initial Dry Density (t/m³):** 1.25
**Final Liquor Solids Conc. (g/L):** -
**Geostatic Stress Ratio K₀ (-):** 0.99

**Strain Rate (mm/min):**

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<tr>
<th>Volumetric Strain (%)</th>
<th>Axial Strain (%)</th>
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<tbody>
<tr>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>0.5%</td>
<td>5%</td>
</tr>
<tr>
<td>1.0%</td>
<td>10%</td>
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<td>1.5%</td>
<td>15%</td>
</tr>
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<td>2.0%</td>
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</tr>
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<td>55%</td>
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<tr>
<td>6.0%</td>
<td>60%</td>
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**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh
**Reviewed by:** R. Fanni
**D. Reid**
**Triaxial Test Report**

### Isotropically Consolidated Drained (CID)

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<tr>
<th>Initial Height (mm):</th>
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<th>Final Liquor Content (%):</th>
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<th>Strain Rate (mm/min):</th>
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<td>B Response (%):</td>
<td>99%</td>
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<td>Trimmings GWC (%):</td>
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<td>Final Void Ratio (-):</td>
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<td>Mean Effective Consolidation Stress (kPa):</td>
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<td>Final Liquor Solids Conc. (g/L):</td>
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<td>Geostatic Stress Ratio $K_0$ (-):</td>
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**Preparation Notes:** Sample was moist tamped to a loose condition

**Address:** 61 Petrie Terrace, Brisbane

**Project:** NTSF Embankment Failure ITRB

**Location:** Cadia Mine

**Test ID:** 18017 - sa-4 CID loose 400kPa

---

**Graph:**

- **Mobilised Friction Angle (Degrees)** vs **Axial Strain (%)**

---

**Tested by:** K. Koh

**Reviewed by:** R. Fanni, D. Reid

---

**THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL**
# Triaxial Test Report

## Isotropically Consolidated Drained (CID)

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTSF Embankment Failure ITRB  
**Location:** Cadia Mine  
**Date:** 6/08/2018  
**Sample ID:** TS2  
**Project No.:** 18101980  
**Sample:** 18017 - sa-5 CID loose 1200kPa

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<tr>
<td>Initial Void Ratio (-)</td>
<td>0.42</td>
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<tr>
<td>Final Void Ratio (-)</td>
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</tr>
<tr>
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<td>Final Liquor Solids Conc. (g/L)</td>
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<tr>
<td>Trimmings GWC (%)</td>
<td>8.1%</td>
</tr>
</tbody>
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**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh  
**Reviewed by:** R. Fanni, D. Reid

---

**Sample Before Test**

**Sample After Test**

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
# Triaxial Test Report

**Isotropically Consolidated Drained (CID)**

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTSF Embankment Failure ITRB  
**Location:** Cadia Mine  
**Date:** 6/08/2018  
**Test ID:** 18017 - sa-5 CID loose 1200kPa  
**Sample ID:** TS2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Initial Height (mm)</td>
<td>145.9</td>
</tr>
<tr>
<td>Initial Diameter (mm)</td>
<td>66.1</td>
</tr>
<tr>
<td>Initial Dry Density (t/m³)</td>
<td>1.25</td>
</tr>
<tr>
<td>Final Liquor Content (%)</td>
<td>15.5%</td>
</tr>
<tr>
<td>Final Dry Density (t/m³)</td>
<td>1.90</td>
</tr>
<tr>
<td>Final Void Ratio (-)</td>
<td>0.42</td>
</tr>
<tr>
<td>Mean Effective Consolidation Stress (kPa)</td>
<td>1201</td>
</tr>
<tr>
<td>Geostatic Stress Ratio K₀ (-)</td>
<td>1.00</td>
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</tbody>
</table>

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**Tested by:** K. Koh  
**Reviewed by:** R. Fanni, D. Reid

![Deviator Stress vs. Axial Strain](chart.png)
### Triaxial Test Report

**Isotropically Consolidated Drained (CID)**

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NT SF Embankment Failure ITRB  
**Location:** Cadia Mine  
**Test ID:** 18017 - sa-5 CID loose 1200kPa

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<tr>
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<td>99%</td>
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**Preparation Notes:** Sample was moist tamped to a loose condition

**Sample ID:** TS2

**Reviewed by:** R. Fanni  
**Tested by:** K. Koh  
**Reviewed by:** D. Reid

---

![Graph](attachment:image.png)

---

**Address:** 61 Petrie Terrace, Brisbane  
**Project No.:** 18101980  
**Client:** Hatch  
**Date:** 6/08/2018  
**Project:** NT SF Embankment Failure ITRB  
**Location:** Cadia Mine  
**Test ID:** 18017 - sa-5 CID loose 1200kPa

**Preparation Notes:** Sample was moist tamped to a loose condition

**Sample ID:** TS2

**Reviewed by:** R. Fanni  
**Tested by:** K. Koh  
**Reviewed by:** D. Reid

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**THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL**
## Triaxial Test Report

**Isotropically Consolidated Drained (CID)**

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### Preparation Notes:
- Sample was moist tamped to a loose condition

### Test Results:

<table>
<thead>
<tr>
<th>Initial Height (mm):</th>
<th>145.9</th>
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<th>0.015</th>
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<td>-</td>
<td>Geostatic Stress Ratio $K_0$ (-):</td>
<td>1.00</td>
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</tbody>
</table>

### Graph:

A graph showing the relationship between Axial Strain (%) and Volumetric Strain (%). The curve indicates the typical behavior of soil samples under triaxial test conditions. The y-axis represents volumetric strain (%) ranging from 0.0% to 6.5%, while the x-axis represents axial strain (%) ranging from 0% to 25%.
Triaxial Test Report

Isotropically Consolidated Drained (CID)

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NTSF Embankment Failure ITRB
Location: Cadia Mine

Test ID: 18017 - sa-5 CID loose 1200kPa
Sample ID: TS2

Initial Height (mm): 145.9
Initial Diameter (mm): 66.1
Initial Dry Density (t/m³): 1.25
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Final Liquor Content (%): 15.5%
Final Void Ratio (-): 0.42
Final Liquor Solids Conc. (g/L): -

Strain Rate (mm/min): 0.015
B Response (%): 99%
Mean Effective Consolidation Stress (kPa): 1201

Location: Cadia Mine
Test ID: 18017 - sa-5 CID loose 1200kPa
Sample ID: TS2

Preparation Notes: Sample was moist tamped to a loose condition

Tested by: K. Koh
Reviewed by: R. Fanni D. Reid

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<td>TS2</td>
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<tr>
<td>Location:</td>
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<td>Test ID:</td>
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<table>
<thead>
<tr>
<th>Initial Height (mm):</th>
<th>128.4</th>
<th>Final Void Ratio (-):</th>
<th>0.53</th>
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<tr>
<td>Initial Diameter (mm):</td>
<td>62.9</td>
<td>Final Void Ratio (-):</td>
<td>0.53</td>
<td>Geostatic Stress Ratio $K_0$ (-):</td>
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<tr>
<td>Trimmings GWC (%):</td>
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<td>Final Liquor Solids Conc. (g/L):</td>
<td>-</td>
<td></td>
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<td>Initial Dry Density (t/m$^3$):</td>
<td>1.81</td>
<td>Final Liquor Content (%):</td>
<td>19.6%</td>
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<td>0.015</td>
<td>B Response (%):</td>
<td>97%</td>
<td></td>
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Preparation Notes: Sample was moist tamped

Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid
### Triaxial Test Report

**Isotropically Consolidated Drained (CID)**

**Client:** Hatch  
**Date:** 17/08/2018

**Address:** 61 Petrie Terrace, Brisbane  
**Project No.:** 18101980

**Project:** NTSF Embankment Failure ITRB  
**Sample ID:** TS2

**Location:** Cadia Mine  
**Test ID:** 18017 - sa-6 CID dense 100kPa

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<td>Trimmings GWC (%)</td>
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**Preparation Notes:** Sample was moist tamped

**Tested by:** K. Koh  
**Reviewed by:** R. Fanni / D. Reid

---

![Triaxial Test Diagram](chart.png)
## Triaxial Test Report

### Isotropically Consolidated Drained (CID)

#### Client: Hatch

#### Address: 61 Petrie Terrace, Brisbane

#### Project: NTSF Embankment Failure ITRB

#### Location: Cadia Mine

#### Date: 17/08/2018

#### Project No.: 18101980

#### Sample ID: TS2

#### Test ID: 18017 - sa-6 CID dense 100kPa

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#### Preparation Notes:
Sample was moist tamped

#### Tested by:
K. Koh

#### Reviewed by:
R. Fanni / D. Reid
Triaxial Test Report

Isotropically Consolidated Drained (CID)

Client: Hatch
Date: 17/08/2018
Address: 61 Petrie Terrace, Brisbane
Project No.: 18101980
Project: NTNSF Embankment Failure ITRB
Sample ID: TS2
Location: Cadia Mine
Test ID: 18017 - sa-6 CID dense 100kPa

Initial Height (mm): 128.4
Final Liquor Content (%): 19.6%
Strain Rate (mm/min): 0.015
Initial Diameter (mm): 62.9
Final Dry Density (t/m$^3$): 1.76
B Response (%): 97%
Trimmings GWC (%): 
Final Void Ratio (-): 0.53
Mean Effective Consolidation Stress (kPa): 101
Initial Dry Density (t/m$^3$): 1.81
Final Liquor Solids Conc. (g/L): -
Geostatic Stress Ratio $K_0$ (-): 0.97

Preparation Notes: Sample was moist tamped

Axial Strain (%) vs. Volumetric Strain (%)

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL

Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid

Location: Cadia Mine
Test ID: 18017 - sa-6 CID dense 100kPa
Preparation Notes: Sample was moist tamped

Tested by: K. Koh

Reviewed by: R. Fanni / D. Reid

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<th>Initial Height (mm):</th>
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<td>Final Void Ratio (-):</td>
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<td>Mean Effective Consolidation Stress (kPa):</td>
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**Preparation Notes:** Sample was moist tamped to a dense condition

**Sample Before Test**

**Sample After Test**

**Tested by:** K. Koh

**Reviewed by:** R. Fanni
**Triaxial Test Report**

**Location:** Cadia Mine  
**Test ID:** 18017 - sa-7 CID very dense 200kPa

**Client:** Hatch  
**Date:** 17/08/2018

**Address:** 61 Petrie Terrace, Brisbane  
**Project No.:** 18101980

**Project:** NTSP Embankment Failure ITRB  
**Sample ID:** TS2

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**Deviator Stress (kPa) vs. Axial Strain (%)**

**Preparation Notes:** Sample was moist tamped to a dense condition

**Tested by:** K. Koh  
**Reviewed by:** R. Fanni

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Isotropically Consolidated Drained (CID)

Client: Hatch
Date: 17/08/2018
Address: 61 Petrie Terrace, Brisbane
Project: NTFS Embankment Failure ITRB
Sample ID: TS2
Location: Cadia Mine
Test ID: 18017 - sa-7 CID very dense 200kPa

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Tested by: K. Koh
Reviewed by: R. Fanni

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Client: Hatch  
Address: 61 Petrie Terrace, Brisbane  
Project: NTFS Embankment Failure ITRB  
Location: Cadia Mine  
Sample ID: TS2

Initial Height (mm): 129.0  
Final Liquor Content (%): 16.7%  
Strain Rate (mm/min): 0.015  
Test ID: 18017 - sa-7 CID very dense 200kPa

Initial Diameter (mm): 63.0  
Final Dry Density (t/m³): 1.85  
B Response (%): 96%  
Mean Effective Consolidation Stress (kPa): 201

Trimmings GWC (%): 12.2%  
Final Void Ratio (-): 0.45  
Geostatic Stress Ratio $K_0$ (-): 0.99

Initial Dry Density (t/m³): 1.93  
Final Liquor Solids Conc. (g/L): -  

Preparation Notes: Sample was moist tamped to a dense condition

Tested by: K. Koh  
Reviewed by: R. Fanni

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**Triaxial Test Report**

**Isotropically Consolidated Drained (CID)**

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<td>0.99</td>
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*Preparation Notes: Sample was moist tamped to a dense condition*

*Tested by: K. Koh*

*Reviewed by: R. Fanni*
### Isotropically Consolidated Drained (CID) Test Report

#### Client:
Hatch

#### Address:
61 Petrie Terrace, Brisbane

#### Project:
NTSF Embankment Failure ITRB

#### Location:
Cadia Mine

#### Date:
5/09/2018

#### Project No.:
18101980

#### Sample ID:
TS2

#### Test ID:
18017 - sa-8 CID very dense 1000kPa

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<td>Initial Diameter (mm)</td>
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<tr>
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</tbody>
</table>

### Preparation Notes:
Sample was moist tamped

### Tested by:
K. Koh

### Reviewed by:
R. Fanni
### Triaxial Test Report

**Isotropically Consolidated Drained (CID)**

<table>
<thead>
<tr>
<th>Client:</th>
<th>Hatch</th>
<th>Date:</th>
<th>5/09/2018</th>
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<tbody>
<tr>
<td>Address:</td>
<td>61 Petrie Terrace, Brisbane</td>
<td>Project No.:</td>
<td>18101980</td>
</tr>
<tr>
<td>Project:</td>
<td>NTSF Embankment Failure ITRB</td>
<td>Sample ID:</td>
<td>TS2</td>
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<tr>
<td>Location:</td>
<td>Cadia Mine</td>
<td>Test ID:</td>
<td>18017 - sa-8 CID very dense 1000kPa</td>
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</table>

**Preparation Notes:** Sample was moist tamped

**Deviator Stress (kPa) vs. Axial Strain (%)**

- **Initial Height (mm):** 129.3
- **Final Liquor Content (%):** 14.8%
- **Strain Rate (mm/min):** 0.015
- **Initial Diameter (mm):** 62.9
- **Final Dry Density (t/m³):** 1.93
- **B Response (%):** 97%
- **Trimmings GWC (%):** 12.3%
- **Final Void Ratio (-):** 0.40
- **Mean Effective Consolidation Stress (kPa):** 1001
- **Initial Dry Density (t/m³):** 1.95
- **Final Liquor Solids Conc. (g/L):** -
- **Geostatic Stress Ratio \( K_0 (-) \):** 1.00

**Client:** Hatch

**Address:** 61 Petrie Terrace, Brisbane

**Project:** NTSF Embankment Failure ITRB

**Location:** Cadia Mine

**Test ID:** 18017 - sa-8 CID very dense 1000kPa

**Prepared by:** K. Koh

**Reviewed by:** R. Fanni

---

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
Triaxial Test Report

Isotropically Consolidated Drained (CID)

<table>
<thead>
<tr>
<th>Client: Hatch</th>
<th>Date: 5/09/2018</th>
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<tr>
<td>Address: 61 Petrie Terrace, Brisbane</td>
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<td>Sample ID: TS2</td>
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<td>Location: Cadia Mine</td>
<td>Test ID: 18017 - sa-8 CID very dense 1000kPa</td>
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<table>
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<th>Initial Height (mm):</th>
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<th>Final Liquor Content (%):</th>
<th>14.8%</th>
<th>Strain Rate (mm/min):</th>
<th>0.015</th>
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<tbody>
<tr>
<td>Initial Diameter (mm):</td>
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<td>B Response (%):</td>
<td>97%</td>
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<tr>
<td>Trimmings GWC (%):</td>
<td>12.3</td>
<td>Final Void Ratio (-):</td>
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<td>Mean Effective Consolidation Stress (kPa):</td>
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<tr>
<td>Initial Dry Density (t/m³):</td>
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<td>Final Liquor Solids Conc. (g/L):</td>
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<td>Geostatic Stress Ratio K₀ (-):</td>
<td>1.00</td>
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</table>

Preparation Notes: Sample was moist tamped

Mean Effective Stress ρ' (kPa)

Deviator Stress q (kPa)

Tested by: K. Koh
Reviewed by: R.Fanni
Triaxial Test Report

Isotropically Consolidated Drained (CID)

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NTSF Embankment Failure ITRB
Location: Cadia Mine

Date: 5/09/2018
Project No.: 18101980
Sample ID: TS2
Test ID: 18017 - sa-8 CID very dense 1000kPa

Initial Height (mm): 129.3
Final Liquor Content (%): 14.8%
Strain Rate (mm/min): 0.015

Initial Diameter (mm): 62.9
Final Dry Density (t/m³): 1.93
B Response (%): 97%

Trimmings GWC (%): 12.3%
Final Void Ratio (-): 0.40
Mean Effective Consolidation Stress (kPa): 1001

Initial Dry Density (t/m³): 1.95
Final Liquor Solids Conc. (g/L): -
Geostatic Stress Ratio $K_0$ (-): 1.00

Preparation Notes: Sample was moist tamped

Tested by: K. Koh
Reviewed by: R. Fanni

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
# Triaxial Test Report

**Isotropically Consolidated Drained (CID)**

**Client:** Hatch  
**Date:** 5/09/2018  
**Address:** 61 Petrie Terrace, Brisbane  
**Project No.:** 18101980  
**Location:** Cadia Mine  
**Project:** NTGF Embankment Failure ITRB  
**Sample ID:** TS2  
**Test ID:** 18017 - sa-8 CID very dense 1000kPa

<table>
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<tr>
<th>Initial Height (mm)</th>
<th>Final Liquor Content (%)</th>
<th>Strain Rate (mm/min)</th>
<th>B Response (%)</th>
<th>Mean Effective Consolidation Stress (kPa)</th>
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</thead>
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<tr>
<td>129.3</td>
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<th>Final Dry Density (t/m³)</th>
<th>Trimmings GWC (%)</th>
<th>Final Void Ratio (-)</th>
<th>Geostatic Stress Ratio K₀ (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>62.9</td>
<td>1.93</td>
<td>12.3%</td>
<td>0.40</td>
<td>1.00</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Preparation Notes:</th>
<th>Final Liquor Solids Conc. (g/L):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample was moist tamped</td>
<td>-</td>
</tr>
</tbody>
</table>

**Graph:**

- **Mobilised Friction Angle (Degrees) vs. Axial Strain (%)**
- **Axial Strain (%)**
- **Mobilised Friction Angle (Degrees)**

**Tested by:** K. Koh  
**Reviewed by:** R. Fanni
Annexure EI
TC2 – CSL Test Certificates
### Triaxial CIU Test - Summary

**ASTM D4767**

**PROJECT NO.:** A03353A01  
**DATE:** 2019-01-18  
**PROJECT:** NWM CVO NTSF  
**TESTED BY:** BY  
**SAMPLE:** Tailings  
**CHECKED BY:** JG

**Details:** \( e_i = 0.85 \)

<table>
<thead>
<tr>
<th>SPECIMEN INFORMATION</th>
<th>UNITS</th>
<th>Initial</th>
<th>Vacuum</th>
<th>Saturation</th>
<th>B-value</th>
<th>End of 1st Consolidation</th>
<th>End of 2nd Consolidation</th>
<th>End of 3rd Consolidation</th>
<th>At Maximum Stress Ratio</th>
<th>End of Shear</th>
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<tbody>
<tr>
<td>Specimen Height</td>
<td>mm</td>
<td>140.01</td>
<td>140.27</td>
<td>137.00</td>
<td>134.82</td>
<td>133.72</td>
<td>132.58</td>
<td>115.27</td>
<td>95.19</td>
<td></td>
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<tr>
<td>Specimen Diameter</td>
<td>mm</td>
<td>69.80</td>
<td>69.64</td>
<td>67.09</td>
<td>67.22</td>
<td>66.41</td>
<td>65.92</td>
<td>65.45</td>
<td>70.19</td>
<td>77.25</td>
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<tr>
<td>Area</td>
<td>cm(^2)</td>
<td>38.26</td>
<td>38.09</td>
<td>35.35</td>
<td>35.49</td>
<td>34.64</td>
<td>34.13</td>
<td>33.65</td>
<td>38.70</td>
<td>46.86</td>
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<tr>
<td>Volume</td>
<td>cm(^3)</td>
<td>535.75</td>
<td>534.28</td>
<td>484.28</td>
<td>484.28</td>
<td>467.06</td>
<td>456.42</td>
<td>446.08</td>
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<tr>
<td>Wet Weight</td>
<td>g</td>
<td>836.76</td>
<td>836.76</td>
<td>874.56</td>
<td>981.51</td>
<td>964.28</td>
<td>953.65</td>
<td>943.31</td>
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<tr>
<td>Water Content (%)</td>
<td></td>
<td>6.65</td>
<td>6.65</td>
<td>24.21</td>
<td>25.10</td>
<td>22.90</td>
<td>21.55</td>
<td>20.23</td>
<td>20.23</td>
<td>20.23</td>
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<tr>
<td>Dry Weight (g)</td>
<td></td>
<td>784.59</td>
<td>784.59</td>
<td>784.59</td>
<td>784.59</td>
<td>784.59</td>
<td>784.59</td>
<td>784.59</td>
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<tr>
<td>Wet Density (g/cm(^3))</td>
<td>1.562</td>
<td>1.566</td>
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<td>Dry Density (g/cm(^3))</td>
<td>1.464</td>
<td>1.468</td>
<td>1.620</td>
<td>1.620</td>
<td>1.680</td>
<td>1.719</td>
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<tr>
<td>Specific Gravity of Solids</td>
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<td>2.73</td>
<td>2.73</td>
<td>2.73</td>
<td>2.73</td>
<td>2.73</td>
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<tr>
<td>Solids Volume (cm(^3))</td>
<td>287.394</td>
<td>287.394</td>
<td>287.394</td>
<td>287.394</td>
<td>287.394</td>
<td>287.394</td>
<td>287.394</td>
<td>287.394</td>
<td>287.394</td>
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<tr>
<td>Void Volume (cm(^3))</td>
<td>246.353</td>
<td>246.890</td>
<td>196.890</td>
<td>196.890</td>
<td>179.662</td>
<td>169.029</td>
<td>158.688</td>
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<tr>
<td>Water Volume (cm(^3))</td>
<td>52.175</td>
<td>52.175</td>
<td>189.975</td>
<td>196.926</td>
<td>179.698</td>
<td>169.085</td>
<td>158.724</td>
<td>158.724</td>
<td>158.724</td>
<td>158.724</td>
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<tr>
<td>Void Rate (e) (%)</td>
<td></td>
<td>0.864</td>
<td>0.859</td>
<td>0.685</td>
<td>0.685</td>
<td>0.625</td>
<td>0.588</td>
<td>0.552</td>
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<tr>
<td>Saturation Ratio (%)</td>
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<td>21.01</td>
<td>21.13</td>
<td>96.49</td>
<td>100.02</td>
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<tr>
<td>Effective Confining Stress (kPa)</td>
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<td>50.0</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>200.0</td>
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</table>

#### Shearing (CU)

- Skempton's B Parameter: 0.98
- Back Pressure before shearing: 600.0 kPa
- Confining Stress (\(\sigma_3\)) before shearing: 200 kPa
- Shear Strain Rate: 0.0185 mm/ min

### At Maximum Stress Ratio

- Axial Stain %: 13.06

### At Maximum Deviator Stress:

- Axial Stain %: 28.19
- Deviator Stress kPa: 177.5
- \(\phi'\) (°): 37.5
- \(c'\) (assumed) kPa: 0
- \(\varepsilon\) (assumed) kPa: 0

### Note:
Using Cambridge method

### Test Photos:

Before Test

After Test
Triaxial CIU Test - Charts

(ASTM D4767)

PROJECT NO. : A03353A01
PROJECT : NWM CVO NTSF TEST
SAMPLE : Tailings
Details: $\phi = 0.85$

Stress Path

Excess Pore Pressure - Axial Strain

Deviator Stress - Strain

Stress Ratio - Strain

Consolidation
Volumetric Strain - Time

Consolidation
Effective Radial Stress - Time
Annexure EJ
Interpreted CPTu
Notes:
- Test code: CPT-N1-1
- Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
- Depth to Water: 1.9 m
- Geostatic stress ratio $K_o = 0.7$
- Contractors: Insitu Geotech Services
- Date tested: 13/01/2017
- Coordinates: 55 H 085192, 6201423

Legend:
- Unit A
- Unit B
- Unit C
- Hydrostatic pressure
- Water table depth

Soil Behavior Type, $I_{c(B&J)}$
- sands: clean to silty
- clayey silt to silty clay
- silty sand to sandy silt
- gravelly sand to sand
- clays

Friction ratio, $F$ (%)

Pore pressure, $u_c$ (MPa)

Friction, $f$ (MPa)

Tip resistance, $q_t$ (MPa)

Hydrostatic pressure shown as light blue line

Independent Technical Review Board

Cadia NTSS Failure

Results of CPTu Sounding CPT-N1-1

Drawn by: BM
Reviewed by: IG

APPENDIX E - ANNEXURE EJ
FIGURE EJ1
Test Information

Test code: CPT-N1-1
Depth to Water: 1.9 m
Coordinates: 55 H 0868192, 6291423
Date tested: 13/01/2017
Contractor: Insitu Geotech Services

Legend

- Unit A
- Unit B
- Unit C
- Hydrostatic pressure
- Water table depth

Notes:
- Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
- Geostatic stress ratio \( K_o = 0.7 \)

Cadia NTSF Failure
Independent Technical Review Board
Interpreted Results of CPTu Sounding CPT-N1-1

Drawn by: BM
Reviewed by: IG

APPENDIX E - ANNEXURE EJ

FIGURE EJ2
Test Information

- **Test code:** CPT-N1-1
- **Depth to Water:** 1.9 m
- **Coordinates:** 55H 0685192, 6291423
- **Date tested:** 13/01/2017
- **Contractor:** Insitu Geotech Services

Notes:
- Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
- Geostatic stress ratio $K_0 = 0.7$

Legend

- Unit A
- Unit B
- Unit C
- Hydrostatic pressure
- Water table depth

FIGURE EJ3

**Cadia NTSF Failure**

Independent Technical Review Board


Plot for CPT-N1-1

Drawn by: BM

Reviewed by: IG
Notes:
- Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
- Geostatic stress ratio \( K_o = 0.7 \)
- Date tested: 13/01/2017
- Contractor: Insitu Geotech Services

Legend
- Unit A
- Unit B
- Unit C
- Hydrostatic pressure
- Water table depth

Test Information
- Test code: CPT-N2-1
- Depth to Water: 4.1 m
- Coordinates: 55 H 0685192, 6291423
- Date tested: 13/01/2017
- Contractor: Insitu Geotech Services

Drawn by: BM
Reviewed by: IG

Cadia NTFS Failure
Independent Technical Review Board
Results of CPTu Sounding CPT-N2-1

APPENDIX E - ANNEXURE EJ
FIGURE EJ4
Test Information

- **Test code:** CPT-N2-1
- **Depth to Water:** 4.1 m
- **Coordinates:** 55 H 0685192, 6291423
- **Date tested:** 13/01/2017
- **Contractor:** Insitu Geotech Services

Legend

- **Unit A**
- **Unit B**
- **Unit C**
- Hydrostatic pressure
- Water table depth

Notes:

Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³.

Geostatic stress ratio $K_o = 0.7$

**Cadia NTSF Failure**

**Independent Technical Review Board**

**Interpreted Results of CPTu Sounding CPT-N2-1**

**Figure EJ5**
Test Information

Test code: CPT-N2-1
Depth to Water: 4.1 m
Coordinates: 55 H 0685192, 6291423
Date tested: 13/01/2017
Contractor: In situ Geotech Services

Notes:
- Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
- Geostatic stress ratio K₀ = 0.7

Legend

<table>
<thead>
<tr>
<th>Friction ratio F: %</th>
<th>Legend</th>
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</thead>
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<tr>
<td>0.1</td>
<td>Unit A</td>
</tr>
<tr>
<td>1.1</td>
<td>Unit B</td>
</tr>
<tr>
<td>10</td>
<td>Unit C</td>
</tr>
<tr>
<td>100</td>
<td>Hydrostatic pressure</td>
</tr>
<tr>
<td>1000</td>
<td>Water table depth</td>
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</table>

Updated SBTn chart based on Q tn–Fr (Robertson, 2016)

Notes:
- Demarcation between strain softening and strain hardening behaviour following initial liquefaction (Shuttle & Cunning, 2008)

Screening-level liquefaction assessment chart for sand and silts showing Ic contours (Jeffries & Been 2016). State parameter contours based on (Shuttle & Cunning, 2008)

Cadia NTSF Failure
Independent Technical Review Board
Plot for CPT-N2-1

Drawn by: BM
Reviewed by: IO

APPENDIX E - ANNEXURE EJ

FIGURE EJ46
Test Information

Test code: CPT-N3-1
Depth to Water: 11.5 m
Coordinates: 55 H 0885192, 6291423
Date tested: 13/01/2017
Contractor: Insitu Geotech Services

Legend

Unit A
Unit B
Unit C
Hydrostatic pressure
Water table depth

Notes:

Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
Geostatic stress ratio K₀ = 0.7

Cadia NTFS Failure
Independent Technical Review Board
Results of CPTu Sounding CPT-N3-1

Drawn by: BM
Reviewed by: IG

APPENDIX E - ANNEXURE EJ

FIGURE EJ7
Test code: CPT-N3-1
Depth to Water: 11.5 m
Coordinates: 55 H 0685192, 6291423
Date tested: 13/01/2017
Contractor: Insitu Geotech Services

Notes:
Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
Geostatic stress ratio $K_o = 0.7$

Cadia NTSF Failure
Independent Technical Review Board
Interpreted Results of CPTu Sounding CPT-N3-1

Legend
- Unit A
- Unit B
- Unit C
- Hydrostatic pressure
- Water table depth

APPENDIX E - ANNEXURE EJ
FIGURE EJ8
Test Information

Test code: CPT-N3-1
Depth to Water: 11.5 m
Coordinates: 55 H 0685192, 6291423
Date tested: 13/01/2017
Contractor: Insitu Geotech Services

Legend

Unit A
Unit B
Unit C
Hydrostatic pressure
Water table depth

Notes:
Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
Geostatic stress ratio K₀ = 0.7

Cadia NTSF Failure
Independent Technical Review Board
Plot for CPT-N3-1

Drawn by: BM
Reviewed by: IG
Test Information

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<thead>
<tr>
<th>Test Information</th>
<th>Legend</th>
<th>Notes</th>
</tr>
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<td></td>
<td>Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³. Geostatic stress ratio $K_o = 0.7$.</td>
</tr>
<tr>
<td>Depth to Water: 1.0 m</td>
<td>Unit A</td>
<td></td>
</tr>
<tr>
<td>Coordinates: 55 H 0865192, 6291423</td>
<td>Unit B</td>
<td></td>
</tr>
<tr>
<td>Date tested: 14/01/2017</td>
<td>Unit C</td>
<td></td>
</tr>
<tr>
<td>Contractor: Insitu Geotech Services</td>
<td>Hydrostatic pressure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Water table depth</td>
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</tr>
</tbody>
</table>

Cadia NTSC Failure
Independent Technical Review Board

APPENDIX E - ANNEXURE EJ

FIGURE EJ10
Test Information

Test code: CPT-N01
Depth to Water: 1.0 m
Coordinates: S55 H 0685192, 6291423
Date tested: 14/01/2017
Contractor: Insitu Geotech Services

Legend

- **Unit A**
- **Unit B**
- **Unit C**
- Hydrostatic pressure
- Water table depth

Notes:

Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
Geostatic stress ratio \( K_0 = 0.7 \)

Cadia NTSF Failure
Independent Technical Review Board

Interpretation of CPTu Sounding CPT-N01

Drawn by: BM
Reviewed by: IG

APPENDIX E - ANNEXURE EJ

FIGURE EJ11
Test Information

Test code: CPT-N01
Depth to Water: 1.0 m
Coordinates: 55 H 0685192, 6291423
Date tested: 14/01/2017
Contractor: Insitu Geotech Services

Legend

Unit A
Unit B
Unit C
Hydrostatic pressure
Water table depth

Notes:
Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
Geostatic stress ratio Kₒ = 0.7

Cadia NTSF Failure
Independent Technical Review Board

Screening-level liquefaction assessment chart for sand and silts showing Ic contours (Jeffaries & Been 2016). State parameter contours based on (Shuttle & Cunning, 2008)

Dimensionsless penetration resistance, Q (1-Bq) + 1

Friction ratio \( \psi \): %

Gravelly sands
Sands to sand some silt
Silty sands to sandy silts
Clayey silts
Clays and other sensitive soils

Normalized Cone Resistance, \( Q_{tn} \)

Friction ratio \( \psi \): %

Sand like - Dilative
Sand like - Contractive
Clay like - Contractive - Sensitive
Transitional - Contractive
Clay like - Dilative
Transitional - Dilative

Dimensionless penetration resistance, Q (1-Bq) + 1

Updated SBTn chart based on \( Q_{tn}-Fr \) (Robertson, 2016)

Notes:
Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
Geostatic stress ratio Kₒ = 0.7
Test code: CPT-N02

Depth to Water: 2.7 m
Coordinates: 55 H 0685192, 6291423
Date tested: 12/1/2017
Contractor: Insitu Geotech Services

Notes:
- Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³.
- Geostatic stress ratio K_o = 0.7

Cadia NTSE Failure
Independent Technical Review Board
Results of CPTu Sounding CPT-N02

Legend

- Unit A
- Unit B
- Unit C
- Hydrostatic pressure
- Water table depth

Friction, f (MPa)
Pore pressure, u (MPa)
Friction ratio, F (%)
Test Information

Test code: CPT-N02
Depth to Water: 2.7 m
Coordinates: 55 H 0685192, 6291423
Date tested: 12/1/2017
Contractor: Insitu Geotech Services

Legend

- Unit A
- Unit B
- Unit C
- Hydrostatic pressure
- Water table depth

Notes:

Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
Geostatic stress ratio K₀ = 0.7

Cadia NTSF Failure
Independent Technical Review Board
Interpretation of CPTu Sounding CPT-N02

Drawn by: BM
Reviewed by: IG
Test Information

Test code: CPT-N02
Depth to Water: 2.7 m
Coordinates: 55 H 0685192, 6291423
Date tested: 12/1/2017
Contractor: Insitu Geotech Services

Legend

Unit A
Unit B
Unit C
Hydrostatic pressure
Water table depth

Notes:
Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
Geostatic stress ratio Kₒ = 0.7

Cadia NTSF Failure
Independent Technical Review Board
Plot for CPT-N02

Drawn by: BM
Reviewed by: IG

APPENDIX E - ANNEXURE EJ
FIGURE EJ15
Test Information

Test code: CPT-N03
Depth to Water: 3.6 m
Coordinates: 55H 065129, 6291423
Date tested: 13/01/2017
Contractor: Insitu Geotech Services

Notes:
Soil unit weight 19.5 kN/m² above water and 19.5 kN/m² below water; water unit weight 7.6 kN/m²
Geostatic stress ratio $K_0 = 0.7$

Legend

- Unit A
- Unit B
- Unit C

- Hydrostatic pressure
- Water table depth

Cadia NTTF Failure
Independent Technical Review Board
Results of CPTu Sounding CPT-N03

Drawn by: BM
Reviewed by: IG
Test Information

Test code: CPT-N03
Depth to Water: 3.6 m
Coordinates: 55 H 0685192, 6291423
Date tested: 13/01/2017
Contractor: Insitu Geotech Services

Legend

State parameter, \( \varphi \) (deg)

\( \varphi \) (deg)

Undrained strength ratio

Brittleness

Notes:
Soil unit weight 19.5 kN/m\(^3\) above water and 19.5 kN/m\(^3\) below water; water unit weight 7.6 kN/m\(^3\)
Geostatic stress ratio \( K_0 = 0.7 \)

Legend

Cadia NTSF Failure
Independent Technical Review Board
Interpretation of CPTu Sounding CPT-N03

Drawn by: BM
Reviewed by: IG
Test Information

Test code: CPT-N03
Depth to Water: 3.6 m
Coordinates: 55 H 0885192, 621423
Date tested: 13/01/2017
 Contractor: Insitu Geotech Services

Legend

Unit A
Unit B
Unit C
Hydrostatic pressure
Water table depth

Notes:

Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
Geostatic stress ratio K₀ = 0.7

Cadia NTSF Failure
Independent Technical Review Board
Plot for CPT-N03

Drawn by: BM
Reviewed by: IG

APPENDIX E - ANNEXURE EJ
FIGURE EJ18
Test Information

Test code: CPT-N04
Depth to Water: 4.2
Coordinates: 55 H 068517, 6291152
Date tested: 16/01/2017
Contractor: Insitu Geotech Services

Legend

Unit A
Unit B
Unit C
Hydrostatic pressure
Water table depth

Notes:
Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
Geostatic stress ratio Kₒ = 0.7

Cadia NT SF Failure
Independent Technical Review Board
Results of CPTu Sounding CPT-N04

Drawn by: BM
Reviewed by: IG

APPENDIX E - ANNEXURE EJ
FIGURE EJ19
Test Information

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<tr>
<th>Test code:</th>
<th>CPT-N04</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth to Water:</td>
<td>4.2 m</td>
</tr>
<tr>
<td>Coordinates:</td>
<td>S5 H 088517, 6291152</td>
</tr>
<tr>
<td>Date tested:</td>
<td>16/01/2017</td>
</tr>
<tr>
<td>Contractor:</td>
<td>Insitu Geotech Services</td>
</tr>
</tbody>
</table>

Legend

<table>
<thead>
<tr>
<th>Unit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Unit A</td>
</tr>
<tr>
<td>B</td>
<td>Unit B</td>
</tr>
<tr>
<td>C</td>
<td>Unit C</td>
</tr>
<tr>
<td></td>
<td>Hydrostatic pressure</td>
</tr>
<tr>
<td></td>
<td>Water table depth</td>
</tr>
</tbody>
</table>

Notes:

- Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
- Geostatic stress ratio \( K_0 = 0.7 \)
- Cadia NTSF Failure
- Independent Technical Review Board
- Interpreted Results of CPTu Sounding CPT-N04

APPENDIX E - ANNEXURE EJ

FIGURE EJ20
Test Information

- **Test code:** CPT-N04
- **Depth to Water:** 4.2 m
- **Coordinates:** 55 H 068517, 6291152
- **Date tested:** 16/01/2017
- **Contractor:** Insitu Geotech Services

Legend

- **Unit A**
- **Unit B**
- **Unit C**
- **Hydrostatic pressure**
- **Water table depth**

Notes:

- Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
- Geostatic stress ratio $K_s = 0.7$

Cadia NTSF Failure
Independent Technical Review Board
Plot for CPT-N04

Drawn by: BM
Reviewed by: IG

APPENDIX E - ANNEXURE EJ

FIGURE EJ21
Test Information

Test code: CPT-N05
Depth to Water: 7.6 m
Coordinates: 55 H 0685836, 6290978
Date tested: 16/01/2017
Contractor: In situ Geotech Services

Legend

Unit A
Unit B
Unit C
Hydrostatic pressure
Water table depth

Notes:
Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
Geostatic stress ratio K₀ = 0.7

Cadia NTSF Failure
Independent Technical Review Board
Results of CPTu Sounding CPT-N04

APPENDIX E - ANNEXURE EJ
FIGURE EJ22
Test Information

Test code: CPT-N05
Depth to Water: 7.6 m
Coordinates: 55 H 085836, 6290978
Date tested: 16/01/2017
Contractor: Insitu Geotech Services

Legend

- Unit A
- Unit B
- Unit C
- Hydrostatic pressure
- Water table depth

Notes:
Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
Geostatic stress ratio K₀ = 0.7

Cadia NTSF Failure
Independent Technical Review Board
Interpreted Results of CPTu Sounding CPT-N05

Drawn by: BM
Reviewed by: IG
Test Information

- Test code: CPT-N05
- Depth to Water: 7.6 m
- Coordinates: 55 H 085836, 6290978
- Date tested: 16/01/2017
- Contractor: Insitu Geotech Services

Notes:
- Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
- Geostatic stress ratio $K_o = 0.7$

Legend

- Unit A
- Unit B
- Unit C
- Hydrostatic pressure
- Water table depth

Legend

- Clay like - Contractive - Sensitive
- Sand like - Contractive
- Sand like - Dilative
- Clay like - Dilative
- Transitional - Contractive
- Transitional - Dilative
- Clay like - Dilative

Screening-level liquefaction assessment chart for sand and silts showing $I_c$ contours (Jefferies & Been 2016). State parameter contours based on (Shuttle & Cuning, 2008)

Updated SBTrn chart based on $Q_{tn}$-$Fe$ (Robertson, 2016)

Cadia NTSF Failure
Independent Technical Review Board
Plot for CPT-N05

Drawn by: BM
Reviewed by: IG

FIGURE EJ24
Test Information

Test code: CPT-N06
Depth to Water: 3.7 m
Coordinates: 55 H 085192, 6291423
Date tested: 17/01/2017
Contractor: Insitu Geotech Services

Legend

- Unit A
- Unit B
- Unit C
- Hydrostatic pressure
- Water table depth

Notes:
Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
Geostatic stress ratio K₀ = 0.7

Cadia NTSF Failure
Independent Technical Review Board
Results of CPTu Sounding CPT-N06

Drawn by: BM
Reviewed by: IG

APPENDIX E - ANNEXURE EJ
FIGURE EJ25
### Test Information

- **Test code:** CPT-N06
- **Depth to Water:** 3.7 m
- **Coordinates:** 55 H 0685192, 6291423
- **Date tested:** 17/01/2017
- **Contractor:** Insitu Geotech Services

### Notes:
- Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
- Geostatic stress ratio $K_o = 0.7$

### Legend
- **Unit A**
- **Unit B**
- **Unit C**
- Hydrostatic pressure
- Water table depth

### Interpretation of CPTu Sounding CPT-N06

- **Undrained strength ratio**
- **Brittleness**

- **Gmax from SSDMT**

---

**Figure EJ26**

**Cadia NTFS Failure**

**Independent Technical Review Board**

**Interpreted Results of CPTu Sounding CPT-N06**

---

**APPENDIX E - ANNEXURE EJ**

**FIGURE EJ26**
Test Information

Test code: CPT-N06
Depth to Water: 3.7 m
Coordinates: 55 H 0685192, 6291423
Date tested: 17/01/2017
Contractor: Insitu Geotech Services

Notes:
Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
Geostatic stress ratio K_G = 0.7

Legend

<table>
<thead>
<tr>
<th></th>
<th>Unit A</th>
<th>Unit B</th>
<th>Unit C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hydrostatic pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Water table depth</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Drawing: BM
Reviewed by: IG

APPENDIX E - ANNEXURE EJ

FIGURE EJ27
Test Information

Test code: CPT-N07
Depth to Water: 1.9 m
Coordinates: 55 H 0685192, 6291423
Date tested: 17/01/2017
Contractor: Insitu Geotech Services

Legend

Unit A
Unit B
Unit C
Hydrostatic pressure
Water table depth

Notes:
Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
Geostatic stress ratio K₀ = 0.7

Cadia NTSF Failure
Independent Technical Review Board
Results of CPTu Sounding CPT-N07

Drawn by: BM
Reviewed by: IG
Test Information

Test code: CPT-N07
Depth to Water: 1.9 m
Coordinates: 55 H 0685192, 6291423
Date tested: 17/01/2017
Contractor: Insitu Geotech Services

Legend

- Unit A
- Unit B
- Unit C
- Hydrostatic pressure
- Water table depth
- Depth below ground (m)
- Undrained strength ratio
- Brittleness
- Gmax from SSDMT
- Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
- Geostatic stress ratio K₀ = 0.7

Notes:

Cadia NTSF Failure
Independent Technical Review Board
Interpreted Results of CPTu Sounding CPT-N07
Test Information

Test code: CPT-N07
Depth to Water: 1.9 m
Coordinates: 55 H 0885192, 6291423
Date tested: 17/01/2017
Contractor: Insitu Geotech Services

Notes:
Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
Geostatic stress ratio Kₒ = 0.7

Legend
Unit A
Unit B
Unit C
Hydrostatic pressure
Water table depth

Cadia NTSF Failure
Independent Technical Review Board
Plot for CPT-N07

Drawn by: BM
Reviewed by: IG

APPENDIX E - ANNEXURE EJ

FIGURE EJ30
Test Information

- Test code: CPT-N08A
- Depth to Water: 7.1 m
- Coordinates: 55 H 0685192, 6291423
- Date tested: 11/2/2017
- Contractor: Insitu Geotech Services

Legend

- Unit A
- Unit B
- Unit C
- Hydrostatic pressure
- Water table depth

Notes:

- Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
- Geostatic stress ratio K₀ = 0.7

Cadia NTSF Failure
Independent Technical Review Board

Results of CPTu Sounding CPT-N08A

Drawn by: BM
Reviewed by: IG
Test Information

Test code: CPT-N08A
Depth to Water: 7.1 m
Coordinates: 55 H 0885192, 6291423
Date tested: 11/2/2017
Contractor: Insitu Geotech Services

Legend

- Unit A
- Unit B
- Unit C
- Hydrostatic pressure
- Water table depth

Notes:
Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
Geostatic stress ratio K₀ = 0.7

Cadia NTSF Failure
Independent Technical Review Board
Interpreted Results of CPTu Sounding CPT-N08A

Drawn by: BM
Reviewed by: IG

APPENDIX E - ANNEXURE EJ
FIGURE EJ32
**Test Information**

- **Test code:** CPT-N08A
- **Depth to Water:** 7.1 m
- **Coordinates:** 55 H 0685192, 6291423
- **Date tested:** 11/2/2017
- **Contractor:** Insitu Geotech Services

**Legend**

- Unit A
- Unit B
- Unit C

**Notes:**
- Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³.
- Geostatic stress ratio K₀ = 0.7

**Cadia NTSF Failure**

Independent Technical Review Board
Plot for CPT-N08A

**Legend**

- Clay like - Dilative
- Sand like - Dilative
- Sand like - Contractive
- Transitional - Contractive
- Clay like - Contractive - Sensitive
- Gravelly sands
- Sands to sand some silt
- Silty sands to sandy silts
- Clay and other sensitive soils

**Screening-level liquefaction assessment chart for sand and silts showing Ic contours (Jefferies & Been 2016). State parameter contours based on (Shuttle & Cunning, 2008).**

**Updated SBBn chart based on Qtn–Fr (Robarston, 2016).**
Test Information

- **Test code:** CPT-N09
- **Depth to Water:** 7.1 m
- **Coordinates:** 55 H 0685192, 6291423
- **Date tested:** 10/2/2017
- **Contractor:** Insitu Geotech Services

Notes:
- Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
- Geostatic stress ratio $K_o = 0.7$

Legend

- Unit A
- Unit B
- Unit C
- Hydrostatic pressure
- Water table depth

Cadia NTSG Failure
Independent Technical Review Board

Results of CPTu Sounding CPT-N09

Drawn by: BM
Reviewed by: IG

FIGURE EJ34
Test code: CPT-N09
Depth to Water: 7.1 m
Coordinates: 55 H 0685192, 6291423
Date tested: 10/2/2017
Contractor: Insitu Geotech Services

Legend
- Unit A
- Unit B
- Unit C
- Hydrostatic pressure
- Water table depth

Notes:
Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
Geostatic stress ratio K₀ = 0.7

Cadia NTSC Failure
Independent Technical Review Board
Interpreted Results of CPTu Sounding CPT-N09

Drawn by: BM
Reviewed by: IG

APPENDIX E - ANNEXURE EJ
FIGURE EJ35
Test Information

Test code: CPT-N09
Depth to Water: 7.1 m
Coordinates: 35 H 0685192, 6291423
Date tested: 10/2/2017
Contractor: Insitu Geotech Services

Notes:
- Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
- Geostatic stress ratio K₀ = 0.7

Legend

- Unit A
- Unit B
- Unit C
- Hydrostatic pressure
- Water table depth

Cadia NTSF Failure
Independent Technical Review Board
Plot for CPT-N09

Screening-level liquefaction assessment chart for sand and silts showing ic contours (Jefferies & Been 2016). State parameter contours based on (Shuttle & Cunning, 2008). Demarcation between strain softening and strain hardening behaviour following initial liquefaction (Shuttle & Cunning, 2008).

Updated SBTn chart based on Q–tn–Fr (Robertson, 2016)
Test Information

Test code: CPT-N10
Depth to Water: 7.1 m
Coordinates: 55 H 0685192, 6291423
Date tested: 10/2/2017
Contractor: Insitu Geotech Services

Legend

Unit A
Unit B
Unit C
Hydrostatic pressure
Water table depth

Notes:
Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
Geostatic stress ratio K₀ = 0.7

Cadia NTGF Failure
Independent Technical Review Board
Results of CPTu Sounding CPT-N09

Drawn by: BM
Reviewed by: IG

APPENDIX E - ANNEXURE EJ
FIGURE EJ37
Notes:
Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
Geostatic stress ratio K₀ = 0.7

Test Information
Test code: CPT-N10
Depth to Water: 7.1 m
Coordinates: 55 H 0885192, 6291423
Date tested: 10/2/2017
Contractor: Insitu Geotech Services

Legend
Unit A
Unit B
Unit C
Hydrostatic pressure
Water table depth

Cadia NTSF Failure
Independent Technical Review Board
Interpreted Results of CPTu Sounding CPT-N10

Drawn by: BM
Reviewed by: IG
Test Information

Test code: CPT-N10
Depth to Water: 7.1 m
Coordinates: 55 H 0685192, 6291423
Date tested: 10/2/2017
Contractor: Insitu Geotech Services

Notes:
Soil unit weight 19.5 kN/m³ above water and 19.5 kN/m³ below water; water unit weight 7.6 kN/m³
Geostatic stress ratio K₀ = 0.7

Legend

Unit A
Unit B
Unit C
Hydrostatic pressure
Water table depth

Cadia NTSF Failure
Independent Technical Review Board
Plot for CPT-N10

Drawn by: BM
Reviewed by: IG

APPENDIX E - ANNEXURE EJ

FIGURE EJ39
Annexure EK
Oedometer Test Certificates
# Oedometer Test Report

**Test Method:** AS1289.6.6.1, 3.5.1

**Client:** Hatch Pty Ltd  
**Address:** PO Box 425 SPRING HILL QLD 4004  
**Project:** H356804 - Cadia NTSF Failure  
**Client Id.:** CE408 - DH401 - PS1  
**Depth (m):** 11.00-11.50

**Description:** SILTY SAND - grey

<table>
<thead>
<tr>
<th>Applied Pressure (kPa)</th>
<th>Void Ratio</th>
<th>% Consolidation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.35</td>
<td>0.60</td>
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<tr>
<td>0.40</td>
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<td>0.55</td>
<td>0.40</td>
<td></td>
</tr>
<tr>
<td>0.60</td>
<td>0.35</td>
<td></td>
</tr>
</tbody>
</table>

- **Wet Density (t/m³):** 2.13  
- **Particle Density (t/m³):** 2.72  
- **Initial Moisture (%):** 22.2  
- **Initial Voids Ratio:** 0.561  
- **Initial Degree of Saturation (%):** 100.0

**Test Condition:** Inundated on load

Undisturbed sample supplied by the client  
Remarks: Tested as Received

---

The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards. Tested at Trilab Brisbane Laboratory.

Authorised Signatory

C. Channon
### OEDOMETER TEST REPORT

**Test Method:** AS1289.6.6.1, 3.5.1

**Client:** Hatch Pty Ltd  
**Report No.:** 18080185-OED

**Address:** PO Box 425 SPRING HILL QLD 4004  
**Workorder No.:** 4644

**Project:** H356804 - Cadia NTSF Failure

**Client Id.:** CE408 - DH401 - PS1  
**Depth (m):** 11.00-11.50

**Description:** SILTY SAND- grey

### TEST RESULTS

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<thead>
<tr>
<th>Stage</th>
<th>Load (kPa)</th>
<th>Cc</th>
<th>k (m/s)</th>
<th>Cv (m²/yr)</th>
<th>Mv (kPa x10⁻³)</th>
<th>Cₐ x 10⁻³</th>
<th>% Consolidation</th>
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**Remarks:** Tested as Received

---

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C. Channon

Laboratory Number 9926

Page 2 of 2

REPO3102

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Trilab Pty Ltd  
ABN 25 065 630 506
OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client: Hatch Pty Ltd

Report No.: 18080187-OED

Workorder No. 4644

Address: PO Box 425 SPRING HILL QLD 4004

Test Date: 13/08/2018

Report Date: 3/09/2018

Project: H356804 - Cadia NTSF Failure

Client Id.: CE408 - DH401 - PS3

Depth (m): 25.00-25.45

Description: SILTY SAND- grey

---

Wet Density (t/m$^3$): 1.99
Initial Moisture (%): 19.2

Test Condition: Inundated on load

Applied Pressure (kPa) vs Void Ratio and % Consolidation

- Void Ratio
- % Consolidation

Particle Density (t/m$^3$): 2.66
Initial Voids Ratio: 0.591
Initial Degree of Saturation (%): 87.5

Undisturbed sample supplied by the client

Remarks: Tested as Received

---

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Authorised Signatory

C. Channon

Laboratory Number 9926
## OEDOMETER TEST REPORT

**Test Method:** AS1289.6.6.1, 3.5.1

| Client: | Hatch Pty Ltd | Report No.: | 18080187-OED |
| Address: | PO Box 425 SPRING HILL QLD 4004 | Workorder No.: | 4644 |
| Project: | H356804 - Cadia NTSF Failure | Test Date: | 13/08/2018 |
| Client Id.: | CE408 - DH401 - PS3 | Report Date: | 3/09/2018 |

**Description:** SILTY SAND- grey

### TEST RESULTS

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<th>Cv (m²/yr)</th>
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**Remarks:** Tested as Received

---

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Trilab Pty Ltd
ABN 25 065 630 506

Authorised Signatory
C. Channon

Laboratory Number 9926

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REP03102
OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client: Hatch Pty Ltd

Address: PO Box 425 SPRING HILL QLD 4004

Project: H356804 - Cadia NTSF Failure

Client Id.: CE407 - DH402 - PS1

Description: SILTY SAND- grey

Wet Density (t/m$^3$): 2.02

Initial Moisture (%): 25.0

Test Condition: Inundated on load

Particle Density (t/m$^3$): 2.70

Initial Voids Ratio: 0.674

Initial Degree of Saturation (%): 100.8

Undisturbed sample supplied by the client

Remarks: Tested as Received

Page 1 of 2

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Authorised Signatory

C. Channon

Laboratory Number
9926
**OEDOMETER TEST REPORT**

**Test Method:** AS1289.6.6.1, 3.5.1

**Client:** Hatch Pty Ltd  
**Report No.:** 18080189-OED

**Address:** PO Box 425 SPRING HILL QLD 4004  
**Workorder No:** 4644

**Test Date:** 17/08/2018  
**Project:** H356804 - Cadia NTSF Failure

**Client Id.:** CE407 - DH402 - PS1  
**Depth (m):** 12.00-12.45

**Description:** SILTY SAND - grey

### TEST RESULTS

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<th>k (m/s)</th>
<th>Cv (m²/yr)</th>
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**Remarks:** Tested as Received
OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client: Hatch Pty Ltd

Address: PO Box 425 SPRING HILL QLD 4004

Project: H356804 - Cadia NTSF Failure

Client Id.: CE413 - DH404 - PS2

Depth (m): 25.95-26.40

Description: SILTY SAND - grey

---

Wet Density (t/m³): 2.20
Initial Moisture (%): 23.5
Test Condition: Inundated on load

Particle Density (t/m³): 2.74
Initial Voids Ratio: 0.538
Initial Degree of Saturation (%): 100.0

Undisturbed sample supplied by the client
Remarks: Tested as Received

---

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Tested at Trilab Brisbane Laboratory.

Authorised Signatory

C. Channon

Laboratory Number 9926

ABN 25 065 630 506

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**OEDOMETER TEST REPORT**

**Test Method:** AS1289.6.6.1, 3.5.1

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### TEST RESULTS

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Authorised Signatory

C. Channon

Laboratory Number

9926

Page 2 of 2

REP03102
Annexure EL
Bender Element Test Certificates
### Shear Wave Velocity Measurement on Triaxial Specimen Test Report

- **Client:** Hatch
- **Address:** 61 Petrie Terrace, Brisbane
- **Project No.:** 18101980
- **Project:** NTSF Embankment Failure ITRB
- **Sample ID:** TC1
- **Location:** Cadia Mine
- **Test ID:** 18018 - si-1 BE loose

#### Preparation Notes:
- Moist tamped loose

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<th>Geostatic Stress Ratio, K₀</th>
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<th>Void Ratio, e</th>
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<td>0.500</td>
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#### Diagrams:
- Shear Wave Velocity, Vs vs Mean Effective Stress, p’
- Void Ratio, e vs Mean Effective Stress, p’
- Small Strain Shear Modulus, G₀ vs Mean Effective Stress, p’

---

**Preparation Notes:**
- Moist tamped loose

**Tested by:** Y. Guadalupe

**Reviewed by:** R. Fanni

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
Shear Wave Velocity Measurement on Triaxial Specimen
Test Report

Client: Hatch
Date: 24/10/2018

Address: 61 Petrie Terrace, Brisbane
Project No.: 18101980

Project: NTSC Embankment Failure ITRB
Sample ID: TC1

Location: Cadia Mine
Test ID: 18018 - si-1 BE loose

- Initial Height (mm): 133.2
- Final Height (mm): 114.9
- B Response (%): 97
- Initial Dry Density (t/m³): 1.52
- Final Dry Density (t/m³): 1.826
- Input Signal Frequency (Hz): 2500
- Initial Void Ratio (-): 0.80
- Final Void Ratio (-): 0.50
- Input Signal Amplitude (V): 14.0
- Initial Water Content (%): 29.3
- Final Water Content (%): 18.3

Preparation Notes: Moist tamped loose
 Tested by: Y. Guadalupe
 Reviewed by: R. Fanni

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
Shear Wave Velocity Measurement on Triaxial Specimen
Test Report

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Location: Cadia Mine

Date: 24/10/2018
Project No.: 18101980
Project: NTSF Embankment Failure ITRB
Sample ID: TC1
Test ID: 18018 - si-1 BE loose

Initial Height (mm): 133.2
Final Height (mm): 114.9
Response (%): 97

Initial Void Ratio (-): 0.80
Final Void Ratio (-): 0.50

Initial Water Content (%): 29.3
Final Water Content (%): 18.3

Initial Dry Density (t/m$^3$): 1.52
Final Dry Density (t/m$^3$): 1.83

Input Signal Frequency (Hz): 2500
Input Signal Amplitude (V): 14.0

Moist tamped loose

Tested by: Y. Guadalupe
Reviewed by: R. Fanni
Annexure EM
CSD Triaxial Test Certificates
### Triaxial Test Report

**Constant Shear Drained (CSD) Servo Controlled**

<table>
<thead>
<tr>
<th>Client:</th>
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<th>6/09/2018</th>
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<td>Project No.:</td>
<td>18101980</td>
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<td>Project:</td>
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<td>Sample ID:</td>
<td>HA401 0-2m</td>
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<tr>
<td>Location:</td>
<td>Cadia Mine</td>
<td>Test ID:</td>
<td>18003 - sa-10 CSD loose 200kPa</td>
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<tr>
<td>Initial Height (mm):</td>
<td>144.7</td>
<td>Final Liquor Content (%):</td>
<td>20.9%</td>
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<tr>
<td>Initial Diameter (mm):</td>
<td>64.5</td>
<td>Final Dry Density (t/m³):</td>
<td>1.74</td>
</tr>
<tr>
<td>Trimmings GWC (%):</td>
<td>11.3%</td>
<td>Final Void Ratio (-):</td>
<td>0.57</td>
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<tr>
<td>Initial Dry Density (t/m³):</td>
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<td>Final Liquor Solids Conc. (g/L):</td>
<td>-</td>
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<tr>
<td>Strain Rate (mm/min):</td>
<td>0.03</td>
<td>B Response (%):</td>
<td>99%</td>
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<tr>
<td>Mean Effective Consolidation Stress (kPa):</td>
<td>198</td>
<td></td>
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<tr>
<td>Geostatic Stress Ratio $K_0$ (-):</td>
<td>0.71</td>
<td></td>
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</table>

**Preparation Notes:** Sample was moist tamped to a loose condition

**Sample Before Test**

**Sample After Test**

**Tested by:** K. Koh

**Reviewed by:** R. Fanni
Triaxial Test Report

Constant Shear Drained (CSD) Servo Controlled

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NTSE Embankment Failure ITRB
Location: Cadia Mine

Date: 6/09/2018
Project No.: 18101980
Sample ID: HA401 0-2m
Test ID: 18003 - sa-10 CSD loose 200kPa

Initial Height (mm): 144.7
Initial Diameter (mm): 64.5
Trimmings GWC (%): 11.3%
Initial Dry Density (t/m³): 1.21

Final Liquor Content (%): 20.9
Final Dry Density (t/m³): 1.74
Final Void Ratio (-): 0.57

Geostatic Stress Ratio $K_0 (-)$: 0.71
Mean Effective Consolidation Stress (kPa): 198

Strain Rate (mm/min): 0.03
B Response (%): 99%
Initial Diameter (mm): 64.5
Initial Height (mm): 144.7

Sample was moist tamped to a loose condition

Tested by: K. Koh
Reviewed by: R. Fanni

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
Triaxial Test Report

Constant Shear Drained (CSD) Servo Controlled

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NTSF Embankment Failure ITRB
Location: Cadia Mine

Date: 6/09/2018
Project No.: 18101980
Sample ID: HA401 0-2m
Test ID: 18003 - sa-10 CSD loose 200kPa

Initial Height (mm): 144.7
Initial Diameter (mm): 64.5
Trimmings GWC (%): 11.3%
Initial Dry Density (t/m^3): 1.21

Final Liquor Content (%): 20.9%
Final Dry Density (t/m^3): 1.74
Final Void Ratio (-): 0.57
Final Liquor Solids Conc. (g/L): -

Strain Rate (mm/min): 0.03
B Response (%): 99%
Mean Effective Consolidation Stress (kPa): 198
Geostatic Stress Ratio K₀ (-): 0.71

Preparation Notes: Sample was moist tamped to a loose condition

Tested by: K. Koh
Reviewed by: R. Fanni
### Constant Shear Drained (CSD) Servo Controlled

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project No.:** 18101980  
**Project:** NTWF Embankment Failure ITRB  
**Sample ID:** HA401 0-2m  
**Location:** Cadia Mine  
**Test ID:** 16003 - sa-10 CSD loose 200kPa

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<tr>
<td>Final Liquor Content (%)</td>
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**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh  
**Reviewed by:** R. Fanni

*THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL*
Triaxial Test Report

Constant Shear Drained (CSD) Servo Controlled

Client: Hatch  
Address: 61 Petrie Terrace, Brisbane  
Project No.: 18101980  
Project: NTBF Embankment Failure ITRB  
Sample ID: HA401 0-2m  
Test ID: 18003 - sa-10 CSD loose 200kPa

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Preparation Notes: Sample was moist tamped to a loose condition

Tested by: K. Koh  
Reviewed by: R. Fanni

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
# Triaxial Test Report

## Constant Shear Drained (CSD) Servo Controlled

<table>
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<tr>
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<td>Project:</td>
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<tr>
<td>Date:</td>
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<td>Mean Effective Consolidation Stress (kPa):</td>
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<td>Geostatic Stress Ratio $K_0$ (-):</td>
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## Triaxial Test Report

### Constant Shear Drained (CSD) Servo Controlled

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<td>Test ID:</td>
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### Preparation Notes:
Sample was moist tamped to a loose condition

### Graph

- **Axial Strain (%)**
- **Deviator Stress (kPa)**
- **Shear-induced Pore Pressure (kPa)**

<table>
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<th>Initial Height (mm):</th>
<th>148.0</th>
<th>Final Liquor Content (%):</th>
<th>20.9%</th>
<th>Strain Rate (mm/min):</th>
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<td>Geostatic Stress Ratio $K_0$ (-):</td>
<td>0.75</td>
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</tbody>
</table>

### Diagrams

- Shear-induced Pore Pressure
- Deviator Stress

### Tested by:
R. Fanni

### Reviewed by:
R. Fanni

---

**THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL**
### Triaxial Test Report

**Constant Shear Drained (CSD) Servo Controlled**

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<td>NTSF Embankment Failure ITRB</td>
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</tr>
<tr>
<td>Geostatic Stress Ratio $K_0$ (-):</td>
<td>0.75</td>
</tr>
</tbody>
</table>

Sample was moist tamped to a loose condition

---

**Graph:**

- **Deviator Stress $q$ (kPa):**
- **Mean Effective Stress $p'$ (kPa):**

Tested by: R. Fanni
Reviewed by: R. Fanni
Triaxial Test Report

Constant Shear Drained (CSD) Servo Controlled

Client: Hatch  
Address: 61 Petrie Terrace, Brisbane  
Project: NTSF Embankment Failure IT RB  
Location: Cadia Mine  
Test ID: 18018 - si-9 CSD loose

Date: 8/10/2018  
Project No.: 18101980  
Sample ID: TC1

Initial Height (mm): 148.0  
Final Liquor Content (%): 20.9%  
Strain Rate (mm/min): 0.03  
Strain Rate (mm/min): 351

Initial Diameter (mm): 69.6  
Final Dry Density (t/m$^3$): 1.74  
B Response (%): 99%  
Initial Dry Density (t/m$^3$): 1.22

Trimmings GWC (%): 10.9%  
Final Void Ratio (-): 0.57  
Mean Effective Consolidation Stress (kPa): 351

Initial Height (mm): 148.0  
Final Liquor Content (%): 20.9%  
Strain Rate (mm/min): 0.03  
Strain Rate (mm/min): 351

Initial Diameter (mm): 69.6  
Final Dry Density (t/m$^3$): 1.74  
B Response (%): 99%  
Initial Dry Density (t/m$^3$): 1.22

Trimmings GWC (%): 10.9%  
Final Void Ratio (-): 0.57  
Mean Effective Consolidation Stress (kPa): 351

Volumetric Strain (%)

Axial Strain (%)

Preparation Notes: Sample was moist tamped to a loose condition

Tested by: R. Fanni  
Reviewed by: R. Fanni

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
**Triaxial Test Report**

**Constant Shear Drained (CSD) Servo Controlled**

**Client:** Hatch  
**Date:** 8/10/2018

**Address:** 61 Petrie Terrace, Brisbane  
**Project No.:** 18101980

**Project:** NT SF Embankment Failure ITRB  
**Sample ID:** TC1

**Location:** Cadia Mine  
**Test ID:** 18018 - si-9 CSD loose

- **Initial Height (mm):** 148.0  
- **Final Liquor Content (%):** 20.9%  
- **Strain Rate (mm/min):** 0.03

- **Initial Diameter (mm):** 69.6  
- **Final Dry Density (t/m$^3$):** 1.74  
- **B Response (%):** 99%

- **Trimmings GWC (%):** 10.9%  
- **Final Void Ratio (-):** 0.57  
- **Mean Effective Consolidation Stress (kPa):** 351

- **Initial Dry Density (t/m$^3$):** 1.22  
- **Final Liquor Solids Conc. (g/L):** -  
- **Geostatic Stress Ratio $K_0$ (-):** 0.75

**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** R. Fanni  
**Reviewed by:** R. Fanni

---

**Graph:**

- **Mobilised Friction Angle (Degrees)** vs. **Axial Strain (%)**

---

**Legend:**

- Axial Strain (%)
- Mobilised Friction Angle (Degrees)
Annexure EN
Cyclic Direct Simple Shear (CDSS) Certificates
## Cyclic Direct Simple Shear Test Report

### Client: Hatch

### Address: 61 Petrie Terrace, Brisbane

### Project: NTSF Embankment Failure ITRB

### Location: Cadia Mine

### Test ID: 18018 si-css1 very loose

<table>
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<th>Parameter</th>
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<tbody>
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<td>Vertical Effective Stress (kPa)</td>
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<tr>
<td>Diameter (mm)</td>
<td>100.5</td>
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<td>Shearing Height (mm)</td>
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<td>Final Bulk Density (t/m$^3$)</td>
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<tr>
<td>Final Dry Density (t/m$^3$)</td>
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### Preparation Notes:

- Moist tamped in one layer

### Tested by:

- K. Koh

### Reviewed by:

- R. Fanni

---

![Graph 1](#)  
**Shear Stress (kPa)** versus **Shear Strain (%)**

![Graph 2](#)  
**Shear Stress (kPa)** versus **Vertical Effective Stress (kPa)**
**Monotonic Direct Simple Shear Test Report - Consolidated Undrained**

**Perth Laboratory**
84 Guthrie Street, Osborne Park

---

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<td>Test ID:</td>
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**Preparation Notes:** Moist tamped in one layer

**Tested by:** K. Koh

**Reviewed by:** R. Fanni

---

**Shear Stress (kPa)** vs **Shear Strain (%)**

**Shear Stress (kPa)** vs **Vertical Effective Stress (kPa)**

---

**THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL**
## Cyclic Direct Simple Shear Test Report

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTSF Embankment Failure ITRB  
**Location:** Cadia Mine  

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**Preparation Notes:** Moist tamped in one layer  
**Tested by:** R. Fanni  
**Reviewed by:** R. Fanni

---

### Graph 1: Shear Stress vs. Shear Strain

![Graph showing shear stress vs. shear strain](image1)

### Graph 2: Vertical Effective Stress vs. Shear Stress

![Graph showing vertical effective stress vs. shear stress](image2)
Monotonic Direct Simple Shear Test Report -
Consolidated Undrained

Client: Hatch  Date: 8/09/2018
Address: 61 Petrie Terrace, Brisbane  Project No.: 18101980
Project: NTSF Embankment Failure ITRB  Sample ID: TC1 - Tailings
Location: Cadia Mine  Test ID: 18018 si-css1 very loose

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![Shear Stress vs. Shear Strain Graph]

![Vertical Effective Stress vs. Shear Stress Graph]

Preparation Notes: Moist tamped in one layer  Tested by: R. Fanni
Reviewed by: R. Fanni

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## Cyclic Direct Simple Shear Test Report

**Client:** Hatch  
**Date:** 8/09/2018  
**Address:** 61 Petrie Terrace, Brisbane  
**Project No.:** 18101980  
**Project:** NTSF Embankment Failure ITRB  
**Location:** Cadia Mine  
**Sample ID:** TC1 - Tailings  
**Test ID:** 18018 si-css3 very loose

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**Preparation Notes:** Moist tamped in one layer

**Tested by:** R. Fanni

**Reviewed by:** R. Fanni

---

**Graphs:**

1. **Shear Stress vs. Shear Strain (%)**
2. **Shear Stress vs. Vertical Effective Stress (kPa)**

---

**Additional Information:**
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### Monotonic Direct Simple Shear Test Report - Consolidated Undrained

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTSF Embankment Failure ITRB  
**Location:** Cadia Mine  
**Project No.:** 18101980  
**Sample ID:** TC1 - Tailings  
**Date:** 8/09/2018  
**Client:** Hatch  
**Location:** 61 Petrie Terrace, Brisbane  
**Project No.:** 18101980  
**Test ID:** 18018 si-css3 very loose

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#### Preparation Notes:
Moist tamped in one layer

#### Tested by:
R. Fanni

#### Reviewed by:
R. Fanni

---

**Graphs:**
- **Graph 1:** Shear Stress (kPa) vs. Shear Strain (%)
- **Graph 2:** Vertical Effective Stress (kPa) vs. Vertical Effective Stress (kPa)
Cyclic Direct Simple Shear Test Report

Client: Hatch
Date: 8/11/2018
Address: 61 Petrie Terrace, Brisbane
Project: NTSF Embankment Failure ITRB
Location: Cadia Mine

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THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
Post-cyclic Direct Simple Shear Test Report - Consolidated Undrained

Perth Laboratory
84 Guthrie Street, Osborne Park

Client: Hatch  Date: 8/11/2018
Address: 61 Petrie Terrace, Brisbane  Project No.: 18101980
Project: NTSF Embankment Failure ITRB  Sample ID: TC1 - Tailings
Location: Cadia Mine  Test ID: 18018 si-css4 loose

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# Cyclic Direct Simple Shear Test Report

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTSF Embankment Failure ITRB  
**Location:** Cadia Mine  
**Date:** 18/11/2018

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![Graph of Shear Stress vs. Shear Strain](image1)

![Graph of Vertical Effective Stress vs. Shear Stress](image2)

**Preparation Notes:** Moist tamped in one layer

**Tested by:** K. Koh

**Reviewed by:** R. Fanni

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
### Post-cyclic Direct Simple Shear Test Report
- **Consolidated Undrained**

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**Graph 1:**

![Graph showing shear stress vs. shear strain](image)

**Graph 2:**

![Graph showing vertical effective stress vs. shear stress](image)

---

**Preparation Notes:** Moist tamped in one layer

**Tested by:** K. Koh

**Reviewed by:** R. Fanni

---

*THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL*
Initial Shearing Height (mm) 28.8

Initial Static Shear Stress (kPa) 15.0

Cyclic Direct Simple Shear Test Report

Perth Laboratory
84 Guthrie Street, Osborne Park

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NTSF Embankment Failure ITRB
Location: Cadia Mine

Date: 18/11/2018
Project No.: 18101980
Sample ID: TC1 - Tailings
Test ID: 18018 si-csa6 very loose

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Preparation Notes: Moist tamped in one layer
Tested by: K. Koh
Reviewed by: R. Fanni

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
Post-cyclic Direct Simple Shear Test Report  
- Consolidated Undrained

Client: Hatch  
Date: 18/11/2018

Address: 61 Petrie Terrace, Brisbane  
Project No.: 18101980

Project: NTSF Embankment Failure ITRB  
Sample ID: TC1 - Tailings

Location: Cadia Mine  
Test ID: 18018 si-cs6 very loose

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Preparation Notes: Moist tamped in one layer

Tested by: K. Koh
Reviewed by: R. Fanni

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
Cyclic Direct Simple Shear Test Report

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NT SF Embankment Failure ITRB
Location: Cadia Mine

Date: 12/03/2019
Project No.: 18101980
Sample ID: TC1 - Tailings
Test ID: 18018 si-cs s7 very loose

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Preparation Notes: Moist tamped in one layer

Tested by: R. Fanni
Reviewed by: R. Fanni

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## Post-cyclic Direct Simple Shear Test Report

### Consolidated Undrained

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTSF Embankment Failure ITRB  
**Location:** Cadia Mine  
**Date:** 12/03/2019  
**Project No.:** 18101980  
**Test ID:** 18018 si-css7 very loose

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### Graphs

1. **Graph 1:** Shear Stress vs. Shear Strain
2. **Graph 2:** Vertical Effective Stress vs. Shear Stress

**Preparation Notes:** Moist tamped in one layer  
**Tested by:** R. Fanni  
**Reviewed by:** R. Fanni

---

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
Cyclic Direct Simple Shear Test Report

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NT_SM_EmBankment_Failure_ITRB
Location: Cadia Mine
Date: 13/01/2019
Project No.: 18101980
Test ID: TC1 - Tailings
Sample ID: 18018 si-css8 very loose

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Preparation Notes: Moist tamped in one layer

Tested by: R. Fanni
Reviewed by: R. Fanni

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
Post-cyclic Direct Simple Shear Test Report - Consolidated Undrained

Client: Hatch  
Address: 61 Petrie Terrace, Brisbane  
Project: NTSE Embankment Failure ITRB  
Location: Cadia Mine

Date: 13/01/2019  
Project No.: 18101980  
Sample ID: TC1 - Tailings  
Test ID: 18018 si-css8 very loose

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<tr>
<td>Shearing Strain Rate (mm/min)</td>
<td>0.017</td>
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Preparation Notes: Moist tamped in one layer

Tested by: R. Fanni
Reviewed by: R. Fanni
**Cyclic Direct Simple Shear Test Report - Custom Waveform**

**Client:** Hatch  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTSF Embankment Failure ITRB  
**Location:** Cadia Mine

<table>
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<tbody>
<tr>
<td>Vertical Effective Stress (kPa)</td>
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<tr>
<td>Diameter (mm)</td>
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<td>Initial Shearing Height (mm)</td>
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<td>Final Bulk Density (t/m$^3$)</td>
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<td>Final Dry Density (t/m$^3$)</td>
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**Preparation Notes:** Moist tamped in one layer  
**Tested by:** R. Fanni  
**Reviewed by:** R. Fanni

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Cyclic Direct Simple Shear Test Report - Custom Waveform

Client: Hatch  Date: 12/03/2019
Address: 61 Petrie Terrace, Brisbane  Project No.: 18101980
Project: NTSF Embankment Failure ITRB  Sample ID: TC1 - Tailings
Location: Cadia Mine  Test ID: 18018 si-css11 very loose

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<td>Final Dry Density (t/m³)</td>
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<td>Initial Static Shear Stress (kPa)</td>
<td>89.9</td>
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<td>Average Shear Stress Applied (kPa)</td>
<td>N/A</td>
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<td>Cycle Period (seconds)</td>
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Preparation Notes: Moist tamped in one layer

Tested by: R. Fanni  Reviewed by: R. Fanni

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
Post-cyclic Direct Simple Shear Test Report - Consolidated Undrained

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NTSF Embankment Failure ITRB
Location: Cadia Mine

Date: 12/03/2019
Project No.: 18101980
Sample ID: TC1 - Tailings
Test ID: 18018 si-css11 very loose

<table>
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<tr>
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<tbody>
<tr>
<td>Vertical Effective Stress (kPa)</td>
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<tr>
<td>Post-consolidation Shearing Height (mm)</td>
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<tr>
<td>Final Bulk Density (t/m³)</td>
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<tr>
<td>Final Dry Density (t/m³)</td>
<td>1.76</td>
</tr>
<tr>
<td>Initial Static Shear Stress (kPa)</td>
<td>89.9</td>
</tr>
<tr>
<td>Shearing Strain Rate (mm/min)</td>
<td>0.017</td>
</tr>
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</table>

**Diagram:**
- Shear Stress (kPa) vs. Shear Strain (%)
- Shear Stress (kPa) vs. Vertical Effective Stress (kPa)

Preparation Notes: Moist tamped in one layer

Tested by: R. Fanni
Reviewed by: R. Fanni

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
Monotonic Direct Simple Shear Test Report - Consolidated Undrained

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NTSF Embankment Failure ITRB
Location: Cadia Mine
Date: 12/03/2019
Project No.: 18101980
Sample ID: TC1 - Tailings
Test ID: 18018 si-mss9 very loose

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<td>Shearing Strain Rate (mm/min)</td>
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Preparation Notes: Moist tamped in one layer

Tested by: R. Fanni
Reviewed by: R. Fanni
Monotonic Direct Simple Shear Test Report - Consolidated Undrained

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NTBF Embankment Failure ITRB
Location: Cadia Mine

Date: 12/03/2019
Project No.: 18101980
Sample ID: TC1 - Tailings
Test ID: 18018 si-mss10 very loose

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<tr>
<td>Shearing Strain Rate (mm/min)</td>
<td>0.017</td>
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</tbody>
</table>

Preparation Notes: Moist tamped in one layer

Tested by: K. Koh
Reviewed by: R. Fanni

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Annexure EO
Golder Stress Path Test Results
# Triaxial Test Report

## Stress Path Dead-Weights

**Location:** Cadia Mine  
**Address:** 61 Petrie Terrace, Brisbane  
**Project:** NTSF Embankment Failure ITRB  
**Client:** Hatch  
**Date:** 17/01/2019  
**Project No.:** 18101980  
**Sample ID:** TC1  
**Test ID:** 18018 - si-10 Stress Path Test C

<table>
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<th>Reviewed by</th>
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<tbody>
<tr>
<td>Sample was moist tamped to a loose condition</td>
<td>K. Koh</td>
<td>R. Fanni / D. Reid</td>
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<table>
<thead>
<tr>
<th>Initial Height (mm):</th>
<th>148.3</th>
<th></th>
<th>Strain Rate (mm/min):</th>
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<tbody>
<tr>
<td>Initial Diameter (mm):</td>
<td>69.1</td>
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<td>Final Liquor Content (%):</td>
<td>19.1%</td>
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<tr>
<td>Trimmings GWC (%):</td>
<td>10.9%</td>
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<td>Final Dry Density (t/m³):</td>
<td>1.80</td>
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<tr>
<td>Initial Dry Density (t/m³):</td>
<td>1.24</td>
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<td>Final Void Ratio (-):</td>
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<tr>
<td>Final Liquor Solids Conc. (g/L):</td>
<td>-</td>
<td></td>
<td>Mean Effective Consolidation Stress (kPa):</td>
<td>188</td>
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<tr>
<td>Geostatic Stress Ratio K₀ (-):</td>
<td>0.62</td>
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</table>

**Geostatic Stress Ratio**

### B Response (%): 98%

**Mean Effective Consolidation Stress:** 188 kPa

---

**THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL**
Triaxial Test Report

Stress Path Dead-Weights

Client: Hatch
Date: 17/01/2019
Address: 61 Petrie Terrace, Brisbane
Project: NTSF Embankment Failure ITRB
Location: Cadia Mine

Test ID: 18018 - si-10 Stress Path Test C
Sample ID: TC1

Initial Height (mm): 148.3
Initial Diameter (mm): 69.1
Initial Dry Density (t/m³): 1.24
Trimmings GWC (%): 10.9

Final Void Ratio (-): 0.52
Final Liquor Content (%): 19.1%
Final Dry Density (t/m³): 1.80
Final Liquor Solids Conc. (g/L): -

Strain Rate (mm/min): N/A
B Response (%): 98%
Mean Effective Consolidation Stress (kPa): 188
Geostatic Stress Ratio K₀ (-): 0.62

Preparation Notes: Sample was moist tamped to a loose condition

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL

Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid
Triaxial Test Report

Stress Path Dead-Weights

Client: Hatch  Date: 17/01/2019
Address: 61 Petrie Terrace, Brisbane  Project No.: 18101980
Project: NTSF Embankment Failure ITRB  Sample ID: TC1
Location: Cadia Mine  Test ID: 18018 - si-10 Stress Path Test C

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Tested by: K. Koh
Reviewed by: R. Fanni / D. Reid

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**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh

**Reviewed by:** R. Fanni / D. Reid
## Stress Path Dead-Weights

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<th>Date</th>
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<td>Location</td>
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**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh

**Reviewed by:** R. Fanni / D. Reid

**Diagram:**
- **Mobilised Friction Angle (Degrees)**
  - **Axial Strain (%)**
  - **0%** to **35%**
  - **0** to **40** degrees

**Graph:**
- **X-axis:** Axial Strain (%)
- **Y-axis:** Mobilised Friction Angle (Degrees)

---

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<tr>
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<td>Trimmed Liquor Content (%)</td>
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**Preparation Notes:** Sample was moist tamped to a loose condition

**Tested by:** K. Koh

**Reviewed by:** R. Fanni / D. Reid

**Graph:**
- Deviator Stress
- Pore Pressure change (kPa)
- Axial Strain (%)

**Start of final undrained stage to failure**

**Stress Path Dead-Weights**

**Perth Laboratory**
84 Guthrie Street, Osborne Park

**Triaxial Test Report**

**Sample ID:** TC1

**Date:** 23/01/2019

**Sample:** 18101980

**Location:** Cadia Mine

**Initial Height (mm):** 148.7

**Initial Diameter (mm):** 68.9

**Trimmings GWC (%):** 10.9%

**Initial Dry Density (t/m³):** 1.24

**Final Liquor Content (%):** 20.4%

**Final Dry Density (t/m³):** 1.76

**Final Void Ratio (-):** 0.56

**Geostatic Stress Ratio K₀ (-):** 0.61
Triaxial Test Report

Stress Path Dead-Weights

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NTSF Embankment Failure ITRB
Location: Cadia Mine

Test ID: 18018 - si-11 Stress Path Test C
Sample ID: TC1

Initial Height (mm): 148.7
Initial Diameter (mm): 68.9
Initial Dry Density (t/m³): 1.24
Trimmings GWC (%): 10.9%

Final Liquor Content (%): 20.4%
Final Dry Density (t/m³): 1.76
Final Void Ratio (-): 0.56
Final Liquor Solids Conc. (g/L): -
Mean Effective Consolidation Stress (kPa): N/A

Geostatic Stress Ratio K₀ (-): 0.61

B Response (%): 98%
Strain Rate (mm/min): N/A

Location: Cadia Mine
Test ID: 18018 - si-11 Stress Path Test C
Sample ID: TC1

Preparation Notes: Sample was moist tamped to a loose condition

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL

Triaxial Test Report

Stress Path Dead-Weights

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NTSF Embankment Failure ITRB
Location: Cadia Mine

Test ID: 18018 - si-11 Stress Path Test C
Sample ID: TC1

Initial Height (mm): 148.7
Initial Diameter (mm): 68.9
Initial Dry Density (t/m³): 1.24
Trimmings GWC (%): 10.9%

Final Liquor Content (%): 20.4%
Final Dry Density (t/m³): 1.76
Final Void Ratio (-): 0.56
Final Liquor Solids Conc. (g/L): -
Mean Effective Consolidation Stress (kPa): N/A

Geostatic Stress Ratio K₀ (-): 0.61

B Response (%): 98%
Strain Rate (mm/min): N/A

Location: Cadia Mine
Test ID: 18018 - si-11 Stress Path Test C
Sample ID: TC1

Preparation Notes: Sample was moist tamped to a loose condition

THIS DOCUMENT SHALL ONLY BE REPRODUCED IN FULL
Stress Path Dead-Weights

Client: Hatch
Address: 61 Petrie Terrace, Brisbane
Project: NT SF Embankment Failure ITRB
Location: Cadia Mine

Initial Height (mm): 148.7
Initial Diameter (mm): 68.9
Trimmings GWC (%): 10.9%
Initial Dry Density (t/m³): 1.24

Final Liquor Content (%): 20.4%
Final Dry Density (t/m³): 1.76
Final Void Ratio (-): 0.56
Final Liquor Solids Conc. (g/L): -

Strain Rate (mm/min): N/A
B Response (%): 98%
Mean Effective Consolidation Stress (kPa): 188
Geostatic Stress Ratio K₀ (-): 0.61

Preparation Notes: Sample was moist tamped to a loose condition
Reviewed by: R. Fanni / D. Reid
Tested by: K. Koh

Client: Hatch
Date: 23/01/2019
Project No.: 18101980
Sample ID: TC1
Test ID: 18018 - si-11 Stress Path Test C

Location: Cadia Mine
Test ID: 18018 - si-11 Stress Path Test C

Initial Height (mm): 148.7
Initial Diameter (mm): 68.9
Trimmings GWC (%): 10.9%
Initial Dry Density (t/m³): 1.24

Final Liquor Content (%): 20.4%
Final Dry Density (t/m³): 1.76
Final Void Ratio (-): 0.56
Final Liquor Solids Conc. (g/L): -

Strain Rate (mm/min): N/A
B Response (%): 98%
Mean Effective Consolidation Stress (kPa): 188
Geostatic Stress Ratio K₀ (-): 0.61

Preparation Notes: Sample was moist tamped to a loose condition
Reviewed by: R. Fanni / D. Reid
Tested by: K. Koh
### Triaxial Test Report

**Stress Path Dead-Weights**

#### Client: Hatch
#### Address: 61 Petrie Terrace, Brisbane
#### Project: NTSoF Embankment Failure ITREB
#### Location: Cadia Mine

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Initial Height (mm)</td>
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</tr>
<tr>
<td>Final Liquor Content (%)</td>
<td>20.4%</td>
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<tr>
<td>Strain Rate (mm/min)</td>
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<tr>
<td>Initial Diameter (mm)</td>
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<tr>
<td>Final Dry Density (t/m^3)</td>
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<td>B Response (%)</td>
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<td>Trimmings GWC (%)</td>
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<tr>
<td>Mean Effective Consolidation Stress (kPa)</td>
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<tr>
<td>Initial Dry Density (t/m^3)</td>
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<tr>
<td>Geostatic Stress Ratio K_0 (-)</td>
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</tr>
</tbody>
</table>

#### Preparation Notes:
Sample was moist tamped to a loose condition

#### Tested by: K. Koh
#### Reviewed by: R. Fanni / D. Reid

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Annexure EP
KCB Stress Path Test Results
### Triaxial CD Test - Summary

**Triaxial CD Test - Summary**

**ASTM D7181**

**PROJECT NO.:** A02353A01  
**DATE:** 2019-03-01  
**PROJECT:** Cadia Dam  
**TESTED BY:**  
**SAMPLE:** Tailings  
**CHECKED BY:** JG  
**TEST NO.:** TX04 - Stress Path / Dead Weight #2

<table>
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<tr>
<th>SPECIMEN INFORMATION</th>
<th>UNITS</th>
<th>Initial</th>
<th>Vacuum</th>
<th>Saturation</th>
<th>B value</th>
<th>End 1st Cons</th>
<th>End 2nd Cons</th>
<th>End 3rd Cons</th>
<th>End 4th Cons</th>
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* one way drainage

**Photos:**  
Before Test  
After Test
Triaxial CD Test - Charts

ASTM D7181

PROJECT NO.: A03353A01
DATE: 2019-03-01
PROJECT: Cadia Dam
TEST BY: BY
SAMPLE: Tailings
CHECKED BY: JG
TEST NO.: TX04 - Stress Path / Dead Weight #2

Stress Path

\[ q = \sigma_1 - \sigma_3 \text{(kPa)} \]
\[ p' = \left( \frac{\sigma_1 + 2\sigma_3}{3} \right) \text{(kPa)} \]

Volumetric Strain vs. Axial Strain

Deviator Stress vs. Strain

Void Ratio vs. Strain

Consolidation

Volumetric Strain vs. SQRT Time

Stress Ratio vs. Axial Strain
**Triaxial CD Test - Summary**  
*(ASTM D7181)*

**PROJECT NO.:** A03353A01  
**DATE:** 2019-01-28  
**PROJECT:** Cadia Dam  
**TESTED BY:** BY  
**SAMPLE:** Tailings  
**CHECKED BY:** JG  
**TEST NO.:** TX03 - Stress Path / Dead Weight

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<th>B value</th>
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<th>End 2nd Cons</th>
<th>End 3rd Cons</th>
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<th>End Test</th>
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<td>730.33</td>
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<td>730.33</td>
<td>730.33</td>
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<tr>
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<td>100</td>
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<td>0.98</td>
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**Stress Path (CD)**

- Skempton's B Parameter: 0.98
- Back Pressure before shearing: 151.7 kPa
- Confining Stress ($\sigma_3'$) before shearing: 188.8 kPa
- Stress Rate: $<$0.5 kPa / min

**Photos:**

Before Test

After Test
Triaxial CD Test - Charts

(AMT D7181)

PROJECT NO.: A03353A01
PROJECT: Cadia Dam
SAMPLE: Tailings
TEST NO.: TX03 - Stress Path / Dead Weight

Stress Path

\[ q = \sigma_1 - \sigma_3 \] (kPa)

\[ p = \frac{(\sigma_1 + 2\sigma_3)}{3} \] (kPa)

Volumetric Strain vs. Axial Strain

Deviator Stress vs. Strain

Void Ratio vs. Strain

Consolidation

Volumetric Strain vs. SQRT Time

Stress Ratio vs. Axial Strain
## Cyclic Triaxial Test
*(ASTM D5311)*

**PROJECT NO.:** A03353A01  
**DATE:** 2019-01-11  
**PROJECT:** Cadia Tailings Dam  
**TESTED BY:** BY  
**SAMPLE:** Tailings  
**CHECKED BY:** JG

**Details:**  
$e_i = 1.0$

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<th>SPECIMEN INFORMATION</th>
<th>UNITS</th>
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<th>Vacuum</th>
<th>Saturation</th>
<th>B-value</th>
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<td>211.897</td>
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<td>148.654</td>
<td>148.667</td>
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<td>179.497</td>
<td>168.104</td>
<td>158.481</td>
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<td></td>
<td>1.003</td>
<td>0.989</td>
<td>0.792</td>
<td>0.792</td>
<td>0.724</td>
<td>0.676</td>
<td>0.632</td>
<td>0.597</td>
<td>0.555</td>
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</tr>
<tr>
<td>Saturation Ratio (Sr)</td>
<td>%</td>
<td>41.27</td>
<td>41.86</td>
<td>97.08</td>
<td>99.37</td>
<td>99.31</td>
<td>99.26</td>
<td>99.21</td>
<td>99.17</td>
<td>99.10</td>
<td>99.10</td>
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<tr>
<td>Effective Confining Stress</td>
<td>kPa</td>
<td>25</td>
<td>50</td>
<td>100</td>
<td>188.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

### Stress Path (CD)

- **Skempton's B Parameter:** 0.98
- **Back Pressure before shearing:** kPa 400.0
- **Confining Stress ($\sigma_3$) before shearing:** kPa 188.8
- **Stress Rate:** kPa/min <0.5

**Note:** using cambridge method

### Test Photos:

![Before Test](image1)

![After Test](image2)
Cyclic Triaxial Test - Chart 1

ASTM D5311

PROJECT NO.: A63353A01
PROJECT: Cadia Tailings Dam
SAMPLE: Tailings
Details: \( e_i = 1.0 \)

Cyclic Wave Form (first cycle)

Excess Pore Pressure - Number of Cycles

Deviator Stress - Number of Cycles

Axial Strain - Number of Cycles
Annexure EQ

Test Procedures
LABORATORY TESTING PROCEDURES

Laboratory testing of the tailings and foundation soils is undertaken according to the procedures provided in Table 1 and Table 2, respectively.

Table 1: Laboratory testing procedures for tailings characterisation

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sample Preparation</strong></td>
<td></td>
</tr>
<tr>
<td>Bulk Sample Preparation</td>
<td>GAPMW 1.1.2</td>
</tr>
<tr>
<td>Total Dissolved Solids Measurement of Bulk Sample</td>
<td>GAPMW 1.1.5</td>
</tr>
<tr>
<td><strong>Triaxial Testing</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Specimen Preparation</strong></td>
<td></td>
</tr>
<tr>
<td>Moist Tamped Loose Specimen Preparation for Triaxial Testing</td>
<td>GAPMW 3.1.1</td>
</tr>
<tr>
<td>Moist Tamped Dense Specimen Preparation for Triaxial Testing</td>
<td>GAPMW 3.1.2</td>
</tr>
<tr>
<td><strong>Testing</strong></td>
<td></td>
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<tr>
<td>Strain Controlled Triaxial Test of Moist Tamped Reconstituted Specimen Isotropically Consolidated</td>
<td>GAPMW 3.2.1</td>
</tr>
<tr>
<td>Constant Shear Drained Test with Servo Stress Controlled</td>
<td>GAPMW 3.2.4</td>
</tr>
<tr>
<td>Constant Shear Drained Test with Dead-Weight Stress Controlled</td>
<td>GAPMW 3.2.5</td>
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<tr>
<td><strong>Cyclic Direct Simple Shear Testing</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Specimen Preparation</strong></td>
<td></td>
</tr>
<tr>
<td>Moist Tamped Loose Specimen Preparation for Direct Simple Shear Testing</td>
<td>GAPMW 4.1.1</td>
</tr>
<tr>
<td><strong>Testing</strong></td>
<td></td>
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<tr>
<td>Cyclic Direct Simple Shear Test</td>
<td>GAPMW 4.2.2</td>
</tr>
<tr>
<td><strong>Bender Elements Testing</strong></td>
<td></td>
</tr>
<tr>
<td>Shear Wave Velocity Measurement Using Bender Elements for Triaxial Test of Specimen Consolidated Anisotropically</td>
<td>GAPMW 3.4.2</td>
</tr>
</tbody>
</table>

Table 2: Laboratory testing procedures for foundation soil characterisation

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sample Preparation</strong></td>
<td></td>
</tr>
<tr>
<td>Bulk Sample Preparation</td>
<td>GAPMW 1.1.4</td>
</tr>
<tr>
<td>Tube Sample Preparation</td>
<td>GAPMW 1.2.1</td>
</tr>
<tr>
<td>Block Sample Preparation</td>
<td>GAPMW 1.2.2</td>
</tr>
<tr>
<td><strong>Consolidation Testing</strong></td>
<td></td>
</tr>
<tr>
<td>Constant Rate of Strain Consolidation Test</td>
<td>GAPMW 2.1</td>
</tr>
<tr>
<td><strong>Triaxial Testing</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Specimen Preparation</strong></td>
<td></td>
</tr>
<tr>
<td>Intact Specimen Preparation for Triaxial Testing</td>
<td>GAPMW 3.1.5</td>
</tr>
<tr>
<td><strong>Testing</strong></td>
<td></td>
</tr>
<tr>
<td>Strain Controlled Triaxial Test of Intact Specimen Isotropically Consolidated</td>
<td>GAPMW 3.3.1</td>
</tr>
<tr>
<td><strong>Direct Simple Shear Testing</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Specimen Preparation</strong></td>
<td></td>
</tr>
<tr>
<td>Compacted Specimen Preparation for Direct Simple Shear Testing</td>
<td>GAPMW 4.1.2</td>
</tr>
<tr>
<td>Intact Specimen Preparation for Direct Simple Shear Testing</td>
<td>GAPMW 4.1.3</td>
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<td><strong>Testing</strong></td>
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</tr>
<tr>
<td>Monotonic Direct Simple Shear Test</td>
<td>GAPMW 4.2.1</td>
</tr>
</tbody>
</table>
Foundation Soils
GAPMW 1.1.4 – BULK SAMPLE PREPARATION

Scope

The purpose of this procedure is to provide the steps for preparation of a bulk sample to a target moisture content.

Equipment

The sample preparation was undertaken using a mixing tray.

Procedure

The sample preparation is undertaken using the following steps:

1) The received sample is emptied from the bucket and placed on a mixing tray (Figure 1).

2) The sample is mixed thoroughly and sealed in a sample bag. A subsample is taken to determine the initial moisture content of the sample.

3) Demineralised water is added to bring the sample to a target moisture content.

4) The sample is mixed thoroughly in the bag and left to cure. A subsample is taken to check the moisture content of the cured sample before testing.

Figure 1: Received sample placed on a mixing tray
GAPMW 1.2.1 – TUBE SAMPLE PREPARATION

Scope

The purpose of this procedure is to provide the steps for preparation of a tube sample for testing.

Equipment

The tube samples were extruded using a Geo-Con Universal Vertical Extruder (Figure 1).

Figure 1: Geo-Con tube sample extruder
Procedure

The sample preparation is undertaken using the following steps:

1) The end caps of the tube sample are removed, and the length of voids measured from both ends of the tube to estimate available sample length for testing.

2) The tube is inverted and positioned with the top facing downwards in the extruder.

3) The sample is slowly extruded from the bottom of the tube for triaxial and index testings. For direct simple shear and constant rate of strain consolidation testings, the sample is slowly extruded into a stainless-steel ring of the same diameter as the tube.

4) The extruded specimen is cut and trimmed to the required size for testing.

5) The trimmings are used for gravimetric water content measurements and the remaining trimmings sealed in a sample bag for index testing.

6) The tube is wrapped with cling film, covered with end caps and stored for further testing.

Pictures of this procedure are provided in Figure 2 to Figure 7.

Figure 2: As received tube sample

Figure 3: Top end of tube

Figure 4: Bottom end of tube
Figure 5: Sample extruded for triaxial testing

Figure 6: Sample extruded into a stainless-steel ring for DSS and CRS testings

Figure 7: Trimming of specimen to required size for testing
GAPMW 1.2.2 – BLOCK SAMPLE PREPARATION

Scope
The purpose of this procedure is to provide the steps for preparation of a block sample for testing.

Equipment
The block samples were prepared using stainless-steel coring rings and scalpel (Figure 1).

![Stainless-steel coring ring and scalpel](image-url)

**Figure 1: Stainless-steel coring ring and scalpel**

Procedure
The sample preparation is undertaken using the following steps:

1) The box is opened from the top to access the block sample.
2) Specimens are carefully cored from the surface of the block sample using stainless-steel coring rings and a scalpel.
3) The cored specimens are cut and trimmed to the required size for testing. The trimmed specimens are wrapped with cling film and stored in a sealed bag.
4) The trimmings are used for gravimetric water content measurements and the remaining trimmings sealed in a sample bag for index testing.
5) The block sample is wrapped with cling film and aluminium foil. The top of the box is sealed, and the block sample stored for further testing.

Pictures of this procedure are provided in Figure 2 to Figure 6.
Figure 2: As received block sample

Figure 3: Accessing block sample from the top of box

Figure 4: Coring specimen from block sample
Figure 5: Cored specimens: before coring (left) and after coring (right)

Figure 6: Wrapping and sealing block sample after coring
GAPMW 2.1 – CONSTANT RATE OF STRAIN CONSOLIDATION TEST

Scope

The purpose of this procedure is to provide the steps for undertaking constant rate of strain (CRS) consolidation testing. CRS testing can be undertaken significantly faster than a conventional oedometer as the typical rule of loading stages of 24 hours duration is not required. During the test the specimen is loaded continuously maintaining an approximate constant axial strain rate. During axial loading, excess pore pressure is allowed to develop at the base of the specimen to allow inference of hydraulic conductivity and coefficient of consolidation. The hydraulic conductivity can be also directly measured by undertaking constant head permeability testing at different loading stages, from the base pump to the top surface of the specimen.

Equipment

The CRS test is undertaken in a GDS automatic oedometer device, with the software capable to undertake CRS testing. Testing is undertaken in accordance with ASTM D4186\(^1\). The device is provided of a 50kN load frame, fully enclosed stainless-steel cell, cell and base pumps, pore pressure differential transducer (PPT) mounted at the base of the cell, 5 mm spring-loaded LVDT displacement sensor and 32 kN capacity submersible load cell. The GDS automatic oedometer is illustrated in a picture and schematically in Figure 1. The GDS automatic oedometer device is equipped of a stepper motor driven unit controlled either manually or from a PC. A CRS cell is fitted on the loading pedestal. The CRS cell is similar to a conventional triaxial cell as both cells are closed to the external environment allowing the cell to be entirely filled with water. However, in a CRS cell the specimen is exposed to the cell pressure, while in a triaxial cell, the specimen is separated from the cell environment by a membrane.

Figure 1: GDS load frame with stainless-steel CRS cell (left) and schematic of CRS testing device (right)

Procedure

The CRS test is undertaken in a 60 mm diameter specimen. The specimen is restrained by a stainless-steel ring provided of top and bottom porous stones and filter papers. The base is separated from the cell environment via a system of sealing O-rings, allowing to measure excess pore pressure at the base of the specimen during axial loading. The specimen is confined in a stainless-steel chamber with axial stresses measured by a submersible load cell. Vertical strain is measured with a LVDT, pressures are provided by 3 MPa capacity pumps, while the specimen base pressure is measured using a pore pressure transducer.

The test is undertaken using the following steps:

1) The base porous stone and filter paper are placed dry on the CRS base to prevent swelling of the specimen.

2) The specimen is extruded from the tube or cored from the block sample and placed within a stainless-steel CRS ring. The top end of the specimen is trimmed to form a flat surface.

3) The top porous stone and filter paper are placed dry on the top end of the specimen inside the CRS ring and the bottom end of the specimen is trimmed to the size required for the testing.

4) Trimmings are taken during specimen preparation from both ends of the specimen to enable measurement of the initial gravimetric water content.

5) The specimen mass is taken, and initial height measured using a digital calliper.

6) The specimen is placed on the base porous stone and filter paper.

7) The remaining CRS components including the sealing O-rings are assembled (Error! Reference source not found.).

8) The CRS cell is closed and a seating load of 10 kPa applied.

9) The test commenced, and the stress is increased to 25 kPa and left to consolidate under this load.

10) The cell is flushed with CO₂ for approximately 1 hour and then flooded with deaired demineralised water under constant height conditions.

11) Back pressure is ramped up to 500 kPa over a period of time depending on material type under double drainage and constant height conditions. If the stress dropped below 25 kPa, the back pressure saturation is interrupted to bring the stress back to 25 kPa before continuing saturation.

12) Once back pressure saturation is completed, constant head permeability test is undertaken under 25 kPa constant stress.

13) The constant rate of strain test is undertaken by targeting an axial strain rate until a target stress is achieved. The strain rate is guessed based on material type with the intent to provide excess pore pressure ratio (\( Ru = \frac{\text{excess pore pressure}}{\text{total stress}} \)) within 3% – 15%.

14) Unloading and reloading loop from 400 kPa to 100 kPa is undertaken.

15) The constant rate of strain test is continued to a target vertical stress of 3000 kPa.
16) Once the target vertical stress is achieved, the total vertical stress is maintained, and constant head permeability test is undertaken.

17) The specimen and cell pressures are finally unloaded, and the CRS disassembled.

Figure 2: CRS test device setup: base porous stone and filter paper (left), specimen in stainless-steel ring with top porous stone and filter paper (middle), sealing components assembled (right)
GAPMW 3.1.5 – INTACT SPECIMEN PREPARATION FOR TRIAXIAL TESTING

Scope
The purpose of this procedure is to prepare an intact (undisturbed) specimen for triaxial testing. The specimen is generally extruded from a tube or cored from a block sample.

Equipment
The preparation is undertaken using a scalpel, split mould and membrane stretcher (Figure 1). Standard triaxial end caps (Figure 2) are used in this procedure.

Figure 1: Scalpel and split mould to trim specimen (left) and membrane stretcher (right)

Figure 2: Standard triaxial end caps with porous stones and filter papers
Procedure
The following steps are undertaken to prepare the intact specimen:

1) The specimen extruded from the tube sample\(^1\) is trimmed to a height of approximately 2 times the specimen diameter using a scalpel and a split mould to hold the specimen.

2) Initial specimen mass is measured and the dimensions taken using a digital calliper measuring both diameter and height at different locations.

3) Porous stone and filter paper are placed dry (to reduce initial swelling) on the bottom end cap and the specimen is placed on top.

4) A membrane is placed around the specimen using a membrane stretcher and sealed to the bottom end cap with sealing grease and O-rings.

5) Top filter paper and porous stone are placed dry on the specimen. The top end cap is added and the membrane is sealed.

6) The triaxial device is assembled and the cell filled with water.

The typical specimen during and after preparation is shown in Figure 3.

![Figure 3: Specimen placed on bottom end cap (left) and specimen sealed with membrane and O-rings (right)](image)

---

\(^1\) GAPMW 1.2.1 Tube Sample Preparation
GAPMW 3.3.1 – STRAIN CONTROLLED TRIAXIAL TEST OF INTACT SPECIMEN ISOTROPICALLY CONSOLIDATED

Scope
Triaxial testing involves the preparation of a cylindrical specimen of material, wrapped in an impervious membrane. A confining stress is then applied to the specimen, and the material allowed to come to equilibrium under the applied stress. The initial stress can either be isotropic (the same all around the specimen), or $K_0$, which typically involves a higher vertical stress than horizontal stress on the specimen.

The purpose of this procedure is to undertake a strain controlled triaxial test of intact specimen extruded from a tube sample. Tests are undertaken consolidating a specimen isotropically and sheared under undrained strain control conditions.

Equipment
The tests were undertaken using a standard GDS triaxial device (Figure 1) with 50 kN digital load frame, 3 MPa 200 cc pressure volume controllers, submersible load cell, pore pressure transducer and linear variable displacement transducer.

Figure 1: Standard GDS triaxial device
Procedure

The test is undertaken using the following steps:

1) The specimen is prepared using the intact specimen preparation procedure\(^1\).

2) The cell and back pressure are increased to promote back pressure saturation of the specimen. Ramping of the cell and back pressure is undertaken typically within a period of 24 hours. A back pressure of 500 kPa was generally used. During this process, an approximate difference between cell and back pressure of 20 kPa is maintained, to prevent the specimen being subjected to significant effective stresses.

3) Once the target saturation back pressure is reached and volume change is negligible, degree of saturation is assessed performing a B-value check. For this, the specimen drainage valves are closed, and an all-around pressure is applied to the specimen while monitoring and recording the pore pressure response at the base of the specimen. All tests undertaken in this study obtained a B-value of 0.95 or greater.

4) The specimen is consolidated to the target stress in one step, via two stages, one undrained loading stage and a final drained dissipation stage. In the undrained loading stage, the specimen drainage valves are closed, and an isotropic confining pressure is applied to the specimen until the pore pressure response is steady. In the drained dissipation stage, the specimen drainage valves are opened to allow consolidation.

5) Once consolidation is complete, the specimen is sheared either drained or undrained depending on the desired test conditions. The specimen is generally sheared to a minimum of 20% axial strain or terminated before if significant deformation occurs.

6) After the test is completed, the specimen drainage valves are closed and the water in the cell is emptied.

7) The specimen is removed and end of test moisture content is taken. Area correction is applied based on the visually-observed shape of the deformed specimen at the end of shearing (i.e. right cylinder, parabola or slip plane).

The typical end of test specimen is provided in Figure 2.

\(^1\) GAPMW 3.1.5 Intact Specimen Preparation for Triaxial Testing
Figure 2: End of test typical deformed specimen with a slip plane
GAPM 4.1.2 – COMPACTED SPECIMEN PREPARATION FOR DIRECT SIMPLE SHEAR TESTING

Scope
The purpose of this procedure is to prepare a compacted specimen for direct simple shear (DSS) testing.

Equipment
The preparation was undertaken using a special DSS mould designed to allow preparation of compacted specimen. This mould allows to undertake preparation of a specimen with accurate height control during compaction. The DSS mould is shown in Figure 1.

Figure 1: DSS mould for preparation of compacted specimen

Procedure
The specimen preparation is undertaken using the following steps:

1) The DSS is prepared with the rings and a latex membrane neatly fixed against the inner wall of the rings.
2) The top end platen is attached to the top cap of the mould and the DSS bolted to the base of the mould.
3) The sample is prepared to its optimum moisture content and placed inside the DSS.
4) The sample is compacted to a known density (98% of standard maximum dry density) in one layer by lowering the top cap of the mould. The height and volume of the specimen is pre-determined by the inner dimensions of the DSS in the mould.
5) The DSS with compacted specimen is removed from the mould and finished to assemble to the device.
6) The DSS device is assembled and the top platen is lowered down using the computer-controlled software to a given bedding load of generally 25 kPa.

---

1 GAPMW 1.1.4 Bulk Sample Preparation to Optimum Moisture Content
7) The DSS base is tightened via four screws located at each corner to the main device, the restraint arms to reduce specimen rotation during shear assembled and the test commenced.

The specimen preparation procedure is shown in Figure 2 to Figure 5.

Figure 2: DSS prepared with rings and membrane

Figure 3: DSS bolted to the base of mould (left) and top end platen attached to top cap of mould (right)
Figure 4: DSS specimen inside compactor mould: before compaction (left) and after compaction (right)

Figure 5: DSS device assembled with restraint arms mounted
GAPMW 4.1.3 – INTACT SPECIMEN PREPARATION FOR DIRECT SIMPLE SHEAR TESTING

Scope
The purpose of this procedure is to prepare an intact (undisturbed) specimen for direct simple shear (DSS) testing. The specimen is generally extruded from a tube or cored from a block sample.

Equipment
The preparation is undertaken using a scalpel and 60 mm diameter stainless-steel ring shown in Figure 1.

![Figure 1: 60 mm diameter stainless-steel ring and scalpel](image)

Procedure
The specimen preparation is undertaken using the following steps:

1) The specimen extruded from 63 mm diameter tube sample\(^1\) is trimmed to a diameter of 60 mm using a scalpel and 60 mm diameter stainless-steel ring. The specimen from block sample\(^2\) is cored directly into a 60 mm stainless-steel ring.

2) The top and bottom ends are trimmed to a specimen height of approximately 27 mm.

3) The specimen is placed on the bottom platen of the DSS and the latex membrane and rings are placed around the specimen.

4) The DSS device is assembled and the top platen is lowered down using the computer-controlled software to a given bedding load of generally 10 kPa.

5) The DSS base is tightened via four screws located at each corner to the main device, the restrain arms to reduce specimen rotation during shear assembled and the test commenced.

The specimen preparation procedure is shown in Figure 2 to Figure 5.

\(^1\) GAPMW 1.2.1 Tube Sample Preparation
\(^2\) GAPMW 1.2.2 Block Sample Preparation
Figure 2: Trimming specimen extruded from 63 mm diameter tube sample to 60 mm diameter

Figure 3: Trimmed specimen on DSS base platen (left) and covered with membrane (right)

Figure 4: DSS rings in place (left) and membrane folded outwards for DSS device assembly (right)
Figure 5: DSS device assembled with restrain arms mounted
GAPMW 4.2.1 – MONOTONIC DIRECT SIMPLE SHEAR TEST

Scope

Direct simple shear (DSS) testing involves preparation of a cylindrical specimen with a typical height to diameter ratio of about 0.4 within a membrane that is laterally constrained by a stack of low-friction metal rings. The material is vertically consolidated to the desired stress with or without an initial static shear stress ($\alpha$, bias). Owing to the lateral restraint provided by the stack of rings, consolidation occurs under a $K_0$ condition (i.e. zero lateral strain). Once consolidation is completed, the specimen is sheared monotonically by moving the lower platen horizontally while the top platen remains still. Monotonic loading is analogous to static undrained loading, such as when undrained conditions initiate within contractive material.

It should be noted that while DSS testing provides undrained strength parameters, the test itself is not undrained. Rather than restrict drainage, constant volume conditions are enforced via computer control of the test. Should the specimen contract, the top platen would begin to move downwards, reducing the height of the specimen. However, the computer control system prevents this from occurring by reducing the vertical stress to maintain a constant height. The excess pore pressures that would have developed within the specimen can then be inferred from the changes in vertical stress required to maintain constant height. This testing method has been shown to provide the same results as tests with enforced drainage conditions (Finn 1985, Dyvik et al. 1987).

Equipment

Specimens were tested using a GDS electro-mechanical dynamic cyclic simple shear (EMDCSS) system shown in Figure 1.

Figure 1: GDS electro-mechanical DSS device

The device is capable of carrying out DSS testing under monotonic and cyclic conditions. The GDS DSS base and top platens are specially designed to allow saturation to occur by applying a flow, generally from the bottom of the specimen to its top via a pump or a water reservoir. Leaks are prevented introducing a series of O-rings at the base and top of the DSS platens and by placement of a sealing agent.

DSS testing is undertaken in 60 mm diameter compacted (bulk) and intact (tube or block) specimens using dead zone end platens (Figure 2 and Figure 3).

Figure 2: Schematic of DSS specimen between dead zone end platens

Figure 3: Dead zone end platen
The test is undertaken using the following steps:

1) A specimen is prepared according to the compacted\textsuperscript{3} or intact\textsuperscript{4} specimen preparation procedures.

2) The DSS device is assembled and the top platen is lowered down using the computer-controlled software to a given bedding load of generally 10 kPa.

3) The initial specimen height is calculated based on height calibration undertaken using a block of known height, and the test is commenced.

4) The specimen is consolidated to the vertical effective stress for saturation and water is flushed through the specimen from the base to the top. If the sample appears saturated, the saturation step is not undertaken.

5) The specimen is consolidated to the target vertical effective stress in stages.

6) The specimen is sheared monotonically at a strain rate of around 2\% per hour.

7) Once the test is completed, the DSS is dissembled, the specimen removed and dried in a 110°C oven to obtain the mass of dry solids and moisture content of the specimen.

The typical end of test specimen is provided in Figure 4.

\textbf{Figure 4: End of test specimen}

\textsuperscript{3} GAPMW 4.1.2 Compacted Specimen Preparation for Direct Simple Shear Testing  
\textsuperscript{4} GAPMW 4.1.3 Intact Specimen Preparation for Direct Simple Shear Testing
Tailings
GAPMW 1.1.2 – BULK SAMPLE PREPARATION

Scope
The purpose of this procedure is to provide the steps for preparation of a bulk sample to a homogeneous condition that is suitable for testing.

Equipment
The sample preparation was undertaken using a 40°C oven, drying trays and 2.36 mm opening size sieve.

Procedure
The sample preparation is undertaken using the following steps:

1) The received sample is emptied from the bucket, placed on drying trays and dried in a 40°C oven to a moisture content of around 7–12% or first prepared as a thick slurry by adding process water before drying.

2) The 40°C oven-dried moist sample is passed through a 2.36 mm opening size sieve, separating the agglomerates from the sieved material. The agglomerates are broken down by hand and re-sieved until all material passes through the sieve.

3) The sieved sample is mixed thoroughly and sealed in a sample bag for testing.

Pictures of this procedure are provided in Figure 1 to Figure 4.

Figure 1: Sample prepared as thick slurry
Figure 2: As received sample in drying trays

Figure 3: Sieving process

Figure 4: Sieved material
GAPMW 1.1.5 – TOTAL DISSOLVED SOLIDS MEASUREMENT OF BULK SAMPLE

Scope
The purpose of this procedure is to provide the steps to measure the total dissolved solids of a bulk sample.

Equipment
The test is undertaken using a funnel, filter paper, syringe and beakers.

Procedure
The test is undertaken using the following steps:

1) A subsample is taken from the sample prepared according to the bulk sample preparation procedure

2) The specimen is placed in a beaker and dried in the 110°C oven

3) A known amount of demineralised water is added to the oven-dried specimen, mixed thoroughly, and left to settle

4) Clear solution is decanted using a syringe and filtered into another beaker through a funnel

5) The mass of the decanted solution is taken and the solution dried in the 110°C oven to determine the salt (dissolved solids) content

6) The total dissolved solids in the bulk sample is calculated from the salt content of decanted solution, amount of added demineralised water and the initial dry mass of the specimen.

Pictures of this procedure are provided in Figure 1 and Figure 2.

Figure 1: Filter-funnel setup and specimen before decanting

---

1 GAPMW 1.1.2 Bulk Sample Preparation
Figure 2: Decanted clear solution and specimen after decanting
GAPMW 3.1.1 – MOIST TAMPED LOOSE SPECIMEN PREPARATION FOR TRIAXIAL TESTING

Scope
The purpose of this procedure is to prepare a loose specimen using the moist tamping preparation technique for triaxial testing.

Equipment
The preparation is undertaken using a split mould to allow preparation of loose specimens of 72 mm diameter and 149 mm height.

To enable placement of a specimen into the freezer without transfer of the entire triaxial base, a specially designed modular base platen system is used. The modular base consists of:

1) A “cradle” that mounts to the triaxial base with a recess
2) A base platen that fits tightly within the cradle recess
3) A drainage line for the base of the specimen exiting from the side of the base platen
4) Additional valves connected to the top and bottom drainage lines, to allow sealing the specimen at locations closer than the outer drainage control valves of the triaxial cell and removal of the sample for freezing.

The split mould and modular base are shown in Figure 1 and Figure 2, respectively. The modular base and top cap are shown in Figure 3 to Figure 4.

Figure 1: Split mould schematic view
Figure 2: Split mould internal (left) and external view (right)

Figure 3: Modular base (left) and lubricated end platens (right)

Figure 4: Modular base with lubricated end platens (left) and top cap with lubricated end platens (right)
Procedure

The following steps are undertaken to prepare the loose moist tamped specimens:

1) Porous stones, filter papers and layers of trimmed latex membrane lubricated with high vacuum silicone grease are placed at the top and bottom end caps.

2) A cylindrical split mould is placed on the triaxial base pedestal with a membrane held against the walls of the mould by suction provided from a vacuum pump.

3) The sample is tamped using the undercompaction technique proposed by Ladd 1978\(^1\) to promote a homogenous density along the specimen height. In this procedure, the sample is compacted in eight layers of equal thickness and varying masses.

4) Specimens are prepared tamping the material within the mould in eight layers using an under-compaction percentage of 10\% for the first (bottom) layer and 0\% for the final (top) layer (Figure 5).

5) Once the specimen is tamped, the top cap is placed and a suction of maximum 20 kPa is applied to the specimen with a vacuum pump to enable the specimen shape to be maintained during mould removal and test setup.

6) Initial specimen dimensions are taken using a digital calliper measuring both diameter and height at different locations.

7) The triaxial device is assembled and the cell filled with water.

The under-compaction percentage adopted for the tamping of the loose specimens is provided in Figure 5. Pictures of this procedure are provided in Figure 6 to Figure 7.

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Figure 6: Split moulds with membrane under suction (left) and during specimen preparation with scarified layer prior tamping of next layer (right)

Figure 7: Tamped specimen prior placement of top cap (left) and with top cap after removal of split mould (right)
GAPMW 3.1.2 – MOIST TAMPER DENSE SPECIMEN PREPARATION FOR TRIAXIAL TESTING

Scope
The purpose of this procedure is to prepare a dense specimen, while avoiding the application of significant compaction stresses that may lead to an overconsolidated specimen after subsequent consolidation in a triaxial cell. The specimen is compacted by combining drop height compaction with gentle vibration of the mould.

Equipment
The compaction mould is designed to prepare the specimen in 8 layers, each with a height of 18 mm. Specimens are prepared to an approximate height of 144 and diameter of 63 mm.

A suction top cap typically used for undertaking extension triaxial testing is used in this procedure. The suction cap is used to limit the rotation of the top cap during shearing, thus forcing shearing to occur vertically. This allows shearing to continue to high strains even after shear bands develop in dense specimens.

The compaction mould developed for this process is schematically illustrated in Figure 1 and shown in Figure 2 to Figure 6.

Figure 1: Tamper schematic view
Figure 2: View of different components of compactor: mould base platen with the inner sleeve (left), outer sleeve (middle) and adjustable height tamper with top platen to allow controlling the height (right).

Figure 3: Mould base platen with sandwich of paper filter, latex membrane and paper filter at its bottom.

Figure 4: Tamper with top platen to allow controlling the tamping height.
Figure 5: Tamper dismantled with various spacers

Figure 6: Tamper mounted with screws to allow dropping height control
Procedure

The following steps are undertaken to prepare the dense specimens:

1) The sample is prepared at a moisture content such that vibration will induce additional densification (i.e. wetter than typical moist tamping to produce loose samples)

2) Compaction is undertaken in eight layers using the Ladd undercompaction technique (Ladd 1978\(^1\)) with an under-compaction percentage of 5% to 10% for the first (bottom) layer and 0% for the final (top) layer (Figure 7).

3) A sandwich of filter paper, latex membrane and filter paper is placed at the bottom of the mould to prevent the specimen from bonding to the mould, which could lead to damage of the specimen during subsequent extrusion.

4) The inner sleeve is placed at the bottom of the mould.

5) The outer sleeve encasing the inner sleeve is screwed to the bottom platen.

6) The first layer is placed and gently levelled.

7) The tamper is placed on top of the sample and tamping is provided by dropping the tamper from a height of approximately 2 cm or less, until compaction via drop height can no longer occur.

8) The mould is then gently vibrated by providing horizontal manual rotations until the tamper is in contact with the edges of the outer mould, thus indicating that the target height has been achieved.

9) If free standing water is present on the specimen surface, this is removed with a syringe.

10) The first tamper spacer is unscrewed to allow the second layer to be tamped to its target height.

11) Steps 6 to 10 are repeated until all layers have been compacted.

12) The screws at the bottom of the compaction mould are removed and the inner sleeve housing the specimen taken out.

13) The tamper’s spacers are reassembled, the inner sleeve containing the specimen is placed within the tamper and left for a couple of hours to allow the draining of water from the specimen, thus allowing the specimen to become slightly unsaturated.

14) The tamper is then used to extrude the specimen and the specimen trimmed as required to its target height for the testing.

15) Initial specimen dimensions are taken using a digital calliper measuring both diameter and height at different locations.

16) Porous stones, filter papers and layers of lubricated trimmed latex membrane are placed at the top and bottom end caps.

17) A latex membrane is placed around the sample sealed by O-rings.

18) The triaxial device is assembled and the cell filled with water.

---

The typical under-compaction percentage adopted for the tamping of the dense specimens is provided in Figure 7. Pictures of this procedure are provided in Figure 8 to Figure 10.

**Figure 7**: Typical under-compaction percent used for tamping of the dense specimens

**Figure 8**: Water at surface of sample at vibration of mould (left) and specimen after compaction inside inner sleeve
Figure 9: Specimen on top of tamper during water draining stage (left) and water draining from specimen (right)

Figure 10: Specimen extruded using tamper (left) and sample on triaxial base platen (right)
Figure 11: Specimen with suction top cap assembled and inside cell
Scope

Triaxial testing involves the preparation of a cylindrical specimen of material, wrapped in an impervious membrane. A confining stress is then applied to the specimen, and the material allowed to come to equilibrium under the applied stress. The initial stress can either be isotropic (the same all around the specimen), or $K_0$, which typically involves a higher vertical stress than horizontal stress on the specimen.

The purpose of this procedure is to undertake strain controlled triaxial test of specimen prepared using the moist tamping technique. The specimens are prepared using either the moist tamped loose or dense preparation procedures. Tests are undertaken consolidating a specimen isotropically and sheared under drained or undrained strain control conditions.

Equipment

The tests were undertaken using a standard GDS triaxial device (Figure 1) with 50 kN digital load frame, 3 MPa 200 cc pressure volume controllers, submersible load cell, pore pressure transducer and linear variable displacement transducer.

Figure 1: Standard GDS triaxial device
**Procedure**

The test is undertaken using the following steps:

1) The specimen is prepared using either the moist tamped loose\(^1\) or dense\(^2\) preparation procedures.

2) The moist tamped loose specimen is flushed with CO\(_2\) for approximately 1 hour, followed by flushing with deaired deionised water imposing a differential head of approximately 5 kPa from the bottom to the top of the specimen. Flushing is carried out until bubbles are no longer observed leaving the top of the specimen. Flushing with CO\(_2\) and deaired deionised water is not carried out for the dense specimens as these specimens are prepared in a near-saturated condition.

3) The cell and back pressure are increased to promote saturation of the material by forcing air into solution. Ramping of the cell and back pressure is undertaken typically within a period of six hours. During this process, an approximate difference between cell and back pressure of 20 kPa is maintained, to prevent the specimen being subjected to significant effective stresses.

4) Once the target saturation back pressure is reached, and volume change is negligible, degree of saturation is assessed performing a B-value check. For this, the specimen drainage valves are closed, and an all-around pressure is applied to the specimen while monitoring and recording the pore pressure response at the base of the specimen. All tests undertaken in this study obtained a B-value of 0.95 or greater, which indicated that the pore pressure response of the specimen was 95% or greater than of the applied load, indicating a material of sufficient saturation for testing.

5) The specimen is consolidated to the target stress in one step, via two stages, one undrained loading stage and a final drained dissipation stage. In the first stage, the specimen drainage valves are closed, and an isotropic confining pressure is applied to the specimen until the pore pressure response is steady. In the second stage, the specimen drainage valves are opened to allow consolidation.

6) Once consolidation is complete, the specimen is sheared either drained or undrained depending on the desired test conditions. The specimen is generally sheared to a minimum of 20% axial strain, to enable critical state conditions to be inferred where possible.

7) After the test is completed, the specimen drainage valves are closed and the water in the cell is emptied.

8) The specimen void ratio is determined by measuring moisture content at the end of test, adopting the freezing method (Sladen and Handford, 1987\(^3\)) which involves carefully removing the specimen from the triaxial apparatus and freezing the specimen with the membrane, caps and drainage lines attached to prevent any water loss.

9) Area correction is applied based on the visually-observed shape of the deformed specimen at the end of shearing (i.e. right cylinder or parabola).

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\(^1\) GAPMW 3.1.1 Moist tamped loose sample preparation for triaxial testing

\(^2\) GAPMW 3.1.2 Moist tamped dense specimen preparation for triaxial testing

Figure 2: End of test typical deformed specimen to a parabola shape (left) and right cylinder shape (right)

Figure 3: Frozen specimen before removal of membrane and caps (left) and after (right)
GAPMW 3.2.4 – CONSTANT SHEAR DRAINED TEST WITH SERVO STRESS CONTROLLED

Scope
The purpose of this procedure is to provide the steps for undertaking constant shear drained (CSD) testing using a stress servo controller.

Equipment
A standard triaxial GDS device with an additional a servo controller is used to undertake the CSD collapse testing (Figure 1). The servo controller is a DigiRFM device manufactured by GDS which enables direct connection of the load cell and load frame (Figure 2). This direct linkage greatly increases the response time of the load frame. The DigiRFM allows via adjustment of the PID setting to achieve a maximum speed of the load frame of over 90 mm/min if the specified load suddenly reduces.
Procedure

The test is undertaken using the following steps:

1) A specimen is prepared to its target density and consistency using the loose moist tamping preparation procedure.
2) A suction of maximum 20 kPa is applied to the specimen with a vacuum pump to enable the specimen shape to be maintained during test setup.
3) Initial specimen dimensions are taken using a digital calliper measuring both diameter and height at different specimen locations.
4) The triaxial device is assembled and the cell filled with water.
5) The specimen is flushed with CO₂ for approximately one hour.
6) The specimen is then flushed with water imposing a differential head of approximately 5 kPa from the bottom to the top of the specimen; flushing is carried out until bubbles are no longer observed to emerge from the pipe connected to the top of the specimen.
7) Back pressure saturation is undertaken over ~3 hours, maintaining a mean effective stress of 20 kPa.
8) Once the target saturation back pressure is reached, and volume change is negligible, a B-check is undertaken targeting a B value greater than 95%.
9) The specimen is then unloaded over ~3 hours to a cell pressure of 0 kPa and back pressure of -20 kPa.
10) The cell water is drained, the cell removed, and the specimen dimension taken using a digital calliper, to allow a more accurate measurement of specimen diameter for subsequent anisotropic consolidation.
11) The specimen is then reloaded following step 7.
12) The specimen is slowly consolidated anisotropically (i.e. confining and deviator stress increased) to its target $K_0$. The confining stress increase occurs at an approximate rate of 5 kPa per hour.
13) Once the target consolidation pressure is achieved, the specimen is left under the target anisotropic stress conditions for approximately 24 hours.
14) The CSD stage is then commenced by slowly increasing the back pressure at a rate of 15 kPa per hour. Test data are captured at intervals of one second, to provide stress conditions as close to failure as practicable.

15) Once failure occurs the specimen drainage valves are closed, and specimen void ratio determined by measuring its moisture content at the end of test, adopting the freezing method (Sladen and Handford, 1987\(^1\)).

The CSD stage is video recorded with sound, to capture the rapid failure that initiates when the stress conditions reach the relevant instability stress ratio for the specimen’s state.

The testing steps are provided in a diagram shown in Figure 3.

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**Figure 3: CSD testing steps diagram**

GAPMW 3.2.5 – CONSTANT SHEAR DRAINED TEST WITH DEAD-WEIGHT STRESS CONTROLLED

Scope
The purpose of this procedure is to provide the steps for undertaking constant shear drained (CSD) testing using a 'dead-weight' hanger system.

Equipment
A standard triaxial GDS device has been modified to undertake CSD collapse testing using dead-weights. The adjustments made to the standard triaxial device to allow CSD test to be undertaken are indicated in Figure 1. The system in use for a CSD test is shown in Figure 2.

![Figure 1: Front and side view of triaxial device modified for CSD testing using a dead-weights hanger system](image-url)
Procedure

The test is undertaken using the following steps:

1) A specimen is prepared to its target density and consistency.

2) A suction of maximum 20 kPa is applied to the specimen with a vacuum pump to enable the specimen shape to be maintained during test setup.

3) Initial specimen dimensions are taken using a digital calliper measuring both diameter and height at different specimen locations.

4) The triaxial device is assembled and the cell filled with water.

5) The dead-weights hanger system is connected to the loading ram. Its vertical travel is initially controlled by using the triaxial cross-bar to gently lower the loading ram and hanger system down when necessary to “dock” to the specimen.

6) The specimen is flushed with CO₂ for approximately one hour.
7) The specimen is then flushed with water imposing a differential head of approximately 5 kPa from the bottom to the top of the specimen; flushing is carried out until bubbles are no longer observed to emerge from the pipe connected to the top of the specimen.

8) Back pressure saturation is undertaken over ~3 hours, maintaining an effective stress of 20 kPa. During this stage the clamp locking the dead-weights hanger system is unlocked and the weights are progressively added to prevent the cell pressure from lifting the hanger system. By keeping a dead-weight slightly higher than that required to balance the cell pressure, the hanger remains in a constant position resting on the cross bar.

9) Once the target saturation back pressure is reached and volume change is negligible, a $B$-check is undertaken targeting a $B$ value greater than 95%.

10) The specimen is then unloaded over ~3 hours to a cell pressure of 0 kPa and back pressure of -20 kPa.

11) The cell water is drained, the cell removed, and the specimen dimension taken using a digital calliper, to allow a more accurate measurement of specimen diameter for subsequent anisotropic consolidation.

12) The specimen is then reloaded following step 8.

13) The specimen is slowly consolidated anisotropically (i.e. deviator stress increased) to its target anisotropic stress conditions by adding weights to the hanger system. The application of load to the specimen is regulated through use of the cross bar, to prevent any rapid loading occurring during this process. The deviator stress increase occurs at an approximate rate of 12 kPa per hour (i.e. approximately 4 kg of weight per hour assuming a specimen diameter of 65 mm). Owing to the manual loading requirement, the anisotropic consolidation is undertaken in stages, i.e. 10 hours of loading during daytime and 14 hours of standby, maintaining a constant stress overnight.

14) Once the target consolidation pressure is achieved, the specimen is left under $K_0$ consolidation for 24 hours.

15) The CSD stage is then commenced by slowly increasing the back pressure at a rate of 10 kPa per hour. Test data are captured at intervals of 1 second, to provide stress conditions as close to failure as practicable.

16) Once failure occurs the specimen drainage valves are closed, and specimen void ratio determined by measuring its moisture content at the end of test, adopting the freezing method.

The CSD stage is video recorded with sound, to capture the rapid failure that initiates when the stress conditions reach the relevant instability stress ratio for the specimen’s state.

The testing steps are provided in a diagram shown in Figure 3.
STEP 1. Specimen preparation

STEP 2. Suction applied to specimen to maintain its shape

STEP 3. Initial specimen dimensions taken

STEP 4 and 5. Assembling of triaxial device and specimen docking

STEP 6 and 7. CO₂ and water flushing

STEP 8. Back pressure saturation

STEP 9. B-Check

STEP 10. Unloading back pressure

STEP 11. Dissembling of triaxial cell and measure of new specimen dimensions for $K_0$ consolidation

STEP 12. Reloading back pressure

STEP 13. Anisotropic consolidation (15 kPa/hour)

STEP 14. Standby consolidation under $K_0$ for 24 hours

STEP 15. CSD stage increasing back pressure to 10 kPa/hour

STEP 16. Void ratio determination

Figure 3: CSD testing steps diagram
GAPMW 3.4.2 – SHEAR WAVE VELOCITY MEASUREMENT USING BENDER ELEMENTS FOR TRIAXIAL TEST OF SPECIMEN CONSOLIDATED ANISOTROPICALLY

Scope

The purpose of this procedure is to provide the steps for measuring the shear wave velocity \( V_s \) of a triaxial specimen consolidated anisotropically using bender elements. When \( V_s \) and the bulk density \( \rho_b \) of the specimen at the time of measurement are known, the small strain shear modulus \( G_0 \) can be determined by the following equation:

\[
G_0 = \rho_b \cdot V_s^2
\]

The shear wave velocity is calculated by recording the time \( t \) required for the wave to travel through the specimen from the bottom through the top. Rather than the length of the specimen, the travel distance is defined as the length between the tip of the bender elements or tip-to-tip distance \( L_{tt} \). Therefore, the shear wave velocity is calculated by the following equation:

\[
V_s = \frac{L_{tt}}{t}
\]

Figure 1 shows an example of a transmitted and received signal using bender elements.

![Graph showing transmitted and received signals](image_url)

**Figure 1: Transmitted and received signals using bender element system**

Different criteria have been explored to select the point at which the arrival time \( t \) occurs in a bender element system such as (A) first deflection, (B) first bump maximum, (C) zero after first bump, and (D) major first peak as shown in Figure 2 (Lee and Santamarina, 2005).
Shear Wave Velocity Measurement using Bender Elements for Triaxial Test of Specimen Consolidated Anisotropically

Equipment

A GDS wave function generator and data acquisition device is added to a standard triaxial GDS equipment. The triaxial cell is equipped with a pair of caps that have bender elements protruding from the centre of the caps as shown in Figure 3.

Procedure

The test is undertaken using the following steps:

1) A specimen is prepared in accordance to the loose moist tamped triaxial preparation procedure, with the following exemptions:
   a) The standard caps are replaced with a pair of caps with bender elements
   b) A connection ring for the cell is required at the base to allow access of the connection ports for the bender element caps

Figure 2: Different first arrival points as described by Lee and Santamarina, 2005

Figure 3: Set of caps with bender elements
c) Installation of the bender elements caps requires proper alignment during the setup

2) A suction of maximum 20 kPa is applied to the specimen with a vacuum pump to enable the specimen shape to be maintained during test setup.

3) Initial specimen dimensions are taken using a digital calliper measuring both diameter and height at different specimen locations

4) The triaxial device is assembled and the cell filled with water.

5) The specimen is flushed with CO₂ for approximately one hour.

6) The specimen is then flushed with water imposing a differential head of approximately 5 kPa from the bottom to the top of the specimen; flushing is carried out until bubbles are no longer observed to emerge from the pipe connected to the top of the specimen.

7) Back pressure saturation is undertaken over ~3 hours, maintaining a mean effective stress of 20 kPa.

8) Once the target saturation back pressure is reached, and volume change is negligible, a B-check is undertaken targeting a B value greater than 95%.

9) The specimen is then unloaded over ~3 hours to a cell pressure of 0 kPa and back pressure of -20 kPa.

10) The cell water is drained, the cell removed, and the specimen dimension taken using a digital calliper, to allow a more accurate measurement of specimen diameter for subsequent anisotropic consolidation.

11) The specimen is then reloaded following step 7.

12) Using the BE program, the following parameters must be defined:
   a) Specimen height
   b) Data sampling frequency and time
   c) Amplification factor or gain (auto)
   d) Input signal waveform (sinusoidal), period (varies) and amplitude (14V)
   e) Wave type: compressional wave (P) or shear wave (S)
   f) Trigger type (manual)

13) The input signal is sent by pressing the trigger button.

14) Several periods are used to determine a range with a good quality signal.

15) At least three signals with different periods are recorded individually.

16) The height of the specimen at the time of measurement is recorded.

17) The specimen is consolidation under anisotropic conditions targeting a $K_0$ of 0.6.

18) The process is repeated as many times as required, typically at the end of each consolidation stage generally every approximately 100 kPa mean effective stress. Arrival time and thus shear wave velocity can be obtained using the GDS program or during the data process analysis.

19) At the end of testing, the deviatoric stress is reduced to near zero stress to achieve near isotropic conditions allowing drainage of the specimen during the process.
20) After achieving steady conditions, confining stresses are further reduced to a confining effective stress of 20 kPa at the same time the back pressure is reduced to zero allowing the specimen to drain.

21) Following the reduction of stresses to 20 kPa, the cell pressure is reduced to zero and the back pressure to -20 kPa.

22) After the specimen achieves steady conditions the drainage valves are closed, and the cell is disassembled while the sample is under suction.

23) The end of test sample dimensions is taken using a digital calliper measuring both diameter and height at different locations to allow its comparison with the specimen void ratio inferred from the end of test freezing method (Sladen and Handford, 1987²).

24) The top cap with the bender element is carefully removed and replaced with a standard cap provided of drainage valves.

25) The specimen is flipped upside down and the bottom cap is also replaced with a standard cap of drainage valves.

26) The specimen void ratio is determined by measuring its moisture content at the end of test, adopting the freezing method which involves freezing the specimen with the membrane, replaced standard caps and drainage lines attached.

The specimen at step 10 (specimen measurement after saturation prior to $K_0$ consolidation) and step 23 (end of test specimen measurement) is shown in Figure 4.

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Figure 4: Specimen condition prior to $K_0$ consolidation (left) and at end of test (right)
GAPMWW 4.1.1 – MOIST TAMPED LOOSE SPECIMEN PREPARATION FOR DIRECT SIMPLE SHEAR TESTING

Scope
The purpose of this procedure is to prepare a loose specimen using the moist tamping preparation technique for direct simple shear (DSS) testing.

Equipment
The preparation was undertaken using a special DSS mould designed to allow preparation of loose specimen and a suction pump. This mould allows to undertaking preparation of a specimen while allowing the membrane to be neatly fixed on the DSS rings by application of suction.

The GDS specimen preparation mould and the DSS mould while suction is applied are shown in Figure 1.

![Figure 1: GDS specimen preparation mould (left) and DSS mould while suction is applied (right)](image)

Procedure
The specimen preparation is undertaken using the following steps:

1) The DSS is prepared with the rings with a latex membrane neatly fixed against the walls of the mould by applying suction.

2) The sample is placed inside the DSS and tamped to a known density in one layer while applying suction. A stainless steel ring is used to facilitate placement of the material inside the DSS while tamping to the height of the last DSS ring.

3) The DSS device is assembled and the top platen is lowered down using the computer-controlled software to a given bedding load of approximately 10 kPa.

4) The suction is removed, and the specimen preparation mould dissembled.

5) The DSS base is tightened via four screws located at each corner to the main device, the restrain arms to reduce specimen rotation during shear assembled and the test commenced.

The specimen preparation procedure is shown in Figure 2 to Figure 5.
Figure 2: Placement of loose sample in DSS mould with stainless steel ring used to facilitate material placement

Figure 3: Tamped specimen outside DSS device (left) and fitted on the DSS base while still under suction (right)
Figure 4: Top DSS platen lowered down to specimen surface (left) and with specimen preparation mould disassembled (right)

Figure 5: DSS device assembled without (left) and with (right) restrain arms mounted
**GAPMW 4.2.2 – CYCLIC DIRECT SIMPLE SHEAR TEST**

**Scope**

Direct simple shear (DSS) testing involves preparation of a cylindrical specimen with a typical height to diameter ratio of about 0.4 within a membrane which is laterally constrained by a stack of low-friction metal rings. The material is vertically consolidated to the desired stress with or without an initial static shear stress (α, bias). Owing to the lateral restraint provided by the stack of rings, consolidation occurs under a $K_0$ condition (i.e. zero lateral strain). Once consolidation is completed, the specimen is sheared cyclically by moving the lower platen horizontally while the top platen remains still. Following cyclic loading, the specimen is sheared monotonically to provide an indication of post-cyclic strength. This may, in some instances, provide an assessment of post-liquefaction strength.

It should be noted that while DSS testing provides undrained strength parameters, the test itself is not undrained. Rather than restrict drainage, constant volume conditions are enforced via computer control of the test. Should the specimen contract, the top platen would begin to move downwards, reducing the height of the specimen. However, the computer control system prevents this from occurring by reducing the vertical stress to maintain a constant height. The excess pore pressures that would have developed within the specimen can then be inferred from the changes in vertical stress required to maintain constant height. This testing method has been shown to provide the same results as tests with enforced drainage conditions (Finn 1985\(^1\), Dyvik et al. 1987\(^2\)).

**Equipment**

Specimens were tested using a GDS electro-mechanical dynamic cyclic simple shear (EMDCSS) system shown in Figure 1.

---


The device is capable of carrying out DSS testing under monotonic and cyclic conditions. The GDS DSS base and top platens are specially designed to allow saturation to occur by applying a flow, generally from the bottom of the specimen to its top via a pump or a water reservoir.

**Procedure**

The test is undertaken using the following steps:

1) A specimen is prepared according to the loose tamping preparation procedure\(^3\) in a 100 mm diameter specimen.

2) The specimen is consolidated to the vertical effective stress for saturation of generally 15 kPa and water is flushed through the specimen from the base to the top.

3) For tests without bias, the specimen is consolidated to the target vertical effective stress in stages. For tests with a bias, the specimen is consolidated to the target vertical and horizontal effective stresses by ramping at a vertical stress rate of 10 ~ 25 kPa/hour.

4) The specimen is sheared cyclically by applying a sinusoidal cyclic stress at a loading frequency of 1 Hz.

5) Once the cyclic shear stage is completed, a post-cyclic monotonic shearing stage is undertaken. For testing with bias that during cyclic loading reached the maximum positive shear strain of the device, a “reverse” post-cyclic monotonic shear stage is undertaken – i.e. where post-cyclic shearing is in the opposite direction the bias application.

6) Once the test is completed, the DSS is dissembled, the specimen removed and dried in a 110°C oven for moisture content measurement.

The typical end of test specimen is provided in Figure 2.

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\(^3\) GAPMW 4.1.1 Moist Tamped Loose Specimen Preparation for Direct Simple Shear Testing
Annexure ER
Stress Path Triaxial Test Video Footage