Memorandum

25 November 2019

To	Memorandum dated 5 September 2019		
Copy to			
From	GHD Pty Ltd	Tel	(07) 3316 3000
Subject	Cover Page to Memorandum dated 5 September 2019	Job no.	41 32235

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Memorandum

5 September 2019

To	file		
Copy to			
From	[redacted]	Tel	[redacted]
Subject		Job no.	4132235

1 Scope and purpose

The purpose of this memo is to present the findings of the review of the existing shear strength test data for the roller-compacted concrete (RCC) lift joints, provide recommendations for design shear strengths to be adopted for the stability analyses of the dam, and present recommendations on any further work to be done to achieve greater confidence in the results.

The information used in this review is as follows:

- Stability analyses and associated assumptions as presented in the 2016 SunWater dam safety review[1]
- RCC testing as presented in the 2016 SunWater report on geotechnical investigations[2]
- RCC test result data provided by [redacted] by USB on 25/10/2018
- RCC test data from samples obtained as part of the 2019 geotechnical investigations
- Powerpoint presentation of photos and Excel core logs of the 2006 post-construction investigation borehole provided by [redacted] of Entura by email on 31/7/2019

A key reference in this assessment is the ANCOLD guideline on design of concrete gravity dams[3].

2 Summary of previous shear strength assumptions

2.1 Original design assumptions (BDA, 2004)

BDA (2004) [4] gives the shear strength parameters used in the design of the dam as follows:

- Without bedding mix
  - Cohesion – 325 kPa
  - Friction angle – 40.4°

[1] SUNWATER LIMITED, 2016, *Paradise Dam – Dam Safety Review – Revise Report 2016*, SunWater, Brisbane.

[2] SUNWATER LIMITED, 2016, *Paradise Dam - Geotechnical Investigations of Primary, Secondary and Tertiary Spillway Foundations*, SunWater, Brisbane.

[3] AUSTRALIAN NATIONAL COMMITTEE ON LARGE DAMS (ANCOLD), 2013, *Guidelines on Design Criteria for Concrete Gravity Dams*, ANCOLD.

[4] BURNETT DAM ALLIANCE (BDA), 2004, *Burnett River Dam – Detail Design Report*, BDA.

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- With bedding mix
  - Cohesion – 2,400 kPa
  - Friction angle – 42.0°

It is noted that these values appear to have been based on a Lift Joint Quality Index (LJQI) of "good". For a LJQI of "poor", the shear strength parameters would be:

- Without bedding mix (untreated)
  - Cohesion – 250 kPa
  - Friction angle – 35.0°
- With bedding mix
  - Cohesion – 2,000 kPa
  - Friction angle – 38.7°

It is understood that the Alliance adopted a shear strength of 250 kPa cohesion and 35° friction based on a poor LJQI. No testing was undertaken to confirm that this was achieved. It is understood that this was based on recommendations from BDA's RCC consultant, [redacted], as published in Schrader (1999)[5].

Acceptance criteria adopted for sliding were 3.0, 2.0 and 1.3 for normal, unusual and extreme load cases.

2.2 Adopted parameters for dam safety review stability analyses

The shear strength parameters adopted for the stability analyses undertaken as part of the SunWater dam safety review are as follows:

- Base case (peak shear strength) – 50 kPa cohesion and 47° friction
- Sensitivity (residual shear strength) – 0 kPa cohesion and 41° friction

It is noted that a comment is made in the dam safety review report that the shear strength was increased by 2-3° to account for the large scale asperities on the lift joint. Further comment on this is provided below.

It is understood that the acceptance criteria used in this assessment were as listed in Table 6.1 of ANCOLD (2013) for "well defined" peak and residual strengths, as follows:

- Peak shear strength – 2.0, 1.5 and 1.3 for normal, unusual and extreme load cases
- Residual shear strength –1.5, 1.3 and 1.1 for normal, unusual and extreme load cases

[5] SCHRADER, E.K., 1999, "Shear strength and lift joint quality of RCC" in *Hydropower & Dams*, issue no 1.

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3 Evaluation of 2015 RCC shear strength testing data

3.1 Shear strength assessment

3.1.1 Overview of samples

As part of the investigations reported in the 2016 SunWater report on geotechnical investigations, a programme of laboratory shear strength testing was undertaken on RCC lift joint samples taken from two vertical boreholes drilled from crest of the left abutment (DD600) and secondary spillway (DD601), and four horizontal cores from the downstream face of the primary spillway. The location of the vertical boreholes are shown on Figure 3.1.

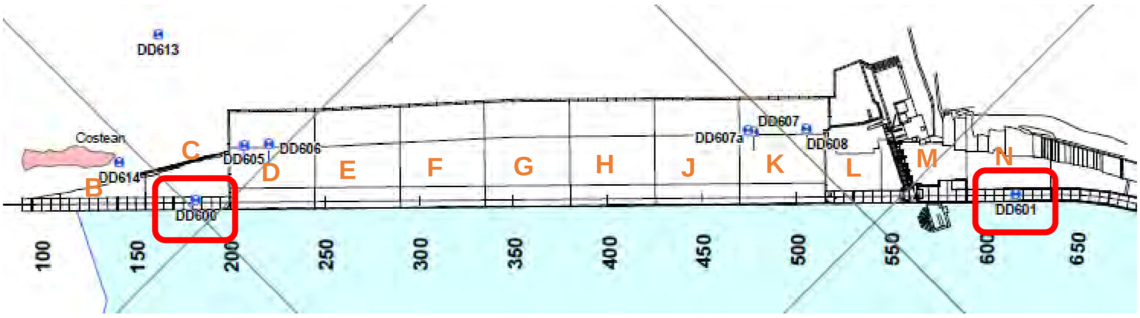

Figure 3.1 Borehole locations for lift joint shear testing samples

Photos of the lift joints samples taken from the vertical boreholes are included in Figure 3.2 and Figure 3.3. Photos of the horizontally-cored samples have been extracted from the Technical Review Panel report included in Appendix K of the SunWater CRA report (see Attachment 1). These cores were taken from the toe of Monoliths F and G. The locations of all the holes in the downstream face primary spillway are not known. The sample from Monolith G is the only one that was tested and the laboratory certificate records this as being from Ch 340.

The laboratory test certificates are included in Attachment 2.

3.1.2 ANCOLD approach

In assessing the shear strengths to be used for design, it is important to understand the basis of the ANCOLD guidelines in terms of acceptance criteria. The guidelines state that the dam should be analysed using both peak and residual strengths and compared against the relevant acceptance criteria. The guidelines also set out different acceptance criteria for situations where the parameters are “well defined” or “not well defined”. ANCOLD states that parameters are “well defined” when “a sufficient number of tests have been done on concrete core from the dam and lift surface to give the strength parameters with reasonable certainty”. It goes on to say that “strength parameters adopted for analyses should be exceeded by about 80% of the test data”.

With reference to Figure 3.4, the peak shear strength is the peak strength achieved on a bonded lift joint or through intact concrete and is achieved at small displacements. The sliding shear strength is the peak strength achieved on an unbonded lift joint and the residual strength is the lowest strength achieved at large displacements on lift joints that were originally either bonded or unbonded. Also, it

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is important to note that the strength envelope is typically curved with higher friction angles at low confining stresses, and approaching residual at high confining stresses.

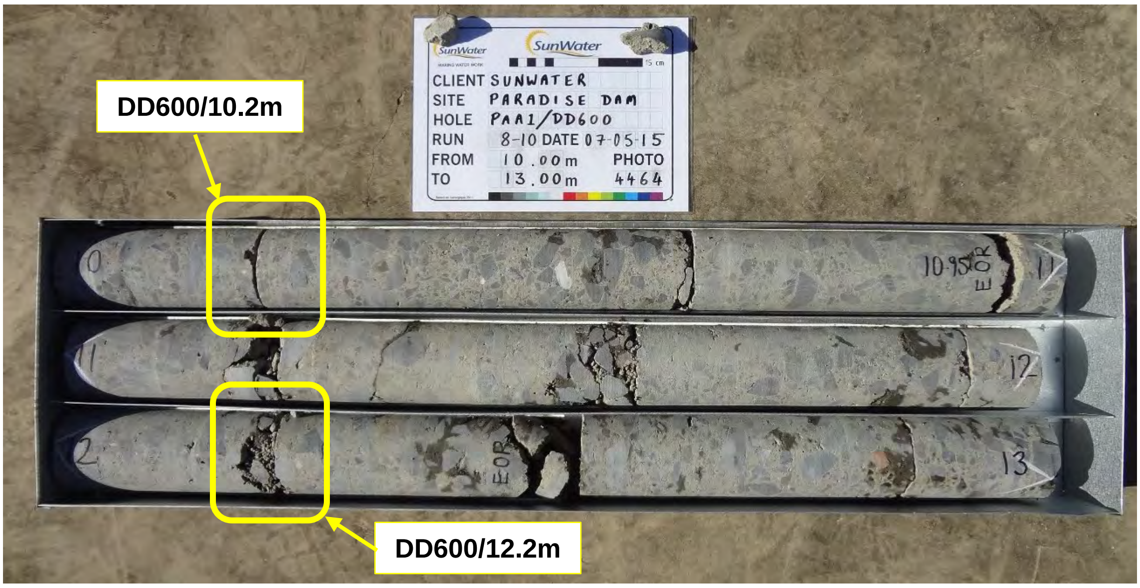

Figure 3.2 Core photos for DD600 test samples

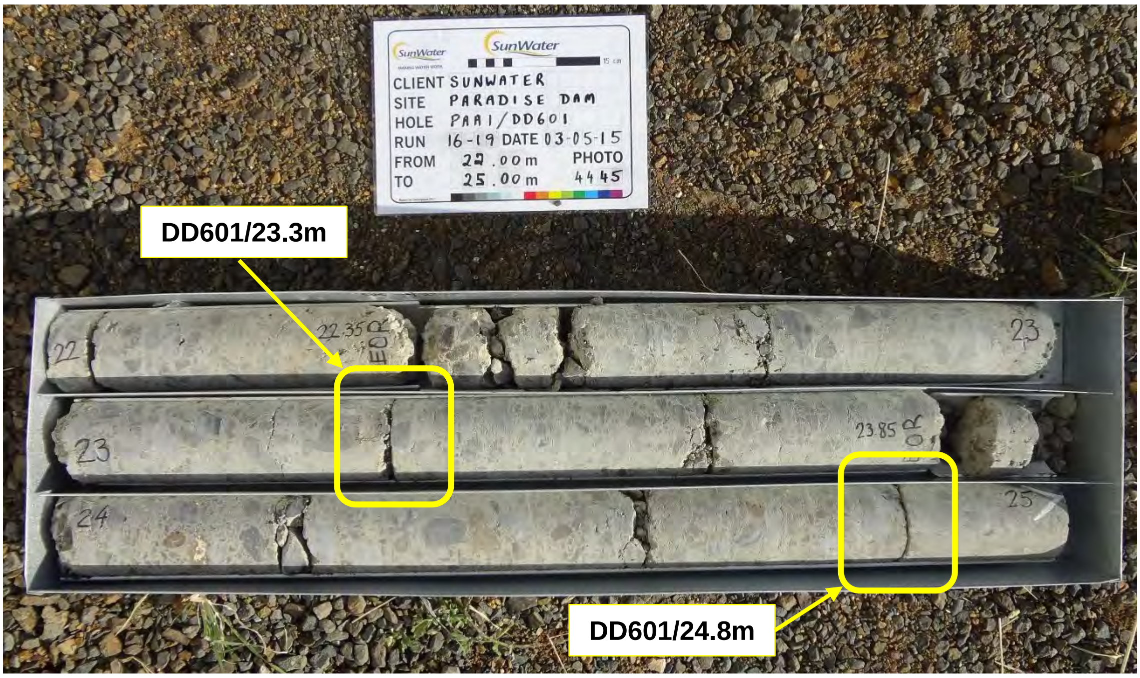

Figure 3.3 Core photos for DD601 test samples

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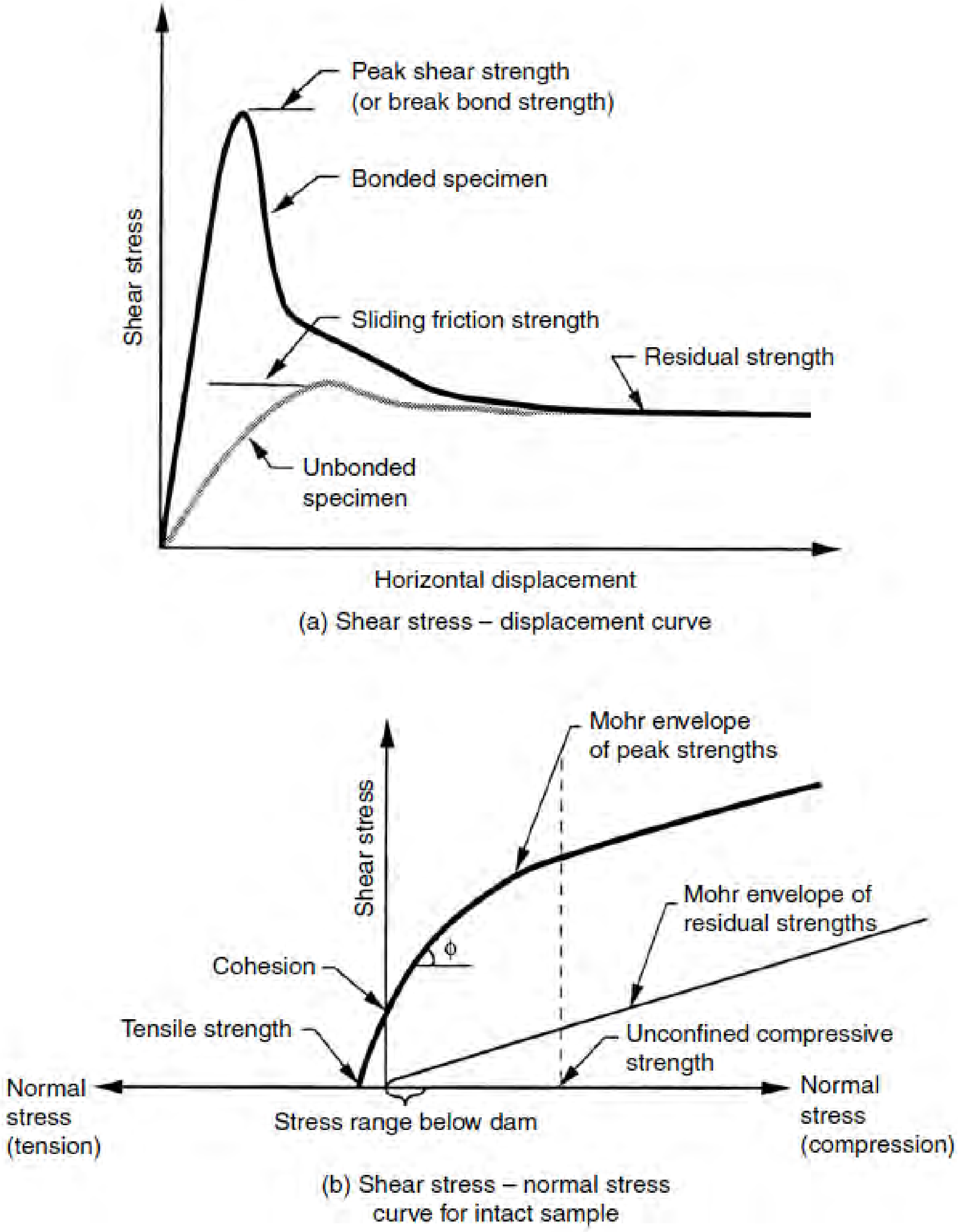

Figure 3.4 Shear strength terminology based on EPRI (1992)[6]

[6] ELECTRIC POWER RESEARCH INSTITUTE (EPRI), 1992, *Uplift Pressures, Shear Strengths and Tensile Strengths for Stability Analysis of Concrete Gravity Dams (Vol 1)*, EPRI, Palo Alto, CA.

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A summary of the laboratory testing is included in Table 3.1. As summarised in this table, there typically appears to be minimal difference between peak and residual strength. Also, it is noted that assessment of the borehole logs and core photographs from holes through the RCC indicate that it is common for lift joints to be unbonded (80-90% of lift joints unbonded in DD600 and DD601) and therefore the sliding friction strength or residual strength is considered appropriate and cohesion should not be included.

Table 3.1 Summary of 2015 laboratory testing

Sample ID	Type	Normal stress	Shear stress	Cohesion (kPa)	Friction angle (°)	Comments
DD600/10.2	Peak	101.3 201.5 398.8	167.3 257.8 455.9	65.3	44.3	Tested over three stages to obtain peak then reset to test residual strength over three stages. No comments provided on test certificate.
	Residual	101.3 201.5 398.8	137.2 220.3 431.4	28.2	45.2	
DD600/12.2	Residual	540 885 1400	212 251 342	0	15	Particle size:shear plane ratio significantly less than preferred 12:1 resulting in disturbance and particle reorientation between test stages.
	"Peak"	540 885 1400	470 550 365			The above comment on particle size:shear plane ratio applies to these results also. Although not reported, the peak shear stresses from each stage have been read off the plot to give an indication of the peak strength. Noted that Stage 3 does not show a significant difference between peak and residual.
DD601/23.3	Peak	228.0 460.8 693.2	155.5 346.5 487.0	4.4	35.1	Tested over three stages to obtain peak then reset to test residual strength over three stages. Noted that peak strength is lower than residual. No comments provided on test certificate.
	Residual	228.0 460.8 693.2	182.9 361.8 536.7	10.2	37.2	

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Sample ID	Type	Normal stress	Shear stress	Cohesion (kPa)	Friction angle (°)	Comments
DD601/24.8	Residual	540 885 1400	445 747 1022	0	37.5	No peak evident on plots of shear stress against displacement. No comments provided on test certificate.
Ch340/1	Peak	300	326	0	47.4	No significant difference noted between peak and residual.
	Residual	300	306 322 317	0 0 0	45.6 47.0 46.6	
Ch340/2	Peak	600	503	0	40.0	No significant difference noted between peak and residual
	Residual	600	526 518 539	0 0 0	41.2 40.8 41.9	
Ch340/3	Peak	900	1054	0	49.5	Reduction in strength from peak to residual
	Residual	900	669 556 663	0 0 0	36.6 31.7 36.4	

The data was further analysed by estimating the secant shear strength for every stage tested. For DD600/12.2, the "peak" values were used in this assessment. The median and 20th percentile (ie "well defined") shear strength was then determined from the data set as summarised in Table 3.2. In calculating this, the average of the results from each stage of the tests on the horizontal cores was used rather than each value to avoid skewing the result. In effect, one result was adopted per sample per stage.

Table 3.2 Summary of derived shear strength results – ANCOLD approach – 2015 testing

Data set	Median shear strength	20th percentile shear strength
All results	40.2	36.1
Filtered for normal stress of 200-600 kPa	41.0	38.3

All the normal/shear stress pairs are plotted in Figure 3.5 together with the interpreted median and 20th percentile shear strength envelope. This has been presented for all results, as well as filtered to show only the results for a normal stress range of 200-600 kPa which covers the expected range of normal stresses. This stress range was selected as being representative of the effective normal stress expected under the main sections of the dam. A plot of normal stress against secant friction angle is also provided in Figure 3.6. It is evident from this plot that the adopted design shear strength

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is strongly influenced by the test results on samples from sample DD601/23.3m. It is noted however that there is no basis to discount these results on the basis of the information available.

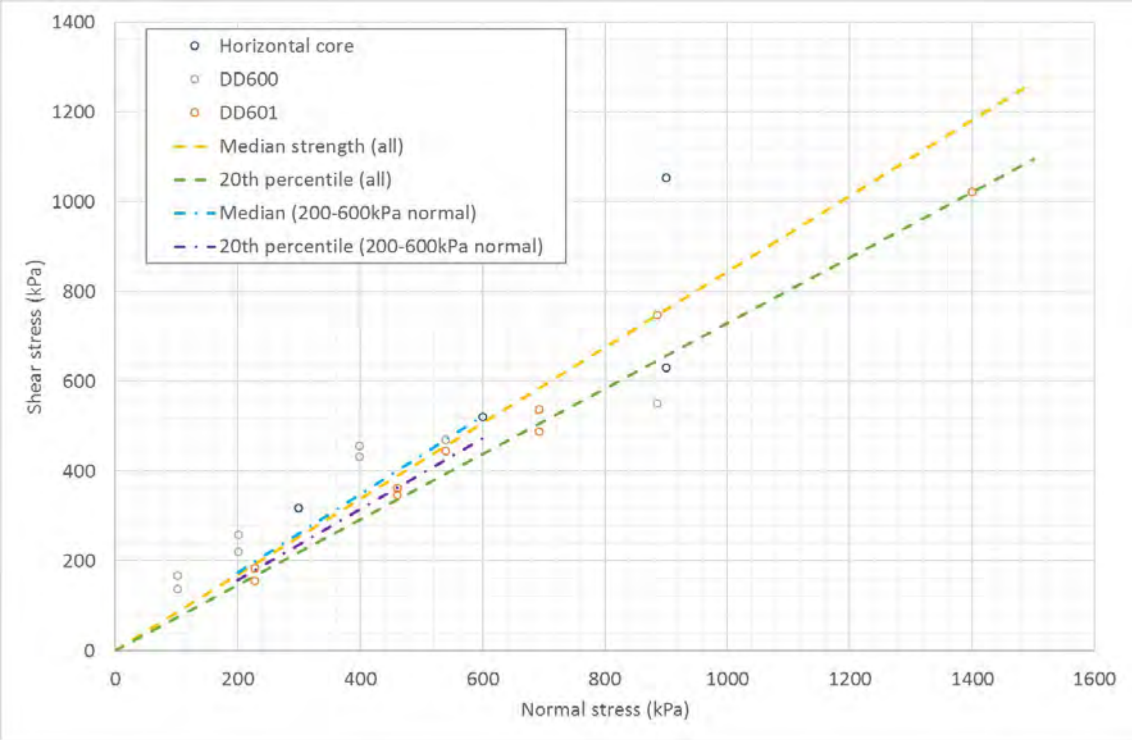

Figure 3.5 RCC lift joint shear strength – Plot of all normal and shear stress pairs and interpreted strength envelopes – ANCOLD approach – 2015 testing

A limitation of this approach is that it assumes that the distribution of the sample strength results truly reflects the distribution of the actual strength. This is unlikely to be the case, especially given the small number of results available. The statistical assessment presented below takes into account this uncertainty.

3.1.3 Statistical assessment approach

An alternative approach was also considered to derive a shear strength based on a statistical assessment of the sample results. This was undertaken by establishing confidence limits such that there was a certain probability that the actual strength was greater than the selected strength. This is different to the approach described in Section 3.1.2 as this method takes into account the variability in the sample results rather than accepting that the sample results truly reflect the distribution. In this case, a confidence level of 97.5% was adopted.

The following describes the process followed for this assessment:

1. A line of best fit was adopted for the data set.
2. For each test, an expected value of shear strength was calculated based on the trend line for each normal stress.

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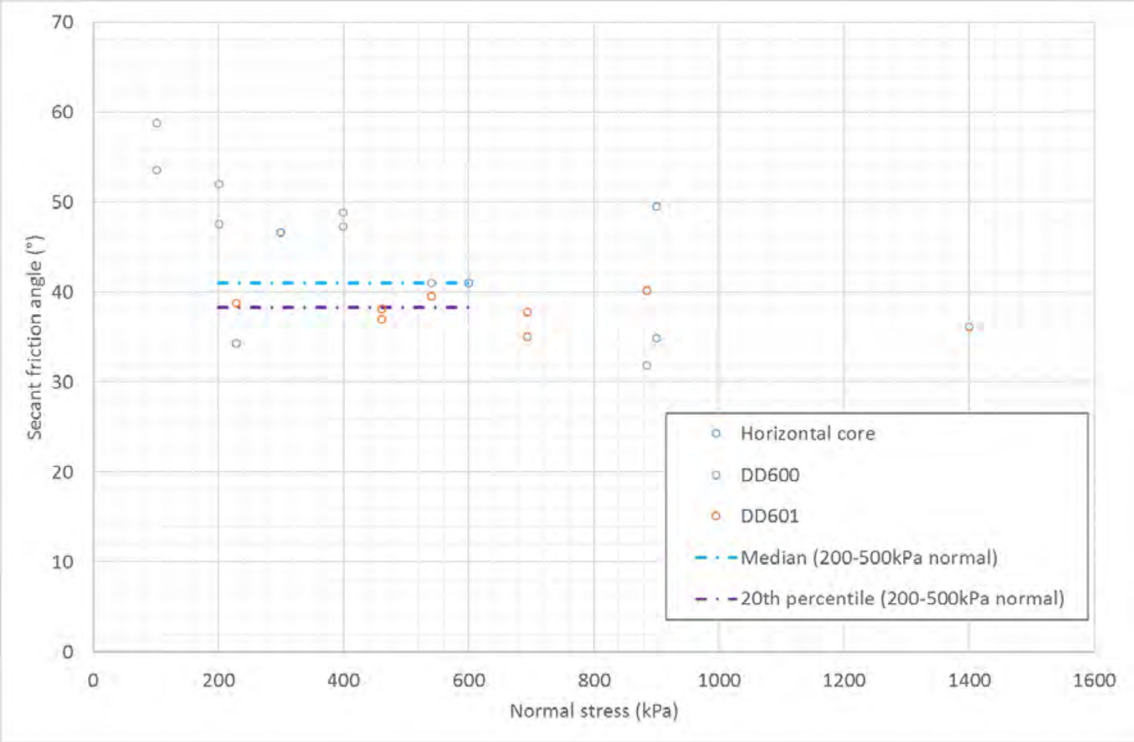

Figure 3.6 RCC lift joint shear strength – Plot of normal stress against secant friction angle – ANCOLD approach – 2015 testing

3. The shear strength result from the test was then normalised by dividing by the expected value from Point 2.
4. The standard deviation and the standard error of the normalised values were calculated.
5. Obtain the t value for the adopted confidence level.
6. Calculate the 97.5% CL value of shear strength as:

   $$\tau_{97.5\%CL} = (c + \sigma_N \tan\phi)_{mean} . \left(1 - t\frac{\sigma}{\sqrt{n}}\right)$$

   or:

   $$c_{97.5\%CL} = c_{mean} . \left(1 - t\frac{\sigma}{\sqrt{n}}\right)$$ and

   $$\tan\phi_{97.5\%CL} = \tan\phi_{mean} . \left(1 - t\frac{\sigma}{\sqrt{n}}\right)$$

This method was applied to produce a design shear strength based on cohesion and friction and also considering a friction only strength. As with the approach in Section 3.1.2, a strength was derived using all the test data and also by filtering to the representative stress range of 200 to 600 kPa. It is noted that the shear strength result of 365 kPa for the 1400 kPa normal stress for sample DD600/12.2 was excluded from the assessment given the comments on particle size potentially affecting the result.

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The results from this assessment are summarised in Table 3.3. The results for the stress range of 200 to 600 kPa are plotted on Figure 3.7 together with the results from the ANCOLD approach.

Table 3.3 Summary of derived shear strength results – Statistical assessment – 2015 testing

Stress range	Cohesion and friction		Friction only
	c (kPa)	ϕ (°)	ϕ (°)
All results	70.4	33.0	34.8
200-600 kPa	62.6	33.5	36.7

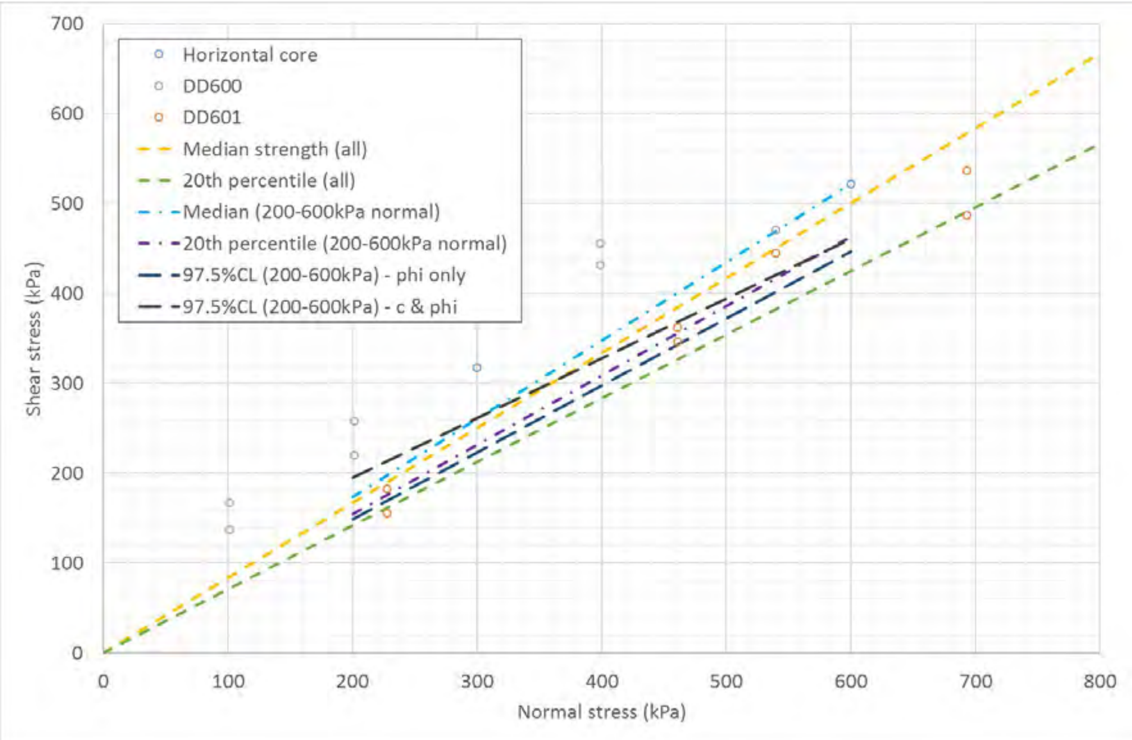

Figure 3.7 Comparison of results from two approaches – ANCOLD approach – 2015 testing

From comparison with the actual shear strength test results, it is considered that the friction only strength of 36.7° is more representative of the results, and that the c and ϕ result appears to overestimate the shear strength at lower stresses. A bilinear strength envelope is considered appropriate to account for the curved nature of the envelope. For normal stresses above 600 kPa, a strength approximately 28° is recommended. A cohesion intercept of approximately 130 kPa would apply above normal stresses of 600 kPa.

3.2 Assessment of RCC lift joint quality based on 2015 cored holes

For boreholes DD600 and DD601, borehole imaging was undertaken by RAAX. An assessment was undertaken of the core photos against the RAAX images to assess whether the retrieved core as

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shown by the core photos was representative of the insitu conditions. The report on the imaging noted that there were difficulties with turbidity of the water in the borehole despite attempts to treat with a flocculating agent. A comparison was undertaken for 1-15 m depth in DD600 (images lacking clarity below about 10 m) and 1-9 m depth in DD601. This side-by-side comparison is included in Attachment 3. It is noted that the alignment of the core photos and the RAAX imagery is approximate only.

From the limited comparison possible, it appears that the condition of the core is generally representative of the insitu conditions within the RCC although the breakage of the core may be greater than in the hole. In most locations, breaks, or boney/broken section in the core appear to correspond with inferred defects in the RAAX imagery. It is likely that the action of coring the vertical holes may have resulted in shearing of previously intact lift joints.

The SunWater dam safety review report notes that only about 20% of lift joints in DD600 were bonded and in DD601, this was only about 10%.

3.3 Review of 2014-15 TRP comments on lift joint shear strength

The lift joint shear strength was discussed during the Technical Review Panel meetings held as part of the safety review and CRA. The following points are noted in terms of chronology:

- The horizontal cored holes were drilled on 2 December 2014.
- An inspection of the horizontal cores was undertaken by [redacted] (a member of the TRP) on 15 December 2014 and a letter report dated 30 December 2014 was provided to SunWater.
- Boreholes DD600 and DD601 were drilled in May 2015.
- It is understood that the last TRP meeting was held in late August 2015 and only the laboratory test results of the tests on the horizontal core samples would have been available.
- The testing on samples from DD600 and DD601 was undertaken in November-December 2015.

The December 2014 letter report by [redacted] makes the following comments:

- The downstream face conventional concrete was of good quality, but the RCC immediately behind the facing was of poor quality and broke up on drilling indicating "that it was not well-compacted and looked as though it may have dried out quite quickly".
- The concrete facing was 1-1.7 m thick, the poor quality RCC was 0.5-0.6 m thick and thereafter the cores could be extracted intact.
- In the good RCC, three of the samples (G1B/2.25-2.75 & 2.75-3.20 and F3B/1.7-2.31) showed good aggregate-to-aggregate contact with a comment in relation to G1B that:

  With the bonding effect that is there, I am sure that we would have some "intact" strength present, in other words, some "cohesion" component when we represent the effective shear strength as the "Mohr" straight line function by a friction value, φ', and a cohesion factor, c'.

- The fourth sample (F3B/2.31-2.77) "separated easily along the layer boundary surface". It is commented that from his experience, the reviewer considers this is representative of a "local area that had dried somewhat before the next layer was placed" and "that such can happen over some small areas, but in general the surface would be as suggested by the core sample from 1.70 m to 2.31 m in Hole F3B".

- The RCC on either side of the layer appeared to very good with "no concerns about the shear strength of the intact RCC".
- For Sample F3B/2.31-2.77, the interpretation from observations is that the surface would have a peak strength of at least 45° but comments that "I realise that there were some lower results, possibly down to 38º or even a bit lower, but to me the RCC surface in Photographs 11-13 is better than 40º".
- A peak shear strength of 200-300 kPa cohesion and 45° friction is advocated for bonded lift joints.
- It is also commented that where bedding mix was used on lift joints, the bonding effect would be better.

Subsequent to this letter report, the TRP report from the August 2015 meeting includes the following comments, noting that the report is dated 15 December 2015:

- Presumably after observing the logs and core photos from DD600 to DD603 which were drilled in May 2015, the following was noted:

  Now that we know about the lack of quality in the RCC layer boundaries in the secondary spillway, we will need to be very conscious about these weaknesses elsewhere. Even so, we should also be mindful of the results of the horizontal cored holes that were done by SunWater in December 2014. Over a length of nearly 4 m in one hole we went from poor to very good quality joint conditions. In other words, we need to remember that the drill holes only pick up spot points for us to check the quality.

- In relation to the shear strength, it is commented that "over a full width of a section we should have a strength of at least 45º and a first time slide strength of close enough to the same value".
- In relation to the secondary spillway, the following is noted:

  Perhaps the really disappointing aspect from the secondary spillway drilling is that, if the holes were in fact drilled into the RCC that had been treated with bedding mix, generally near the upstream face, then the results of the drilling have not been able to show the improvement that the original designers probably would have hoped for.

In the reporting from the TRP from the August 2015, it is noted that there is no mention of the higher shear strengths previously suggested in the December 2014 letter report. The December 2015 TRP report appears to suggest a friction only shear strength of 45° and no cohesion. The reason for the change is not clearly stated, but it is inferred that this is in response to viewing the core from DD600 to DD603 and reviewing the test results on the horizontal core.

A key point to note is that it is understood that the TRP would only have seen the testing on the horizontal core and did not have the opportunity to review the later shear strength testing on samples from DD600 and DD601.

4 Evaluation of 2019 RCC shear strength testing data

4.1 Testing approach

4.1.1 Overview of samples

The samples for the 2019 testing of the shear strength of the lift joints were taken from horizontal cores extracted from the downstream face of the secondary spillway and left abutment. These cores were obtained as part of the 2019 geotechnical investigations which were part of the preliminary design phase of the Dam Improvement Project. The focus was on these locations as it was easier to centre the hole on a lift joint as the lift joints were generally visible on the downstream face of these sections. The downstream face of the primary spillway is faced with reinforced concrete which covers the RCC.

Based on core photographs, samples were selected and shipped to the Trilab laboratory in Geebung. Two visits to the laboratory took place to view the core, select samples and agree the process for testing.

Based on the two visits to the laboratory, a listing of the samples observed and comments on their suitability for testing is included in Table 4.1 and Table 4.2. The sample ID is “RCC-X/Y.Y-Z.Z” where X is the dam monolith reference, and “Y.Y-Z.Z” is the depth of the sample from the collar of the hole. The colour coding in the table is included to show those samples that have already been tested (green), those not considered suitable for testing (red) and those considered suitable but not yet tested (unshaded). Testing on the three samples listed in Table 4.2 is currently underway with results expected early September 2019.

Table 4.1 Description of 2019 RCC core samples – 25/6/2019 laboratory visit

Sample ID	Comments	Photo	Suitability for testing
RCC-B/ 0-1.1	• Bonded lift joint • Sample from downstream face • Conventional concrete fillet evident at upstream face • Poorly compacted material outside of conventional concrete zone	 	Not suitable as result will be heavily influenced by the conventional concrete fillet at the downstream face Possibly use as a trial sample to assess sample preparation and testing approach

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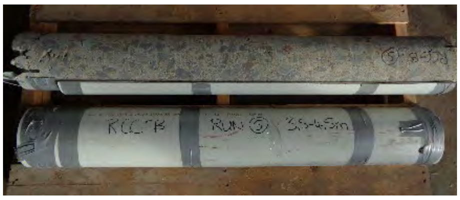
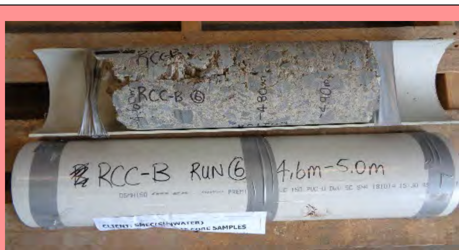
Sample ID	Comments	Photo	Suitability for testing
RCC-B/ 1.1-2.4	• Bonded lift joint • Lift joint about 50 mm from bottom of sample		Suitable for direct shear testing – three samples selected
RCC-B/ 2.4-3.5	• PVC casing incorrectly labelled as “RCC-B Run 4 4.6-5.0m”. Label should be “RCC-B Run 4 2.4-3.5m” • Bonded lift joint • Minor honey-combing/loss of aggregate along lift joint	 	Suitable for direct shear testing if required – sample locations not selected
RCC-B/ 3.5-4.5	• Bonded lift joint		Suitable for direct shear testing if required – sample locations not yet selected
~~RCC-B/ 4.6-5.0~~	~~• Bonded lift joint~~ ~~• Honeycombing/loss of aggregate along lift joint~~ See Table 4.2		~~Suitable for direct shear testing if required – sample locations not yet selected~~
RCC-N/ 3.3-4.2	• No lift joint in sample		Suitable for density and compressive strength

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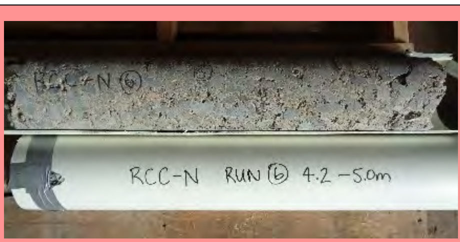
Sample ID	Comments	Photo	Suitability for testing
RCC-N/ 4.2-5.0	• No lift joint in sample		Suitable for density and compressive strength
RCC-Q/ 1.8-2.3	• Bonded lift joint • Lift joint about 30 mm from bottom of sample		Sample "RCC-Q/3.9-4.95" selected given greater thickness of sample below lift joint
RCC-Q/ 2.5-3.3	• Bonded lift joint • Significant segregation along lower part of upper lift • Lift joint about 30 mm from bottom of sample		Sample "RCC-Q/3.9-4.95" selected given greater thickness of sample below lift joint
RCC-Q/ 3.9-4.95	• Bonded lift joint • Lift joint about 40-45 mm from bottom of sample		Selected for direct shear testing – three samples to be selected Considered to be the best option from Mono Q samples, ie the greatest depth below the lift joint
RCC-S/ 2.3-3.3	• Bonded lift joint • Significant segregation along lower part of upper lift • Friable material along base of upper lift joint		Selected for testing – ~~possibly triaxial rather than direct shear with lift joint orientated at about 65° to the horizontal~~ As discussed at meeting 18/7/2019, undertake direct shear test

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Sample ID	Comments	Photo	Suitability for testing
RCC-S/ 4.2-4.9	• Similar to RCC-S/2.3-3.3 but less segregation and better quality		Possibly suitable for direct shear testing

Table 4.2 Description of 2019 RCC core samples – 18/7/2019 laboratory visit

Sample ID	Comments	Photo	Suitability for testing
RCC-B/ 4.5-5.0	• Previously reviewed as noted in Table 4.1 and sample was bonded • Cause of debonding not known, eg degradation on exposure or physical disturbance • Now considered as debonded lift joint • Some loose particles on lift joint	Photo from 18/7/2019:  Photo from 25/6/2019: 	Selected for direct shear testing – at least two samples to be selected
RCC-P/ 1.5-2.0	• Bonded lift joint • Minor segregation noted		Selected for direct shear testing – three samples to be selected
RCC-S/ 1.3-1.9	• Bonded lift joint • Minor segregation noted		Selected for direct shear testing – three samples to be selected

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4.1.2 Proposed testing methodology

The direct shear testing is being undertaken in accordance with ASTM D5607[7] at Trilab's Gebung laboratory using their 300 mm GCTS Direct Shear Testing System. It was necessary to fabricate inserts for the testing apparatus to allow multiple samples to be prepared in advance and to expedite the testing.

The apparatus and the ASTM standard allow the testing to be undertaken either submerged or unsubmerged. There appears to be no clear guidance available on the effects of this and which alternative should be selected. It is considered that undertaking the testing submerged will possibly yield a lower shear strength and that this may have a greater effect on the residual testing than for the peak strength. For this programme of testing, the testing was undertaken submerged as this may be more representative of lift joints within the dam, especially in the lower part of the structure.

The intent of the testing was to obtain as much information from each of the samples obtained. The methodology for the direct shear testing of the samples with intact lift joints is proposed as follows:

- Select three samples from each section of core to be tested and prepare as required
- Normal stresses recommended for testing are 200 kPa (σ_n-1), 500 kPa (σ_n-2) and 1,000 kPa (σ_n-3)
- Sample 1 from each section of core is to be tested as follows:
  - Test at σ_n-1 to obtain “peak bonded” shear strength and stop test as soon as failure is achieved
  - Test at normal stress of σ_n-1 to obtain “peak unbonded” shear strength and stop test as soon as failure is achieved
  - Test at normal stress of σ_n-2 to obtain “peak unbonded” shear strength and stop test as soon as failure is achieved
  - Test at normal stress of σ_n-3 to obtain “peak unbonded” shear strength and stop test as soon as failure is achieved
  - Test at normal stress of σ_n-1 to obtain “residual” shear strength
  - Reset the sample or reverse the direction of shearing and retest at normal stress of σ_n-1 to obtain check on “residual” shear strength
  - Test at normal stress of σ_n-2 to obtain “residual” shear strength
  - Reset the sample or reverse the direction of shearing and retest at normal stress of σ_n-2 to obtain check on “residual” shear strength
  - Test at normal stress of σ_n-3 to obtain “residual” shear strength
  - Reset the sample or reverse the direction of shearing and retest at the same normal stress as the “peak bonded” test above to obtain check on “residual” shear strength
- Sample 2 from each section of core is to be tested as follows:
  - Test at σ_n-2 to obtain “peak bonded” shear strength and stop test as soon as failure is achieved
  - Undertake tests for “peak unbonded” and “residual” shear strength as listed for Sample 1
- Sample 3 from each section of core is to be tested as follows:

[7] ASTM, 2016, *Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force*, West Conshohocken, PA.

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– Test at σ_n-3 to obtain "peak bonded" shear strength and stop test as soon as failure is achieved
– Undertake tests for "peak unbonded" and "residual" shear strength as listed for Sample 1

In addition to the testing, the following are also required for all test samples:

- Photographs of all samples before cutting, before casting into the moulds, and before and after testing
- Photographs of the lift joint/failure surface after each stage of testing (where possible)
- Profiles of the lift joint/failure surface after each stage of testing
- Comment on the condition of the joint/failure surface after each stage (where possible) and whether the surfaces appear to more smooth cement mortar, coarse aggregate or other
- Density of all samples before testing

4.2 Shear strength assessment

The assessment of the shear strength was generally undertaken using the same approach as outlined in Sections 3.1.2 and 3.1.3. At this stage, only test results on the samples highlighted in green in Table 4.1 have been included in this assessment. The test certificates are included in Attachment 4.

Initially, an assessment was undertaken using only the 2019 test results to assess their statistical similarity against the 2015 data. The data was then combined for the assessment of the shear strength noting that all the data from the 2015 testing was essentially residual strengths.

The 2019 testing yielded "peak bonded", "peak unbonded" and "residual unbonded" strengths and these are presented in Figure 4.1 to Figure 4.3, respectively, noting that the trendline included on each of these figures is a mean best fit only. The statistical assessment is discussed below.

The data was assessed using the statistical approach presented in Section 3.1.3. The data was grouped as "peak bonded", "peak unbonded" and "residual unbonded" to give an assessed strength for each. This assessment focussed on the normal stress range of 200-600 kPa given this is the expected range of normal stress for the maximum height section. The results of this assessment are summarised in Table 4.3 and plotted in Figure 4.4 noting that the "peak bonded" and "peak unbonded" results are based on the 2019 testing only and the "residual unbonded" results are based on the combined 2015 and 2019 testing.

Table 4.3 Summary of derived shear strength results – Statistical approach – 2019 testing

Parameter	Cohesion and friction	
	c (kPa)	ϕ (°)
"Peak bonded" – 200-600 kPa	97	36.0
"Peak unbonded" – 200-600 kPa	145	36.0
"Residual unbonded" – 200-600 kPa – c & ϕ	65	33.4
"Residual unbonded" – 200-600 kPa – ϕ only	0	39.3

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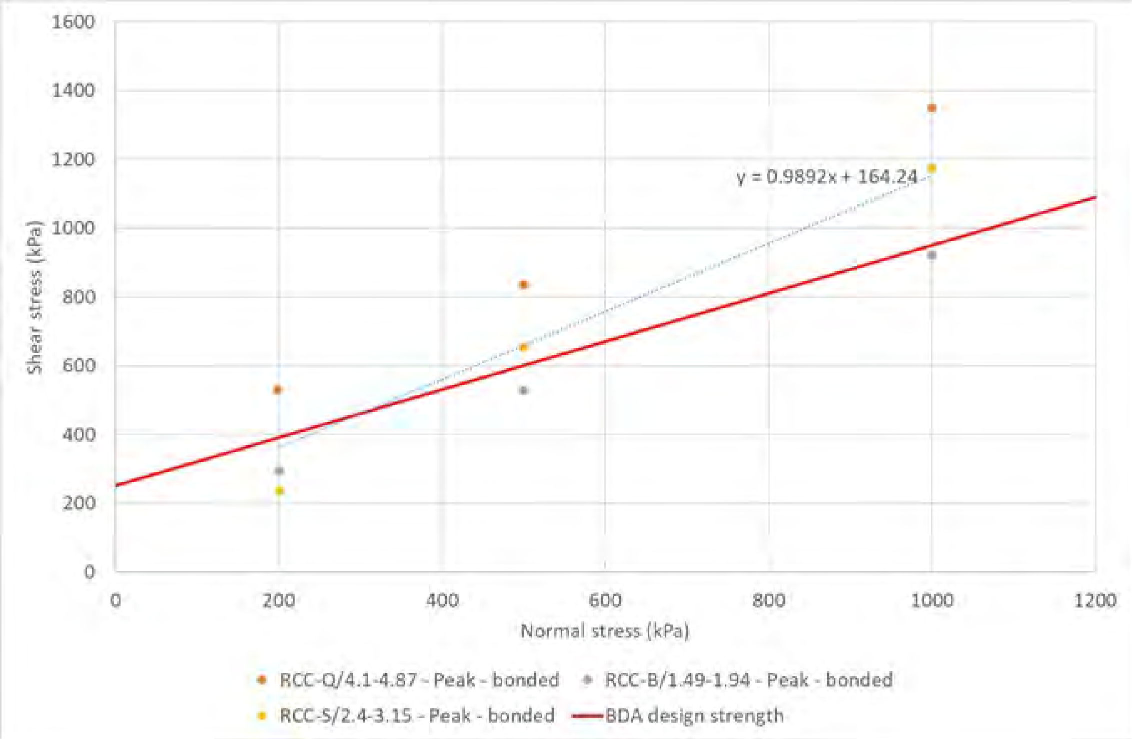

Figure 4.1 2019 "peak bonded" shear strength results

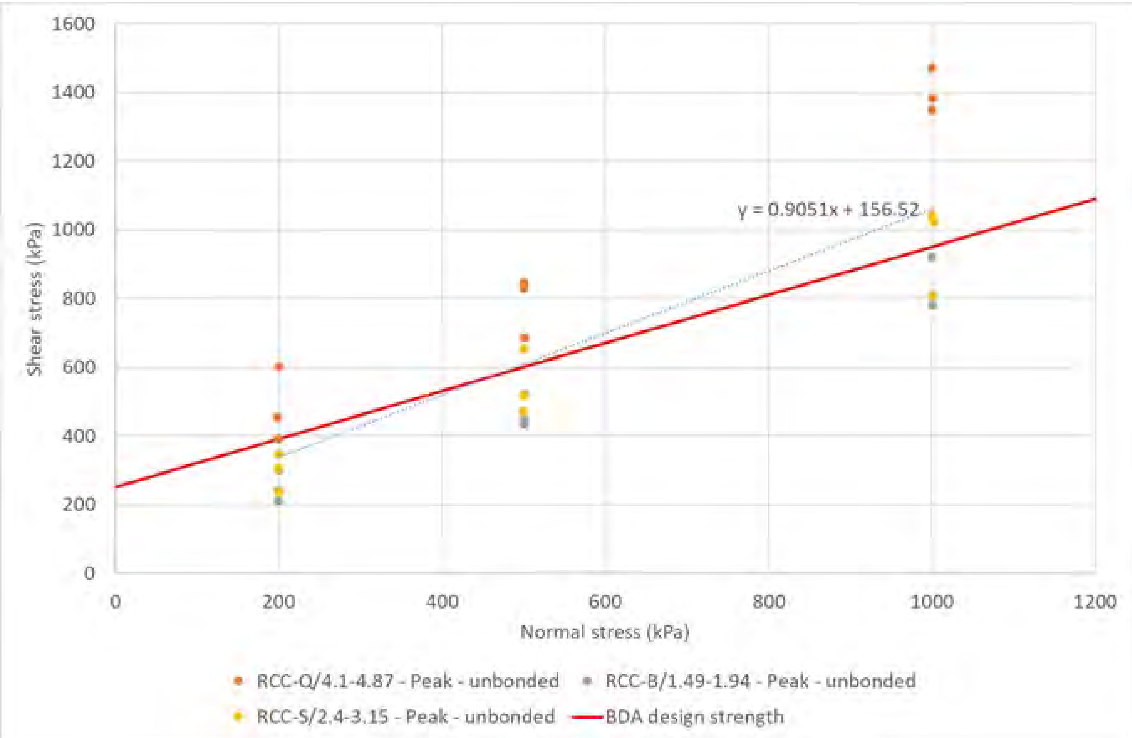

Figure 4.2 2019 "peak unbonded" shear strength results

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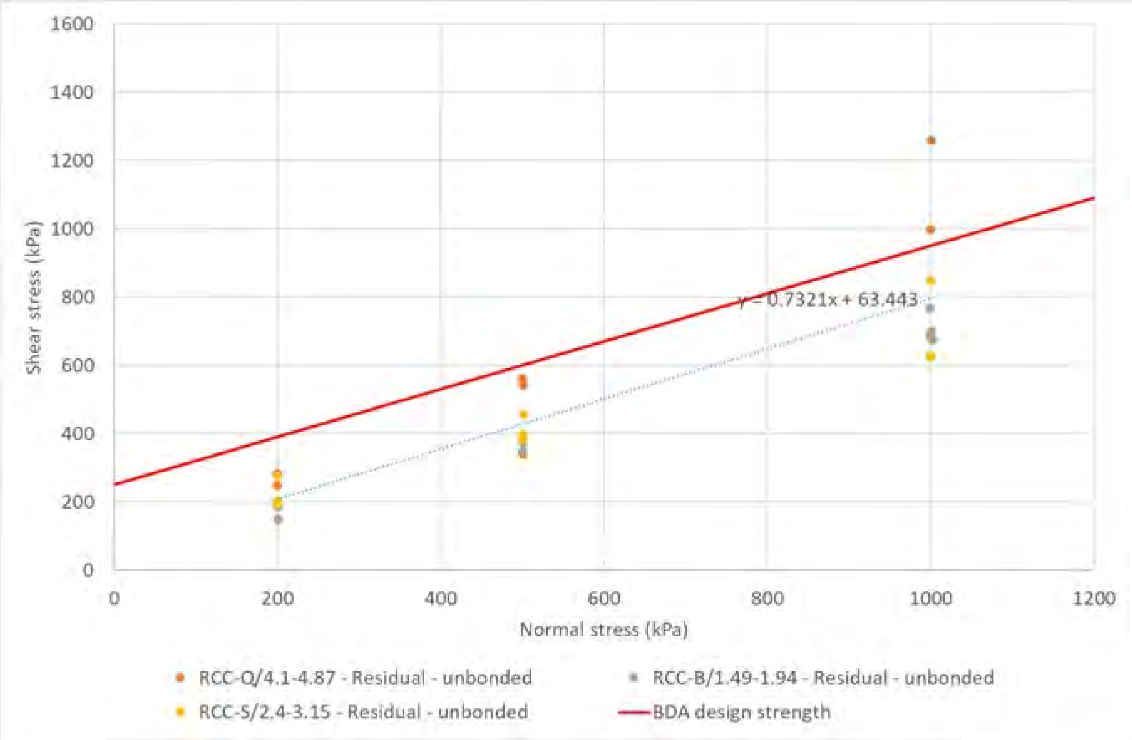

Figure 4.3 2019 "residual unbonded" shear strength results

It is noted that the interpreted "peak bonded" strength based on the statistical approach is lower than the interpreted strength for the "peak unbonded" case. This is due to the limited number of samples and the spread of the data for the "peak bonded" case which increases the standard error and therefore reduces the statistical assessment of the strength.

4.3 Revised assessment of RCC lift joint quality based on 2019 cored holes

The assessed strength of the lift joints is heavily dependent on the quality of the joint, especially whether it is debonded or segregated. The areal extent of debonding or segregation is also critical. As part of the 2019 geotechnical investigations, four holes were cored within one monolith with the aim of assessing lift joint quality across the monolith. A 90 m deep vertical borehole (labelled PD-04) was already proposed in Monolith Q at about Ch 704.6. Three additional shallower vertical holes were drilled in the same monolith to assess the areal variability in the lift joint quality. The holes used in the assessment of the lift joint quality variability are listed in Table 4.4.

In addition to the core logs and photographs, optical and acoustic televiewer (OTV and ATV) data was also obtained. Based on this information, each lift joint in the four boreholes was classified as follows:

- Bonded
  - Logged as intact joint and no break in retrieved core; OR
  - Looks to be clean break in core photos but no clearly discernible joint in OTV/ATV and break considered to be caused by drilling

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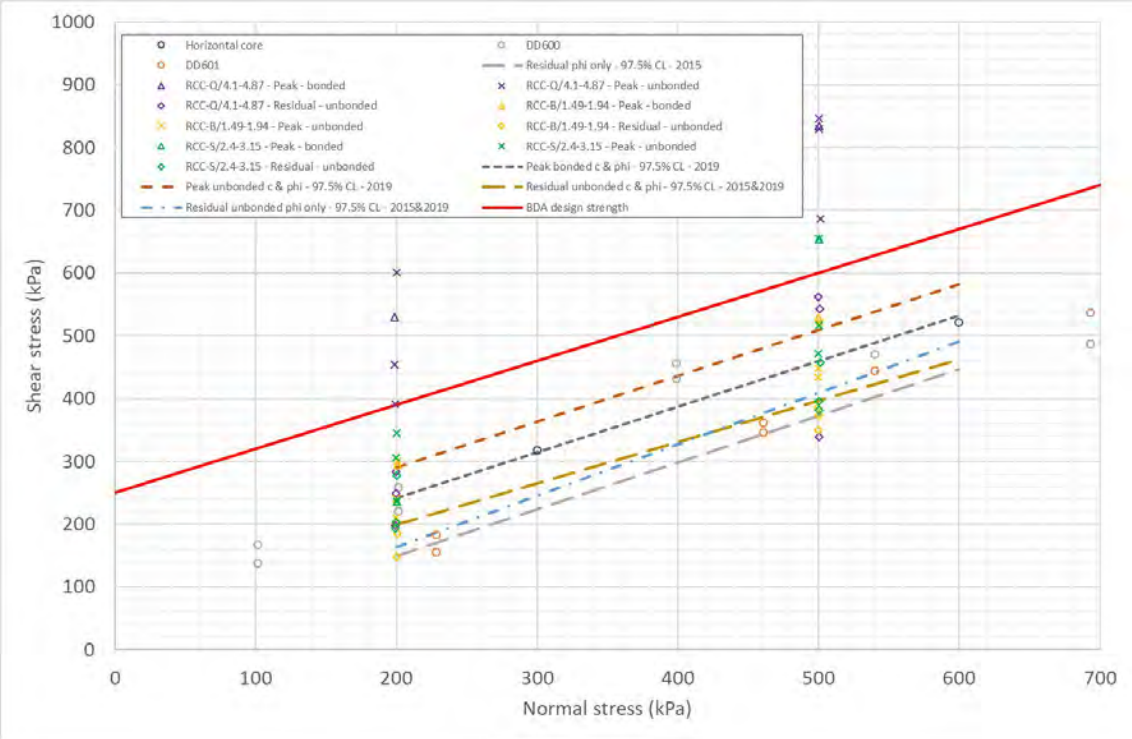

Figure 4.4 RCC lift joint shear strength – Plot of all normal and shear stress pairs and interpreted strength envelopes – Statistical approach – 2015 & 2019 testing

Table 4.4 Boreholes for lift joint quality assessment

Borehole ID	Chainage	Offset from upstream face (m)
PD-04	704.6	2.4
PD-10	708.5	5.0
PD-11	725.0	5.0
PD-12	725.2	2.5

- Segregated
  - Core photo shows broken/voided section, often logged as “crushed”; AND
  - Evidence of segregated/voided section in OTV/ATV log
- Debonded
  - Joint noted on logs; AND
  - Joint able to be identified in OTV/ATV log but no evidence of segregation

The assessment of the lift joint quality in the four boreholes based on the core logs, core photographs and OTV/ATV data is provided side-by-side in Figure 4.5. Bonded joints are marked green,

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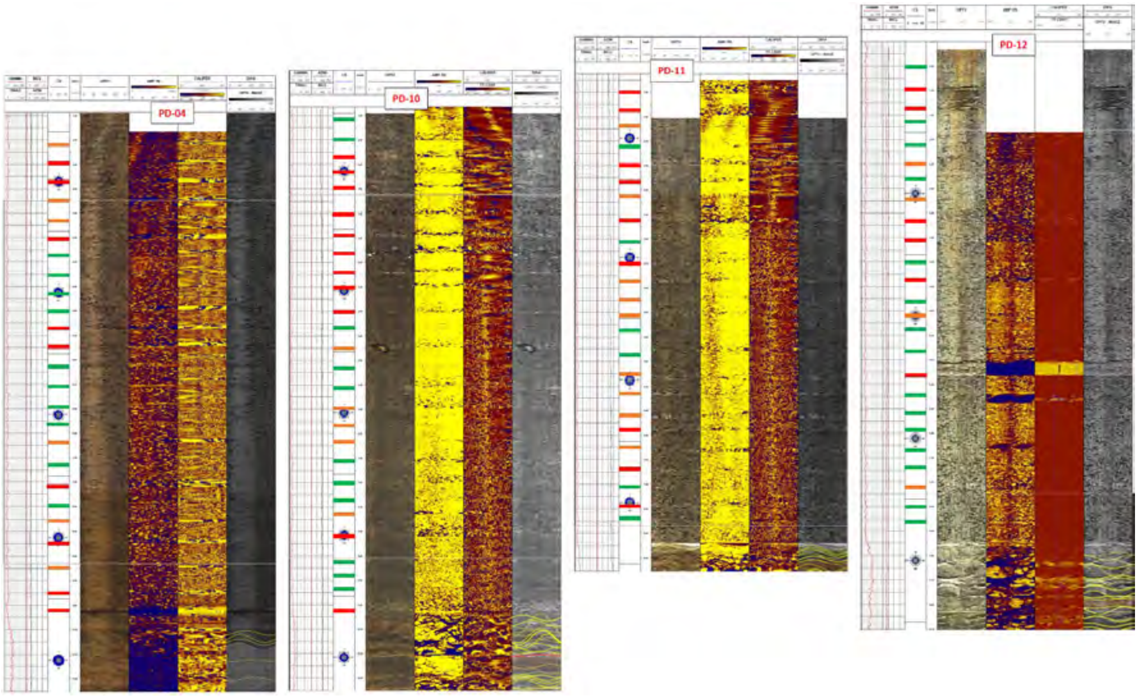
debonded as orange, and segregated as red. It is noted that there is an inherent potential error of ±50-100 mm on the depths recorded on the logs and core photographs.

Figure 4.5 Summary of lift joint quality assessment in Monolith Q



The following points are provided as a summary of this assessment:

- Some interpretation is required in this assessment.
- Approximately 60% of the lift joints across the four holes were categorised as either debonded or segregated.
- The debonding and segregation appears to be worse in a depth range from about 2.5 m to 4 m.
- About 10 of the 24 lifts encountered had joints in at least three of the four holes categorised as debonded or segregated.
- Given the inherent error in the recorded depth of joints, it is possible that there are more joints where all four holes are debonded.

Based on this assessment, it is considered that there is a high likelihood of debonded or segregated zones extending across lift joints.

5 Review of 2006 post-construction cored hole

In early 2006, the Alliance undertook an investigation of the completed dam by coring an inclined borehole from the crest of Monolith L and angled at 60° to the horizontal towards Monolith K. The borehole passed through the monolith joint into Monolith K. The location of the cored hole is shown in Figure 5.1. The core obtained from this investigation was approximately 146 mm diameter. The age of the RCC at the time of coring was 6-12 months depending on the level of the lift. The

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information available for this review was a Powerpoint presentation containing photos of the setup and recovered core and Excel core logs, both prepared by the Alliance.

Figure 5.1 Photograph of setup for 2006 investigation borehole

Key points to note from this investigations are as follows:

- 108 lifts were encountered in the borehole
- The breakdown of the logging of the lift joints was as follows:
  - Good bond – 10%
  - Broken by drilling – 12%
  - No bond – 78%
- Unbonded joints were typically smooth
- Segregation was commonly evident in core photos
- The only testing undertaken was for compressive and tensile strength
- No shear strength testing was undertaken

Selected examples of lift joints from the core photos provided are included in Figure 5.2.

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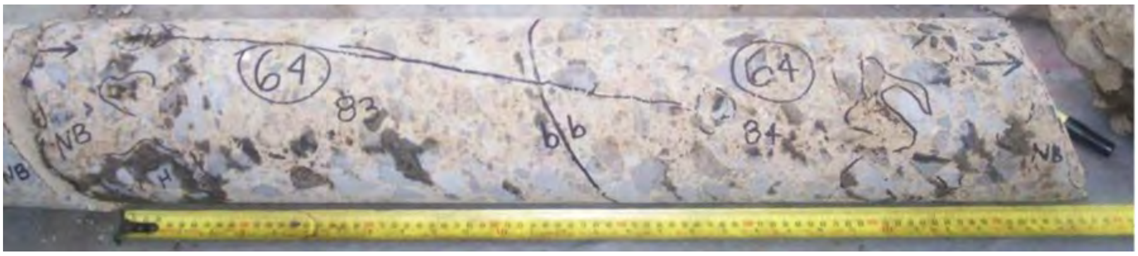


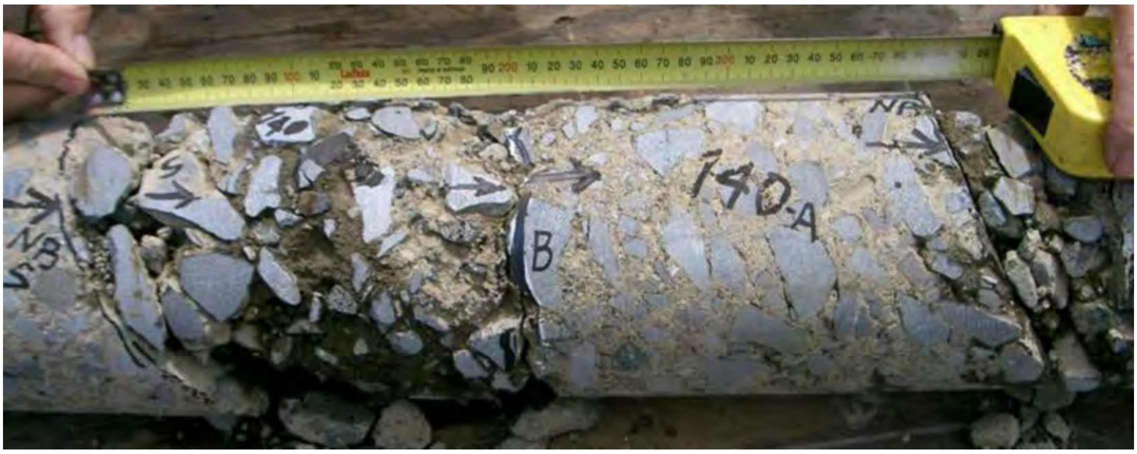
Bonded lift joint – Run 11 – Layers 83 & 84 – ~57.5 mAHD

Unbonded lift joint – Run 11 – Top of Layer 82 – ~57.2 mAHD

Unbonded lift joint – Run 11 – Base of Layer 83 – ~57.2 mAHD

Unbonded lift joint – Run 13 – Top of Layer 67 – ~52.5 mAHD

Unbonded lift joint – Run 13 – Base of Layer 68 – ~52.5 mAHD



Segregated zone – Run 2 – Layer 140 – ~75.2 mAHD

Figure 5.2 Examples of lift joints from core photos of 2006 post-construction borehole

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6 Conclusions

It is considered likely that there are widespread zones of debonding and segregation on the lift joints. These joint surfaces are likely to have a smooth rolled top surface with no mechanical interlock of aggregate and minimal bond across the lift joint. The investigations undertaken by BDA in 2006, Sunwater in 2014-15, and now in 2019 indicate that of the order of 60-90% of lift joints are unbonded.

Given the likely smooth nature of the joint surface, the peak unbonded values from the testing are not considered appropriate and residual strengths, ie for a smooth surface, should be adopted. It is also noted that the 2015 testing on debonded samples showed minimal difference in strength between peak and residual. There may be zones within the dam that are bonded due to greater application of bedding mix, eg along the upstream face. It is not considered appropriate to adopt a weighted average strength to rely in part on the cohesion that may be available in these bonded sections. This is due to the strain incompatibility in mobilising the cohesion in the bonded part and the frictional strength over the remainder at the same displacement.

On the basis of this assessment, it is recommended that a lift joint shear strength of 39.3° and no cohesion should be used for the stability analysis of the dam monoliths for normal stresses up to 600 kPa with a bilinear envelope above this with a strength of 170 kPa and 28°.

It is also not considered appropriate to include an allowance for large scale asperities. For example, an increase of 3° would require asperities with an amplitude of approximately 100 mm over a wavelength of about 4 m which is not considered realistic given the level of control typically associated with placement of RCC lifts.

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ATTACHMENT 1 – PHOTOGRAPHS OF 2014 HORIZONTALLY CORED SAMPLES FROM PRIMARY SPILLWAY TOE

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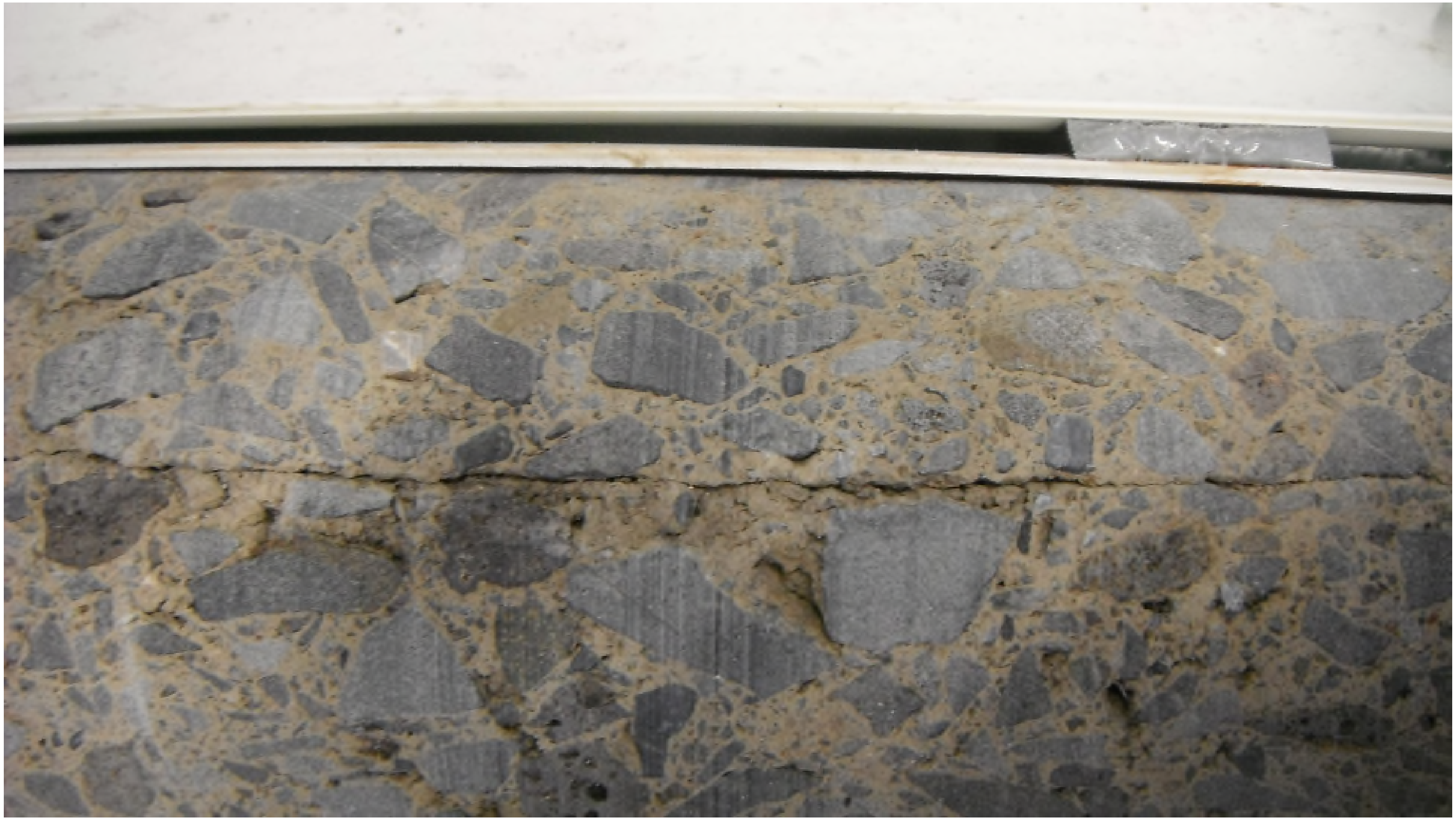
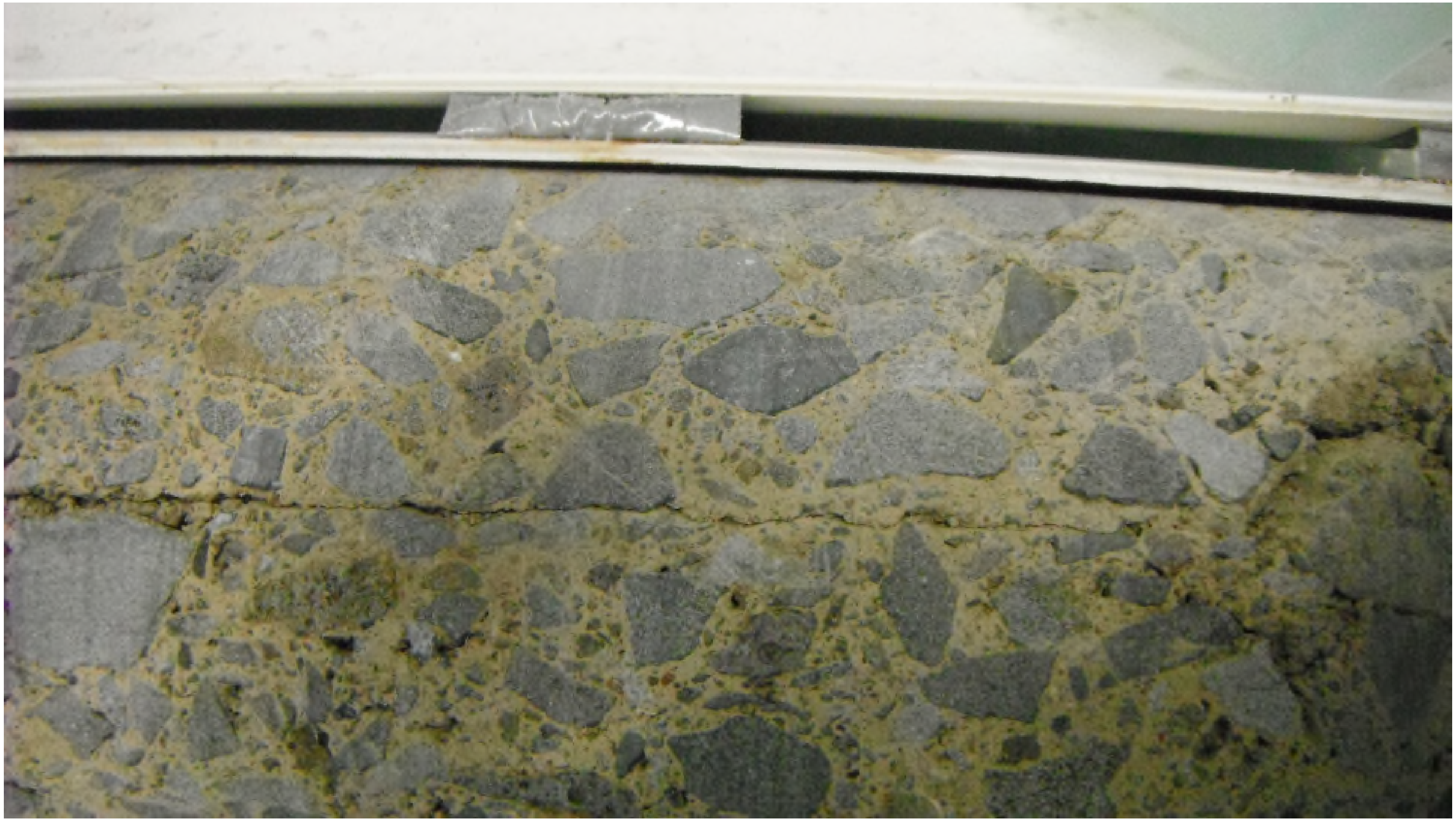
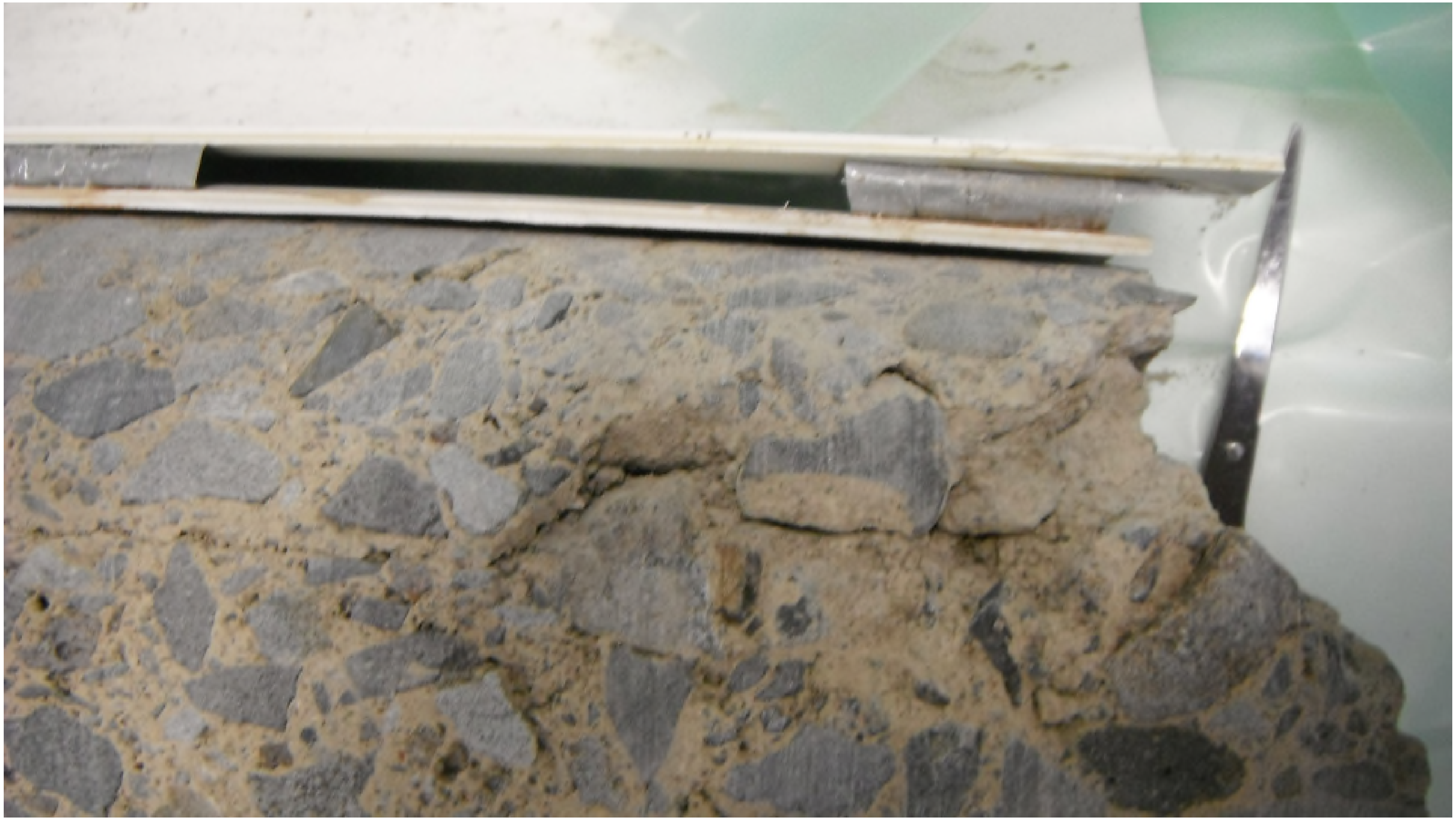
Photograph 1 – Hole G1B (2.75 m to 3.20) – Core at 3.20 m end.



Photograph 2 – Hole G1B (2.75 m to 3.20) – Central section of core closer to 3.20 m end.

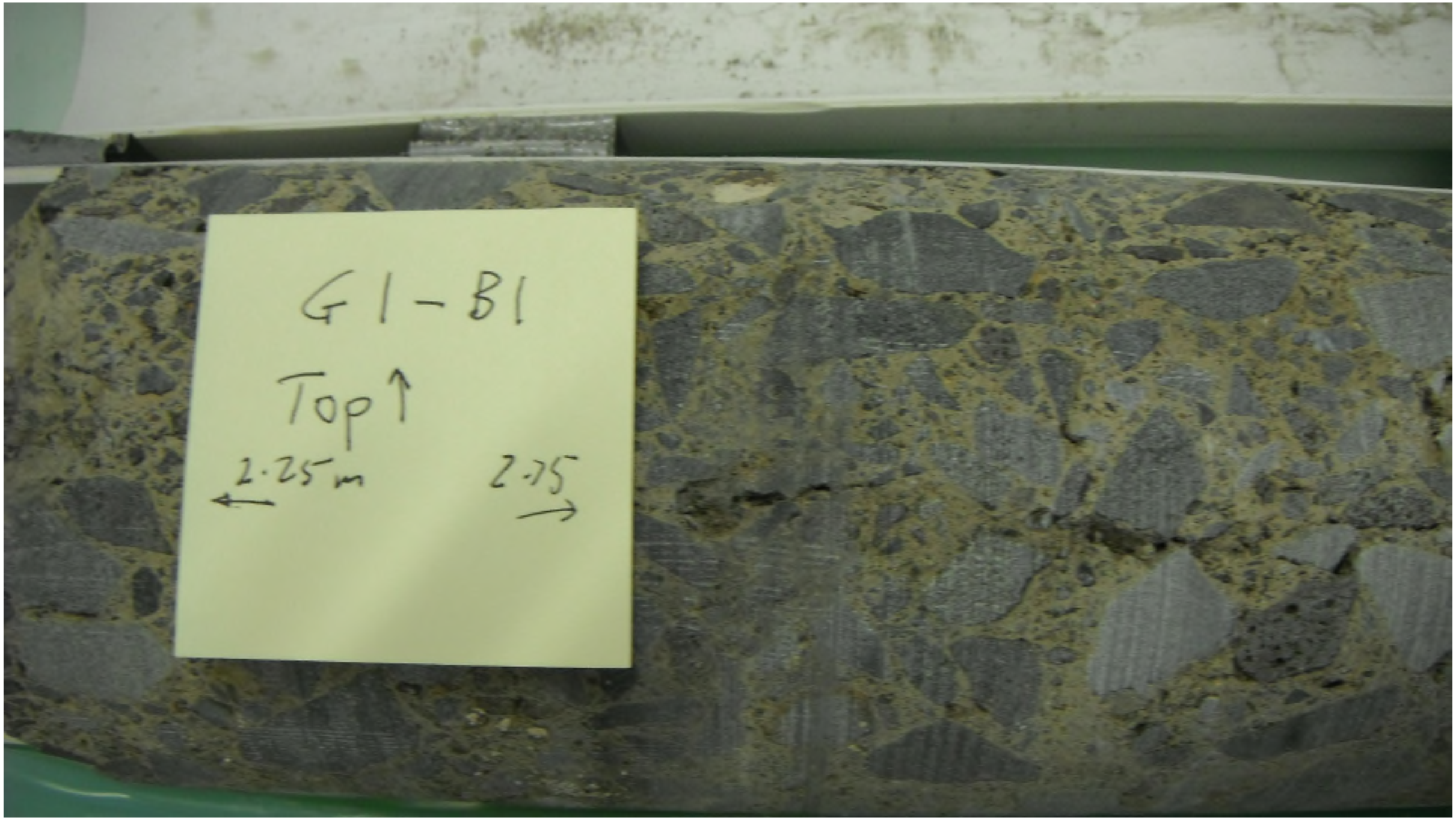


Photograph 3 – Hole G1B (2.75 m to 3.20) – Central section closer to 2.75 m end.



Photograph 4 – Hole G1B (2.75 m to 3.20) – Core at 2.75 m end.

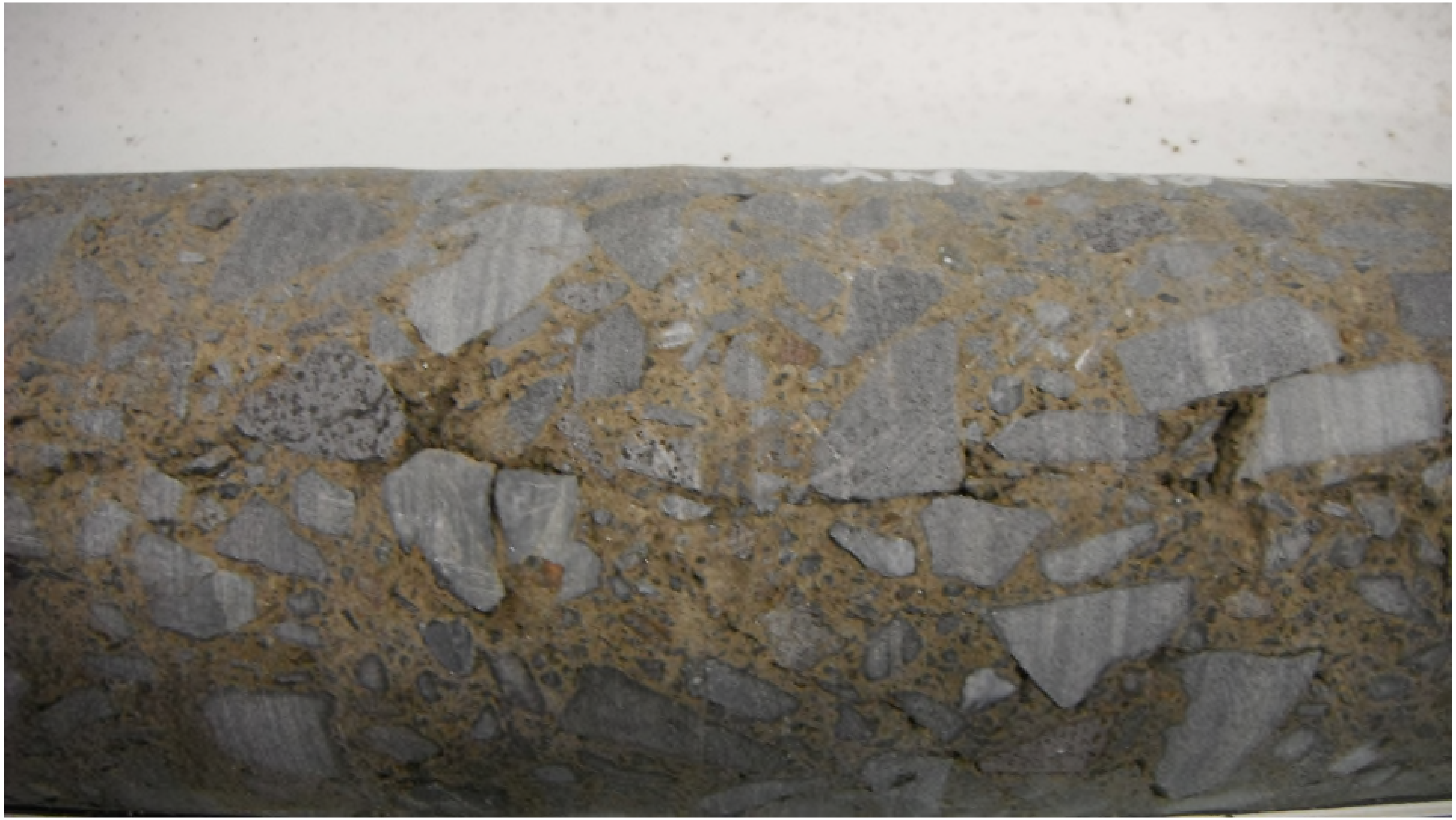
Photograph 5 – Hole G1B (2.25 m to 2.75) – Core at 2.75 m end.



Photograph 6 – Hole G1B (2.25 m to 2.75) – Core over central section of core.

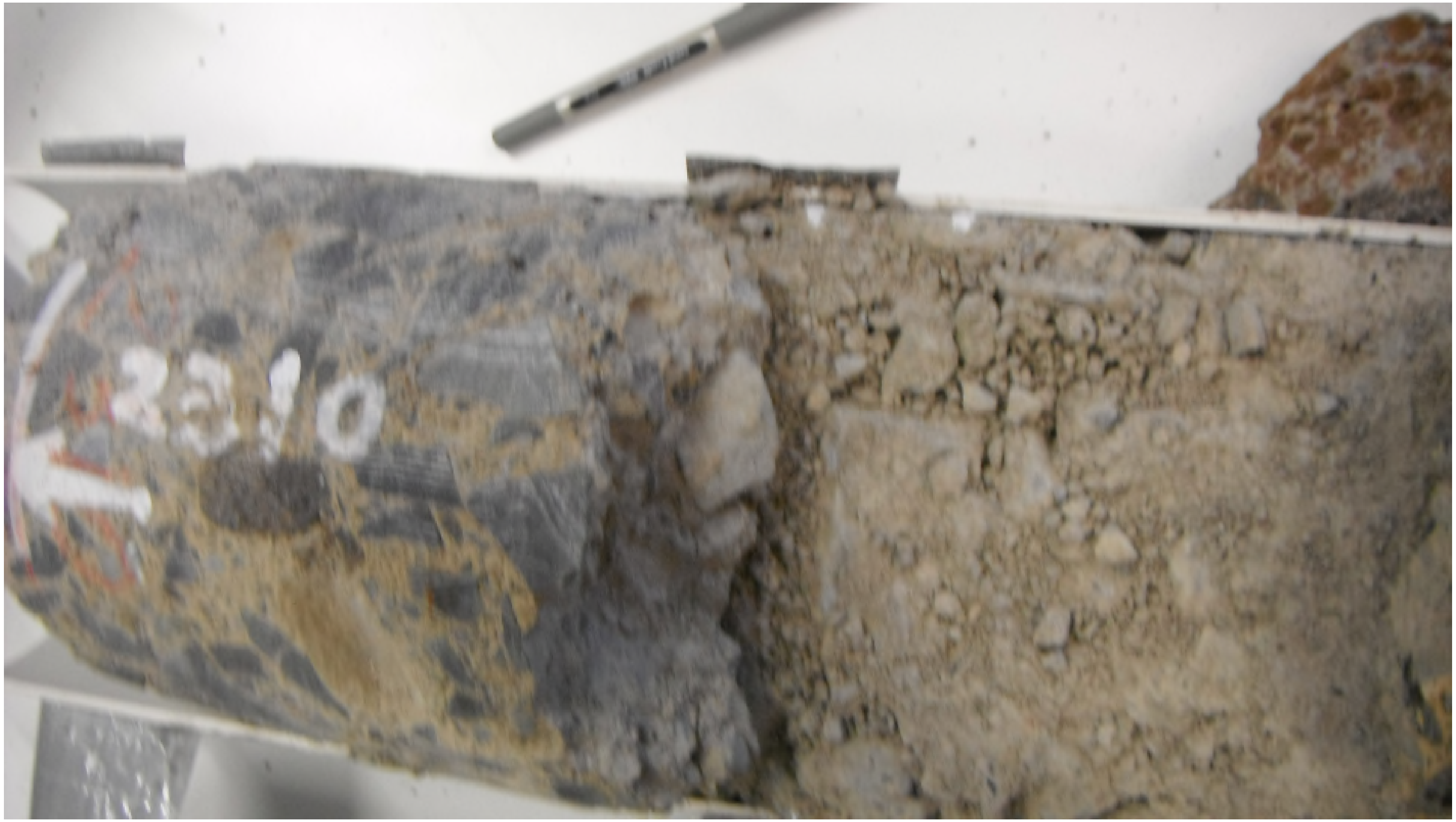
Photograph 7 – Hole G1B (2.25 m to 2.75) – Core at 2.25 m end.

Photograph 8 – Hole F1B (1.7 m to 2.31) – Core at 2.31 m end.

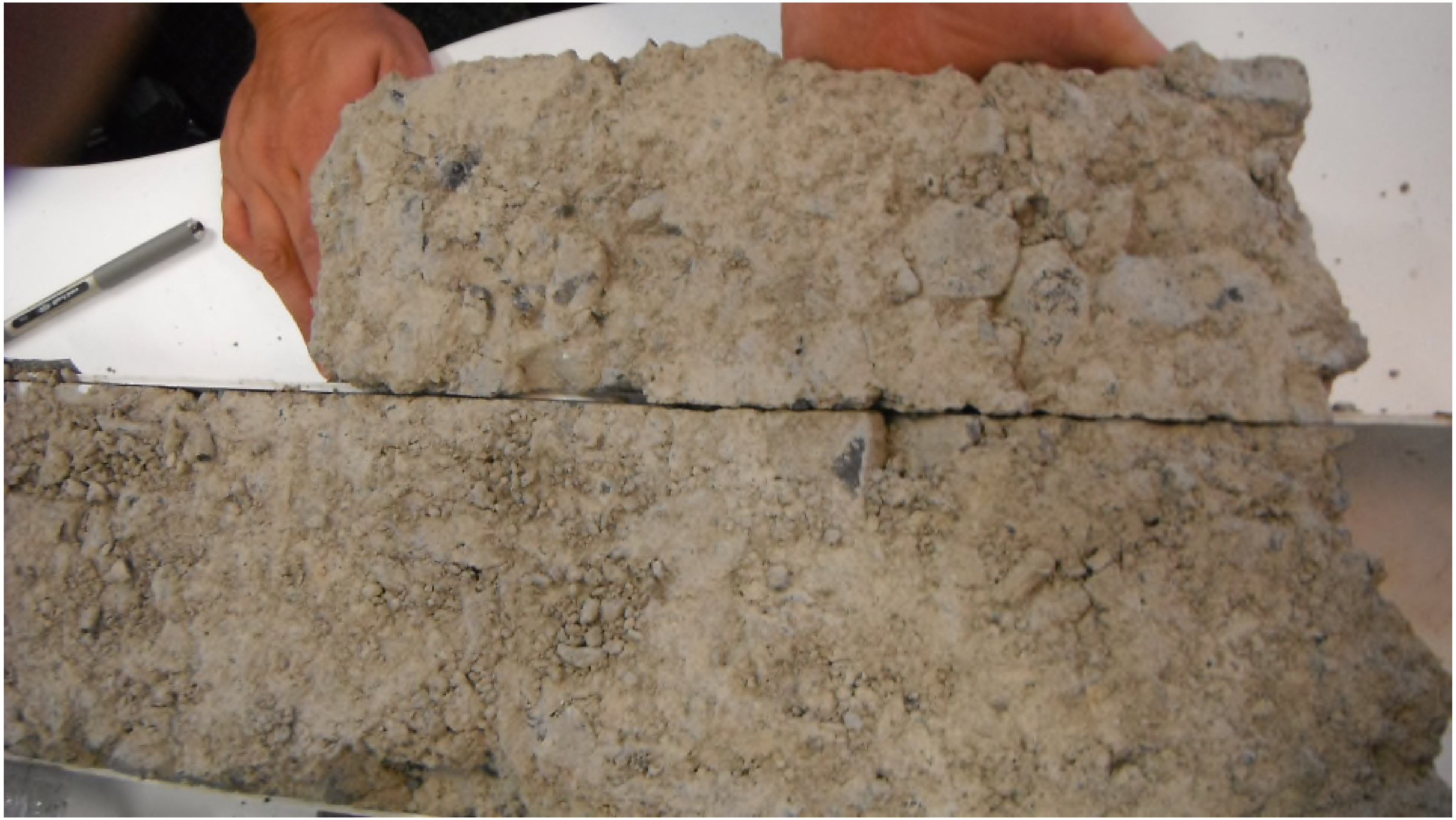


Photograph 9 – Hole F1B (1.7 m to 2.31) – Core over central section.

Photograph 10 – Hole F1B (1.7 m to 2.31) **–** Core at 1.7 m end.



Photograph 11 Hole F1B (2.31 m to 2.77) – Core at 2.31 m end.



Photograph 12 Hole F1B (2.31 m to 2.77) – Two halves of core towards the 2.77 m end.

Photograph 13 Hole F1B (2.31 m to 2.77) – Two halves of core towards the 2.77 m end, viewed from the innermost end of the hole.

ATTACHMENT 2 – LABORATORY TEST CERTIFICATES – 2015 TESTING

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Report on
Direct Shear Strength Test of Rock

Test Method ASTM D 3080 Direct shear test of soils

Queensland Government
Department of Transport and Main Roads
Materials Services - Brisbane
35 Butterfield Street Herston Q 4006

Client	*SunWater Limited* *Level 10, 179 Turbot Street, Brisbane QLD 4000*
Project	*Paradise Dam RCC Core Testing*
Purchase Order number	*5700084604*
Sender's number	*G1-B1*
Sample location	*Ch. 340 2nd step above apron slab (near D/S toe of spillway)*
Sample description	*ø142 mm x 130 mm RCC core (Cored hoizontally through lift joint)*
Date sampled	*2/12/2014*
Article number	*GS15/124A*
Date tested	*27/05/2015*

Test Parameters

Specimen Length (mm)	130
Specimen Diameter (mm)	142
Horizontal Displacement * (mm/min)	0.1
Normal Stress (kPa)	300
Loading Orientation	Vertical

Shear Stress Results (kPa)

Peak shear	326
Residual shear - run 1	306
Residual shear - run 2	322
Residual shear - run 3	317

Lower half of specimen after test

Remarks Sample supplied by client. Tested as received. Specimen inundated prior to shearing. Specimen tested along lift joint. *For Peak Shear Stress, specimen sheared at 0.1 mm/minute and Residual Shear Stress, specimen sheared at 1 mm/minute.

[redacted]

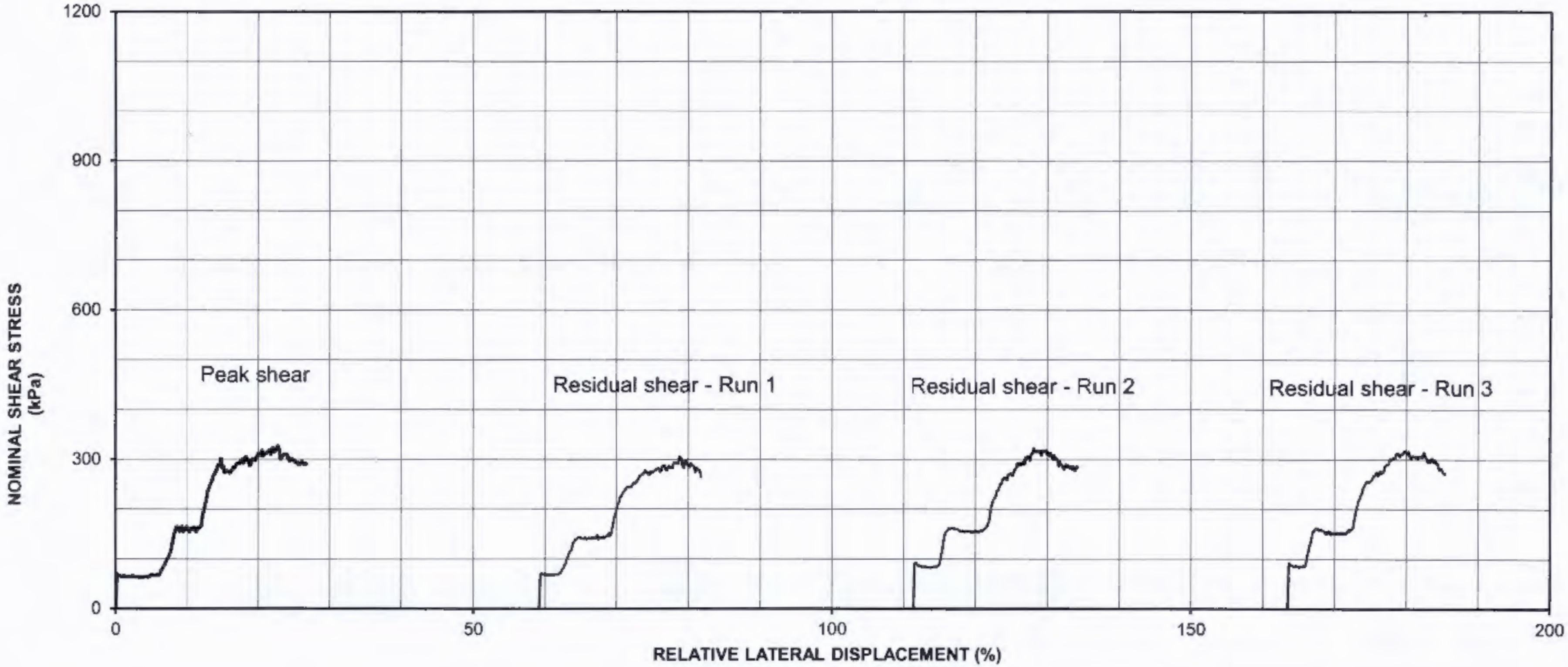
Report number 31656
Date 10/06/2015

Department of Transport and Main Roads
Materials Services - Brisbane
35 Butterfield Street Herston Q 4006

Queensland Government

Report on Direct Shear Strength Test of Rock

Client SunWater Limited **Article number** GS15/124A



[redacted]

Client Details: SunWater Limited

Level 10, 179 Turbot Street, Brisbane QLD 4000

Report No: 31656
Date Reported: 10/06/2015

Report on
Direct Shear Strength Test of Rock

Test Method ASTM D 3080 Direct shear test of soils

Queensland Government

Department of Transport and Main Roads
Materials Services - Brisbane
35 Butterfield Street Herston Q 4006

Client	*SunWater Limited* *Level 10, 179 Turbot Street, Brisbane QLD 4000*
Project	*Paradise Dam RCC Core Testing*
Purchase Order number	*5700084604*
Sender's number	*G1-B1*
Sample location	*Ch. 340 2nd step above apron slab (near D/S toe of spillway)*
Sample description	*ø142 mm x 130 mm RCC core (Cored hoizontally through lift joint)*
Date sampled	*2/12/2014*
Article number	*GS15/124B*
Date tested	*20/05/2015*

Test Parameters

Specimen Length (mm)	130
Specimen Diameter (mm)	142
Horizontal Displacement * (mm/min)	0.1
Normal Stress (kPa)	600
Loading Orientation	Vertical

Shear Stress Results (kPa)

Peak shear	503
Residual shear - run 1	526
Residual shear - run 2	518
Residual shear - run 3	539

Lower half of specimen after test

Remarks Sample supplied by client. Tested as received. Specimen inundated prior to shearing. Specimen tested along lift joint. *For Peak Shear Stress, specimen sheared at 0.1 mm/minute and Residual Shear Stress, specimen sheared at 1 mm/minute.

[redacted]

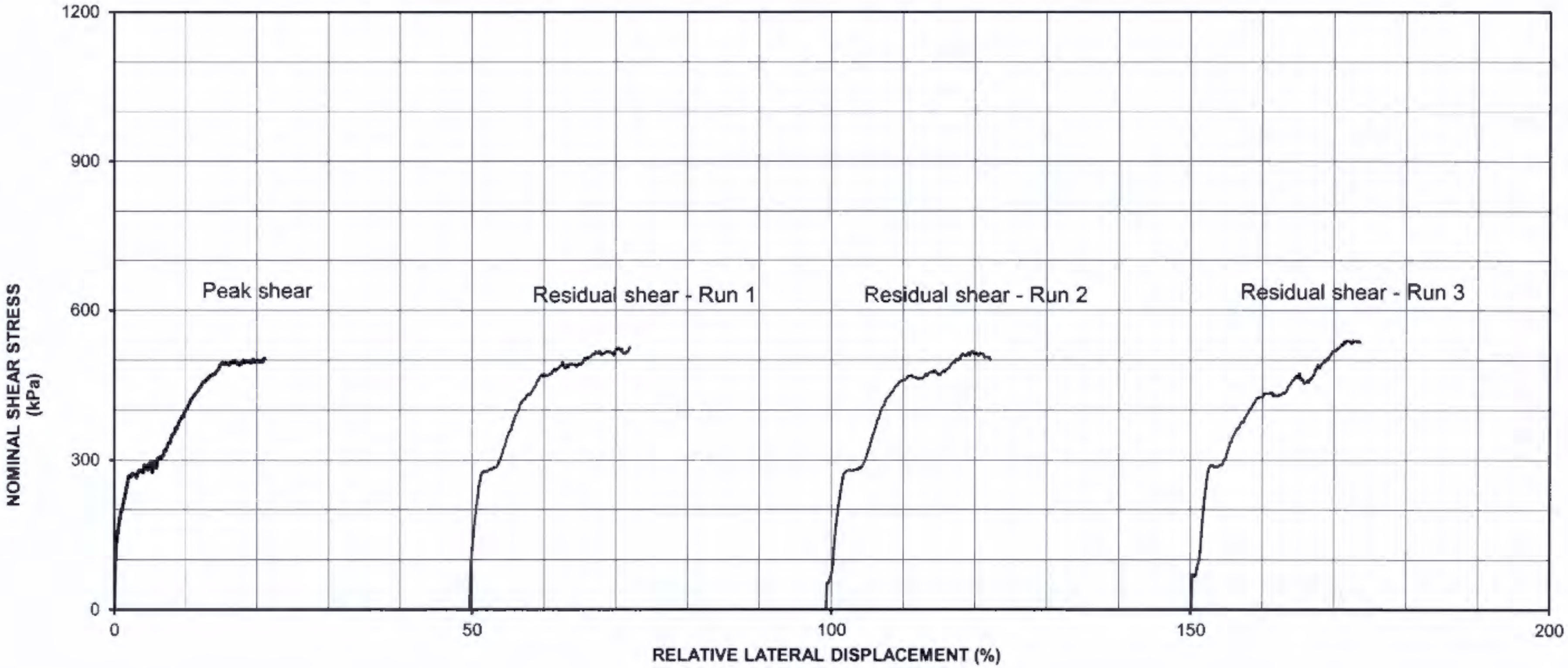
Report number 31657
Date 10/06/2015

Department of Transport and Main Roads
Materials Services - Brisbane
35 Butterfield Street Herston Q 4006

Queensland Government

Report on Direct Shear Strength Test of Rock

Client SunWater Limited **Article number** GS15/124B



Client Details: SunWater Limited
Level 10, 179 Turbot Street, Brisbane QLD 4000

[redacted]

Report No: 31657
Date Reported: 10/06/2015

Report on
Direct Shear Strength Test of Rock

Test Method ASTM D 3080 Direct shear test of soils

Queensland Government

Department of Transport and Main Roads
Materials Services - Brisbane
35 Butterfield Street Herston Q 4006

Client	*SunWater Limited* *Level 10, 179 Turbot Street, Brisbane QLD 4000*
Project	*Paradise Dam RCC Core Testing*
Purchase Order number	*5700084604*
Sender's number	*G1-B1*
Sample location	*Ch. 340 2nd step above apron slab (near D/S toe of spillway)*
Sample description	*ø142 mm x 130 mm RCC core (Cored hoizontally through lift joint)*
Date sampled	*2/12/2014*
Article number	*GS15/124C*
Date tested	*14/05/2015*

Test Parameters

Specimen Length (mm)	130
Specimen Diameter (mm)	142
Horizontal Displacement * (mm/min)	0.1
Normal Stress (kPa)	900
Loading Orientation	Vertical

Shear Stress Results (kPa)

Peak shear	1054
Residual shear - run 1	669
Residual shear - run 2	556
Residual shear - run 3	663

Lower half of specimen after test

Remarks Sample supplied by client. Tested as received. Specimen inundated prior to shearing. Specimen tested along lift joint. *For Peak Shear Stress, specimen sheared at 0.1 mm/minute and Residual Shear Stress, specimen sheared at 1 mm/minute.

[redacted]

[redacted]

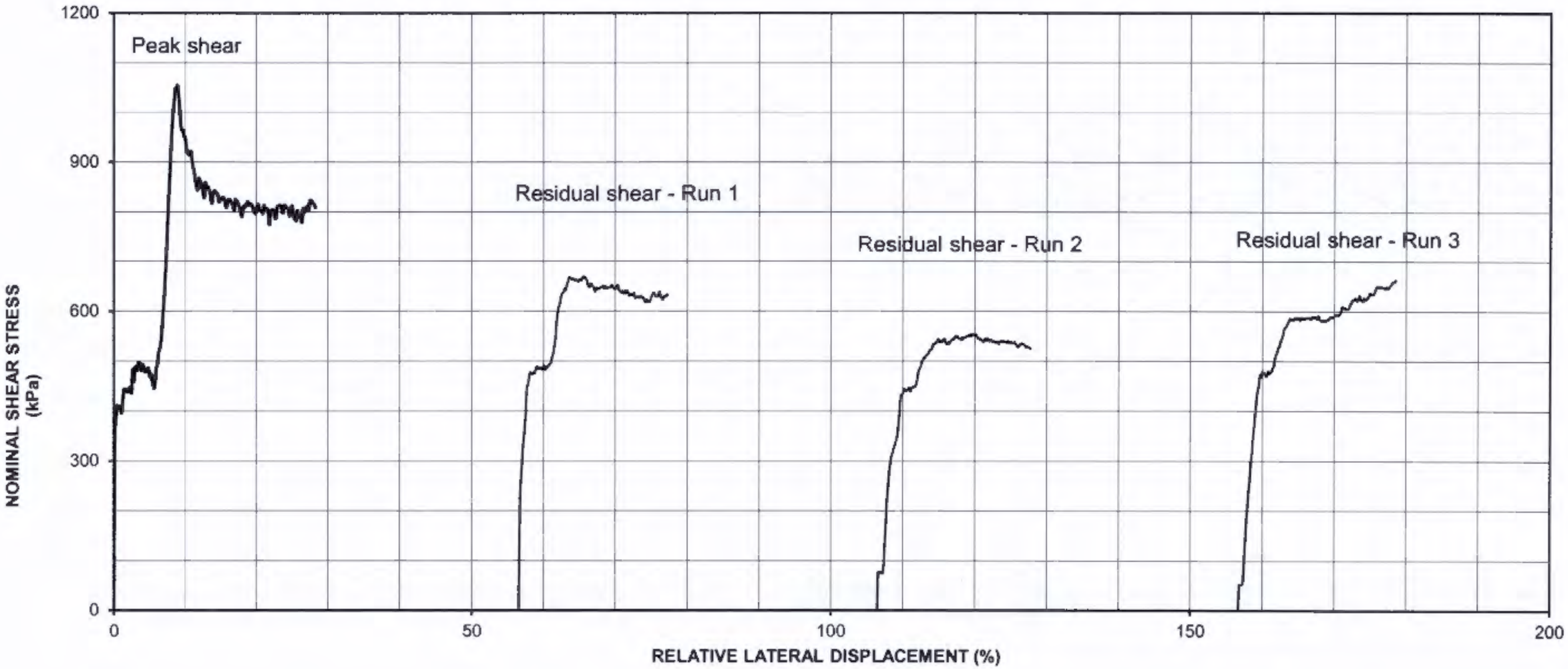
Report number 31658
Date 10/06/2015

Department of Transport and Main Roads
Materials Services - Brisbane
35 Butterfield Street Herston Q 4006

Queensland Government

Report on Direct Shear Strength Test of Rock

Client SunWater Limited **Article number** GS15/124C



Client Details: SunWater Limited

Level 10, 179 Turbot Street, Brisbane QLD 4000

[redacted]

Report No: 31658

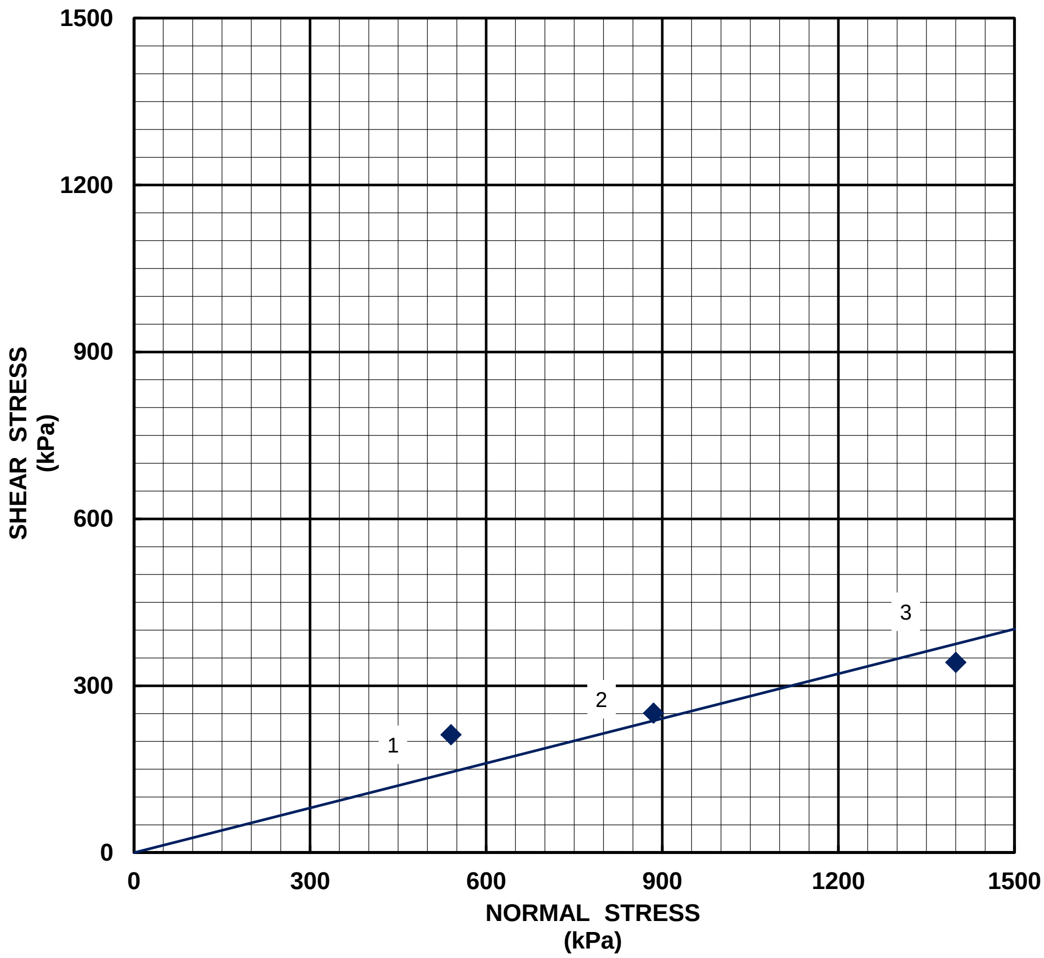
Date Reported: 10/06/2015

DIRECT SHEAR TEST REPORT
TEST METHOD ASTM D 3080

PROJECT: Paradise Dam Phase 3 Investigation **CLIENT:** SunWater **DATES TESTED:** 3/12/2015
SAMPLE No.: PAA1/DD600 **PROJECT No.:** - **LOCATION:** DD600 **DEPTH:** @~12.2m
SAMPLE DESCRIPTION: RCC lift joint **APPARATUS:** 100 mm diameter by 175 mm high
PREPARATION OF SPECIMEN: 83 mm diameter by 175mm high specimen sectioned from RCC drill core to test lift joint. **RATE OF DISPLACEMENT:** 1mm/minute
TYPE OF TEST: Inundated, Consolidated, Drained, Multi-stage, Residual Direct Shear

STAGE NUMBER	APPLIED NORMAL STRESS (kPa)	SHEAR STRESS (kPa)
1	540	212
2	885	251
3	1400	342

Residual Cohesion C' 0 kPa (See remarks) **Residual Angle of Friction ϕ'** 15.0° (See Remarks)



Remarks: Particle size to shear plane ratio is significantly less than the preferred 12:1 resulting substantial disturbance and re-orientation of particles along the shear plane between each shearing stage.

Variations to Method: Values have been derived by determining the line of best fit from linear regression calculations. Determination and supply of Cohesion Intercept & Internal Angle of Friction results are not required by this test method and have been supplied at the request of the client.

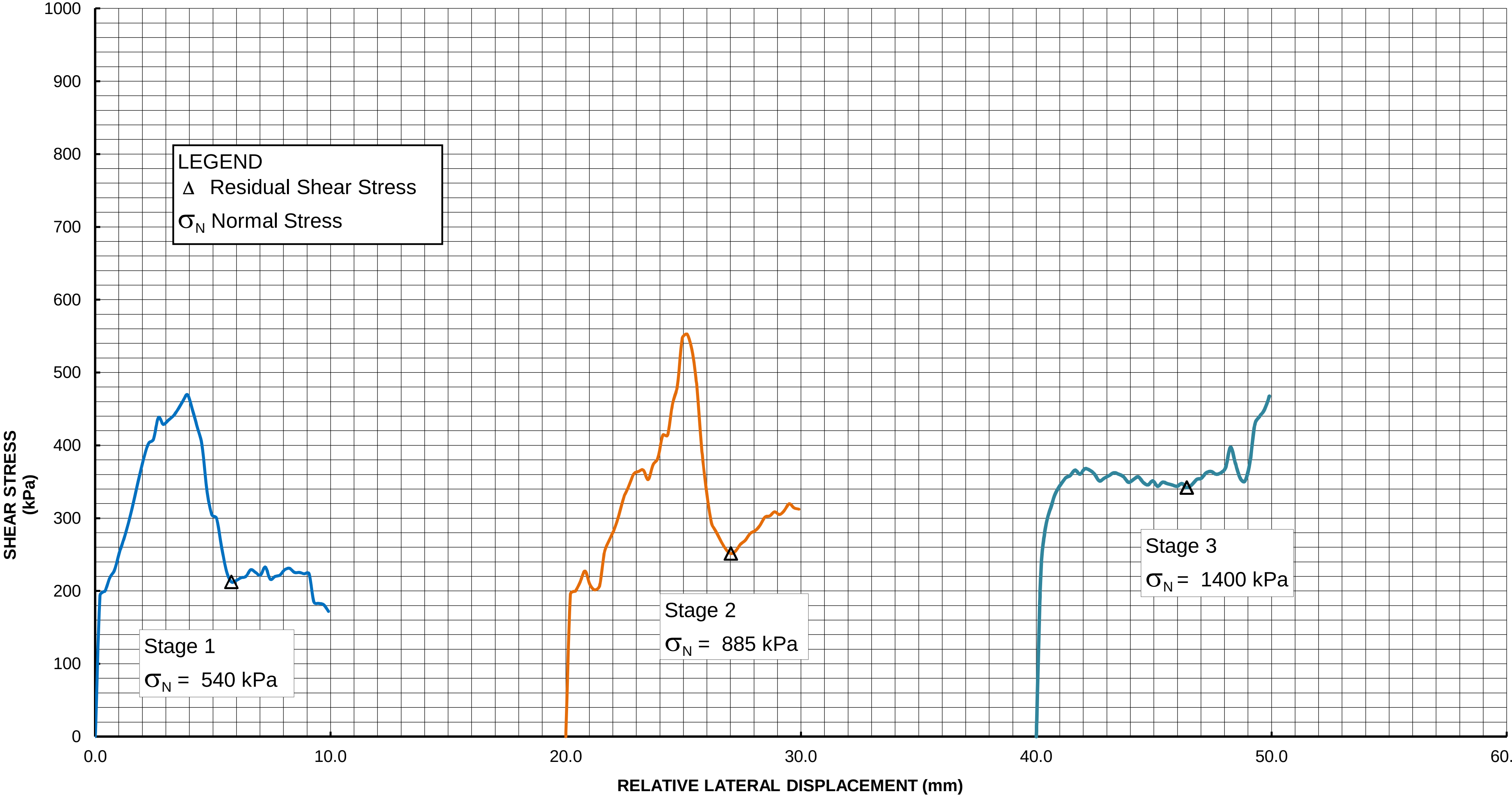
Client Details: SunWater
179 Turbot St, Brisbane, Qld

Checked By: [redacted]

Date Reported: 8-Dec-2015 **Page:** 1 of 3

DIRECT SHEAR TEST REPORT
TEST METHOD ASTM D 3080

PROJECT : Paradise Dam Phase 3 Investigation **CLIENT:** SunWater **SAMPLE No. :** PAA1/DD600 @ ~12.2m **PROJECT No. :** -



Remarks:

Client Details: SunWater
179 Turbot St, Brisbane, Qld

Checked By: [redacted]

Date Reported: 8-Dec-2015

DIRECT SHEAR TEST REPORT
TEST METHOD ASTM D 3080

PROJECT : Paradise Dam Phase 3 Investigation **SAMPLE No. :** PAA1/DD600 @ ~12.2m

PAA1/DD600 Lift Joint at ~12.2 m Before Test

Top of Specimen After Test

Base of Specimen After Test

Remarks:

Client Details: SunWater
179 Turbot St, Brisbane, Qld

Checked By: [redacted]

Date Reported: 8/12/2015 **Page:** 3 of 3

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DIRECT SHEAR TEST REPORT

Test Method: ASTM D5607

Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SunWater Limited	**Report No.**	15110196- DS
Project	Paradise Dam RCC Core Testing	**Test Date**	16/11/2015
		Report Date	20/11/2015
Client ID	PAA1/DD600	**Depth (m)**	10.20
Description		**Sample Type**	Single individual specimen - 3 Stages.

Sample Details

Stage 1

Sample Depth (m)	10.2
Specimen Shape	Circle
Specimen Dimensions (mm)	83.1
Initial Moisture Content (%)	3.3
Initial Wet Density(t/m^3)	2.44
Dry Density(t/m^3)	2.37
Rate of Strain (mm/min)	0.05

Notes/Remarks:

Graph not to scale

Sample/s supplied by the client

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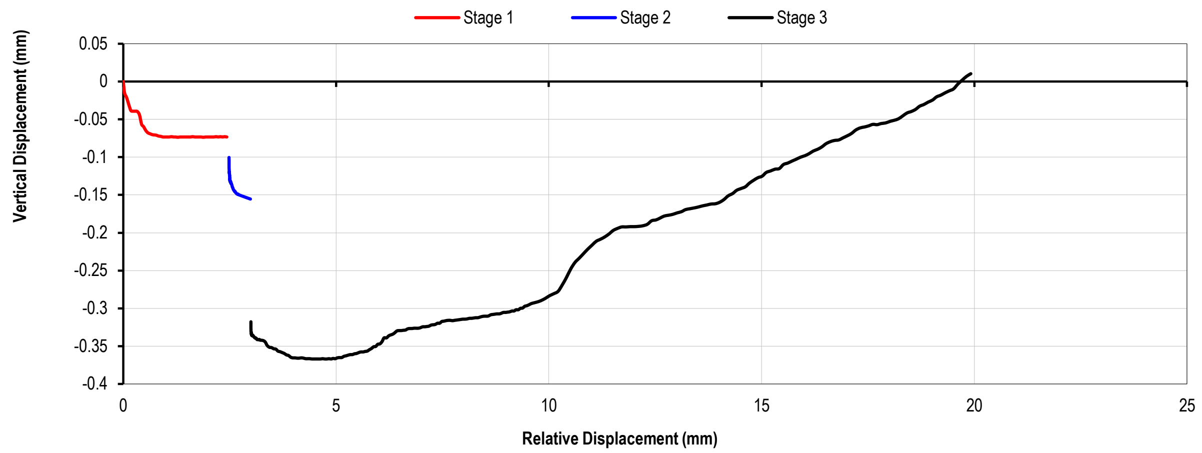
DIRECT SHEAR TEST REPORT

Test Method: ASTM D5607

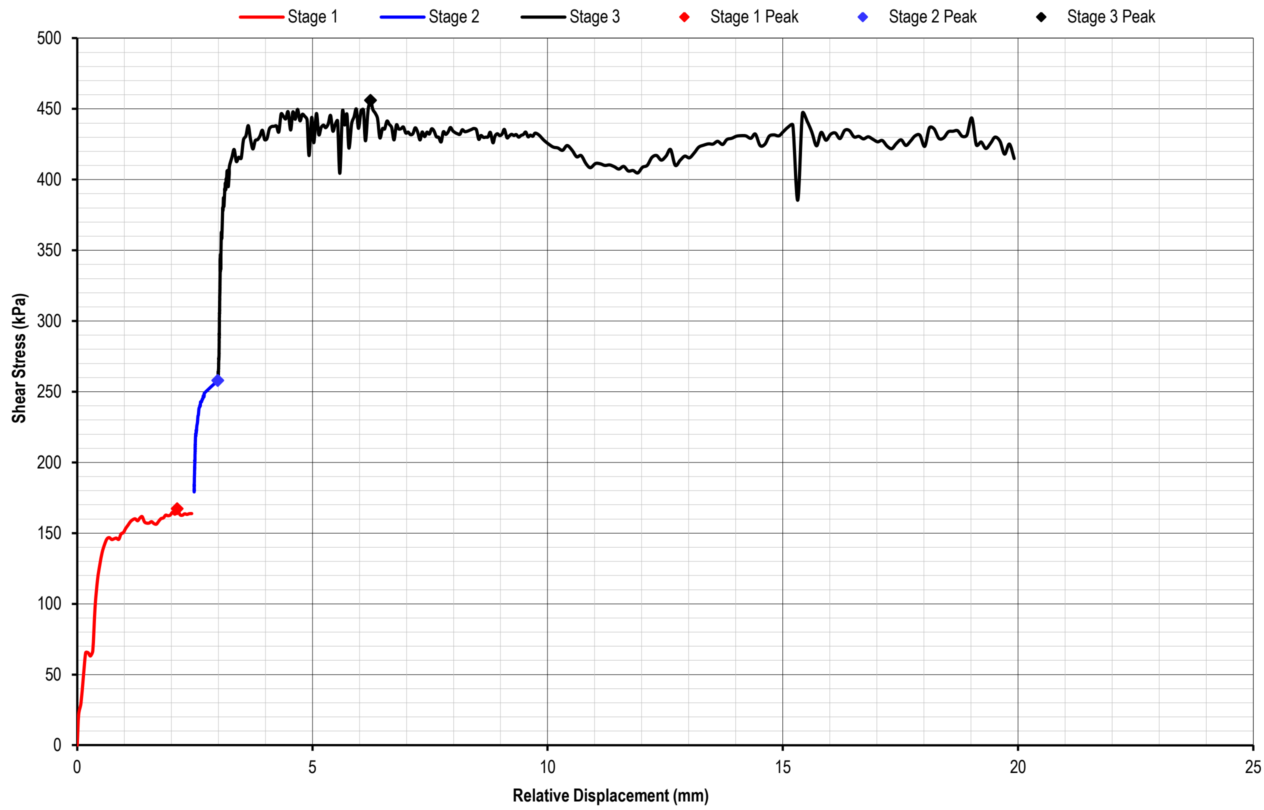
Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SunWater Limited	**Report No.**	15110196- DS

Peak Vertical Displacement/Relative Displacement Plot



Peak Shear Stress/Displacement Plot



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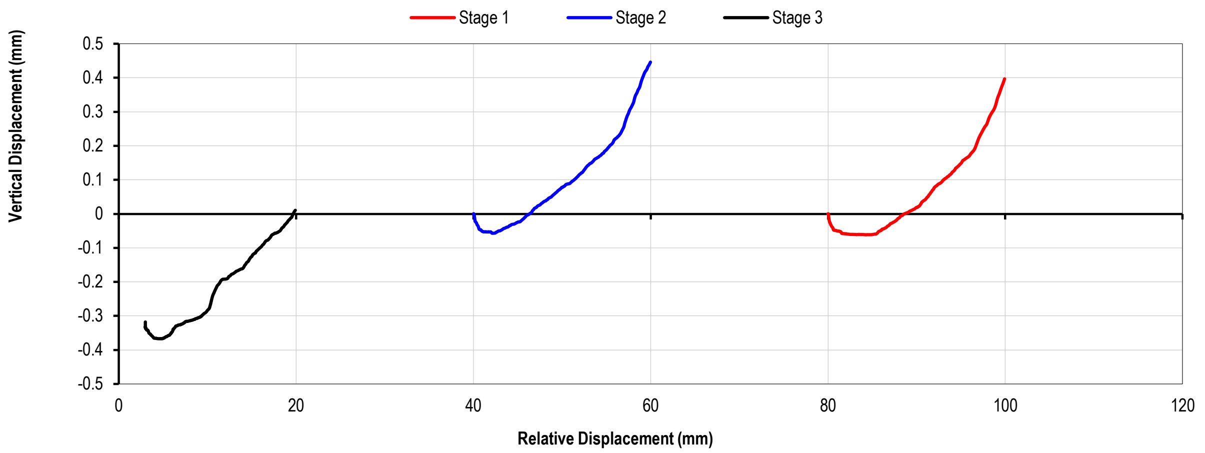
DIRECT SHEAR TEST REPORT

Test Method: ASTM D5607

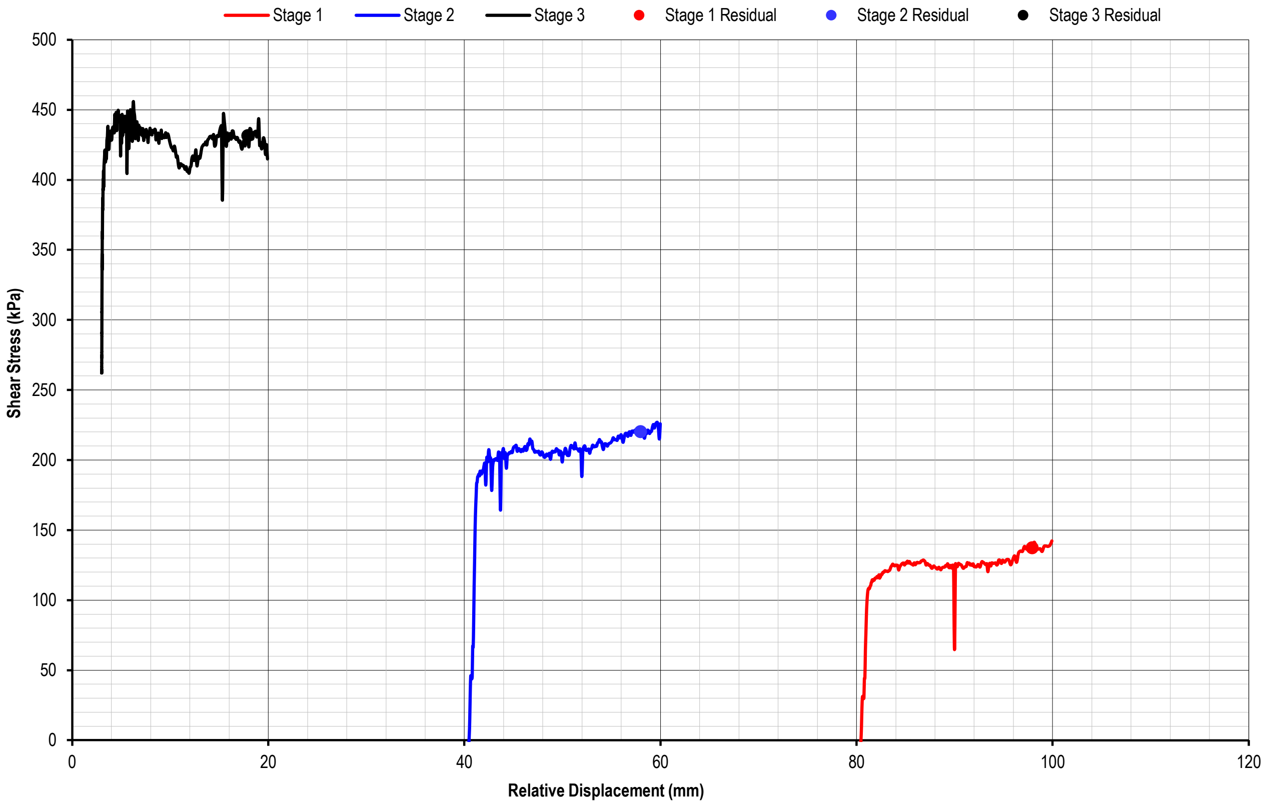
Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SunWater Limited	**Report No.**	15110196- DS

Residual Vertical Displacement/Relative Displacement Plot



Residual Shear Stress/Displacement Plot



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DIRECT SHEAR TEST REPORT

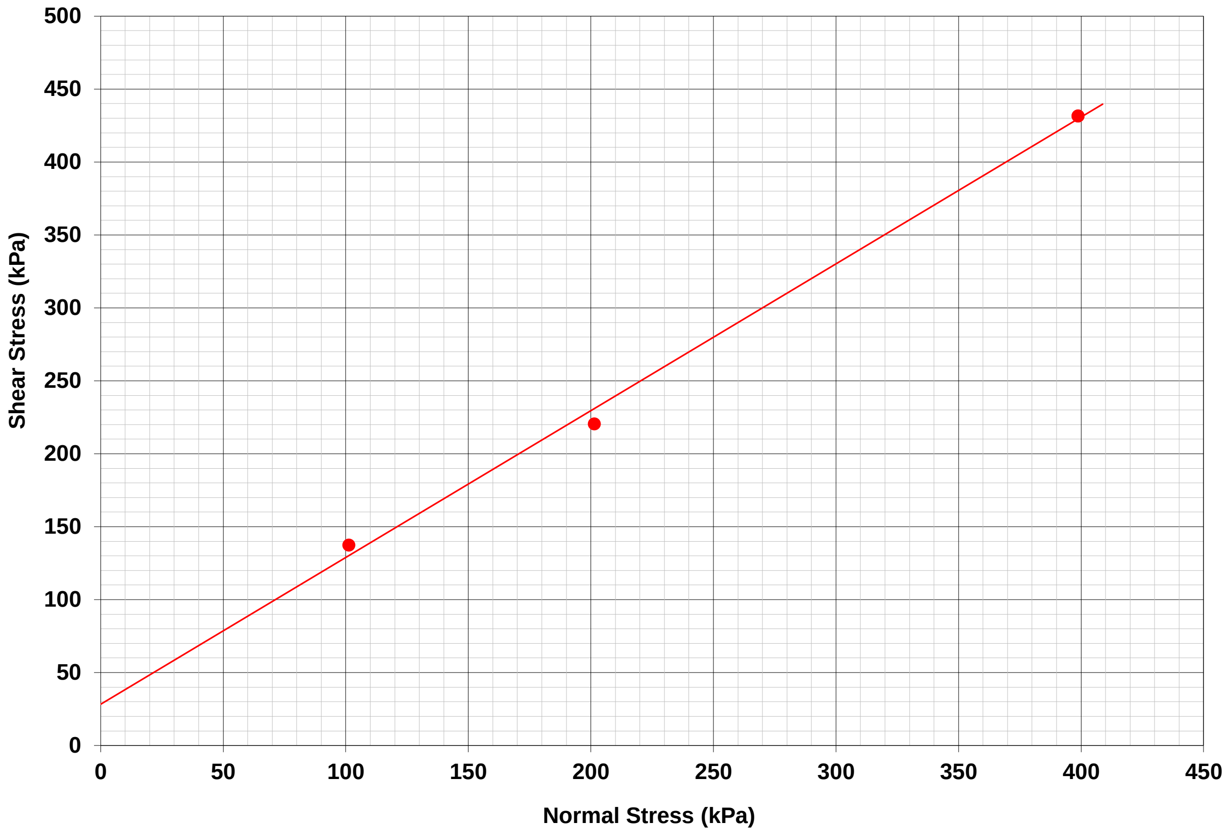
Test Method: ASTM D5607

Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SunWater Limited	**Report No.**	15110196- DS

Failure Criteria **Residual**

Residual - Normal Stress vs Shear Stress



Shear Angle (^{o})	**45.2**	**Cohesion (kPa)**	**28.2**	**R^2**	**0.999**

Stage	**Residual Displacement**	**Normal Stress**	**Shear Stress**
	(mm)	(kPa)	(kPa)
1	97.93	101.3	137.2
2	57.98	201.5	220.3
3	17.91	398.8	431.4
		Machine Description	Constant Normal Stress Direct Shear

Notes/Remarks:

Graph not to scale

Sample/s supplied by the client

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DIRECT SHEAR TEST REPORT

Test Method: ASTM D5607

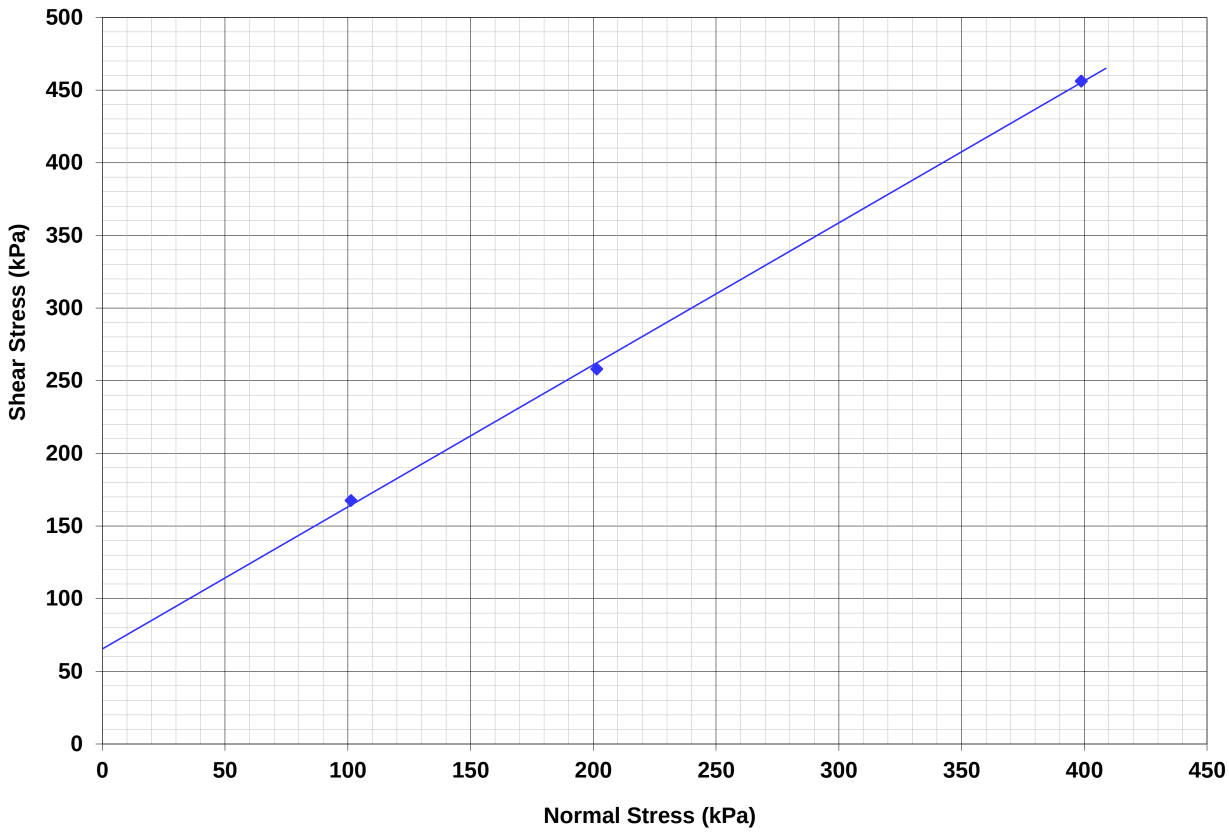
Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client SunWater Limited

Report No. 15110196- DS

Failure Criteria **Peak**

Peak - Normal Stress vs Shear Stress



Shear Angle (°) 44.3	Cohesion (kPa) 65.3	R^2 1.000

Stage	Displacement at Peak Stress	Normal Stress	Shear Stress
	(mm)	(kPa)	(kPa)
1	2.13	101.3	167.3
2	2.99	201.5	257.8
3	6.24	398.8	455.9

Machine Description: Constant Normal Stress Direct Shear

Notes/Remarks:

Graph not to scale

Sample/s supplied by the client

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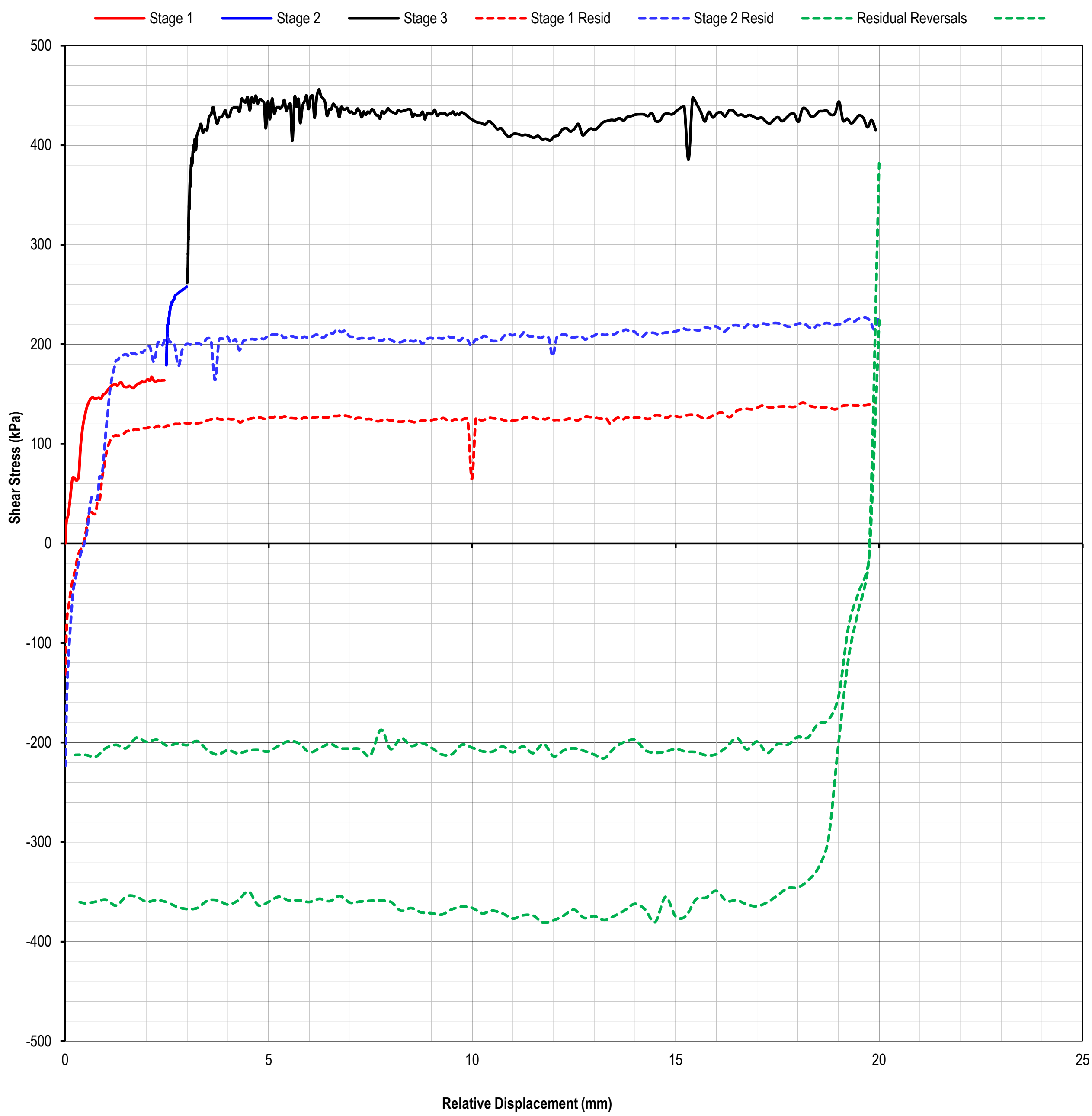
DIRECT SHEAR TEST REPORT

Test Method: ASTM D5607

Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SunWater Limited	**Report No.**	15110196- DS

Shear Stress/Displacement Plot



Notes/Remarks:

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DIRECT SHEAR TEST REPORT

Test Method: ASTM D5607

Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SunWater Limited	**Report No.**	15110196- DS

Stage 1 - Before Photo

Stage 1 - After Photo

Photo not to scale

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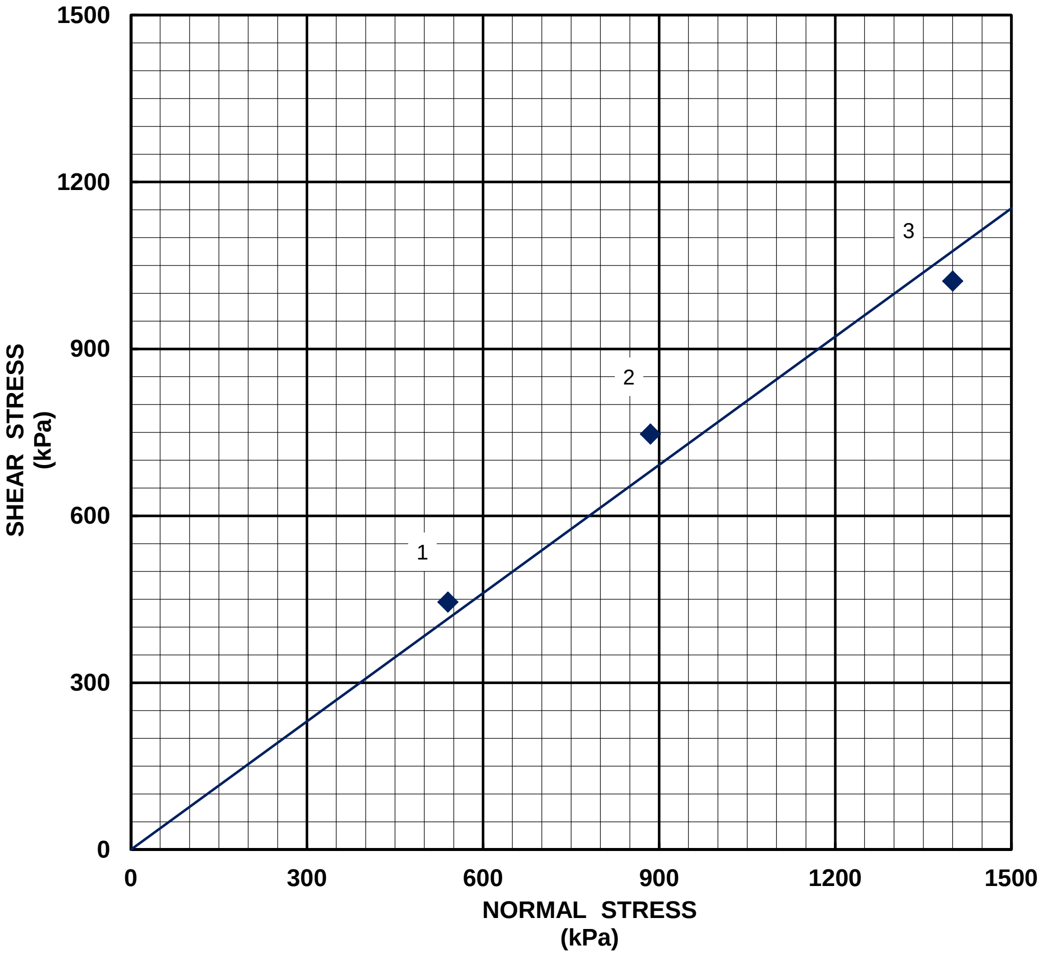
ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

DIRECT SHEAR TEST REPORT
TEST METHOD ASTM D 3080

PROJECT: Paradise Dam Phase 3 Investigation **CLIENT:** SunWater **DATES TESTED:** 3/12/2015
SAMPLE No.: PAA1/DD601 **PROJECT No.:** - **LOCATION:** DD601 **DEPTH:** @~24.8 m
SAMPLE DESCRIPTION: RCC lift joint **APPARATUS:** 100 mm diameter by 175 mm high
PREPARATION OF SPECIMEN: 83 mm diameter by 175mm high specimen sectioned from RCC drill core to test lift joint. **RATE OF DISPLACEMENT:** 1mm/minute
TYPE OF TEST: Inundated, Consolidated, Drained, Multi-stage, Residual Direct Shear

STAGE NUMBER	APPLIED NORMAL STRESS (kPa)	SHEAR STRESS (kPa)
1	540	445
2	885	747
3	1400	1022

Residual Cohesion C' 0 kPa (See remarks) **Residual Angle of Friction** ϕ' 37.5^{o} (See Remarks)



Remarks: Values have been derived by determining the line of best fit from linear regression calculations.

Variations to Method: Determination and supply of Cohesion Intercept & Internal Angle of Friction results are not required by this test method and have been supplied at the request of the client.

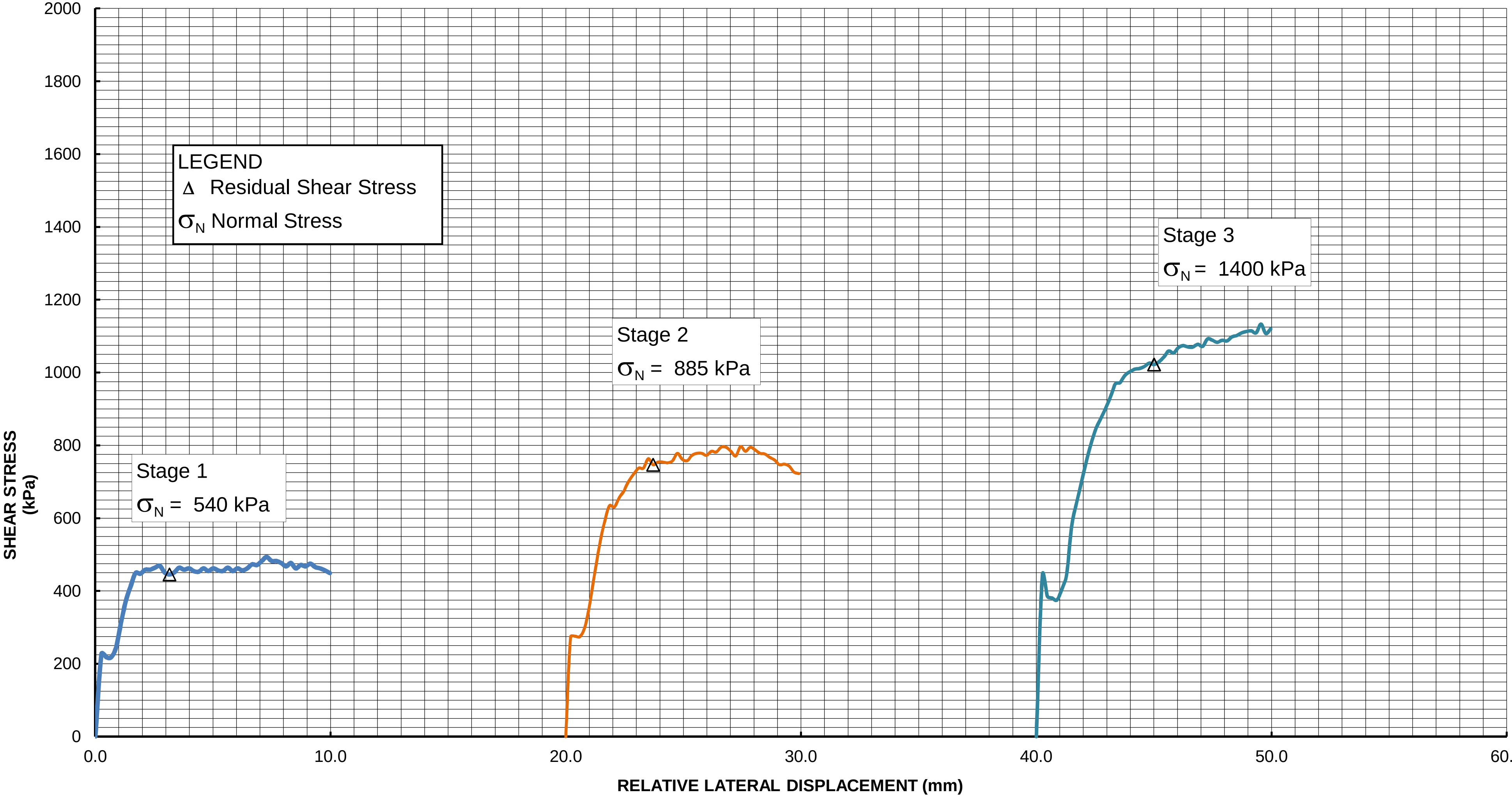
Client Details: SunWater
179 Turbot St, Brisbane, Qld

Checked By: [redacted]

Date Reported: 8-Dec-2015

DIRECT SHEAR TEST REPORT
TEST METHOD ASTM D 3080

PROJECT : Paradise Dam Phase 3 Investigation **CLIENT:** SunWater **SAMPLE No. :** PAA1/DD601 @ ~24.8 m **PROJECT No. :** -



Remarks:

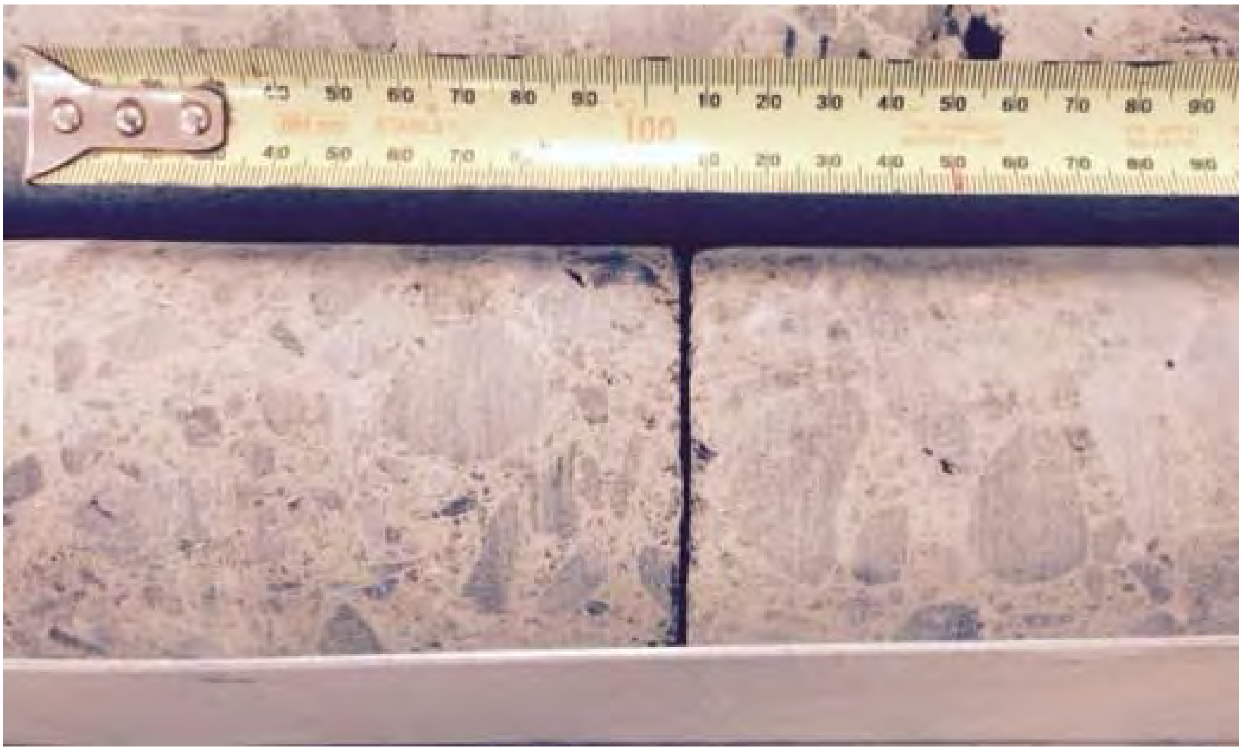
Client Details: SunWater
179 Turbot St, Brisbane, Qld

Checked By: [redacted]

Date Reported: 8-Dec-2015

DIRECT SHEAR TEST REPORT
TEST METHOD ASTM D 3080

PROJECT : Paradise Dam Phase 3 Investigation **SAMPLE No. :** PAA1/DD601 @ ~24.8 m



PAA1/DD601 Lift Joint at ~24.8 m Before Test

Top of Specimen After Test

Base of Specimen After Test

Remarks:

Client Details: SunWater
179 Turbot St, Brisbane, Qld

Checked By: [redacted]

Date Reported: 8/12/2015

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DIRECT SHEAR TEST REPORT

Test Method: ASTM D5607

Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SunWater Limited	**Report No.**	15110197- DS
Project	Paradise Dam RCC Core Testing	**Test Date**	18/11/2015
		Report Date	20/11/2015
Client ID	PAA1/DD601	**Depth (m)**	23.32
Description		**Sample Type**	Single individual specimen - 3 Stages.

Sample Details

Stage 1

Sample Depth (m)	23.32
Specimen Shape	Circle
Specimen Dimensions (mm)	83.1
Initial Moisture Content (%)	4.5
Initial Wet Density(t/m^3)	2.49
Dry Density(t/m^3)	2.38
Rate of Strain (mm/min)	0.05

Notes/Remarks:

Graph not to scale

Sample/s supplied by the client

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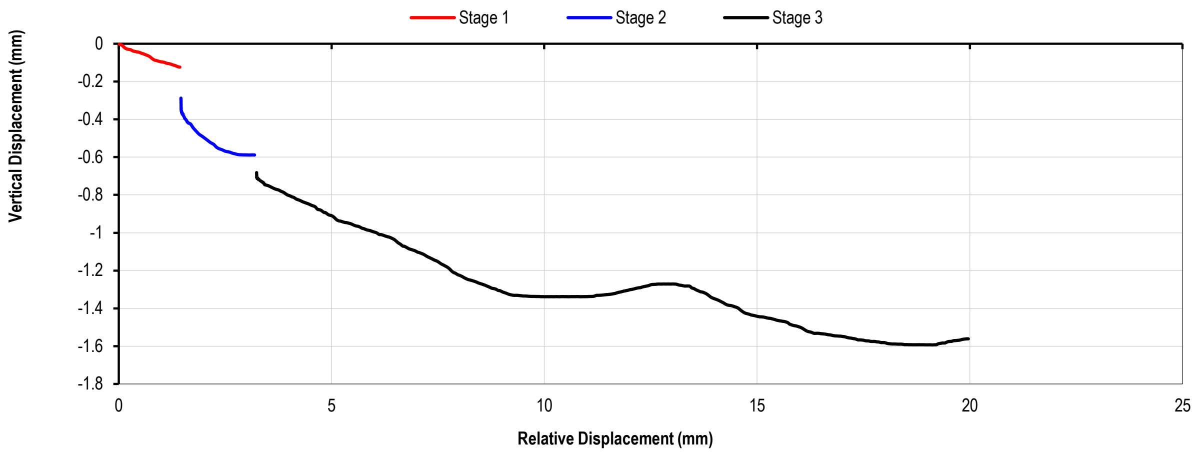
DIRECT SHEAR TEST REPORT

Test Method: ASTM D5607

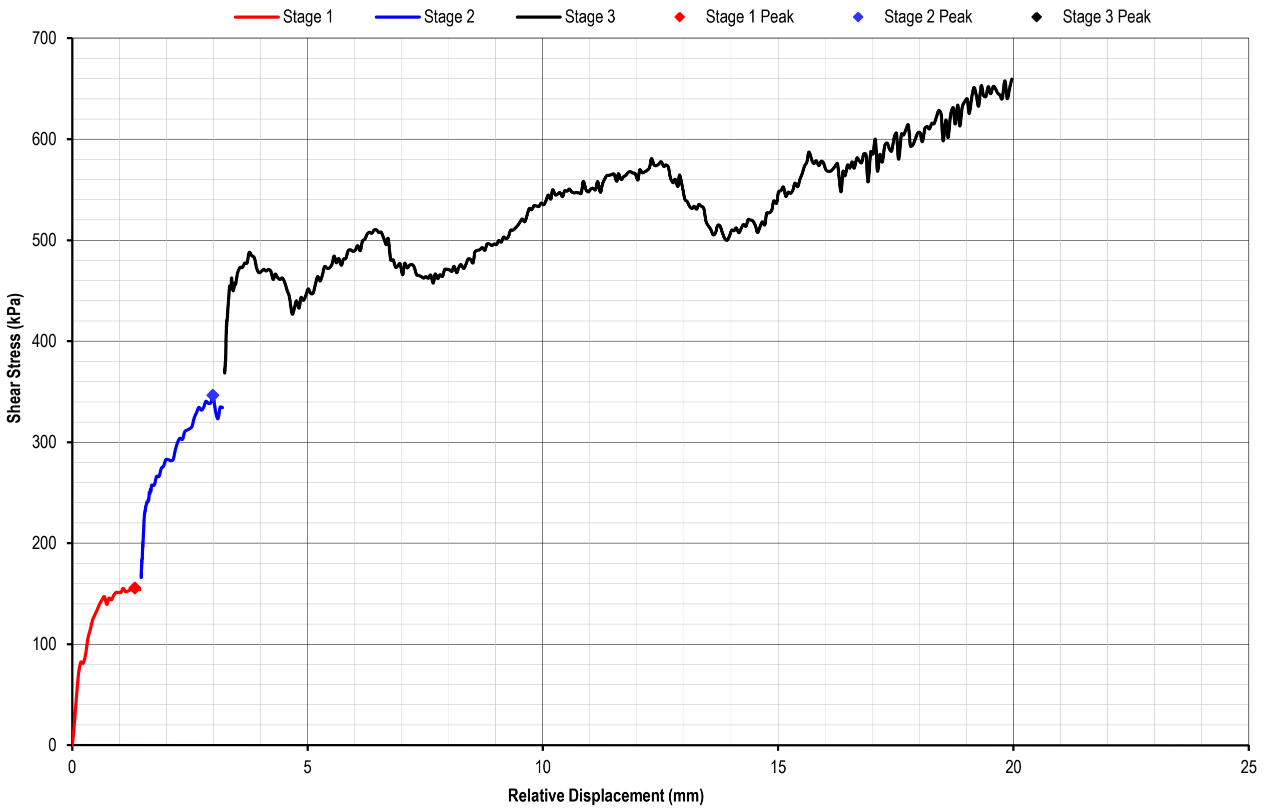
Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SunWater Limited	**Report No.**	15110197- DS

Peak Vertical Displacement/Relative Displacement Plot



Peak Shear Stress/Displacement Plot



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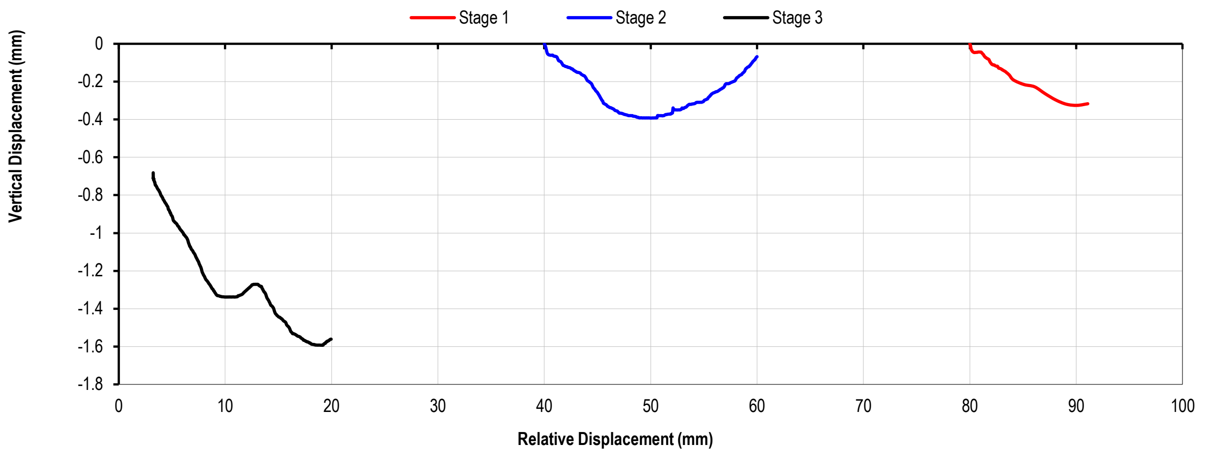
DIRECT SHEAR TEST REPORT

Test Method: ASTM D5607

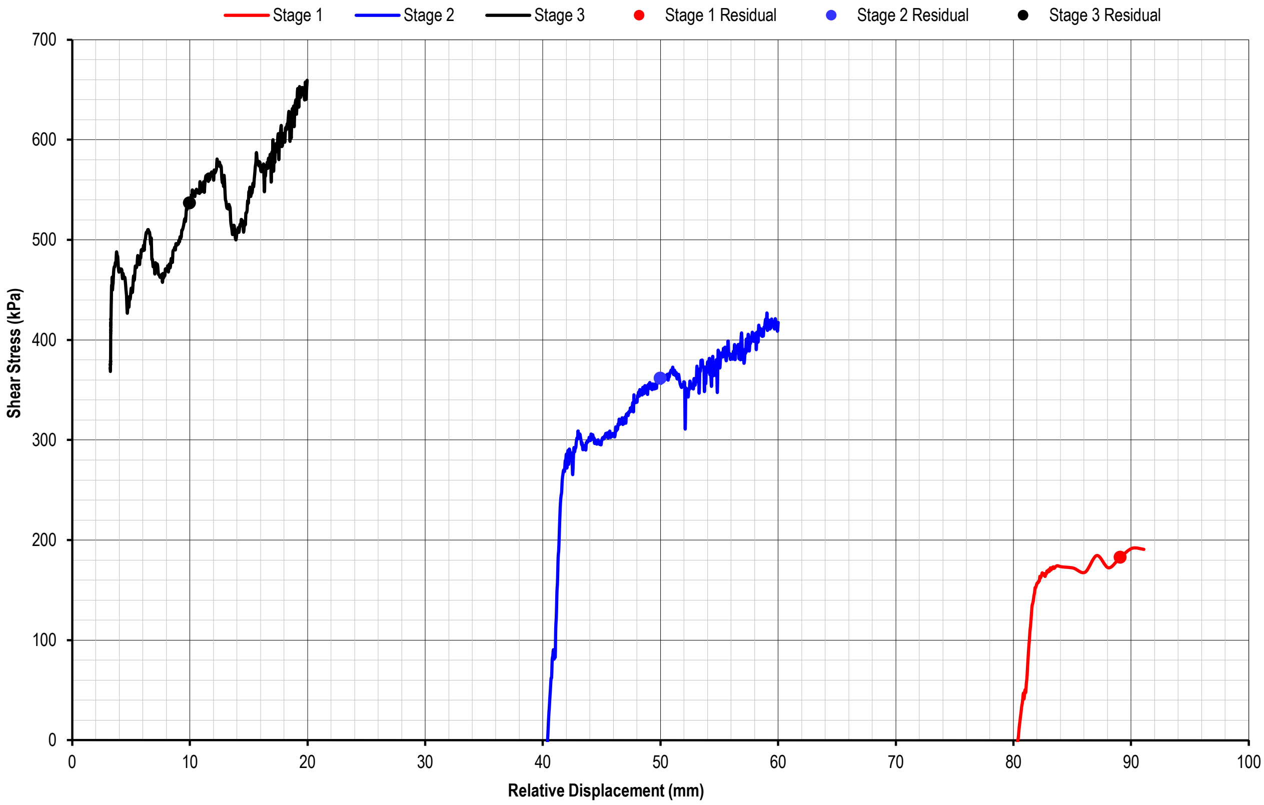
Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SunWater Limited	**Report No.**	15110197- DS

Residual Vertical Displacement/Relative Displacement Plot



Residual Shear Stress/Displacement Plot



Notes/Remarks:

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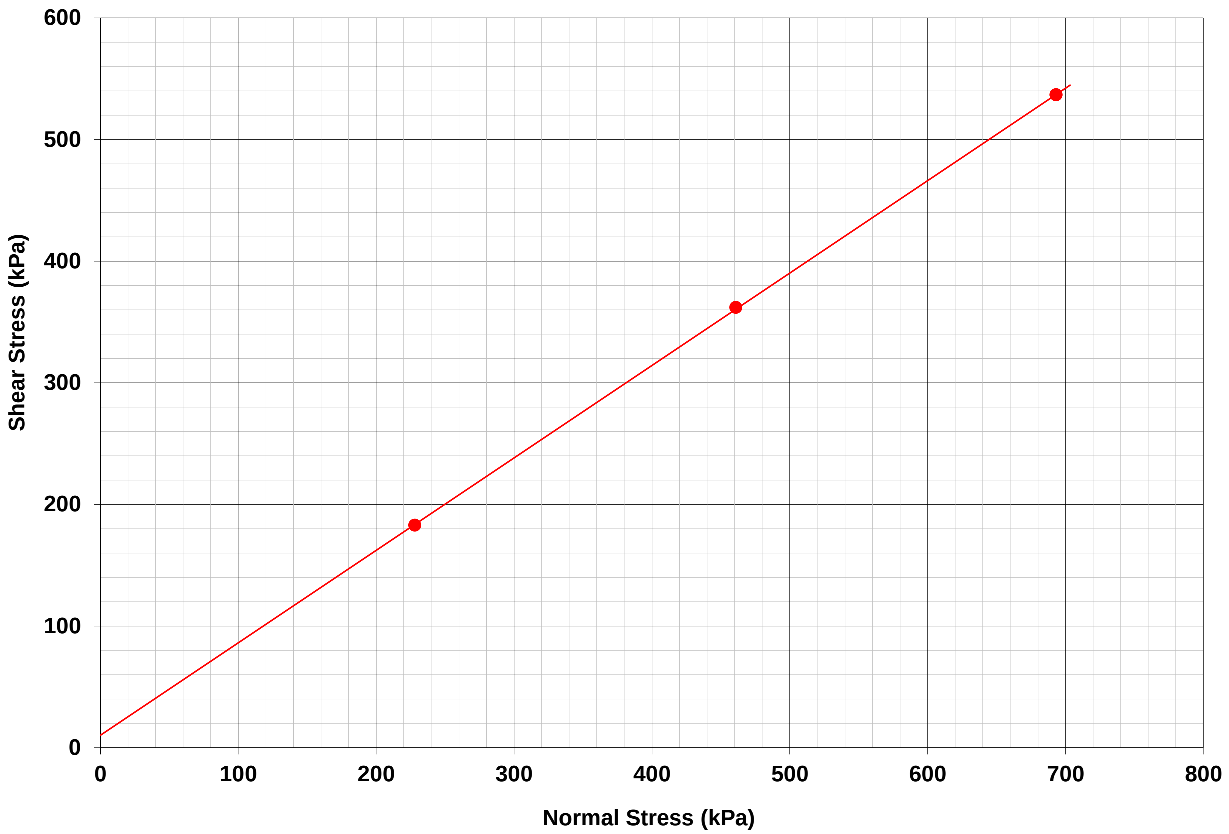
DIRECT SHEAR TEST REPORT

Test Method: ASTM D5607

Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SunWater Limited	**Report No.**	15110197- DS
Failure Criteria	**Residual**		

Residual - Normal Stress vs Shear Stress



Shear Angle (^{o})	**37.2**	**Cohesion (kPa)**	**10.2**	**R^2**	**1.000**

Stage	**Residual Displacement**	**Normal Stress**	**Shear Stress**
	(mm)	(kPa)	(kPa)
1	89.09	228.0	182.9
2	50.00	460.8	361.8
3	9.97	693.2	536.7
		Machine Description	Constant Normal Stress Direct Shear

Notes/Remarks:

Graph not to scale

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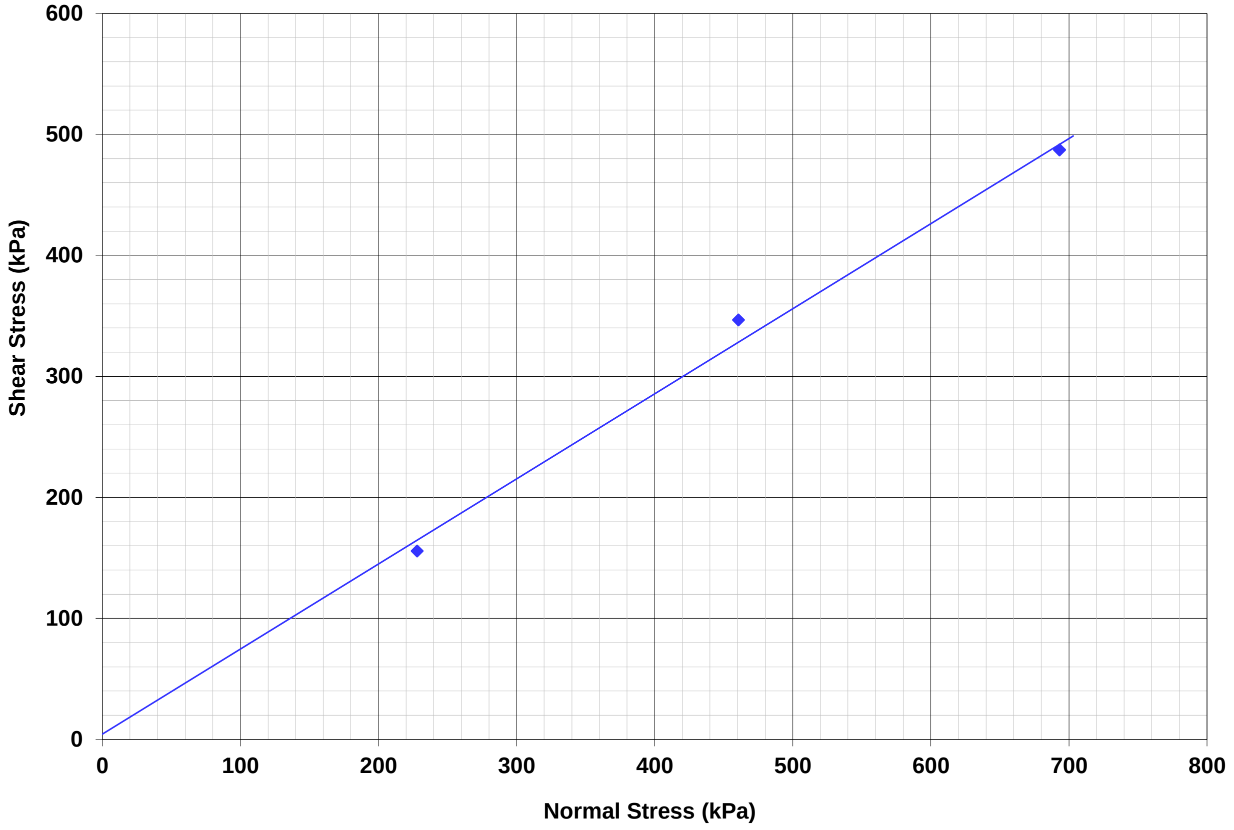
DIRECT SHEAR TEST REPORT

Test Method: ASTM D5607

Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SunWater Limited	**Report No.**	15110197- DS
Failure Criteria		**Peak**	

Peak - Normal Stress vs Shear Stress



Shear Angle (^{o})	35.1	Cohesion (kPa)	4.4	R^2	0.997

Stage	Displacement at Peak Stress	Normal Stress	Shear Stress
	(mm)	(kPa)	(kPa)
1	1.33	228.0	155.5
2	2.99	460.8	346.5
3	3.76	693.2	487.0
		Machine Description	Constant Normal Stress Direct Shear

Notes/Remarks:

Graph not to scale

Sample/s supplied by the client

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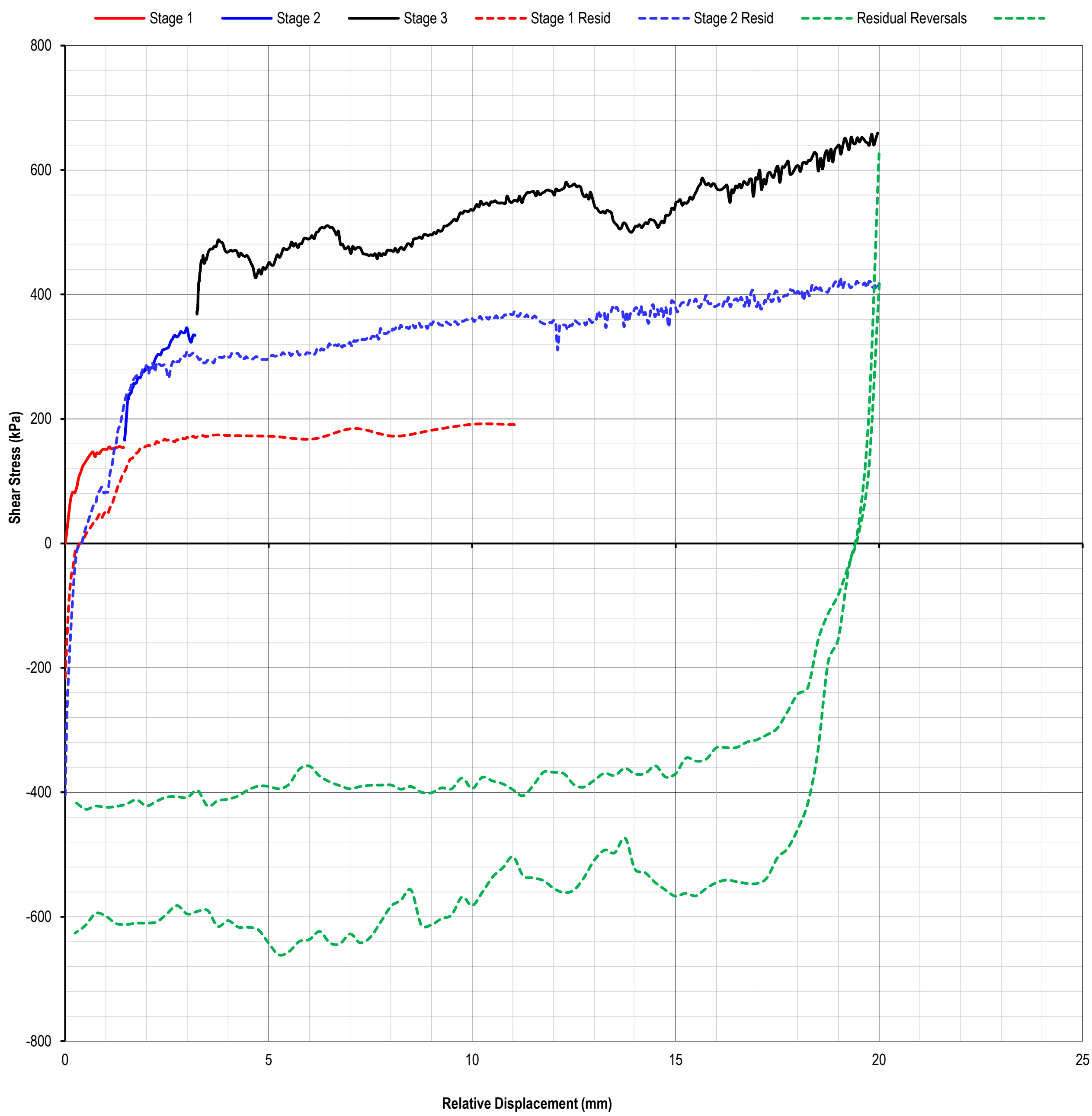
DIRECT SHEAR TEST REPORT

Test Method: ASTM D5607

Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SunWater Limited	**Report No.**	15110197- DS

Shear Stress/Displacement Plot



Notes/Remarks:

Graph not to scale

Sample/s supplied by the client

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DIRECT SHEAR TEST REPORT

Test Method: ASTM D5607

Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SunWater Limited	**Report No.**	15110197- DS

After Photo

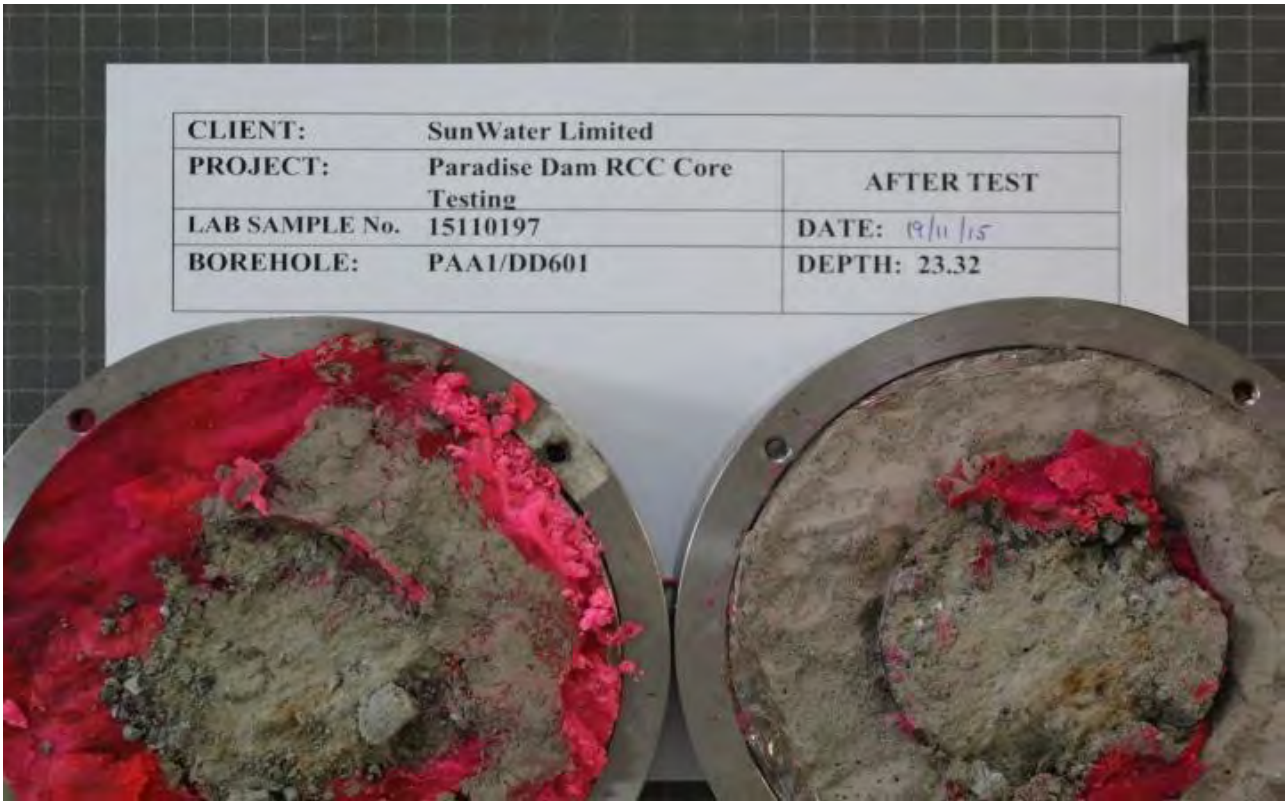

Photo not to scale

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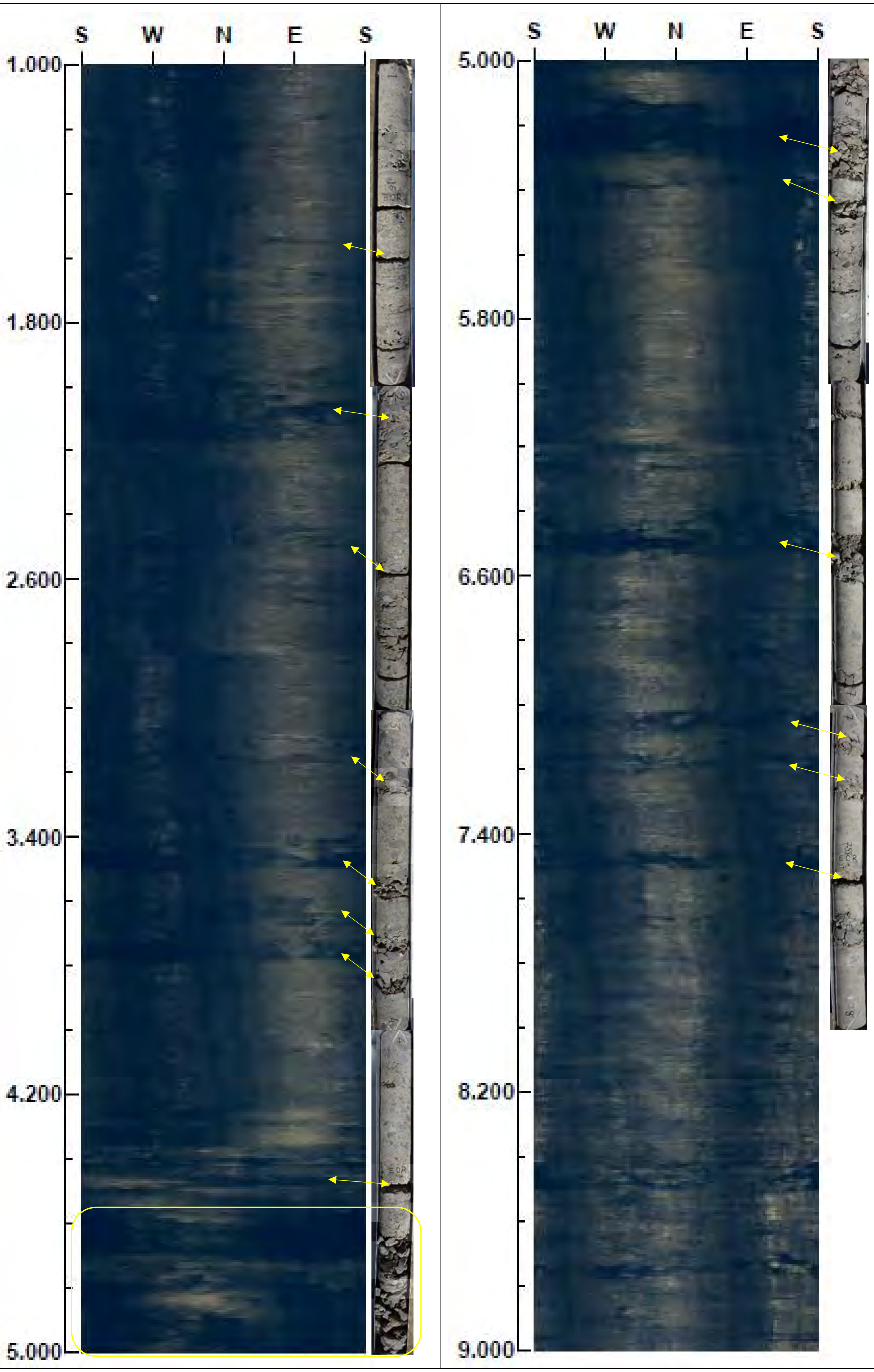
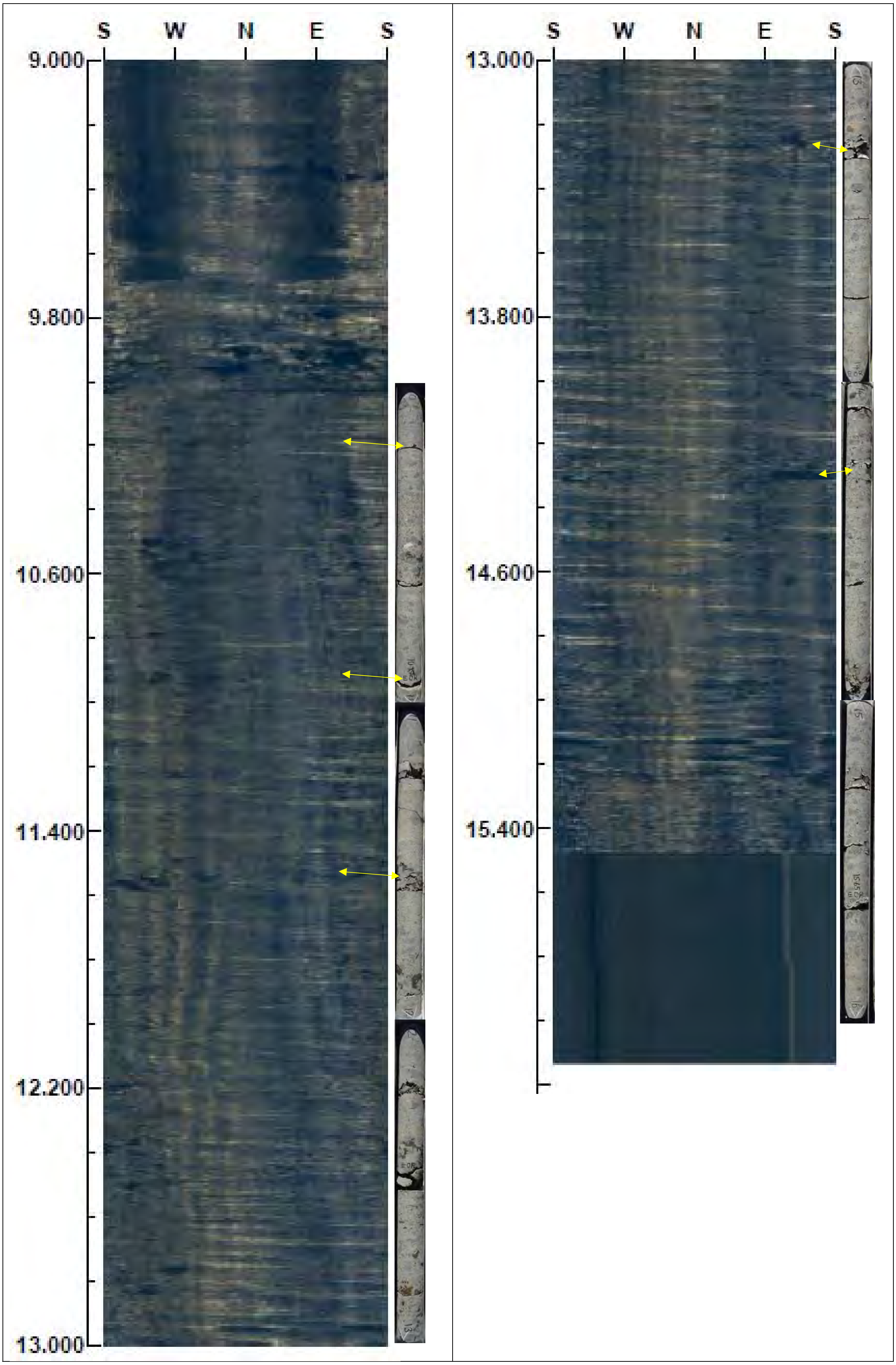
ATTACHMENT 3 – COMPARISON OF RAAX IMAGERY AND CORE PHOTOS – 2015 BOREHOLES

GHD Pty Ltd ABN 39 008 488 373
Level 9 145 Ann Street Brisbane Queensland 4000 GPO Box 668 Brisbane QLD 4001 Australia
T +61 7 3316 3000 **F** +61 7 3316 3333 **E** bnemail@ghd.com **W** www.ghd.com

BOREHOLE DD600




S W N E S
9.000
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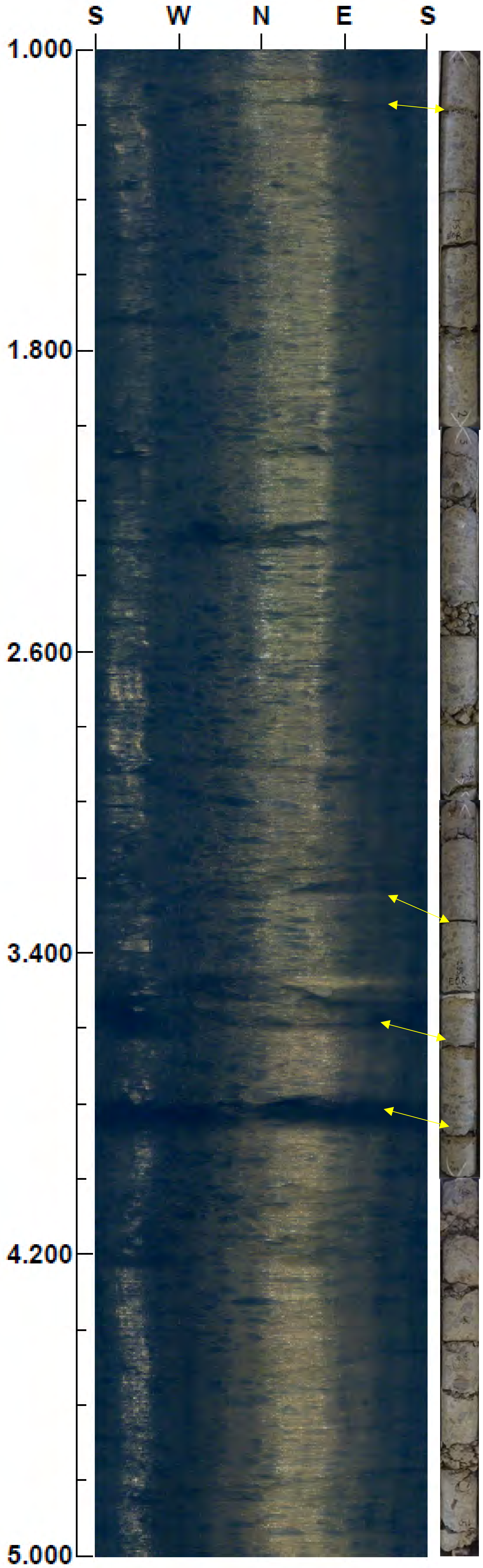
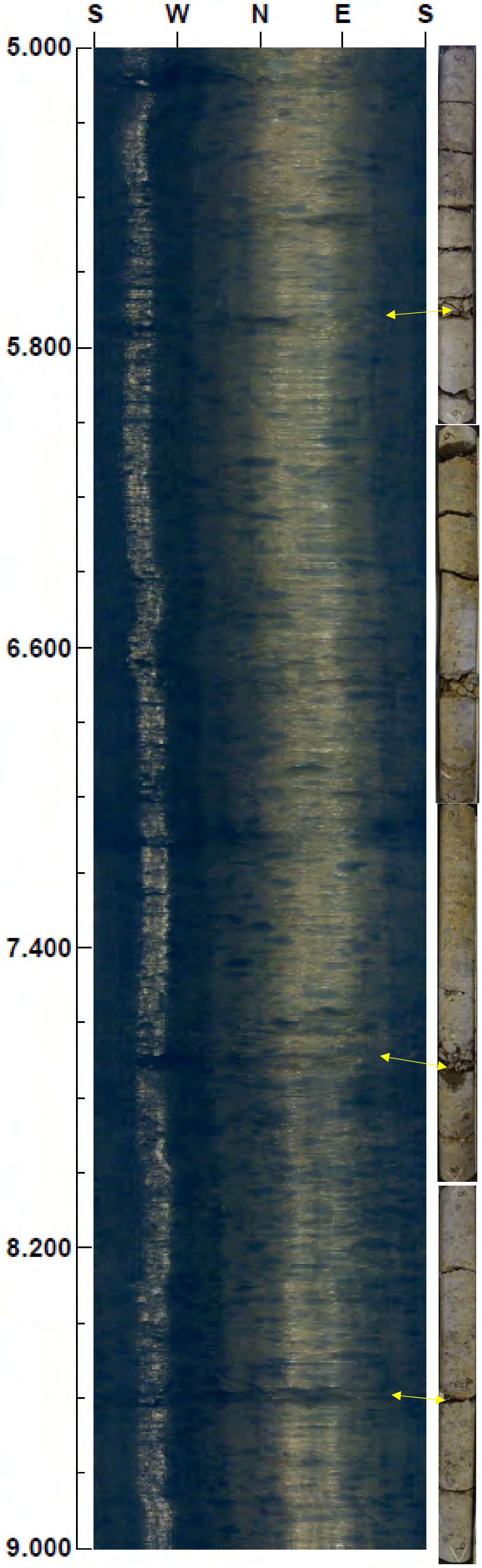
BOREHOLE DD601





Memorandum

ATTACHMENT 4 – LABORATORY TEST CERTIFICATES – 2019 TESTING

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DIRECT SHEAR TEST REPORT

ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070508- DS
		Workorder No	0006228
Address	Level 6, 480 St Pauls Tce Fortitude Valley QLD 4006	**Test Date**	31/07/2019
		Report Date	2/08/2019
Project	Paradise Dam Geotechnical Investigation		
Client ID	RCC-B - Bonded Lift Joint	**Depth (m)**	1.49-1.64
Description	-	**Sample Type**	Single individual concrete core specimen - INTACT.

SAMPLE DETAILS

Specimen Condition	As Received
Specimen Dimensions (mm)	144.99*144.79
Rate of Strain (mm/min)	0.100
Initial Moisture Content (%)	3.1
Initial Wet Density(t/m^3)	2.48

Note: Wet Density as per AS1012.12.2-1998 is not covered by NATA terms of accreditation and is provided for information only.

TEST RESULTS

RESIDUAL RESULTS

Residual Unbonded Shear Angle (°)	**32.8**	**Residual Unbonded Cohesion (kPa)** **55.1**	**R^2 0.998**
	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	10.00	199.5	201.5
500 kPa	24.00	500.5	372.8
1000 kPa	37.99	1001.1	701.6

PEAK RESULTS

Peak Unbonded Shear Angle (°)	**30.7**	**Peak Unbonded Cohesion (kPa)** **198.0**	**R^2 0.995**
	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	2.80	200.6	300.2
500 kPa	4.66	500.8	521.8
1000 kPa	5.45	1000.6	781.4

INTACT STRENGTH

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	2.29	200.6	293.8

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Sample/s supplied by the client

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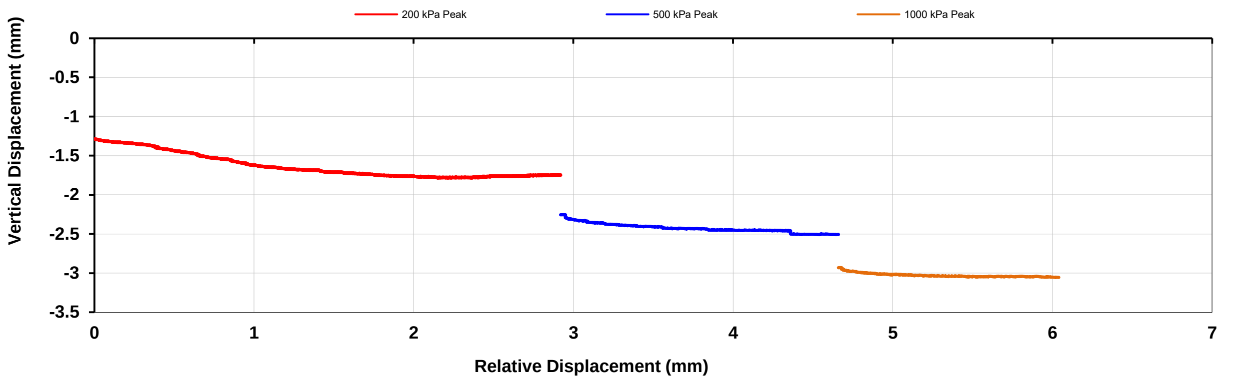
DIRECT SHEAR TEST REPORT

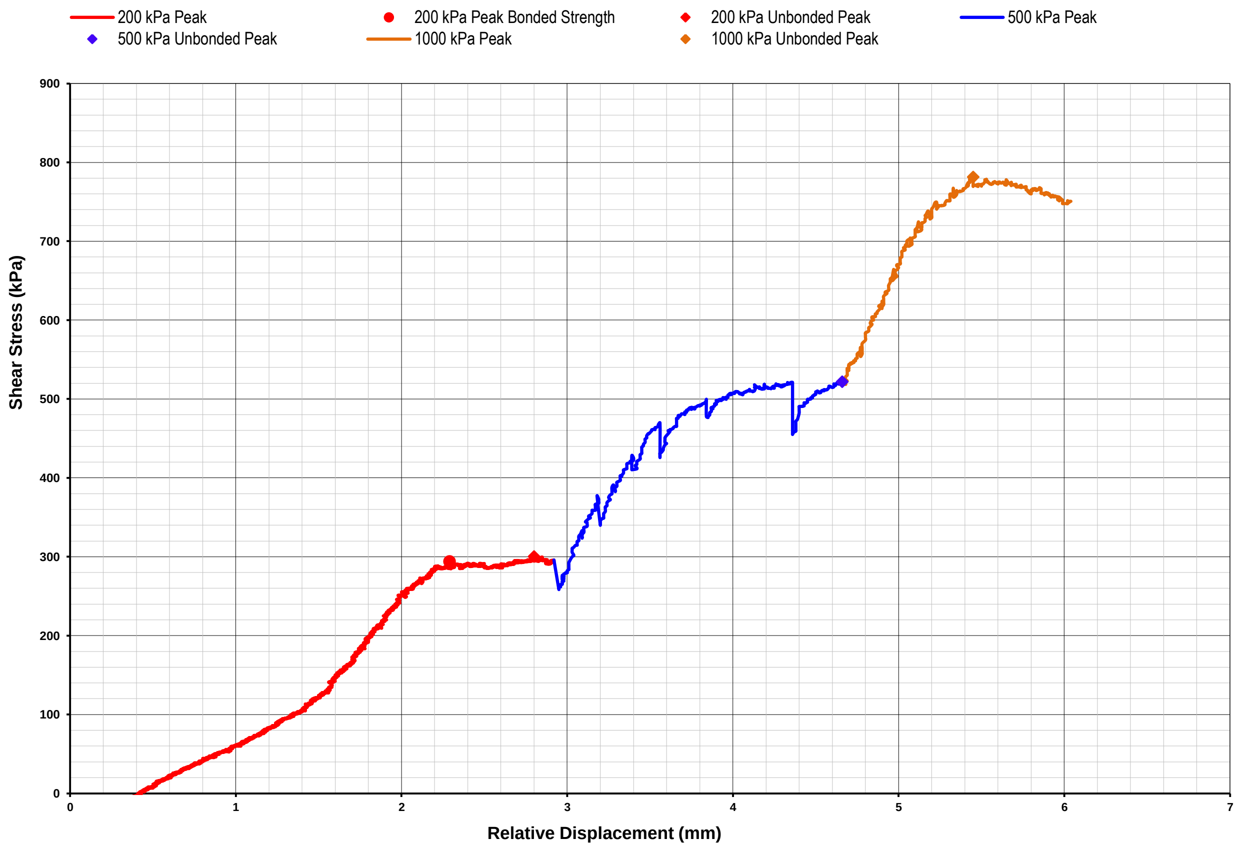
ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070508- DS

Peak Vertical Displacement/Relative Displacement Plot



Shear Stress/Relative Displacement Plot



Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Graph not to scale

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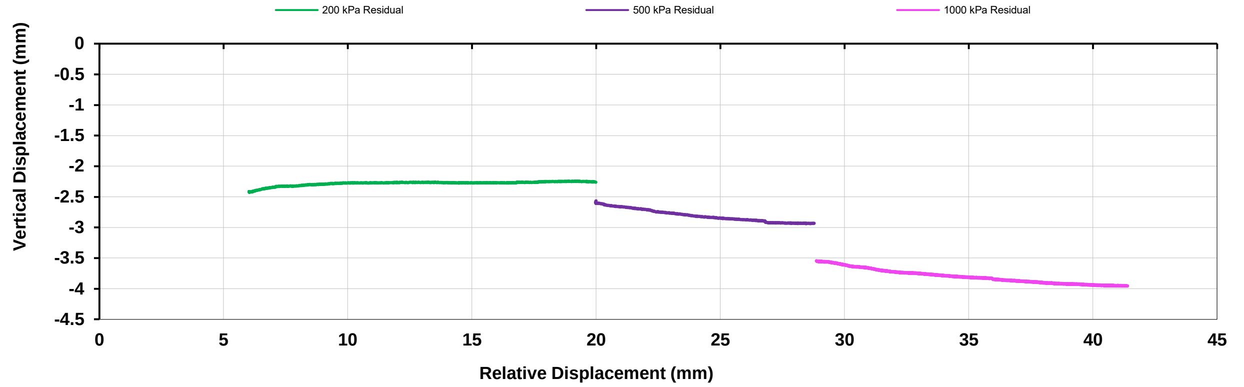
DIRECT SHEAR TEST REPORT

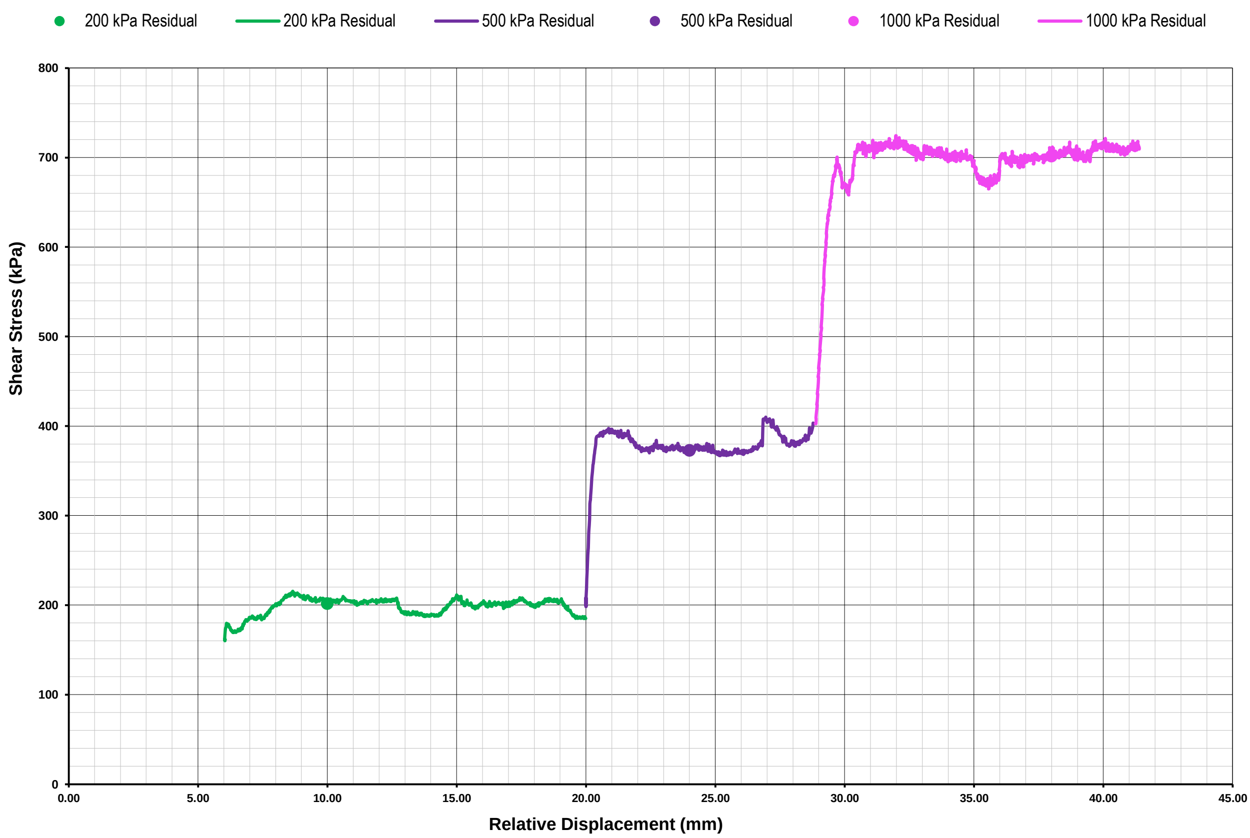
ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070508- DS

Residual Vertical Displacement/Relative Displacement Plot



Residual Shear Stress/Relative Displacement Plot



Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Graph not to scale

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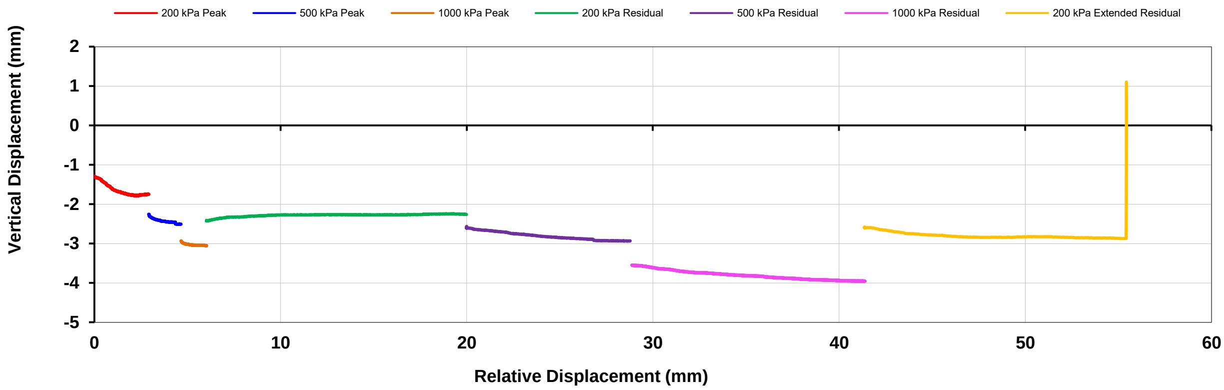
DIRECT SHEAR TEST REPORT

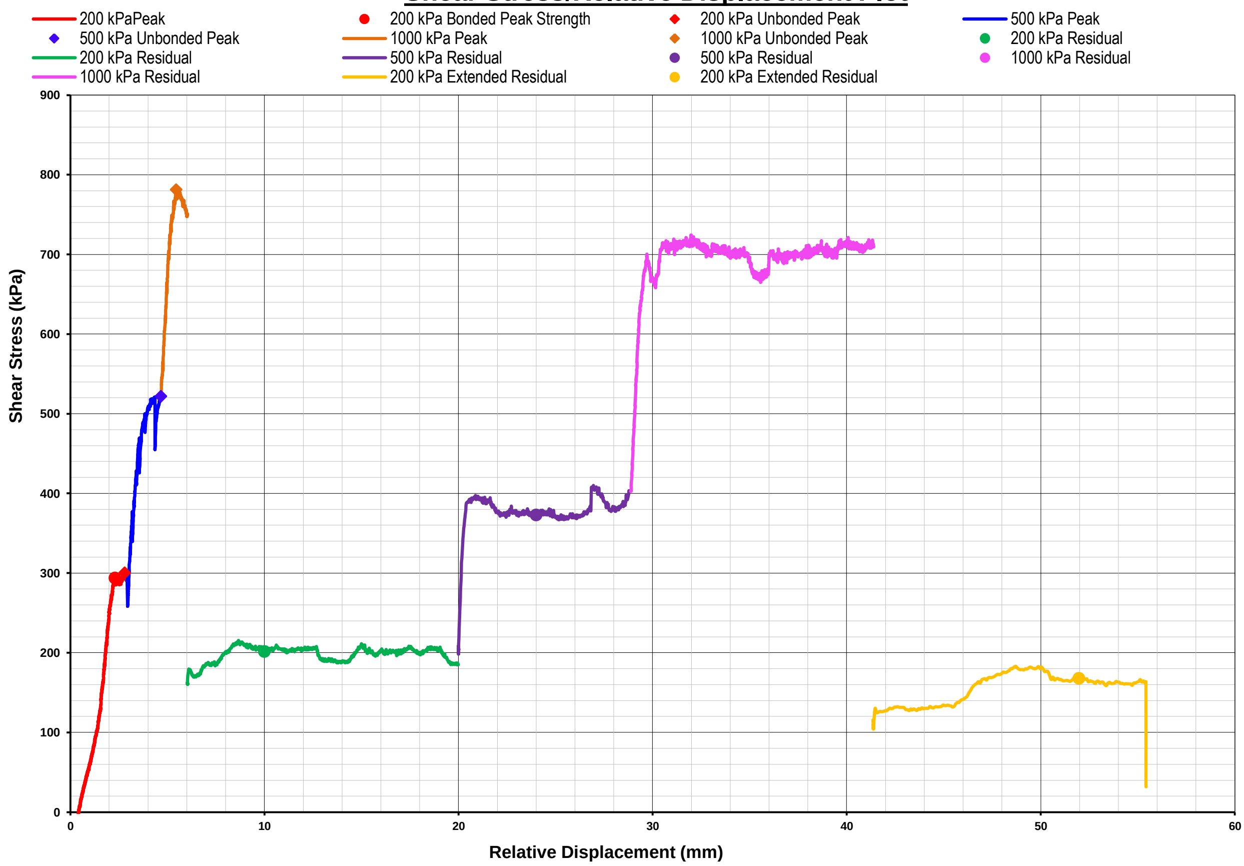
ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070508- DS

Peak & Residual Vertical Displacement/Relative Displacement Plot



Shear Stress/Relative Displacement Plot



Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Graph not to scale

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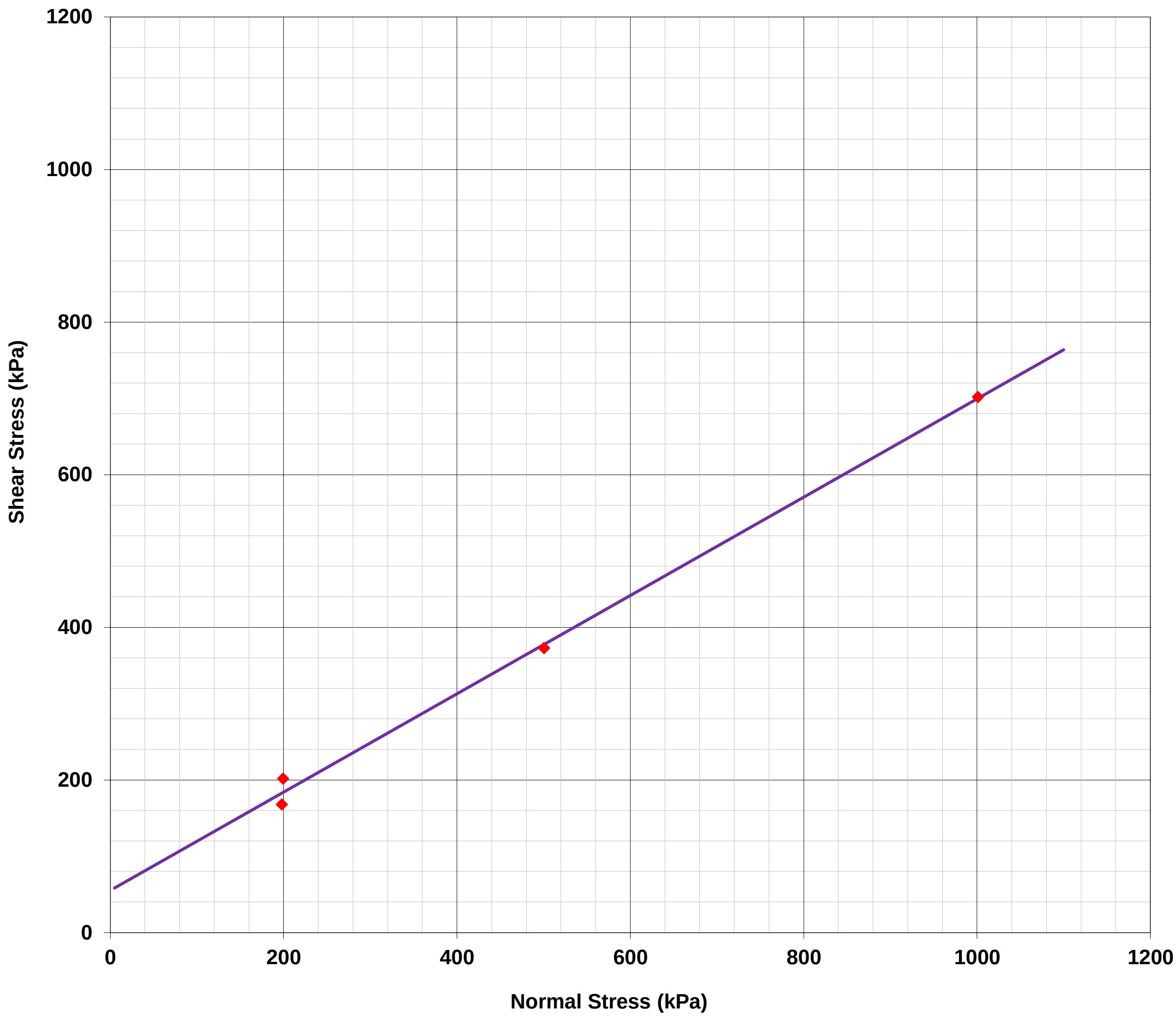
DIRECT SHEAR TEST REPORT

ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070508- DS

Residual - Corrected Normal Stress vs Corrected Shear Unbonded Stress



Residual Unbonded Shear Angle (°) **32.8**		**Residual Unbonded Cohesion (kPa)** **55.1**	**R^2 0.998**
	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	10.00	199.5	201.5
500 kPa	24.00	500.5	372.8
1000 kPa	37.99	1001.1	701.6
200 kPa Extended	51.96	198.0	167.7

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Graph not to scale

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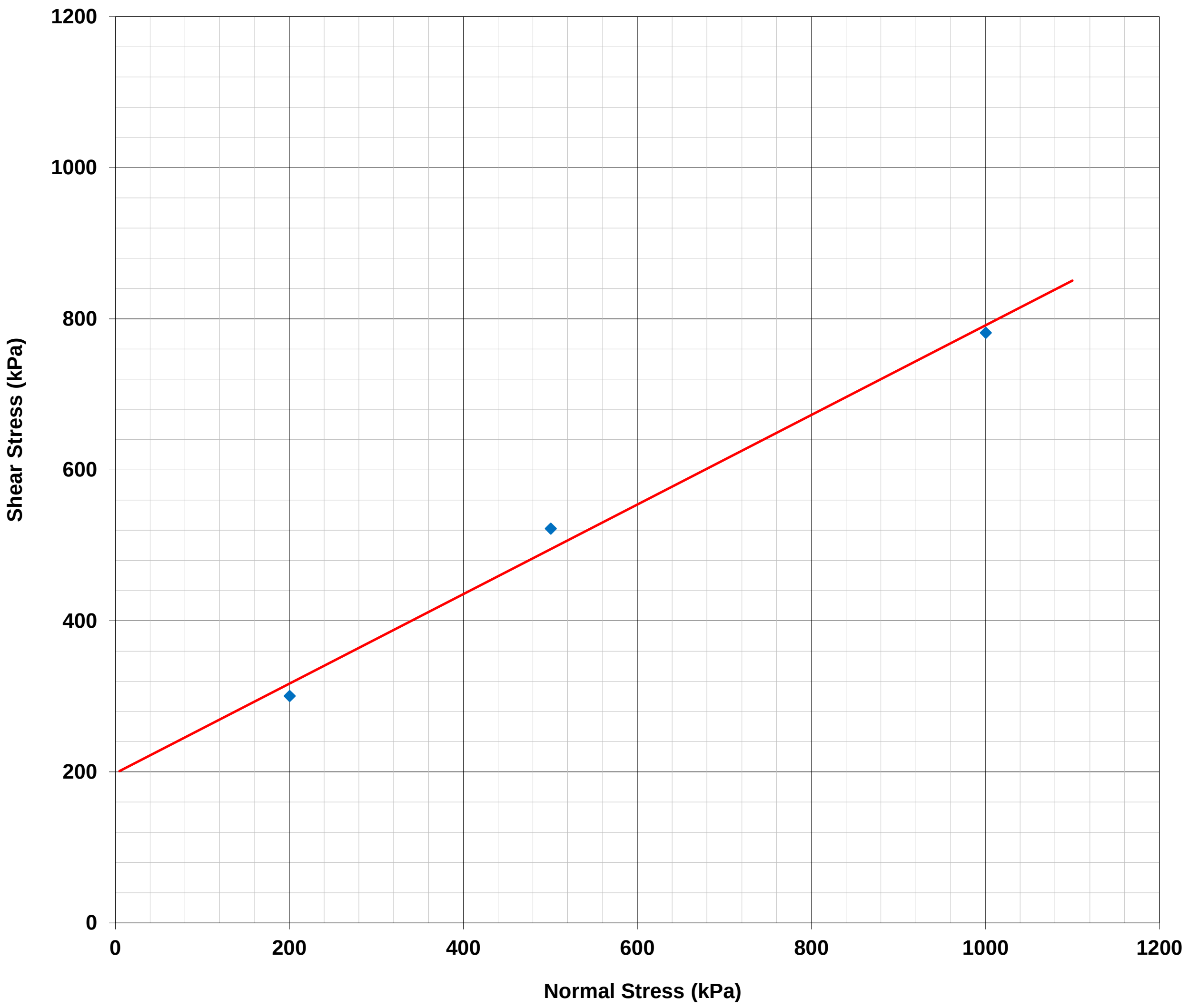
DIRECT SHEAR TEST REPORT

ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070508- DS

Peak - Corrected Normal Stress vs Corrected Unbonded Shear Stress



Peak Unbonded Shear Angle (°) 30.7		**Peak Unbonded Cohesion (kPa)** 198.0	**R^2 0.995**
	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	2.80	200.6	300.2
500 kPa	4.66	500.8	521.8
1000 kPa	5.45	1000.6	781.4

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Graph not to scale

Sample/s supplied by the client

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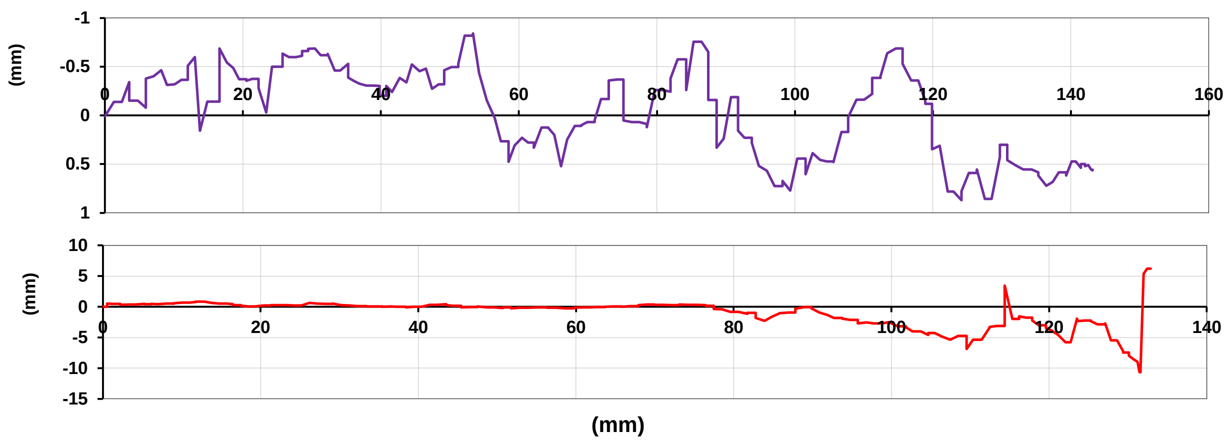
ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

DIRECT SHEAR TEST REPORT

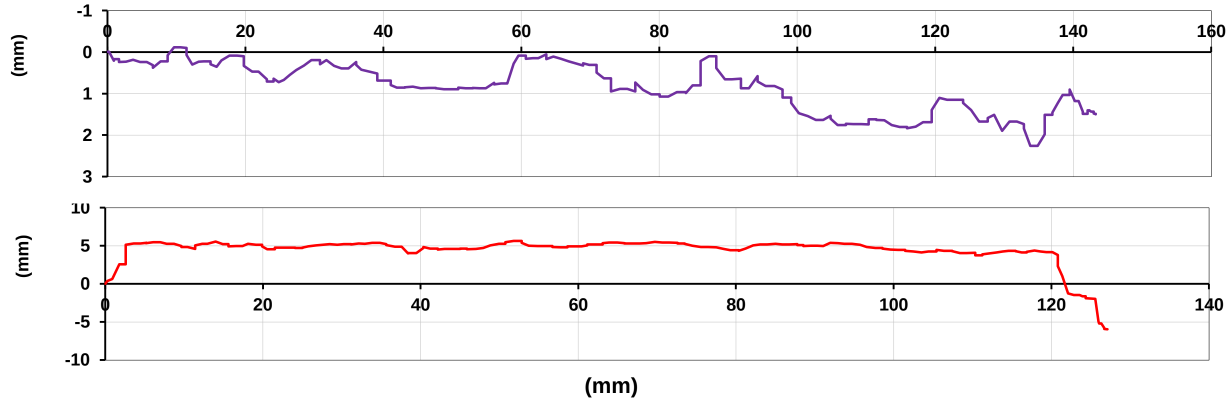
ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070508- DS

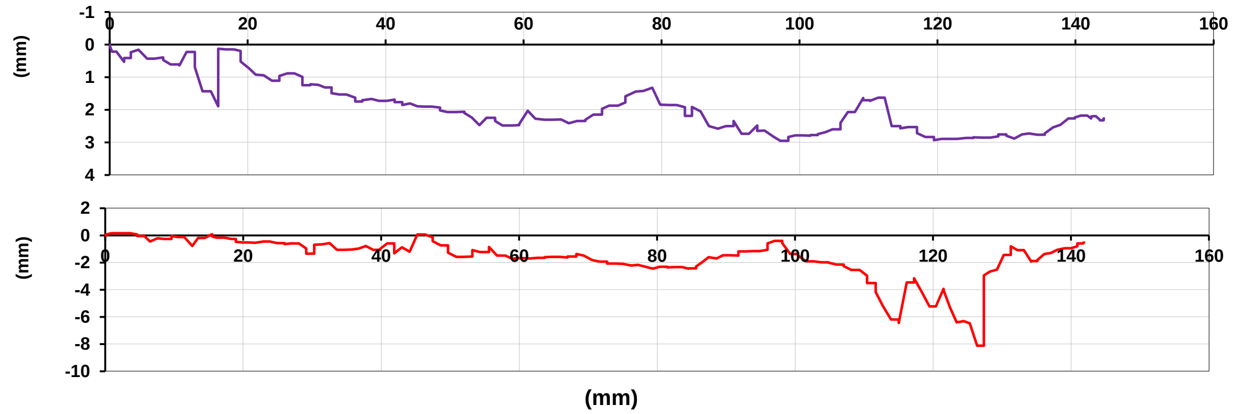
Top and Bottom Profile - Position 1 - After Shearing



Top and Bottom Profile - Position 2 - After Shearing



Top and Bottom Profile - Position 3 - After Shearing



Graph not to scale

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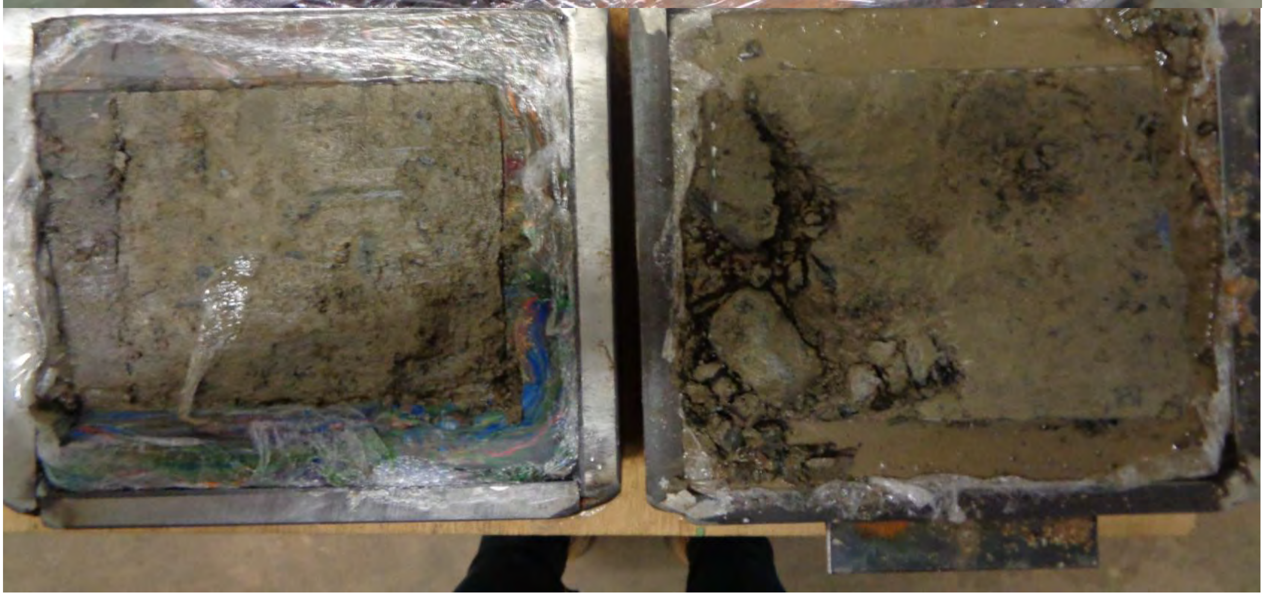
DIRECT SHEAR TEST REPORT

ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070508- DS



Notes/Remarks:

Photo not to scale

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DIRECT SHEAR TEST REPORT

ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070509- DS
		Workorder No	0006228
Address	Level 6, 480 St Pauls Tce Fortitude Valley QLD 4006	**Test Date**	1/08/2019
		Report Date	2/08/2019
Project	Paradise Dam Geotechnical Investigation		
Client ID	RCC-B - Bonded Lift Joint	**Depth (m)**	1.64-1.79
Description	-	**Sample Type**	Single individual concrete core specimen - INTACT.

SAMPLE DETAILS

Specimen Condition	As Received
Specimen Dimensions (mm)	145.40*144.94
Rate of Strain (mm/min)	0.100
Initial Moisture Content (%)	3.1
Initial Wet Density(t/m^3)	2.48

Note: Wet Density as per AS1012.12.2-1998 is not covered by NATA terms of accreditation and is provided for information only.

TEST RESULTS

RESIDUAL RESULTS

Residual Unbonded Shear Angle (°)	36.3	Residual Unbonded Cohesion (kPa)	31.4	R^2 0.999

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	16.00	201.0	185.0
500 kPa	25.99	499.6	385.5
1000 kPa	31.99	999.0	768.4

PEAK RESULTS

Peak Unbonded Shear Angle (°)	36.8	Peak Unbonded Cohesion (kPa)	60.4	R^2 1.000

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
500 kPa	3.41	500.0	434.0
200 kPa	3.82	199.6	209.9
1000 kPa	5.29	1000.4	808.7

INTACT STRENGTH

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
500 kPa	2.18	500.0	528.7

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Sample/s supplied by the client

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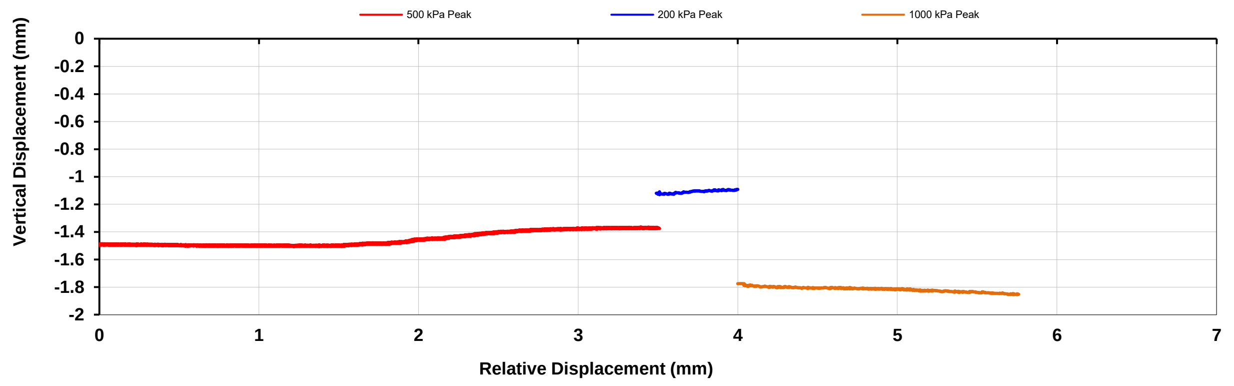
DIRECT SHEAR TEST REPORT

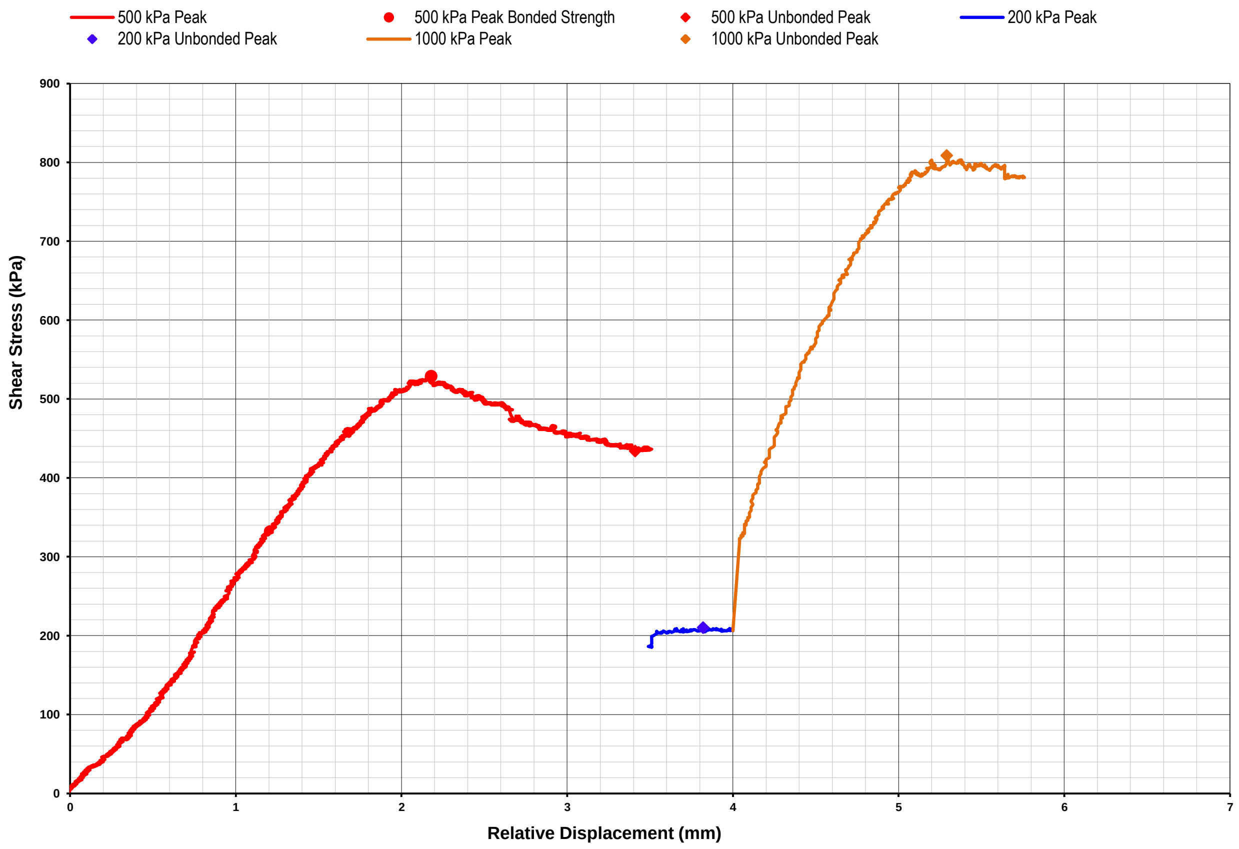
ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070509- DS

Peak Vertical Displacement/Relative Displacement Plot



Shear Stress/Relative Displacement Plot



Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Graph not to scale Sample/s supplied by the client

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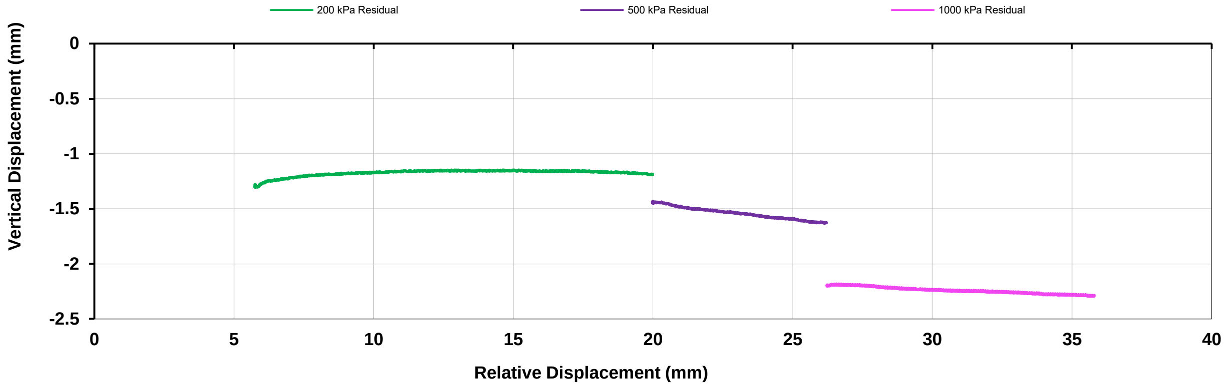
DIRECT SHEAR TEST REPORT

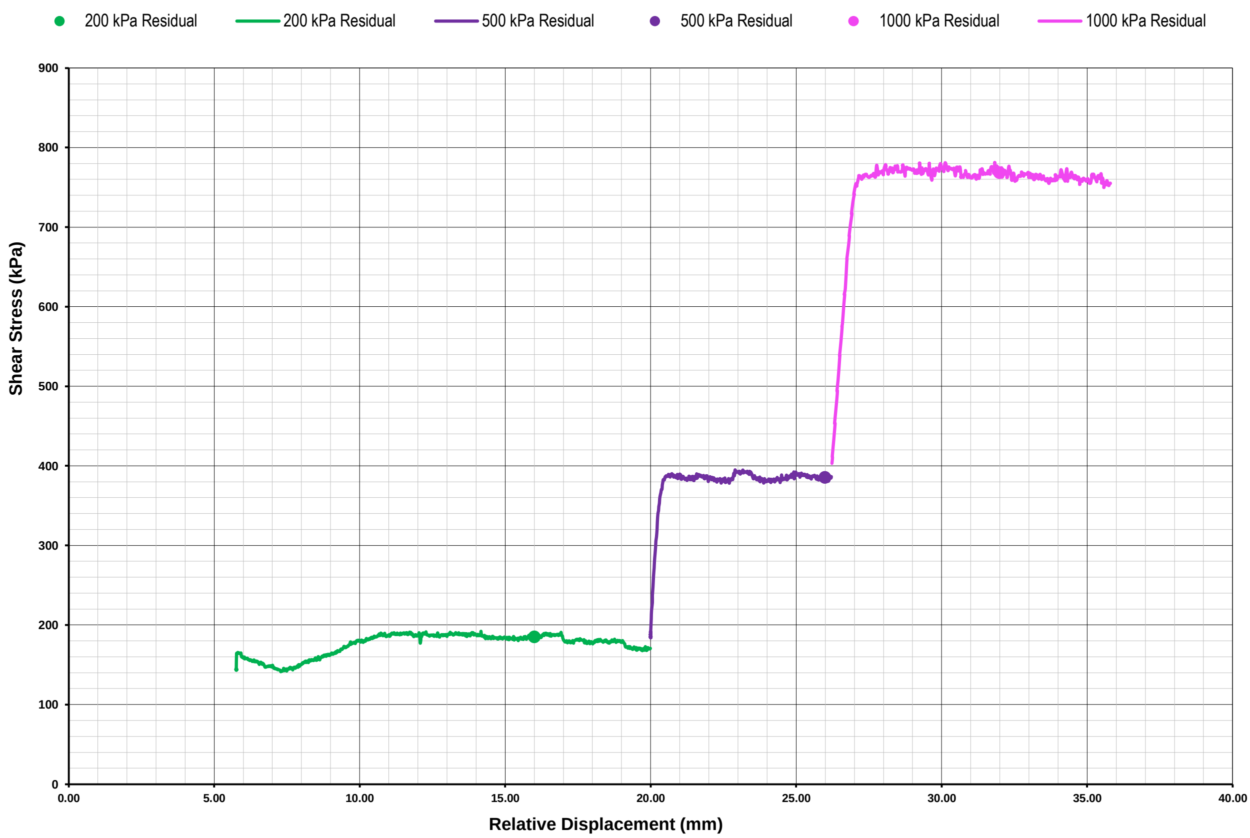
ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070509- DS

Residual Vertical Displacement/Relative Displacement Plot



Residual Shear Stress/Relative Displacement Plot



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Authorised Signatory: [redacted]

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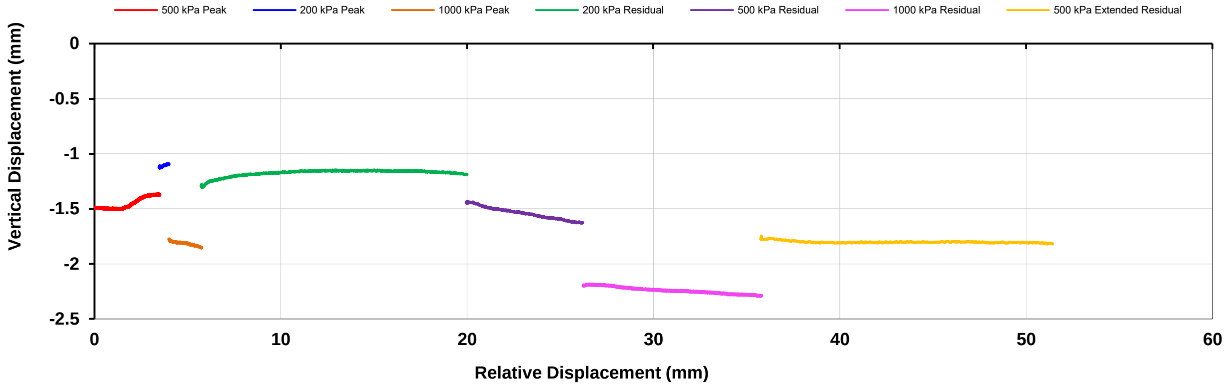
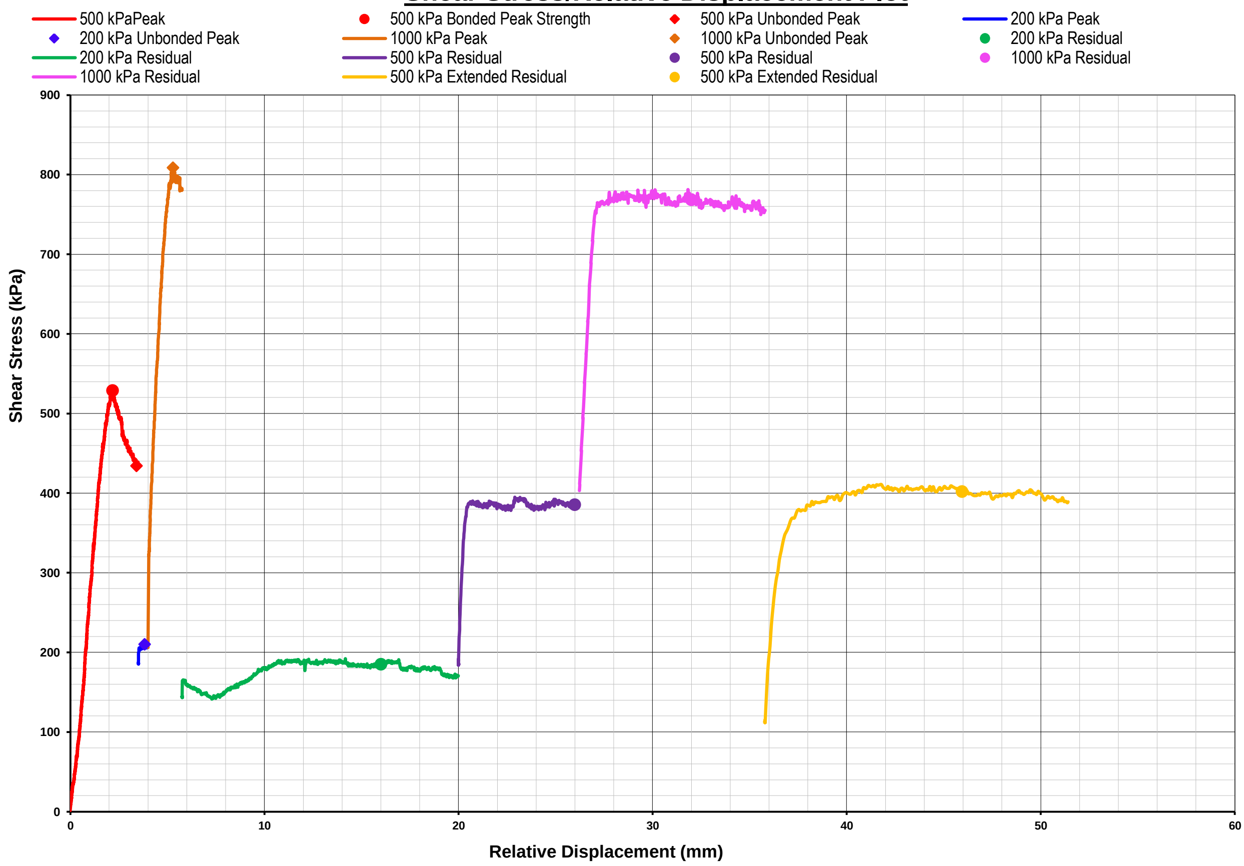
Client	SMEC Australia Pty Ltd	**Report No.**	19070509- DS

Peak & Residual Vertical Displacement/Relative Displacement Plot



Shear Stress/Relative Displacement Plot



Notes/Remarks:

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Graph not to scale

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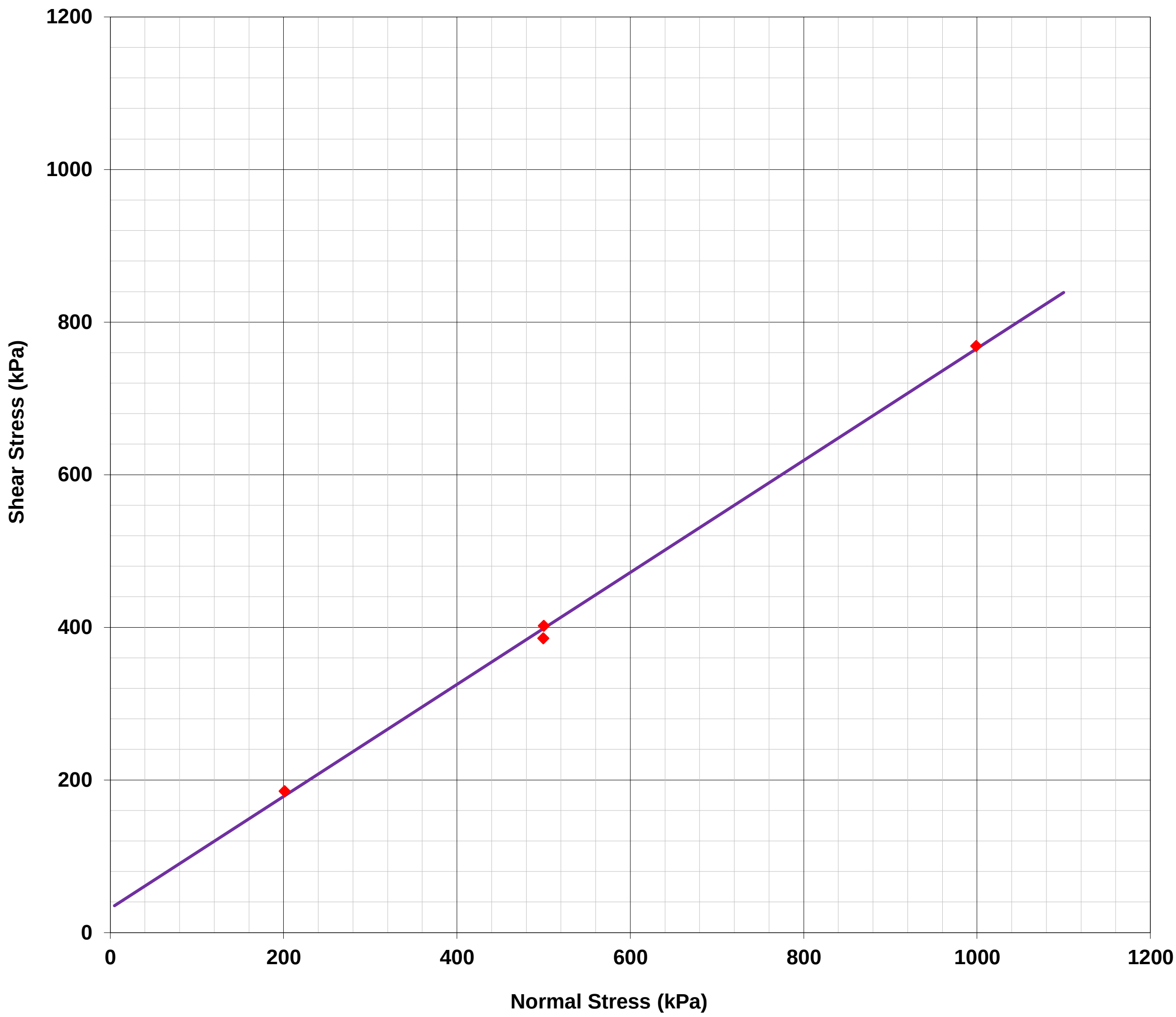
ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070509- DS

Residual - Corrected Normal Stress vs Corrected Shear Unbonded Stress



Residual Unbonded Shear Angle (^{o}) 36.3		**Residual Unbonded Cohesion (kPa)** 31.4	**R^2 0.999**
	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	16.00	201.0	185.0
500 kPa	25.99	499.6	385.5
1000 kPa	31.99	999.0	768.4
500 kPa Extended	45.95	500.1	401.7

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Graph not to scale Sample/s supplied by the client

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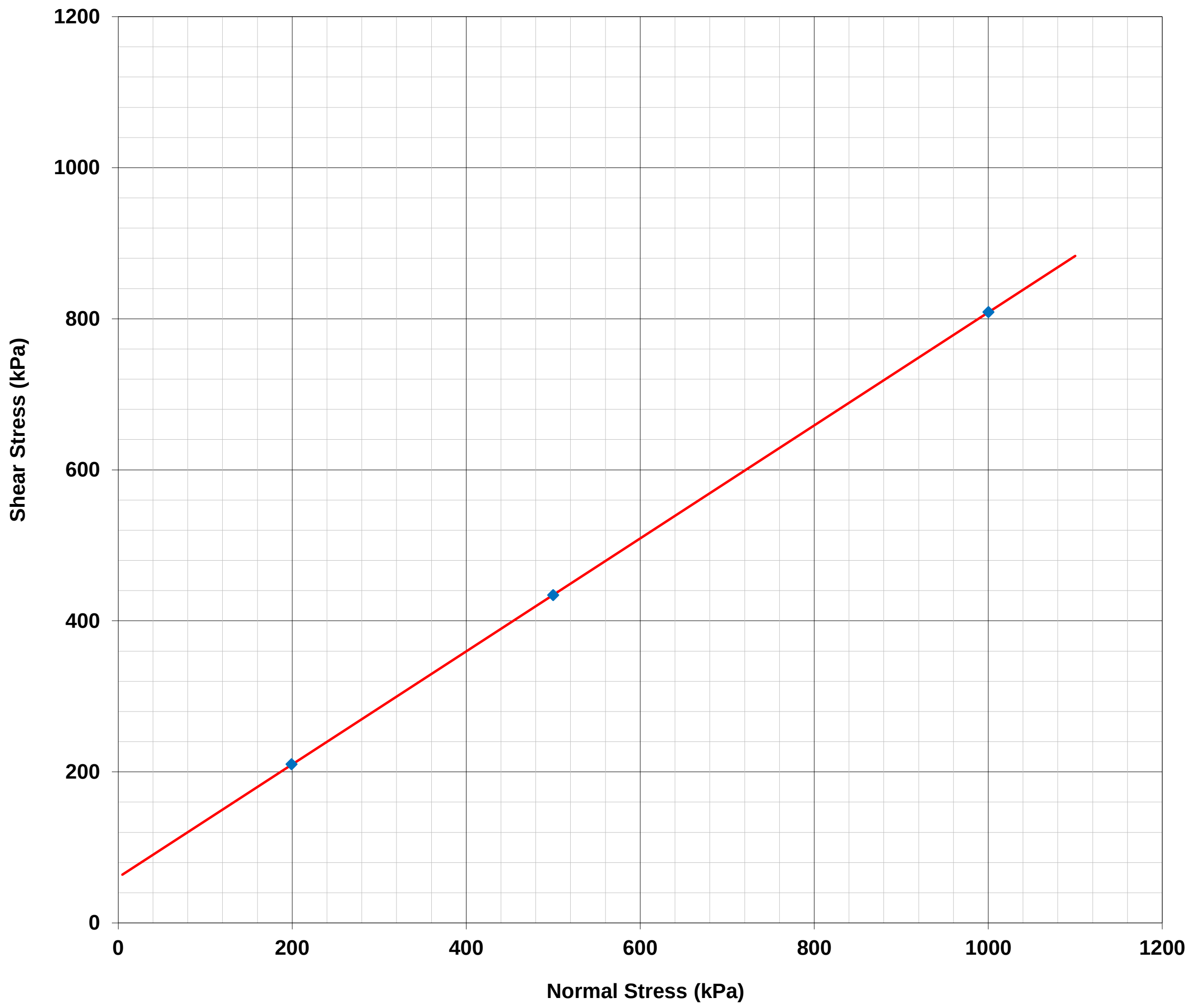
Client	SMEC Australia Pty Ltd	**Report No.**	19070509- DS

Peak - Corrected Normal Stress vs Corrected Unbonded Shear Stress



Peak Unbonded Shear Angle (^{o})	36.8	Peak Unbonded Cohesion (kPa) 60.4	R^2 1.000
	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
500 kPa	3.41	500.0	434.0
200 kPa	3.82	199.6	209.9
1000 kPa	5.29	1000.4	808.7

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Graph not to scale

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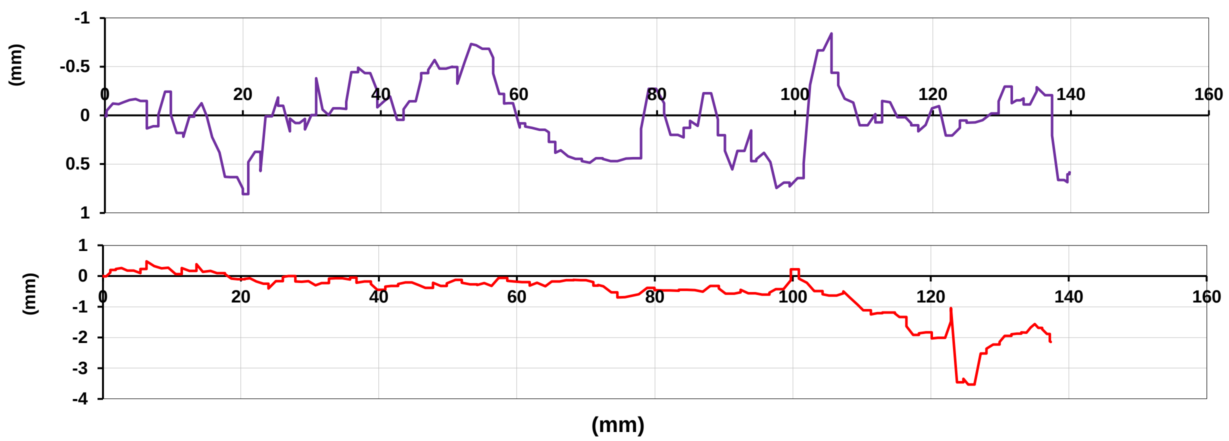
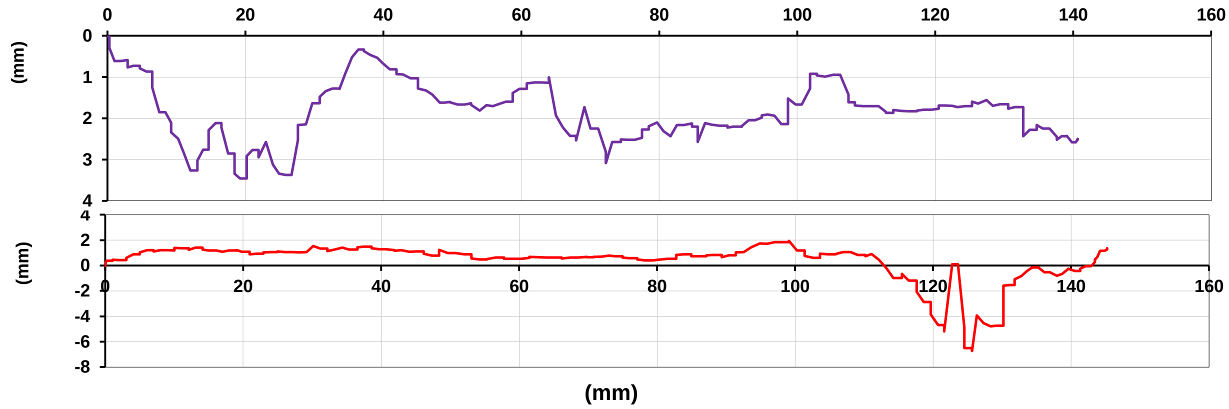
Client	SMEC Australia Pty Ltd	**Report No.**	19070509- DS

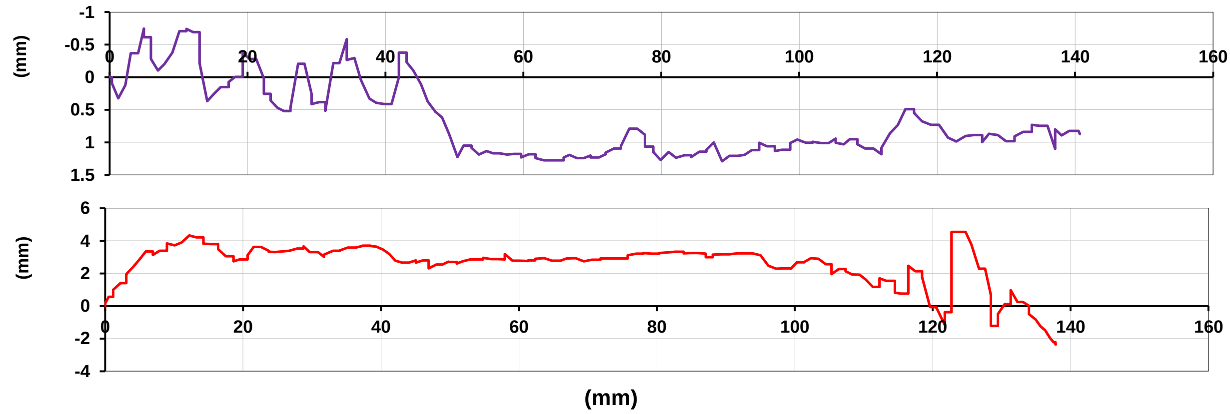
Top and Bottom Profile - Position 1 - After Shearing



Top and Bottom Profile - Position 2 - After Shearing



Top and Bottom Profile - Position 3 - After Shearing



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DIRECT SHEAR TEST REPORT

ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070509- DS

Notes/Remarks:

Photo not to scale

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DIRECT SHEAR TEST REPORT

ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070510- DS
		Workorder No	0006228
Address	Level 6, 480 St Pauls Tce Fortitude Valley QLD 4006	**Test Date**	0/01/1900
		Report Date	7/08/2019
Project	Paradise Dam Geotechnical Investigation		
Client ID	RCC-B - Bonded Lift Joint	**Depth (m)**	1.79-1.94
Description	-	**Sample Type**	Single individual concrete core specimen - INTACT.

SAMPLE DETAILS

Specimen Condition	As Received
Specimen Dimensions (mm)	148.53*144.70
Rate of Strain (mm/min)	0.100
Initial Moisture Content (%)	3.1
Initial Wet Density(t/m^3)	2.50

Note: Wet Density as per AS1012.12.2-1998 is not covered by NATA terms of accreditation and is provided for information only.

TEST RESULTS

RESIDUAL RESULTS

Residual Unbonded Shear Angle (°)	**34.0**	**Residual Unbonded Cohesion (kPa)** **13.0**	**R^2 0.999**

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	13.99	200.5	148.4
500 kPa	22.00	499.7	349.1
1000 kPa	35.95	1002.4	674.8

PEAK RESULTS

Peak Unbonded Shear Angle (°)	**40.7**	**Peak Unbonded Cohesion (kPa)** **48.6**	**R^2 0.997**

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
1000 kPa	4.10	1000.0	921.4
200 kPa	4.26	199.8	240.2
500 kPa	5.92	500.1	447.8

INTACT STRENGTH

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
1000 kPa	4.10	1000.0	921.4

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Sample/s supplied by the client

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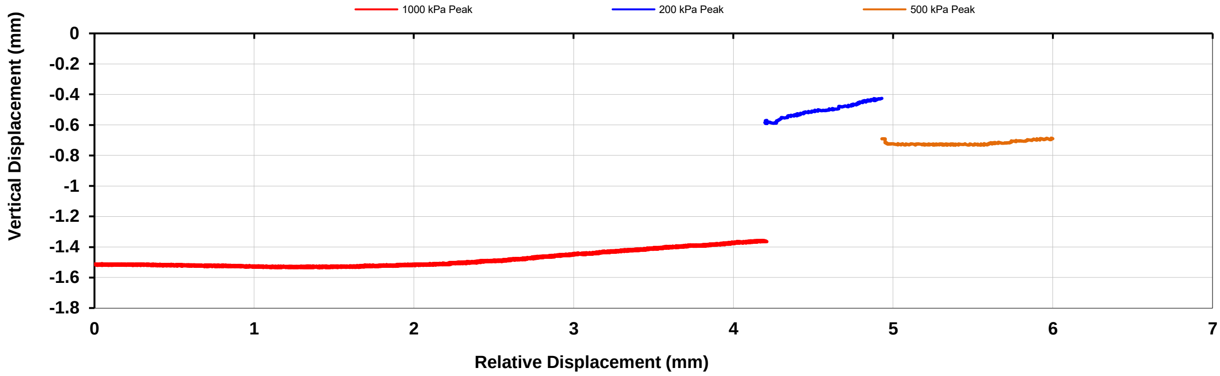
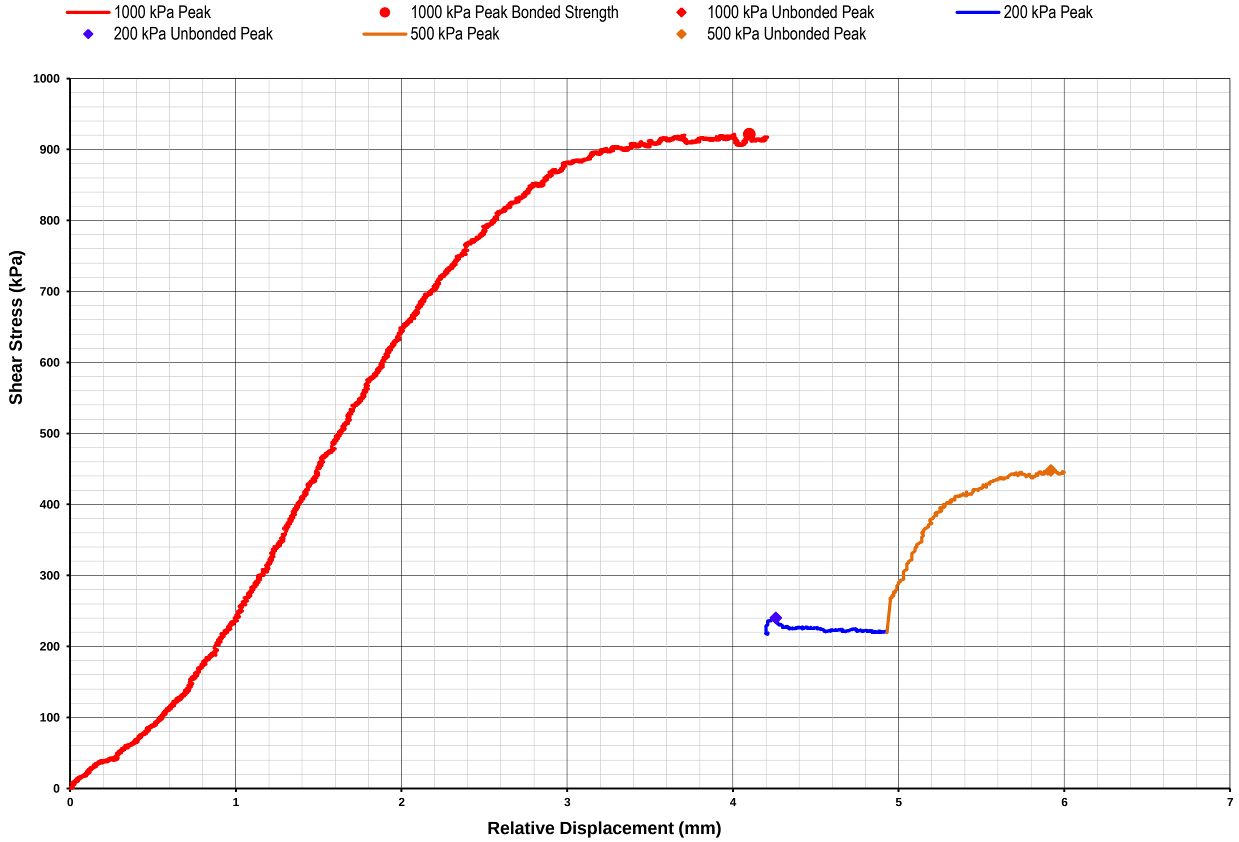
ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070510- DS

Peak Vertical Displacement/Relative Displacement Plot



Shear Stress/Relative Displacement Plot



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Graph not to scale

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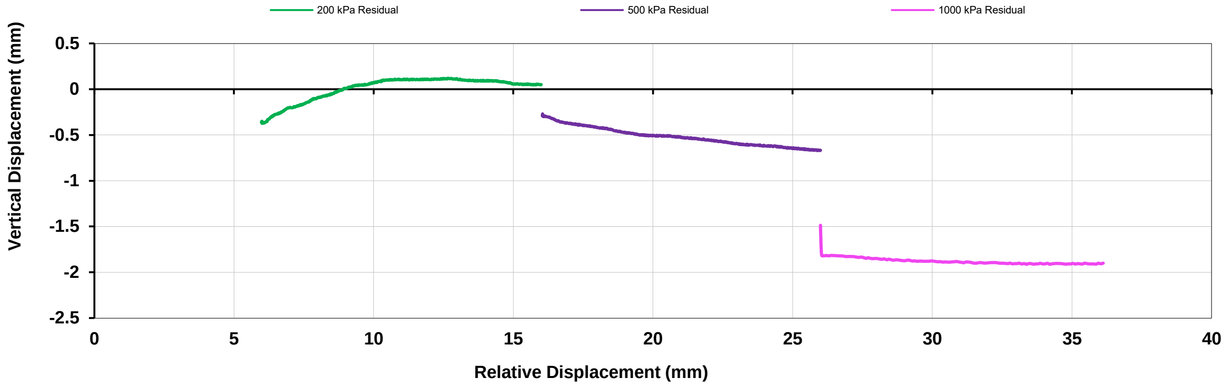
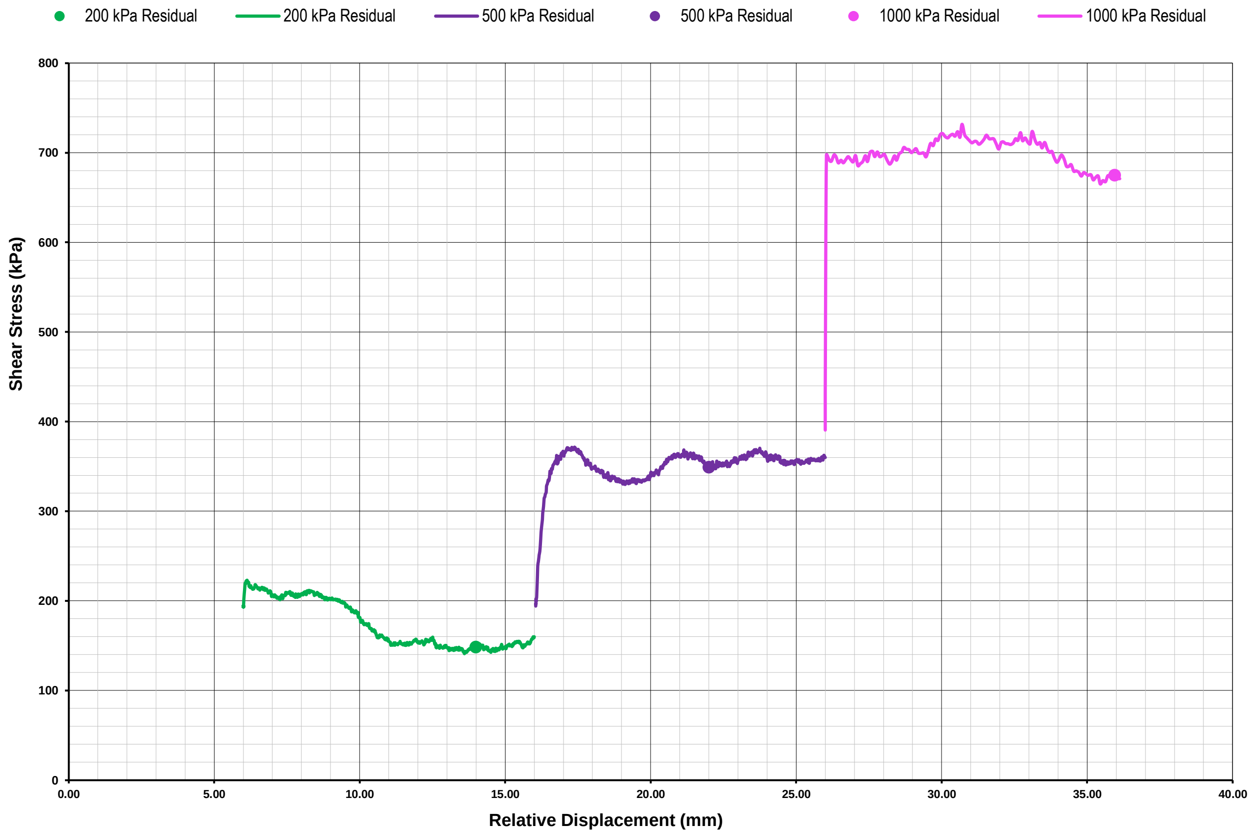
Client	SMEC Australia Pty Ltd	**Report No.**	19070510- DS

Residual Vertical Displacement/Relative Displacement Plot



Residual Shear Stress/Relative Displacement Plot



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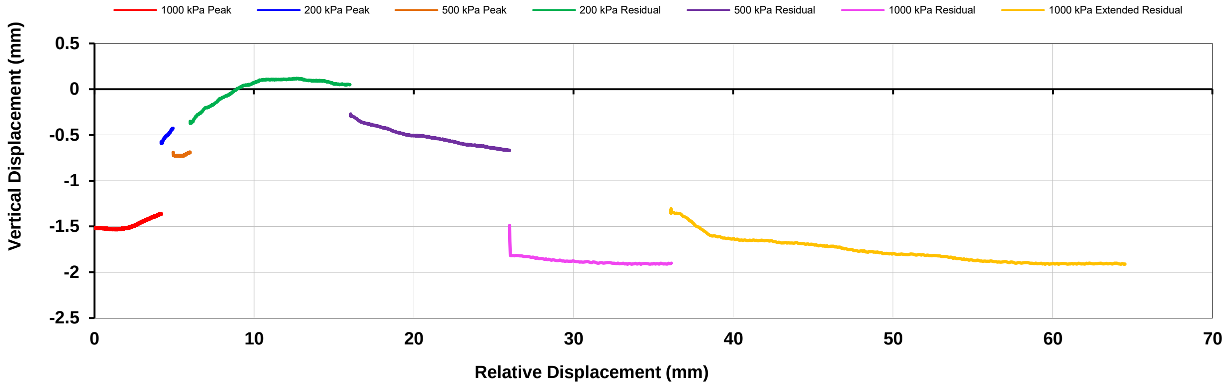
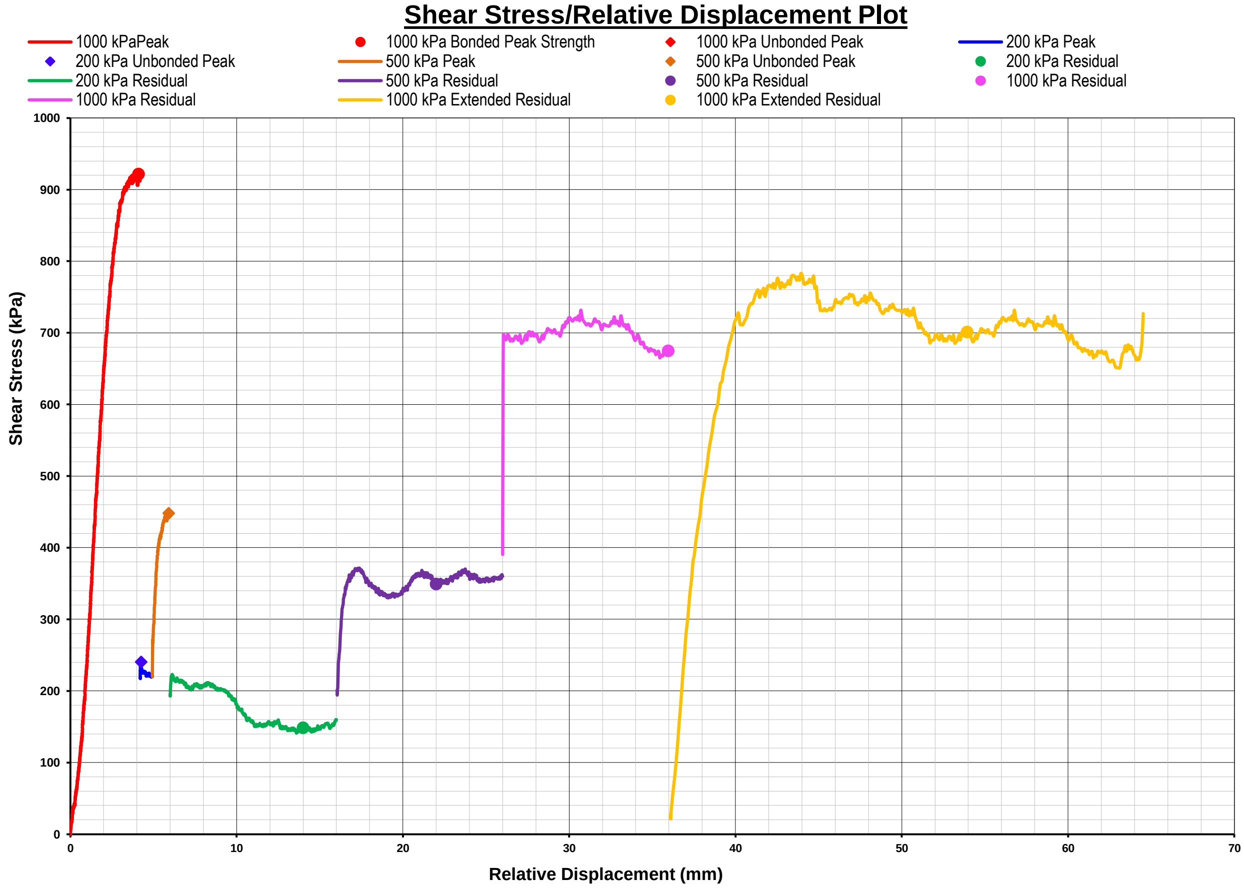
Peak & Residual Vertical Displacement/Relative Displacement Plot



Shear Stress/Relative Displacement Plot



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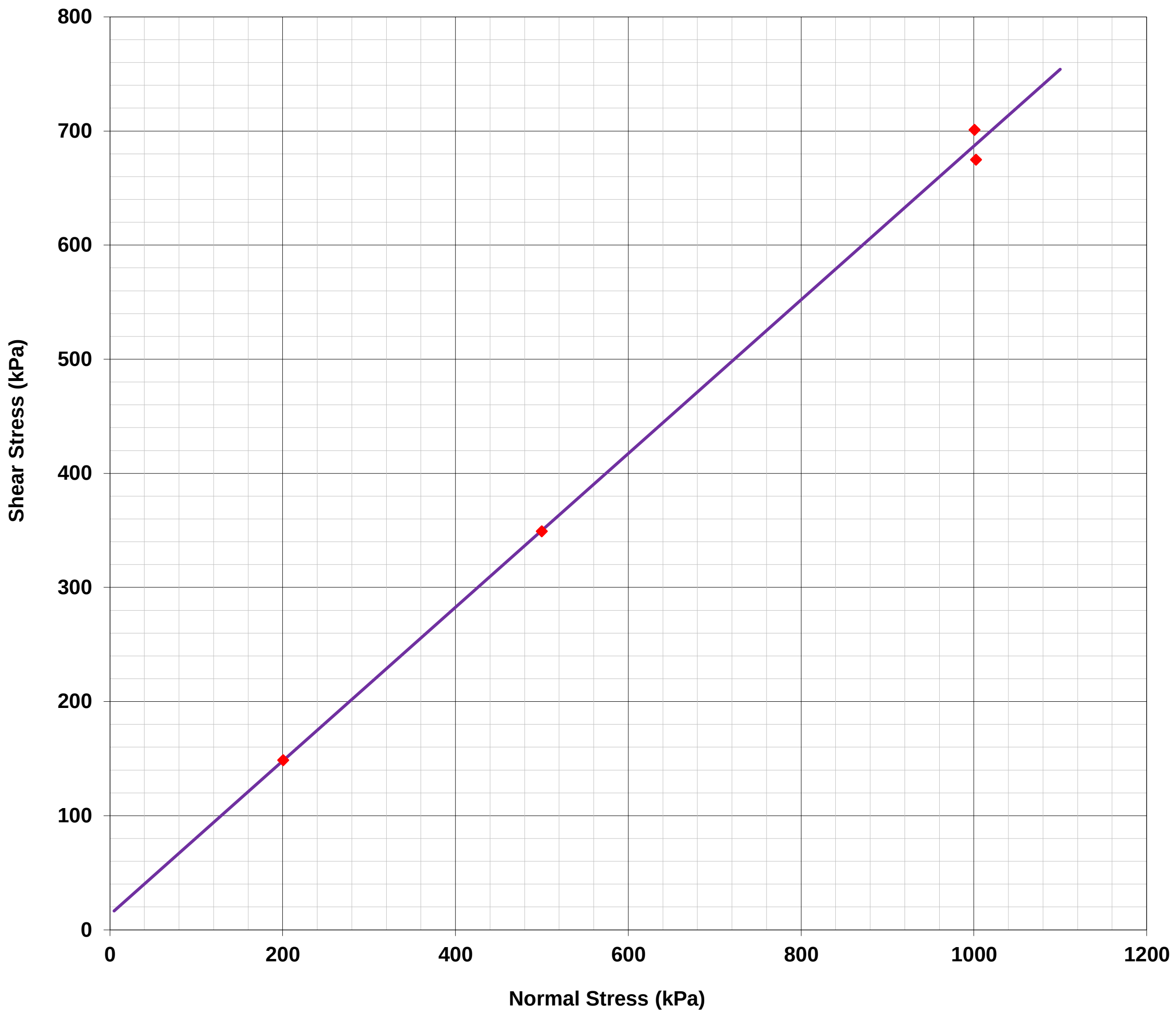
Client	SMEC Australia Pty Ltd	**Report No.**	19070510- DS

Residual - Corrected Normal Stress vs Corrected Shear Unbonded Stress



Residual Unbonded Shear Angle (°)	**34.0**	**Residual Unbonded Cohesion (kPa)**	**13.0**	**R^2 0.999**

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	13.99	200.5	148.4
500 kPa	22.00	499.7	349.1
1000 kPa	35.95	1002.4	674.8
500 kPa Extended	53.94	1000.8	700.9

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

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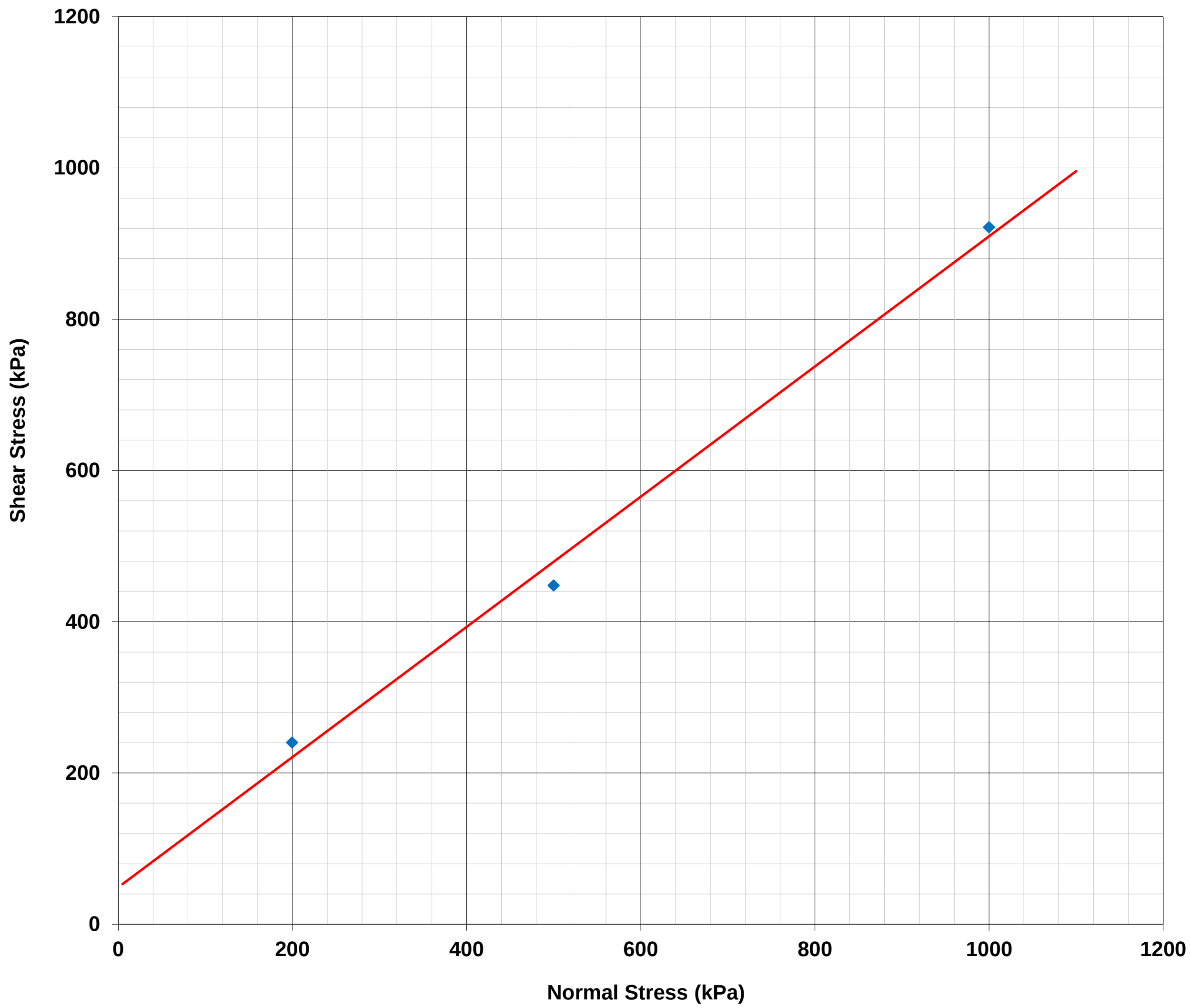
Peak - Corrected Normal Stress vs Corrected Unbonded Shear Stress



Peak Unbonded Shear Angle (°)	**40.7**	**Peak Unbonded Cohesion (kPa)**	**48.6**	**R^2 0.997**

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
1000 kPa	4.10	1000.0	921.4
200 kPa	4.26	199.8	240.2
500 kPa	5.92	500.1	447.8

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Graph not to scale

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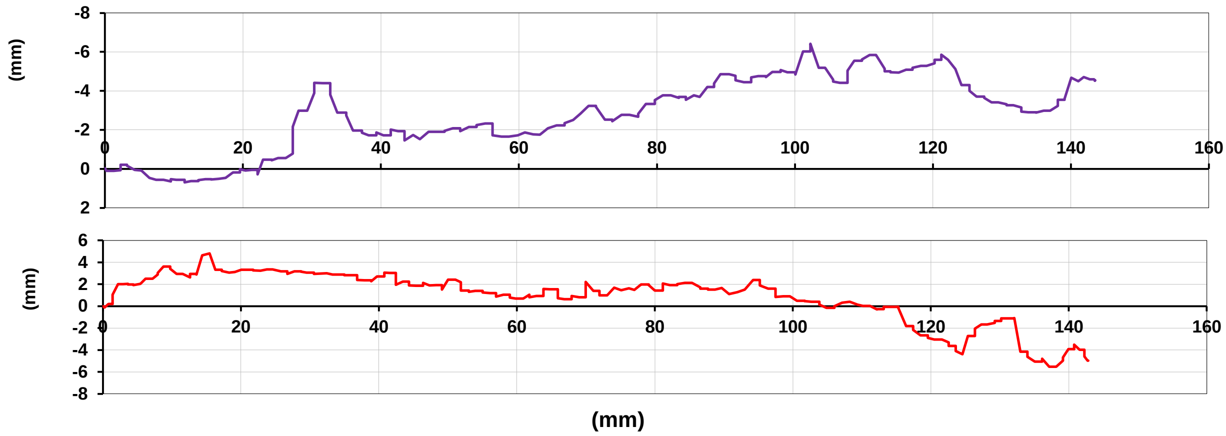
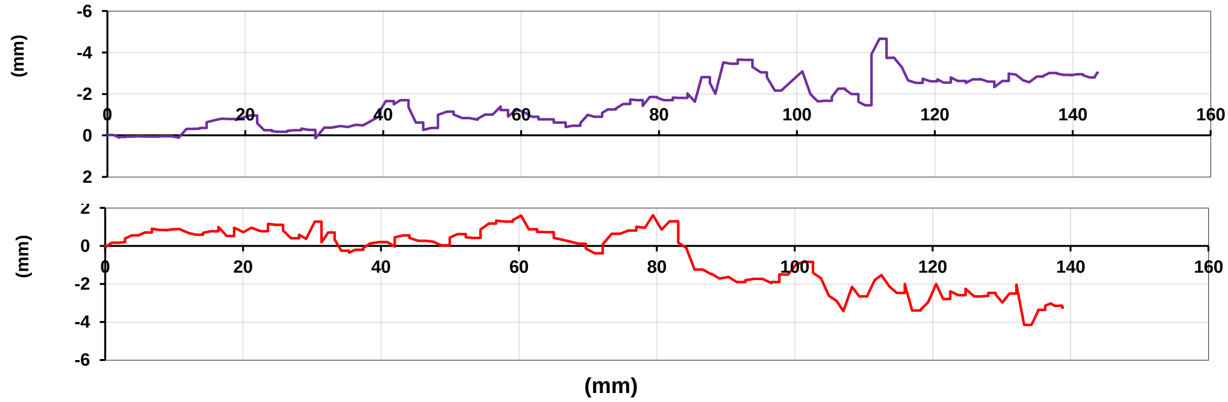
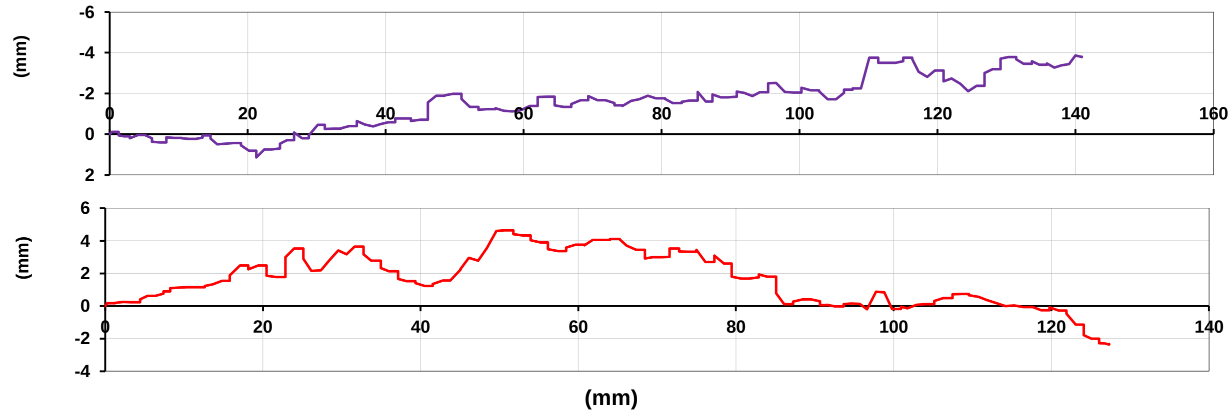
Top and Bottom Profile - Position 1 - After Shearing



Top and Bottom Profile - Position 2 - After Shearing



Top and Bottom Profile - Position 3 - After Shearing



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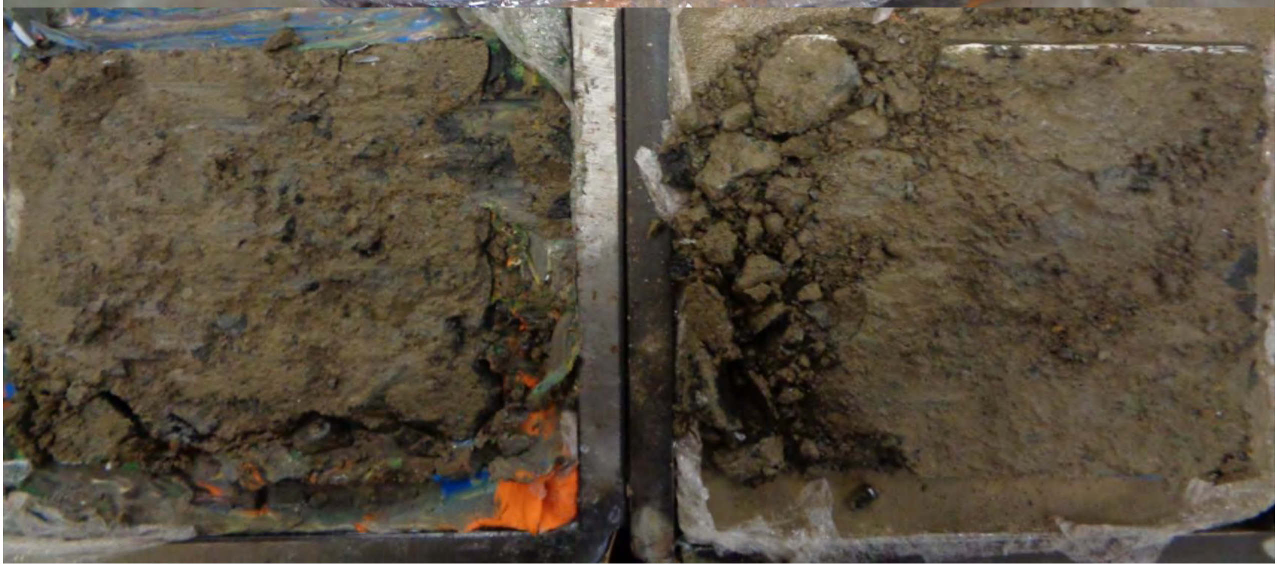
DIRECT SHEAR TEST REPORT

ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070510- DS



Notes/Remarks:

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DIRECT SHEAR TEST REPORT

ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070511- DS
		Workorder No	0006228
Address	Level 6, 480 St Pauls Tce Fortitude Valley QLD 4006	**Test Date**	26/07/2019
		Report Date	29/07/2019
Project	Paradise Dam Geotechnical Investigation		
Client ID	RCC-Q - Bonded Lift Joint	**Depth (m)**	4.10-4.25
Description	-	**Sample Type**	Single individual concrete core specimen - INTACT.

SAMPLE DETAILS

Specimen Condition	As Received
Specimen Dimensions (mm)	136.83*144.73
Rate of Strain (mm/min)	0.100
Initial Moisture Content (%)	4.9
Initial Wet Density(t/m^3)	2.49

Note: Wet Density as per AS1012.12.2-1998 is not covered by NATA terms of accreditationand is provided for information only.

TEST RESULTS

RESIDUAL RESULTS

Residual Unbonded Shear Angle (°)	**42.9**	**Residual Unbonded Cohesion (kPa)** **72.5**	**R^2 0.998**

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	19.00	199.7	283.8
500 kPa	22.00	501.0	543.0
1000 kPa	32.99	999.5	999.8

PEAK RESULTS

Peak Unbonded Shear Angle (°)	**51.7**	**Peak Unbonded Cohesion (kPa)** **206.0**	**R^2 1.000**

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	2.06	198.6	454.5
500 kPa	3.81	500.5	845.7
1000 kPa	6.14	999.8	1471.3

INTACT STRENGTH

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	1.82	198.6	530.2

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Sample/s supplied by the client

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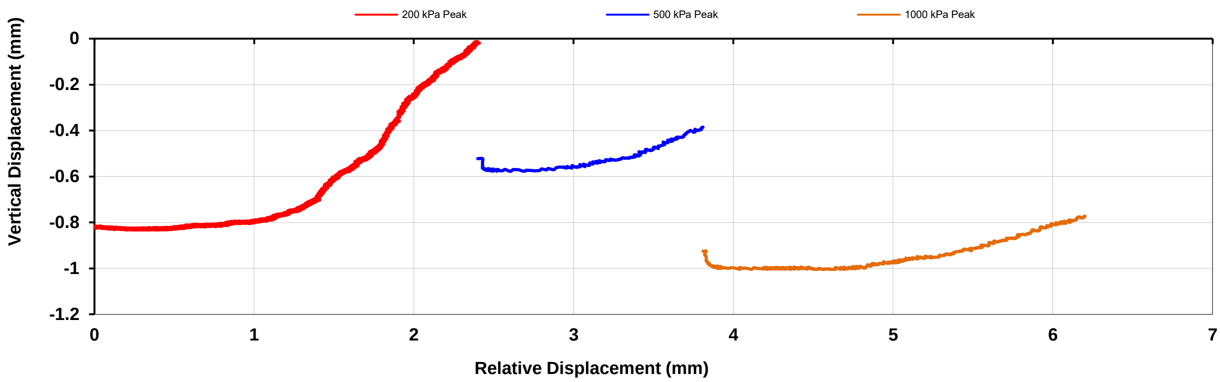
DIRECT SHEAR TEST REPORT

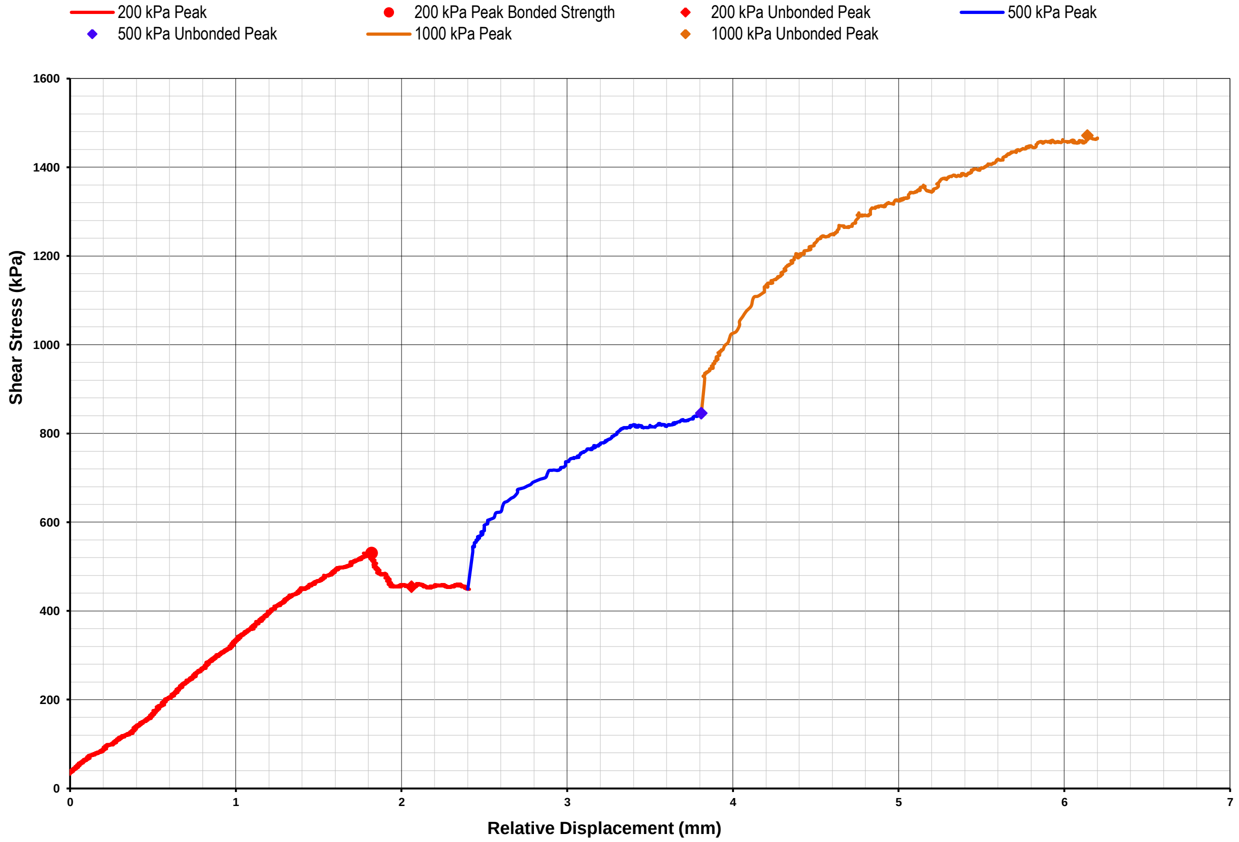
ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070511- DS

Peak Vertical Displacement/Relative Displacement Plot



Shear Stress/Relative Displacement Plot



Notes/Remarks:

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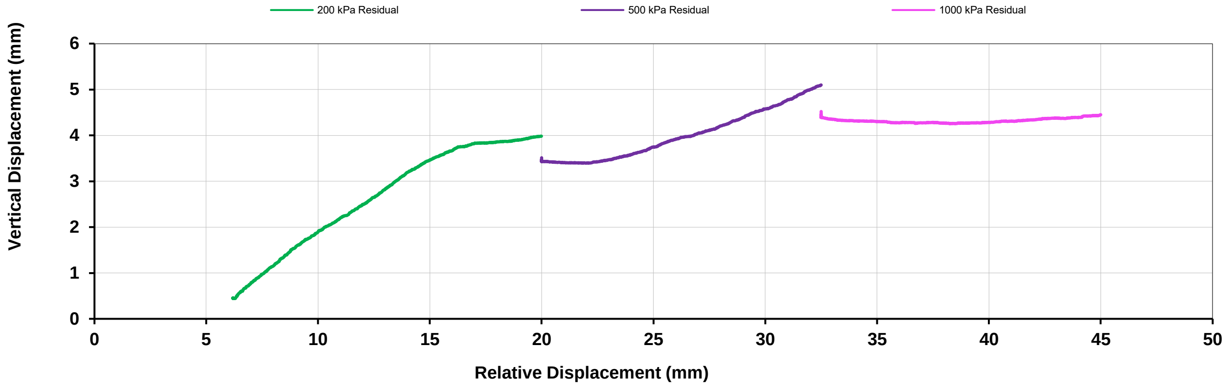
DIRECT SHEAR TEST REPORT

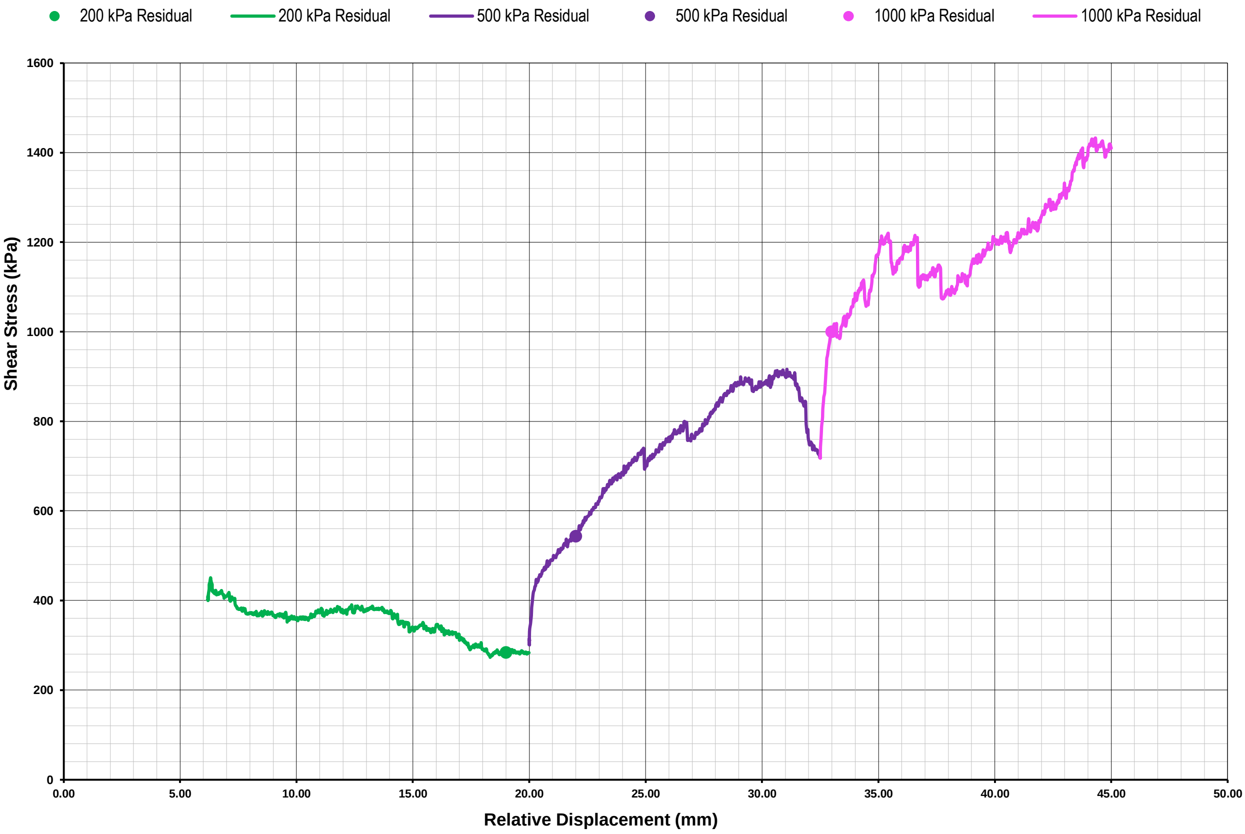
ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070511- DS

Residual Vertical Displacement/Relative Displacement Plot



Residual Shear Stress/Relative Displacement Plot



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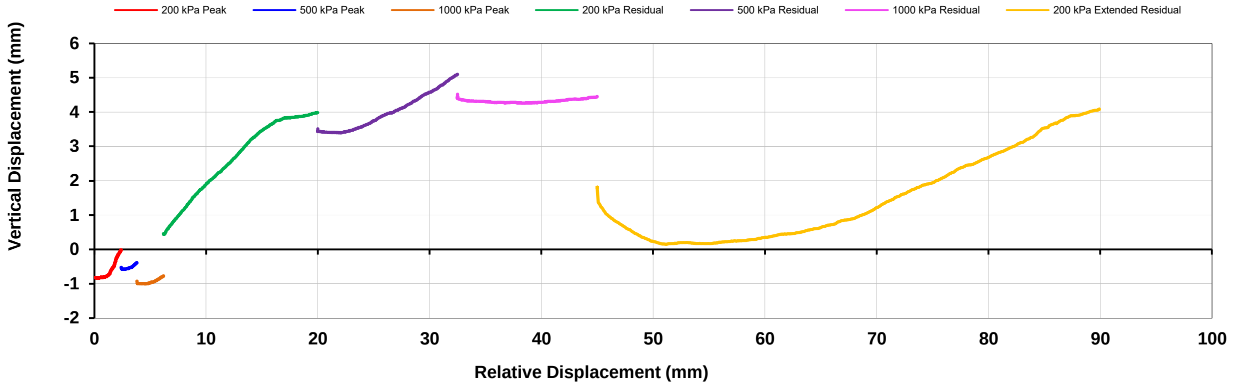
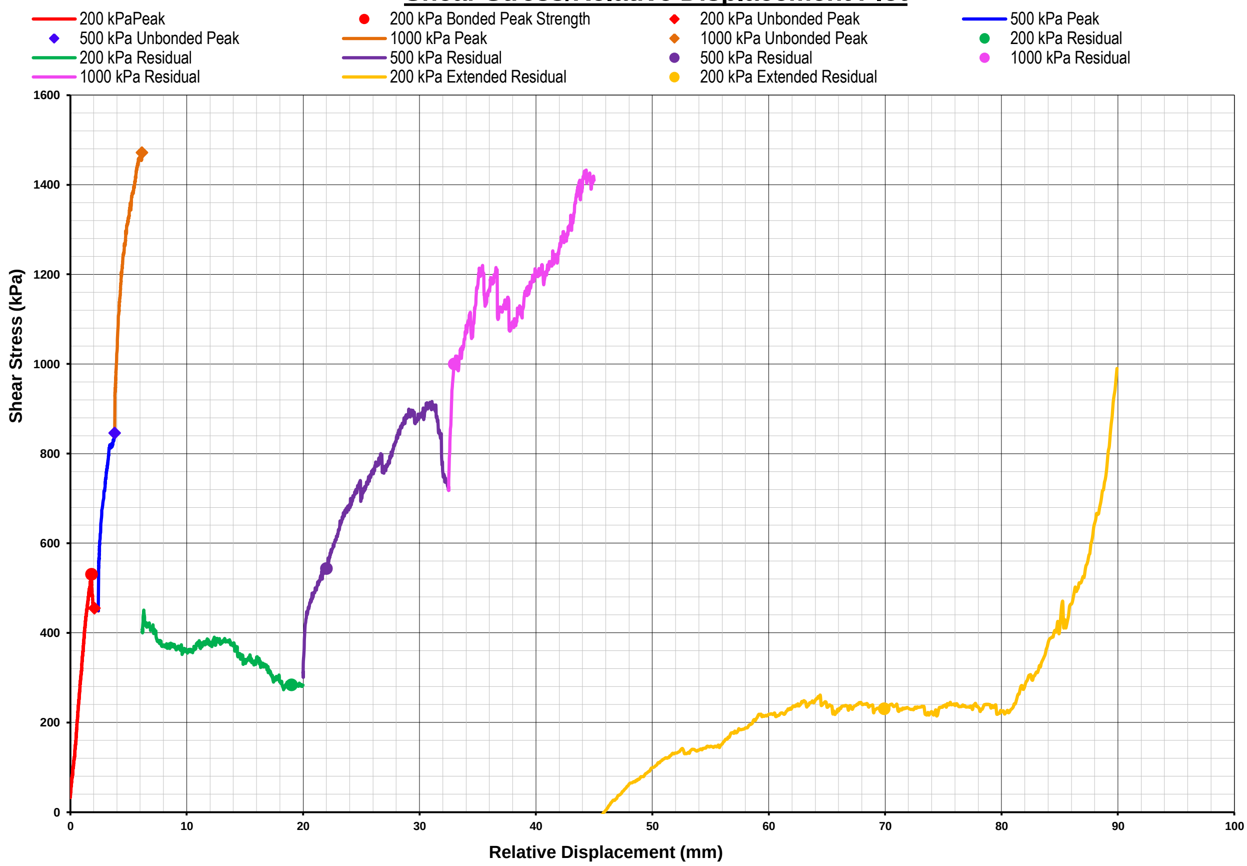
Client	SMEC Australia Pty Ltd	**Report No.**	19070511- DS

Peak & Residual Vertical Displacement/Relative Displacement Plot



Shear Stress/Relative Displacement Plot



Notes/Remarks:

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Graph not to scale

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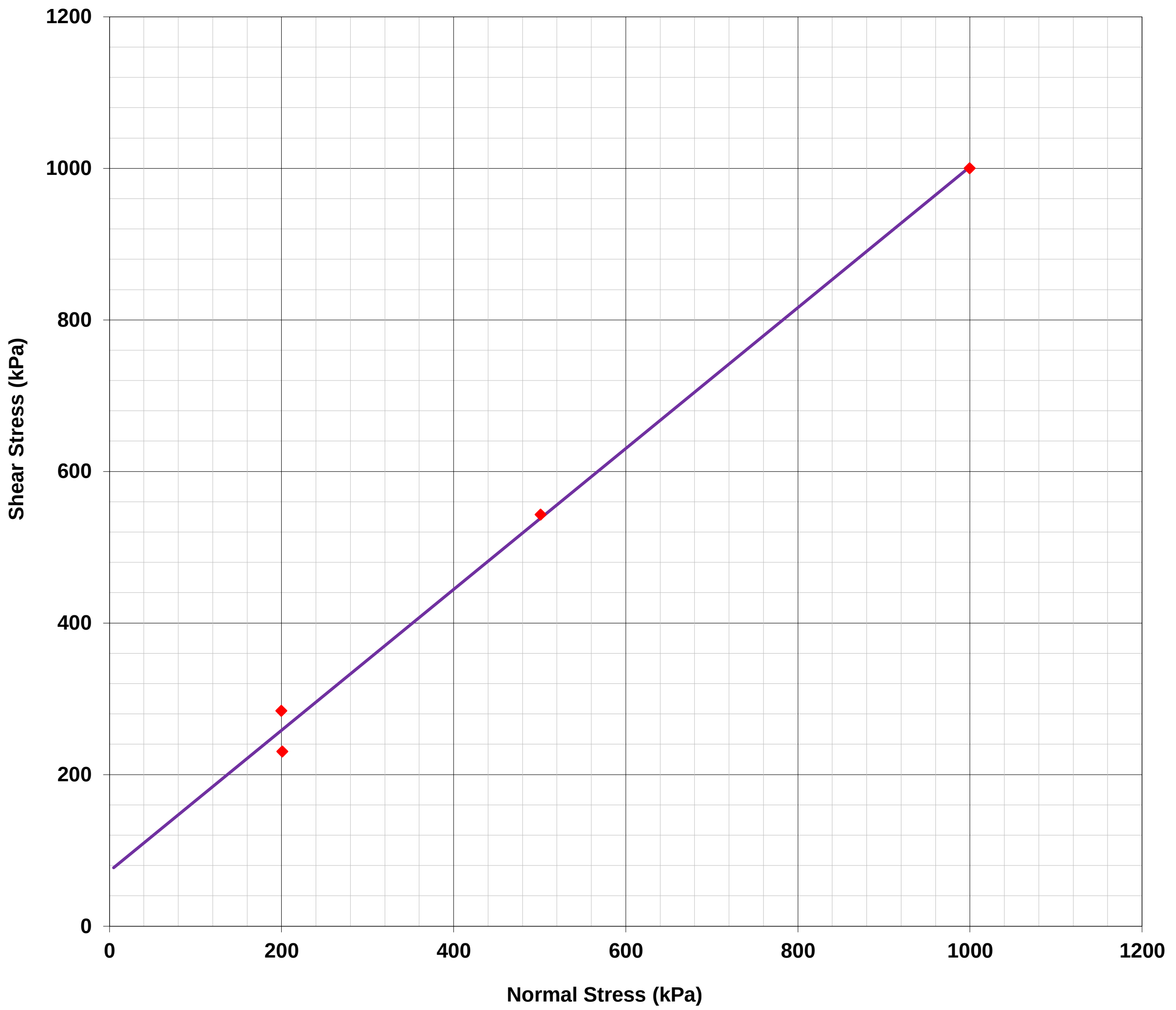
ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070511- DS

Residual - Corrected Normal Stress vs Corrected Shear Unbonded Stress



Residual Unbonded Shear Angle (^{o})	**42.9**	**Residual Unbonded Cohesion (kPa)**	**72.5**	**R^2 0.998**

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	19.00	199.7	283.8
500 kPa	22.00	501.0	543.0
1000 kPa	32.99	999.5	999.8
200 kPa Extended	69.93	200.8	230.4

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Graph not to scale

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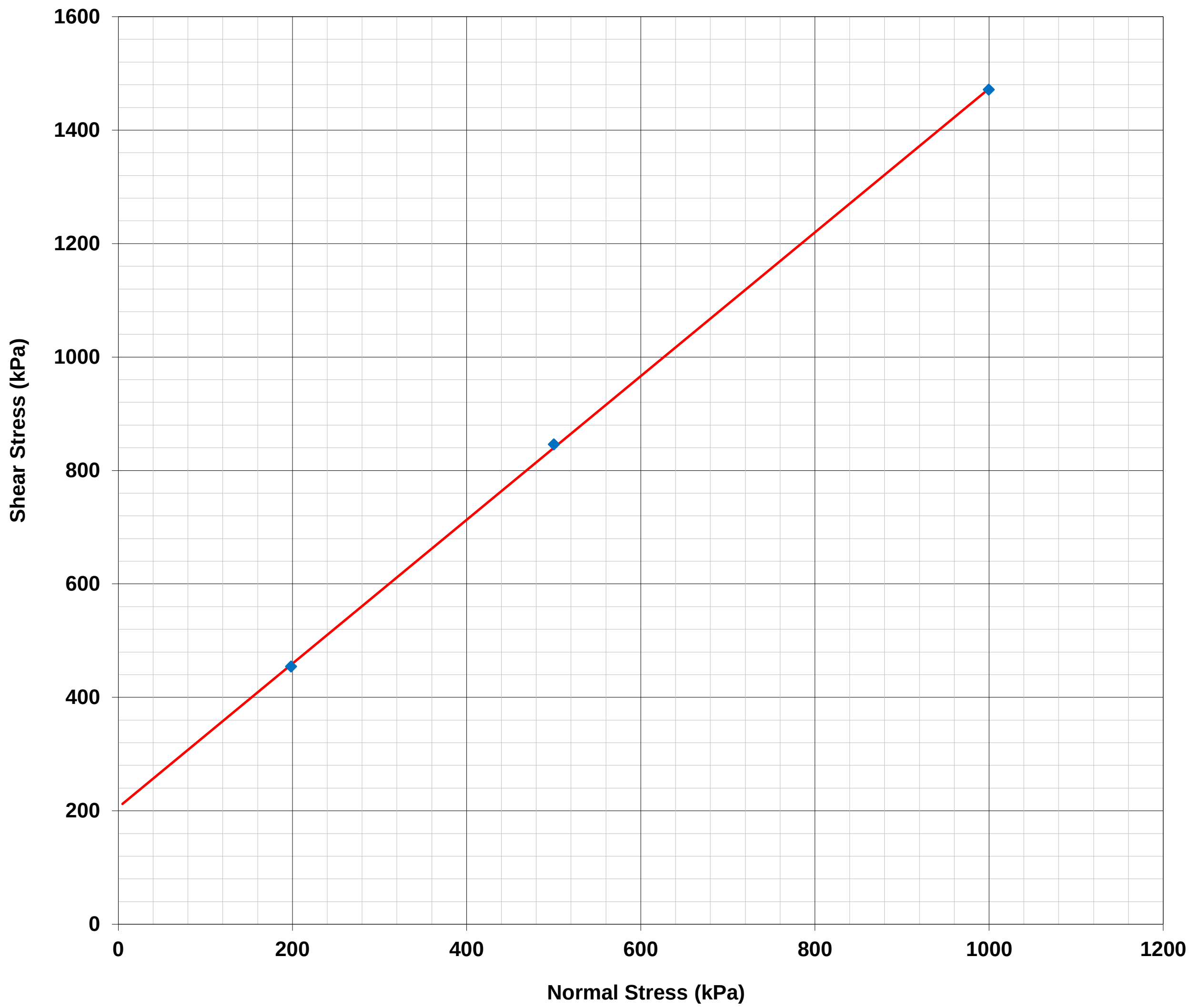
Client	SMEC Australia Pty Ltd	**Report No.**	19070511- DS

Peak - Corrected Normal Stress vs Corrected Unbonded Shear Stress



Peak Unbonded Shear Angle (°)	**51.7**	**Peak Unbonded Cohesion (kPa)**	**206.0**	**R^2 1.000**

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	2.06	198.6	454.5
500 kPa	3.81	500.5	845.7
1000 kPa	6.14	999.8	1471.3

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

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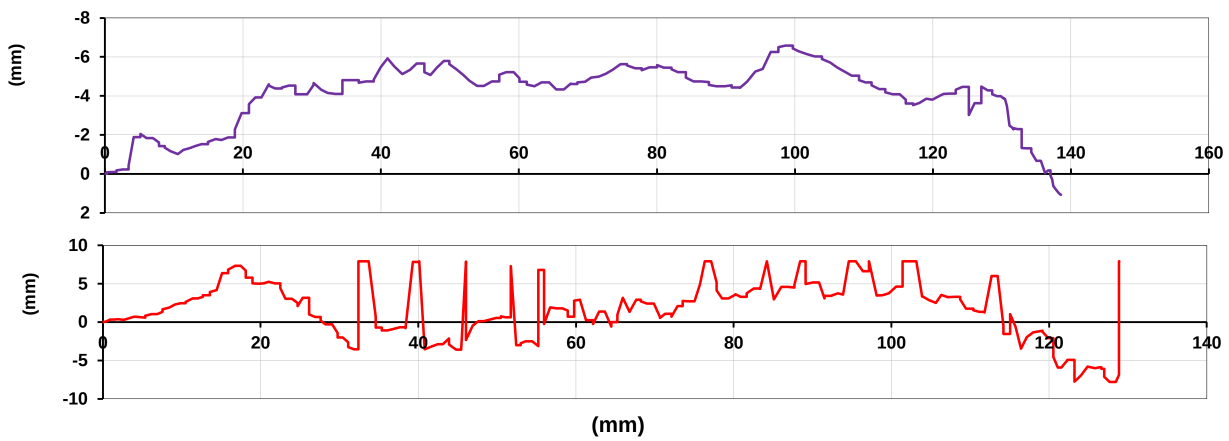
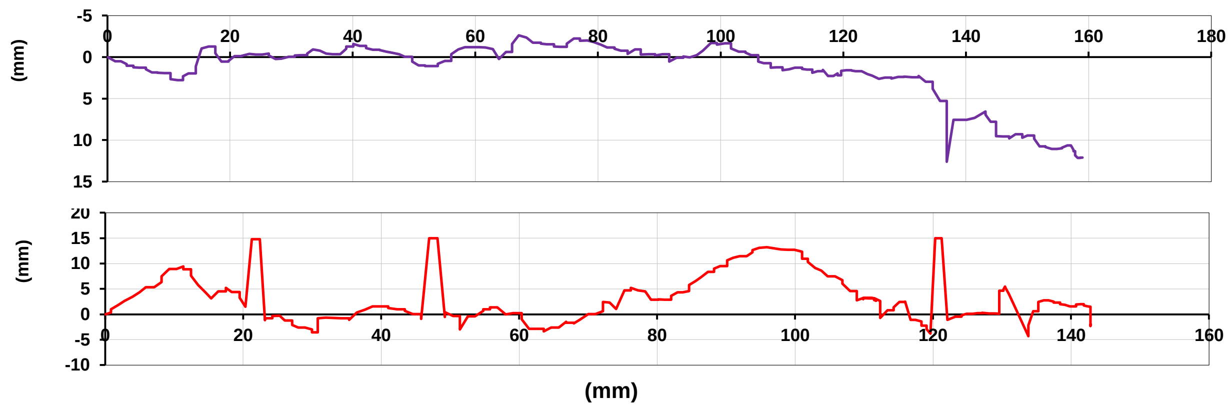
Client	SMEC Australia Pty Ltd	**Report No.**	19070511- DS

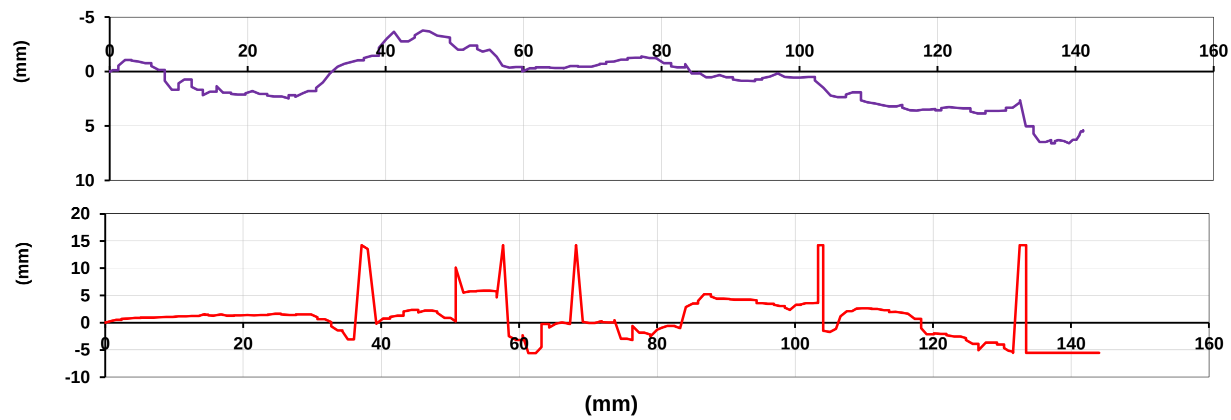
Top and Bottom Profile - Position 1 - After Shearing



Top and Bottom Profile - Position 2 - After Shearing



Top and Bottom Profile - Position 3 - After Shearing



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Client	SMEC Australia Pty Ltd	**Report No.**	19070511- DS

Notes/Remarks:

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DIRECT SHEAR TEST REPORT

ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070512- DS
		Workorder No	0006228
Address	Level 6, 480 St Pauls Tce Fortitude Valley QLD 4006	**Test Date**	29/07/2019
		Report Date	30/07/2019
Project	Paradise Dam Geotechnical Investigation		
Client ID	RCC-Q - Bonded Lift Joint	**Depth (m)**	4.44-4.59
Description	-	**Sample Type**	Single individual concrete core specimen - INTACT.

SAMPLE DETAILS

Specimen Condition	As Received
Specimen Dimensions (mm)	145.97*145.02
Rate of Strain (mm/min)	0.100
Initial Moisture Content (%)	4.9
Initial Wet Density(t/m^3)	2.49

Note: Wet Density as per AS1012.12.2-1998 is not covered by NATA terms of accreditationand is provided for information only.

TEST RESULTS

RESIDUAL RESULTS

Residual Unbonded Shear Angle (°)	**31.5**	**Residual Unbonded Cohesion (kPa)**	**71.2**	**R^2 0.990**

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	19.98	199.4	198.0
500 kPa	26.00	500.3	339.1
1000 kPa	36.00	999.4	685.8

PEAK RESULTS

Peak Unbonded Shear Angle (°)	**44.7**	**Peak Unbonded Cohesion (kPa)**	**376.8**	**R^2 0.996**

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
500 kPa	3.08	500.4	829.4
200 kPa	3.62	200.4	601.3
1000 kPa	6.00	1000.8	1382.1

INTACT STRENGTH

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
500 kPa	3.50	500.4	834.4

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Sample/s supplied by the client

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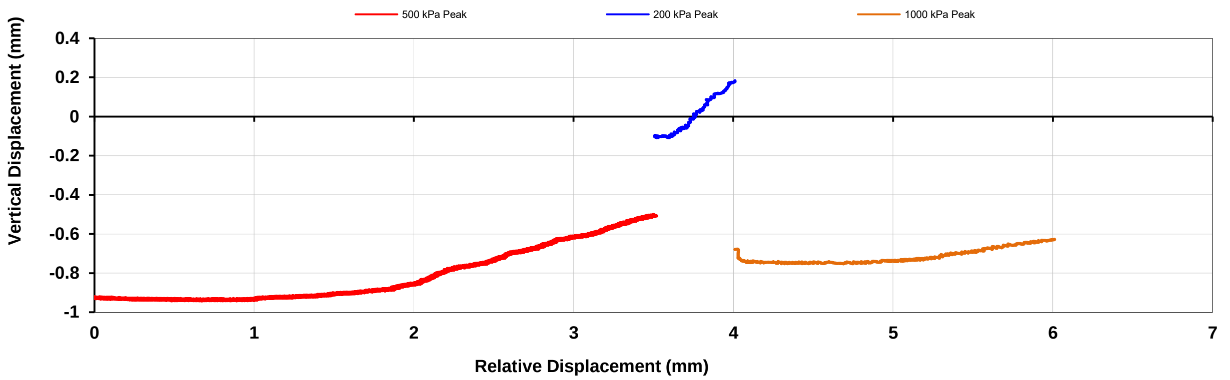
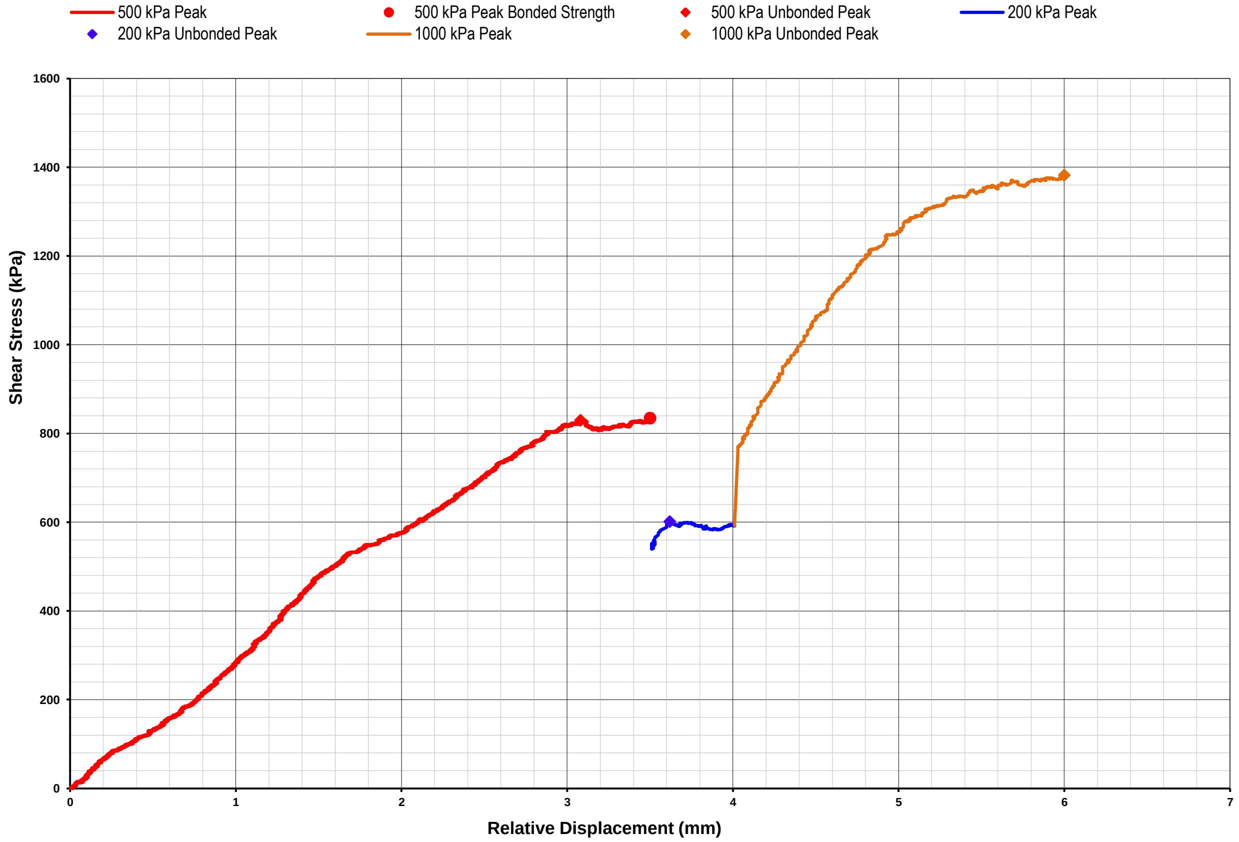
Client	SMEC Australia Pty Ltd	**Report No.**	19070512- DS

Peak Vertical Displacement/Relative Displacement Plot



Shear Stress/Relative Displacement Plot



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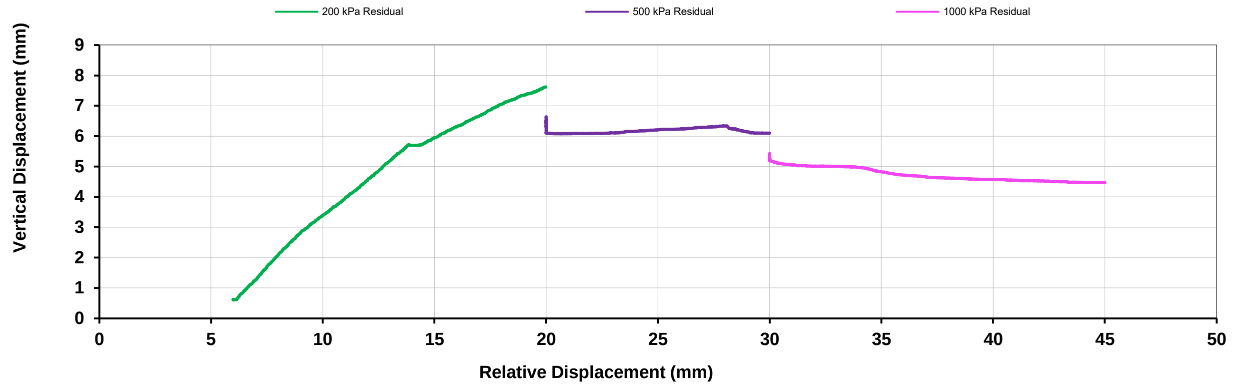
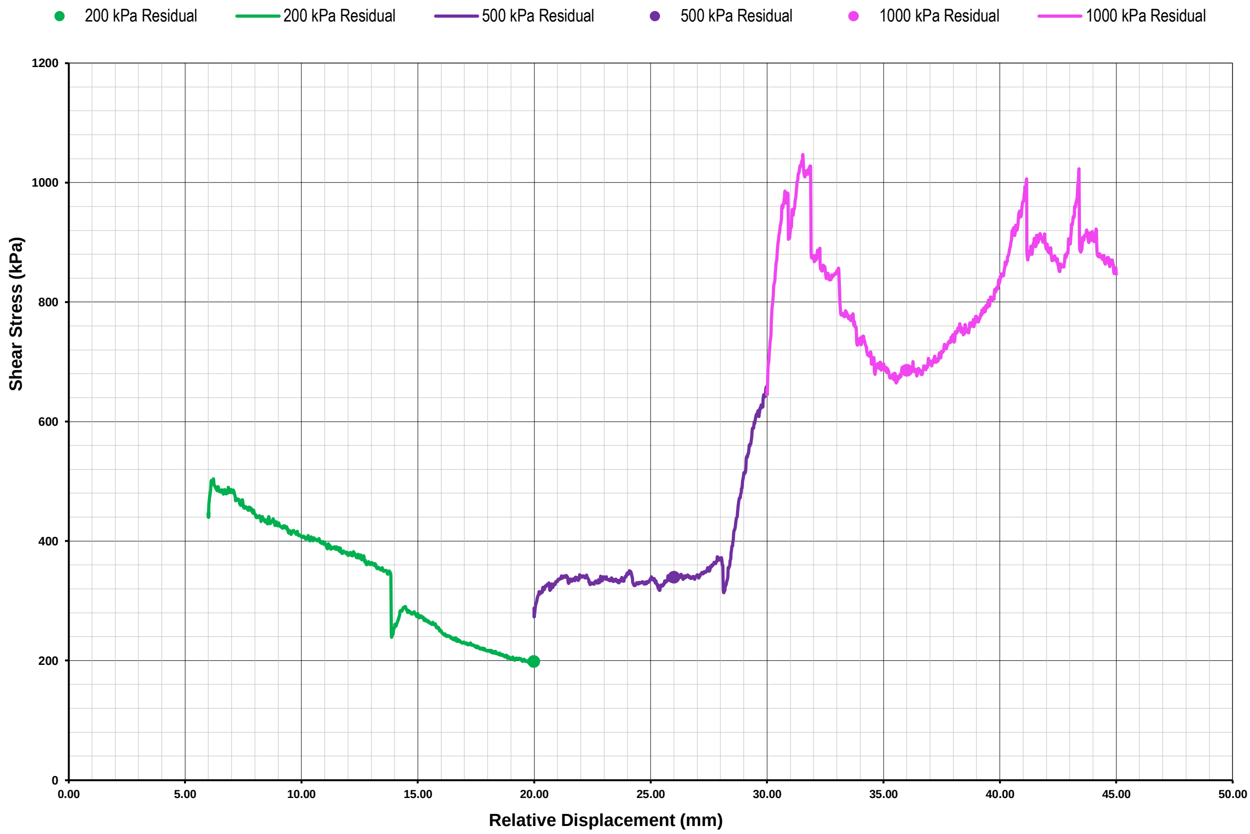
Client	SMEC Australia Pty Ltd	**Report No.**	19070512- DS

Residual Vertical Displacement/Relative Displacement Plot



Residual Shear Stress/Relative Displacement Plot



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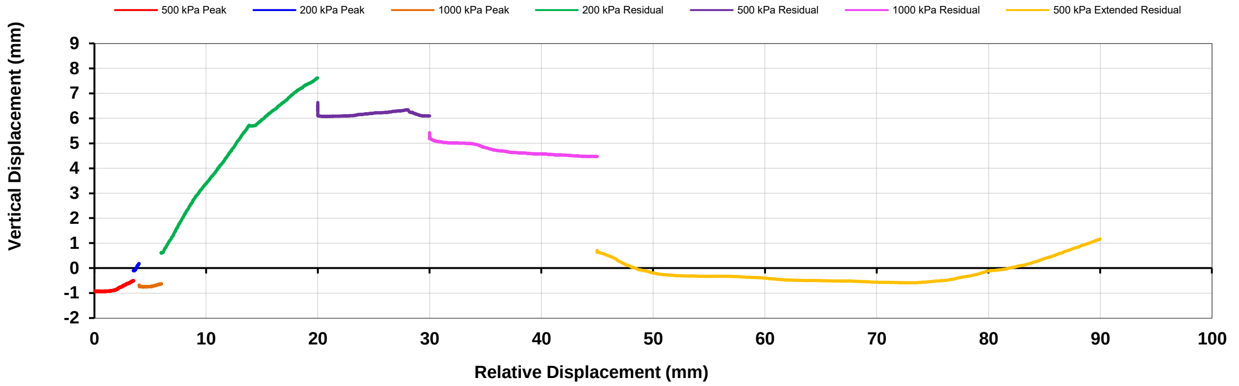
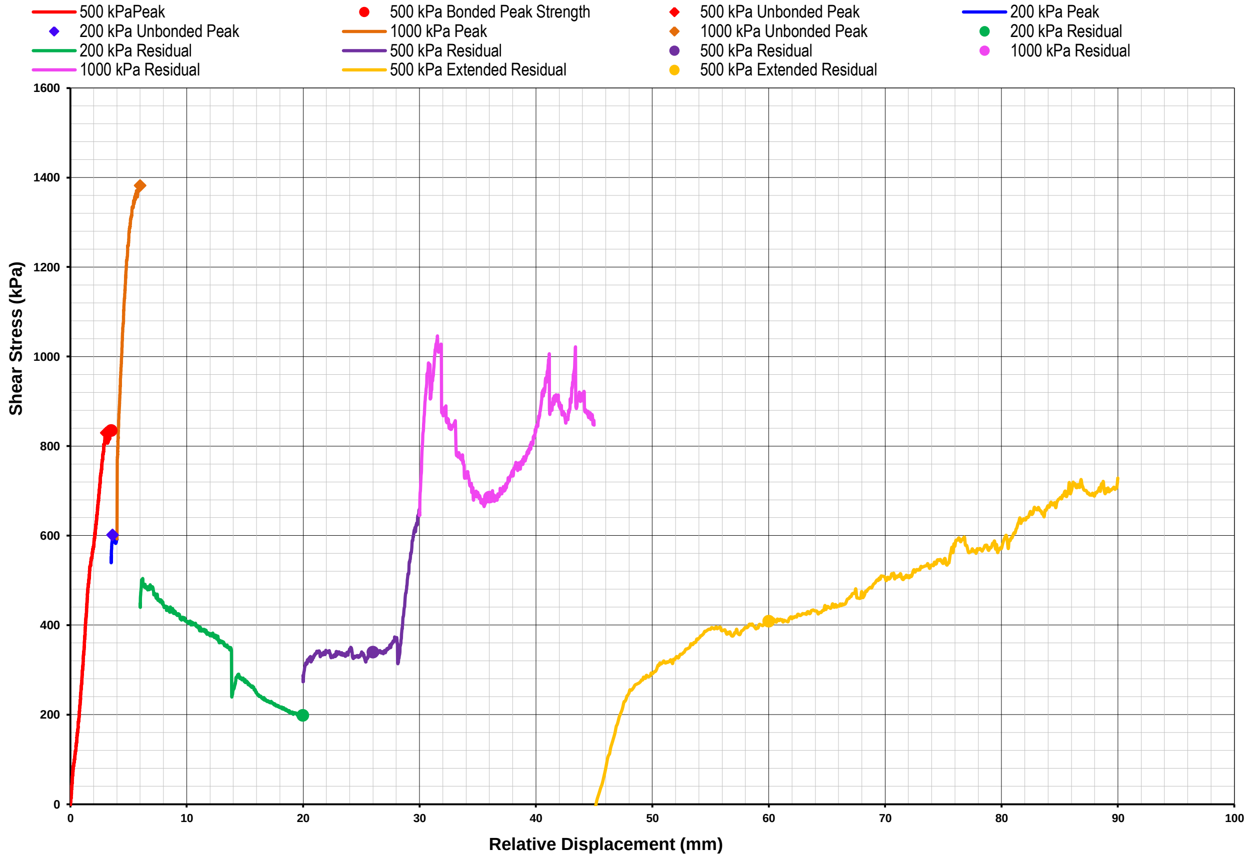
Client	SMEC Australia Pty Ltd	**Report No.**	19070512- DS

Peak & Residual Vertical Displacement/Relative Displacement Plot



Shear Stress/Relative Displacement Plot



Notes/Remarks:

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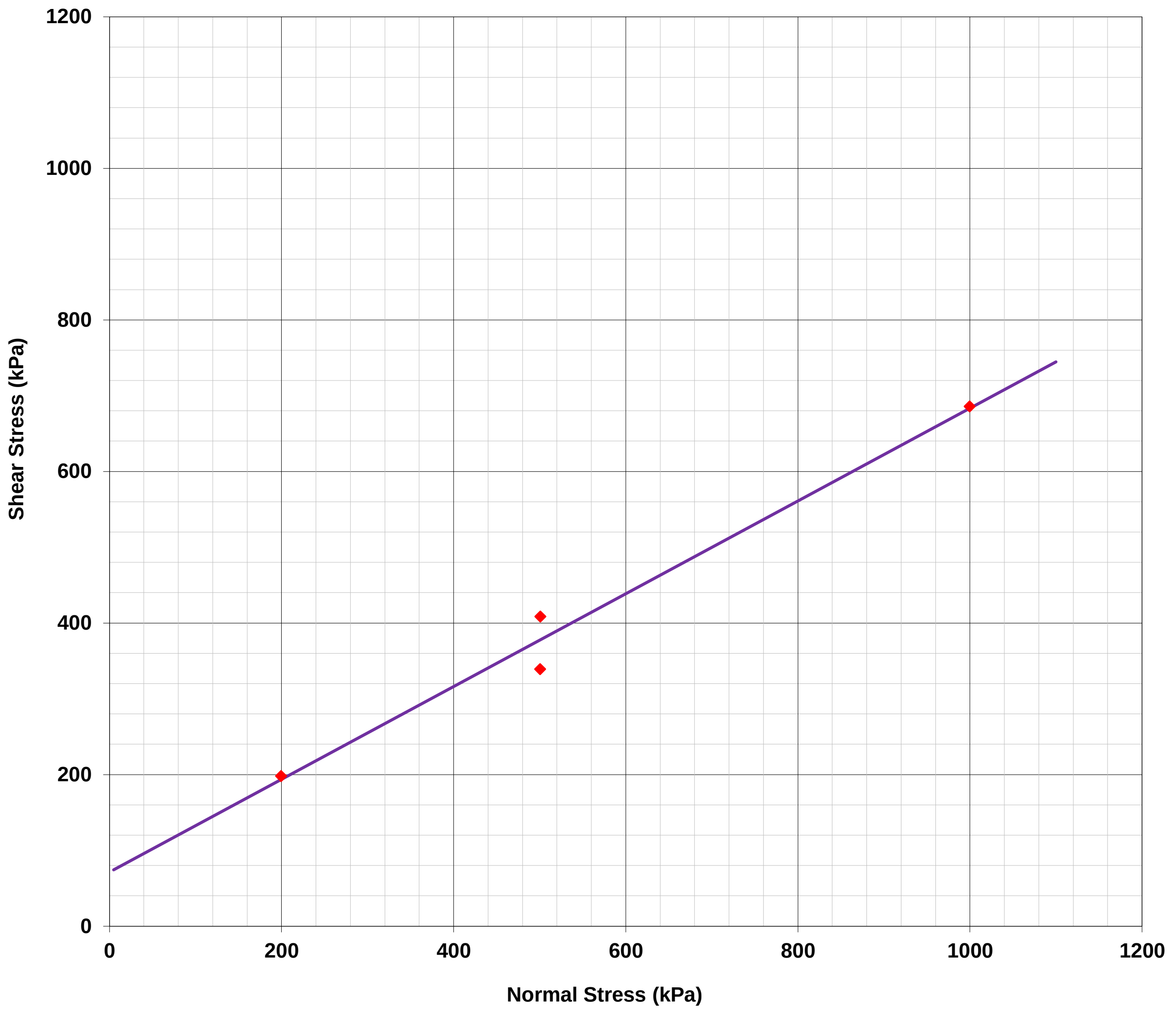
DIRECT SHEAR TEST REPORT

ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070512- DS

Residual - Corrected Normal Stress vs Corrected Shear Unbonded Stress



Residual Unbonded Shear Angle (°)	**31.5**	**Residual Unbonded Cohesion (kPa)**	**71.2**	**R^2 0.990**

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	19.98	199.4	198.0
500 kPa	26.00	500.3	339.1
1000 kPa	36.00	999.4	685.8
500 kPa Extended	59.99	500.6	408.5

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Graph not to scale

Sample/s supplied by the client

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Tested at Trilab Brisbane Laboratory

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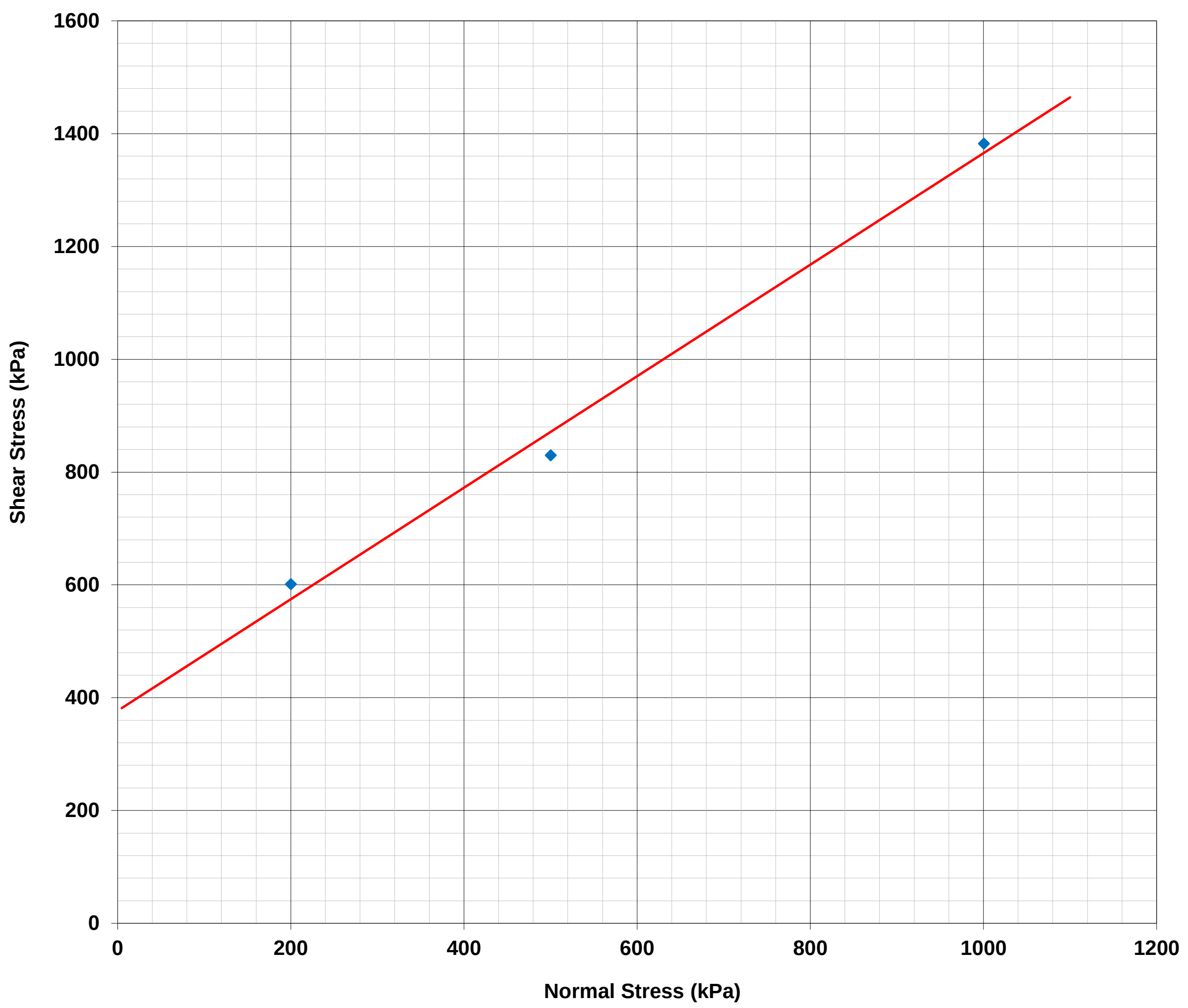
Ph: +61 8 9258 8323

DIRECT SHEAR TEST REPORT

ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070512- DS

Peak - Corrected Normal Stress vs Corrected Unbonded Shear Stress



Peak Unbonded Shear Angle (^{o})	44.7	Peak Unbonded Cohesion (kPa)	376.8	R^2 0.996

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
500 kPa	3.08	500.4	829.4
200 kPa	3.62	200.4	601.3
1000 kPa	6.00	1000.8	1382.1

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Graph not to scale Sample/s supplied by the client

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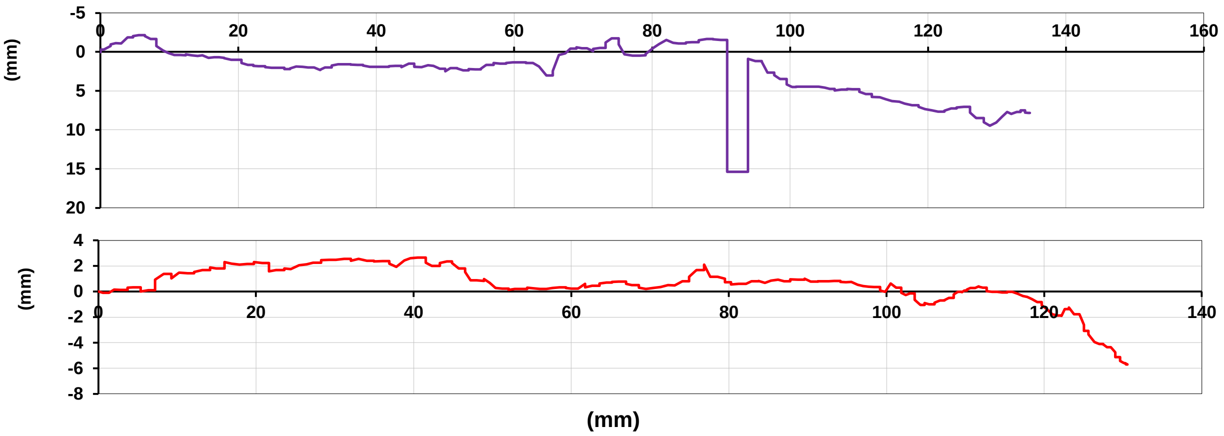
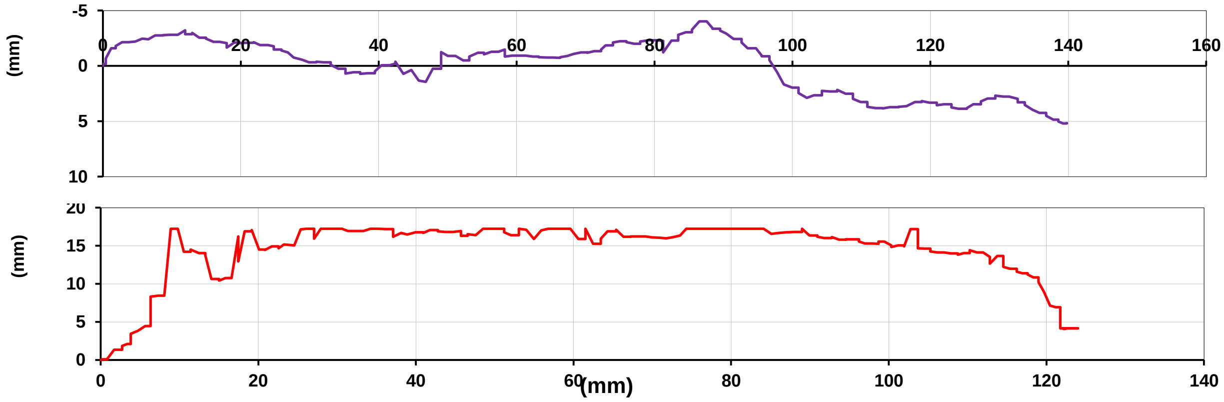
Client	SMEC Australia Pty Ltd	**Report No.**	19070512- DS

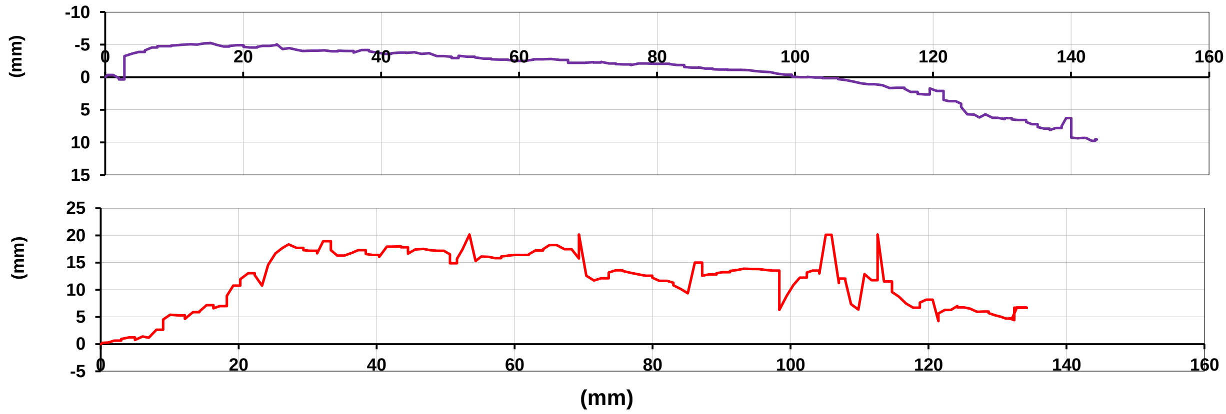
Top and Bottom Profile - Position 1 - After Shearing



Top and Bottom Profile - Position 2 - After Shearing



Top and Bottom Profile - Position 3 - After Shearing



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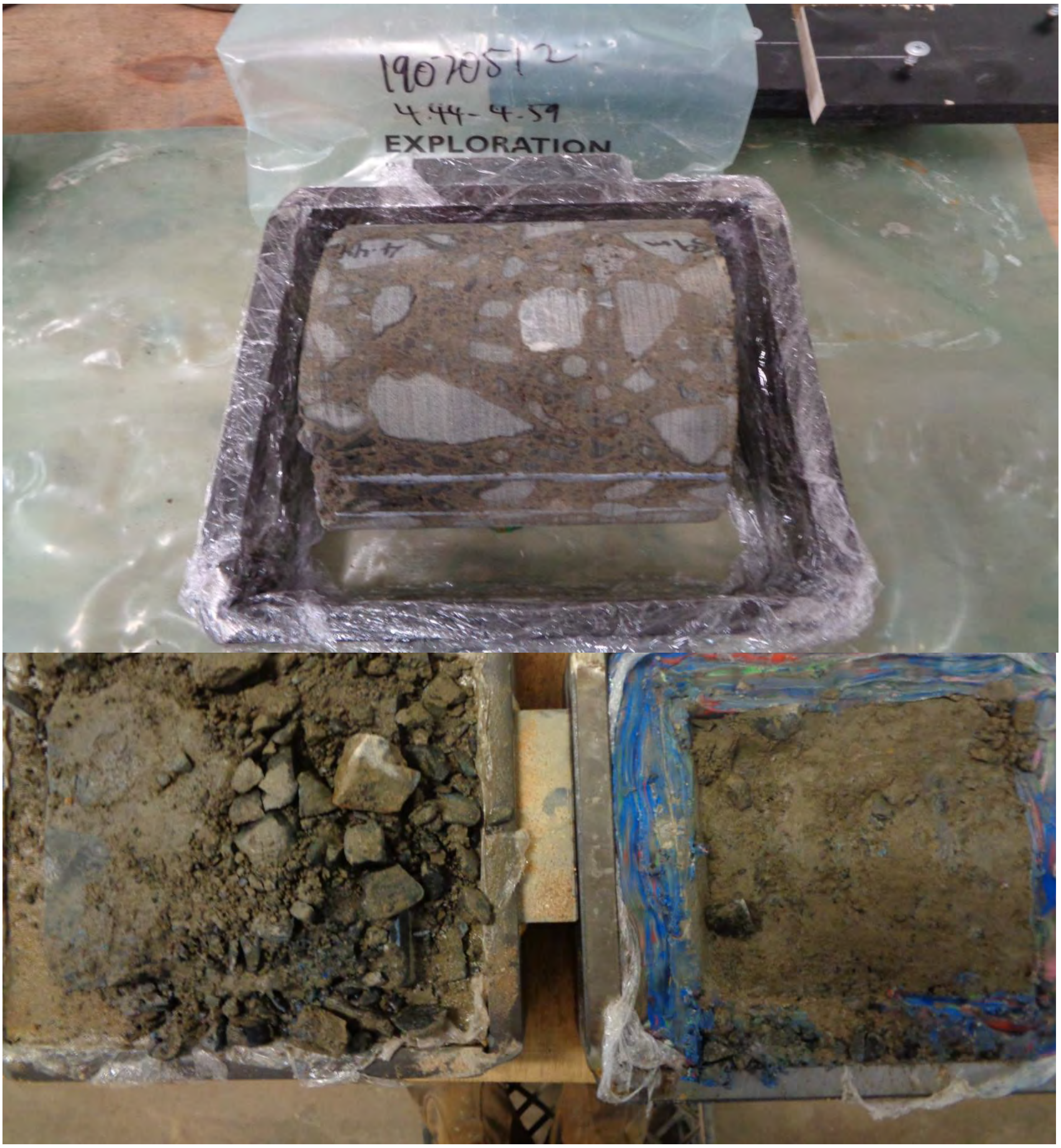
Client	SMEC Australia Pty Ltd	**Report No.**	19070512- DS



Notes/Remarks:

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DIRECT SHEAR TEST REPORT

ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070513- DS
		Workorder No	0006228
Address	Level 6, 480 St Pauls Tce Fortitude Valley QLD 4006	**Test Date**	30/07/2019
		Report Date	31/07/2019
Project	Paradise Dam Geotechnical Investigation		
Client ID	RCC-Q - Bonded Lift Joint	**Depth (m)**	4.72-4.87
Description	-	**Sample Type**	Single individual concrete core specimen - INTACT.

SAMPLE DETAILS

Specimen Condition	As Received
Specimen Dimensions (mm)	147.94*145.57
Rate of Strain (mm/min)	0.100
Initial Moisture Content (%)	4.9
Initial Wet Density(t/m^3)	2.48

Note: Wet Density as per AS1012.12.2-1998 is not covered by NATA terms of accreditationand is provided for information only.

TEST RESULTS

RESIDUAL RESULTS

Residual Unbonded Shear Angle (°)	46.8	Residual Unbonded Cohesion (kPa)	33.1	R^2 0.956

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	18.00	199.5	248.9
500 kPa	26.00	500.0	561.8
1000 kPa	37.00	1001.0	1259.3

PEAK RESULTS

Peak Unbonded Shear Angle (°)	50.4	Peak Unbonded Cohesion (kPa)	123.0	R^2 0.997

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
1000 kPa	4.94	999.8	1349.4
200 kPa	5.09	199.3	391.4
500 kPa	6.51	501.2	685.9

INTACT STRENGTH

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
1000 kPa	4.94	999.8	1349.4

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Sample/s supplied by the client

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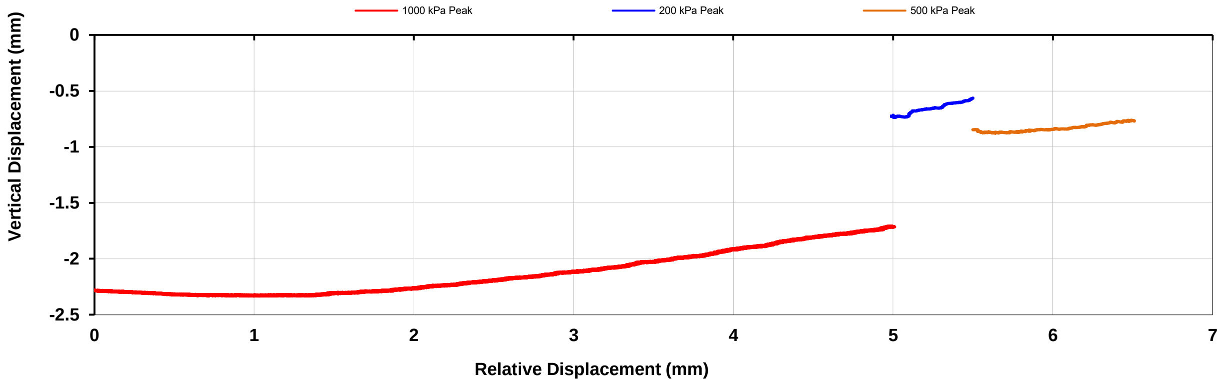
DIRECT SHEAR TEST REPORT

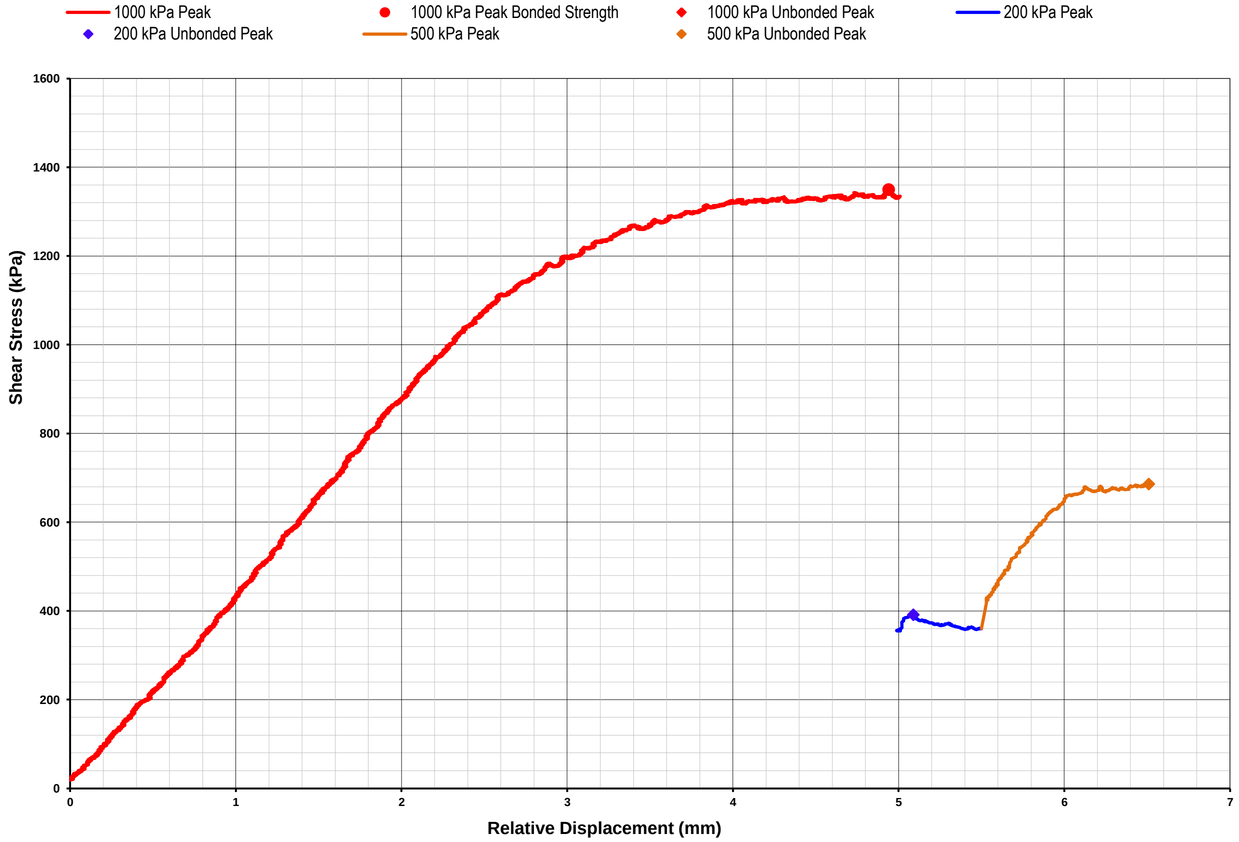
ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070513- DS

Peak Vertical Displacement/Relative Displacement Plot



Shear Stress/Relative Displacement Plot



Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Graph not to scale

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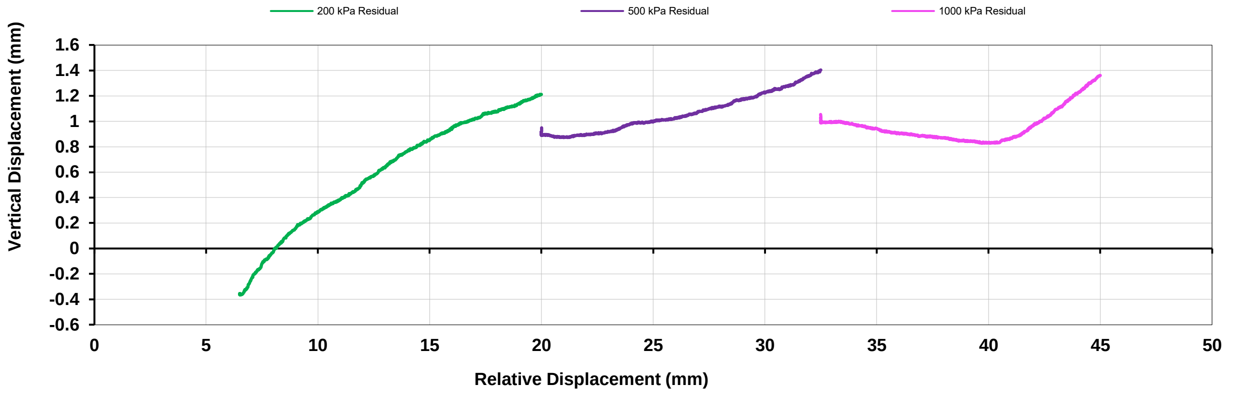
DIRECT SHEAR TEST REPORT

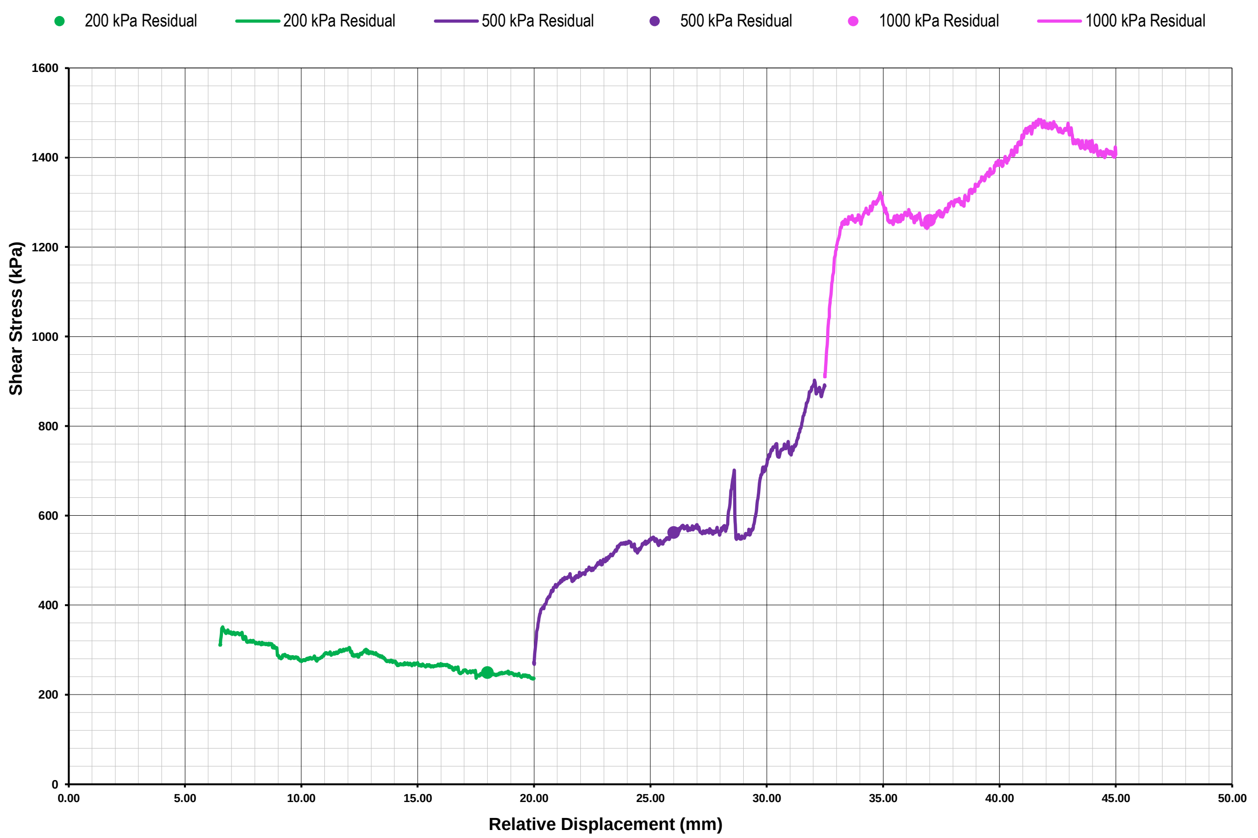
ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070513- DS

Residual Vertical Displacement/Relative Displacement Plot



Residual Shear Stress/Relative Displacement Plot



Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Graph not to scale

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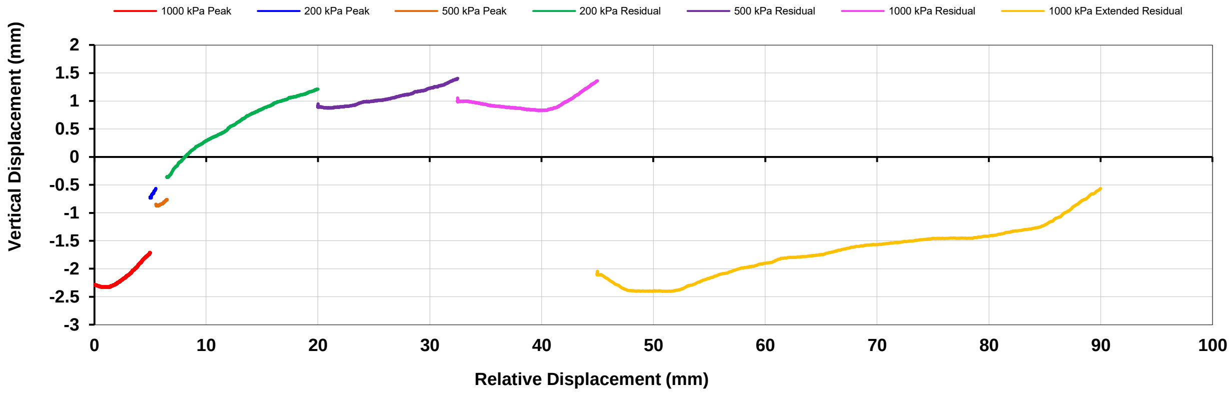
DIRECT SHEAR TEST REPORT

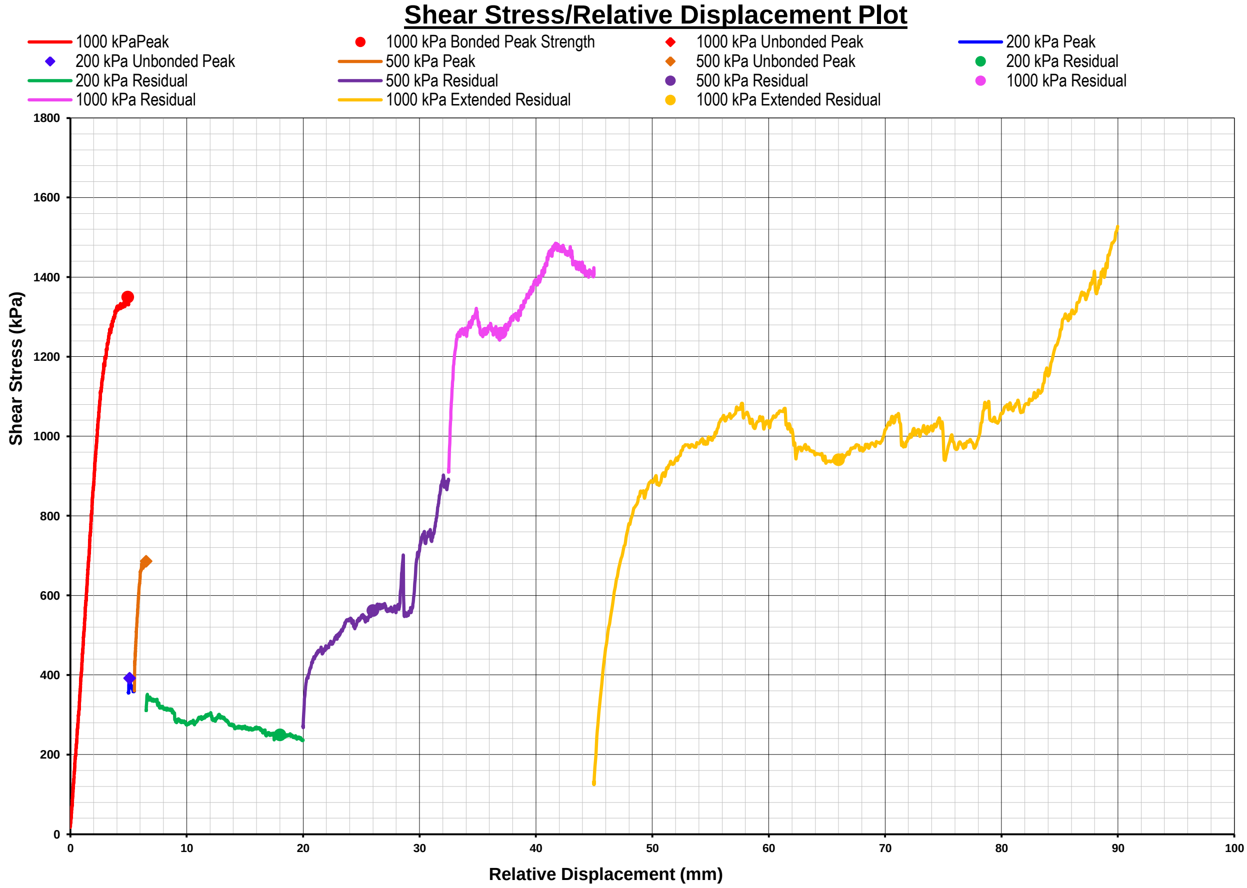
ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070513- DS

Peak & Residual Vertical Displacement/Relative Displacement Plot



Shear Stress/Relative Displacement Plot



Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Graph not to scale — Sample/s supplied by the client

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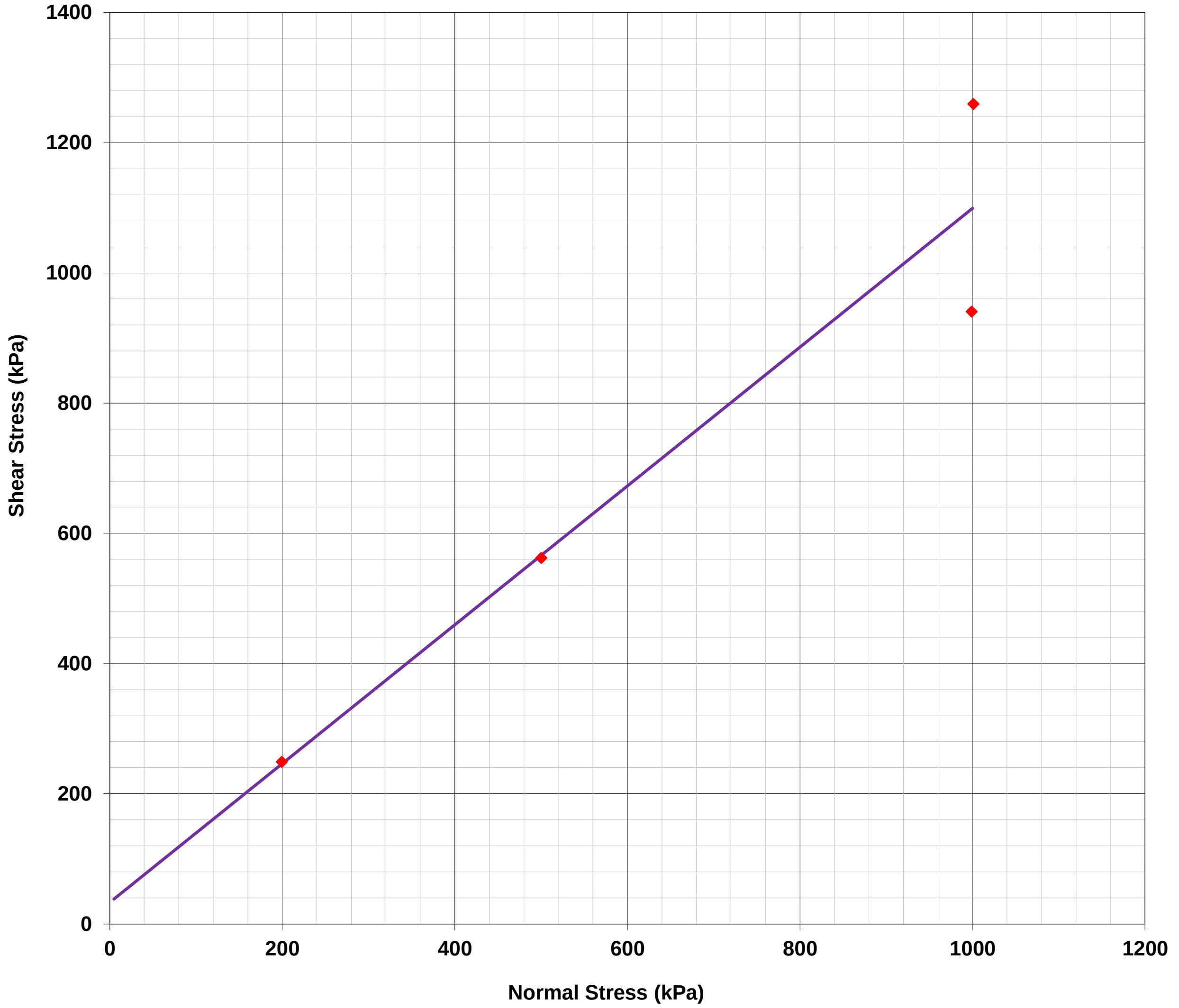
DIRECT SHEAR TEST REPORT

ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070513- DS

Residual - Corrected Normal Stress vs Corrected Shear Unbonded Stress



Residual Unbonded Shear Angle (^{o})	**46.8**	**Residual Unbonded Cohesion (kPa)**	**33.1**	**R^2 0.956**

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	18.00	199.5	248.9
500 kPa	26.00	500.0	561.8
1000 kPa	37.00	1001.0	1259.3
500 kPa Extended	65.99	999.1	940.6

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Graph not to scale

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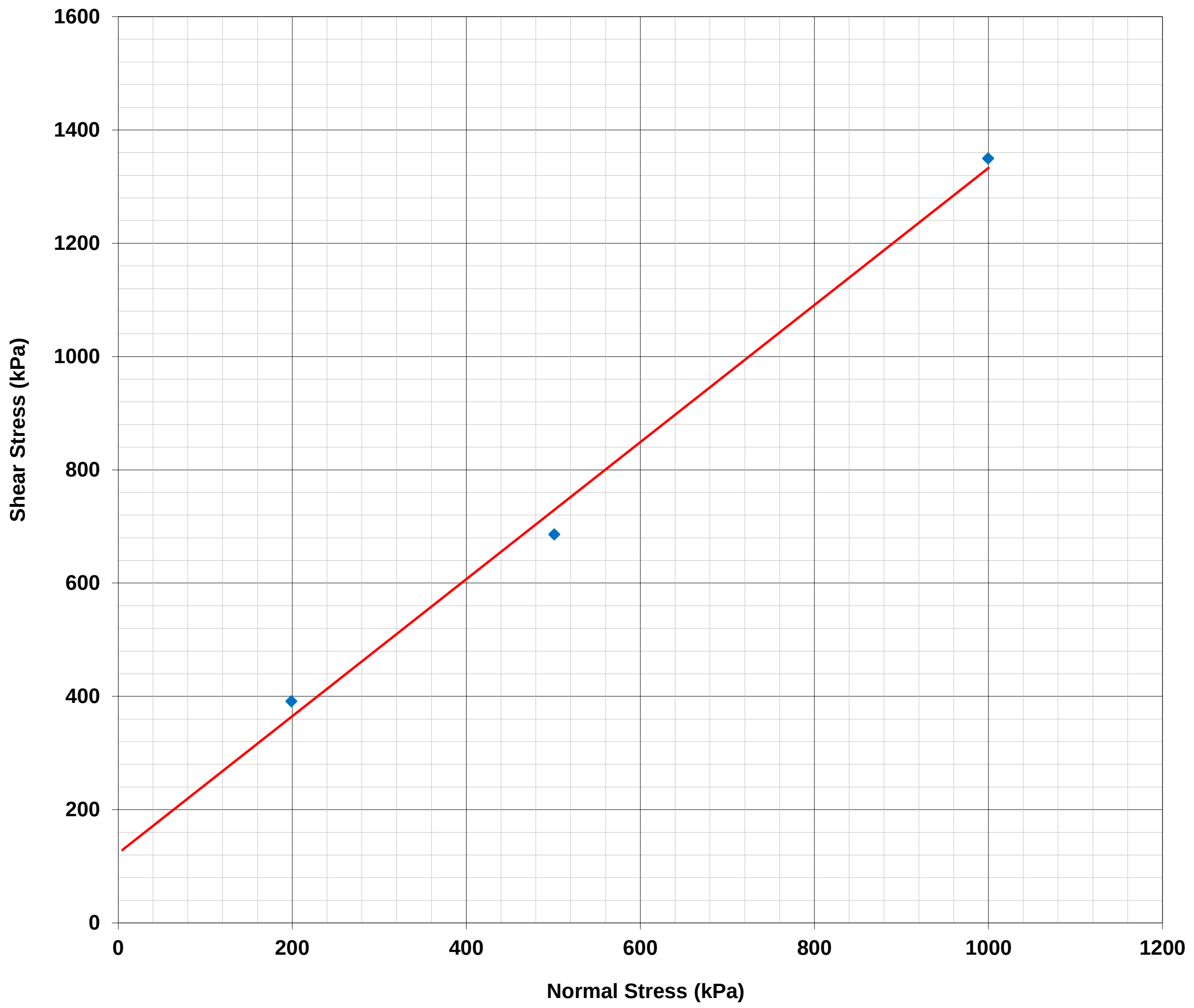
ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070513- DS

Peak - Corrected Normal Stress vs Corrected Unbonded Shear Stress



Peak Unbonded Shear Angle (^{o})	50.4	Peak Unbonded Cohesion (kPa)	123.0	R^2 0.997

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
1000 kPa	4.94	999.8	1349.4
200 kPa	5.09	199.3	391.4
500 kPa	6.51	501.2	685.9

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Graph not to scale

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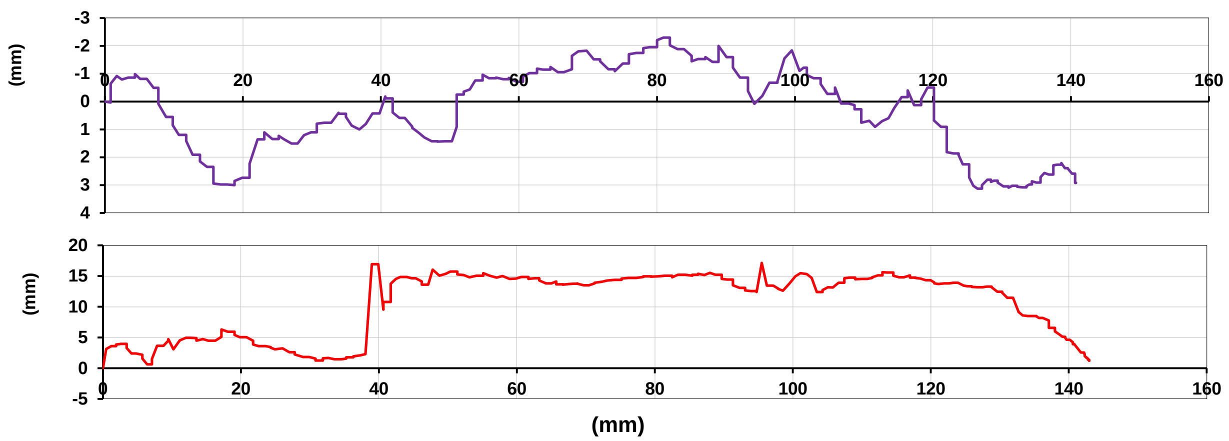
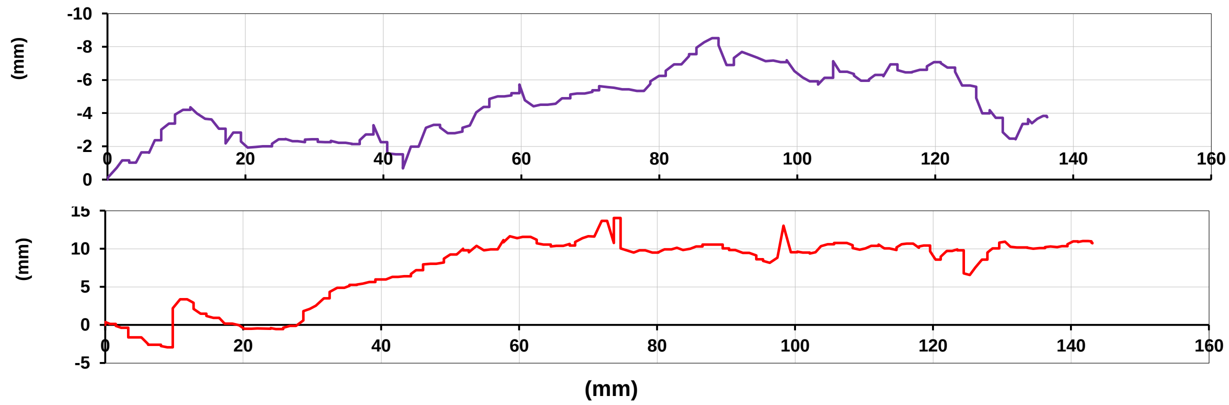
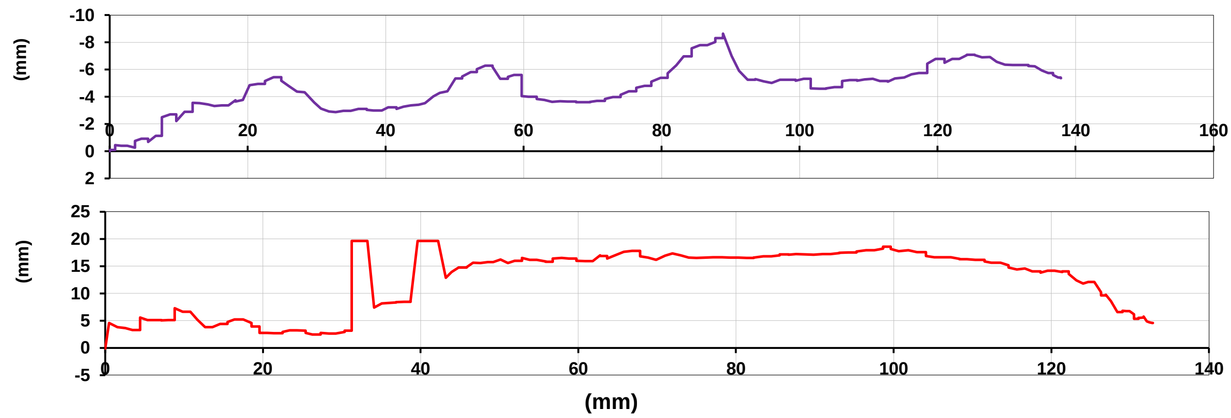
Top and Bottom Profile - Position 1 - After Shearing



Top and Bottom Profile - Position 2 - After Shearing



Top and Bottom Profile - Position 3 - After Shearing



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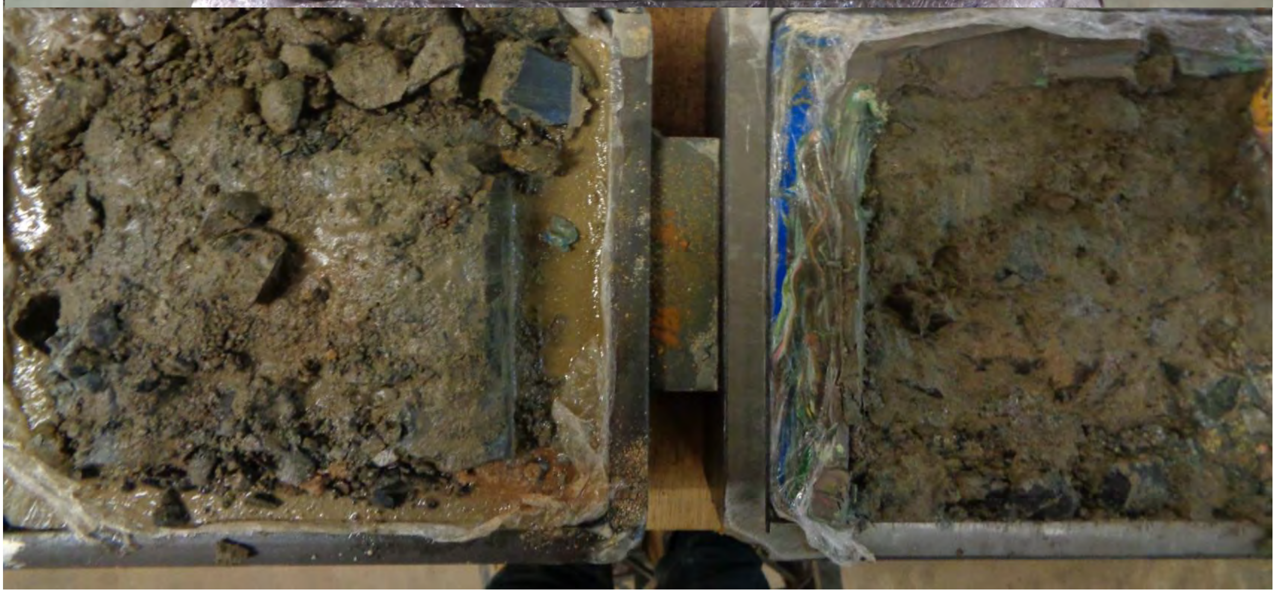

Notes/Remarks:

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DIRECT SHEAR TEST REPORT

ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070514- DS
		Workorder No	0006228
Address	Level 6, 480 St Pauls Tce Fortitude Valley QLD 4006	**Test Date**	6/08/2019
		Report Date	10/08/2019
Project	Paradise Dam Geotechnical Investigation		
Client ID	RCC-S - Bonded Lift Joint	**Depth (m)**	2.40-2.55
Description	-	**Sample Type**	Single individual concrete core specimen - INTACT.

SAMPLE DETAILS

Specimen Condition	As Received
Specimen Dimensions (mm)	150.83*143.55
Rate of Strain (mm/min)	0.100
Initial Moisture Content (%)	3.7
Initial Wet Density(t/m^3)	2.45

Note: Wet Density as per AS1012.12.2-1998 is not covered by NATA terms of accreditation and is provided for information only.

TEST RESULTS

RESIDUAL RESULTS

Residual Unbonded Shear Angle (°)	**29.2**	**Residual Unbonded Cohesion (kPa)** **82.0**	**R^2 0.994**
	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	18.00	199.4	193.6
500 kPa	28.00	500.3	395.7
1000 kPa	44.00	1000.5	629.0

PEAK RESULTS

Peak Unbonded Shear Angle (°)	**35.4**	**Peak Unbonded Cohesion (kPa)** **103.1**	**R^2 0.999**
	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	3.46	200.3	236.4
500 kPa	4.99	499.8	471.6
1000 kPa	6.77	1000.7	807.7

INTACT STRENGTH

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	3.46	200.3	236.4

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Sample/s supplied by the client

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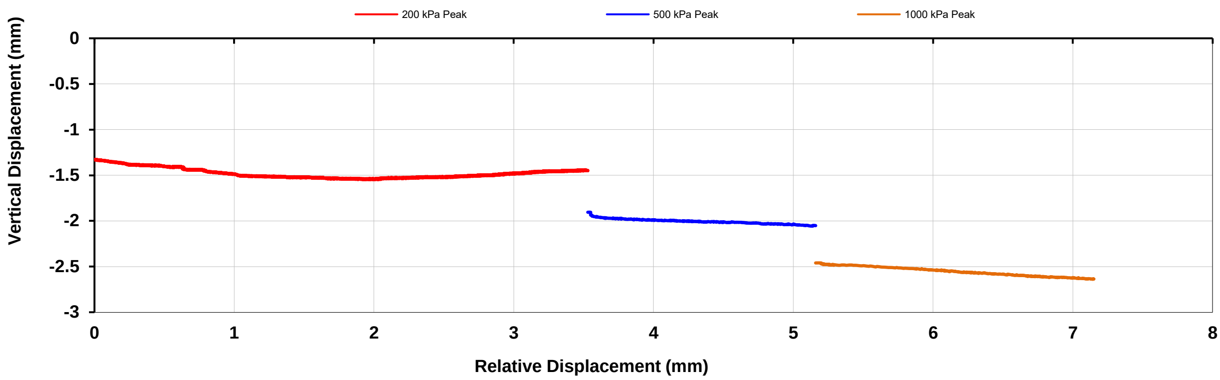
DIRECT SHEAR TEST REPORT

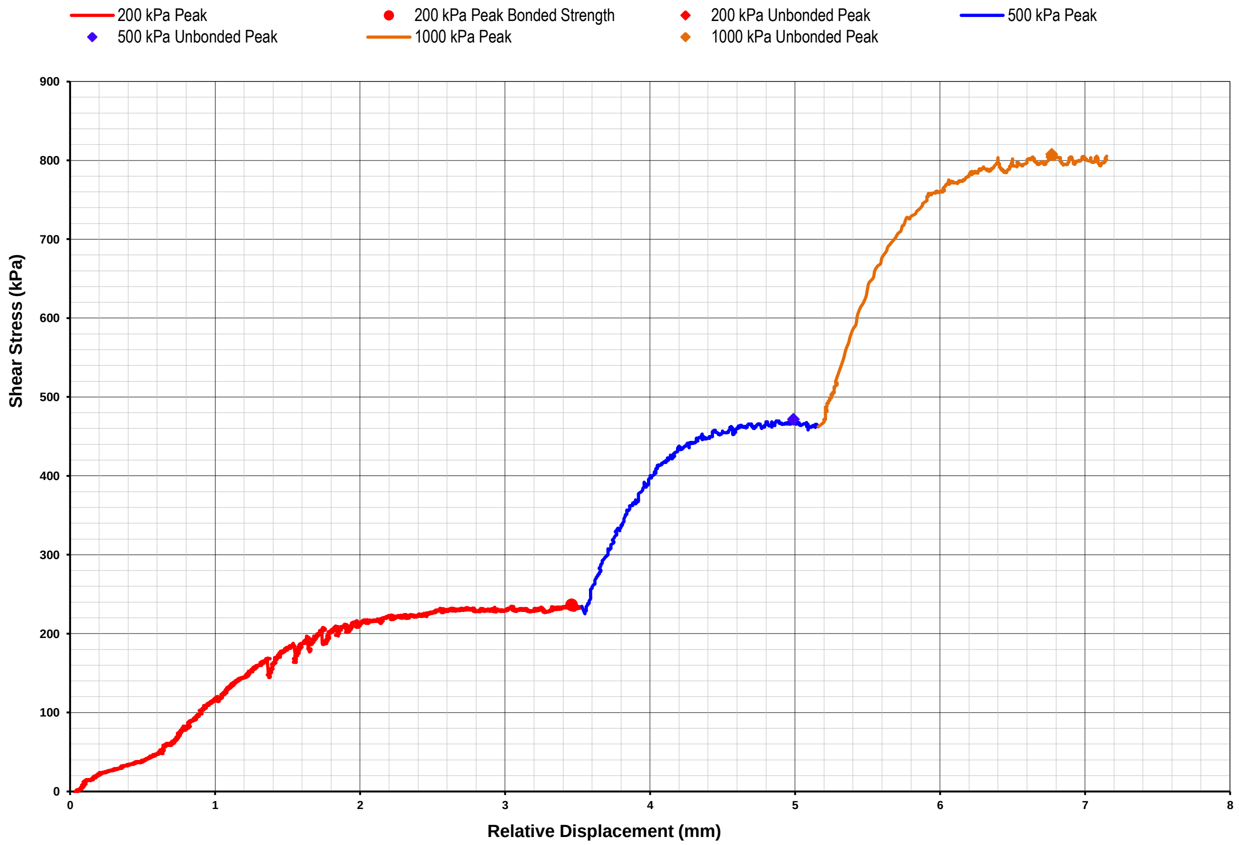
ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070514- DS

Peak Vertical Displacement/Relative Displacement Plot



Shear Stress/Relative Displacement Plot



Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Graph not to scale

Sample/s supplied by the client

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Trilab
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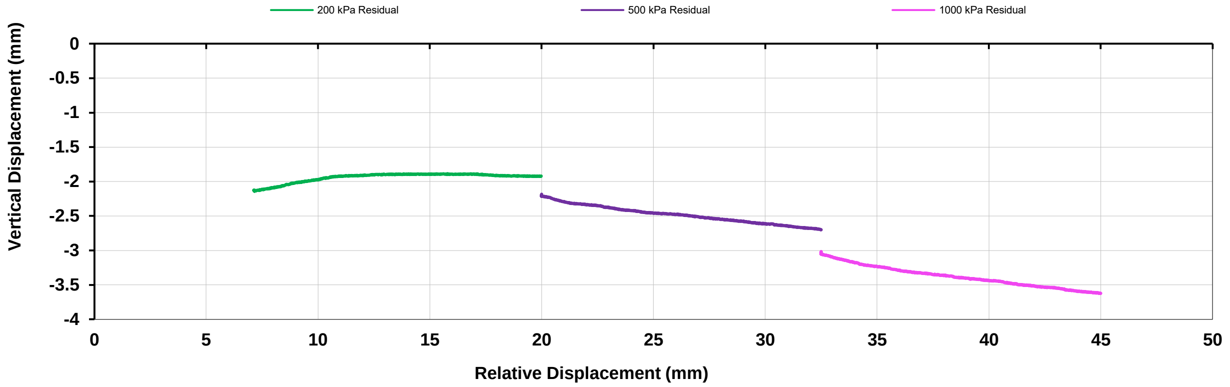
DIRECT SHEAR TEST REPORT

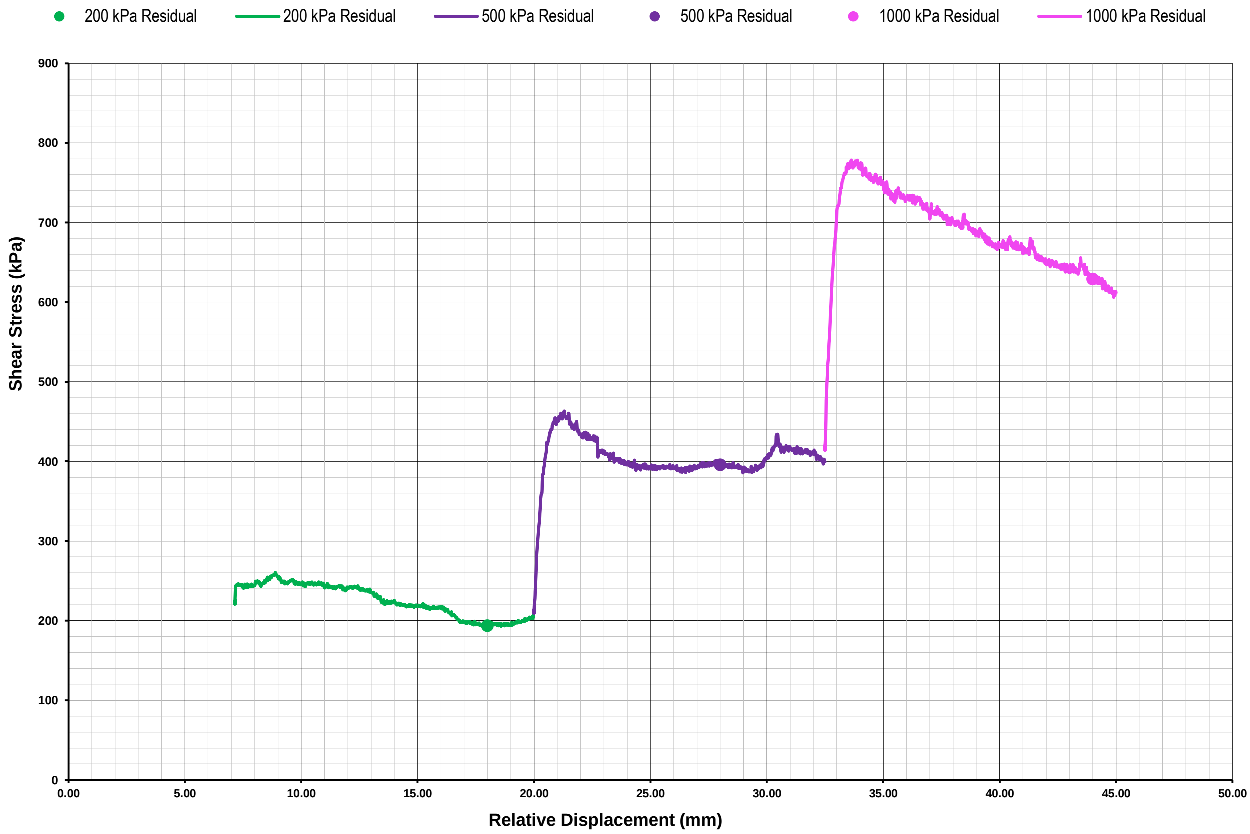
ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070514- DS

Residual Vertical Displacement/Relative Displacement Plot



Residual Shear Stress/Relative Displacement Plot



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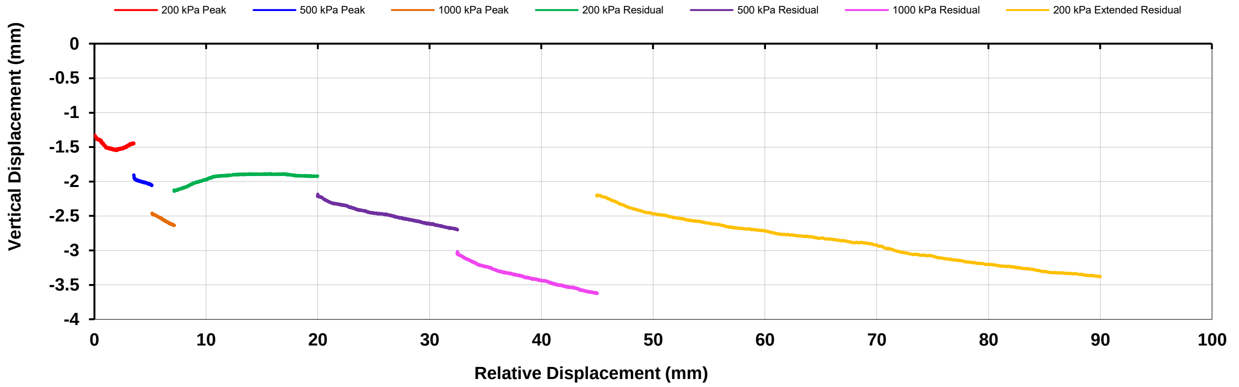
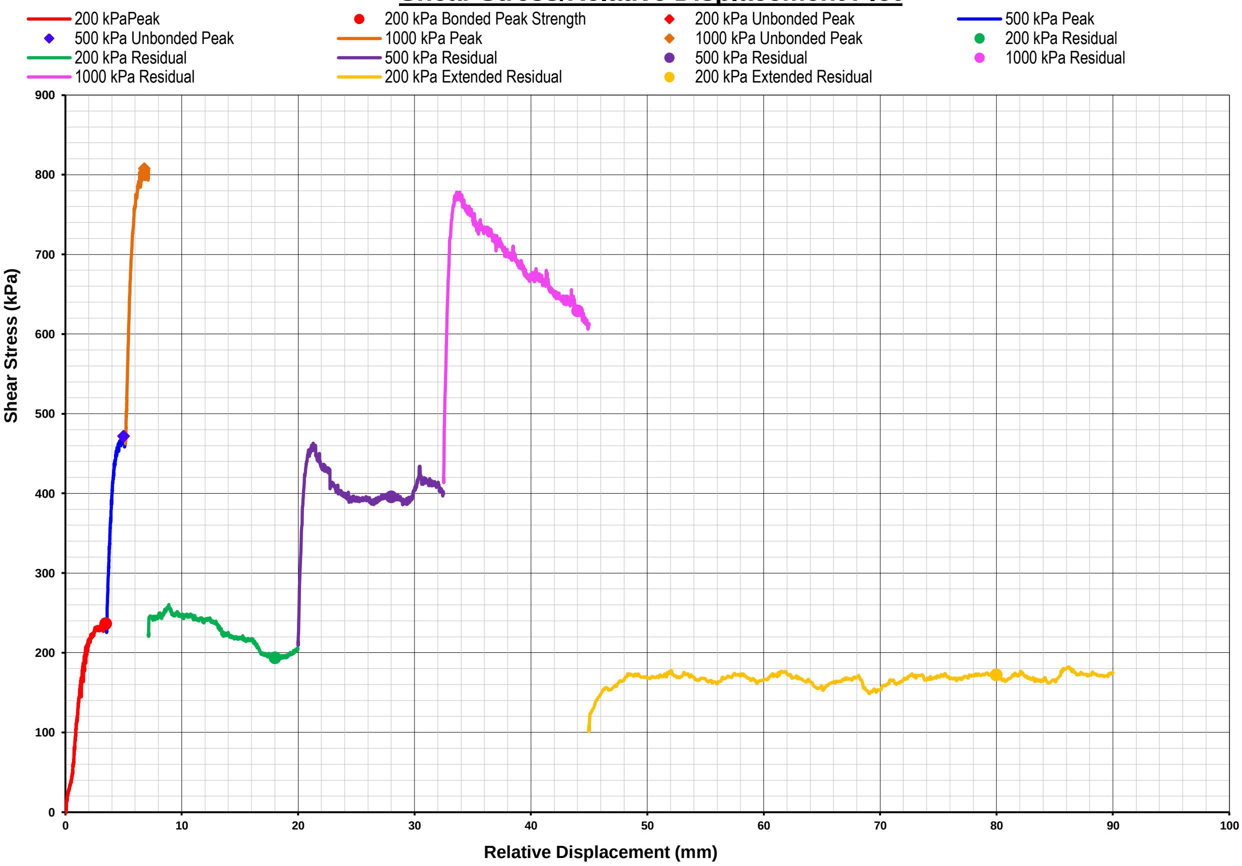
Client	SMEC Australia Pty Ltd	**Report No.**	19070514- DS

Peak & Residual Vertical Displacement/Relative Displacement Plot



Shear Stress/Relative Displacement Plot



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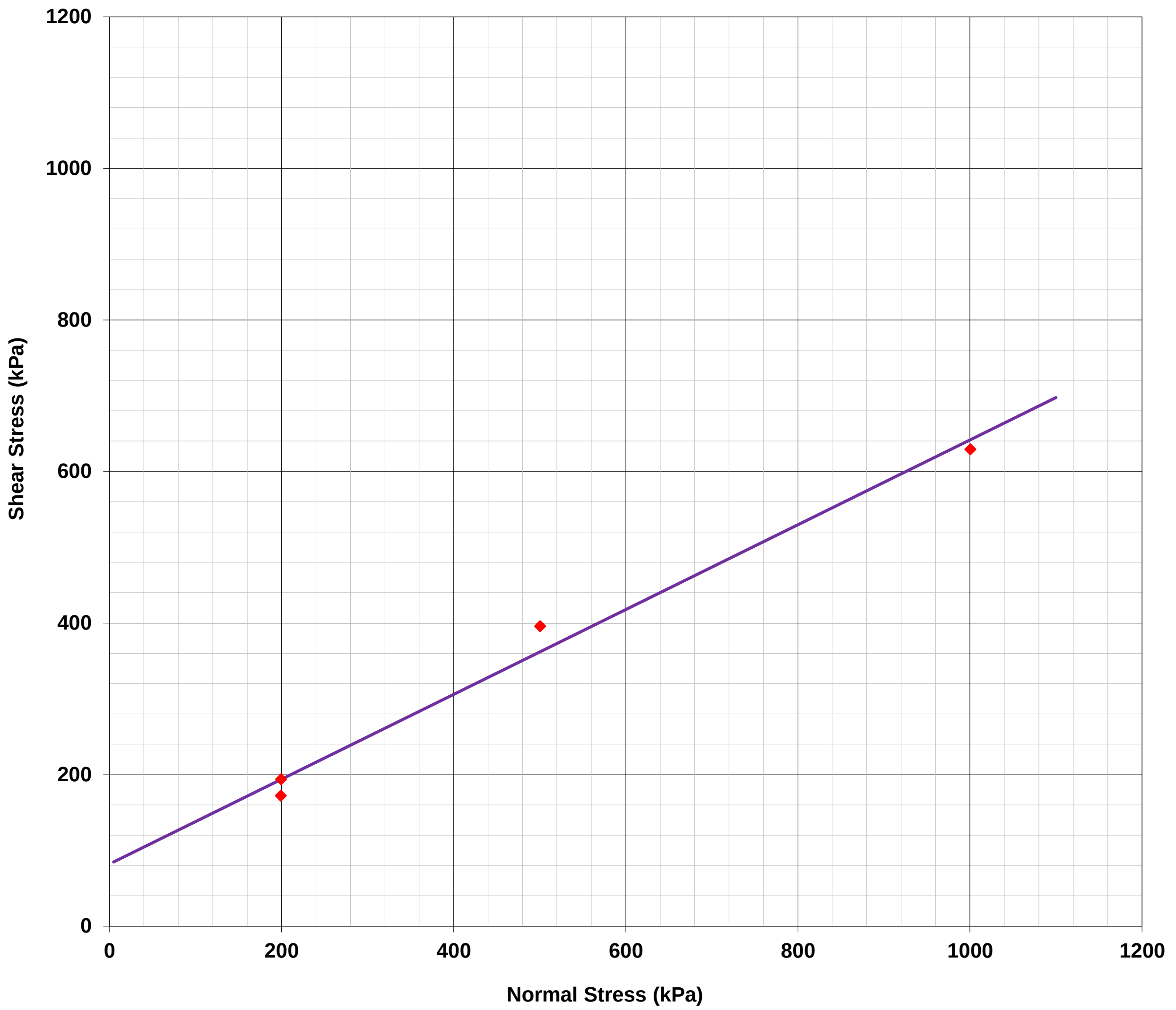
ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070514- DS

Residual - Corrected Normal Stress vs Corrected Shear Unbonded Stress



Residual Unbonded Shear Angle (°)	29.2	Residual Unbonded Cohesion (kPa)	82.0	R^2 0.994

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	18.00	199.4	193.6
500 kPa	28.00	500.3	395.7
1000 kPa	44.00	1000.5	629.0
200 kPa Extended	79.99	199.0	172.1

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Graph not to scale

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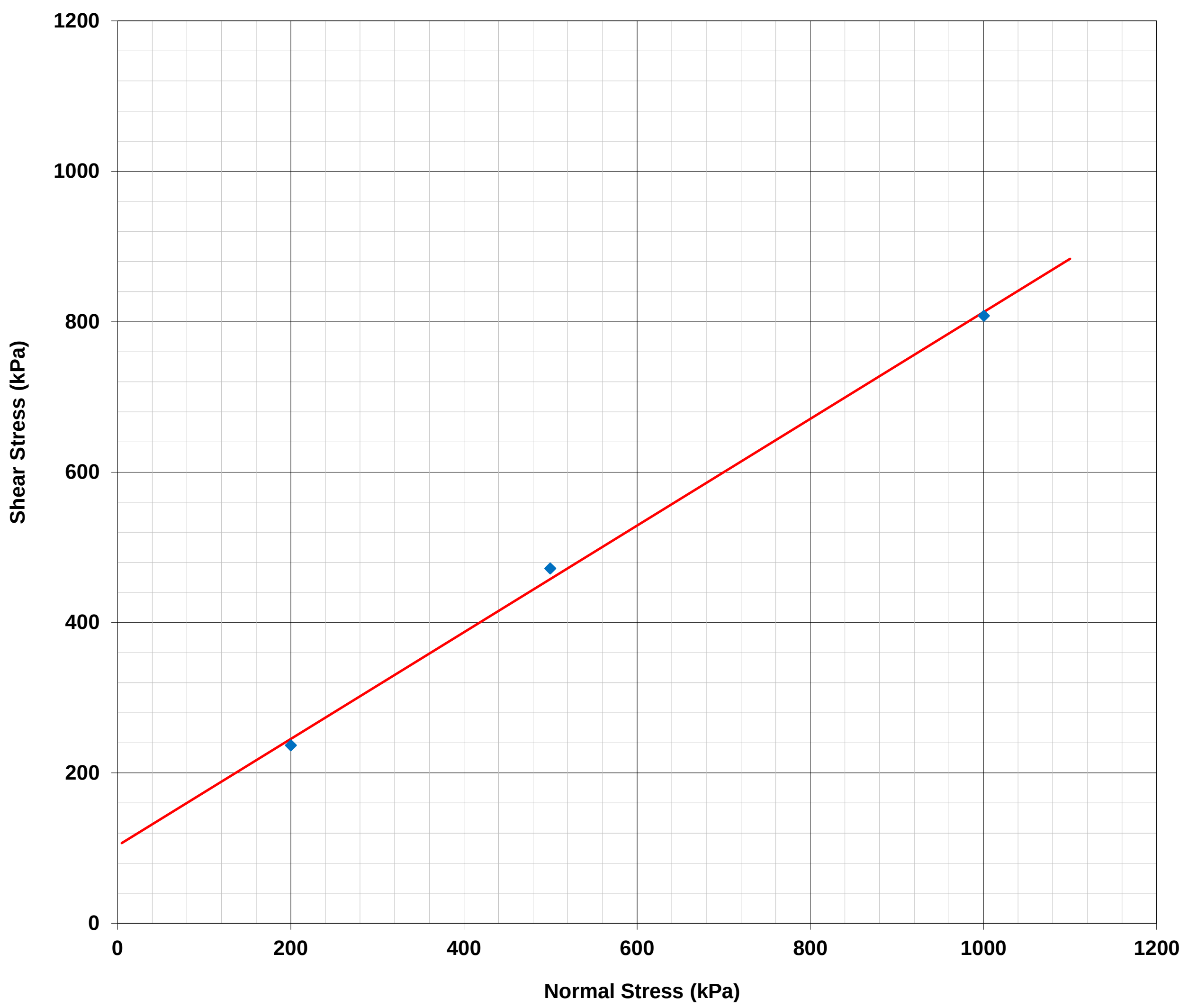
Client	SMEC Australia Pty Ltd	**Report No.**	19070514- DS

Peak - Corrected Normal Stress vs Corrected Unbonded Shear Stress



Peak Unbonded Shear Angle (^{o})	**35.4**	**Peak Unbonded Cohesion (kPa)**	**103.1**	**R^2**	**0.999**

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	3.46	200.3	236.4
500 kPa	4.99	499.8	471.6
1000 kPa	6.77	1000.7	807.7

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

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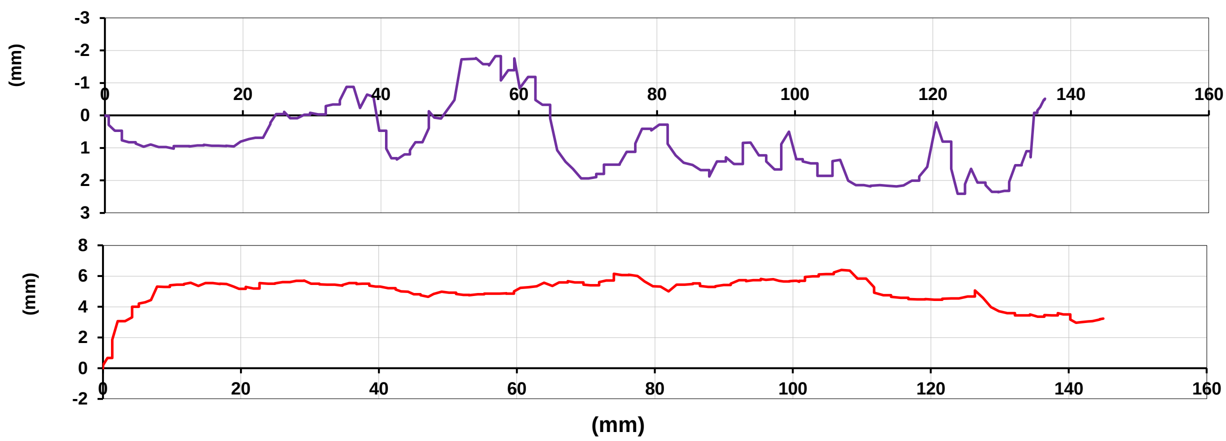
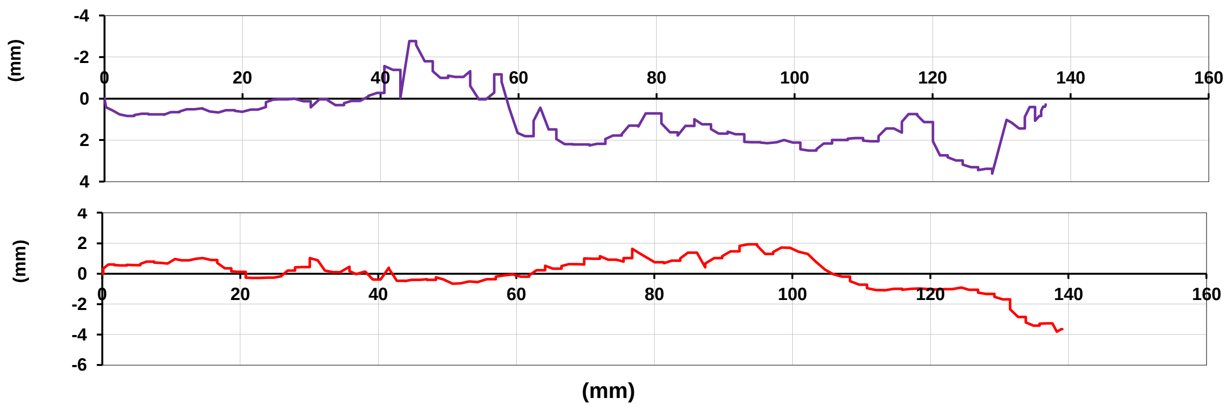
Client	SMEC Australia Pty Ltd	**Report No.**	19070514- DS

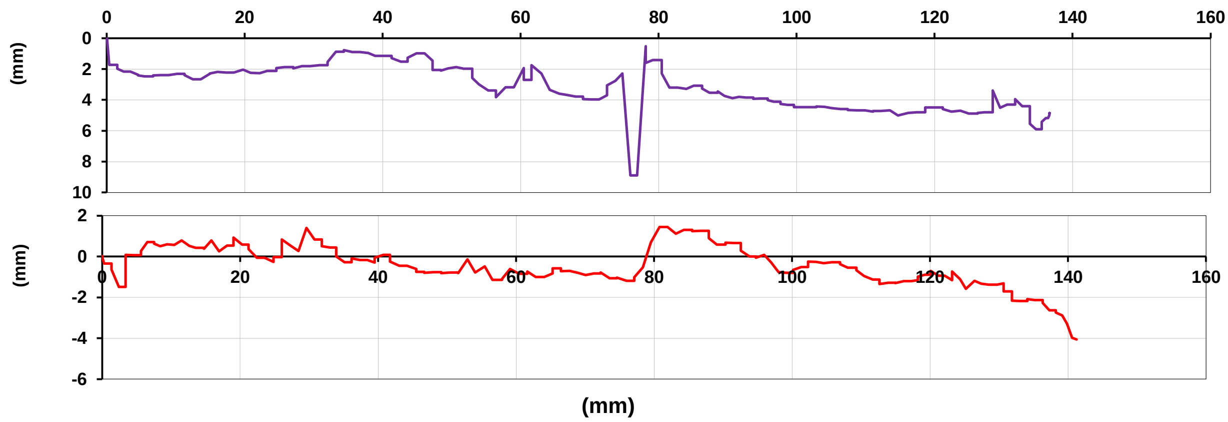
Top and Bottom Profile - Position 1 - After Shearing



Top and Bottom Profile - Position 2 - After Shearing



Top and Bottom Profile - Position 3 - After Shearing



Graph not to scale

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DIRECT SHEAR TEST REPORT

ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070514- DS

Notes/Remarks:

Photo not to scale

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DIRECT SHEAR TEST REPORT

ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070515- DS
		Workorder No	0006228
Address	Level 6, 480 St Pauls Tce Fortitude Valley QLD 4006	**Test Date**	7/08/2019
		Report Date	10/08/2019
Project	Paradise Dam Geotechnical Investigation		
Client ID	RCC-S - Bonded Lift Joint	**Depth (m)**	2.70-2.85
Description	-	**Sample Type**	Single individual concrete core specimen - INTACT.

SAMPLE DETAILS

Specimen Condition	As Received
Specimen Dimensions (mm)	147.93*144.33
Rate of Strain (mm/min)	0.100
Initial Moisture Content (%)	3.7
Initial Wet Density(t/m^3)	2.59

Note: Wet Density as per AS1012.12.2-1998 is not covered by NATA terms of accreditation and is provided for information only.

TEST RESULTS

RESIDUAL RESULTS

Residual Unbonded Shear Angle (°)	**36.0**	**Residual Unbonded Cohesion (kPa)** **102.9**	**R^2 0.993**
	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	17.98	200.1	277.5
500 kPa	24.00	501.4	457.9
1000 kPa	38.00	999.9	847.9

PEAK RESULTS

Peak Unbonded Shear Angle (°)	**39.8**	**Peak Unbonded Cohesion (kPa)** **201.8**	**R^2 0.996**
	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
500 kPa	2.85	500.3	654.2
200 kPa	4.08	200.3	346.1
1000 kPa	9.00	1002.0	1022.5

INTACT STRENGTH

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
500 kPa	2.85	500.3	654.2

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Sample/s supplied by the client

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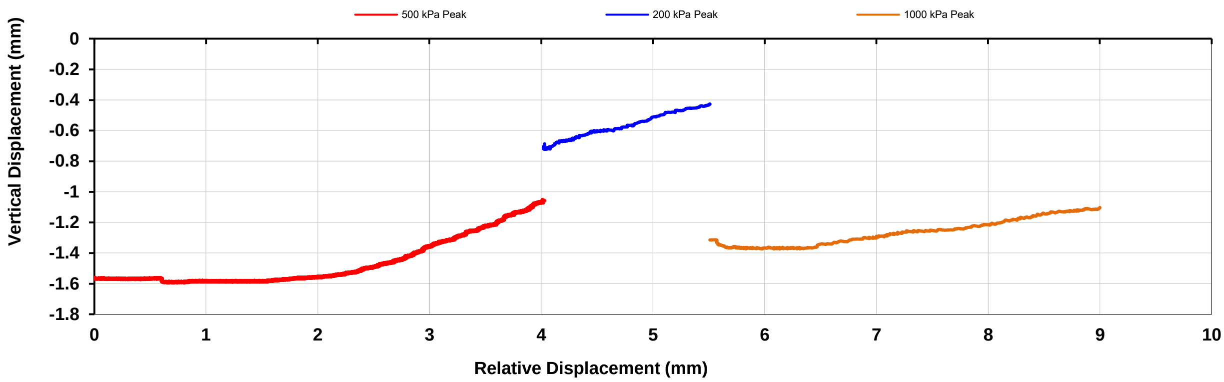
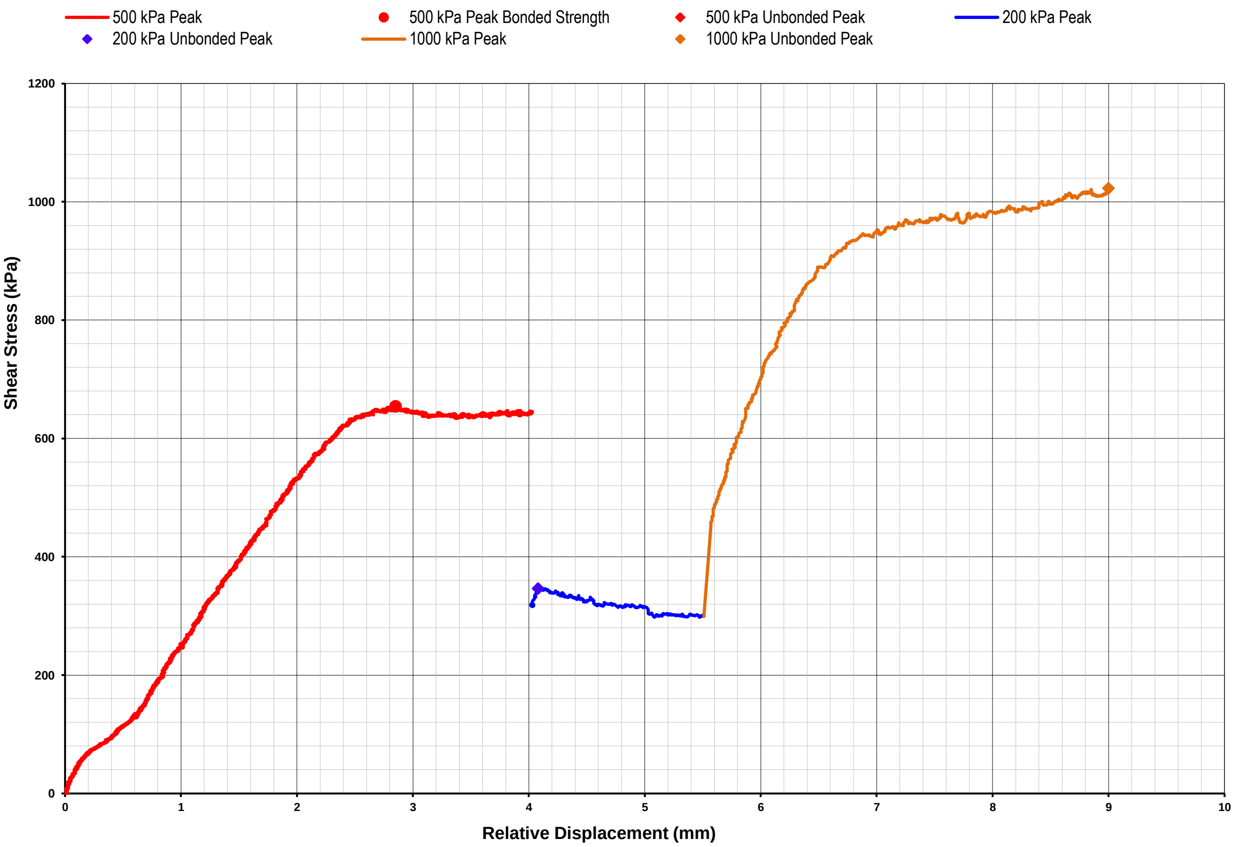
Client	SMEC Australia Pty Ltd	**Report No.**	19070515- DS

Peak Vertical Displacement/Relative Displacement Plot



Shear Stress/Relative Displacement Plot



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Graph not to scale

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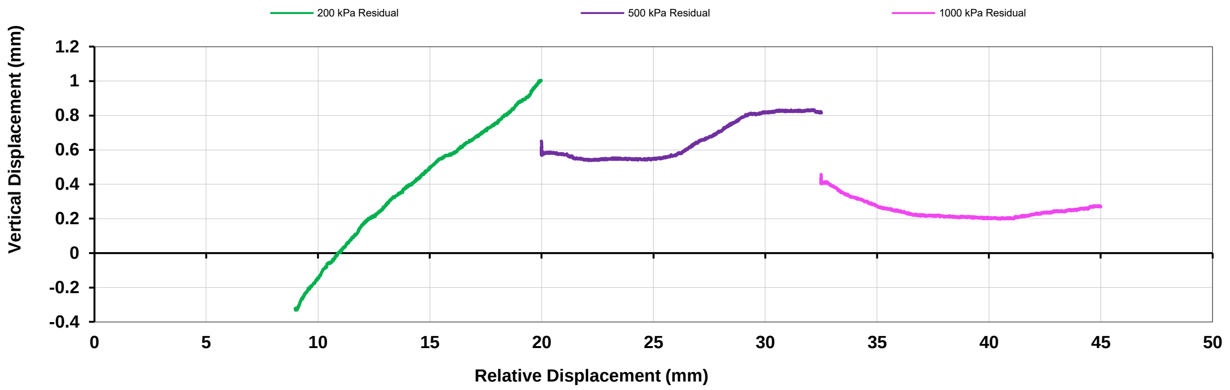
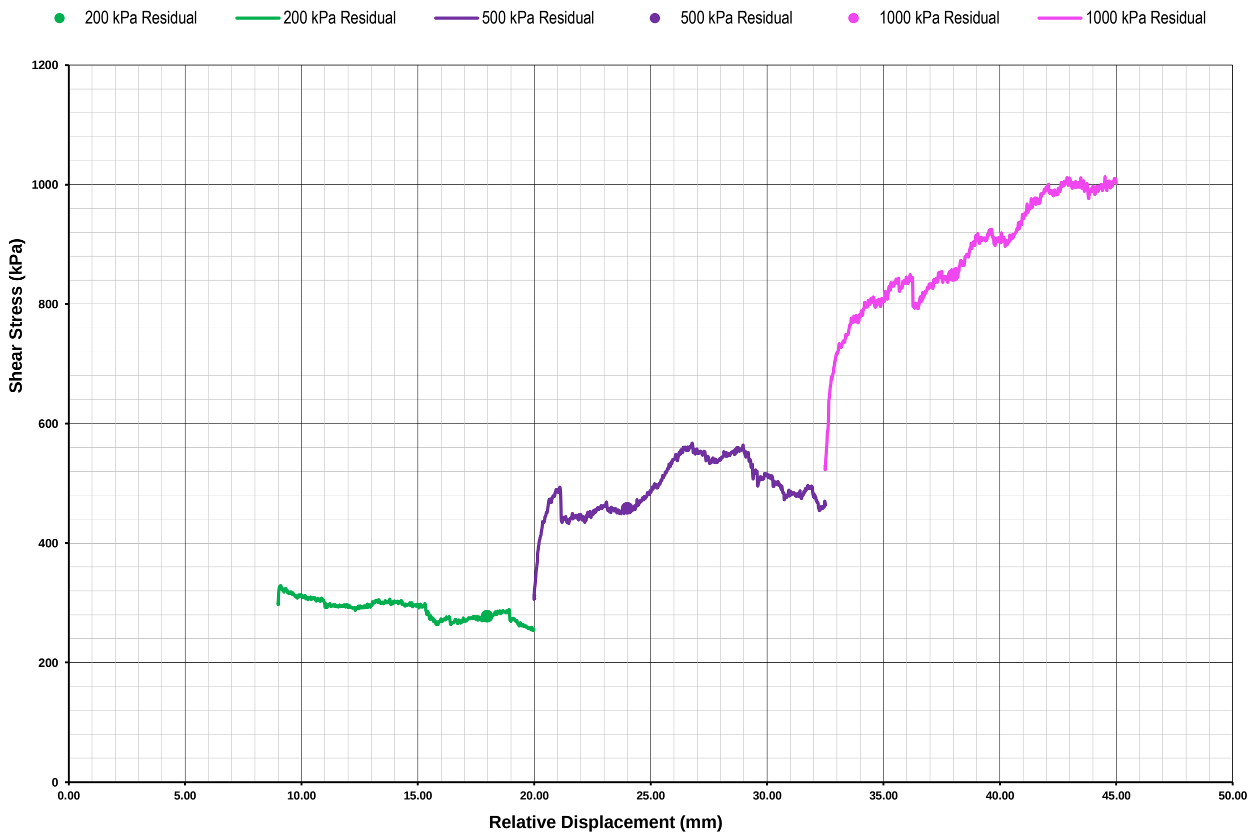
Residual Vertical Displacement/Relative Displacement Plot



Residual Shear Stress/Relative Displacement Plot



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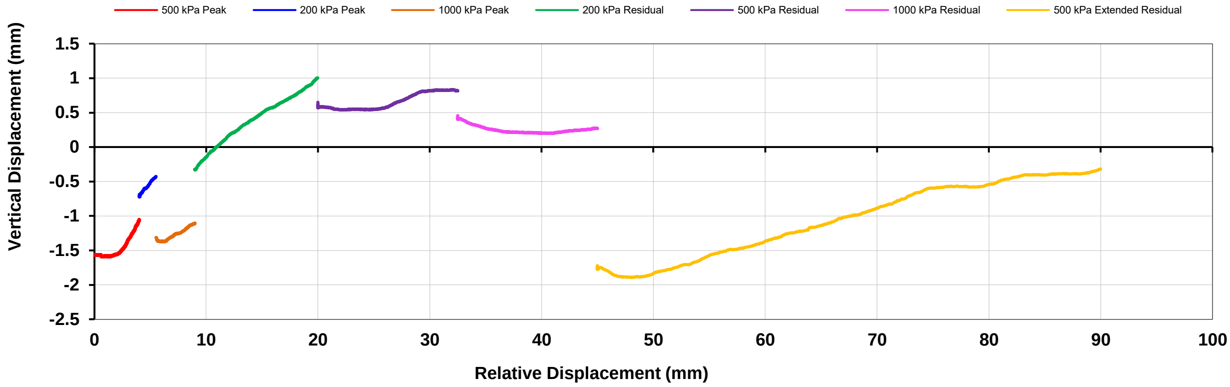
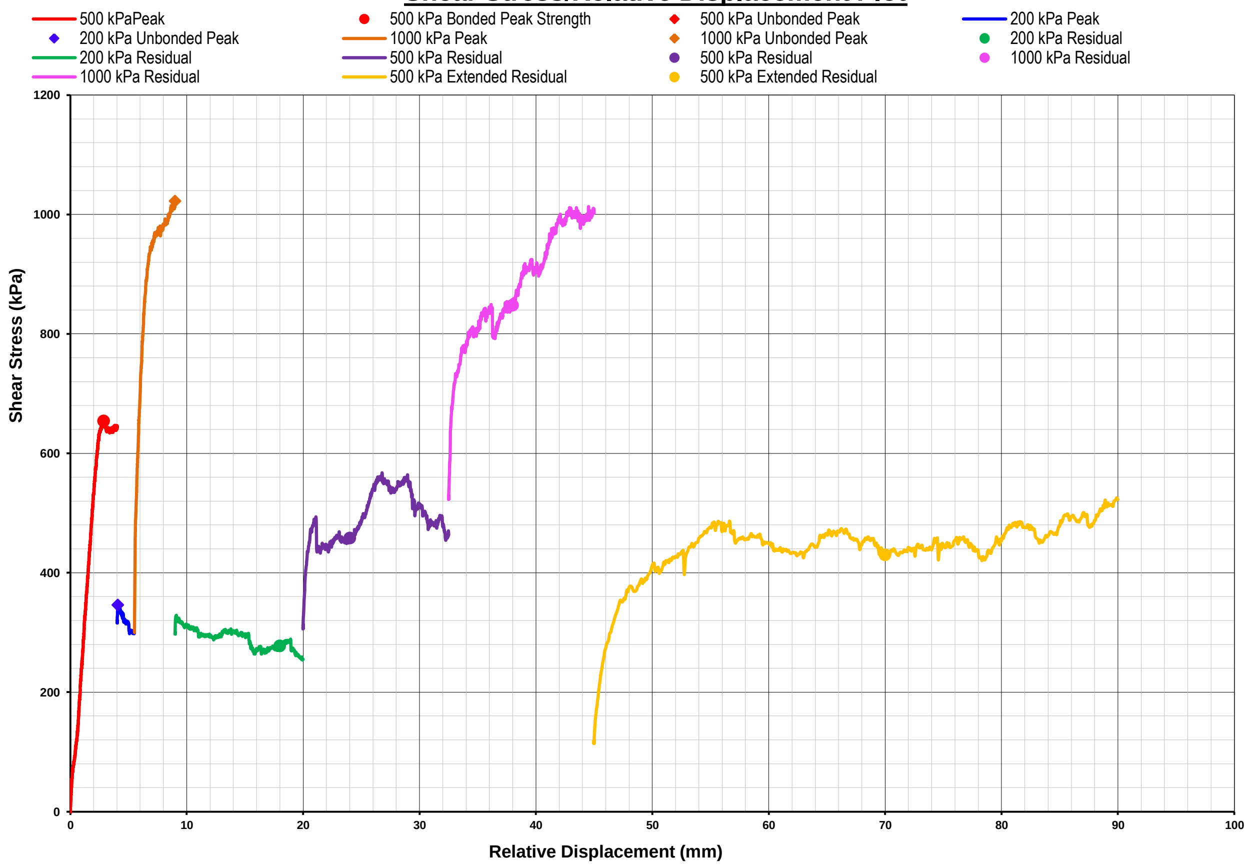


Shear Stress/Relative Displacement Plot



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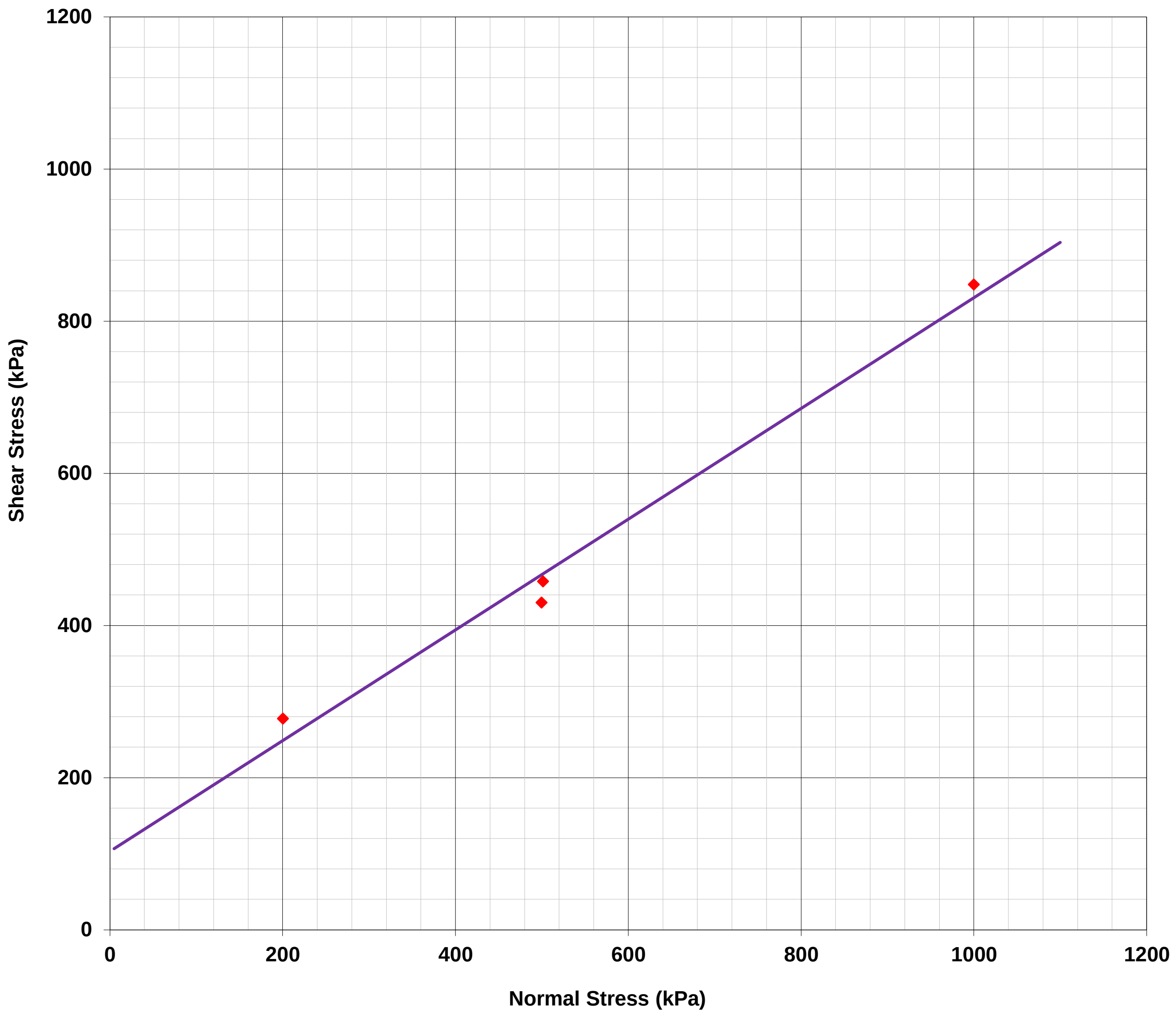
Client	SMEC Australia Pty Ltd	**Report No.**	19070515- DS

Residual - Corrected Normal Stress vs Corrected Shear Unbonded Stress



Residual Unbonded Shear Angle (°)	36.0	Residual Unbonded Cohesion (kPa)	102.9	R^2 0.993

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	17.98	200.1	277.5
500 kPa	24.00	501.4	457.9
1000 kPa	38.00	999.9	847.9
500 kPa Extended	69.99	499.6	430.0

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Graph not to scale

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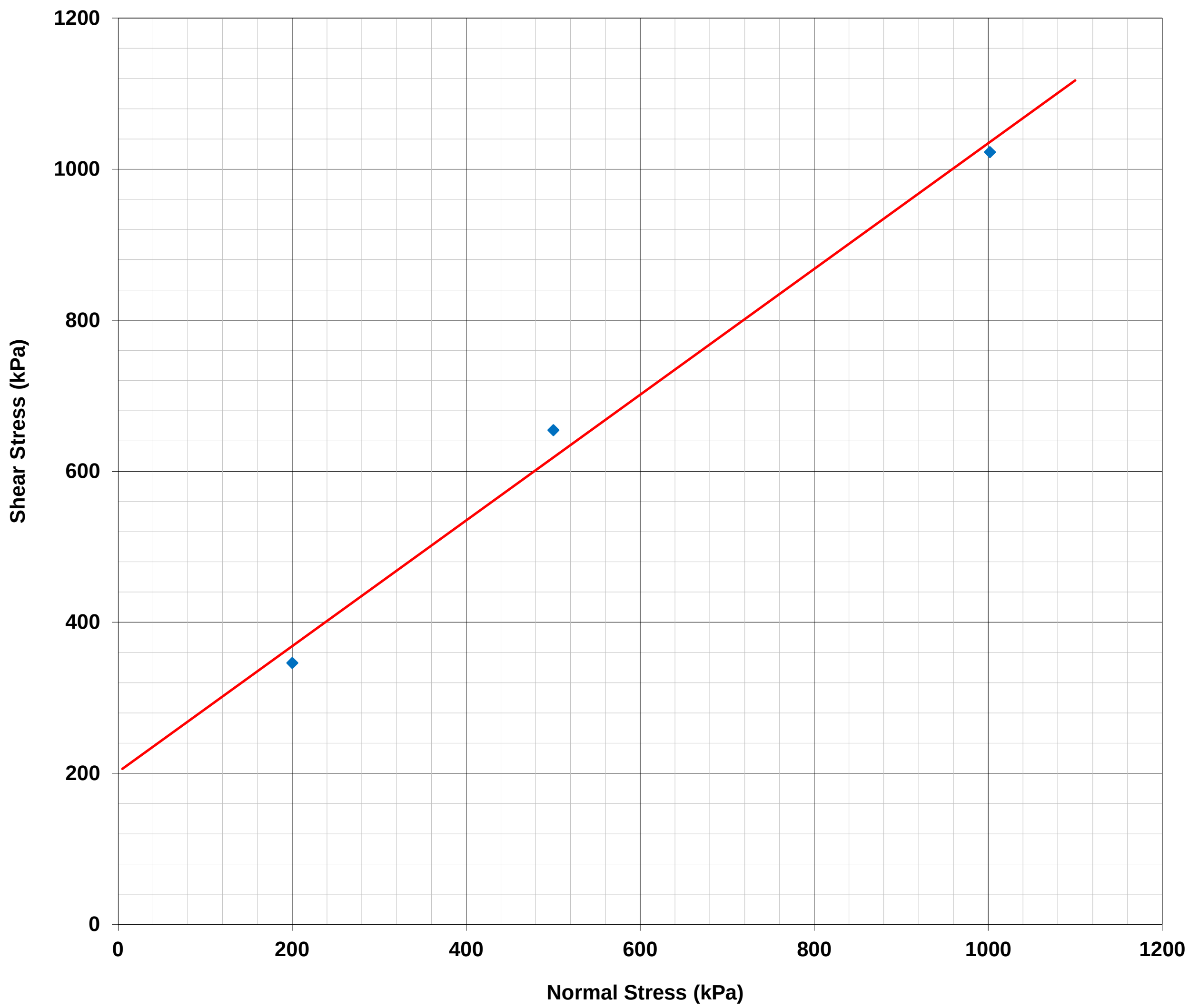
Client	SMEC Australia Pty Ltd	**Report No.**	19070515- DS

Peak - Corrected Normal Stress vs Corrected Unbonded Shear Stress



Peak Unbonded Shear Angle (°) 39.8		**Peak Unbonded Cohesion (kPa)** 201.8	**R^2 0.996**
	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
500 kPa	2.85	500.3	654.2
200 kPa	4.08	200.3	346.1
1000 kPa	9.00	1002.0	1022.5

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Graph not to scale Sample/s supplied by the client

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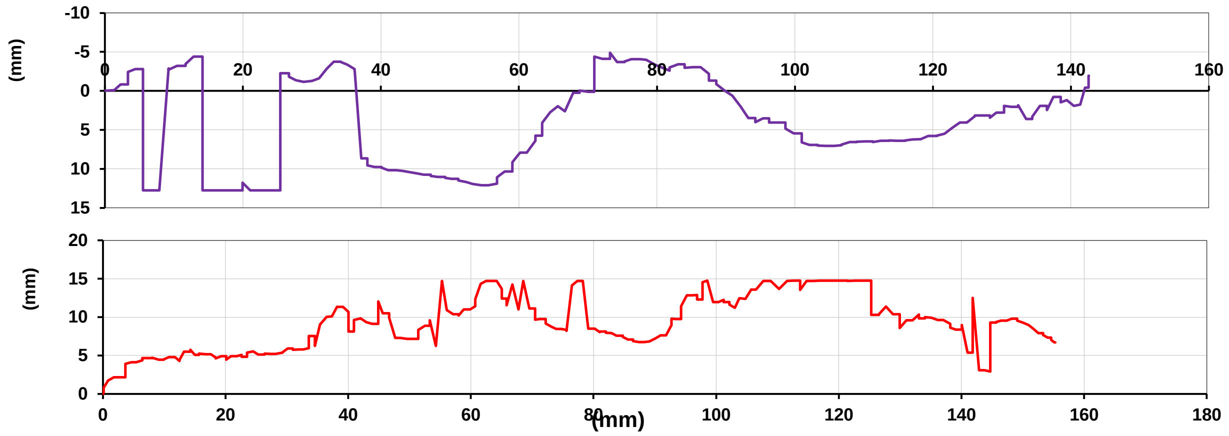
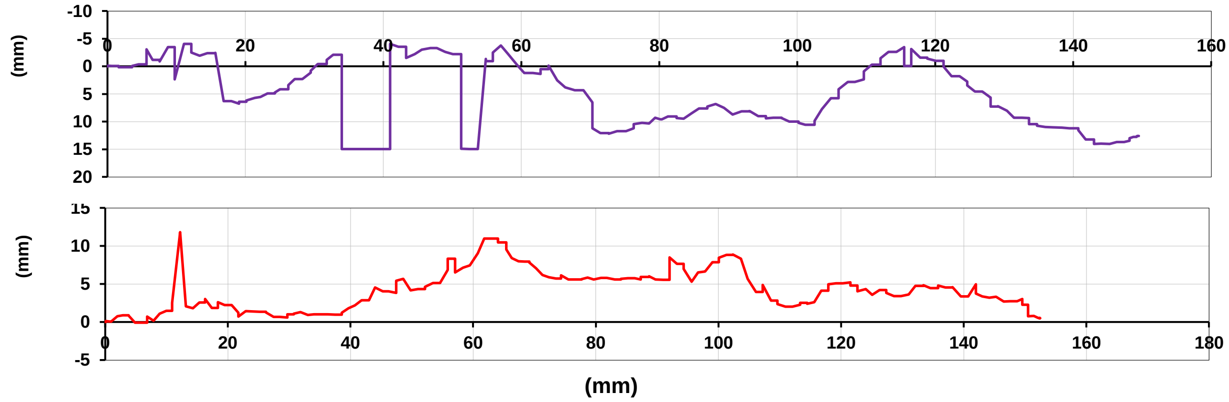
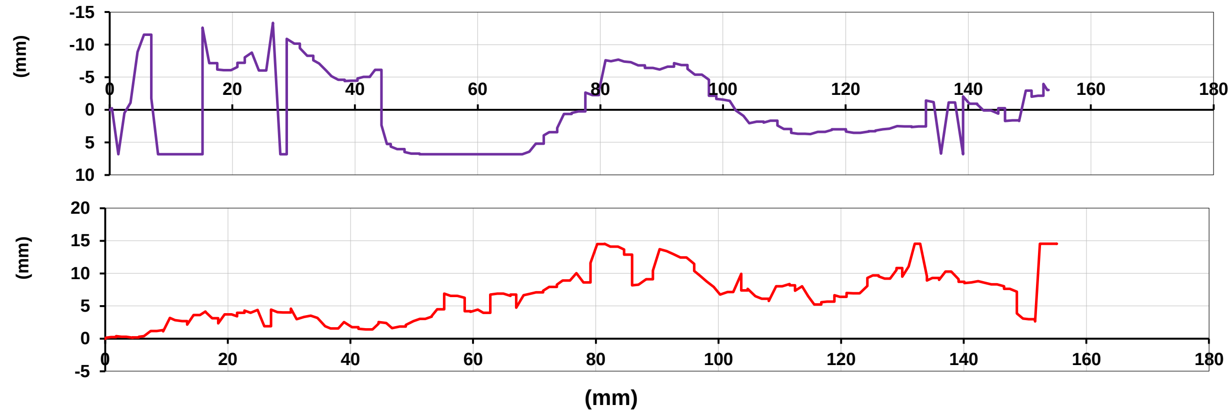
Top and Bottom Profile - Position 1 - After Shearing



Top and Bottom Profile - Position 2 - After Shearing



Top and Bottom Profile - Position 3 - After Shearing



Graph not to scale

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DIRECT SHEAR TEST REPORT

ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070515- DS

Notes/Remarks:

Photo not to scale

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DIRECT SHEAR TEST REPORT

ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070516- DS
		Workorder No	0006228
Address	Level 6, 480 St Pauls Tce Fortitude Valley QLD 4006	**Test Date**	8/08/2019
		Report Date	10/08/2019
Project	Paradise Dam Geotechnical Investigation		
Client ID	RCC-S - Bonded Lift Joint	**Depth (m)**	3.00-3.15
Description	-	**Sample Type**	Single individual concrete core specimen - INTACT.

SAMPLE DETAILS

Specimen Condition	As Received
Specimen Dimensions (mm)	151.29*144.09
Rate of Strain (mm/min)	0.100
Initial Moisture Content (%)	3.7
Initial Wet Density(t/m^3)	2.43

Note: Wet Density as per AS1012.12.2-1998 is not covered by NATA terms of accreditation and is provided for information only.

TEST RESULTS

RESIDUAL RESULTS

Residual Unbonded Shear Angle (°)	**29.7**	**Residual Unbonded Cohesion (kPa)** **91.3**	**R^2 0.992**

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	17.99	199.6	202.4
500 kPa	29.99	500.3	381.5
1000 kPa	42.00	998.9	625.3

PEAK RESULTS

Peak Unbonded Shear Angle (°)	**43.1**	**Peak Unbonded Cohesion (kPa)** **92.1**	**R^2 0.995**

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
1000 kPa	7.40	1000.1	1042.7
200 kPa	7.52	199.9	305.6
500 kPa	8.84	500.2	516.8

INTACT STRENGTH

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
1000 kPa	6.03	1000.1	1174.9

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Sample/s supplied by the client

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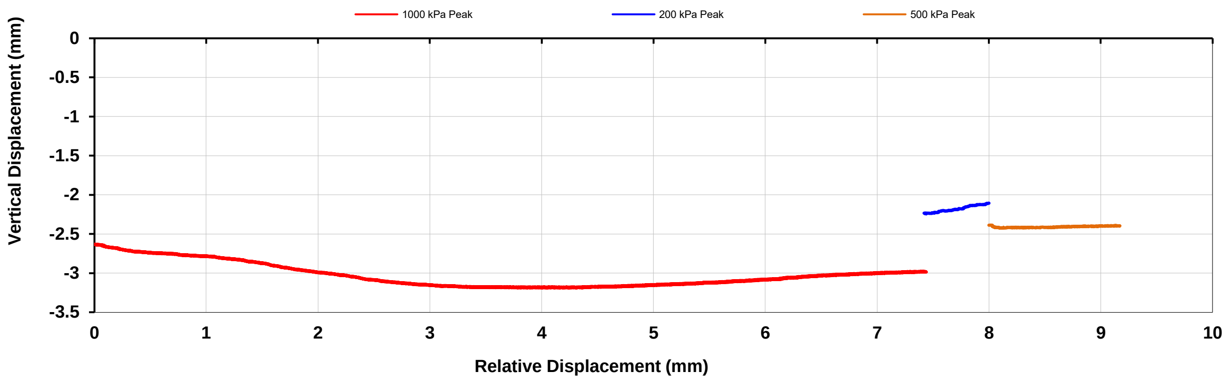
DIRECT SHEAR TEST REPORT

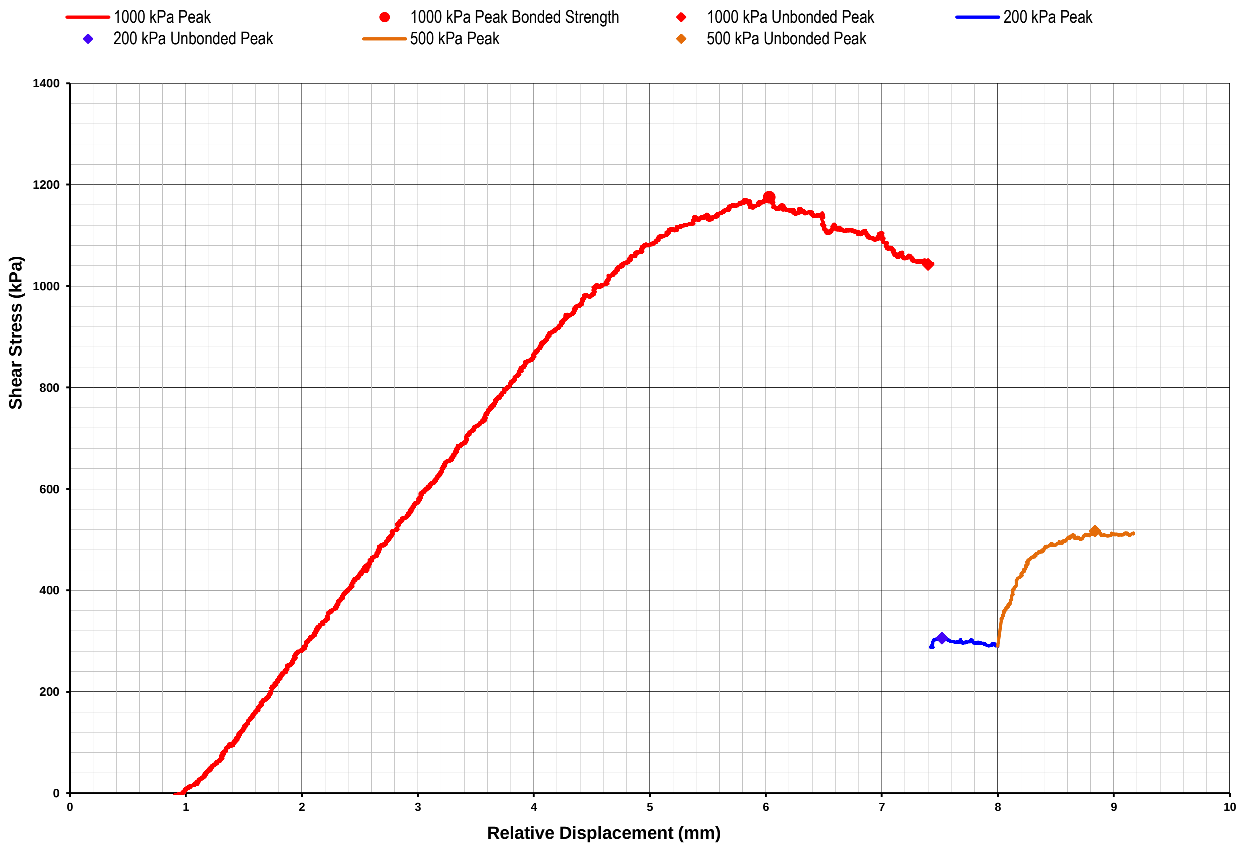
ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070516- DS

Peak Vertical Displacement/Relative Displacement Plot



Shear Stress/Relative Displacement Plot



Notes/Remarks:

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Graph not to scale

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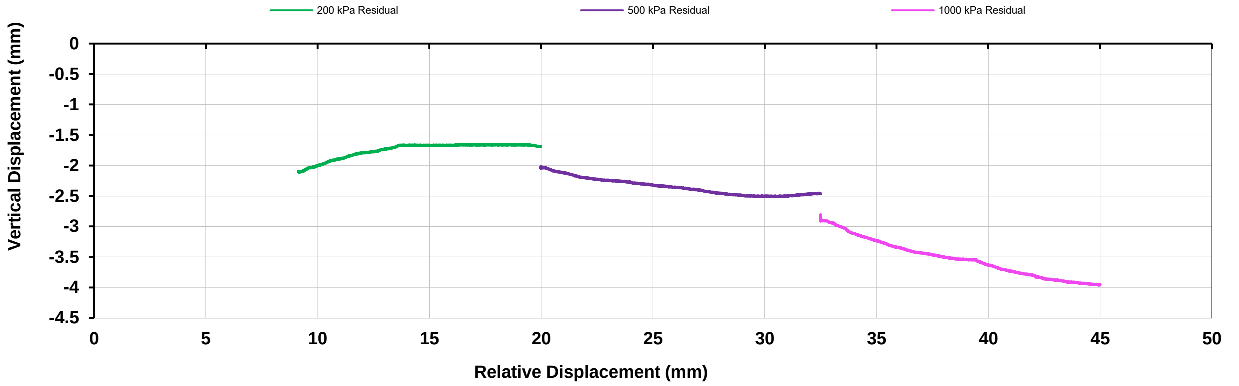
DIRECT SHEAR TEST REPORT

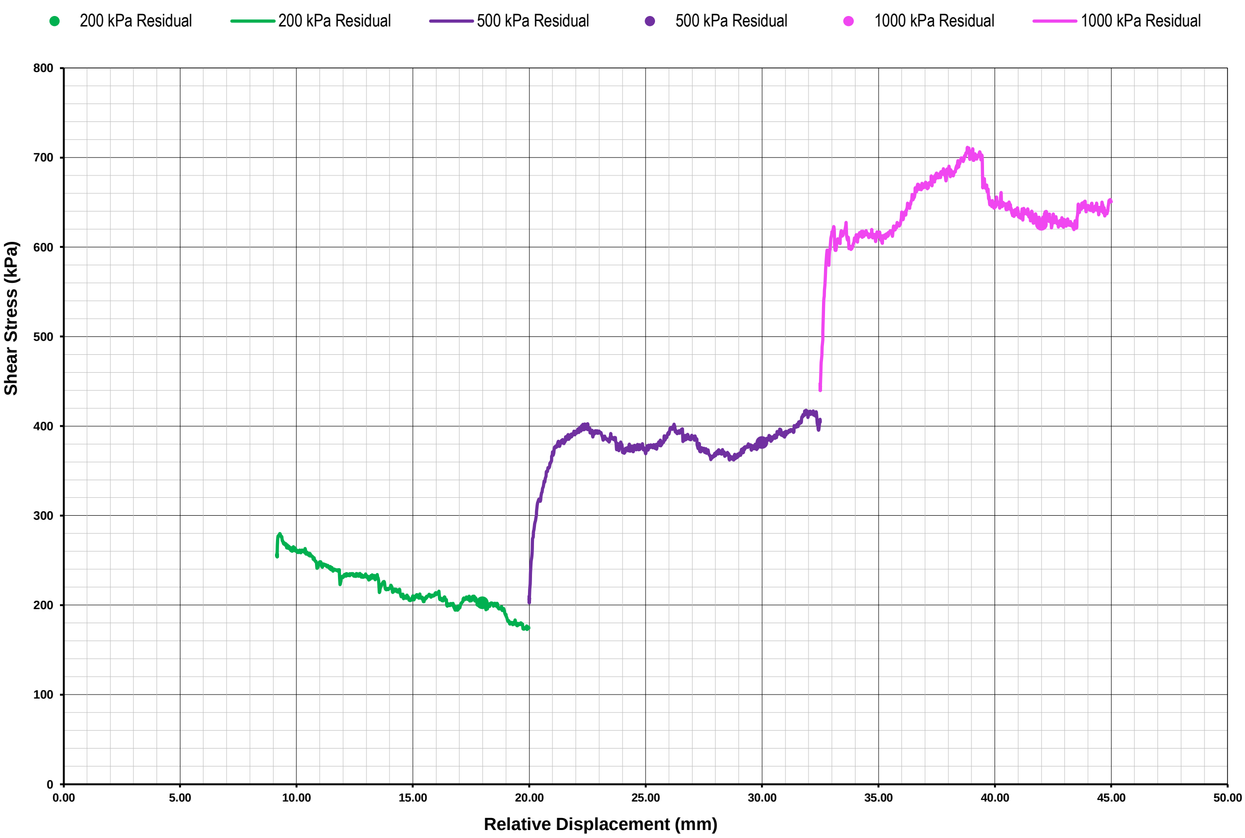
ASTM D5607 - Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force

Client	SMEC Australia Pty Ltd	**Report No.**	19070516- DS

Residual Vertical Displacement/Relative Displacement Plot



Residual Shear Stress/Relative Displacement Plot



Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Graph not to scale

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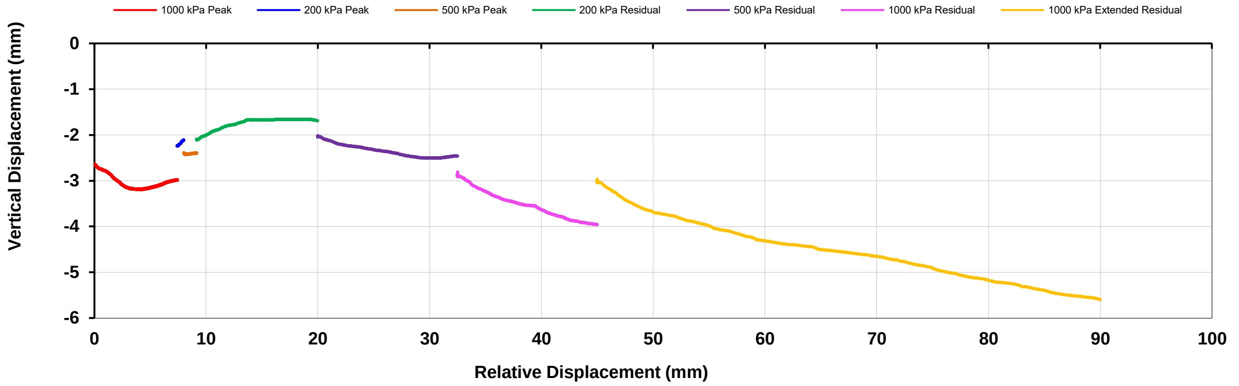
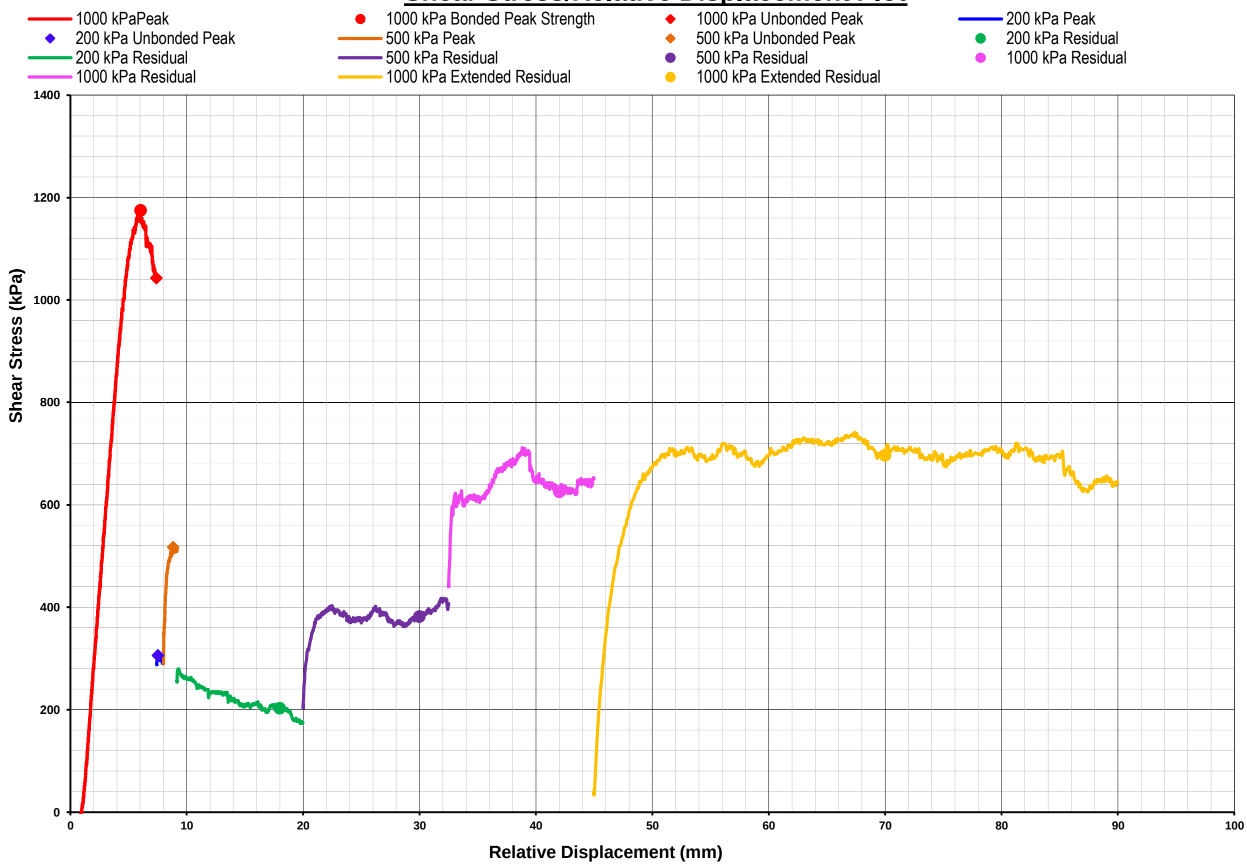
Client	SMEC Australia Pty Ltd	**Report No.**	19070516- DS

Peak & Residual Vertical Displacement/Relative Displacement Plot



Shear Stress/Relative Displacement Plot



Notes/Remarks:

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Graph not to scale

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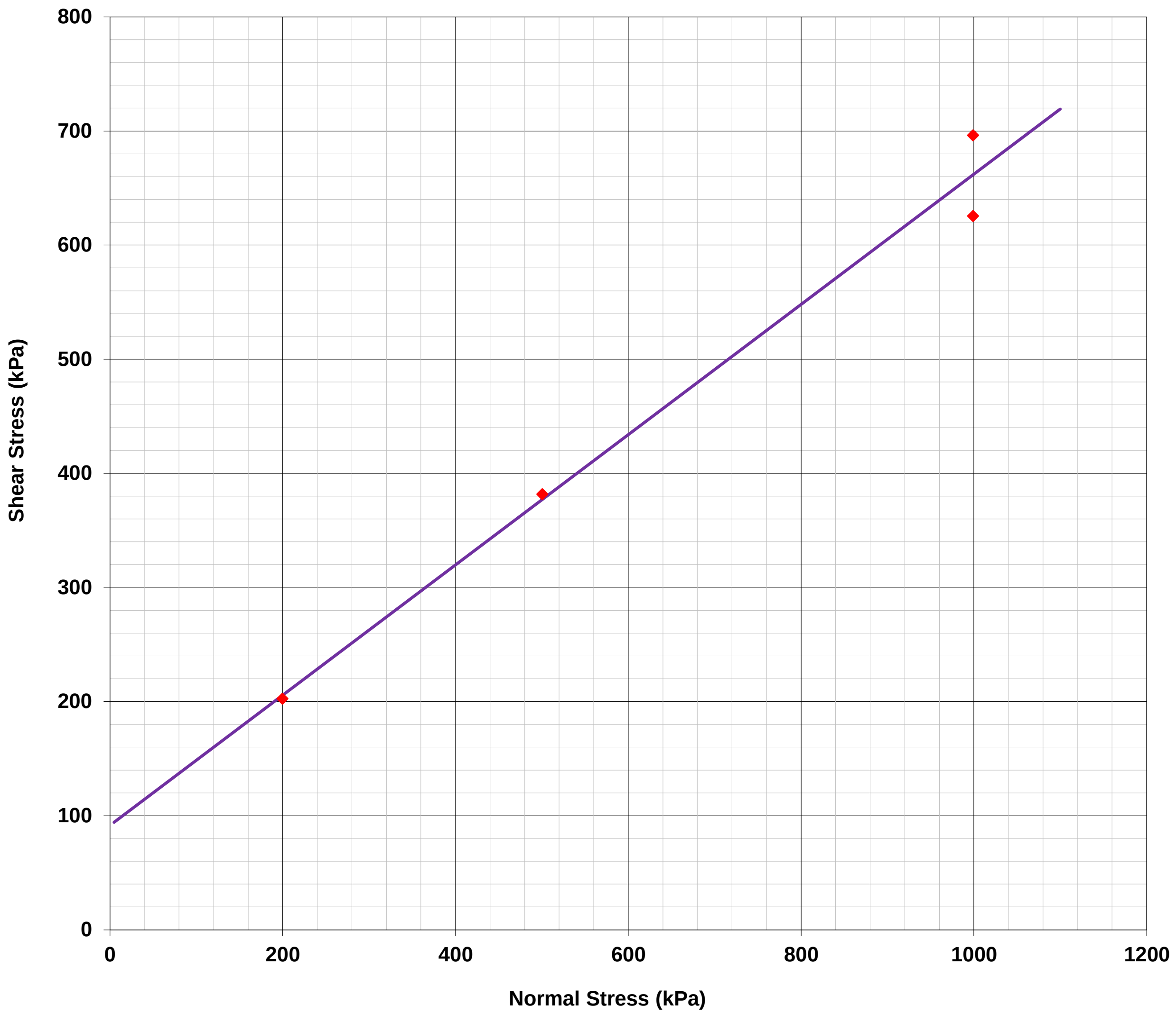
Client	SMEC Australia Pty Ltd	**Report No.**	19070516- DS

Residual - Corrected Normal Stress vs Corrected Shear Unbonded Stress



Residual Unbonded Shear Angle (°)	**29.7**	**Residual Unbonded Cohesion (kPa)**	**91.3**	**R^2 0.992**

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
200 kPa	17.99	199.6	202.4
500 kPa	29.99	500.3	381.5
1000 kPa	42.00	998.9	625.3
500 kPa Extended	69.99	999.1	696.2

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Graph not to scale

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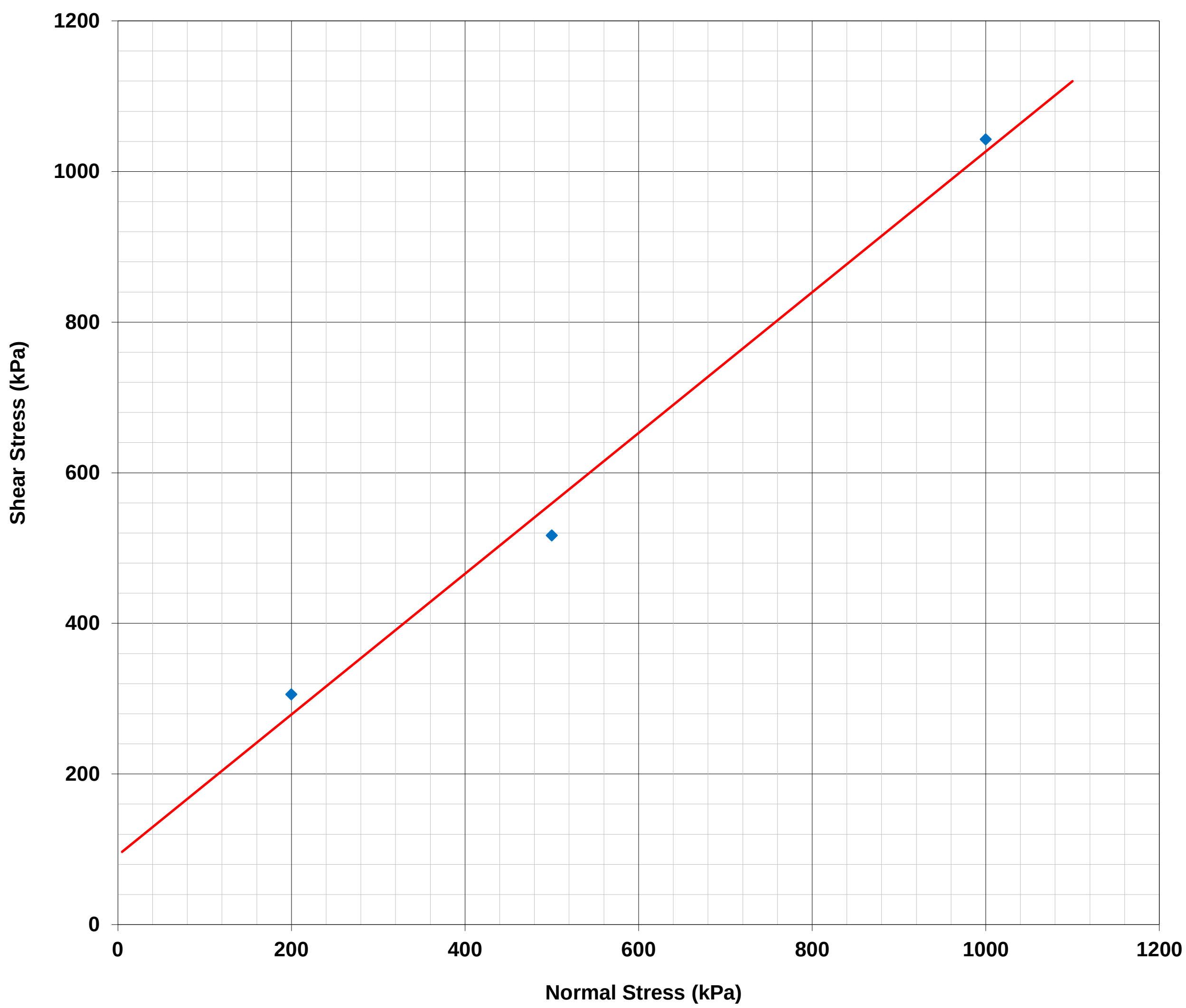
Client	SMEC Australia Pty Ltd	**Report No.**	19070516- DS

Peak - Corrected Normal Stress vs Corrected Unbonded Shear Stress



Peak Unbonded Shear Angle (^{o})	43.1	Peak Unbonded Cohesion (kPa)	92.1	R^2 0.995

	Displacement (mm)	Constant Normal Stress (kPa)	Corrected Shear Stress (kPa)
1000 kPa	7.40	1000.1	1042.7
200 kPa	7.52	199.9	305.6
500 kPa	8.84	500.2	516.8

Notes/Remarks:

Note: Sample tested under constant normal stress, area correction based on square sample equation.

Graph not to scale Sample/s supplied by the client

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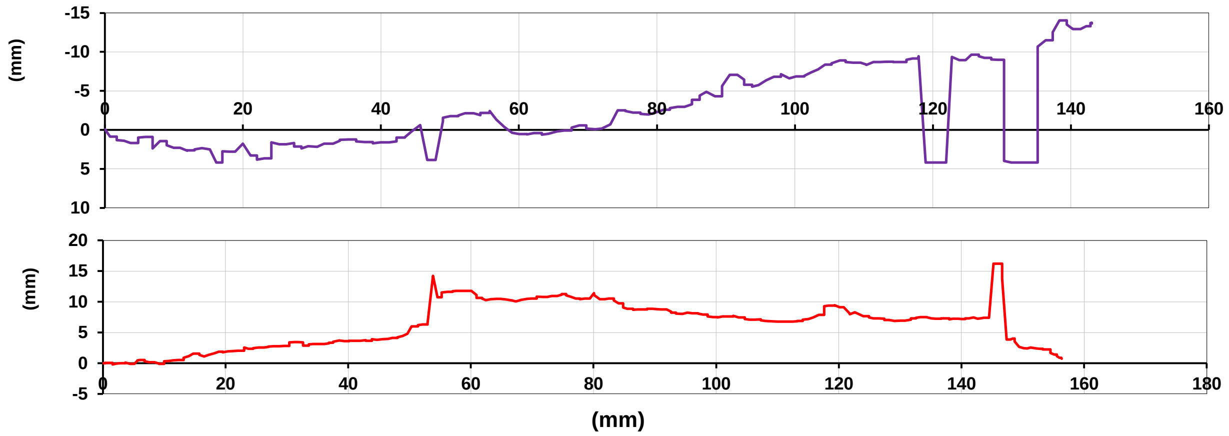
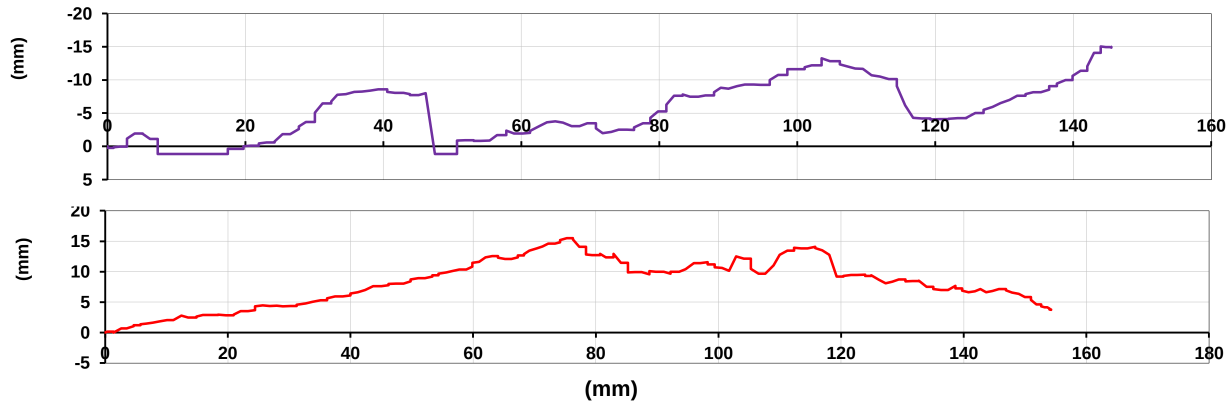
Client	SMEC Australia Pty Ltd	**Report No.**	19070516- DS

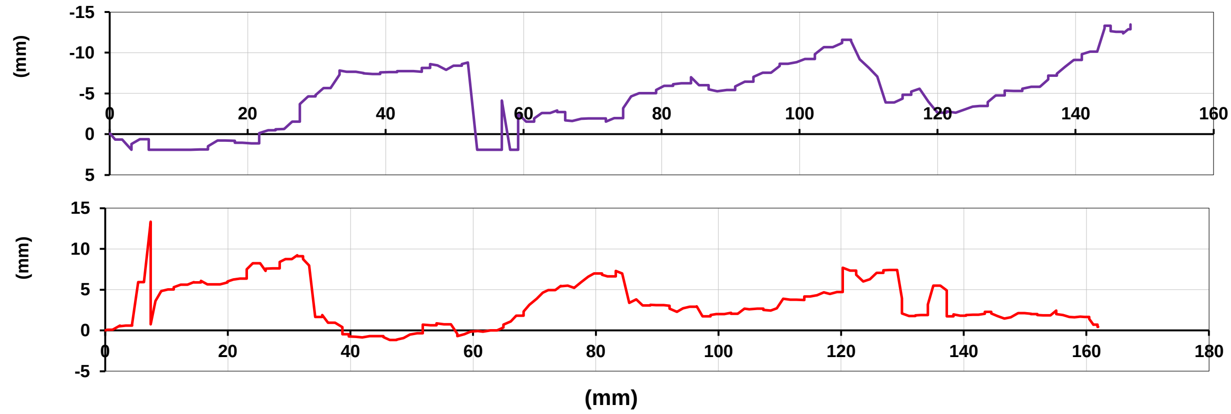
Top and Bottom Profile - Position 1 - After Shearing



Top and Bottom Profile - Position 2 - After Shearing



Top and Bottom Profile - Position 3 - After Shearing



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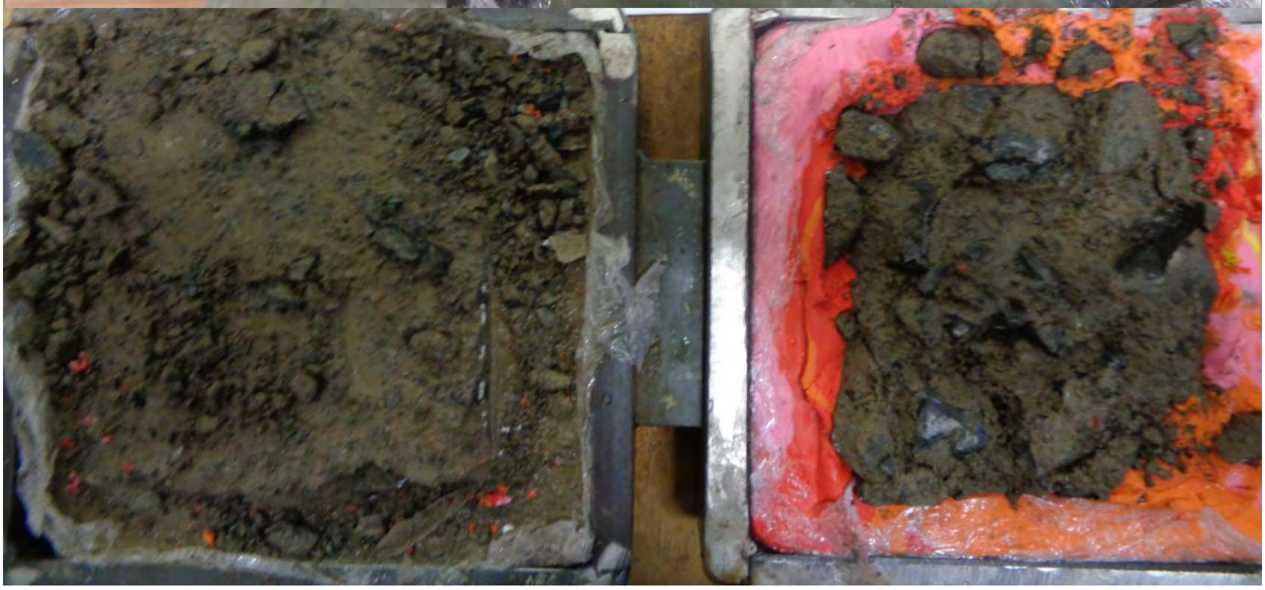

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