Appendix E

Field Investigation & Laboratory Geotechnical Data and Interpretation

December 2019

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ANNEXES

1 INTRODUCTION

1.1 General

This Appendix analyzes the field and laboratory data for the Vale S.A. ("Vale") Córrego do Feijão Mine Dam I ("Dam I") in Brumadinho, Brazil to determine inputs for analyses required as part of the investigation into the failure of Dam I. Some of these parameters could be determined from data collected prior to the failure, such as Cone Penetration Test (CPTu) data. Other parameters required the collection of additional data, which the Panel obtained from two site visits in June and July, 2019, and from laboratory testing. This Appendix summarizes the additional data that were collected, as well as the interpretations that were made. The Appendix should be read together with Appendix B, which summarizes the available data collected prior to the failure.

This Appendix is composed of two parts: (i) a factual portion that summarizes the post-failure field investigations and laboratory testing completed as part of the Panel investigation, and (ii) an interpretative section in which key geotechnical parameters are determined from the current and pre-existing field and laboratory data.

1.2 Summary of Findings

The main findings relevant to the tailings characterization for use in the assessment of potential failure mechanisms and triggers are summarized below:

- The tailings were found to contain a high percentage of iron in the form of hematite, goethite and magnetite.
- The triaxial test data found that the tailings developed an unusual response during shearing. For example, loose tailings samples developed a peak friction angle greater than the critical state friction angle. Dense tailings samples developed a greater amount of dilatancy than typical for other tailings or natural soils.
- This high dilatancy of dense tailings samples led to a very steep stress-strain curve, with a peak undrained strength that is higher than would be estimated from empirical relationships, and a residual undrained (or liquefied) strength that is lower than implied by the empirical relationships.
- While the peak strength of the tailings was found to be higher than would be expected, it was also observed that very little strain (<1%) is required to exceed the peak strength.
- This brittle response is also observable in field vane test data collected prior to the Dam I failure, and laboratory data presented in Appendix B.

- This high peak strength and brittle response is thought to be a reflection of light bonding that was first inferred from CPTu and shear wave velocity (V_s) data and is related to the mineralogy and oxidation of the high iron content tailings.

2 PROGRAM 1 – BULK SAMPLING PROGRAM

2.1 Bulk Sampling Locations

Bulk samples were collected by hand by Klohn Crippen Berger Ltd. (KCB) at various locations across the dam footprint during a site visit conducted on June 4, 2019. The samples collected were intended to be representative of the tailings types impounded in the facility, and residual soil used in construction of some of the containment berms. The samples were excavated by shovel into plastic buckets at each sampling location shown overlain on a pre-failure image of Dam I in Figure 1, and on a post-failure image of Dam I in Figure 2. The sample locations are shown in white on these figures. Representative photographs of the sample locations are shown in Figure 3 to Figure 7, and a summary of sample details and coordinates is listed in Table 1.

Because the samples were intended for use in a laboratory testing program in which the samples would be reconstituted to pre-determined densities, the samples were collected from a range of locations, representative of the range of tailings and dam construction materials. These samples were classified according to the following scheme that was developed for the materials described throughout this Appendix, based on their gradation and position within the impoundment, within containment berms or within the foundation:

- Coarse Tailings – Gradation is dominantly sand-size on particle size distribution (PSD) plots.
- Fine Tailings – Gradation is dominantly silt-size on PSD plots.
- Slimes – Any material that is upstream of the Slimes boundary that is defined in Appendix F and was determined through air photograph and CPTu interpretation.
- Compacted Berm Fill (Tailings) – Containment berm composed of compacted tailings.
- Compacted Berm Fill (Residual Soil) – Containment berm composed of compacted residual soil.
- Residual Soil/Colluvium – Native soil beneath or adjacent to Dam I.

Some observations made while collecting the samples were:

- The exposures of slimes samples (S1 and S2) showed no noticeable structure, except for fine laminations reflecting the sequential deposition, so bulk samples were taken from two locations.
- The coarse tailings showed distinct layering (on a scale of 10s of centimeters (cm)). Bulk samples were taken of the materials at locations S3, S4, S5 and S6. At location S6, two subsamples were also taken on individual beds in an effort to identify the variation in grain size

across these two example beds. These samples were classified as coarse tailings because they were dominantly coarse; however, they contained sufficient fine layers that this material could be subsampled to bound the range of tailings gradations in the tailings beach in later triaxial testing.

The coarse tailings samples were taken from exposed surfaces of intact tailings that represent beach tailings from previous raises below the final dam.

All samples were sealed in plastic sampling bags and then placed in 10-gallon plastic buckets and shipped to KCB’s laboratory in Vancouver for testing. The results of the index and advanced laboratory tests performed on these samples are summarized in Sections 4 and 5 of this Appendix.

Figure 1: View of Sample Locations Overlain on a Pre-Failure Image of Dam I

Figure 2: View of Sample Locations Overlain on a Post-Failure Image of Dam I

Figure 3: Slimes Sampled at Location S1

Figure 4: Slimes Sampled at Location S2

Figure 5: Coarse Tailings Sampled at Location S6a (Left Image) and S6b (Right Image)

Figure 6: Example of Layering Observed within Coarse Tailings

Figure 7: Compacted Residual Soil Sampled at Location S7

Table 1: Sample Details

Location ID	Sample No. – Tailings Type	UTM Coordinates (SIRGAS 2000, Zone 23S)	Comments	Approx. Weight (kg)
S1	bag 1 - Slimes	590,542 E, 7775217 N	Bucket 1 of 10	20
	bag 2 - Slimes		Bucket 1 of 10	
	bag 3 - Slimes		Bucket 2 of 10	15
	bag 4 - Slimes		Bucket 2 of 10	
S2	bag 1 - Slimes	592285 E, 7775206 N	Bucket 3 of 10	15
	bag 2 - Slimes		Bucket 3 of 10	
S3	bag 1- Coarse Tailings	591792 E, 7775188 N	Bucket 4 of 10	25
	bag 2 - Coarse Tailings		Bucket 4 of 10	
S4	bag 1 - Coarse Tailings	591798 E, 7775203 N	Bucket 5 of 10	20
	bag 2 - Coarse Tailings		Bucket 5 of 10	
	bag 3 - Coarse Tailings		Bucket 6 of 10	10
S5	bag 1 - Coarse Tailings	591791 E, 7775196 N	Bucket 7 of 10	25
	bag 2 - Coarse Tailings		Bucket 7 of 10	
S6a	bag 1 - Coarse Tailings	591804 E, 7775194 N	Bucket 8 of 10	20
	bag 2 - Coarse Tailings		Bucket 8 of 10	
S6b	bag 1 - Coarse Tailings	591804 E, 7775194 N	Bucket 9 of 10	10
	bag 2 - Coarse Tailings		Bucket 9 of 10	
	bag 3 - Coarse Tailings		Bucket 9 of 10	
S7	bag 1 – Compacted Berm Fill (Residual Soil)	591788 E, 7775211 N	Bucket 10 of 10	10
	bag 2 – Compacted Berm Fill (Residual Soil)		Bucket 10 of 10	

3 PROGRAM 2 – FIELD INVESTIGATION PROGRAM

3.1 Scope of Field Investigation

A field investigation was requested by the Expert Panel to address data gaps that had been identified. This investigation was completed in July 2019. The field tests/activities conducted as part of this investigation were:

- Guelph permeameter tests to measure near-surface *in situ* hydraulic conductivity within the tailings and compacted berm fill types.
- Tensiometer tests to measure *in situ* suction at the locations of the Guelph permeameter tests.
- Sand-replacement density tests to measure *in situ* density at the locations of the Guelph permeameter tests.

- Flow measurements in the streams flowing through the current valley of Dam I to provide an approximate estimate of the water seeping into the facility from the natural ground during this time of year.
- Drilling/sampling of the natural soil beneath the dam to collect intact samples.

The test/drill hole locations are shown on Figure 1 of Annex 1.

Disturbed samples were collected from every Guelph permeameter and in-situ density test location and were delivered on completion of the field program to KCB's Vancouver laboratory for index testing. Index test results are presented in Section 4.

3.2 Guelph Permeameter Testing

A total of 16 tests were completed on the Dam I tailings and remnant berms, as shown in Figure 2 of Annex 1. Of the 16 tests, five were completed in Fine Tailings, five in Compacted Berm Fill (Tailings), four in Compacted Berm Fill (Residual Soil), and two in Slimes. Tests were completed on intact areas of the remnant dam and only the locations shown on Figure 2 of Annex 1 were accessible. No intact areas of coarse tailings were accessible. Tests were conducted in accordance with ASTM[1] D5126-16. A typical test setup is shown in Figure 3 of Annex 1.

Test results summarizing saturated hydraulic conductivities (K_{sat}) calculated from the Guelph Permeameter tests are shown in Table 2.

---

[1] ASTM is an international standards organization that develops voluntary technical standards for various materials, products, systems, and services. https://www.astm.org/

Table 2: Guelph Permeameter Test Results (Hydraulic Conductivity, K_{sat})

Material Type	Guelph Permeameter ID	[3]Hydraulic Conductivity, Ksat (cm/s)
Fine Tailings	GP-02B	$2.5x10^{-4}$
	GP-08	$7.7x10^{-4}$
	GP-12	$6.2x10^{-4}$
Compacted Berm Fill (Tailings)	GP-03	$5.6x10^{-5}$
	GP-10	$3.1x10^{-4}$
	GP-06	[1]$3.2x10^{-3}$
	GP-16	$3.9x10^{-3}$
Compacted Berm Fill (Residual Soil)	GP-07	[1]$1.4x10^{-4}$
	GP-05	[1]$9.1x10^{-6}$
	GP-09	$2.5x10^{-5}$
	GP-11	$4.5x10^{-4}$
	[2]GP-14	$6.2x10^{-4}$
Slimes	GP-01	$3.1x10^{-5}$
	GP-04B	[1]$2.3x10^{-4}$
	GP-13	$4.9x10^{-5}$
	GP-15	$1.2x10^{-4}$

NOTES:

[1] Steady-state conditions not established during test. Results provided represent the calculated hydraulic conductivity at the end of the test.

[2] Measured hydraulic conductivities indicate the material is within the range of Compacted Berm Fill (Residual Soil). However, the particle size distribution test results and the visual description from field notes indicate that the gradation is more similar to Compacted Berm Fill (Tailings). As a result, GP-14 and DT-12 (the corresponding Sand Replacement Density test location) have been classified as Compacted Berm Fill (Tailings & Residual Soil).

[3] Hydraulic Conductivity measurements utilized the "Single Head Method 1 & 2" outlined in SoilMoisture's Operating Instructions manual.

3.3 Tensiometer Tests

Tensiometer tests were completed within 1.5 m of each Guelph permeameter test location (ground conditions permitting), at 13 locations (shown in Figure 2 of Annex 1). The tensiometer was left in the ground for the duration of each Guelph permeameter test or until the dial had stabilized to allow for a reading to be taken. In the case of GP-04, the ceramic tip broke during testing and the test could not be completed.

A summary of the tensiometer test results is shown in Table 3.

Table 3: Tensiometer Test Results

Guelph Permeameter Test ID	Tensiometer Reading (kPa)	Guelph Permeameter Test ID	Tensiometer Reading (kPa)
GP-01[1]	-	GP-10	10
GP-02[1]	-	GP-11	15
GP-03	15-10	GP-12	15
GP-04	-	GP-13	10
GP-05	22-21	GP-14	20
GP-06	12-10	GP-15	13
GP-07	13	GP-16	22
GP-08	10-15		
GP-09	20		

NOTES:

[1] Due to logistical interruptions at the beginning of Program 2, tensiometers tests could not be completed at GP-01 and 02.

3.4 Sand-Replacement Density Tests

Sand-replacement density tests were conducted within 1.5 m of 14 Guelph permeameter test locations, as shown in Figure 4 of Annex 1 (a single density test was completed adjacent to GP-04A and GP-04B). Of the 14 tests, four were completed in Fine Tailings, five in Compacted Berm Fill (Tailings), four in Compacted Berm Fill (Residual Soil), and two in Slimes. Tests were conducted in accordance with ASTM D1556/D1556M and the Brazilian standard NBR[2] 7185:2016. Typical test setups are shown in Figure 5 and 6 in Annex 1.

A summary of the unit weights calculated from the sand-replacement density tests is shown in Table 4.

---

[2] NBR (Normas Brasileiras Regulamentadoras) standards are technical standards published by the Brazilian Association of Technical Standards, or Associação Brasileira De Normas Técnicas (ABNT) as it is known in Portuguese. https://www.abnt.org.br/

Table 4: Sand-Replacement Density Test Results

Material	Test I.D.	Moist Unit Weight (kN/m³)	Dry Unit Weight (kN/m³)
Fine Tailings	DT-06	21.5	19.4
	DT-10	19.6	16.4
Compacted Berm Fill (Residual Soil)	DT-03	17.0	13.8
	DT-05	20.3	17.0
	DT-07	17.8	14.0
	DT-09	15.1	12.0
	[1]DT-12	15.0	24.1
Compacted Berm Fill (Tailings)	DT-04	24.9	23.7
	DT-08	24.7	17.1
	DT-13	19.3	13.0
	DT-15	24.0	23.2
Slimes	DT-01	22.8	17.8
	DT-02	20.5	17.0
	DT-11	16.4	13.7
	DT-14	18.4	16.2

NOTES:

[1] Measured moist densities indicate the material is within the range of Compacted Berm Fill (Residual Soil) material. However, the particle size distribution test results indicate that the gradation is more similar to Compacted Berm Fill (Tailings). As a result, DT-12 and GP-14 (the corresponding Guelph Permeameter test location) have been classified as Compacted Berm Fill (Tailings & Residual Soil).

3.5 Monitoring Flow Through Current Valley

Surficial flow measurements were made at nine locations across three seepage streams observed in the current valley of Dam I, shown in Figure 7 of Annex 1, that appeared to capture most of the flow from the current dam remnants. The dam remnants appeared visually dry and no significant flow was observed from the tailings on the left abutment, away from the known location of pre-existing streams. Consequently, it was assumed that most of the water flowing through these streams originated from the springs known to exist before the Dam I construction. Rates of flow were measured by creating a rough weir, if necessary, using tailings from the ground adjacent to the stream and recording the amount of time required to fill a 3.6 L bucket using the water flowing through the weir. This was a relatively crude approach and provides only an approximate measure of the flow rate. Typical setups for these tests are shown in Figures 8 and 9 of Annex 1. Flow rate measurements began on July 5, 2019 and were conducted almost daily for the remaining 18 days of the field investigation program. Both morning and evening flow measurements were conducted, for a total of 60 measurements.

A summary of the flow measurements is given in Table 5.

Table 5: Flow Rate Measurements

Date	**Flow Rate (L/s)**																
	Stream 1					**Stream 2**					**Stream 3**					**Total**	
	Location I.D	**Easting (m)**	**Northing (m)**	**Morning Reading (L/s)**	**Evening Reading (L/s)**	**Location I.D**	**Easting (m)**	**Northing (m)**	**Morning Reading (L/s)**	**Evening Reading (L/s)**	**Location I.D**	**Easting (m)**	**Northing (m)**	**Morning Reading (L/s)**	**Evening Reading (L/s)**	**Morning Reading (L/s)**	**Evening Reading (L/s)**
05-Jul-19	-	-	-	-	-	-	-	-	-	-	3A	591861	7774951	1.46	-		
06-Jul-19	-	-	-	-	-	-	-	-	-	-	3B	591868	7774979	0.97	1.87		
07-Jul-19	-	-	-	-	-	-	-	-	-	-	3C	591866	7774972	1.80	1.26		
08-Jul-19	-	-	-	-	-	-	-	-	-	-	3D	519896	7774988	1.50	0.96		
09-Jul-19	-	-	-	-	-	-	-	-	-	-	3E	591911	7774999	1.34	1.48		
10-Jul-19	-	-	-	-	-	-	-	-	-	-	3F	591908	7774978	0.89	1.24		
11-Jul-19	-	-	-	-	-	-	-	-	-	-				0.91	-		
12-Jul-19	-	-	-	-	-	-	-	-	-	-				-	-		
13-Jul-19	-	-	-	-	-	-	-	-	-	-				0.96	-		
14-Jul-19	-	-	-	-	-	-	-	-	-	-	3G	591942	7775012	0.88	0.93	**0.88**	**0.93**
15-Jul-19	1A	591812	7774972	0.04	0.06	2A	591868	7775002	0.22	0.33				0.96	0.80	**1.21**	**1.19**
16-Jul-19				0.08	0.10				0.32	0.40				0.47	1.22	**0.86**	**1.72**
17-Jul-19				0.11	0.13				0.16	0.46				0.98	1.61	**1.26**	**2.20**
18-Jul-19				0.12	0.11				0.38	0.33				1.56	1.46	**2.06**	**1.90**
19-Jul-19				0.11	0.12				0.21	0.25				0.83	1.38	**1.15**	**1.75**
20-Jul-19				0.10	-				0.15	-				1.01	-	**1.25**	**-**
21-Jul-19				0.08	0.10				0.28	0.32				0.89	1.11	**1.26**	**1.54**
22-Jul-19				0.11	0.12				0.21	0.21				1.13	1.08	**1.45**	**1.40**
Average				*0.09*	*0.11*	*Average*			*0.24*	*0.33*	*Average*			*1.09*	*1.26*	**1.42**	**1.70**

3.6 Drilling and Sampling of the Foundation Soils

Four boreholes were completed as part of the July 2019 field investigation, located as shown in Figure 10 of Annex 1. Drilling was advanced using a track-mounted hydraulic rotary rig (shown in Figures 11 and 12 of Annex 1), with water as the drilling lubricant. The drilling methodology was:

- Positioned drilling rig at each borehole location using a handheld GPS.
- Drilled in 1 m depth intervals, extracting and logging core (see Figures 13 and 14 of Annex 1).
- Conducted standard penetration tests (SPTs) at 1 m depth intervals within the compacted fill above the foundation (see Figures 15 and 16 of Annex 1).
- Collected Shelby tube samples using a hydraulic piston sampler in the foundation soils. A total of 12 samples were collected. Sampling was terminated once recovery was less than 50%. Shelby tubes were collected from all boreholes except BH-03 as the natural ground was not reached at this location. Once the samples were recovered, they were maintained in an upright position. The ends of the tube samples were sealed with wax after extraction from the borehole (see example in Figure 17 of Annex 1). The Shelby tubes were then transported to KCB's Vancouver laboratory in a wooden box that conforms to ASTM D4220-14 (see Figure 18 of Annex 1).

Borehole logs, including locations, are presented in Annex 1. A summary of the borehole details is given in Table 6. Due to the limited accuracy of the handheld GPS device used in the field, the coordinates of the test hole locations should be considered approximate.

Table 6: Borehole As-Built Details

Location ID	Easting (m)	Northing (m)	[1]Estimated Ground Elevation (m)	Date Completed
BH-01	591793	7774986.0	863.7	July 17, 2019
BH-02	591793.4	7774932.6	857.8	July 19, 2019
BH-03	591689.2	7774982.9	870.7	July 23, 2019
BH-04	591797.0	7774937.8	859.0	July 23, 2019

NOTE:
[1] Ground elevation estimated from handheld GPS at the time of drilling and using 2019 LiDAR data.

4 INDEX LABORATORY TESTING

4.1 Scope

The test types, test procedures, and number of tests conducted are given in Annex 2. This section describes the results of the index tests on all material types. The basic objectives of the program were to characterize the index test properties of each material type for comparison with the pre-existing data, and to confirm the representativeness of the samples.

Index tests were conducted on samples collected as part of Program 1 and 2 (refer to Sections 0 and 3). Locations of samples are shown in Annex 1.

The index testing conducted on the soil samples included PSD tests, specific gravity tests, moisture content determination, and Atterberg limit tests. Additional tests included X-ray diffraction (XRD) analysis and scanning electron microscopy (SEM) imaging. The following index test results are detailed in Annex 3.

4.2 Particle Size Distribution

A total of 44 PSD tests were completed on samples collected from Program 1 and 2. These tests were conducted in accordance with the ASTM D422. The following PSD tests were conducted:

- 12 PSD tests on Coarse Tailings
- two PSD tests on Fine Tailings
- 10 PSD tests on Slimes
- six PSD tests on Compacted Berm Fill (Residual Soil)
- six PSD tests on Compacted Berm Fill (Tailings)
- eight PSD tests on Foundation material collected from Shelby Tube samples

The results are shown on Figure 8 to Figure 13.

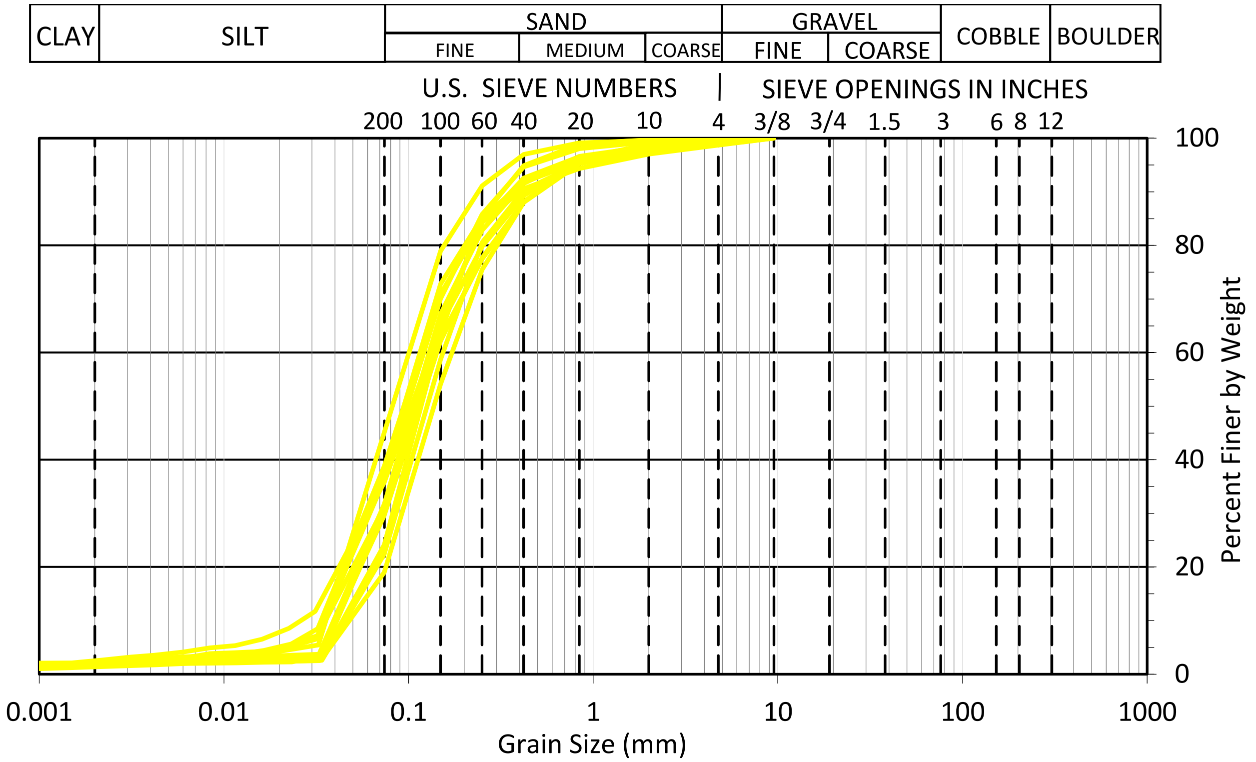


Figure 8: PSD Curves of Coarse Tailings Samples

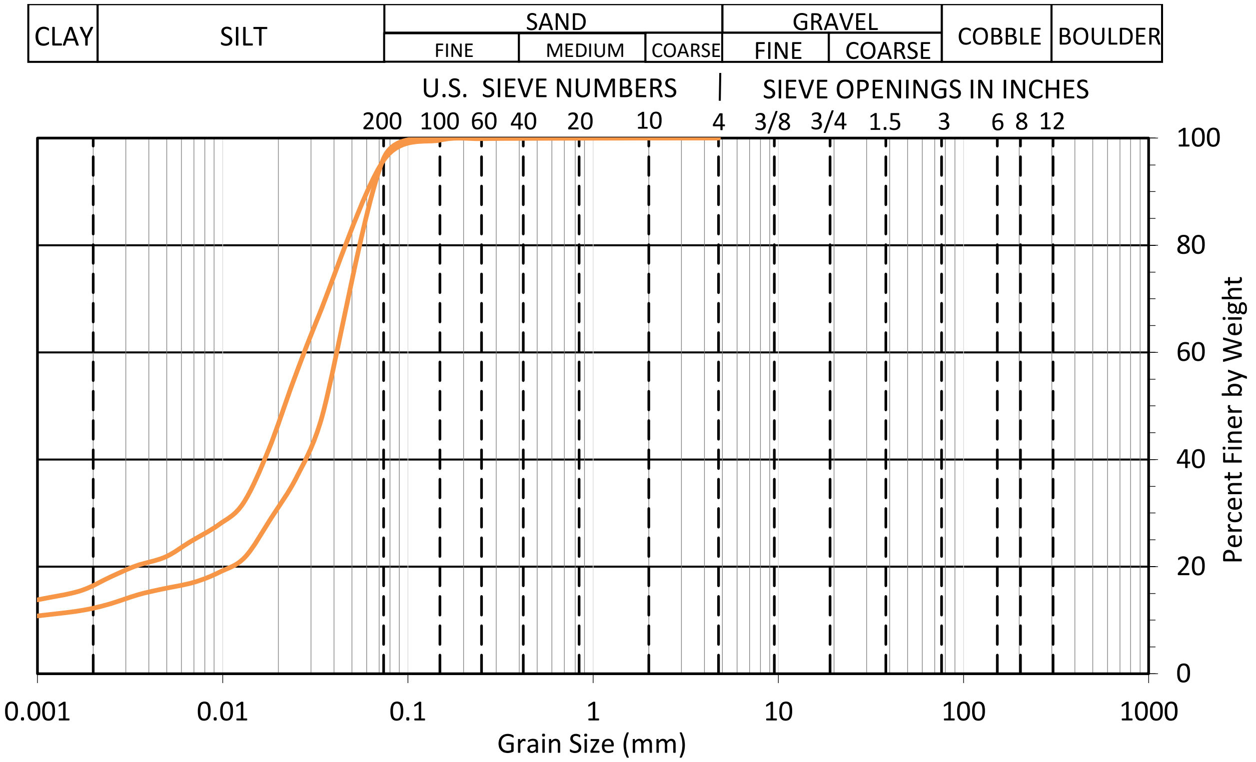


Figure 9: PSD Curves of Fine Tailings Samples

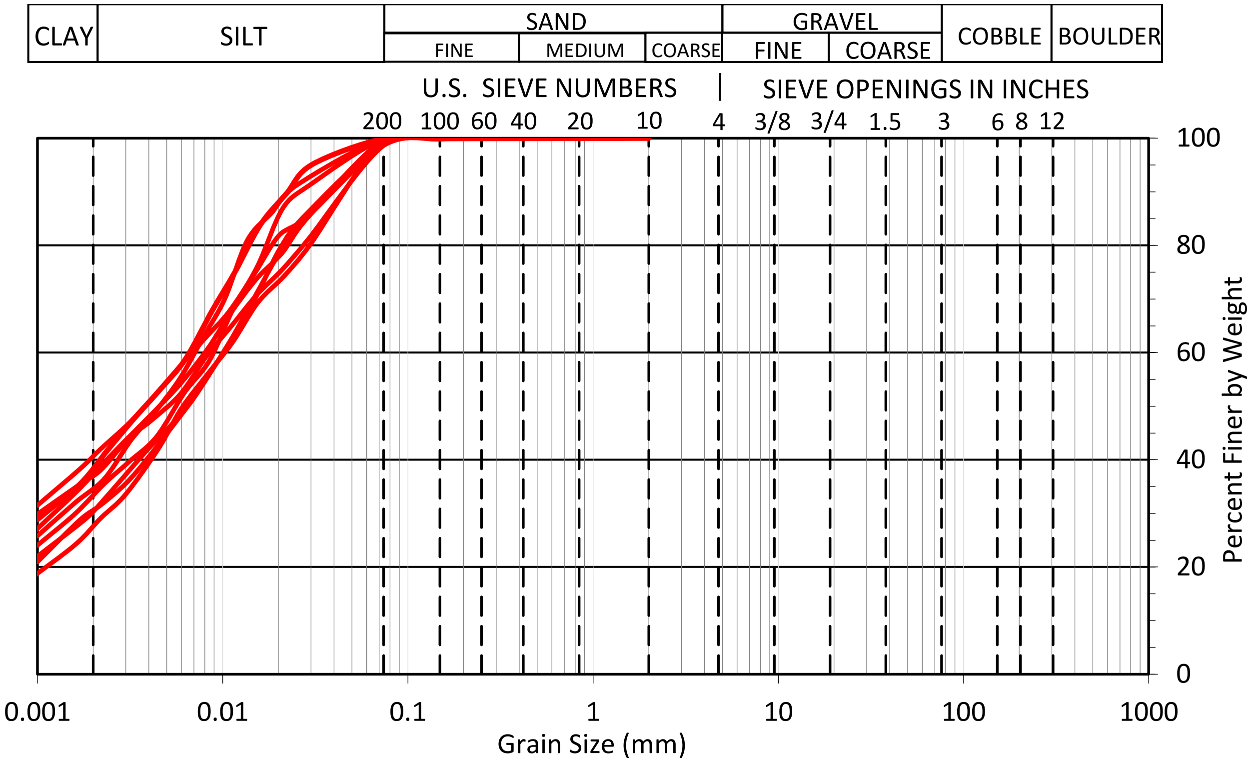


Figure 10: PSD Curves of Slimes Samples

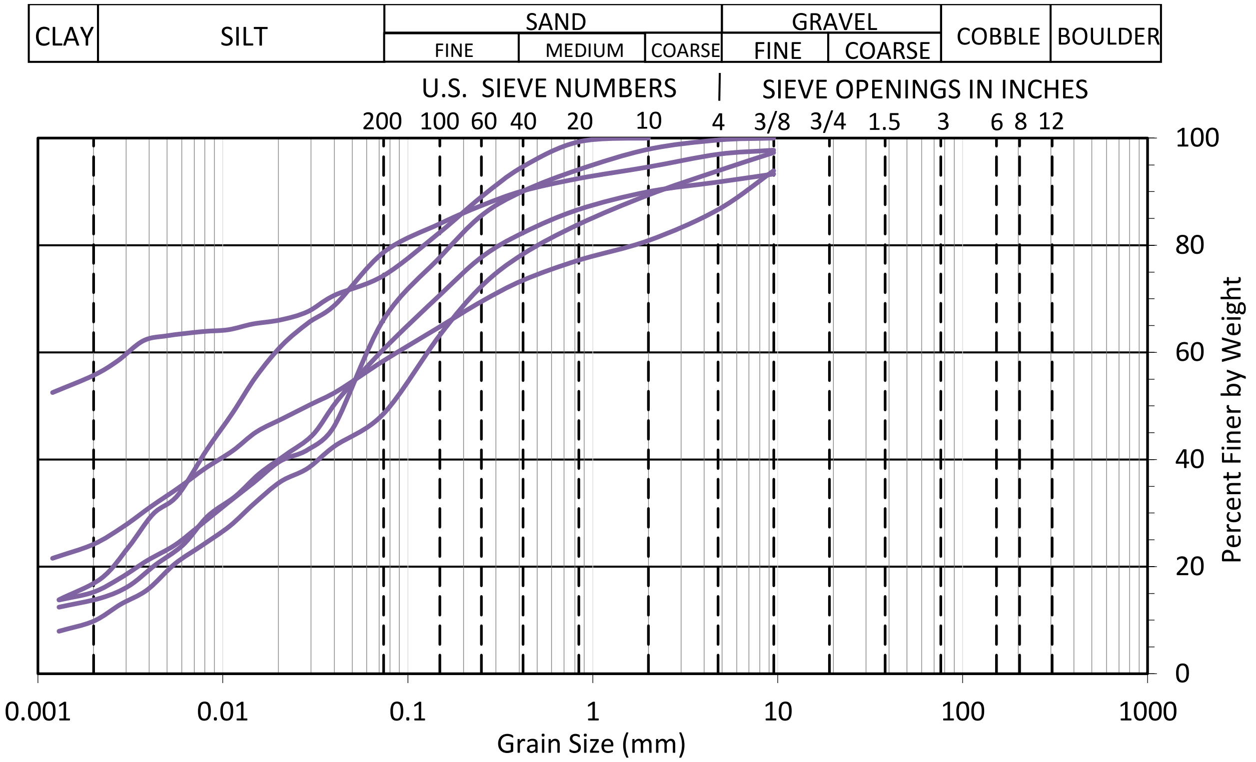


Figure 11: PSD Curves of Compacted Berm Fill (Residual Soil)

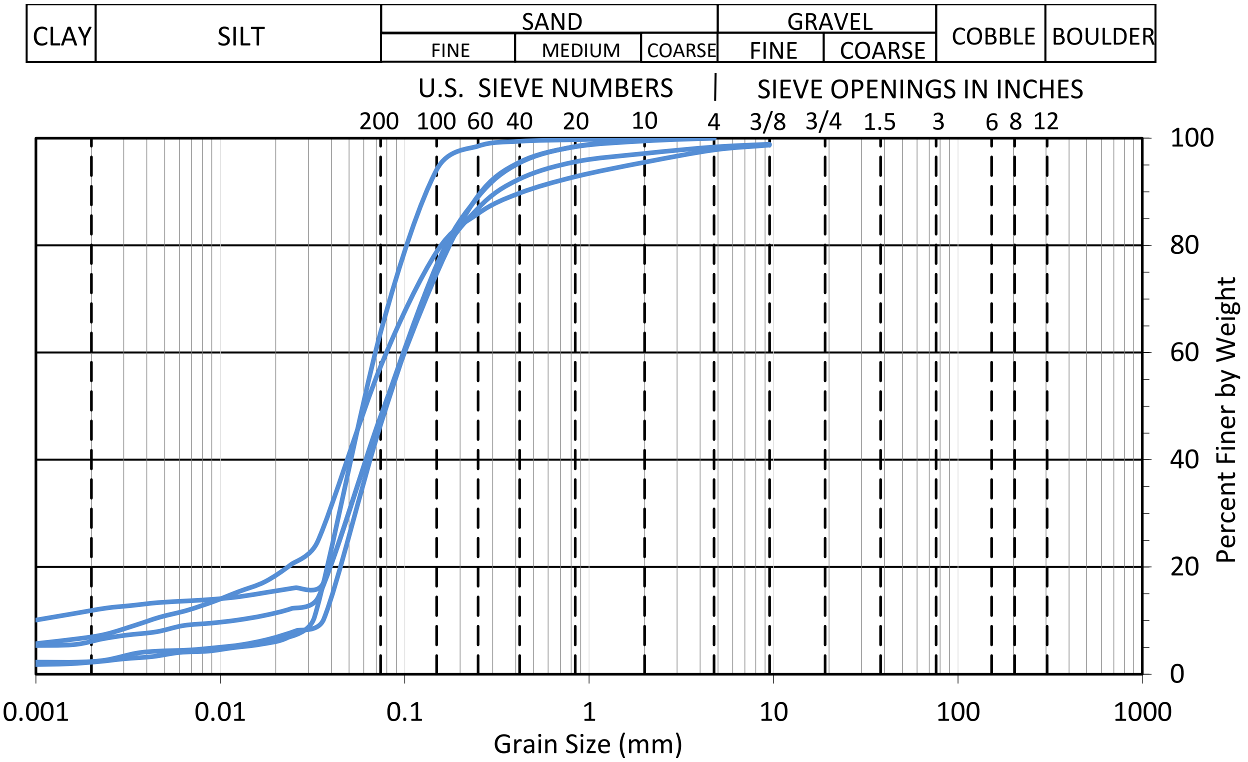


Figure 12: PSD Curves of Compacted Berm Fill (Tailings)

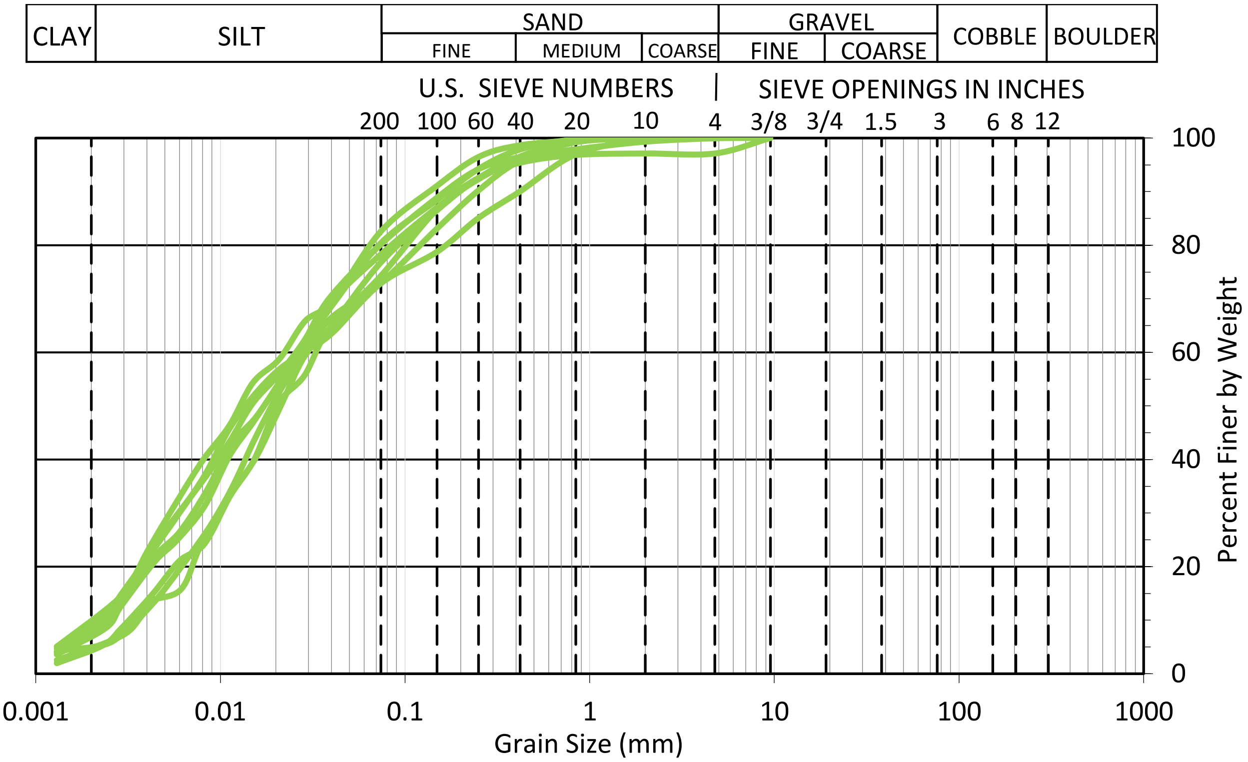


Figure 13: PSD Curves of Residual Soil Samples

4.3 Specific Gravity

29 specific gravity tests were undertaken on the samples collected in Program 1, including 17 on Coarse Tailings, nine on Slimes and three on Compacted Berm Fill (Residual Soil). 14 specific gravity tests were undertaken on the samples collected during Program 2, including four on the Compacted Berm Fill (Tailings), two on the Fine Tailings, four on Compacted Berm Fill (Residual Soil) and four on the Slimes material. Nine specific gravity tests were completed on Foundation material collected from borehole samples from Program 2. The results of these tests are summarized in Table 7.

These tests were conducted to the ASTM D854 standard.

Table 7: Specific Gravity Results

Material	Average Specific Gravity Program 1	Average Specific Gravity Program 2
Coarse Tailings	4.89 (4.64-4.99)	-
Fine Tailings	-	3.89 (3.87-3.90)
Slimes	4.00 (3.92-4.07)	3.91 (3.61-4.32)
Compacted Berm (Residual Soil)	3.14 (3.12-3.16)	2.75 (2.67-2.86)
Compacted Berm (Tailings)	-	4.39 (4.10-4.93)
Foundation Soil	-	2.81 (2.79-2.83)

NOTE:

[1] Values shown in parentheses indicate the range of results (min-max).

4.4 Moisture Content

24 tests were undertaken on samples collected from Program 1 to determine the moisture content of the Fine and Coarse Tailings, Slimes and Compacted Berm samples in the dam remnants. 31 tests were undertaken on samples collected from Program 2 to determine the moisture content of the Fine Tailings, Slimes, Compacted Berm Fill (Tailings), and Compacted Berm Fill (Residual Soil) at the locations of the Guelph Permeameter tests. Six tests were undertaken on Foundation material collected from borehole samples in Program 2. The results of these tests are summarized in Table 8.

These tests were conducted to the ASTM D2216 standard.

Table 8: Summary of Moisture Content Test Results

Material	Average Moisture Content (%) Program 1[2]	Average Moisture Content (%) Program 2[2]
Coarse Tailings	10.2 (5.6-14.8)	-
Fine Tailings	-	19.5 (10.6-31.4)
Slimes	25.9 (22.0-33.7)	24.1 (13.1-36.5)
Compacted Berm (Residual Soil)	19.8 (18.2-22.3)	24.6 (17.1-33.8)
Compacted Berm (Tailings)	-	8.7 (3.4-15.4)
Foundation Soil	-	38.9 (28.3-43.5)

NOTES:

[1] Values shown in parentheses indicate the range of results (min-max).

[2] Air drying method used.

4.5 Atterberg Limits

16 Atterberg limit tests were performed on samples collected during Program 1; eight on Slimes samples collected from the upstream extent of Dam I, and eight on Compacted Berm Fill (Residual Soil). 18 Atterberg limit tests were conducted on samples collected during Program 2. The Liquid limit (WL), Plastic limit (PL), and plasticity index ranges of Fine Tailings from previous testing programs, as summarized in Appendix B, are 18-30%, 14-23%, and 4-7%, respectively. The laboratory test results for Fine Tailings are generally in agreement with previous results.

In addition, eight Atterberg Limit Tests were conducted on Foundation material (residual soil) collected during Program 2.

These tests were conducted to the ASTM D4318 standard, and the results are summarized in Table 9.

Table 9: Atterberg Limit Test Results

Material	Average Atterberg Limit Test Results Program 1			Average Atterberg Limit Test Results Program 2		
	WL	WP	PI	WL	WP	PI
Coarse Tailings	-	-	-	-	-	-
Fine Tailings	-	-	-	21 (19-22)	17 (16-18)	4 (3-4)
Slimes	44 (34-49)	26 (22-31)	18 (12-22)	42 (15-53)	24 (11-30)	18 (4-26)
Compacted Berm (Residual Soil)	34 (30-36)	25 (23-26)	10 (7-11)	52 (35-66)	31 (25-38)	20 (9-28)
Compacted Berm (Tailings)	-	-	-	20 (16-29)	16 (14-18)	4 (1-11)
Foundation Soil	-	-	-	60 (54-68)	41 (33-56)	18 (10-29)

NOTES:

[1] Values shown in parentheses indicate the range of results (min-max).

[2] Samples GP-01/DT-01 and GP-04B/DT-02, collected on the beach of the west abutment, initially targeted Fine Tailings but were subsequently reclassified as Slimes based on the results of field and index testing. This is consistent with satellite images of Dam I, discussed in Appendix F, in which the pond was consistently closer to the dam crest in the west compared to the east.

4.6 X-Ray Diffraction

XRD analyses were conducted at the University of British Columbia (UBC) on samples of Slimes and Coarse Tailings collected during Program 1. XRD results are provided in Annex 4. The tests were intended to identify the mineralogy of the Slimes and Coarse Tailings. Four XRD tests were completed; two on Slimes samples and two on Coarse Tailings samples.

All samples were dominantly hematite (Slimes roughly 40% to 50%; Coarse Tailings roughly 80% to 90%). The Slimes also had a significant percentage of goethite (~30%) and a greater percentage of kaolinite (~5% to 10%), quartz (~5%), talc (~2% to 3%) and bayerite (~2% to 3%) than the Coarse Tailings. The Coarse Tailings contained between roughly 5% and 10% magnetite. Four XRD tests were also competed on samples of Fine Tailings from Program 2. The results of the quantitative phase analysis are provided in Table 10 and show similar mineralogy to the slimes samples from Program 1, with the main exceptions being less goethite (~10% to 20%) and more quartz (~12% to 29%).

The Coarse Tailings samples from Program 1 in June 2019, were representative of tailings at depth within the dam, whereas the samples from Program 2 in July 2019, were representative of surface tailings. The mineralogy of the samples collected in Programs 1 and 2 is within the range of previous sampling and testing at other locations throughout the impoundment, as summarized in Figure 5-32 in Appendix B.

Table 10: XRD Results

Mineral	**Ideal Formula**	**Program 1**				**Program 2**			
		# 1 Sample 1 Bag 2 X-Ray (Slimes)	**# 2 Sample 1 Bag 4 X-Ray (Slimes)**	**# 3 Sample 3 Bag 2 X-Ray (Coarse Tailings)**	**# 4 Sample 5 Bag 1 X-Ray (Coarse Tailings)**	**DT-01 (Fine Tailings)**	**DT-02 (Fine Tailings)**	**DT-06 (Fine Tailings)**	**DT10 (Fine Tailings)**
Hematite	$\alpha\text{-}Fe_2O_3$	50.1	44.4	87.7	86.8	43.1	54.1	50.3	44.3
Goethite	$A\text{-}Fe^{3+}O(OH)$	32.0	34.0	3.4	3.0	20.7	15.3	10.2	13.7
Magnetite	Fe_3O_4	0.4	0.4	6.5	7.6	1.9	1.5	1.3	1.3
Quartz	SiO_2	5.4	6.6	1.6	1.5	14.9	12	28.5	21.8
Kaolinite	$Al_2Si_2O_5(OH)_4$	6.2	8.9	0.6	0.6	11.6	10.9	6.4	13.5
Talc	$Mg_3Si_4O_{10}(OH)_2$	2.7	2.3	-	-	3.1	2	1.4	1.1
Gibbsite	$Al(OH)_3$	0.9	1.0	0.3	0.4	3	2.2	1.4	3
Bayerite	$Al(OH)_3$	2.2	2.4	-	-	1.7	2	0.5	1.4
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

4.7 Scanning Electron Microscope

Samples of Slimes and Coarse Tailings were subjected to scanning electron microscopy (SEM) imaging by UBC using a Philips XL30 electron microscope. Imaging was completed on two Slimes and two Coarse Tailings samples collected during Program 1, to qualitatively assess particle structure, angularity and other parameters at a microscopic level. These tests showed that the particle shape of the Coarse Tailings and Slimes is similar. Both contain typically sub-angular to angular particles, often with a pitted surface.

Examples of these SEM images can be seen in Figure 14 and Figure 15. See Annex 5 for all images.

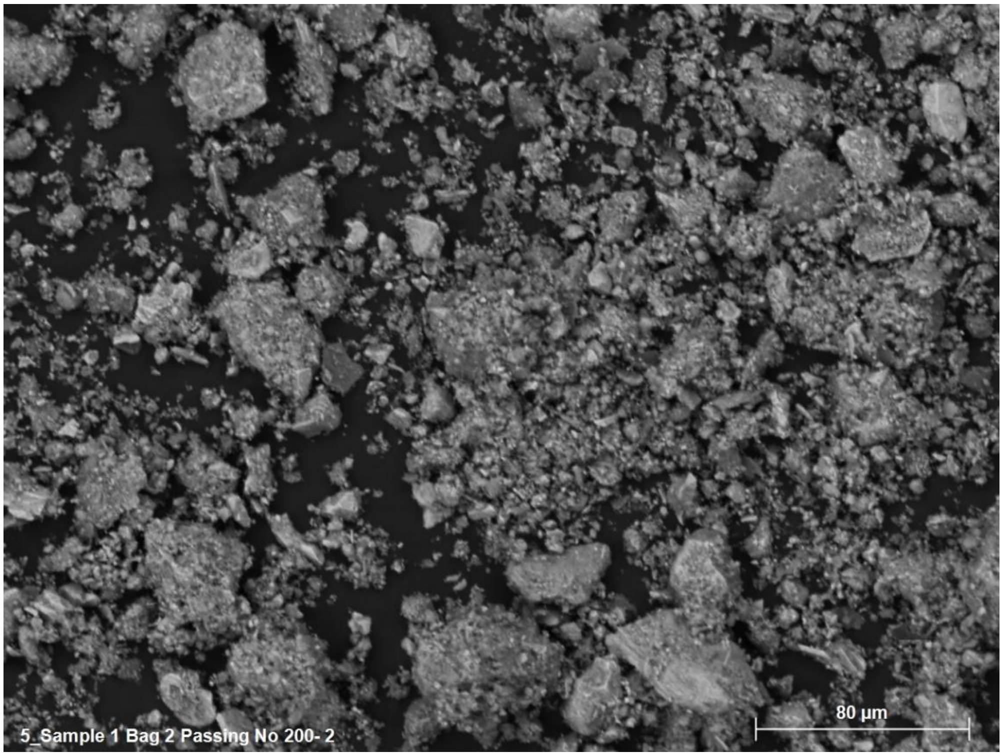


Figure 14: SEM Image of Sample 1 Bag 2 (Slimes) Passing the No. 200 Sieve

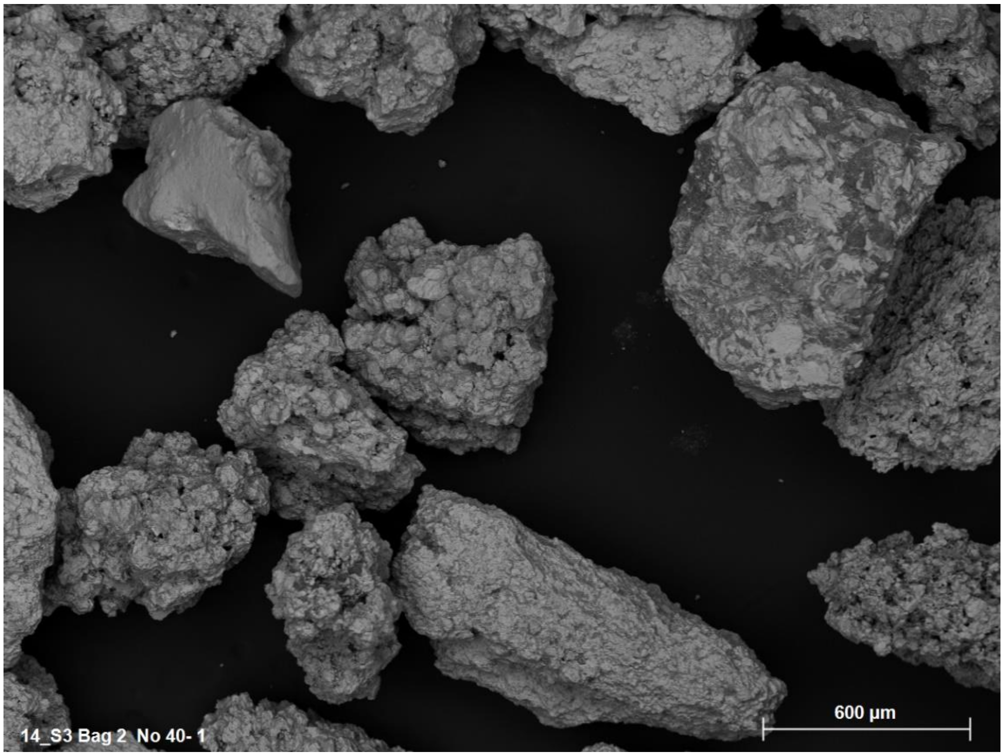


Figure 15: SEM Image of Sample 3 Bag 2 (Coarse Tailings) Retained on the No. 40 Sieve

4.8 Additional SEM Testing

As discussed further in Sections 5 and 6, an additional component of shear strength was observable in the laboratory testing, which was attributed to particle bonding inferred from the V_s data. To better understand this bonding, additional SEM testing was conducted at the University of Queensland in Australia ("UQ").

Samples of Slimes and mixtures of Coarse Tailings, some of which had undergone earlier triaxial testing, were subjected to Secondary Electron (SE) and Back Scattered Electron (BSE) SEM at a micrometer (µm) scale (an increase in scale of 10 to 100 times compared to the SEM conducted at UBC). Fine-grained, clay-sized particles of iron oxide, were shown to act as cements, forming fine particles in the case of the Slimes, bonding smaller particles (10's of µm) to larger particles (100's of µm), and bonding smaller particles together. These cements may be responsible for the additional component of strength observed in the triaxial testing.

The results of the SEM testing completed at UQ are summarized in Annex 6.

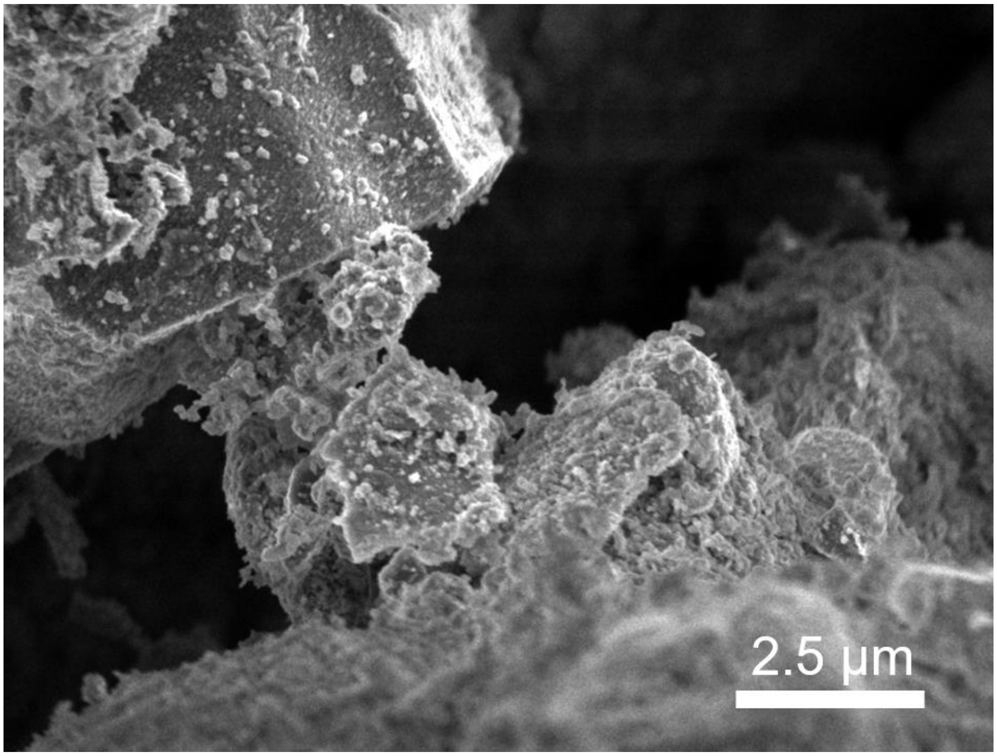


Figure 16: SEM Image of Coarse Tailings Sample Showing Iron Oxide Bonding

4.9 Soil-Water Characterization Curves

Unsaturated permeability testing was completed by the Geotechnical Research Center at the University of Alberta to develop soil-water characteristic curves (SWCCs) for various tailings gradations. The SWCCs were completed using two methods; (i) Tempe cell and (ii) HYPROP 2 device. Tests were completed on samples collected during Program 2 and on a reconstituted sample of Coarse Tailings. A summary of the SWCC testing carried out is shown in Table 11, and is discussed further in Annex 7.

Table 11: SWCC Testing Summary

Material	Sample I.D.	Tempe Cell Method	HYPROP 2 Method
Slimes	DT-01	X	
	DT-02	X	X
Fine Tailings	DT-06	X	X
	DT-10	X	
Coarse Tailings (Reconstituted Sample – Average Gradation)	AG A03255A01	X	X
Compacted Berm Fill (Tailings/Residual Soil)	GP-03/09	X	X
Compacted Berm Fill (Tailings & Residual Soil)	GP-14	X	X

5 ADVANCED LABORATORY TESTING

This section describes the results of advanced laboratory testing performed on reconstituted tailings samples. The test types, procedures and numbers of tests are detailed in Annex 2. The objective of this testing program was to develop engineering parameters for use in analyses by the Panel.

5.1 Reconstituted Samples

Reconstituted samples were prepared from the bulk samples of Coarse Tailings collected in Program 1. This involved combining the bulk samples, sieving them and then separating them into component grain sizes. These individual components were then recombined in the required proportions and mixed thoroughly to create any of the representative gradations discussed below. The gradation of reconstituted samples was confirmed through another PSD test prior to and after testing. The PSD test results for all advanced testing performed on reconstituted tailings samples are provided in Annex 8.

One of the main parameters of interest during this program was the slope of the critical state line (CSL) for various tailings gradations. Due to the potential impact of fines on the CSL, it was decided to develop CSLs for representative gradations. In the first instance, the Average gradation of the tailings from the laboratory tests previously completed at the site was used as the representative gradation. In order to assess the impact of variations of fines content on the CSL, representative samples of the 20th (Coarse) and 80th (Fine) percentiles from previous laboratory testing were also reconstituted and tested. Table 12 summarizes the representative gradations tested. As a comparison, the reconstituted gradation curves were overlain onto historical PSD curves, summarized in Appendix B, as shown in Figure 17. The comparison shows that the reconstituted gradations are in general alignment with the gradations of historical tailings samples.

Table 12: Gradations of Representative Samples

Sieve Opening Size (mm)	U.S. Sieve No.	Percent Finer (%) - Average	Percent Finer (%) -Fine	Percent Finer (%) -Coarse
9.51	3/8 inches	100.0	100	100
4.76	4	100.0	100	99.2
2	10	99.0	100	96.8
0.841	20	97.0	100	91.2
0.42	40	92.5	100	79.2
0.25	60	84.5	100	67.2
0.149	100	72.0	88	55
0.074	200	51.5	71.2	32.8

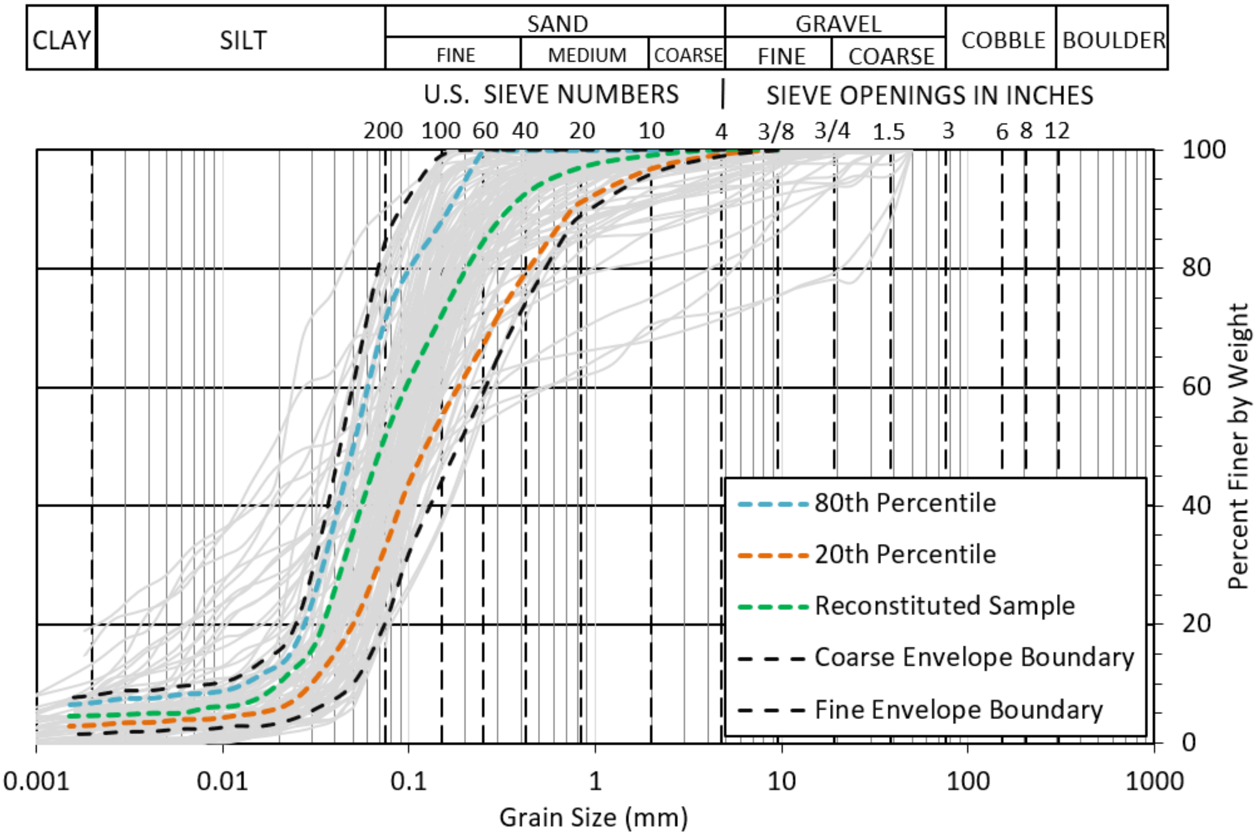


Figure 17: Reconstituted Gradations of the Fine, Coarse and Average Tailings

5.2 Triaxial Compression Testing

5.2.1 Scope

35 triaxial tests were completed, including:

- 22 standard strain-controlled isotropically consolidated drained (CID);
- two standard strain-controlled isotropically consolidated undrained (CIU);
- eight standard strain-controlled anisotropically consolidated undrained (CAU);
- one dead load-controlled anisotropically consolidated undrained (CAU-DL);
- one dead load-controlled anisotropically consolidated undrained with creep (CAU-DL-C); and
- one dead load-controlled anisotropically consolidated drained (CAD-DL).

Tests were performed on loose and dense reconstituted samples of the three representative gradations (Fine, Coarse and Average). The samples were tested at initial mean effective stresses (*p*′) ranging from 40 kilopascals (kPa) to 1500 kPa.

The main objective of the triaxial testing program was to determine the critical state line (CSL) of the various representative tailings gradations. Additional tests were completed on samples significantly dense of the CSL to develop dilatancy parameters, and a series of undrained triaxial compression tests was completed to assess trends in peak and residual undrained strengths.

5.2.2 Procedure for Standard Strain-Controlled Triaxial Test

The standard strain-controlled triaxial tests were conducted to the ASTM D4767-11 (CIU/CAU) and ASTM D7181-11 (CID/CAD) standards. The reconstituted samples were consolidated to the required mean effective stress level. This consolidation phase was followed by the shearing phase under either drained or undrained conditions (CID/CAD or CIU/CAU), using strain-controlled loading. Initial testing targeted initial void ratios for loose and dense states by using measured void ratios from previous sampling at the site. Initial void ratios for samples intended to be loose and dense were taken as the 80th and 20th percentile of the historical range, respectively, of samples of similar gradation to those of the Average gradation. Once an initial suite of triaxial tests had been completed to determine the CSL, this combined with the estimated state parameter from pre-failure CPTu tests, allowed the Panel to specify void ratios for the remainder of the laboratory testing.

Samples were prepared by moist tamping in general accordance with the procedure outlined by Jefferies and Been (2016).[3] Additionally, samples were prepared in 11 horizontal layers and volume change was measured throughout the test (see Figure 18). A washed sieve analysis was completed on each specimen prior to each triaxial test. After the triaxial tests were completed, the specimens, together with the top and bottom platens, were frozen for an accurate determination of moisture content. This moisture content was then used to calculate the final void ratio, assuming fully saturated conditions which was compared with the void ratio tracked during testing. After testing, the gradation of each triaxial sample was re-tested to assess if grain crushing had occurred. The test results are provided in Annex 8.

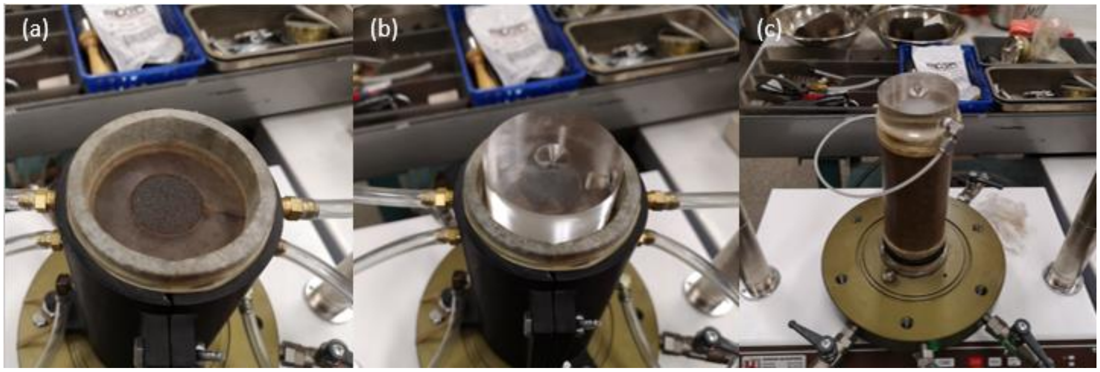


Figure 18: Triaxial Test Setup: (a) Modified Porous Stone; (b) Specimen Placement by Moist Tamping, (c) Final Specimen Set Up

---

[3] Jefferies, M.,& Been, K. (2016). *Soil liquefaction: A critical state approach* (2nd ed.). London: Taylor & Francis.

5.2.3 Procedure for Dead-Load Controlled Triaxial Test

Dead-load controlled triaxial test samples were prepared in the same way as the standard triaxial testing samples, to achieve a uniform initial void ratio. After saturation, the samples were consolidated anisotropically to the target mean effective stress (p') and deviator stress (q). At the end of the anisotropic consolidation phase, the vertical load was replaced with a deadweight, and all pumps were switched to manual control. The vertical load was increased by adding 500 g sand bags in the four plastic buckets attached to the loading frame, and the actual load increment was measured by the load cell. For the drained test (CAD-DL), when the sample displacement and volume stopped changing, another load increment was added. For the undrained test (CAU-DL), the loading rate was set to approximately 1 kPa/min.

The final dead load test was consolidated anisotropically in the same drained manner as the previous two tests, but instead of increasing the load after consolidation, the load was held constant and any displacements in the sample were monitored. This final test was referred to as a dead load-controlled anisotropically consolidated undrained with creep (CAU-DL-C) test. This CAU-DL-C test was competed in stages and the load was held constant after consolidation to a lateral stress coefficient (K_0) of 0.5 and 0.4. The test was terminated after the sample failed during anisotropic consolidation from K_0 = 0.4 to 0.3.

Table 13 summarizes the different triaxial tests conducted.

Table 13: Summary of Triaxial Tests

Material	**Test No.**	**Consolidated Void Ratio**	**Consolidation Pressure (kPa)**	**Test Type**	**Fines Content (%)**	
					Before Test	**After Test**
Average Reconstituted Samples	TX01	0.87	1500	CID	51.9	54.5
	TX02	1.0	200	CID	51.6	50.7
	TX03	0.9	1000	CID	51.6	52.7
	TX04	0.97	500	CIU	51.3	49.9
	TX05	0.68	500	CID	51.9	50.9
	TX06	0.84	1500	CID	51.3	53.9
	TX07	0.84	2000	CIU	51.6	50.6
	TX08	0.9	40	CID	52.1	51.1
	TX09	0.82	100	CID	50.9	48.8
	TX18	0.79	100	CID	48.6	-
	TX19	0.76	100	CID	48.6	50.2
	TX20	0.66	500	CID	48.6	50.0
	TX21	0.72	500	CID	49.7	50.0
	TX30	0.83	196	CAU, K_0=0.5	50.4	51.1
	TX31	0.76	198	CAU, K_0=0.5	50.4	51.3
	TX32	0.81	200	CAU, K_0=0.5	50.4	51.3
Fine Reconstituted Samples	TX10	0.96	50	CID	71.3	68.3
	TX11	0.97	100	CID	71.4	72.3
	TX12	0.85	500	CID	71.5	73.8
	TX13	0.85	1000	CID	71.3	70.8
	TX22	0.91	200	CID	68.7	69.2
	TX23	0.87	200	CID	69.0	68.7
	TX24	0.84	356	CID	68.8	68.5
	TX26	0.99	198	CAU, K_0=0.5	66.7	68.9
	TX27	0.92	198	CAU, K_0=0.5	72.9	71.2
	TX28	0.82	198	CAU, K_0=0.5	72.9	70.9
	TX29	0.82	200	CAU, K_0=0.5	70.6	71.2
Coarse Reconstituted Samples	TX14	0.96	50	CID	32.9	30.0
	TX15	0.79	100	CID	32.3	28.9
	TX16	0.75	500	CID	32.3	29.4
	TX17	0.81	1000	CID	32.9	32.6
	TX25	0.88	198	CAU, K_0=0.5	28.0	28.7
	TXDW01	0.91[4]	86	CAD-DL, K_0=0.5	29.4	27.6
	TXDW02	0.88	150	CAU-DL, K_0=0.5	28.0	30.2
	TXDW03	0.87	75	CAU-DL-C, K_0=0.5 & 0.4	34.1	32.1

NOTES:

[1] Pre-consolidation void ratio of loose tailings estimated from measured void ratio test results summarized in Appendix B. Taken as the 80th percentile of samples of similar gradation to those of the June 4 samples.

[2] Pre-consolidation void ratio of dense tailings. Estimated from measured void ratio test results summarized in Appendix B. Taken as the 20th percentile of samples of similar gradation to those of the June 4 samples.

[3] Test Type: Isotropically Consolidated Undrained Test (CIU), Isotropically Consolidated Drained Test (CID), Anisotropically Consolidated Undrained Test (CAU), Anisotropically Consolidated Drained Test (CAD).

[4] Sample failed during anisotropic consolidation.

5.2.4 Standard Strain-Controlled, CID, CIU and CAU Test Results

Results from the triaxial compression tests are summarized in Annex 8. These results were plotted to show void ratio (e) versus mean effective stress (p') and deviator stress (q) versus p'. Graphs were produced for the three representative tailings gradations (Fine, Coarse and Average).

Critical State Line (CSL)

The CSL is defined as the relationship between the e and p', for a given soil unit, for a condition when the soil will shear at constant volume and constant shear stress. As shown in Figure 20 through Figure 22, a curved power law relationship was selected as the best representation of the CSL for the three representative tailings gradations. The curved relationship of the CSL for all three representative tailings gradations (Fine, Coarse and Average) was represented by the following equation:

Equation 5-1:

$$\boldsymbol{e = A - B\left(\frac{p'}{p_{ref}}\right)^{C}}$$

Where:

- p' – Mean Effective Stress (kPa)
- p_{ref} – Reference Stress Condition, taken as 100 kPa
- A – Selected as 1.29, 1.19 and 1.22 for Fine, Coarse and Average tailings gradations, respectively
- B – Selected as 0.34 for all tailings gradations
- C – Selected as 0.11 for all tailings gradations

An alternate linear relationship for the CSL was also calculated and can be represented by the following equation:

Equation 5-2:

$$\boldsymbol{e = \Gamma - \lambda_e \ln(p')}$$

Where:

- p' – Mean Effective Stress (kPa)
- Γ – void ratio on the CSL at a p' of 1 kPa
- λ_e – slope of the CSL

Γ for the Fine, Coarse and Average tailings gradations was calculated as Γ = 1.12, 1.01 and 1.04, respectively. λ_e for the Fine, Coarse and Average tailings gradations was calculated as 0.039.

All three CSL curves were plotted onto one graph to make comparisons between the CSL's for each gradation (see Figure 19). It is noteworthy that the slope of the CSL was the same for the range of tailings gradations tested.

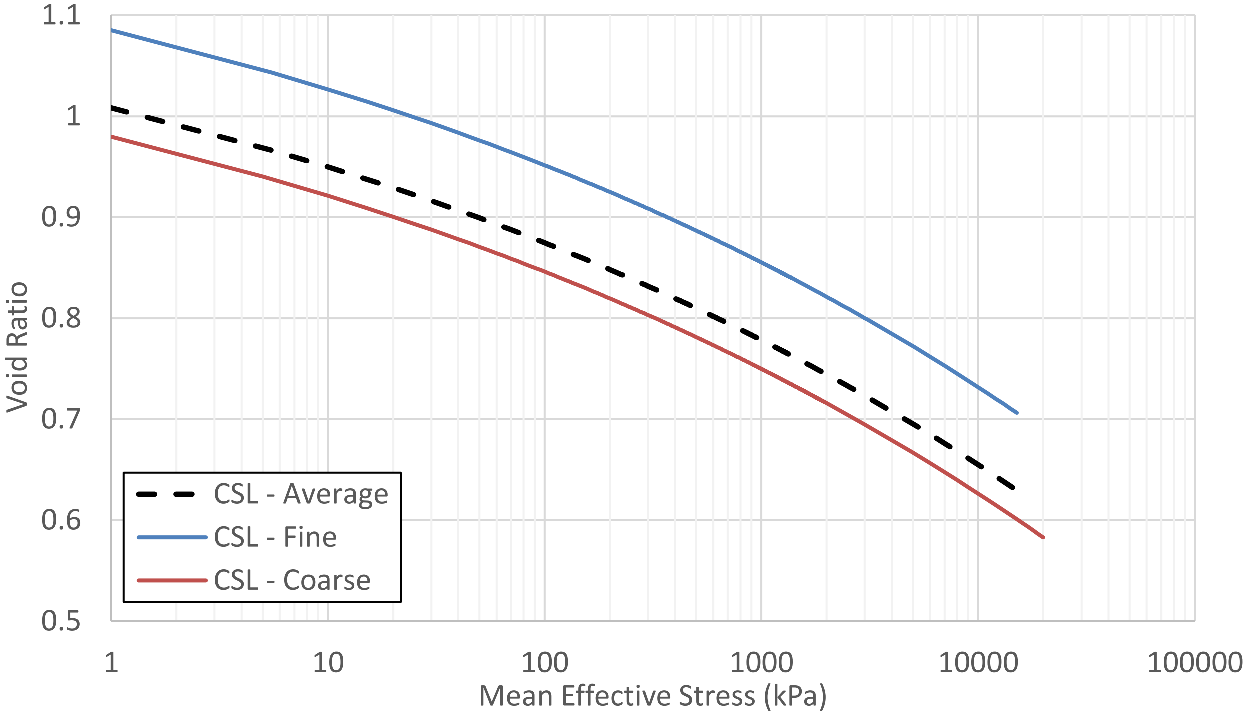


Figure 19: CSL Curves of All Three Tailings Gradations Tested

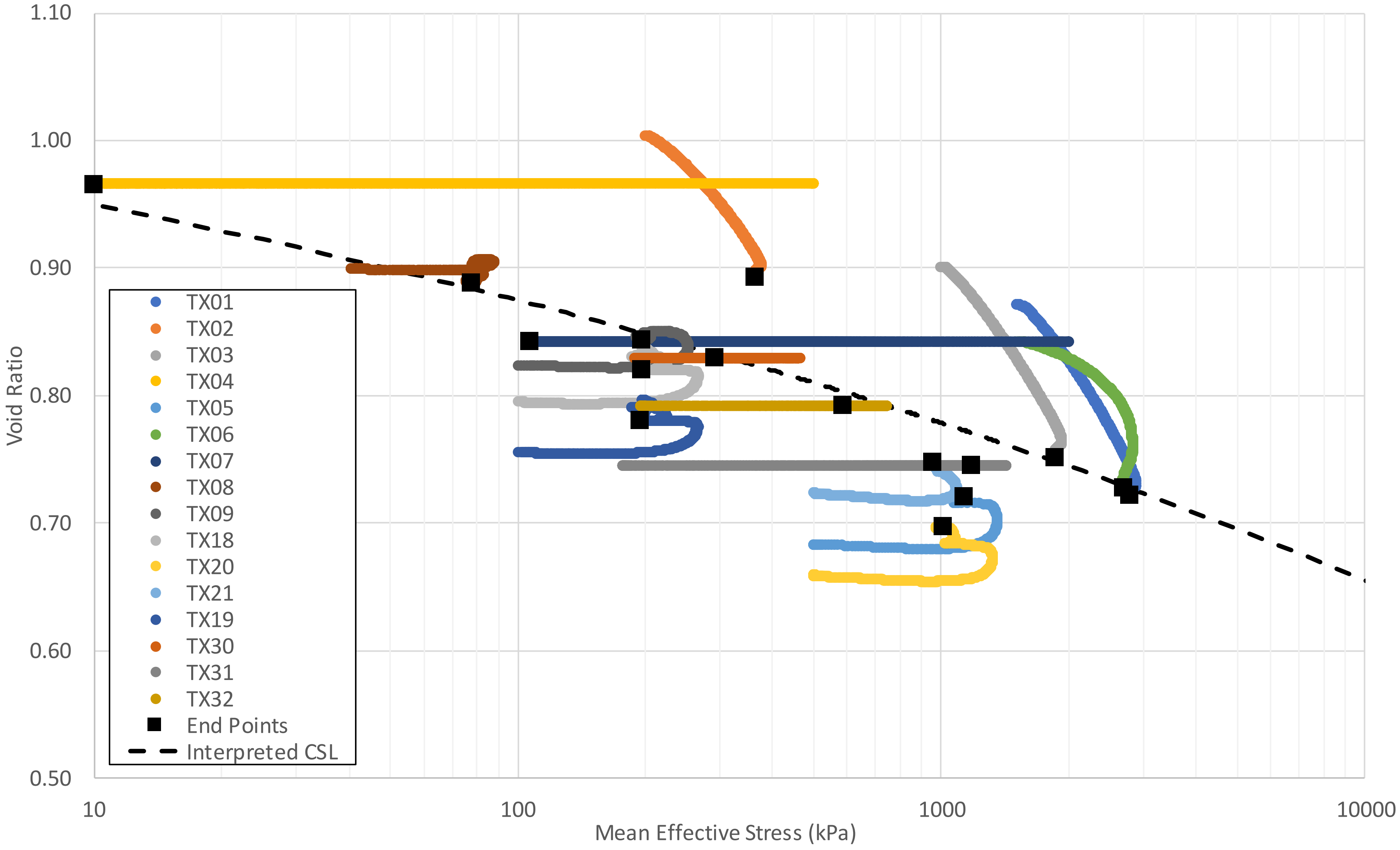


Figure 20: CSL Plot for Average Tailings Gradations Tested

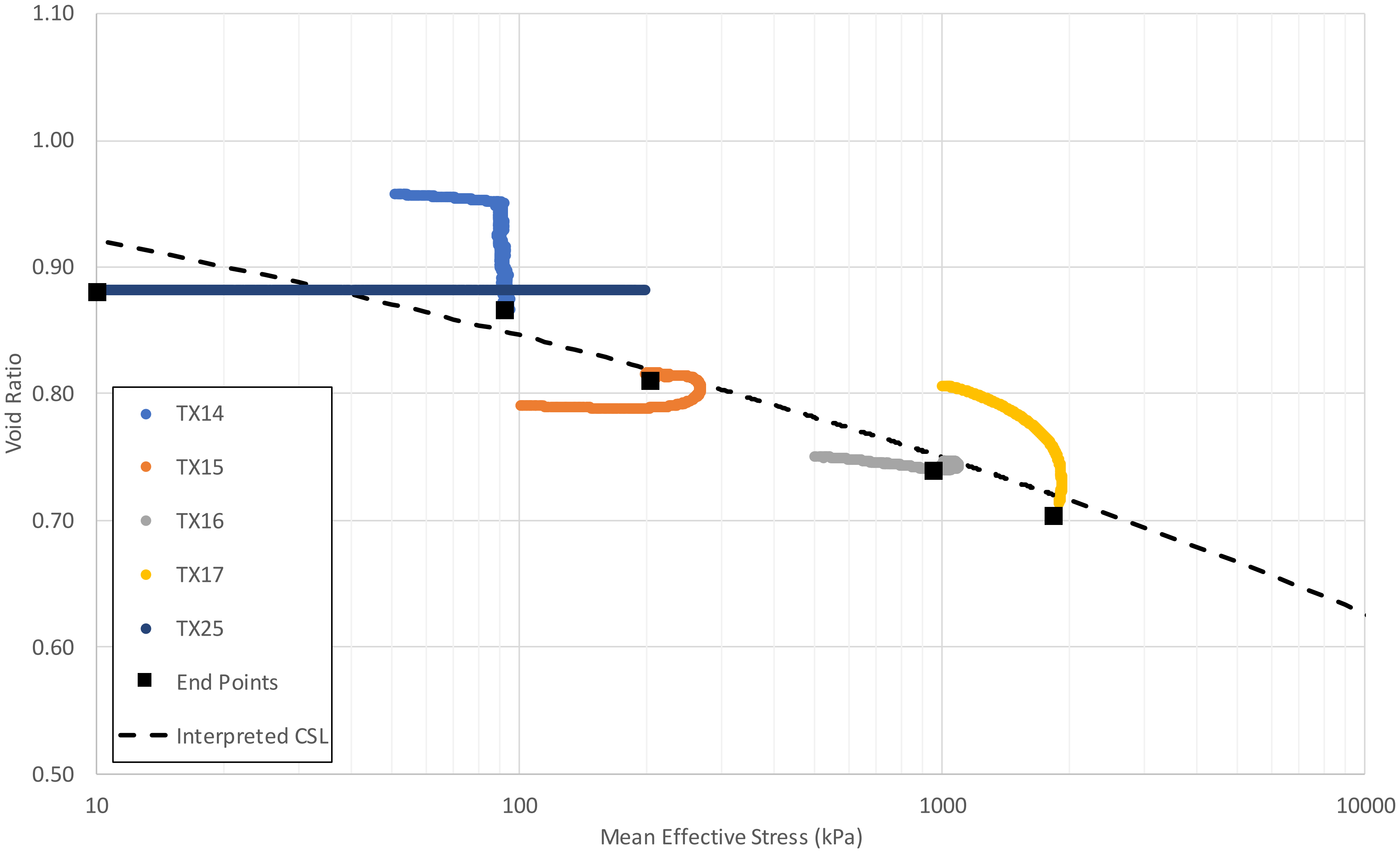


Figure 21: CSL Plot for Coarse Tailings Gradations Tested

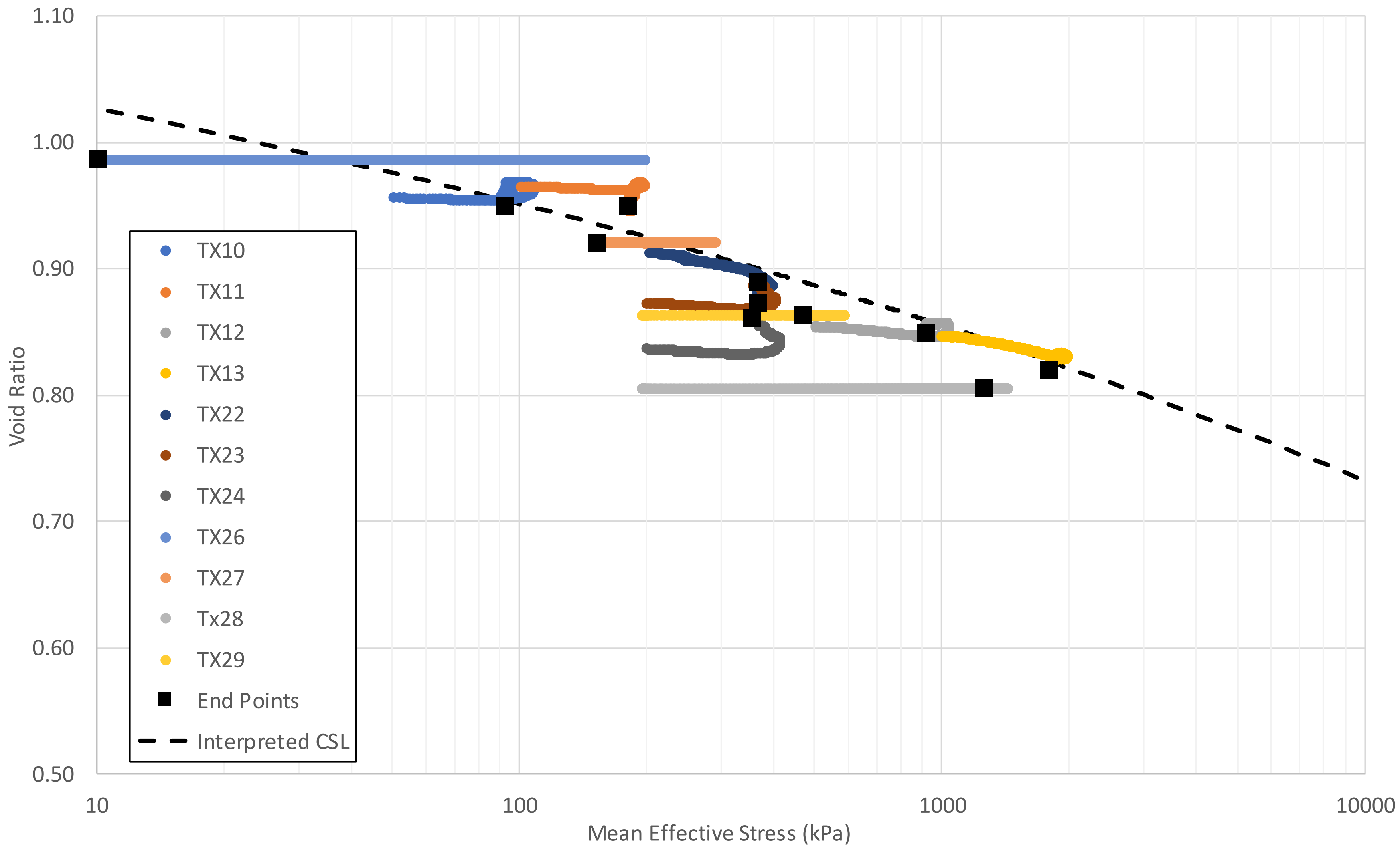


Figure 22: CSL Plot for Fine Tailings Gradations Tested

Critical State Friction Angle

The stress paths for the three representative tailings gradations tested are shown on Figure 23 through Figure 25 on a q versus p' plot. The gradient of a line drawn through the end points of those stress paths is referred to as the critical state friction ratio (M_{tc}) and it varied between 1.35 and 1.39. The equivalent critical state friction angles (ϕ'_c) for the Fine, Coarse and Average tailings gradations tested are 34°, 34°, and 33°, respectively. The range of values of M_{tc} was confirmed using the intercept of a trend on a graph of maximum stress ratio (q/p') versus minimum dilatancy, which produced the same value. This graph is shown in Figure 43.

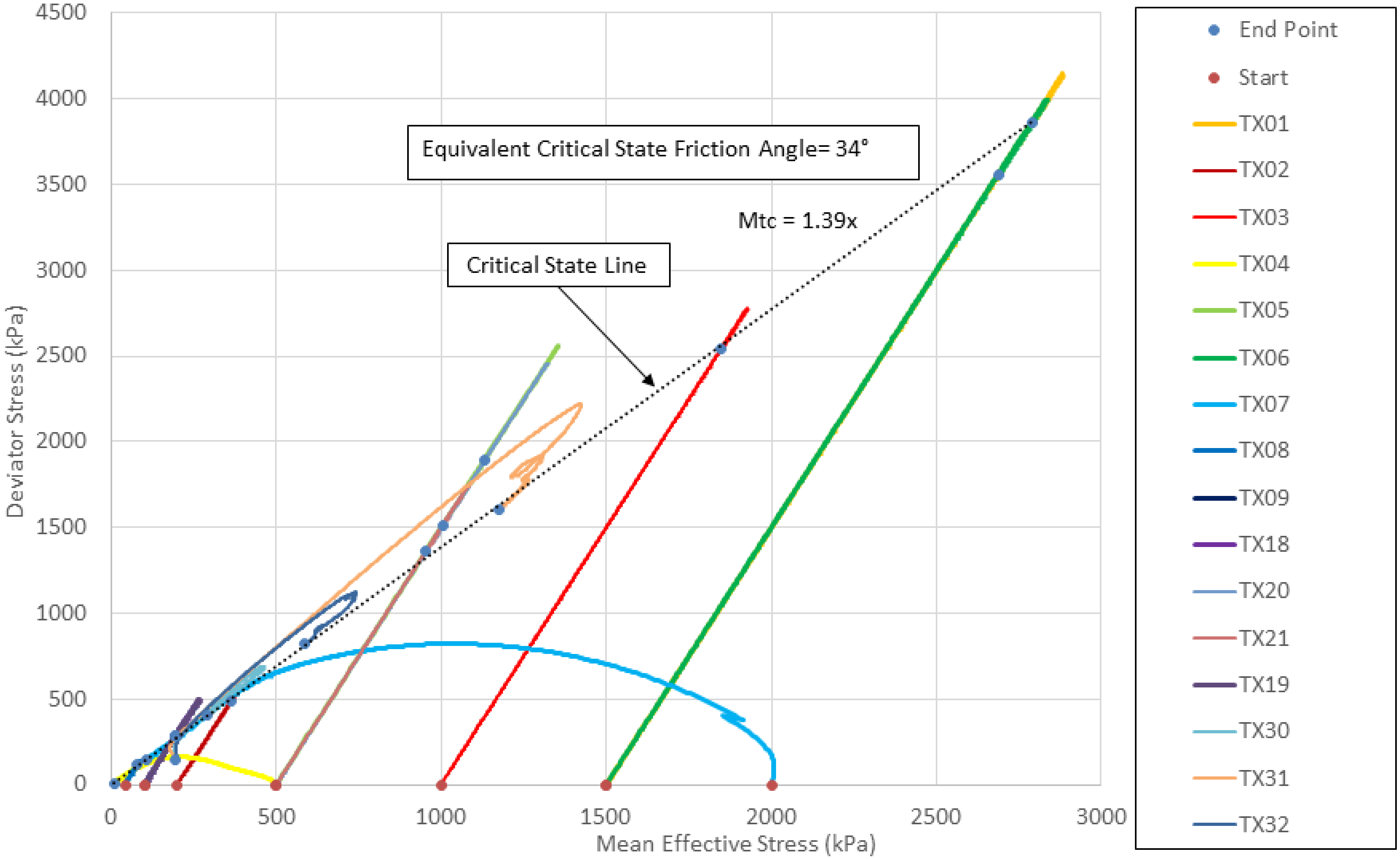


Figure 23: Stress paths from CID and CIU on Average Tailings Gradations

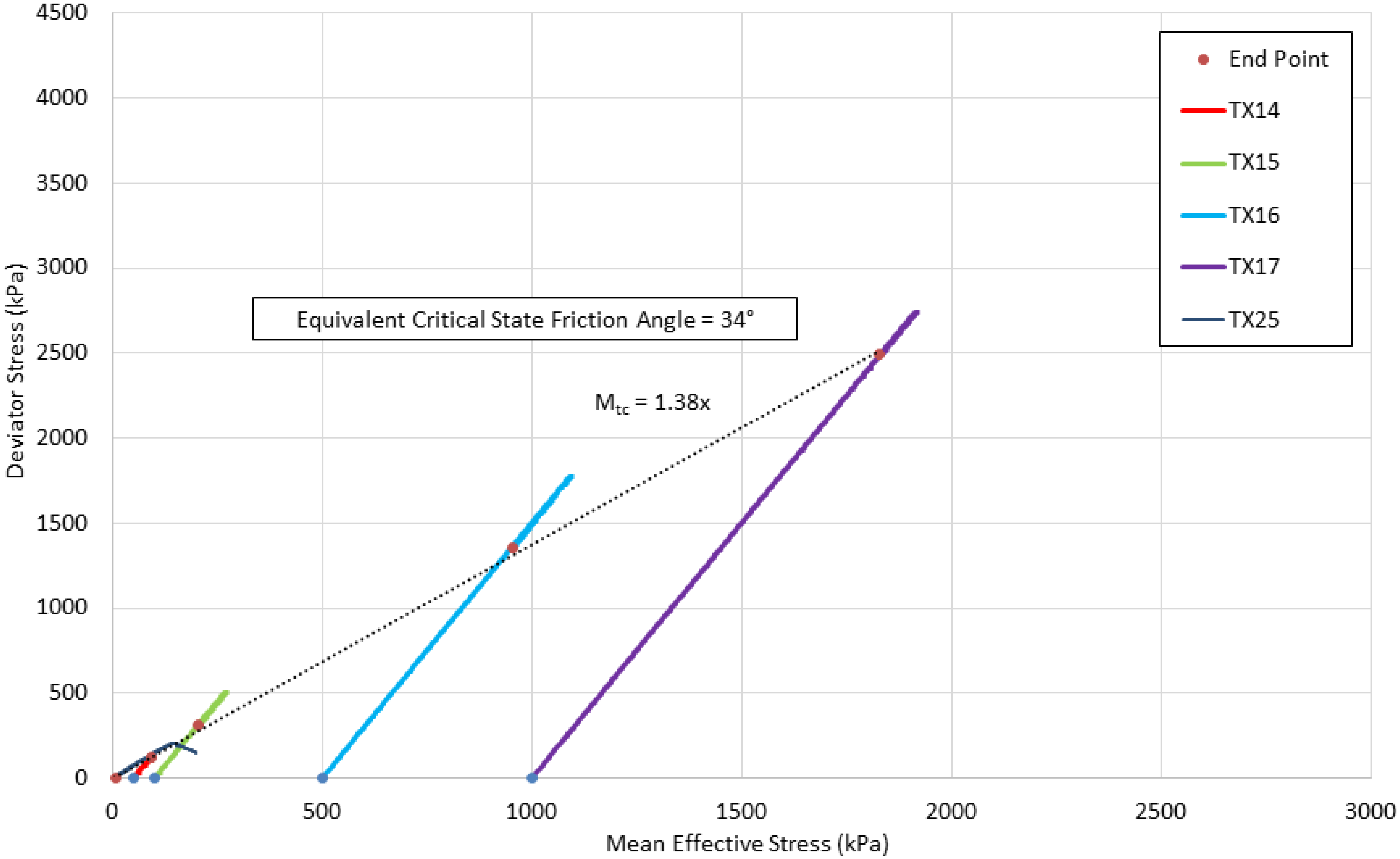


Figure 24: Stress paths from CID and CIU on Coarse Tailings Gradations

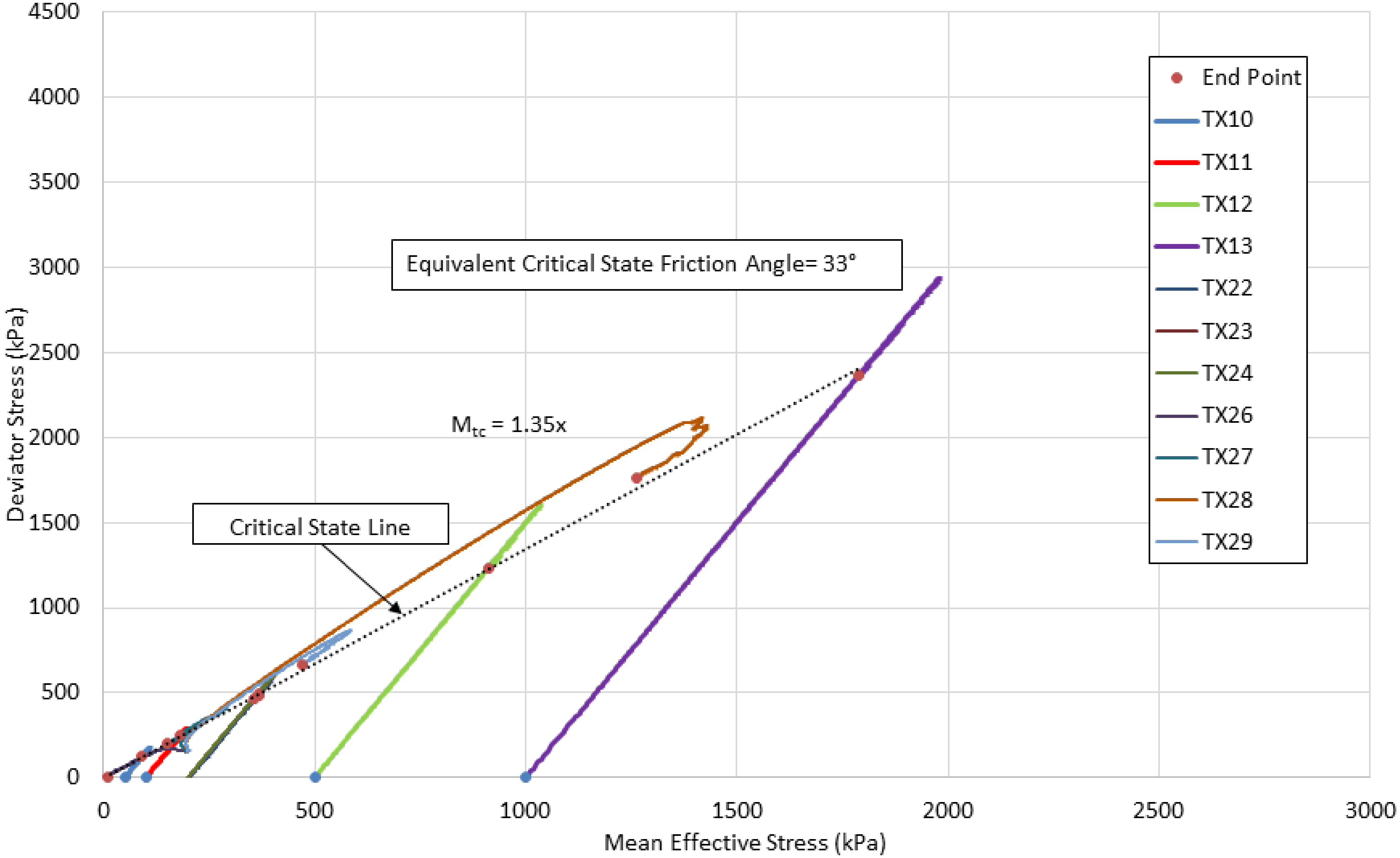


Figure 25: Stress paths from CID and CIU on Fine Tailings Gradation

CAU Test Results

Eight aniostropically consolidated undrained (CAU) triaxial tests were completed on the Fine, Coarse and Average Tailings gradations to assess the undrained response of samples at various state parameters. All samples were consolidated anisotropically to a mean effective stress of 200 kPa and a K_0 of 0.5 before starting the undrained loading. The Fine, Coarse and Average gradation samples were prepared to a consolidated void ratio that ranged between 0.76 and 0.99.

The results of two loose samples (ψ = +0.07), one Fine Tailings gradation and one Coarse Tailings gradation, are compared in Figure 26. Both samples generated an extremely brittle response during the undrained loading. The samples failed at 0.3 % and 0.8 % axial strain for the Fine and Coarse gradations, respectively. The peak and residual deviator stresses for the Fine gradations were 167.3 kPa and 1.8 kPa, respectively. For the Coarse gradations, the peak and residual deviator stresses were 204.4 kPa and 2.7 kPa, respectively. These equate to peak and residual strength ratios (S_u/p') of 0.42 to 0.51 (equivalent to S_u/σ'_v = 0.28 to 0.34) and 0.005 to 0.01, respectively. The peak strengths are significantly higher than empirical estimates based on CPTu data, such as those of Olson and Stark (2003)[4], and the residual (or liquefied) strengths are significantly lower than empirical estimates, such as those of Robertson (2010).[5]

The test results confirmed that the Fine and Coarse gradations behave in a similar manner during undrained shearing.

---

[4] Olson, S., & Stark, T.D. (2003). Yield strength ratio and liquefaction analysis of slopes and embankments. *American Society of Civil Engineers Journal of Geotechnical and Geoenvironmental Engineering*, *129*(8), 727-737.

[5] Robertson, P.K. (2010). Evaluation of flow liquefaction and liquefied strength using the cone penetration test. *American Society of Civil Engineers Journal of Geotechnical Engineering*, *136*(6), 842-853.

Coarse Gradation (TX25) **Fine Gradation (TX26)**

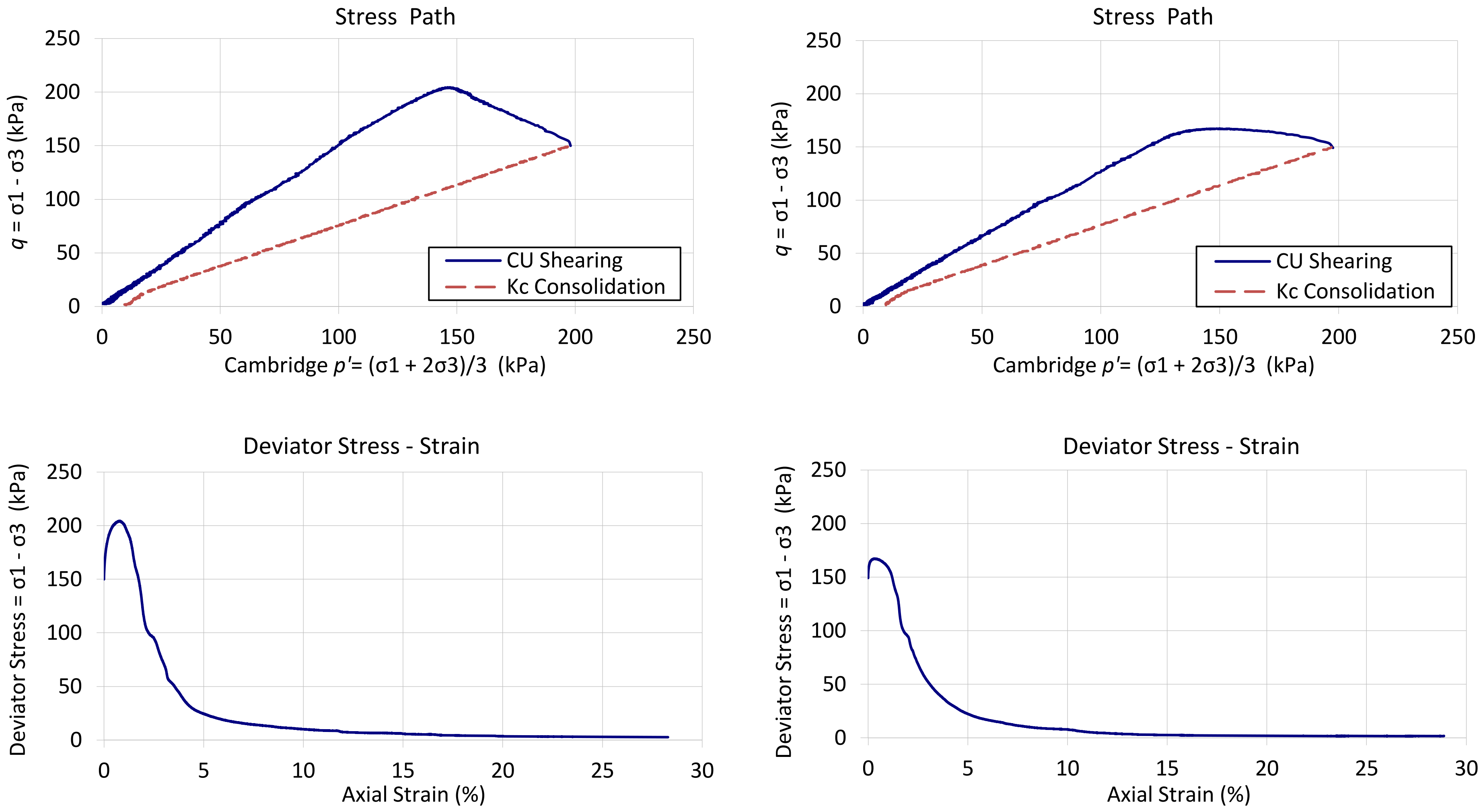


Figure 26: Results of Consolidated Anisotropic Undrained (CAU,K_0=0.5) Strain-Controlled Triaxial Tests

5.2.5 Dead Load Test Results

Two dead load tests were completed for comparison with the strain-controlled tests. Both tests were completed on the Coarse Tailings gradation. The first test (TXDW01) was completed as a drained test and was intended to replicate test TX14, which was a strain-controlled CID test completed at an initial mean effective stress of 50 kPa and a state parameter of +0.09. That test showed an abrupt reduction in volume at around 1 % strain, at a constant mean effective stress (p') of roughly 90 kPa and deviator stress (q) of roughly 120 kPa (see Figure 21). The purpose of the equivalent dead load test was to see if this volumetric reduction would lead to pore pressure generation and strength loss under dead load conditions. The equivalent dead load test was consolidated anisotropically to stresses approaching those at which TX14 failed; however, the sample failed in a rapid manner at p' = 86 kPa and q = 110 kPa (see Figure 27).

The second dead load test (TXDW02) was completed for comparison with the strain-controlled CAU test (TX25) completed at an initial mean effective stress of 200 kPa and a K_0 of 0.5. Except for the dead weight load application, TXDW02 was completed in exactly the same manner as TX25. TXDW02 failed at an axial strain of 0.7 % and generated a peak q of 220.8 kPa (see Figure 28). This equates to a peak strength ratio (S_u/p') of 0.55. The residual strength ratio of this sample could not be measured because the failure occurred in a rapid manner and lead to complete failure of the sample. These results are similar to those of the equivalent strain-controlled test (TX25), illustrating general consistency across testing methods.

5.2.6 Dead Load with Creep Test Results

The dead load with creep test (CAU-DL-C – see Section 5.2.3) was completed to assess the potential for strain accumulation with time when a sample of loose tailings is loaded to various stress levels. This was investigated by loading the sample to assigned K_0 values and then holding the applied load constant. During the first stage of this test, the sample was loaded to a K_0 of 0.5 at a mean effective stress (p') of 100 kPa and a deviator stress (q) of 74 kPa. The sample was then held at this p' and q with the drainage valves open for 4,012 minutes. During this time, the sample accumulated 0.05 % axial strain.

The second stage of the test involved decreasing the K_0 to 0.4 at the same p' by increasing the q to 100 kPa. The sample was then held at this p' and q for 2,539 minutes; this time with the drainage valves closed. The sample accumulated 0.13 % axial strain during this time. The drainage valves were then re-opened and the sample was consolidated anisotropically to a target K_0 of 0.3. The sample failed during this anisotropic consolidation at a K_0 of 0.33. Because the test was being completed using dead-load apparatus, this failure of the sample led to rapid strain accumulation and the test could not continue.

Strain Controlled (CID – TX14) Results – Shearing Stage

Dead Load (TXDW01) Results – Anisotropic Consolidation Stage Only

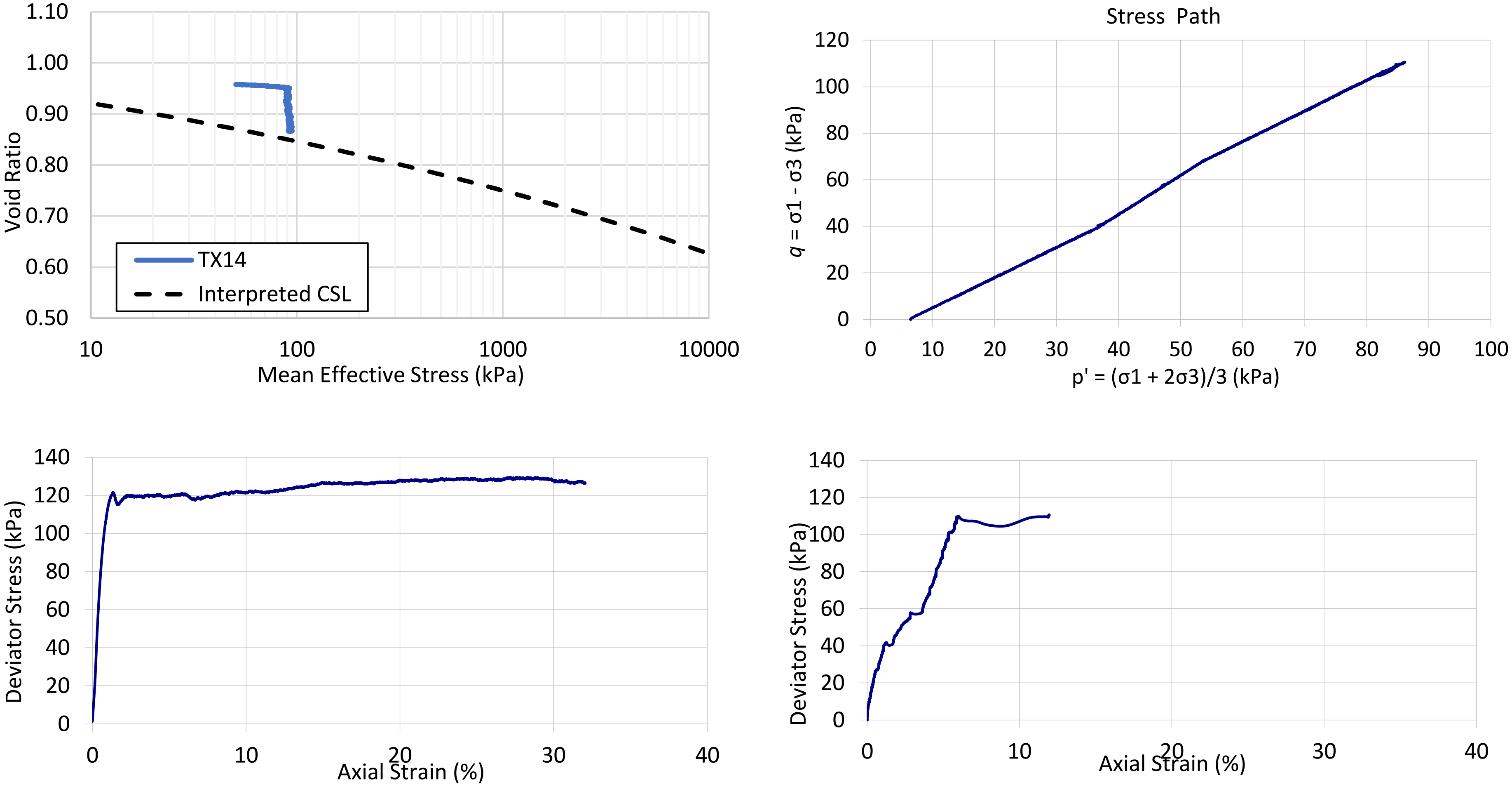


Figure 27: Comparison of TX14 and TXDW01

Dead-Load Controlled CAU Test Results (TXDW03)

Dead Load CAU Test Results (TXDW02)

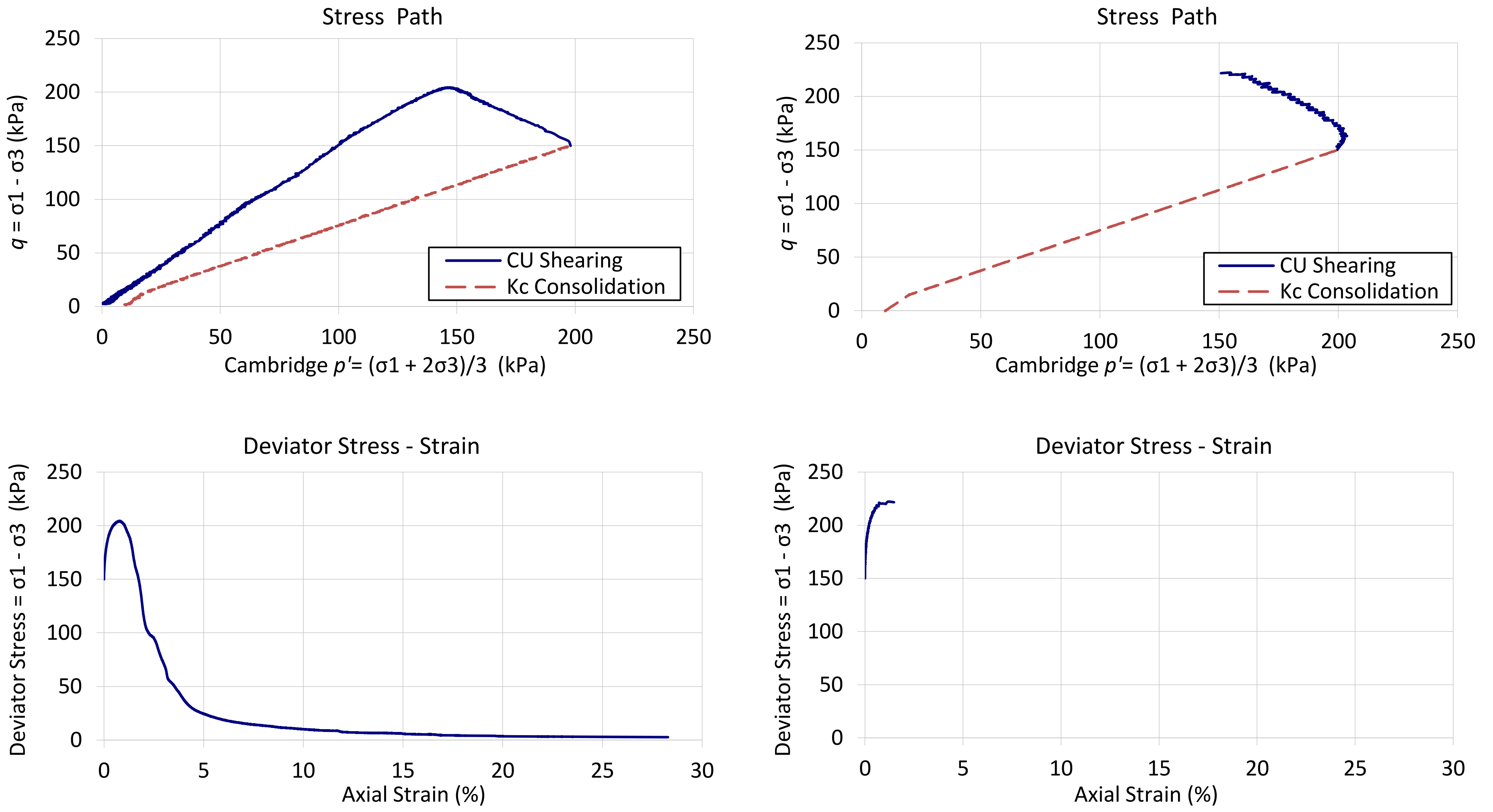
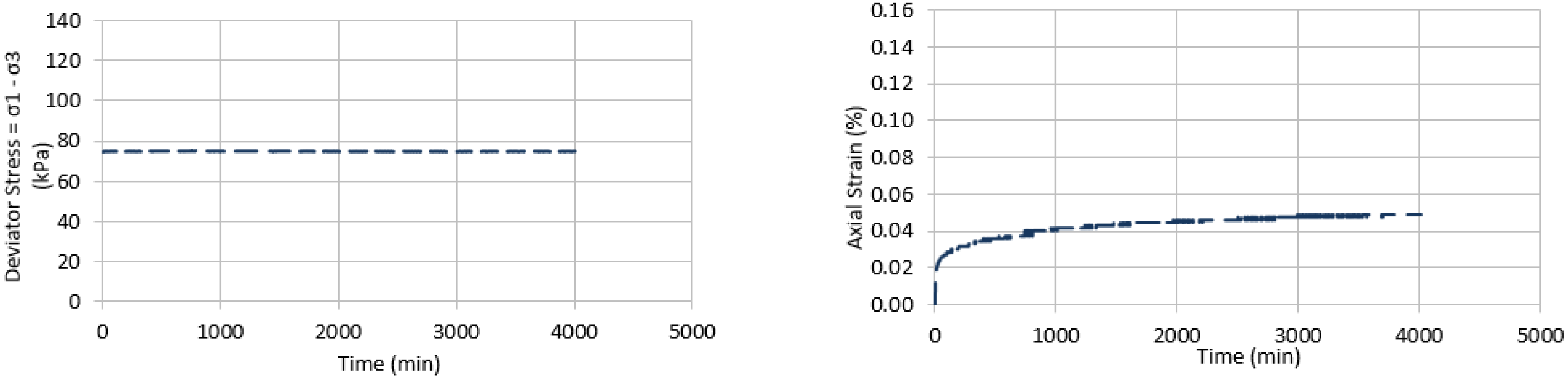


Figure 28: Comparison of Strain-Controlled and Dead Load-Controlled Triaxial Test Results

Lateral Stress Coefficient (K_0) = 0.5



Lateral Stress Coefficient (K_0) = 0.4

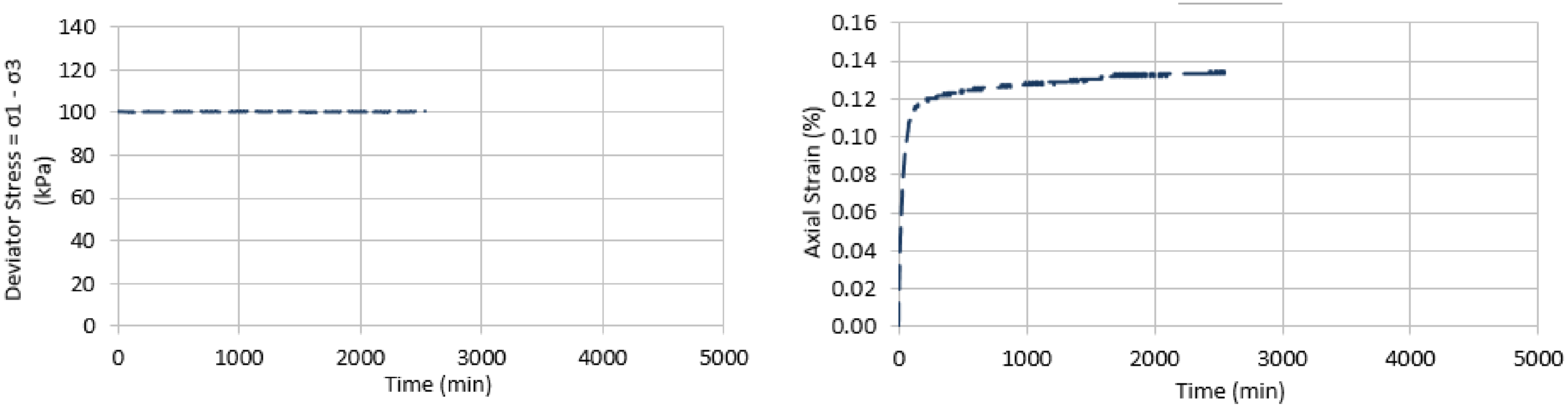


Figure 29: Dead-Load Controlled CAU Test Results (TXDW03) – K_0 = 0.5 & 0.4

Lateral Stress Coefficient (K_0) = 0.4 to 0.3

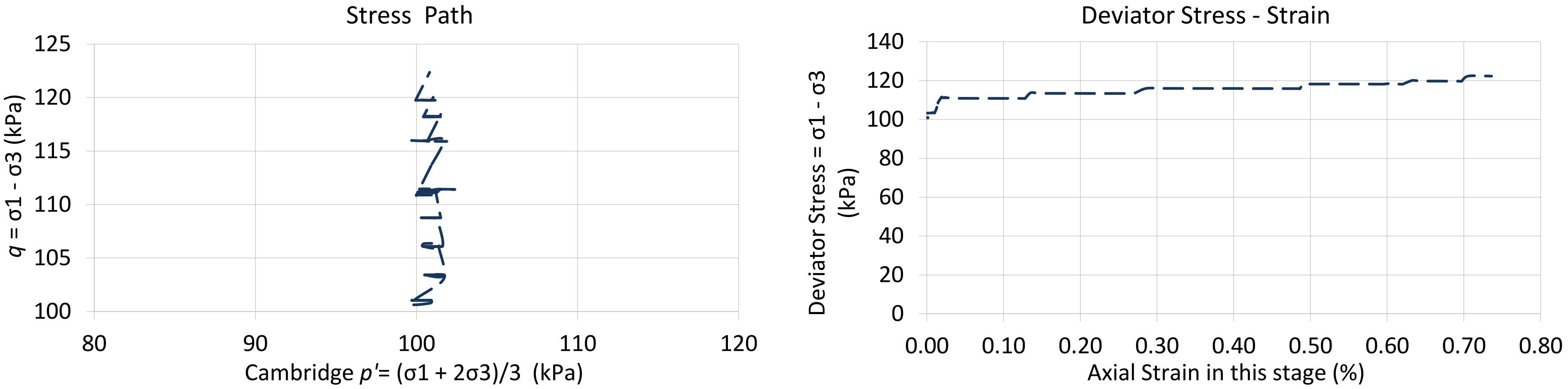


Figure 30: Dead-Load Controlled CAU Test Results (TXDW03) – K_0 = 0.4 to 0.3

5.3 Bender Element Test

5.3.1 Scope

Bender element tests were completed on separate isotropically-consolidated samples to the triaxial tests described in Section 5.2, throughout the consolidation stage of the tests, to determine a relationship between e, p' and shear wave velocity (V_s).

5.3.2 Procedure

There is currently no internationally accepted standard for the bender element test. The test was conducted following recommendations outlined in the "Interpretation of International Parallel Test on The Measurement of G_{max} Using Bender Elements" (Yamashita et al. 2009).[6]

Geocomp's LoadTrac-II/FlowTrac-II system with incorporated WaVeMe system was used to consolidate the specimens and measure the wave travel time to obtain shear wave velocities at different consolidation stages. The WaVeMe system consists of piezo-ceramic plates, known as P and S Sensors, commonly referred to as bender elements. An electrical signal was applied to the transmitting sensors to distort the specimen and induce a voltage potential to produce a signal. The input and output potential were continuously recorded, and the travel time was determined.

The S-wave arrival time was measured using a single S-wave at different frequencies ranging from 5 kHz to 15 kHz, as recommended by Yamashita et al. (2009).

Shear wave velocities were calculated using the following formula:

Equation 5-3:

$$\boldsymbol{V_s = \frac{H_t}{T_s}}$$

Where:

- H_t = Distance between the two bender element tips, which is dependent on the specimen height at different consolidation load increments.
- T_s = S-wave arrival time, determined using Time Domain method.

The S-wave travelling time was determined using the distance between the two bender element tips (and the height of the specimen) at different consolidation load increments.

Shear modulus (G_{max}) was calculated using the following formula:

---

[6] Yamashita, S., Kawaguchi, T., Nakata, Y., Mikami, T., Fujiwara, T., & Shibuya, S. (2009). Interpretation of international parallel test on the measurement of G_{max} using bender elements. *Soils and Foundations*, *49*(4), 631-650.

Equation 5-4:

$$G_{max} = \rho * V_s^2$$

Where:

- ρ = Density at each consolidation load increment.

5.3.3 Results

Bender element tests were completed on loose and dense representative tailings gradations (Fine, Coarse and Average), consolidated to 1500 kPa. The specimens were placed at a void ratio, e_i, ranging from 0.7 to 1.2. A summary of the completed bender element tests is given in Table 14. The test results are detailed in Annex 8.

Table 14: Summary of Bender Element Tests

Material	Test No.	Initial Void Ratio	Consolidation Pressure (kPa)
Average Gradation	TXBD01	1.2	50, 100, 200, 400, 600, 800, 1000, 1200, 1500
	TXBD02	0.9	50, 100, 200, 400, 600, 800, 1000, 1200, 1500
	TXBD03	1.0	50, 100, 200, 400, 600, 800, 1000, 1200, 1500
	TXBD08	0.8	50, 100, 200, 400, 600, 800, 1000, 1200, 1500
Fine Gradation	TXBD04	1.1	50, 100, 200, 400, 600, 800, 1000, 1200, 1500
	TXBD05	0.9	50, 100, 200, 400, 600, 800, 1000, 1200, 1500
	TXBD10	0.7	50, 100, 200, 400, 600, 800, 1000, 1200, 1500
Coarse Gradation	TXBD06	1.1	50, 100, 200, 400, 600, 800, 1000, 1200, 1500
	TXBD07	0.9	50, 100, 200, 400, 600, 800, 1000, 1200, 1500
	TXBD09	0.7	50, 100, 200, 400, 600, 800, 1000, 1200, 1500

The data were plotted as normalized shear wave velocity (V_{s1}) versus void ratio, using the approach of Cunning et al. (1995),[7] to develop relationships for void ratio, shear wave velocity and mean effective stress that could be used to estimate the in-situ void ratio from the V_s results. It was found that the Coarse and Average gradation data could be fitted with the same relationship, whereas a different relationship was developed for the Fine gradation data.

---

[7] Cunning, J.C., Robertson, P.K., & Sego, D.C. (1995). Shear wave velocity to evaluate in situ state of cohesionless soils. *Canadian Geotechnical Journal*, 32, 848-858.

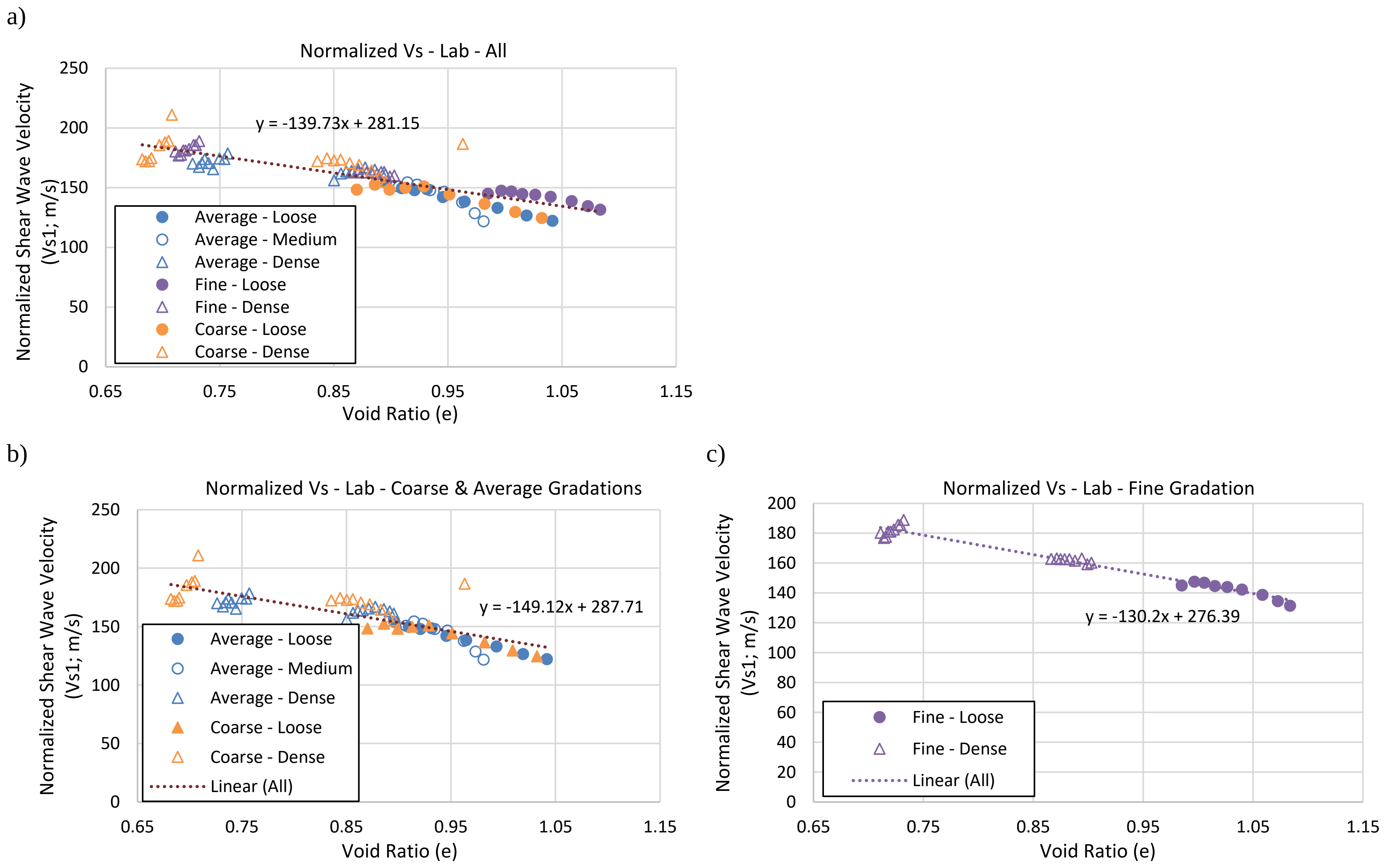


Figure 31: Normalized Shear Wave Velocity Versus Void Ratio Relationships For: a) All Data, b) Average and Coarse Gradations, and c) Fine Gradation

5.4 Direct Simple Shear Tests

5.4.1 Scope

Six monotonic direct simple shear (DSS) tests were completed on Shelby Tube samples of the Foundation soils collected in Program 2, to measure the peak undrained shear strength and stiffness. Each Shelby tube was scanned using X-ray apparatus to produce an image of the material inside the tube. This was to check if the material was disturbed either from the drilling process or from transport. These images were also used to determine sections of samples that would be used for the DSS tests. Images of these X-ray scans are shown in Annex 8. Specimens were sheared to a maximum of 20% shear strain before reversing the shearing direction and completing one shearing cycle in the opposite direction. The specimens were sheared at a rate of 5%/hr.

5.4.2 Procedure

DSS tests were conducted in accordance with ASTM D6528. All shearing was done undrained by holding the sample volume constant. This was done by changing the vertical load automatically so that the sample height remained constant. The DSS specimens were consolidated to confining pressures of 350 kPa, 370 kPa, 520 kPa and 800 kPa. These confining pressures were selected to be greater than the vertical effective stress experienced by the soil at these locations prior to failure of the dam.

A summary of the samples used for DSS tests is shown in Table 15.

Table 15: Summary Table of DSS Tests

Sample Number	Confining Pressures (kPa)	Approximate Elevation of Sample (m)
BH-01 Shelby Tube 01	520	860.0
BH-01 Shelby Tube 02	520	859.2
BH-02 Shelby Tube 01	800	854.2
BH-02 Shelby Tube 02	800	853.1
BH-04 Shelby Tube 01	350	855.2
BH-04 Shelby Tube 02	370	853.5

5.4.3 Test Results

A summary of the DSS test results is given in Table 16, and the results are detailed in Annex 8. Selected test results are illustrated on Figure 32. The peak undrained shear strength ratio ranged from 0.29 to 0.43. The peak was typically reached in excess of 10 % shear strain and there was no significant loss of strength on the initial cycle of shearing. These results suggest that the Foundation soils (residual soil) did not develop brittle behavior during undrained shearing.

Table 16: Summary of DSS Tests

Test ID	Moisture Content		Void Ratio		Axial Strain after Consolidation (%)	Vertical Effective Stress, σ'_{vc} (kPa)	Peak Undrained Shear Strength (kPa)	Maximum Excess Pore Pressure Ratio, $\Delta U/\sigma'_{vc}$	Maximum Undrained Stress Ratio, τ/σ'_{vc}
	Initial, W_i (%)	Final, W_f (%)	At Placement, e_i	Final Void Ratio, e_0 (1)					
DSS01 BH-01	35	37	1.06	1.17	8	520	175	386	0.34
DSS02 BH-01	38	40	1.21	1.15	7	520	184	406	0.35
DSS03 BH-02	43	43	1.31	1.40	10	800	221	657	0.28
DSS04 BH-02	29	29	0.96	0.85	9	800	199	630	0.25
DSS05 BH-04	36	42	1.25	1.21	5	350	154	272	0.44
DSS06 BH-04	30	30	0.94	0.91	9	370	131	303	0.35

NOTE:

[1] Void ratios after consolidation were calculated using height measurements

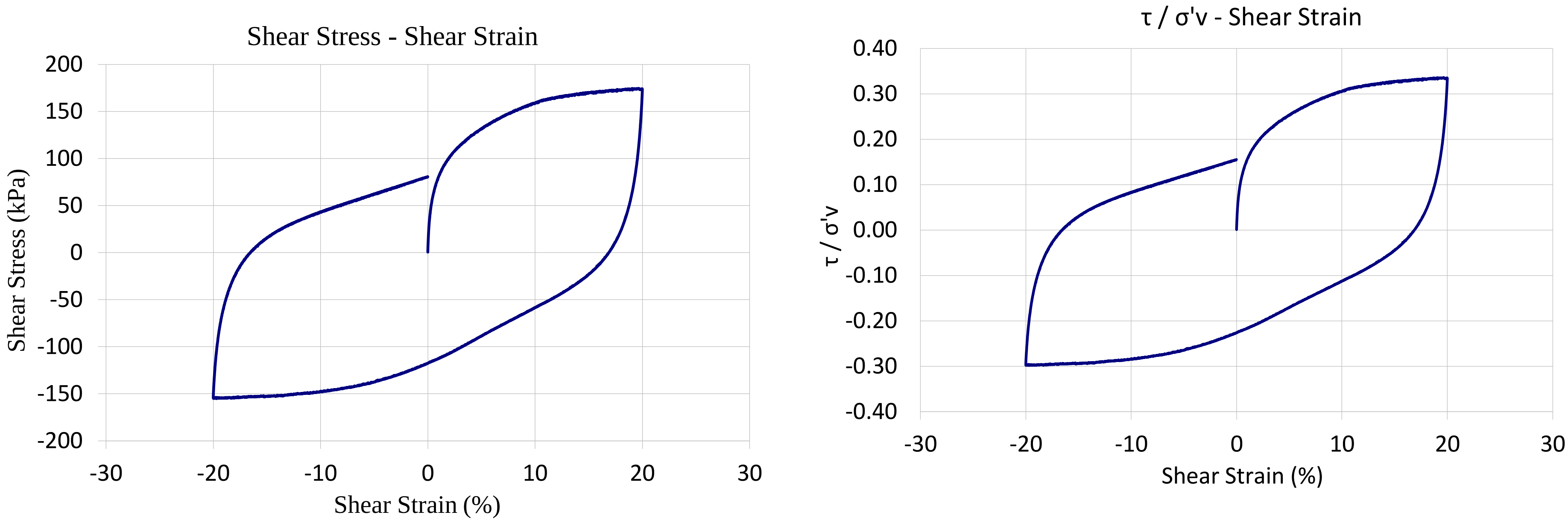


Figure 32: DSS Test Results (DSS01) - Residual Soil Foundation Material

6 DEFORMATION ANALYSIS PARAMETERS FROM FIELD AND LABORATORY TESTING

6.1 General

Parameters were calculated from the field and laboratory data for the main purpose of completing deformation and stability analyses intended to simulate the conditions prior to the dam failure and to test potential failure mechanisms and triggers. The analyses are discussed in Appendix H. The parameters required for the various analyses were:

- Mohr-Coulomb deformation analyses – Elastic moduli, peak drained shear strength, peak undrained shear strength and residual undrained shear strength. These were derived from triaxial test data. The assigned modulus values were informed by the estimated state parameter of the tailings derived from the CPTu.
    - This model was used for initial 2D and 3D deformation analyses.
- Strain-weakening deformation analyses – The parameters were the same as those required for the Mohr-Coulomb analyses, except that in these analyses both the peak and residual strengths are specified in the same analysis as well as the strain required to transition from peak to residual. The strain at which post-peak strength loss occurs and the strain to the residual strength were informed by the estimated state parameter of the tailings derived from the CPTu.

This model was used for the final 2D and 3D deformation analyses. The trends developed for this model's parameters were considered the best representation of the soil response.

- Critical state deformation analyses (using NorSand constitutive model) – Critical state properties, dilatancy parameters, in-situ density (or state parameter) and elastic moduli. The critical state and dilatancy parameters were derived from the triaxial data. The in-situ state parameter was estimated from the CPTu data and the elastic moduli were estimated from the bender element and V_s data.

This model was used for sensitivity analyses in the 2D deformation analyses. It was also used for spherical cavity expansion analyses as part of the CPTu interpretation.

- Stability analyses – Peak and liquefied undrained shear strengths derived from triaxial testing data and compared with CPTu data.

The approaches to derive these parameters and the results obtained are described in the following sections.

6.2 Mohr-Coulomb Model Inputs

Elastic moduli and strength parameters selected for Mohr-Coulomb analyses were calculated as secant moduli from drained triaxial compression test data. Element test simulations of the triaxial tests were completed using the finite-difference software FLAC, version 8.0 as a check to confirm that the calculated moduli and shear strengths were producing representative results. The element tests completed as part of this work are shown in Annex 8.

6.2.1 Drained Parameters

A secant Young's modulus (E) was calculated at 50% of the peak stress, and a drained Poisson's ratio (ν) of 0.2 was assumed for all tailings (the analysis was not sensitive to this parameter). Shear (G) and bulk (K) moduli were calculated from these results for input into the analyses.

Relationships of K and G versus state parameter were developed. To generalize the relationships, the modulus values were normalized by the mean effective stress. These relationships are shown in Figure 33 and Figure 34.

A relationship of peak friction angle (ϕ') versus state parameter was also developed for use in the analyses. This assessment identified an unusual characteristic of the tailings in this investigation. It is typical for loose samples to develop a peak friction angle that is equal to the critical state friction angle; however, for the samples tested, the peak friction angle was typically approximately two degrees higher than the critical state friction angle of 34° discussed in Section 5.2.4. This is interpreted to be a reflection of bonding present within these tailings, due to their high iron content and oxidation of iron.

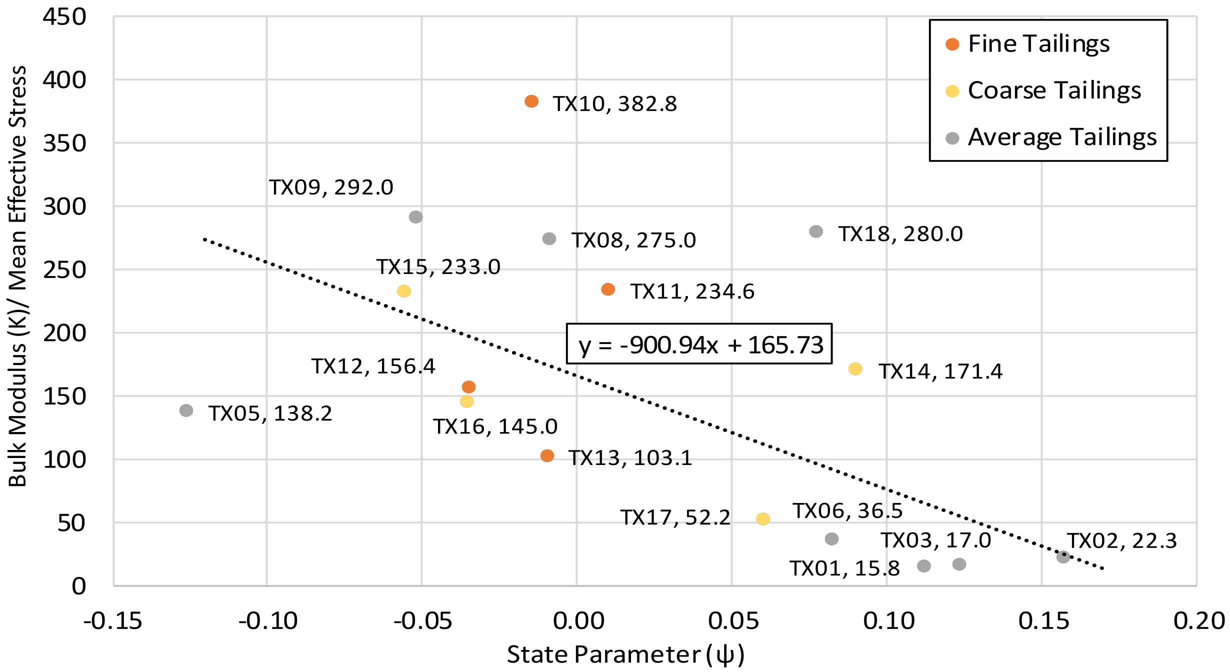


Figure 33: Relationship Between Bulk Modulus (K) and State Parameter (ψ)

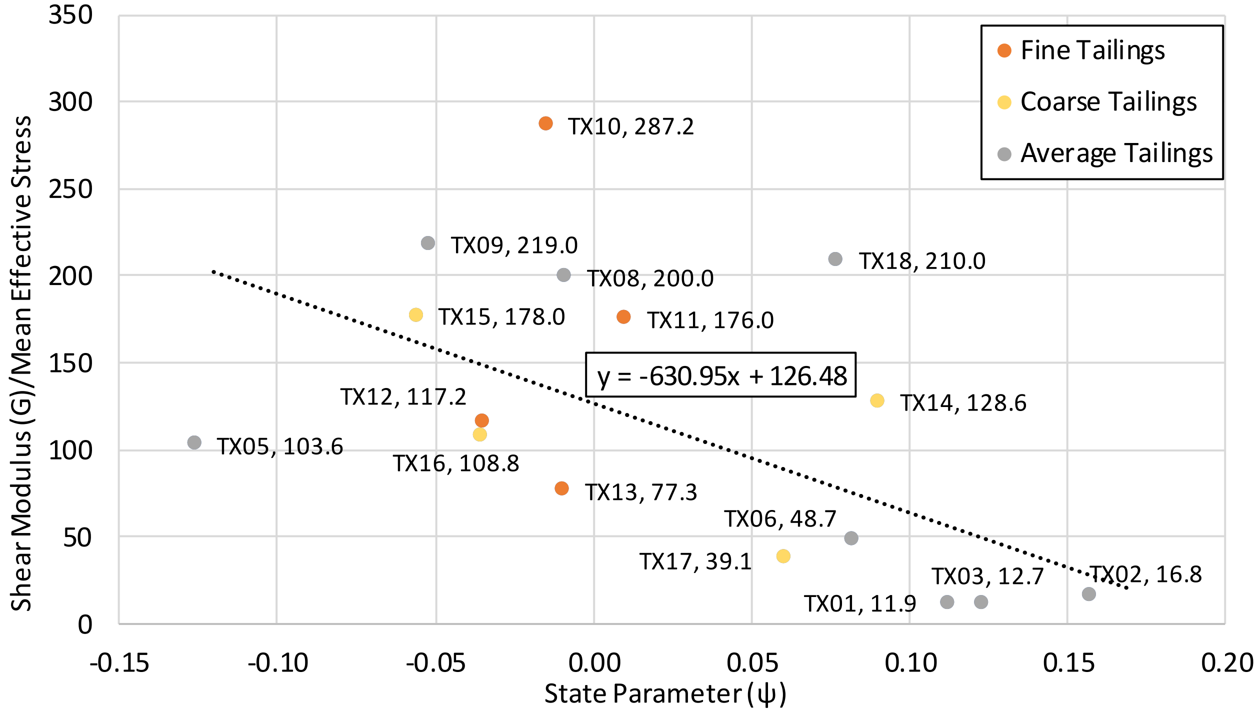


Figure 34: Relationship Between Shear Modulus (G) and State Parameter (ψ) for Drained Analysis

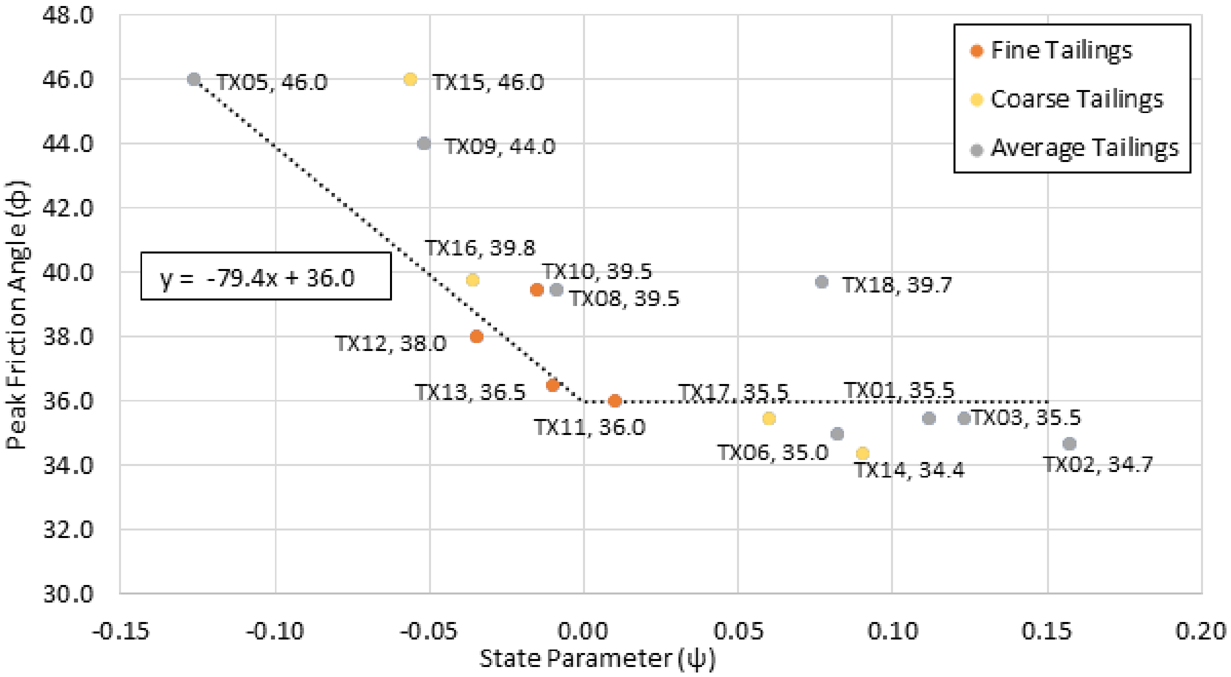


Figure 35: Relationship Between Peak Friction Angle and State Parameter (ψ) for Drained Analysis

6.3 Strain-Weakening Parameters

6.3.1 Drained Parameters

Strain-weakening analyses were completed to capture the loss of strength that occurs during either drained or undrained shear of the tailings. To model the strain weakening response, the amount of plastic strain (i.e., strain after the peak strength has been reached) until strength loss occurs ($\varepsilon_{P\text{-}SL}$) was calculated from the triaxial tests, together with the amount of strain until the residual strength is reached (ε_{P-R}). Element test simulations of the triaxial tests were completed using these values to verify that they were capturing the post-peak behavior of the tests appropriately. The element tests completed as part of this work are shown in Annex 8.

For input to subsequent deformation analyses, relationships of $\varepsilon_{P\text{-}SL}$ and ε_{P-R} versus state parameter were developed. These relationships are shown in Figure 33 and Figure 34.

Samples that were consolidated to a loose state generally showed a ductile response, whereas samples consolidated to a dense state generally showed a more brittle response. Values of $\varepsilon_{P\text{-}SL}$ and ε_{P-R} for loose samples were generally higher than those of the dense samples.

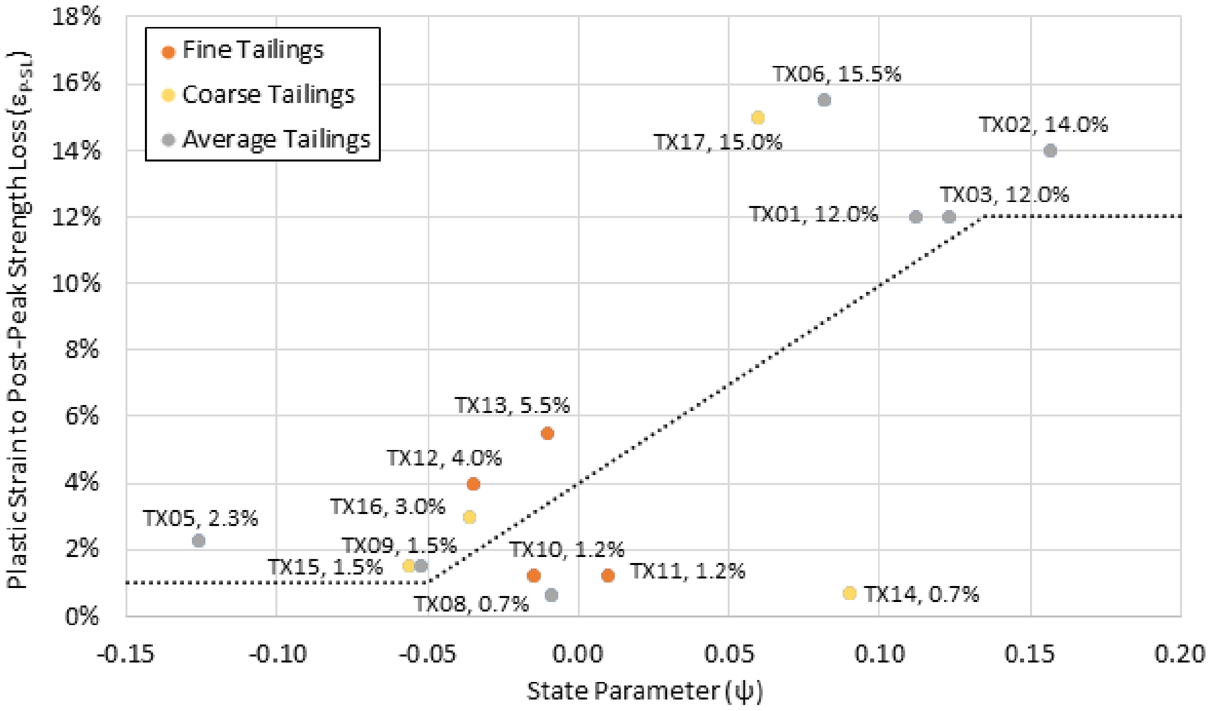


Figure 36: Relationship Between Plastic Strain to Post-Peak Strength Loss ($\varepsilon_{P\text{-}SL}$) and State Parameter ($\psi$) for Drained Analysis

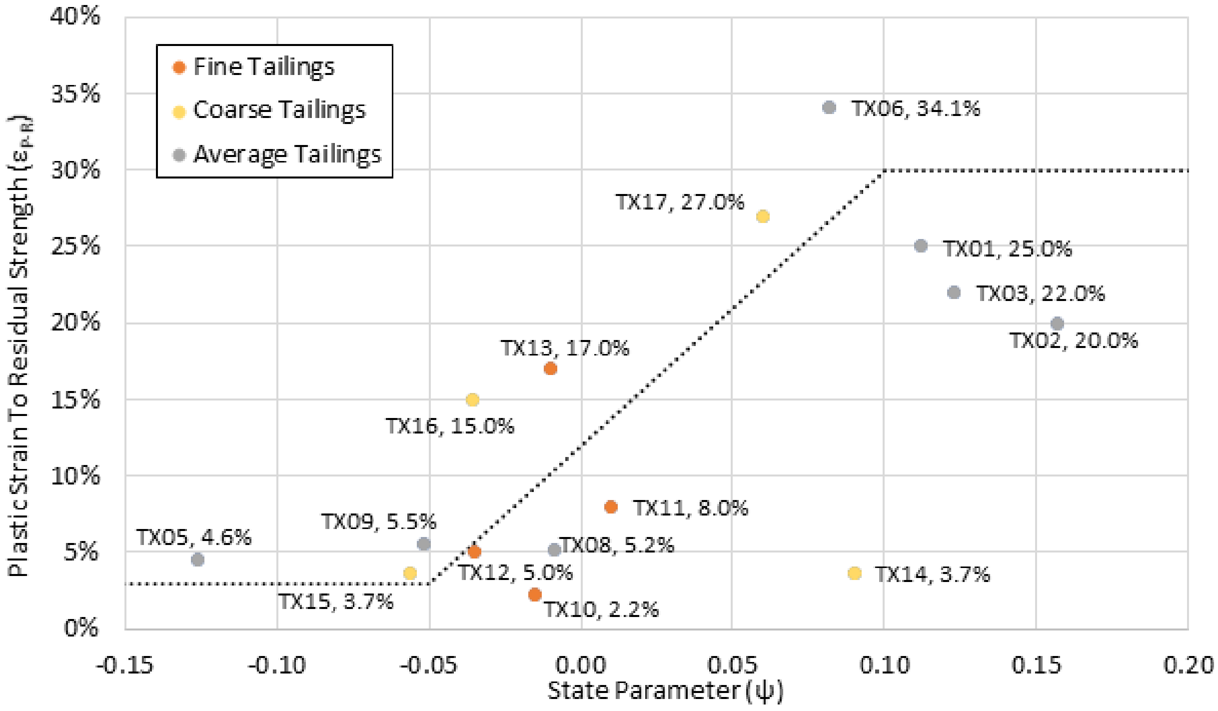


Figure 37: Relationship Between Plastic Strain to Residual Strength (ε_{P-R}) and State Parameter (ψ) for Drained Analysis

6.3.2 Undrained Parameters

Undrained strength ratios for all tailings were calculated at 50% of the peak deviator stress, and a ν of 0.49. G was calculated from these results for input to the analyses.

Relationships relating G and peak and residual undrained shear strength ratios to state parameter were developed for input into the analyses. G was normalized by dividing by the mean effective stress. K was calculated from G and ν using:

Equation 6-1:

$$K = \frac{2G(1+\nu)}{3(1-(2\nu))}$$

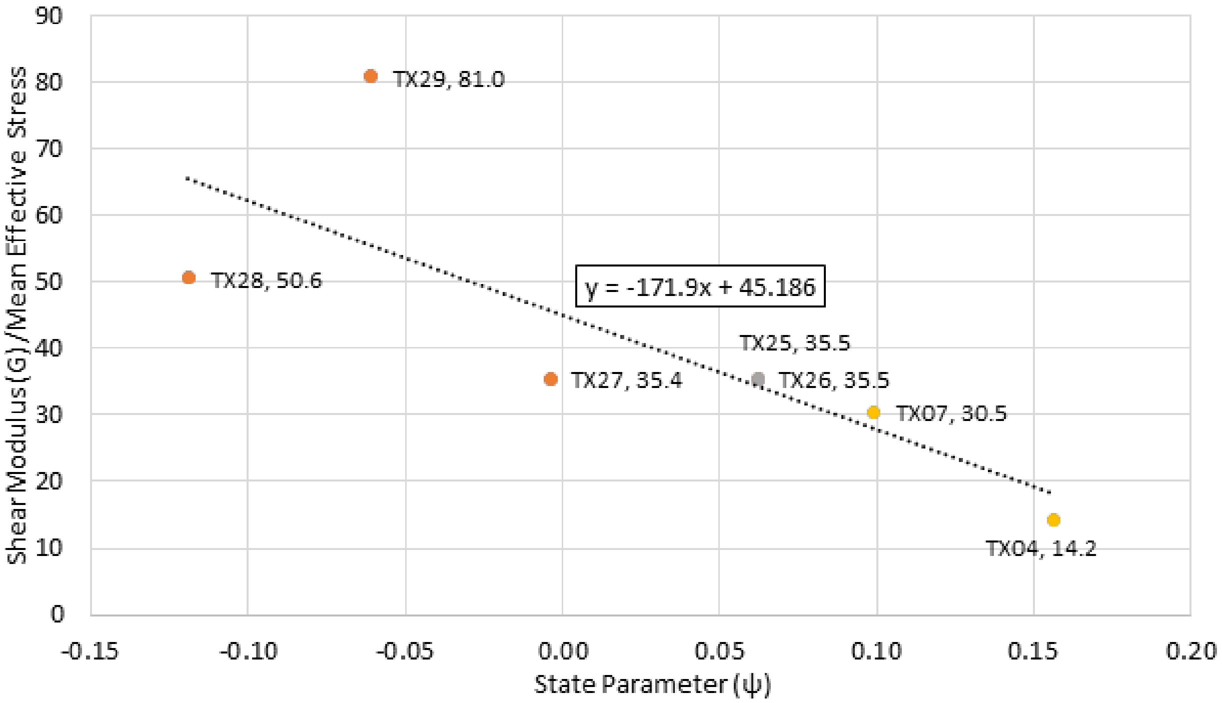


Figure 38: Relationship Between Shear Modulus (G) and State Parameter (ψ) for Undrained Analysis

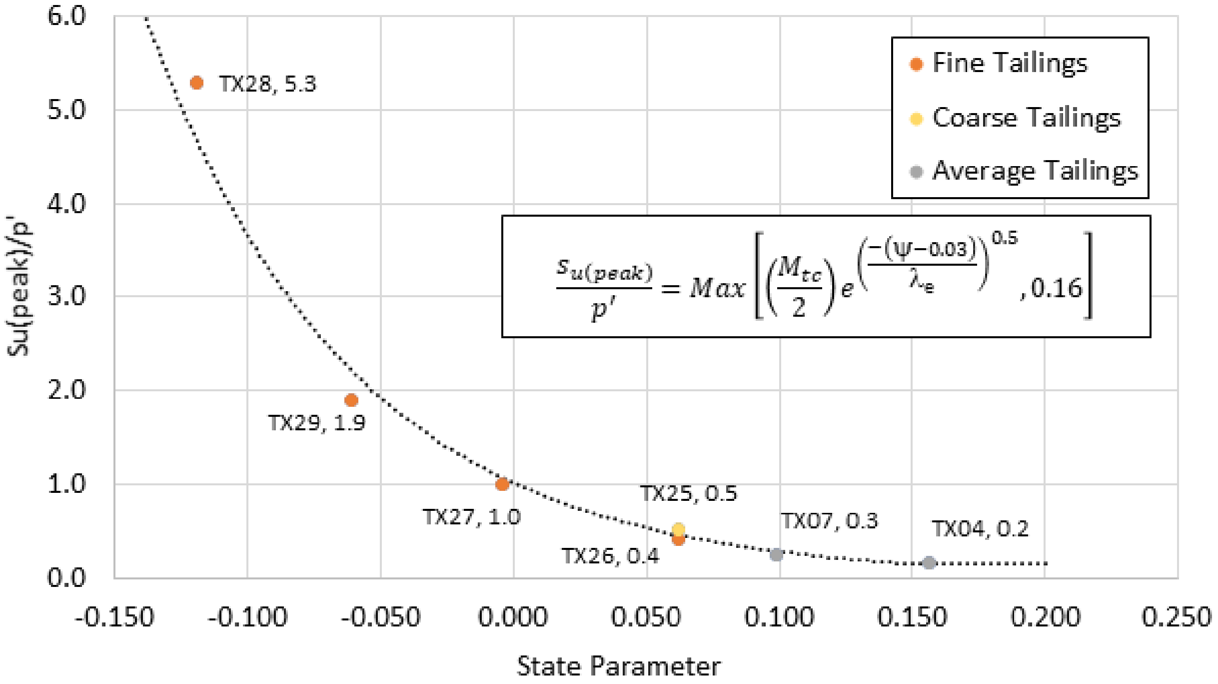


Figure 39: Relationship Between Su(peak)/*p'* and State Parameter (ψ) for Undrained Analysis

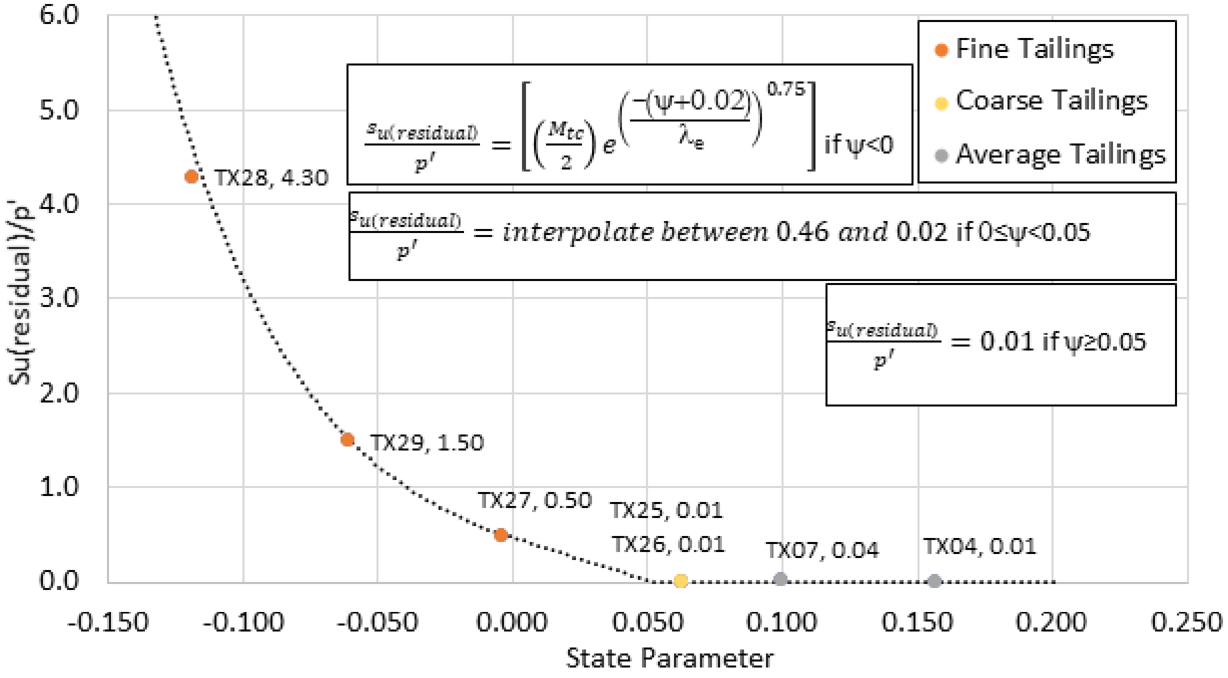


Figure 40: Relationship Between Su(residual)/*p'* and State Parameter (ψ) for Undrained Analysis

To model the strain weakening response of the undrained triaxial compression tests, trends relating plastic strain to post-peak strain ($\varepsilon_{P\text{-}SL}$) and plastic strain to residual strength (ε_{P-R}) to state parameter were developed in the manner described for the drained triaxial compression tests. These parameters were then verified using element test analyses, provided in Annex 8.

The $\varepsilon_{P\text{-}SL}$ and ε_{P-R} versus ψ relationships are shown in Figure 41 and Figure 42.

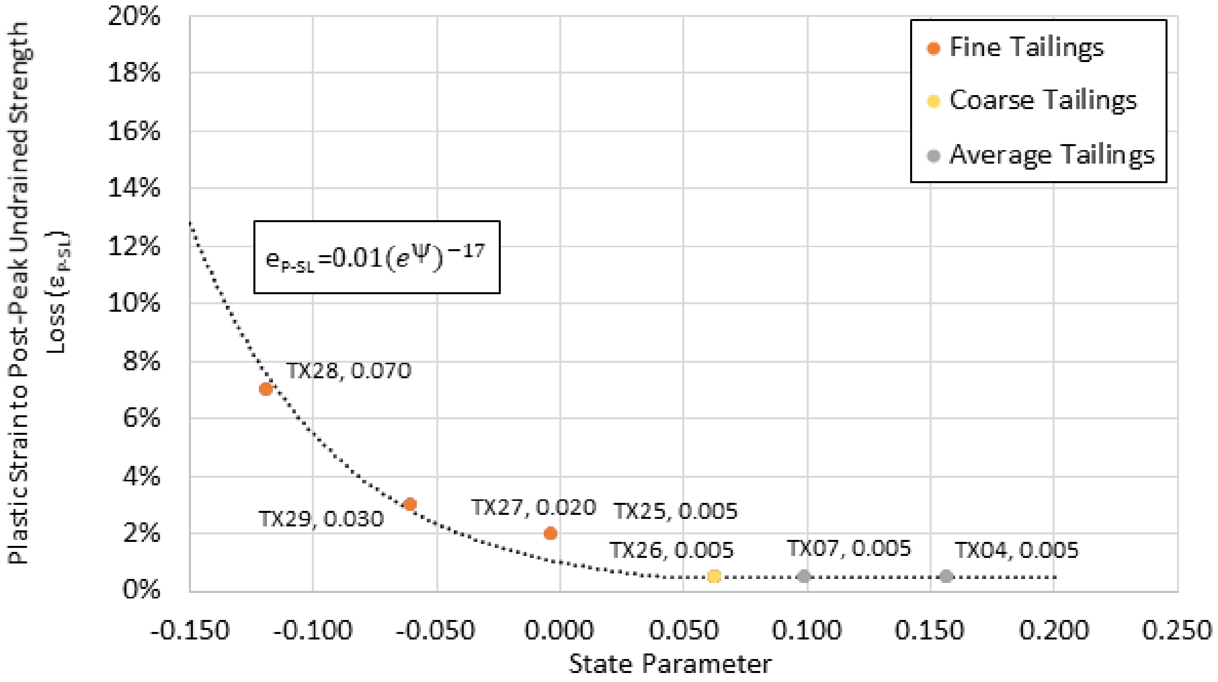


Figure 41: Relationship Between Plastic Strain to Post-Peak Strength Loss ($\varepsilon_{P\text{-}SL}$) and State Parameter (ψ) for Undrained Analysis

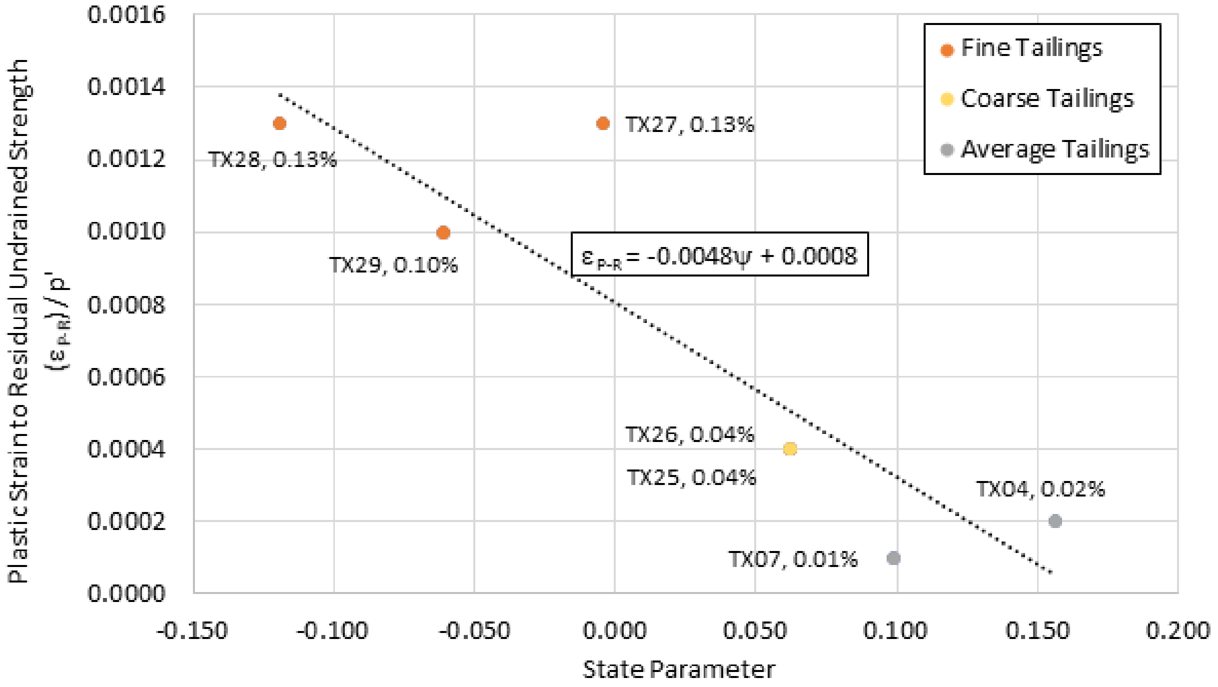


Figure 42: Relationship between Plastic Strain to Residual Strength (ε_{P-R}) and State Parameter (ψ) for Undrained Analysis

6.4 Critical State Model Inputs

The CSL and M values used in the analyses were those discussed in Section 5.2.4. The other parameters are discussed below.

6.4.1 Volumetric Coupling Parameter, N

Dilatancy parameters were derived from triaxial tests performed on the Fine, Coarse and Average Tailings gradation samples. The stress dilatancy plot on Figure 43 was used to determine the volumetric coupling parameter, N. The slope of the line on Figure 43 is equal to (1-N), giving a value of N=0.27. The intercept of the trend line on Figure 43 can be used as an alternate method for calculating M_{tc}, often referred to as the Bishop method. This value of 1.31 is similar to the values calculated from the end of test points on the graph of *q* versus *p′* discussed in Section 5.2.4 and equates to a critical state friction angle of 34°, consistent with the values discussed previously.

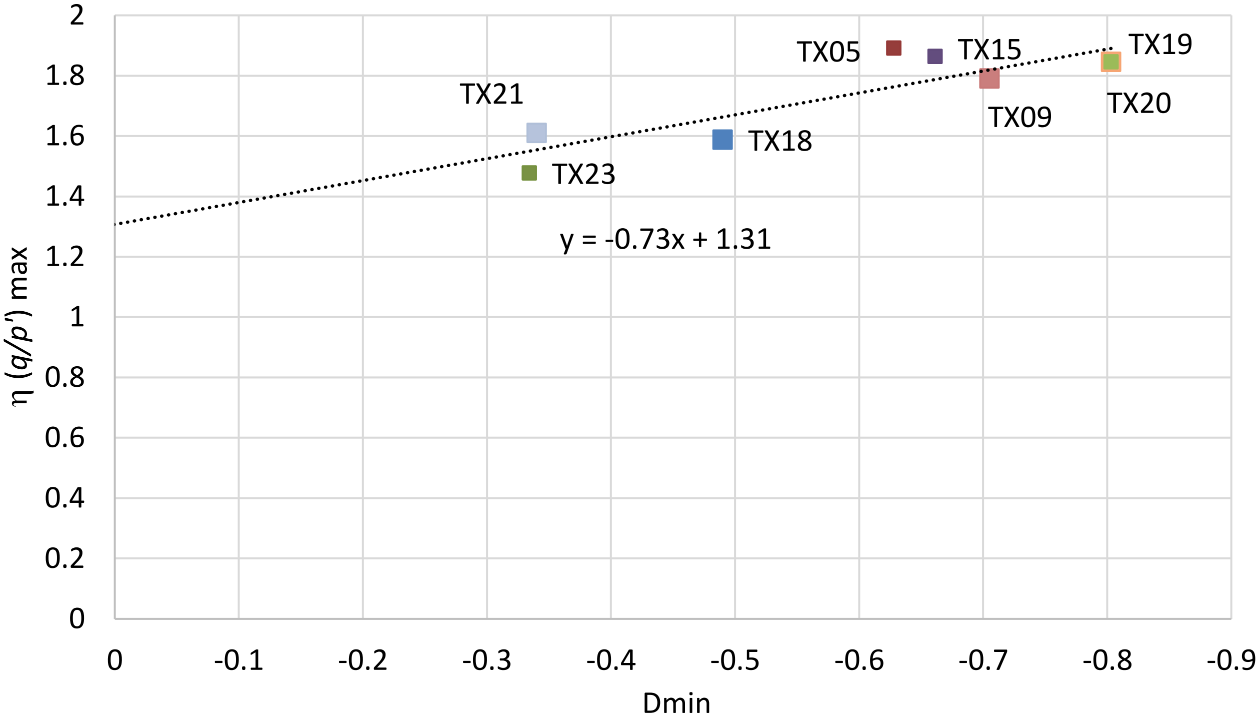


Figure 43: Dilatancy – Stress Ratio Relationship for Average Tailings Gradation

6.4.2 Dilatancy Parameter, χ_{tc}

The parameter χ_{tc} is the slope of the trend line for minimum dilatancy (equal to the dilatancy at peak stress ratio) versus the state parameter at peak stress ratio. Figure 44 shows that this parameter is higher than typical as well as being variable. As for the unusual response seen in the peak friction angle discussed earlier, this response is assumed to be a result of bonding of the tailings. During later element test analyses of the triaxial test results using the NorSand constitutive model, sensitivity analyses were completed using different values of this parameter to determine its effect on the results. As a result of those sensitivity analyses, a value of 6 was selected for use in the analyses. This high value of χ_{tc} led to numerical instability and sensitivity analyses were ultimately completed for this parameter in the full-scale analyses.

This variability in dilatancy was investigated in the triaxial testing program by completing three tests of the Average Tailings gradation at the same initial mean effective stress (100 kPa), at increasingly dense state parameters. The results on Figure 45, show a reduced dilatancy (i.e., peak of the stress-strain curve) at a state parameter of -0.08 compared with the looser sample with a state parameter -0.05.

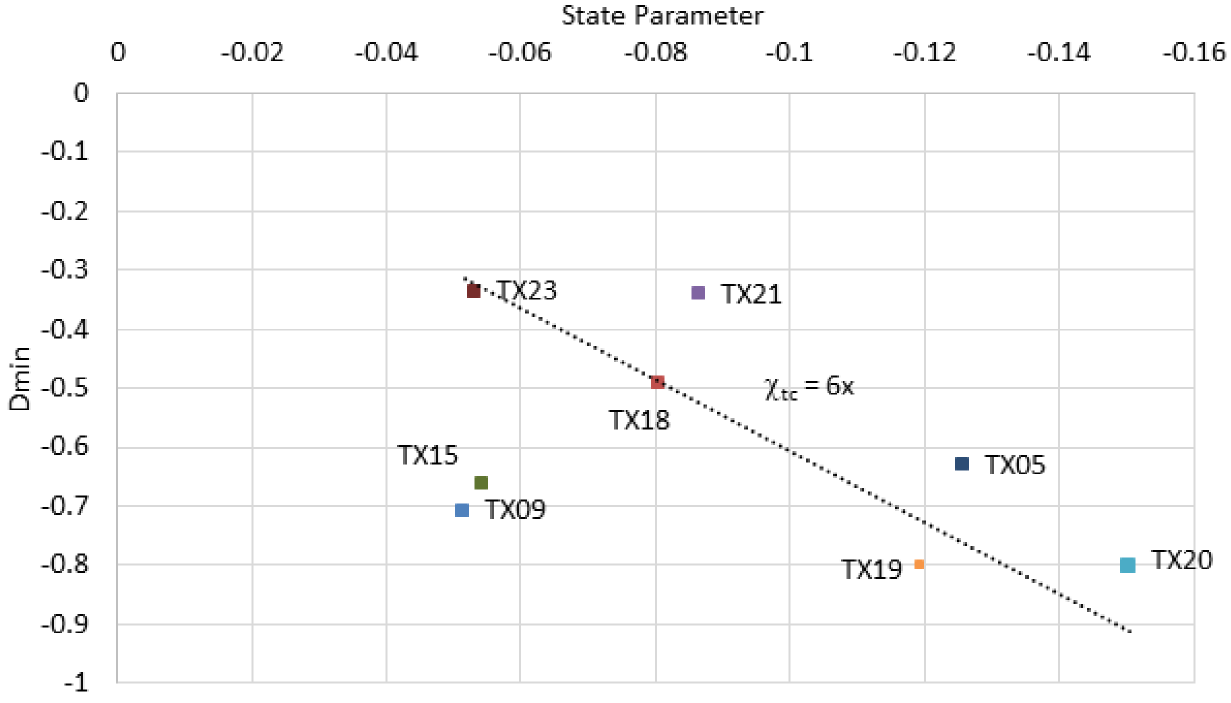


Figure 44: Dilatancy – State Parameter Relationship for Average Tailings Gradations

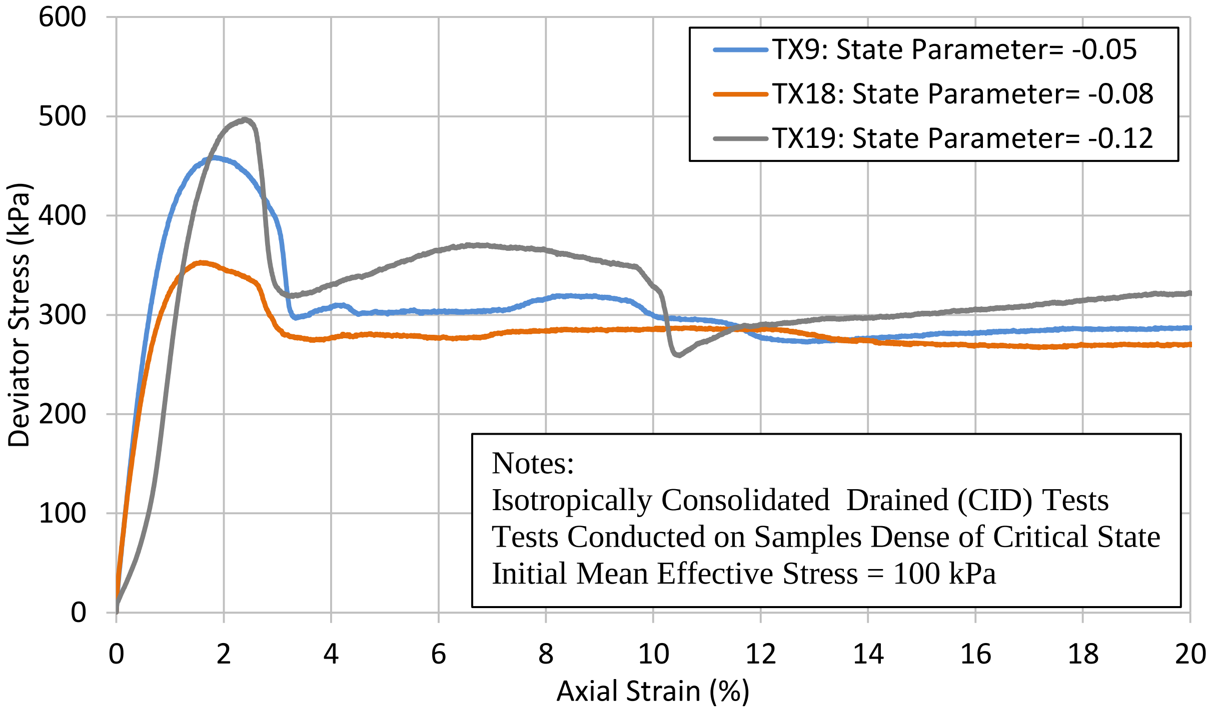


Figure 45: Comparison of Stress-Strain Curves for Samples Tested at The Same Mean Effective Stress, but Increasingly Dense States

6.4.3 Elasticity, G_{max}

The trend of small-strain shear modulus (G_{max}) with *p'*, determined from the bender element and field V_s data, was used in the analyses. G_{max} was derived from the V_s using the following formula:

Equation 6-2:

$$G_{max}(MPa) = \frac{v_s(^m/_s)^2}{10^6} x\rho_{bulk}(^{kg}/_{m^3})$$

All the G_{max} results were plotted against their associated *p'* in Figure 46. A reasonable trend was found using the following relationship (see Equation 6-3).

Equation 6-3:

$$G_{max} = 100\left(\frac{p'}{pref}\right)^{0.5}, where\ p_{ref} = 100\ kPa$$

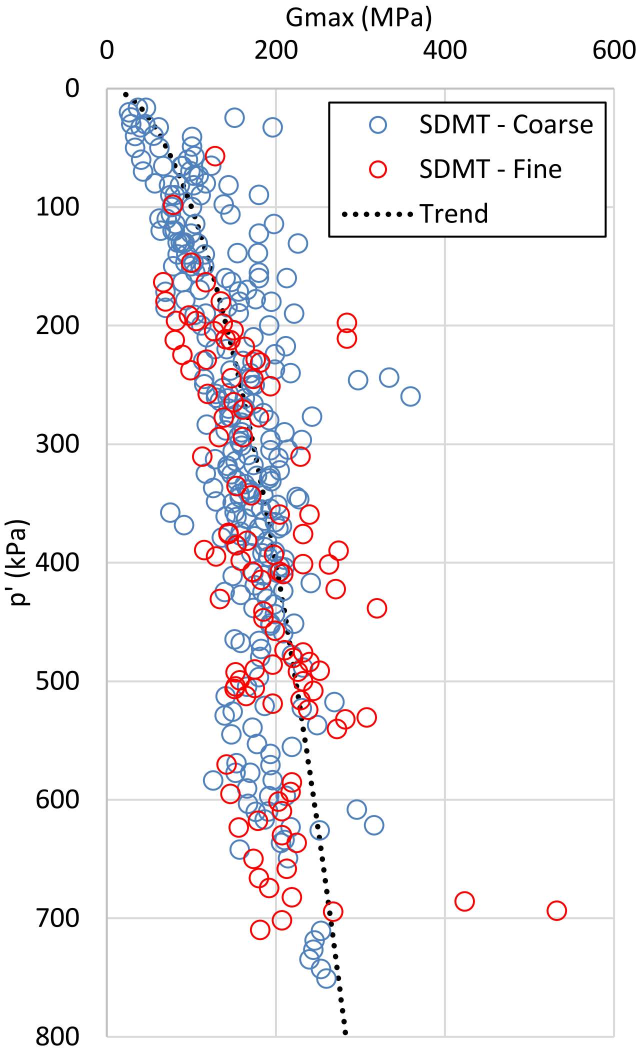


Figure 46: G_{max} Trend from Seismic Dilatometer (V_s) Data

6.4.4 Hardening, H0, Hψ

The plastic hardening modulus was determined by Iterative Forward Modeling (IFM) of the triaxial test result. The objective of this calibration was not to get the best fit to each individual test, but to obtain the best overall fit to all the tests. In the calibration process, initially constant values of H were used. Once good fits were obtained, a relationship between initial state parameter and H was developed and the tests were refitted using this relationship. The derived trend for hardening was H_0=160 and H_ψ=1037.

Equation 6-4: $$\boldsymbol{H = H_0 - H_\psi}$$

Where,

- H = plastic hardening modulus,
- H_0= modulus intercept (H vs. Ψ relationship); and
- H_{Ψ}=modulus gradient.

6.5 State Parameter

The state parameter used in the analyses was determined from CPTu data, as discussed in Section 7.5.

6.6 Parameter Summary

The material properties used in the analyses are summarized in Table 17.

Table 17: Summary of Parameters Selected from Laboratory Testing

Properties	Fine/Average/Coarse Tailings
Mohr-Coulomb Drained Parameters	
Shear Modulus/p'	$G = -631\psi+126.5$
Bulk Modulus/p'	$K = -900.9\psi+165.7$
Peak Friction Angle	If $\psi < 0$, $\phi' = -79.4\psi + 36°$; If $\psi > 0$, $\phi' = 36°$
Strain Weakening – Drained Parameters	
Strain to Peak ($\varepsilon_{P\text{-}SL}$)	If $\psi \leq -0.05$, $\varepsilon_{P\text{-}SL}= 0.01$; If $-0.05 \leq \psi \leq 0.14$, $\varepsilon_{P\text{-}SL}= 0.59\psi + 0.040$; If $\psi \geq 0.14$, $\varepsilon_{P\text{-}SL}= 0.12$
Strain to Residual ($\varepsilon_{P\text{-}R}$)	If $\psi \leq -0.05$, $\varepsilon_{P-R}= 0.03$; If $-0.05 \leq \psi \leq 0.1$, $\varepsilon_{P-R}= 1.8\psi + 0.12$; If $\psi \geq 0.1$, $\varepsilon_{P-R}= 0.13$
Residual Friction Angle	$\phi' = 34°$
Strain Weakening - Undrained Parameters	
Shear Modulus	$G = -171.9x\psi+45.2$
Bulk Modulus	$K=(2G(1+\nu))/(3(1-2\nu))$
Poisson's Ratio (ν)	0.49
Peak Undrained Shear Strength Ratio	$s_{u(peak)}/p'$= Max $((M_{tc}/2)*\exp(-(\psi+\psi_{offset})/ \lambda_e)^{0.5}, 0.16)$; $\psi_{offset} = -0.03$
Residual Undrained Shear Strength Ratio	If $\psi < 0$, $s_{u(residual)}/p'$= Max $((M_{tc}/2)*\exp(-(\psi+\psi_{offset})/ \lambda_e)^{0.75}, 0.01)$; If $\psi \geq 0.05$, $s_{u(residual)}/p'=0.01$; $\psi_{offset} = +0.02$
Strain to Peak ($\varepsilon_{P\text{-}SL}$)	$\varepsilon_{P\text{-}SL}=0.01e(\psi)^{-17}$
Strain to Residual ($\varepsilon_{P\text{-}R}$)/p'	$\varepsilon_{P-R} = -0.0048\psi+0.0008$
Critical State Model (NorSand) Parameters	

Γ	1.12/1.04/1.02
λ_e	0.039
Curved CSL Parameter A	1.29/1.22/1.19
Curved CSL Parameter B	0.34
Curved CSL Parameter C	0.11
M_{tc}	1.38
N	0.27
X_{tc}	6
G_{max}	$G_{max} = 100x(p'/pref)^{0.5}$
H_0	160
$H\psi$	1037
Γ	1.12/1.04/1.02
CH Soil Model Parameters	
E_{ref}	800
ν	0.4
Rf	0.99
n	0.15
c	0
ϕ	*p'* <370kPa = 22.5; *p'* > 800 = 17; interpolate for intermediate *p'*

7 CPTU AND V_S DATA INTERPRETATION

7.1 General

As part of this assessment, a review of the available CPTu data was completed. This included the delineation of tailings materials within the dam into similar tailings types (i.e., Fine and Coarse Tailings, and Slimes), as discussed in Section 7.3. A description of how that delineation was developed in two- and three-dimensions is presented in Appendix F. This section describes the process used to calculate undrained strength parameters and state parameters from the CPTu data. The raw CPTu data available for this investigation included 28 CPTu and nine shear wave velocity tests (V_s) completed as part of geotechnical investigations in 2005, 2016 and 2018 (as summarized in Appendix B). Figure 47 shows the locations of CPTu tests at Dam I.

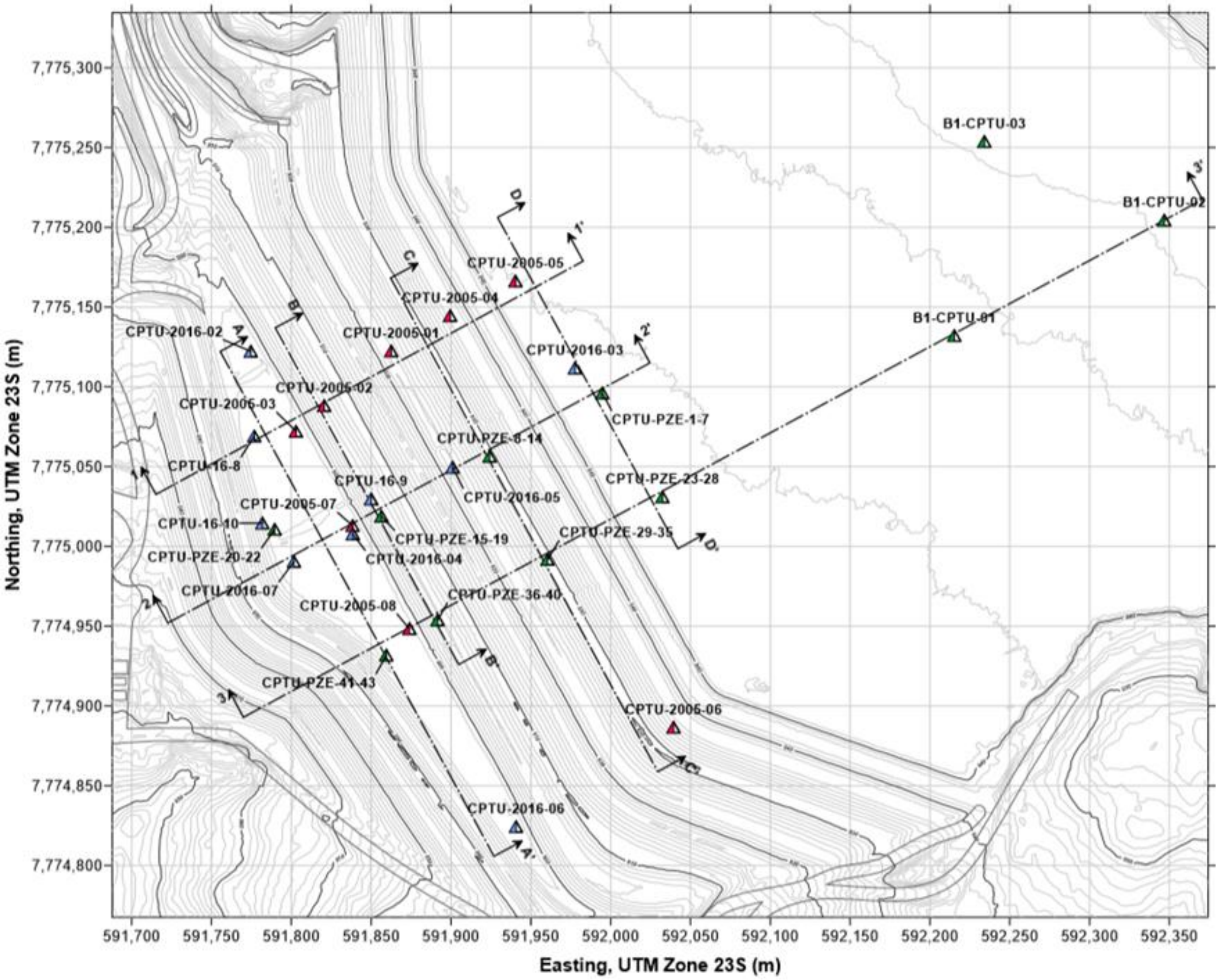


Figure 47: CPTu Location Plan[8]

7.2 CPTu Data Processing

The methodology used to process the CPTu data consisted of the following steps:

- Processed the raw CPTu data, which included cone tip resistance (qc), sleeve friction (fs), and dynamic pore pressure (u2);
- Processed the raw pore pressure dissipation test (PPDT) data to estimate the depth of the water table and hydraulic gradient;
- Calculated the corrected tip resistance (qt), friction ratio (Rf), state parameter (ψ), soil behavior type index (Ic), static pore pressure (u), equivalent clean sand tip resistance (Qtn,cs), post-liquefaction strength ratios ($Su_{(LIQ)}/\sigma'_v$), peak undrained strength ratios

---

[8] Appendix B, Figure 2-1b.

($Su_{(peak)}/\sigma'_v$) and the apparent fines content (%), for each CPTu and plotted the results against elevation.

CPTu profile plots are given in Annex 9.

7.3 Tailings Delineation

A review of the CPTu data, presented in Annex 9, indicated that the tailings within Dam I could be sub-divided into three materials, Coarse Tailings, Fine Tailings and Slimes, down the tailings beach, of which the Fine and Coarse Tailings were most relevant to the failure, being closest to the face of Dam I. The Fine and Coarse Tailings types were developed by grouping regions within Dam I with similar strengths and CPTu behavior types. The boundaries between these regions were delineated based on the criteria in Table 18 and are shown on the CPTu profiles for each CPTu included in Annex 9. Generally, it was observed that the Coarse Tailings layers had a lower apparent fines content, higher tip resistance (but were still susceptible to flow liquefaction, as per Robertson (2010)), and a soil behavior type index ≤ 2.6. The Fine Tailings layers were observed to have a higher apparent fines content, lower tip resistance, and a soil behavior type index > 2.6.

Table 18: Tailings Delineation Criteria

[1]Tailings Material Type	Material Index, I_c	Apparent Fines Content (%)
Coarse Tailings	≤ 2.6	≤ 50 %
Fine Tailings	> 2.6	> 50 %

NOTES:

[1] A third tailings material type, Slimes, was assumed to exist upstream of the beach location based on CPTu data collected (B1-CPTu-01, 02, 03) within the pond that exhibited very low strengths.

[2] Fine Tailings layers were also distinguishable using a lower tip resistance compared to the Coarse Tailings.

7.4 Peak and Liquefied Strength Estimation using CPTu Data

The peak undrained shear strength ratio, $s_{u(peak)}/\sigma'_{v0}$, was calculated using the following formula developed by Olson and Stark (2003).

Equation 7-1: $$\frac{s_{u(peak)}}{\sigma'_{v0}} = \mathbf{0.205 + 0.0143}(q_{c1}) \text{ ; Provided: } q_{c1} \lesssim \mathbf{6.5\ MPa}$$

The liquefied, undrained shear strength ratio, $s_{u(liq)}/\sigma'_{v0}$, was calculated using the following relationship outlined by Robertson (2010).

Equation 7-2: $\frac{s_{u(liq)}}{\sigma'_{v0}} = \frac{0.02199-0.0003124 \cdot Q_{tn,cs}}{1-0.02676 \cdot Q_{tn,cs}+0.0001783 \cdot Q_{tn,cs}^2}$; Provided:

$$\begin{cases} Q_{tn,cs} \leq 70 \\ 0.03 \leq \frac{s_{u(liq)}}{\sigma'_{v0}} \leq tan\varphi' \end{cases}$$

Using these relationships, a range of values was calculated for both Fine and Coarse Tailings. To develop a set of representative values for each tailings unit, histograms of the data were produced, as shown in Annex 9. The strength values were compared with the undrained strengths measured in the triaxial tests. It was noted that the peak strength from the triaxial tests was significantly higher than the peak undrained strength estimated from these empirical relationships and the liquefied strength was lower in the triaxial tests than implied by these relationships. This is considered to be a reflection of the different mineralogy of these tailings compared to the soils used to develop the empirical CPTu correlations, and the bonding of the tailings, which is not captured in these empirical relationships. As a result, preference was given to the triaxial testing data for assigning the peak and liquefied strengths of the tailings. The peak and residual undrained strength ratio trends described in Section 6.2 were used in the analyses.

7.5 State Parameter Estimation Using CPTu Data

Various methods are available to calculate the in-situ state parameter from CPTu data. The methods of Robertson (2009),[9] Plewes et al. (1992)[10] and Jefferies and Been (2016) were used in this assessment. The Robertson (2009) and Plewes et al. (1992) methods are empirical and do not require laboratory testing or numerical analysis, but rely on relationships developed from a database of mainly silica based sandy soils. The method developed by Jefferies and Been (2016) is a more site-specific approach that relies on numerical simulations and incorporates index and laboratory testing data.

This section discusses the three methods examined to characterize the in-situ state parameter of Fine and Coarse Tailings.

7.5.1 Robertson (2009) Method

The Robertson (2009) method uses corrected tip resistance (q_t) and sleeve friction (f) from CPTu data to calculate a normalized cone resistance (Q_{tn}) using Equation 7-3.

Equation 7-3: $Q_{tn} = \left[\left(\frac{q_t-\sigma_v}{p_a}\right)\right]\left(\frac{p_a}{\sigma'_v}\right)^n$

---

[9] Robertson, P.K. (2009). Interpretation of cone penetration tests – a unified approach. *Canadian Geotechnical Journal*, *46*(11), 1337-1355.

[10] Plewes, H.D., Davies, M.P., & Jefferies, M.G. (1992). CPT based screening procedure for evaluating liquefaction susceptibility. Proceedings from *The 45th Canadian Geotechnical Conference*, 41-49. Richmond, BC: BiTech Publishers Ltd.

Where,

- σ_v= in-situ total vertical stress
- σ'_v= in-situ total effective vertical stress
- p_a= atmospheric pressure
- n= stress component ($n \leq 1$)

The normalized cone resistance (Q_{tn}) is adjusted to account for fines content, minerology and plasticity using the correction factor K_c,, to calculate an equivalent clean sand value ($Q_{tn,cs}$), as shown in Equation 7-4.

Equation 7-4: $$\boldsymbol{Q_{tn,cs} = K_c Q_{tn}}$$

Where,

- K_c= 1.0, if $I_c \leq 1.64$
- K_c=$5.581I_c^3 - 0.403I_c^4 - 21.63I_c^2 + 33.75I_c - 17.88$, if I_c>1.64

The in-situ state parameter (ψ) is then calculated using Equation 7-5.

Equation 7-5: $$\psi = \mathbf{0.56 - 0.33\log(\boldsymbol{Q_{tn,cs}})}$$

7.5.2 Plewes et al. (1992) Method

The Plewes et al. (1992) method normalizes q_t using mean effective stress and dynamic pore water pressure and relates it to (ψ) using Equation 7-6, Equation 7-8, Equation 7-9 and Equation 7-9.

Equation 7-6: $$\boldsymbol{Q_p(1 - B_q) + 1 = \bar{k}\, exp(-\bar{m}\psi)}$$

Equation 7-7: $$\boldsymbol{B_q = \frac{(u - u_0)}{(q_t - \sigma'_{v0})}}$$

Equation 7-8: $$\boldsymbol{\frac{\bar{k}}{M_{tc}} = 3 + \frac{0.85}{\lambda_{10}}}$$

Equation 7-9: $$\boldsymbol{\bar{m} = 11.9 - 13.3\lambda_{10}}$$

Where,

- Q_p=normalized cone resistance

- B_q= pore pressure ratio
- M_{tc}= critical friction ratio
- λ_{10}= slope of the critical state line
- $\bar{k}$ and $\bar{m}$= semi empirical parameters for estimating ψ

While the method provides empirical relationships for estimating λ_{10} and M_{tc}, it also indicates that development of the soil's CSL through triaxial testing on intact or reconstituted soil samples can be used to refine estimates of λ_{10} and M_{tc} and provide an estimate of (ψ) that is more soil specific. The calculation of (ψ) was completed using a λ_{10} value of 0.09 and a M_{tc} value of 1.38 as discussed in Section 6.4.1.

7.5.3 Cavity Expansion Method – Jefferies and Been (2016)

The Jefferies and Been (2016) method uses the critical state parameters discussed i in Section 6.4.1 in numerical simulations of the spherical cavity expansion, which is treated as an analogue to the CPTu. These simulations are used to develop site-specific values of $\bar{k}$ and $\bar{m}$ (see Plewes, et al. (1992) method), to calculate ψ from CPTu data. These analyses used the NorSand constitutive model with the inputs discussed in Section 6 and summarized in Table 17.

7.5.4 Results

Using the three methods described above, estimates of (ψ) were calculated for both Fine and Coarse Tailings at each CPTu location, as shown in Annex 9. Histograms of the data were produced, as shown in Annex 9. The histograms are overlain for the Coarse and Fine Tailings in Figure 48 and Figure 49, which also show the distributions of these data used in the analyses (see Appendix H). The Robertson (2009) method was ultimately not used for the Fine Tailings because use of the fines content correction in that relationship was not considered appropriate given the similarity in slope of the CSL for the Coarse and Fine Tailings.

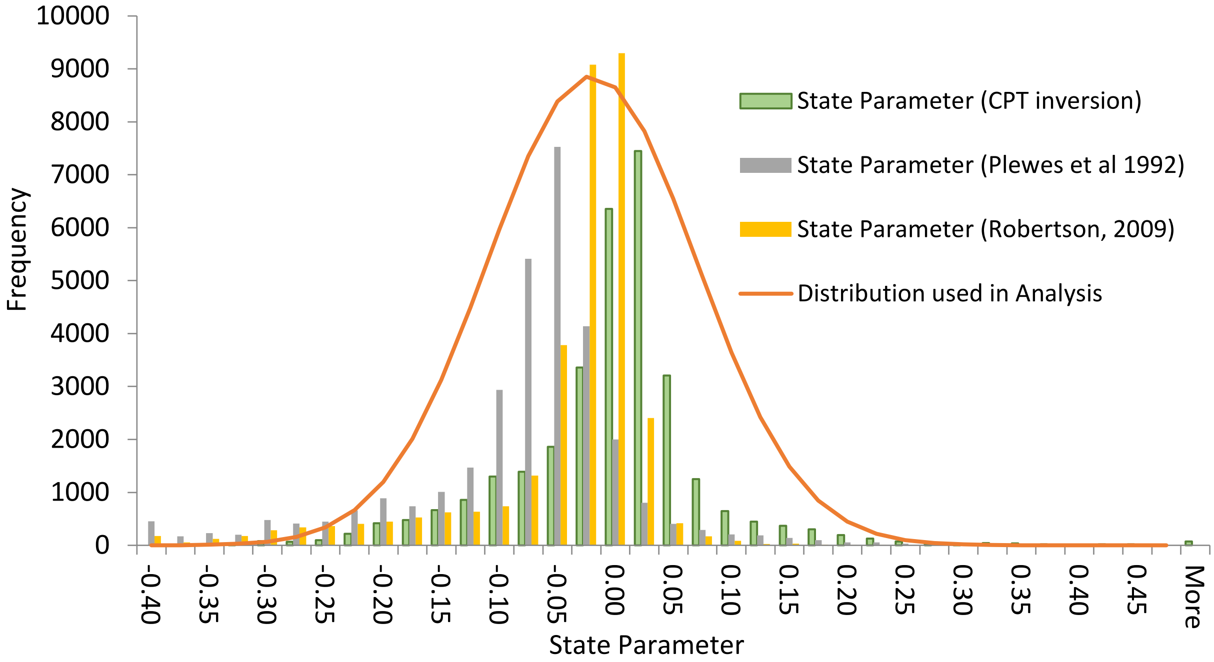


Figure 48: State Parameter (ψ) Distribution for Coarse Tailings

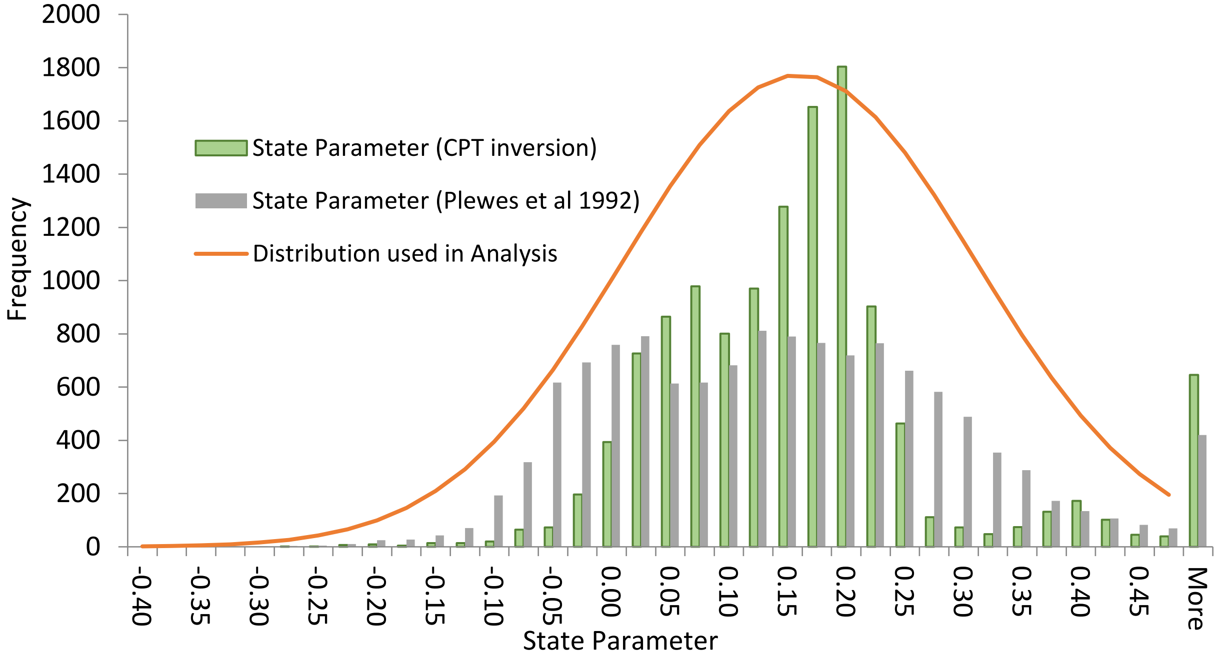


Figure 49: State Parameter (ψ) Distribution for Fine Tailings

In general, the results indicate that the three methods estimate a similar range of state parameter for Coarse Tailings.

For Fine Tailings, the Plewes et al (1992) and Jefferies and Been (2016) methods estimated a similar range of ψ; however, the distribution from the Plewes et al (1992) method was more uniform. Both methods showed that the ψ of Fine Tailings was significantly higher than the Coarse Tailings.

Due to the variation in ψ throughout the tailings, and between methods of analysis, the distributions of ψ shown in Figure 48 and Figure 49 were used in the analyses rather than selecting a 'characteristic state' from these ranges. See Appendix H for the way in which this was used in the analyses. These distributions encompass the range of ψ calculated from the various methods.

7.6 Assessment of Cementation from CPTu Data

Robertson (2016)[11] developed a relationship between Q_{tn} and small-strain rigidity index I_G to screen CPTu and SMDT data for signs of bonding. This relationship, termed the modified normalized small-strain index (K_G^*), was used to identify signs of bonding within the Fine and Coarse Tailings. Soils with a K_G^*> 330 tend to have significant bonding with higher values of K_G^* indicating a higher presence of bonding. As indicated on the CPTu plots in Annex 9, signs of bonding within the Fine and Coarse Tailings were identified, with K_G^* values typically plotting towards the lower boundary of bonded soils (see example in Figure 50). This result is consistent with the conclusions of the SEM testing conducted at UQ, as discussed in Section 4.8.

---

[11] Robertson, P.K. (2018). Cone penetration test (CPT) based soil behaviour type (SBT) classification system – an update. *Canadian Geotechnical Journal*, *53*(12), 1910-1927.

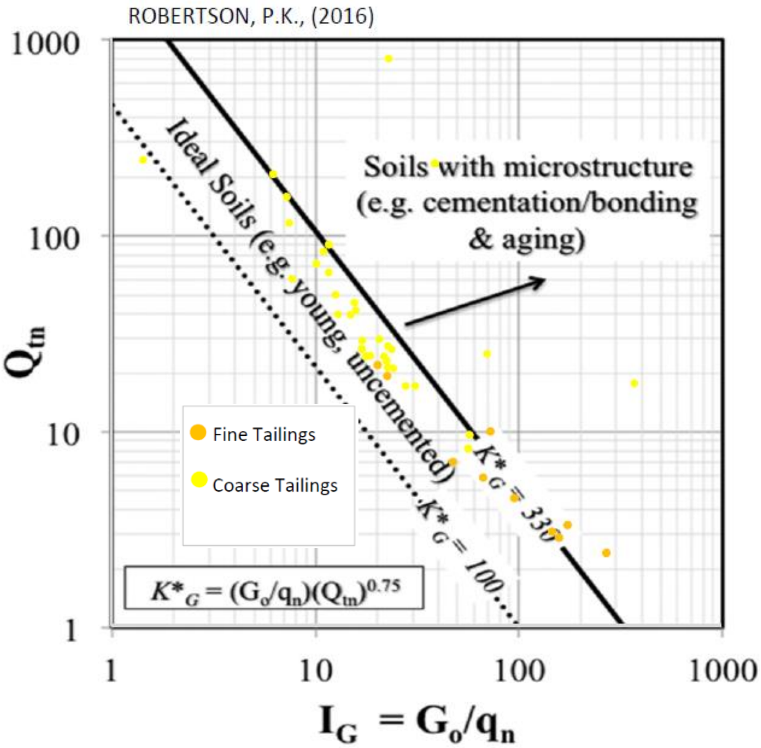


Figure 50: Q_{tn} vs I_G Chart to Identify soils with Microstructure

7.7 Comparison of CPTu Data and Field Vane Test Data

Field Vane Tests were completed previously at Dam I, as discussed in Appendix B. As part of this testing, peak, residual and remolded undrained shear strengths were measured, as well as the stress-strain curves. These strength parameters were not used directly in the analyses of this investigation, but the stress-strain curves from these tests was used as supporting evidence that a rapid loss of strength develops in these materials, consistent with the observations of bonding described earlier and results of laboratory triaxial testing discussed in Section 5.2. Figure 51 and Figure 52 present example stress-strain curves from field vane tests on Fine and Coarse Tailings, respectively.

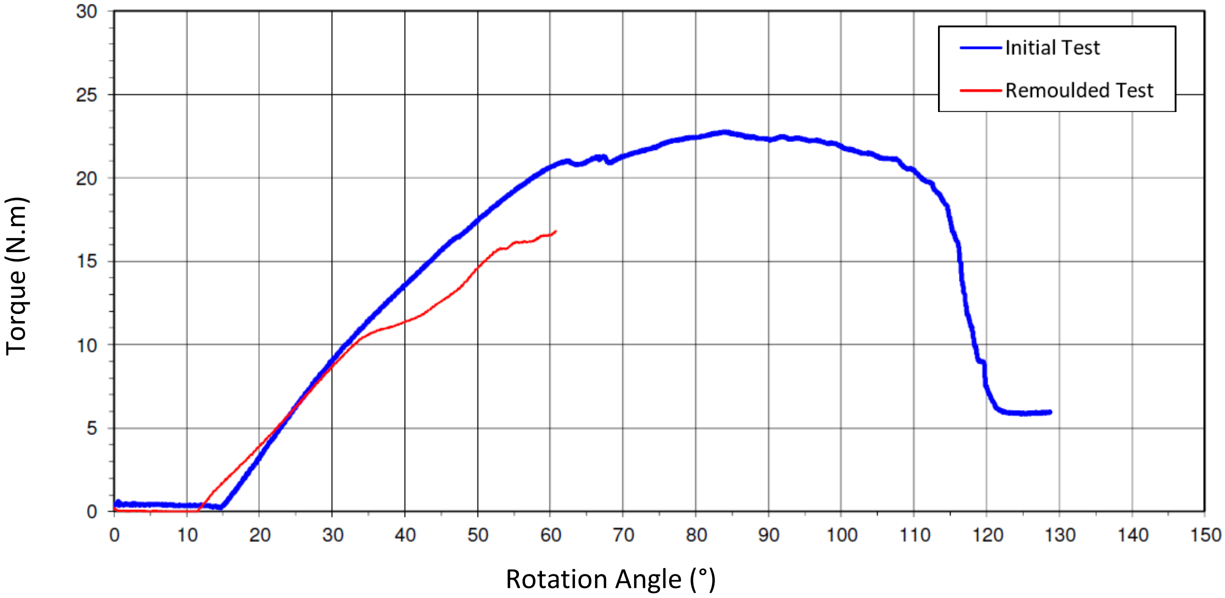


Figure 51: Vane Shear Test Result – VT-16-11 (Depth 22.5 m)

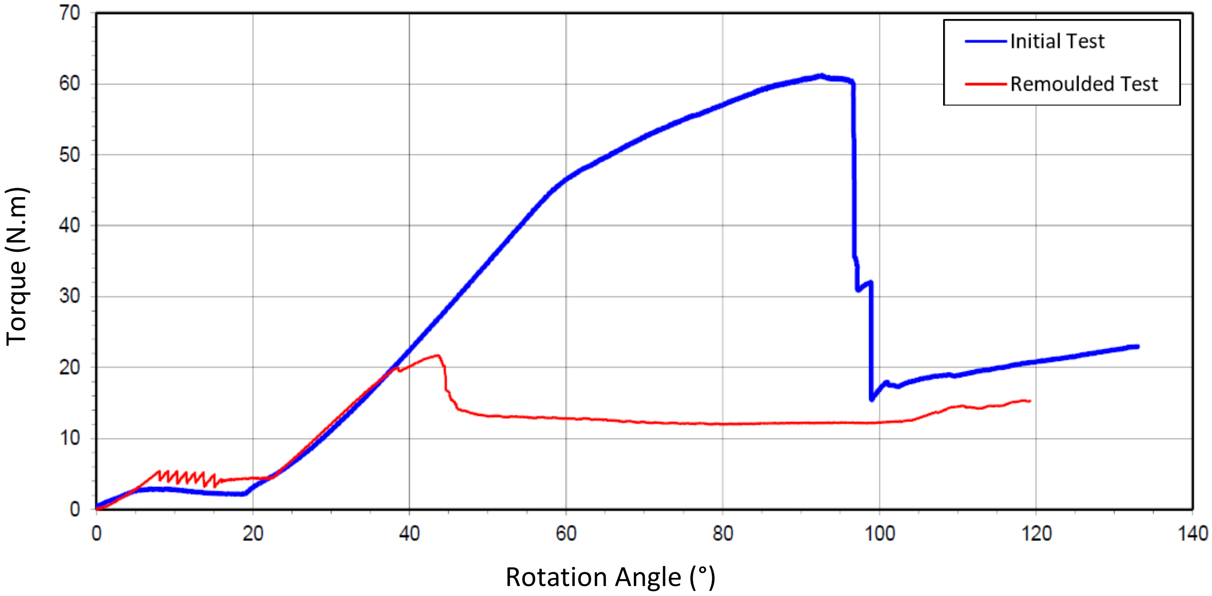


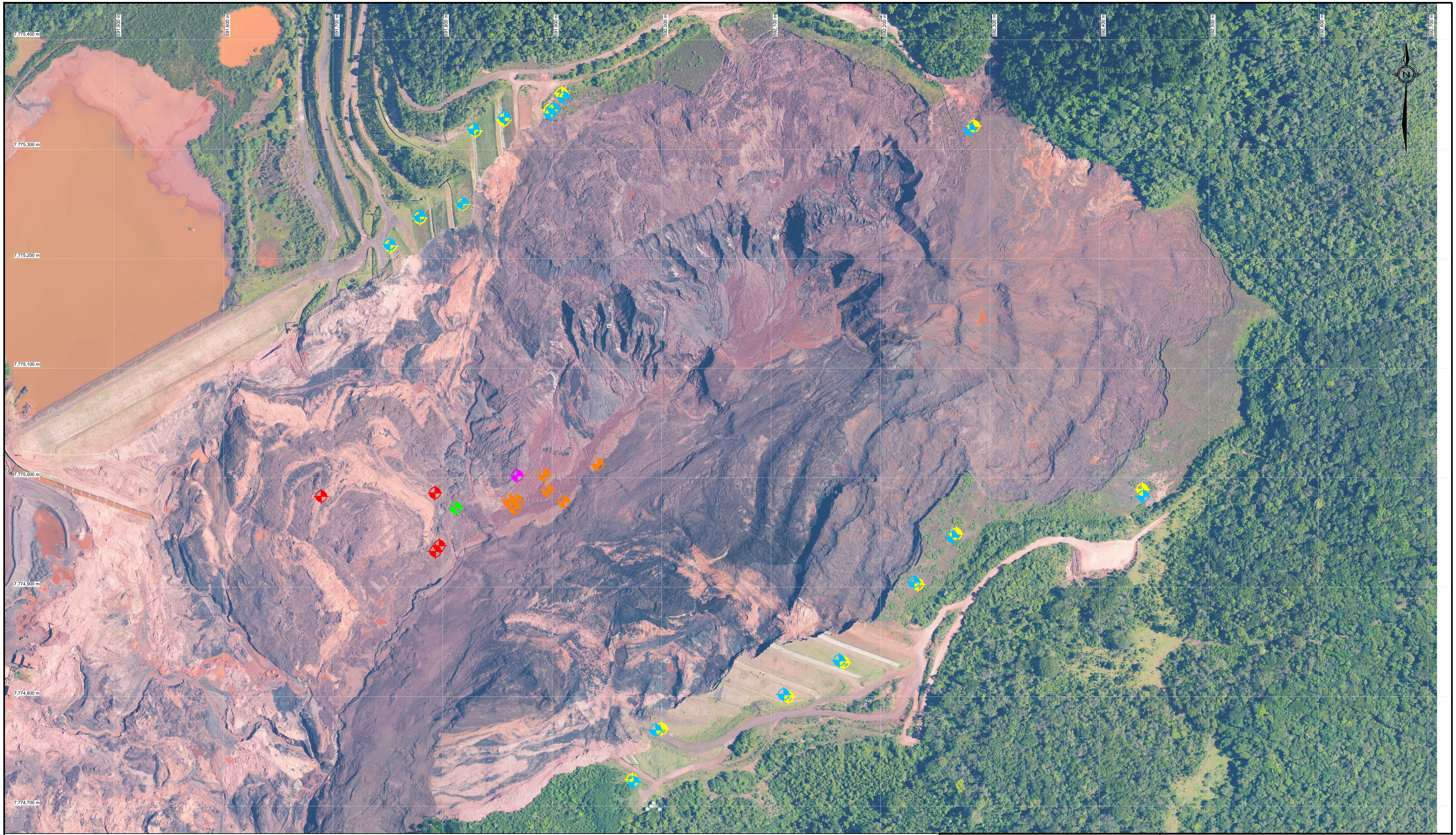
Figure 52: Vane Shear Test Result – VT-16-12 (Depth 9.0 m)

Appendix E

Annex 1 – Field Investigation Data

December 2019

Field Investigations



NOTES:

1. DRAWING COORDINATES ARE BASED ON UTM ZONE 23S GRID SYSTEM. ALL COORDINATES ARE IN METERS.
2. LOCATIONS OF FLOW MEASUREMENTS ARE APPROXIMATE AND ARE BASED ON A HANDHELD GPS DEVICE.

LEGEND:

- ⊕ BOREHOLE LOCATION
- ⊕ GUELPH PERMEAMETER MEASUREMENT LOCATION
- ⊕ DENSITY TEST MEASUREMENT LOCATION
- ⊕ STREAM 1 MEASUREMENT LOCATION
- ⊕ STREAM 2 MEASUREMENT LOCATION
- ⊕ STREAM 3 MEASUREMENT LOCATION

CLIENT

PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES
OF THE FAILURE OF FEIJAO DAM 1

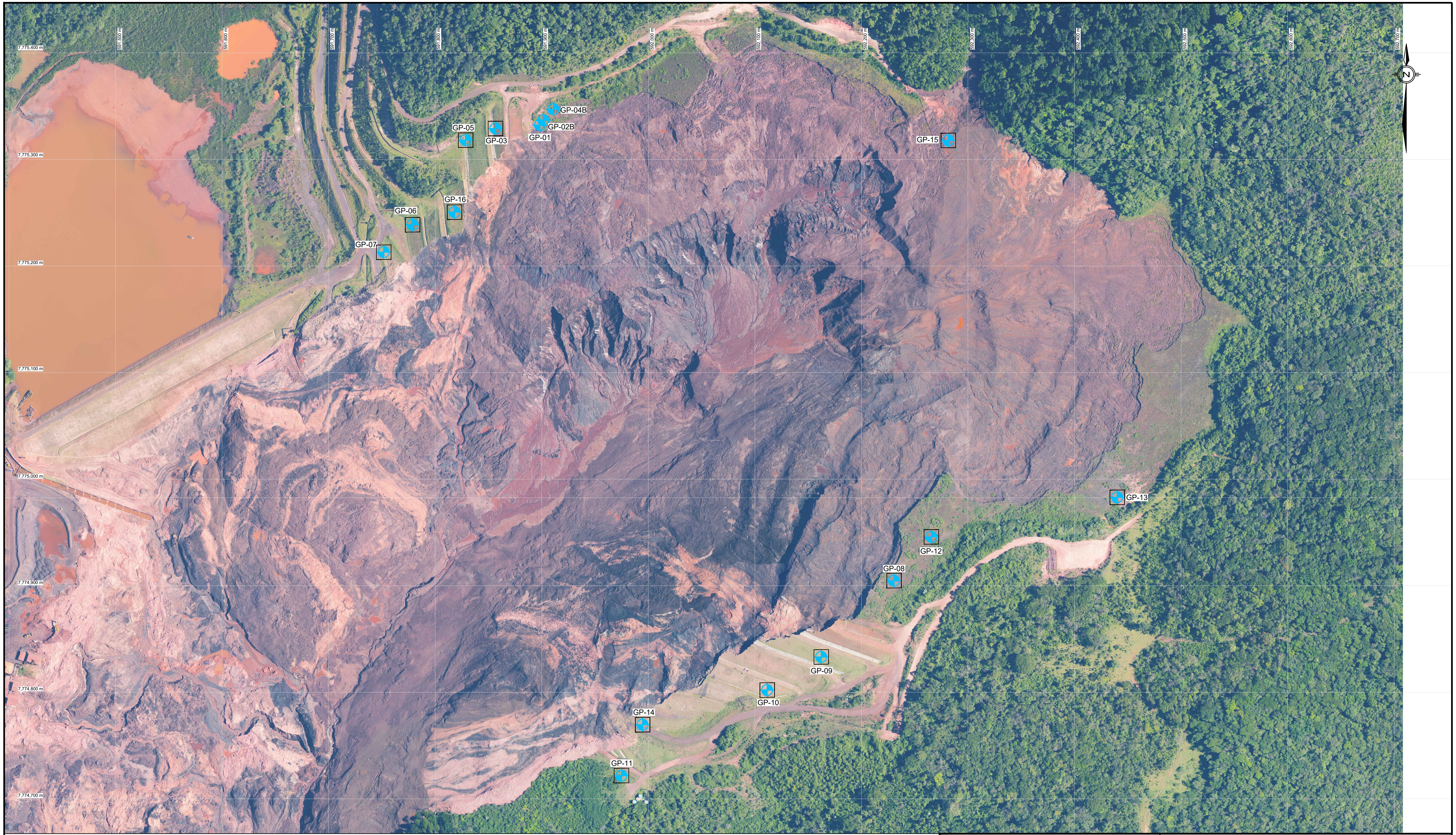
TITLE
FIELD INVESTIGATION TEST LOCATIONS

SCALE
N.T.S

PROJECT No.
0

FIG. No.
1

KCB-FIG-B-L



NOTES:

1. DRAWING COORDINATES ARE BASED ON UTM ZONE 23S GRID SYSTEM. ALL COORDINATES ARE IN METERS.

LEGEND:

⊕	GUELPH PERMEAMETER TEST LOCATIONS
☐	TENSIOMETER TEST LOCATIONS

CLIENT

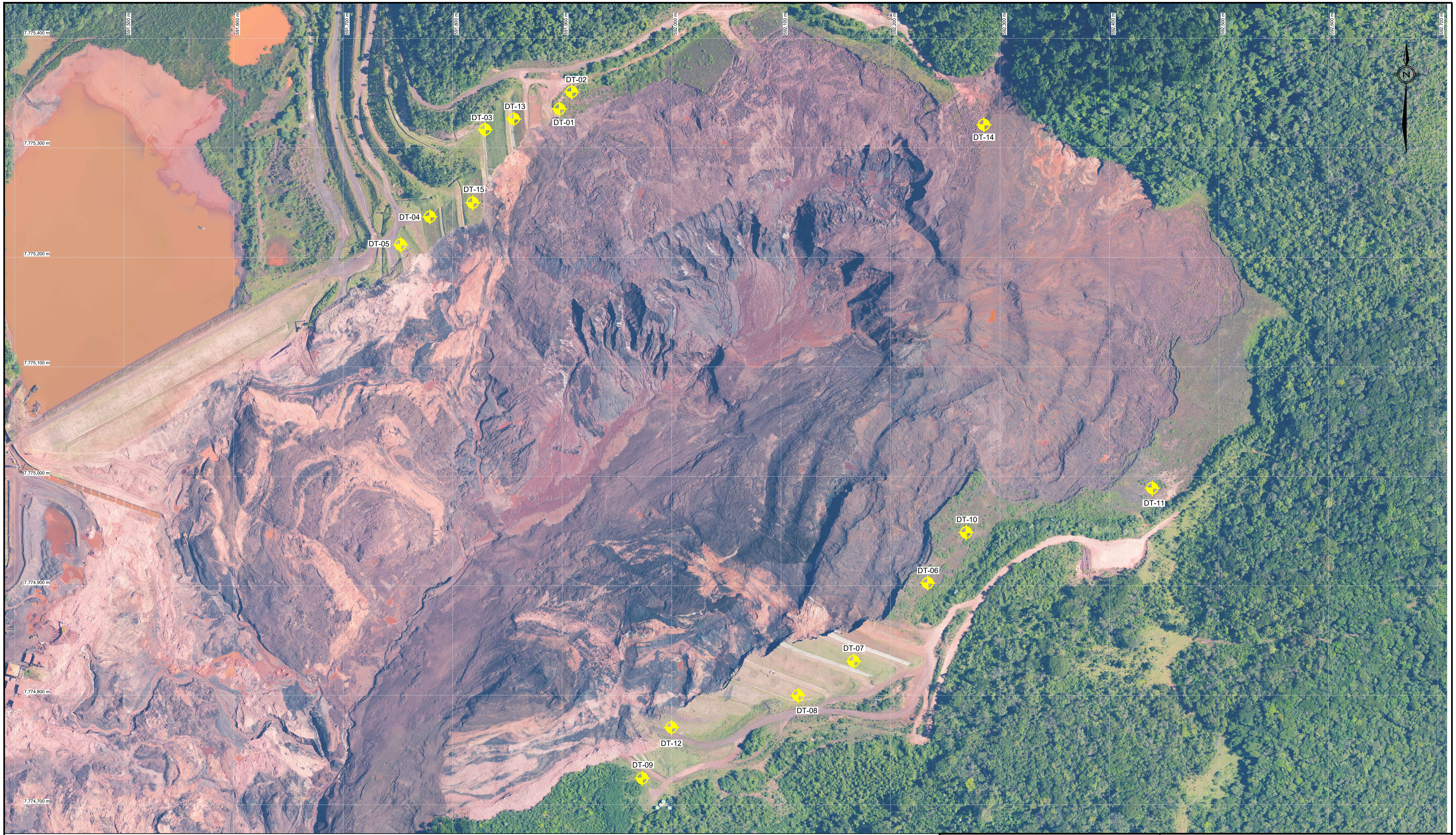
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJAO DAM 1

TITLE
GUELPH PERMEAMETER & TENSIOMETER TEST LOCATIONS

SCALE	PROJECT No.	FIG. No.
N.T.S	0	2

KCB-FIG-B-L

Figure 3 Guelph Permeameter Test at Location GP-01 (July 2, 2019)



NOTES:

1. DRAWING COORDINATES ARE BASED ON UTM ZONE 23S GRID SYSTEM. ALL COORDINATES ARE IN METERS.

LEGEND:

⊕ DENSITY TEST LOCATIONS

CLIENT

PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJAO DAM 1

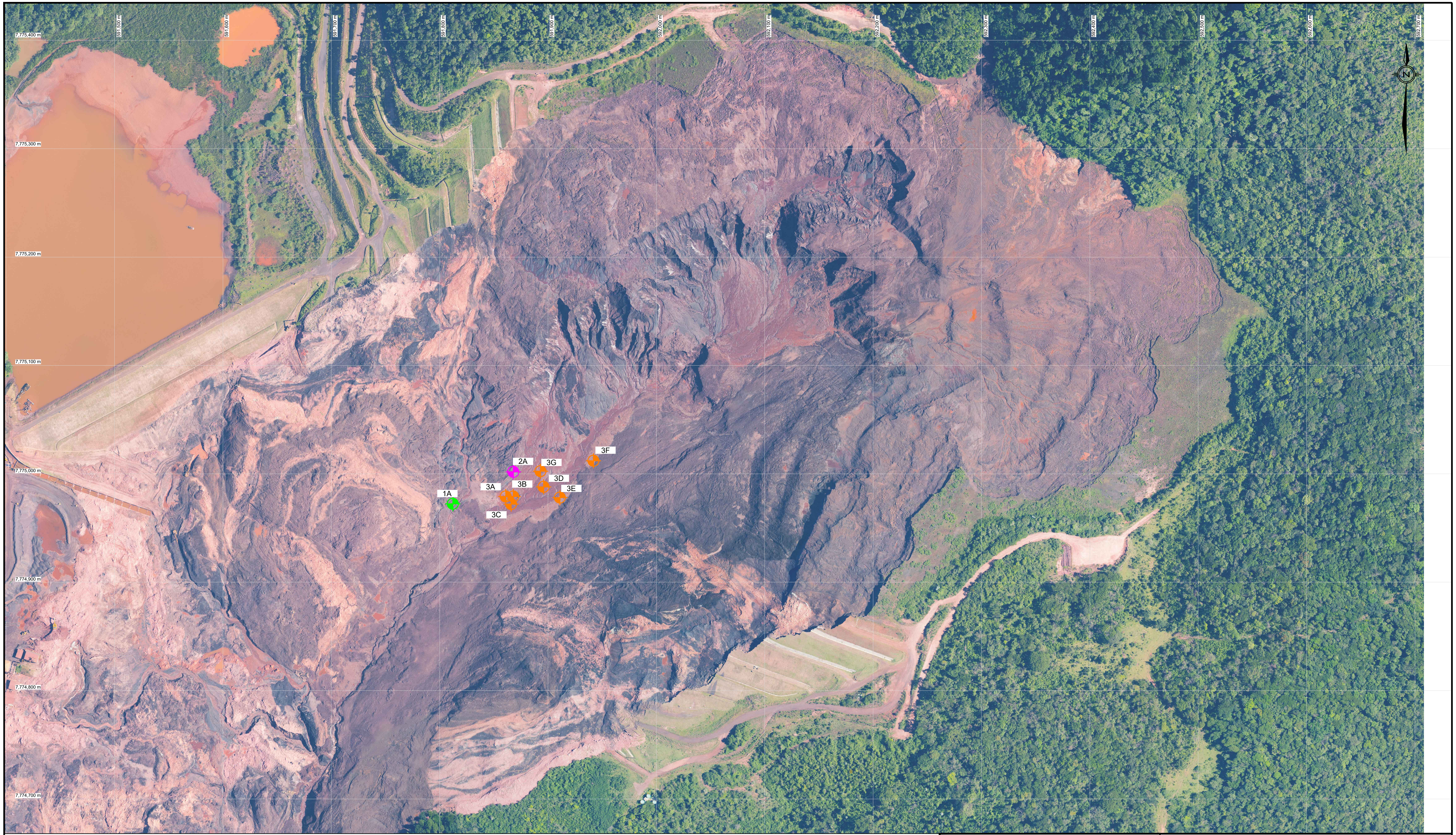
TITLE
SAND-REPLACEMENT DENSITY
TEST LOCATIONS

SCALE	PROJECT No.	FIG. No.
N.T.S	0	4

KCB-FIG-B-L

Figure 5 Sand Replacement Test DT-01 (July 4, 2019)

Figure 6 Sand Replacement Test DT-07 (July 9, 2019)



NOTES:

1. DRAWING COORDINATES ARE BASED ON UTM ZONE 23S GRID SYSTEM. ALL COORDINATES ARE IN METERS.
2. LOCATIONS OF FLOW MEASUREMENTS ARE APPROXIMATE AND ARE BASED ON A HANDHELD GPS DEVICE.

LEGEND:

⊕ STREAM 1 FLOW RATE LOCATIONS
⊕ STREAM 2 FLOW RATE LOCATIONS
⊕ STREAM 3 FLOW RATE LOCATIONS

CLIENT

PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES
OF THE FAILURE OF FEIJAO DAM 1

TITLE
FLOW RATE
MEASUREMENT LOCATIONS

SCALE	PROJECT No.	FIG. No.
N.T.S	0	7

KCB-FIG-B-L

Figure 8 Flow Rate Measurement at Stream 2 (July 18, 2019)

Figure 9 Flow Rate Measurement at Stream 3 (July 18, 2019)

NOTES:

1. DRAWING COORDINATES ARE BASED ON UTM ZONE 23S GRID SYSTEM. ALL COORDINATES ARE IN METERS.

LEGEND:

⊕ BOREHOLE LOCATIONS

CLIENT

PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJAO DAM 1

TITLE
BOREHOLE LOCATIONS

SCALE	PROJECT No.	FIG. No.
N.T.S	0	10

KCB-FIG-B-L

Figure 11 Rotary Drilling Rig Observed at Site on June 4, 2019

Figure 12 Rotary Drilling Rig Used at Borehole Sites

Figure 13 Collected Core Samples of Compacted Fill at BH-01 (3 m to 6 m)

Figure 14 Collected Core Samples of Compacted Fill at BH-01 (6 m to 9 m)

Figure 15 **Standard Penetration Testing (SPT) at BH-01**

Figure 16 Collected SPT Samples at BH-01

Figure 17 Sealing of a Shelby Tube Using Wax

Figure 18 Packaged Shelby Tube Samples

Borehole Logs

BOREHOLE LOG BH-01

STARTED: 2019/07/11 **FINISHED:** 2019/07/17

DRILL METHOD: Mud Rotary

GROUND ELEV. (m): 863.70

COORDINATES (m): N 7774986 E 591793

DEPTH (m)	SPT BLOWS	SAMPLE TYPE	SAMPLE No.
		Grab	BH01/01
1			
	5, 10		
		Grab	BH01/02
		Grab	BH01/03
2			
	67		
		Grab	BH01/04
3			
	6, 9		
		Shelby	BH01/05
4			
		Grab	BH01/06
		Shelby	BH01/07
5			
		Grab	BH01/08
		Shelby	BH01/09
		Grab	BH01/10
6			
		Grab	BH01/11
7			
		Grab	BH01/12
8			
		Grab	BH01/13
9			
		Grab	BH01/14
10			

DESCRIPTION OF MATERIALS

SILT (MH); sandy (fine to medium grained, trace coarse grained), trace clay, high plasticity, firm to stiff, moisture content is less than the plastic limit, brownish yellow to yellowish red, moderate cementation, homogeneous. [FILL]

From 1.0 m to 1.45 m: SPT-01

At 1.65 m: 350 mm zone; trace sand (coarse grained, less than 4.1 mm, subangular to subrounded).

At 2.0 m: SPT-02 Refused

NO RECOVERY [DRILLER DISTURBED]

2.50
861.20

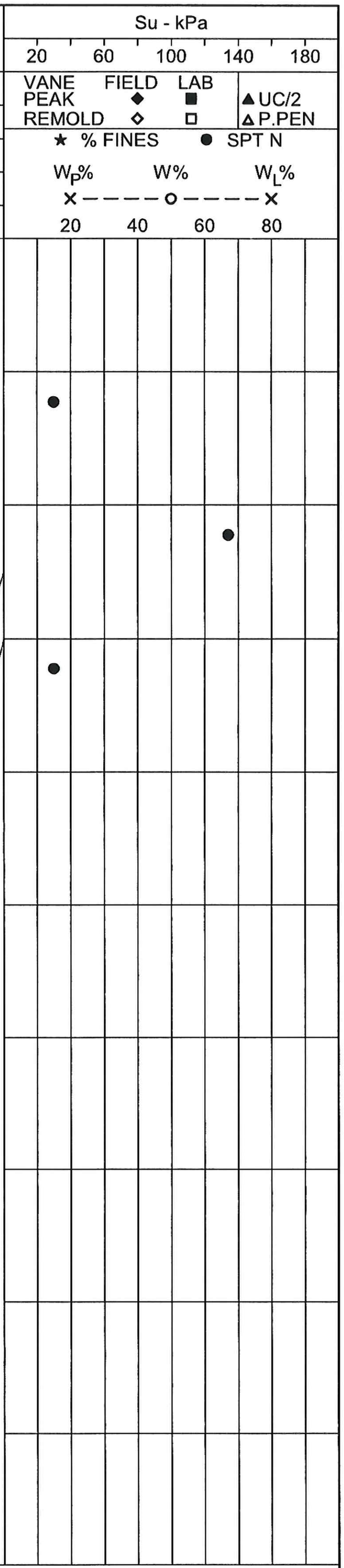
At 2.3 m: 200 mm zone; GRAVEL (fine to coarse grained, less than 55 mm, subangular to subrounded), well graded, moist, homogeneous.

3.00
860.70

SILT(MH); sandy (fine grained), trace clay, trace gravel (fine grained, less than 5 mm, angular to subangular), high plasticity, firm to stiff, moisture content is less than the plastic limit, brownish yellow to yellowish red, homogeneous. [FILL]

SILT (MH); sandy (fine grained), trace clay, high plasticity, firm to stiff, moisture content is less than the plastic limit, light brown to brownish yellow (some yellowish red veins less than 1 mm thick, possibly biotite oxidation), moderate cementation, homogeneous. [FOUNDATION]

At 3.0 m to 3.45 m: SPT-03
At 3.5 m: SHELBY 01
At 3.88 m: trace sand (fine to medium grained), high plastic, some greenish grey zones (less than 2 mm thick), some light brown to reddish brown zones (less than 2 mm thick), trace light grey veins (less than 1 mm thick).
At 4.5 m: SHELBY 02
NO RECOVERY [DRILLER DISTURBED]
At 5.5 m: SHELBY 03



Continued Next Page

PROJECT NO.:

PROJECT: APPENDIX E

LOCATION: Feijão Dam 01, Toe of slope

LOGGED BY: HS (0m-18m) **CHECKED BY: JMD**

SHEET 1 OF 2

BOREHOLE LOG_SPT A03355A01_VSA_BH_LOGS.GPJ KCBL_CALGARY.GDT 19-12-5

BOREHOLE LOG BH-01

STARTED: 2019/07/11 **FINISHED:** 2019/07/17

DRILL METHOD: Mud Rotary

GROUND ELEV. (m): 863.70

COORDINATES (m): N 7774986 E 591793

Su - kPa: 20 60 100 140 180

VANE PEAK FIELD ◆ LAB ■ ▲ UC/2

REMOLD ◇ □ △ P.PEN

★ % FINES ● SPT N

W_P% ×- - - - W% ○- - - - W_L% ×

20 40 60 80

DEPTH (m)	SPT BLOWS	SAMPLE TYPE	SAMPLE No.	SYMBOL	DESCRIPTION OF MATERIALS
		Grab	BH01/15		
11		Grab	BH01/16		
12		Grab	BH01/17		
13		Grab	BH01/18		
14		Grab	BH01/19		
14.80 848.90					
15		Grab	BH01/20		SILT (MH); some sand (fine grained, trace coarse grained), trace gravel (fine grained, less than 5mm, subangular to angular), trace clay, high plasticity, poorly graded, stiff to very stiff, light brown to light grey, moisture content is less than plastic limit, moderate to low cementation, homogeneous. [FOUNDATION]
16		Grab	BH01/21		At 16.2m to 17.0 m: Low plasticity.
17		Grab	BH01/22		
18.00 845.70					End of Hole at: 18 m
19					
20					

PROJECT NO.:

PROJECT: APPENDIX E

LOCATION: Feijão Dam 01, Toe of slope

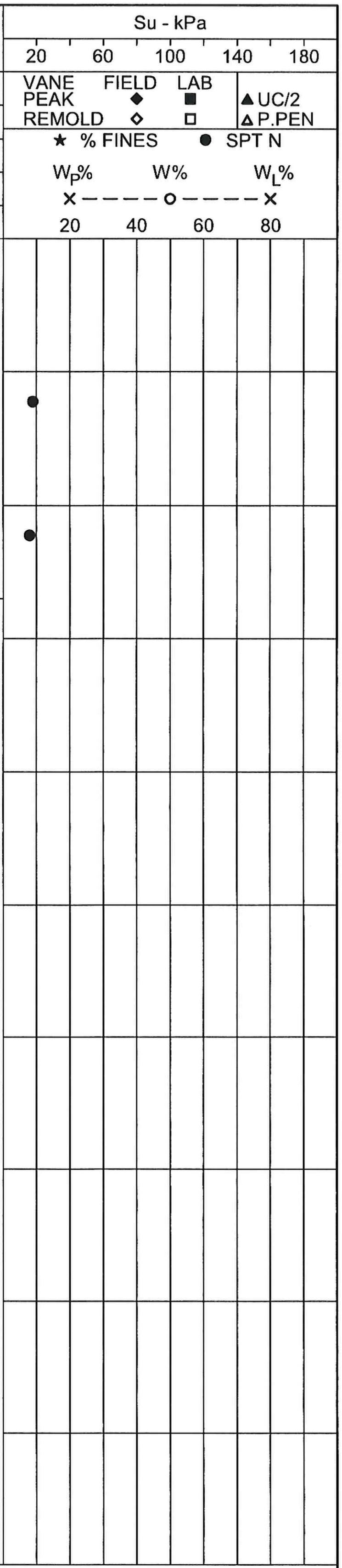
LOGGED BY: HS (0m-18m) **CHECKED BY: JMD**

SHEET 2 OF 2

BOREHOLE LOG BH-02

STARTED: 2019/07/18 **FINISHED:** 2019/07/19
DRILL METHOD: Mud Rotary
GROUND ELEV. (m): 857.80
COORDINATES (m): N 7774932.55 E 591793.43

DEPTH (m)	SPT BLOWS	SAMPLE TYPE	SAMPLE No.	SYMBOL	DESCRIPTION OF MATERIALS
		Grab	BH02/01		SILT (MH); sandy (fine to medium grained), trace gravel (fine grained, subangular to subrounded, less than 5 mm), trace clay, high plastic, firm to stiff, reddish brown to dark brown and dark grey, moisture content is less than the plastic limit, moderate cemenation, homogeneous. [FILL]
1	4, 5	Grab	BH02/02		From 1.0 m to 1.45 m: SPT-01
2	3, 5	Grab	BH02/03		From 2.0 m to 2.45 m: SPT-02
					2.70 855.10 SILT (MH); some sand (fine to medium grained, trace coarse grained), trace clay, high plastic, firm to stiff, light brown to brownish yellow, light grey zones (less than 1 mm thick), greenish grey zones (less than 1 mm thick), dark grey zones (less than 1 mm thick), weak cementation, moisture content is less than the plastic limit, homogeneous. [FOUNDATION]
3		Grab	BH02/04		
		Shelby	BH02/05		At 3.5 m: SHELBY 01
4		Grab	BH02/06		
		Shelby	BH02/07		At 4.5 m: SHELBY 02
5		Grab	BH02/08		
		Shelby	BH02/09		At 5.5 m: SHELBY 03
6		Grab	BH02/10		At 6.5 m: 500 mm zone; some sand (fine to medium grained, poorly graded).
		Shelby	BH02/11		At 6.5 m: SHELBY 04
7		Grab	BH02/12		At: 6.95 m: some sand (fine to medium grained).
		Shelby	BH02/13		At 7.5 m: SHELBY 05
8		Grab	BH02/14		
		Shelby	BH02/15		At: 8.5 m SHELBY 06
9		Grab	BH02/16		
		Shelby	BH02/17		
10					10.00



Continued Next Page

PROJECT NO.:
PROJECT: APPENDIX E
LOCATION: Feijão Dam 01, Toe of slope
LOGGED BY: HS (0m-10.5m) CHECKED BY: JMD
SHEET 1 OF 2

BOREHOLE LOG BH-02

STARTED: 2019/07/18 **FINISHED:** 2019/07/19

DRILL METHOD: Mud Rotary

GROUND ELEV. (m): 857.80

COORDINATES (m): N 7774932.55 E 591793.43

Su - kPa
20 60 100 140 180

	FIELD	LAB	
VANE PEAK	◆	■	▲ UC/2
REMOLD	◇	□	△ P.PEN

★ % FINES ● SPT N

W_P% W% W_L%
× – – – – o – – – – ×
20 40 60 80

DEPTH (m)	SPT BLOWS	SAMPLE TYPE	SAMPLE No.	SYMBOL	DESCRIPTION OF MATERIALS
		Grab	BH02/18		847.80 End of Hole at: 10.5 m
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

PROJECT NO.:

PROJECT: APPENDIX E

LOCATION: Feijão Dam 01, Toe of slope

LOGGED BY: HS (0m-10.5m) CHECKED BY: JMD

SHEET 2 OF 2

BOREHOLE LOG BH-03

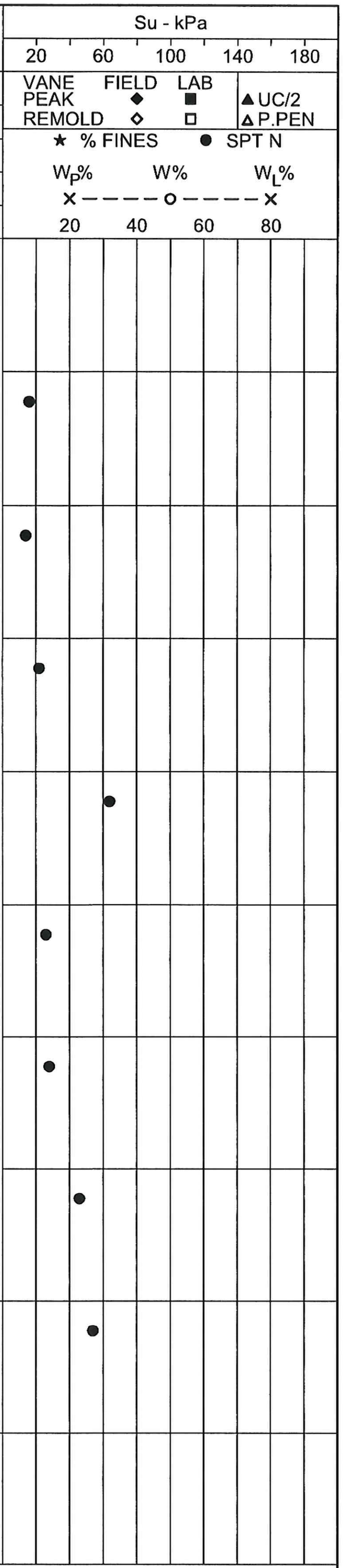
STARTED: 2019/07/22 **FINISHED:** 2019/07/23

DRILL METHOD: Mud Rotary

GROUND ELEV. (m): 870.70

COORDINATES (m): N 7774982.91 E 591689.16

DEPTH (m)	SPT BLOWS	SAMPLE TYPE	SAMPLE No.	SYMBOL		DESCRIPTION OF MATERIALS
0		Grab	BH03/01			SILT (MH); sandy (fine to medium grained, trace coarse grained), trace clay, high plasticity, firm to stiff, moisture content is less than plastic limit, brownish yellow to yellowish red, weak cementation, homogeneous. [FILL]
1	3, 5	Grab	BH03/02			From 1.0 m to 1.45 m: SPT-01
2	3, 4	Grab	BH03/03			From 2.0 m to 2.45 m: SPT-02
3	6, 5	Grab	BH03/04			From 3.0 m to 3.45 m: SPT-03
4	21, 11	Grab	BH03/05			At 4.0 m: trace gravel (fine grained, less than 6 mm, subrounded to subangular). From 4.0 m to 4.45 m: SPT-04
5	6, 7	Grab	BH03/06			From 5.0 m to 5.45 m: SPT-05
6	7, 7	Grab	BH03/07			From 6.0 m to 6.45 m: SPT-06
7	11, 12	Grab	BH03/08			From 7.0 m to 7.45 m: SPT-07
8	13, 14	Grab	BH03/09		8.00 862.70	SILT (MH); some sand (medium to coarse grained), some gravel (coarse grained, less than 75 mm, Ironstone), trace clay, high plastic, reddish brown to dark brown, driller disturbed (cutting head damaged during drilling). [FILL] At 8.0 m to 8.45 m: SPT-08
9					9.00 861.70	End of Hole at: 9 m
10						



PROJECT NO.:

PROJECT: APPENDIX E

LOCATION: Feijão Dam 01, Toe of slope

LOGGED BY: HS (0m-9m) **CHECKED BY: JMD**

SHEET 1 OF 1

BOREHOLE LOG_SPT A03355A01_VSA_BH_LOGS.GPJ KCBL_CALGARY.GDT 19-12-5

BOREHOLE LOG BH-04

STARTED: 2019/07/23 **FINISHED:** 2019/07/23

DRILL METHOD: Mud Rotary

GROUND ELEV. (m): 859.00

COORDINATES (m): N 7774937.82 E 591797.01

Su - kPa: 20 60 100 140 180

VANE	FIELD	LAB	
PEAK	◆	■	▲ UC/2
REMOLD	◇	□	△ P.PEN

★ % FINES ● SPT N

W_P% W% W_L%

× – – – – o – – – – ×

20 40 60 80

DEPTH (m)	SPT BLOWS	SAMPLE TYPE	SAMPLE No.	SYMBOL	DESCRIPTION OF MATERIALS
		Grab	BH04/01		SILT (MH); sandy (fine to medium grained, trace coarse grained), trace clay, high plastic, firm to stiff, moisture content is less than the plastic limit, reddish brown to dark brown to dark grey, moderate cementation, homogeneous. [FILL]
3.50 855.50		Grab	BH04/02		SILT (MH); some sand (fine to medium grained, trace coarse grained), trace clay, high plastic, firm to stiff, light brown to brownish yellow, light grey zones (less than 1 mm thick), greenish grey zones (less than 1 mm thick), dark grey zones (less than 1 mm thick), weak cementation, moist, homogeneous. [FOUNDATION]
		Shelby	BH04/03		At 3.7 m: SHELBY 01
		Grab	BH04/04		NO RECOVERY: Failed Shelby sample, overdrilled to 5.3 m.
		Shelby	BH04/04		At 5.3 m: SHELBY 02A
5.65 853.35					End of Hole at: 5.65 m

BOREHOLE LOG_SPT A03355A01_VSA_BH_LOGS.GPJ KCBL_CALGARY.GDT 19-12-5

PROJECT NO.:

PROJECT: APPENDIX E

LOCATION: Feijão Dam 01, Toe of slope

LOGGED BY: HS (0m-5.65) CHECKED BY: JMD

SHEET 1 OF 1

Appendix E

Annex 2 – Summary of Tests

December 2019

Table 1 **Summary Table of Test Type and Procedures**

Test Type	Laboratory	Standard	Additional Reference		Number of Tests								
				Coarse Tailings	Fine Tailings	Slimes	Compacted Berm (Residual Soil)	Compacted Berm (Tailings)	Foundation Material	Average Gradation	Coarse Gradation	Fine Gradation	Total
Washed Sieve	KCB V	ASTM D422-63(2007)e2		12	2	2	6	6	8	39	22	28	125
Hydrometer	KCB V	ASTM D422-63(2007)e2		12	2	10	6	6	8	39	22	28	133
Specific Gravity	KCB V	ASTM D854-14		17	2	13	7	4	9	-	-	-	52
Water Content	KCB V	ASTM D2216-19		12	8	15	14	10	6	-	-	-	65
Atterberg Limit	KCB V	ASTM D4318-17e1		-	2	14	16	4	12	-	-	-	48
X-ray Diffraction	University of British Columbia	N/A		2	-	2	-	-	-		-	-	4
Scanning Electron Microscope (SEM)	University of British Columbia and University of Queensland	N/A		2	-	3	-	-	-	2	-	-	7
Triaxial Compression	KCB V	ASTM D4767-11(CIU) ASTM D7181-11(CIU)		-	-	-	-	-	-	16	7	12	35
Direct Simple Shear Test	KCB V	ASTM D6528-17		-	-	-	-	-	6	-	-	-	6
Bender Element Tests	KCB V	N/A	Yamashita et al. 2009	-	-	-	-	-	-	4	3	3	10

Appendix E

Annex 3 – Index Test Data

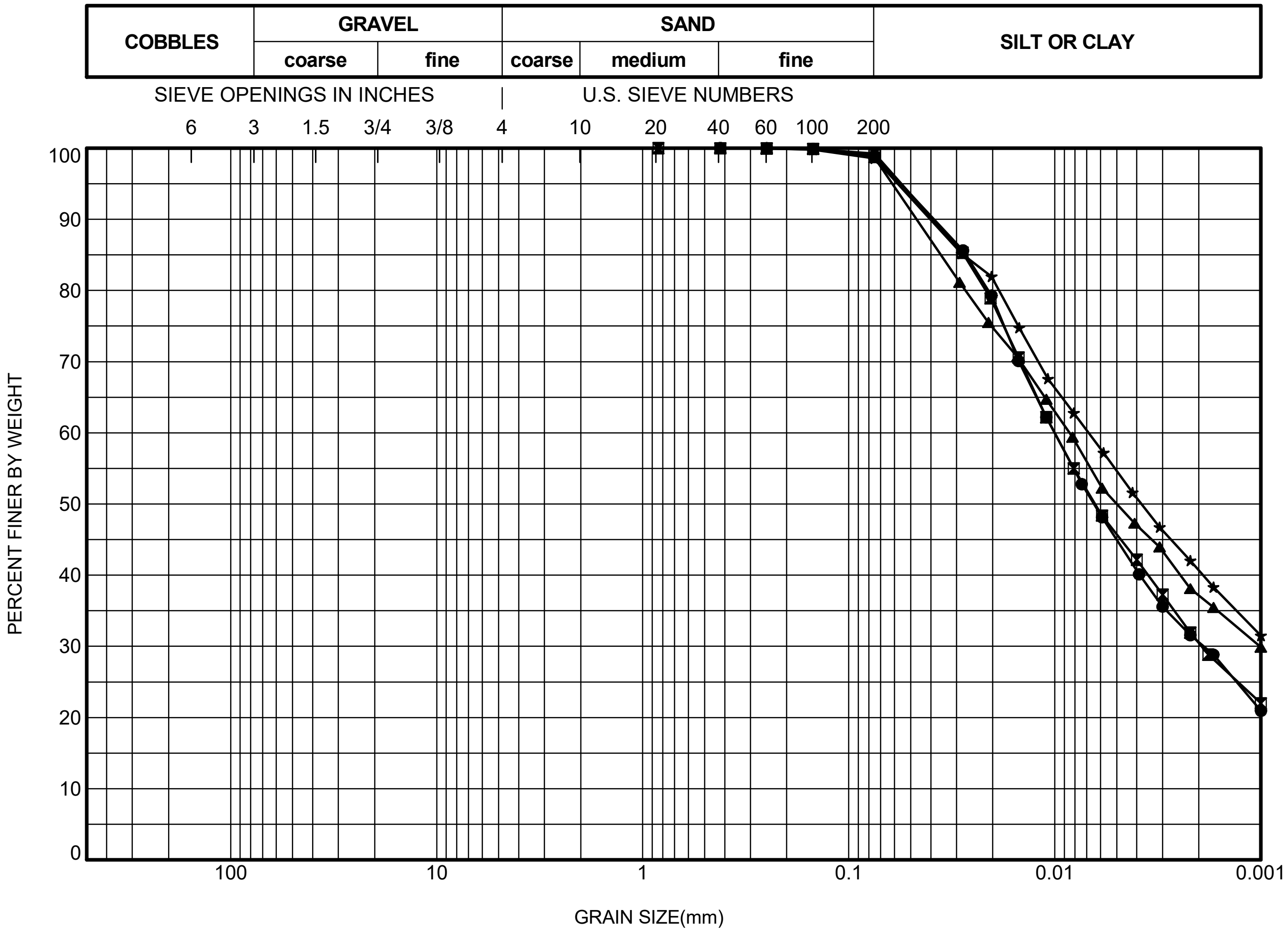
December 2019

Program 1

Particle Size Distribution
Specific Gravity Tests
Moisture Content
Atterberg Limit Test

Particle Size Distribution

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	S 1	0.00							0.0	1.1	98.9
⊠	S 1	0.00							0.0	0.8	99.2
▲	S 1	0.00							0.0	1.4	98.6
★	S 1	0.00							0.0	1.4	98.6

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	S 1	Bag 1	0.00		43	26	17	Slimes. Pail 1
⊠	S 1	Bag 2	0.00		41	25	16	Slimes. Pail 1
▲	S 1	Bag 3	0.00		43	24	20	Slimes. Pail 2
★	S 1	Bag 4	0.00		46	26	20	Slimes. Pail 2

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

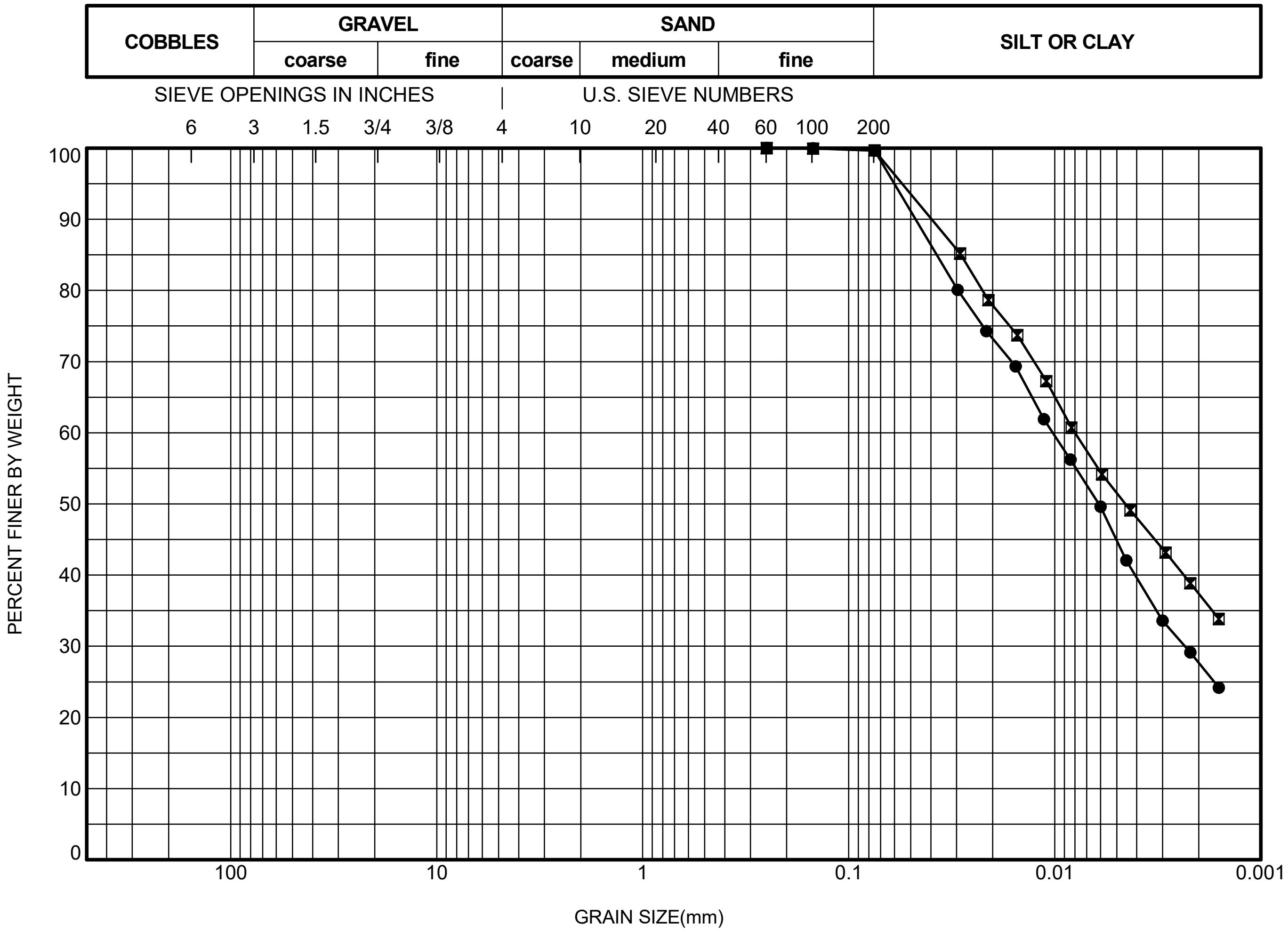
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: HM **CHECKED BY:** JG

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	S 2	0.00							0.0	0.4	99.6
☒	S 2	0.00							0.0	0.3	99.7

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	S 2	Bag 1	0.00		48	31	17	Slimes. Pail 3
☒	S 2	Bag 2	0.00		49	27	22	Slimes. Pail 3

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

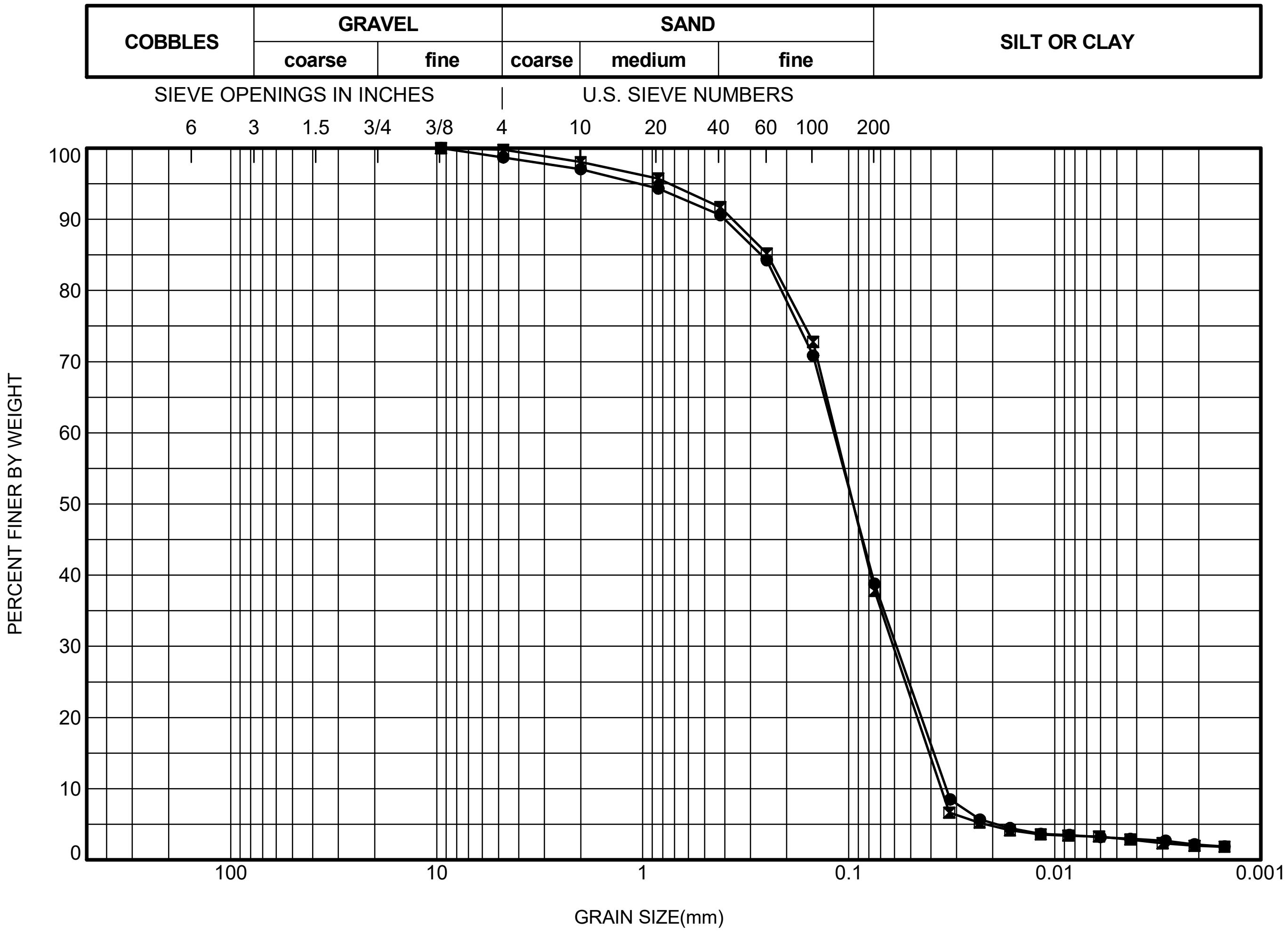
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: HM **CHECKED BY:** JG

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	S 3	0.00	0.266	0.118	0.095				1.3	59.9	38.8
☒	S 3	0.00	0.248	0.116	0.095				0.2	62.0	37.8

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	S 3	Bag 1	0.00					Beach tailings. Pail 4
☒	S 3	Bag 2	0.00					Beach tailings. Pail 4

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

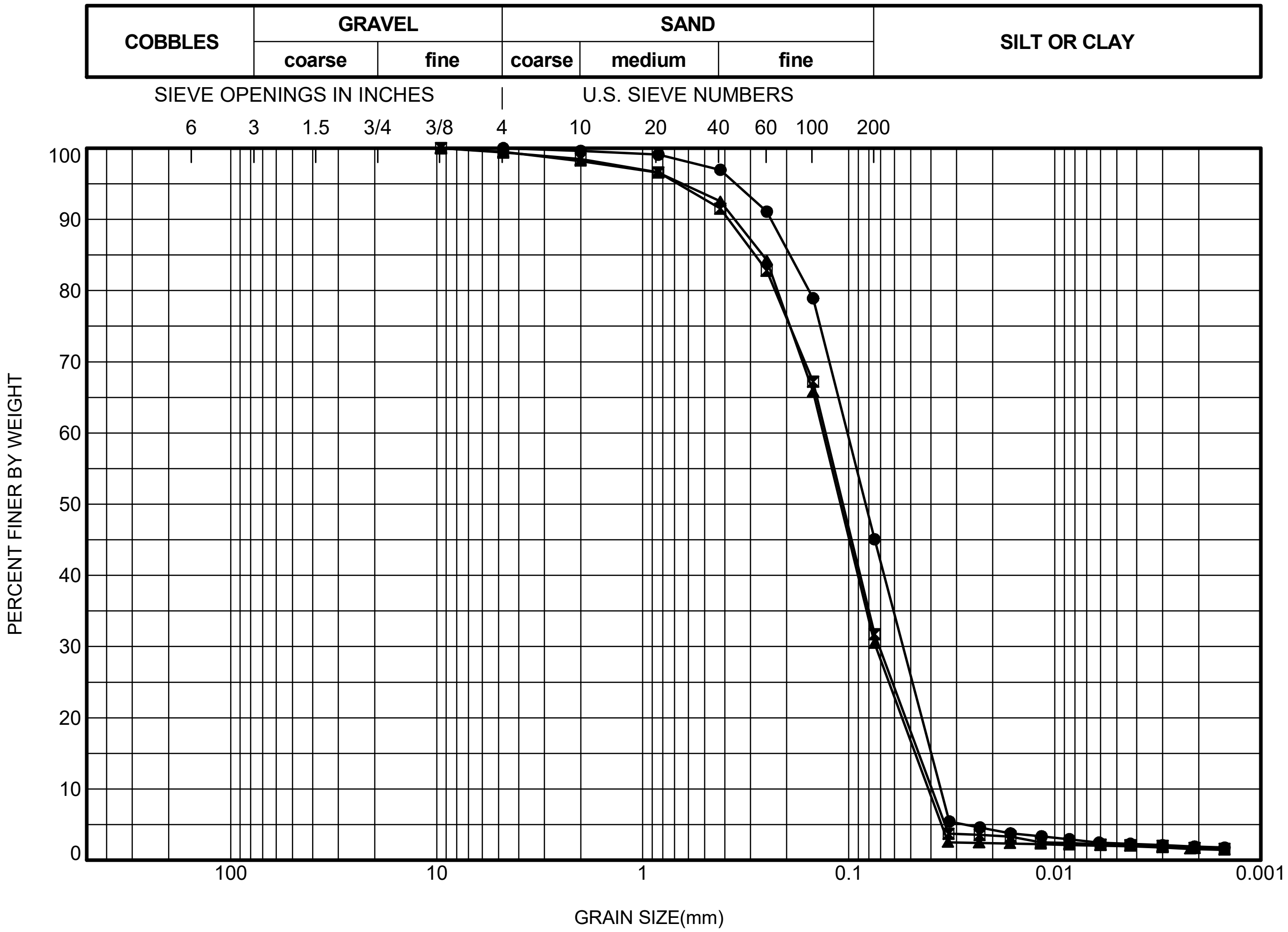
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: HM **CHECKED BY:** JG

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	S 4	0.00	0.193	0.102	0.083				0.0	54.9	45.1
☒	S 4	0.00	0.285	0.130	0.107				0.6	67.7	31.7
▲	S 4	0.00	0.261	0.133	0.110				0.5	69.0	30.5

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	S 4	Bag 1	0.00					Beach tailings. Pail 5
☒	S 4	Bag 2	0.00					Beach tailings. Pail 5
▲	S 4	Bag 3	0.00					Beach tailings. Pail 6

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

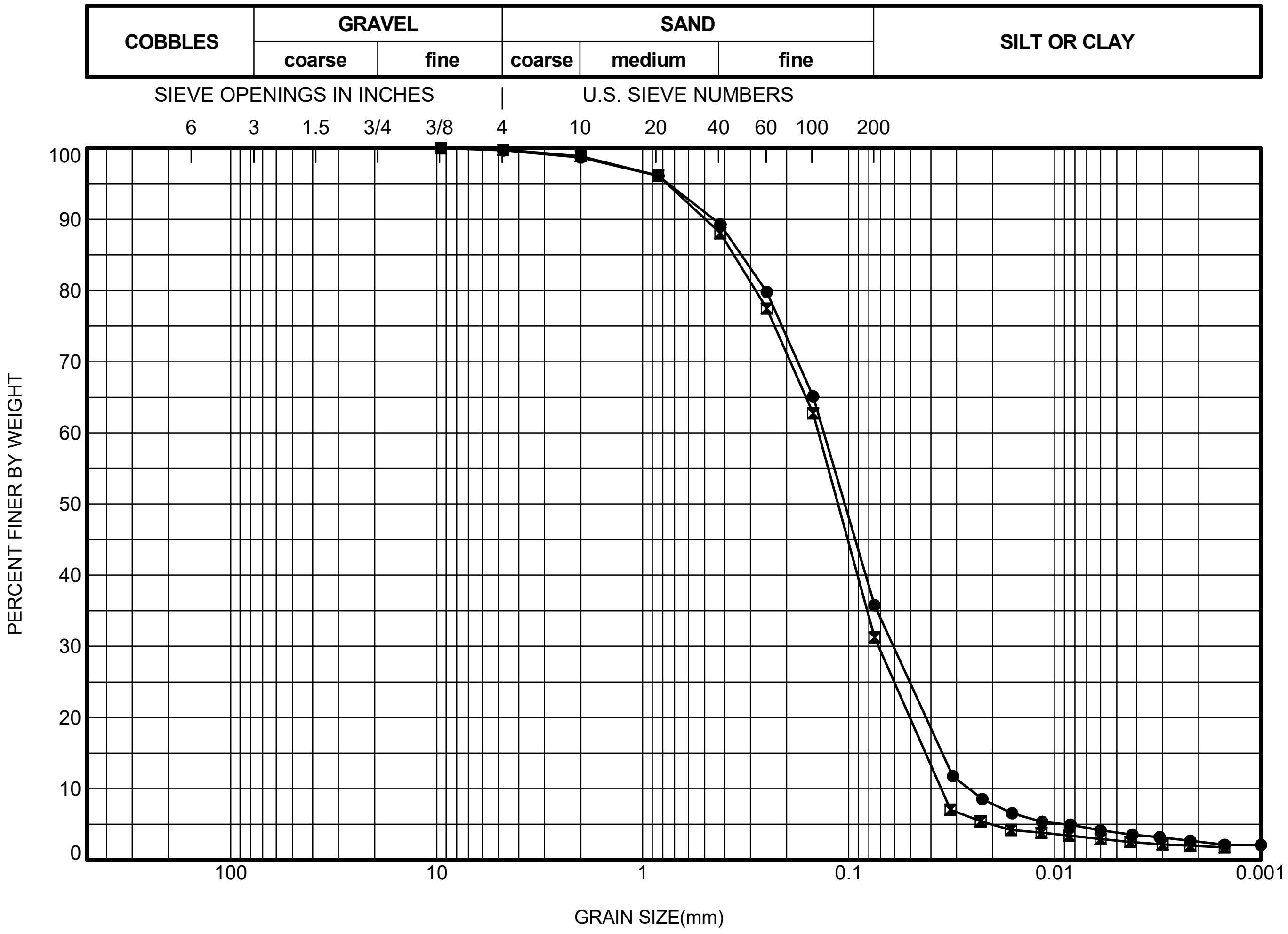
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: HM **CHECKED BY:** JG

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	S 5	0.00	0.332	0.132	0.105				0.3	63.9	35.8
☒	S 5	0.00	0.362	0.140	0.113				0.2	68.5	31.3

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	S 5	Bag 1	0.00					Beach tailings. Pail 7
☒	S 5	Bag 2	0.00					Beach tailings. Pail 7

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

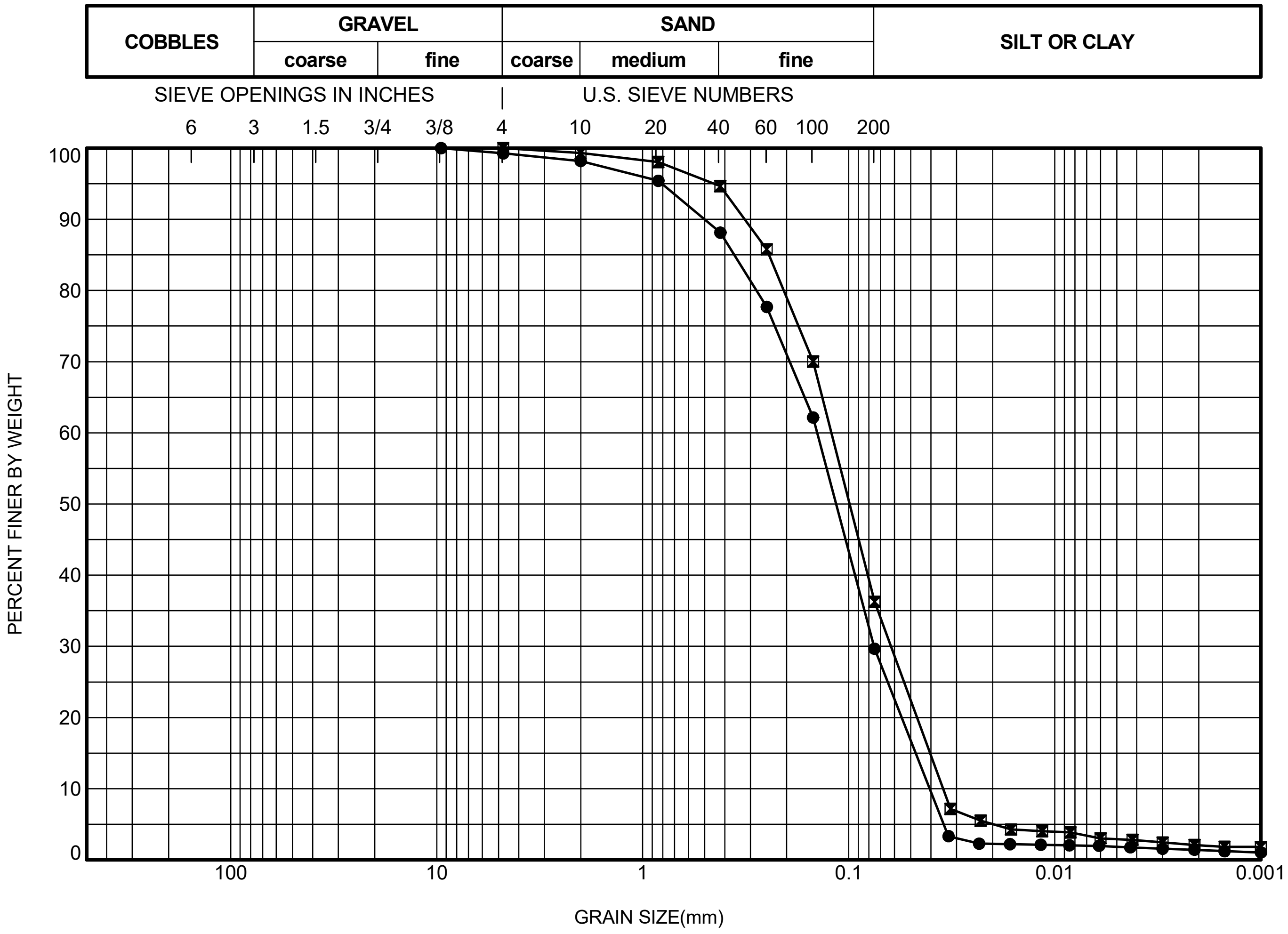
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: HM **CHECKED BY:** JG

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	S 6	0.00	0.359	0.142	0.115				0.7	69.6	29.7
⧗	S 6	0.00	0.244	0.122	0.099				0.0	63.7	36.3

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	S 6	Bag 1	0.00					Beach tailings. Pail 8
⧗	S 6	Bag 2	0.00					Beach tailings. Pail 8

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

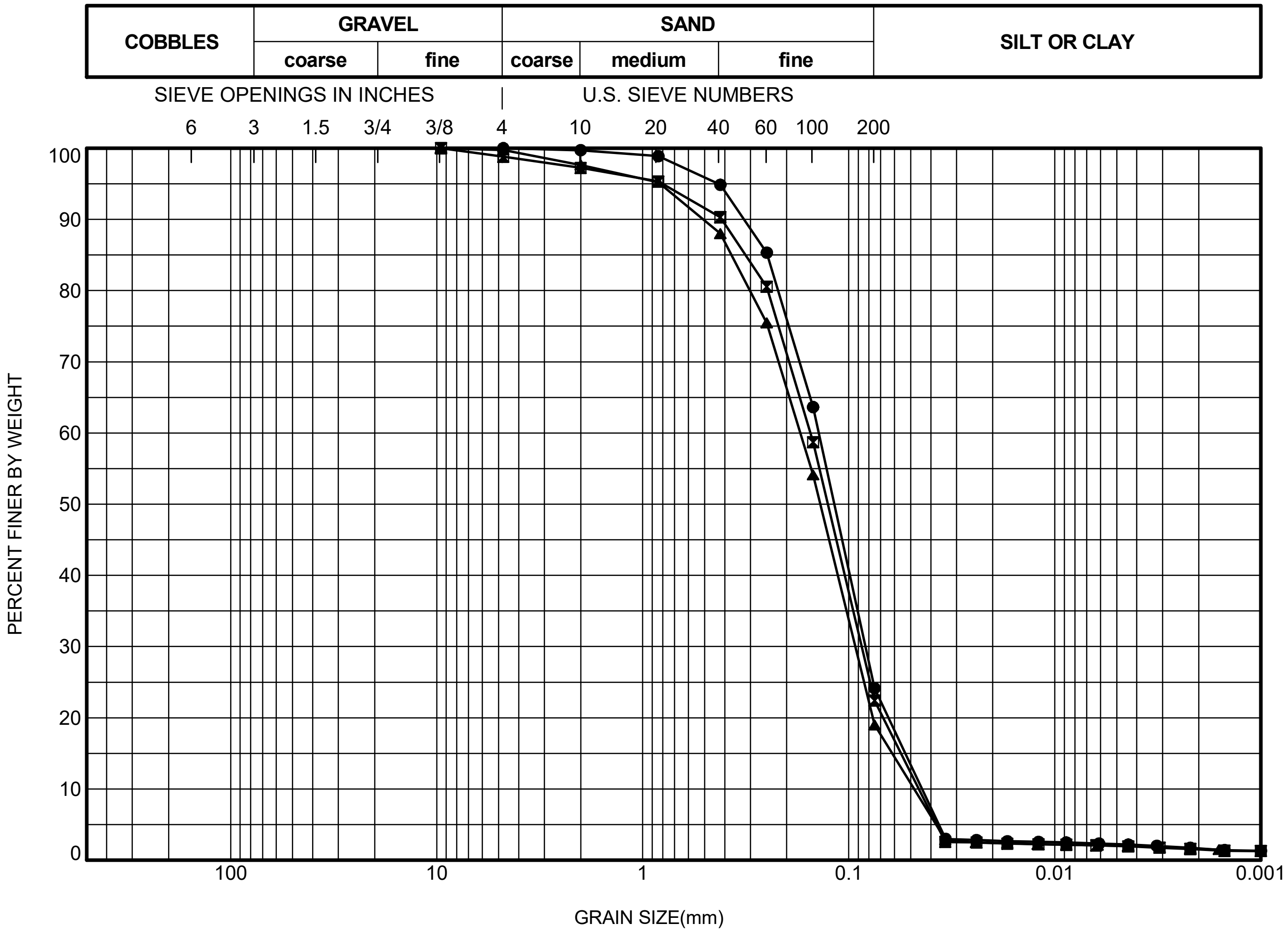
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: HM **CHECKED BY:** JG

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	S 6b	0.00	0.248	0.140	0.118				0.0	75.9	24.1
☒	S 6b	0.00	0.317	0.154	0.126				1.2	76.4	22.4
▲	S 6b	0.00	0.371	0.172	0.138				0.2	80.8	19.0

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	S 6b	Bag 1	0.00					Beach tailings. Pail 9
☒	S 6b	Bag 2	0.00					Beach tailings. Pail 9
▲	S 6b	Bag 3	0.00					Beach tailings. Pail 9

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

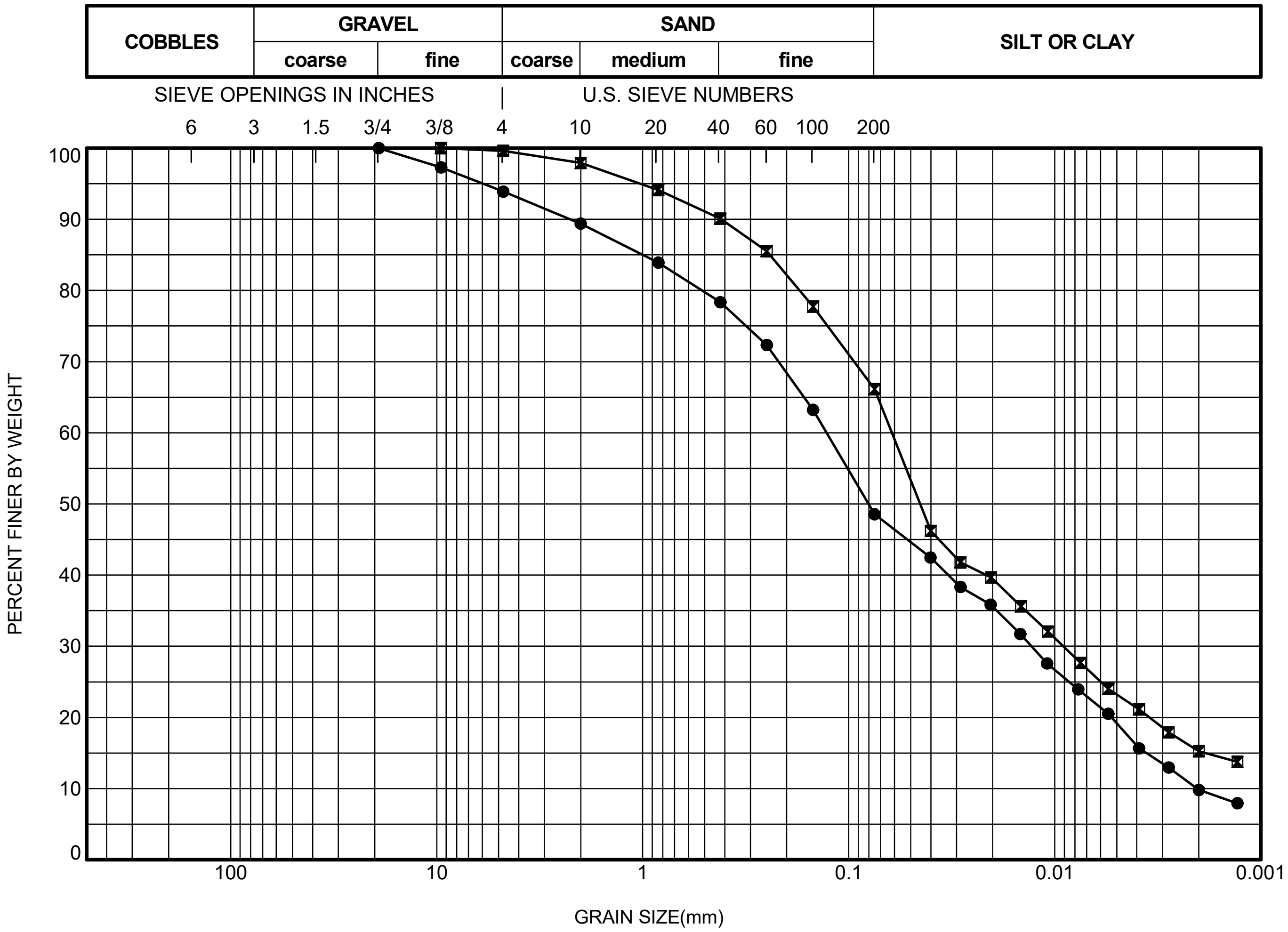
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: HM **CHECKED BY:** JG

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	S 7	0.00	0.998	0.128	0.080				6.1	45.3	48.6
☒	S 7	0.00	0.241						0.4	33.5	66.1

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	S 7	Bag 1	0.00		30	23	7	Residual Soil. Pail 10. Dried at 45C/dried 45C
☒	S 7	Bag 2	0.00		35	25	10	Residual Soil Pail 10. Natural/ dried 45C

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

PROJECT:

LOCATION:

FIGURE:

DRAWN BY: HM **CHECKED BY:** JG

Specific Gravity Tests

SPECIFIC GRAVITY OF SOIL SOLIDS (ASTM-D854)

Hole Number	S1			S1		
Sample Number	Bag 1			Bag 3		
Depth (m)						
Sample Description	Slimes			Slimes		
Flask No.	11	SG-6	SG-10	SG-5	KL-2	SG-9
Volume of Flask @ 20^{o} C ml	500	500	500	500	500	500
Method of Air removal	boiling	boiling	boiling	boiling	boiling	boiling
De-airing Period hr	2	2	2	2	2	2
Test temperature ^{o}C	22.2	22.1	22.1	22.1	22.1	22.1
Mass of Flask+Water (M_a) g	678.58	670.54	669.95	672.12	675.50	667.84
Mass of Flask+Water+Soil (M_b) g	726.58	718.98	718.20	720.29	723.74	716.26
Mass of Dish/Flask+Soil	244.03	236.38	236.08	238.15	241.46	234.09
Mass of Dish/Flask	180.38	172.18	171.94	173.90	177.06	169.66
Mass of Dry Soil (M_o) g	63.65	64.20	64.14	64.25	64.40	64.43
Correction factor (K) @ Test Temperature	0.99952	0.99954	0.99954	0.99954	0.99954	0.99954
Specific Gravity of Solids @ 20^{o} C	**4.065**	**4.072**	**4.035**	**3.994**	**3.983**	**4.023**
Average Specific Gravity of Solids @ 20^{o} C	**4.06**			**4.00**		

Hole Number	S2					
Sample Number	Bag 1					
Depth (m)						
Sample Description	Slimes					
Flask No.	10	12	SG-2			
Volume of Flask @ 20^{o} C ml	500	500	500			
Method of Air removal	boiling	boiling	boiling			
De-airing Period hr	2	2	2			
Test temperature ^{o}C	22.5	22.6	22.5			
Mass of Flask+Water (M_a) g	679.64	680.38	671.54			
Mass of Flask+Water+Soil (M_b) g	729.12	733.56	719.38			
Mass of Dish/Flask+Soil	247.53	253.35	237.46			
Mass of Dish/Flask	181.51	182.10	173.27			
Mass of Dry Soil (M_o) g	66.02	71.25	64.19			
Correction factor (K) @ Test Temperature	0.99945	0.99943	0.99945			
Specific Gravity of Solids @ 20^{o} C	**3.989**	**3.941**	**3.924**			
Average Specific Gravity of Solids @ 20^{o} C	**3.95**					

Specific Gravity of Solids @ 20^{o} C = $(K \times M_o)/(M_o + M_a - M_b)$

PROJECT#:	A03355A01		
PROJECT:			
LOCATION:			
DATE:	2019-06-12		
TESTED BY:	HM	CHECKED BY:	JG

SPECIFIC GRAVITY OF SOIL SOLIDS (ASTM-D854)

Hole Number	S3			S4		
Sample Number	Bag 1			Bag 1		
Depth (m)						
Sample Description	Beach Tailings			Beach Tailings		
Flask No.	SG-4	12	SG-7	8	KL-3	SG-2
Volume of Flask @ 20° C ml	500	500	500	500	500	500
Method of Air removal	boiling	boiling	boiling	boiling	boiling	boiling
De-airing Period hr	2	2	2	2	2	2
Test temperature ° C	22.3	22.4	22.4	22.4	22.5	22.4
Mass of Flask+Water (M_a) g	670.67	680.41	667.77	678.62	675.78	671.54
Mass of Flask+Water+Soil (M_b) g	751.38	761.22	749.12	742.66	740.36	732.03
Mass of Dish/Flask+Soil	273.98	283.69	271.46	260.50	258.14	249.11
Mass of Dish/Flask	172.56	182.11	169.41	180.44	177.35	173.26
Mass of Dry Soil (M_o) g	101.42	101.58	102.05	80.06	80.79	75.85
Correction factor (K) @ Test Temperature	0.99950	0.99948	0.99948	0.99904	0.99945	0.99948
Specific Gravity of Solids @ 20° C	**4.895**	**4.888**	**4.927**	**4.993**	**4.981**	**4.936**
Average Specific Gravity of Solids @ 20° C	**4.90**			**4.97**		

Hole Number	S4			S5		
Sample Number	Bag 3			Bag 2		
Depth (m)						
Sample Description	Beach Tailings			Beach Tailings		
Flask No.	10	SG-3	SG-11	SG-8	SG-12	1
Volume of Flask @ 20° C ml	500	500	500	500	500	500
Method of Air removal	boiling	boiling	boiling	boiling	boiling	boiling
De-airing Period hr	2	2	2	2	2	2
Test temperature ° C	22.4	22.5	22.5	22.6	22.6	22.6
Mass of Flask+Water (M_a) g	679.66	672.25	670.38	670.60	670.59	667.22
Mass of Flask+Water+Soil (M_b) g	751.81	743.83	743.12	748.75	751.88	749.18
Mass of Dish/Flask+Soil	273.47	265.04	264.15	270.24	274.34	271.38
Mass of Dish/Flask	181.52	173.92	172.18	172.38	172.53	168.77
Mass of Dry Soil (M_o) g	91.95	91.12	91.97	97.86	101.81	102.61
Correction factor (K) @ Test Temperature	0.99948	0.99943	0.99945	0.99943	0.99943	0.99943
Specific Gravity of Solids @ 20° C	**4.642**	**4.661**	**4.780**	**4.962**	**4.959**	**4.966**
Average Specific Gravity of Solids @ 20° C	**4.69**			**4.96**		

Specific Gravity of Solids @ 20° C = $(K \times M_o)/(M_o + M_a - M_b)$

PROJECT#:	A03355A01		
PROJECT:			
LOCATION:			
DATE:	2019-06-12		
TESTED BY:	HM	CHECKED BY:	JG

SPECIFIC GRAVITY OF SOIL SOLIDS (ASTM-D854)

Hole Number	S6			S6b		
Sample Number	Bag 2			Bag 2		
Depth (m)						
Sample Description	Beach Tailings			Beach Tailings		
Flask No.	SG-4	SG-6	SG-5	3	KL-3	
Volume of Flask @ 20° C ml	500	500	500	500	500	
Method of Air removal	boiling	boiling	boiling	boiling	boiling	
De-airing Period hr	2	2	2	2	2	
Test temperature ° C	23.1	22.6	22.6	22.5	23.1	
Mass of Flask+Water (M_a) g	670.59	670.47	672.06	671.43	675.72	
Mass of Flask+Water+Soil (M_b) g	744.70	748.15	747.04	741.86	749.88	
Mass of Dish/Flask+Soil	265.30	269.40	267.77	261.65	270.85	
Mass of Dish/Flask	172.56	172.16	173.90	172.69	177.35	
Mass of Dry Soil (M_o) g	92.74	97.24	93.87	88.96	93.50	
Correction factor (K) @ Test Temperature	0.99931	0.99943	0.99943	0.99948	0.99924	
Specific Gravity of Solids @ 20° C	**4.975**	**4.969**	**4.966**	**4.798**	**4.831**	
Average Specific Gravity of Solids @ 20° C	**4.97**			**4.81**		

Hole Number						
Sample Number						
Depth (m)						
Sample Description						
Flask No.						
Volume of Flask @ 20° C ml						
Method of Air removal						
De-airing Period hr						
Test temperature ° C						
Mass of Flask+Water (M_a) g						
Mass of Flask+Water+Soil (M_b) g						
Mass of Dish/Flask+Soil						
Mass of Dish/Flask						
Mass of Dry Soil (M_o) g						
Correction factor (K) @ Test Temperature						
Specific Gravity of Solids @ 20° C						
Average Specific Gravity of Solids @ 20° C						

Specific Gravity of Solids @ 20° C = $(K \times M_o)/(M_o + M_a - M_b)$

PROJECT#:	A03355A01		
PROJECT:			
LOCATION:			
DATE:	2019-06-12		
TESTED BY:	HM	CHECKED BY:	JG

SPECIFIC GRAVITY OF SOIL SOLIDS (ASTM-D854)

Hole Number	S7					
Sample Number	Bag 1					
Depth (m)						
Sample Description						
Flask No.	8	SG-3	SG-7			
Volume of Flask @ 20° C ml	500	500	500			
Method of Air removal	boiling	boiling	boiling			
De-airing Period hr	2	2	2			
Test temperature ° C	22.6	22.7	22.7			
Mass of Flask+Water (M_a) g	678.62	672.24	667.75			
Mass of Flask+Water+Soil (M_b) g	721.07	714.61	706.02			
Mass of Dish/Flask+Soil	242.94	235.88	225.49			
Mass of Dish/Flask	180.47	173.93	169.43			
Mass of Dry Soil (M_o) g	62.47	61.95	56.06			
Correction factor (K) @ Test Temperature	0.99943	0.99941	0.99941			
Specific Gravity of Solids @ 20° C	**3.119**	**3.162**	**3.149**			
Average Specific Gravity of Solids @ 20° C	**3.14**					

Hole Number						
Sample Number						
Depth (m)						
Sample Description						
Flask No.						
Volume of Flask @ 20° C ml						
Method of Air removal						
De-airing Period hr						
Test temperature ° C						
Mass of Flask+Water (M_a) g						
Mass of Flask+Water+Soil (M_b) g						
Mass of Dish/Flask+Soil						
Mass of Dish/Flask						
Mass of Dry Soil (M_o) g						
Correction factor (K) @ Test Temperature						
Specific Gravity of Solids @ 20° C						
Average Specific Gravity of Solids @ 20° C						

Specific Gravity of Solids @ 20° C = $(K \times M_o)/(M_o + M_a - M_b)$

PROJECT#:	A03355A01		
PROJECT:			
LOCATION:			
DATE:	2019-06-12		
TESTED BY:	HM	CHECKED BY:	JG

Moisture Content

WATER CONTENT OF SOIL

(ASTM D2216)

Hole Number	Sample Number	Depth (m)	Wet Weight + Tare (g)	Dry Weight + Tare (g)	Tare (g)	Water Weight (g)	Total Dry Weight (g)	Water Content (%)	Notes
S1	Bag 1		160.06	144.90	84.39	15.16	60.51	**25.05**	
S1	Bag 1		228.49	201.55	90.15	26.94	111.40	**24.18**	
S1	Bag 2		252.88	222.70	85.92	30.18	136.78	**22.06**	
S1	Bag 3		233.76	205.06	87.73	28.70	117.33	**24.46**	
S1	Bag 4		289.64	253.21	105.13	36.43	148.08	**24.60**	
S2	Bag 1		288.93	237.89	86.47	51.04	151.42	**33.71**	
S2	Bag 2		273.25	233.78	88.91	39.47	144.87	**27.25**	

PROJECT No.: A03355A01

PROJECT NAME:

LOCATION:

DATE: 2019/06/17

TESTED BY: HM, JG CHECKED BY: JG

WATER CONTENT OF SOIL

(ASTM D2216)

Hole Number	Sample Number	Depth (m)	Wet Weight + Tare (g)	Dry Weight + Tare (g)	Tare (g)	Water Weight (g)	Total Dry Weight (g)	Water Content (%)	Notes
S3	Bag 1		251.30	233.80	85.30	17.50	148.50	11.78	
S3	Bag 2		216.23	204.64	88.24	11.59	116.40	9.96	
S4	Bag 1		230.14	219.25	86.29	10.89	132.96	8.19	
S4	Bag 2		299.04	271.46	84.46	27.58	187.00	14.75	
S4	Bag 3		285.01	259.91	86.76	25.10	173.15	14.50	
S5	Bag 1		288.28	278.42	103.55	9.86	174.87	5.64	
S5	Bag 2		282.46	273.56	120.18	8.90	153.38	5.80	
S6	Bag 1		281.70	258.23	90.74	23.47	167.49	14.01	
S6	Bag 2		302.33	285.71	102.38	16.62	183.33	9.07	
S6B	Bag 1		235.88	224.85	113.20	11.03	111.65	9.88	
S6B	Bag 2		302.65	283.89	118.42	18.76	165.47	11.34	
S6B	Bag 3		338.22	323.21	134.27	15.01	188.94	7.94	

PROJECT No.: A03355A01

PROJECT NAME:

LOCATION:

DATE: 2019/06/17

TESTED BY: HM, JG CHECKED BY: JG

WATER CONTENT OF SOIL

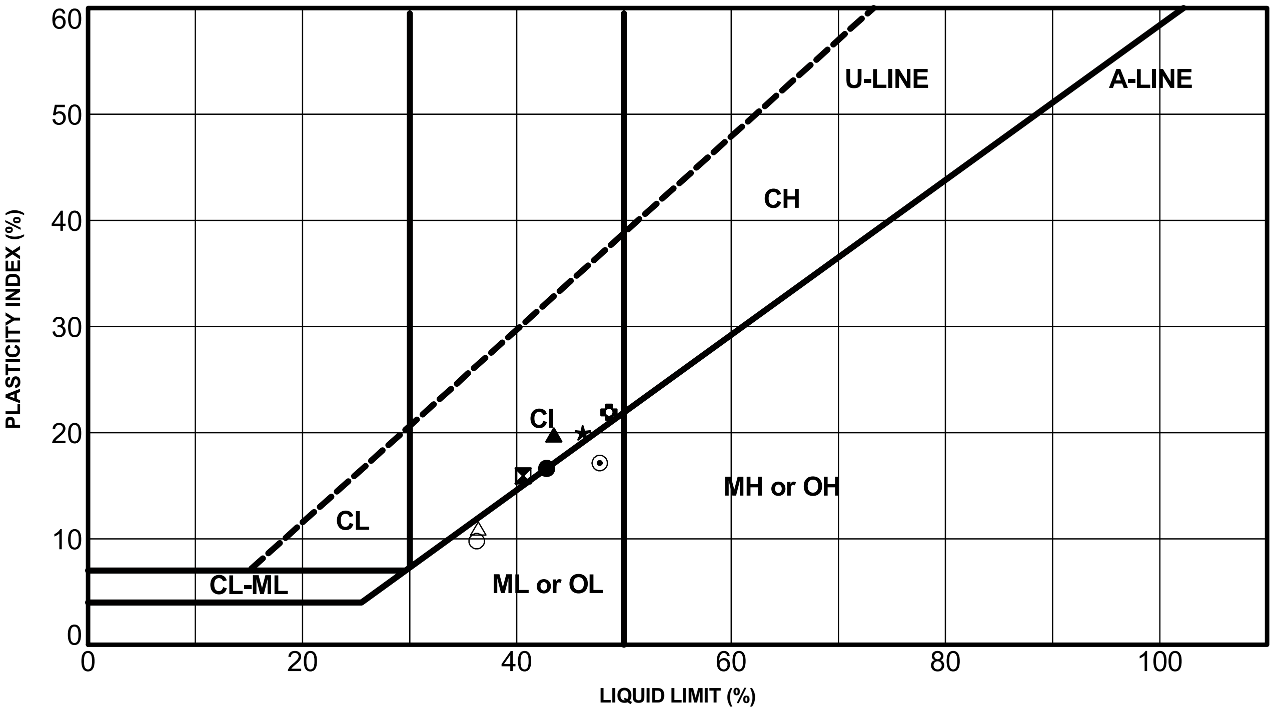
(ASTM D2216)

Hole Number	Sample Number	Test Number	Wet Weight + Tare (g)	Dry Weight + Tare (g)	Tare (g)	Water Weight (g)	Total Dry Weight (g)	Water Content (%)	Notes
S7	Bag1	WC 1	316.15	308.70	268.82	7.45	39.88	**18.68**	WC @ 110 ^{o}C
S7	Bag1	WC 2	213.98	198.68	114.00	15.30	84.68	**18.07**	WC @ 45 ^{o}C
S7	Bag 1	WC 2	213.98	198.68	114.00	15.30	84.68	**18.07**	13th of June
S7	Bag 1	WC 2	213.98	198.66	114.00	15.32	84.66	**18.10**	14th of June
S7	Bag 1	WC 2	213.98	198.65	114.00	15.33	84.65	**18.11**	15th of June
S7	Bag 1	WC 2	213.98	198.62	114.00	15.36	84.62	**18.15**	16th of June
S7	Bag 1	WC 2	213.98	198.62	114.00	15.36	84.62	**18.15**	17th of June
S7	Bag2	WC 1	356.92	342.79	279.41	14.13	63.38	**22.29**	WC @ 110 ^{o}C
S7	Bag2	WC 2	261.20	238.11	123.62	23.09	114.49	**20.17**	WC @ 45 ^{o}C
S7	Bag 2	WC 2	261.20	238.11	123.62	23.09	114.49	**20.17**	13th of June
S7	Bag 2	WC 2	261.20	238.10	123.62	23.10	114.48	**20.18**	14th of June
S7	Bag 2	WC 2	261.20	238.10	123.62	23.10	114.48	**20.18**	15th of June
S7	Bag 2	WC 2	261.20	238.10	123.62	23.10	114.48	**20.18**	16th of June
S7	Bag 2	WC 2	261.20	238.10	123.62	23.10	114.48	**20.18**	17th of June

PROJECT No.: A03355A01
PROJECT NAME:
LOCATION:
DATE: 2019/06/17
TESTED BY: HM, JG CHECKED BY: JG

Atterberg Limit Tests

PLASTICITY CHART



	HOLE	SAMPLE	DEPTH (m)	W_L	W_P	PI	% FINES	REMARKS/SAMPLE DESCRIPTION
●	S 1	Bag 1	0.0	43	26	17	98.9	Slimes. Pail 1
⧗	S 1	Bag 2	0.0	41	25	16	99.2	Slimes. Pail 1
▲	S 1	Bag 3	0.0	43	24	20	98.6	Slimes. Pail 2
★	S 1	Bag 4	0.0	46	26	20	98.6	Slimes. Pail 2
⊙	S 2	Bag 1	0.0	48	31	17	99.6	Slimes. Pail 3
✿	S 2	Bag 2	0.0	49	27	22	99.7	Slimes. Pail 3
○	S 7	Bag 1	0.0	36	26	10		Residual Soil. Pail 10. Natural/dried 110C
△	S 7	Bag 2	0.0	36	25	11		Residual Soil Pail 10. Natural/ dried 110C

PROJECT NO.: A03355A01

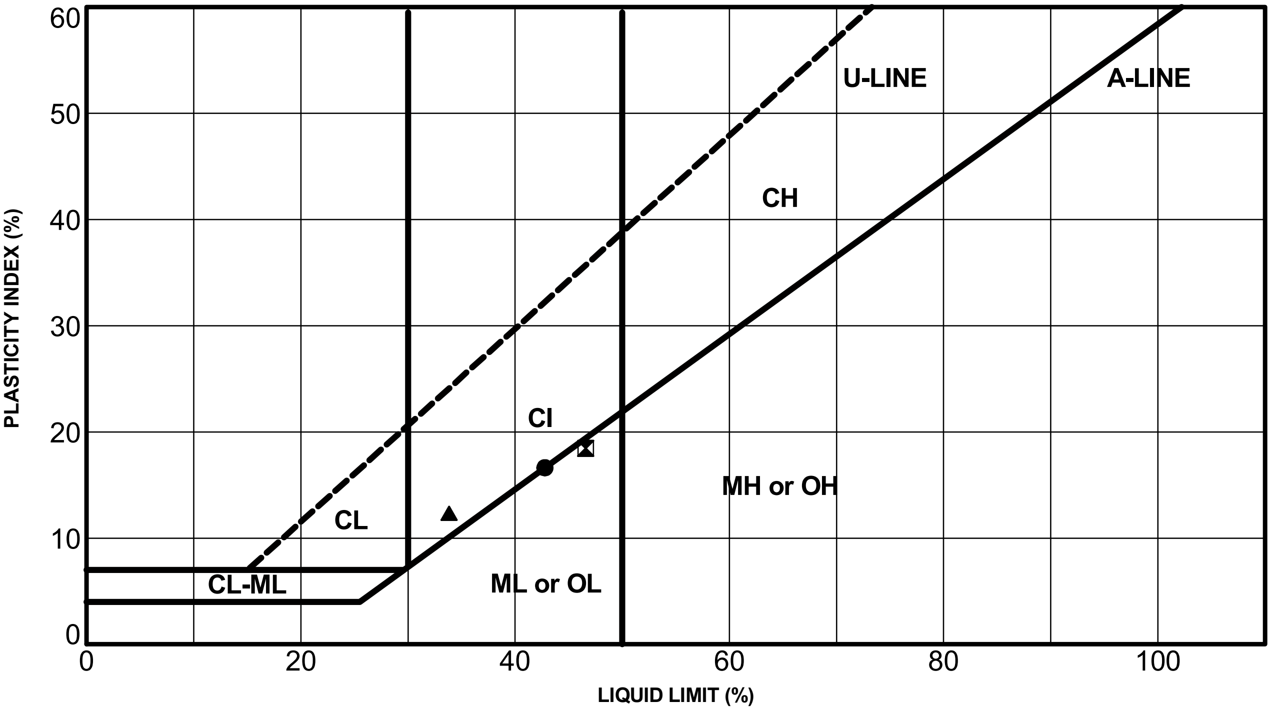
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: HM **CHECKED BY:** JG

PLASTICITY CHART



	HOLE	SAMPLE	DEPTH (m)	W_L	W_P	PI	% FINES	REMARKS/SAMPLE DESCRIPTION
●	S 1	Bag 1	0.0	43	26	17	98.9	Slimes. Pail 1
⧗	S 1	Bag 1	0.0	47	28	18		Dark Slimes. Pail 1
▲	S 1	Bag 1	0.0	34	22	12		Orange Slimes. Pail 1

PROJECT NO.: A03355A01

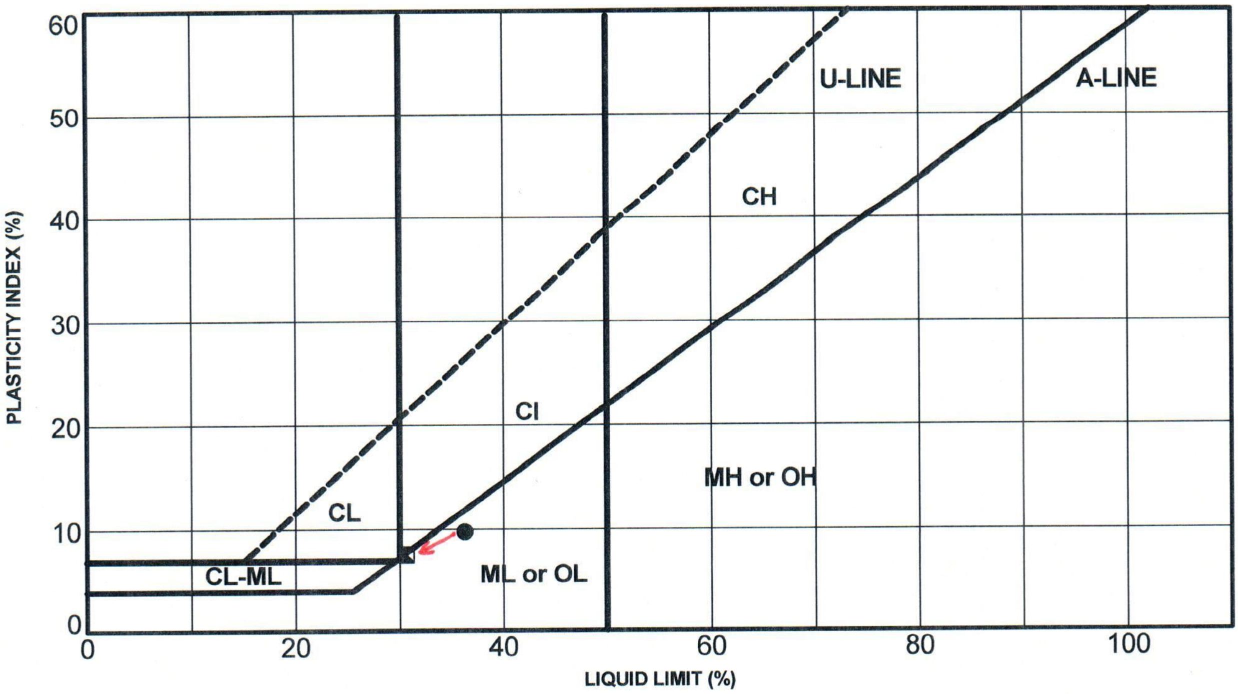
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: HM **CHECKED BY:** JG

PLASTICITY CHART



	HOLE	SAMPLE	DEPTH (m)	W_L	W_P	PI	% FINES	REMARKS/SAMPLE DESCRIPTION
●	S 7	Bag 1	0.0	36	26	10		Residual Soil. Pail 10. Natural/dried 110C
⧗	S 7	Bag 1	0.0	31	23	8		Residual Soil. Pail 10. Dried at 45C/dried 110C

PROJECT NO.: A03355A01

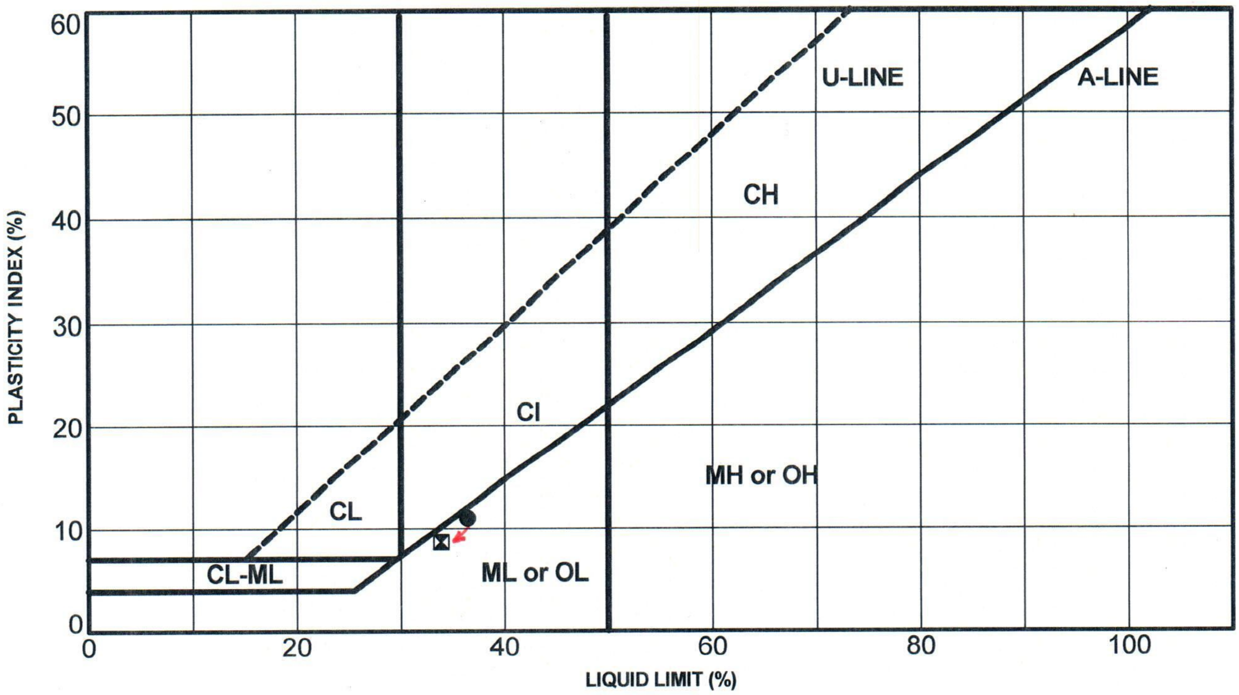
PROJECT: VSA - Confidential

LOCATION:

FIGURE:

DRAWN BY: HM **CHECKED BY:** JG

PLASTICITY CHART



	HOLE	SAMPLE	DEPTH (m)	W_L	W_P	PI	% FINES	REMARKS/SAMPLE DESCRIPTION
●	S 7	Bag 2	0.0	36	25	11		Residual Soil Pail 10. Natural/ dried 110C
☒	S 7	Bag 2	0.0	34	25	9		Residual Soil Pail 10 dried at 45C/ dried 110C

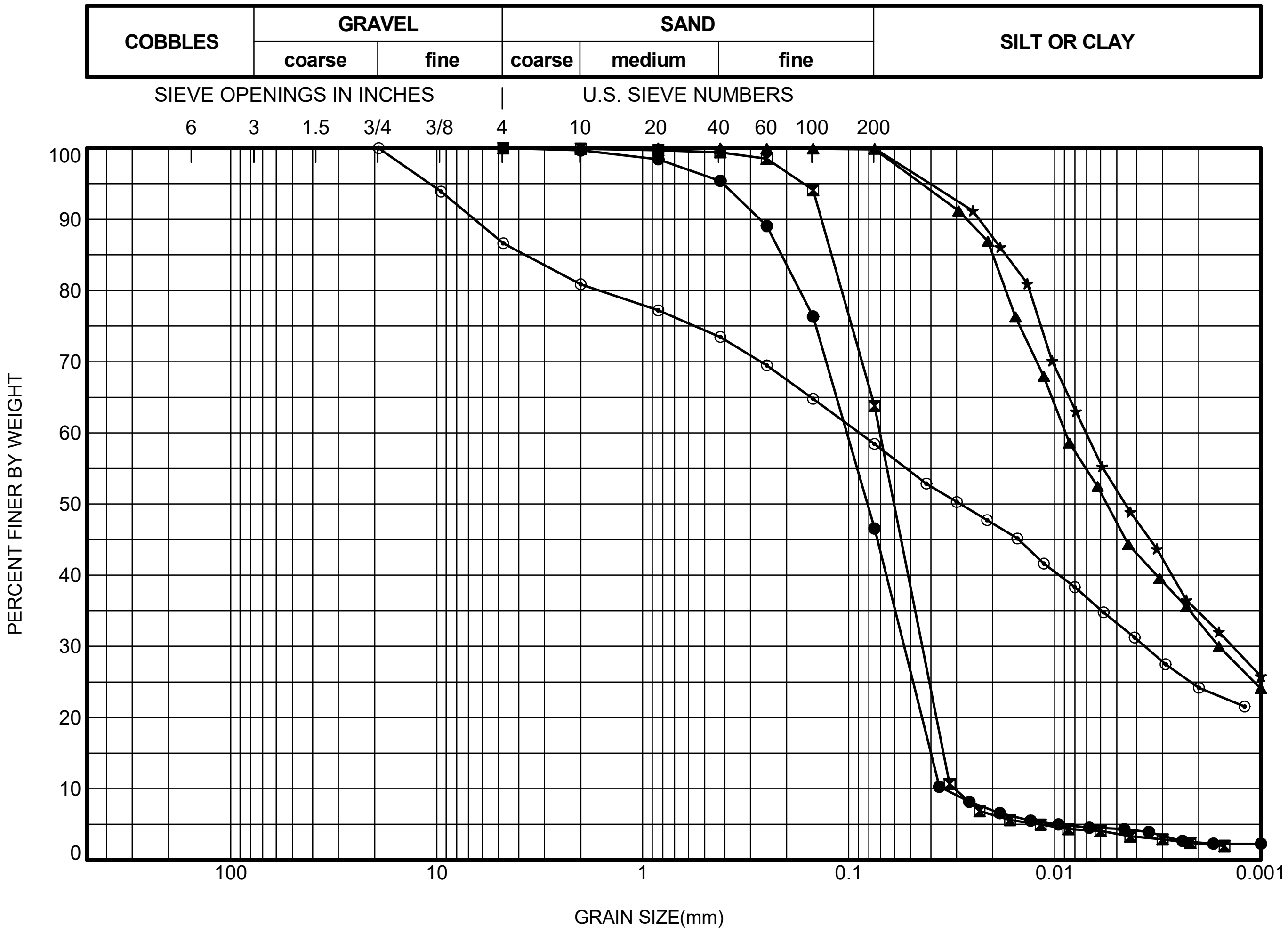
PROJECT NO.: A03355A01
PROJECT: VSA - Confidential
LOCATION:
FIGURE:
DRAWN BY: HM **CHECKED BY:** JG

Program 2

Particle Size Distribution
Specific Gravity Tests
Moisture Content
Atterberg Limit Test

Particle Size Distribution

GRAIN SIZE DISTRIBUTION



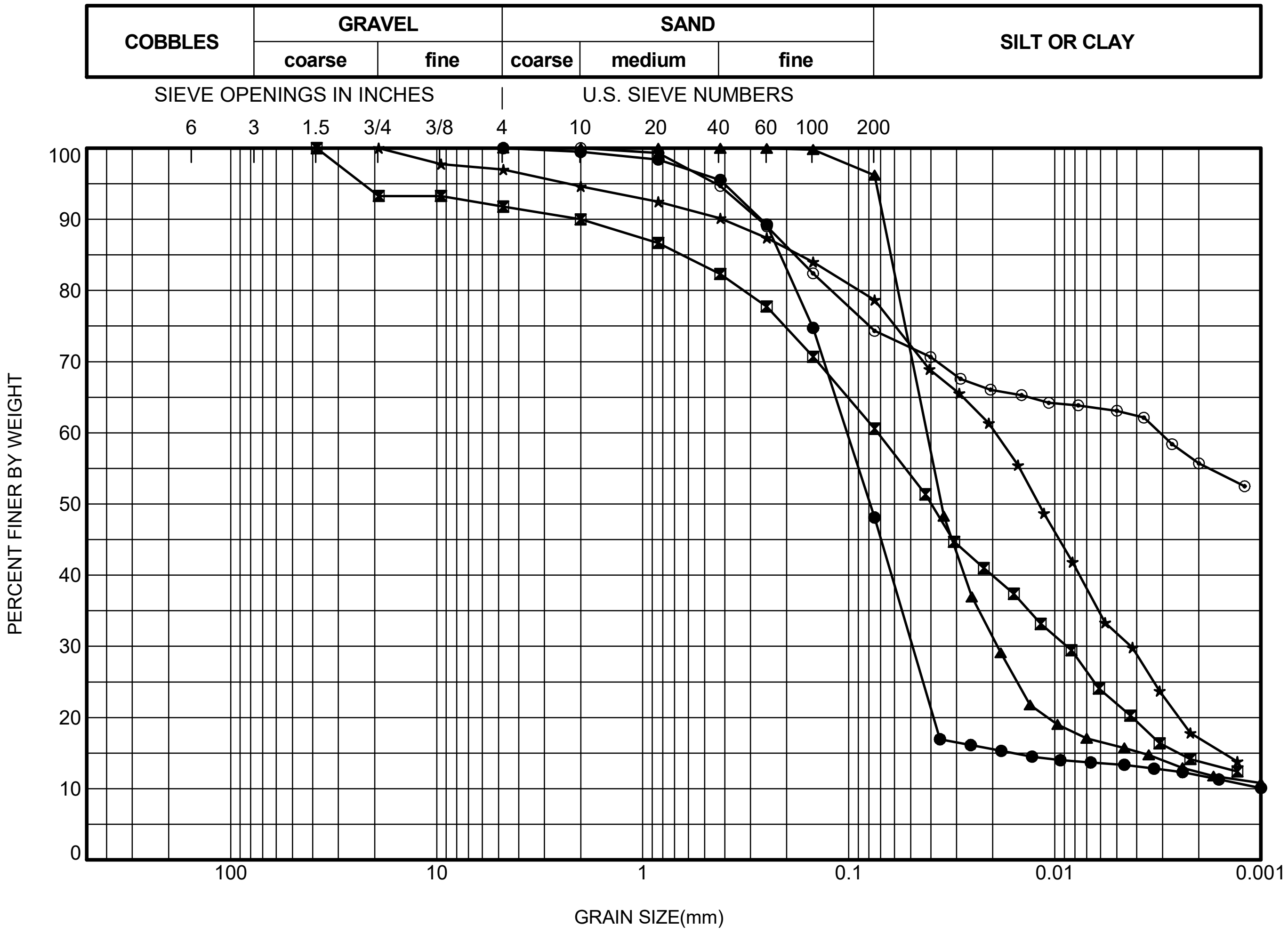
	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	DT04	0.00	0.212	0.102	0.081				0.0	53.4	46.6
⧗	DT08	0.00	0.121						0.0	36.2	63.8
▲	GP01	0.00							0.0	0.2	99.8
★	GP04B	0.00							0.0	0.0	100.0
⊙	GP05	0.00	3.716	0.089					13.4	28.2	58.4

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	DT04	BS01	0.00					
⧗	DT08	BS01	0.00					
▲	GP01	BS01	0.00		48	29	20	
★	GP04B	BS01	0.00		53	27	26	
⊙	GP05	BS01	0.00		35	26	9	Air dried sample

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01
PROJECT:
LOCATION:
FIGURE:
DRAWN BY: AX **CHECKED BY:** JG

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	GP06	0.00	0.215	0.102	0.079				0.0	51.9	48.1
⧗	GP07	0.00	0.643						8.2	31.2	60.6
▲	GP08	0.00							0.0	3.8	96.2
★	GP09	0.00	0.173						3.0	18.3	78.7
⊙	GP11	0.00	0.183						0.0	25.7	74.3

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	GP06	BS01	0.00		16	15	1	
⧗	GP07	BS01	0.00		42	27	15	Air dried sample
▲	GP08	BS01	0.00		19	16	3	
★	GP09	BS01	0.00		62	37	25	Air dried sample
⊙	GP11	BS01	0.00					

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

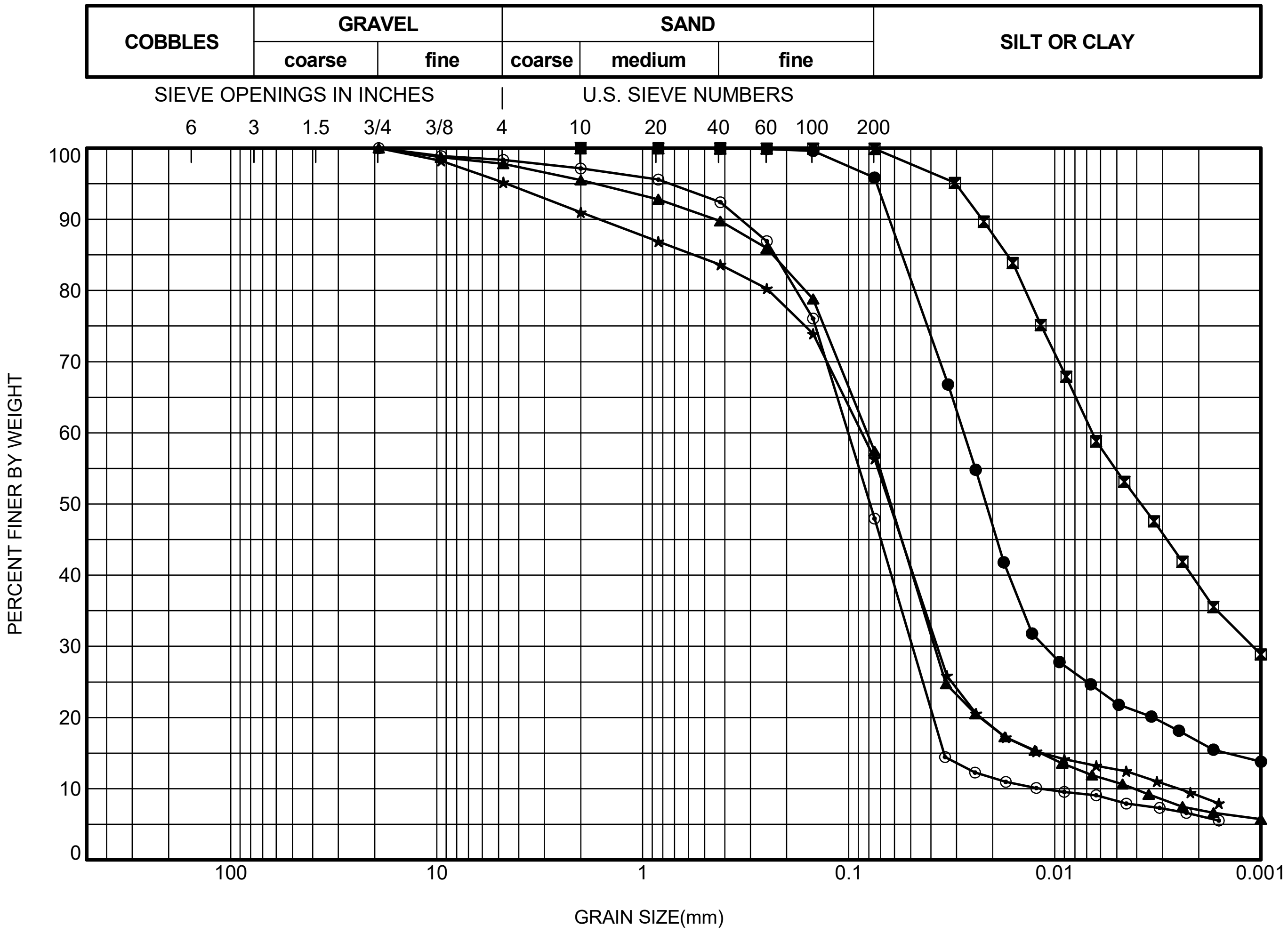
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** JG

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	GP12	0.00							0.0	4.2	95.8
⧗	GP13	0.00							0.0	0.1	99.9
▲	GP14	0.00	0.234	0.082					2.2	40.4	57.4
★	GP15	0.00	0.563	0.087					4.8	38.8	56.3
⊙	GP16	0.00	0.228	0.101	0.079				1.7	50.4	48.0

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	GP12	BS01	0.00		22	18	4	
⧗	GP13	BS01	0.00		49	27	22	
▲	GP14	BS01	0.00		18	15	3	
★	GP15	BS01	0.00		15	11	4	
⊙	GP16	BS01	0.00		16	14	2	

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

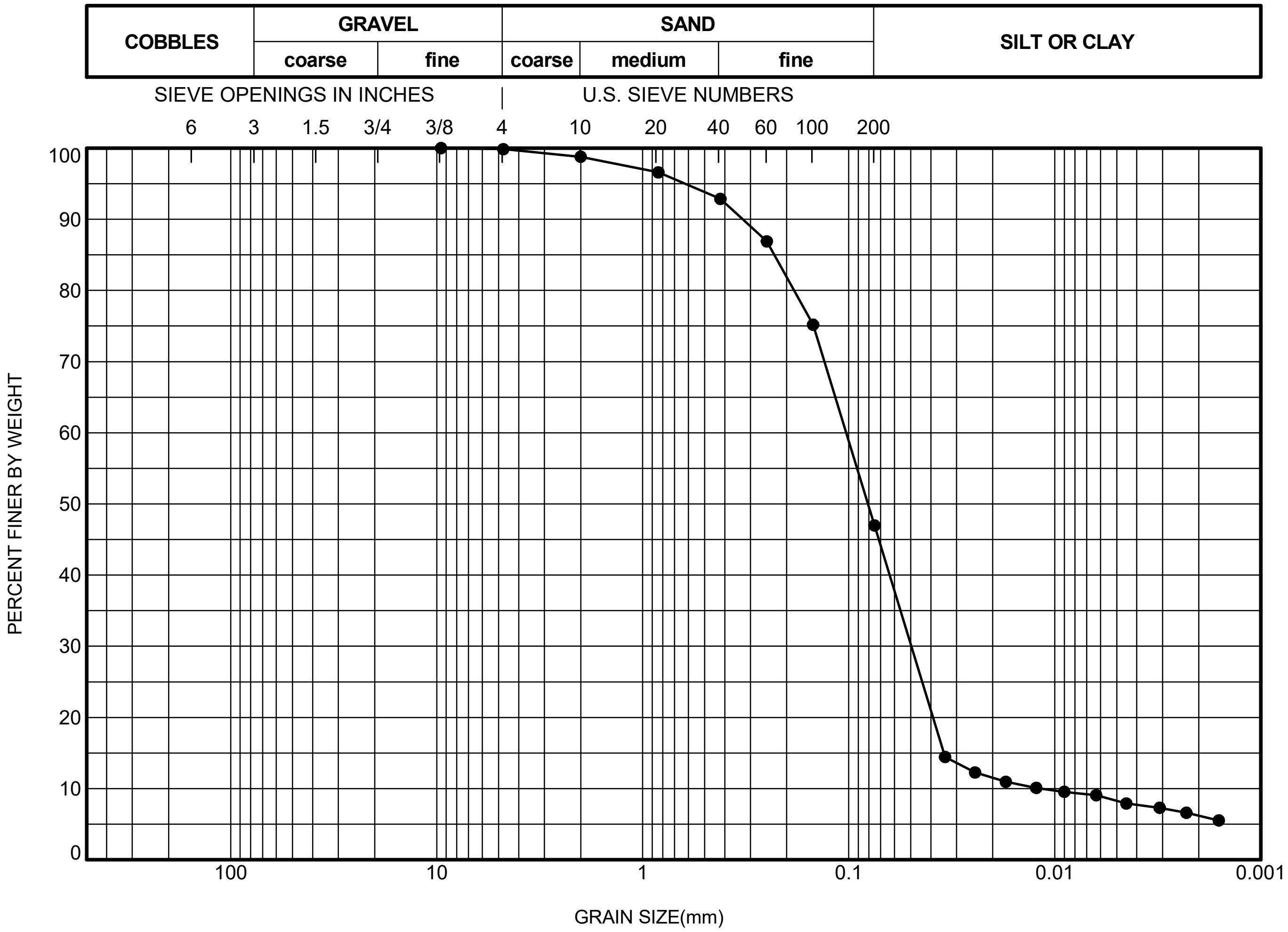
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** JG

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	GP16	0.00	0.230	0.103	0.081				0.1	52.9	47.0

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	GP16	BS01	0.00					attempt 2

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

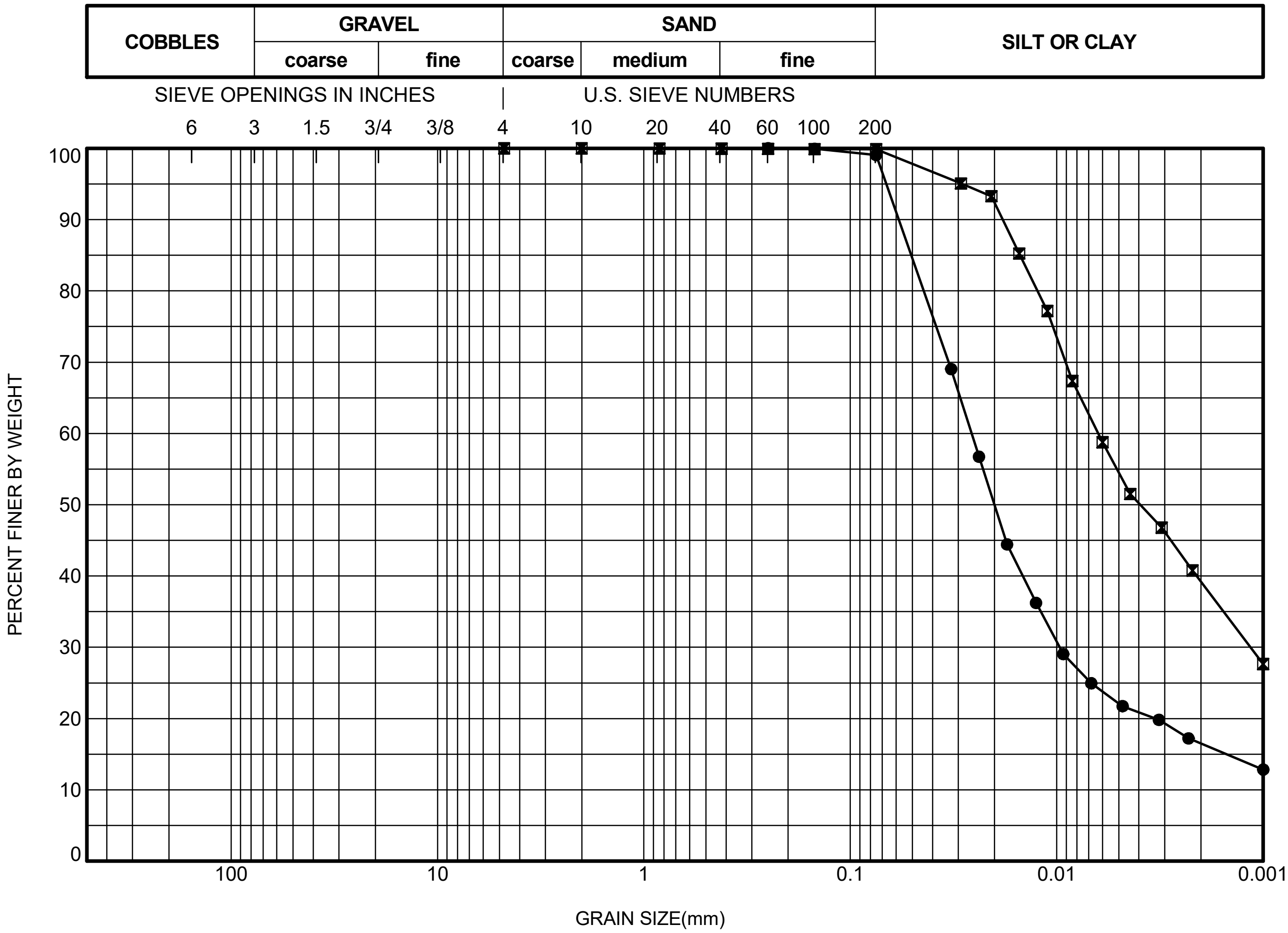
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** JG

GRAIN SIZE DISTRIBUTION



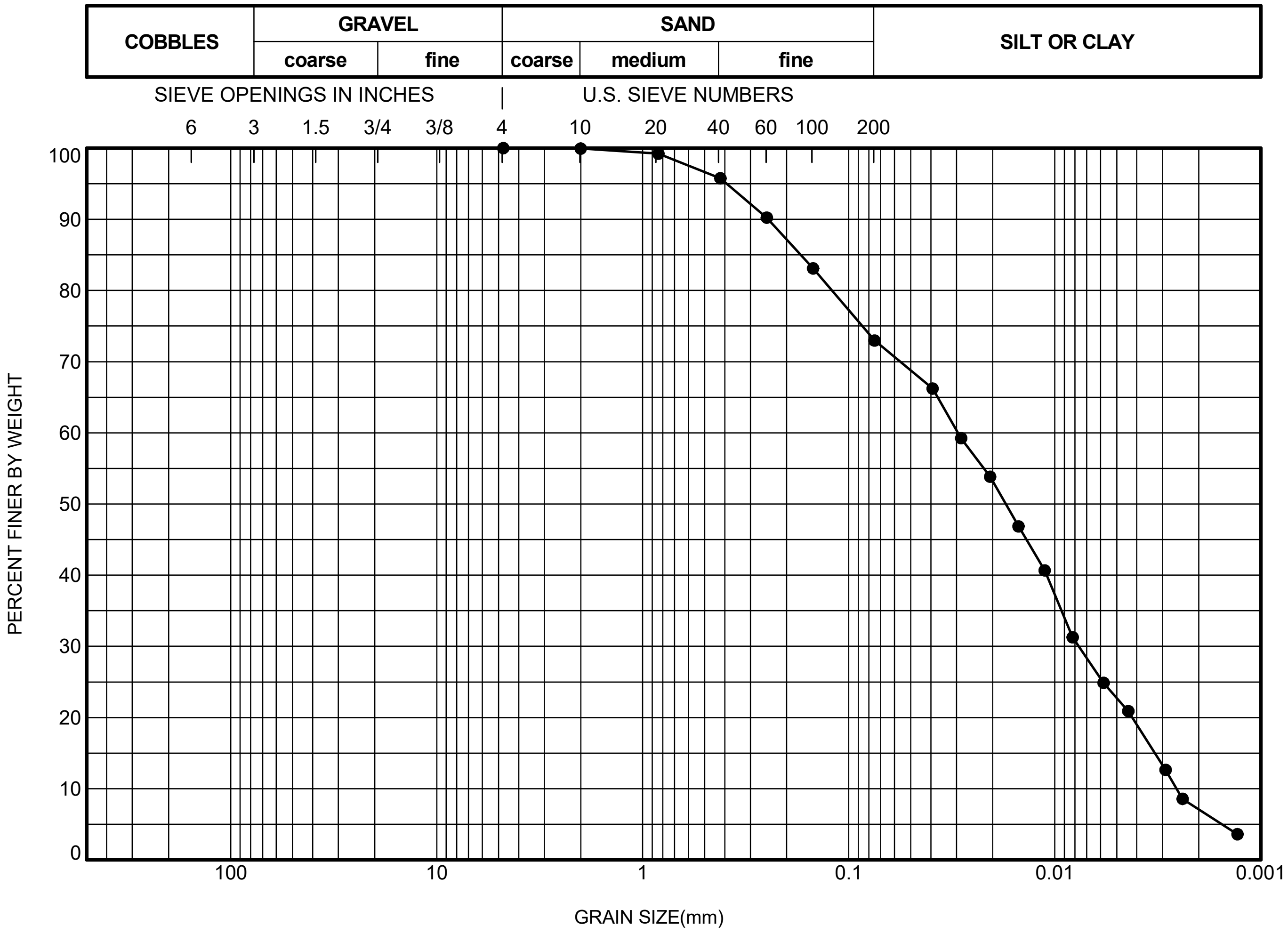
	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	Slimes 1	0.00							0.0	0.9	99.1
☒	Slimes 2	0.00							0.0	0.1	99.9

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	Slimes 1		0.00		34	22	11	Pail 13
☒	Slimes 2		0.00		52	30	22	Pail 14

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01
PROJECT:
LOCATION: Brazil
FIGURE:
DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



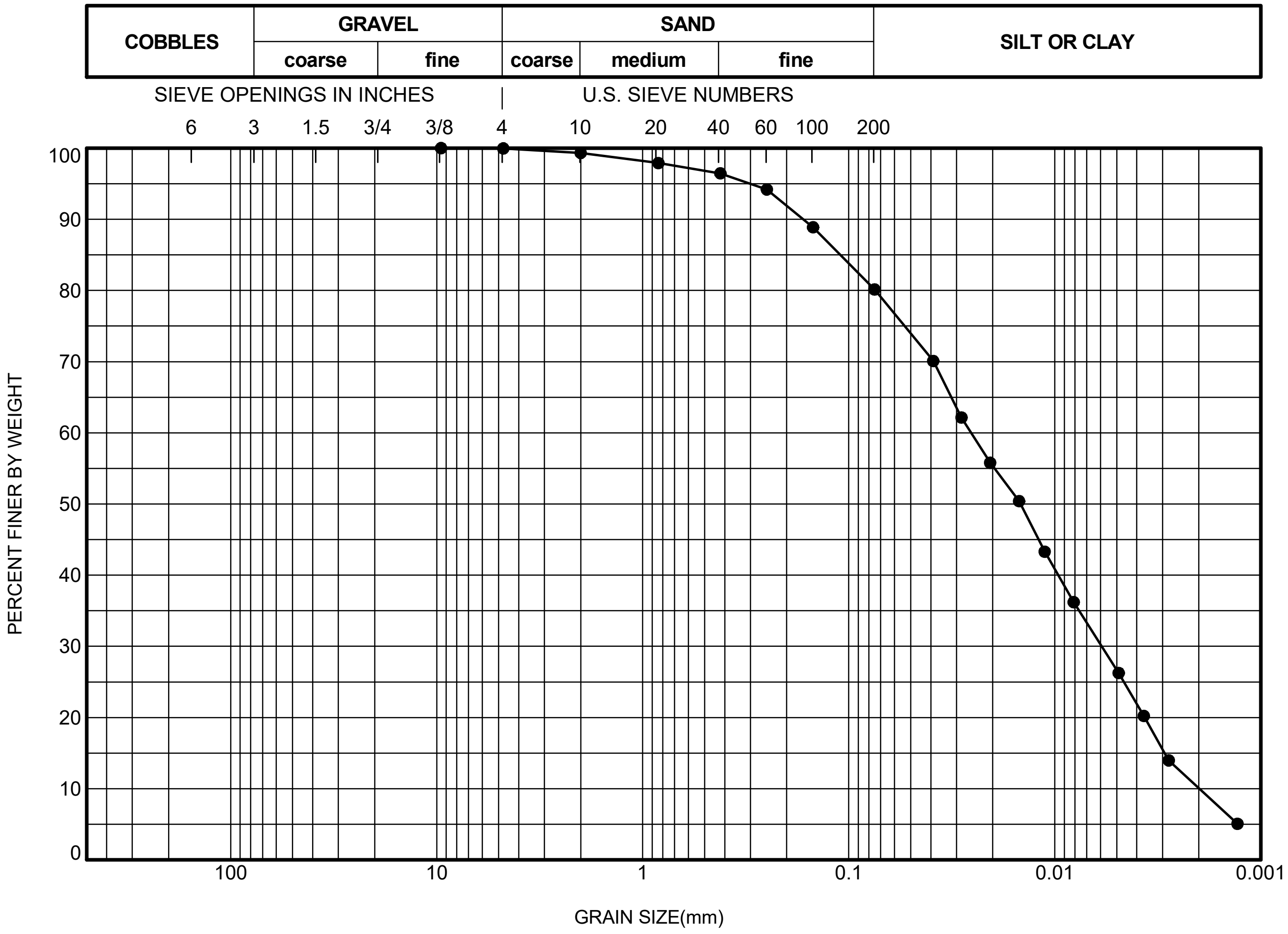
	HOLE	DEPTH (ft)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	BH-01	3.50	0.171						0.0	27.0	73.0

	HOLE	SAMPLE	DEPTH (ft)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	BH-01	01	3.50		56	36	20	Air Dried

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01
PROJECT:
LOCATION: Brazil
FIGURE:
DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (ft)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	BH-01	4.50	0.110						0.0	19.8	80.1

	HOLE	SAMPLE	DEPTH (ft)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	BH-01	02	4.50		59	42	17	Air Dried

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

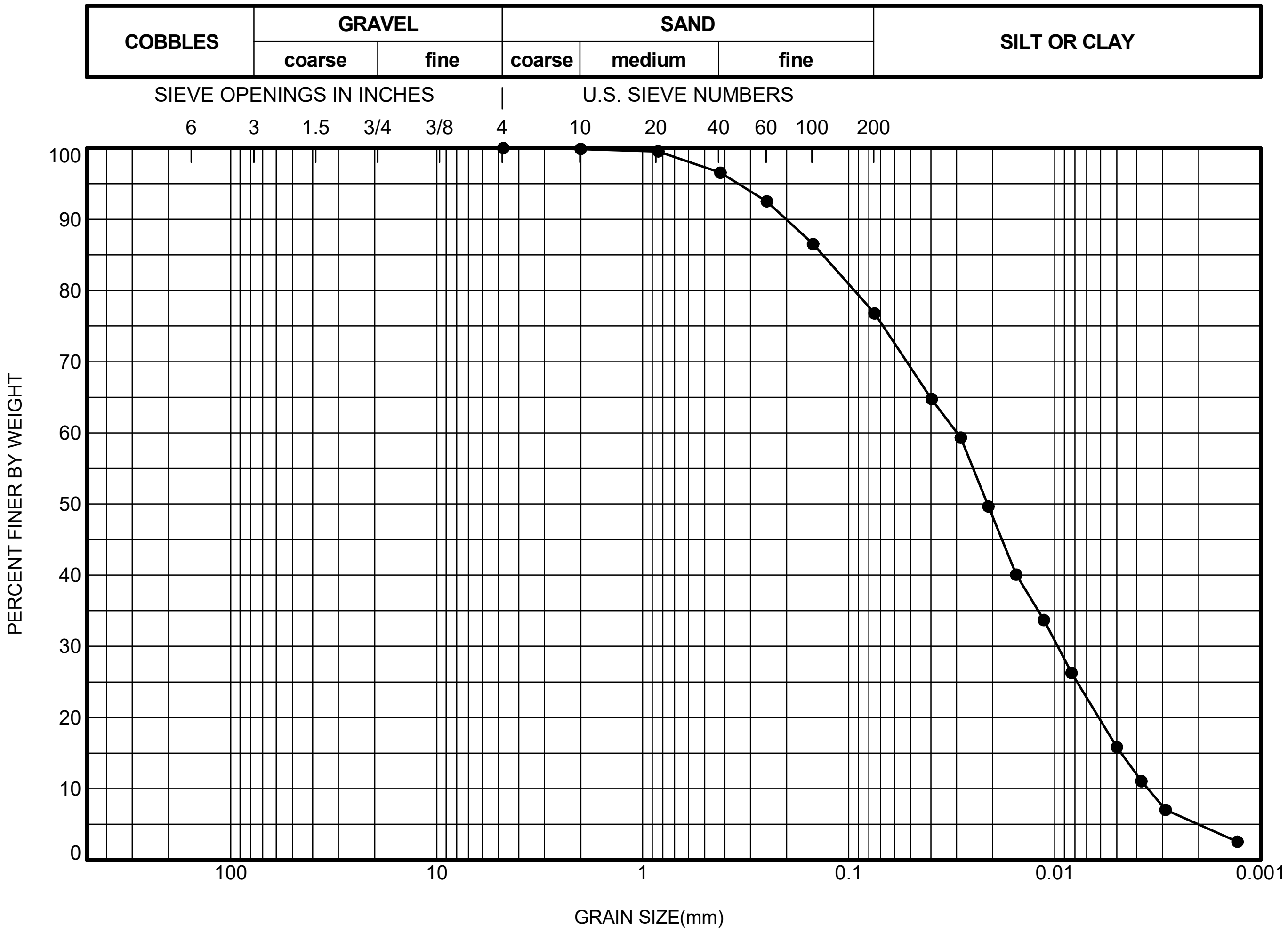
PROJECT:

LOCATION: Brazil

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



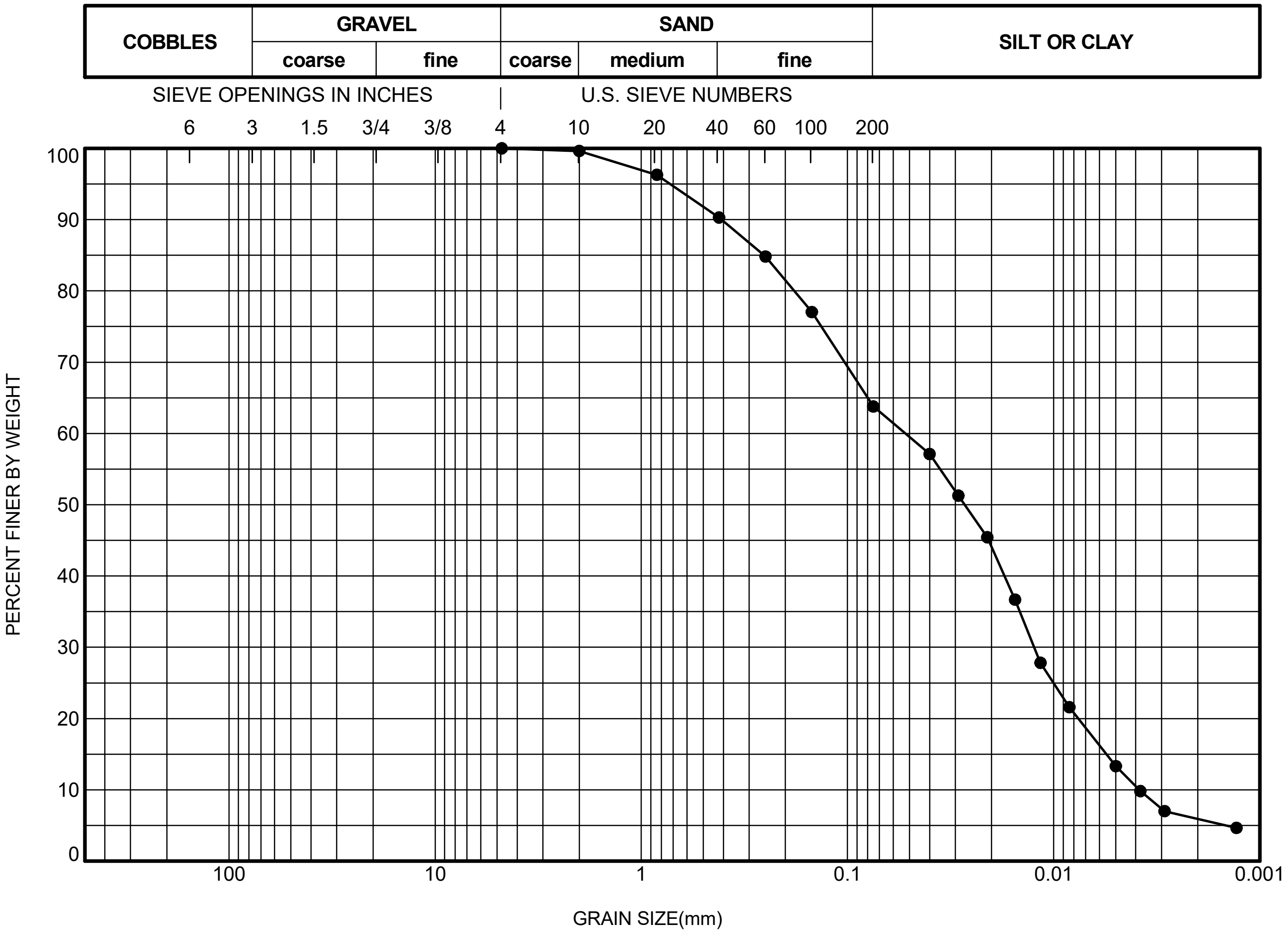
	HOLE	DEPTH (ft)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	BH-02	3.50	0.134						0.0	23.2	76.8

	HOLE	SAMPLE	DEPTH (ft)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	BH-02	01	3.50		58	48	10	Air Dried

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01
PROJECT:
LOCATION: Brazil
FIGURE:
DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (ft)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	BH-02	0.00	0.254						0.0	36.2	63.8

	HOLE	SAMPLE	DEPTH (ft)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	BH-02	02	0.00		52	37	15	Air Dried

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

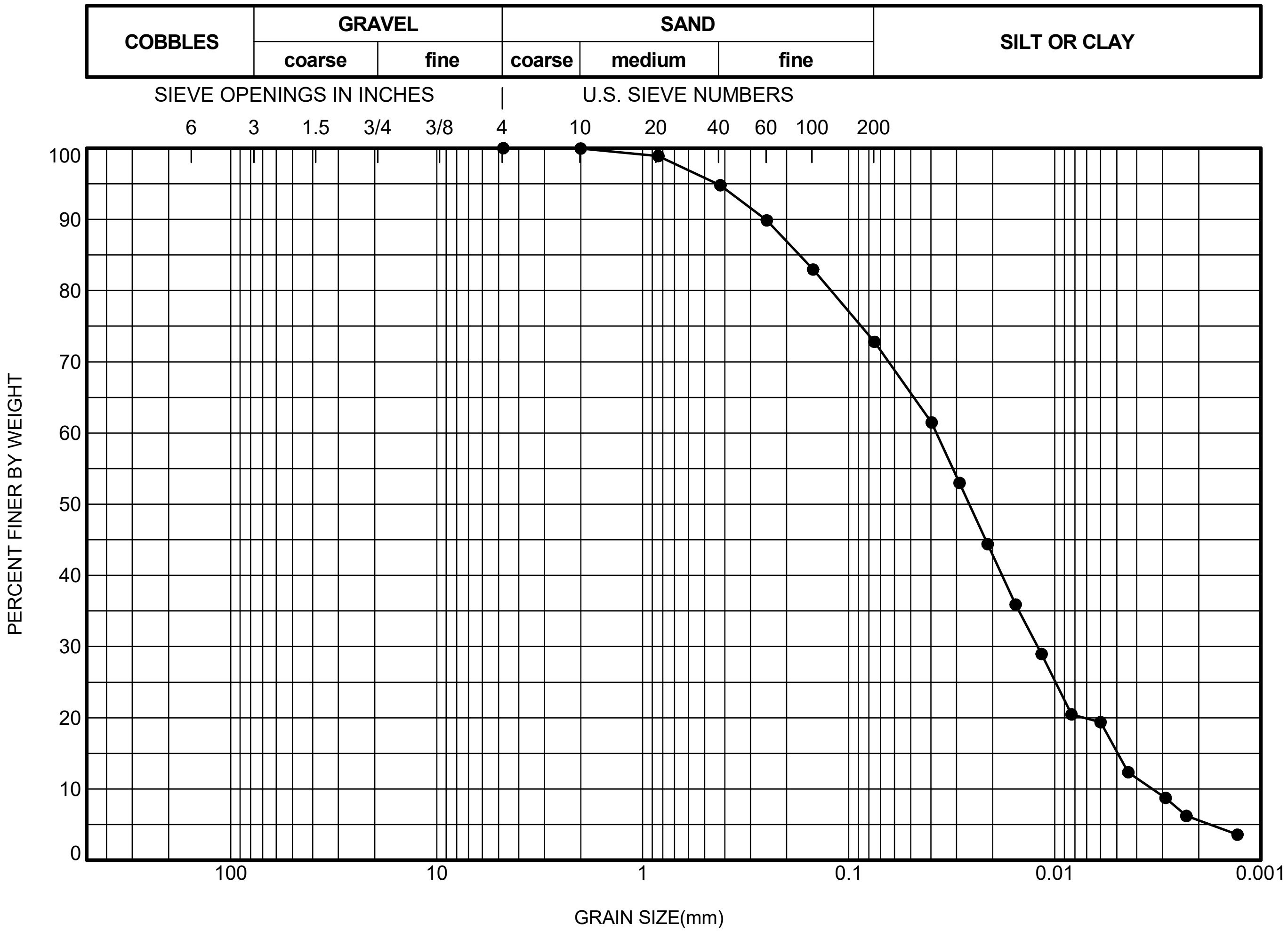
PROJECT:

LOCATION: Brazil

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (ft)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	BH-04	0.00	0.174						0.0	27.2	72.8

	HOLE	SAMPLE	DEPTH (ft)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	BH-04	01	0.00		59	50	9	Air Dried

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

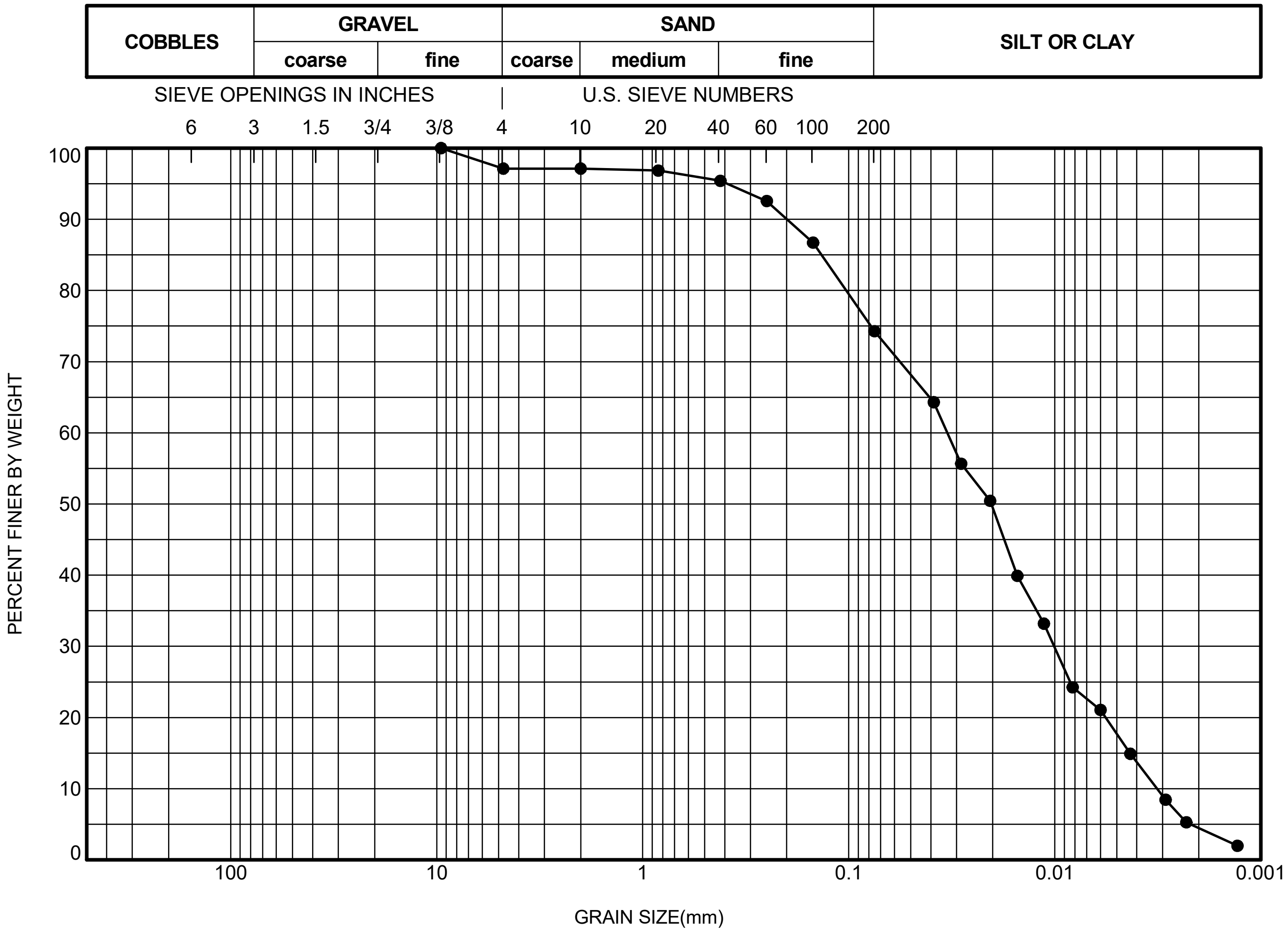
PROJECT:

LOCATION: Brazil

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (ft)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	BH-04	5.30	0.136						2.9	22.8	74.3

	HOLE	SAMPLE	DEPTH (ft)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	BH-04	02	5.30		55	38	17	Air Dried

CU = COEFFICIENT OF UNIFORMITY = D60/D10 PARTICLE SIZES, e.g. D85, in mm Tested by Wet Sieving Method (ASTM D1140 & D422)

PROJECT NO.: A03355A01

PROJECT:

LOCATION: Brazil

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

Specific Gravity Tests

SPECIFIC GRAVITY OF SOIL SOLIDS (ASTM-D854)

Hole Number	DT-04	GP-1
Sample Number	BS-01	BS-01
Depth (m)		
Sample Description	More sandy than other samples	
Flask No.	KL-2	SG9
Volume of Flask @ 20^o C ml	500	500
Method of Air removal	boiling	boiling
De-airing Period hr	2	2
Test temperature ^{o} C	22.6	22.6
Mass of Flask+Water (M_a) g	675.44	667.80
Mass of Flask+Water+Soil (M_b) g	742.07	711.38
Mass of Dish/Flask+Soil	260.64	227.83
Mass of Dish/Flask	177.05	169.67
Mass of Dry Soil (M_o) g	83.59	58.16
Correction factor (K) @ Test Temperature	0.99943	0.99943
Specific Gravity of Solids @ 20^o C	**4.926**	**3.987**
Average Specific Gravity of Solids @ 20^o C	**4.93**	**3.99**

Hole Number	GP-4B	GP-5
Sample Number	BS-01	BS-01
Depth (m)		
Sample Description		Residual
Flask No.	SG6	12
Volume of Flask @ 20^o C ml	500	500
Method of Air removal	boiling	boling
De-airing Period hr	2	2
Test temperature ^{o} C	22.9	22.6
Mass of Flask+Water (M_a) g	670.42	680.38
Mass of Flask+Water+Soil (M_b) g	707.29	720.22
Mass of Dish/Flask+Soil	222.53	243.40
Mass of Dish/Flask	172.15	182.10
Mass of Dry Soil (M_o) g	50.38	61.30
Correction factor (K) @ Test Temperature	0.99936	0.99943
Specific Gravity of Solids @ 20^o C	**3.727**	**2.855**
Average Specific Gravity of Solids @ 20^o C	**3.73**	**2.85**

Specific Gravity of Solids @ 20^o C = $(K \times M_o)/(M_o + M_a - M_b)$

PROJECT#:	A03355A01		
PROJECT:			
LOCATION:	Brazil		
DATE:	2019-08-17		
TESTED BY:	HM	CHECKED BY:	JG

SPECIFIC GRAVITY OF SOIL SOLIDS (ASTM-D854)

Hole Number	GP-6	GP-7
Sample Number	BS-01	BS-01
Depth (m)		
Sample Description		Residual
Flask No.	SG10	SG7
Volume of Flask @ 20° C ml	500	500
Method of Air removal	boiling	boiling
De-airing Period hr	2	2
Test temperature ° C	22.6	22.7
Mass of Flask+Water (M_a) g	669.89	667.74
Mass of Flask+Water+Soil (M_b) g	720.15	702.58
Mass of Dish/Flask+Soil	238.39	224.21
Mass of Dish/Flask	171.93	169.42
Mass of Dry Soil (M_o) g	66.46	54.79
Correction factor (K) @ Test Temperature	0.99943	0.99941
Specific Gravity of Solids @ 20° C	**4.100**	**2.745**
Average Specific Gravity of Solids @ 20° C	**4.10**	**2.74**

Hole Number	GP-8	GP-9
Sample Number	BS-01	BS-01
Depth (m)		
Sample Description		Residual
Flask No.	SG4	11
Volume of Flask @ 20° C ml	500	500
Method of Air removal	boling	boiling
De-airing Period hr	2	2
Test temperature ° C	22.5	22.6
Mass of Flask+Water (M_a) g	670.66	678.51
Mass of Flask+Water+Soil (M_b) g	718.67	715.71
Mass of Dish/Flask+Soil	237.32	238.88
Mass of Dish/Flask	172.57	180.36
Mass of Dry Soil (M_o) g	64.75	58.52
Correction factor (K) @ Test Temperature	0.99945	0.99943
Specific Gravity of Solids @ 20° C	**3.866**	**2.743**
Average Specific Gravity of Solids @ 20° C	**3.87**	**2.74**

Specific Gravity of Solids @ 20° C = $(K \times M_o)/(M_o + M_a - M_b)$

PROJECT#:	A03355A01		
PROJECT:			
LOCATION:	Brazil		
DATE:	2019-08-17		
TESTED BY:	HM	CHECKED BY:	JG

SPECIFIC GRAVITY OF SOIL SOLIDS (ASTM-D854)

Hole Number	GP-11	GP-12
Sample Number	BS-01	BS-01
Depth (m)		
Sample Description		
Flask No.	SG3	3
Volume of Flask @ 20^{o} C ml	500	500
Method of Air removal	boiling	boling
De-airing Period hr	2	2
Test temperature ^{o} C	22.6	22.6
Mass of Flask+Water (M_a) g	672.24	671.41
Mass of Flask+Water+Soil (M_b) g	707.89	716.46
Mass of Dish/Flask+Soil	230.93	233.24
Mass of Dish/Flask	173.92	172.68
Mass of Dry Soil (M_o) g	57.01	60.56
Correction factor (K) @ Test Temperature	0.99943	0.99943
Specific Gravity of Solids @ 20^{o} C	**2.667**	**3.902**
Average Specific Gravity of Solids @ 20^{o} C	**2.67**	**3.90**

Hole Number	GP-13	GP-14
Sample Number	BS-01	BS-01
Depth (m)		
Sample Description		
Flask No.	KL-3	10
Volume of Flask @ 20^{o} C ml	500	500
Method of Air removal	boiling	boiling
De-airing Period hr	2	2
Test temperature ^{o} C	22.6	22.6
Mass of Flask+Water (M_a) g	675.77	679.65
Mass of Flask+Water+Soil (M_b) g	722.81	729.53
Mass of Dish/Flask+Soil	242.42	247.34
Mass of Dish/Flask	177.35	181.53
Mass of Dry Soil (M_o) g	65.07	65.81
Correction factor (K) @ Test Temperature	0.99943	0.99943
Specific Gravity of Solids @ 20^{o} C	**3.607**	**4.129**
Average Specific Gravity of Solids @ 20^{o} C	**3.61**	**4.13**

Specific Gravity of Solids @ 20^{o} C = $(K \times M_o)/(M_o + M_a - M_b)$

PROJECT#:	A03355A01		
PROJECT:			
LOCATION:	Brazil		
DATE:	2019-08-17		
TESTED BY:	HM	CHECKED BY:	JG

SPECIFIC GRAVITY OF SOIL SOLIDS (ASTM-D854)

Hole Number	GP-15			GP-16		
Sample Number	BS-01			BS-01		
Depth (m)						
Sample Description						
Flask No.		SG12			1	
Volume of Flask @ 20° C ml		500			500	
Method of Air removal		boiling			boiling	
De-airing Period hr		2			2	
Test temperature ° C		22.6			22.6	
Mass of Flask+Water (M_a) g		670.59			667.22	
Mass of Flask+Water+Soil (M_b) g		719.70			716.61	
Mass of Dish/Flask+Soil		236.41			232.66	
Mass of Dish/Flask		172.53			168.77	
Mass of Dry Soil (M_o) g		63.88			63.89	
Correction factor (K) @ Test Temperature		0.99943			0.99943	
Specific Gravity of Solids @ 20° C		**4.323**			**4.404**	
Average Specific Gravity of Solids @ 20° C	**4.32**			**4.40**		

Hole Number						
Sample Number						
Depth (m)						
Sample Description						
Flask No.						
Volume of Flask @ 20° C ml						
Method of Air removal						
De-airing Period hr						
Test temperature ° C						
Mass of Flask+Water (M_a) g						
Mass of Flask+Water+Soil (M_b) g						
Mass of Dish/Flask+Soil						
Mass of Dish/Flask						
Mass of Dry Soil (M_o) g						
Correction factor (K) @ Test Temperature						
Specific Gravity of Solids @ 20° C						
Average Specific Gravity of Solids @ 20° C						

Specific Gravity of Solids @ 20° C = $(K \times M_o)/(M_o + M_a - M_b)$

PROJECT#:	A03355A01		
PROJECT:			
LOCATION:	Brazil		
DATE:	2019-08-17		
TESTED BY:	HM	CHECKED BY:	JG

Moisture Content

WATER CONTENT OF SOIL

(ASTM D2216)

Hole Number	Sample Number	Depth (m)	Wet Weight + Tare (g)	Dry Weight + Tare (g)	Tare (g)	Water Weight (g)	Total Dry Weight (g)	Water Content (%)	Notes
DT01	BS01		482.19	392.68	73.45	89.51	319.23	**28.0**	
DT02	BS01		328.81	288.34	86.46	40.47	201.88	**20.0**	
DT03	BS01		476.04	398.28	71.71	77.76	326.57	**23.8**	
DT04	BS01		303.80	296.75	90.77	7.05	205.98	**3.4**	
DT05	BS01		289.81	255.78	80.32	34.03	175.46	**19.4**	
DT06	BS01		286.29	267.23	87.73	19.06	179.50	**10.6**	
DT07	BS01		605.72	495.22	86.79	110.50	408.43	**27.1**	
DT08	BS01		245.31	239.08	85.29	6.23	153.79	**4.1**	
DT09	BS01		360.48	310.62	118.39	49.86	192.23	**25.9**	
DT10	BS01		258.52	233.32	102.36	25.20	130.96	**19.2**	
DT11	BS01		353.45	312.15	103.55	41.30	208.60	**19.8**	
DT12	BS01		323.53	290.92	78.71	32.61	212.21	**15.4**	
DT13	BS01		322.38	295.20	79.10	27.18	216.10	**12.6**	
DT14	BS01		286.24	222.83	88.47	63.41	134.36	**47.2**	
DT15	BS01		362.69	354.54	114.53	8.15	240.01	**3.4**	
GP01	BS01		220.33	188.98	103.08	31.35	85.90	**36.5**	
GP02A	BS01		272.14	232.37	105.64	39.77	126.73	**31.4**	
GP02B	BS01		237.00	212.78	88.92	24.22	123.86	**19.6**	
GP03	BS01		240.57	225.01	109.18	15.56	115.83	**13.4**	
GP04A	BS01		370.88	326.90	109.20	43.98	217.70	**20.2**	
GP04B	BS01		288.98	235.52	79.76	53.46	155.76	**34.3**	
GP05	BS01		225.90	197.19	79.02	28.71	118.17	**24.3**	
GP06	BS01		262.53	254.49	76.57	8.04	177.92	**4.5**	
GP07	BS01		291.30	263.20	99.34	28.10	163.86	**17.1**	
GP08	BS01		342.34	309.73	93.22	32.61	216.51	**15.1**	
GP09	BS01		210.57	174.76	68.67	35.81	106.09	**33.8**	
GP10	BS01		304.61	282.61	111.19	22.00	171.42	**12.8**	
GP11	BS01		291.26	250.49	90.22	40.77	160.27	**25.4**	
GP12	BS01		291.89	257.47	90.80	34.42	166.67	**20.7**	
GP13	BS01		274.28	247.67	90.25	26.61	157.42	**16.9**	
GP14	BS01		328.83	310.04	90.28	18.79	219.76	**8.6**	

PROJECT No.: A03355A01

PROJECT NAME:

LOCATION:

DATE: 2019-08-12

TESTED BY: AX CHECKED BY: JG

WATER CONTENT OF SOIL

(ASTM D2216)

Hole Number	Sample Number	Depth (m)	Wet Weight + Tare (g)	Dry Weight + Tare (g)	Tare (g)	Water Weight (g)	Total Dry Weight (g)	Water Content (%)	Notes
GP15	BS01		223.41	209.03	99.64	14.38	109.39	**13.1**	
GP16	BS01		366.60	356.86	79.48	9.74	277.38	**3.5**	

PROJECT No.: A03355A01

PROJECT NAME:

LOCATION:

DATE: 2019-08-12

TESTED BY: AX CHECKED BY: JG

WATER CONTENT OF SOIL

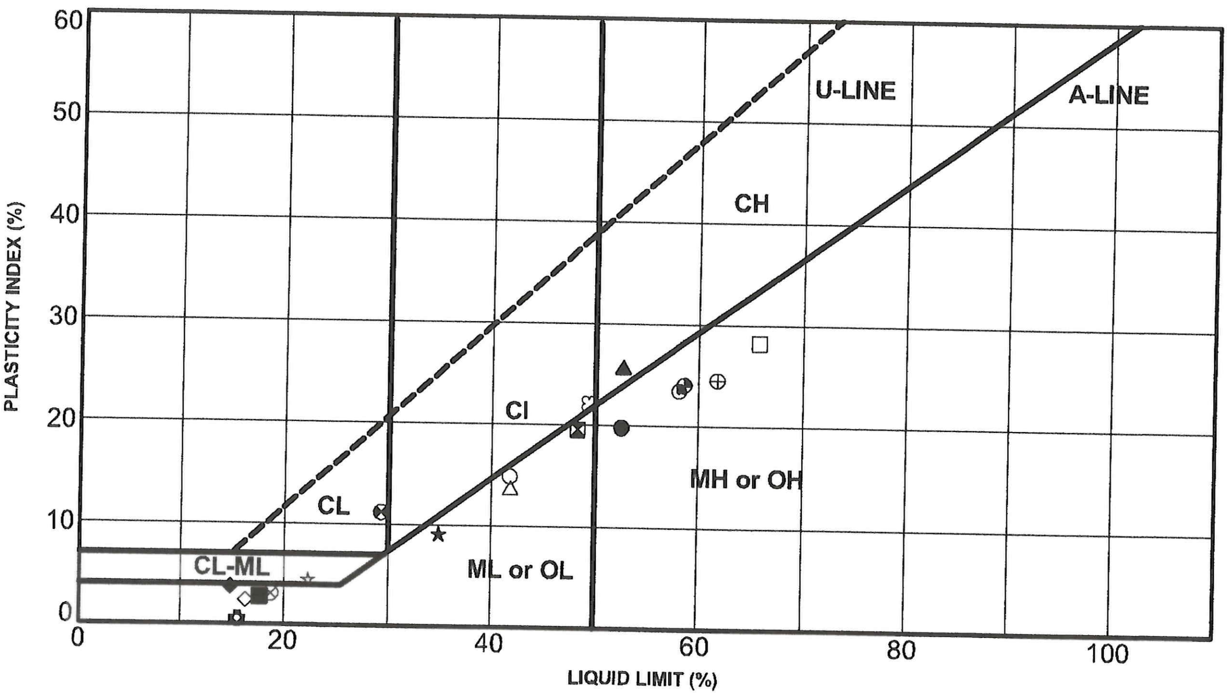
(ASTM D2216)

Hole Number	Sample Number	Depth (m)	Wet Weight + Tare (g)	Dry Weight + Tare (g)	Tare (g)	Water Weight (g)	Total Dry Weight (g)	Water Content (%)	Notes
BH01	Shelby 1	3.5	273.11	234.29	129.78	38.82	104.51	**37.1**	
BH01	Shelby 2	4.5	277.18	238.29	145.12	38.89	93.17	**41.7**	
BH02	Shelby 1	3.5	304.56	247.17	115.09	57.39	132.08	**43.5**	
BH02	Shelby 2		294.80	249.21	87.88	45.59	161.33	**28.3**	
BH04	Shelby 1		289.59	242.53	129.19	47.06	113.34	**41.5**	
BH04	Shelby 2	5.3	206.95	167.01	69.74	39.94	97.27	**41.1**	

PROJECT No.: A03355A01
PROJECT NAME:
LOCATION: Brazil
DATE: 2019-10-04
TESTED BY: HM CHECKED BY: BY

4 Atterberg Limit Tests

PLASTICITY CHART



	HOLE	SAMPLE	DEPTH (m)	W_L	W_P	PI	% FINES	REMARKS/SAMPLE DESCRIPTION
●	DT03	BS01	0.0	53	33	20		
⊠	GP01	BS01	0.0	48	29	20	99.8	
▲	GP04B	BS01	0.0	53	27	26	100.0	
★	GP05	BS01	0.0	35	26	9	58.4	Air dried sample
⊙	GP05	BS01	0.0	58	35	23		Prepared immediately
✿	GP06	BS01	0.0	16	15	1	48.1	
○	GP07	BS01	0.0	42	27	15	60.6	Air dried sample
△	GP07	BS01	0.0	42	28	14		Prepared immediately
⊗	GP08	BS01	0.0	19	16	3	96.2	
⊕	GP09	BS01	0.0	62	37	25	78.7	Air dried sample
□	GP09	BS01	0.0	66	38	28		Prepared immediately
⊗	GP10	BS01	0.0	29	18	11		
◕	GP11	BS01	0.0	59	35	24	67.4	
☆	GP12	BS01	0.0	22	18	4	95.8	
✿	GP13	BS01	0.0	49	27	22	99.9	
■	GP14	BS01	0.0	18	15	3	57.4	
◆	GP15	BS01	0.0	15	11	4	56.3	
◇	GP16	BS01	0.0	16	14	2	48.0	

PROJECT NO.: A03355A01

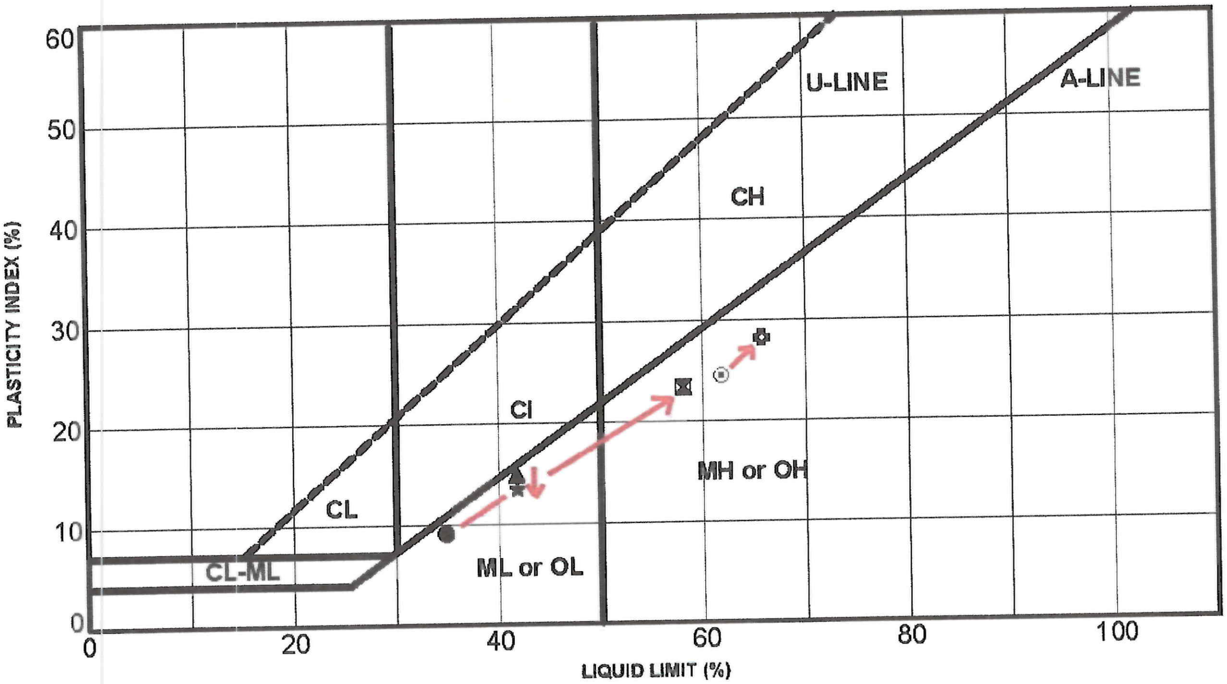
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** JG

PLASTICITY CHART



	HOLE	SAMPLE	DEPTH (ft)	W_L	W_P	PI	% FINES	REMARKS/SAMPLE DESCRIPTION
●	GP05	BS01	0.0	35	26	9		Air dried sample
⊠	GP05	BS01	0.0	58	35	23		Prepared immediately
▲	GP07	BS01	0.0	42	27	15		Air dried sample
★	GP07	BS01	0.0	42	28	14		Prepared immediately
⊙	GP09	BS01	0.0	62	37	25		Air dried sample
✿	GP09	BS01	0.0	66	38	28		Prepared immediately

PROJECT NO.: A03355A01

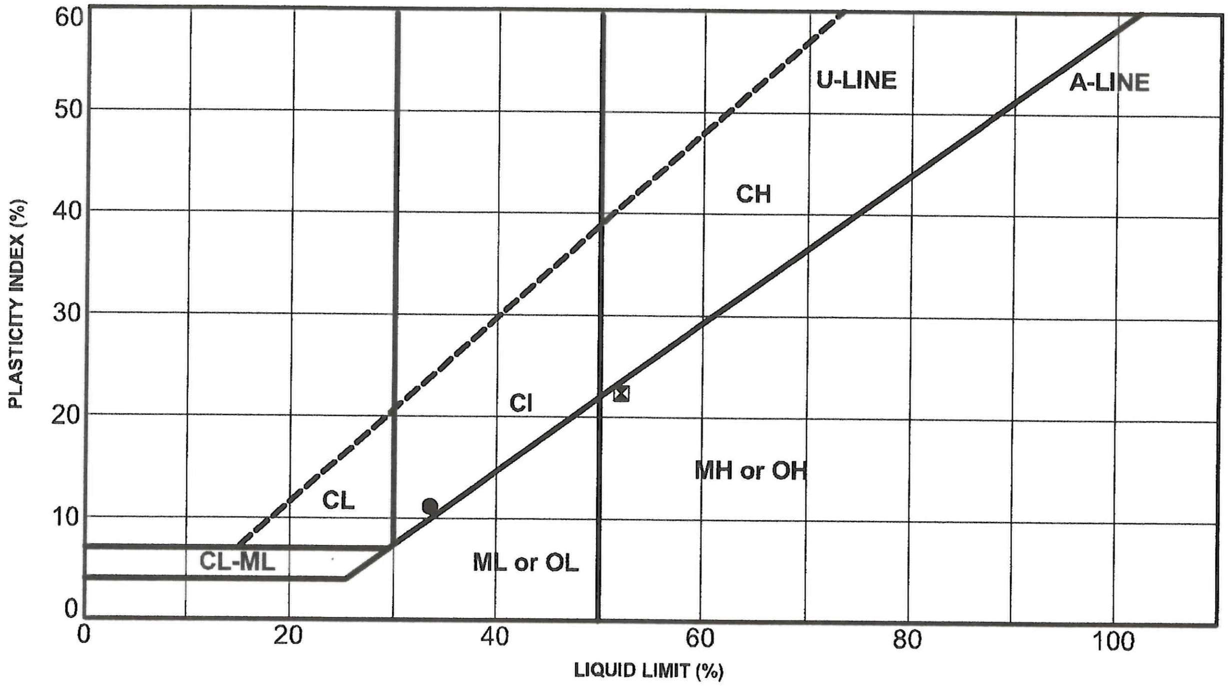
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** JG

PLASTICITY CHART



	HOLE	SAMPLE	DEPTH (m)	W_L	W_P	PI	% FINES	REMARKS/SAMPLE DESCRIPTION
●	Slimes 1		0.0	34	22	11	99.1	Pail 13
☒	Slimes 2		0.0	52	30	22	99.9	Pail 14

PROJECT NO.: A03355A01

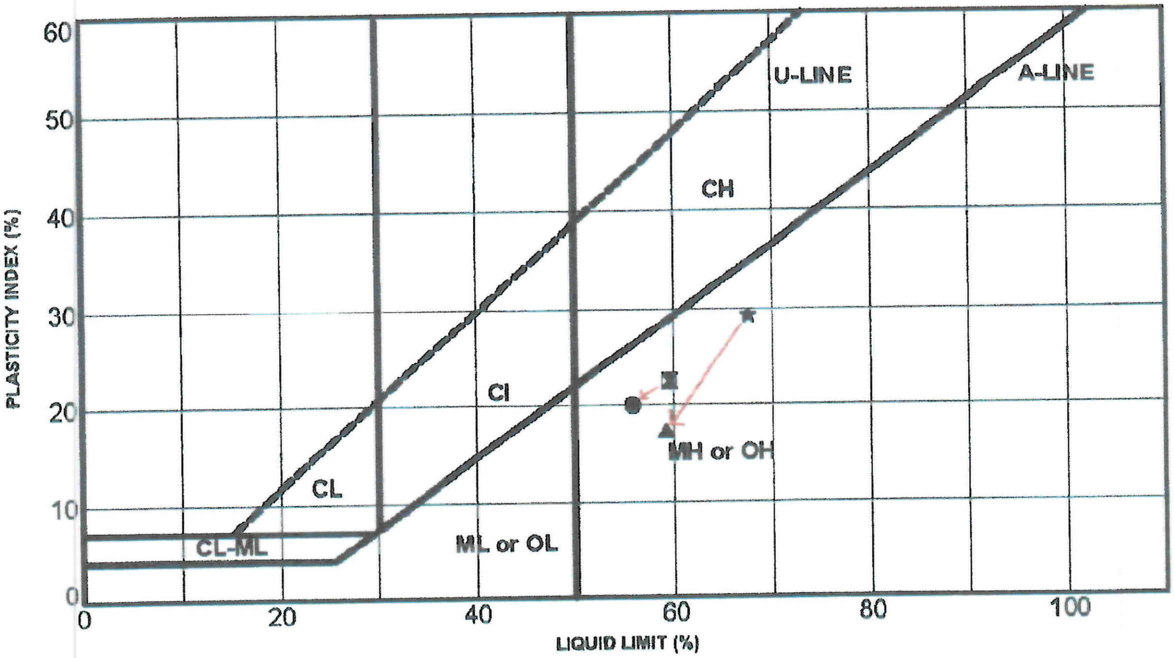
PROJECT:

LOCATION: Brazil

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

PLASTICITY CHART



	HOLE	SAMPLE	DEPTH (m)	W_L	W_P	PI	% FINES	REMARKS/SAMPLE DESCRIPTION
●	BH-01	01	3.5	56	36	20	73.0	Air Dried
⊠	BH-01	01	3.5	60	37	22	67.9	Natural
▲	BH-01	02	4.5	59	42	17	80.1	Air Dried
★	BH-01	02	4.5	68	38	29	82.6	Natural

KC_ATTERBERG SI A03355A01 BZT19072.GPJ SIEVE.GDT 19-10-4

PROJECT NO.: A03355A01

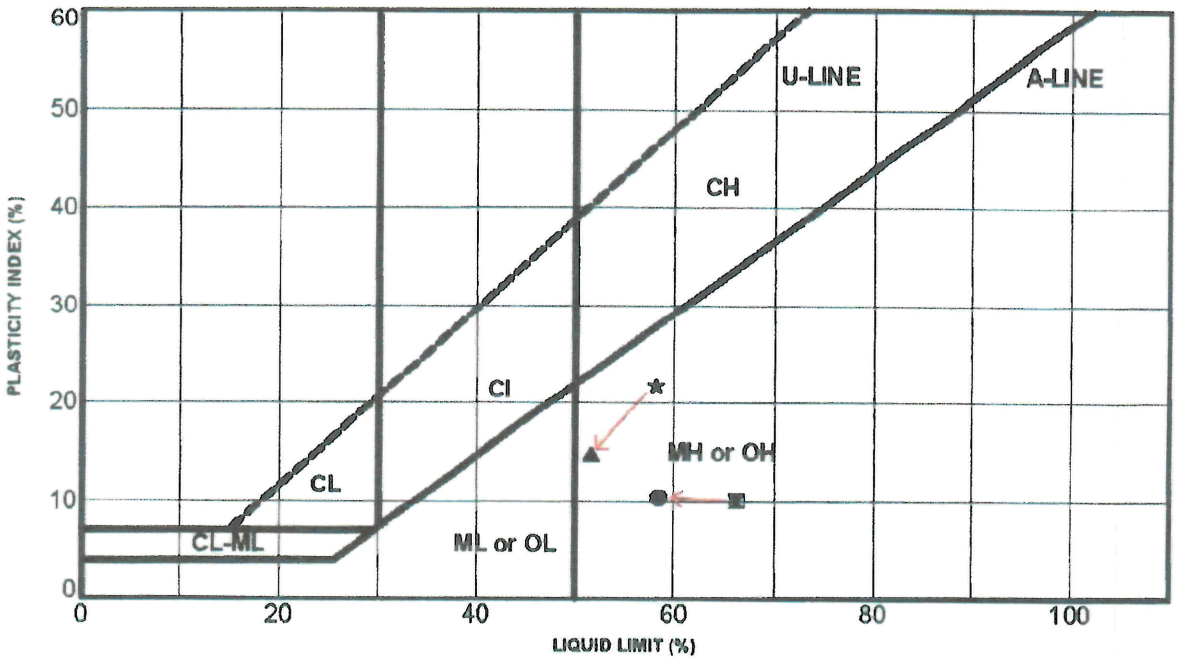
PROJECT:

LOCATION: Brazil

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

PLASTICITY CHART



	HOLE	SAMPLE	DEPTH (m)	W_L	W_P	PI	% FINES	REMARKS/SAMPLE DESCRIPTION
●	BH-02	01	3.5	58	48	10	76.8	Air Dried
☒	BH-02	01	3.5	66	56	10	71.2	Natural
▲	BH-02	02	4.5	52	37	15	63.8	Air Dried
★	BH-02	02	4.5	58	36	22	53.3	Natural

PROJECT NO.: A03355A01

PROJECT:

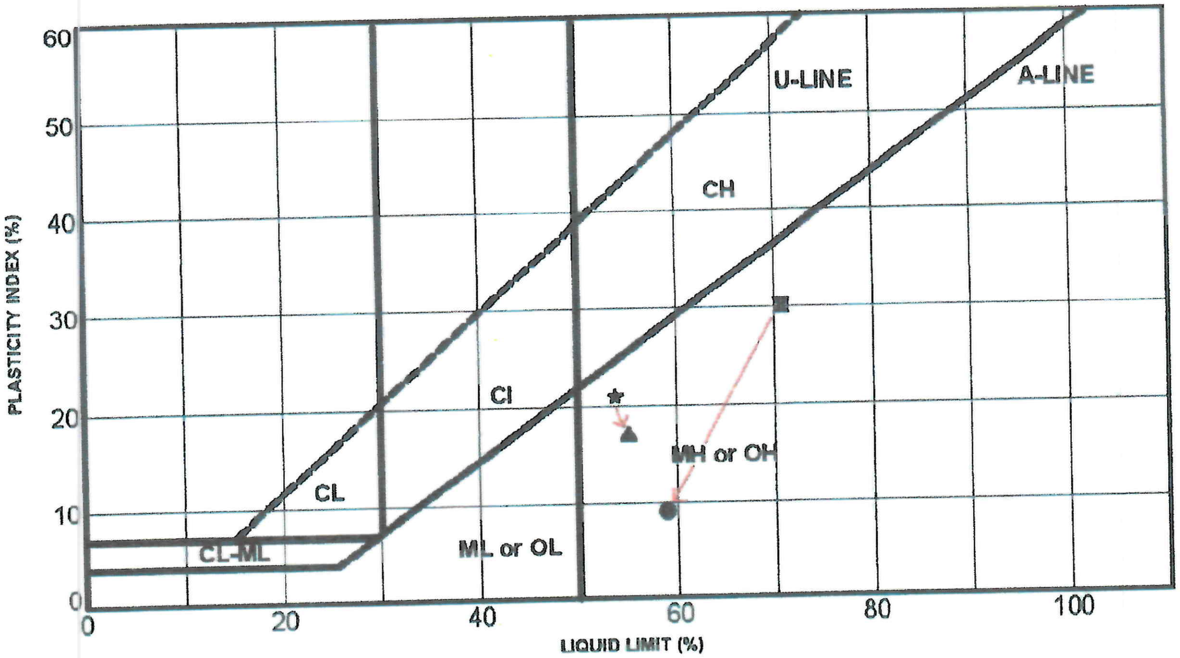
LOCATION: Brazil

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

KC_ATTERBERG-SI A03355A01 BZ T19072.GPJ SIEVE.GDT 19-10-4

PLASTICITY CHART



	HOLE	SAMPLE	DEPTH (m)	W_L	W_P	PI	% FINES	REMARKS/SAMPLE DESCRIPTION
●	BH-04	01	3.0	59	50	9	72.8	Air Dried
⊠	BH-04	01	3.0	71	41	30	73.2	Natural
▲	BH-04	02	5.3	55	38	17	74.3	Air Dried
★	BH-04	02	5.3	54	33	21	74.1	Natural

KC_ATTERBERG-SI A03355A01 BZ T19072.GPJ SIEVE.GDT 19/10/4

PROJECT NO.: A03355A01

PROJECT:

LOCATION: Brazil

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

Appendix E

Annex 4 – X-Ray Diffraction Report

December 2019

University of British Columbia X-Ray Diffraction Report

QUANTITATIVE PHASE ANALYSIS OF 4 POWDER SAMPLES USING THE RIETVELD METHOD AND X-RAY POWDER DIFFRACTION DATA

Project: A03355A01

Klohn Crippen Berger
#500 – 2955 Virtual Way
Vancouver, BC V5M 4X6

Jacob Kabel, B.Sc.
Elisabetta Pani, Ph.D.
Edith Czech, M.Sc.
Jenny Lai, B.Sc.
Lan Kato, B.A.

Dept. of Earth, Ocean & Atmospheric Sciences
The University of British Columbia
6339 Stores Road
Vancouver, BC V6T 1Z4

July 18, 2019

EXPERIMENTAL METHOD

The samples of **Project A03355A01** were reduced to the optimum grain-size range for quantitative X-ray analysis (<10 μm) by grinding under ethanol in a vibratory McCrone Micronizing Mill for 10 minutes. Continuous-scan X-ray powder-diffraction data were collected over a range 3-80°2θ with CoKα radiation on a Bruker D8 Advance Bragg-Brentano diffractometer equipped with an Fe filter foil, 0.6 mm (0.3°) divergence slit, incident- and diffracted-beam Soller slits and a LynxEye-XE detector. The long fine-focus Co X-ray tube was operated at 35 kV and 40 mA, using a take-off angle of 6°.

RESULTS

The X-ray diffractograms were analyzed using the International Centre for Diffraction Database PDF-4 using Search-Match software by Bruker. X-ray powder-diffraction data of the samples were refined with Rietveld program Topas 4.2 (Bruker AXS). The results of quantitative phase analysis by Rietveld refinements are given in Table 1. These amounts represent the relative amounts of crystalline phases normalized to 100%. The Rietveld refinement plots are shown in Figures 1-4.

Table 1. Results of quantitative phase analysis (wt.%) – Project A03355A01

Mineral	**Ideal Formula**	**#1** **Sample 1 Bag2 X-Ray**	**#2** **Sample 1 Bag4 X-Ray**	**#3** **Sample 3 Bag2 X-Ray**	**#4** **Sample 5 Bag1 X-Ray**
Hematite	$\alpha\text{-}Fe_2O_3$	50.1	44.4	87.7	86.8
Goethite	$\alpha\text{-}Fe^{3+}O(OH)$	32.0	34.0	3.4	3.0
Magnetite	Fe_3O_4	0.4	0.4	6.5	7.6
Quartz	SiO_2	5.4	6.6	1.6	1.5
Kaolinite	$Al_2Si_2O_5(OH)_4$	6.2	8.9	0.6	0.6
Talc	$Mg_3Si_4O_{10}(OH)_2$	2.7	2.3		
Gibbsite	$Al(OH)_3$	0.9	1.0	0.3	0.4
Bayerite	$Al(OH)_3$	2.2	2.4		
Total		100.0	100.0	100.0	100.0

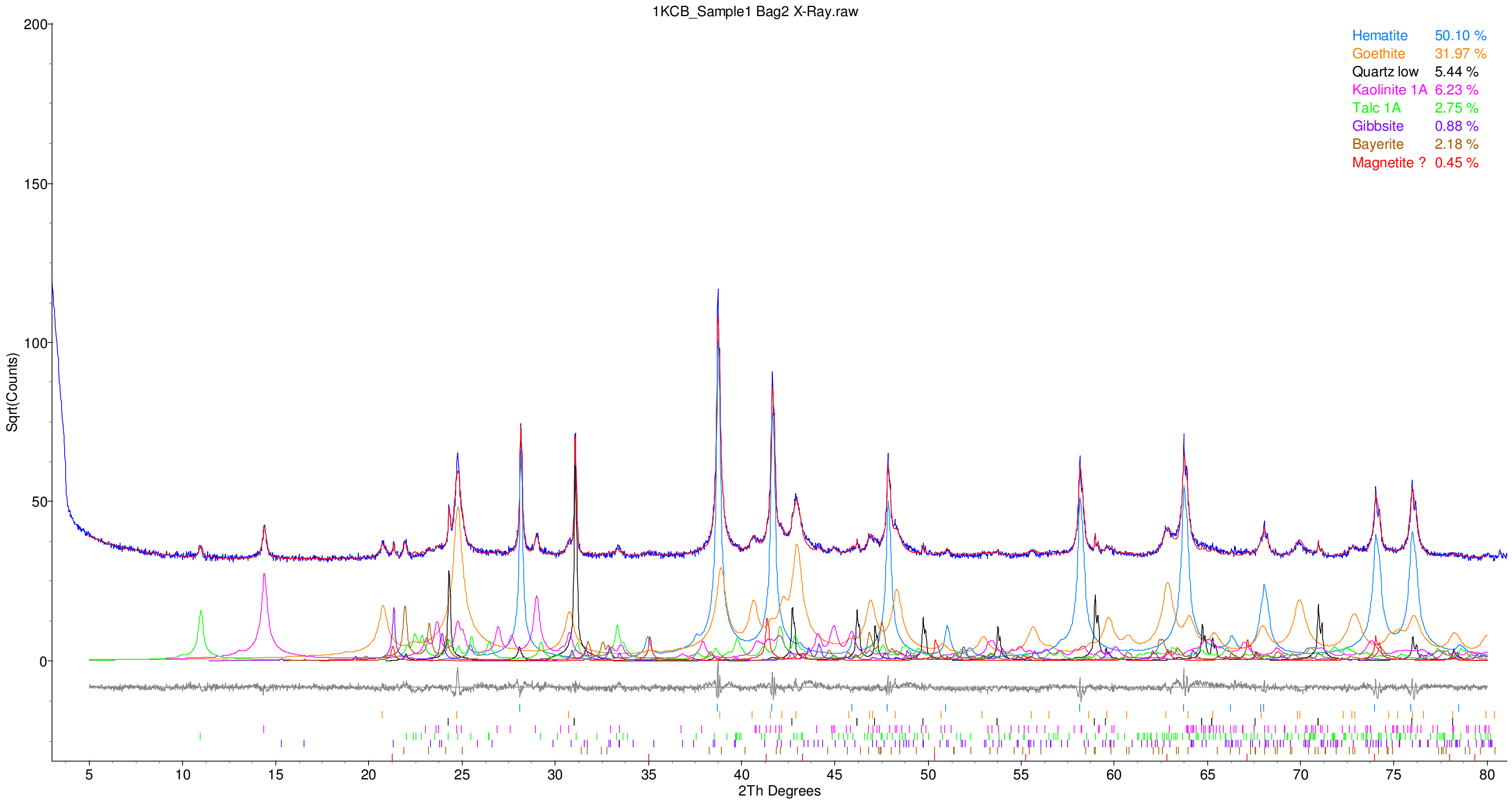


Figure 1. Rietveld refinement plot of **Sample 1 Bag2 X-Ray** (blue line - observed intensity at each step; red line - calculated pattern; solid grey line below - difference between observed and calculated intensities; vertical bars - positions of all Bragg reflections). Coloured lines are individual diffraction patterns of all phases.

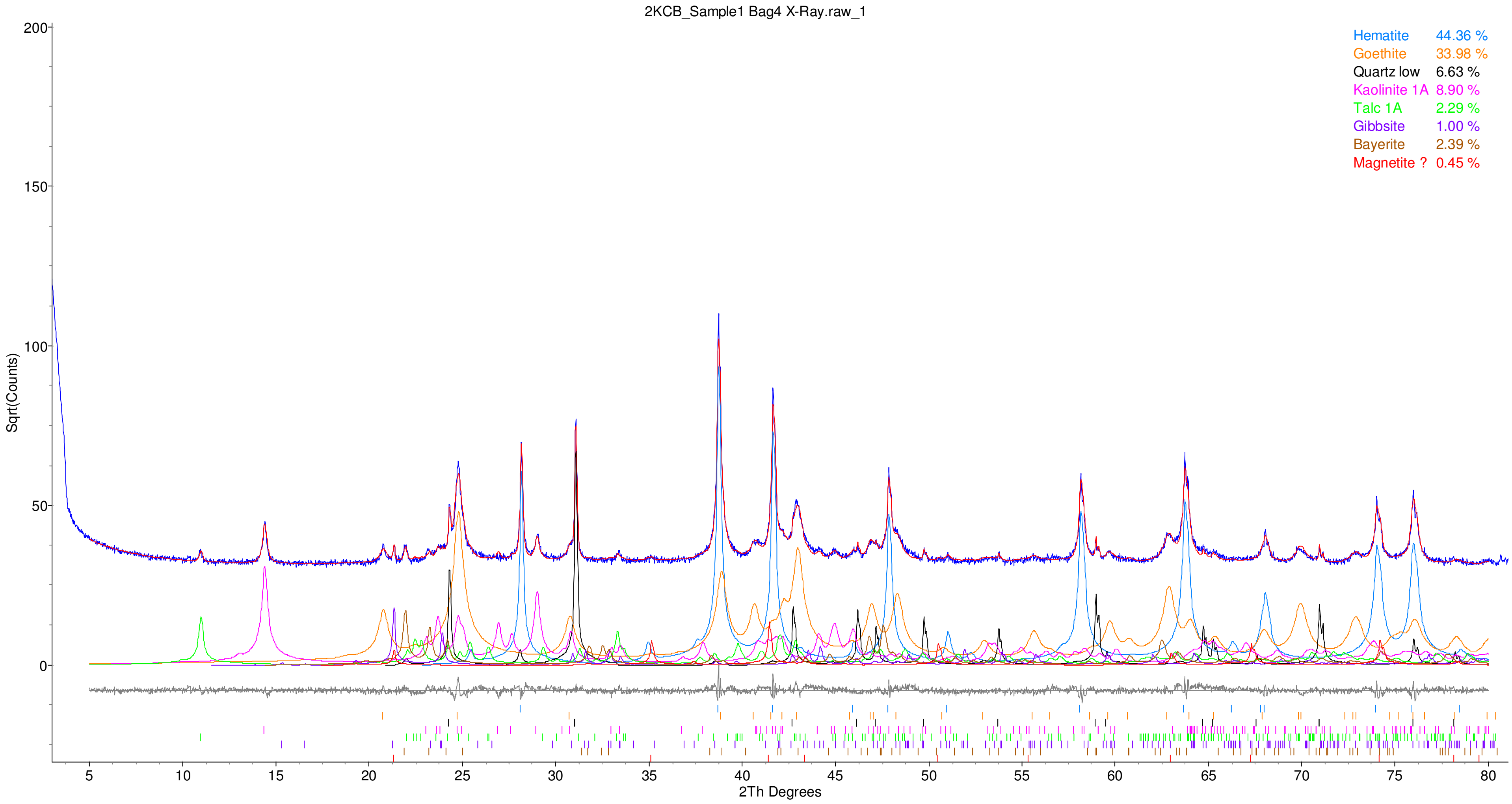


Figure 2. Rietveld refinement plot of **Sample 1 Bag4 X-Ray** (blue line - observed intensity at each step; red line - calculated pattern; solid grey line below - difference between observed and calculated intensities; vertical bars - positions of all Bragg reflections). Coloured lines are individual diffraction patterns of all phases.

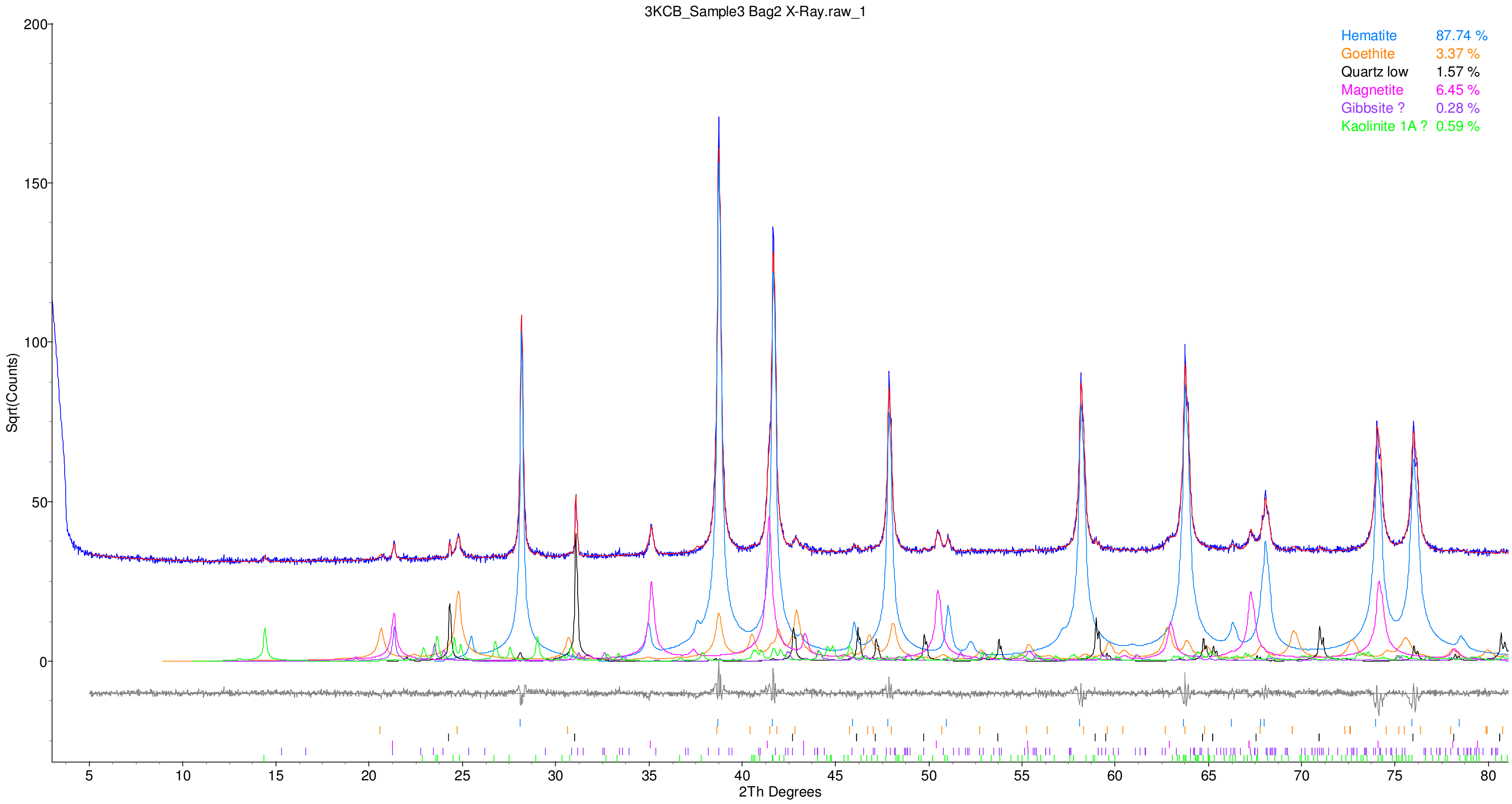


Figure 3. Rietveld refinement plot of **Sample 3 Bag2 X-Ray** (blue line - observed intensity at each step; red line - calculated pattern; solid grey line below - difference between observed and calculated intensities; vertical bars - positions of all Bragg reflections). Coloured lines are individual diffraction patterns of all phases.

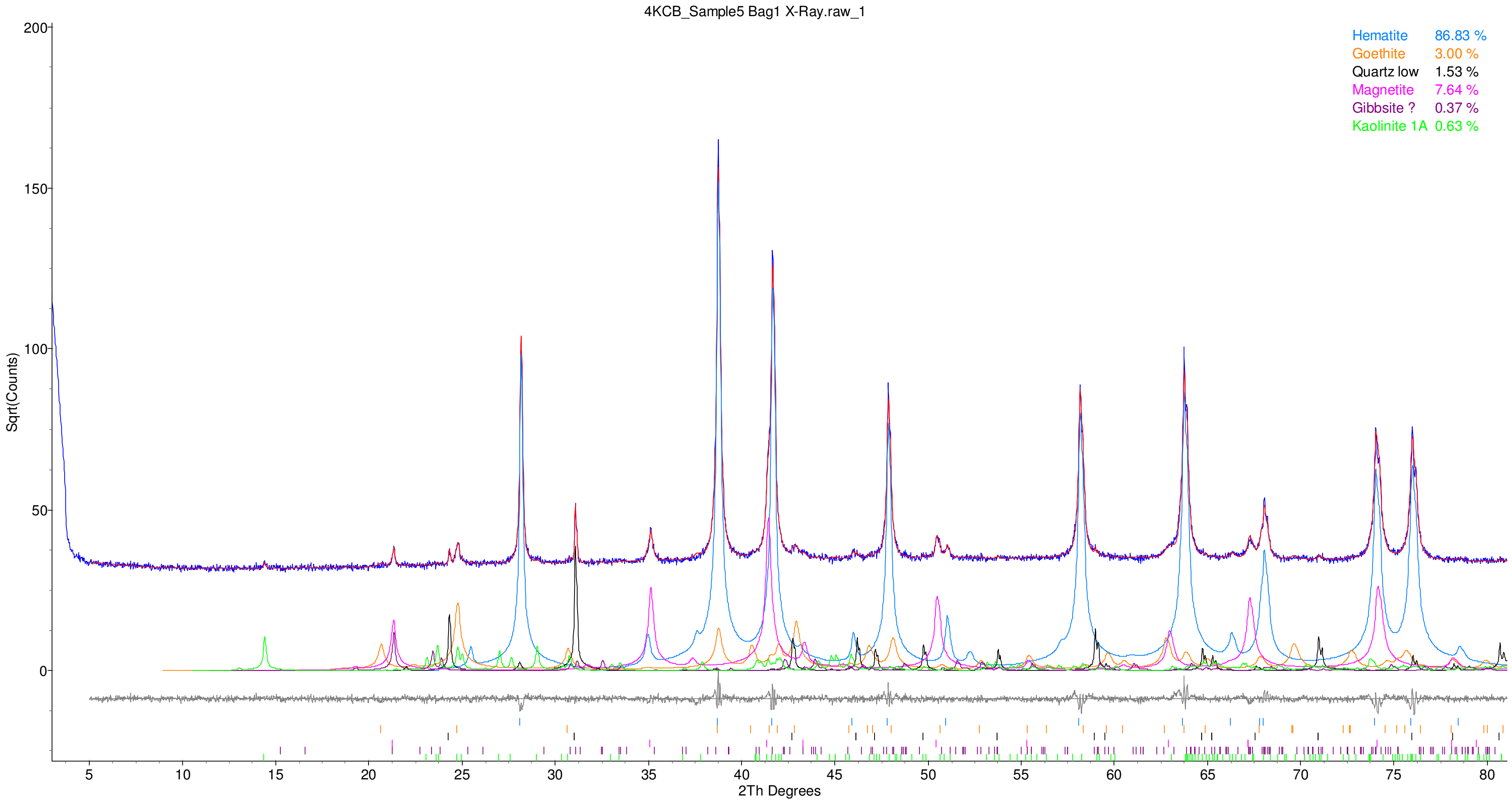
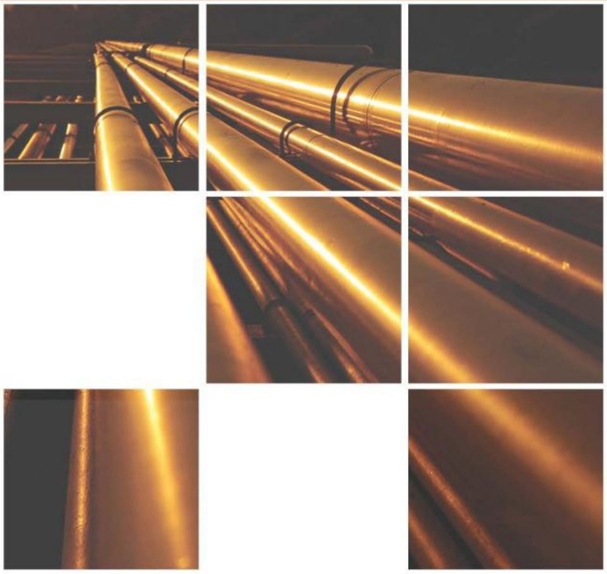


Figure 4. Rietveld refinement plot of **Sample 5 Bag1 X-Ray** (blue line - observed intensity at each step; red line - calculated pattern; solid grey line below - difference between observed and calculated intensities; vertical bars - positions of all Bragg reflections). Coloured lines are individual diffraction patterns of all phases.

University of Alberta X-Ray Diffraction Report

BULK X-RAY DIFFRACTION (XRD) ANALYSIS USING RIETVELD METHOD OF FOUR SAMPLES



Company: **UNIVERSITY OF ALBERTA**

Work Order No: 19A20079

Date: October, 2019

AGAT Geology Department
3801 – 21st Street N.E.
Calgary, Alberta T2E 6T5

AGAT Laboratories

BULK XRD ANALYSIS USING RIETVELD METHOD

Introduction: Four samples identified as '**BT-01, DT-02, DT-06, and DT-10**' were received by the AGAT Laboratories Geology Department for bulk X-Ray Diffraction (XRD) analysis using Rietveld Method.

Sample Preparation: Each sample was homogenized carefully considering nature of materials and a subsample (~ 100 grams) was crushed with a vibratory disc mill (RS200; Retsch) to reduce the size of materials. The crushed subsample was homogenized again and approximately 3 grams was taken for micronizing using a planetary ball mill.

X-Ray Data Collection and Analysis:

Diffractometer Name:	XPERT PRO X-RAY DIFFRACTOMETER
Instrumental Parameters:	Radiation Source – Copper (Cu)
	Generator settings - 40 mA, 45 kV
	Start position [°2θ] - 4
	End position [°2θ] - 80
	Step size [°2θ] - 0.03
	Scan step time [s] – 0.5
Data Analysis:	ICDD PDF-4 Mineral 2019 powder diffraction database
	X'PERT HighScore for mineral identification
	TOPAS for quantitative phase analysis (QPA) using Rietveld Method
Detection Limit:	0.5 – 1.0 % depending on the type and nature of sample

Quantitative Phase Analysis: Using HighScore program, the different mineral phases of the XRD patterns were identified. Once the mineral phases were identified, Rietveld refinements were performed by importing the trace pattern into TOPAS 5. This program (TOPAS 5) is used for Rietveld analysis to quantify the mineralogy. Four refined diffractograms are attached with this report as appendix. The quantitative mineral phases of four samples are given in the Tables 1-4.

Sample 1 – DT-01; Date Sampled- October 08, 2019

Results: The XRD results (**Table 1**) show that this sample consists mainly of oxides (hematite and magnetite) with lesser amounts of hydroxides (goethite, gibbsite, and bayerite), tectosilicate (quartz), and phyllosilicates (kaolinite and talc) minerals.

Table 1: Results of quantitative mineral analysis (relative weight %) of X-ray diffraction data for sample 1 (**DT-01**) using Rietveld method

Mineral Name	**Compound Name**	**Standard Chemical Formula**	**Mineral Concentration, wt.%**
Hematite	Iron oxide	Fe_2O_3	**43.1**
Goethite	Iron oxide hydroxide	FeO(OH)	**20.7**
Quartz	Silicon oxide	SiO_2	**14.9**
Kaolinite	Aluminum silicate hydroxide	$Al_2Si_2O_5(OH)_4$	**11.6**
Talc steatite soapstone	Magnesium silicate hydrate	$Mg_3(Si_4O_{10})(OH)_2$	**3.1**
Gibbsite	Aluminum hydroxide	$Al(OH)_3$	**3.0**
Magnetite	Iron oxide	Fe_3O_4	**1.9**
Bayerite	Aluminum hydroxide	Al(OH)3	**1.7**
		Total:	**100**

Sample 2 – DT-02; Date Sampled- October 08, 2019

Results: The XRD results (**Table 2**) show that this sample consists mainly of oxides (hematite and magnetite) with lesser amounts of hydroxides (goethite, gibbsite, and bayerite), tectosilicate (quartz), and phyllosilicates (kaolinite and talc) minerals.

Table 2: Results of quantitative mineral analysis (relative weight %) of X-ray diffraction data for sample 2 (**DT-02**) using Rietveld method

Mineral Name	Compound Name	Standard Chemical Formula	Mineral Concentration, wt.%
Hematite	Iron oxide	Fe_2O_3	**54.1**
Goethite	Iron oxide hydroxide	FeO(OH)	**15.3**
Quartz	Silicon oxide	SiO_2	**12.0**
Kaolinite	Aluminum silicate hydroxide	$Al_2Si_2O_5(OH)_4$	**10.9**
Gibbsite	Aluminum hydroxide	$Al(OH)_3$	**2.2**
Bayerite	Aluminum hydroxide	Al(OH)3	**2.0**
Talc steatite soapstone	Magnesium silicate hydrate	$Mg_3(Si_4O_{10})(OH)_2$	**2.0**
Magnetite	Iron oxide	Fe_3O_4	**1.5**
		Total:	**100**

Sample 3 – DT-06; Date Sampled- October 08, 2019

Results: The XRD results (**Table 3**) show that this sample consists mainly of oxides (hematite and magnetite) with lesser amounts of tectosilicate (quartz), hydroxides (goethite, gibbsite, and bayerite), and phyllosilicates (kaolinite and talc) minerals.

Table 3: Results of quantitative mineral analysis (relative weight %) of X-ray diffraction data for sample 3 (**DT-06**) using Rietveld method

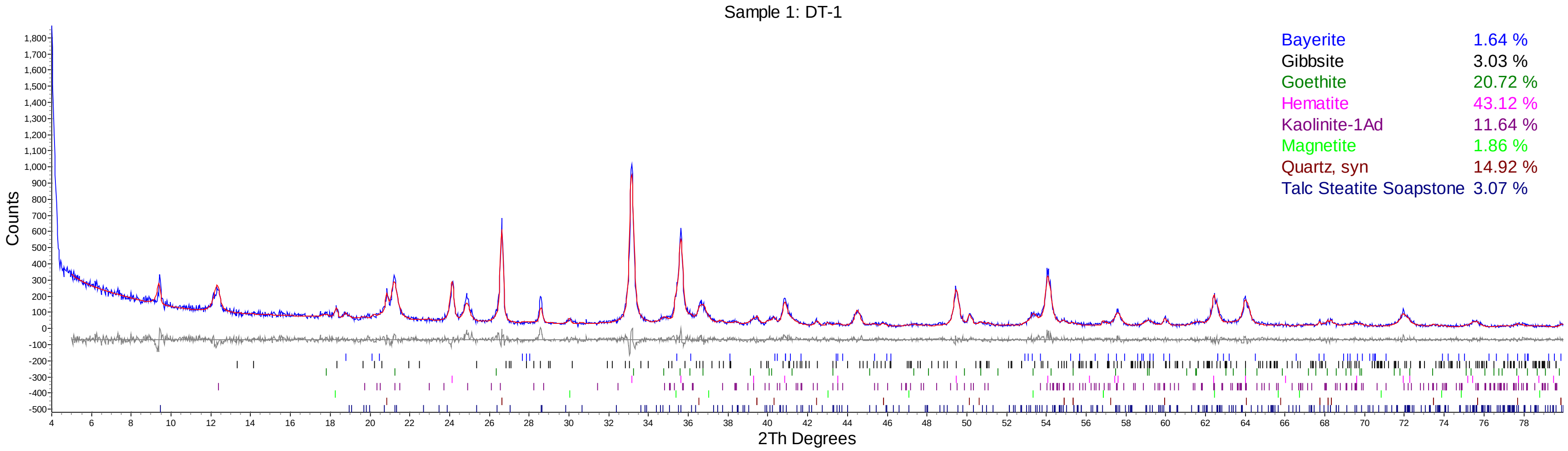
Mineral Name	Compound Name	Standard Chemical Formula	Mineral Concentration, wt.%
Hematite	Iron oxide	Fe_2O_3	**50.3**
Quartz	Silicon oxide	SiO_2	**28.5**
Goethite	Iron oxide hydroxide	FeO(OH)	**10.2**
Kaolinite	Aluminum silicate hydroxide	$Al_2Si_2O_5(OH)_4$	**6.4**
Gibbsite	Aluminum hydroxide	$Al(OH)_3$	**1.4**
Talc steatite soapstone	Magnesium silicate hydrate	$Mg_3(Si_4O_{10})(OH)_2$	**1.4**
Magnetite	Iron oxide	Fe_3O_4	**1.3**
Bayerite	Aluminum hydroxide	Al(OH)3	**0.5**
		Total:	**100**

Sample 4 – DT-10; Date Sampled- October 08, 2019

Results: The XRD results (**Table 4**) show that this sample consists mainly of oxides (hematite and magnetite) with lesser amounts of tectosilicate (quartz), hydroxides (goethite, gibbsite, and bayerite), and phyllosilicates (kaolinite and talc) minerals.

Table 4: Results of quantitative mineral analysis (relative weight %) of X-ray diffraction data for sample 4 (**DT-10**) using Rietveld method

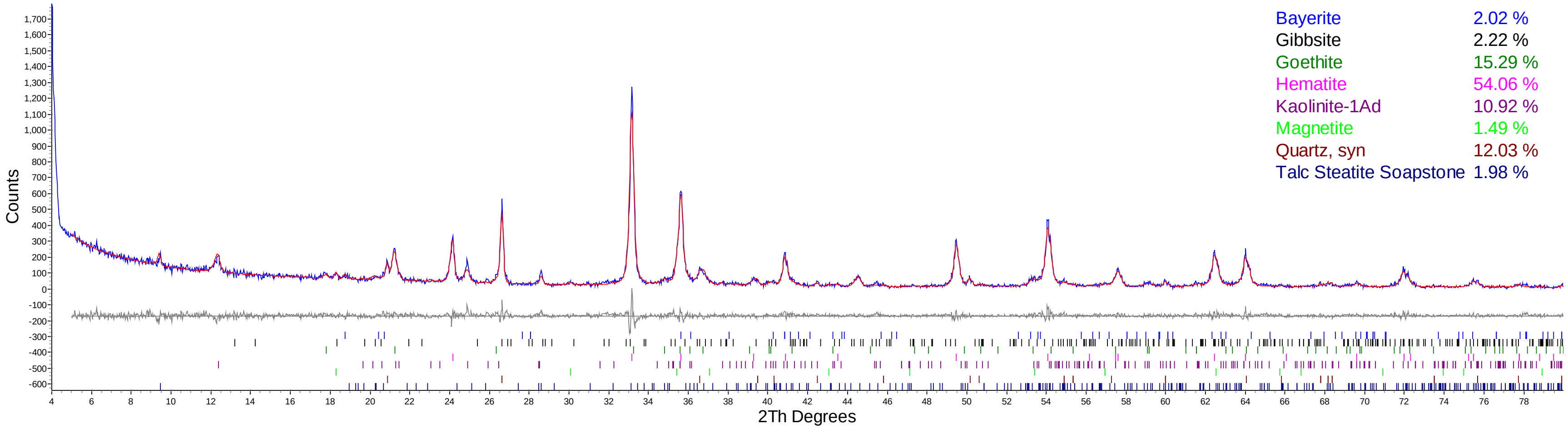
Mineral Name	**Compound Name**	**Standard Chemical Formula**	**Mineral Concentration, wt.%**
Hematite	Iron oxide	Fe_2O_3	**44.3**
Quartz	Silicon oxide	SiO_2	**21.8**
Goethite	Iron oxide hydroxide	FeO(OH)	**13.7**
Kaolinite	Aluminum silicate hydroxide	$Al_2Si_2O_5(OH)_4$	**13.5**
Gibbsite	Aluminum hydroxide	$Al(OH)_3$	**3.0**
Bayerite	Aluminum hydroxide	Al(OH)3	**1.4**
Magnetite	Iron oxide	Fe_3O_4	**1.3**
Talc steatite soapstone	Magnesium silicate hydrate	$Mg_3(Si_4O_{10})(OH)_2$	**1.1**
		Total:	**100**

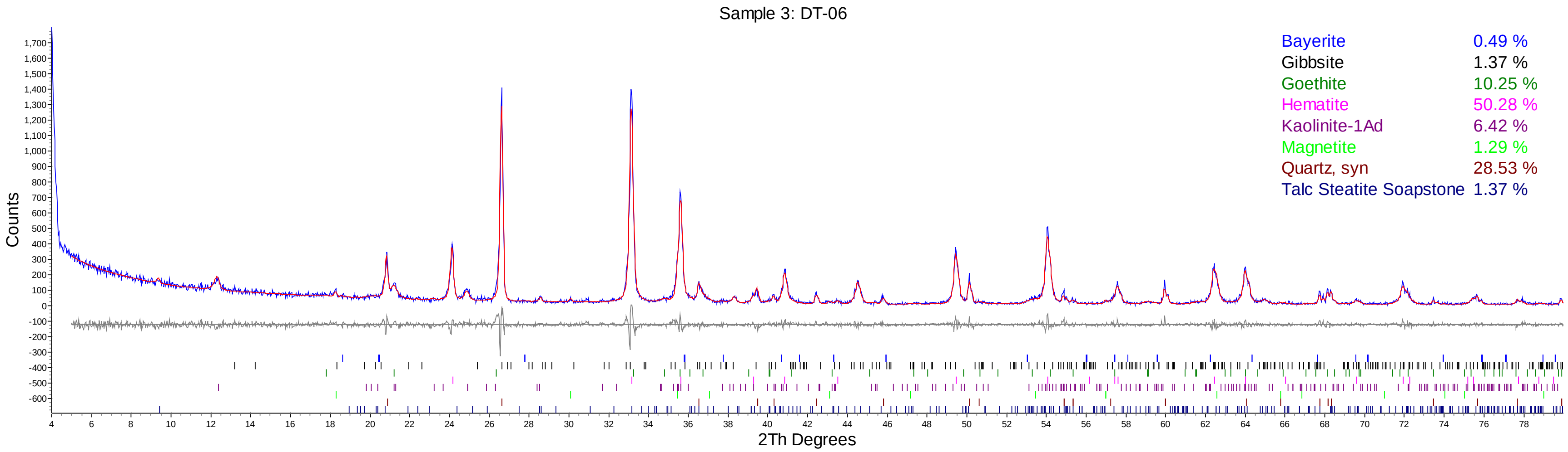


Sample 1: DT-1

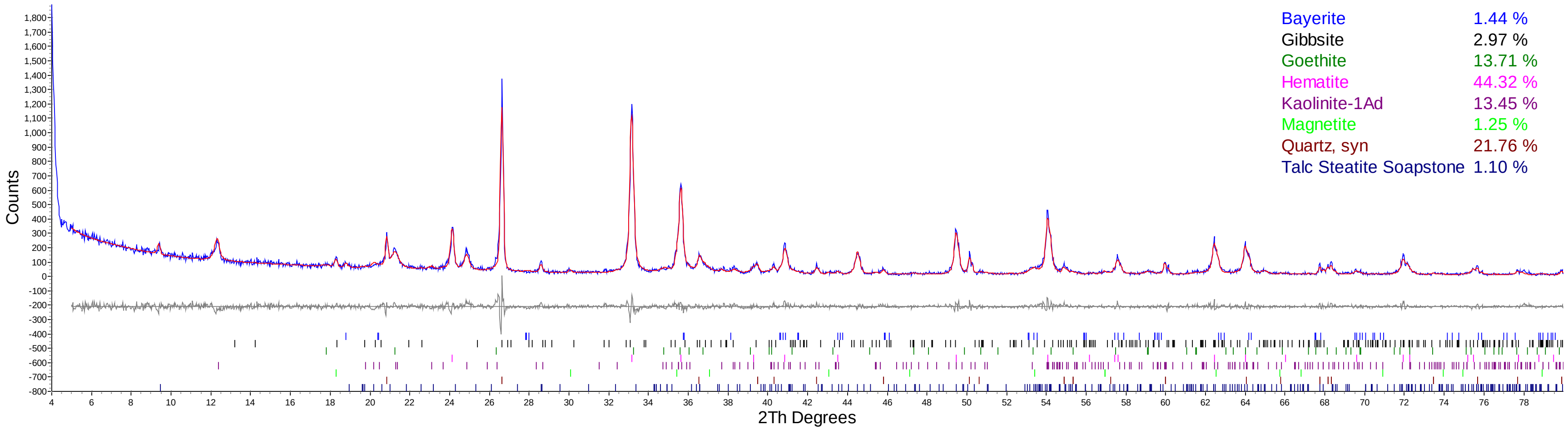
Bayerite 1.64 %
Gibbsite 3.03 %
Goethite 20.72 %
Hematite 43.12 %
Kaolinite-1Ad 11.64 %
Magnetite 1.86 %
Quartz, syn 14.92 %
Talc Steatite Soapstone 3.07 %
Counts
1,800
1,700
1,600
1,500
1,400
1,300
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
52
54
56
58
60
62
64
66
68
70
72
74
76
78
2Th Degrees

Sample 2: DT-02




Sample 3: DT-06
Bayerite 0.49 %
Gibbsite 1.37 %
Goethite 10.25 %
Hematite 50.28 %
Kaolinite-1Ad 6.42 %
Magnetite 1.29 %
Quartz, syn 28.53 %
Talc Steatite Soapstone 1.37 %
Counts
1,700
1,600
1,500
1,400
1,300
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
52
54
56
58
60
62
64
66
68
70
72
74
76
78
2Th Degrees

Sample 4: DT-10

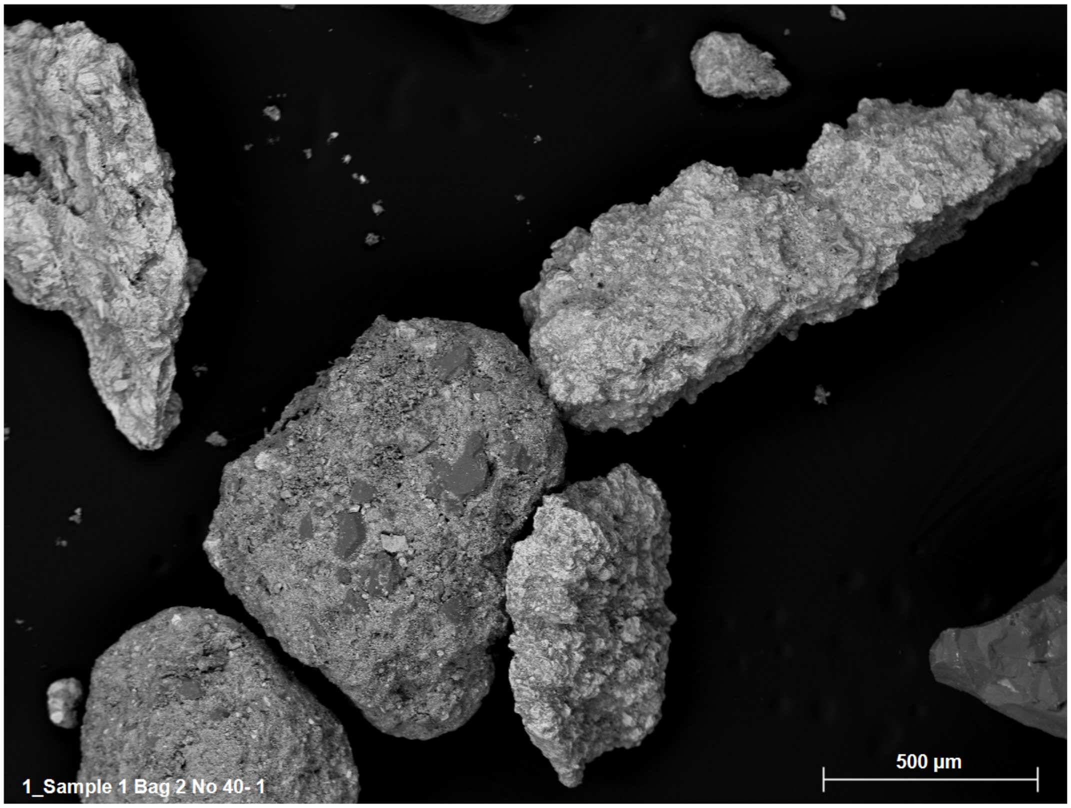


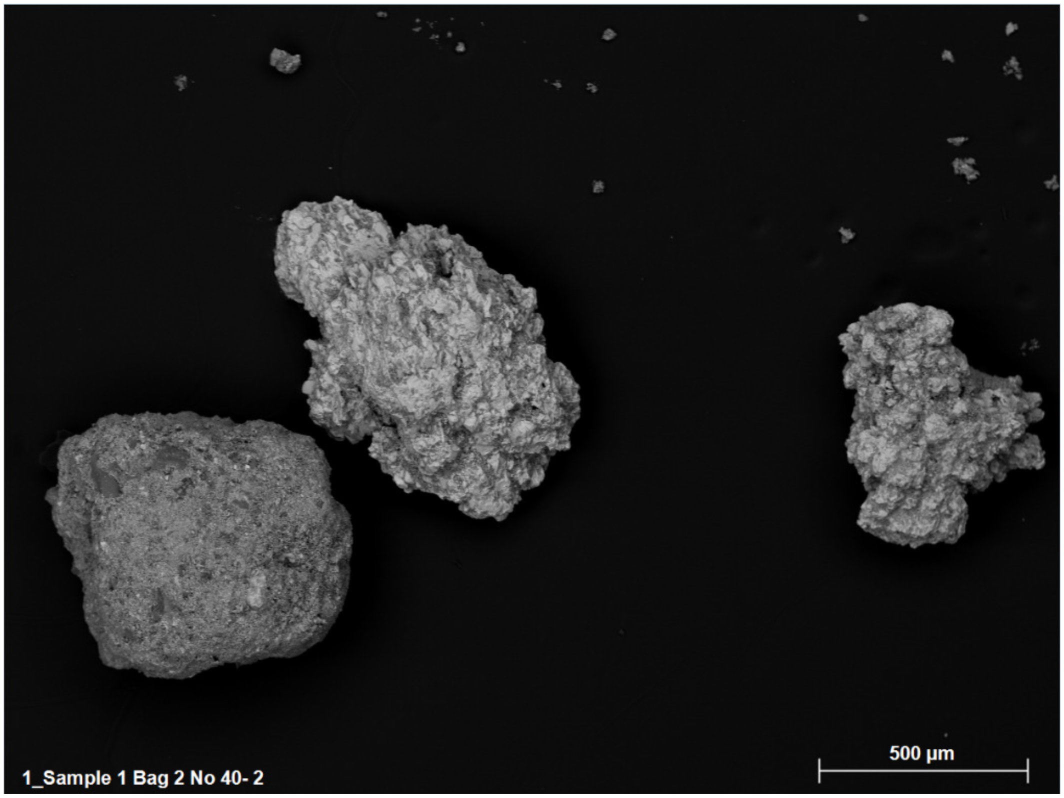
Appendix E

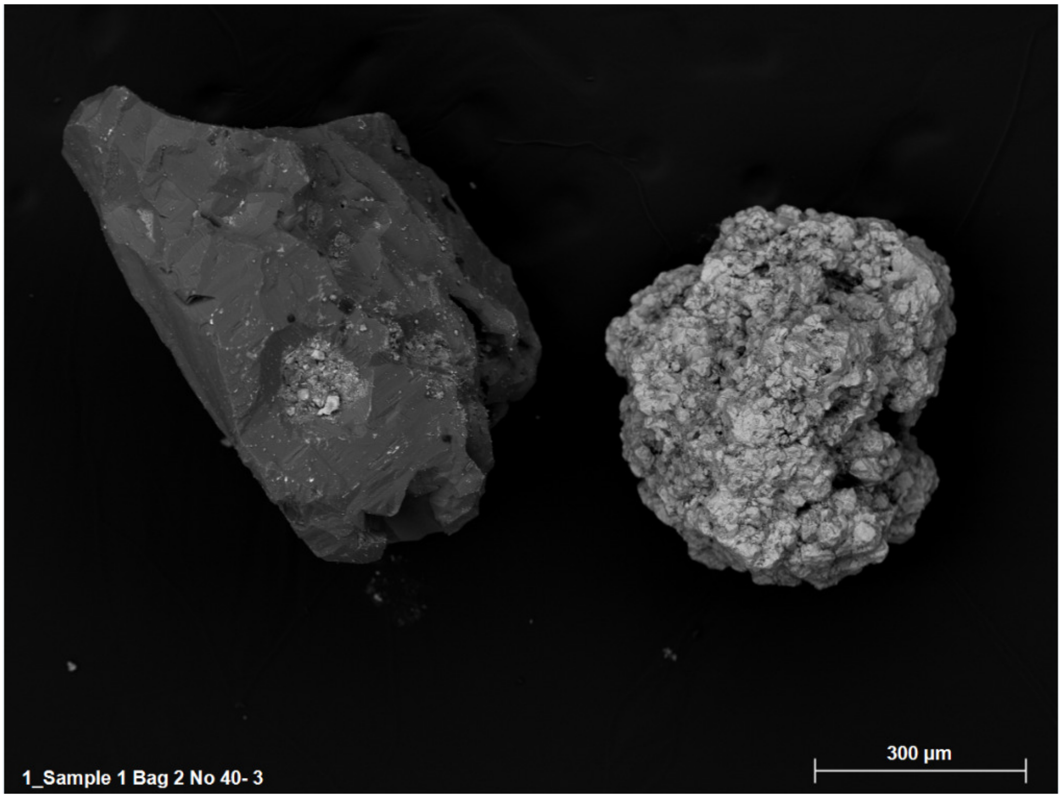
Annex 5 – Scanning Electron Microscopy Images

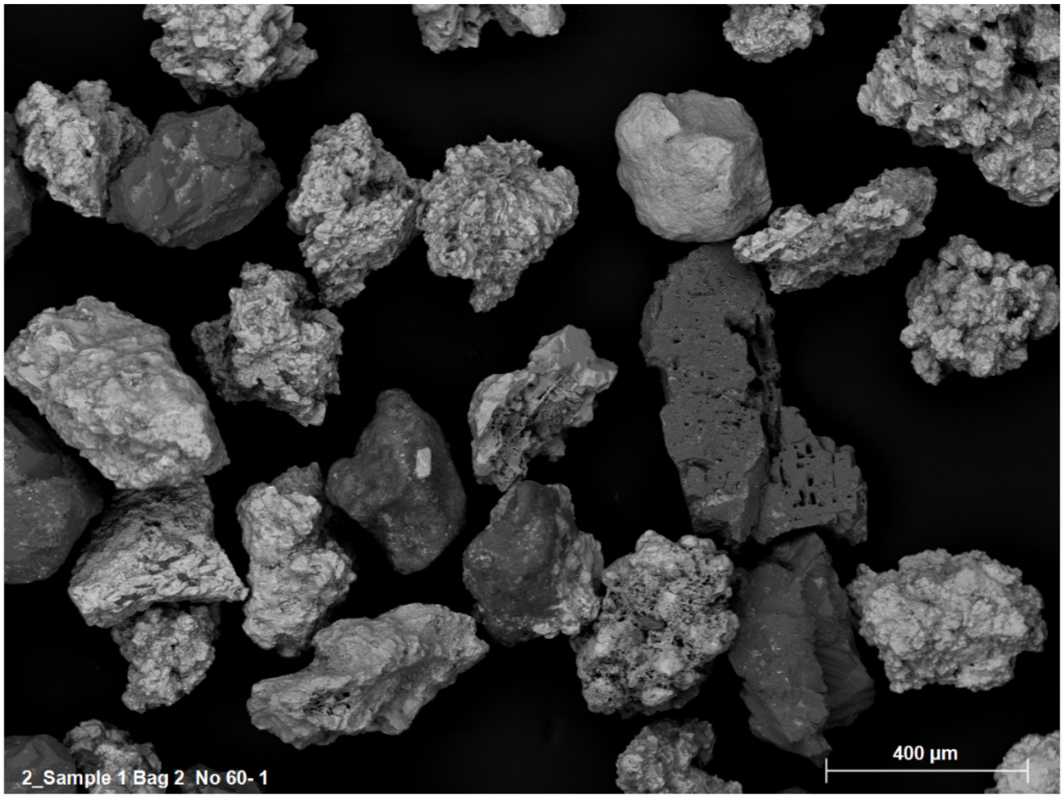
December 2019

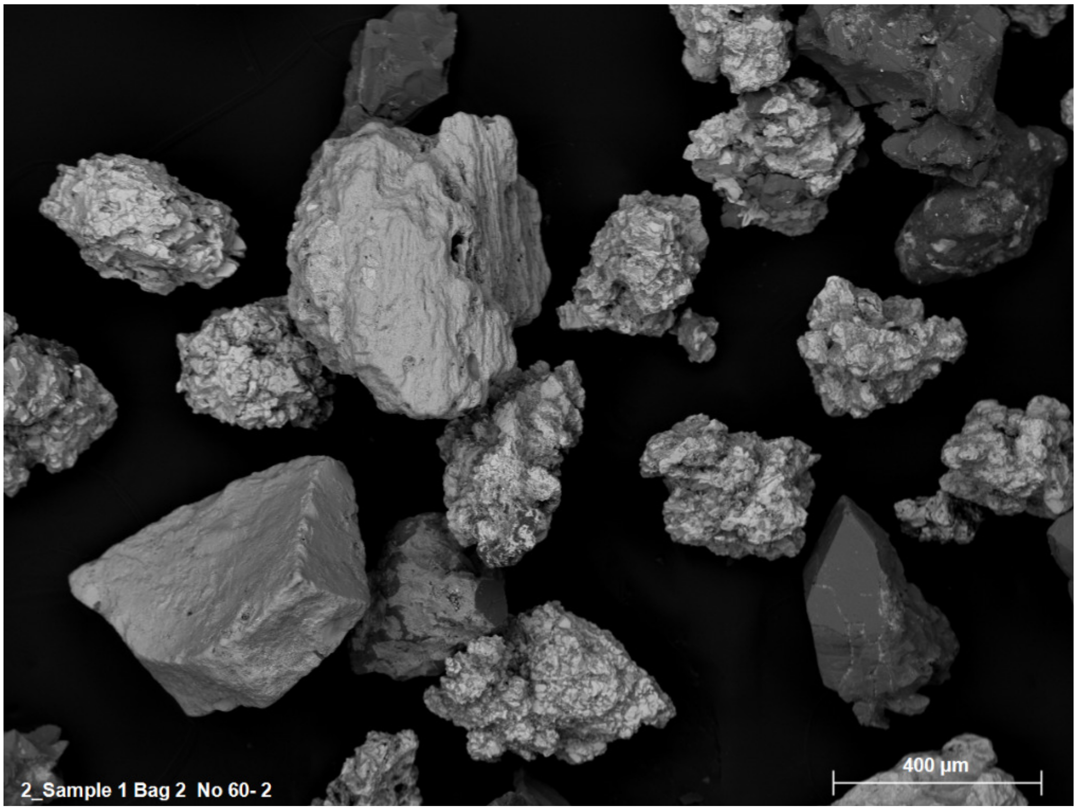
University of British Columbia Scanning Electron Microscope (SEM) Imaging

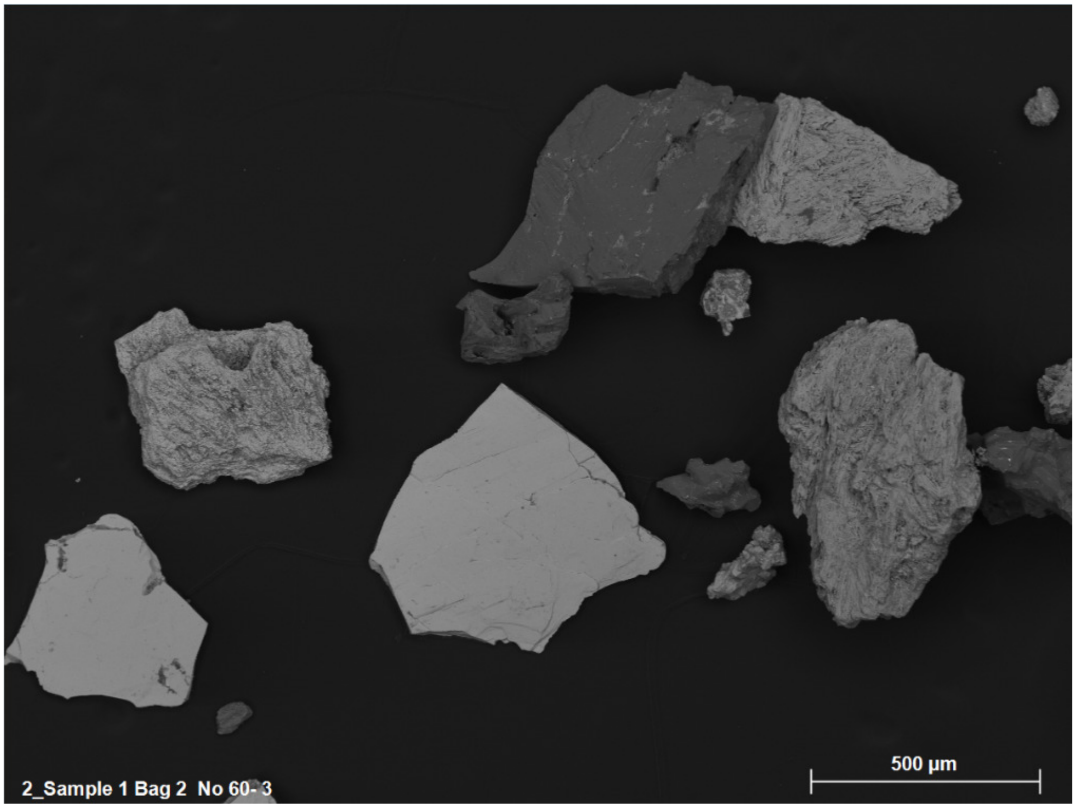

500 µm
1_Sample 1 Bag 2 No 40- 1

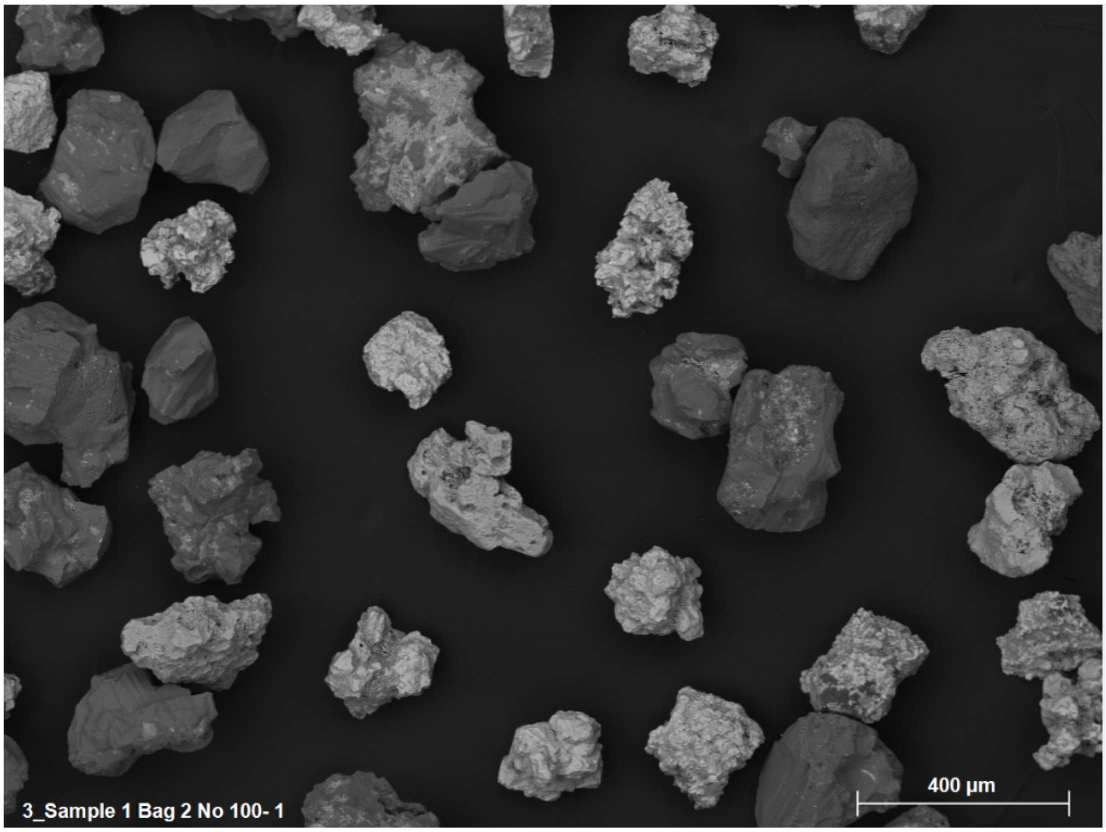

500 µm
1_Sample 1 Bag 2 No 40- 2

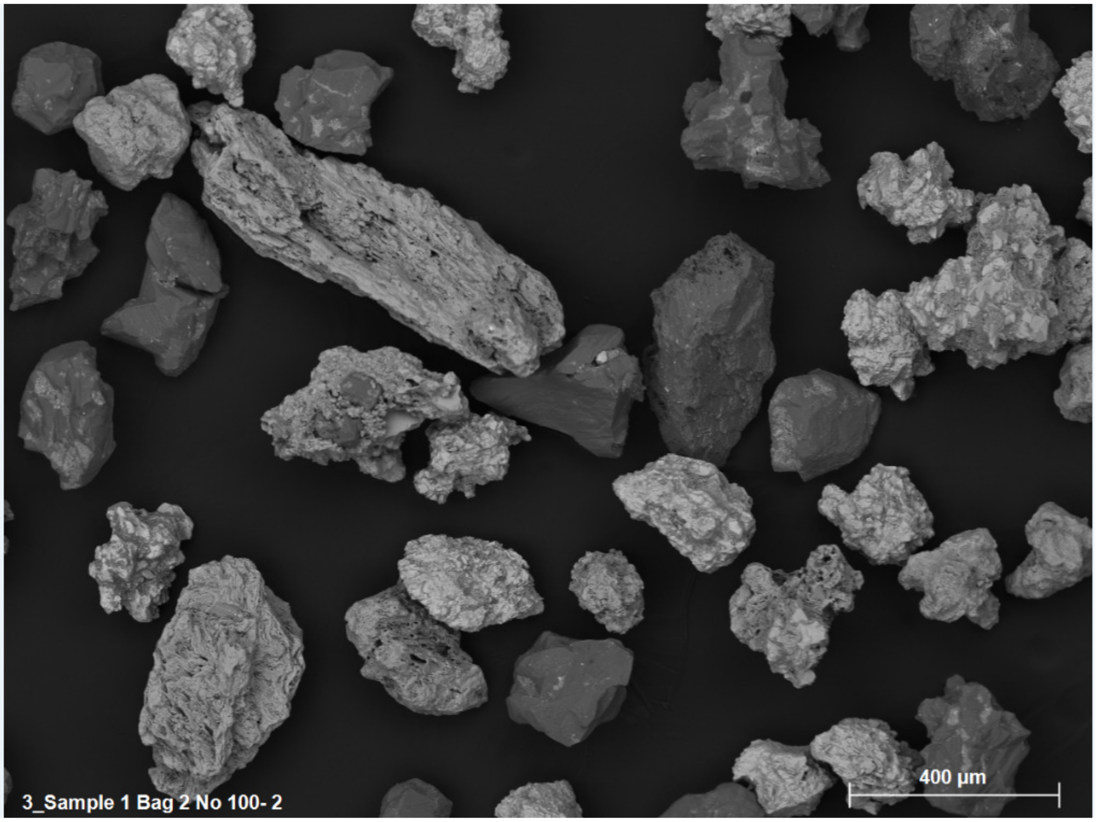

300 µm
1_Sample 1 Bag 2 No 40- 3

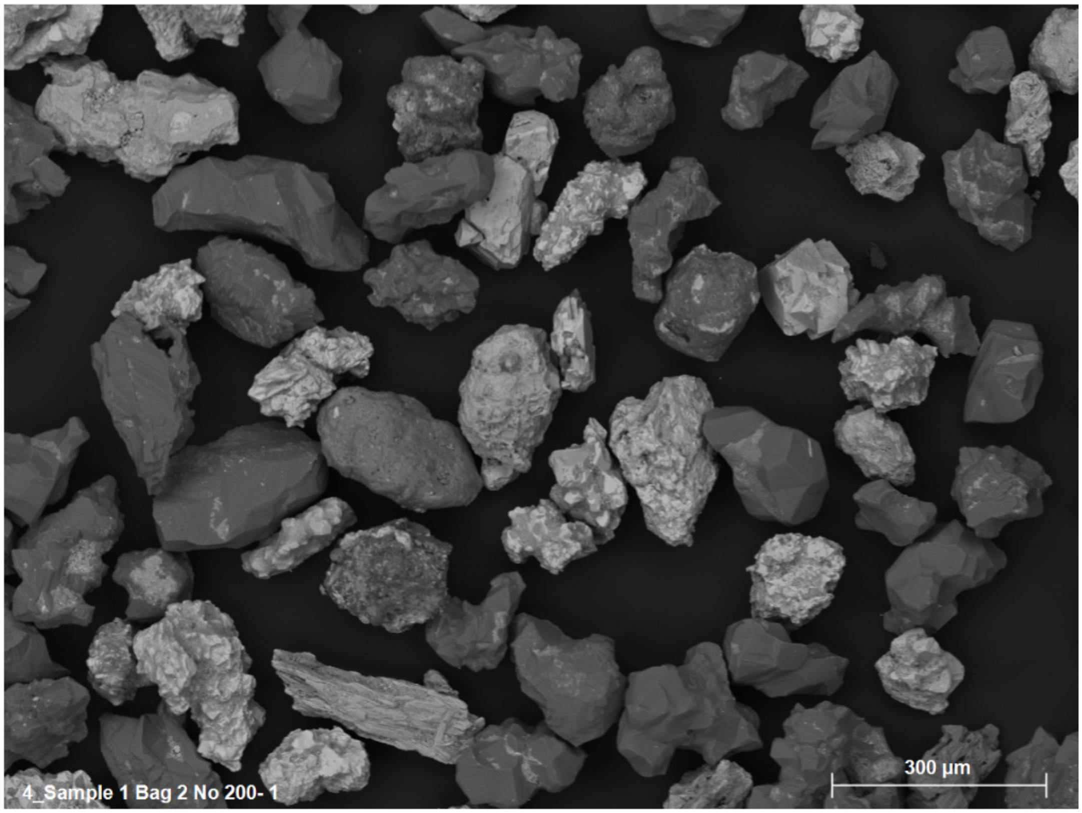

400 µm
2_Sample 1 Bag 2_No 60- 1

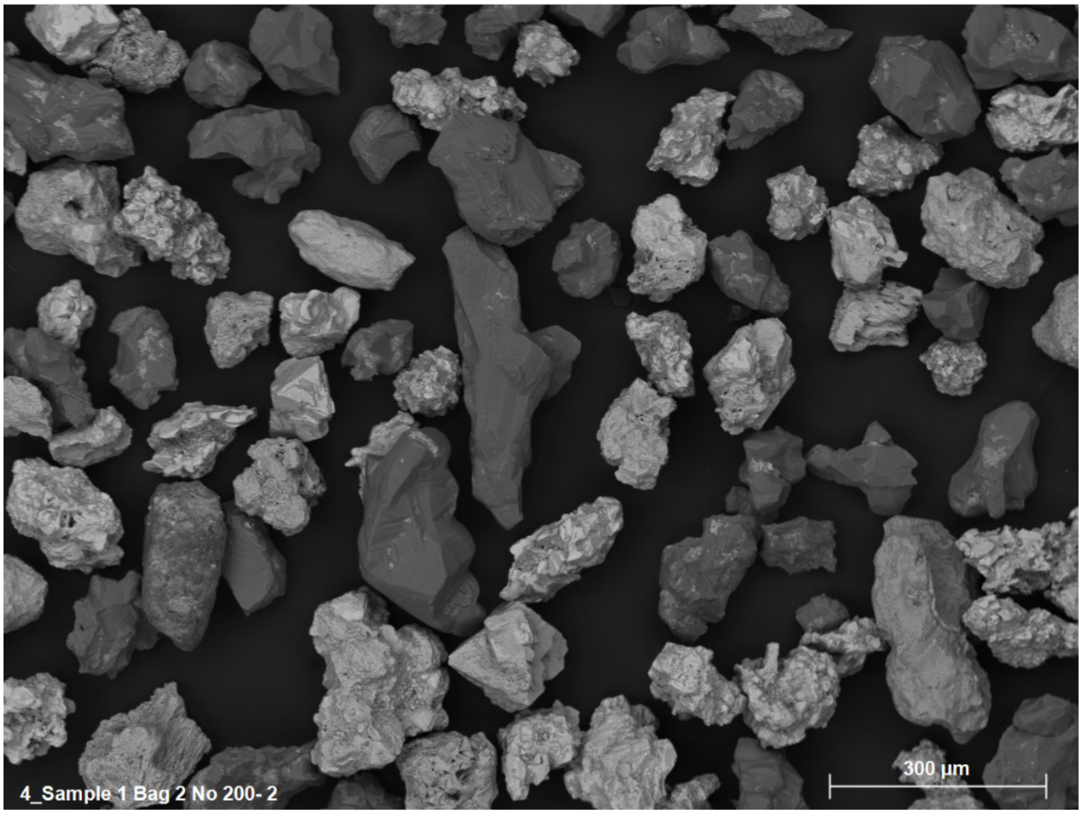

400 µm
2_Sample 1 Bag 2 No 60- 2

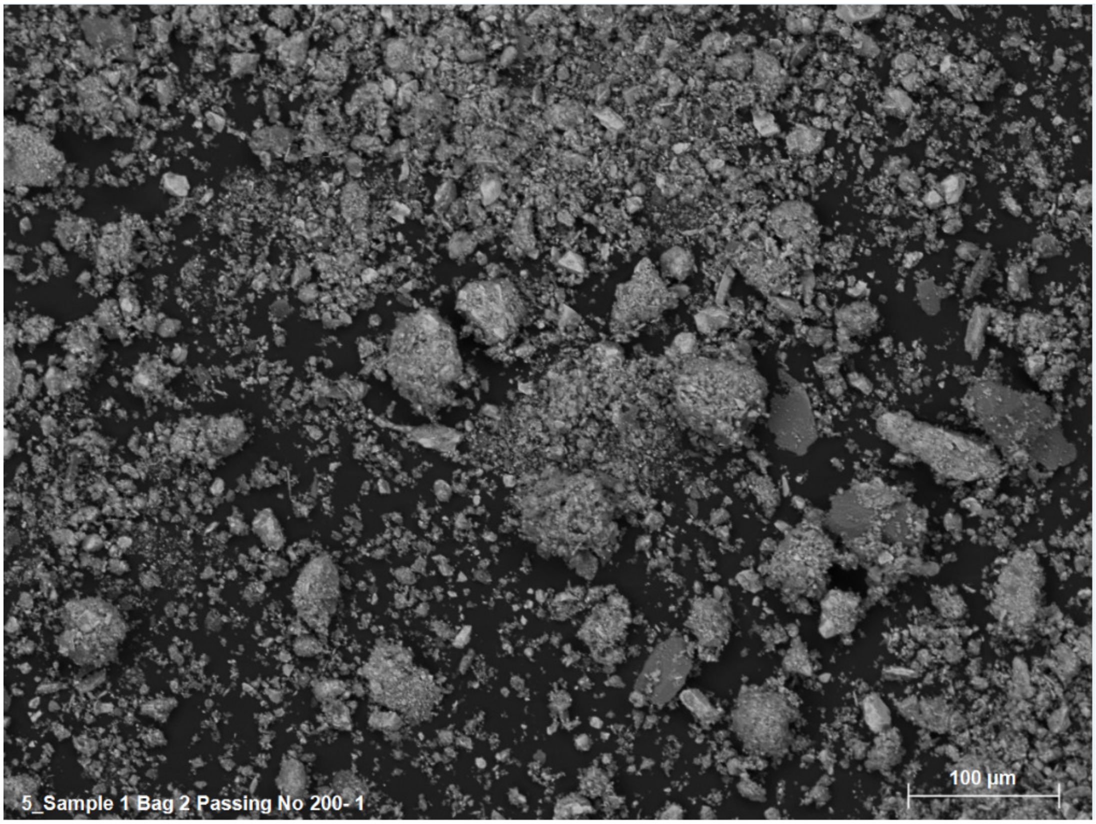

500 µm
2_Sample 1 Bag 2 No 60- 3

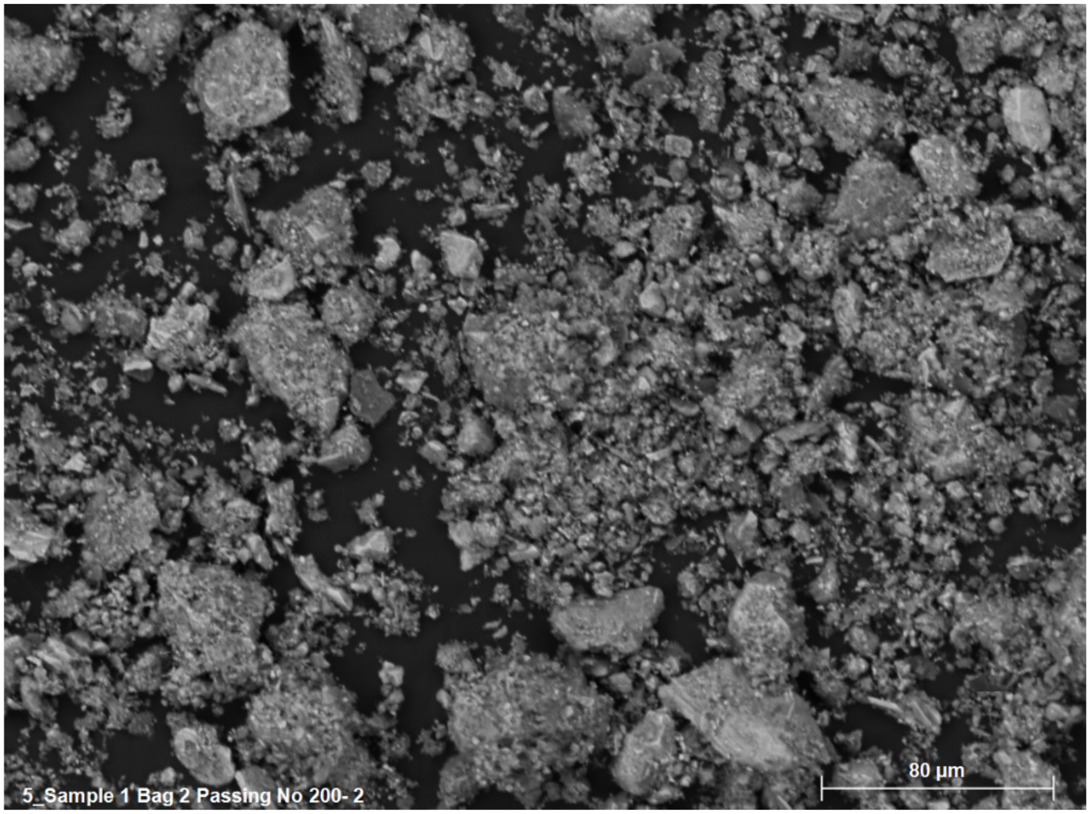

400 µm
3_Sample 1 Bag 2 No 100- 1

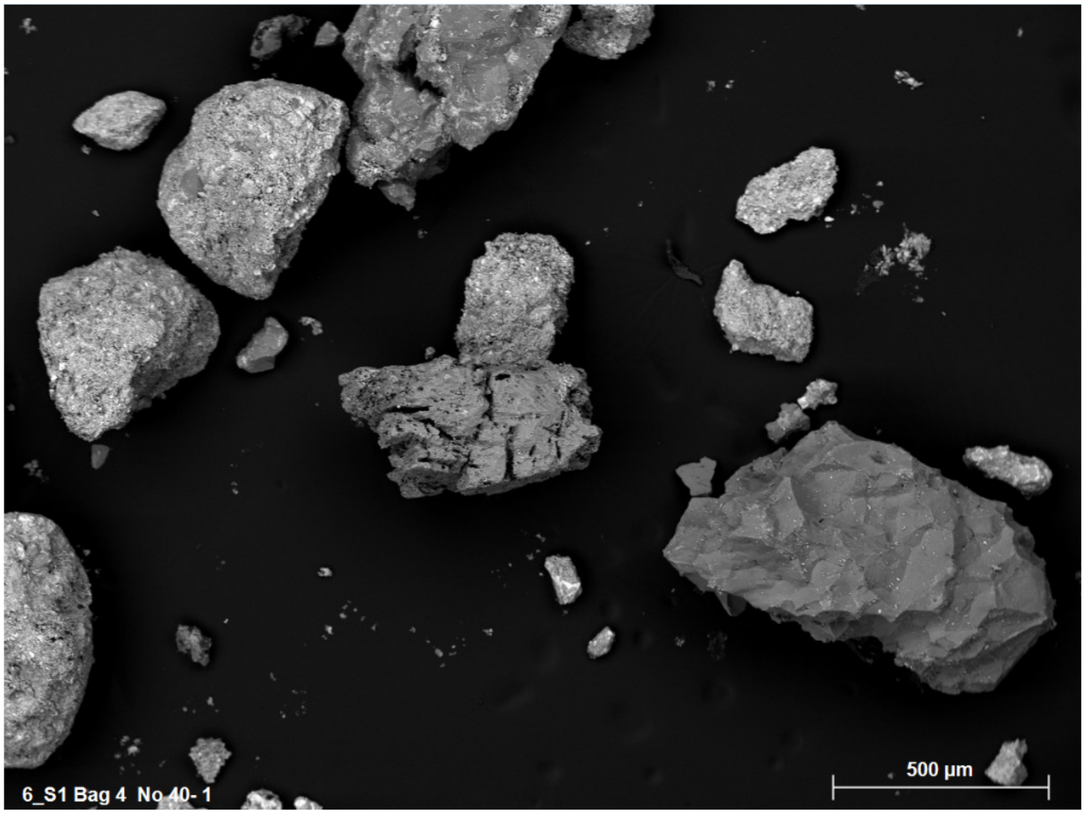

400 µm
3_Sample 1 Bag 2 No 100- 2

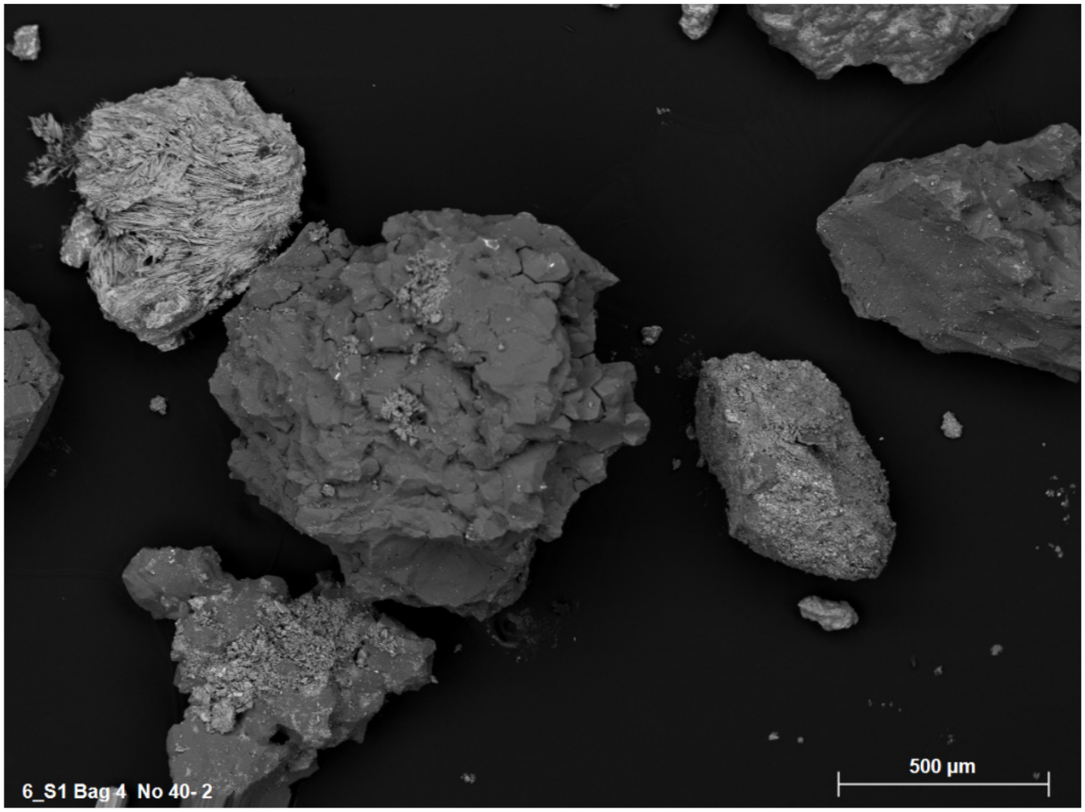

300 µm
4_Sample 1 Bag 2 No 200- 1

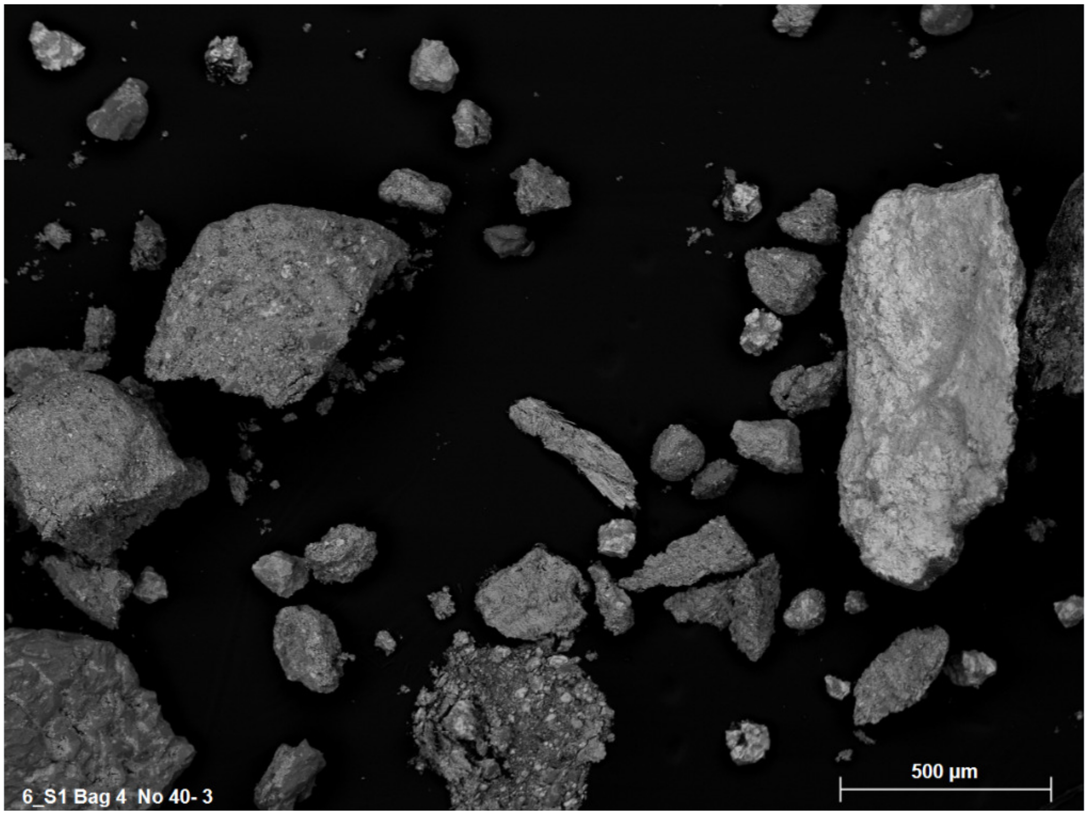

300 µm
4_Sample 1 Bag 2 No 200- 2

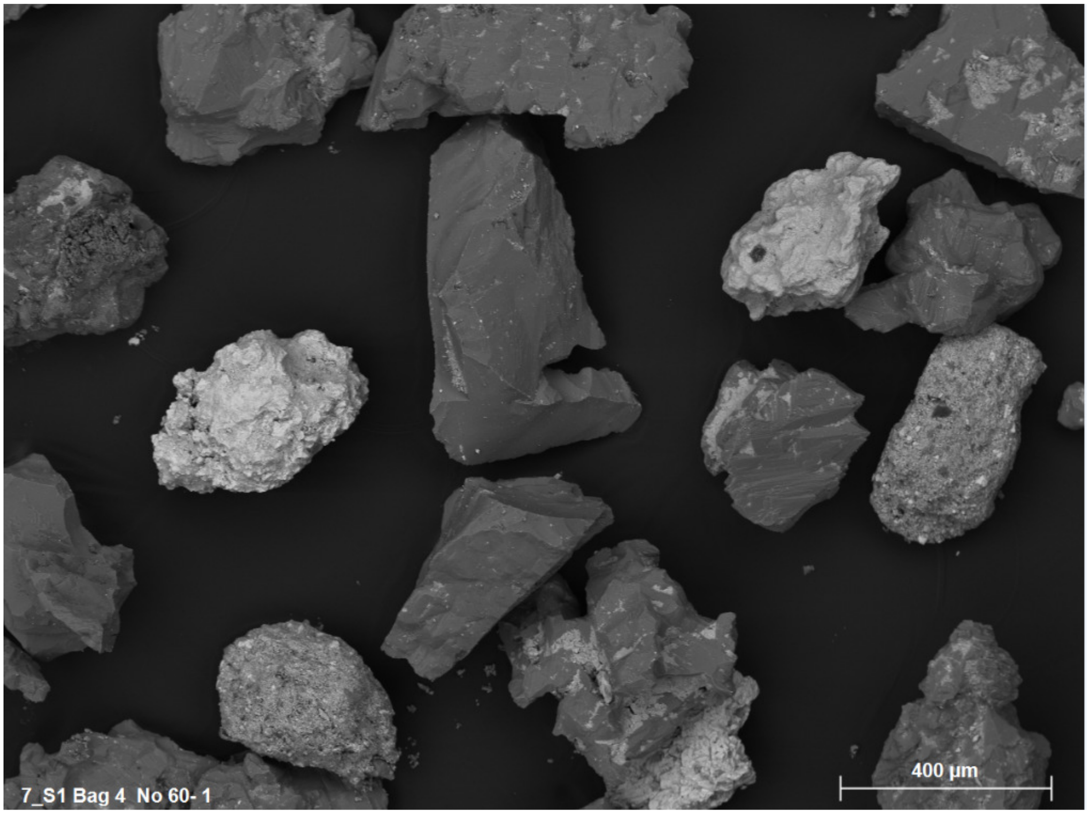

100 µm
5_Sample 1 Bag 2 Passing No 200- 1

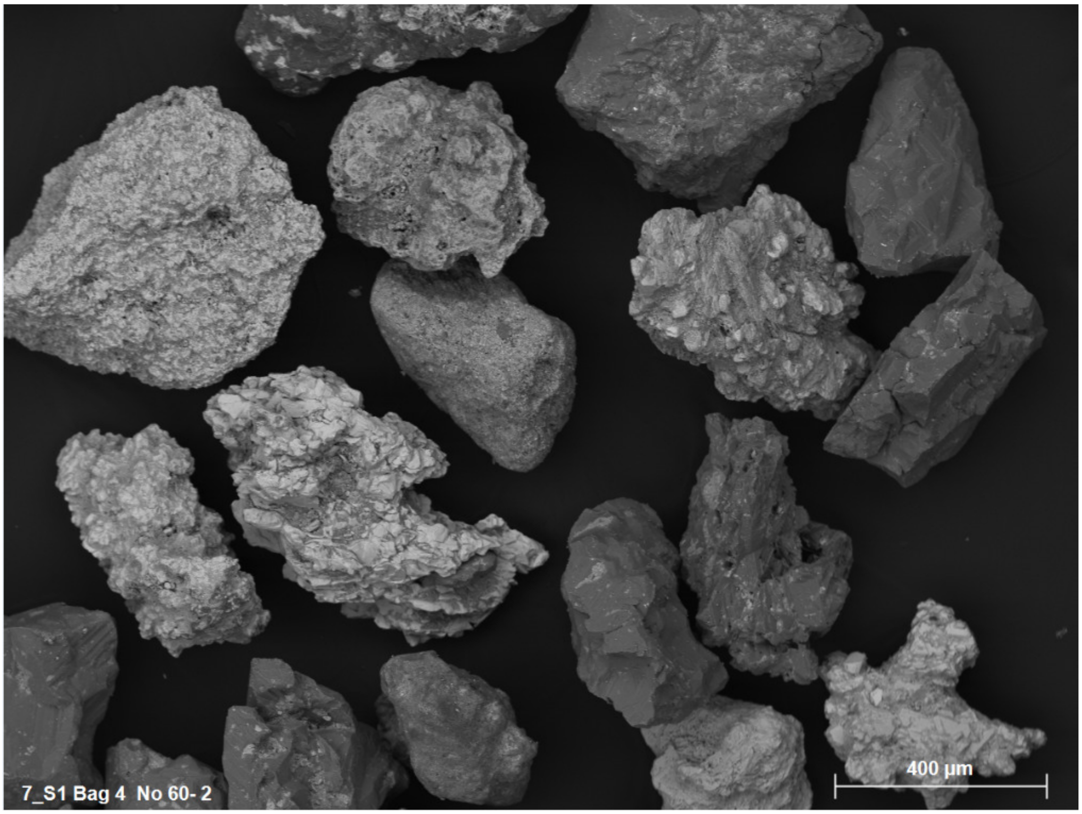

80 µm
5_Sample 1 Bag 2 Passing No 200- 2

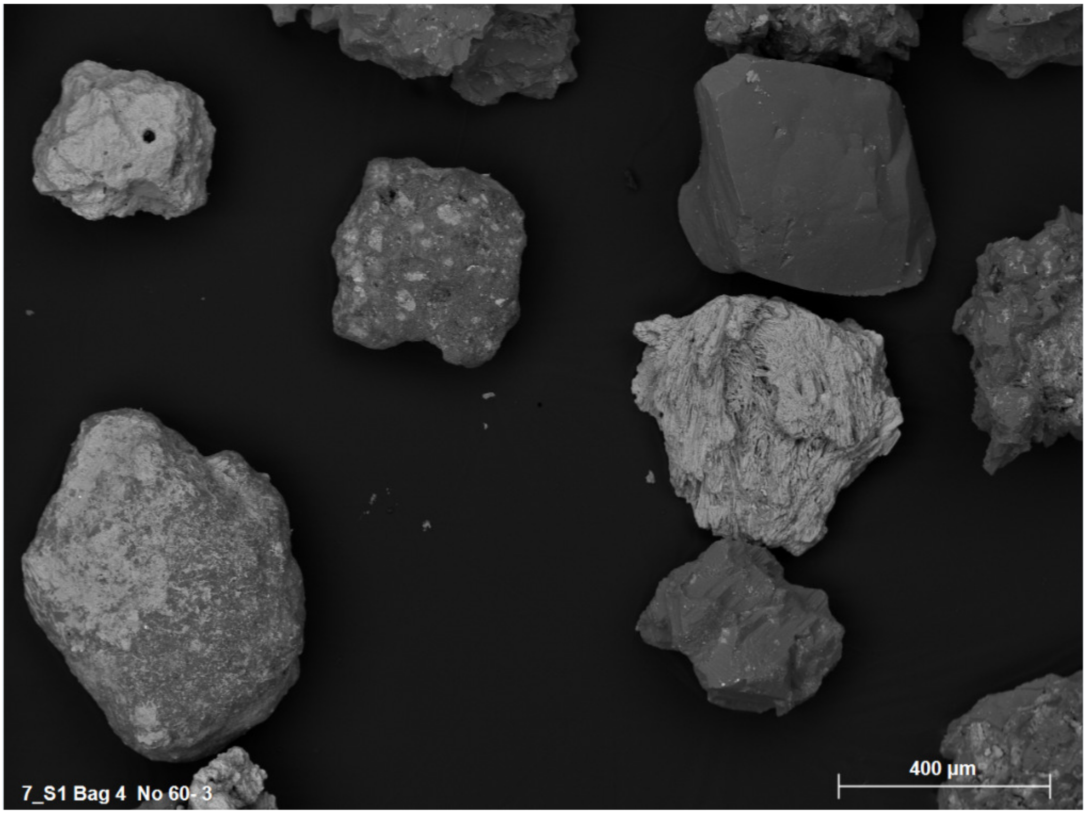

500 µm
6_S1 Bag 4 No 40- 1

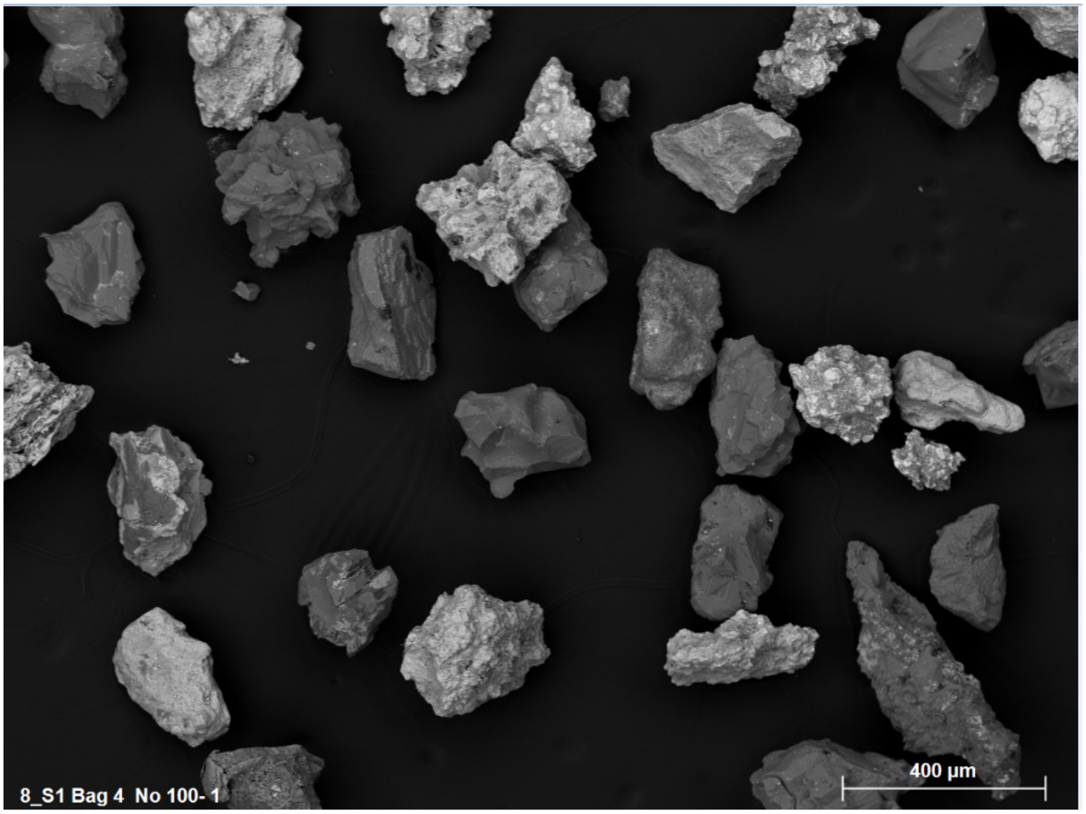

500 µm
6_S1 Bag 4 No 40- 2

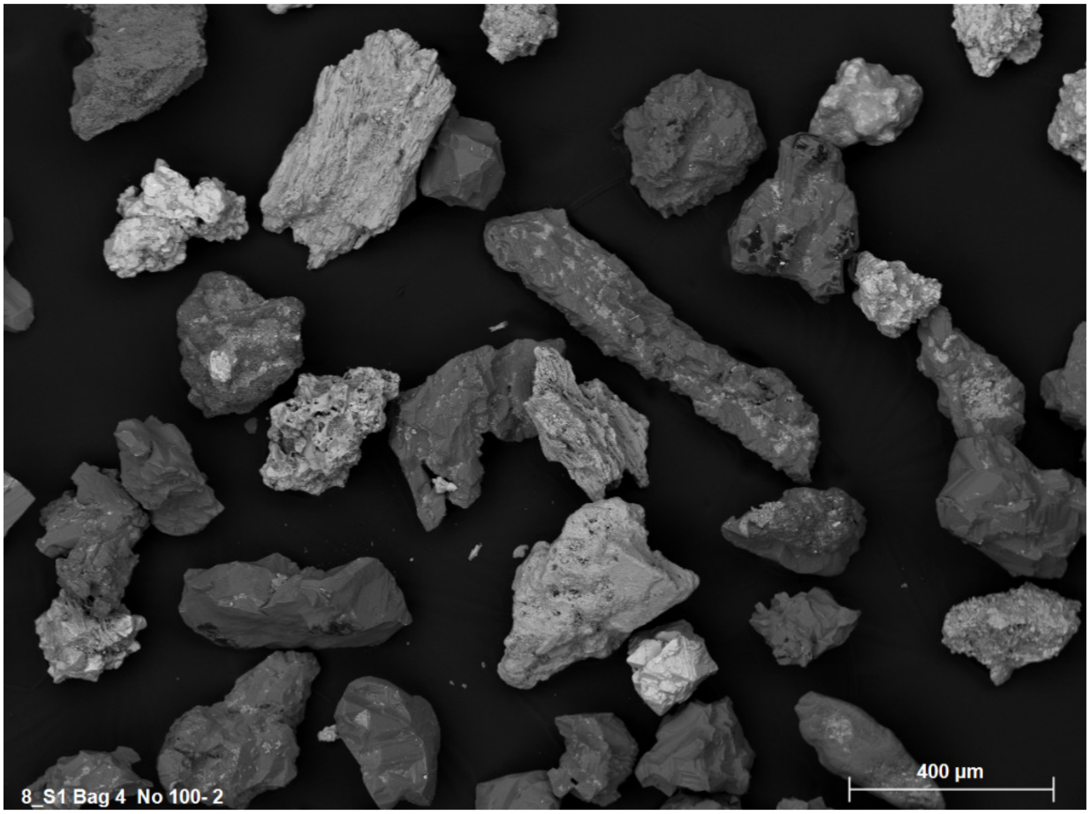

500 µm
6_S1 Bag 4 No 40- 3

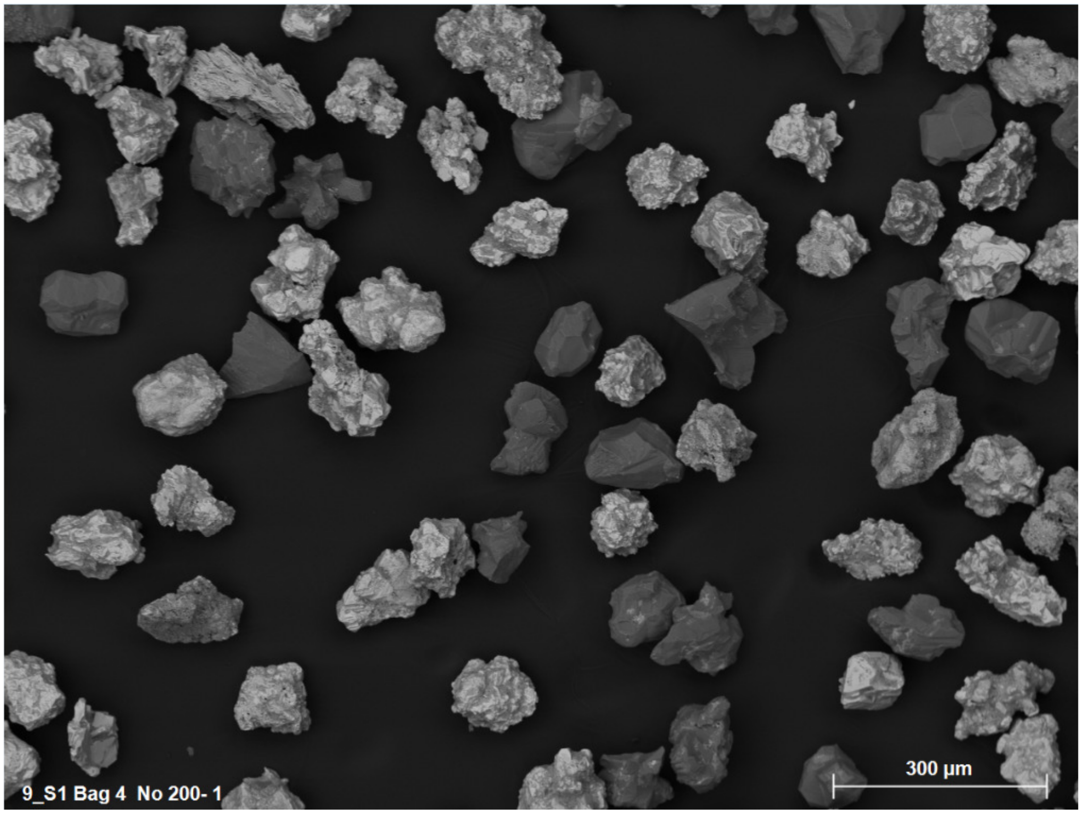

400 µm
7_S1 Bag 4 No 60- 1

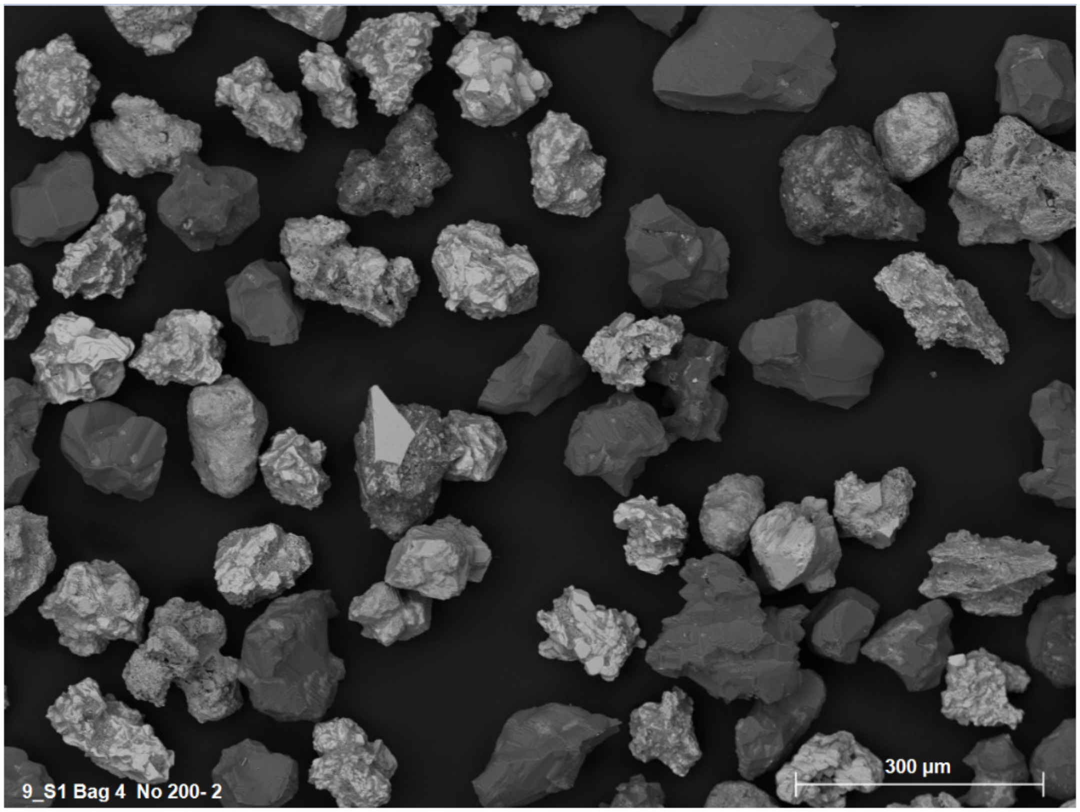

400 µm
7_S1 Bag 4 No 60- 2

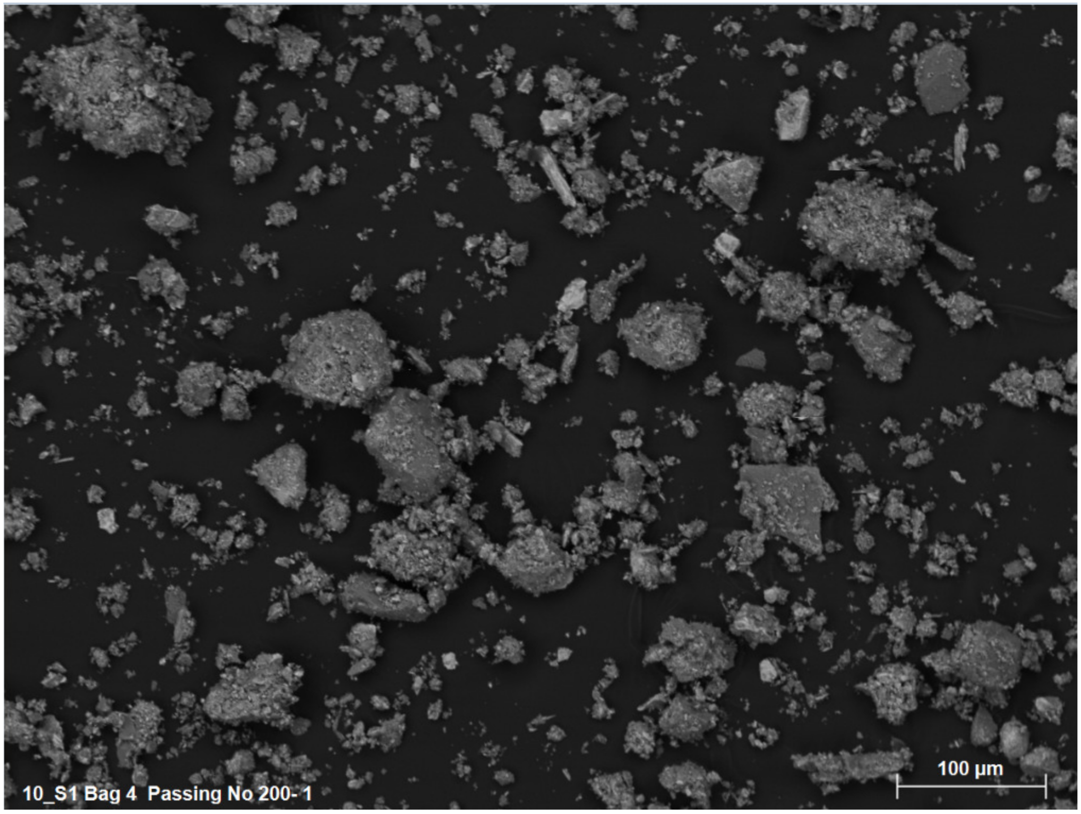

400 µm
7_S1 Bag 4 No 60- 3

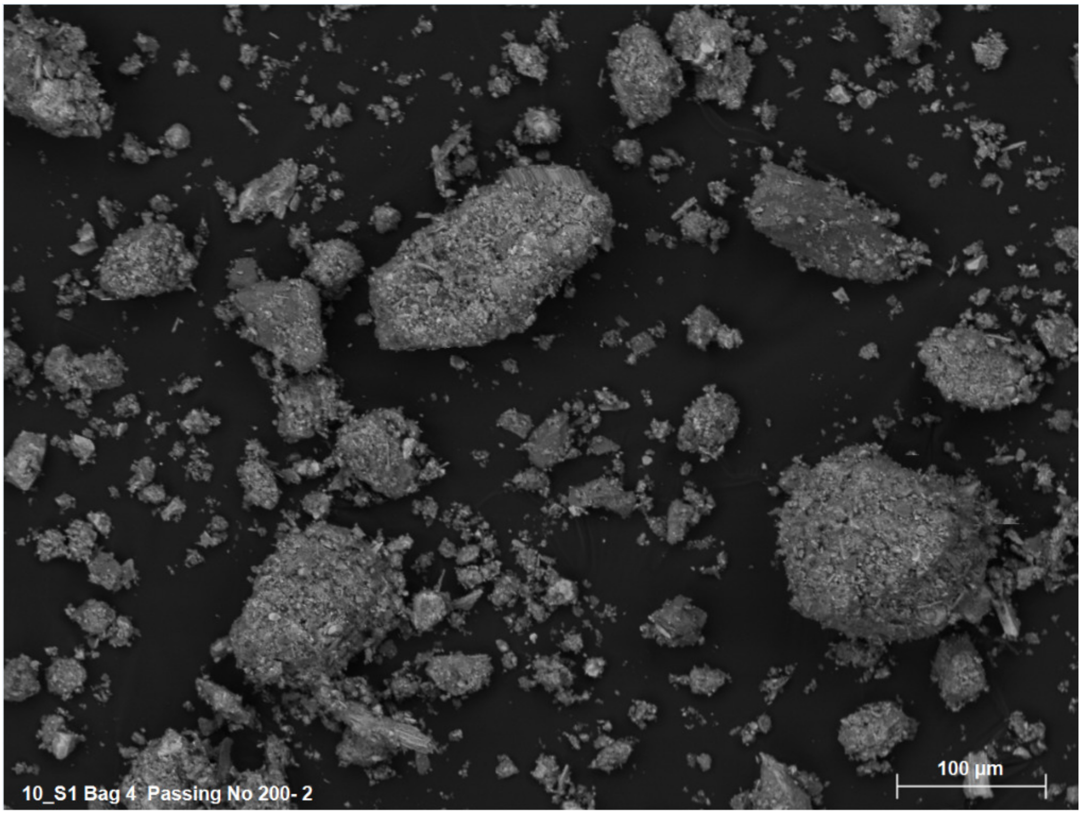

400 µm
8_S1 Bag 4 No 100- 1

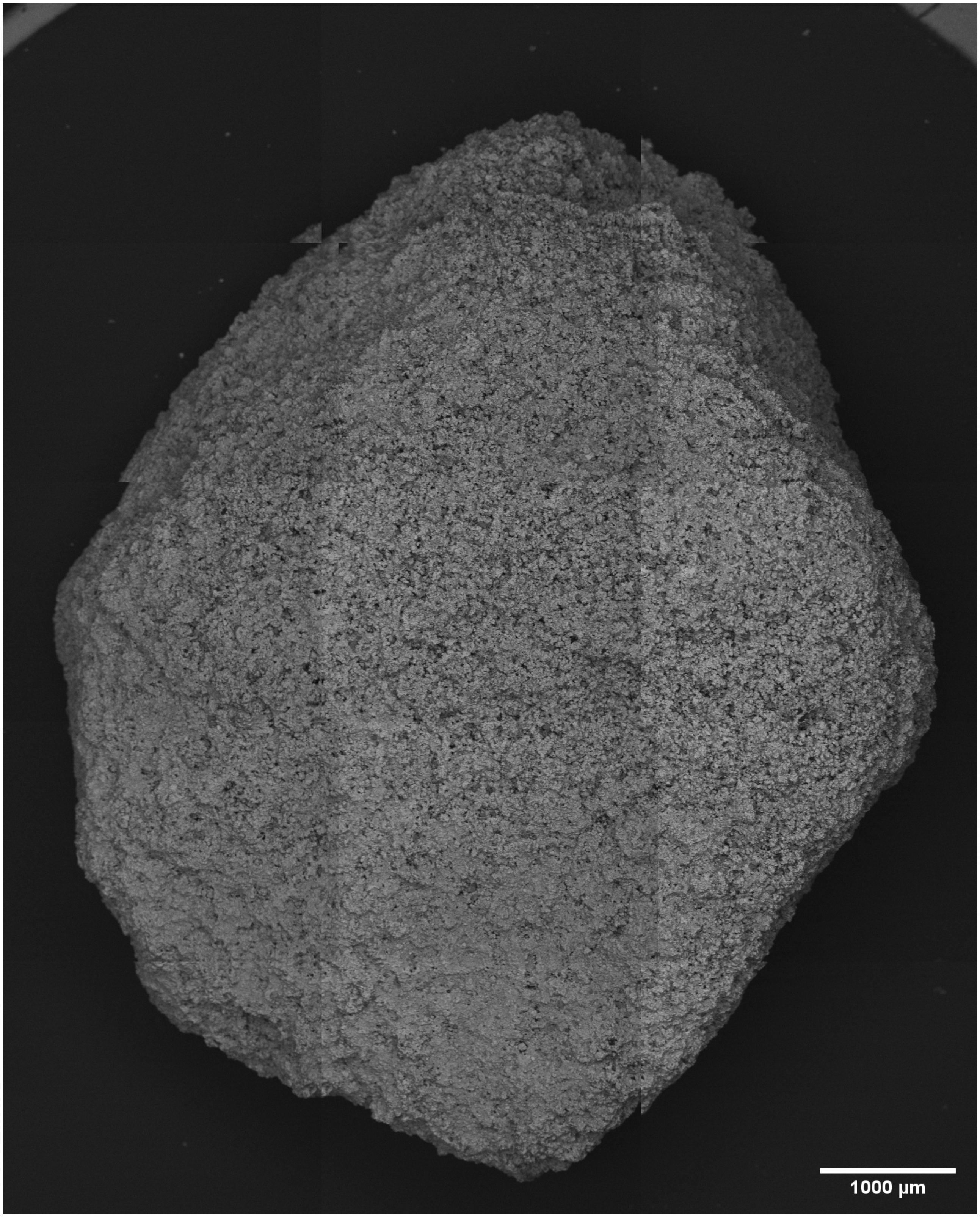

400 µm
8_S1 Bag 4 No 100- 2

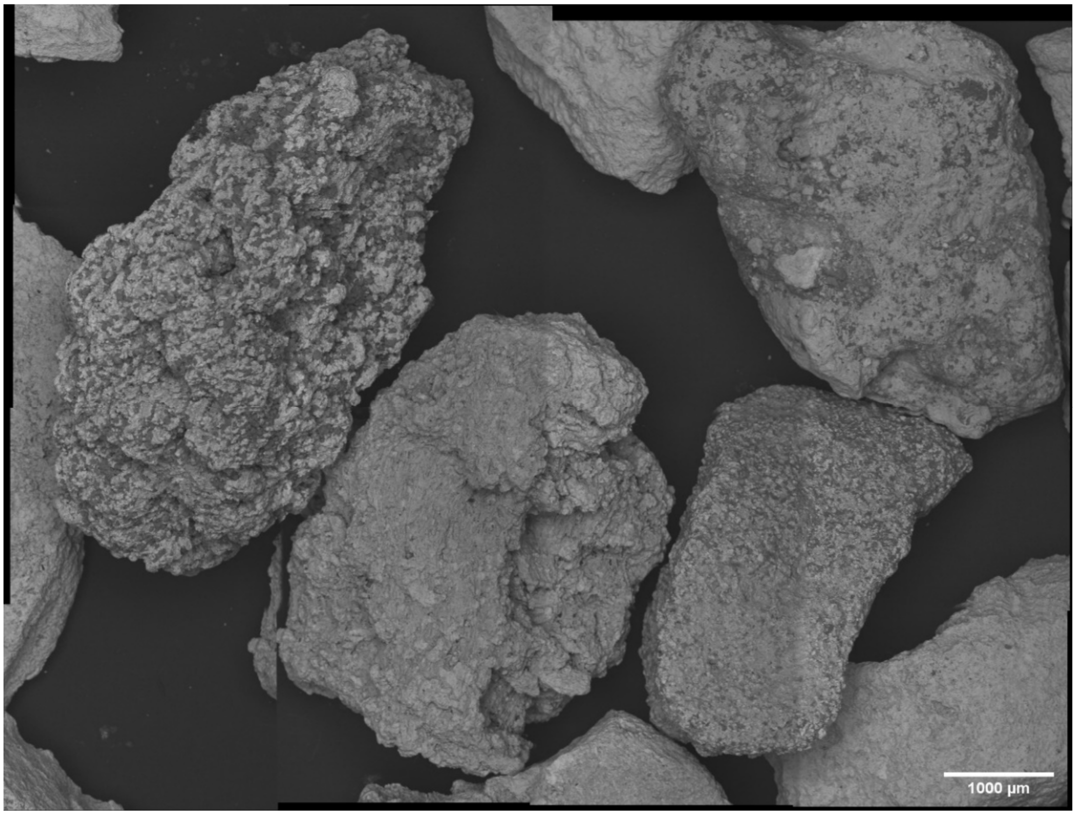

300 µm
9_S1 Bag 4 No 200- 1

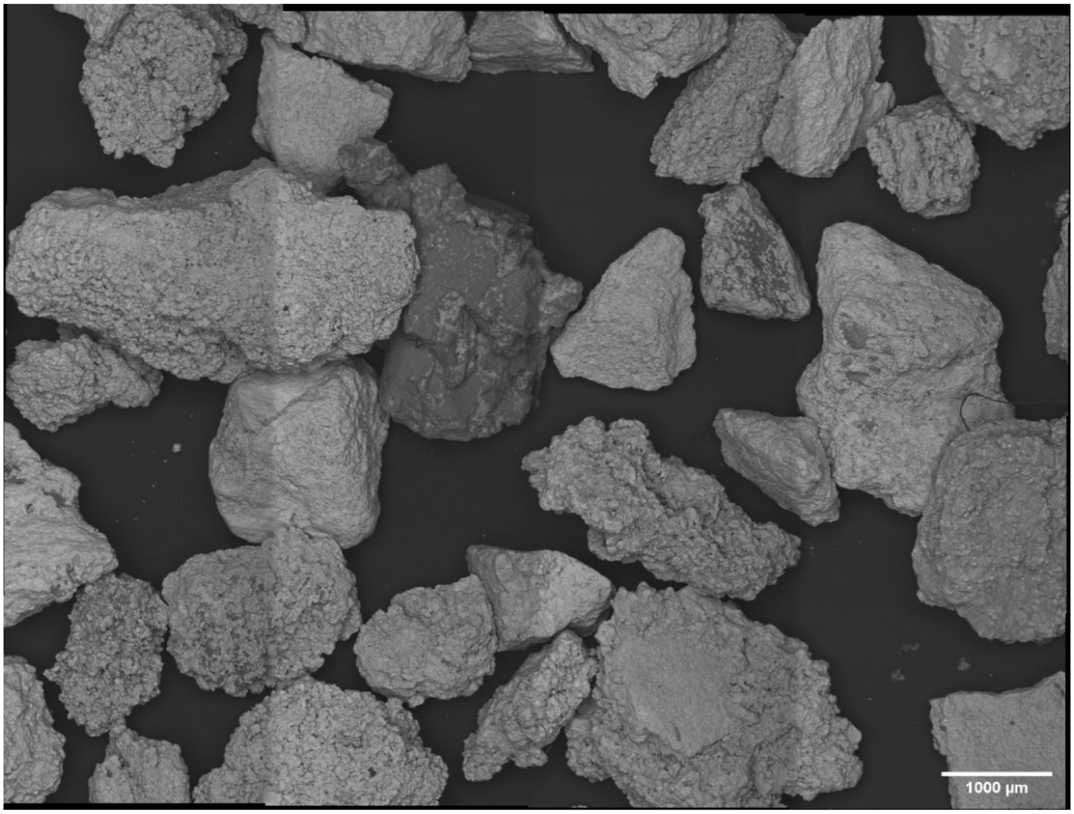

300 µm
9_S1 Bag 4 No 200- 2

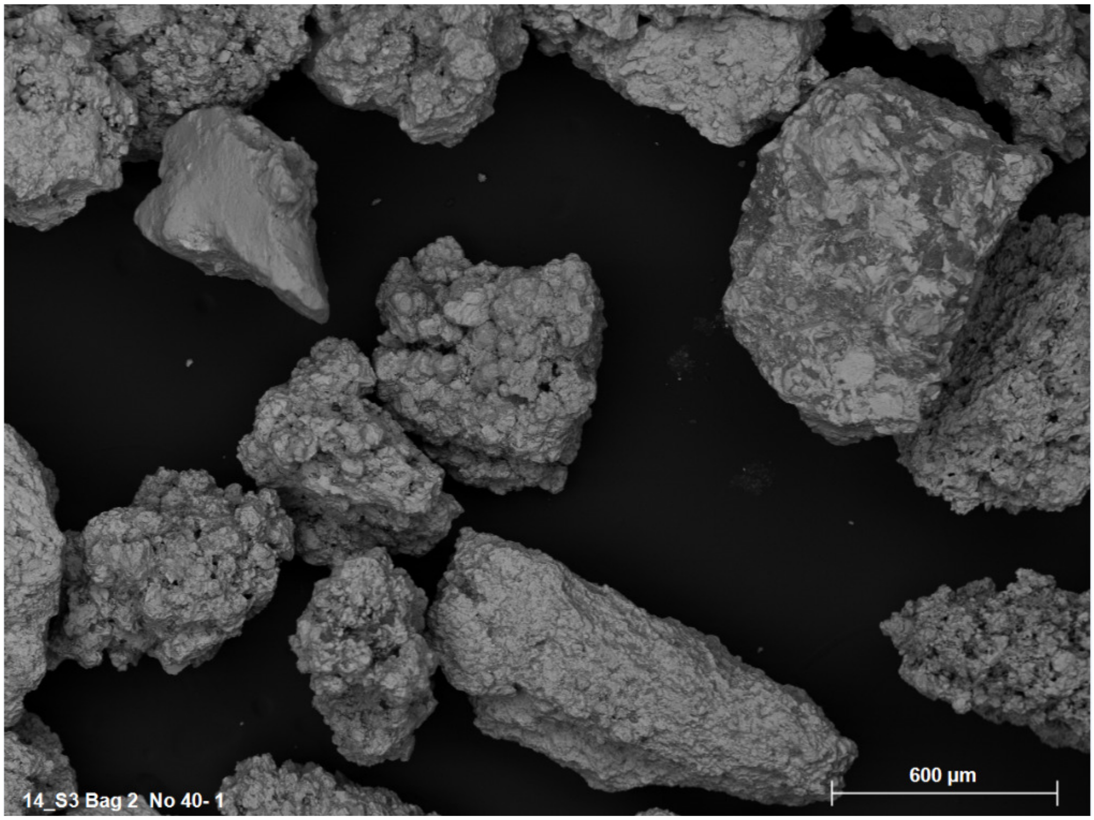

100 µm
10_S1 Bag 4 Passing No 200- 1

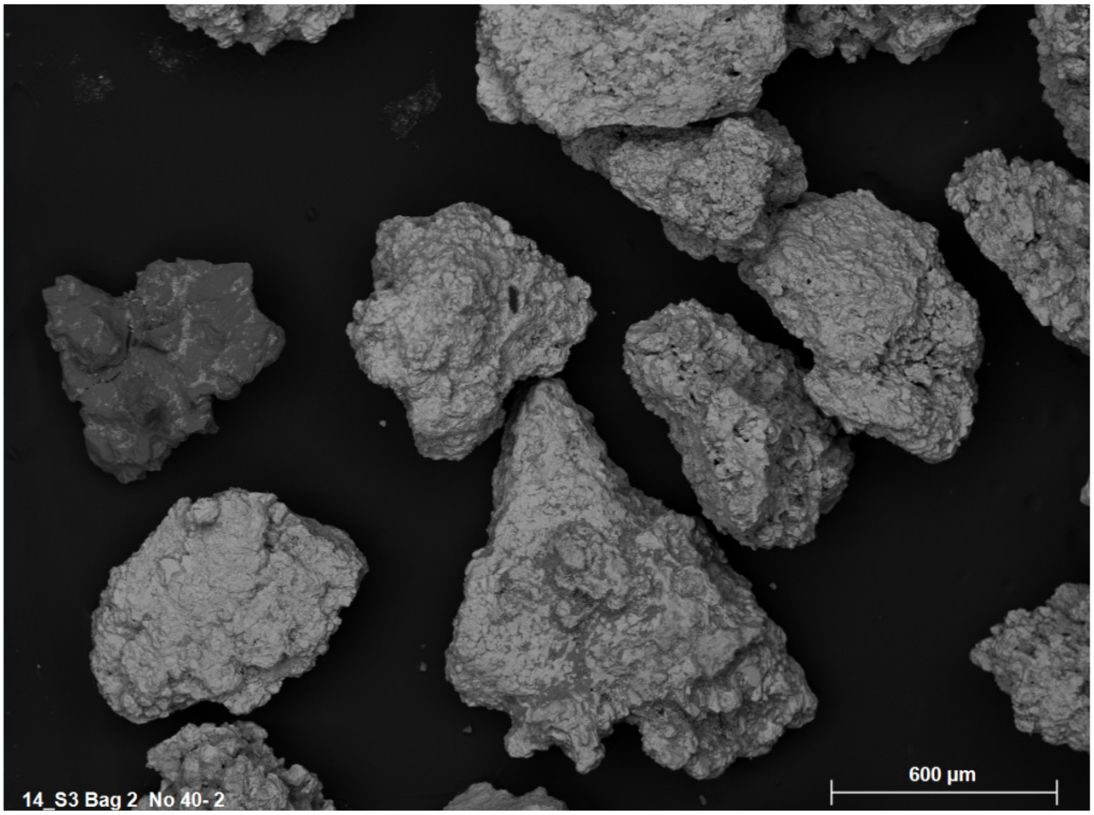

100 µm
10_S1 Bag 4 Passing No 200- 2

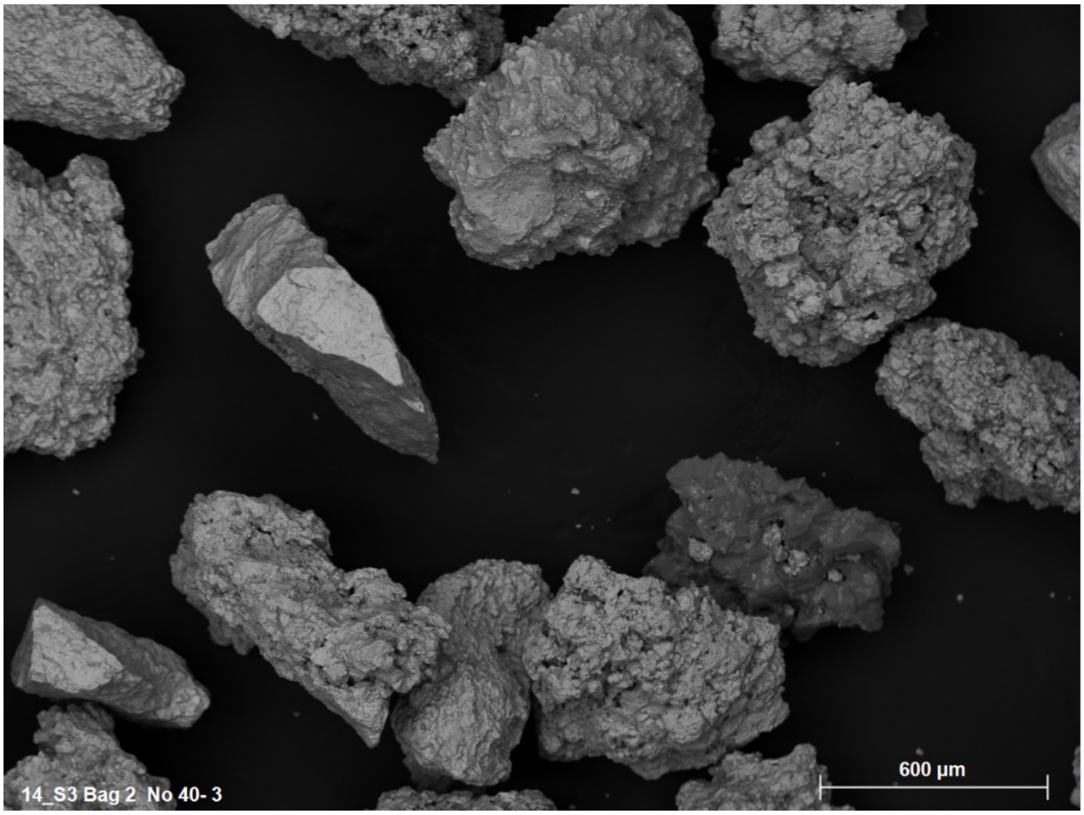

1000 µm

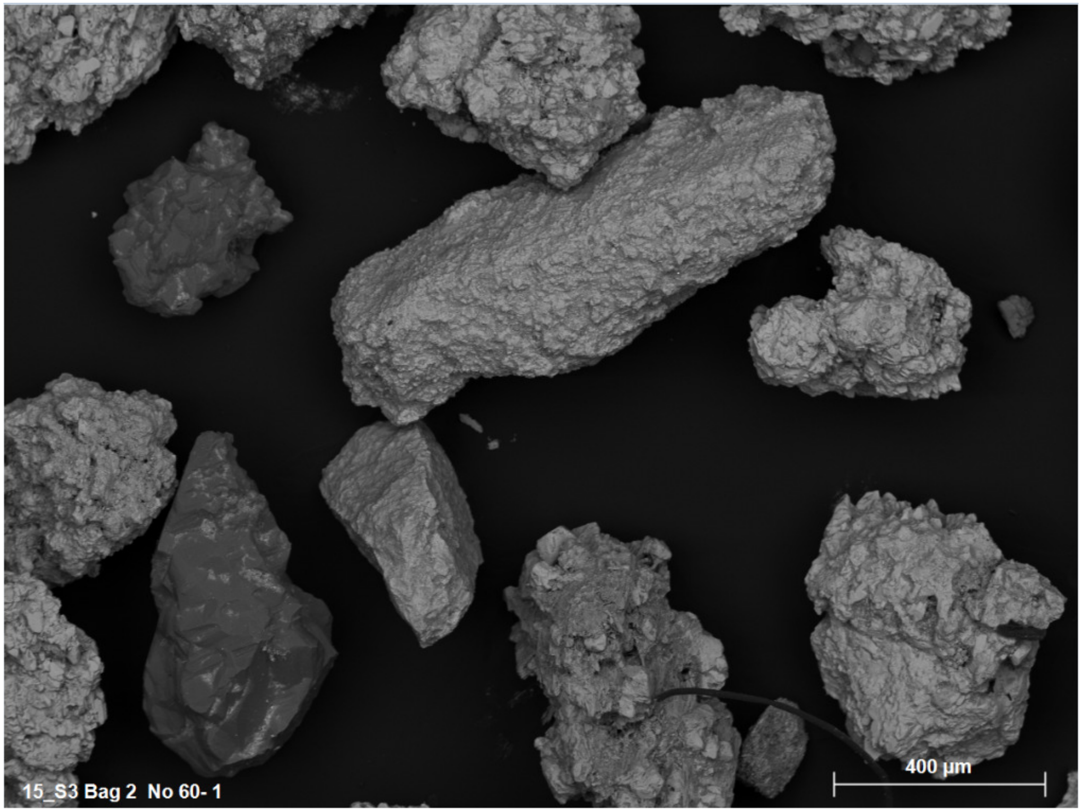

1000 µm

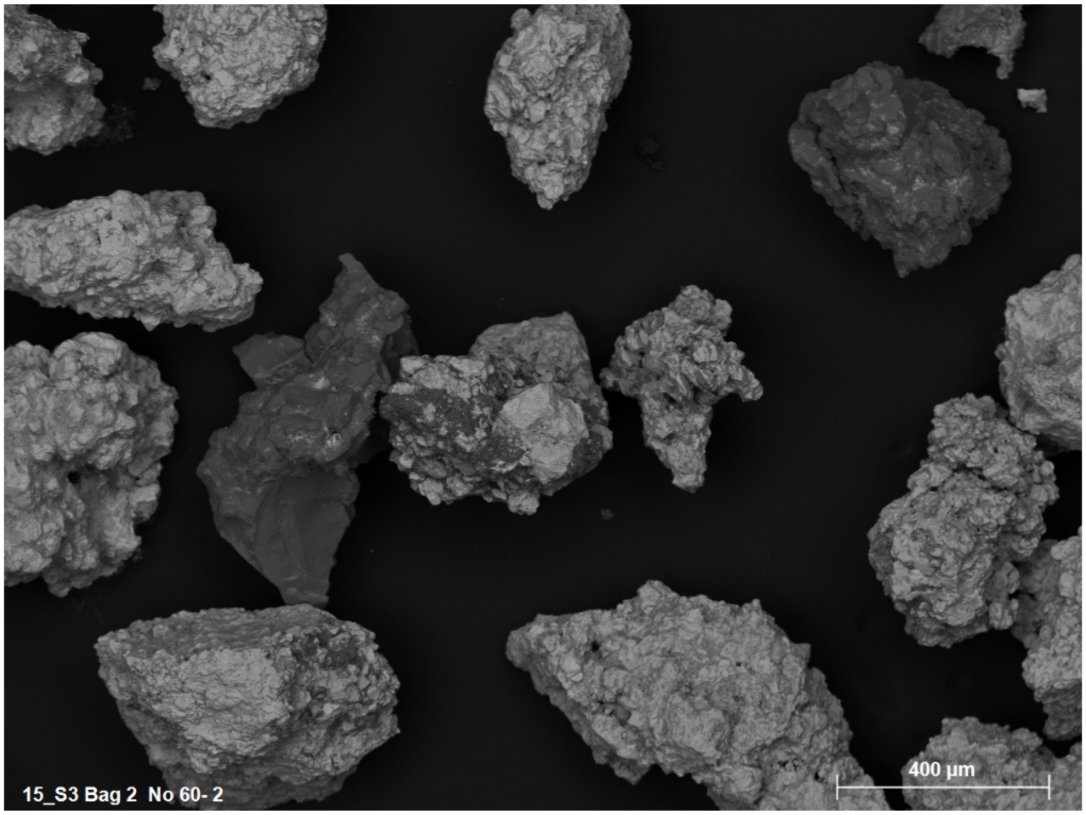

1000 µm

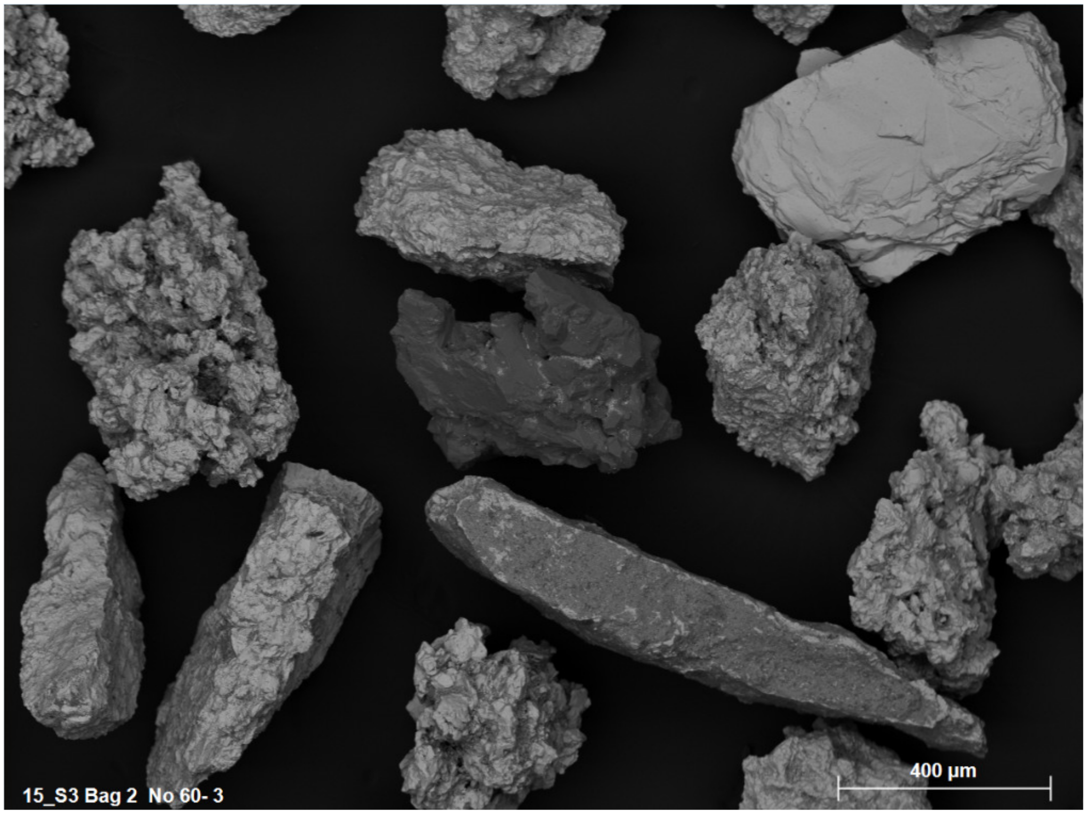

600 µm
14_S3 Bag 2 No 40- 1

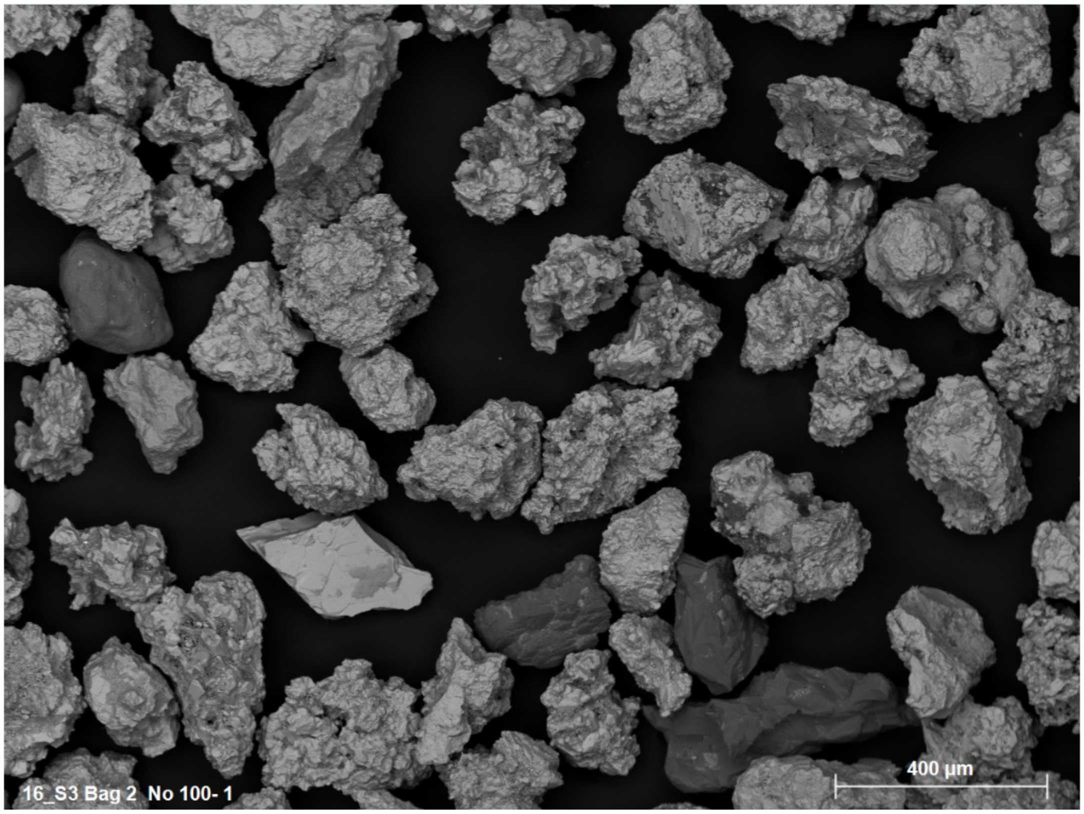

600 µm
14_S3 Bag 2 No 40- 2

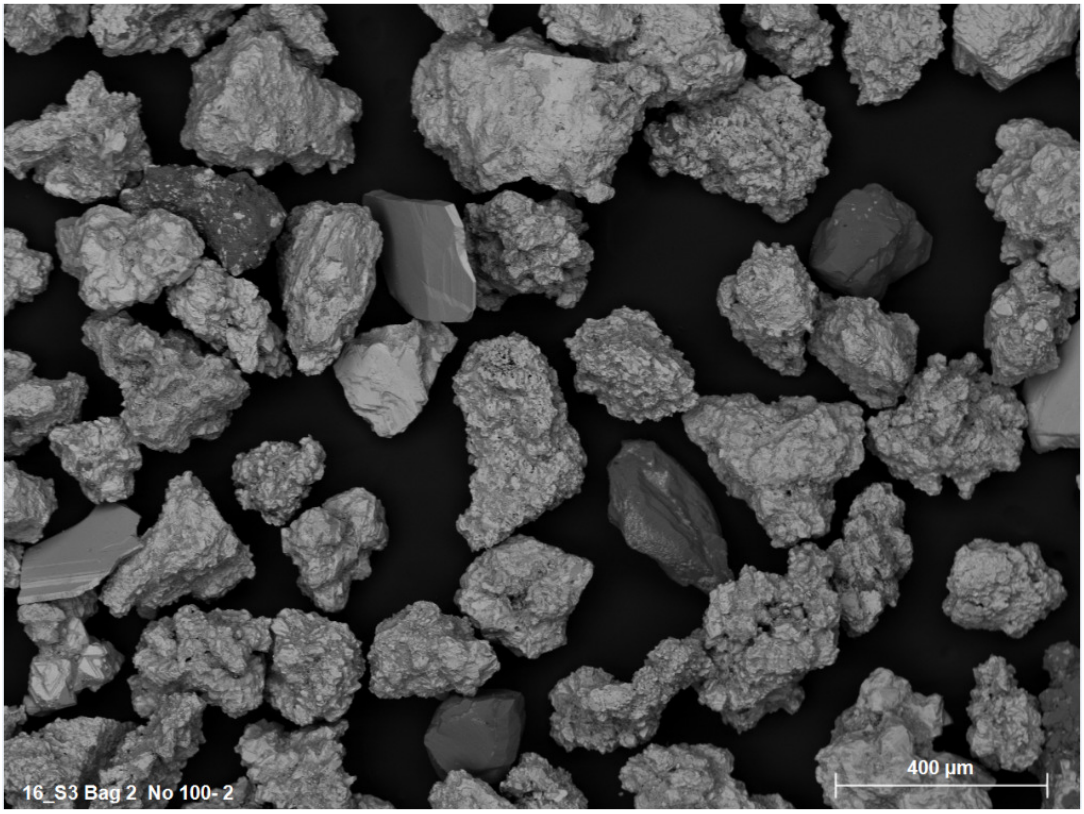

600 µm
14_S3 Bag 2 No 40- 3

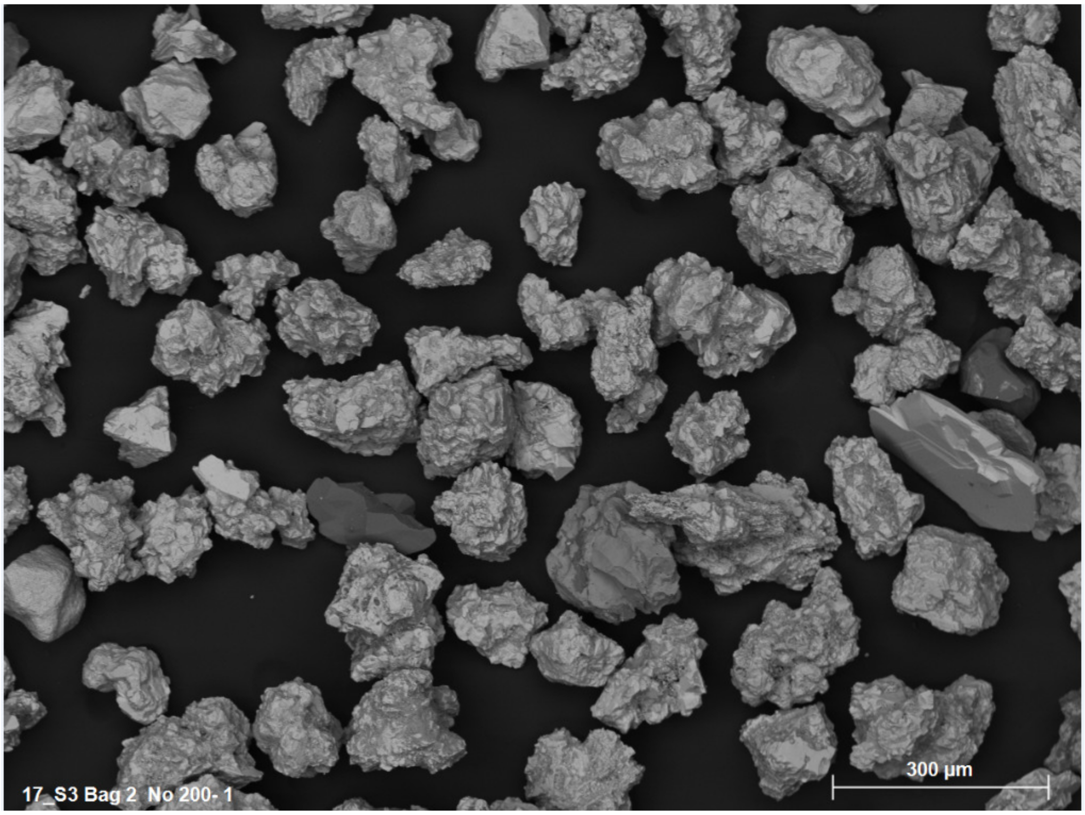

400 µm
15_S3 Bag 2 No 60- 1

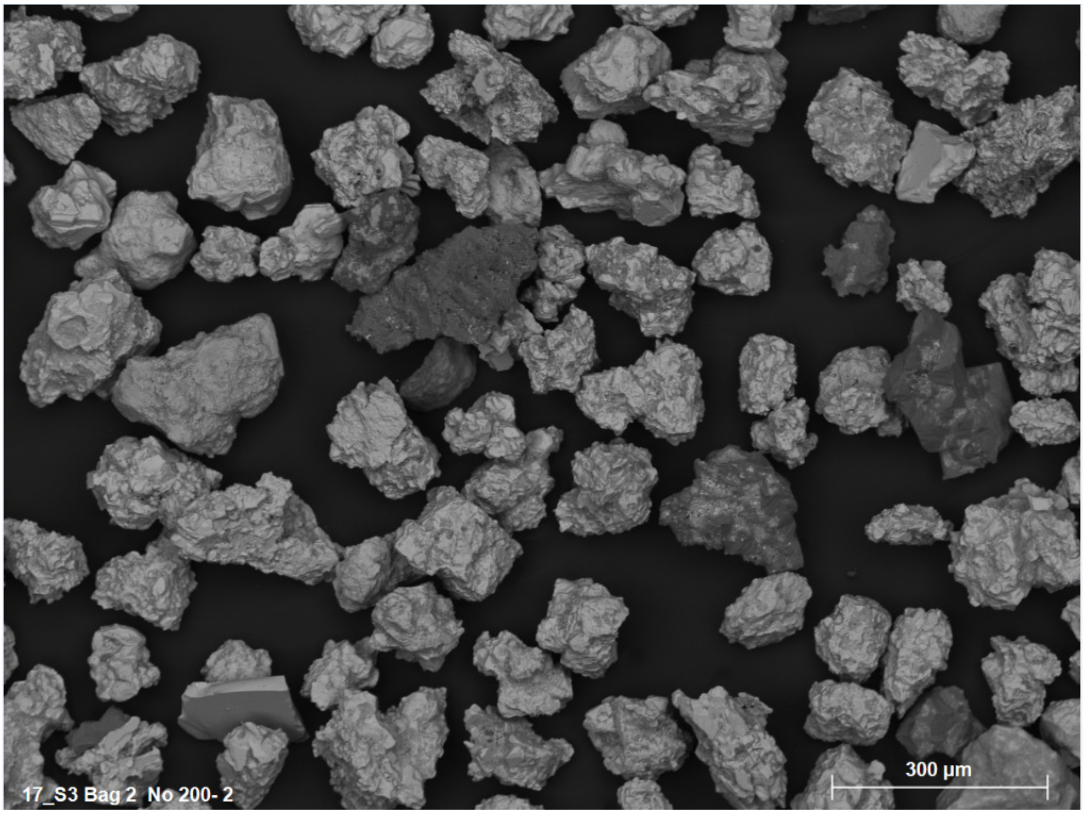

400 µm
15_S3 Bag 2 No 60- 2

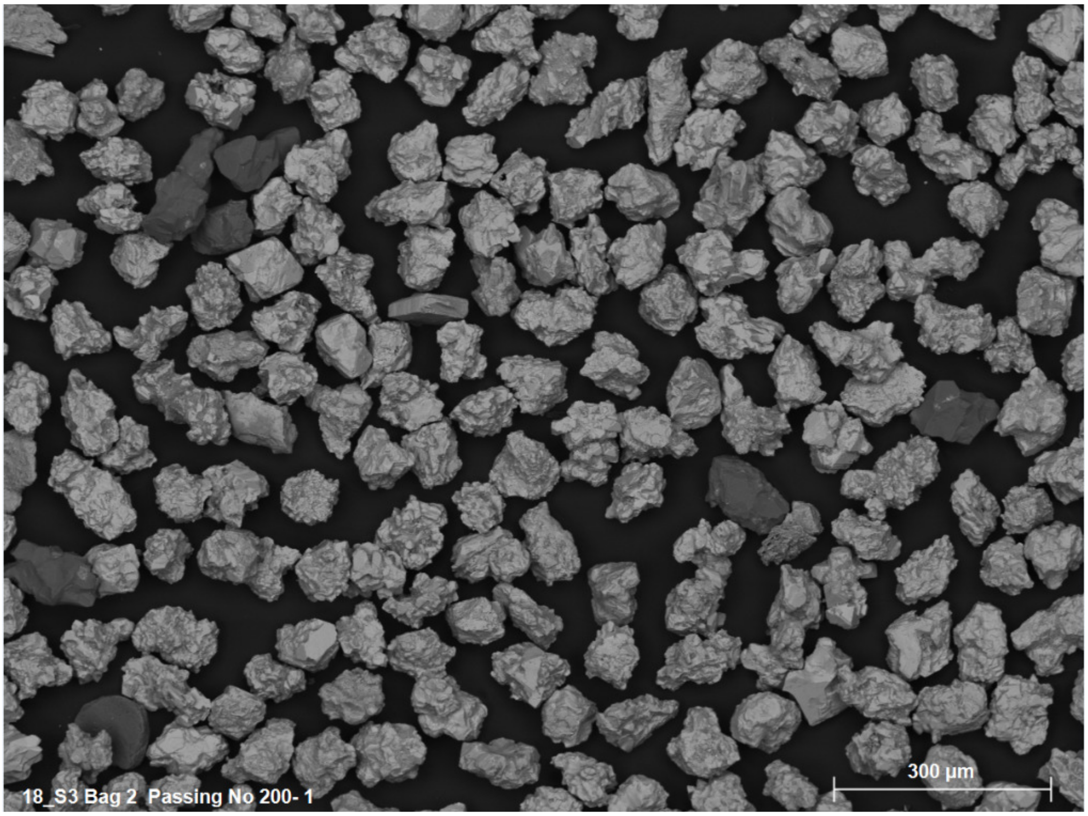

400 µm
15_S3 Bag 2 No 60- 3

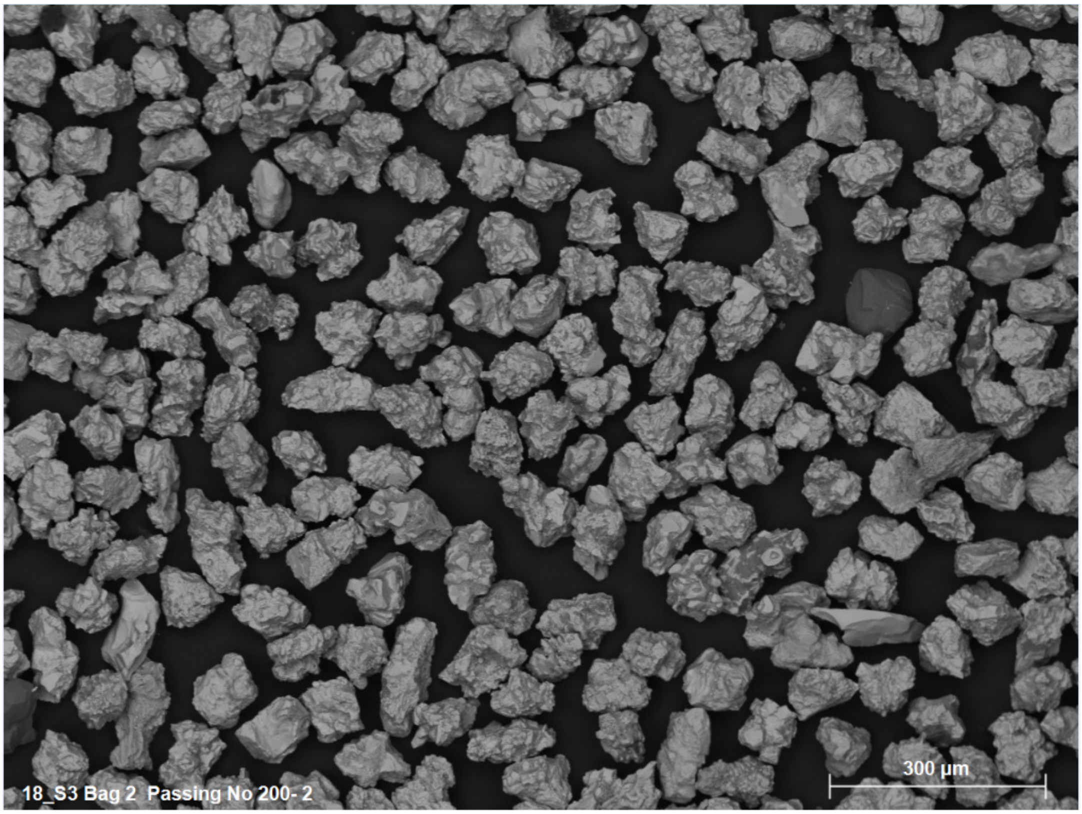

400 µm
16_S3 Bag 2 No 100- 1

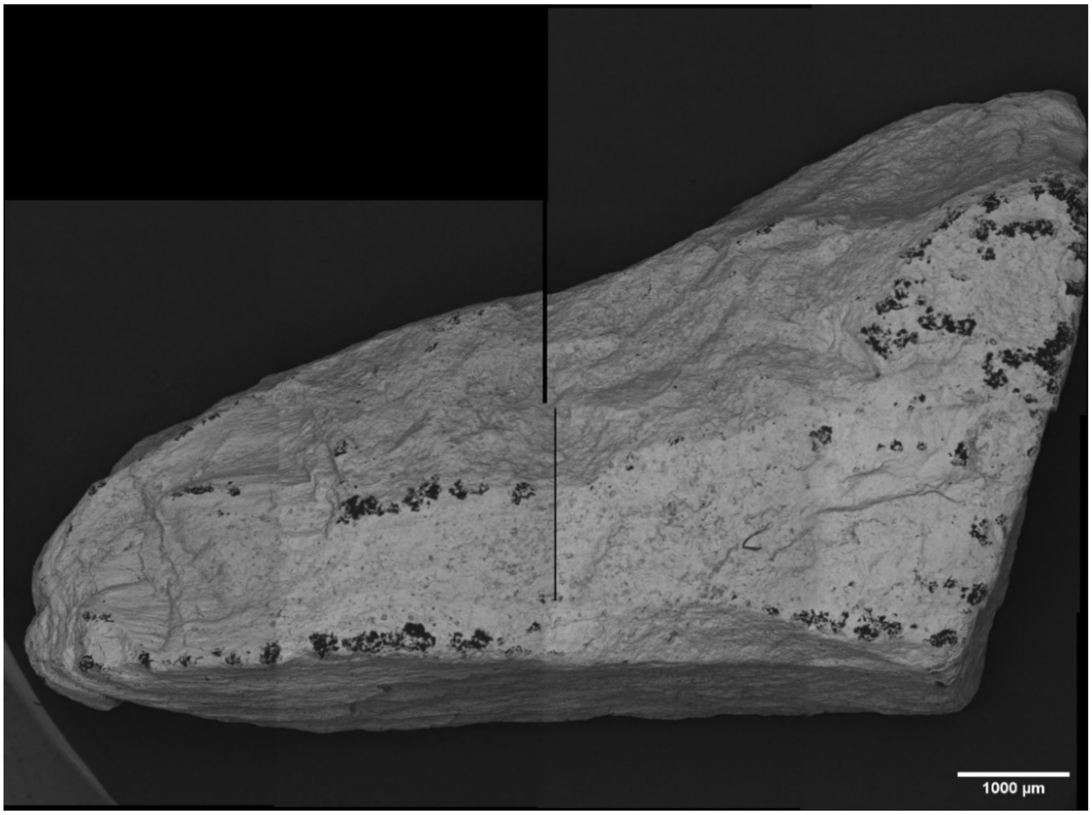

400 µm
16_S3 Bag 2 No 100- 2

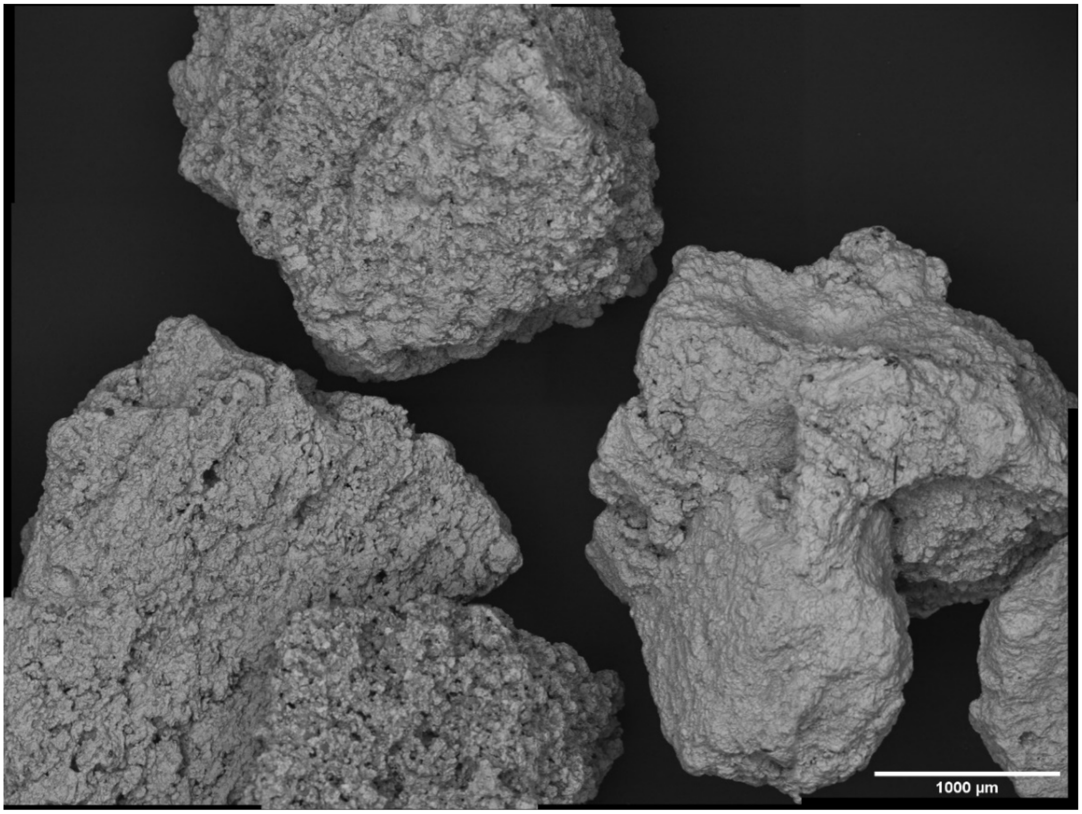

300 µm
17_S3 Bag 2 No 200- 1

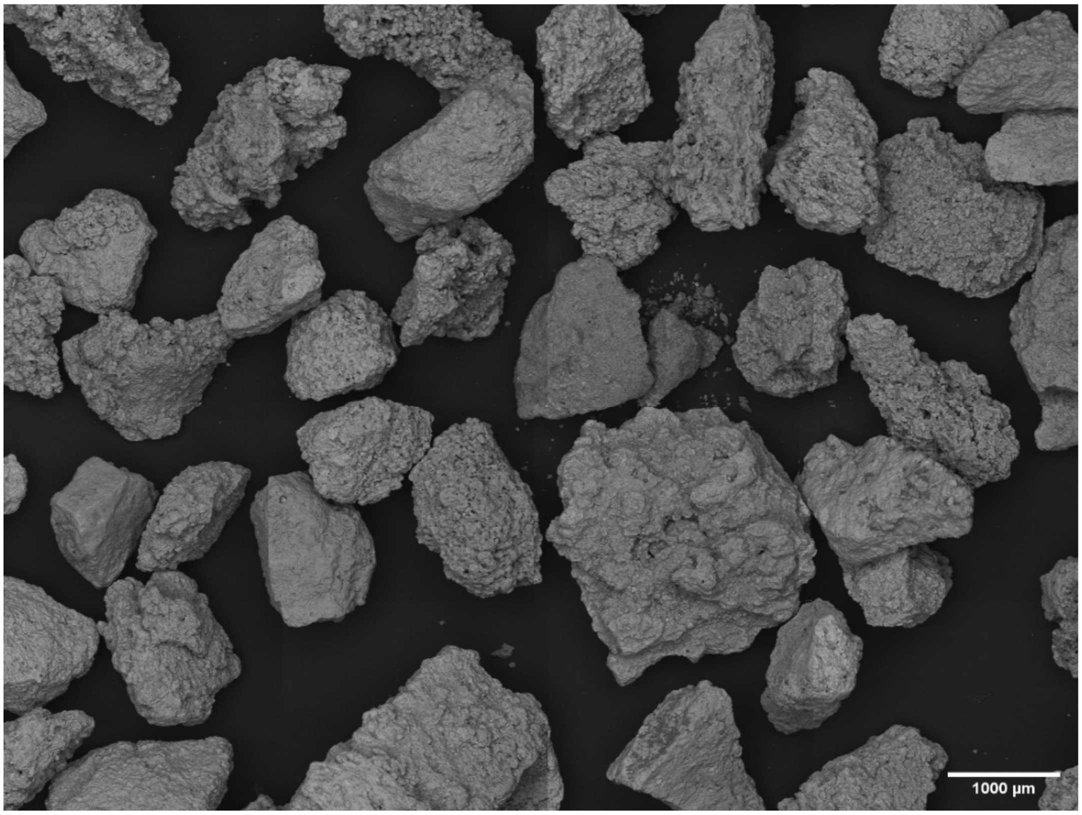

300 µm
17_S3 Bag 2 No 200- 2

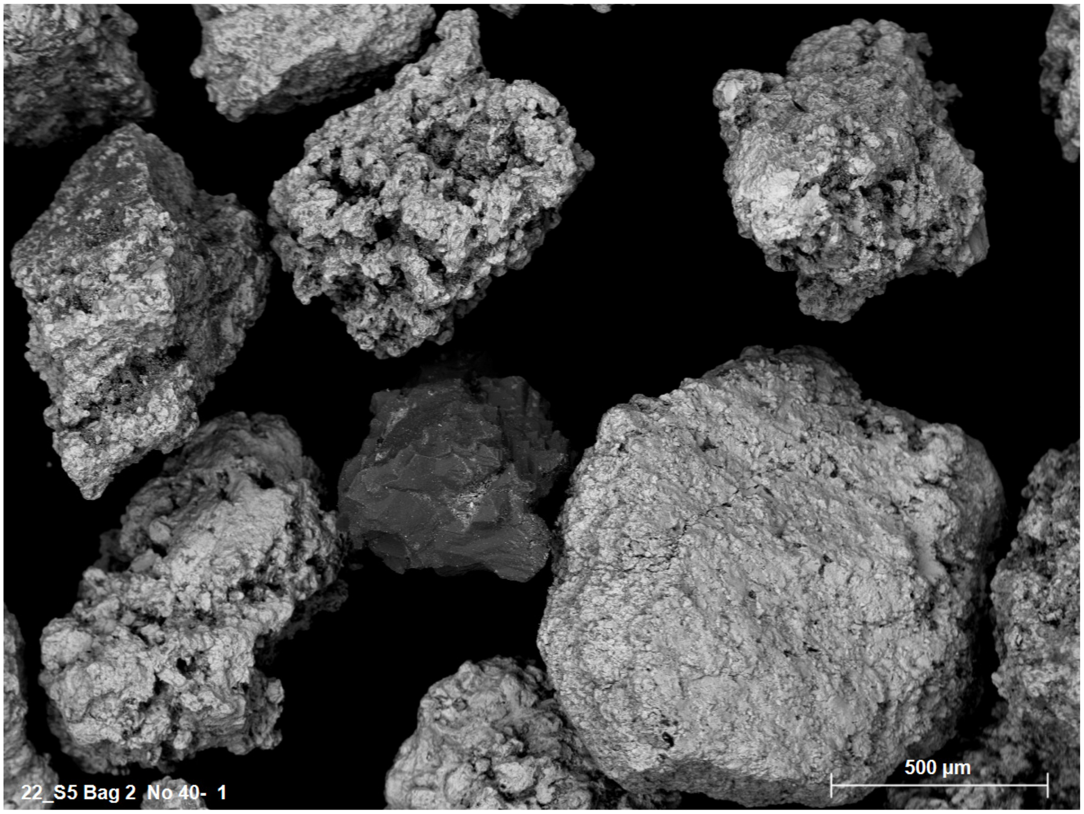

300 µm
18_S3 Bag 2 Passing No 200- 1

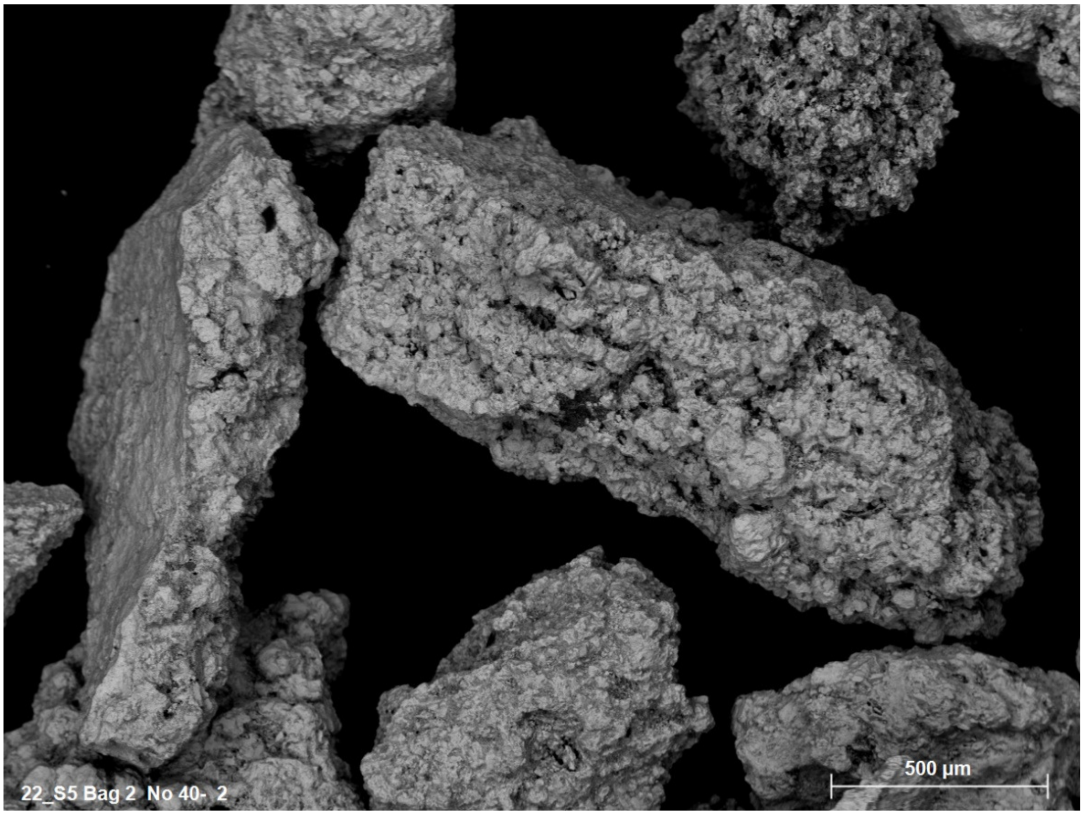

300 µm
18_S3 Bag 2 Passing No 200- 2

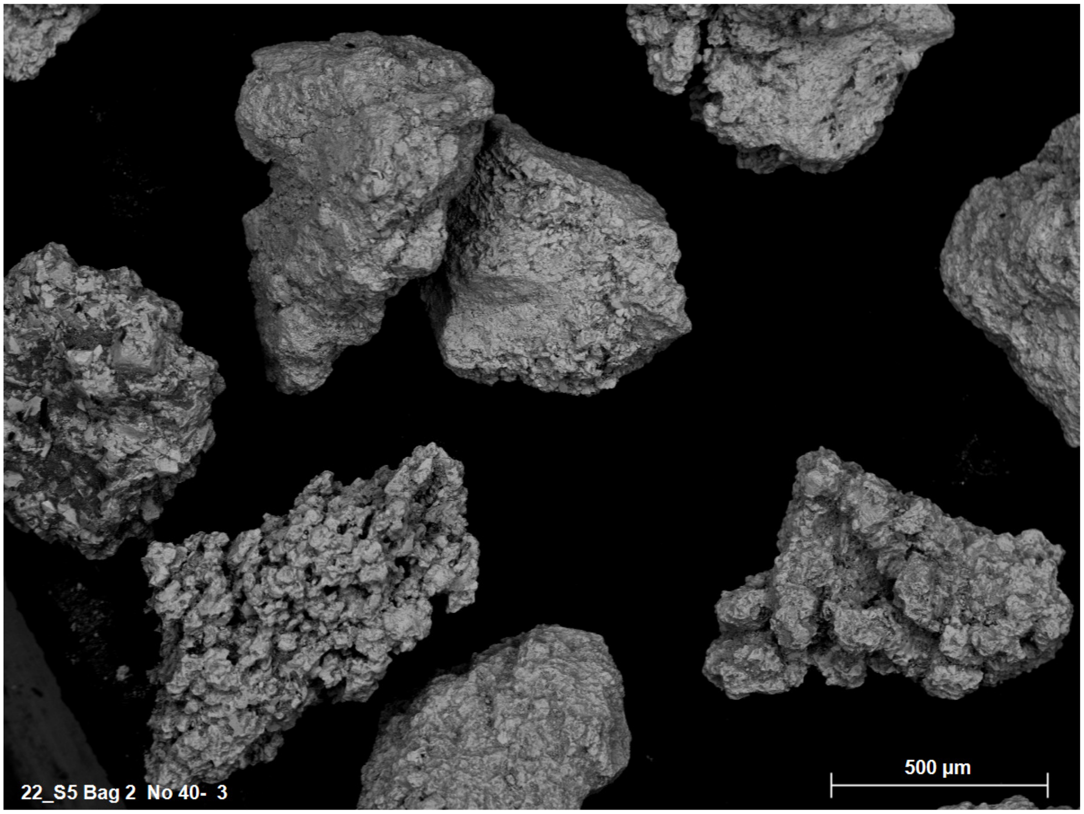

1000 µm

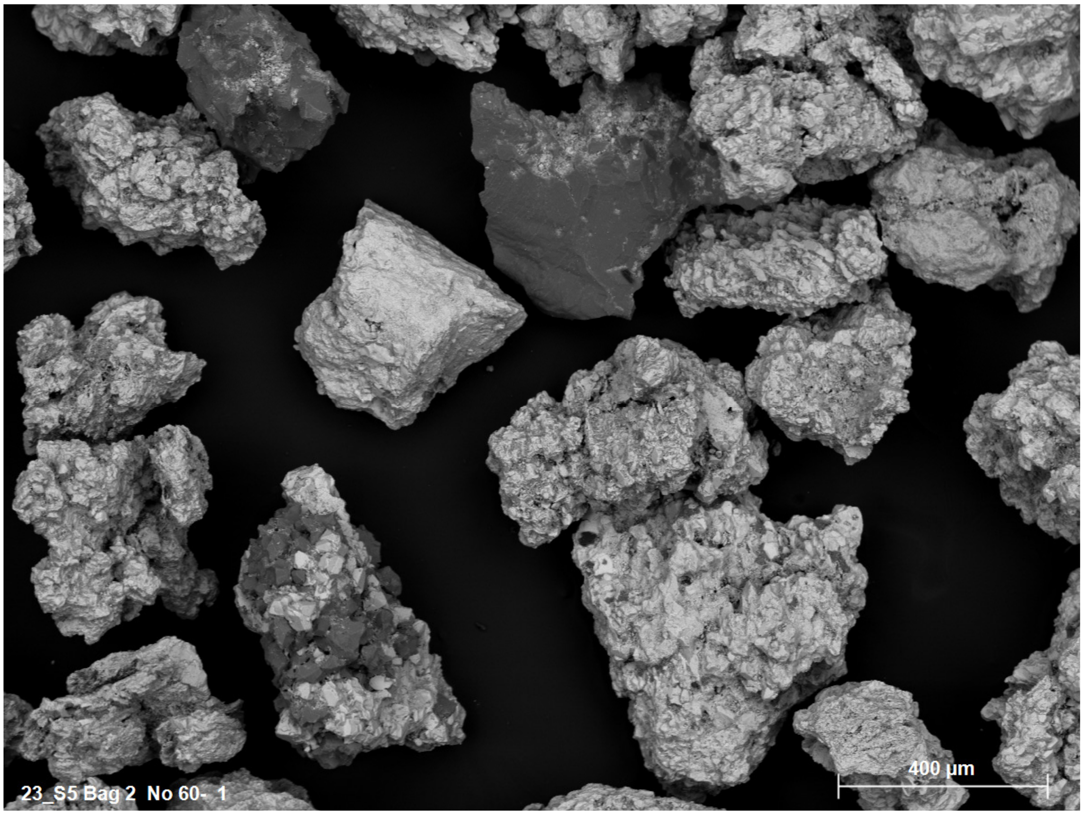

1000 µm

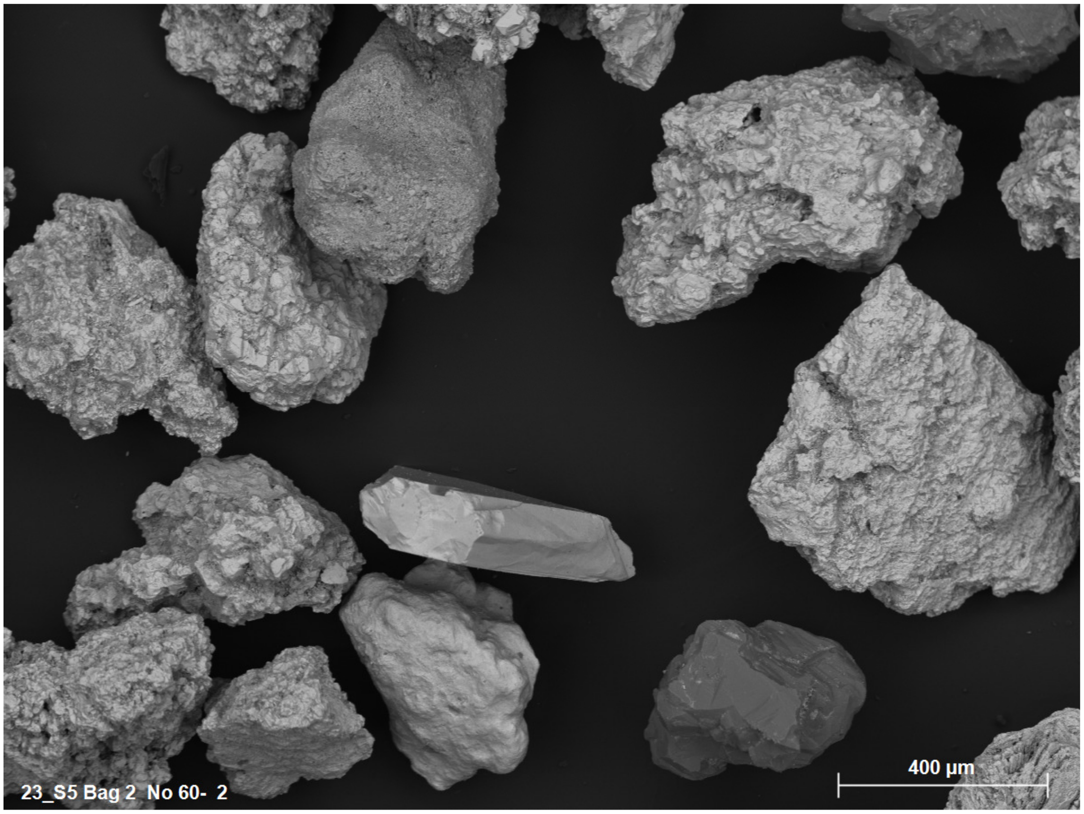

1000 µm

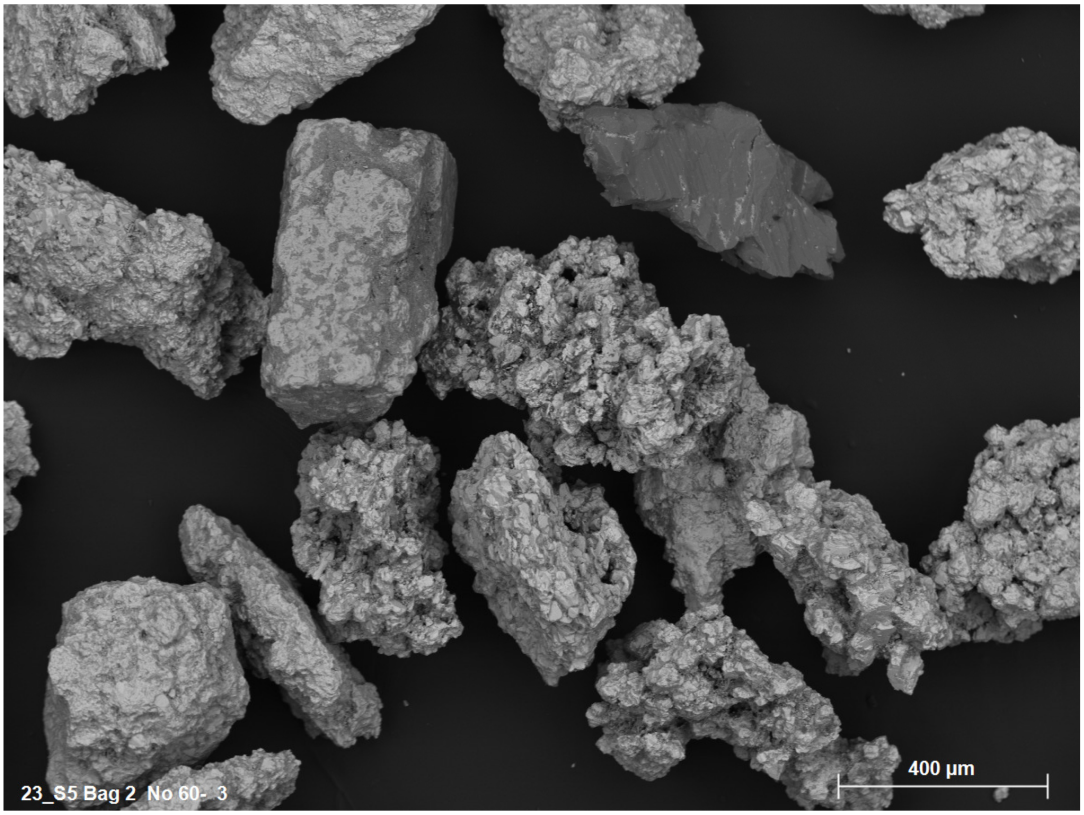

500 µm
22_S5 Bag 2 No 40- 1

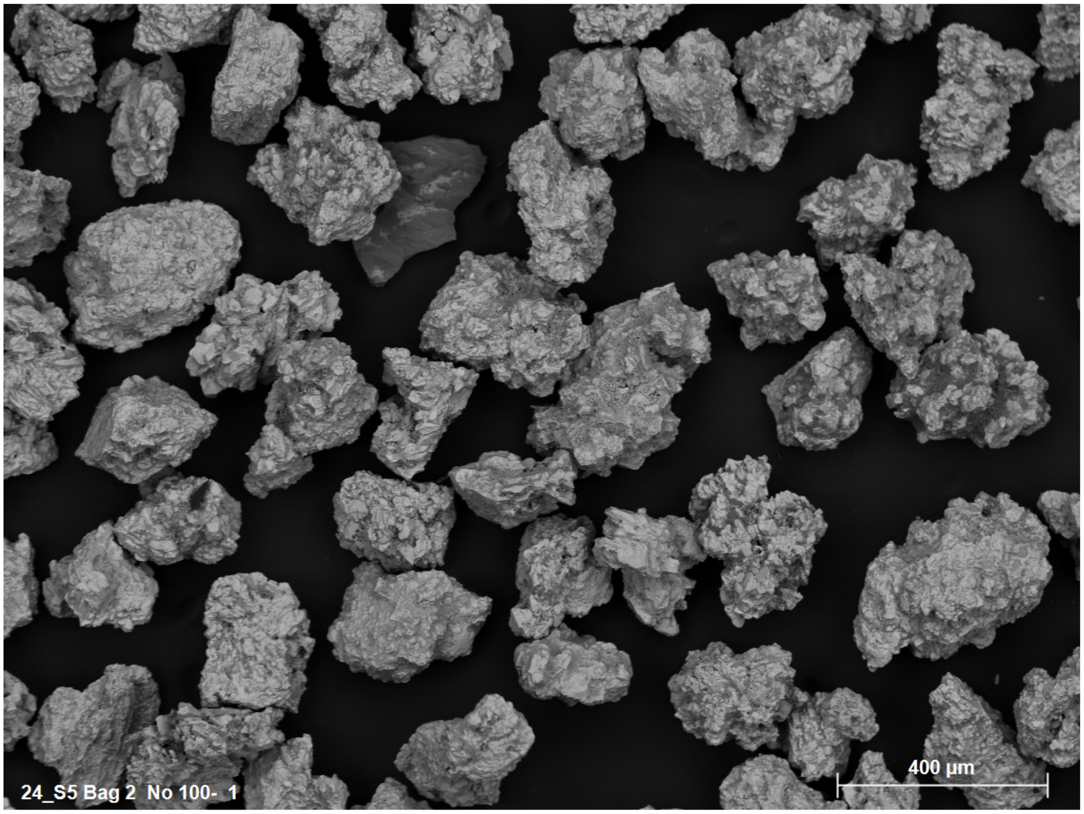

500 µm
22_S5 Bag 2 No 40- 2

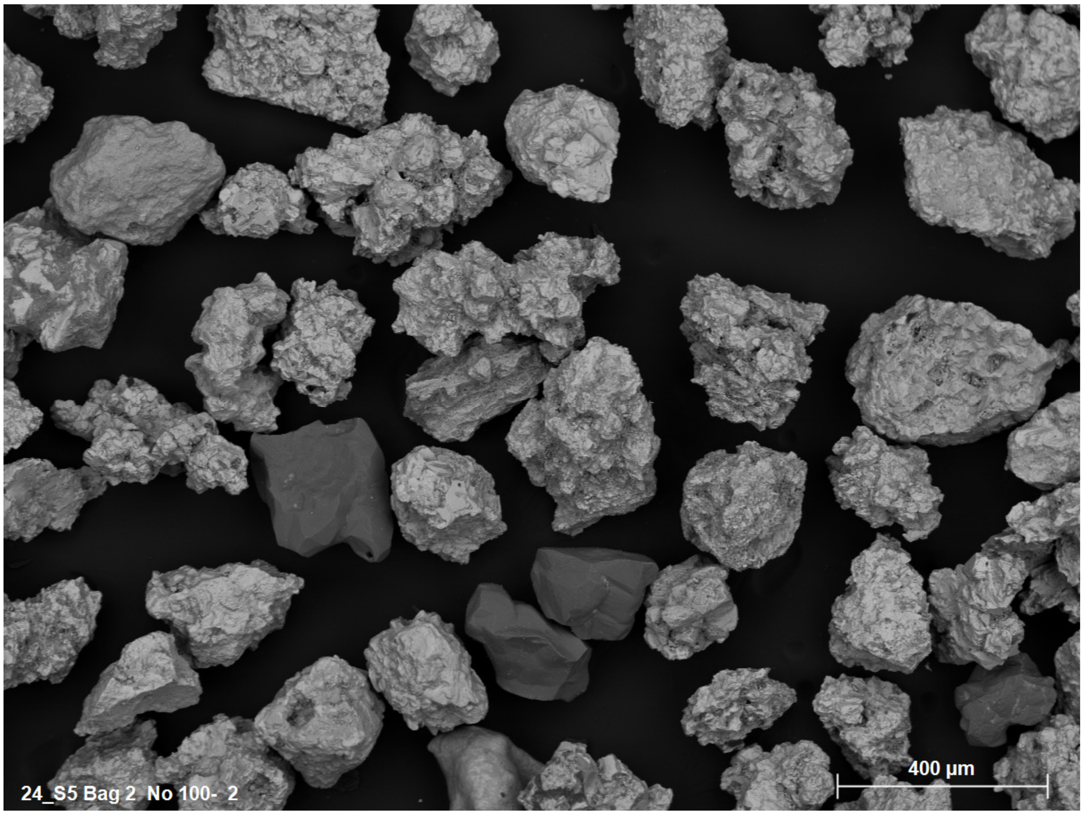

500 µm
22_S5 Bag 2 No 40- 3

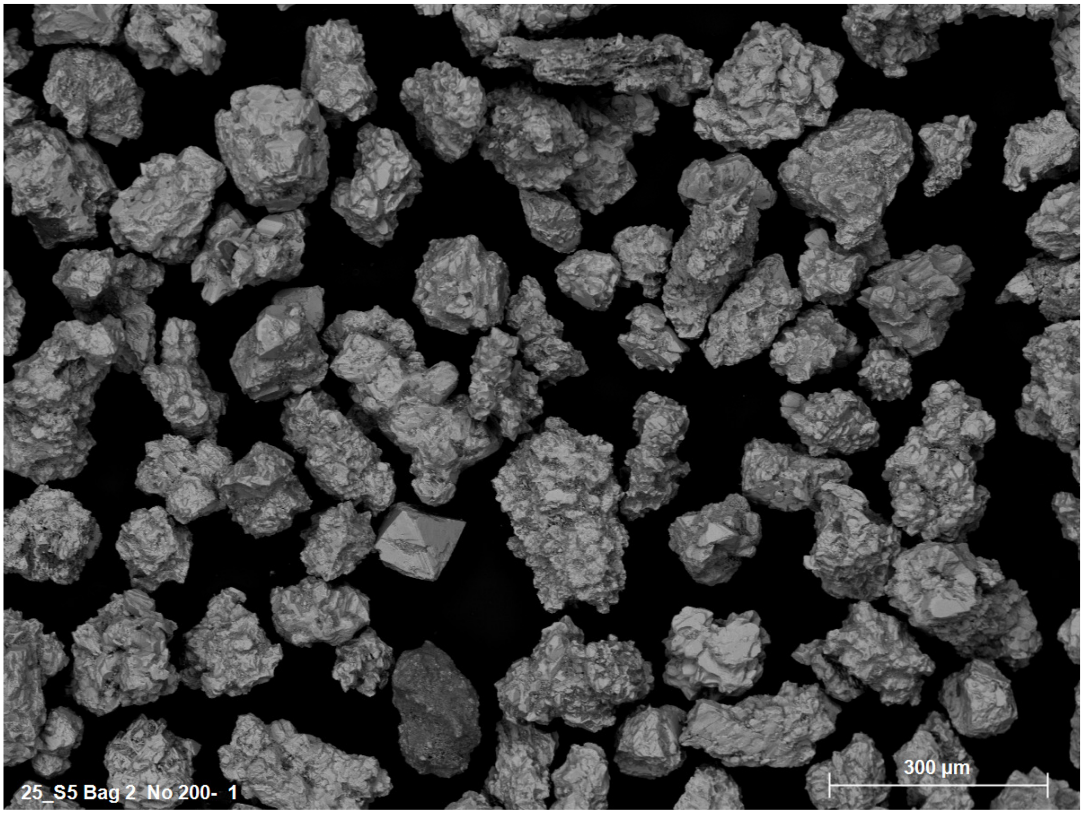

400 µm
23_S5 Bag 2 No 60- 1

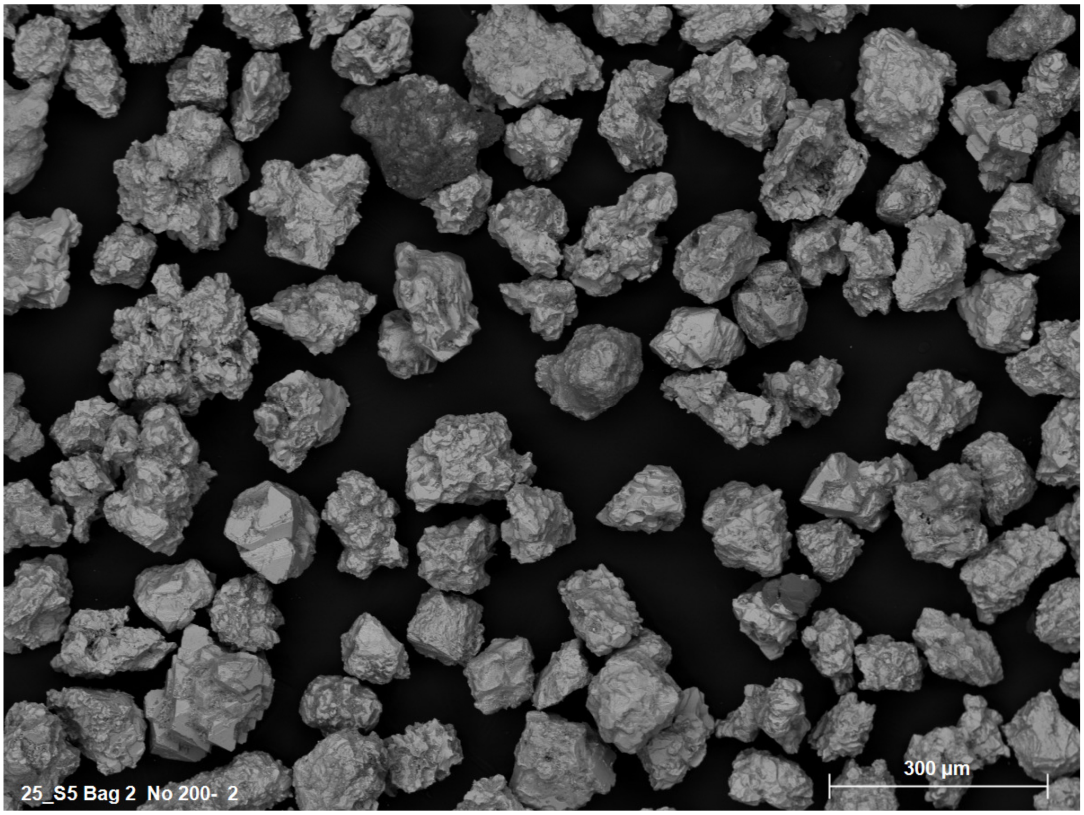

400 µm
23_S5 Bag 2 No 60- 2

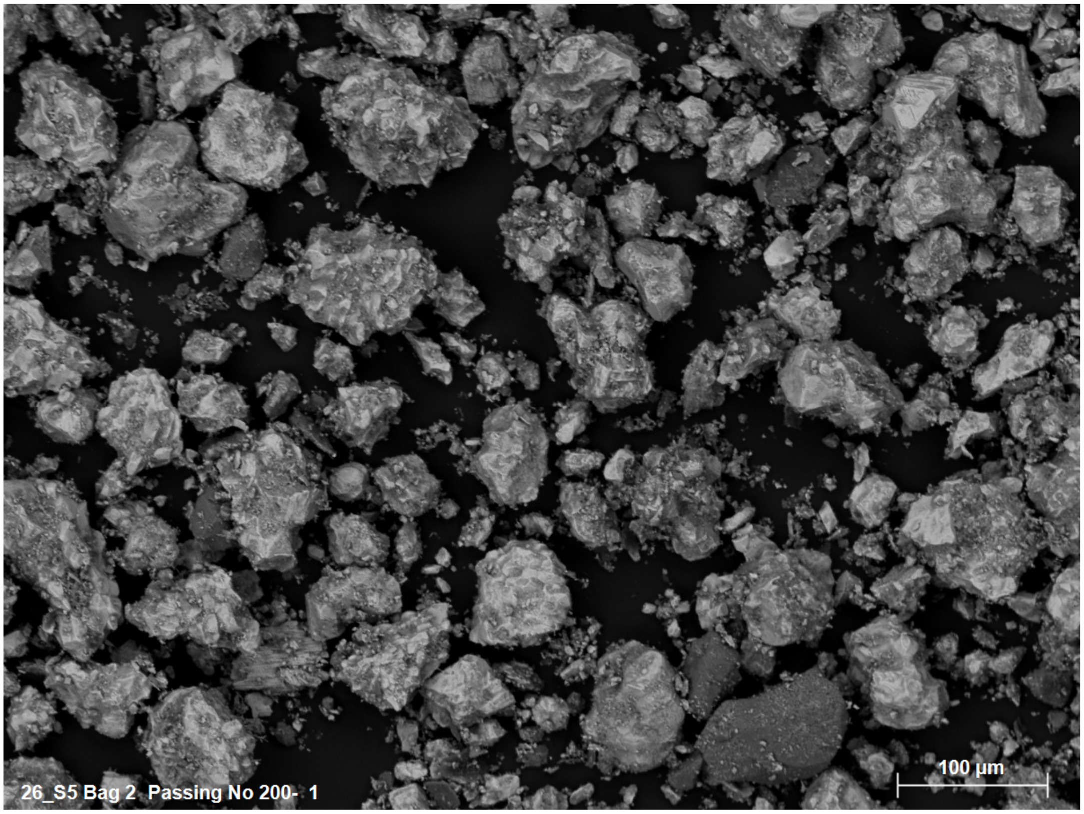

400 µm
23_S5 Bag 2 No 60- 3

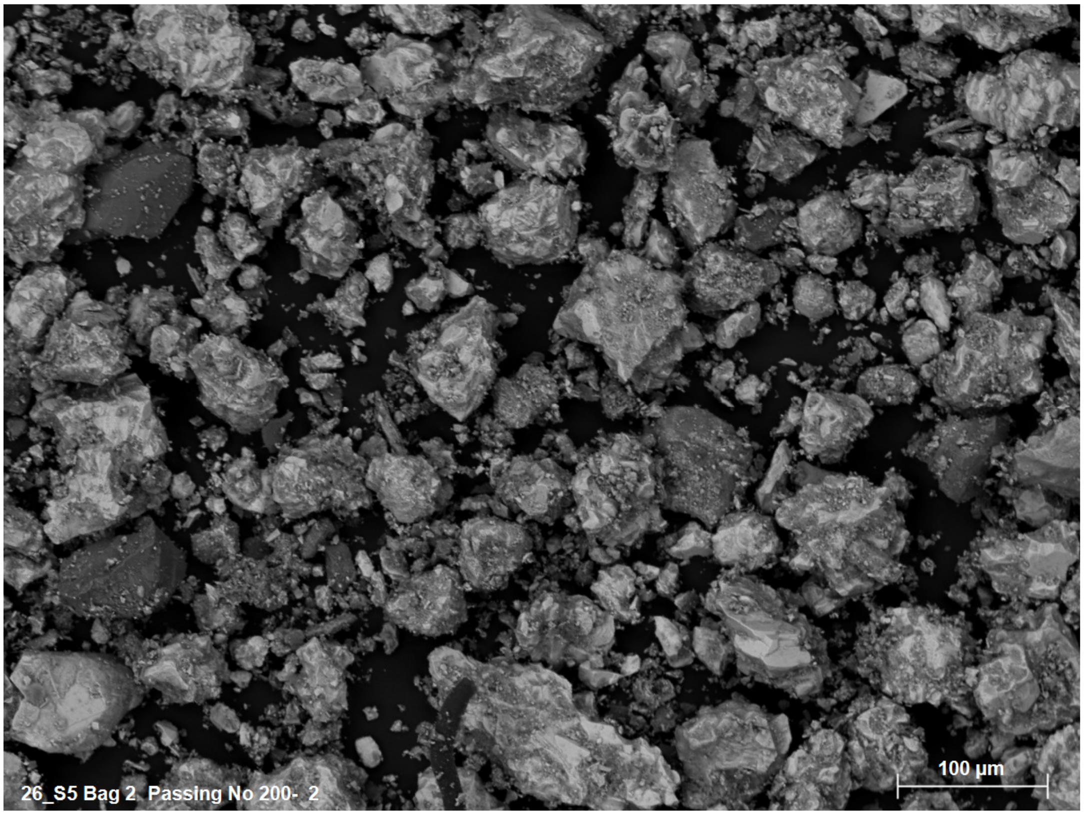

400 µm
24_S5 Bag 2 No 100- 1


400 µm
24_S5 Bag 2 No 100- 2


300 µm
25_S5 Bag 2 No 200- 1


25_S5 Bag 2 No 200- 2
300 µm


26_S5 Bag 2 Passing No 200- 1
100 µm


26_S5 Bag 2 Passing No 200- 2
100 µm

Appendix E

Annex 6 – Scanning Electron Microscopy Testing Report

December 2019

University of Queensland Scanning Electron Microscope (SEM) Testing Report

THE UNIVERSITY
OF QUEENSLAND
AUSTRALIA

Professor Gordon Southam
School of Earth & Environmental Sciences
The University of Queensland
St.Lucia, QLD 4072
Tel: +617 3365 8505
Fax: +617 3365 6899
Email: g.southam@uq.edu.au

CRICOS PROVIDER NUMBER 00025B

November 2019

Attention: Klohn Crippen Berger

Re: Laboratory Testing to Evaluate Cementation (Bonding) in Tailings Samples

Introduction

Additional laboratory testing was carried out by the University of Queensland (Australia) in order to better understand the physical nature of the tailings samples described below, and their characteristics of cementation (bonding), in order to evaluate whether such characteristics is a function of particle size, or can be attributed to the process of sample preparation and strength testing.

Samples Tested

Samples were received from the Klohn Crippen and Berger (KCB) laboratory in Vancouver, Canada. The samples were comprised of:

1. Slimes
2. Untested Average Gradation (a mixture of Fine and Coarse Tailings after sample preparation [drying and sieving], but before strength testing)
3. Tested Average Gradation (a similar mixture of Fine and Coarse Tailings after sample preparation [drying and sieving] and strength testing)

The photograph of the Slimes sample (Figure 1) shows an agglomerated lump that could physically be broken to a fine powder consisting of particles typically ≤ 10 µm in size. In contrast, the untested and tested Average Gradations were a mixture of mm- to µm-sized particles.

Figure 1. Photograph of Slimes sample

Testing Methodology – Scanning Electron Microscopy (SEM)

Sub-samples of each of the three supplied samples were dried in a 40°C oven overnight (the oven temperature was limited to avoid excessive alteration of the samples), vacuum embedded in plastic, and polished to sub-µm-size for Back Scattered Electron (BSE) SEM. The dried sub-samples proved difficult to embed in plastic, and were first examined using Secondary Electron SEM (SE-SEM).

For the BSE-SEM examination, each sub-sample was re-embedded in plastic, re-polished, degassed at 50°C overnight and coated with 10 nm iridium using a Quorum Q150T sputter coater prior to examination using a JEOL7100 SEM in BSE-mode with an accelerating voltage of 15 kV.

Results

SE-SEM imaging of the Slimes sub-sample highlighted the consolidated nature (Fig. 1 and Fig. 2a) of this fine-grained, ≤10-µm-sized material (Fig. 2b). At high resolution (Fig. 2c and d), sub-µm-scale thin films of secondary iron oxides were observed coating the µm- to 10-µm-sized particles.

BSE-SEM imaging showed the Slimes to be a generally homogenous (Fig. 3), comprising predominantly iron oxides, with minor clay and quartz. X-Ray diffraction (XRD) analysis of the Slimes revealed that the Slimes comprised 40 to 50% hematite, about 30% goethite, 5 to 10% kaolinite, about 5% quartz, and other minor minerals.[1] At high magnification, the 10's of µm-sized particles were enclosed within the sub-µm clay-sized matrix.

The untested and tested Average Gradation sub-samples could not be differentiated using SEM imaging. Both were observed to comprise both individual particles and bonded particles (Fig. 4). In both samples, fine-grained µm clay-sized particles acted as cements, bonding smaller (10's of µm-sized) particles to larger (100's of µm-sized) particles (Fig. 4A and C), and bonding smaller particles together (Fig. 4B and D). Although less dominant, clay minerals also played a role in bonding these particles (Fig. 5). XRD analysis of the Fine Tailings revealed that they comprised 40 to 55% hematite, 10 to 20% goethite, 1 to 2% magnetite, 10 to 30% quartz, 5 to 15% kaolinite, and other minor minerals.[2] XRD analysis of the Coarse Tailings revealed that they comprised 80 to 90% hematite, 5 to 10% magnetite, about 3% goethite, 1 to 2% quartz, and <1% kaolinite and other minerals.[3]

---

[1] See Annex E4.

[2] See Annex E4.

[3] See Annex E4.

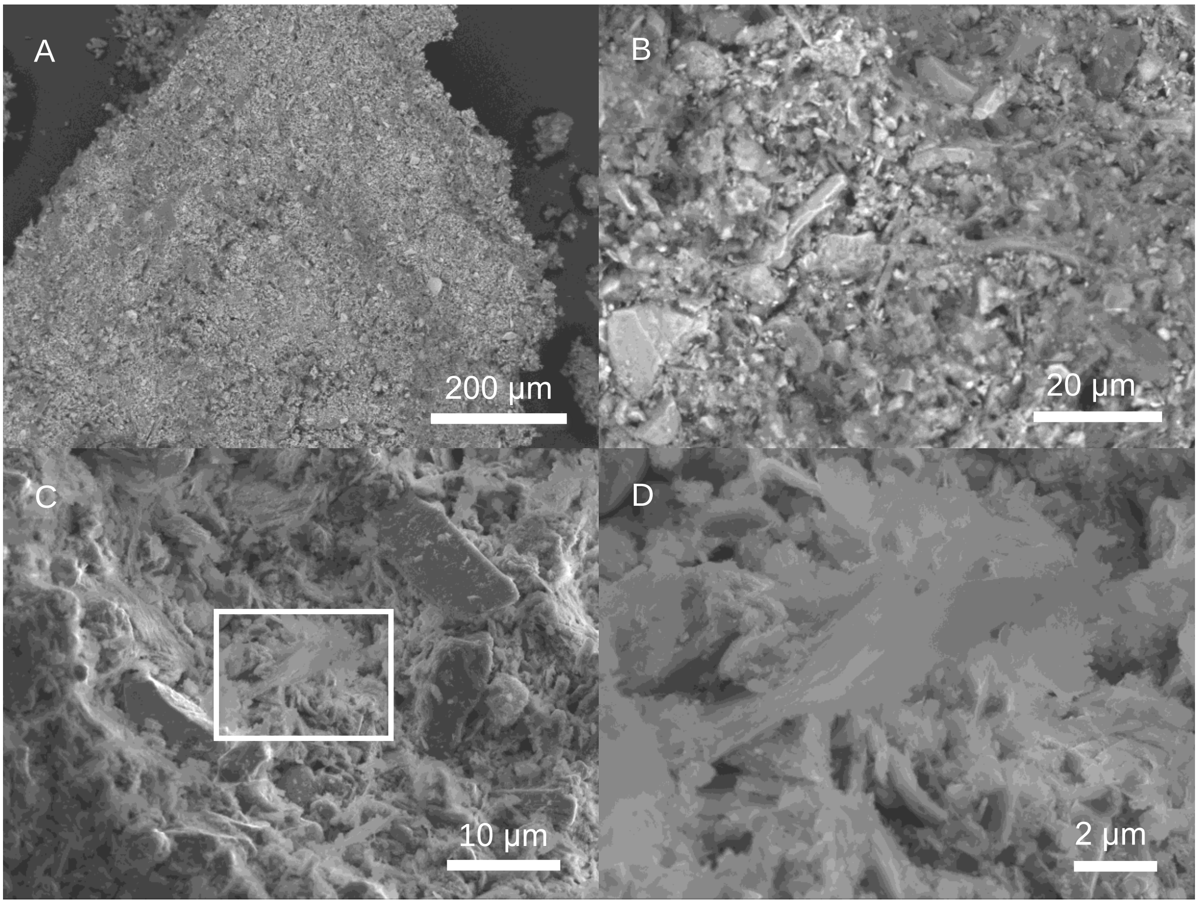


Figure 2. Representative SE-SEM micrographs of the Slimes sub-sample highlighting the fine-grained nature of the agglomerated material (images A and B), and the presence of thin films of platy, secondary iron oxide coatings (images C and D). The box in image C corresponds to image D, highlighting one of these coatings.

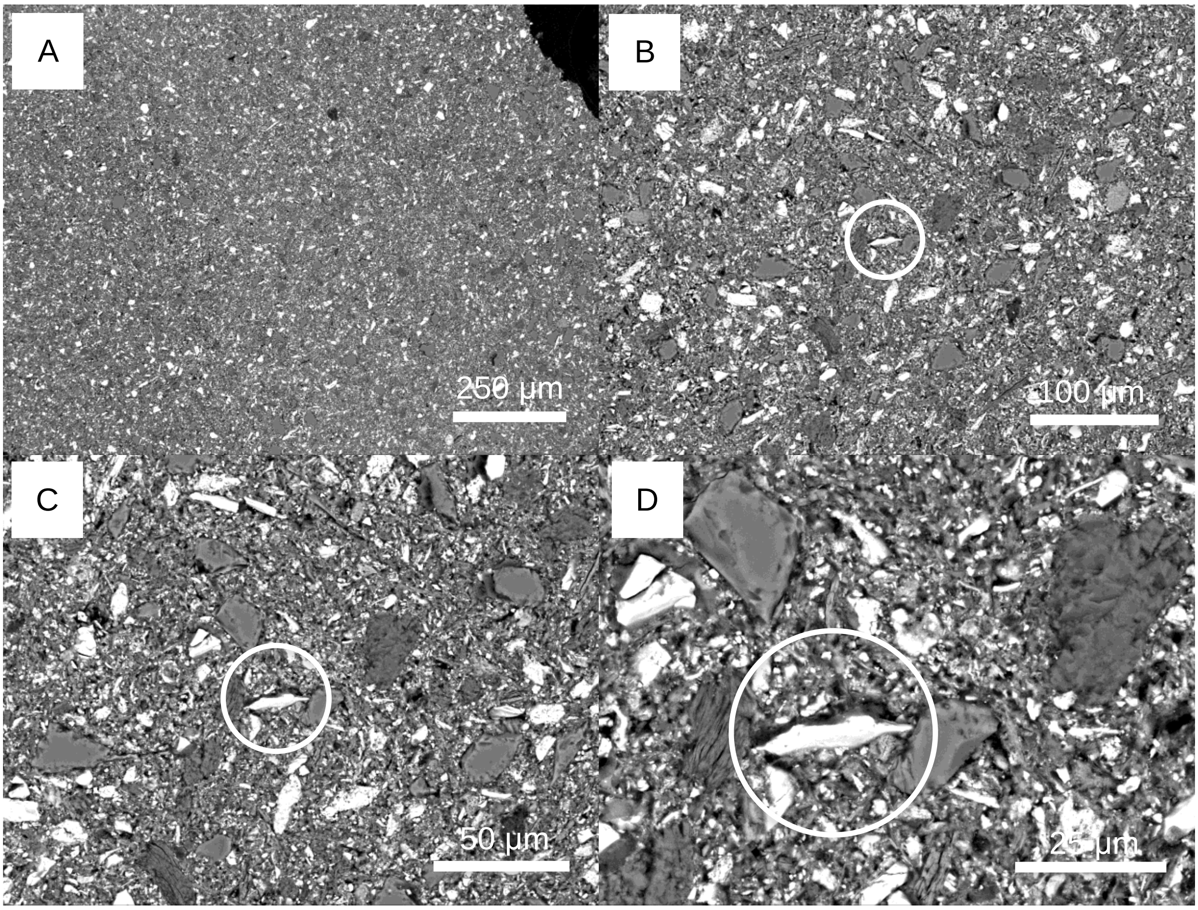


Figure 3. A focal series of representative BSE-SEM micrographs of the Slimes sub-sample, demonstrating the generally homogenous distribution of fine-gained particles. The circles in images B to D highlight the same iron oxide particle. In image D, the three main materials that comprise the sample are clearly visible: iron oxide (bright material; e.g., the circled grain), quartz (light grey, ‘solid’ with conchoidal fractures), and the layered clay minerals (darkest grey-scale material).

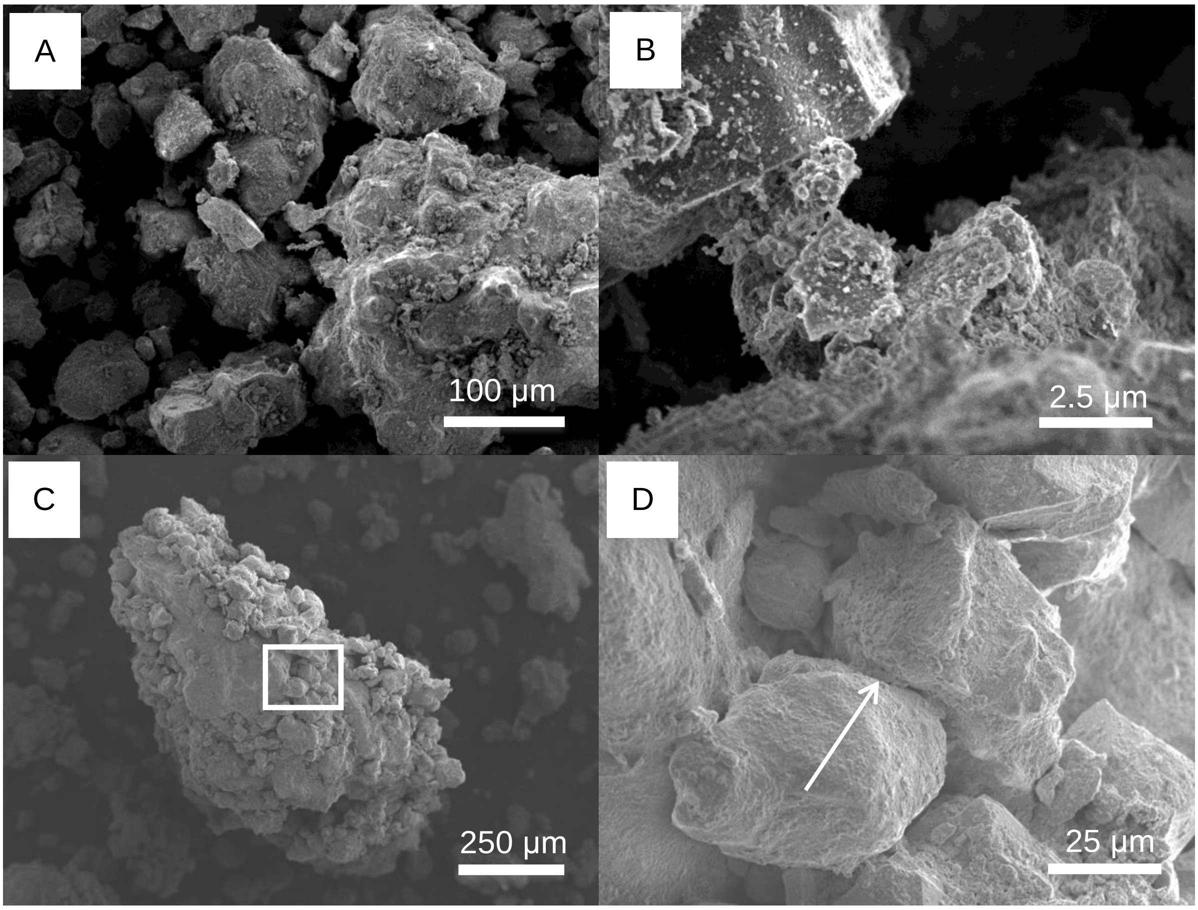


Figure 4. Representative SE-SEM micrographs of untested (images A and B) and tested (images C and D) Average Gradation sub-samples showing fine particles bonded to, and cross-linking, larger particles (images A and C versus image B), in which fine-grained clay-sized particles appear to act like a column of cement linking two smaller particles. The finer-grained particles in image C are iron oxide nodules, and these are in turn bonded to the larger particle by iron oxide cement. The box in image C corresponds to image D, highlighting small iron oxide nodules that are bonded by coatings of µm-scale clay-sized iron oxide cement (arrow).

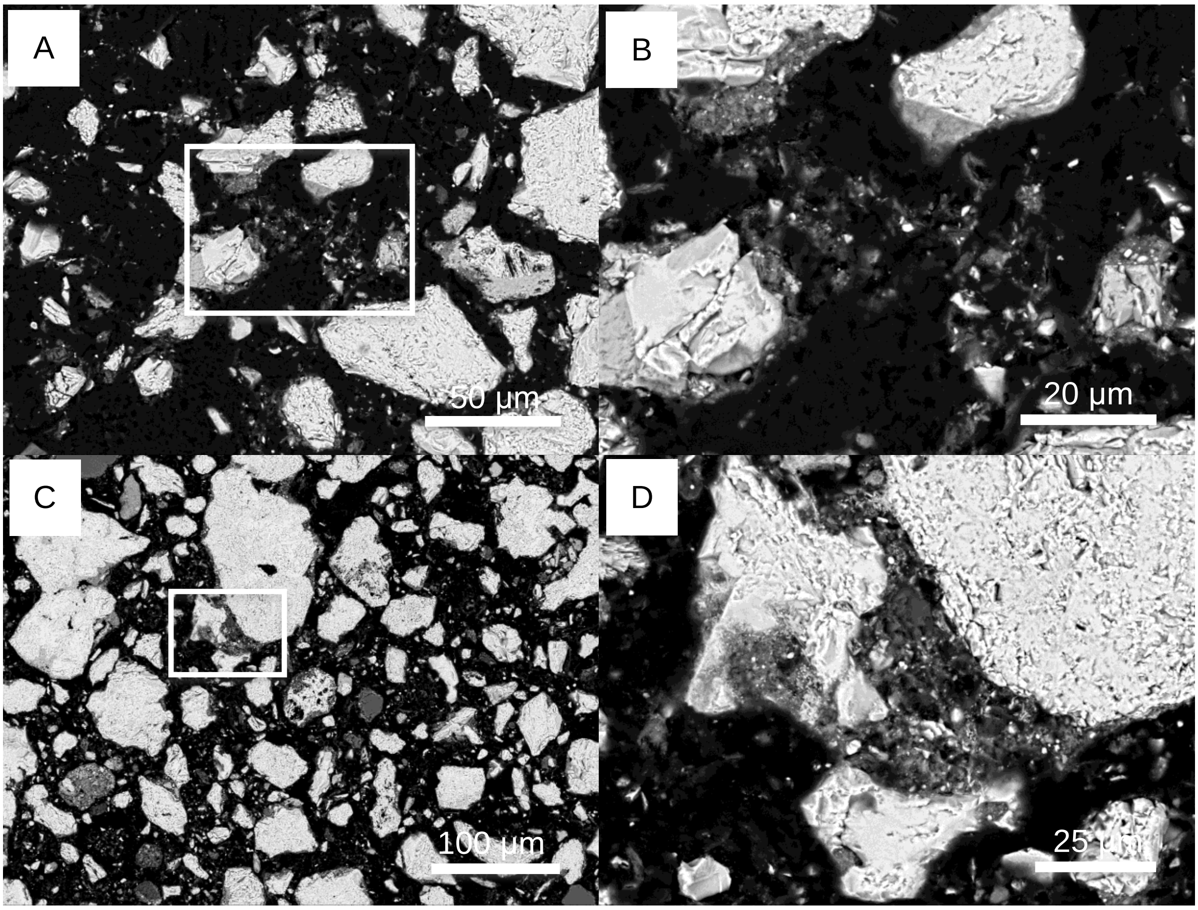


Figure 5. Representative BSE-SEM micrographs of untested (images A and B) and tested (images C and D) Average Gradation sub-samples. The boxes in images A and C correspond to the images in B and D, respectively. Note the distribution of µm-scale iron oxide, quartz and clay-sized particles between the 10's to 100's of µm-scale clasts, in particular, the iron oxide clasts in image D, which have bonded to one other via finer-grained particles.

Discussion and Interpretation

The purpose of the testing was to better understand the physical nature of the iron ore tailings, and their cementation (bonding) in particular, as a function of particle size, and as a result of sample preparation and strength testing. Further, it was also intended to investigate whether sample preparation and strength testing resulted in a loss of bonding between particles and hence a loss of strength.

Thin films of secondary iron oxides were observed on the Slimes, but were not observed in the untested and tested Average Gradation samples. The likely explanation for this is the very much greater surface area per unit volume of the finer-grained Slimes, which provided more opportunity for secondary iron oxide formation and bonding. Although they were not observed in the Average Gradation samples, based on their observation and structure in the Slimes sample, any secondary iron oxide thin films present in undisturbed Fine and Coarse Tailings may have been destroyed by sampling, sample preparation and testing.

The widespread occurrence of clay-sized iron oxides in the Average Gradation samples suggests that they may be responsible for the transient strength of the Average Gradation samples. The clay-sized iron oxides are a constant in all three samples, coating, linking and bonding larger particles to one another.

Dr. Gordon Southam

BSc Microbiology, PhD Microbiology

Appendix E

Annex 7 – Soil-Water Characteristic Curves

December 2019

University of Alberta Soil Water Characteristic Report

Final Report

for

Soil Water Characteristic Curve Measurements

Prepared for

Klohn Crippen Berger

by

Dr. Louis K. Kabwe
University of Alberta Geotechnical Center

November 26, 2019

1. INTRODUCTION

This report presents detailed data for twelve (12) measured soil-water characteristic curves (SWCC). The tables and figures in the main body of the report summarize the results for each of the tests. The tables and figures are briefly discussed. Also given are figures that compare the test results of the two methods used: i) the Tempe cell and ii) the HYPROP 2 device.

In summary, the results show the air entry values (AEV) for the samples tested ranged from 3 to 40 kPa. These are characteristic of sand and silt. Results also show that the two methods used yield comparable results.

2. BACKGROUND

The SWCC has become a valuable tool for the estimation of unsaturated soil property functions in geotechnical engineering practices (Fredlund and Rahardjo, 1993; Fredlund, 2002). The SWCC is used to describe the relationship between the amount of water in the soil and the corresponding values of matric suction ($u_a - u_w$). The SWCC is commonly measured using the Tempe pressure plate cell for soils with low to moderate AEVs up to 500 kPa and can require several weeks to complete, depending on soil type. The newly developed HYPROP 2 device (METER Environment, 2018) takes only days to generate a SWCC in the wet range (up to 300 kPa) and it does this automatically. The objective of this testing program was to measure the SWCC of various samples using the Tempe cell and HYPROP 2 devices.

3. DEVICES AND TEST PROCEDURES

3.1 Apparatuses

Two devices were used in this testing program: a Tempe pressure cell apparatus and a new HYPROP 2 device (METER Environment, 2018). The Tempe cell apparatus is shown in Figure 1 and the HYPROP 2 device is shown in Figure 2. The Tempe cell device is made up of three main components (see Figure 1): i) the bottom part fitted with a 500 kPa (5 bar) ceramic high air entry disc and an outlet for water from the sample, ii) an acrylic cylinder (7 cm in diameter x 9 cm high) to hold the sample, and iii) a top cap fitted with an inlet for air pressure supply. The HYPROP 2 device (see Figure 2) comprises a bottom part fitted with two mini-tensiometers to measure water potential and a cell (8 cm in diameter x 5 cm high) to hold the sample and a balance for weighing the sample.

Figure 1. Tempe Cell Components and Measurement Set Up

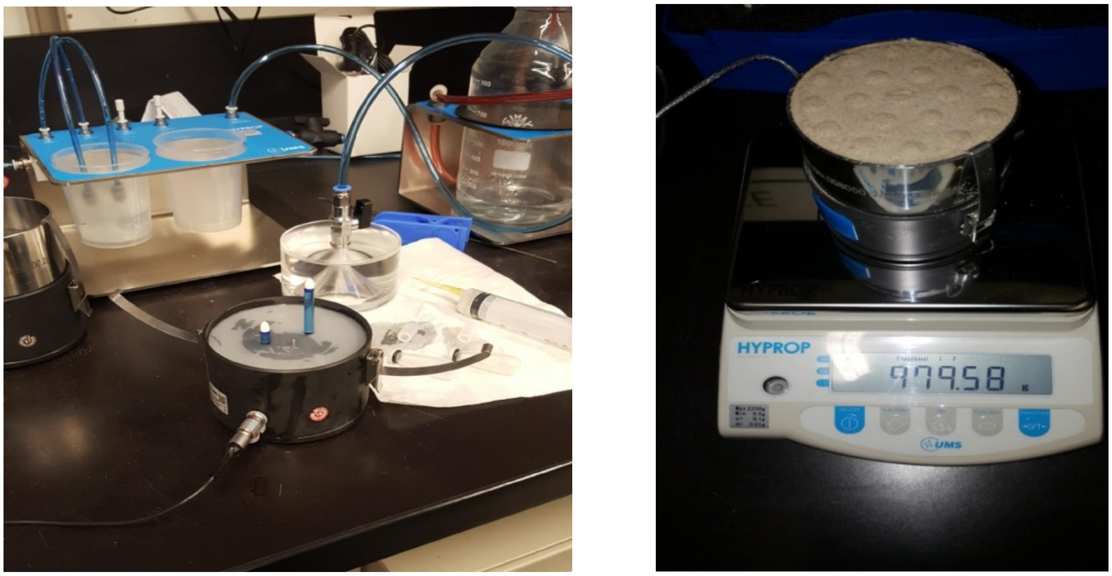


Figure 2. HYPROP 2 Components and Measurement Set Up

3.2 Tempe Cell Test Procedure

The SWCC was measured following the standard method recommended by Fredlund and Rahardjo (1993). Once a saturated sample is confined in a Tempe cell (Figure 1), the air pressure is applied over the sample through the inlet on top of the cap and porewater released from the sample is collected at the base of the cell. The change in mass of the sample is monitored by weighing the overall mass of the soil specimen until the mass change stops, and it is assumed that equilibrium is reached. At this stage, the applied air pressure is equal to the soil suction. Higher air pressure steps are applied until the maximum suction is reached. At the end of the test, the sample is removed from the cell and the final water content is determined by oven-drying. This water content together with the previous changes in weight are used to back-calculate the water contents corresponding to each suction value. The matric suction is then plotted against corresponding water contents to give the SWCC.

3.3 HYPROP 2 Test Procedure

Before measurement, a saturated sample is confined in a measuring cell and two precision mini-tensiometers are inserted in the sample to measure water potential at different levels within the saturated soil sample while the sample rests on a laboratory balance. The HYPROP 2 is set up to run automatically. The HYPROP-Fit software detects the balance, and the measuring head automatically assigns measuring values to the tensions. Over time, the sample dries, and the instrument measures the changing water potential and the changing sample weight simultaneously. Moisture content is calculated from the weight measurements, and the instrument plots' changes in water potential correlated to changes in moisture content. HYPROP 2 generates a SWCC of soil samples in 3 to 9 days.

4. SAMPLES

Samples tested were received in plastic bags. The amount of material in each bag ranged from 200 g to 6.5 Kg. The samples for Tempe cell tests were dried in an oven at 105 °C, prior to the tests. Samples for HYPROP 2 testing were used directly from their storage bags. All the tests were carried out in the Unsaturated Soil Mechanics Laboratory of the University of Alberta Geotechnical Centre.

Table 4.1. Summary of Samples Selected for Testing

Sample Name	**Sample Mass (g)**	**Tempe Cell**	**Hyprop**
DT-01	3400	X	
DT-02	5400	X	X
DT-06	5260	X	X
DT-10	4100	X	
GP-03/09	680	X	X
GP-14	770	X	X
AG A03255A01		X	X

5. SUMMARY OF TESTS RESULTS

5.1 SWCCs Measured using the Tempe Cell

5.1.1 Testing Status

Table 5.1. Summary of Test Status using the Tempe Cell

Sample ID	**SWCC**	**Notes**
DT-01	Completed	Fine Tailings
DT-02	Completed	Fine Tailings
DT-06	Completed	Fine Tailings
DT-10	Completed	Fine Tailings
AG A03255A01	Completed	Coarse Tailings
GP-03/09	Completed	Loose Residual Topsoil
GP-14	Completed	Loose Residual Topsoil

AG: Average Gradation

5.1.2 Summary of Tempe Cell Test Results

Table 5.2. Summary of Tempe Cell SWCC Properties

Sample ID	**AEV (kPa)**
DT-01	~ 15
DT-02	~ 20
DT-06	~ 40
DT-10	~ 15
AG A03255A01	~ 9
GP-03/09	~ 3
GP-14	~6

AEV = Air Entry Value

In summary, the AEV of the samples tested and completed using the Tempe cell ranged from 3 to 40 kPa, which are characteristic of sand and silt. Figure 3 shows the measured SWCCs completed using the Tempe cell method.

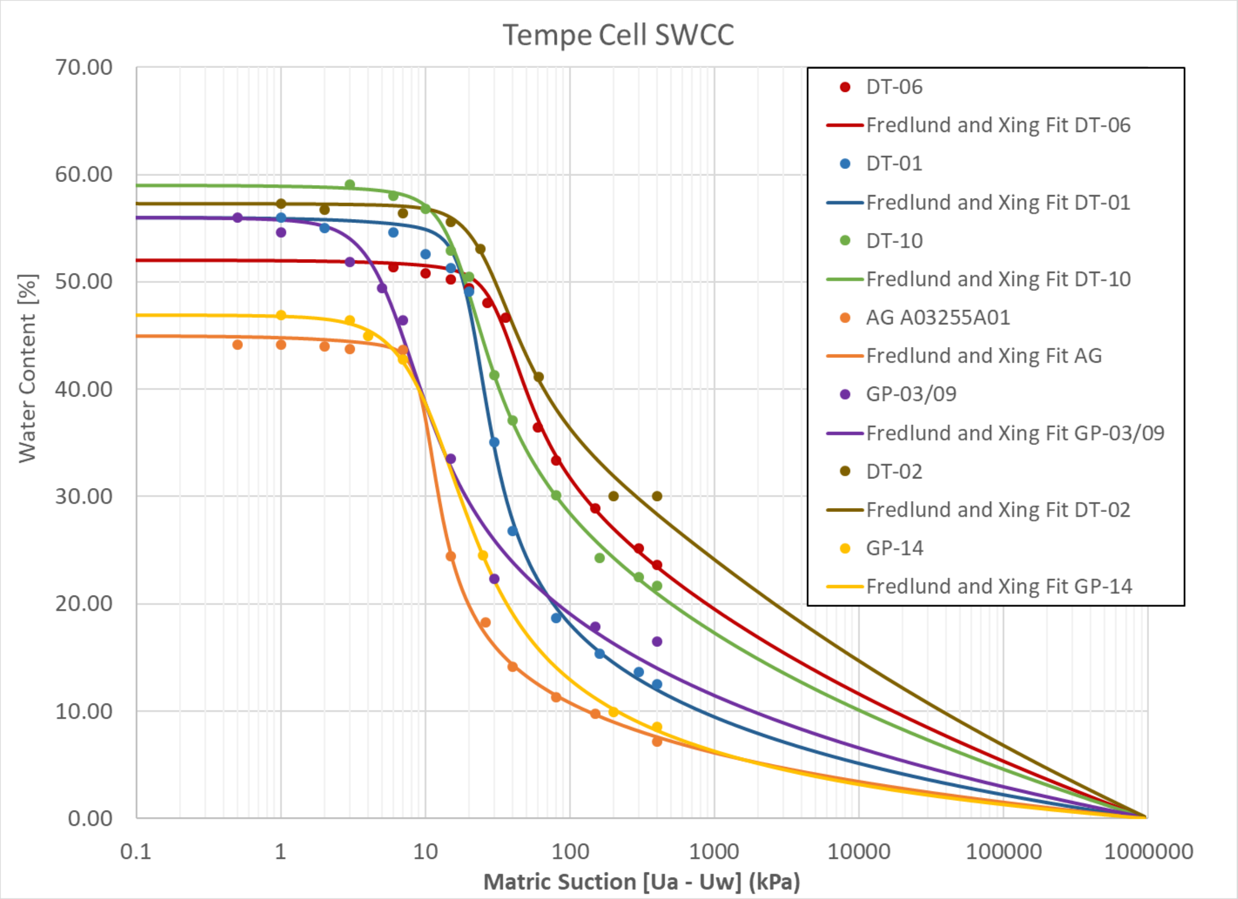


Figure 3. SWCC Plots Measured using the Tempe Cell

5.2 SWCCs Measured using the HYPROP 2 Device

5.2.1 Testing Status

Table 5.3. Summary of Test Status using HYPROP 2 Device

Sample ID	SWCC	Notes
DT-02	Completed	
DT-06	Completed	Power loss during test
AG A03255A01	Completed	
GP-03/09	Completed	
GP-14	Completed	

AG: Average Gradation

5.2.2 Summary of Test Results

Table 5.4. Summary of HYPROP SWCC Properties

Sample ID	AEV (kPa)
DT-02	~30
DT-06	~40
AG A03255A01	~ 8
GP-03/09	~ 4
GP-14	~ 3

In summary, the AEV of the samples tested and completed up to date using the HYPROP 2 device ranged from 3 to 40 kPa, which are characteristic of sand and silt. Figure 4 shows the completed measured SWCCs using the HYPROP 2 method.

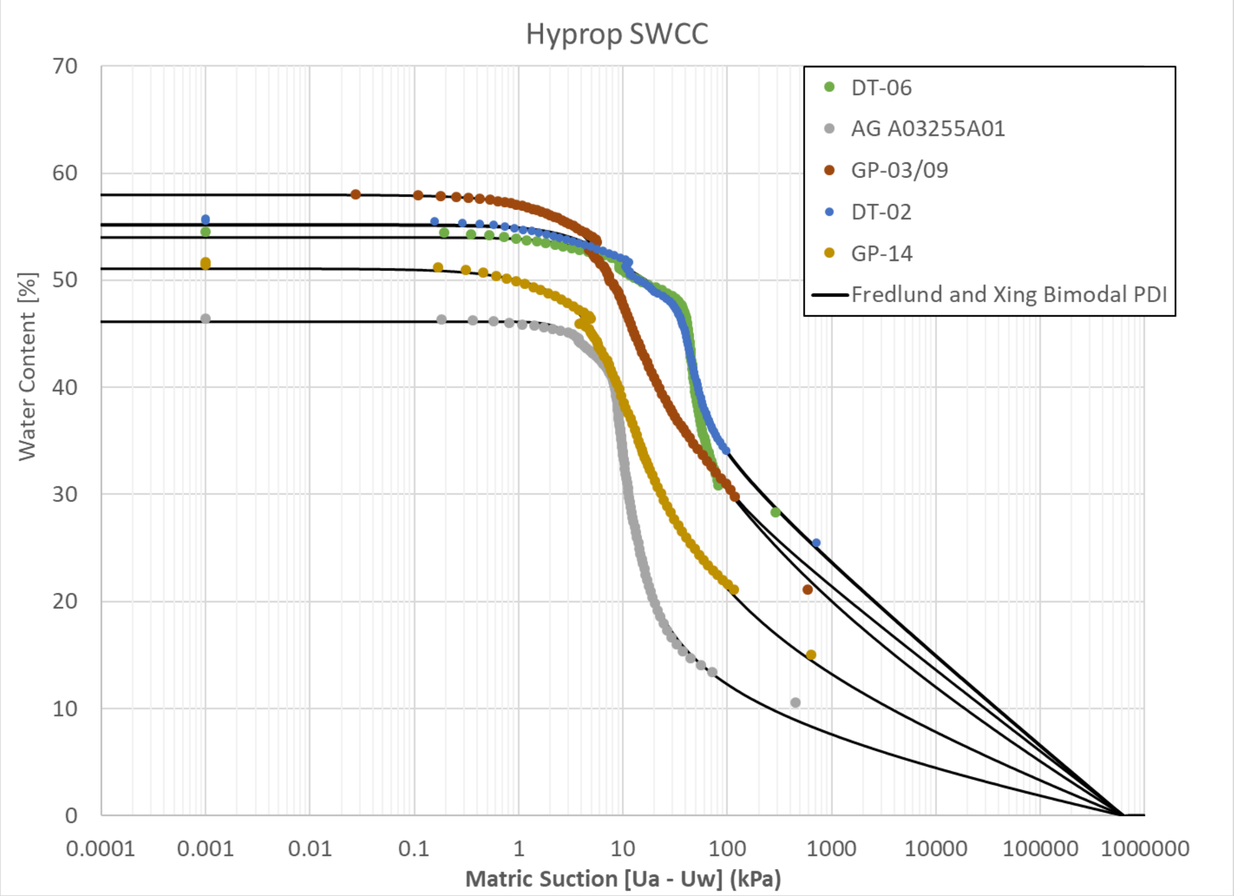


Figure 4. SWCC Plots Measured using the HYPROP 2 Device

5.3 Comparison between the Tempe Cell and HYPROP 2 Tests Results

The following figures display the HYPROP 2 data for each test separately, along with Tempe cell data. It is interesting to note that the Tempe cell and HYPROP 2 device yield comparable results in Figures 5 to 9.

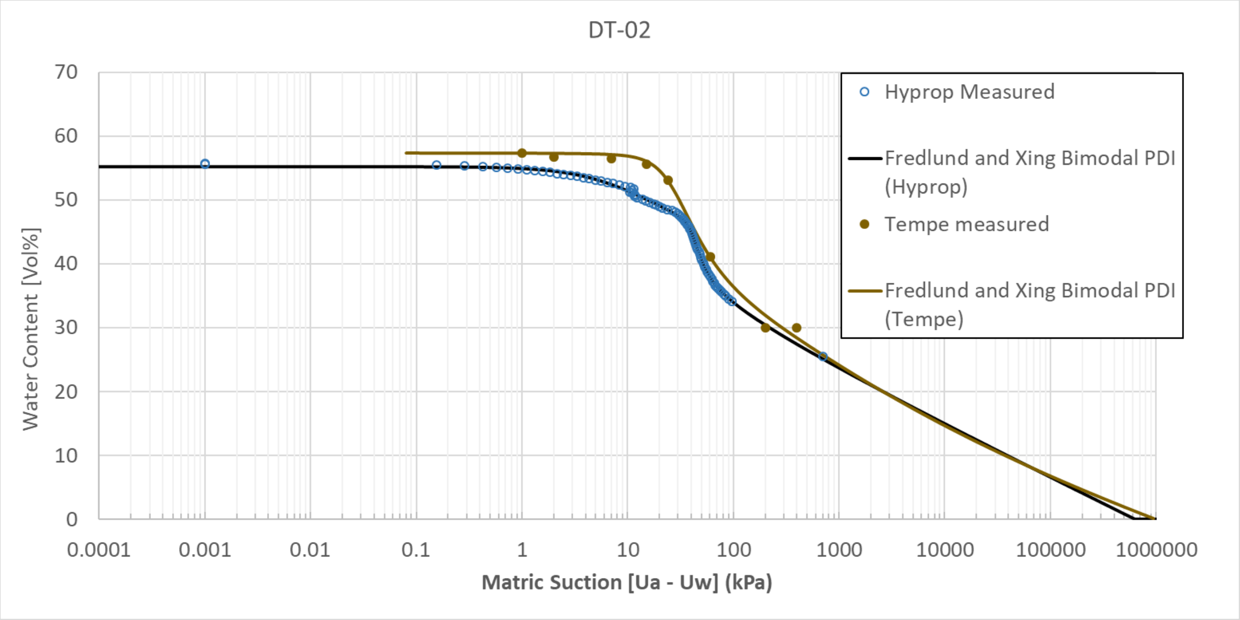


Figure 5. SWCC Data for DT-02

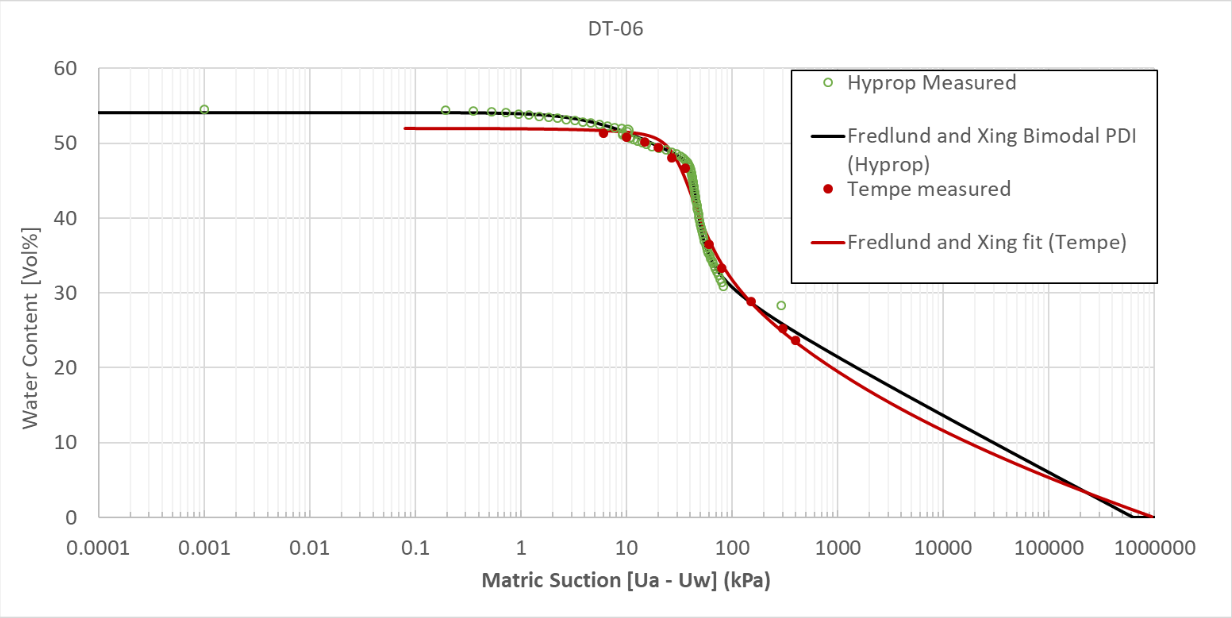


Figure 6. SWCC Data for DT-06

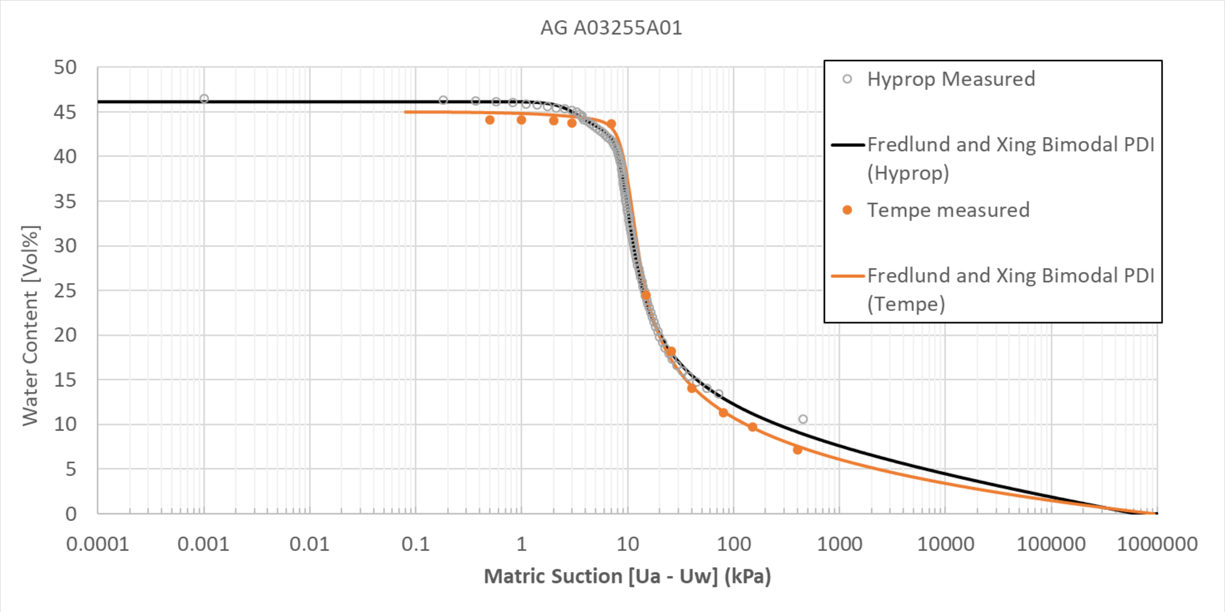


Figure 7. SWCC Data for AG A03255A01

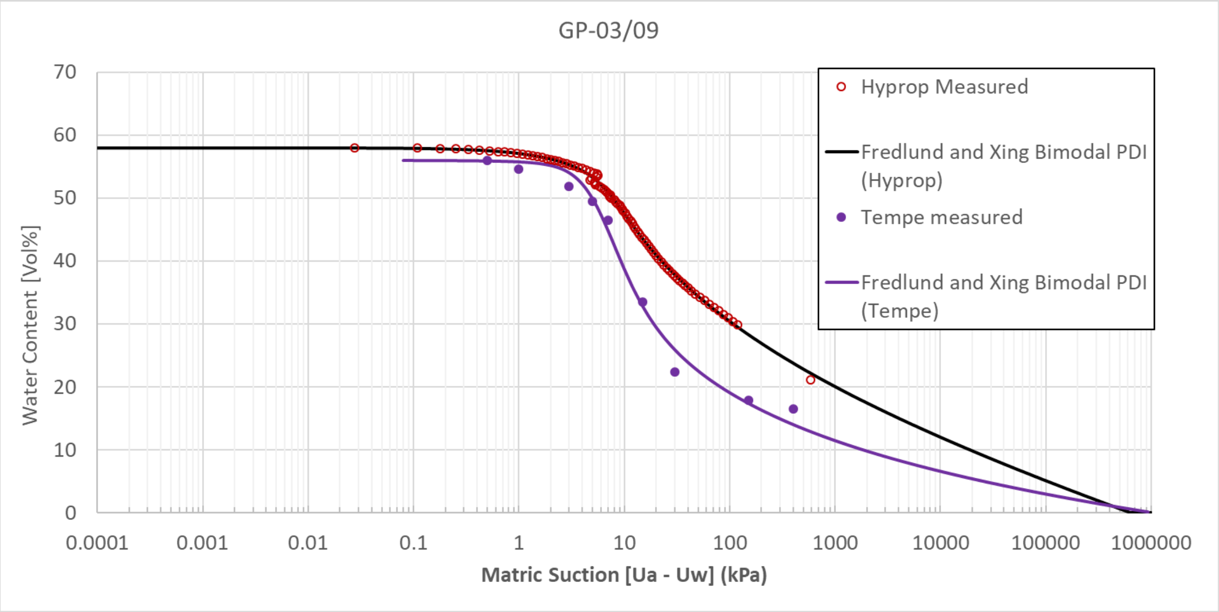


Figure 8. SWCC Data for GP-03/09

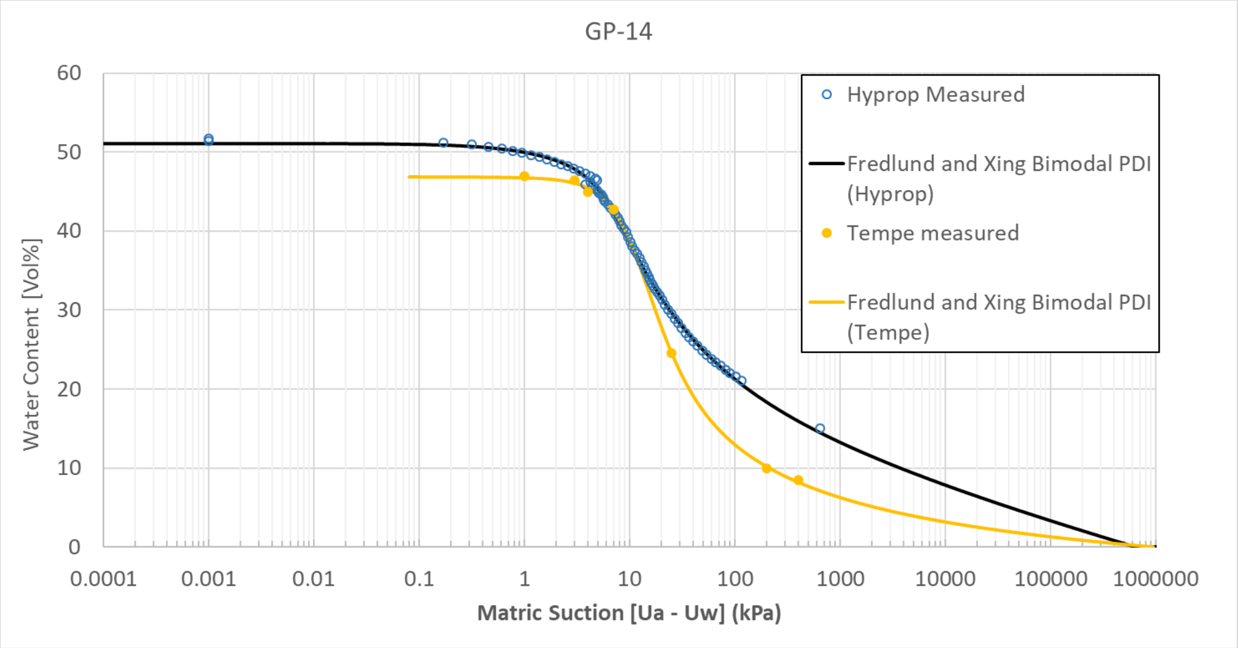


Figure 9. SWCC Data for GP-14

5.4 Summary

A total of 12 SWCCs curves have been completed. Five SWCCs have been completed with the HYPROP 2 Device and seven SWCCs have been completed using the Tempe Cell method.

6. REFERENCES

Fredlund, D.G. 2002. Use of soil water characteristic curve in the implementation of unsaturated soil mechanics. UNSAT 2002. Proceedings of the Third International Conference on Unsaturated Soils, Recife, Brazil, March 10-13, pp. 887-904.

Fredlund. D.G. and Rahardjo, H. 1993. Soil mechanics for unsaturated soils. John Wiley and Sons New York, N.Y.

HYPROP 2 User Manual v **2018**/3. METER Environment.

APPENDIX

Table A.1. Summary of Samples Received

SAMPLE NAME	MASS (kg)
DT-01	3.4
DT-02	5.4
DT-03	3.6
DT-04	6.44
DT-05	3.7
DT-06	5.26
DT-07	3.3
DT-08	5.04
DT-09	3.1
DT-10	4.1
DT-11	3.1
DT-12	2.5
DT-13	4.2
GP-01	0.17
GP-02-A	0.4
GP-02-B	0.27
GP-03	0.44
GP-04-A	0.8
GP-04-B	0.84
GP-05	0.16
GP-06	1.39
GP-07	0.64
GP-08	1.39
GP-09	0.24
GP-10	0.41
GP-11	0.61
GP-12	0.73
GP-13	1.17
GP-14	0.77
GP-15	0.36
GP-16	1.44

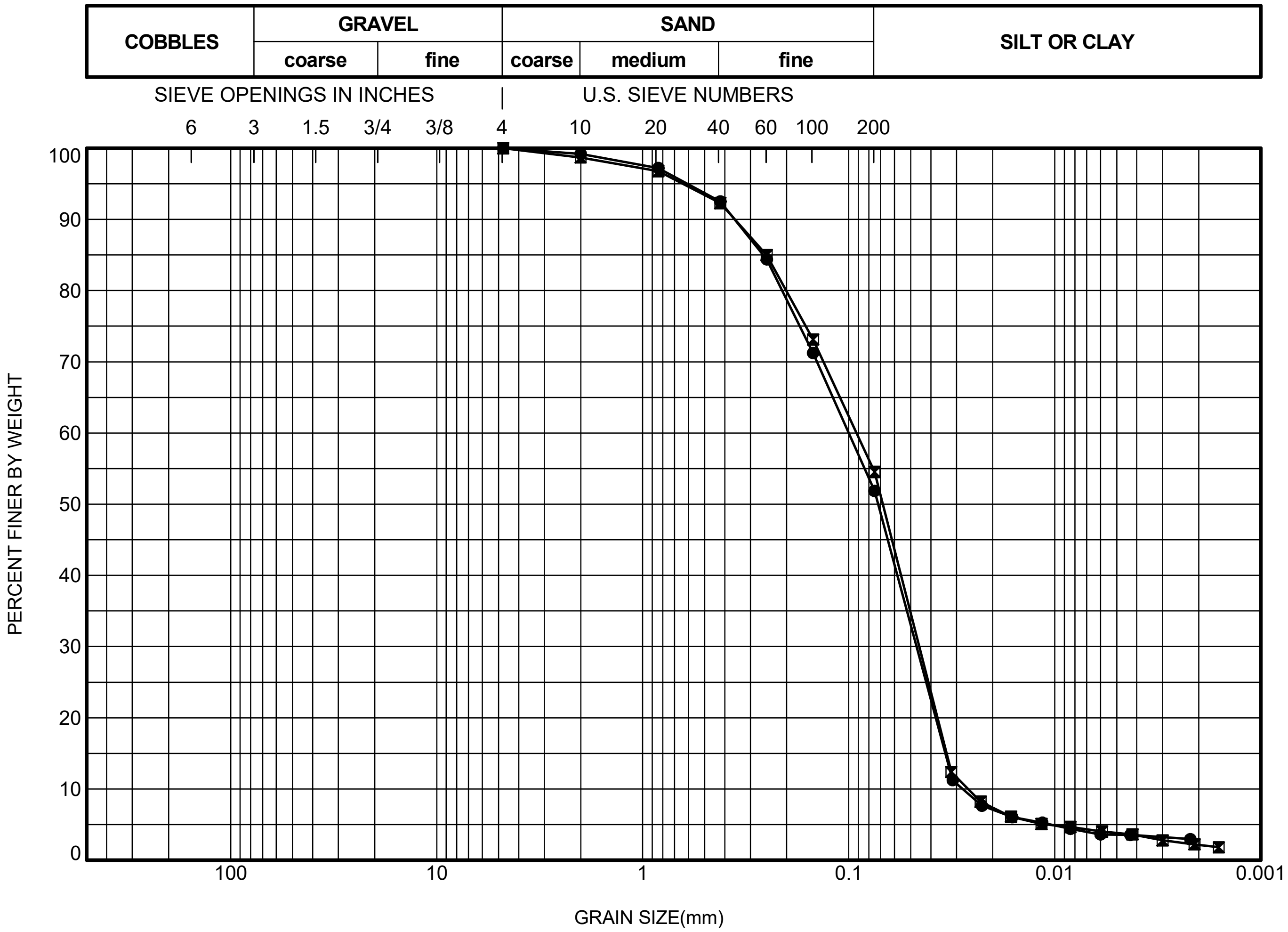
Appendix E

Annex 8 – Advanced Testing Data

December 2019

Particle Size Distribution of Triaxial Gradients

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX01-CID	0.00	0.260	0.100					0.0	48.1	51.9
☒	TX01-CID	0.00	0.251	0.092					0.0	45.5	54.5

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX01-CID	Average	0.00					Before Testing (TX01/TX05)
☒	TX01-CID	Average	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

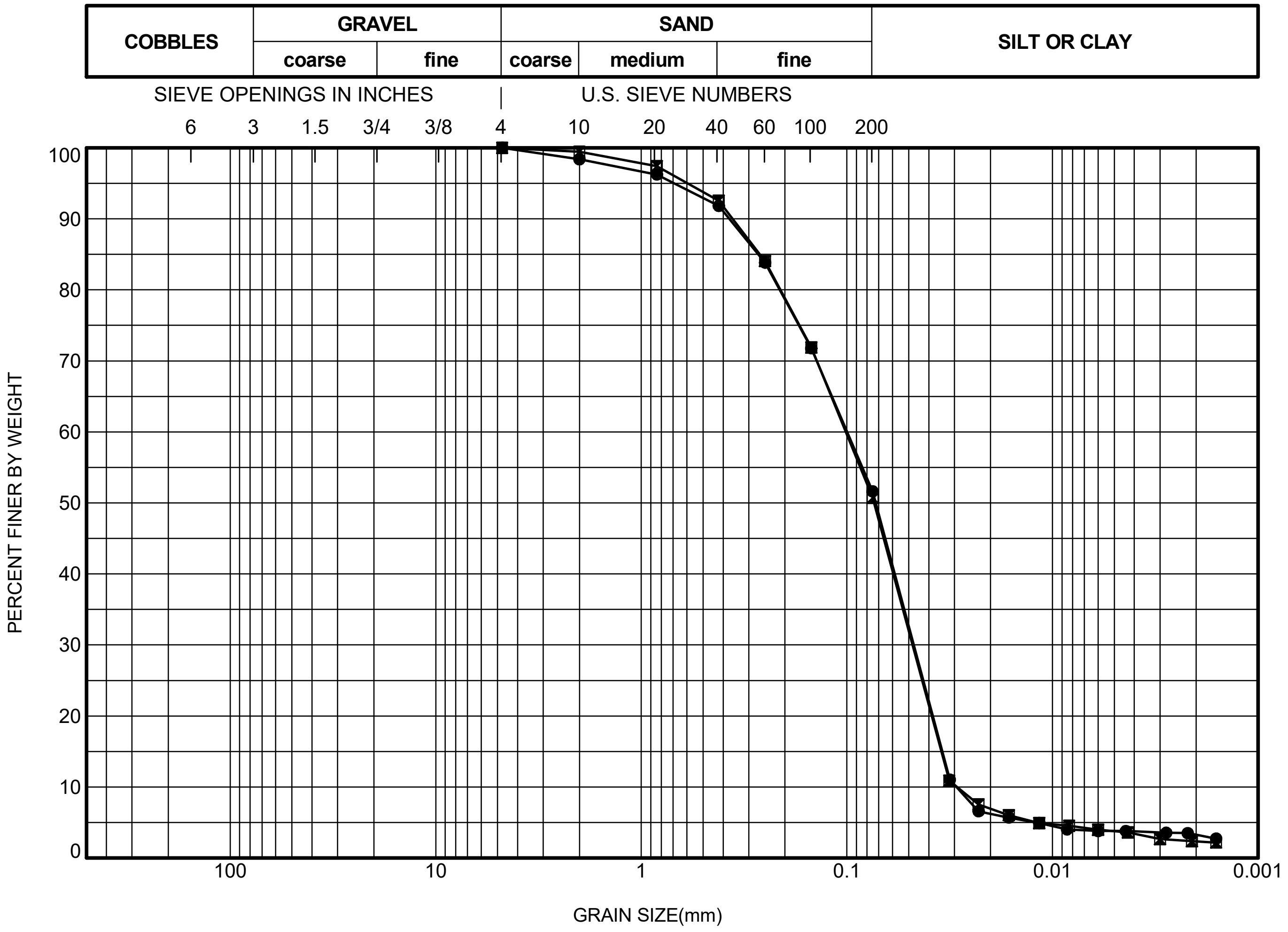
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX02-CID	0.00	0.270	0.100					0.0	48.4	51.6
☒	TX02-CID	0.00	0.265	0.101					0.0	49.3	50.7

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX02-CID	Average	0.00					Before Testing (TX02/TX03/TXBE01)
☒	TX02-CID	Average	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

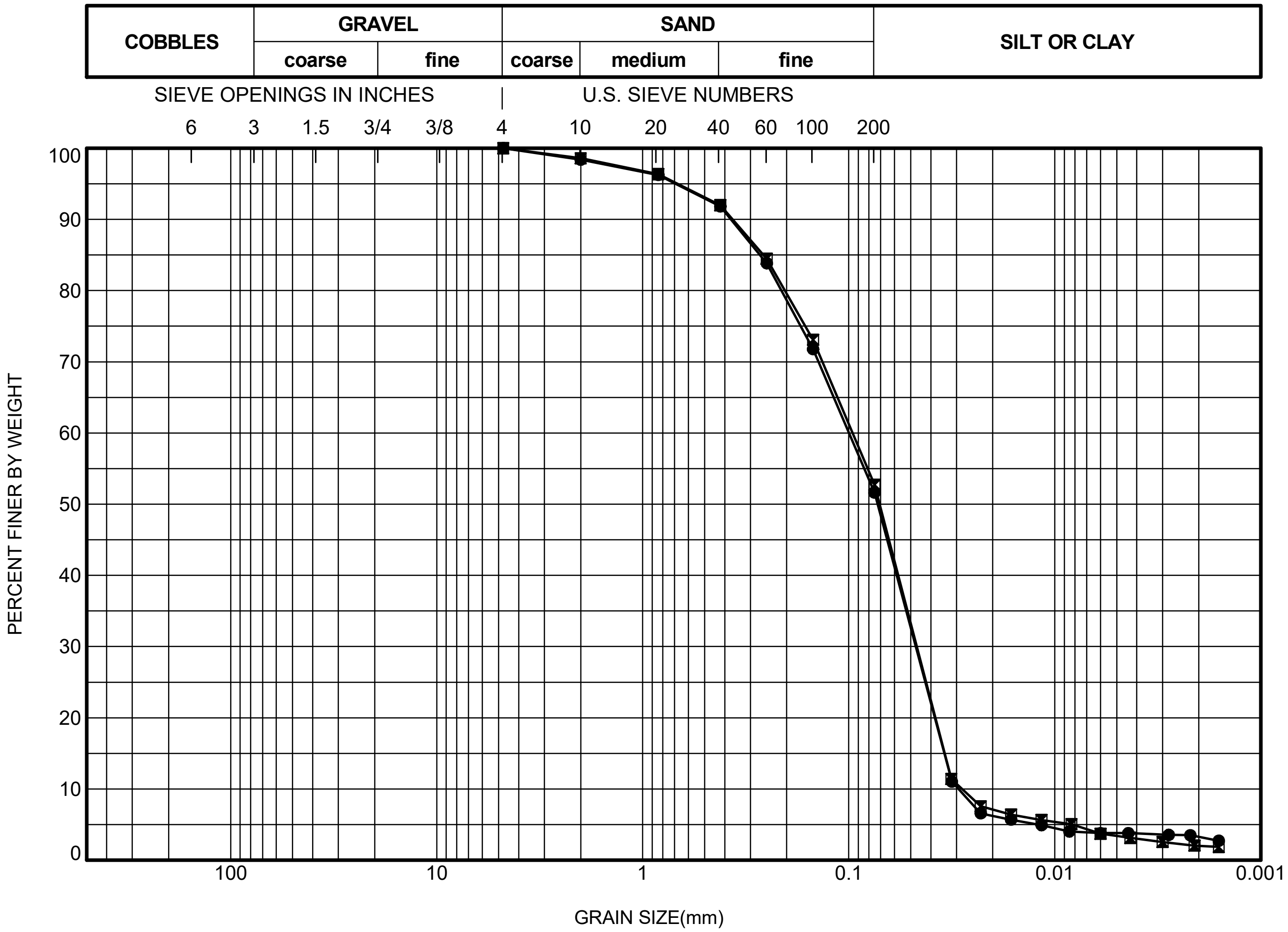
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX03-CID	0.00	0.270	0.100					0.0	48.4	51.6
☒	TX03-CID	0.00	0.260	0.096					0.0	47.3	52.7

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX03-CID	Average	0.00					Before Testing (TX02/TX03/TXBE01)
☒	TX03-CID	Average	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

PROJECT:

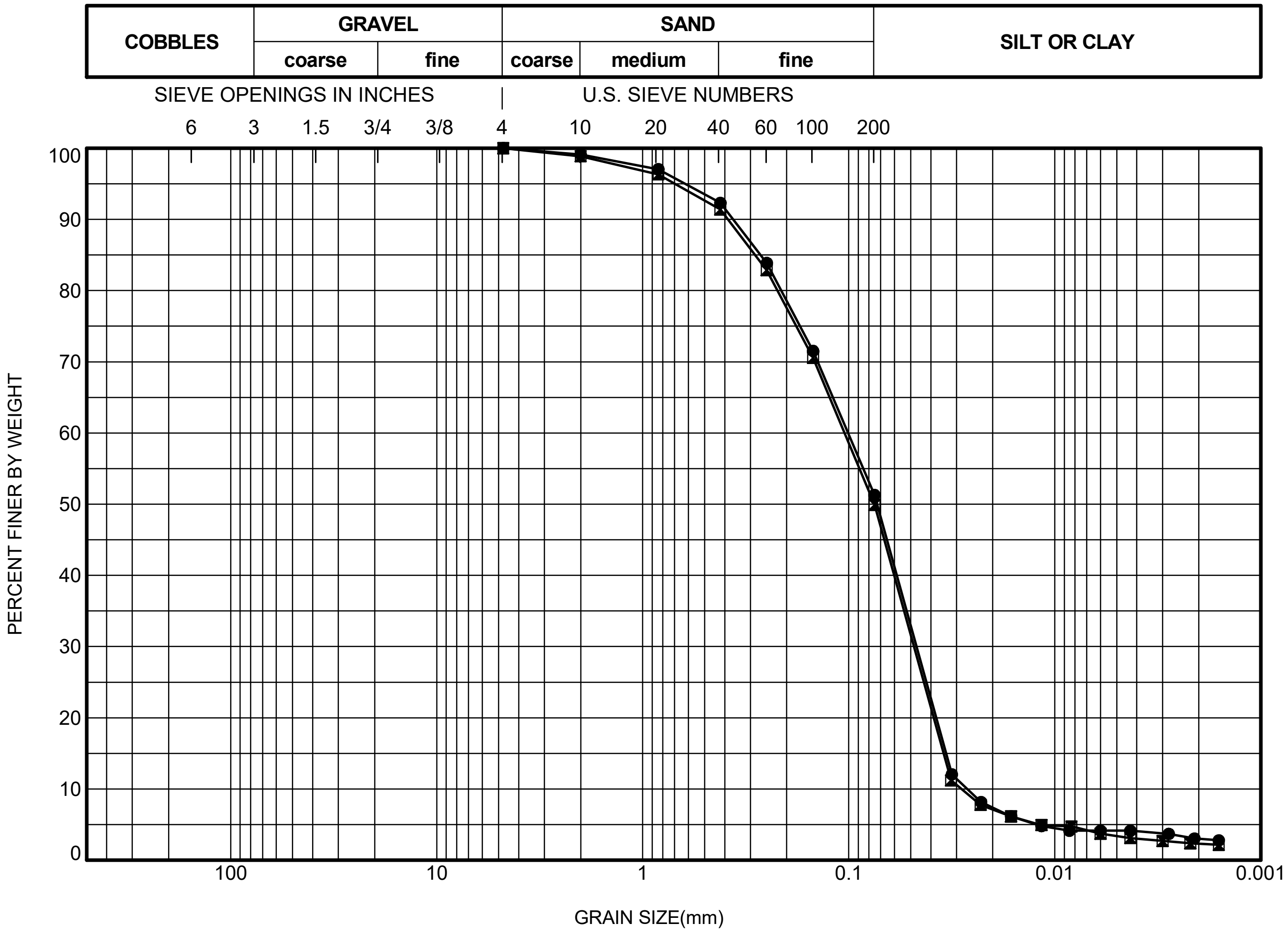
LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

KC_GRAIN_SIZE-SI A03355A01 TRIAXIAL TESTS PSDS.GPJ SIEVE.GDT 19-11-20

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX04-CIU	0.00	0.268	0.101					0.0	48.7	51.3
☒	TX04-CIU	0.00	0.285	0.105	0.075				0.0	50.1	49.9

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX04-CIU	Average	0.00					Before Testing (TX04/TX06/TXBE02)
☒	TX04-CIU	Average	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

PROJECT:

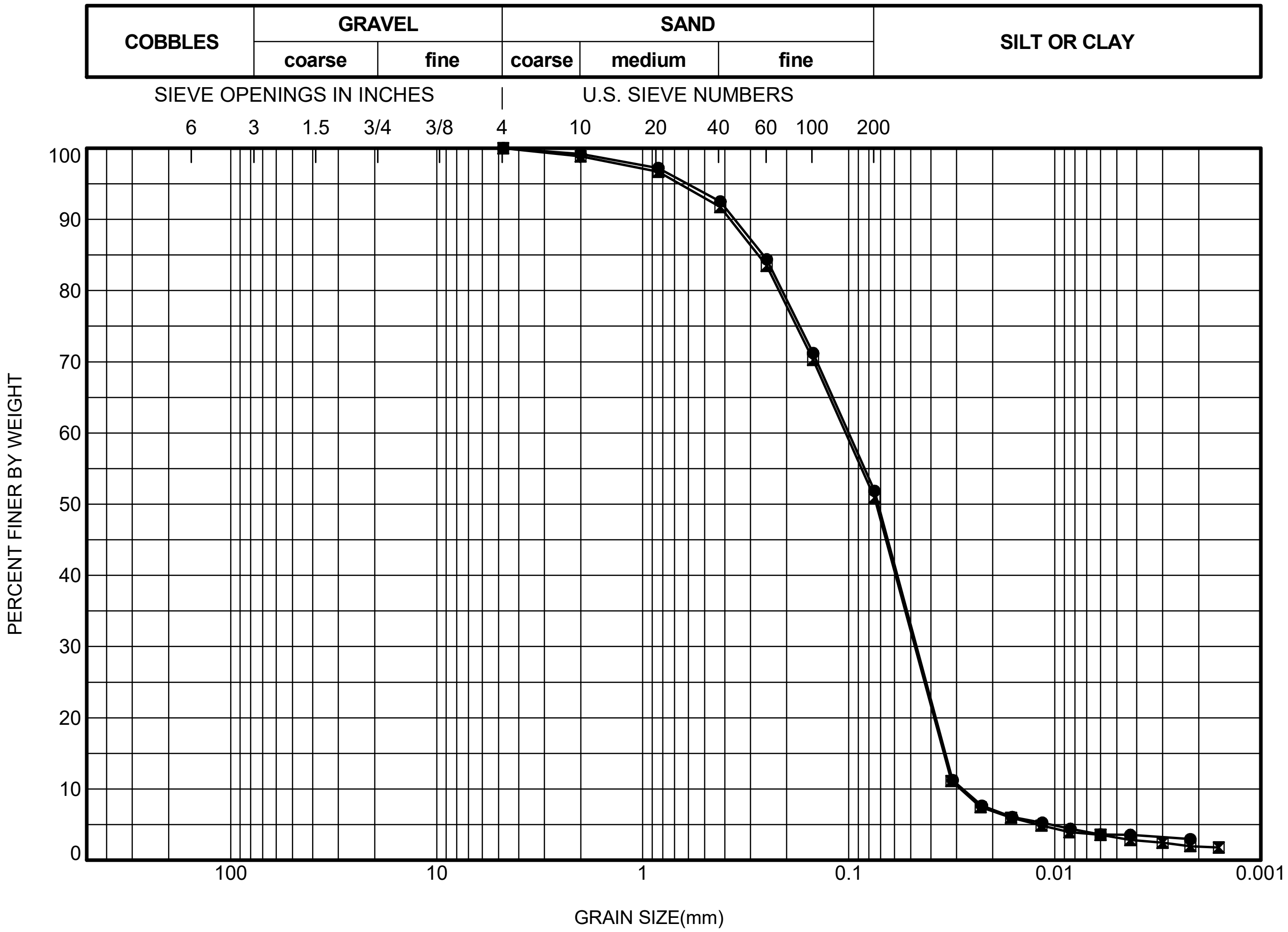
LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

KC_GRAIN_SIZE-SI A03355A01 TRIAXIAL TESTS PSDS.GPJ SIEVE.GDT 19-11-20

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX05-CID	0.00	0.260	0.100					0.0	48.1	51.9
☒	TX05-CID	0.00	0.275	0.104					0.0	49.1	50.9

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX05-CID	Average	0.00					Before Testing (TX01/TX05)
☒	TX05-CID	Average	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

PROJECT:

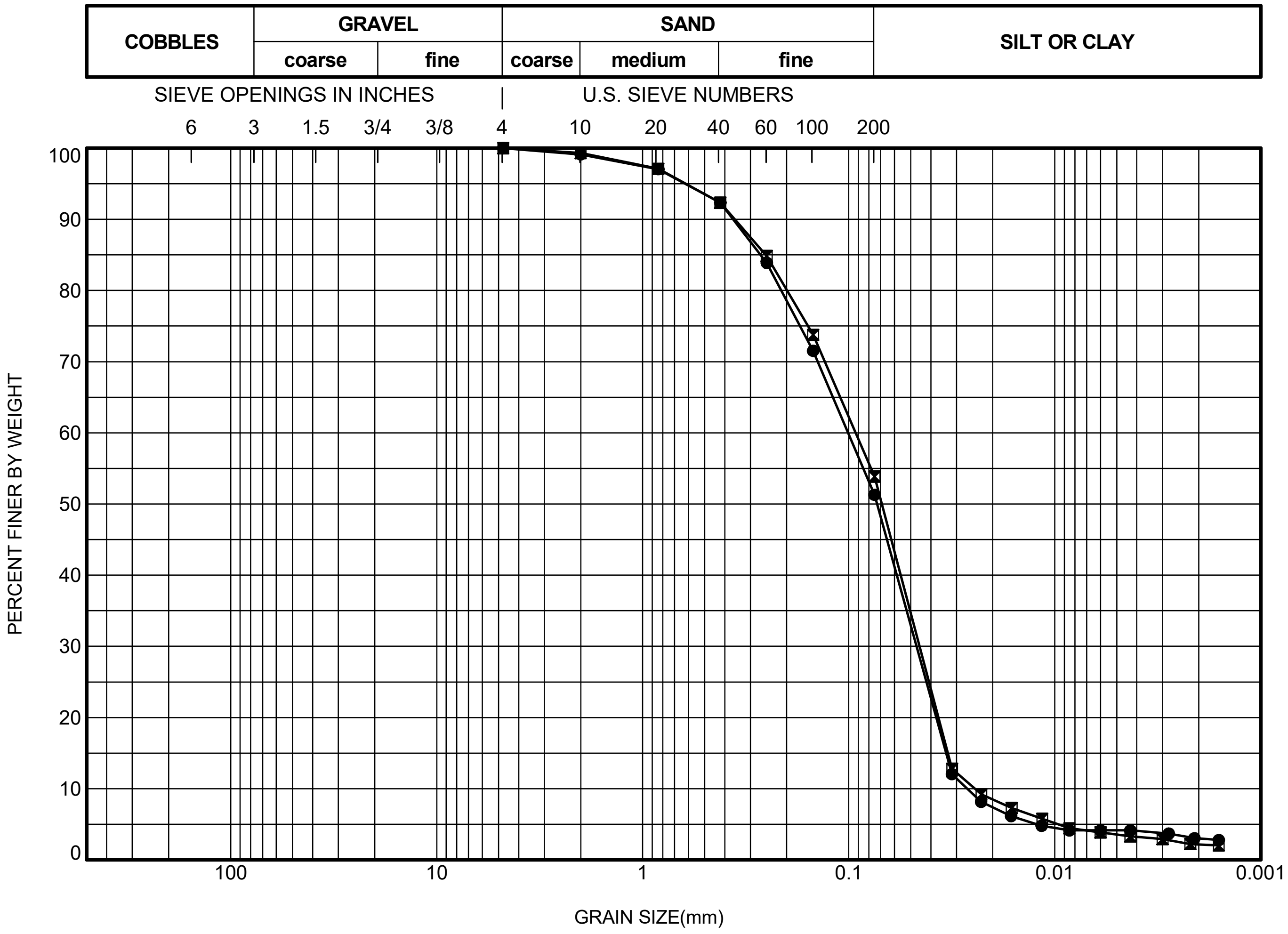
LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

KC_GRAIN_SIZE-SI A03355A01 TRIAXIAL TESTS PSDS.GPJ SIEVE.GDT 19-11-20

GRAIN SIZE DISTRIBUTION



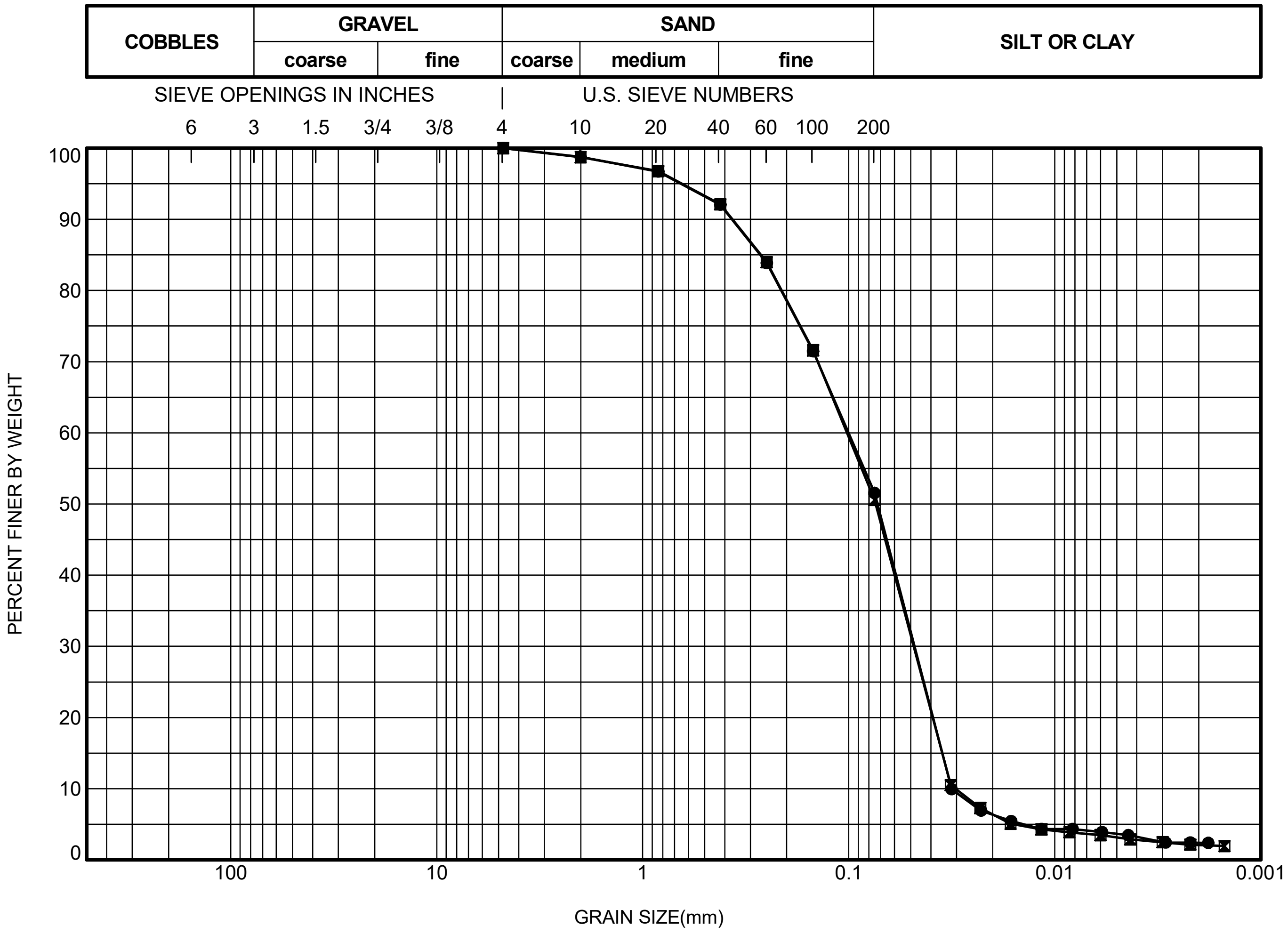
	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX06-CID	0.00	0.268	0.101					0.0	48.7	51.3
☒	TX06-CID	0.00	0.253	0.093					0.0	46.1	53.9

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX06-CID	Average	0.00					Before Testing (TX04/TX06/TXBE02)
☒	TX06-CID	Average	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01
PROJECT:
LOCATION:
FIGURE:
DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX07-CIU	0.00	0.269	0.100					0.0	48.4	51.6
☒	TX07-CIU	0.00	0.267	0.102					0.0	49.4	50.6

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX07-CIU	Average	0.00					Before Testing (TX07/TXBE03)
☒	TX07-CIU	Average	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

PROJECT:

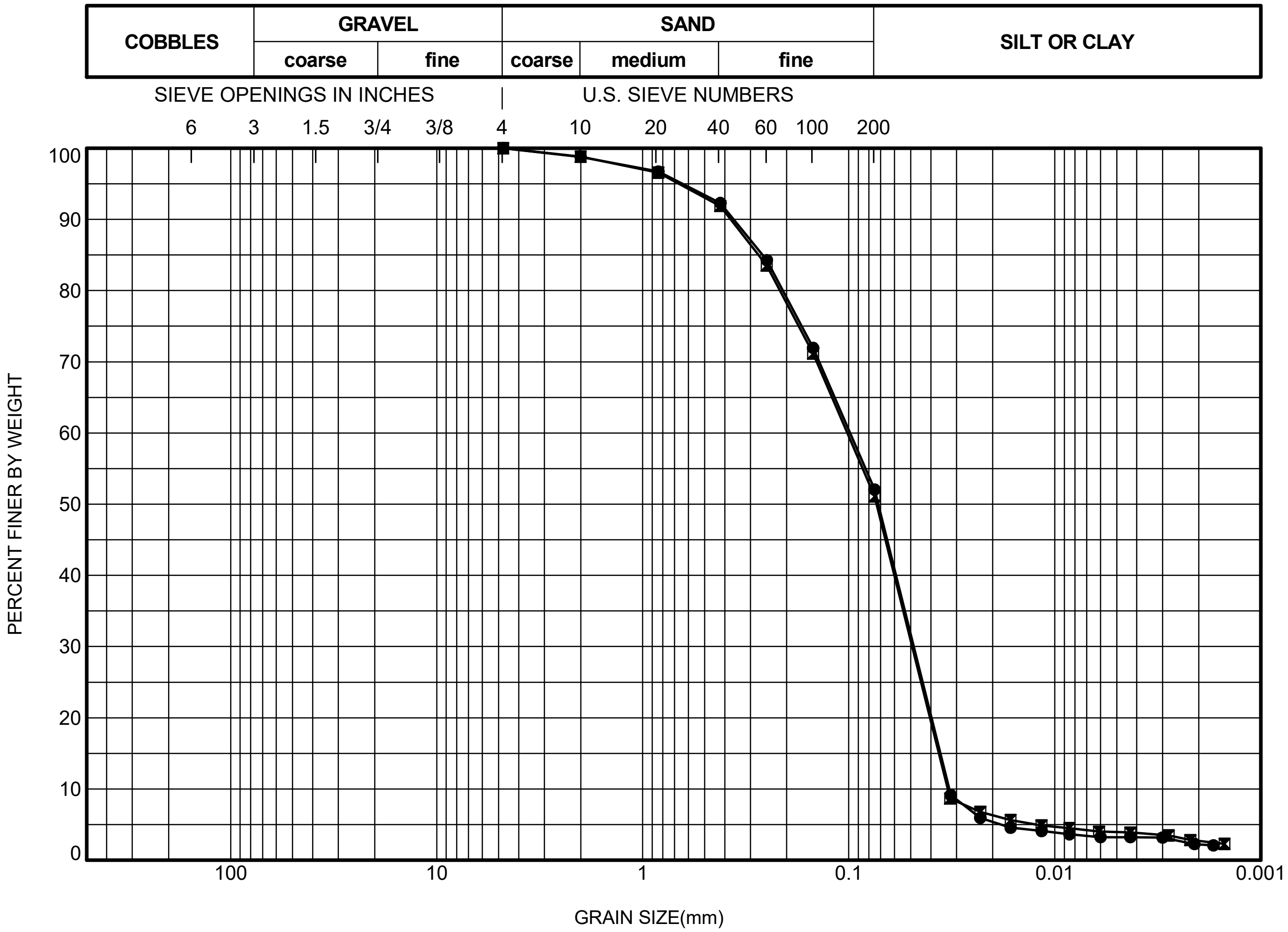
LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

KC_GRAIN_SIZE-SI A03355A01 TRIAXIAL TESTS PSDS.GPJ SIEVE.GDT 19-11-20

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX08-CID	0.00	0.262	0.099					0.0	47.9	52.1
☒	TX08-CID	0.00	0.274	0.102					0.0	48.9	51.1

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX08-CID	Average	0.00					Before Testing
☒	TX08-CID	Average	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

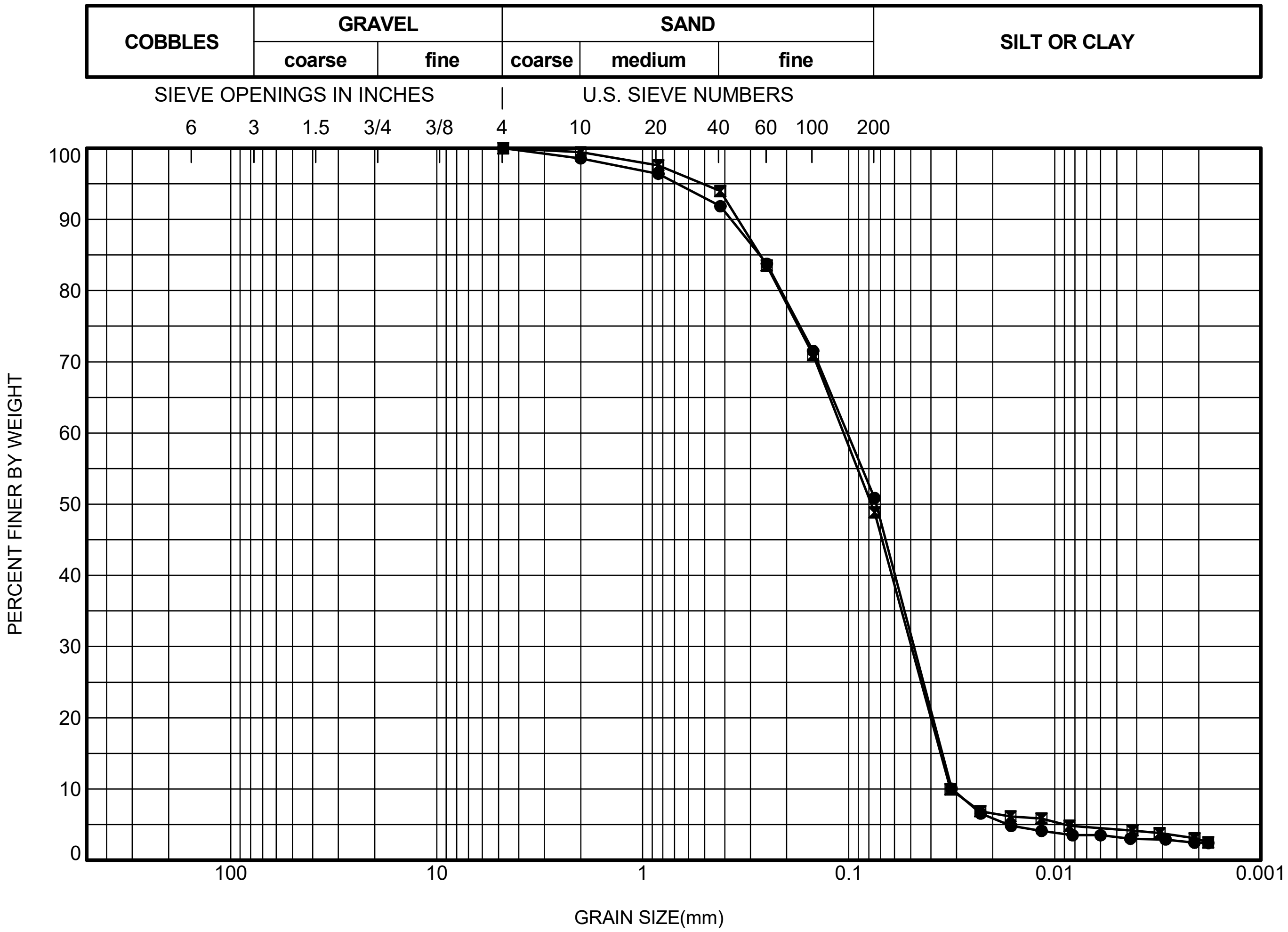
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



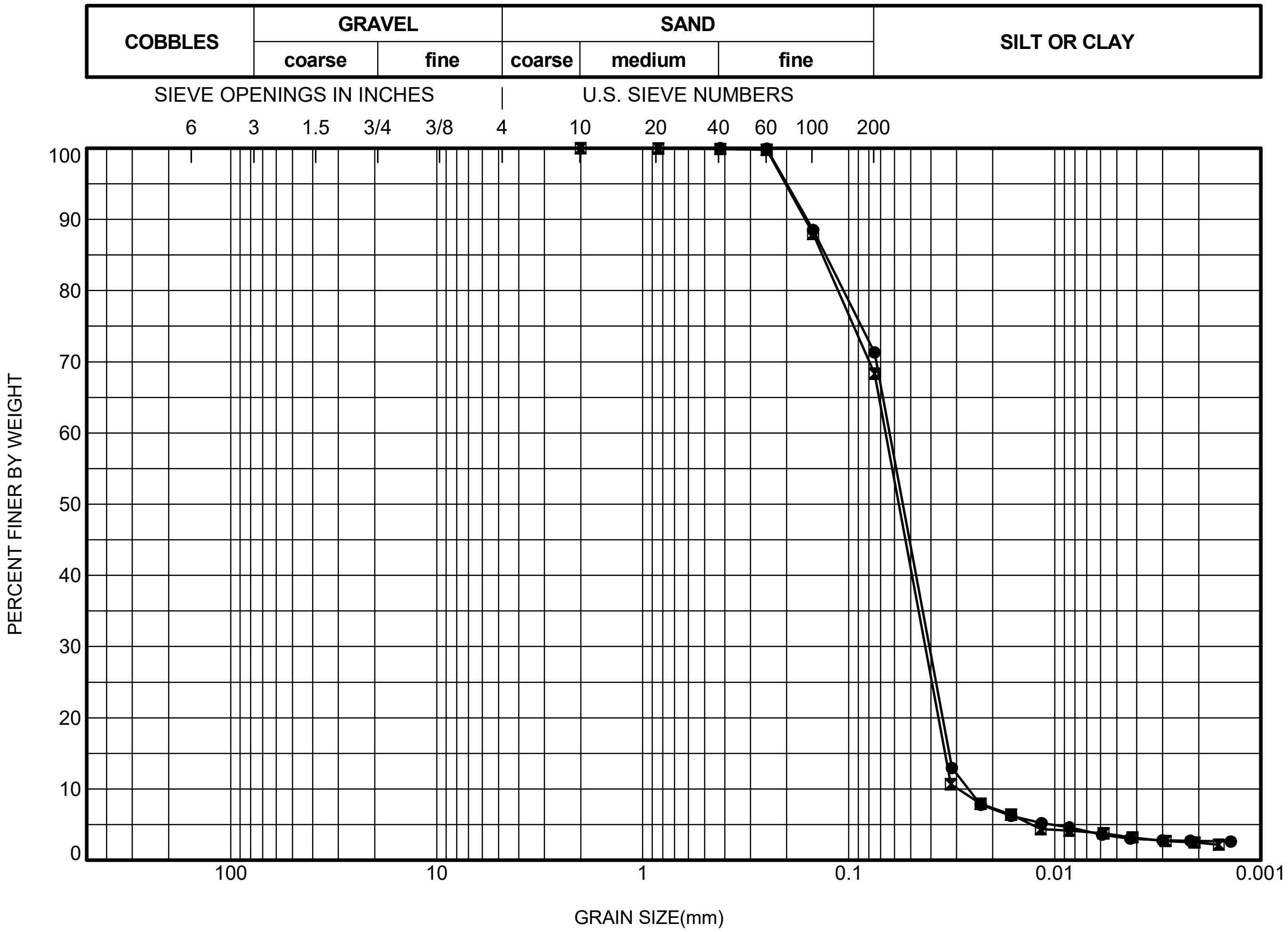
	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX09-CID	0.00	0.271	0.102					0.0	49.1	50.9
☒	TX09-CID	0.00	0.269	0.106	0.078				0.0	51.2	48.8

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX09-CID	Average	0.00					Before Testing
☒	TX09-CID	Average	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01
PROJECT:
LOCATION:
FIGURE:
DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX10-CID	0.00	0.130						0.0	28.7	71.3
☒	TX10-CID	0.00	0.134						0.0	31.7	68.3

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX10-CID	Fine	0.00					Before Testing (TX10/TX11)
☒	TX10-CID	Fine	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

KC_GRAIN_SIZE-SI A03355A01 TRIAXIAL TESTS PSDS.GPJ SIEVE.GDT 19-11-20

PROJECT NO.: A03355A01

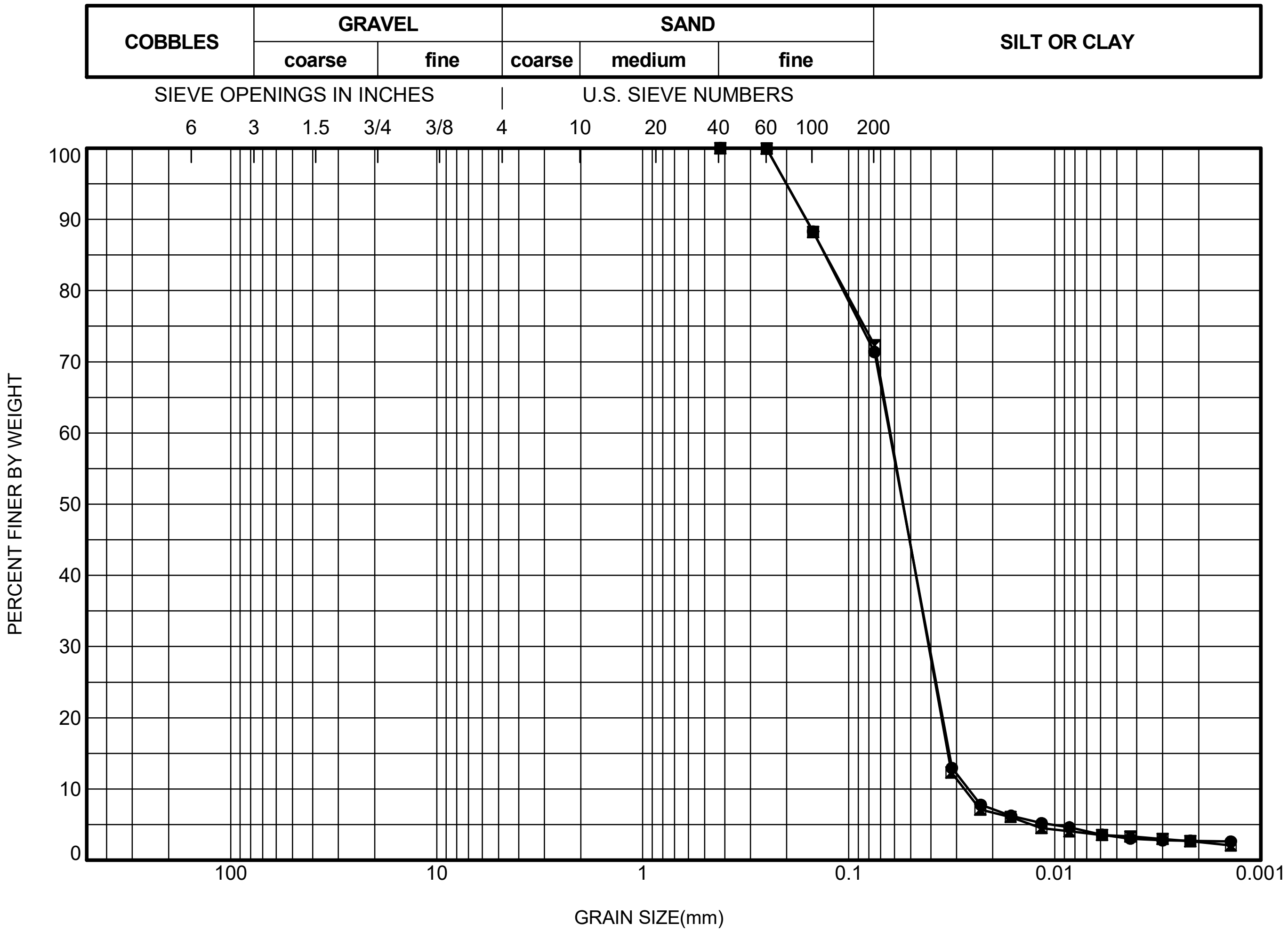
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX11-CID	0.00	0.130						0.0	28.6	71.4
☒	TX11-CID	0.00	0.130						0.0	27.7	72.3

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX11-CID	Fine	0.00					Before Testing (TX10/TX11)
☒	TX11-CID	Fine	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

PROJECT:

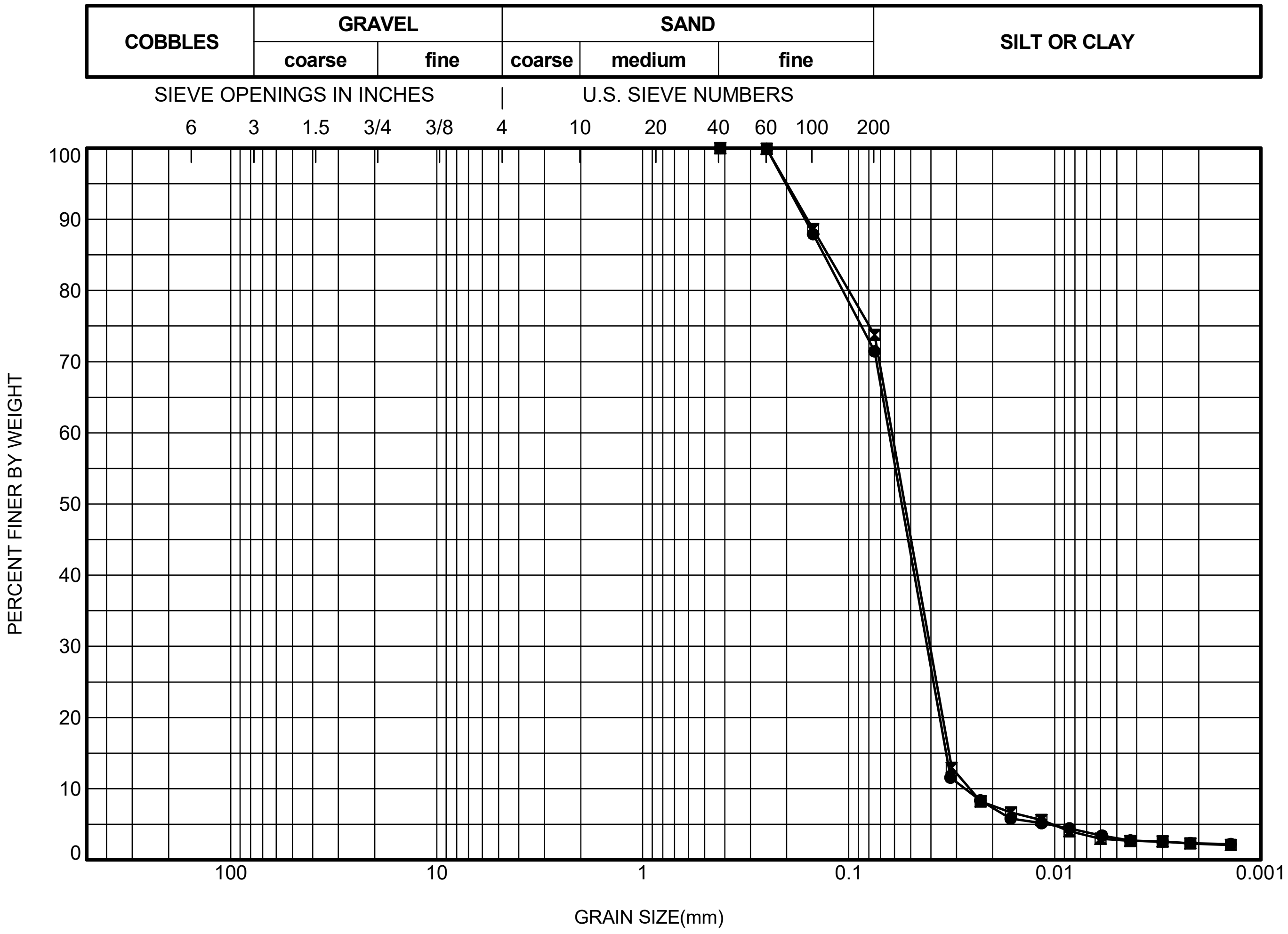
LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

KC_GRAIN_SIZE-SI A03355A01 TRIAXIAL TESTS PSDS.GPJ SIEVE.GDT 19-11-20

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX12-CID	0.00	0.132						0.0	28.5	71.5
⧗	TX12-CID	0.00	0.126						0.0	26.2	73.8

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX12-CID	Fine	0.00					Before Testing (TX12/TXBE05)
⧗	TX12-CID	Fine	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

PROJECT:

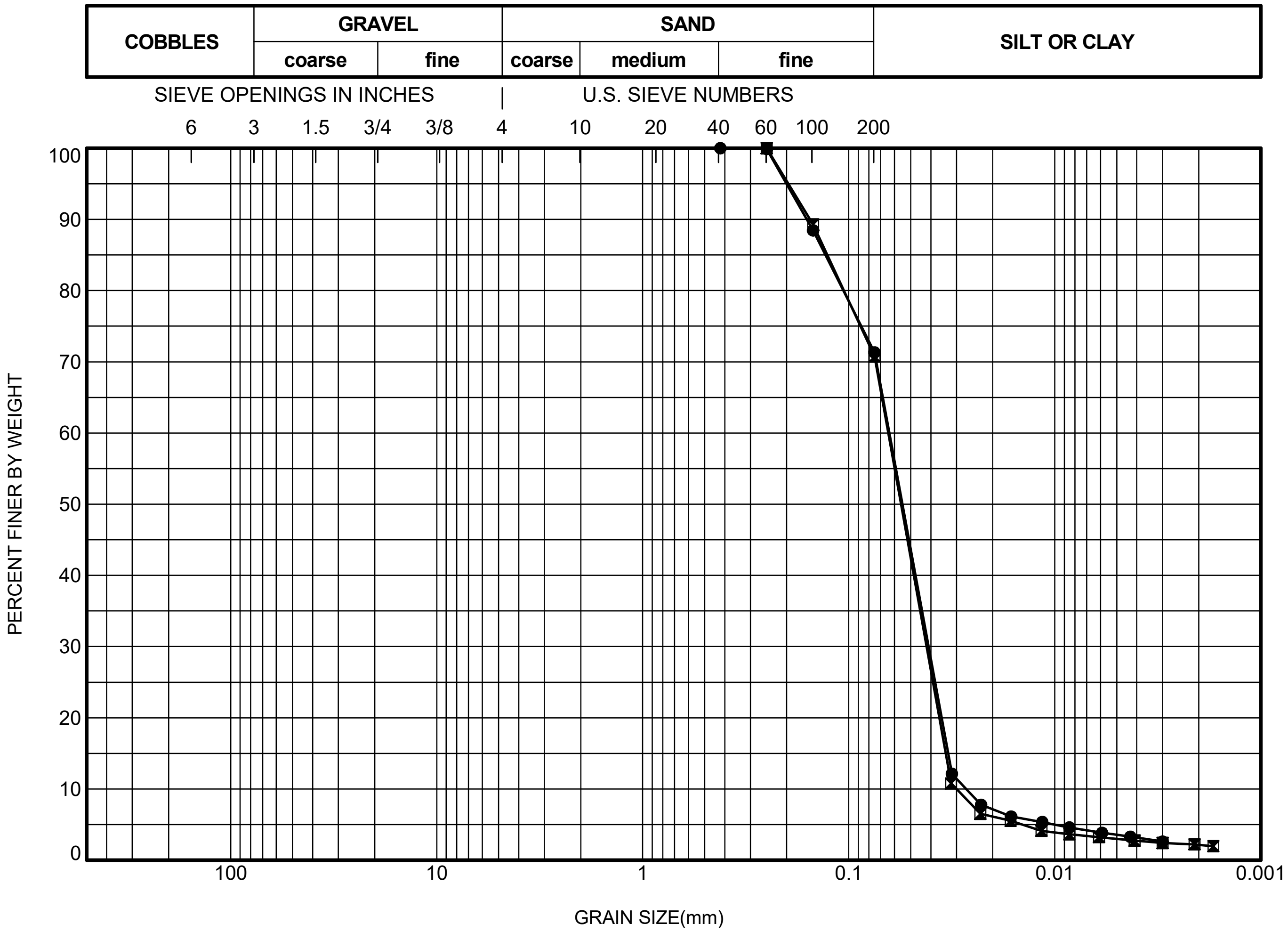
LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

KC_GRAIN_SIZE-SI A03355A01 TRIAXIAL TESTS PSDS.GPJ SIEVE.GDT 19-11-20

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX13-CID	0.00	0.130						0.0	28.7	71.3
☒	TX13-CID	0.00	0.127						0.0	29.2	70.8

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX13-CID	Fine	0.00					Before Testing (TX13/TXBE04)
☒	TX13-CID	Fine	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

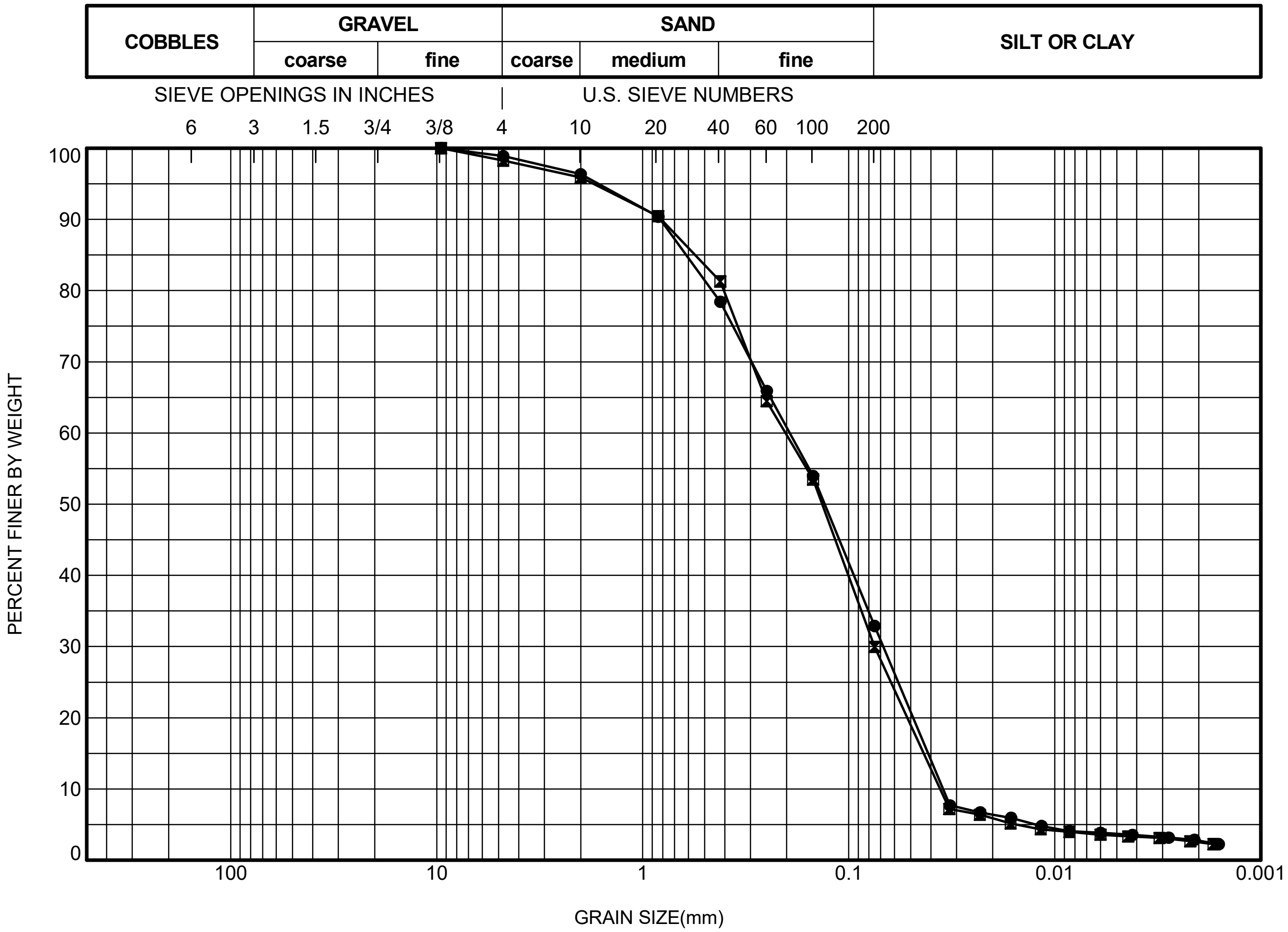
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX14-CID	0.00	0.615	0.194	0.131				1.1	66.0	32.9
☒	TX14-CID	0.00	0.556	0.203	0.135				1.7	68.3	30.0

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX14-CID	Coarse	0.00					Before Testing (TX14/TX17)
☒	TX14-CID	Coarse	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

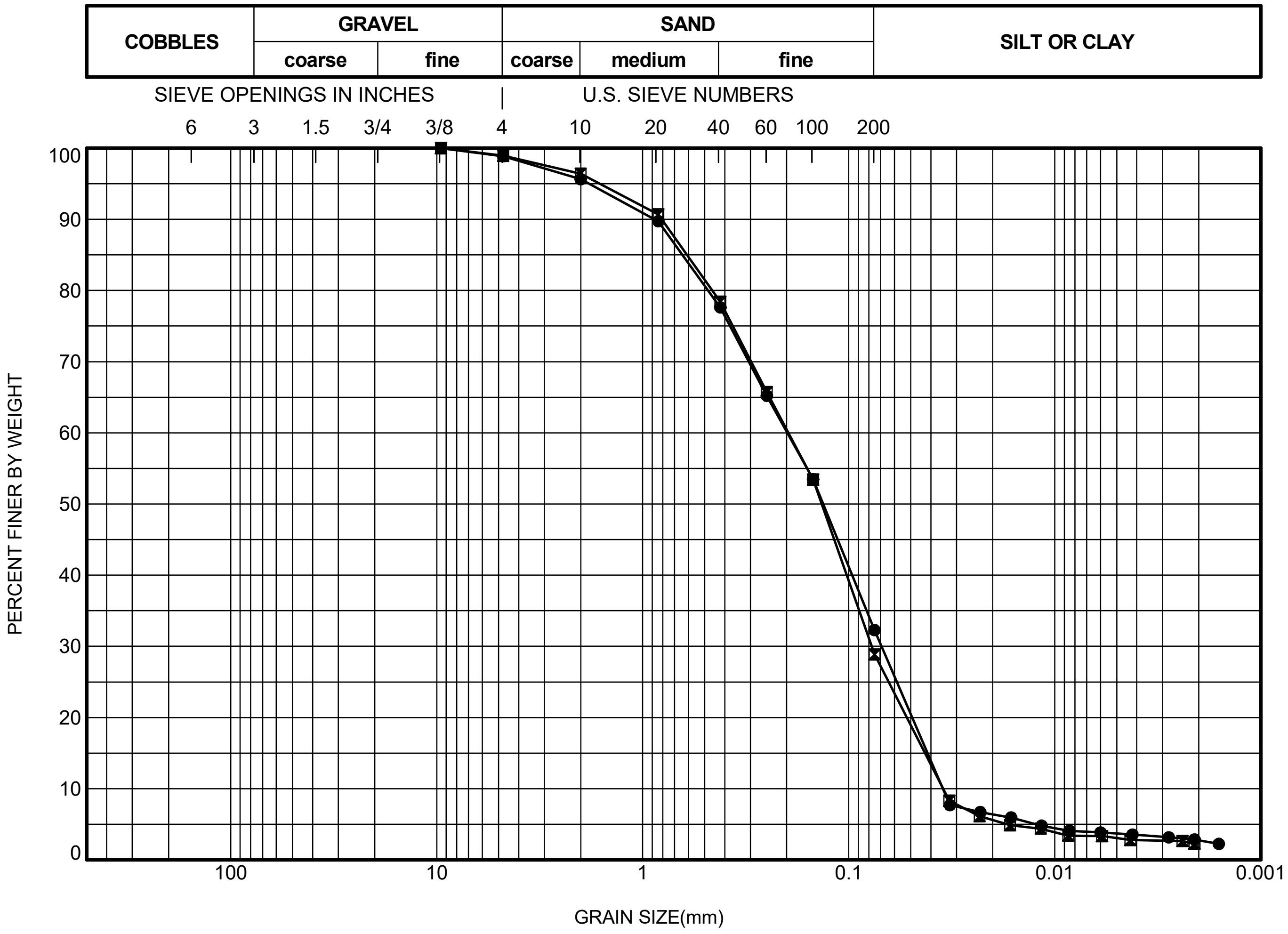
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX15-CID	0.00	0.641	0.199	0.133				1.1	66.6	32.3
⧗	TX15-CID	0.00	0.610	0.196	0.135				1.1	70.1	28.9

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX15-CID	Coarse	0.00					Before Testing (TX15/TX16)
⧗	TX15-CID	Coarse	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

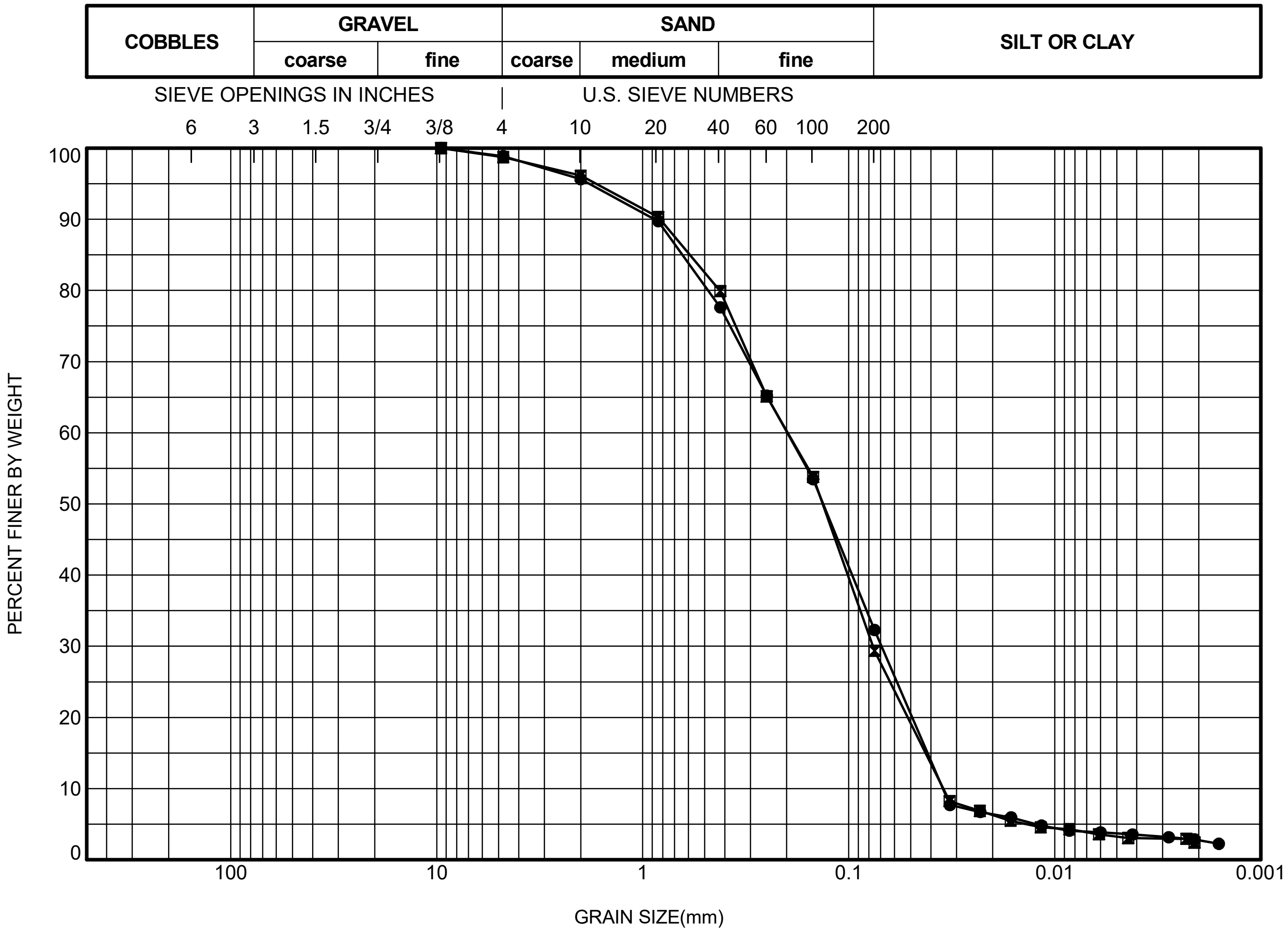
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX16-CID	0.00	0.641	0.199	0.133				1.1	66.6	32.3
☒	TX16-CID	0.00	0.590	0.198	0.134				1.3	69.4	29.4

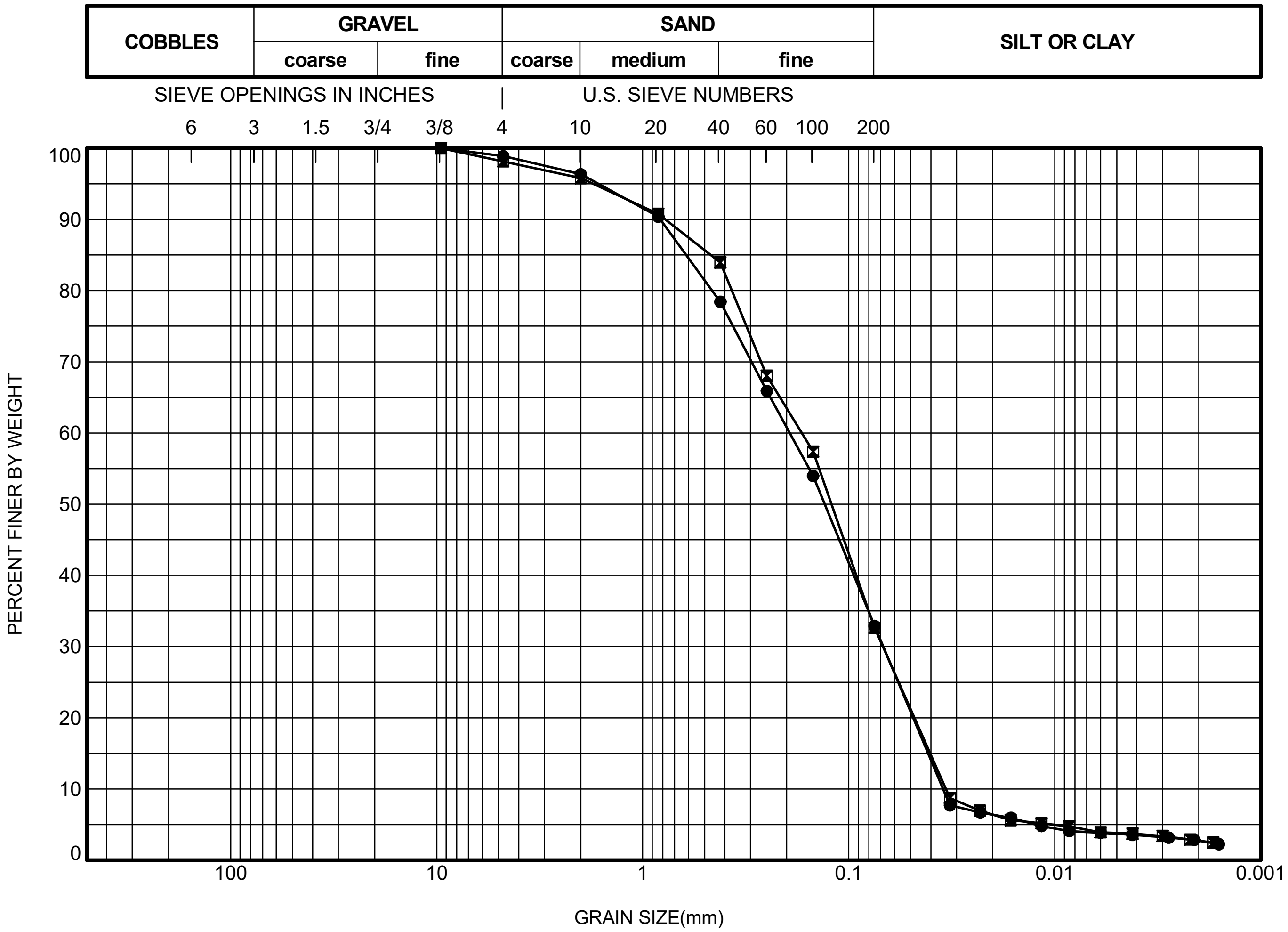
	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX16-CID	Coarse	0.00					Before Testing (TX15/TX16)
☒	TX16-CID	Coarse	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01
PROJECT:
LOCATION:
FIGURE:
DRAWN BY: AX **CHECKED BY:** BY

KC_GRAIN_SIZE-SI A03355A01 TRIAXIAL TESTS PSDS.GPJ SIEVE.GDT 19-11-20

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX17-CID	0.00	0.615	0.194	0.131				1.1	66.0	32.9
☒	TX17-CID	0.00	0.467	0.169	0.121				1.8	65.5	32.6

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX17-CID	Coarse	0.00					Before Testing (TX14/TX17)
☒	TX17-CID	Coarse	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

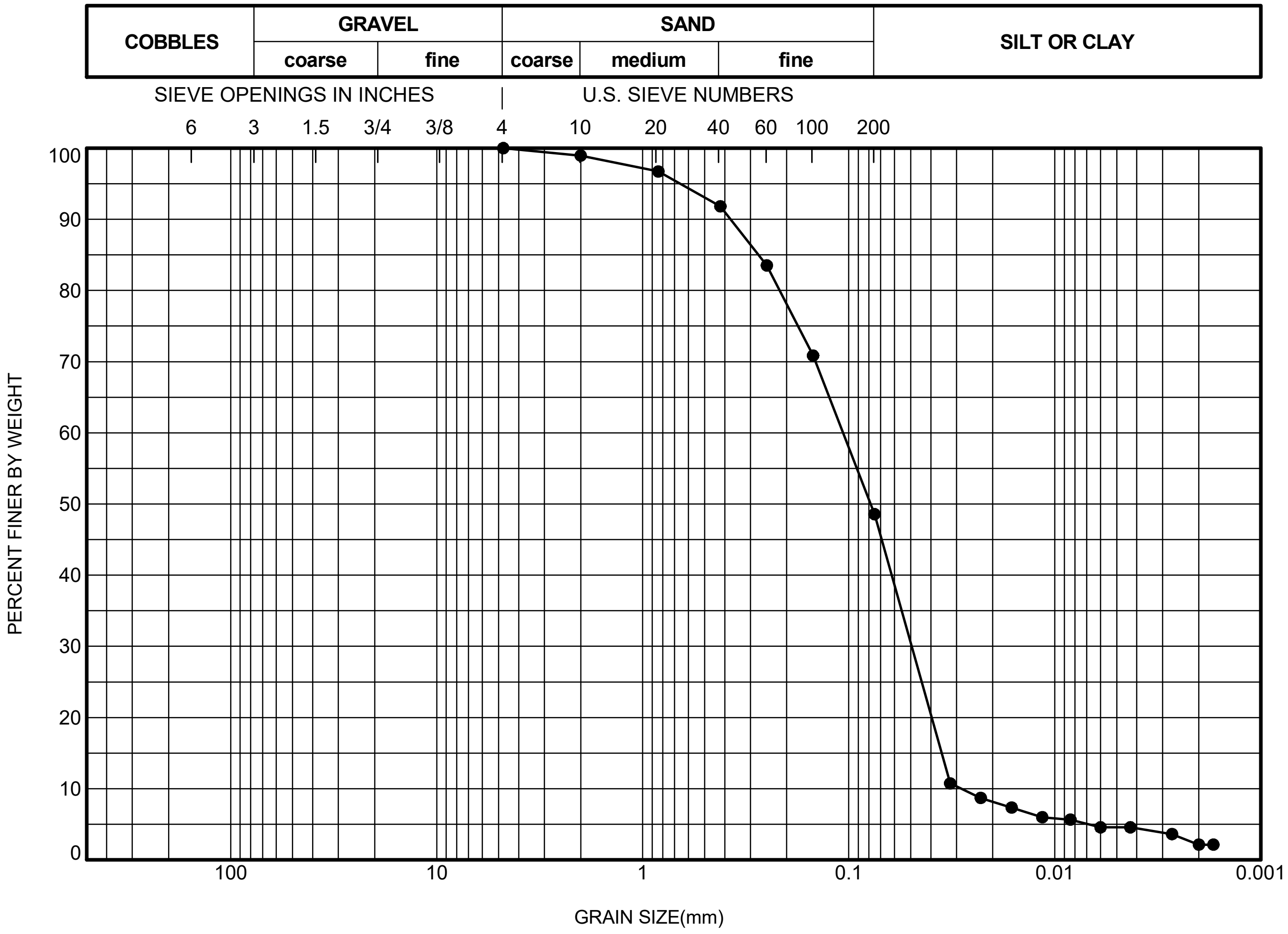
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX18-CID	0.00	0.274	0.107	0.078				0.0	51.4	48.6

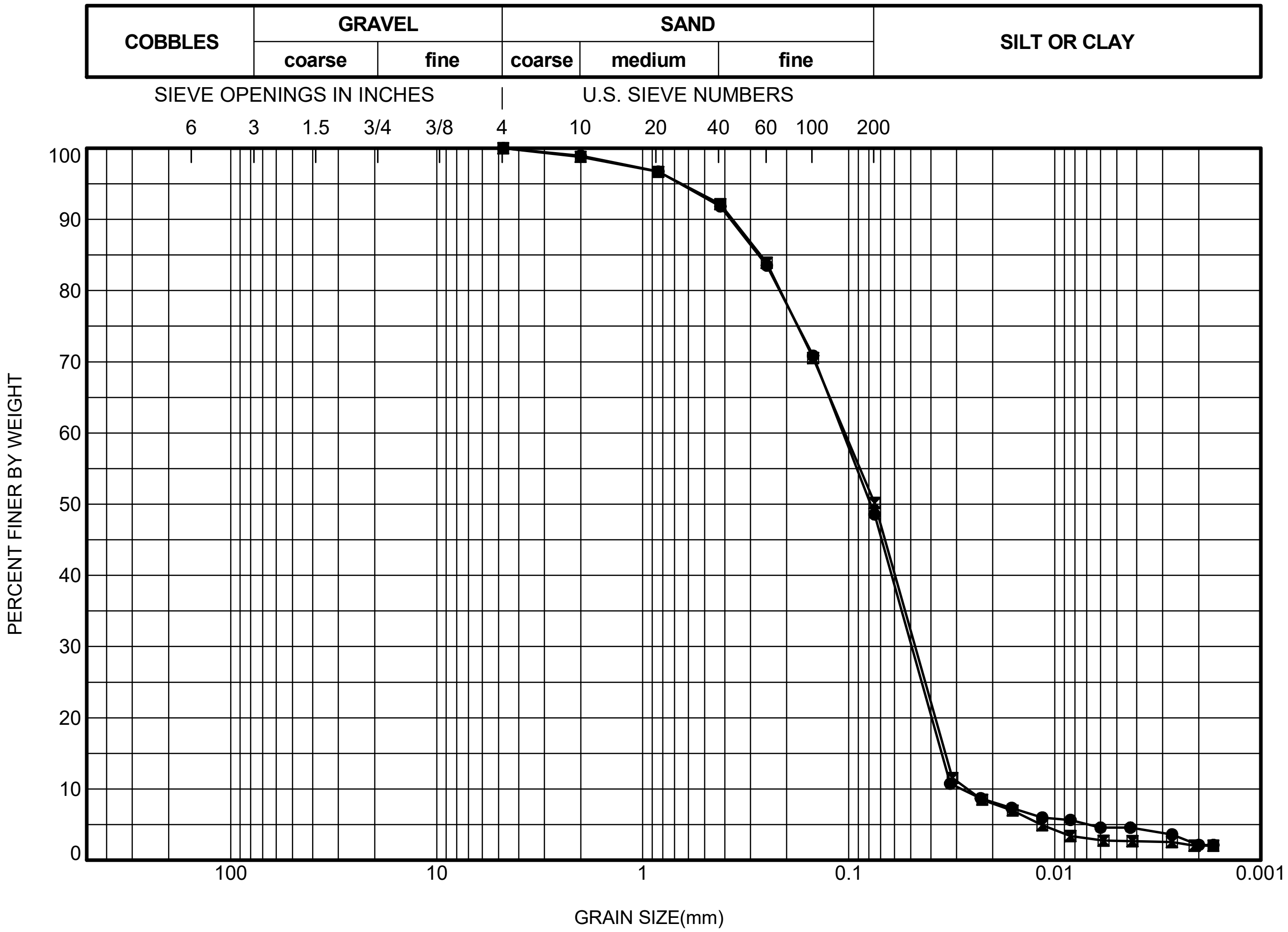
	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX18-CID	Average	0.00					Before Testing (TX18/TX19/TX20)

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01
PROJECT:
LOCATION:
FIGURE:
DRAWN BY: AX **CHECKED BY:** BY

KC_GRAIN_SIZE-SI A03355A01 TRIAXIAL TESTS PSDS.GPJ SIEVE.GDT 19-11-20

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX19-CID	0.00	0.274	0.107	0.078				0.0	51.4	48.6
☒	TX19-CID	0.00	0.268	0.104					0.0	49.8	50.2

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX19-CID	Average	0.00					Before Testing (TX18/TX19/TX20)
☒	TX19-CID	Average	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

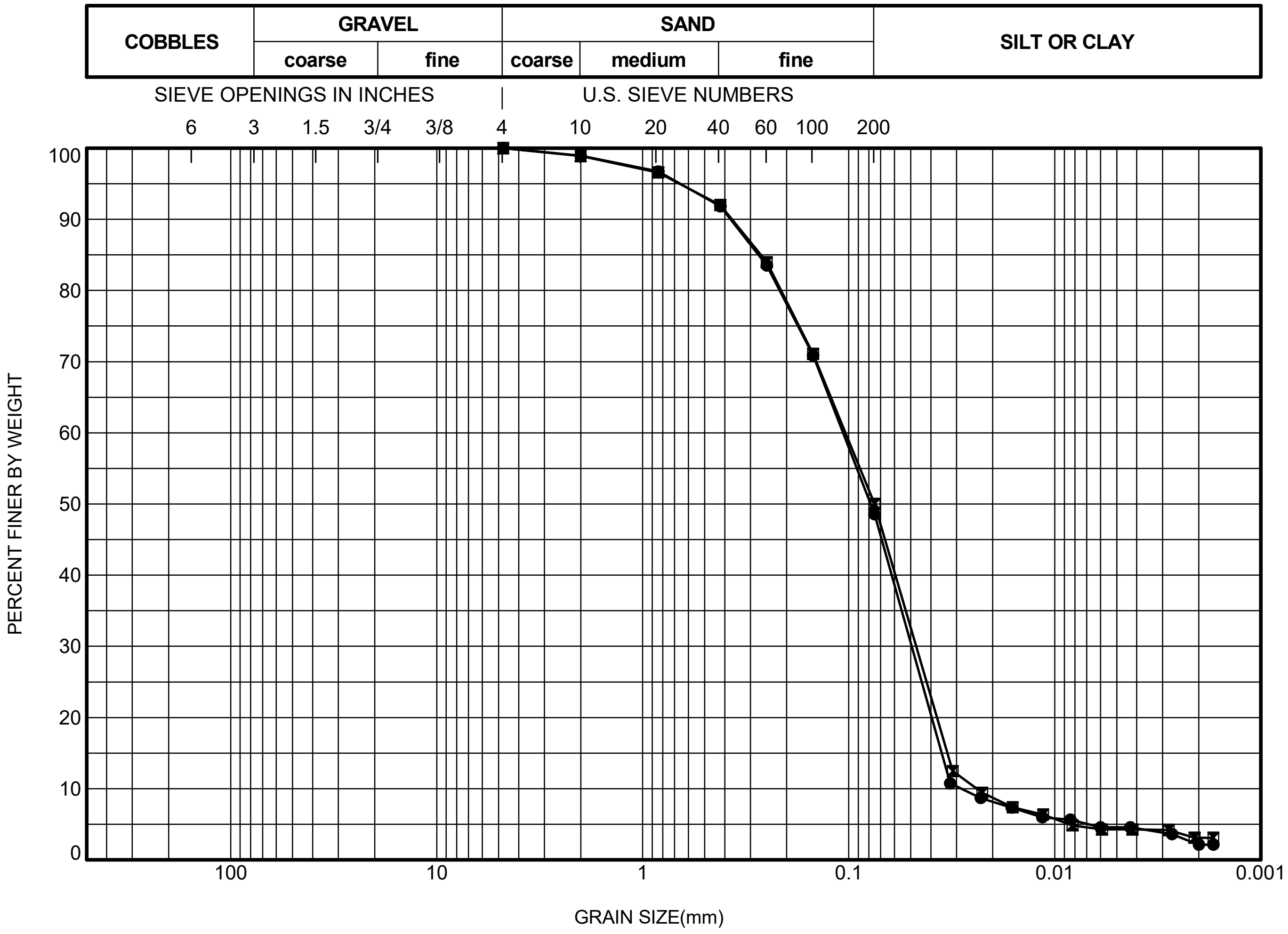
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX20-CID	0.00	0.274	0.107	0.078				0.0	51.4	48.6
☒	TX20-CID	0.00	0.267	0.104					0.0	50.0	50.0

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX20-CID	Average	0.00					Before Testing (TX18/TX19/TX20)
☒	TX20-CID	Average	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

PROJECT:

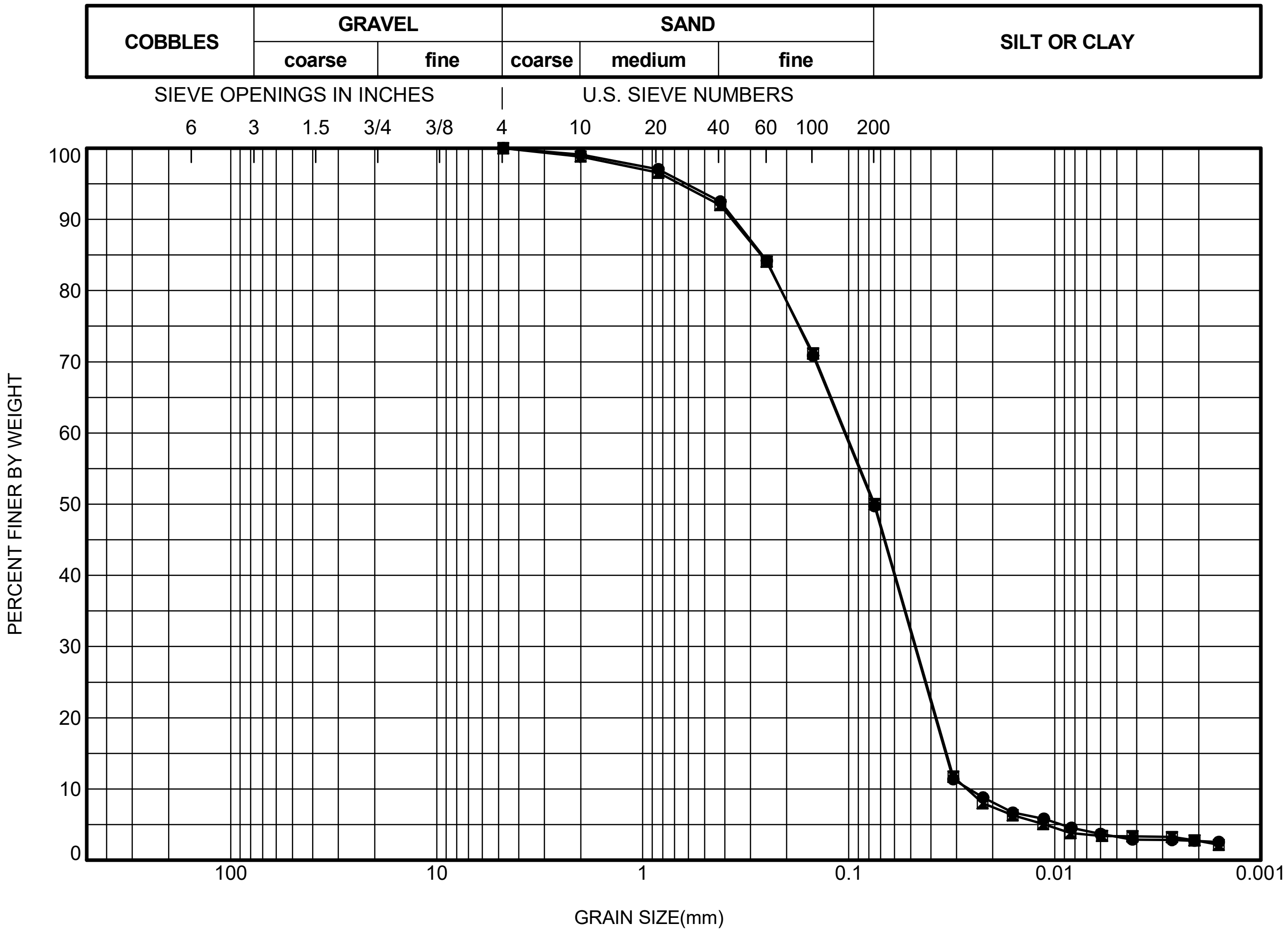
LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

KC_GRAIN_SIZE-SI A03355A01 TRIAXIAL TESTS PSDS.GPJ SIEVE.GDT 19-11-20

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX21-CID	0.00	0.263	0.105	0.076				0.0	50.3	49.7
☒	TX21-CID	0.00	0.266	0.104	0.075				0.0	50.0	50.0

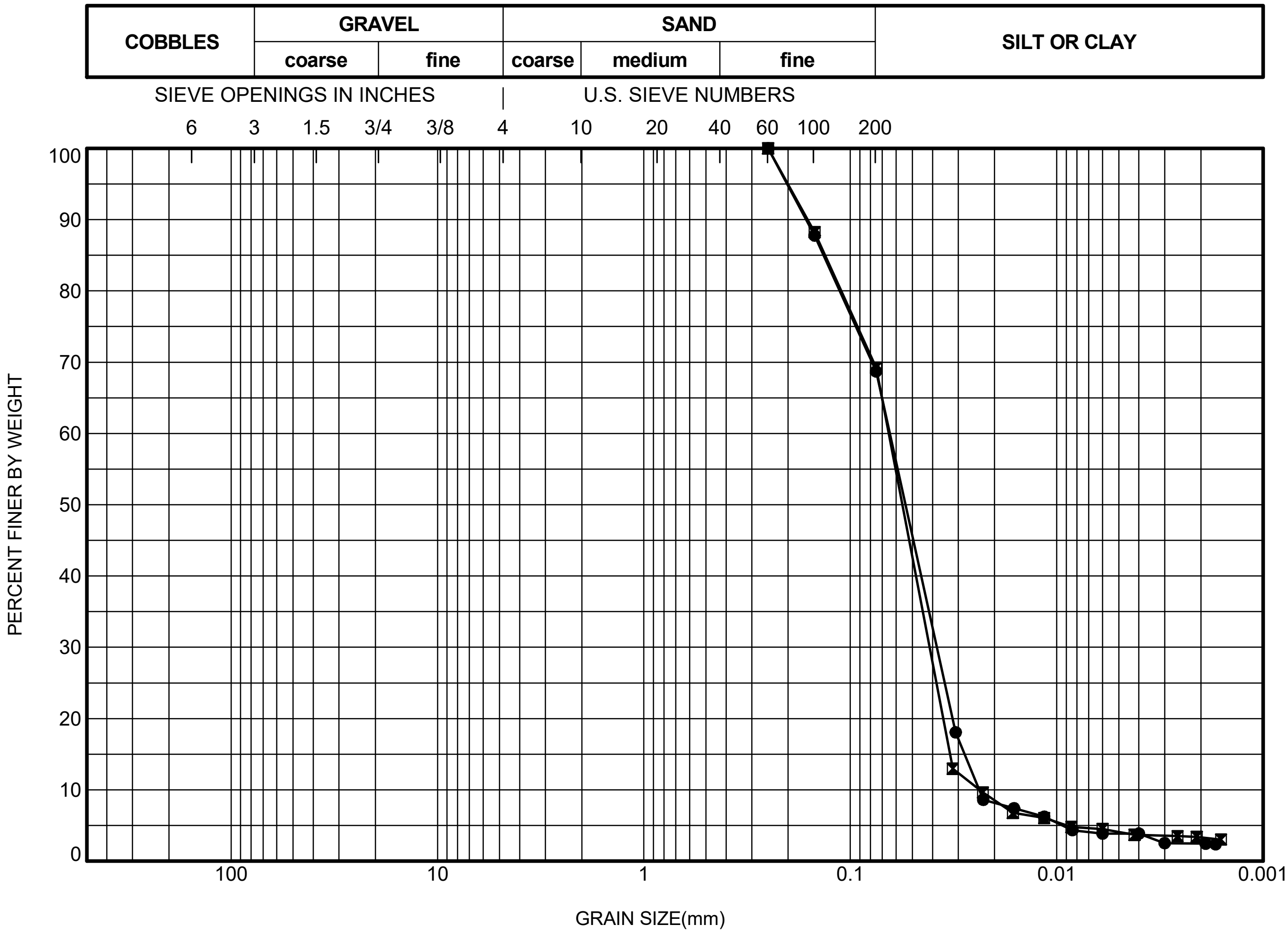
	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX21-CID	Average	0.00					Before Testing
☒	TX21-CID	Average	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01
PROJECT:
LOCATION:
FIGURE:
DRAWN BY: AX **CHECKED BY:** BY

KC_GRAIN_SIZE-SI A03355A01 TRIAXIAL TESTS PSDS.GPJ SIEVE.GDT 19-11-20

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX22-CID	0.00	0.135						0.0	31.3	68.7
☒	TX22-CID	0.00	0.133						0.0	30.8	69.2

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX22-CID	Fine	0.00					Before Testing
☒	TX22-CID	Fine	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

PROJECT:

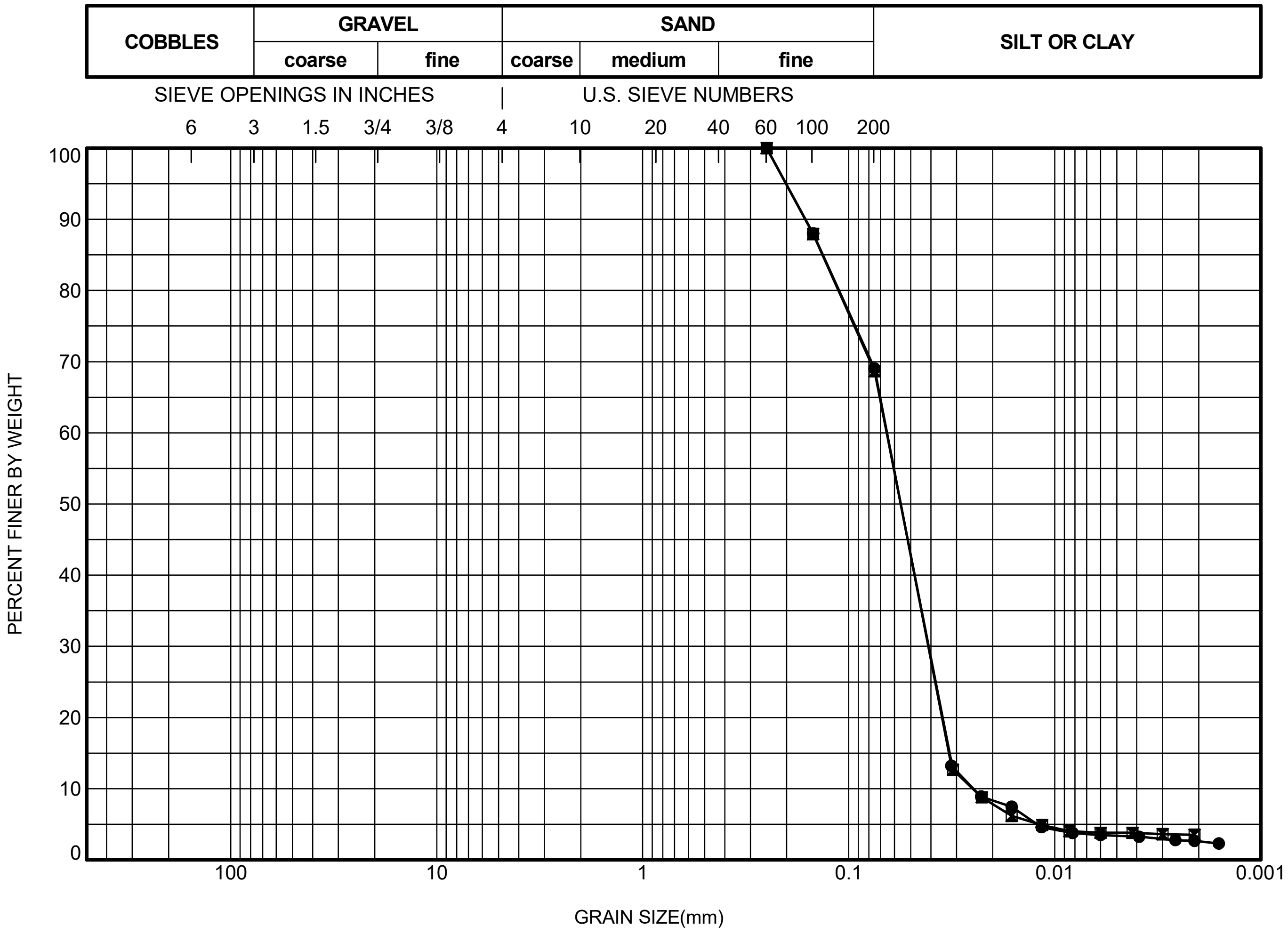
LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

KC_GRAIN_SIZE-SI A03355A01 TRIAXIAL TESTS PSDS.GPJ SIEVE.GDT 19-11-20

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX23-CID	0.00	0.134						0.0	31.0	69.0
⧗	TX23-CID	0.00	0.134						0.0	31.3	68.7

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX23-CID	Fine	0.00					Before Testing
⧗	TX23-CID	Fine	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

PROJECT:

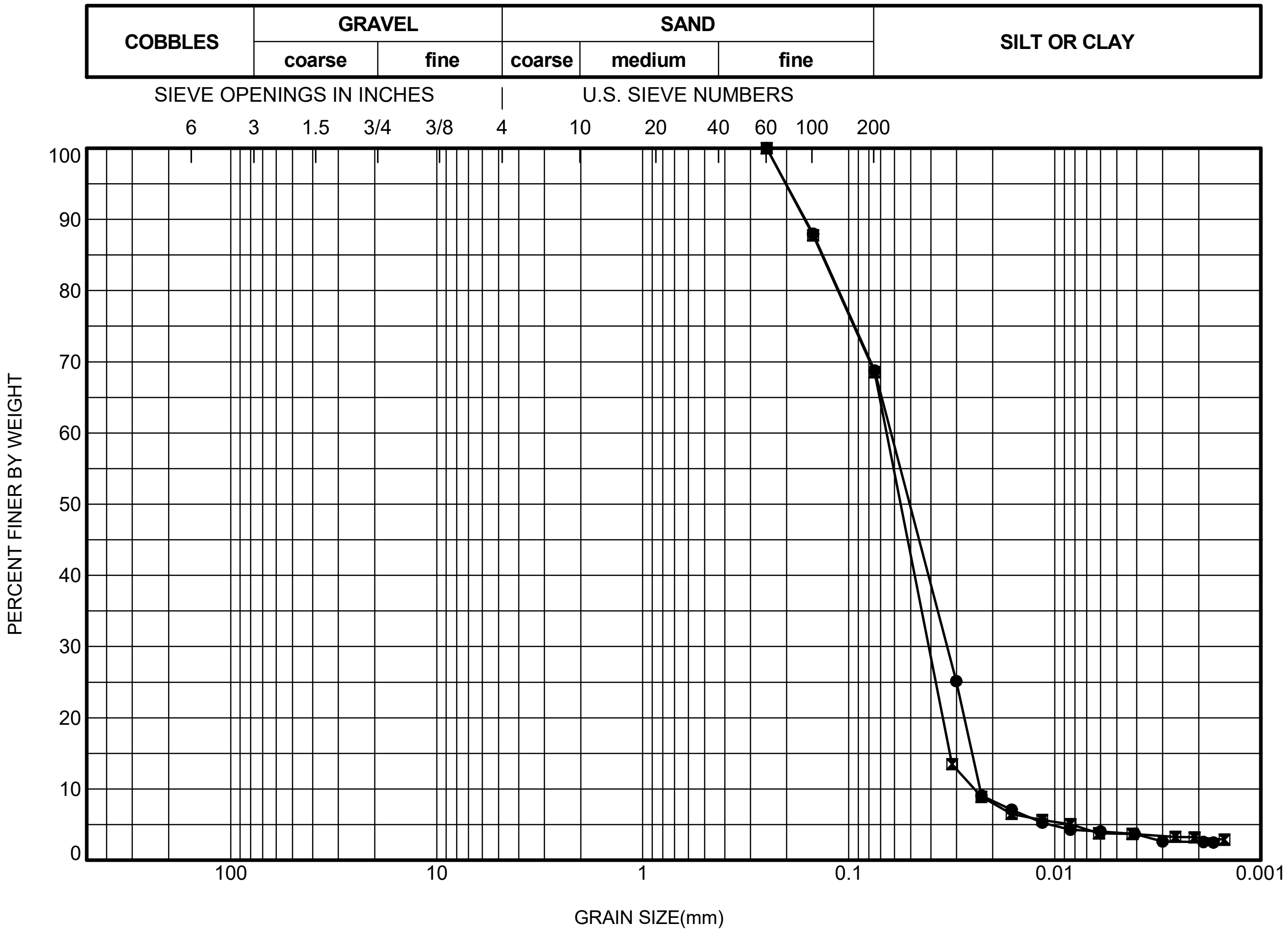
LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

KC_GRAIN_SIZE-SI A03355A01 TRIAXIAL TESTS PSDS.GPJ SIEVE.GDT 19-11-20

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX24-CID	0.00	0.134						0.0	31.2	68.8
☒	TX24-CID	0.00	0.135						0.0	31.5	68.5

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX24-CID	Fine	0.00					Before Testing
☒	TX24-CID	Fine	0.00		13	13	NP	After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

PROJECT:

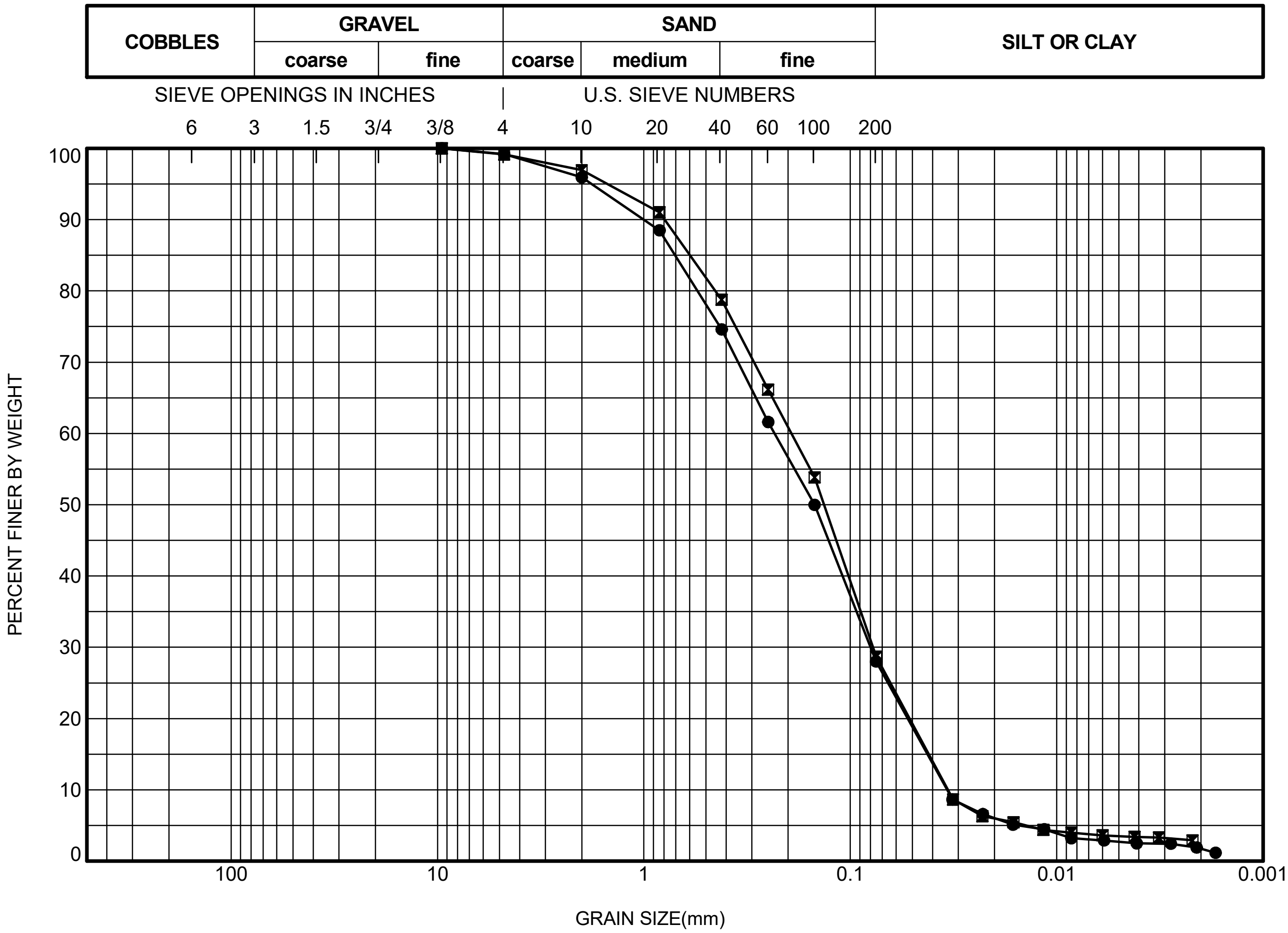
LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

KC_GRAIN_SIZE-SI A03355A01 TRIAXIAL TESTS PSDS.GPJ SIEVE.GDT 19-11-20

GRAIN SIZE DISTRIBUTION



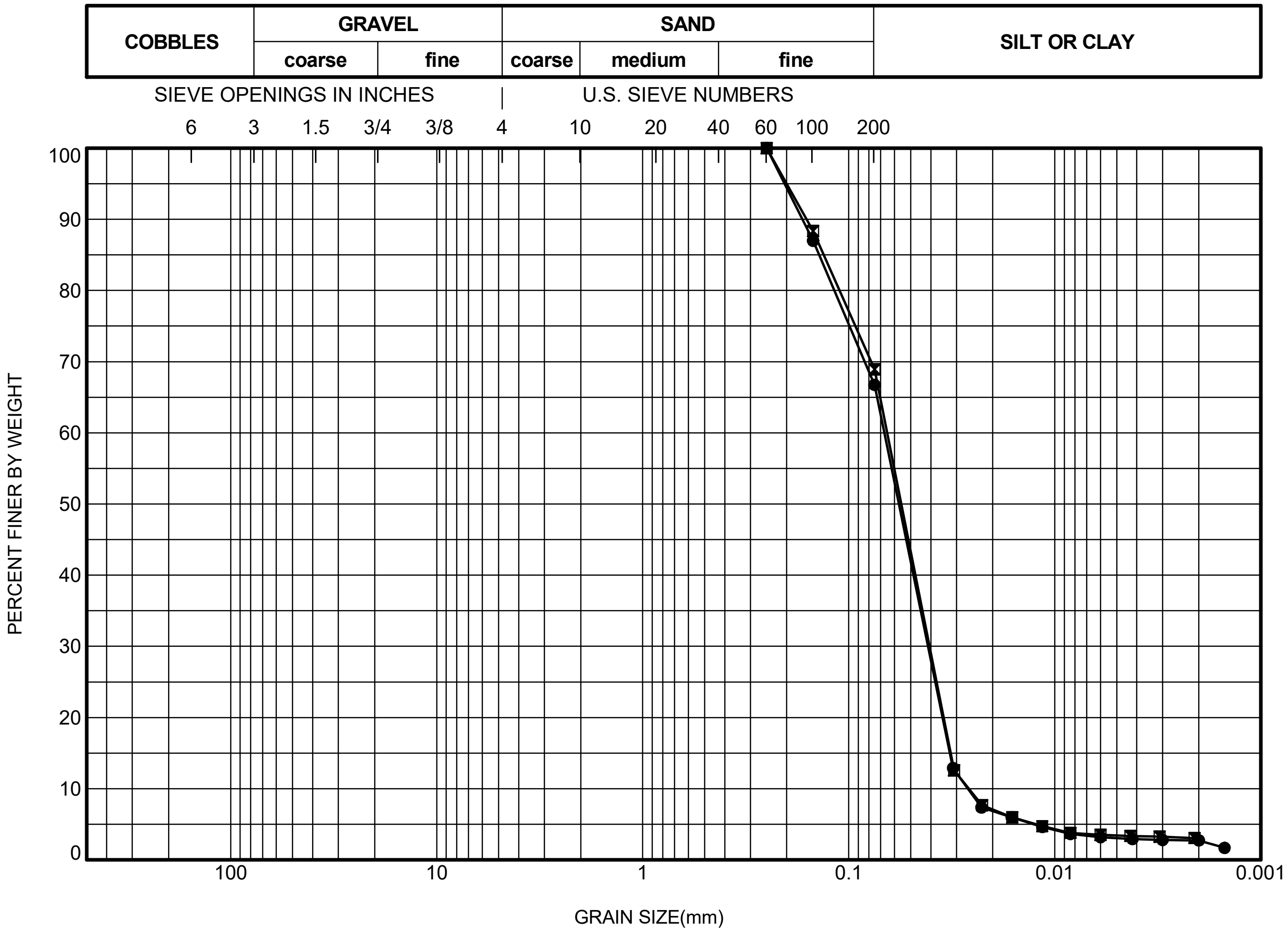
	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX25-CAU	0.00	0.705	0.233	0.149				0.8	71.2	28.0
☒	TX25-CAU	0.00	0.597	0.193	0.134				0.9	70.4	28.7

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX25-CAU	Coarse	0.00					Before Testing (TX25/TXDW02)
☒	TX25-CAU	Coarse	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01
PROJECT:
LOCATION:
FIGURE:
DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX26-CAU	0.00	0.139						0.0	33.3	66.7
☒	TX26-CAU	0.00	0.132						0.0	31.1	68.9

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX26-CAU	Fine	0.00					Before Testing
☒	TX26-CAU	Fine	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

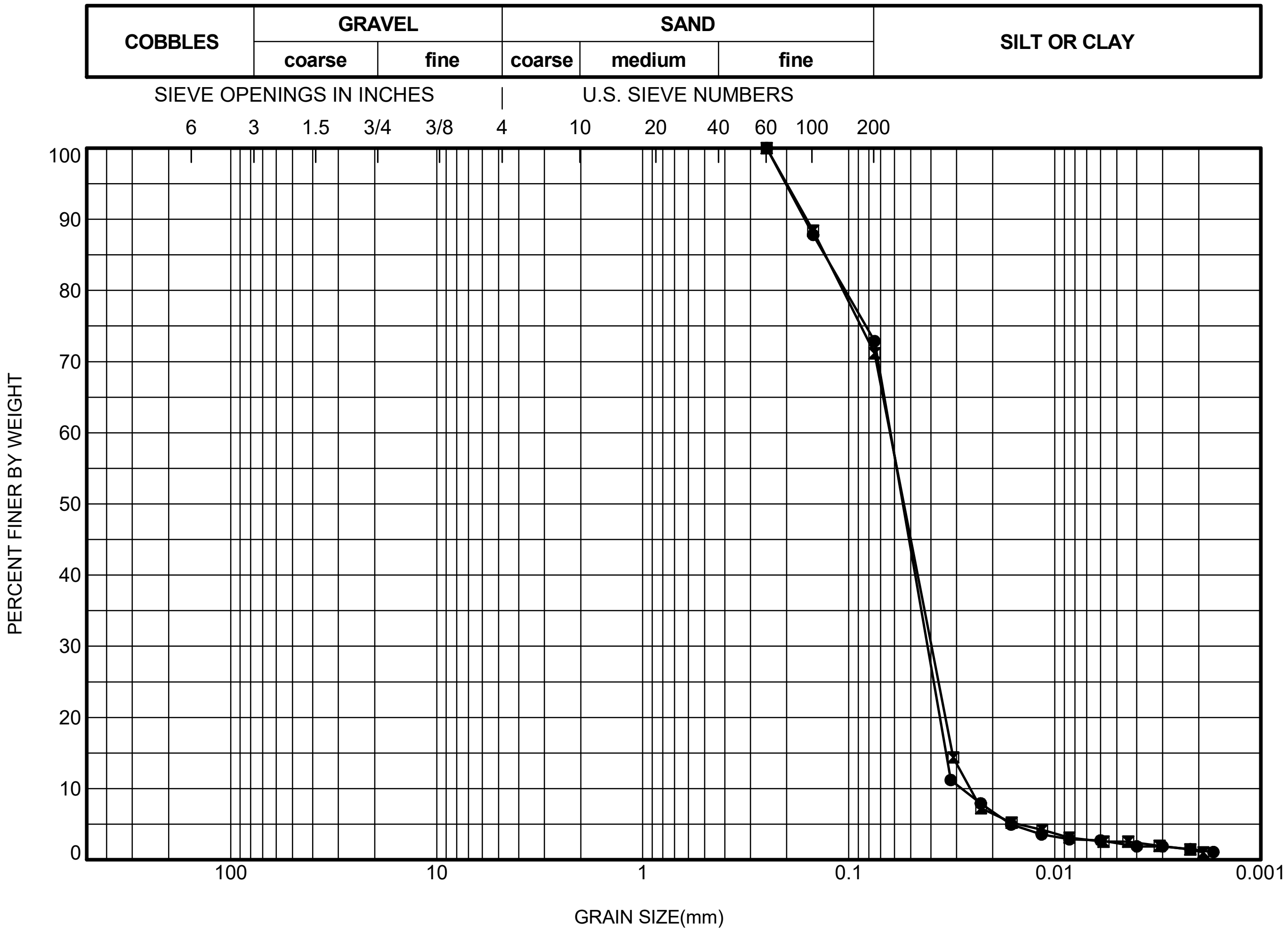
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX27-CAU	0.00	0.131						0.0	27.1	72.9
☒	TX27-CAU	0.00	0.130						0.0	28.8	71.2

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX27-CAU	Fine	0.00					Before Testing (TX27/TX28)
☒	TX27-CAU	Fine	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

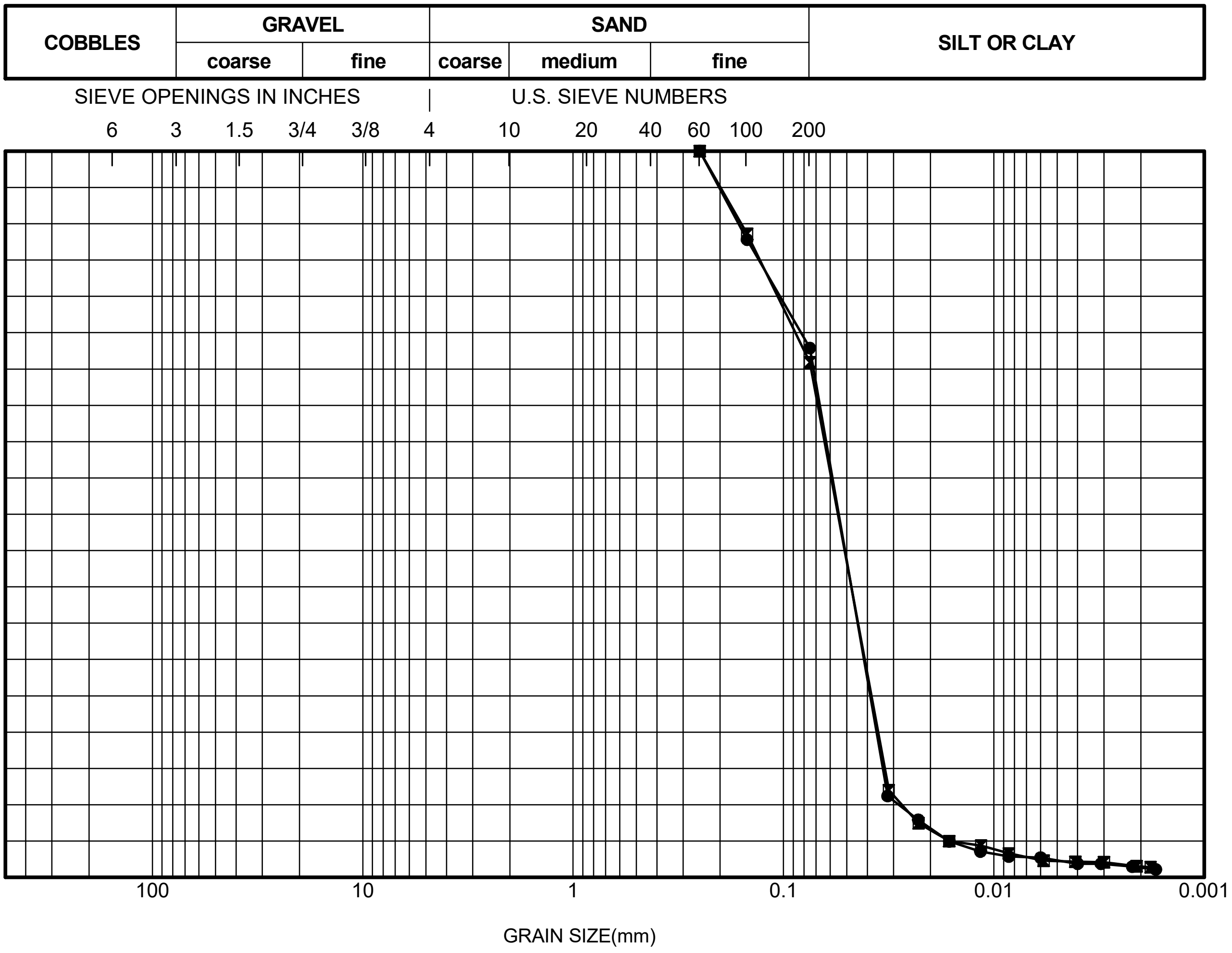
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX28-CAU	0.00	0.131						0.0	27.1	72.9
☒	TX28-CAU	0.00	0.130						0.0	29.1	70.9

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX28-CAU	Fine	0.00					Before Testing (TX27/TX28)
☒	TX28-CAU	Fine	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

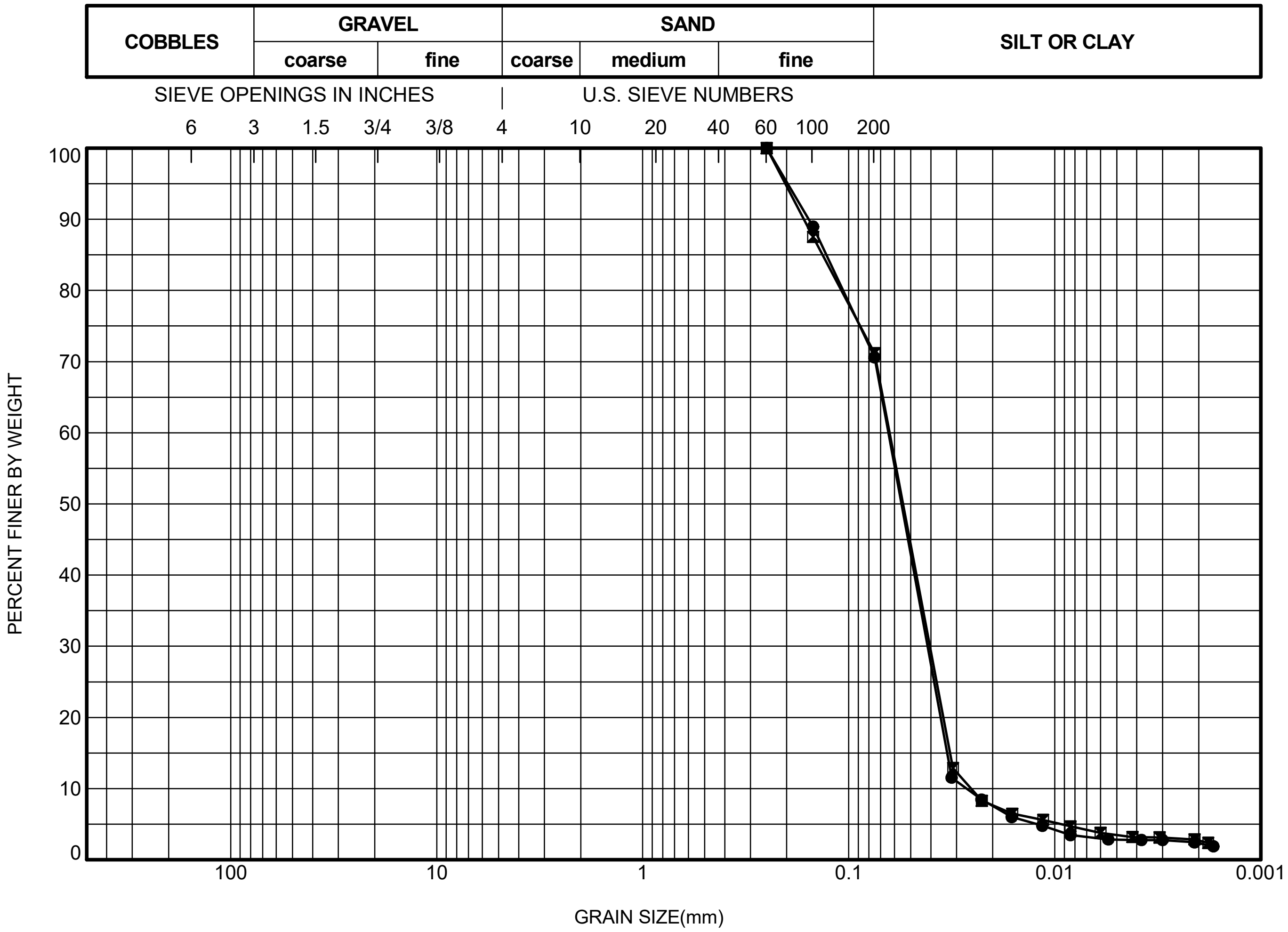
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX29-CAU	0.00	0.128						0.0	29.4	70.6
☒	TX29-CAU	0.00	0.134						0.0	28.8	71.2

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX29-CAU	Fine	0.00					Before Testing (TX29/TXBE10)
☒	TX29-CAU	Fine	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

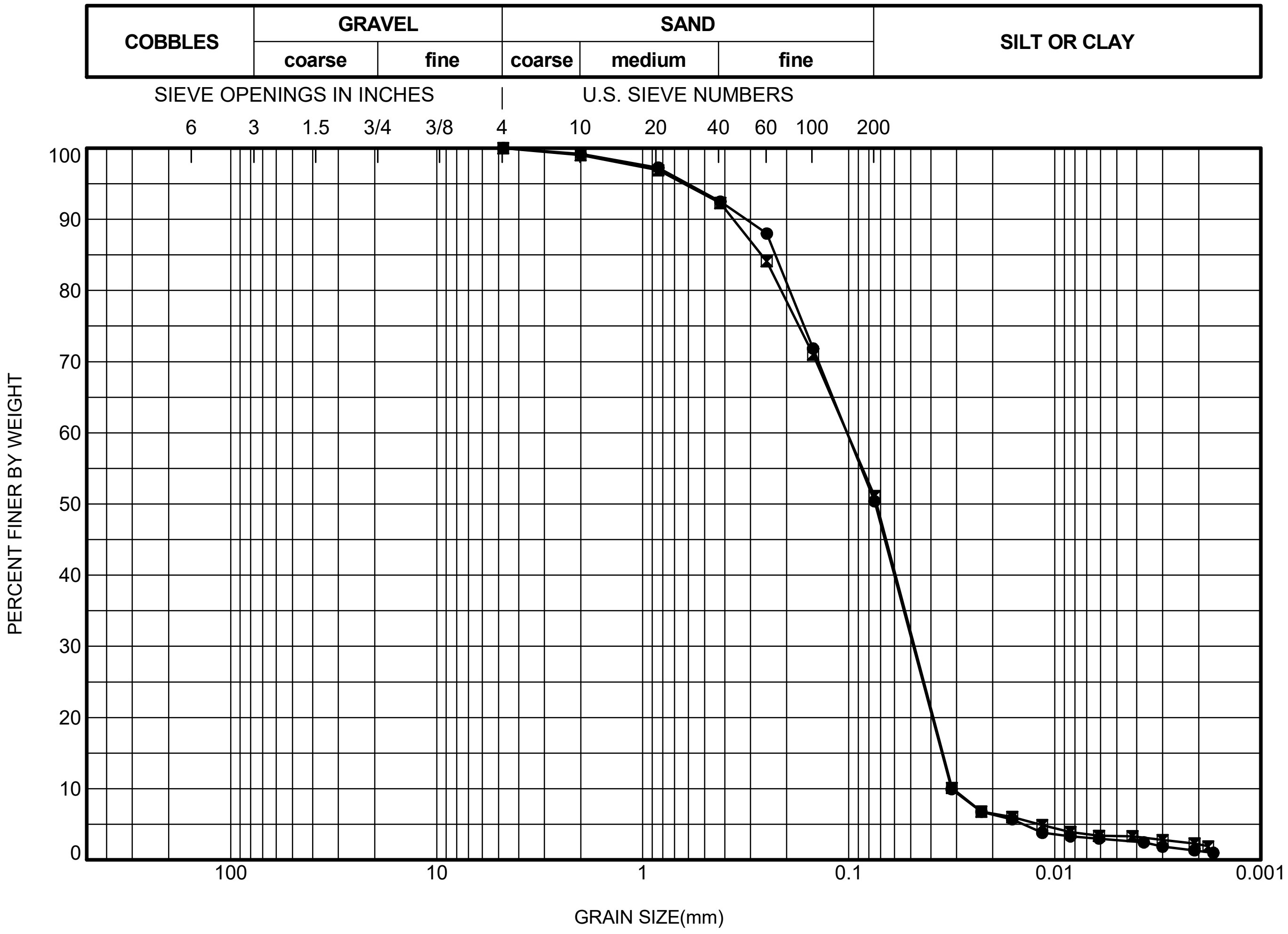
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX30-CAU	0.00	0.227	0.102					0.0	49.6	50.4
☒	TX30-CAU	0.00	0.265	0.102					0.0	48.9	51.1

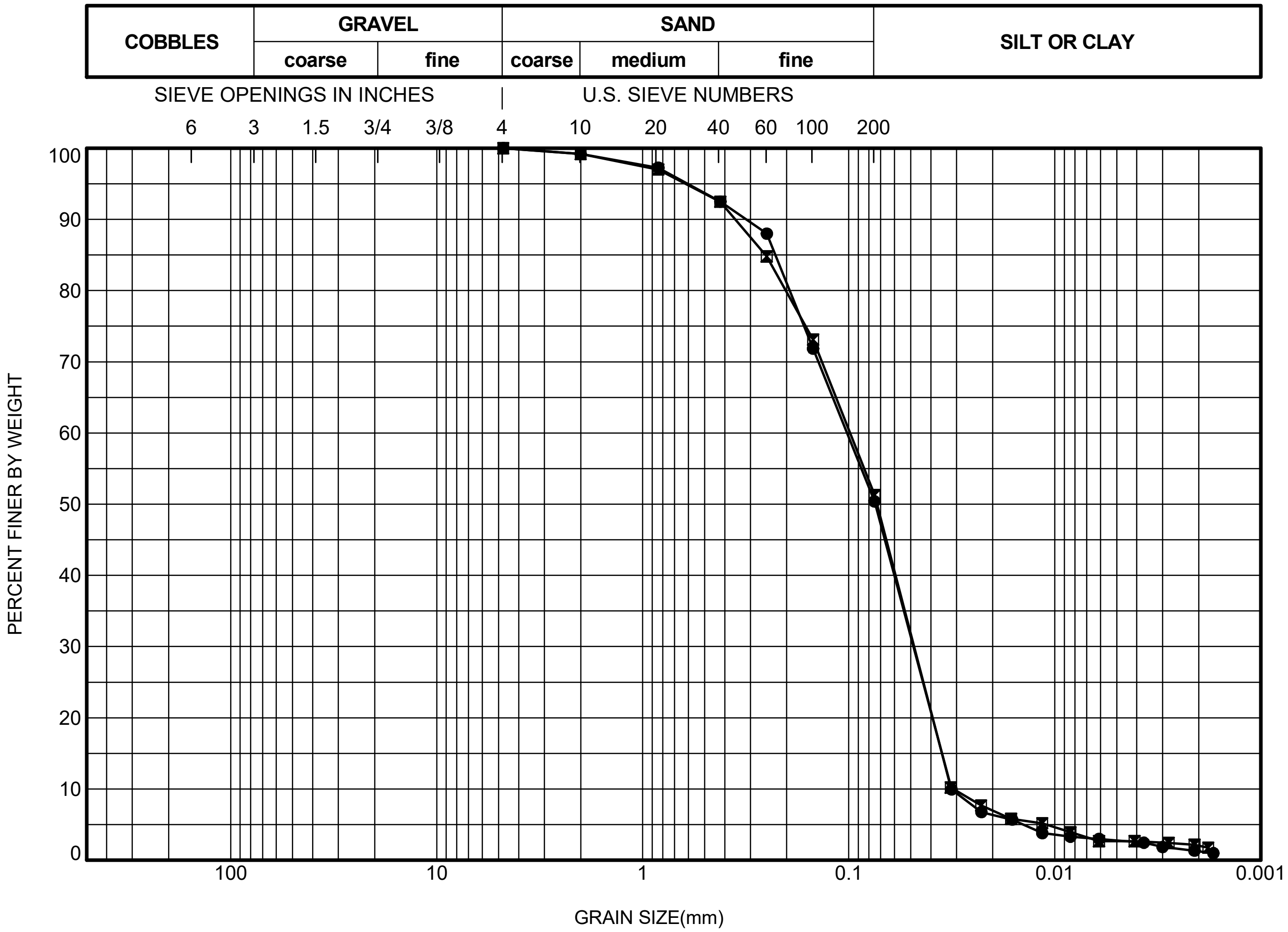
	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX30-CAU	Average	0.00					Before Testing (TX30/TX31/TX32)
☒	TX30-CAU	Average	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01
PROJECT:
LOCATION:
FIGURE:
DRAWN BY: AX **CHECKED BY:** BY

KC_GRAIN_SIZE-SI A03355A01 TRIAXIAL TESTS PSDS.GPJ SIEVE.GDT 19-11-20

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX31-CAU	0.00	0.227	0.102					0.0	49.6	50.4
☒	TX31-CAU	0.00	0.253	0.099					0.0	48.7	51.3

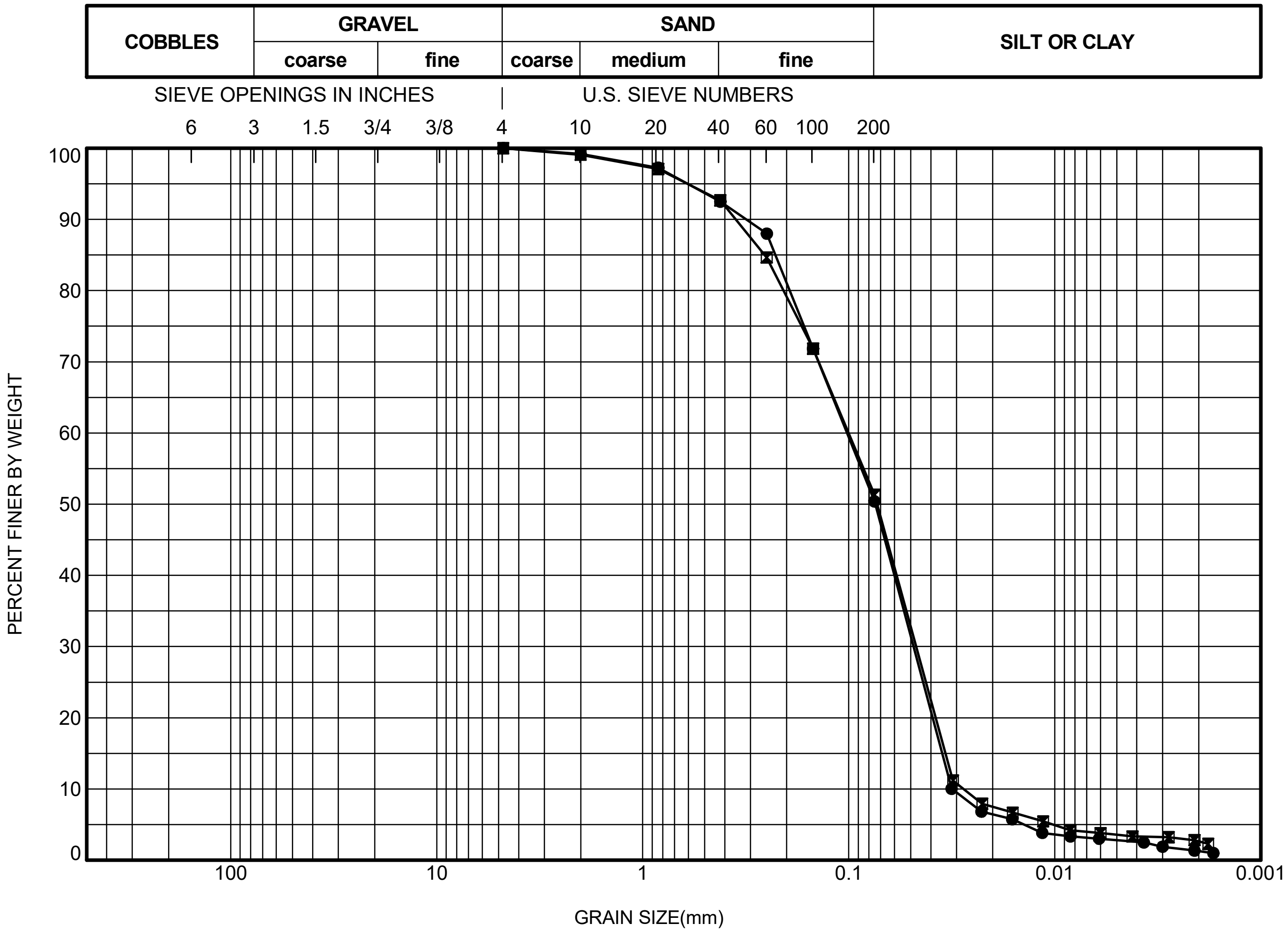
	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX31-CAU	Average	0.00					Before Testing (TX30/TX31/TX32)
☒	TX31-CAU	Average	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01
PROJECT:
LOCATION:
FIGURE:
DRAWN BY: AX **CHECKED BY:** BY

KC_GRAIN_SIZE-SI A03355A01 TRIAXIAL TESTS PSDS.GPJ SIEVE.GDT 19-11-20

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TX32-CAU	0.00	0.227	0.102					0.0	49.6	50.4
☒	TX32-CAU	0.00	0.256	0.100					0.0	48.7	51.3

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TX32-CAU	Average	0.00					Before Testing (TX30/TX31/TX32)
☒	TX32-CAU	Average	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

PROJECT:

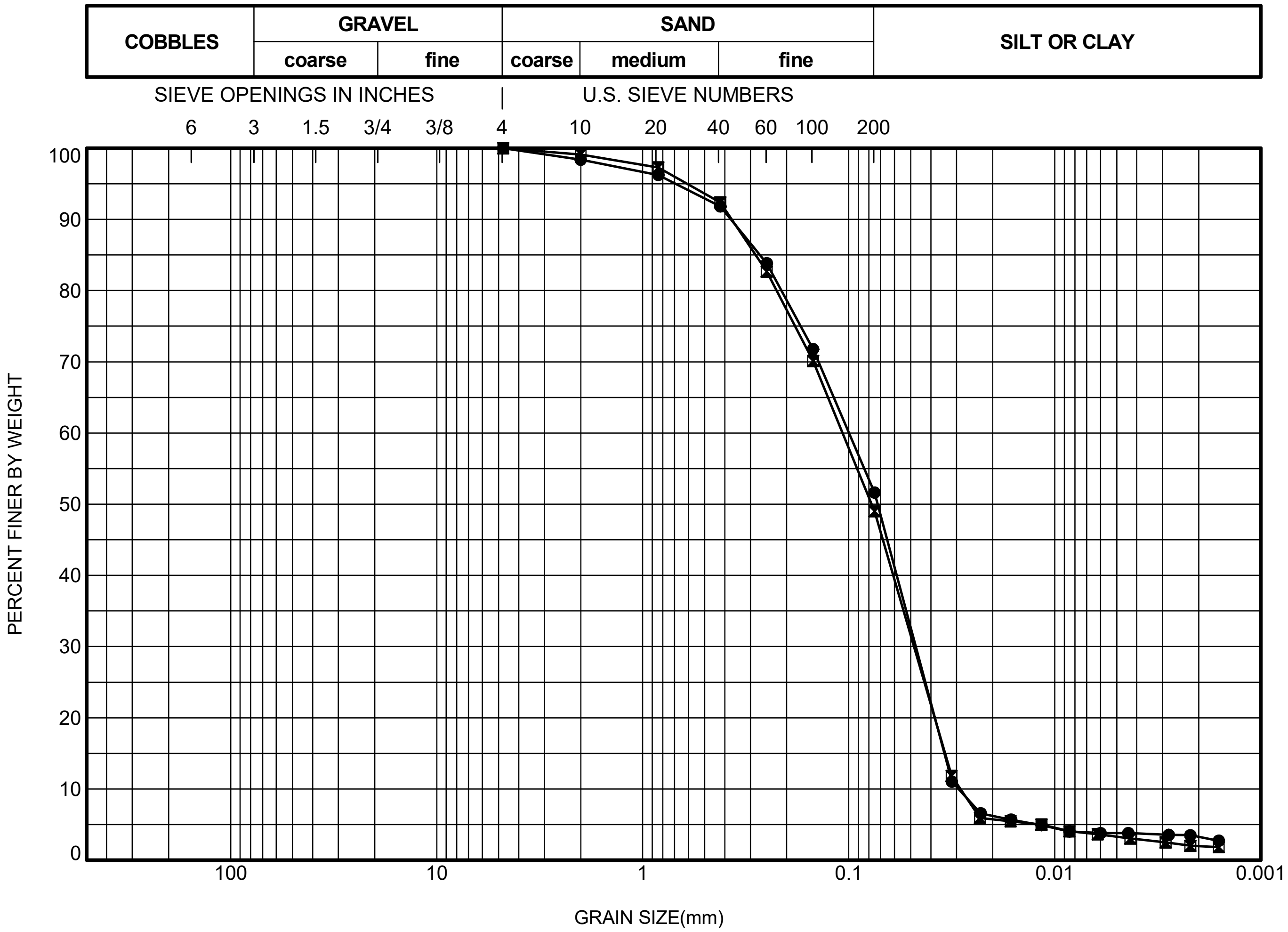
LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

KC_GRAIN_SIZE-SI A03355A01 TRIAXIAL TESTS PSDS.GPJ SIEVE.GDT 19-11-20

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TXBE01	0.00	0.270	0.100					0.0	48.4	51.6
☒	TXBE01	0.00	0.283	0.107	0.077				0.0	51.0	49.0

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TXBE01	Average	0.00					Before Testing (TX02/TX03/TXBE01)
☒	TXBE01	Average	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

PROJECT:

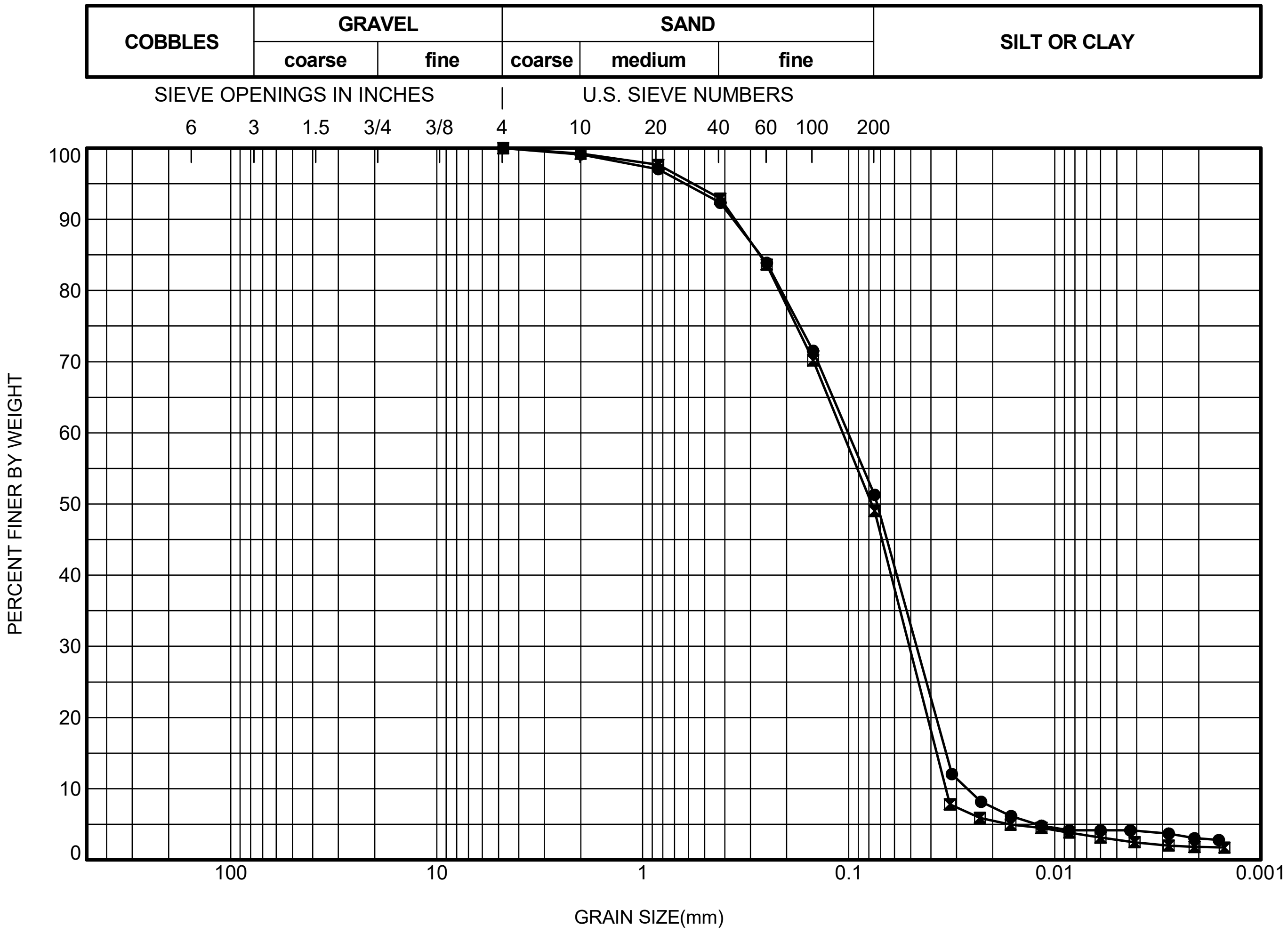
LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

KC_GRAIN_SIZE-SI A03355A01 TRIAXIAL TESTS PSDS.GPJ SIEVE.GDT 19-11-20

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TXBE02	0.00	0.268	0.101					0.0	48.7	51.3
☒	TXBE02	0.00	0.270	0.107	0.077				0.0	51.0	49.0

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TXBE02	Average	0.00					Before Testing (TX04/TX06/TXBE02)
☒	TXBE02	Average	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

PROJECT:

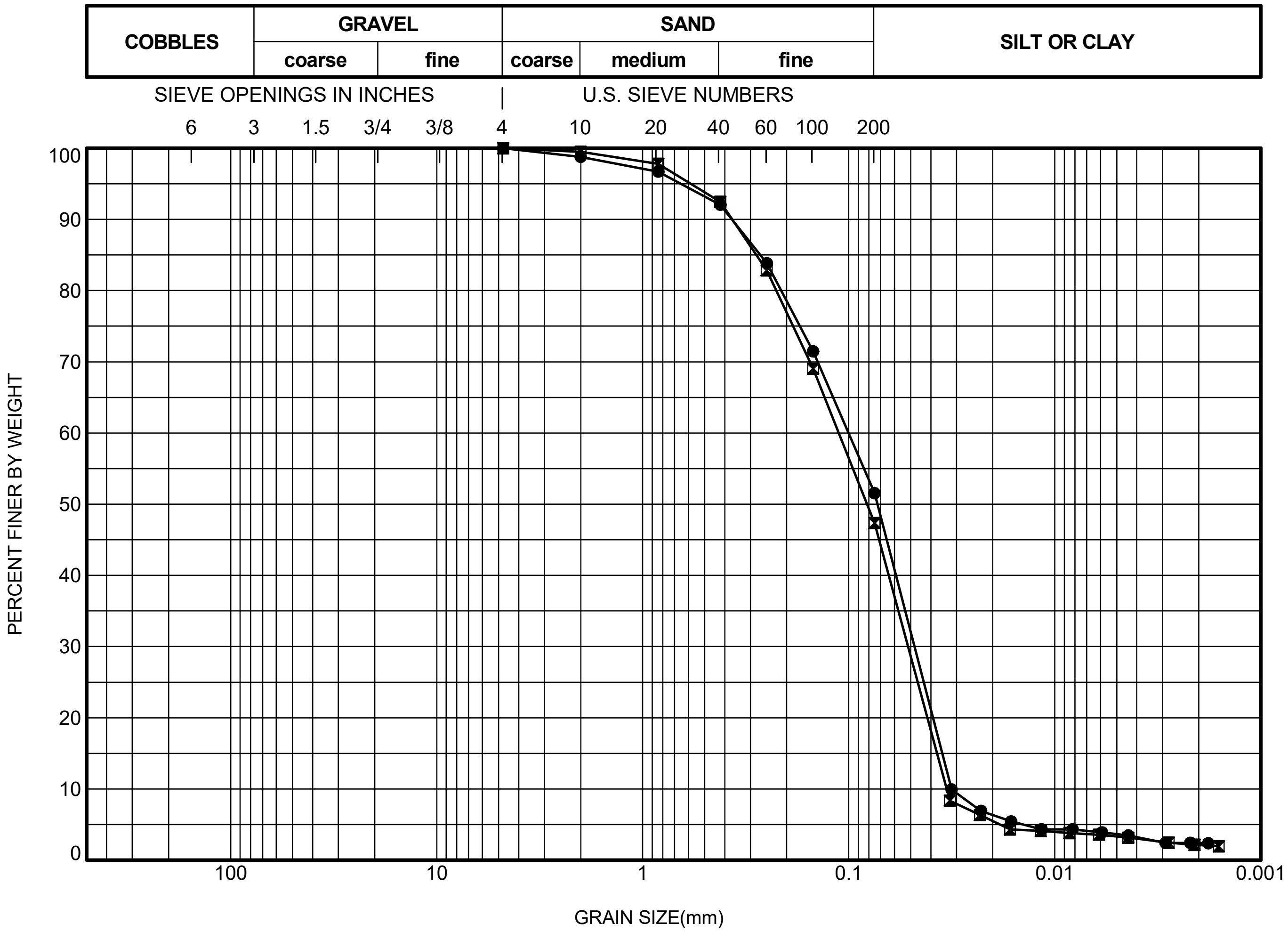
LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

KC_GRAIN_SIZE-SI A03355A01 TRIAXIAL TESTS PSDS.GPJ SIEVE.GDT 19-11-20

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TXBE03	0.00	0.269	0.100					0.0	48.4	51.6
☒	TXBE03	0.00	0.281	0.112	0.082				0.0	52.6	47.4

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TXBE03	Average	0.00					Before Testing (TX07/TXBE03)
☒	TXBE03	Average	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

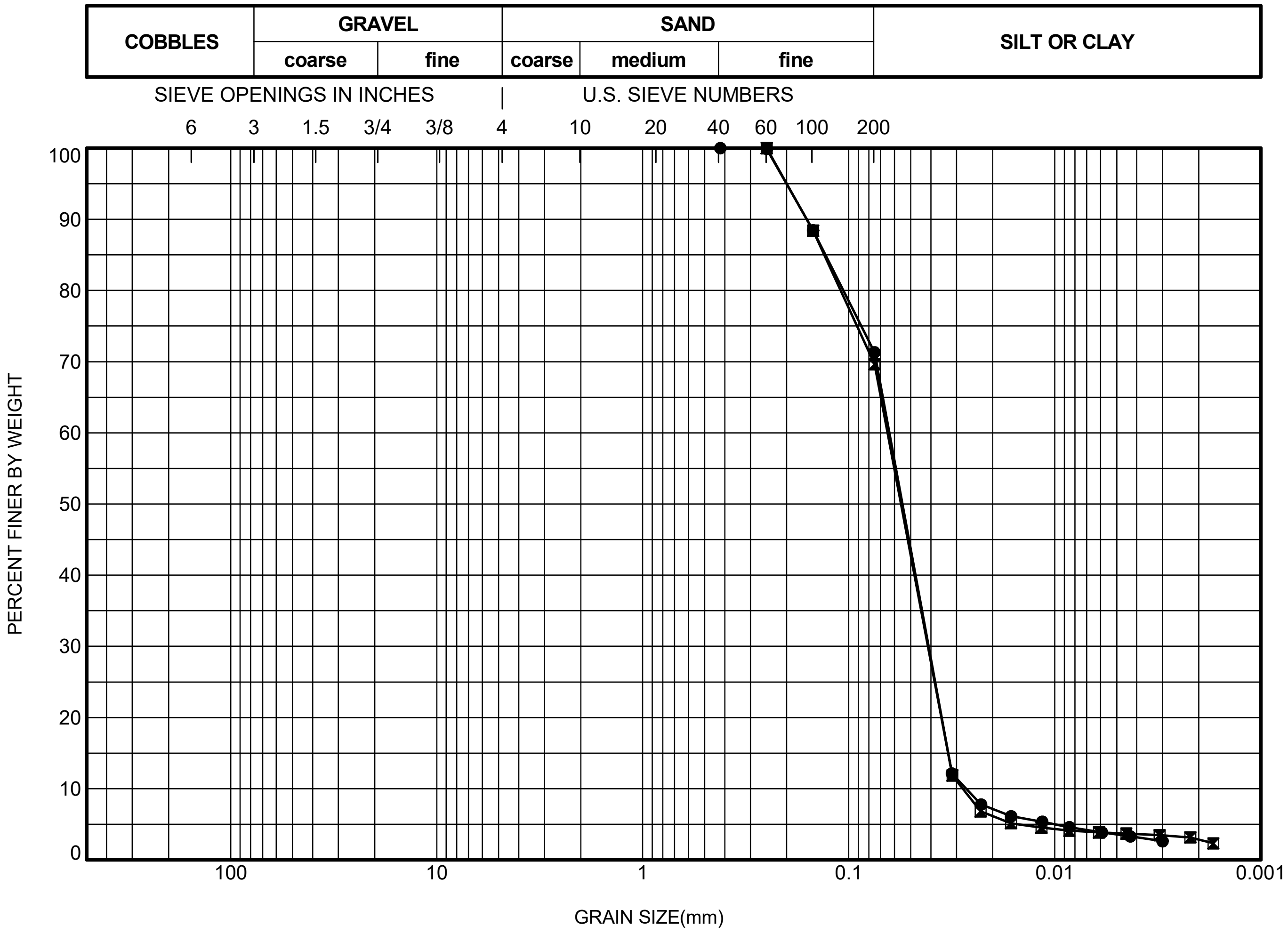
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TXBE04	0.00	0.130						0.0	28.7	71.3
☒	TXBE04	0.00	0.132						0.0	30.4	69.6

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TXBE04	Fine	0.00					Before Testing (TX13/TXBE04)
☒	TXBE04	Fine	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

PROJECT:

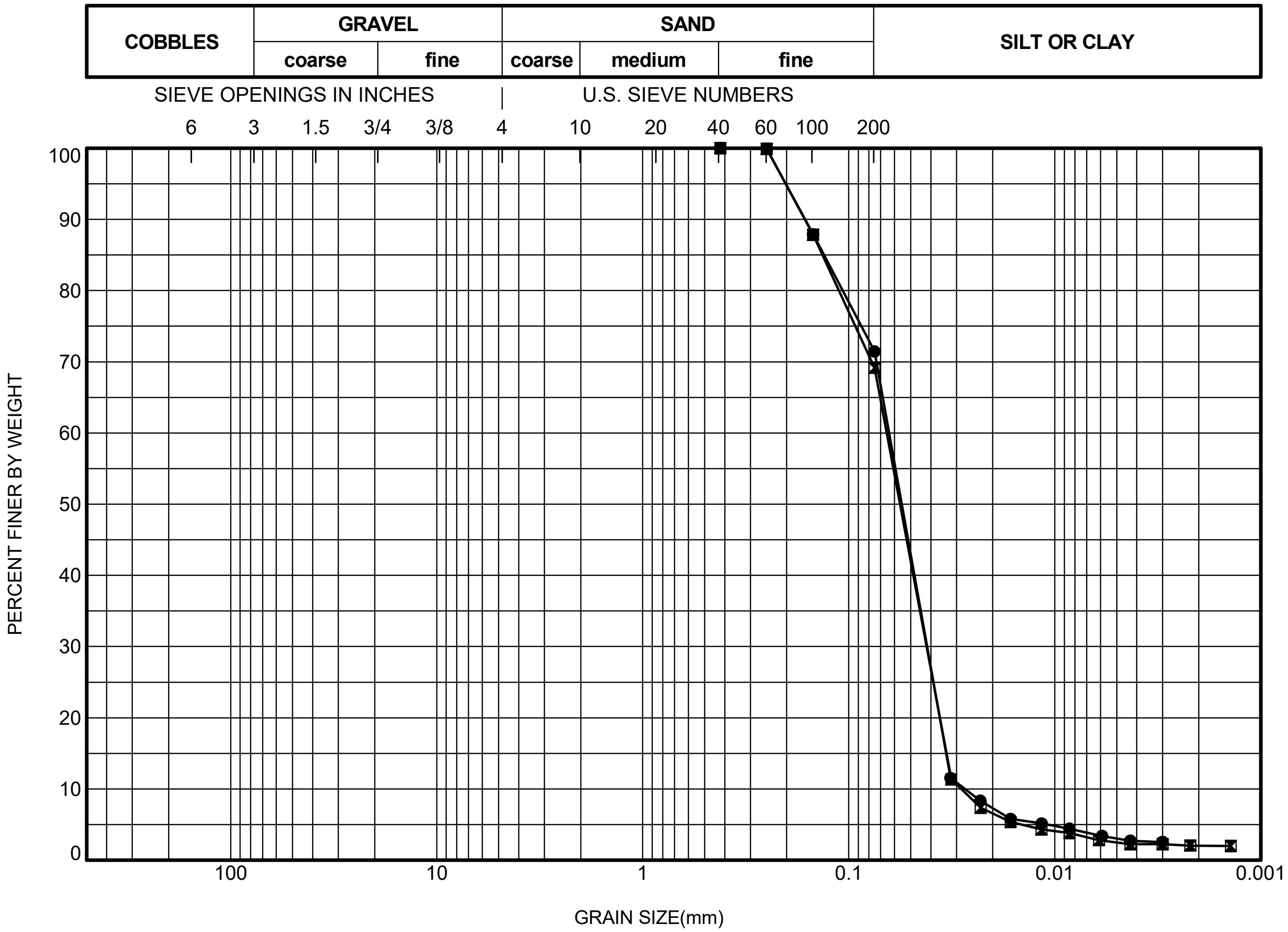
LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

KC_GRAIN_SIZE-SI A03355A01 TRIAXIAL TESTS PSDS.GPJ SIEVE.GDT 19-11-20

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TXBE05	0.00	0.132						0.0	28.5	71.5
☒	TXBE05	0.00	0.134						0.0	30.8	69.2

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TXBE05	Fine	0.00					Fine (TX12/TXBE05)
☒	TXBE05	Fine	0.00					Fine

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

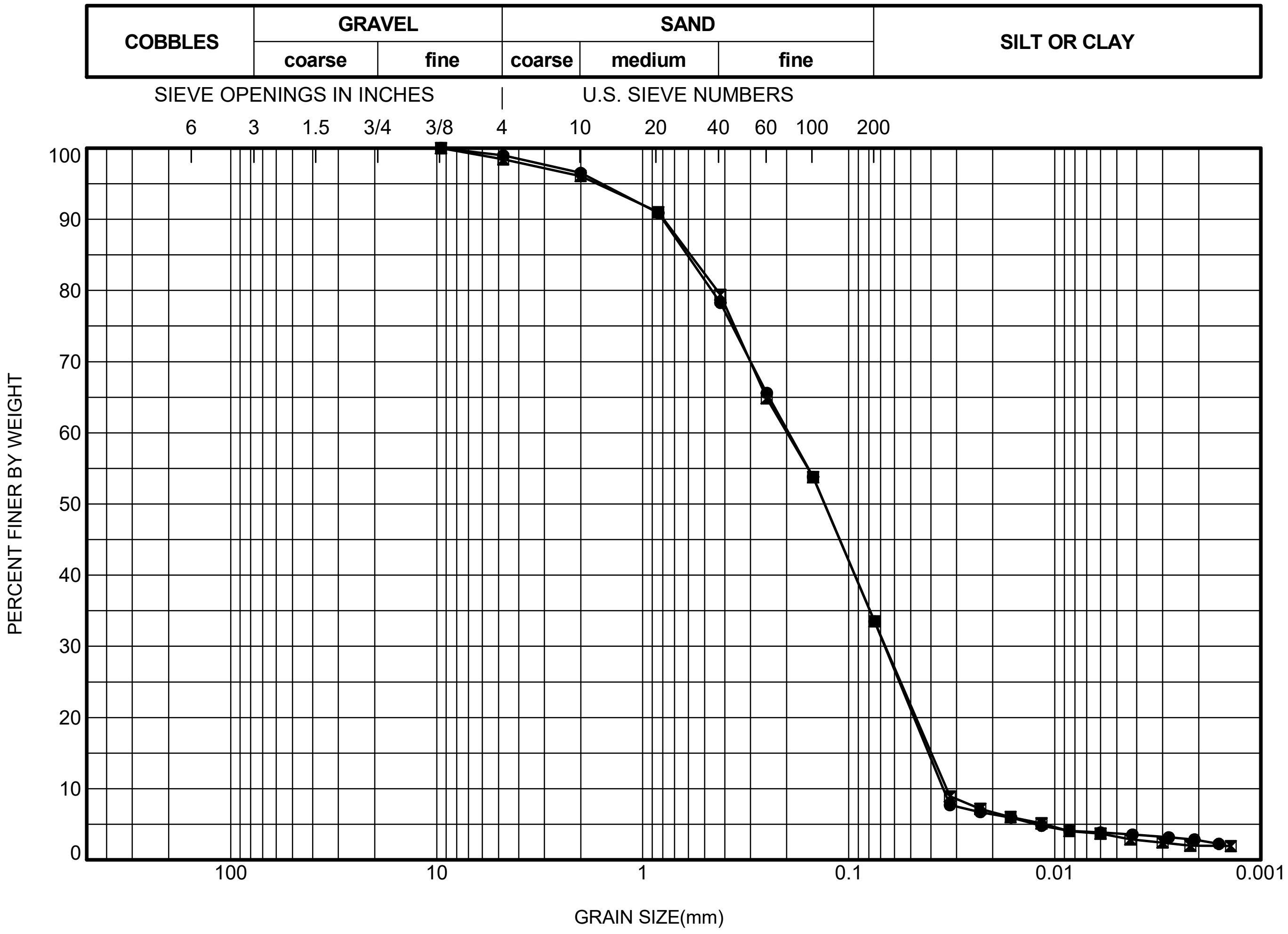
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TXBE06	0.00	0.608	0.196	0.131				1.0	65.5	33.5
☒	TXBE06	0.00	0.587	0.199	0.131				1.6	64.9	33.5

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TXBE06	Coarse	0.00					Before Testing (TXBE06/TXBE07)
☒	TXBE06	Coarse	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

PROJECT:

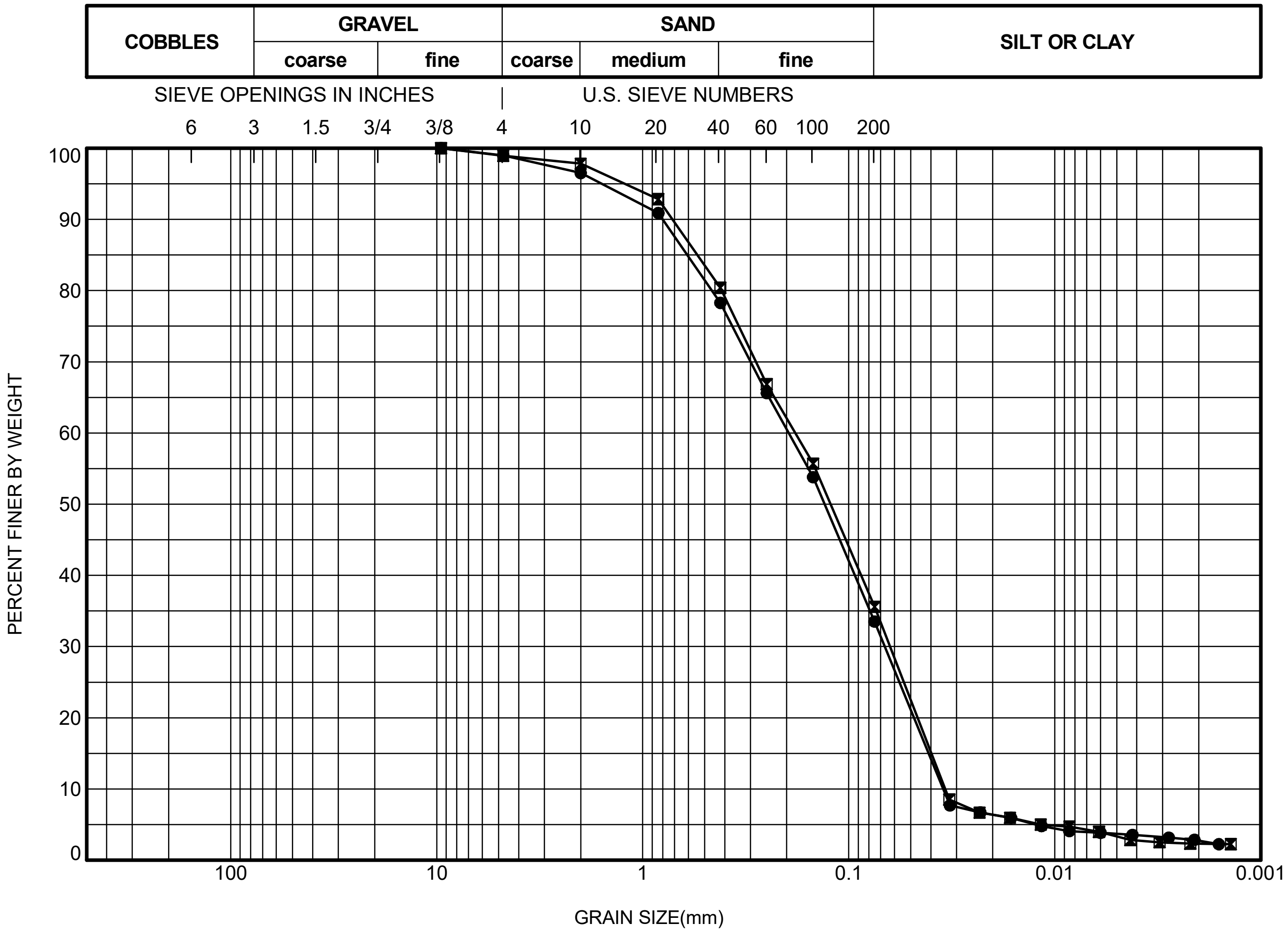
LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

KC_GRAIN_SIZE-SI A03355A01 TRIAXIAL TESTS PSDS.GPJ SIEVE.GDT 19-11-20

GRAIN SIZE DISTRIBUTION



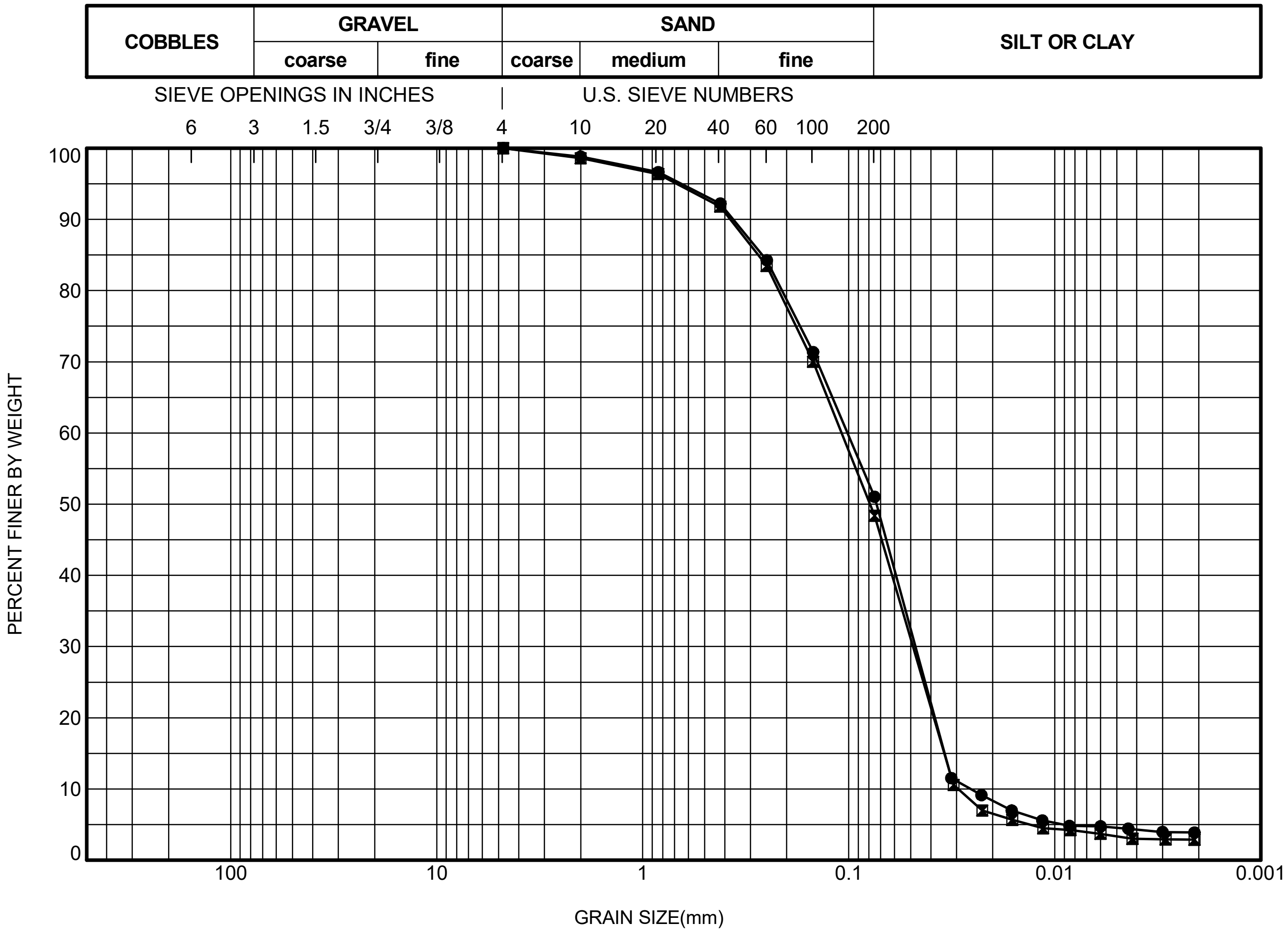
	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TXBE07	0.00	0.608	0.196	0.131				1.0	65.5	33.5
☒	TXBE07	0.00	0.543	0.182	0.123				1.1	63.3	35.6

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TXBE07	Coarse	0.00					Before Testing (TXBE06/TXBE07)
☒	TXBE07	Coarse	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01
PROJECT:
LOCATION:
FIGURE:
DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TXBE08	0.00	0.262	0.102					0.0	49.0	51.0
⧗	TXBE08	0.00	0.275	0.108	0.079				0.0	51.6	48.4

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TXBE08	Average	0.00					Before Testing
⧗	TXBE08	Average	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

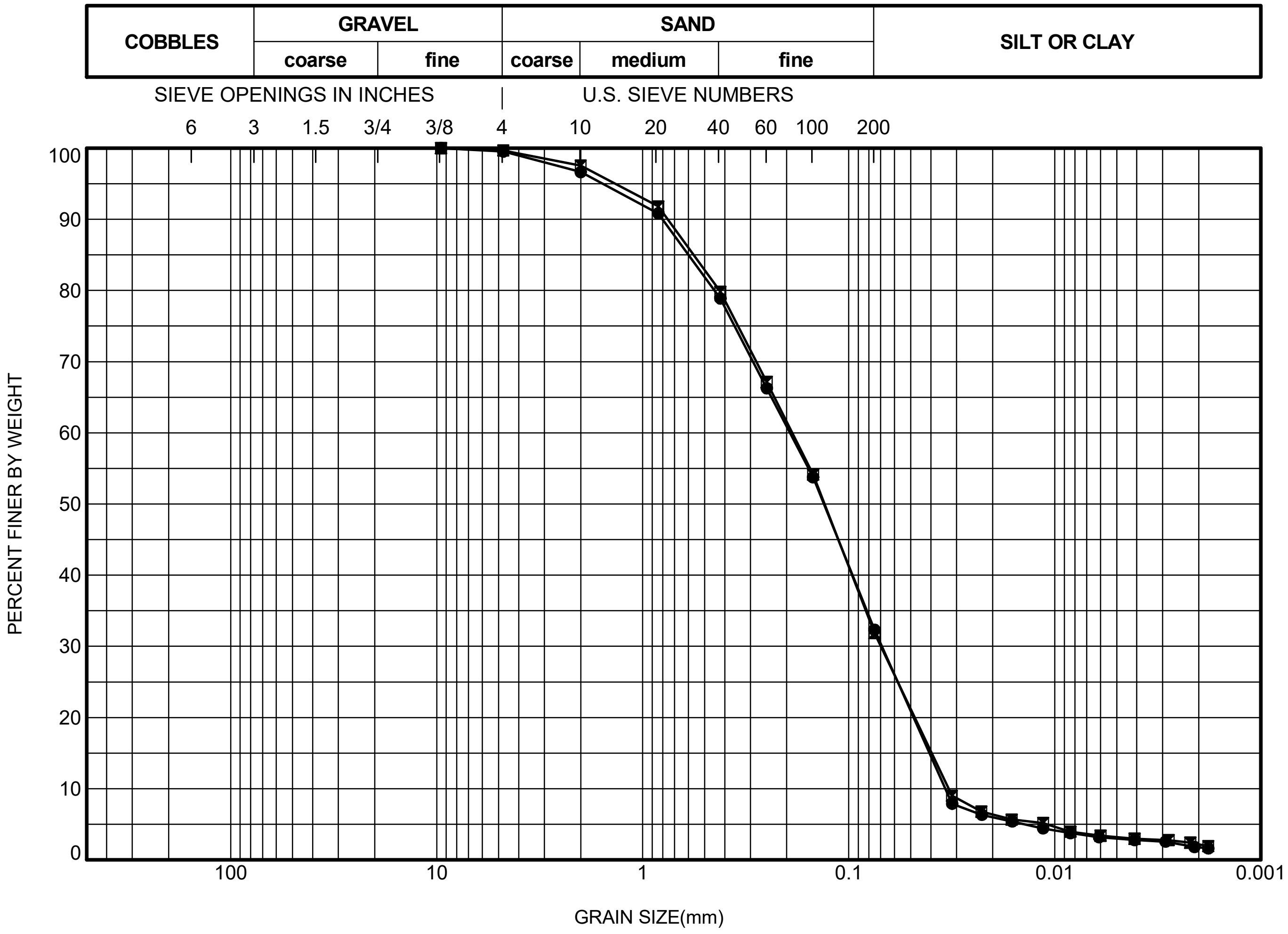
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TXBE09	0.00	0.599	0.193	0.132				0.5	67.2	32.3
☒	TXBE09	0.00	0.566	0.188	0.131				0.3	67.8	31.9

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TXBE09	Coarse	0.00					Before Testing
☒	TXBE09	Coarse	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

PROJECT:

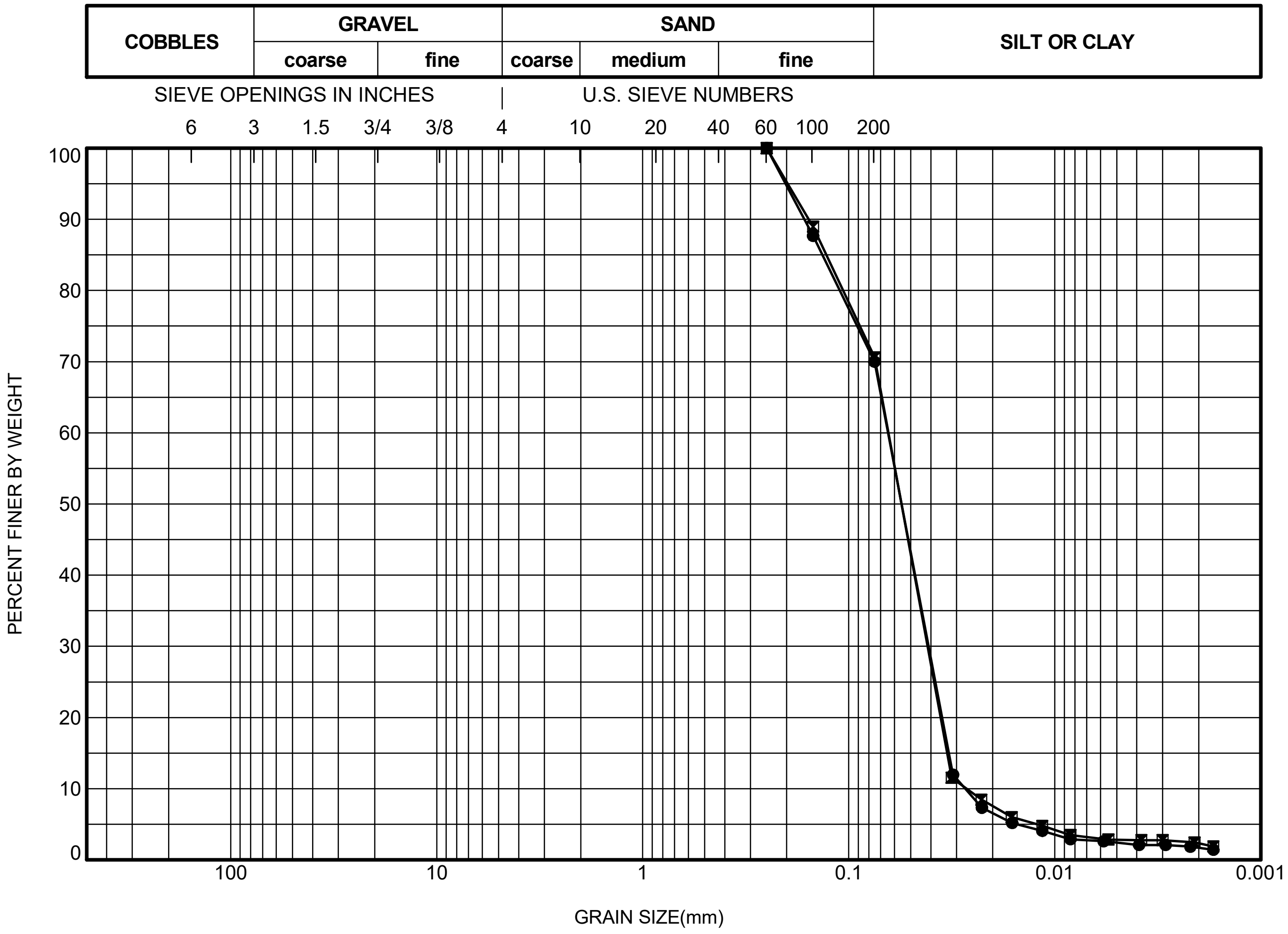
LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

KC_GRAIN_SIZE-SI A03355A01 TRIAXIAL TESTS PSDS.GPJ SIEVE.GDT 19-11-20

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TXBE10	0.00	0.134						0.0	30.0	70.0
☒	TXBE10	0.00	0.128						0.0	29.4	70.6

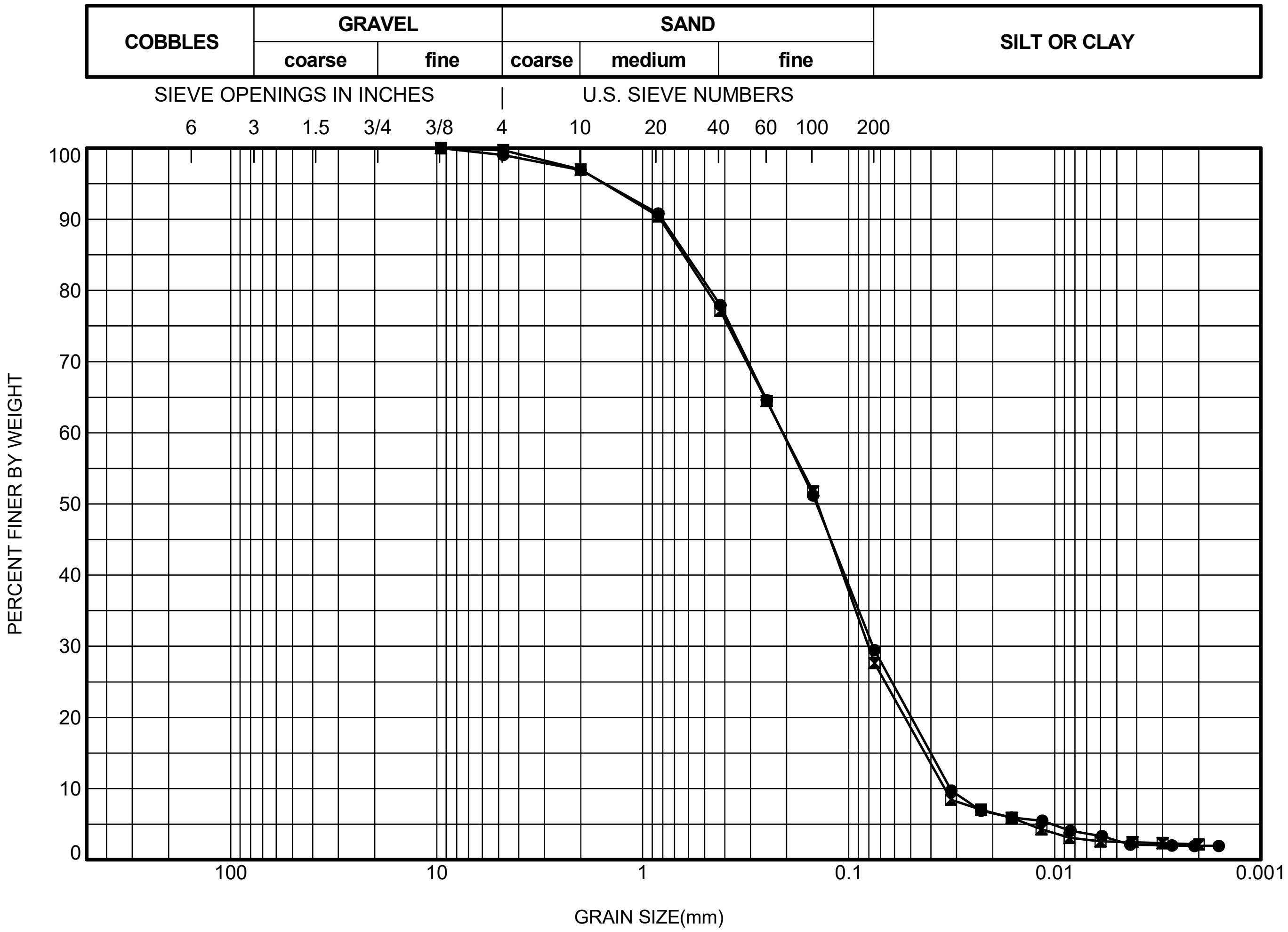
	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TXBE10	Fine	0.00					Before Testing (TX29/TXBE10)
☒	TXBE10	Fine	0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01
PROJECT:
LOCATION:
FIGURE:
DRAWN BY: AX **CHECKED BY:** BY

KC_GRAIN_SIZE-SI A03355A01 TRIAXIAL TESTS PSDS.GPJ SIEVE.GDT 19-11-20

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TXDW01	0.00	0.614	0.209	0.144				1.0	69.6	29.4
☒	TXDW01	0.00	0.633	0.209	0.142				0.3	72.1	27.6

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TXDW01		0.00					Before Testing
☒	TXDW01		0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

PROJECT:

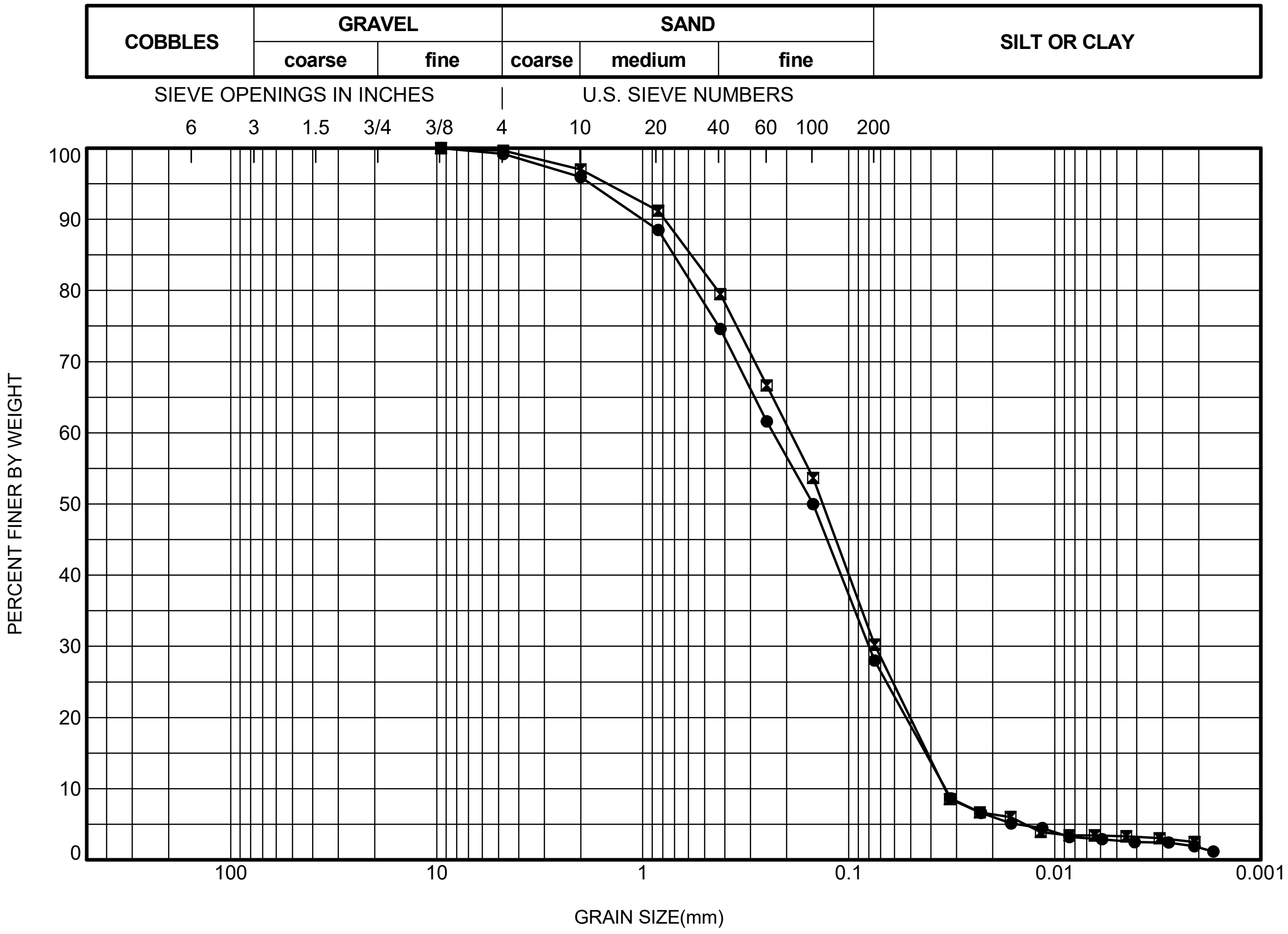
LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

KC_GRAIN_SIZE-SI A03355A01 TRIAXIAL TESTS PSDS.GPJ SIEVE.GDT 19-11-20

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TXDW02	0.00	0.705	0.233	0.149				0.8	71.2	28.0
☒	TXDW02	0.00	0.582	0.192	0.134				0.4	69.4	30.2

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TXDW02		0.00					Before Testing (TX25/TXDW02)
☒	TXDW02		0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

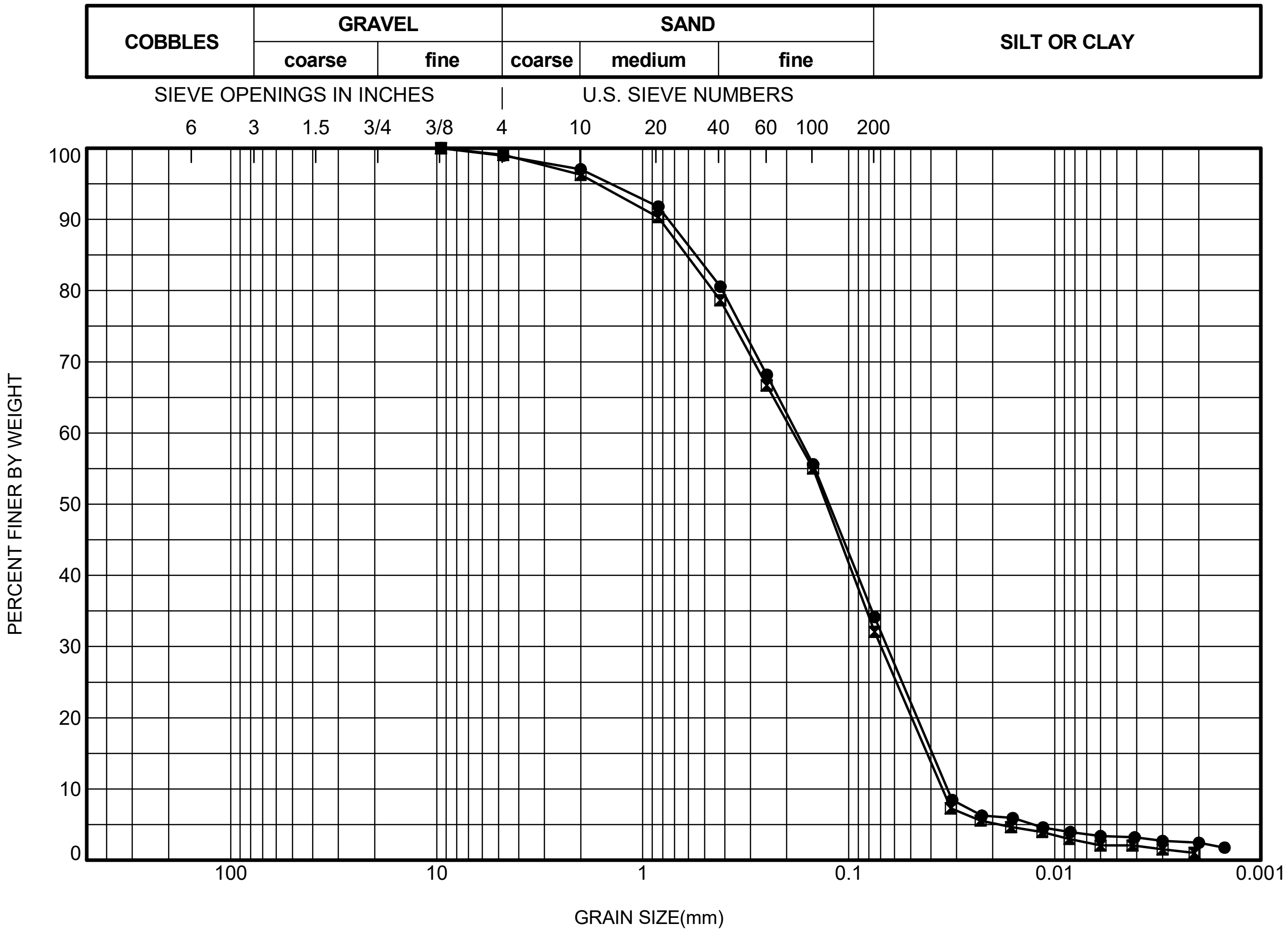
PROJECT:

LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

GRAIN SIZE DISTRIBUTION



	HOLE	DEPTH (m)	D85	D60	D50	D15	D10	CU	%GRAVEL	%SAND	%FINES
●	TXDW03	0.00	0.552	0.179	0.125				1.0	64.8	34.1
☒	TXDW03	0.00	0.613	0.186	0.128				1.0	67.0	32.1

	HOLE	SAMPLE	DEPTH (m)	W%	W_L	W_P	PI	REMARKS / SAMPLE DESCRIPTION
●	TXDW03		0.00					Before Testing
☒	TXDW03		0.00					After Testing

CU = COEFFICIENT OF UNIFORMITY = D60/D10 **PARTICLE SIZES, e.g. D85, in mm** **Tested by Wet Sieving Method (ASTM D1140 & D422)**

PROJECT NO.: A03355A01

PROJECT:

LOCATION:

FIGURE:

DRAWN BY: AX **CHECKED BY:** BY

Individual Triaxial Test Results

Triaxial CD Test - Summary

(ASTM D7181)

PROJECT NO. :	A03355A01	DATE :	2019-07-24
PROJECT :		TESTED BY:	BY
SAMPLE :	Average	CHECKED BY:	JG
TEST NO. :	TX 01 - CID		

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation / B-value	End of 1st Consolidation	End of 2nd Consolidation	End of 3rd Consolidation	End of 4th Consolidation	End of 5th Consolidation	End of 6th Consolidation	At Failure	End of Shear
Specimen Height	mm	140.08	140.08	139.55	139.16	138.88	138.44	137.86	137.10	135.29	107.40	94.13
Specimen Diameter	mm	69.80	69.62	67.51	66.78	66.46	66.15	65.83	65.47	65.27	70.41	75.03
Area	cm^2	38.26	38.07	35.79	35.03	34.70	34.37	34.04	33.66	33.46	38.94	44.21
Volume	cm^3	536.01	533.25	499.46	487.46	481.86	475.86	469.28	461.53	452.72	418.21	416.15
Wet Weight	g	1270.48	1270.48	1464.58	1452.58	1446.98	1440.98	1434.40	1426.65	1417.84	1383.33	1381.27
Water Content	%	5.17	5.17	21.24	20.24	19.78	19.28	18.74	18.10	17.37	14.51	14.34
Dry Weight	g	1208.03	1208.03	1208.03	1208.03	1208.03	1208.03	1208.03	1208.03	1208.03	1208.03	1208.03
Wet Density	g/cm^3	2.370	2.383	2.932	2.980	3.003	3.028	3.057	3.091	3.132	3.308	3.319
Dry Density	g/cm^3	2.254	2.265	2.419	2.478	2.507	2.539	2.574	2.617	2.668	2.889	2.903
Specific Gravity of Solids (assumed)	-	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97
Solids Volume	cm^3	243.063	243.063	243.063	243.063	243.063	243.063	243.063	243.063	243.063	243.063	243.063
Void Volume	cm^3	292.951	290.191	256.398	244.400	238.795	232.802	226.218	218.464	209.660	175.146	173.088
Water Volume	cm^3	62.455	62.455	256.555	244.557	238.952	232.959	226.375	218.621	209.817	175.303	173.245
Void Ratio (e)	-	1.205	1.194	1.055	1.005	0.982	0.958	0.931	0.899	0.863	0.721	0.712
Saturation Ratio (Sr)	%	21.32	21.52	100.06	100.06	100.07	100.07	100.07	100.07	100.08	100.09	100.09
Effective Confining Stress	kPa				50	100	200	400	800	1500		

Shearing (CU)		
Skempton's B Parameter		0.99
Back Pressure before shearing	kPa	499.0
Confining Stress (σ_3') before shearing	kPa	1500
Shear Strain Rate	mm / min	0.033

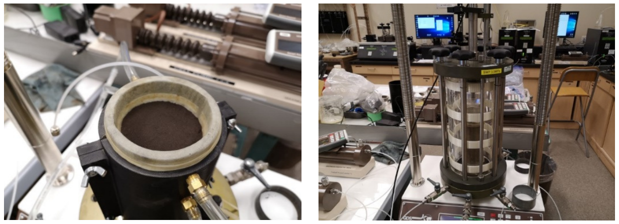
At Maximum Stress Ratio		
Axial Stain	%	**20.60**
Deviator Stress	kPa	**4179.4**
Φ '	º	35.6
c' (assumed)	kPa	**0**

At Maximum Deviator Stress:		
Axial Stain	%	**20.60**
Deviator Stress	kPa	**4179.4**
Φ '	º	35.6
c' (assumed)	kPa	0

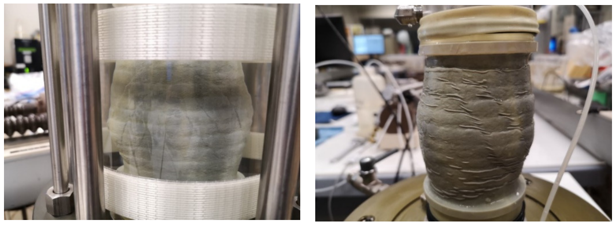
Note: *using cambridge method*

Photos:

Before Test



After Test

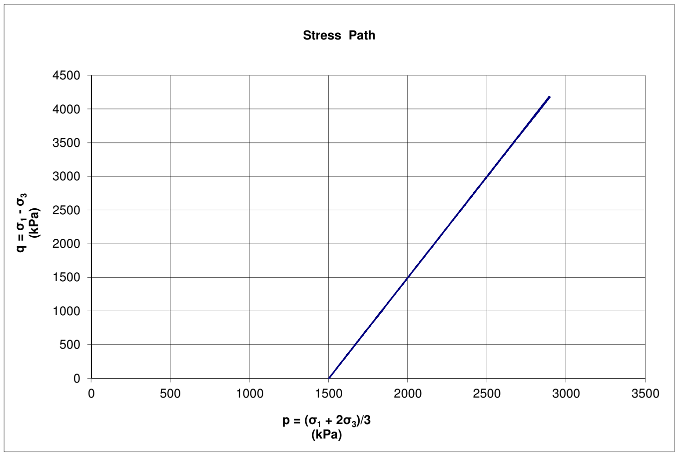


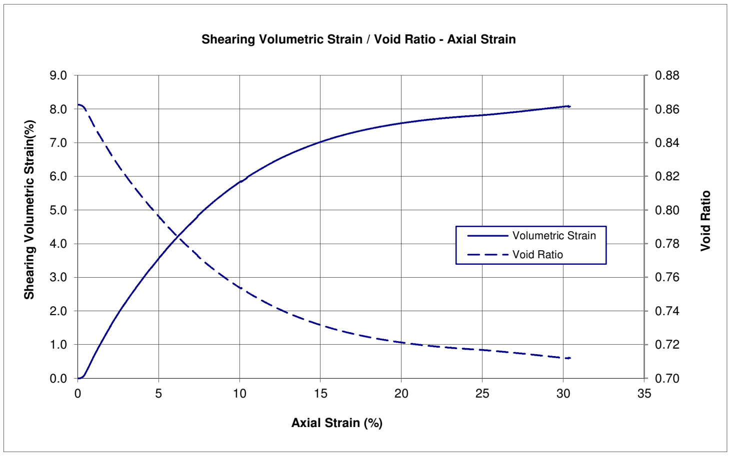
Triaxial CD Test - Charts

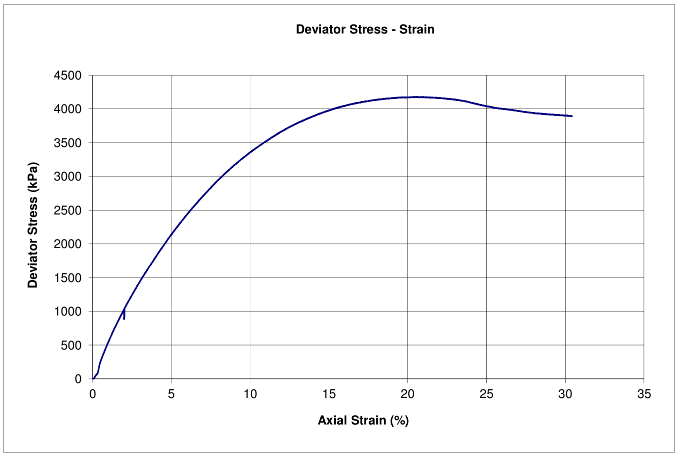
(ASTM D7181)

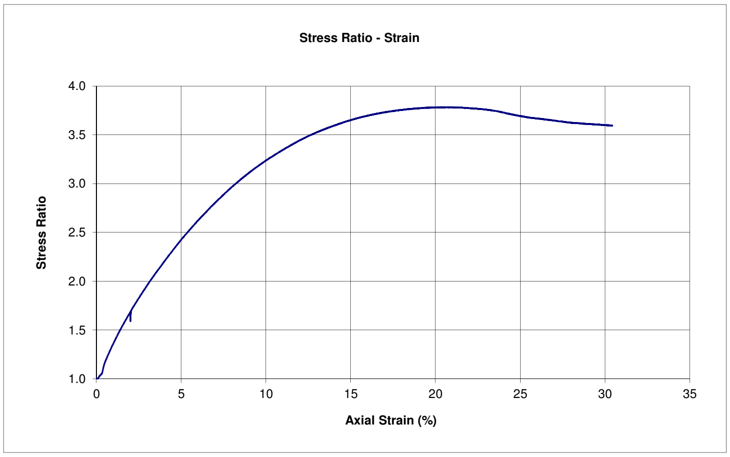
PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Average
TEST NO. : TX 01 - CID

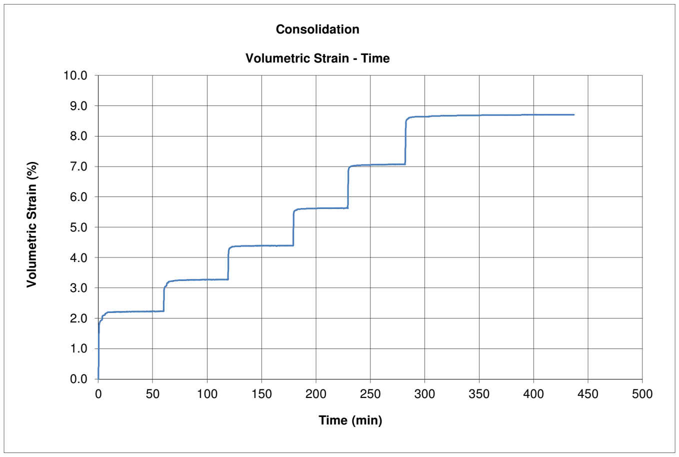
DATE : 2019-07-24
TEST BY: BY
CHECKED BY: JG

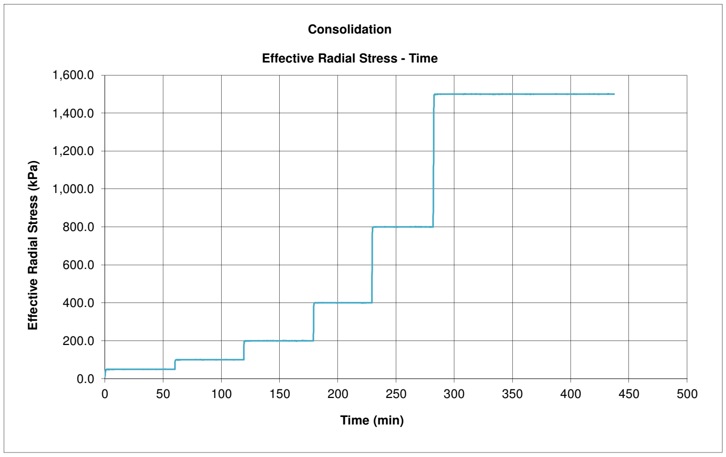












Triaxial CD Test - Summary

(ASTM D7181)

PROJECT NO. : A03355A01

PROJECT :

SAMPLE : Average

TEST NO. : TX 02 - CID

DATE : 2019-07-29

TESTED BY: BY

CHECKED BY: JG

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation / B-value	End of 1st Consolidation	End of 2nd Consolidation	End of 3rd Consolidation	At Failure	End of Shear	
Specimen Height	mm	139.89	139.49	137.41	135.95	135.39	134.75	109.93	88.31	
Specimen Diameter	mm	69.80	69.40	66.94	66.46	66.20	65.92	71.09	79.13	
Area	cm^2	38.26	37.83	35.19	34.69	34.42	34.13	39.70	49.18	
Volume	cm^3	535.29	527.66	483.52	471.58	466.05	459.90	436.36	434.31	
Wet Weight	g	1215.22	1215.22	1406.90	1394.97	1389.43	1383.28	1359.74	1357.69	
Water Content	%	5.13	5.13	21.71	20.68	20.20	19.67	17.63	17.46	
Dry Weight	g	1155.92	1155.92	1155.92	1155.92	1155.92	1155.92	1155.92	1155.92	
Wet Density	g/cm^3	2.270	2.303	2.910	2.958	2.981	3.008	3.116	3.126	
Dry Density	g/cm^3	2.159	2.191	2.391	2.451	2.480	2.513	2.649	2.662	
Specific Gravity of Solids (assumed)	-	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	
Solids Volume	cm^3	232.580	232.580	232.580	232.580	232.580	232.580	232.580	232.580	
Void Volume	cm^3	302.708	295.078	250.938	239.003	233.470	227.321	203.778	201.732	
Water Volume	cm^3	59.299	59.299	250.979	239.044	233.511	227.362	203.819	201.773	
Void Ratio (e)	-	1.302	1.269	1.079	1.028	1.004	0.977	0.876	0.867	
Saturation Ratio (Sr)	%	19.59	20.10	100.02	100.02	100.02	100.02	100.02	100.02	
Effective Confining Stress	kPa				50	100	200			

Shearing (CU)		
Skempton's B Parameter		0.98
Back Pressure before shearing	kPa	400.0
Confining Stress (σ_3') before shearing	kPa	200
Shear Strain Rate	mm / min	0.035

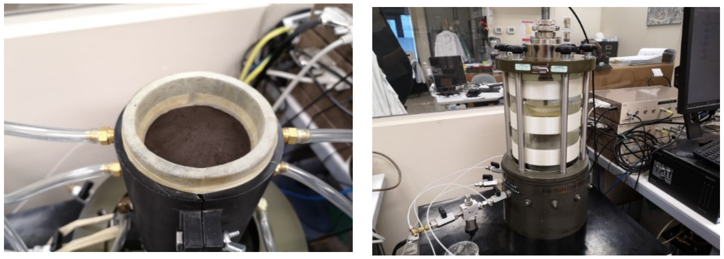
At Maximum Deviator Stress:		
Axial Stain	%	**18.42**
Deviator Stress	kPa	**533.9**
Φ '	º	34.9
c' (assumed)	kPa	**0**

At Maximum Stress Ratio		
Axial Stain	%	**18.82**
Deviator Stress	kPa	**532.4**
Φ '	º	35.0
c' (assumed)	kPa	0

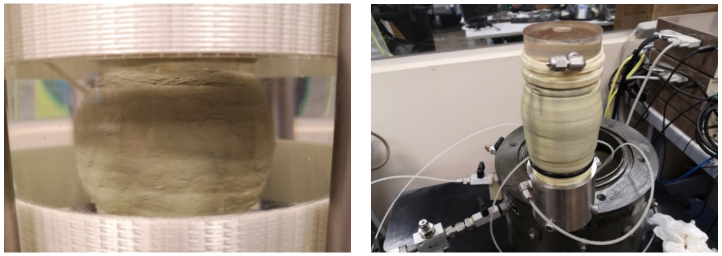
Note: *using cambridge method*

Photos:

Before Test



After Test

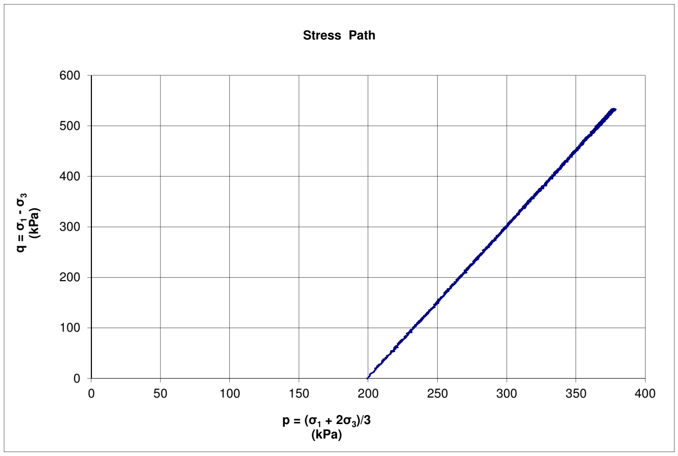


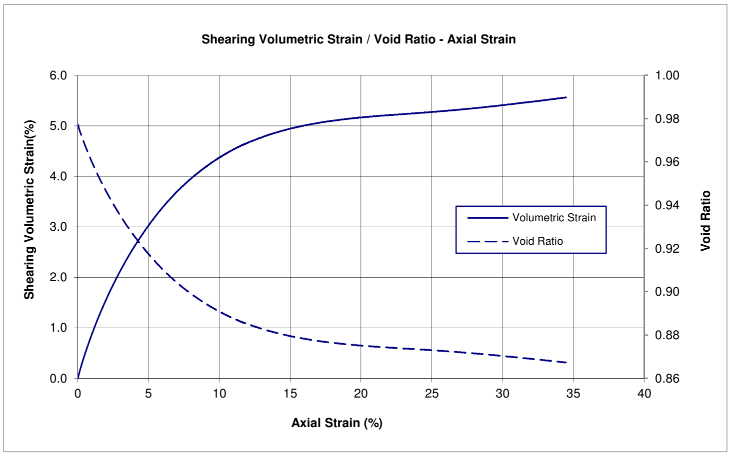
Triaxial CD Test - Charts

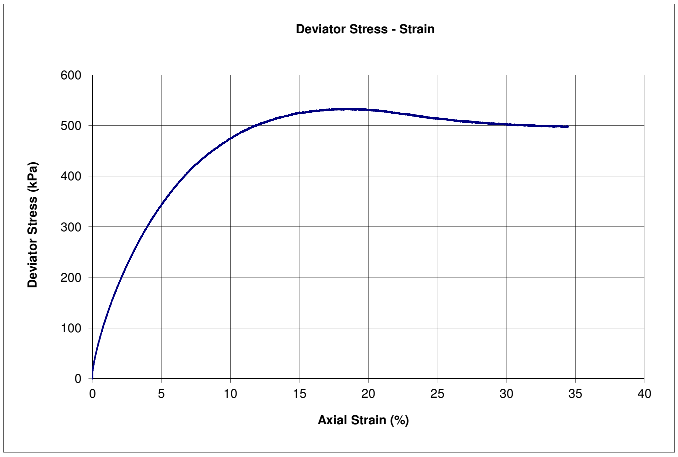
(ASTM D7181)

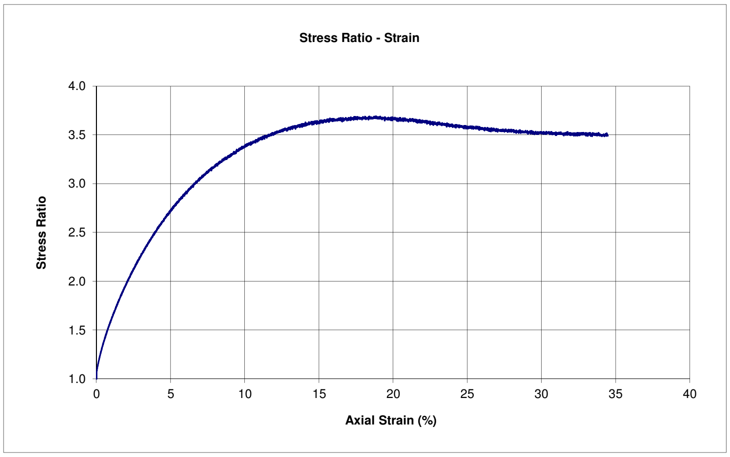
PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Average
TEST NO. : TX 02 - CID

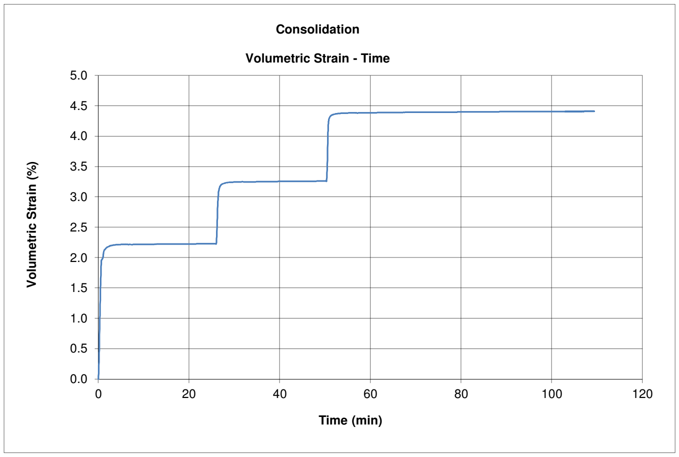
DATE : 2019-07-29
TEST BY: BY
CHECKED BY: JG


Stress Path

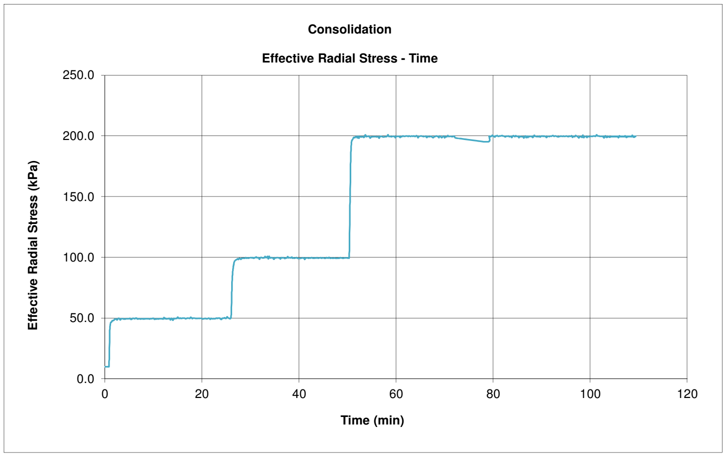

Shearing Volumetric Strain / Void Ratio - Axial Strain


Deviator Stress - Strain


Stress Ratio - Strain


Consolidation

Volumetric Strain - Time


Consolidation

Effective Radial Stress - Time

Triaxial CD Test - Summary

(ASTM D7181)

PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Average
TEST NO. : TX 03 - CID

DATE : 2019-07-29
TESTED BY: BY
CHECKED BY: JG

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation / B-value	End of 1st Consolidation	End of 2nd Consolidation	End of 3rd Consolidation	End of 4th Consolidation	End of 5th Consolidation	End of 6th Consolidation	At Failure	End of Shear
Specimen Height	mm	140.01	139.46	138.34	137.28	136.73	136.15	135.50	134.84	134.28	108.69	89.86
Specimen Diameter	mm	69.80	69.59	66.34	65.61	65.31	64.97	64.61	64.31	64.08	68.61	75.19
Area	cm^2	38.26	38.04	34.56	33.81	33.50	33.15	32.79	32.48	32.25	36.97	44.40
Volume	cm^3	535.75	530.44	478.11	464.12	458.01	451.40	444.31	438.02	433.00	401.85	399.02
Wet Weight	g	1190.38	1190.38	1382.74	1368.76	1362.64	1356.03	1348.94	1342.65	1337.64	1306.49	1303.65
Water Content	%	5.12	5.12	22.11	20.87	20.33	19.75	19.12	18.57	18.12	15.37	15.12
Dry Weight	g	1132.40	1132.40	1132.40	1132.40	1132.40	1132.40	1132.40	1132.40	1132.40	1132.40	1132.40
Wet Density	g/cm^3	2.222	2.244	2.892	2.949	2.975	3.004	3.036	3.065	3.089	3.251	3.267
Dry Density	g/cm^3	2.114	2.135	2.369	2.440	2.472	2.509	2.549	2.585	2.615	2.818	2.838
Specific Gravity of Solids (assumed)	-	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97
Solids Volume	cm^3	227.847	227.847	227.847	227.847	227.847	227.847	227.847	227.847	227.847	227.847	227.847
Void Volume	cm^3	307.900	302.589	250.259	236.276	230.160	223.552	216.463	210.168	205.157	174.005	171.169
Water Volume	cm^3	57.979	57.979	250.339	236.356	230.240	223.632	216.543	210.248	205.237	174.085	171.249
Void Ratio (e)	-	1.351	1.328	1.098	1.037	1.010	0.981	0.950	0.922	0.900	0.764	0.751
Saturation Ratio (Sr)	%	18.83	19.16	100.03	100.03	100.03	100.04	100.04	100.04	100.04	100.05	100.05
Effective Confining Stress	kPa				50	100	200	400	700	1000		

Shearing (CU)		
Skempton's B Parameter		0.99
Back Pressure before shearing	kPa	300.0
Confining Stress (σ_3') before shearing	kPa	1000
Shear Strain Rate	mm / min	0.04

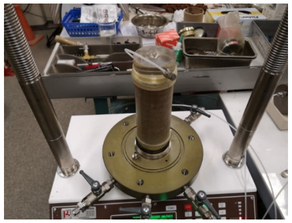
At Maximum Deviator Stress:		
Axial Stain	%	**19.06**
Deviator Stress	kPa	**2781.2**
Φ '	º	35.6
c' (assumed)	kPa	**0**

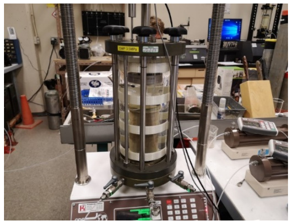
At Maximum Stress Ratio		
Axial Stain	%	**19.35**
Deviator Stress	kPa	**2779.8**
Φ '	º	35.6
c' (assumed)	kPa	0

Note: *using cambridge method*

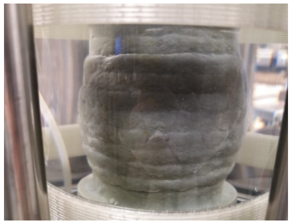
Photos:

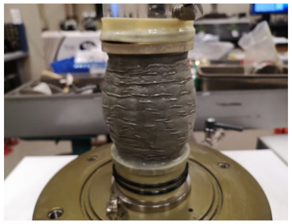
Before Test





After Test





Triaxial CD Test - Charts

(ASTM D7181)

PROJECT NO. : A03355A01

PROJECT :

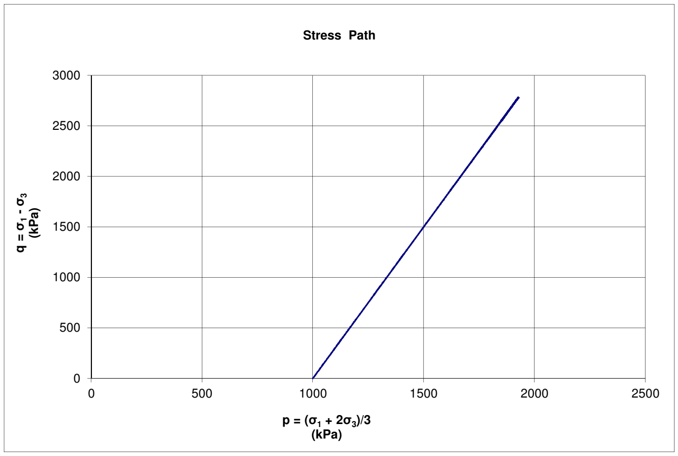
SAMPLE : Average

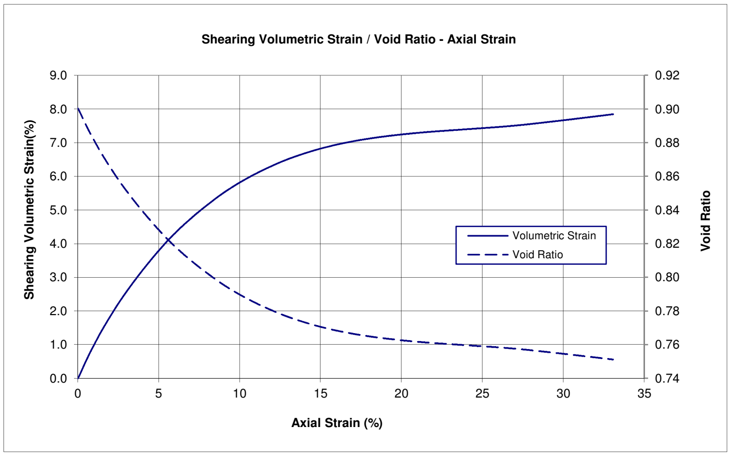
TEST NO. : TX 03 - CID

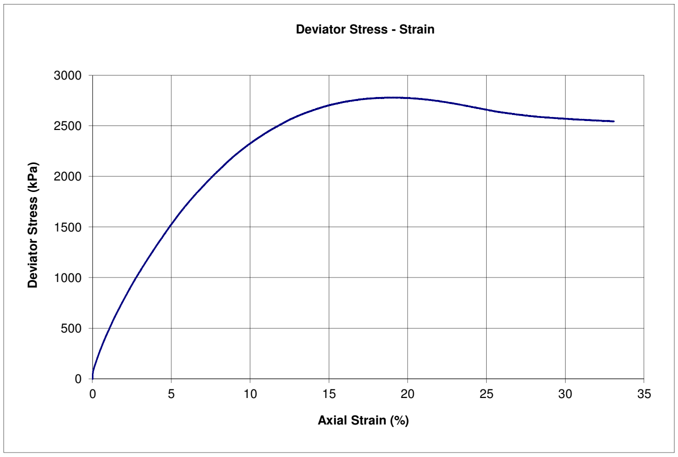
DATE : 2019-07-29

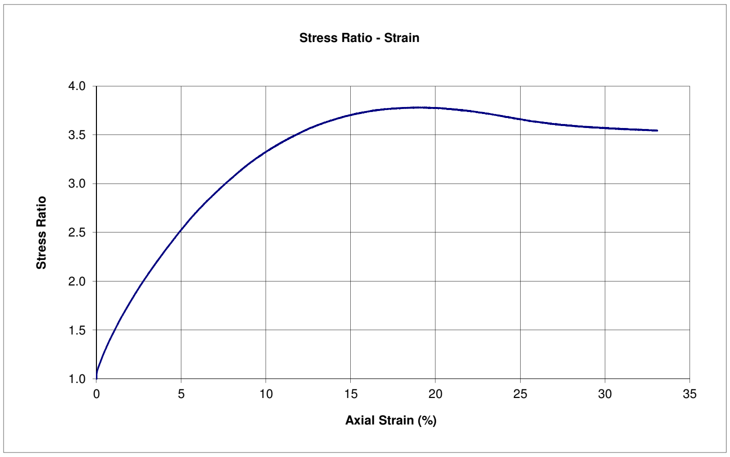
TEST BY: BY

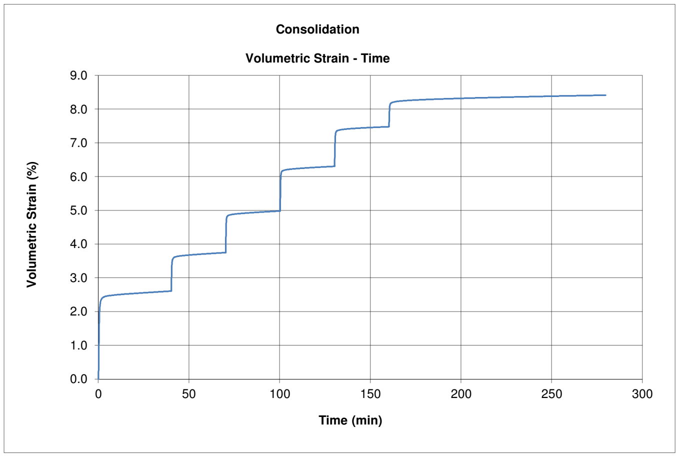
CHECKED BY: JG

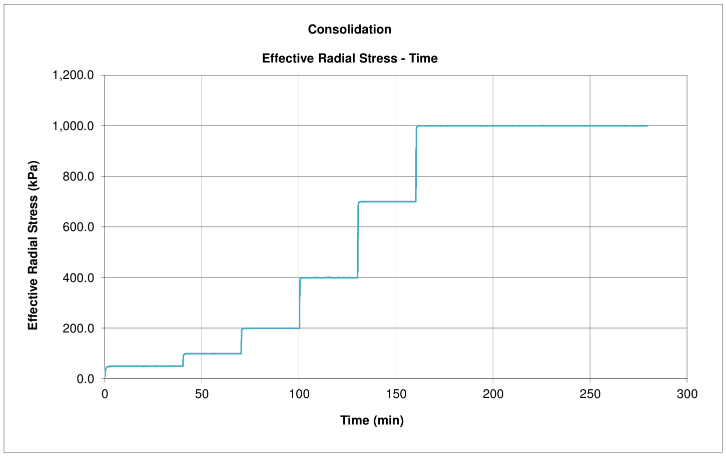












Triaxial CIU Test - Summary

(ASTM D4767)

PROJECT NO. :	A03355A01	DATE :	2019-08-01
PROJECT :		TESTED BY:	BY
SAMPLE :	Average	CHECKED BY:	JG
TEST NO. :	TX04 - CIU		

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B-value	End of 1st Consolidation	End of 2nd Consolidation	End of 3rd Consolidation	End of 4th Consolidation	End of 5th Consolidation	At Maximum Deviator Stress	End of Shear
Specimen Height	mm	139.96	139.85	139.85	138.65	137.00	136.41	135.75	135.15	134.76	133.23	98.31
Specimen Diameter	mm	69.80	69.45	66.59	66.88	66.45	66.19	65.91	65.67	65.49	65.86	76.67
Area	cm^2	38.26	37.88	34.83	35.13	34.68	34.41	34.12	33.87	33.68	34.07	46.17
Volume	cm^3	535.56	529.78	487.10	487.10	475.16	469.39	463.22	457.81	453.91	453.91	453.91
Wet Weight	g	1215.82	1215.82	1409.82	1411.80	1399.86	1394.08	1387.91	1382.50	1378.61	1378.61	1378.61
Water Content	%	5.06	5.06	21.82	21.99	20.96	20.46	19.93	19.46	19.13	19.13	19.13
Dry Weight	g	1157.26	1157.26	1157.26	1157.26	1157.26	1157.26	1157.26	1157.26	1157.26	1157.26	1157.26
Wet Density	g/cm^3	2.270	2.295	2.894	2.898	2.946	2.970	2.996	3.020	3.037	3.037	3.037
Dry Density	g/cm^3	2.161	2.184	2.376	2.376	2.435	2.465	2.498	2.528	2.550	2.550	2.550
Specific Gravity of Solids	-	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97
Solids Volume	cm^3	232.850	232.850	232.850	232.850	232.850	232.850	232.850	232.850	232.850	232.850	232.850
Void Volume	cm^3	302.706	296.932	254.252	254.252	242.315	236.536	230.369	224.960	221.062	221.062	221.062
Water Volume	cm^3	58.557	58.557	252.557	254.532	242.595	236.816	230.649	225.240	221.342	221.342	221.342
Void Ratio (e)	-	1.300	1.275	1.092	1.092	1.041	1.016	0.989	0.966	0.949	0.949	0.949
Saturation Ratio (Sr)	%	19.34	19.72	99.33	100.11	100.12	100.12	100.12	100.12	100.13	100.13	100.13
Effective Confining Stress	kPa					50	100	200	350	500		

Shearing (CU)		
Skempton's B Parameter		0.99
Back Pressure before shearing	kPa	400.0
Confining Stress (σ_3') before shearing	kPa	500
Shear Strain Rate	mm / min	0.04

Note: *using cambridge method*

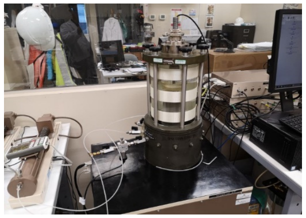
At Maximum Deviator Stress:		
Axial Stain	%	1.14
Deviator Stress	kPa	163.7
Φ '	º	20.3
c' (assumed)	kPa	0

At Maximum Stress Ratio		
Axial Stain	%	10.00
Deviator Stress	kPa	34.9
Φ '	º	33.7
c' (assumed)	kPa	0

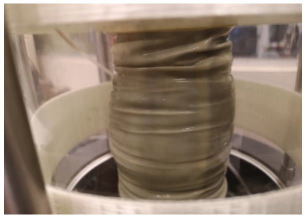
(selected at 10% axial strain)

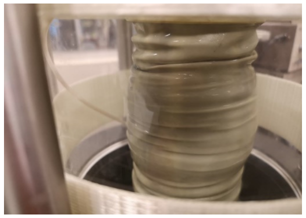
Test Photos:

Before Test



After Test ` `



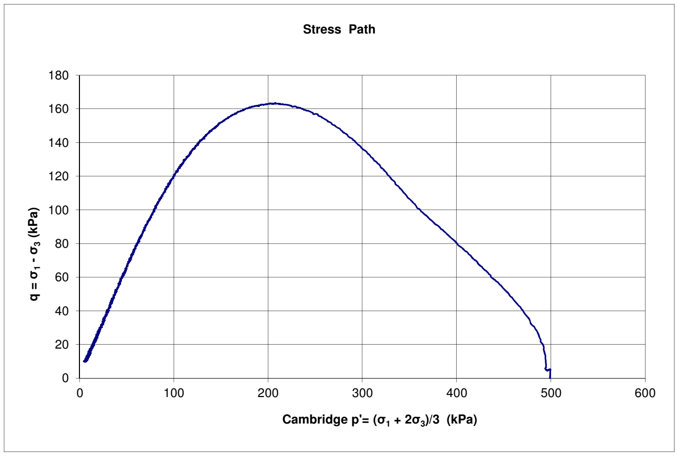


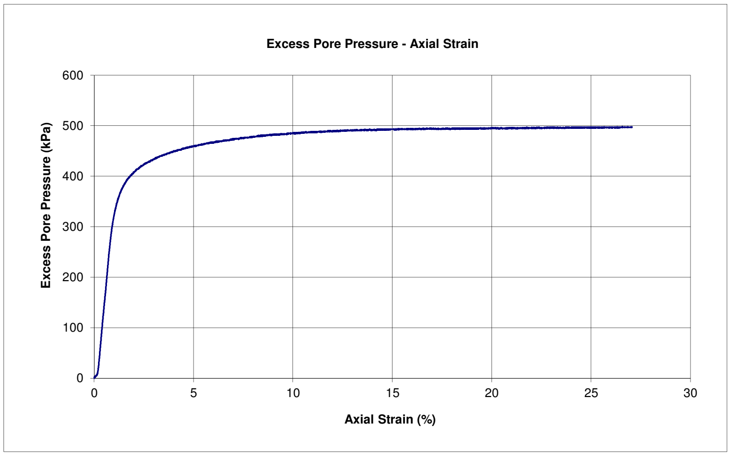
Triaxial CIU Test - Charts

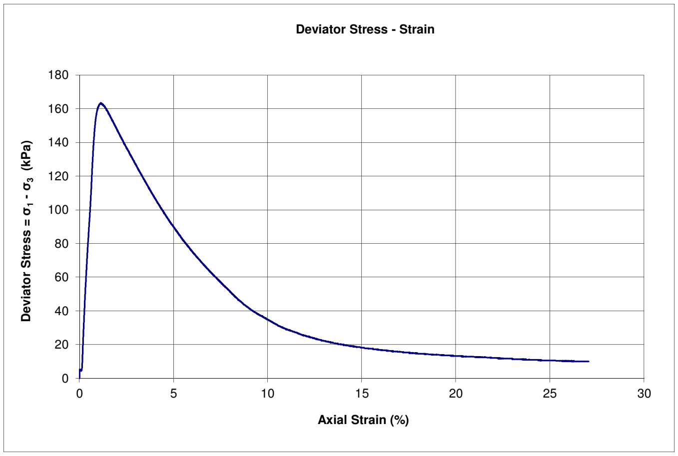
(ASTM D4767)

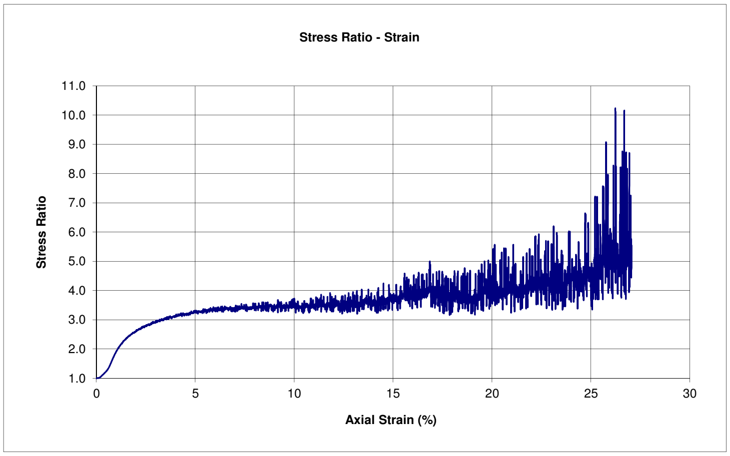
PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Average
TEST NO. : TX04 - CIU

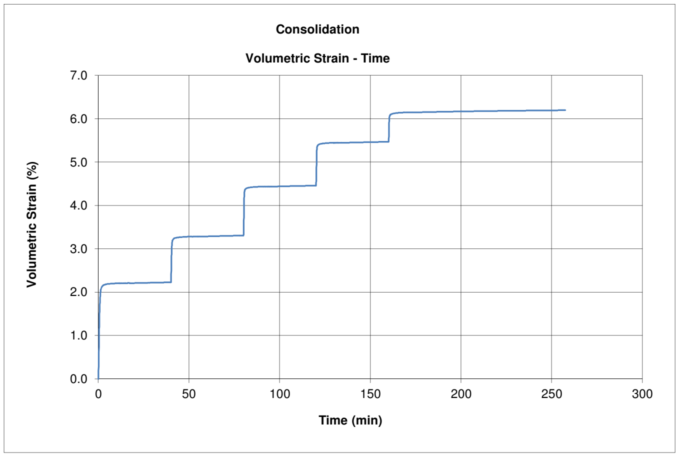
DATE : 2019-08-01
TEST BY: BY
CHECKED BY: JG

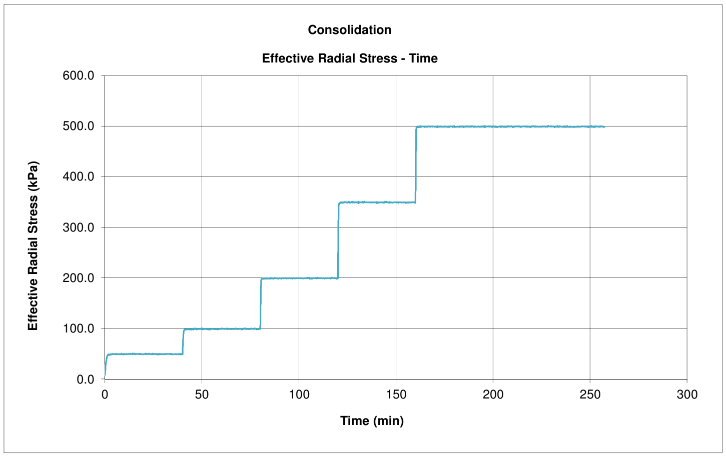












Triaxial CD Test - Summary
(ASTM D7181)

PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Average
TEST NO. : TX05 - CID

DATE : 2019-07-25
TESTED BY: BY
CHECKED BY: JG

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B value	End 1st Cons	End 2nd Cons	End 3rd Cons	End 4th Cons	End 5th Cons	at Failure	End of Shear
Specimen Height	mm	142.60	142.60	142.60	142.56	142.51	142.47	142.40	142.33	142.27	136.86	119.82
Specimen Diameter	mm	70.15	70.15	70.09	70.08	70.01	69.98	69.94	69.90	69.87	71.63	77.00
Area	cm^2	38.65	38.65	38.58	38.57	38.50	38.46	38.42	38.37	38.34	40.29	46.57
Volume	cm^3	551.144	551.144	550.125	549.904	548.632	547.918	547.035	546.150	545.465	551.469	557.968
Wet Weight	g	1749.69	1749.69	1823.69	1835.76	1834.49	1833.77	1832.89	1832.01	1831.32	1837.32	1843.82
Water Content	%	8.82	8.82	13.42	14.17	14.09	14.05	13.99	13.94	13.90	14.27	14.67
Dry Weight	g	1607.88	1607.88	1607.88	1607.88	1607.88	1607.88	1607.88	1607.88	1607.88	1607.88	1607.88
Wet Density	g/cm^3	3.175	3.175	3.315	3.338	3.344	3.347	3.351	3.354	3.357	3.332	3.305
Dry Density	g/cm^3	2.917	2.917	2.923	2.924	2.931	2.935	2.939	2.944	2.948	2.916	2.882
Specific Gravity of Solids	-	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97
Solids Volume	cm^3	323.516	323.516	323.516	323.516	323.516	323.516	323.516	323.516	323.516	323.516	323.516
Void Volume	cm^3	227.627	227.627	226.608	226.388	225.116	224.402	223.519	222.634	221.949	227.953	234.451
Water Volume	cm^3	141.815	141.815	215.815	227.885	226.612	225.898	225.015	224.130	223.445	229.449	235.948
Void Ratio (e)	-	0.704	0.704	0.700	0.700	0.696	0.694	0.691	0.688	0.686	0.705	0.725
Saturation Ratio (Sr)	%	62.30	62.30	95.24	100.66	100.66	100.67	100.67	100.67	100.67	100.66	100.64
Effective Confining Stress	kPa					50	100	200	350	500		

Shearing		
Skempton's B Parameter		0.98
Back Pressure before shearing	kPa	355.6
Confining Stress (σ_3') before shearing	kPa	500
Shear Strain Rate	% / min	0.033

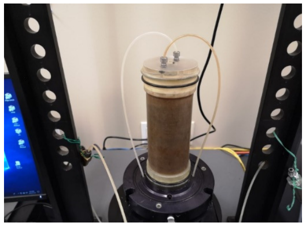
At Max. Deviator Stress:		
Axial Stain (%)	%	**3.80**
Deviator Stress	kPa	**2569.2**
Φ ' (Cambridge)	º	**46.0**
c'	kPa	**0.0**

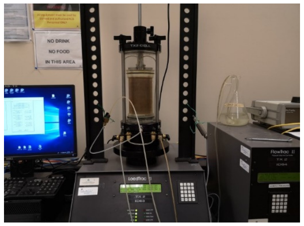
At Max. Obliquity:		
Axial Stain (%)	%	**3.88**
Deviator Stress	kPa	**2568.0**
Φ ' (Cambridge)	º	**46.0**
c'	kPa	**0.0**

Note: *using cambridge method*

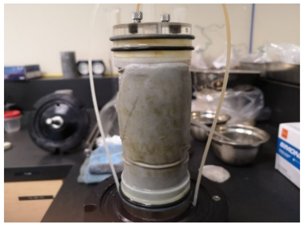
Photos:

Before Test





After Test

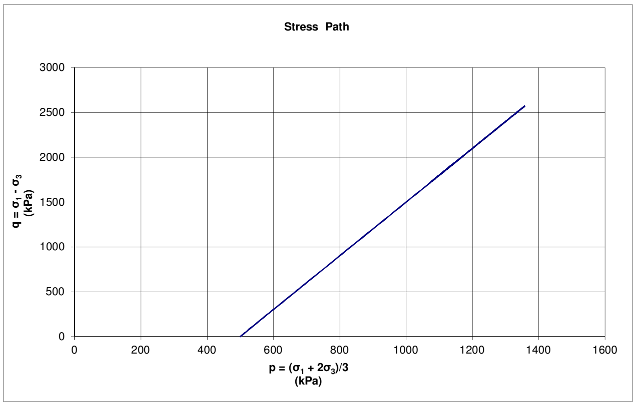


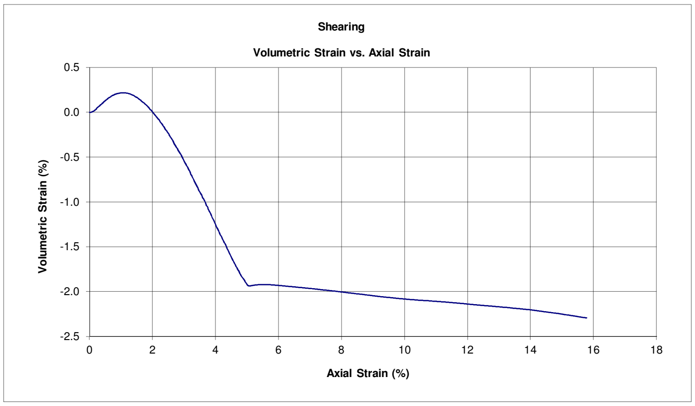
Triaxial CD Test - Charts

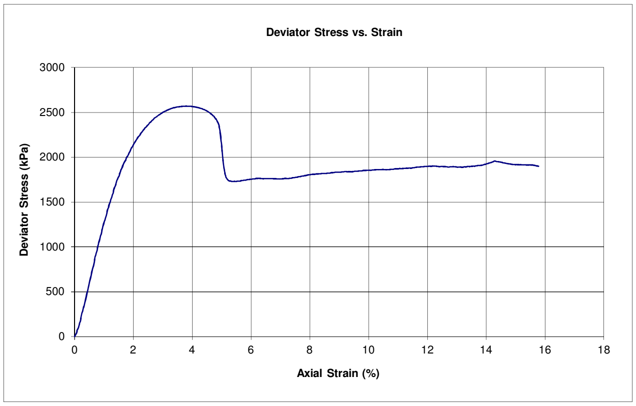
(ASTM D7181)

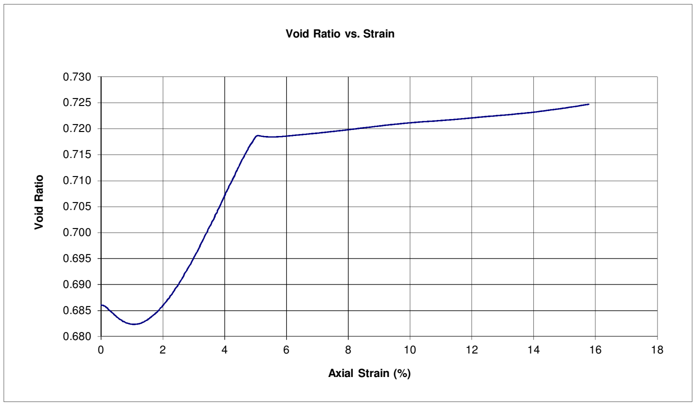
PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Average
TEST NO. : TX05 - CID

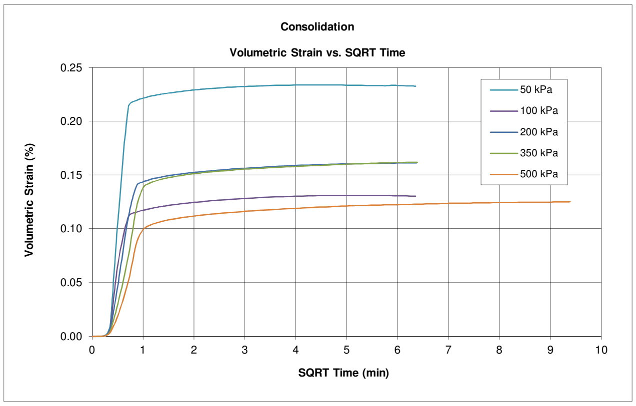
DATE : 2019-07-25
TEST BY: BY
CHECKED BY: JG

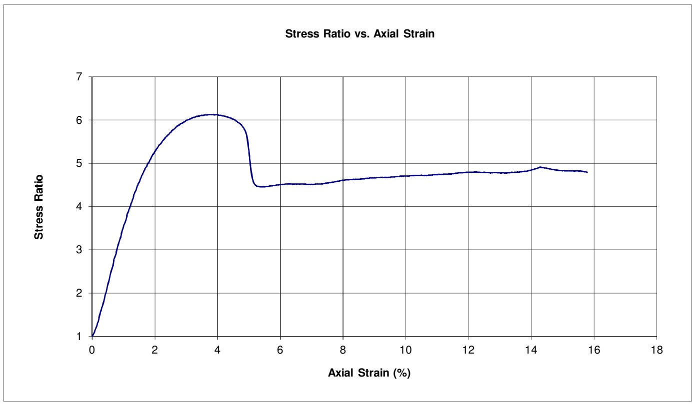












Triaxial CD Test - Summary

(ASTM D7181)

PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Batch 6
TEST NO. : TX 06 - CD

DATE : 2019-07-31
TESTED BY: BY
CHECKED BY:

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation / B-value	End of 1st Consolidation	End of 2nd Consolidation	End of 3rd Consolidation	End of 4th Consolidation	End of 5th Consolidation	End of 6th Consolidation	At Failure	End of Shear
Specimen Height	mm	140.17	140.17	139.71	139.63	139.56	139.47	139.33	139.09	138.73	119.19	115.13
Specimen Diameter	mm	69.81	69.76	69.82	69.71	69.63	69.55	69.44	69.28	69.08	72.86	73.54
Area	cm^2	38.28	38.22	38.29	38.17	38.08	37.99	37.87	37.70	37.48	41.70	42.48
Volume	cm^3	536.51	535.74	534.94	532.95	531.49	529.79	527.62	524.40	519.94	496.99	489.09
Wet Weight	g	1531.25	1531.25	1660.90	1658.91	1657.44	1655.75	1653.57	1650.36	1645.89	1622.95	1615.04
Water Content	%	8.71	8.71	17.91	17.77	17.67	17.55	17.39	17.17	16.85	15.22	14.66
Dry Weight	g	1408.56	1408.56	1408.56	1408.56	1408.56	1408.56	1408.56	1408.56	1408.56	1408.56	1408.56
Wet Density	g/cm^3	2.854	2.858	3.105	3.113	3.119	3.125	3.134	3.147	3.166	3.266	3.302
Dry Density	g/cm^3	2.625	2.629	2.633	2.643	2.650	2.659	2.670	2.686	2.709	2.834	2.880
Specific Gravity of Solids (assumed)	-	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97
Solids Volume	cm^3	283.413	283.413	283.413	283.413	283.413	283.413	283.413	283.413	283.413	283.413	283.413
Void Volume	cm^3	253.100	252.331	251.529	249.535	248.073	246.377	244.203	240.990	236.522	213.578	205.673
Water Volume	cm^3	122.686	122.686	252.336	250.342	248.880	247.184	245.010	241.797	237.329	214.385	206.480
Void Ratio (e)	-	0.893	0.890	0.888	0.880	0.875	0.869	0.862	0.850	0.835	0.754	0.726
Saturation Ratio (Sr)	%	48.47	48.62	100.32	100.32	100.33	100.33	100.33	100.33	100.34	100.38	100.39
Effective Confining Stress	kPa				50	100	200	400	800	1500		

Shearing (CU)		
Skempton's B Parameter		0.99
Back Pressure before shearing	kPa	500.0
Confining Stress (σ_3') before shearing	kPa	1500
Shear Strain Rate	mm / min	0.04

At Maximum Deviator Stress:		
Axial Stain	%	**14.08**
Deviator Stress	kPa	**4000.2**
Φ '	º	34.9
c' (assumed)	kPa	**0**

At Maximum Stress Ratio		
Axial Stain	%	**14.25**
Deviator Stress	kPa	**3998.4**
Φ '	º	34.9
c' (assumed)	kPa	0

Note: *using cambridge method*

Photos:

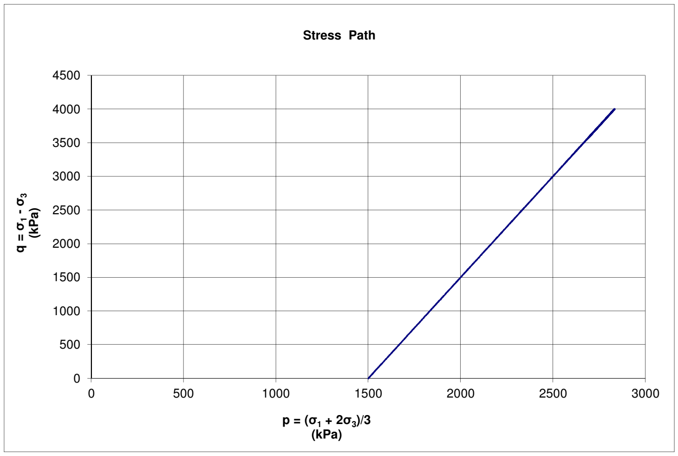
Before Test

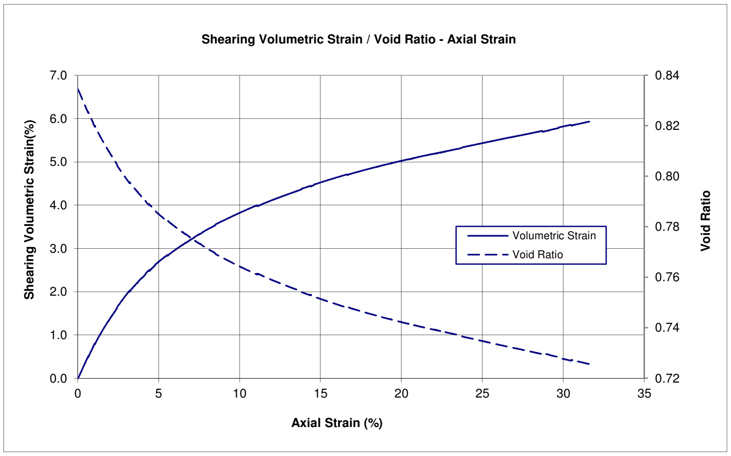
After Test

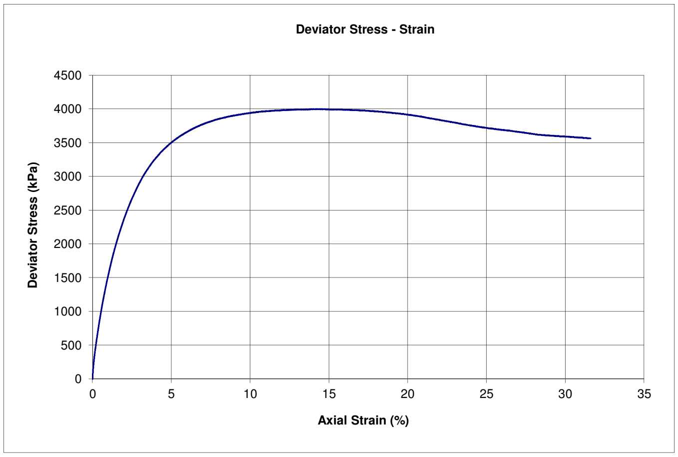
Triaxial CD Test - Charts

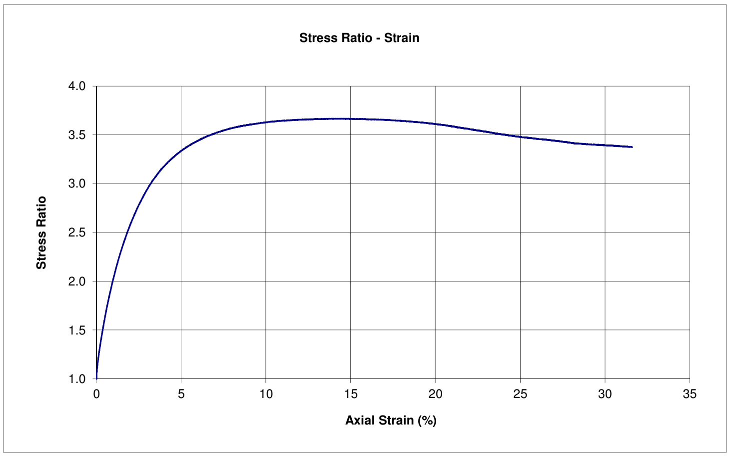
(ASTM D7181)

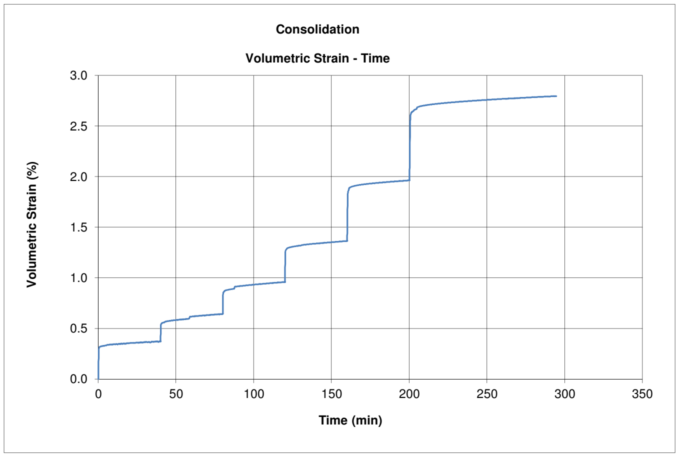
PROJECT NO. :	A03355A01	DATE :	2019-07-31
PROJECT :		TEST BY:	BY
SAMPLE :	Batch 6	CHECKED BY:	
TEST NO. :	TX 06 - CD		

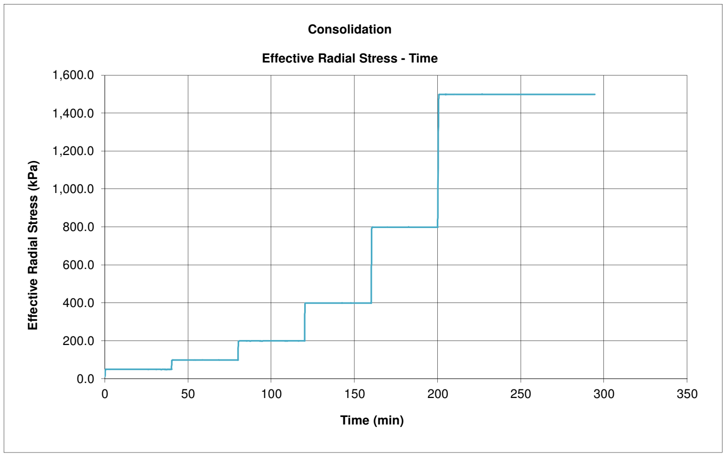












Triaxial CIU Test - Summary

(ASTM D4767)

PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Average
TEST NO. : TX07 - CIU

DATE : 2019-08-02
TESTED BY: BY
CHECKED BY: JG

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation / B Value	End of 1st Consolidation	End of 2nd Consolidation	End of 3rd Consolidation	End of 4th Consolidation	End of 5th Consolidation	End of 6th Consolidation	End of 7th Consolidation	At Maximum Deviator Stress
Specimen Height	mm	139.93	139.25	138.66	137.65	137.30	136.81	136.24	135.48	134.54	134.00	131.23
Specimen Diameter	mm	69.80	69.69	68.12	67.56	67.22	66.85	66.46	66.04	65.60	65.24	65.92
Area	cm^2	38.26	38.14	36.45	35.85	35.48	35.10	34.69	34.26	33.80	33.43	34.13
Volume	cm^3	535.44	531.16	505.34	493.43	487.20	480.21	472.56	464.11	454.73	447.93	447.93
Wet Weight	g	1268.03	1268.03	1472.22	1460.31	1454.08	1447.09	1439.44	1430.99	1421.61	1414.81	1414.81
Water Content	%	4.90	4.90	21.79	20.81	20.29	19.71	19.08	18.38	17.60	17.04	17.04
Dry Weight	g	1208.80	1208.80	1208.80	1208.80	1208.80	1208.80	1208.80	1208.80	1208.80	1208.80	1208.80
Wet Density	g/cm^3	2.368	2.387	2.913	2.960	2.985	3.013	3.046	3.083	3.126	3.159	3.159
Dry Density	g/cm^3	2.258	2.276	2.392	2.450	2.481	2.517	2.558	2.605	2.658	2.699	2.699
Specific Gravity of Solids	-	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97
Solids Volume	cm^3	243.219	243.219	243.219	243.219	243.219	243.219	243.219	243.219	243.219	243.219	243.219
Void Volume	cm^3	292.222	287.942	262.122	250.210	243.979	236.989	229.339	220.892	211.507	204.714	204.714
Water Volume	cm^3	59.231	59.231	263.421	251.509	245.278	238.288	230.638	222.191	212.806	206.013	206.013
Void Ratio (e)	-	1.201	1.184	1.078	1.029	1.003	0.974	0.943	0.908	0.870	0.842	0.842
Saturation Ratio (Sr)	%	20.27	20.57	100.50	100.52	100.53	100.55	100.57	100.59	100.61	100.63	100.63
Effective Confining Stress	kPa				50	100	200	400	800	1500	2000	

Shearing (CU)		
Skempton's B Parameter		0.99
Back Pressure before shearing	kPa	400.0
Confining Stress (σ_3') before shearing	kPa	2000
Shear Strain Rate	mm / min	0.04

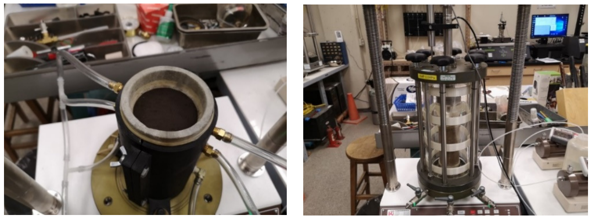
At Maximum Deviator Stress:		
Axial Stain	%	0.58
Deviator Stress	kPa	822.3
Φ '	º	20.3
c' (assumed)	kPa	0

At Maximum Stress Ratio		
Axial Stain	%	9.45
Deviator Stress	kPa	444.0
Φ '	º	35.3
c' (assumed)	kPa	0

***Note:** using cambridge method*

Test Photos:

Before Test



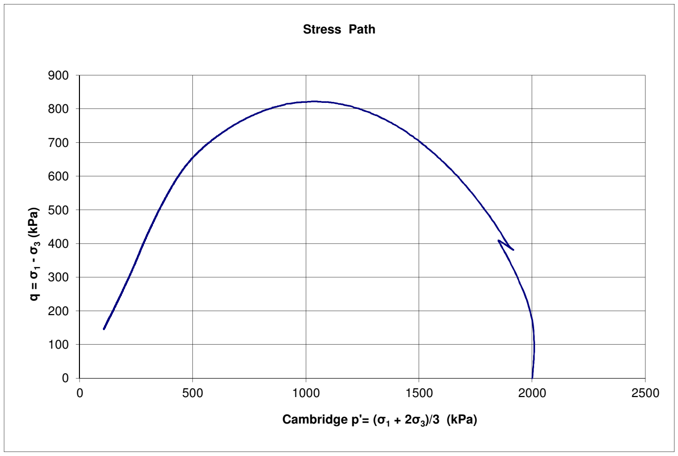
After Test

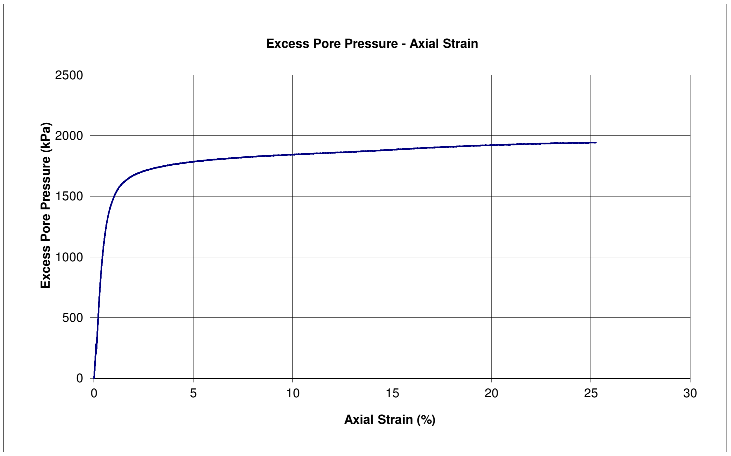
Triaxial CIU Test - Charts

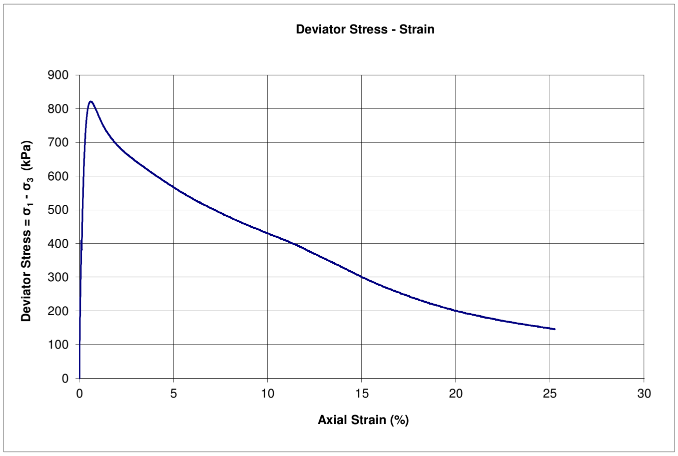
(ASTM D4767)

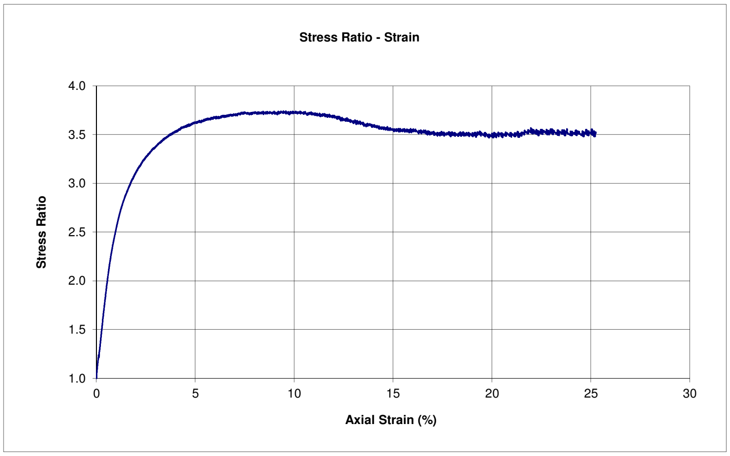
PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Average
TEST NO. : TX07 - CIU

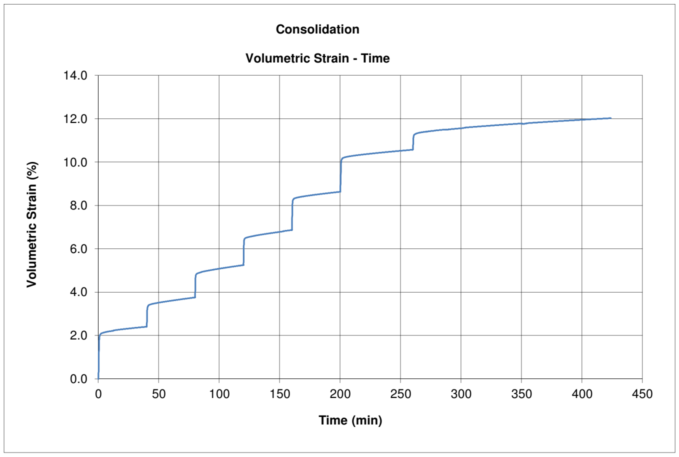
DATE : 2019-08-02
TEST BY: BY
CHECKED BY: JG

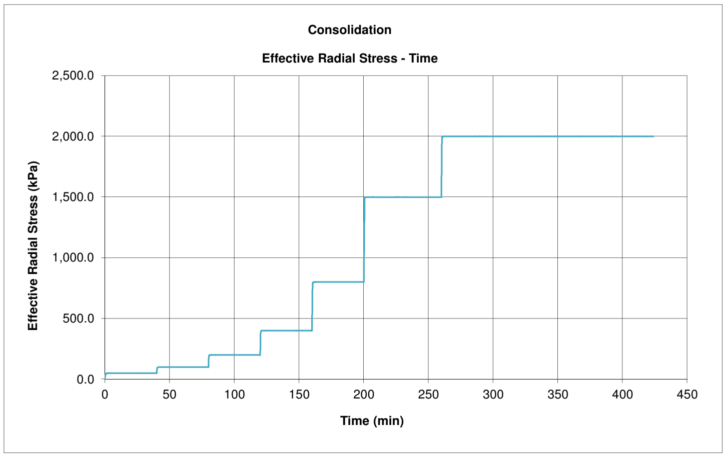












Triaxial CD Test - Summary

(ASTM D7181)

PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Average
TEST NO. : TX 08 - CID

DATE : 2019-08-16
TESTED BY: BY
CHECKED BY: JG

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B-value	End of 1st Consolidation	At Maximum Deviator Stress	End of Shear		
Specimen Height	mm	140.14	140.14	140.14	140.14	140.05	138.19	99.94		
Specimen Diameter	mm	69.90	69.79	69.77	69.78	69.65	70.22	82.23		
Area	cm^2	38.37	38.25	38.24	38.24	38.10	38.73	53.10		
Volume	cm^3	537.78	536.09	535.85	535.85	533.64	535.23	530.72		
Wet Weight	g	1510.55	1510.55	1645.65	1651.61	1649.41	1650.99	1646.49		
Water Content	%	8.15	8.15	17.82	18.25	18.09	18.21	17.88		
Dry Weight	g	1396.72	1396.72	1396.72	1396.72	1396.72	1396.72	1396.72		
Wet Density	g/cm^3	2.809	2.818	3.071	3.082	3.091	3.085	3.102		
Dry Density	g/cm^3	2.597	2.605	2.607	2.607	2.617	2.610	2.632		
Specific Gravity of Solids (assumed)	-	4.97	4.97	4.97	4.97	4.97	4.97	4.97		
Solids Volume	cm^3	281.030	281.030	281.030	281.030	281.030	281.030	281.030		
Void Volume	cm^3	256.752	255.061	254.816	254.816	252.612	254.197	249.694		
Water Volume	cm^3	113.832	113.832	248.932	254.894	252.690	254.275	249.772		
Void Ratio (e)	-	0.914	0.908	0.907	0.907	0.899	0.905	0.888		
Saturation Ratio (Sr)	%	44.34	44.63	97.69	100.03	100.03	100.03	100.03		
Effective Confining Stress	kPa					40				

Shearing (CU)		
Skempton's B Parameter		0.99
Back Pressure before shearing	kPa	500.0
Confining Stress (σ_3') before shearing	kPa	40
Shear Strain Rate	mm / min	0.035

At Maximum Deviator Stress:		
Axial Stain	%	**1.33**
Deviator Stress	kPa	**139.0**
Φ '	º	39.2
c' (assumed)	kPa	**0**

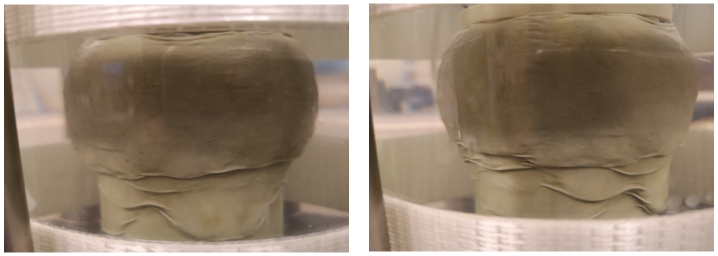
At Maximum Stress Ratio		
Axial Stain	%	**1.23**
Deviator Stress	kPa	**138.5**
Φ '	º	39.3
c' (assumed)	kPa	0

Note: *using cambridge method*

Photos:

Before Test

After Test

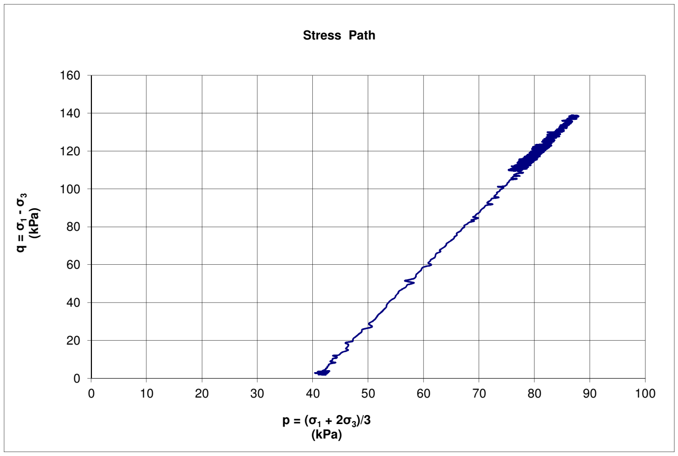


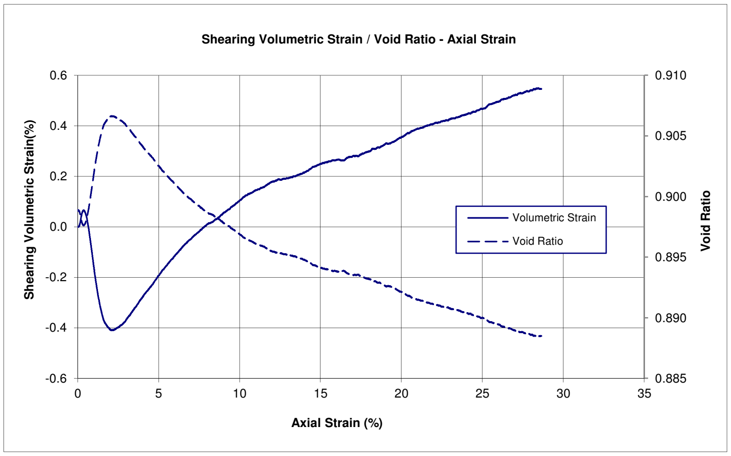
Triaxial CD Test - Charts

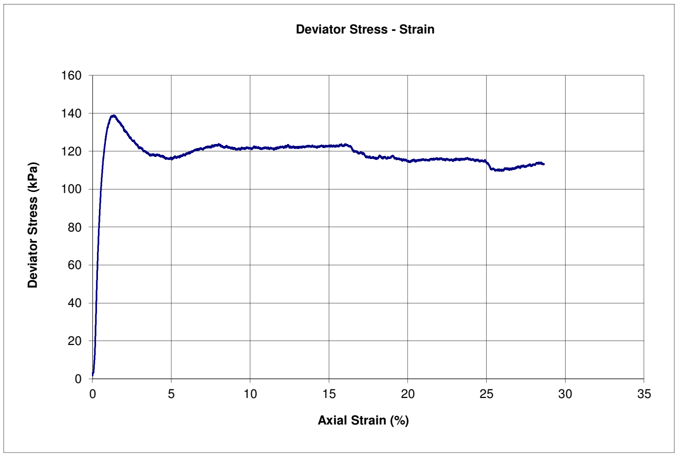
(ASTM D7181)

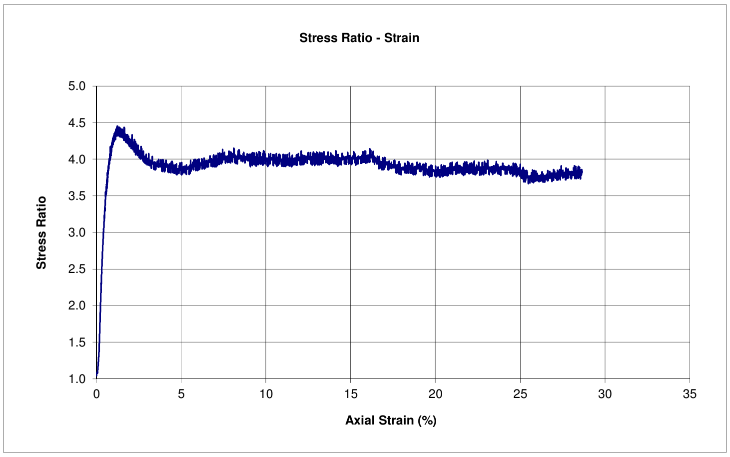
PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Average
TEST NO. : TX 08 - CID

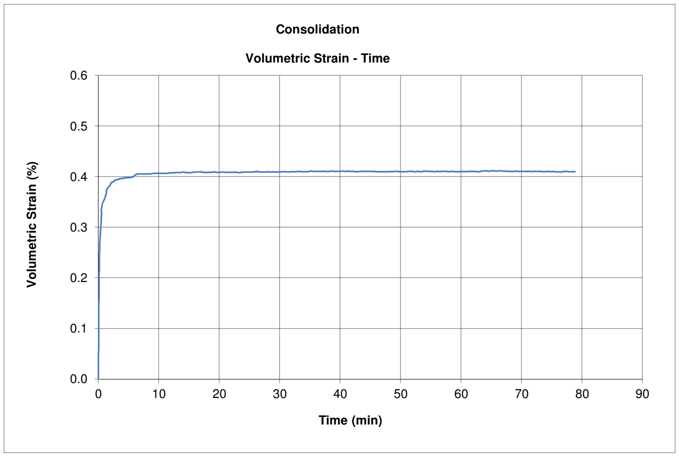
DATE : 2019-08-16
TEST BY: BY
CHECKED BY: JG

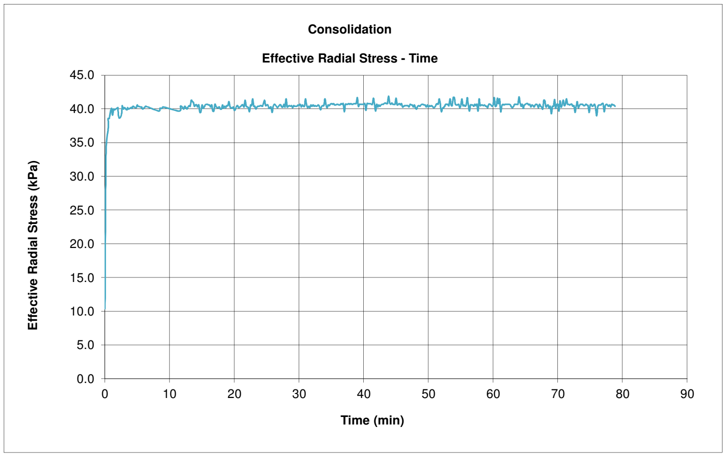












Triaxial CD Test - Summary

(ASTM D7181)

PROJECT NO. : A03355A01

PROJECT :

SAMPLE : Batch 4

TEST NO. : TX 09 - CD

DATE : 2019-08-15

TESTED BY: BY

CHECKED BY:

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation / B-value	End of 1st Consolidation	End of 2nd Consolidation	At Failure	End of Shear		
Specimen Height	mm	140.03	139.56	139.21	139.15	139.10	136.58	97.07		
Specimen Diameter	mm	69.90	69.93	70.08	69.91	69.78	70.68	83.99		
Area	cm^2	38.37	38.41	38.57	38.39	38.24	39.24	55.40		
Volume	cm^3	537.36	536.02	536.94	534.16	531.94	535.94	537.77		
Wet Weight	g	1567.86	1567.86	1699.68	1696.90	1694.68	1698.68	1700.51		
Water Content	%	7.85	7.85	16.92	16.73	16.57	16.85	16.97		
Dry Weight	g	1453.74	1453.74	1453.74	1453.74	1453.74	1453.74	1453.74		
Wet Density	g/cm^3	2.918	2.925	3.165	3.177	3.186	3.170	3.162		
Dry Density	g/cm^3	2.705	2.712	2.707	2.722	2.733	2.712	2.703		
Specific Gravity of Solids (assumed)	-	4.97	4.97	4.97	4.97	4.97	4.97	4.97		
Solids Volume	cm^3	292.503	292.503	292.503	292.503	292.503	292.503	292.503		
Void Volume	cm^3	244.857	243.513	244.441	241.655	239.436	243.440	245.268		
Water Volume	cm^3	114.119	114.119	245.940	243.154	240.935	244.939	246.767		
Void Ratio (e)	-	0.837	0.833	0.836	0.826	0.819	0.832	0.839		
Saturation Ratio (Sr)	%	46.61	46.86	100.61	100.62	100.63	100.62	100.61		
Effective Confining Stress	kPa				50	100				

Shearing (CU)		
Skempton's B Parameter		0.99
Back Pressure before shearing	kPa	499.0
Confining Stress (σ_3') before shearing	kPa	100
Shear Strain Rate	mm / min	0.04

At Maximum Deviator Stress:		
Axial Stain	%	**1.81**
Deviator Stress	kPa	**460.8**
Φ '	º	44.2
c' (assumed)	kPa	**0**

At Maximum Stress Ratio		
Axial Stain	%	**1.82**
Deviator Stress	kPa	**460.2**
Φ '	º	44.2
c' (assumed)	kPa	0

Note: *using cambridge method*

Photos:

Before Test

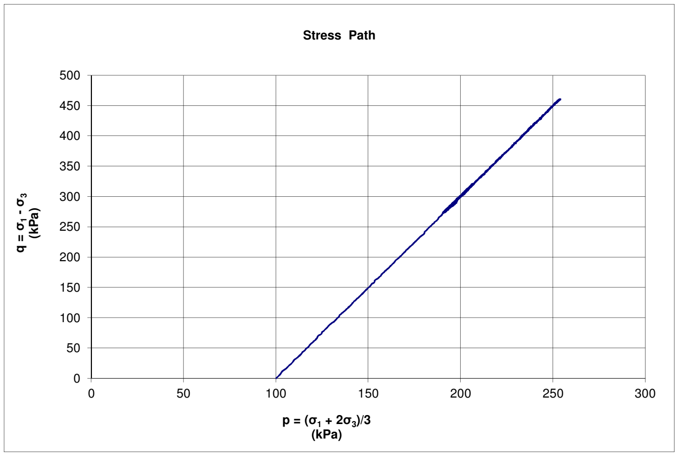
After Test

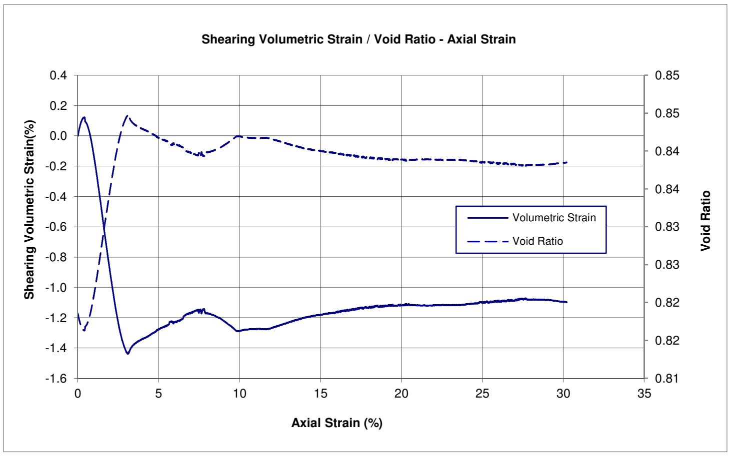
Triaxial CD Test - Charts

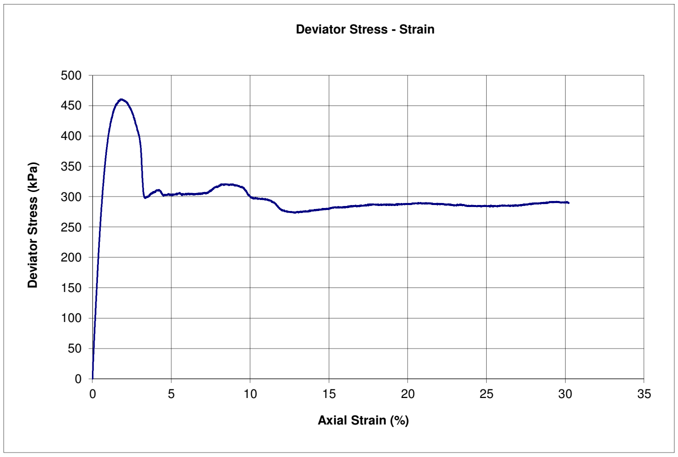
(ASTM D7181)

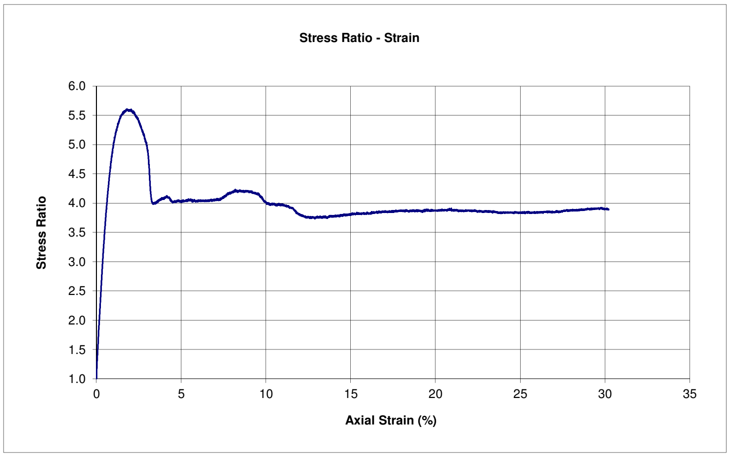
PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Batch 4
TEST NO. : TX 09 - CD

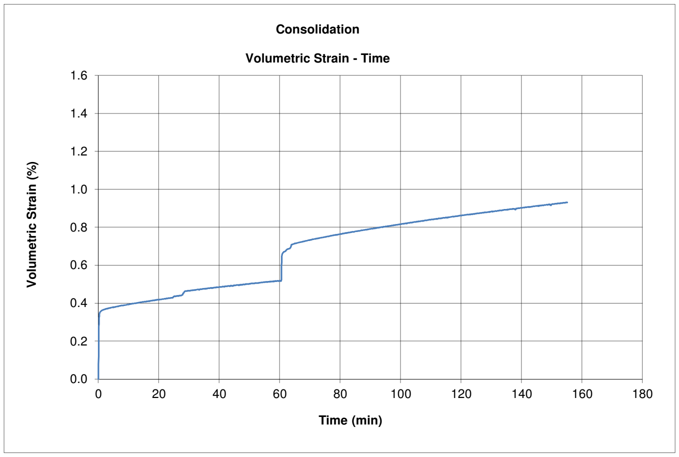
DATE : 2019-08-15
TEST BY: BY
CHECKED BY:


Stress Path

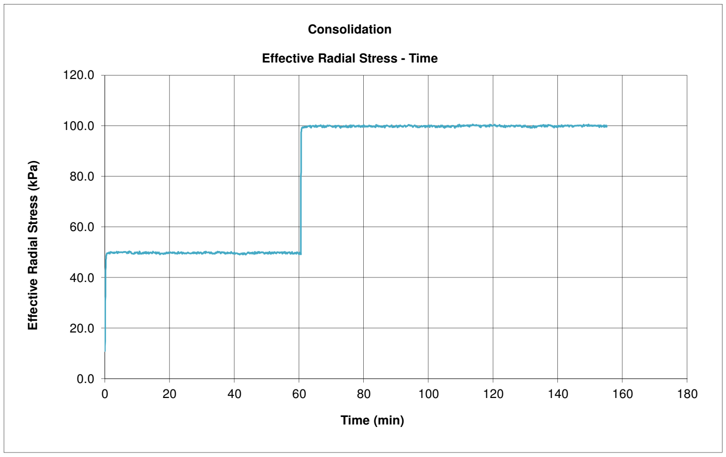

Shearing Volumetric Strain / Void Ratio - Axial Strain


Deviator Stress - Strain


Stress Ratio - Strain


Consolidation

Volumetric Strain - Time


Consolidation

Effective Radial Stress - Time

Triaxial CD Test - Summary

(ASTM D7181)

PROJECT NO. :	A03355A01	DATE :	2019-08-21
PROJECT :		TESTED BY:	BY
SAMPLE :	Fine Gradation	CHECKED BY:	JG
TEST NO. :	TX 10 - CID		

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B-value	End of 1st Consolidation	At Maximum Deviator Stress	End of Shear		
Specimen Height	mm	139.94	139.82	139.82	139.57	139.46	137.45	97.79		
Specimen Diameter	mm	69.80	69.80	69.77	69.77	69.70	70.36	83.17		
Area	cm^2	38.26	38.26	38.24	38.23	38.15	38.88	54.33		
Volume	cm^3	535.48	535.02	534.64	533.64	532.08	534.37	531.32		
Wet Weight	g	1454.05	1454.05	1579.15	1610.67	1609.11	1611.40	1608.35		
Water Content	%	7.80	7.80	17.07	19.41	19.30	19.47	19.24		
Dry Weight	g	1348.84	1348.84	1348.84	1348.84	1348.84	1348.84	1348.84		
Wet Density	g/cm^3	2.715	2.718	2.954	3.018	3.024	3.016	3.027		
Dry Density	g/cm^3	2.519	2.521	2.523	2.528	2.535	2.524	2.539		
Specific Gravity of Solids (assumed)	-	4.96	4.96	4.96	4.96	4.96	4.96	4.96		
Solids Volume	cm^3	271.944	271.944	271.944	271.944	271.944	271.944	271.944		
Void Volume	cm^3	263.536	263.076	262.693	261.693	260.139	262.427	259.373		
Water Volume	cm^3	105.210	105.210	230.310	261.828	260.274	262.562	259.508		
Void Ratio (e)	-	0.969	0.967	0.966	0.962	0.957	0.965	0.954		
Saturation Ratio (Sr)	%	39.92	39.99	87.67	100.05	100.05	100.05	100.05		
Effective Confining Stress	kPa					40				

Shearing (CU)		
Skempton's B Parameter		0.98
Back Pressure before shearing	kPa	498.0
Confining Stress (σ_3') before shearing	kPa	50
Shear Strain Rate	mm / min	0.04

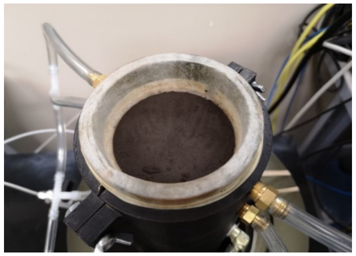
At Maximum Deviator Stress:		
Axial Stain	%	**1.44**
Deviator Stress	kPa	**172.2**
Φ '	º	39.1
c' (assumed)	kPa	**0**

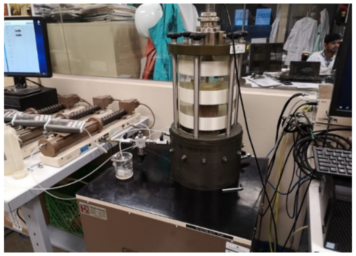
At Maximum Stress Ratio		
Axial Stain	%	**1.35**
Deviator Stress	kPa	**171.4**
Φ '	º	39.5
c' (assumed)	kPa	0

Note: *using cambridge method*

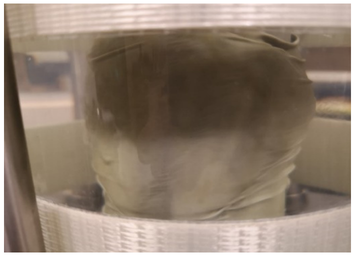
Photos:

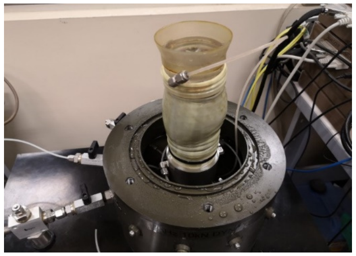
Before Test





After Test

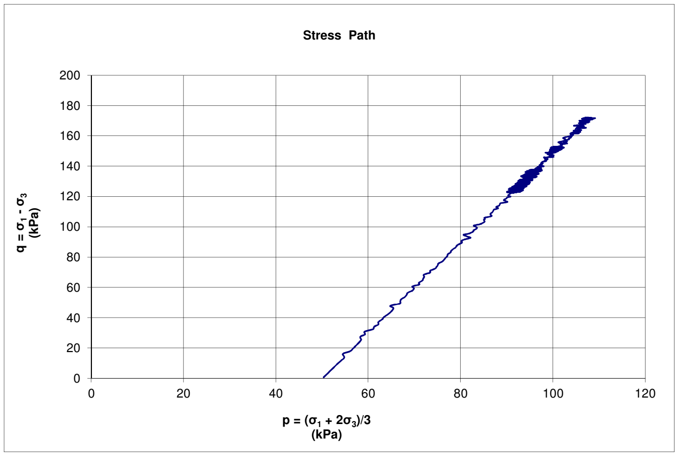


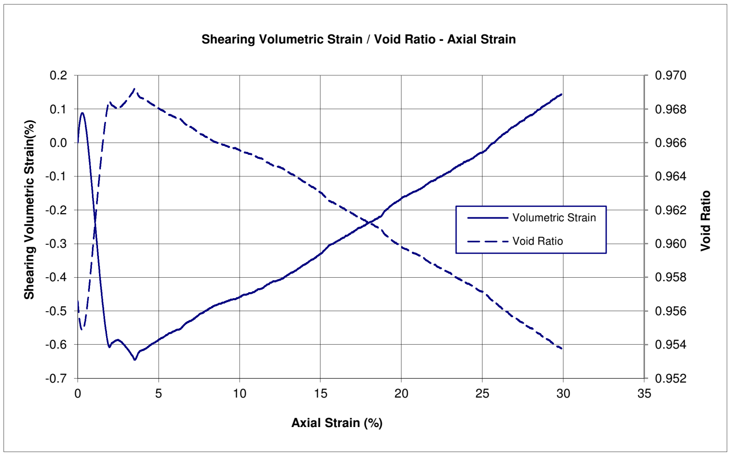


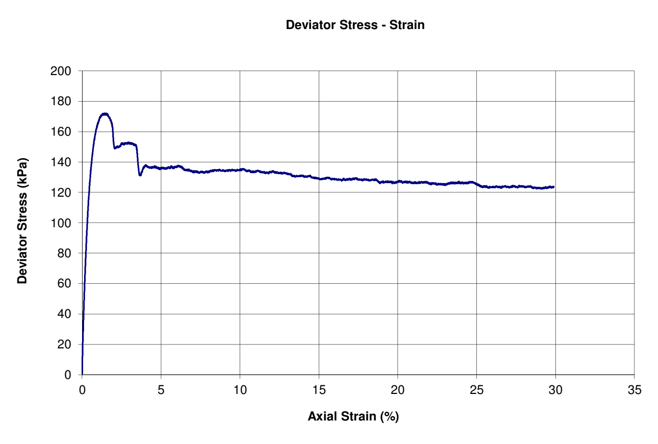
Triaxial CD Test - Charts

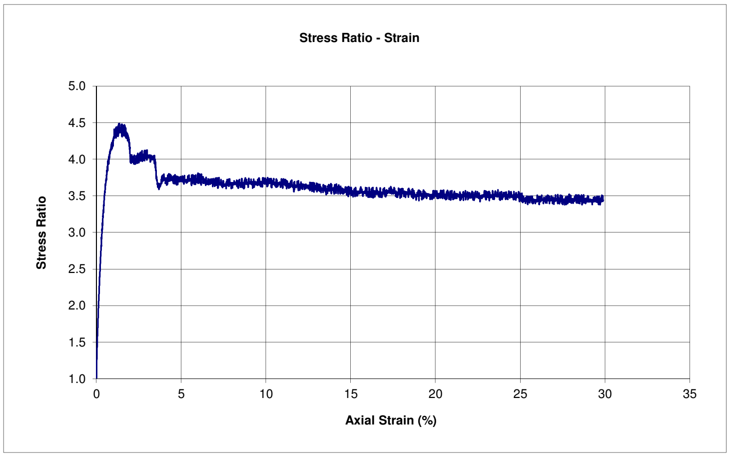
(ASTM D7181)

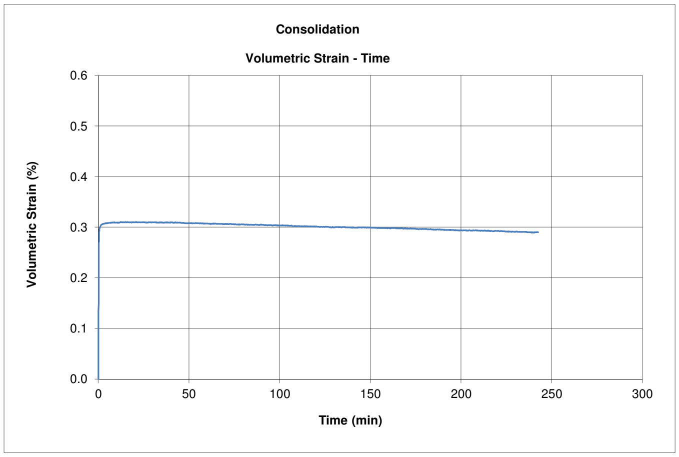
PROJECT NO. :	A03355A01	DATE :	2019-08-21
PROJECT :		TEST BY:	BY
SAMPLE :	Fine Gradation	CHECKED BY:	JG
TEST NO. :	TX 10 - CID		

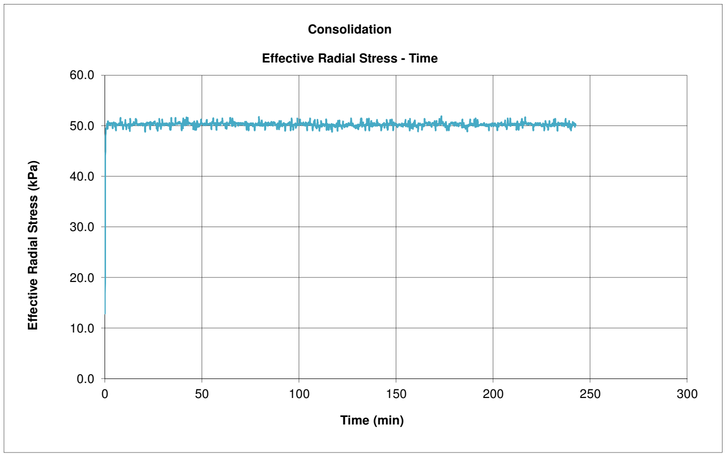












Triaxial CD Test - Summary

(ASTM D7181)

PROJECT NO. :	A03355A01	DATE :	2019-08-26
PROJECT :		TESTED BY:	BY
SAMPLE :	Fine Gradation	CHECKED BY:	JG
TEST NO. :	TX 11 - CD		

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B-Value	End of 1st Consolidation	End of 2nd Consolidation	At Failure	End of Shear	
Specimen Height	mm	140.34	140.34	140.34	140.20	140.13	140.08	137.70	97.47	
Specimen Diameter	mm	70.00	70.00	69.91	69.80	69.70	69.64	70.25	83.07	
Area	cm^2	38.48	38.48	38.39	38.27	38.16	38.09	38.77	54.19	
Volume	cm^3	540.09	540.09	538.70	536.50	534.69	533.53	533.79	528.21	
Wet Weight	g	1453.94	1453.94	1604.94	1611.29	1609.48	1608.32	1608.57	1603.00	
Water Content	%	8.01	8.01	19.23	19.70	19.56	19.48	19.50	19.08	
Dry Weight	g	1346.12	1346.12	1346.12	1346.12	1346.12	1346.12	1346.12	1346.12	
Wet Density	g/cm^3	2.692	2.692	2.979	3.003	3.010	3.014	3.014	3.035	
Dry Density	g/cm^3	2.492	2.492	2.499	2.509	2.518	2.523	2.522	2.548	
Specific Gravity of Solids (assumed)	-	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	
Solids Volume	cm^3	271.394	271.394	271.394	271.394	271.394	271.394	271.394	271.394	
Void Volume	cm^3	268.697	268.697	267.307	265.107	263.300	262.134	262.392	256.813	
Water Volume	cm^3	107.824	107.824	258.824	265.173	263.366	262.200	262.458	256.879	
Void Ratio (e)	-	0.990	0.990	0.985	0.977	0.970	0.966	0.967	0.946	
Saturation Ratio (Sr)	%	40.13	40.13	96.83	100.02	100.02	100.03	100.03	100.03	
Effective Confining Stress	kPa					50	100			

Shearing (CU)		
Skempton's B Parameter		0.99
Back Pressure before shearing	kPa	500.0
Confining Stress (σ_3') before shearing	kPa	100
Shear Strain Rate	mm / min	0.04

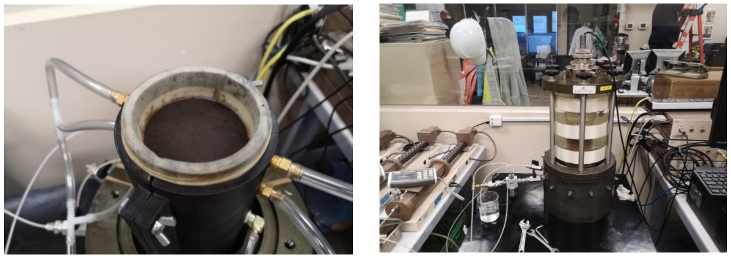
At Maximum Deviator Stress:		
Axial Stain	%	**1.70**
Deviator Stress	kPa	**287.2**
Φ '	º	36.0
c' (assumed)	kPa	**0**

At Maximum Stress Ratio		
Axial Stain	%	**1.72**
Deviator Stress	kPa	**287.0**
Φ '	º	36.2
c' (assumed)	kPa	0

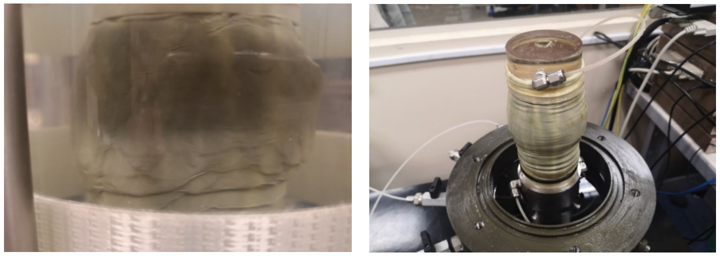
Note: *using cambridge method*

<u>Photos:</u>

Before Test



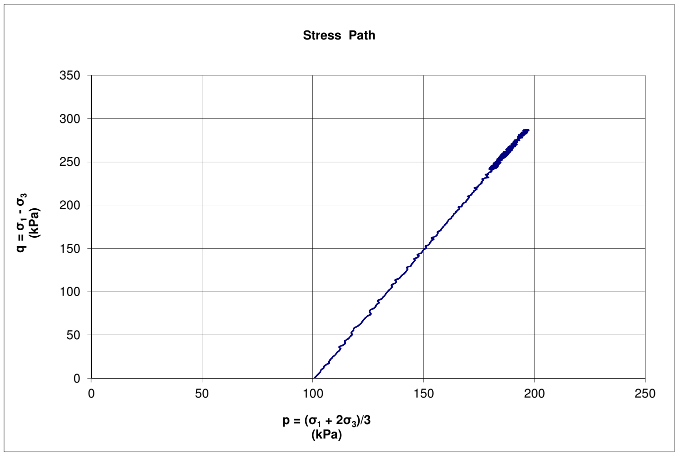
After Test

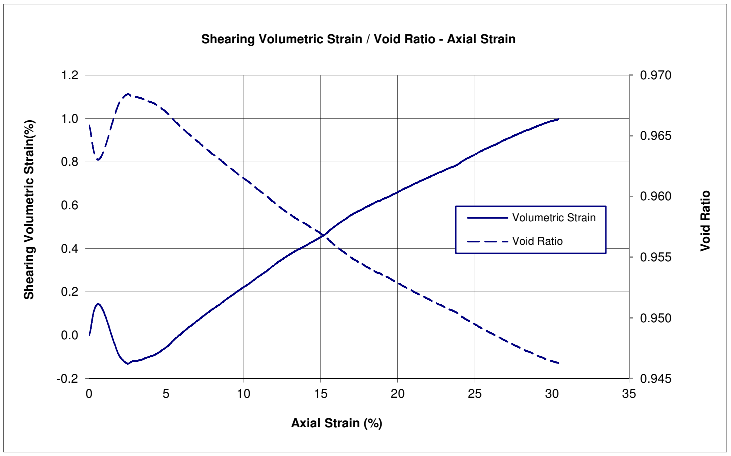


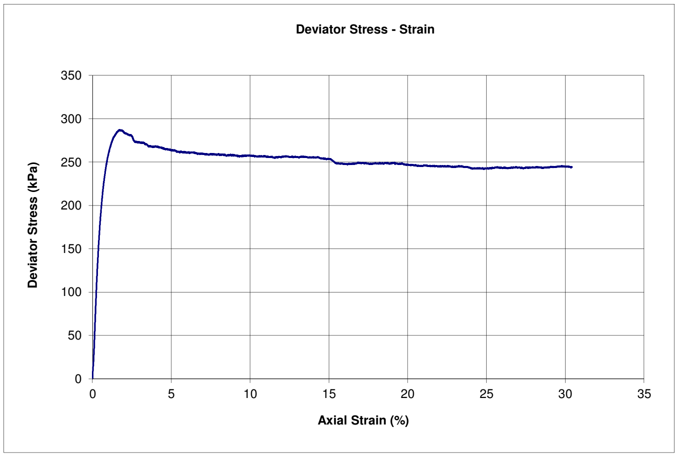
Triaxial CD Test - Charts

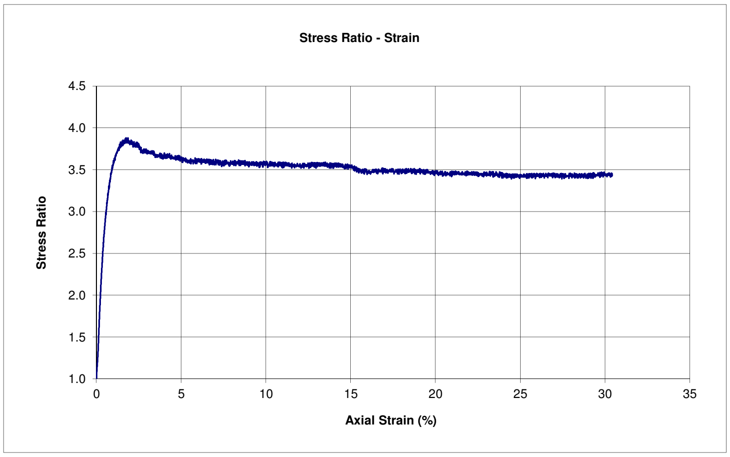
(ASTM D7181)

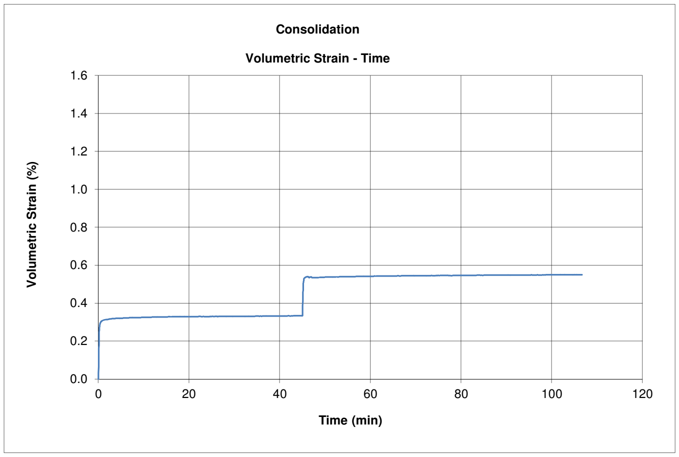
PROJECT NO. :	A03355A01	DATE :	2019-08-26
PROJECT :		TEST BY:	BY
SAMPLE :	Fine Gradation	CHECKED BY:	JG
TEST NO. :	TX 11 - CD		

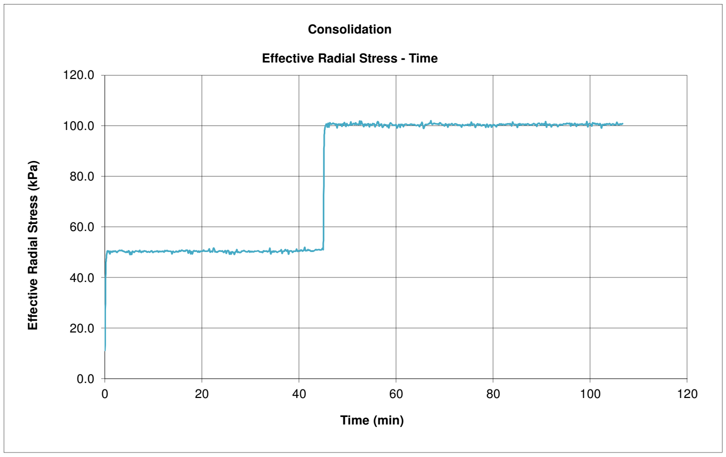












Triaxial CD Test - Summary

(ASTM D7181)

PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Fine Gradation
TEST NO. : TX 12 - CID

DATE : 2019-08-26
TESTED BY: BY
CHECKED BY: JG

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B-value	End of 1st Consolidation	End of 2nd Consolidation	End of 3rd Consolidation	End of 4th Consolidation	End of 5th Consolidation	At Failure	End of Shear
Specimen Height	mm	140.12	140.12	140.12	139.77	139.68	139.63	139.56	139.47	139.39	134.09	96.79
Specimen Diameter	mm	69.90	69.90	69.90	69.89	69.78	69.73	69.67	69.61	69.56	70.90	83.46
Area	cm^2	38.37	38.37	38.37	38.36	38.24	38.19	38.13	38.05	38.00	39.48	54.71
Volume	cm^3	537.71	537.71	537.71	536.21	534.17	533.28	532.09	530.72	529.69	529.38	529.56
Wet Weight	g	1513.44	1513.44	1644.04	1653.02	1650.98	1650.09	1648.90	1647.53	1646.50	1646.19	1646.37
Water Content	%	7.95	7.95	17.27	17.91	17.76	17.70	17.61	17.51	17.44	17.42	17.43
Dry Weight	g	1401.98	1401.98	1401.98	1401.98	1401.98	1401.98	1401.98	1401.98	1401.98	1401.98	1401.98
Wet Density	g/cm^3	2.815	2.815	3.058	3.083	3.091	3.094	3.099	3.104	3.108	3.110	3.109
Dry Density	g/cm^3	2.607	2.607	2.607	2.615	2.625	2.629	2.635	2.642	2.647	2.648	2.647
Specific Gravity of Solids (assumed)	-	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91
Solids Volume	cm^3	285.536	285.536	285.536	285.536	285.536	285.536	285.536	285.536	285.536	285.536	285.536
Void Volume	cm^3	252.169	252.169	252.169	250.669	248.636	247.743	246.549	245.187	244.150	243.842	244.019
Water Volume	cm^3	111.458	111.458	242.058	251.034	249.001	248.108	246.914	245.552	244.515	244.207	244.384
Void Ratio (e)	-	0.883	0.883	0.883	0.878	0.871	0.868	0.863	0.859	0.855	0.854	0.855
Saturation Ratio (Sr)	%	44.20	44.20	95.99	100.15	100.15	100.15	100.15	100.15	100.15	100.15	100.15
Effective Confining Stress	kPa					50	100	200	350	500		

Shearing (CU)		
Skempton's B Parameter		0.99
Back Pressure before shearing	kPa	500.0
Confining Stress (σ_3') before shearing	kPa	500
Shear Strain Rate	mm / min	0.04

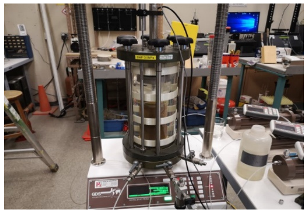
At Maximum Deviator Stress:		
Axial Stain	%	**3.81**
Deviator Stress	kPa	**1609.6**
Φ '	º	38.1
c' (assumed)	kPa	**0**

At Maximum Stress Ratio		
Axial Stain	%	**3.63**
Deviator Stress	kPa	**1609.1**
Φ '	º	38.1
c' (assumed)	kPa	0

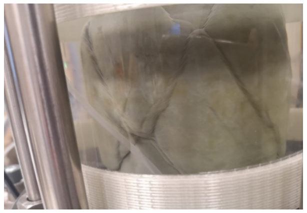
Note: *using cambridge method*

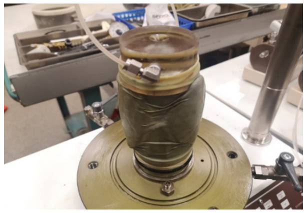
Photos:

Before Test



After Test



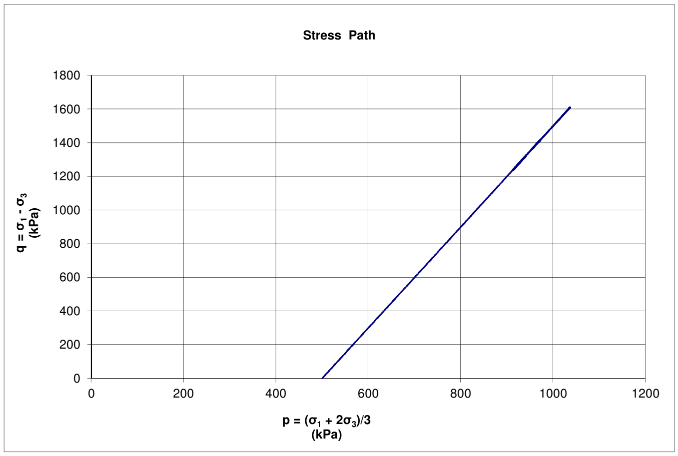


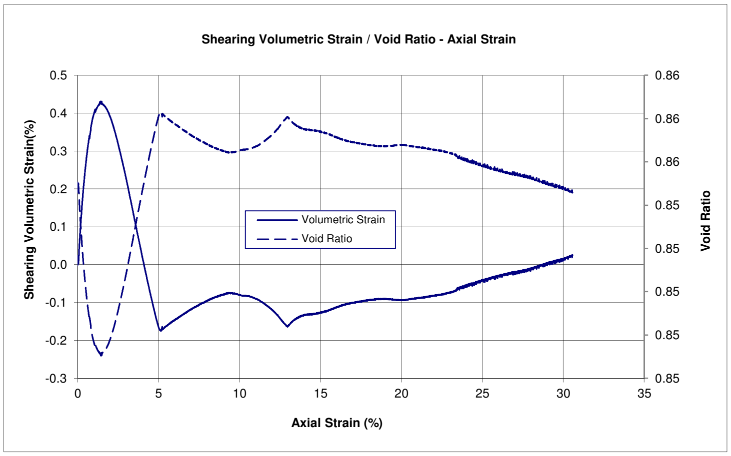
Triaxial CD Test - Charts

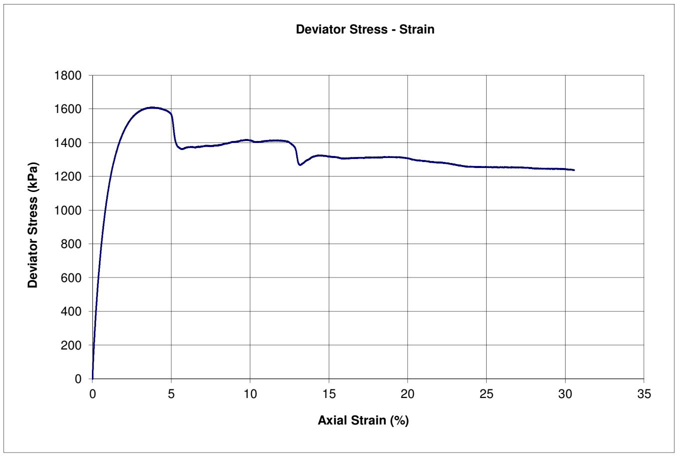
(ASTM D7181)

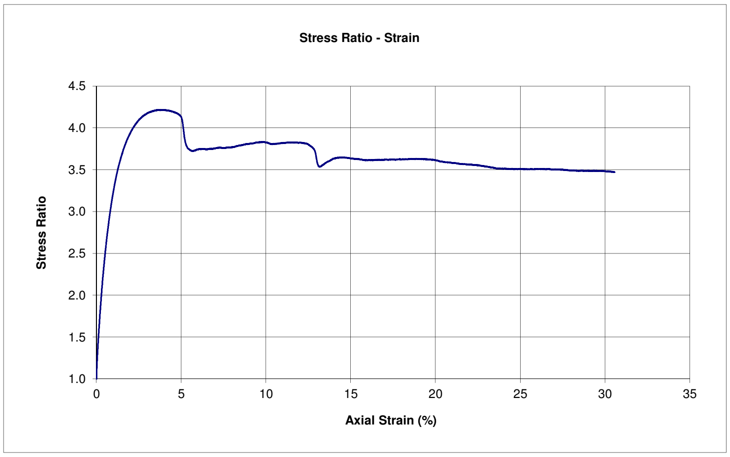
PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Fine Gradation
TEST NO. : TX 12 - CID

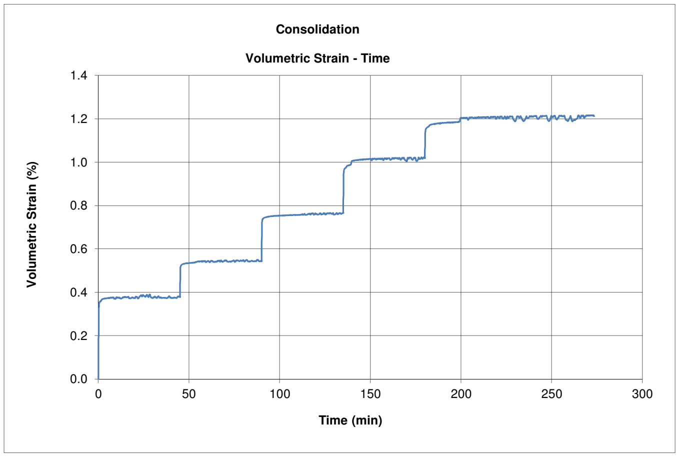
DATE : 2019-08-26
TEST BY: BY
CHECKED BY: JG

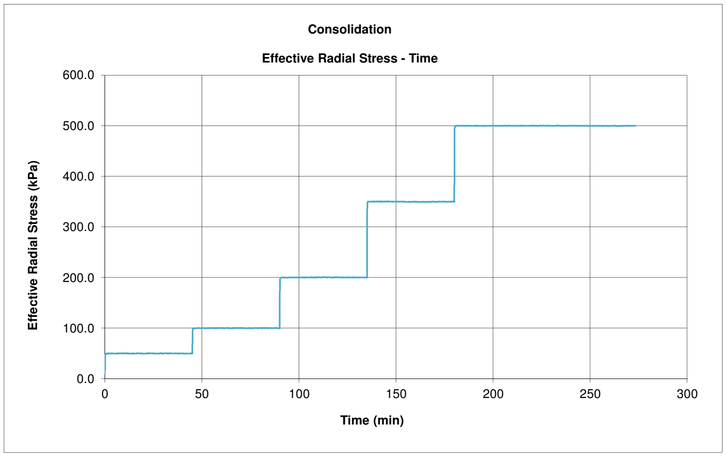












Triaxial CD Test - Summary

(ASTM D7181)

PROJECT NO. :	A03355A01	DATE :	2019-08-20
PROJECT :		TESTED BY:	BY
SAMPLE :	Fine Gradation	CHECKED BY:	JG
TEST NO. :	TX 13 - CID		

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation / B-value	End of 1st Consolidation	End of 2nd Consolidation	End of 3rd Consolidation	End of 4th Consolidation	End of 5th Consolidation	End of 6th Consolidation	At Failure	End of Shear
Specimen Height	mm	140.00	139.88	139.49	139.40	139.34	139.25	139.14	139.00	138.88	130.81	95.60
Specimen Diameter	mm	69.90	69.93	69.96	69.88	69.84	69.79	69.73	69.65	69.58	71.38	83.26
Area	cm^2	38.37	38.41	38.44	38.35	38.31	38.26	38.19	38.10	38.02	40.02	54.45
Volume	cm^3	537.24	537.25	536.25	534.62	533.82	532.76	531.29	529.61	528.03	523.49	520.51
Wet Weight	g	1530.80	1530.80	1668.80	1667.17	1666.37	1665.31	1663.84	1662.17	1660.58	1656.04	1653.07
Water Content	%	7.94	7.94	17.67	17.56	17.50	17.42	17.32	17.20	17.09	16.77	16.56
Dry Weight	g	1418.20	1418.20	1418.20	1418.20	1418.20	1418.20	1418.20	1418.20	1418.20	1418.20	1418.20
Wet Density	g/cm^3	2.849	2.849	3.112	3.118	3.122	3.126	3.132	3.138	3.145	3.163	3.176
Dry Density	g/cm^3	2.640	2.640	2.645	2.653	2.657	2.662	2.669	2.678	2.686	2.709	2.725
Specific Gravity of Solids (assumed)	-	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96
Solids Volume	cm^3	285.926	285.926	285.926	285.926	285.926	285.926	285.926	285.926	285.926	285.926	285.926
Void Volume	cm^3	251.318	251.319	250.319	248.689	247.892	246.834	245.364	243.688	242.100	237.563	234.586
Water Volume	cm^3	112.605	112.605	250.603	248.973	248.176	247.118	245.648	243.972	242.384	237.847	234.870
Void Ratio (e)	-	0.879	0.879	0.875	0.870	0.867	0.863	0.858	0.852	0.847	0.831	0.820
Saturation Ratio (Sr)	%	44.81	44.81	100.11	100.11	100.11	100.12	100.12	100.12	100.12	100.12	100.12
Effective Confining Stress	kPa				50	100	200	400	700	1000		

Shearing (CU)		
Skempton's B Parameter		0.99
Back Pressure before shearing	kPa	500.0
Confining Stress (σ_3') before shearing	kPa	1000
Shear Strain Rate	mm / min	0.04

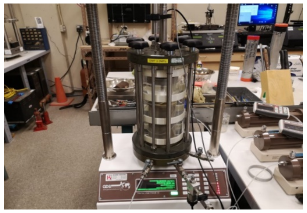
At Maximum Deviator Stress:		
Axial Stain	%	**5.81**
Deviator Stress	kPa	**2930.8**
Φ '	º	36.5
c' (assumed)	kPa	**0**

At Maximum Stress Ratio		
Axial Stain	%	**5.64**
Deviator Stress	kPa	**2928.2**
Φ '	º	36.5
c' (assumed)	kPa	0

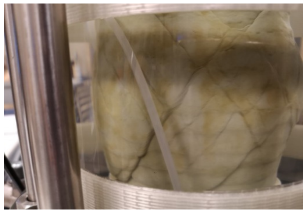
Note: *using cambridge method*

Photos:

Before Test



After Test

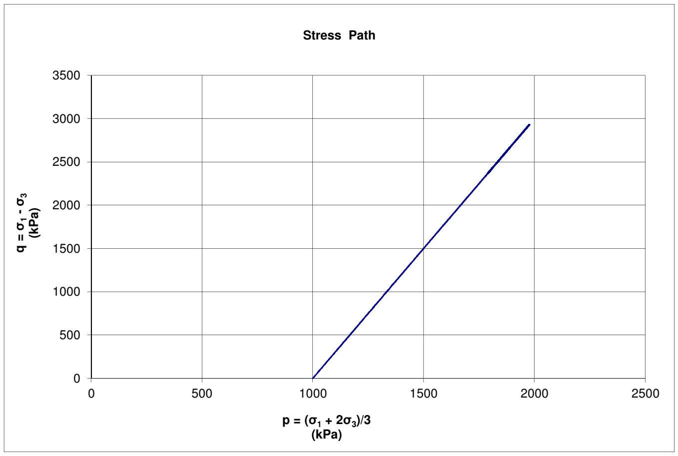


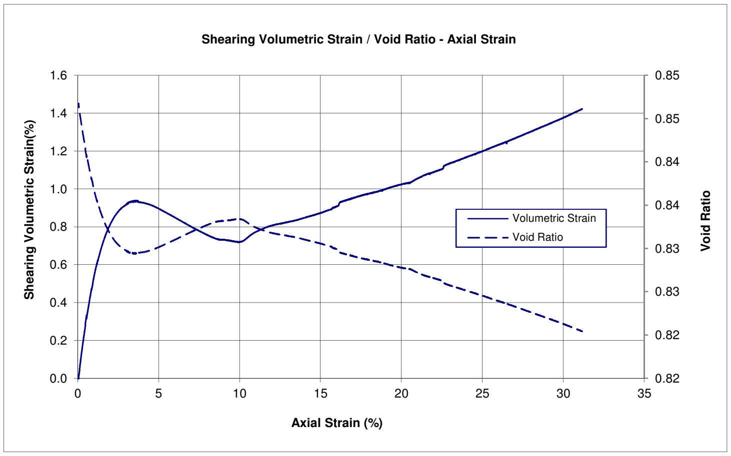
Triaxial CD Test - Charts

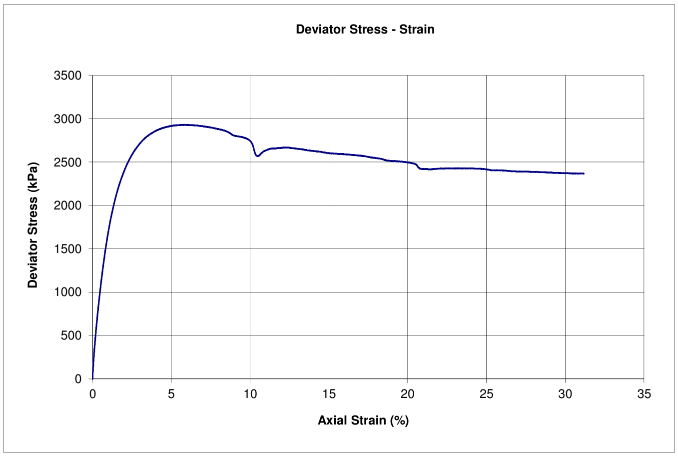
(ASTM D7181)

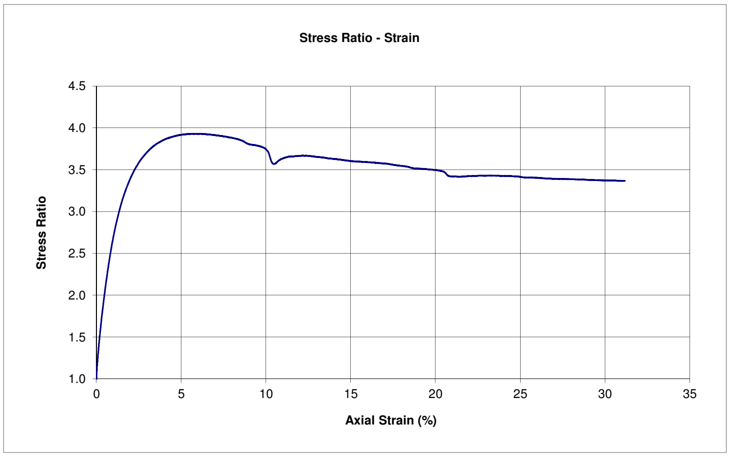
PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Fine Gradation
TEST NO. : TX 13 - CID

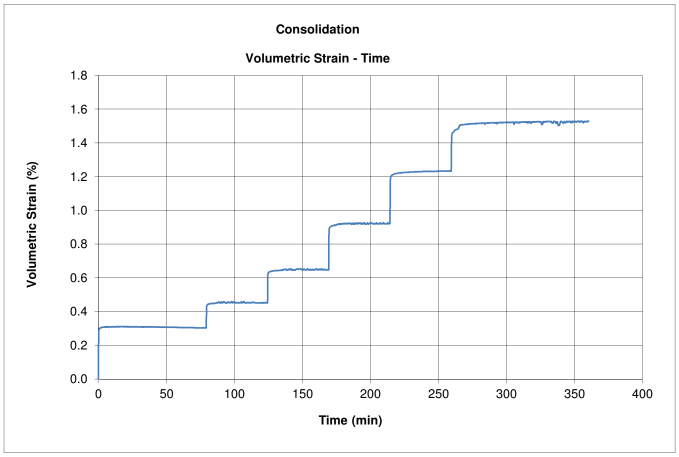
DATE : 2019-08-20
TEST BY: BY
CHECKED BY: JG


Stress Path

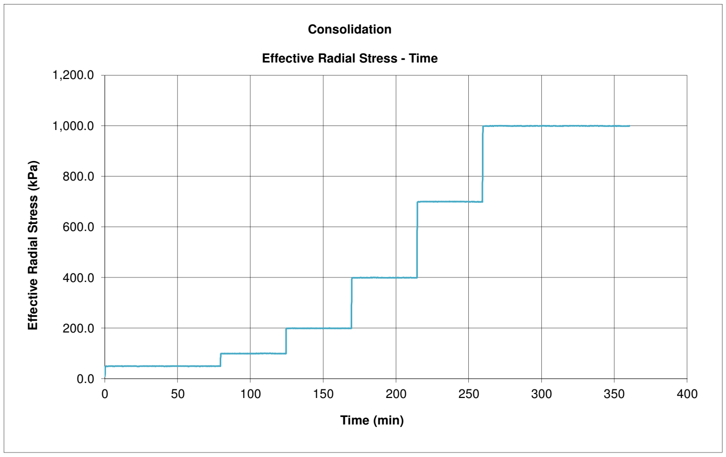

Shearing Volumetric Strain / Void Ratio - Axial Strain


Deviator Stress - Strain


Stress Ratio - Strain


Consolidation

Volumetric Strain - Time


Consolidation

Effective Radial Stress - Time

Triaxial CD Test - Summary
(ASTM D7181)

PROJECT NO. :	A03355A01	DATE :	2019-08-23
PROJECT :		TESTED BY:	BY
SAMPLE :	Coarse Gradation	CHECKED BY:	JG
TEST NO. :	TX 14 - CID		

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B-value	End of 1st Consolidation	At Maximum Deviator Stress	End of Shear		
Specimen Height	mm	140.15	140.15	140.15	140.05	139.99	100.36	95.10		
Specimen Diameter	mm	69.81	69.81	69.78	69.67	69.46	80.18	82.28		
Area	cm^2	38.28	38.28	38.24	38.12	37.90	50.49	53.17		
Volume	cm^3	536.44	536.44	535.91	533.91	530.50	506.69	505.63		
Wet Weight	g	1437.60	1437.60	1587.40	1593.68	1590.28	1566.47	1565.41		
Water Content	%	8.05	8.05	19.31	19.78	19.53	17.74	17.66		
Dry Weight	g	1330.50	1330.50	1330.50	1330.50	1330.50	1330.50	1330.50		
Wet Density	g/cm^3	2.680	2.680	2.962	2.985	2.998	3.092	3.096		
Dry Density	g/cm^3	2.480	2.480	2.483	2.492	2.508	2.626	2.631		
Specific Gravity of Solids (assumed)	-	4.91	4.91	4.91	4.91	4.91	4.91	4.91		
Solids Volume	cm^3	270.977	270.977	270.977	270.977	270.977	270.977	270.977		
Void Volume	cm^3	265.460	265.460	264.929	262.929	259.522	235.715	234.656		
Water Volume	cm^3	107.105	107.105	256.905	263.189	259.782	235.975	234.916		
Void Ratio (e)	-	0.980	0.980	0.978	0.970	0.958	0.870	0.866		
Saturation Ratio (Sr)	%	40.35	40.35	96.97	100.10	100.10	100.11	100.11		
Effective Confining Stress	kPa					50				

Shearing (CU)		
Skempton's B Parameter		0.98
Back Pressure before shearing	kPa	500.0
Confining Stress (σ_3') before shearing	kPa	50
Shear Strain Rate	mm / min	0.04

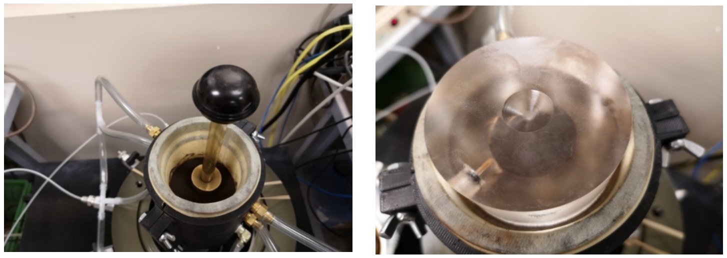
At Maximum Deviator Stress:		
Axial Stain	%	**28.31**
Deviator Stress	kPa	**129.6**
Φ '	º	34.2
c' (assumed)	kPa	**0**

At Maximum Stress Ratio		
Axial Stain	%	**26.76**
Deviator Stress	kPa	**128.3**
Φ '	º	34.6
c' (assumed)	kPa	0

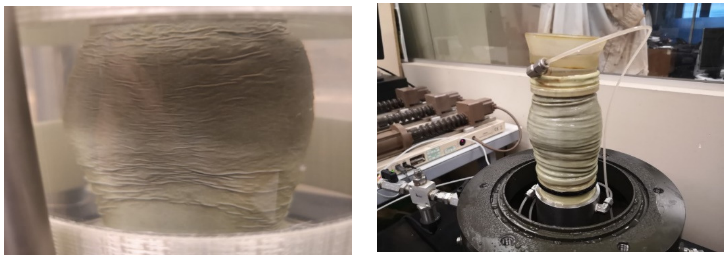
Note: *using cambridge method*

Photos:

Before Test



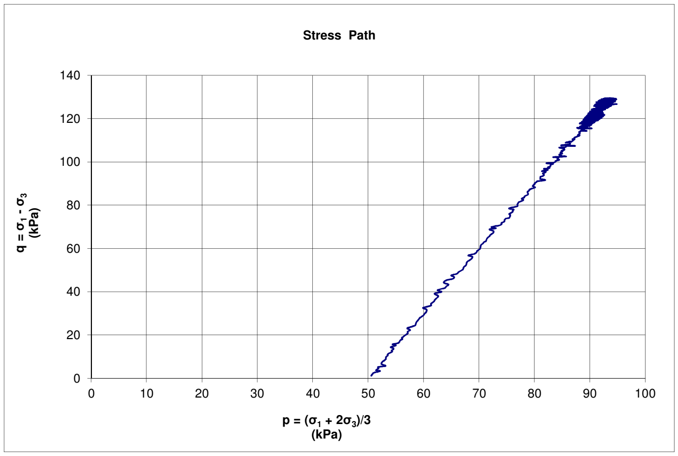
After Test

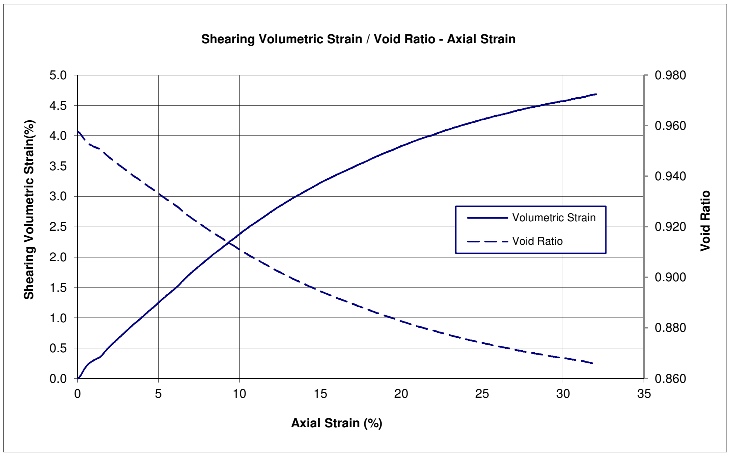


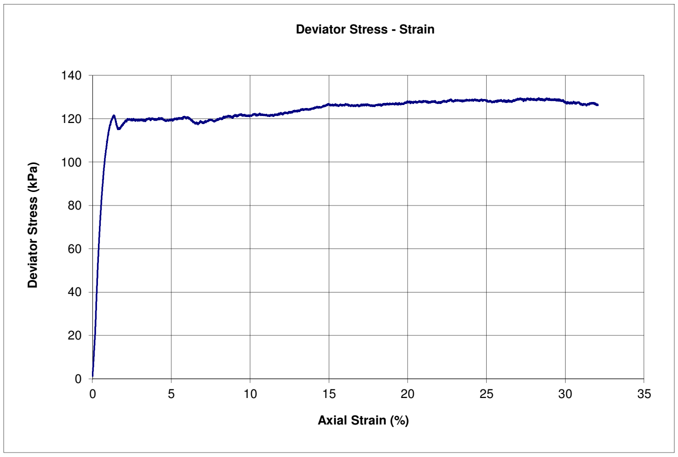
Triaxial CD Test - Charts

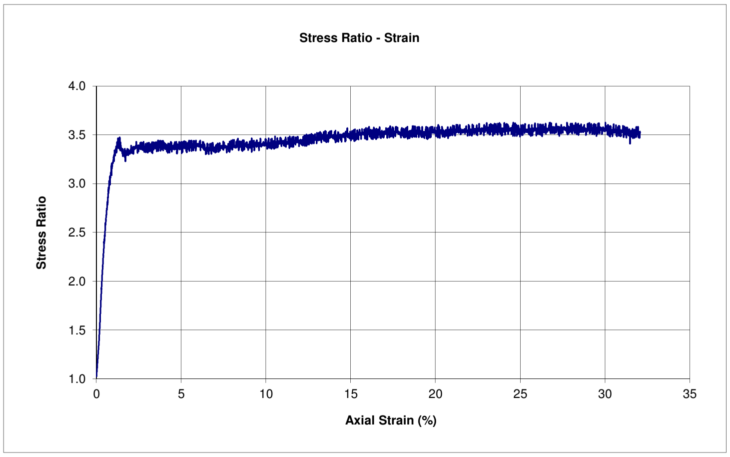
(ASTM D7181)

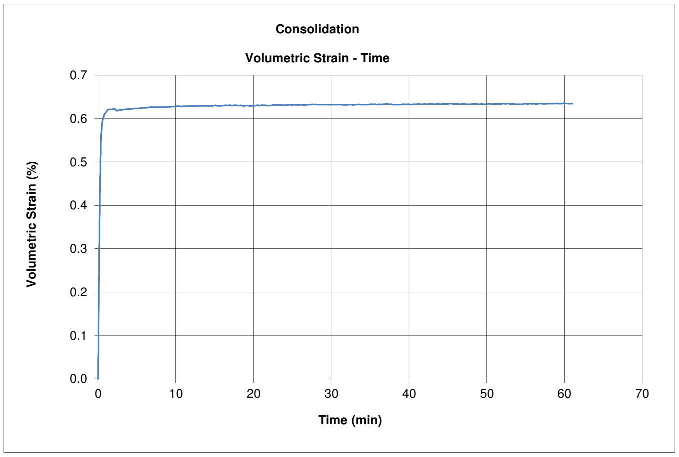
PROJECT NO. :	A03355A01	DATE :	2019-08-23
PROJECT :		TEST BY:	BY
SAMPLE :	Coarse Gradation	CHECKED BY:	JG
TEST NO. :	TX 14 - CID		

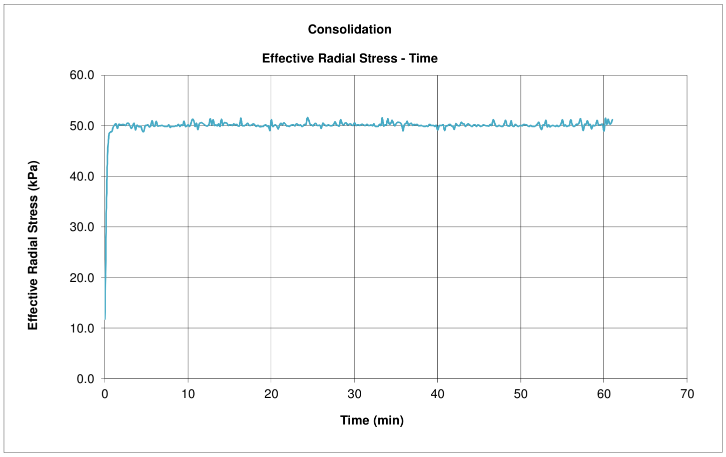












Triaxial CD Test - Summary

(ASTM D7181)

PROJECT NO. :	A03355A01	DATE :	2019-08-28
PROJECT :		TESTED BY:	BY
SAMPLE :	Coarse Gradation	CHECKED BY:	JG
TEST NO. :	TX 15 - CID		

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B-Value	End of 1st Consolidation	End of 2nd Consolidation	At Failure	End of Shear	
Specimen Height	mm	140.15	140.05	140.05	139.95	139.88	139.81	137.05	98.56	
Specimen Diameter	mm	69.90	69.92	69.90	69.83	69.70	69.65	70.60	83.45	
Area	cm^2	38.37	38.40	38.37	38.29	38.16	38.10	39.15	54.69	
Volume	cm^3	537.820	537.744	537.396	535.896	533.729	532.663	536.534	539.079	
Wet Weight	g	1577.12	1577.12	1685.92	1699.03	1696.86	1695.80	1699.67	1702.21	
Water Content	%	8.00	8.00	15.45	16.35	16.20	16.13	16.39	16.57	
Dry Weight	g	1460.30	1460.30	1460.30	1460.30	1460.30	1460.30	1460.30	1460.30	
Wet Density	g/cm^3	2.932	2.933	3.137	3.170	3.179	3.184	3.168	3.158	
Dry Density	g/cm^3	2.715	2.716	2.717	2.725	2.736	2.741	2.722	2.709	
Specific Gravity of Solids (assumed)	-	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91	
Solids Volume	cm^3	297.413	297.413	297.413	297.413	297.413	297.413	297.413	297.413	
Void Volume	cm^3	240.408	240.332	239.984	238.484	236.317	235.251	239.122	241.667	
Water Volume	cm^3	116.824	116.824	225.624	238.735	236.568	235.502	239.373	241.918	
Void Ratio (e)	-	0.808	0.808	0.807	0.802	0.795	0.791	0.804	0.813	
Saturation Ratio (Sr)	%	48.59	48.61	94.02	100.11	100.11	100.11	100.10	100.10	
Effective Confining Stress	kPa					50	100			

Shearing (CU)		
Skempton's B Parameter		0.99
Back Pressure before shearing	kPa	500.0
Confining Stress (σ_3') before shearing	kPa	100
Shear Strain Rate	mm / min	0.04

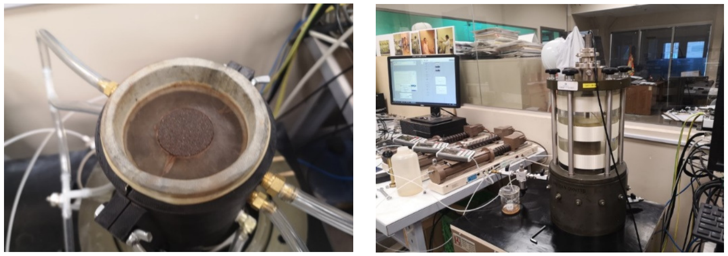
At Maximum Deviator Stress:		
Axial Stain	%	**1.98**
Deviator Stress	kPa	**504.0**
Φ '	º	45.7
c' (assumed)	kPa	**0**

At Maximum Stress Ratio		
Axial Stain	%	**2.05**
Deviator Stress	kPa	**503.1**
Φ '	º	45.9
c' (assumed)	kPa	0

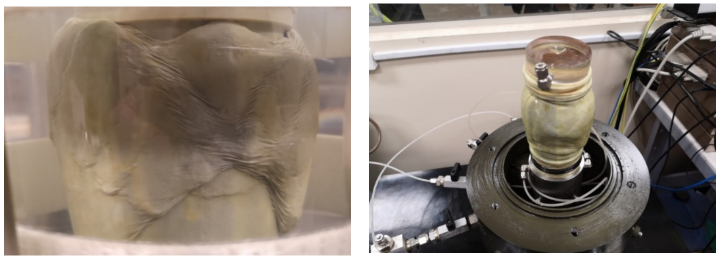
Note: *using cambridge method*

<u>Photos:</u>

Before Test



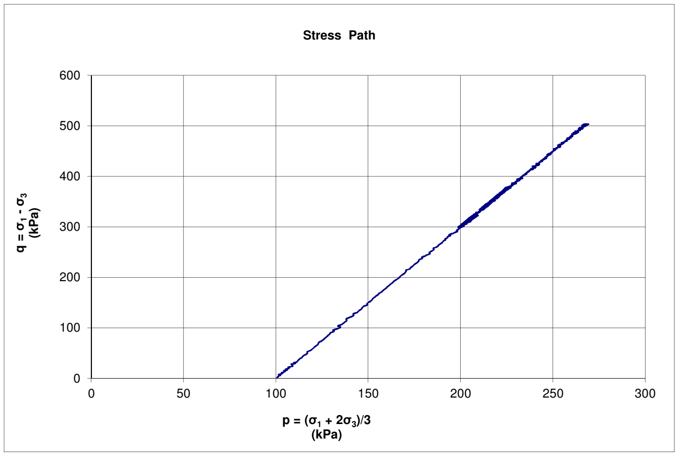
After Test

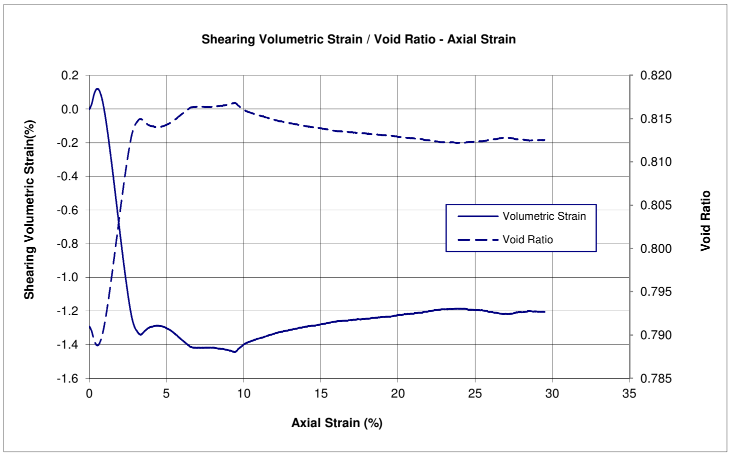


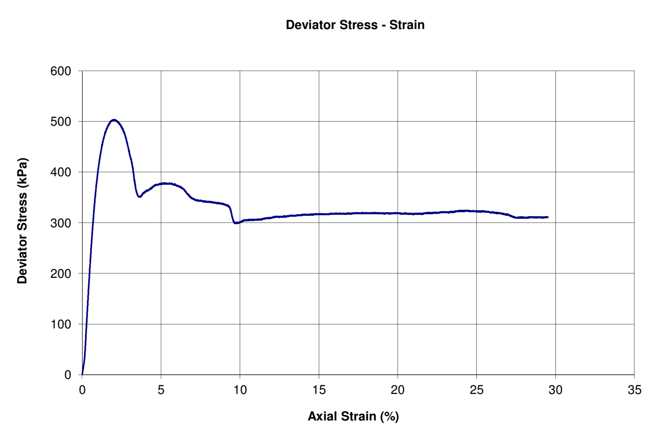
Triaxial CD Test - Charts

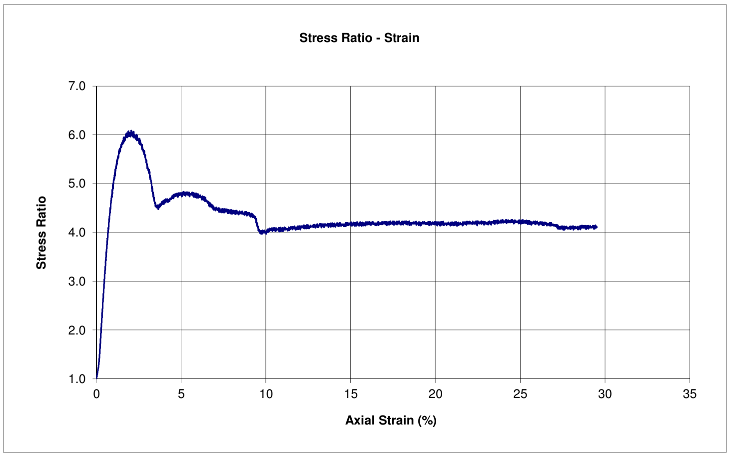
(ASTM D7181)

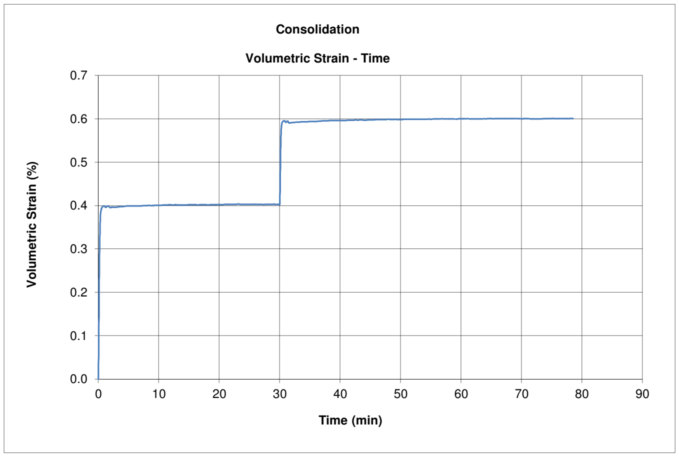
PROJECT NO. :	A03355A01	DATE :	2019-08-28
PROJECT :		TEST BY:	BY
SAMPLE :	Coarse Gradation	CHECKED BY:	JG
TEST NO. :	TX 15 - CID		

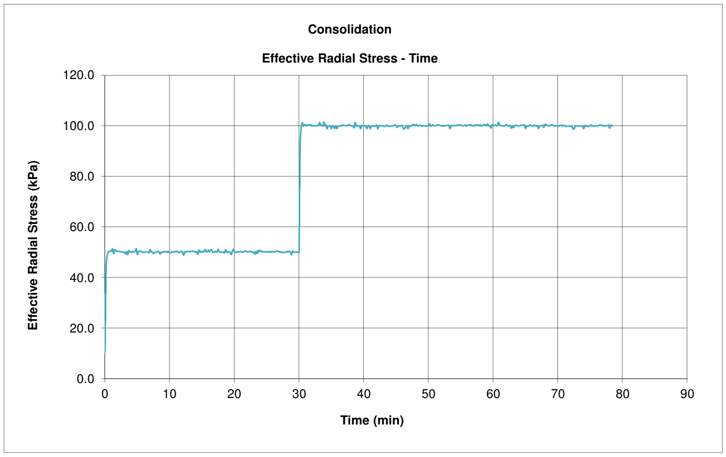












Triaxial CD Test - Summary

(ASTM D7181)

PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Coarse Gradation
TEST NO. : TX 16 - CID

DATE : 2019-08-28
TESTED BY: BY
CHECKED BY: JG

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B-value	End of 1st Consolidation	End of 2nd Consolidation	End of 3rd Consolidation	End of 4th Consolidation	End of 5th Consolidation	At Failure	End of Shear
Specimen Height	mm	140.24	140.24	140.24	139.95	139.85	139.78	139.68	139.58	139.49	134.27	97.75
Specimen Diameter	mm	69.90	69.90	69.88	69.95	69.86	69.82	69.76	69.69	69.64	70.84	82.93
Area	cm^2	38.37	38.37	38.35	38.43	38.33	38.28	38.22	38.15	38.08	39.42	54.02
Volume	cm^3	536.59	538.17	537.84	537.84	536.08	535.10	533.80	532.42	531.23	529.27	528.07
Wet Weight	g	1609.08	1609.08	1714.68	1725.71	1723.94	1722.96	1721.66	1720.28	1719.09	1717.13	1715.93
Water Content	%	7.98	7.98	15.07	15.81	15.69	15.62	15.53	15.44	15.36	15.23	15.15
Dry Weight	g	1490.16	1490.16	1490.16	1490.16	1490.16	1490.16	1490.16	1490.16	1490.16	1490.16	1490.16
Wet Density	g/cm^3	2.999	2.990	3.188	3.209	3.216	3.220	3.225	3.231	3.236	3.244	3.249
Dry Density	g/cm^3	2.777	2.769	2.771	2.771	2.780	2.785	2.792	2.799	2.805	2.816	2.822
Specific Gravity of Solids (assumed)	-	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91
Solids Volume	cm^3	303.496	303.496	303.496	303.496	303.496	303.496	303.496	303.496	303.496	303.496	303.496
Void Volume	cm^3	233.097	234.670	234.348	234.348	232.584	231.602	230.303	228.922	227.734	225.773	224.574
Water Volume	cm^3	118.915	118.915	224.515	235.540	233.776	232.794	231.495	230.114	228.926	226.965	225.766
Void Ratio (e)	-	0.768	0.773	0.772	0.772	0.766	0.763	0.759	0.754	0.750	0.744	0.740
Saturation Ratio (Sr)	%	51.02	50.67	95.80	100.51	100.51	100.51	100.52	100.52	100.52	100.53	100.53
Effective Confining Stress	kPa					50	100	200	350	500		

Shearing (CU)		
Skempton's B Parameter		0.99
Back Pressure before shearing	kPa	500.0
Confining Stress (σ_3') before shearing	kPa	500
Shear Strain Rate	mm / min	0.04

At Maximum Deviator Stress:		
Axial Stain	%	**3.74**
Deviator Stress	kPa	**1775.5**
Φ '	º	39.8
c' (assumed)	kPa	**0**

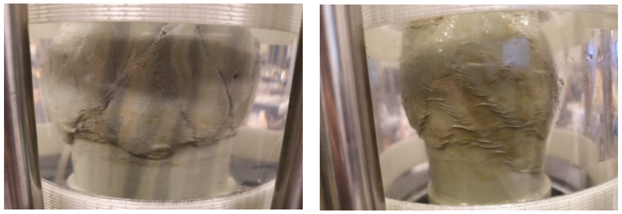
At Maximum Stress Ratio		
Axial Stain	%	**3.87**
Deviator Stress	kPa	**1774.0**
Φ '	º	39.8
c' (assumed)	kPa	0

Note: *using cambridge method*

Photos:

Before Test

After Test

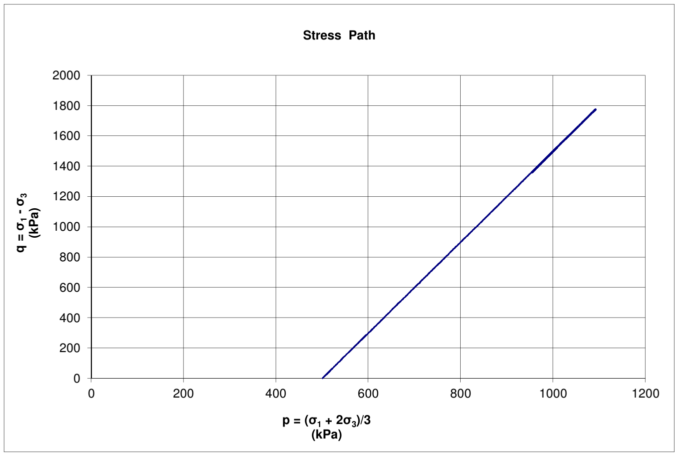


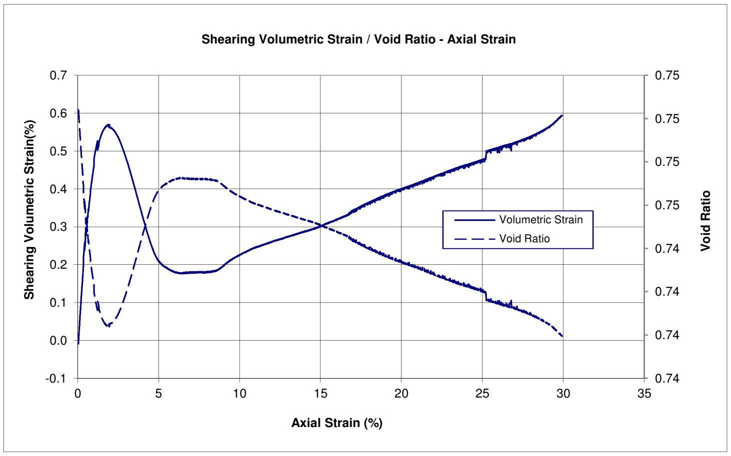
Triaxial CD Test - Charts

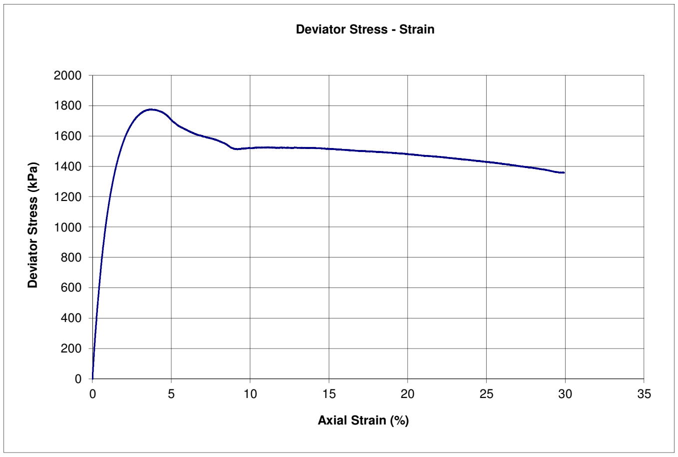
(ASTM D7181)

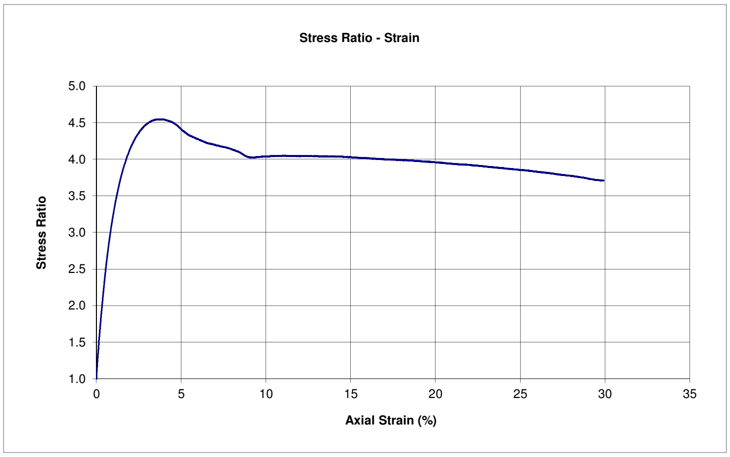
PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Coarse Gradation
TEST NO. : TX 16 - CID

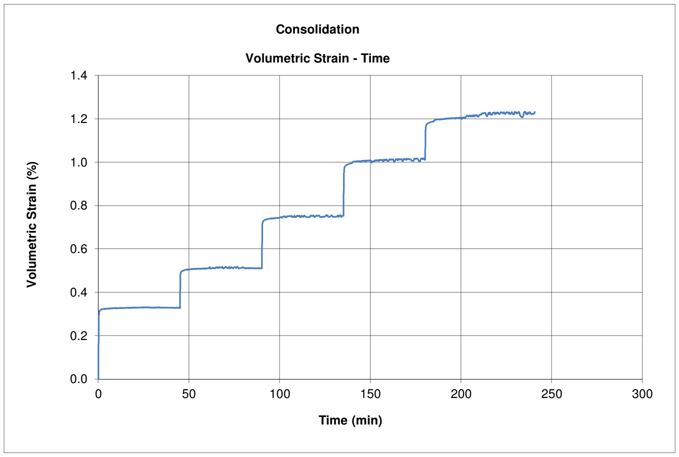
DATE : 2019-08-28
TEST BY: BY
CHECKED BY: JG

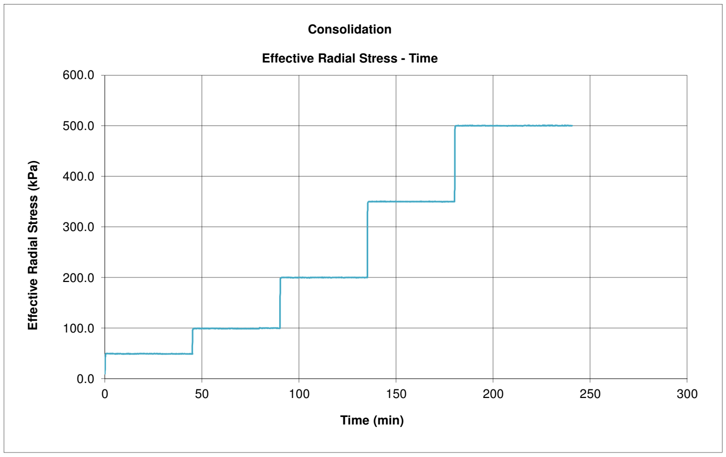












Triaxial CD Test - Summary

(ASTM D7181)

PROJECT NO. :	A03355A01	DATE :	2019-08-22
PROJECT :		TESTED BY:	BY
SAMPLE :	Coarse Gradation	CHECKED BY:	JG
TEST NO. :	TX 17 - CID		

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation / B-value	End of 1st Consolidation	End of 2nd Consolidation	End of 3rd Consolidation	End of 4th Consolidation	End of 5th Consolidation	End of 6th Consolidation	At Failure	End of Shear
Specimen Height	mm	140.12	139.64	139.30	139.22	139.15	139.06	138.90	138.69	138.49	118.20	95.58
Specimen Diameter	mm	69.90	69.72	69.54	69.41	69.34	69.26	69.14	69.00	68.88	72.94	80.53
Area	cm^2	38.37	38.18	37.98	37.84	37.77	37.68	37.54	37.39	37.26	41.79	50.93
Volume	cm^3	537.71	533.11	529.11	526.74	525.54	523.91	521.45	518.56	516.06	493.90	486.80
Wet Weight	g	1513.44	1513.44	1646.44	1644.07	1642.87	1641.25	1638.78	1635.89	1633.39	1611.23	1604.13
Water Content	%	7.89	7.89	17.37	17.20	17.12	17.00	16.83	16.62	16.44	14.86	14.36
Dry Weight	g	1402.76	1402.76	1402.76	1402.76	1402.76	1402.76	1402.76	1402.76	1402.76	1402.76	1402.76
Wet Density	g/cm^3	2.815	2.839	3.112	3.121	3.126	3.133	3.143	3.155	3.165	3.262	3.295
Dry Density	g/cm^3	2.609	2.631	2.651	2.663	2.669	2.677	2.690	2.705	2.718	2.840	2.882
Specific Gravity of Solids (assumed)	-	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91
Solids Volume	cm^3	285.695	285.695	285.695	285.695	285.695	285.695	285.695	285.695	285.695	285.695	285.695
Void Volume	cm^3	252.010	247.412	243.412	241.041	239.844	238.219	235.753	232.862	230.360	208.205	201.104
Water Volume	cm^3	110.678	110.678	243.676	241.305	240.108	238.483	236.017	233.126	230.624	208.469	201.368
Void Ratio (e)	-	0.882	0.866	0.852	0.844	0.840	0.834	0.825	0.815	0.806	0.729	0.704
Saturation Ratio (Sr)	%	43.92	44.73	100.11	100.11	100.11	100.11	100.11	100.11	100.11	100.13	100.13
Effective Confining Stress	kPa				50	100	200	400	700	1000		

Shearing (CU)		
Skempton's B Parameter		0.99
Back Pressure before shearing	kPa	500.0
Confining Stress (σ_3') before shearing	kPa	1000
Shear Strain Rate	mm / min	0.04

At Maximum Deviator Stress:		
Axial Stain	%	**14.65**
Deviator Stress	kPa	**2744.0**
Φ '	º	35.3
c' (assumed)	kPa	**0**

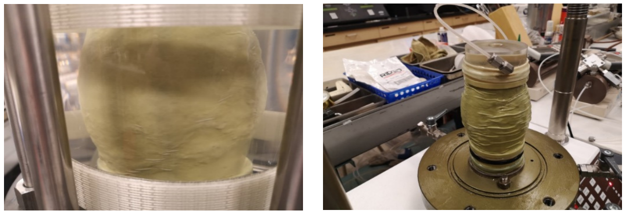
At Maximum Stress Ratio		
Axial Stain	%	**14.89**
Deviator Stress	kPa	**2743.4**
Φ '	º	35.3
c' (assumed)	kPa	0

Note: *using cambridge method*

Photos:

Before Test

After Test



Triaxial CD Test - Charts

(ASTM D7181)

PROJECT NO. : A03355A01

PROJECT :

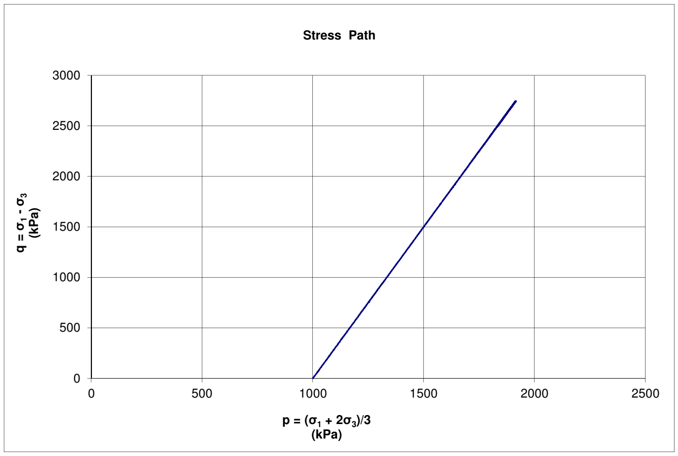
SAMPLE : Coarse Gradation

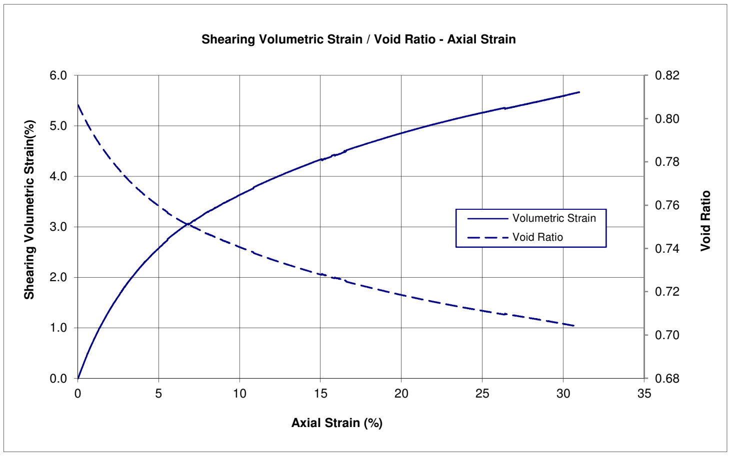
TEST NO. : TX 17 - CID

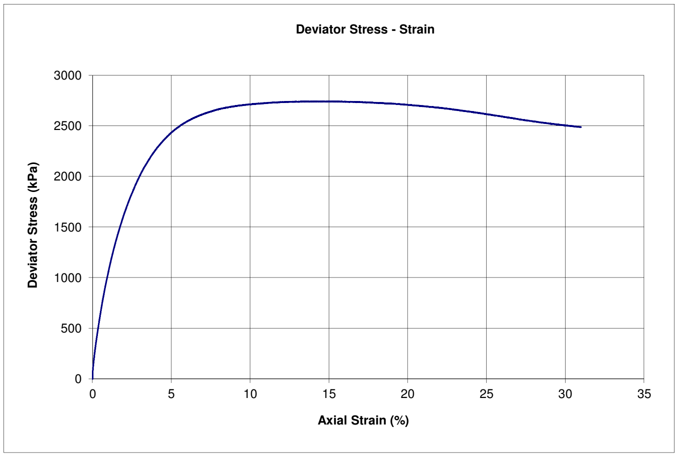
DATE : 2019-08-22

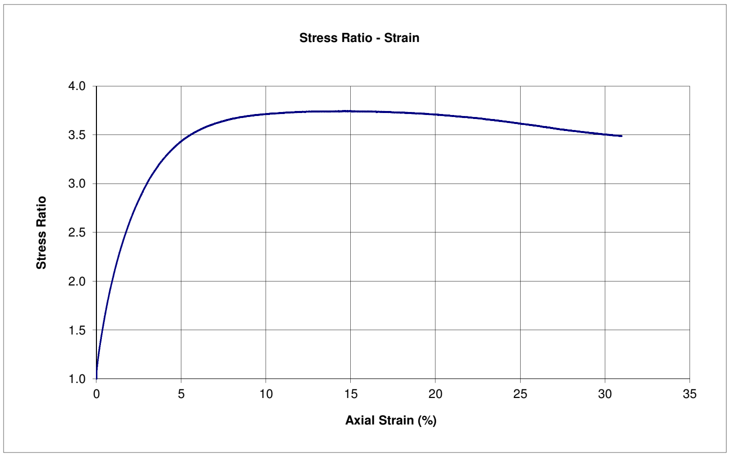
TEST BY: BY

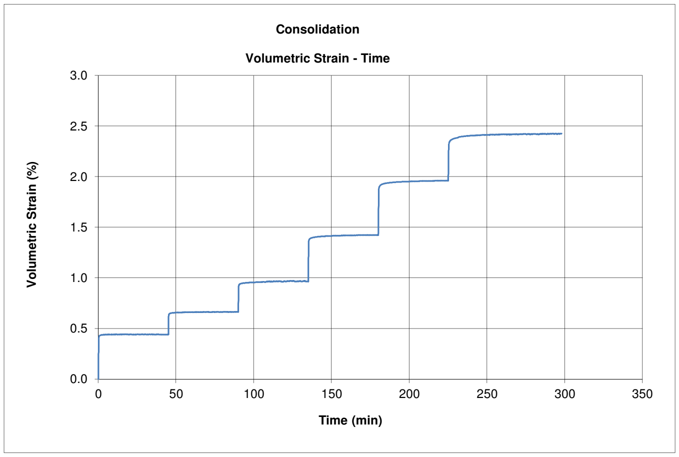
CHECKED BY: JG


Stress Path

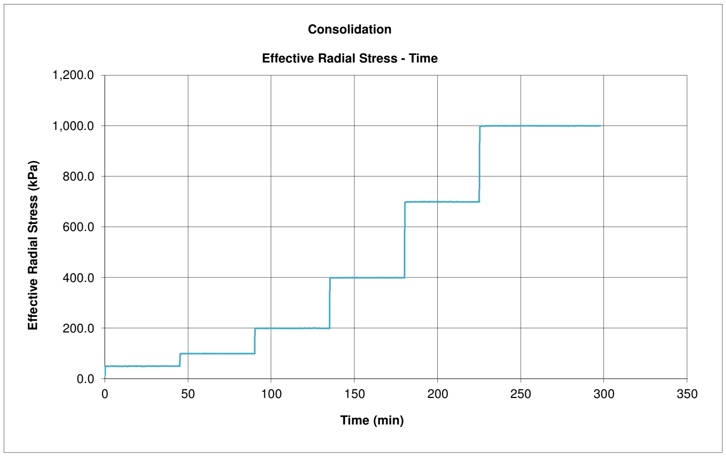

Shearing Volumetric Strain / Void Ratio - Axial Strain


Deviator Stress - Strain


Stress Ratio - Strain


Consolidation

Volumetric Strain - Time


Consolidation

Effective Radial Stress - Time

Triaxial CD Test - Summary

(ASTM D7181)

PROJECT NO. :	A03355A01	DATE :	2019-09-12
PROJECT :		TESTED BY:	AX
SAMPLE :	Average	CHECKED BY:	JG
TEST NO. :	TX 18 - CD		

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B-Value	End of 1st Consolidation	End of 2nd Consolidation	At Failure	End of Shear	
Specimen Height	mm	140.19	140.19	140.19	140.05	139.98	139.93	136.72	90.74	
Specimen Diameter	mm	69.80	69.80	69.71	69.62	69.51	69.44	70.36	86.48	
Area	cm^2	38.26	38.26	38.17	38.06	37.94	37.87	38.88	58.74	
Volume	cm^3	536.436	536.436	535.046	533.046	531.146	529.946	531.586	533.006	
Wet Weight	g	1588.90	1588.90	1698.00	1700.00	1698.10	1696.90	1698.54	1699.96	
Water Content	%	8.75	8.75	16.22	16.35	16.22	16.14	16.25	16.35	
Dry Weight	g	1461.06	1461.06	1461.06	1461.06	1461.06	1461.06	1461.06	1461.06	
Wet Density	g/cm^3	2.962	2.962	3.174	3.189	3.197	3.202	3.195	3.189	
Dry Density	g/cm^3	2.724	2.724	2.731	2.741	2.751	2.757	2.748	2.741	
Specific Gravity of Solids (assumed)	-	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	
Solids Volume	cm^3	293.975	293.975	293.975	293.975	293.975	293.975	293.975	293.975	
Void Volume	cm^3	242.460	242.460	241.070	239.070	237.170	235.970	237.610	239.030	
Water Volume	cm^3	127.843	127.843	236.943	238.943	237.043	235.843	237.483	238.903	
Void Ratio (e)	-	0.825	0.825	0.820	0.813	0.807	0.803	0.808	0.813	
Saturation Ratio (Sr)	%	52.73	52.73	98.29	99.95	99.95	99.95	99.95	99.95	
Effective Confining Stress	kPa					50	100			

Shearing (CU)		
Skempton's B Parameter		0.99
Back Pressure before shearing	kPa	390.0
Confining Stress (σ_3') before shearing	kPa	100
Shear Strain Rate	mm / min	0.04

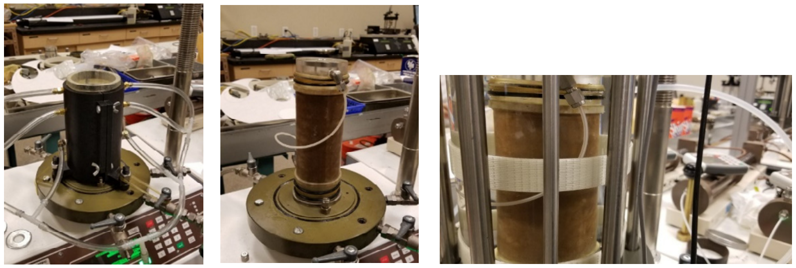
At Maximum Deviator Stress:		
Axial Stain	%	**1.57**
Deviator Stress	kPa	**354.4**
Φ '	º	39.6
c' (assumed)	kPa	**0**

At Maximum Stress Ratio		
Axial Stain	%	**1.57**
Deviator Stress	kPa	**354.4**
Φ '	º	39.6
c' (assumed)	kPa	0

Note: *using cambridge method*

Photos:

Before Test



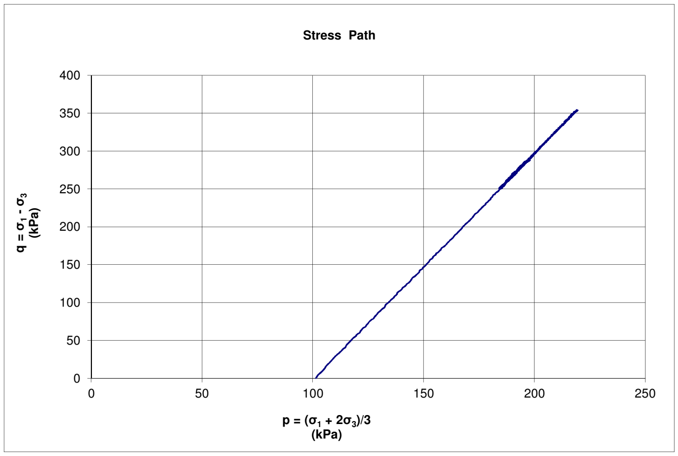
After Test

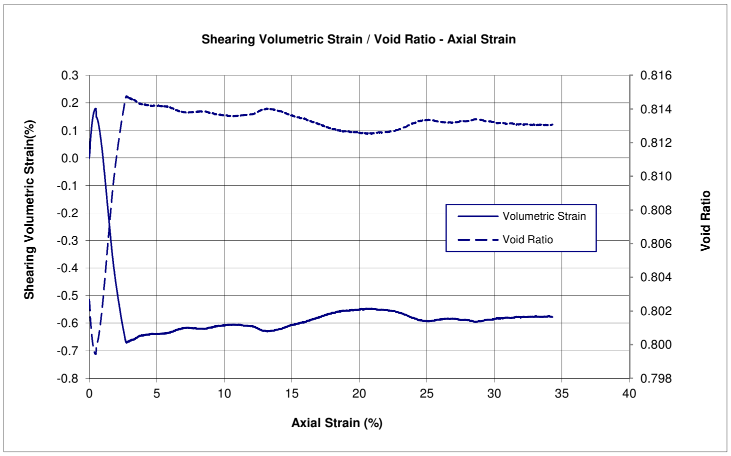
Triaxial CD Test - Charts

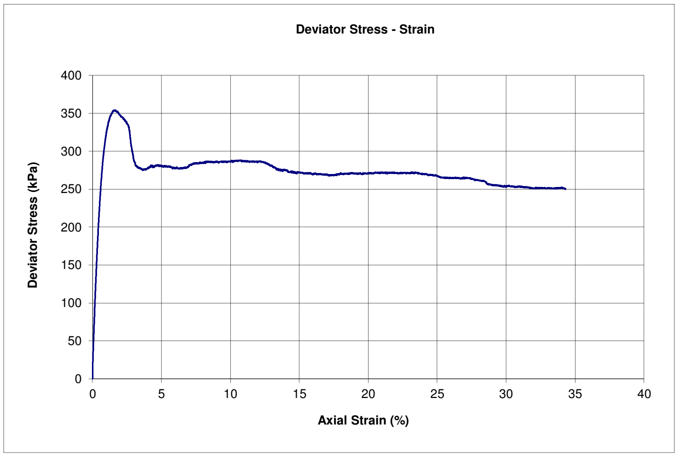
(ASTM D7181)

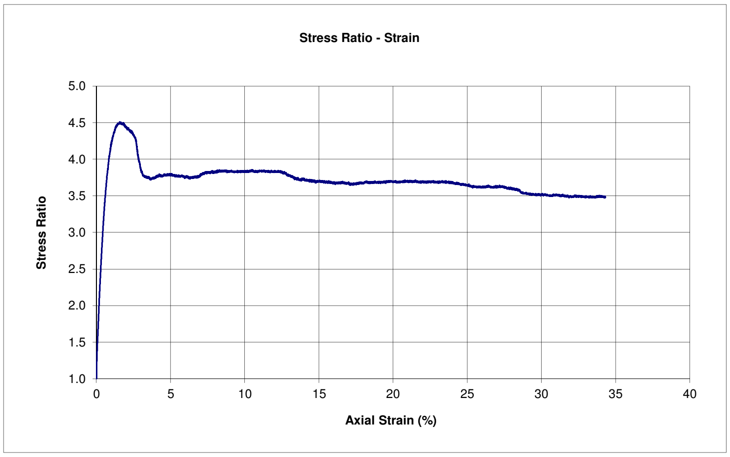
PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Average
TEST NO. : TX 18 - CD

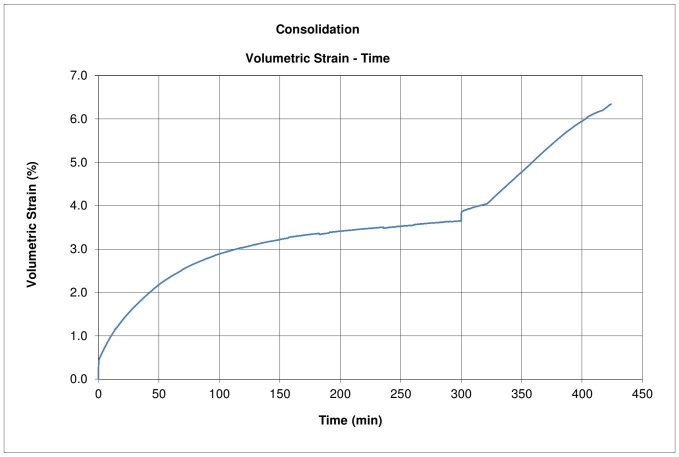
DATE : 2019-09-12
TEST BY: AX
CHECKED BY: JG

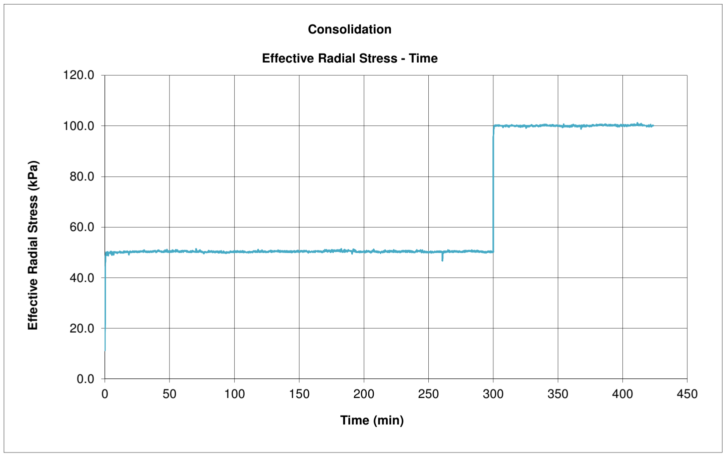












Triaxial CD Test - Summary

(ASTM D7181)

PROJECT NO. : A03355A01

PROJECT :

SAMPLE : Average

TEST NO. : TX 19 - CID

DATE : 2019-09-16

TESTED BY: AX

CHECKED BY: JG

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B-Value	End of 1st Consolidation	End of 2nd Consolidation	At Failure	End of Shear	
Specimen Height	mm	140.54	140.54	140.54	140.40	140.33	140.28	137.07	91.09	
Specimen Diameter	mm	70.00	70.00	69.91	69.95	69.84	69.77	70.99	87.20	
Area	cm^2	38.48	38.48	38.39	38.43	38.31	38.24	39.58	59.71	
Volume	cm^3	540.861	540.861	539.471	539.471	537.571	536.371	542.541	543.931	
Wet Weight	g	1634.35	1634.35	1738.35	1745.09	1743.19	1741.99	1748.16	1749.55	
Water Content	%	8.26	8.26	15.15	15.60	15.47	15.39	15.80	15.89	
Dry Weight	g	1509.65	1509.65	1509.65	1509.65	1509.65	1509.65	1509.65	1509.65	
Wet Density	g/cm^3	3.022	3.022	3.222	3.235	3.243	3.248	3.222	3.216	
Dry Density	g/cm^3	2.791	2.791	2.798	2.798	2.808	2.815	2.783	2.775	
Specific Gravity of Solids (assumed)	-	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	
Solids Volume	cm^3	304.365	304.365	304.365	304.365	304.365	304.365	304.365	304.365	
Void Volume	cm^3	236.496	236.496	235.106	235.106	233.206	232.006	238.176	239.566	
Water Volume	cm^3	124.697	124.697	228.697	235.432	233.532	232.332	238.502	239.892	
Void Ratio (e)	-	0.777	0.777	0.772	0.772	0.766	0.762	0.783	0.787	
Saturation Ratio (Sr)	%	52.73	52.73	97.27	100.14	100.14	100.14	100.14	100.14	
Effective Confining Stress	kPa					50	100			

Shearing (CU)		
Skempton's B Parameter		0.99
Back Pressure before shearing	kPa	390.0
Confining Stress (σ_3') before shearing	kPa	100
Shear Strain Rate	mm / min	0.04

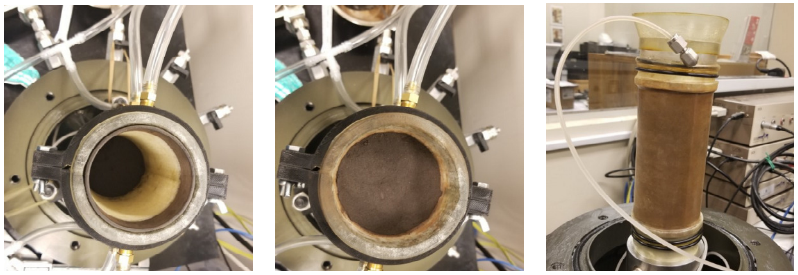
At Maximum Deviator Stress:		
Axial Stain	%	**2.39**
Deviator Stress	kPa	**496.0**
Φ '	º	45.3
c' (assumed)	kPa	**0**

At Maximum Stress Ratio		
Axial Stain	%	**2.45**
Deviator Stress	kPa	**494.2**
Φ '	º	45.5
c' (assumed)	kPa	0

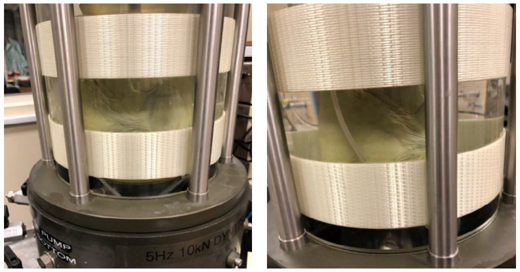
Note: *using cambridge method*

Photos:

Before Test



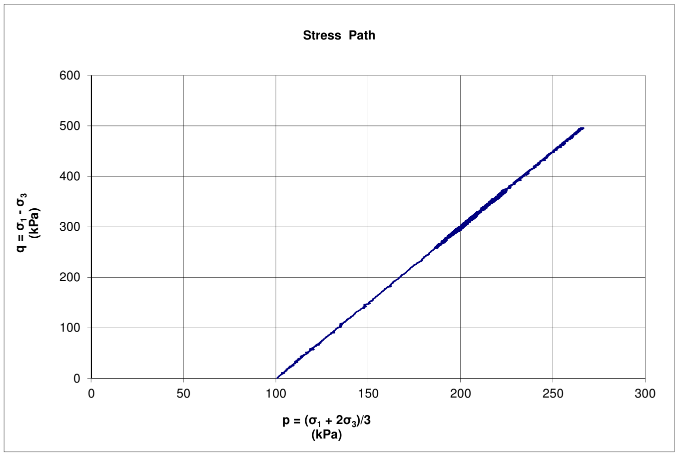
After Test

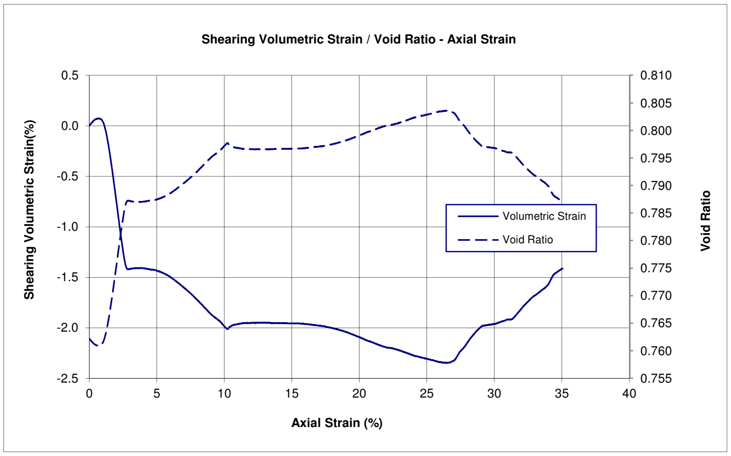


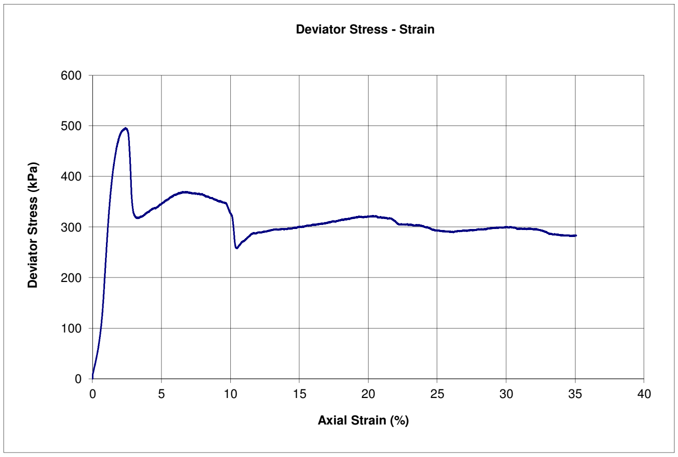
Triaxial CD Test - Charts

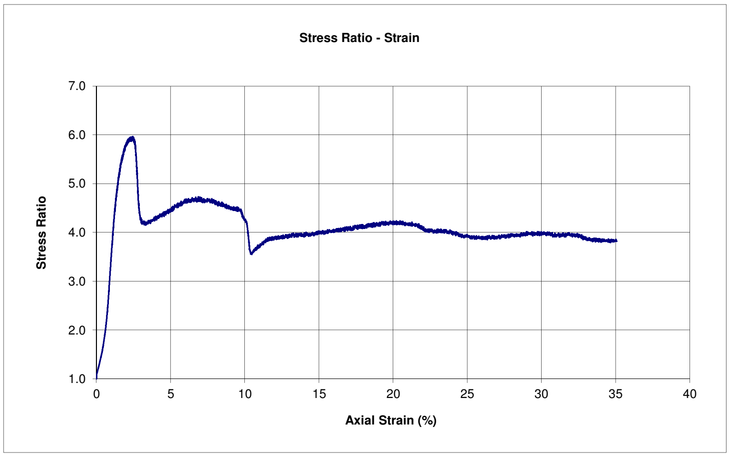
(ASTM D7181)

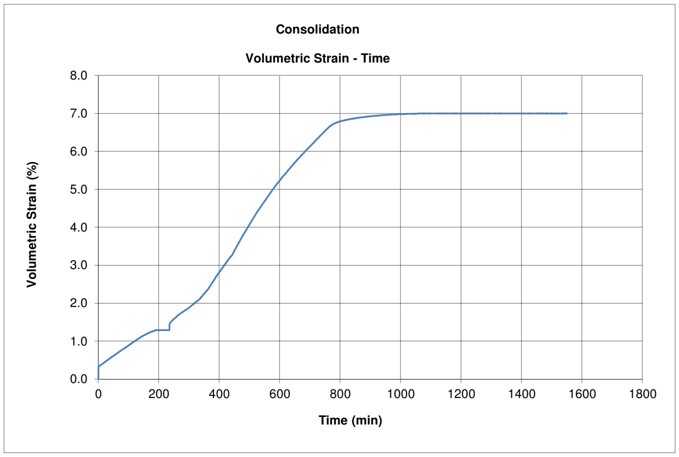
PROJECT NO. :	A03355A01	DATE :	2019-09-16
PROJECT :		TEST BY:	AX
SAMPLE :	Average	CHECKED BY:	JG
TEST NO. :	TX 19 - CID		

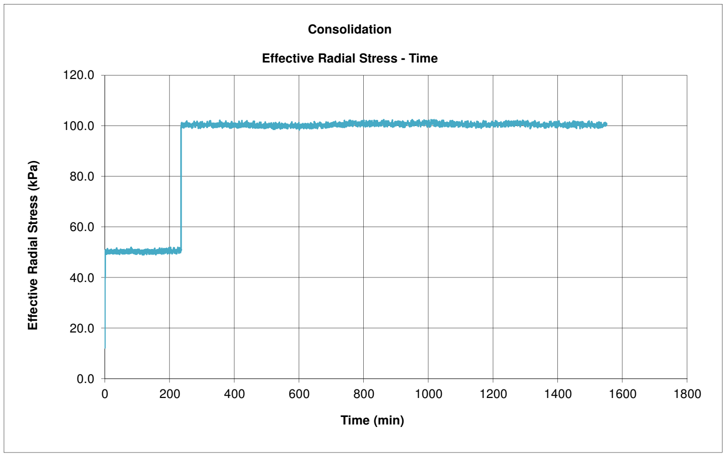












Triaxial CD Test - Summary

(ASTM D7181)

PROJECT NO. :	A03355A01	DATE :	2019-09-19
PROJECT :		TESTED BY:	AX
SAMPLE :	Average	CHECKED BY:	JG
TEST NO. :	TX 20 - CID		

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B-value	End of 1st Consolidation	End of 2nd Consolidation	End of 3rd Consolidation	End of 4th Consolidation	End of 5th Consolidation	At Failure	End of Shear
Specimen Height	mm	140.12	140.12	140.12	140.10	140.07	140.00	139.83	139.83	139.83	134.10	104.11
Specimen Diameter	mm	70.15	70.15	70.15	70.02	69.98	69.92	69.90	69.84	69.79	71.56	81.79
Area	cm^2	38.65	38.65	38.65	38.51	38.46	38.40	38.38	38.31	38.26	40.22	52.54
Volume	cm^3	541.558	541.558	541.558	539.558	538.745	537.626	536.654	535.737	534.924	539.29	547.00
Wet Weight	g	1712.44	1712.44	1799.44	1800.44	1799.63	1798.51	1797.54	1796.62	1795.81	1800.18	1807.89
Water Content	%	7.90	7.90	13.38	13.44	13.39	13.32	13.26	13.20	13.15	13.43	13.91
Dry Weight	g	1587.06	1587.06	1587.06	1587.06	1587.06	1587.06	1587.06	1587.06	1587.06	1587.06	1587.06
Wet Density	g/cm^3	3.162	3.162	3.323	3.337	3.340	3.345	3.350	3.354	3.357	3.338	3.305
Dry Density	g/cm^3	2.931	2.931	2.931	2.941	2.946	2.952	2.957	2.962	2.967	2.943	2.901
Specific Gravity of Solids (assumed)	-	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97
Solids Volume	cm^3	319.328	319.328	319.328	319.328	319.328	319.328	319.328	319.328	319.328	319.328	319.328
Void Volume	cm^3	222.230	222.230	222.230	220.230	219.417	218.298	217.326	216.409	215.596	219.966	227.676
Water Volume	cm^3	125.378	125.378	212.378	213.378	212.565	211.446	210.474	209.557	208.744	213.114	220.824
Void Ratio (e)	-	0.696	0.696	0.696	0.690	0.687	0.684	0.681	0.678	0.675	0.689	0.713
Saturation Ratio (Sr)	%	56.42	56.42	95.57	96.89	96.88	96.86	96.85	96.83	96.82	96.88	96.99
Effective Confining Stress	kPa					50	100	200	350	500		

Shearing (CU)		
Skempton's B Parameter		0.99
Back Pressure before shearing	kPa	390.0
Confining Stress (σ_3') before shearing	kPa	500
Shear Strain Rate	mm / min	0.04

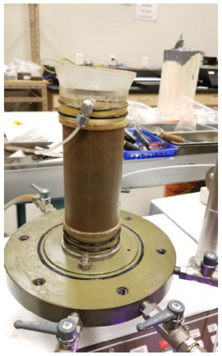
At Maximum Deviator Stress:		
Axial Stain	%	**4.09**
Deviator Stress	kPa	**2444.5**
Φ '	º	45.2
c' (assumed)	kPa	**0**

At Maximum Stress Ratio		
Axial Stain	%	**4.01**
Deviator Stress	kPa	**2443.3**
Φ '	º	45.2
c' (assumed)	kPa	0

Note: *using cambridge method*

Photos: Before Test After Test



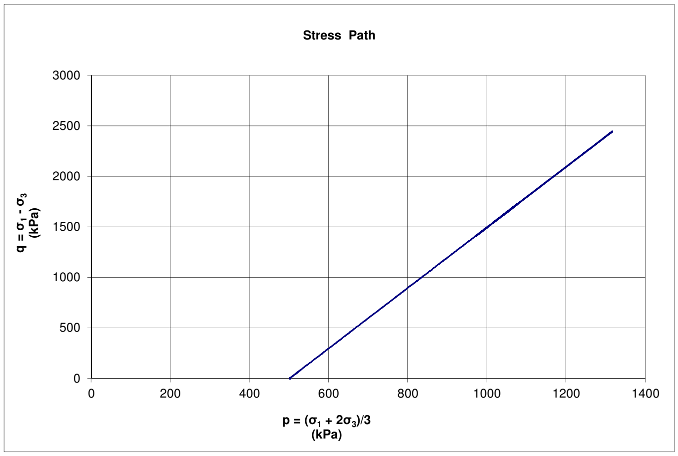


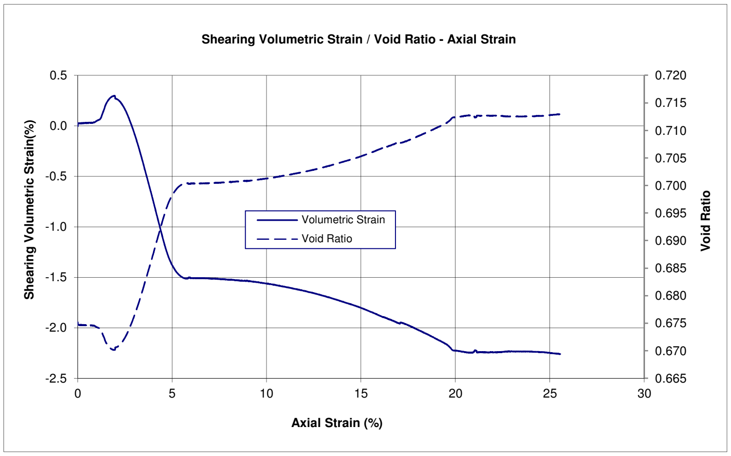
Triaxial CD Test - Charts

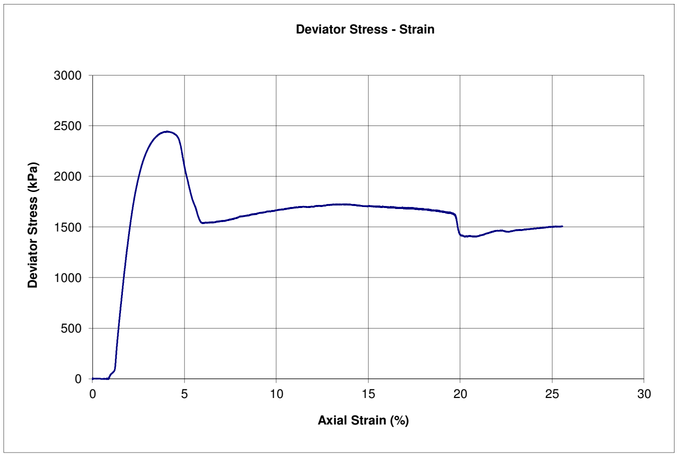
(ASTM D7181)

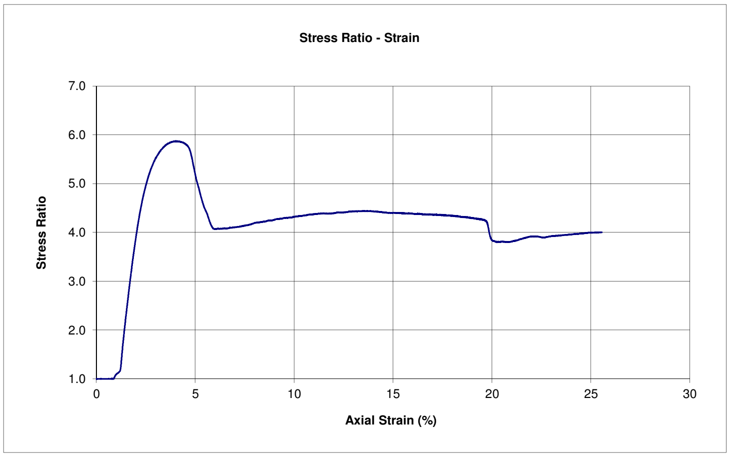
PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Average
TEST NO. : TX 20 - CID

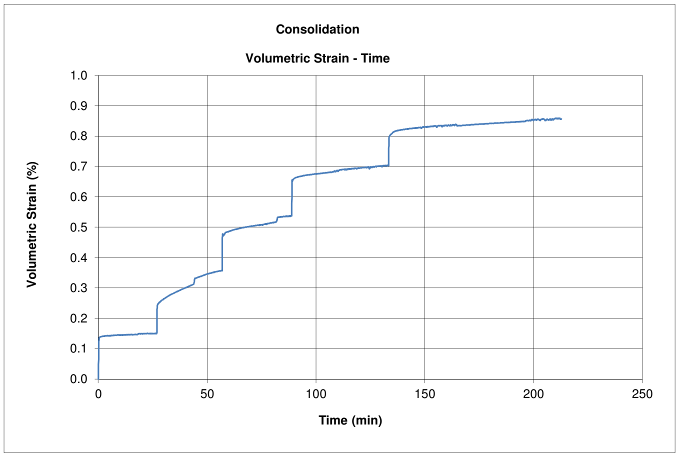
DATE : 2019-09-19
TEST BY: AX
CHECKED BY: JG


Stress Path

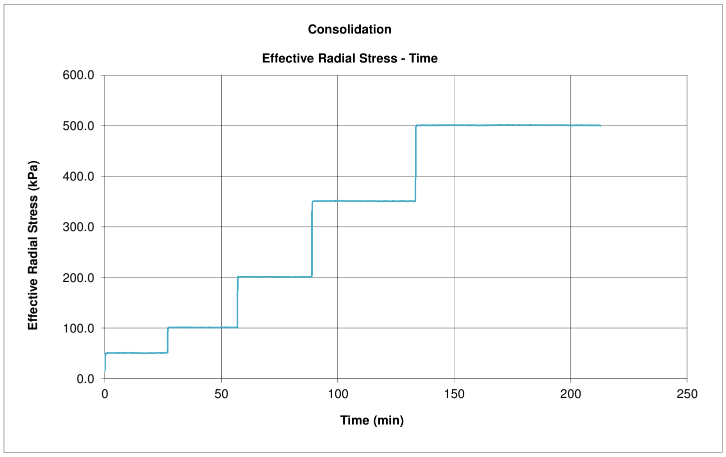

Shearing Volumetric Strain / Void Ratio - Axial Strain


Deviator Stress - Strain


Stress Ratio - Strain


Consolidation

Volumetric Strain - Time


Consolidation

Effective Radial Stress - Time

Triaxial CD Test - Summary

(ASTM D7181)

PROJECT NO. : A03355A01

PROJECT :

SAMPLE : Average

TEST NO. : TX 21 - CID

DATE : 2019-09-19

TESTED BY: AX

CHECKED BY: JG

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B-value	End of 1st Consolidation	End of 2nd Consolidation	End of 3rd Consolidation	End of 4th Consolidation	End of 5th Consolidation	At Failure	End of Shear
Specimen Height	mm	140.23	140.23	139.19	139.17	139.14	139.11	139.05	138.98	138.92	133.71	103.94
Specimen Diameter	mm	70.07	70.07	70.33	70.09	70.05	69.98	69.93	69.89	69.85	71.28	81.33
Area	cm^2	38.56	38.56	38.85	38.59	38.53	38.46	38.41	38.36	38.32	39.90	51.95
Volume	cm^3	540.748	540.748	540.748	536.968	536.155	535.036	534.064	533.147	532.334	533.53	539.96
Wet Weight	g	1636.56	1636.56	1717.36	1732.36	1731.72	1731.15	1730.52	1729.91	1729.45	1730.65	1737.08
Water Content	%	7.77	7.77	13.09	14.08	14.04	14.00	13.96	13.92	13.89	13.97	14.39
Dry Weight	g	1518.57	1518.57	1518.57	1518.57	1518.57	1518.57	1518.57	1518.57	1518.57	1518.57	1518.57
Wet Density	g/cm^3	3.026	3.026	3.176	3.226	3.230	3.236	3.240	3.245	3.249	3.244	3.217
Dry Density	g/cm^3	2.808	2.808	2.808	2.828	2.832	2.838	2.843	2.848	2.853	2.846	2.812
Specific Gravity of Solids (assumed)	-	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97
Solids Volume	cm^3	305.547	305.547	305.547	305.547	305.547	305.547	305.547	305.547	305.547	305.547	305.547
Void Volume	cm^3	235.201	235.201	235.201	231.421	230.608	229.489	228.517	227.600	226.787	227.987	234.417
Water Volume	cm^3	117.993	117.993	198.793	213.793	213.152	212.582	211.948	211.345	210.886	212.086	218.514
Void Ratio (e)	-	0.770	0.770	0.770	0.757	0.755	0.751	0.748	0.745	0.742	0.746	0.767
Saturation Ratio (Sr)	%	50.17	50.17	84.52	92.38	92.43	92.63	92.75	92.86	92.99	93.03	93.22
Effective Confining Stress	kPa					50	100	200	350	500		

Shearing (CU)		
Skempton's B Parameter		0.93
Back Pressure before shearing	kPa	430.0
Confining Stress (σ_3') before shearing	kPa	500
Shear Strain Rate	mm / min	0.04

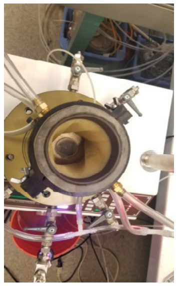
At Maximum Deviator Stress:		
Axial Stain	%	**3.74**
Deviator Stress	kPa	**1741.3**
Φ '	º	39.4
c' (assumed)	kPa	**0**

At Maximum Stress Ratio		
Axial Stain	%	**3.79**
Deviator Stress	kPa	**1740.2**
Φ '	º	39.4
c' (assumed)	kPa	0

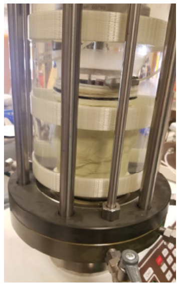
Note: *using cambridge method*

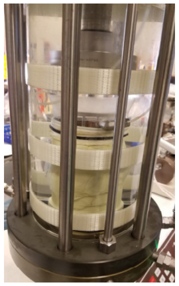
Photos:

Before Test



After Test



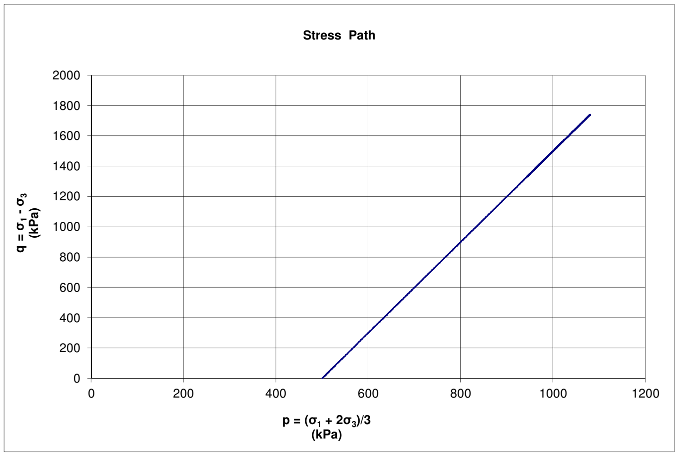


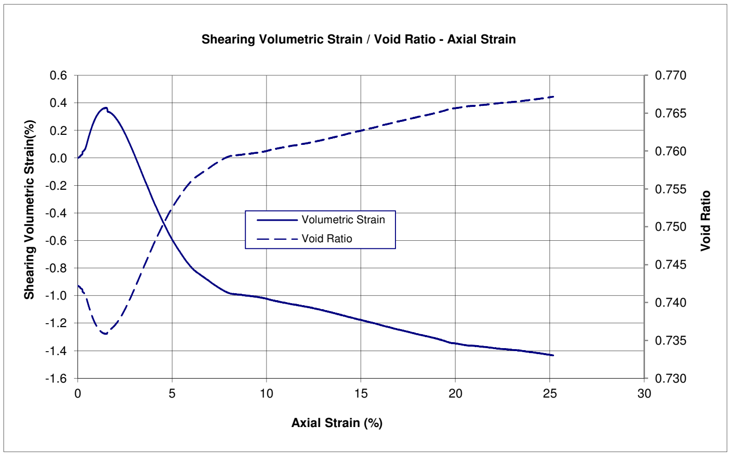
Triaxial CD Test - Charts

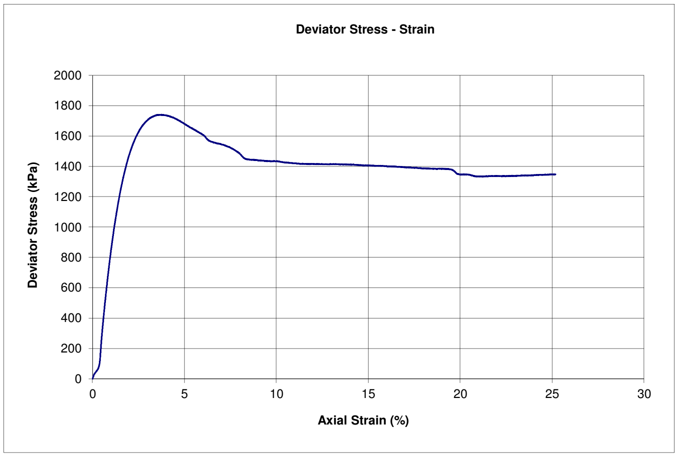
(ASTM D7181)

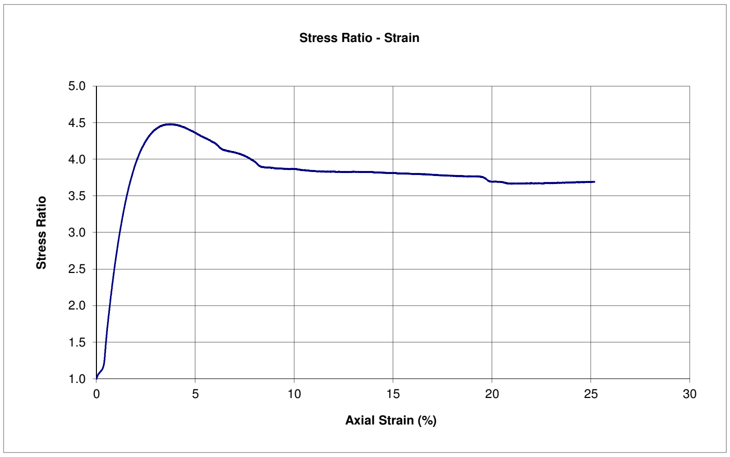
PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Average
TEST NO. : TX 21 - CID

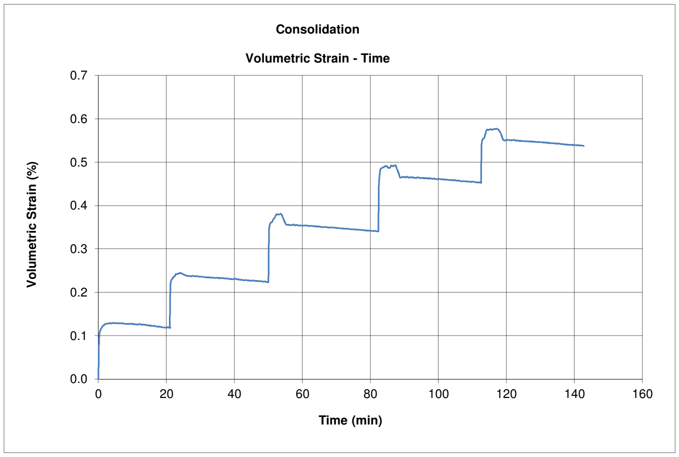
DATE : 2019-09-19
TEST BY: AX
CHECKED BY: JG

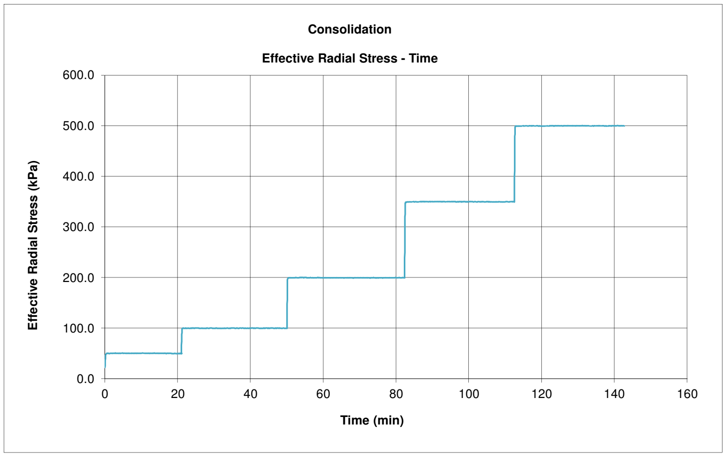












Triaxial CD Test - Summary

(ASTM D7181)

PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Fine
TEST NO. : TX 22 - CID

DATE : 2019-09-19
TESTED BY: AX
CHECKED BY: JG

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation / B-value	End of 1st Consolidation	End of 2nd Consolidation	End of 3rd Consolidation	At Failure	End of Shear	
Specimen Height	mm	140.18	140.18	139.81	139.61	139.50	139.34	125.66	90.46	
Specimen Diameter	mm	70.05	70.05	70.14	70.03	69.93	69.79	73.00	85.72	
Area	cm^2	38.54	38.54	38.64	38.51	38.41	38.25	41.85	57.71	
Volume	cm^3	540.25	540.25	540.25	537.71	535.80	533.05	525.92	522.09	
Wet Weight	g	1431.33	1431.33	1613.68	1611.14	1609.23	1606.49	1599.35	1595.53	
Water Content	%	4.87	4.87	18.23	18.04	17.90	17.70	17.18	16.90	
Dry Weight	g	1364.86	1364.86	1364.86	1364.86	1364.86	1364.86	1364.86	1364.86	
Wet Density	g/cm^3	2.649	2.649	2.987	2.996	3.003	3.014	3.041	3.056	
Dry Density	g/cm^3	2.526	2.526	2.526	2.538	2.547	2.560	2.595	2.614	
Specific Gravity of Solids (assumed)	-	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	
Solids Volume	cm^3	275.174	275.174	275.174	275.174	275.174	275.174	275.174	275.174	
Void Volume	cm^3	265.073	265.073	265.073	262.532	260.624	257.880	250.742	246.918	
Water Volume	cm^3	66.469	66.469	248.819	246.279	244.369	241.629	234.491	230.667	
Void Ratio (e)	-	0.963	0.963	0.963	0.954	0.947	0.937	0.911	0.897	
Saturation Ratio (Sr)	%	25.08	25.08	93.87	93.81	93.76	93.70	93.52	93.42	
Effective Confining Stress	kPa				50	100	200			

Shearing (CU)		
Skempton's B Parameter		0.93
Back Pressure before shearing	kPa	386.0
Confining Stress (σ_3') before shearing	kPa	200
Shear Strain Rate	mm / min	0.035

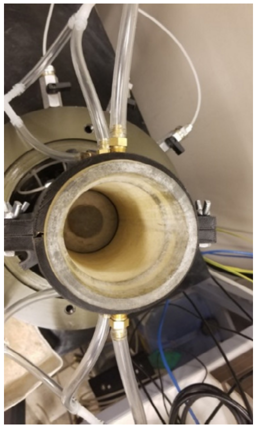
At Maximum Deviator Stress:		
Axial Stain	%	**9.82**
Deviator Stress	kPa	**568.8**
Φ '	º	35.6
c' (assumed)	kPa	**0**

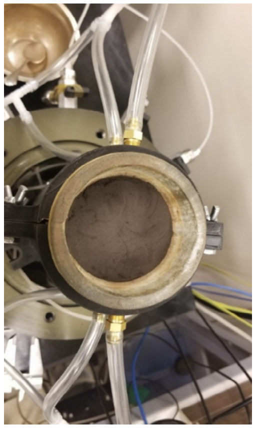
At Maximum Stress Ratio		
Axial Stain	%	**9.51**
Deviator Stress	kPa	**567.6**
Φ '	º	35.7
c' (assumed)	kPa	0

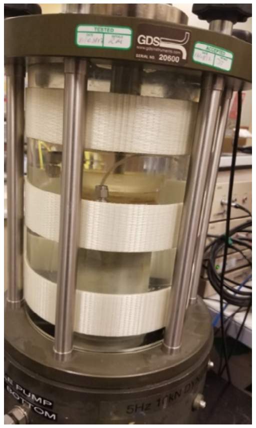
Note: *using cambridge method*

Photos:

Before Test







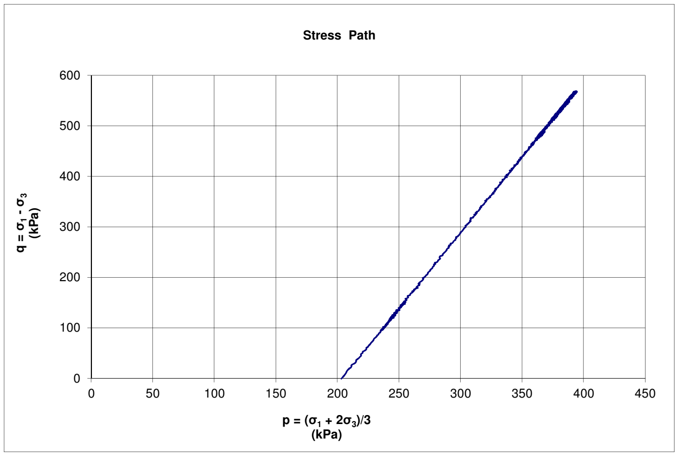
After Test

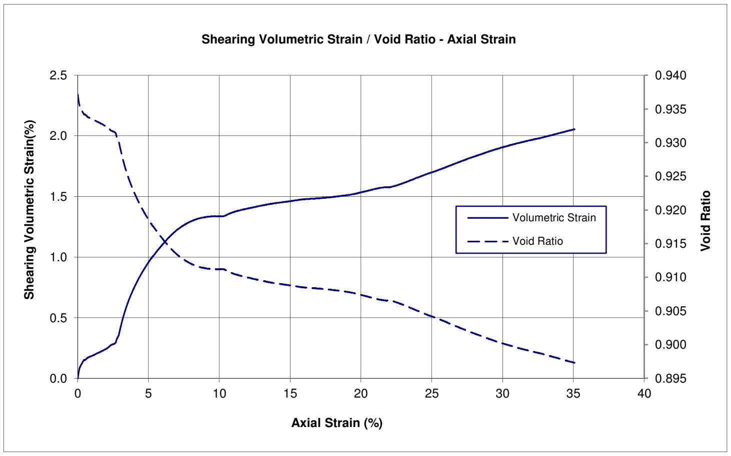
Triaxial CD Test - Charts

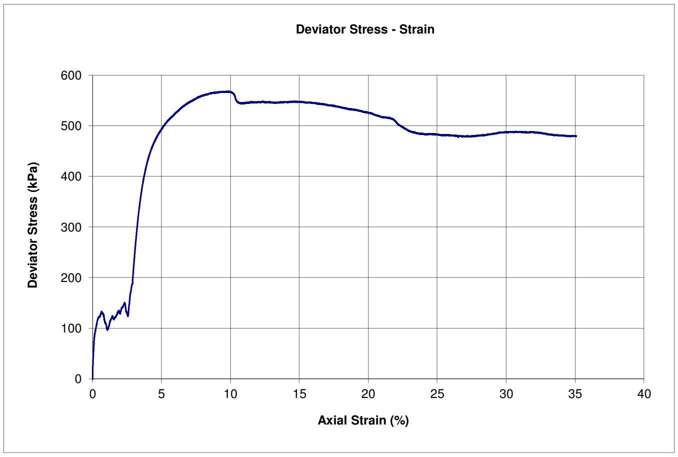
(ASTM D7181)

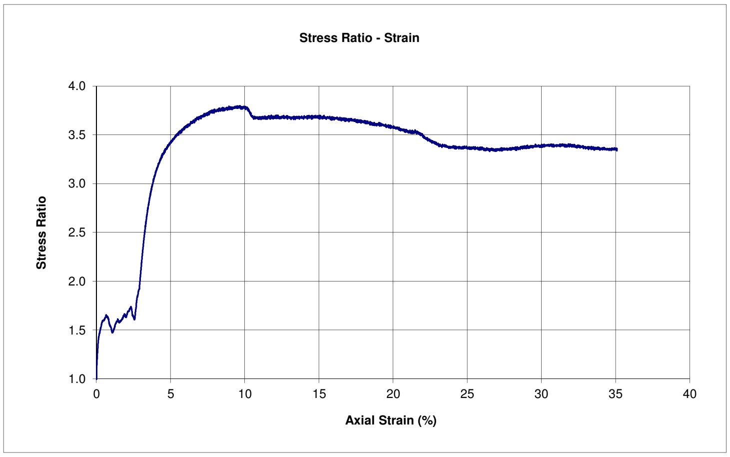
PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Fine
TEST NO. : TX 22 - CID

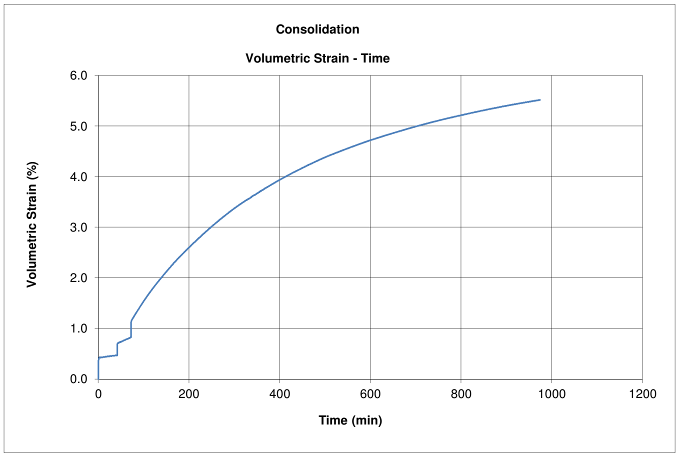
DATE : 2019-09-19
TEST BY: AX
CHECKED BY: JG

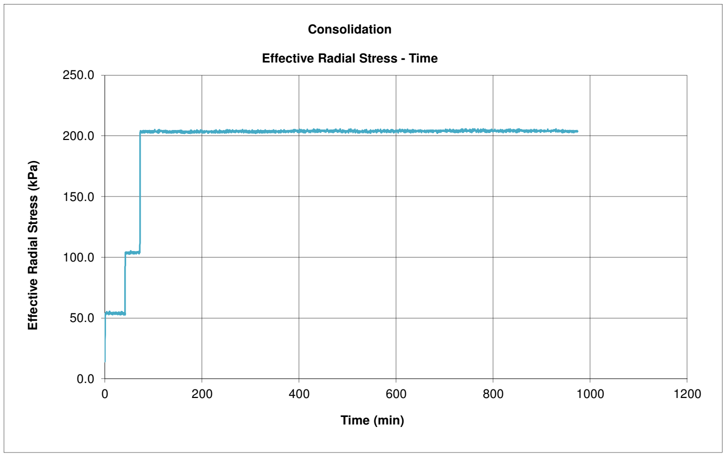












Triaxial CD Test - Summary

(ASTM D7181)

PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Fine Gradation
TEST NO. : TX 23 - CID

DATE : 2019-10-07
TESTED BY: AX
CHECKED BY: JG

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B-value	End of 1st Consolidation	End of 2nd Consolidation	End of 3rd Consolidation	At Failure	End of Shear
Specimen Height	mm	140.28	139.90	139.81	139.32	139.22	139.15	139.04	135.04	94.92
Specimen Diameter	mm	69.90	69.86	69.85	69.97	69.92	69.88	69.83	70.89	84.82
Area	cm^2	38.37	38.33	38.32	38.46	38.39	38.35	38.30	39.47	56.51
Volume	cm^3	538.32	536.25	535.75	535.75	534.54	533.68	532.47	533.03	536.36
Wet Weight	g	1532.31	1532.31	1660.21	1661.82	1660.62	1659.75	1658.54	1659.10	1662.43
Water Content	%	8.70	8.70	17.77	17.89	17.80	17.74	17.65	17.69	17.93
Dry Weight	g	1409.67	1409.67	1409.67	1409.67	1409.67	1409.67	1409.67	1409.67	1409.67
Wet Density	g/cm^3	2.846	2.857	3.099	3.102	3.107	3.110	3.115	3.113	3.099
Dry Density	g/cm^3	2.619	2.629	2.631	2.631	2.637	2.641	2.647	2.645	2.628
Specific Gravity of Solids (assumed)	-	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96
Solids Volume	cm^3	284.207	284.207	284.207	284.207	284.207	284.207	284.207	284.207	284.207
Void Volume	cm^3	254.112	252.039	251.542	251.542	250.336	249.473	248.265	248.818	252.152
Water Volume	cm^3	122.641	122.641	250.541	252.152	250.946	250.083	248.875	249.428	252.762
Void Ratio (e)	-	0.894	0.887	0.885	0.885	0.881	0.878	0.874	0.875	0.887
Saturation Ratio (Sr)	%	48.26	48.66	99.60	100.24	100.24	100.24	100.25	100.25	100.24
Effective Confining Stress	kPa					50	100	200		

Shearing (CU)		
Skempton's B Parameter		0.98
Back Pressure before shearing	kPa	500.0
Confining Stress (σ_3') before shearing	kPa	200
Shear Strain Rate	mm / min	0.04

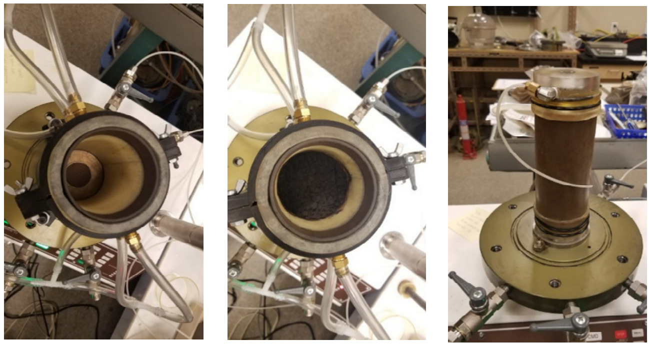
At Maximum Deviator Stress:		
Axial Strain	%	**2.88**
Deviator Stress	kPa	**609.6**
Φ '	º	38.1
c' (assumed)	kPa	0

At Maximum Stress Ratio		
Axial Strain	%	**2.99**
Deviator Stress	kPa	**608.7**
Φ '	º	38.1
c' (assumed)	kPa	0

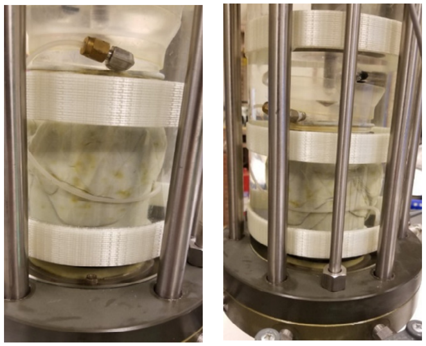
Note: *using cambridge method*

Photos:

Before Test



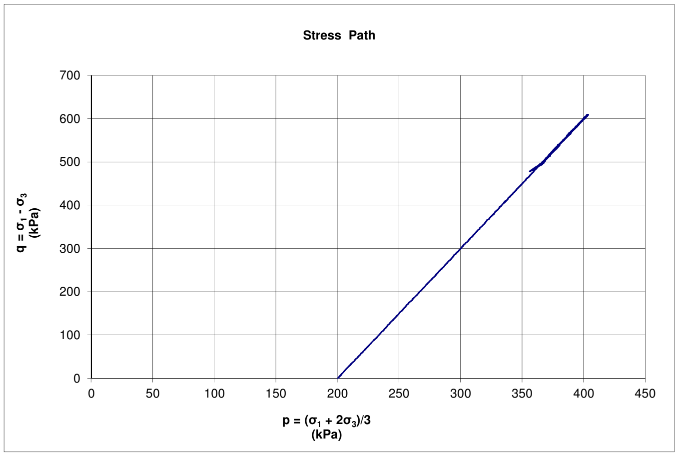
After Test

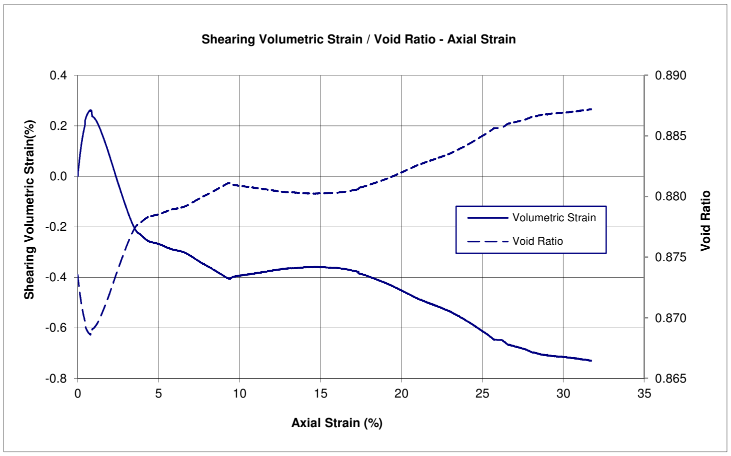


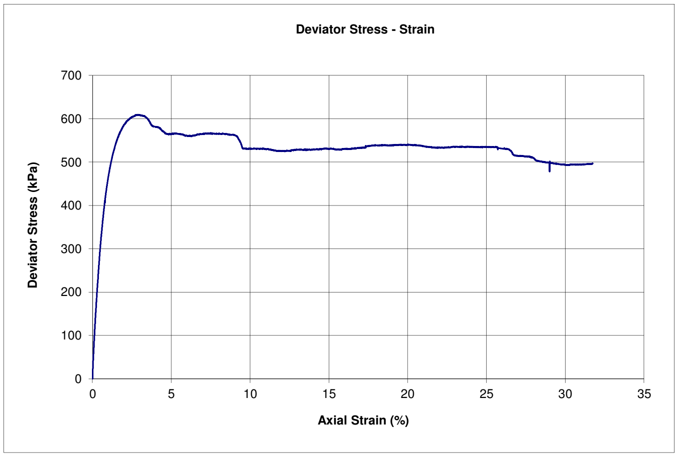
Triaxial CD Test - Charts

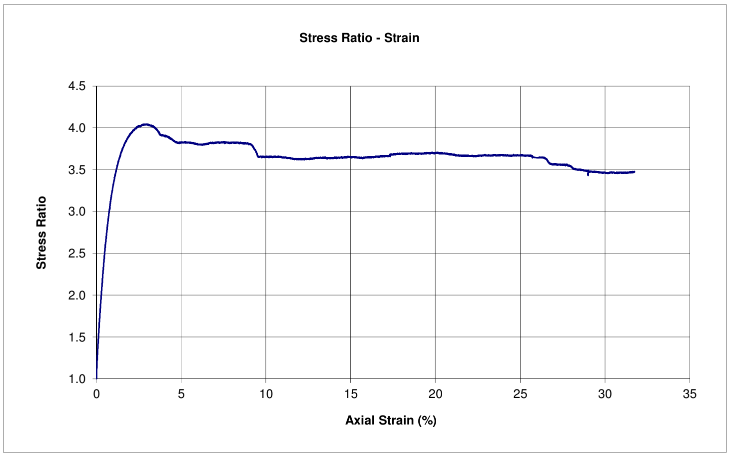
(ASTM D7181)

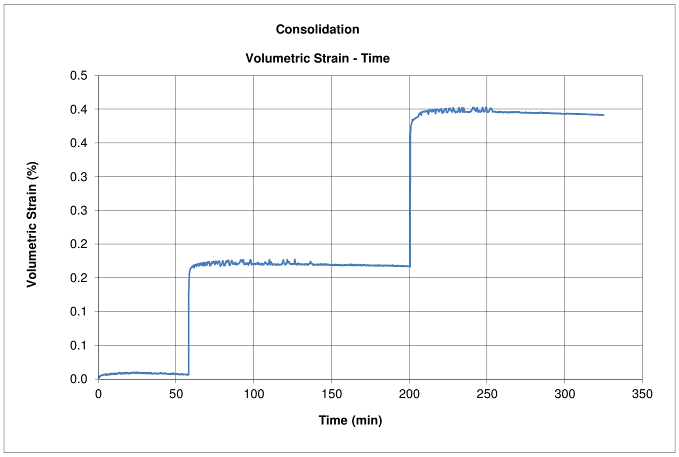
PROJECT NO. :	A03355A01	DATE :	2019-10-07
PROJECT :		TEST BY:	AX
SAMPLE :	Fine Gradation	CHECKED BY:	JG
TEST NO. :	TX 23 - CID		

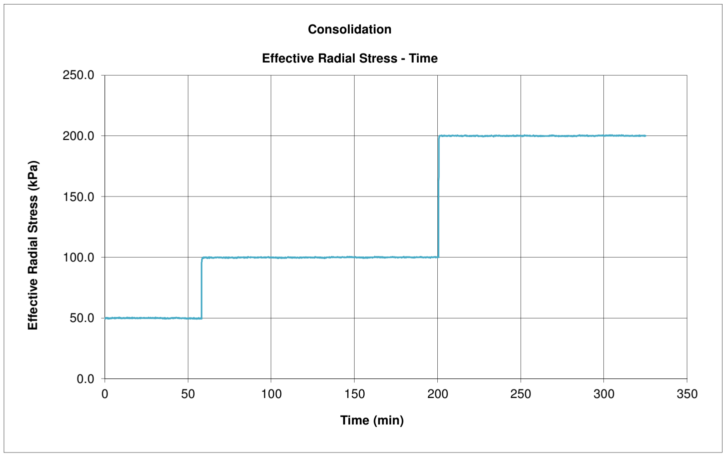












Triaxial CD Test - Summary

(ASTM D7181)

PROJECT NO. :	A03355A01	DATE :	2019-10-04
PROJECT :		TESTED BY:	AX
SAMPLE :	Fine Gradation	CHECKED BY:	JG
TEST NO. :	TX 24 - CID		

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B-value	End of 1st Consolidation	End of 2nd Consolidation	End of 3rd Consolidation	At Failure	End of Shear
Specimen Height	mm	141.69	141.69	141.69	139.12	139.00	138.90	138.77	135.52	91.12
Specimen Diameter	mm	69.98	69.98	69.95	70.49	70.43	70.40	70.36	71.30	87.39
Area	cm^2	38.46	38.46	38.43	39.03	38.96	38.93	38.88	39.93	59.98
Volume	cm^3	544.98	544.98	544.48	543.00	541.58	540.66	539.48	541.11	546.58
Wet Weight	g	1570.56	1570.56	1691.06	1695.70	1694.28	1693.37	1692.19	1693.82	1699.29
Water Content	%	8.80	8.80	17.15	17.47	17.37	17.31	17.23	17.34	17.72
Dry Weight	g	1443.53	1443.53	1443.53	1443.53	1443.53	1443.53	1443.53	1443.53	1443.53
Wet Density	g/cm^3	2.882	2.882	3.106	3.123	3.128	3.132	3.137	3.130	3.109
Dry Density	g/cm^3	2.649	2.649	2.651	2.658	2.665	2.670	2.676	2.668	2.641
Specific Gravity of Solids (assumed)	-	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96
Solids Volume	cm^3	291.034	291.034	291.034	291.034	291.034	291.034	291.034	291.034	291.034
Void Volume	cm^3	253.941	253.941	253.441	251.961	250.541	249.628	248.447	250.078	255.546
Water Volume	cm^3	127.031	127.031	247.531	252.172	250.752	249.839	248.658	250.289	255.757
Void Ratio (e)	-	0.873	0.873	0.871	0.866	0.861	0.858	0.854	0.859	0.878
Saturation Ratio (Sr)	%	50.02	50.02	97.67	100.08	100.08	100.08	100.08	100.08	100.08
Effective Confining Stress	kPa					50	100	200		

Shearing (CU)		
Skempton's B Parameter		0.98
Back Pressure before shearing	kPa	540.0
Confining Stress (σ_3') before shearing	kPa	200
Shear Strain Rate	mm / min	0.04

At Maximum Deviator Stress:		
Axial Stain	%	**2.34**
Deviator Stress	kPa	**636.9**
Φ '	º	37.9
c' (assumed)	kPa	**0**

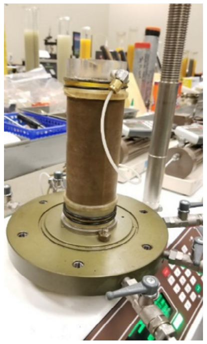
At Maximum Stress Ratio		
Axial Stain	%	**2.34**
Deviator Stress	kPa	**636.9**
Φ '	º	37.9
c' (assumed)	kPa	**0**

Note: *using cambridge method*

Photos:

Before Test

After Test

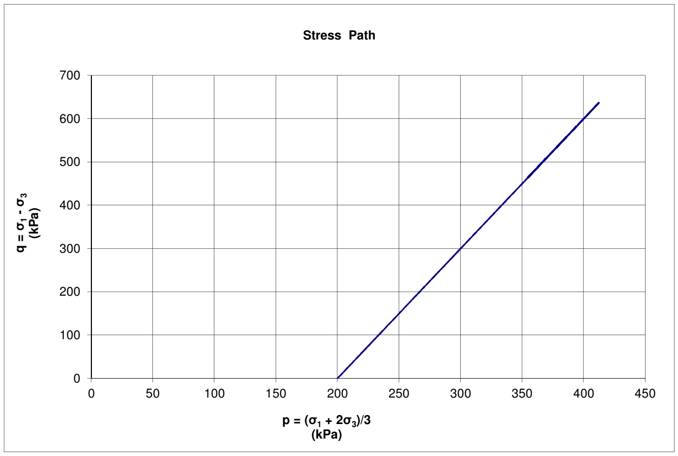


Triaxial CD Test - Charts

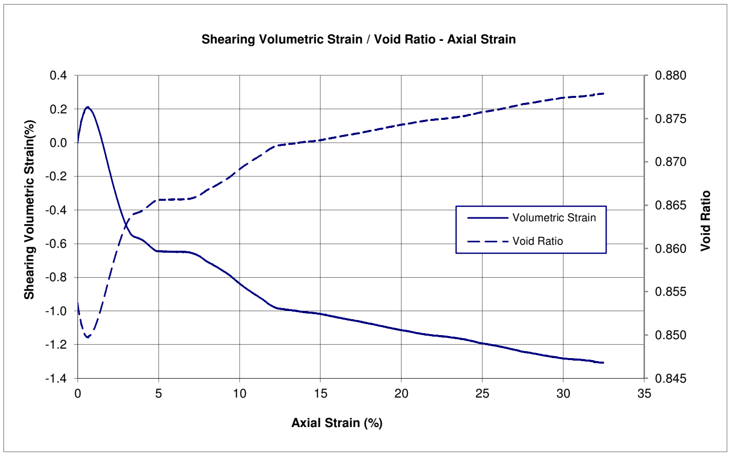
(ASTM D7181)

PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Fine Gradation
TEST NO. : TX 24 - CID

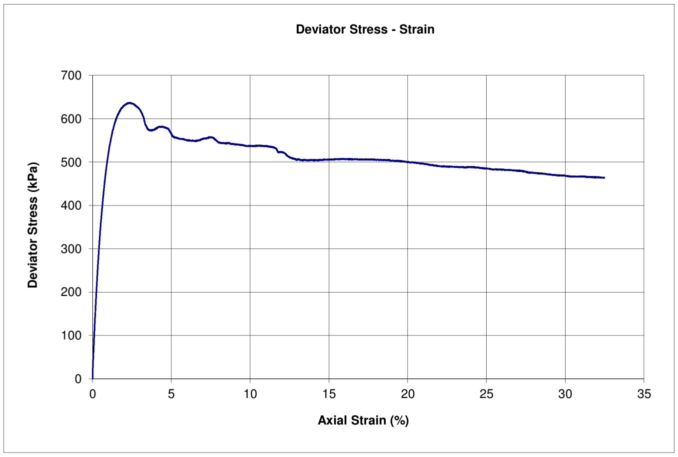
DATE : 2019-10-04
TEST BY: AX
CHECKED BY: JG



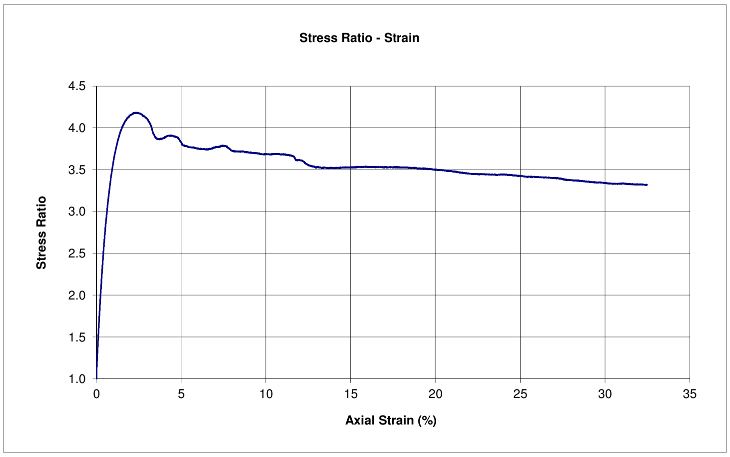
Stress Path



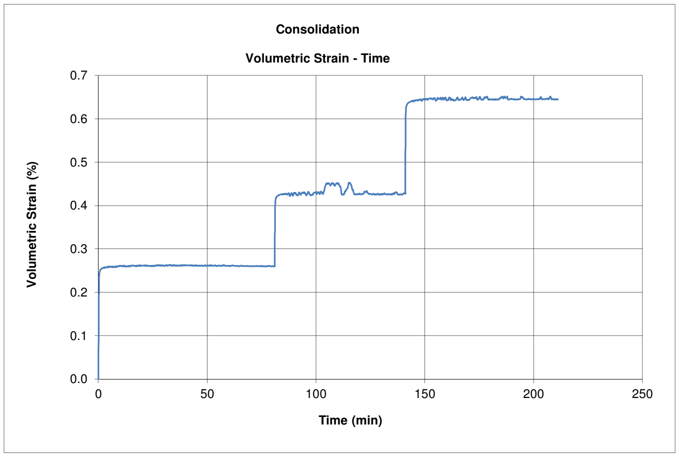
Shearing Volumetric Strain / Void Ratio - Axial Strain



Deviator Stress - Strain

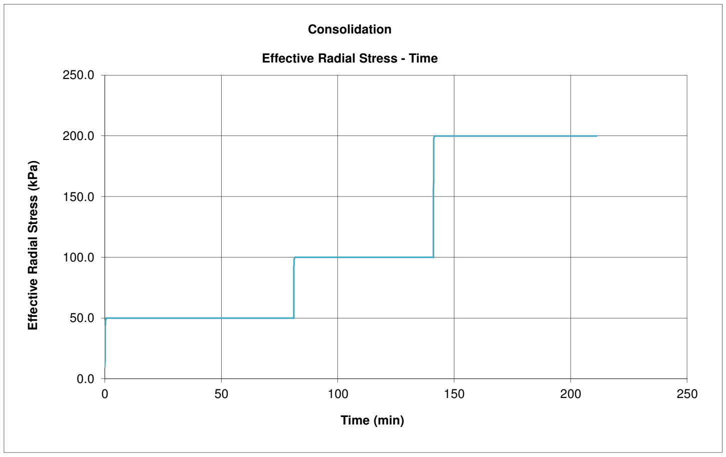


Stress Ratio - Strain



Consolidation

Volumetric Strain - Time



Consolidation

Effective Radial Stress - Time

Triaxial CAU Test - Summary

(ASTM D4767)

PROJECT NO. :	A03355A01	DATE :	2019-10-01
PROJECT :		TESTED BY:	BY
SAMPLE :	Coarse Gradation	CHECKED BY:	JG
Details:	Anisotropic consolidation, Kc = 0.5, p' = 200 kPa, strain control		

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B-value	End of Anisotropic Consolidation*	At Maximum Deviator Stress	End of Shear		
Specimen Height	mm	139.98	140.18	140.18	139.74	138.59	137.54	99.39		
Specimen Diameter	mm	69.80	69.70	69.51	69.56	69.39	69.65	81.94		
Area	cm^2	38.26	38.16	37.95	38.00	37.81	38.10	52.73		
Volume	cm^3	535.63	534.86	532.02	531.02	524.06	524.06	524.06		
Wet Weight	g	1432.50	1432.50	1616.70	1619.75	1612.79	1612.79	1612.79		
Water Content	%	4.79	4.79	18.26	18.49	17.98	17.98	17.98		
Dry Weight	g	1367.02	1367.02	1367.02	1367.02	1367.02	1367.02	1367.02		
Wet Density	g/cm^3	2.674	2.678	3.039	3.050	3.077	3.078	3.078		
Dry Density	g/cm^3	2.552	2.556	2.569	2.574	2.609	2.609	2.609		
Specific Gravity of Solids	-	4.91	4.91	4.91	4.91	4.91	4.91	4.91		
Solids Volume	cm^3	278.415	278.415	278.415	278.415	278.415	278.415	278.415		
Void Volume	cm^3	257.217	256.446	253.603	252.603	245.646	245.642	245.642		
Water Volume	cm^3	65.480	65.480	249.680	252.729	245.772	245.768	245.768		
Void Ratio (e)	-	0.924	0.921	0.911	0.907	0.882	0.882	0.882		
Saturation Ratio (Sr)	%	25.46	25.53	98.45	100.05	100.05	100.05	100.05		
Effective Confining Stress (σ_3')	kPa					150				

** Anisotropic consolidation at 0.01%/min strain rate*

Shearing (CAU)		
Skempton's B Parameter		0.99
Back Pressure before shearing	kPa	499.0
Confining Stress (σ_3') before shearing	kPa	150
Shear Strain Rate	mm / min	0.03

At Maximum Deviator Stress:		
Axial Stain	%	0.75
Deviator Stress	kPa	204.4
Φ '	º	34.3
c' (assumed)	kPa	0

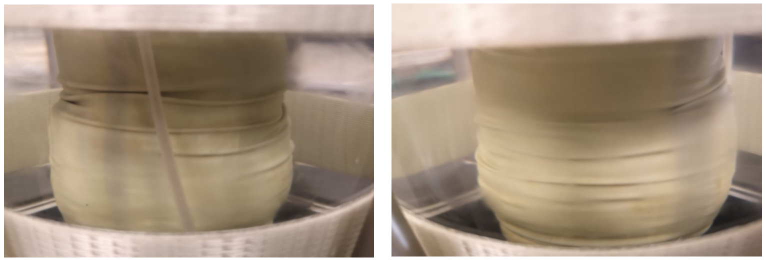
At Maximum Stress Ratio		
Axial Stain	%	-
Deviator Stress	kPa	-
Φ '	º	-
c' (assumed)	kPa	-

Note: *using cambridge method*

Test Photos:

Before Test

After Test `

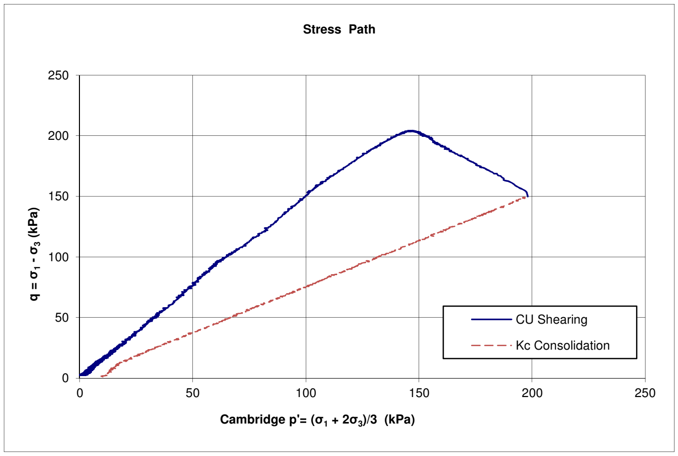


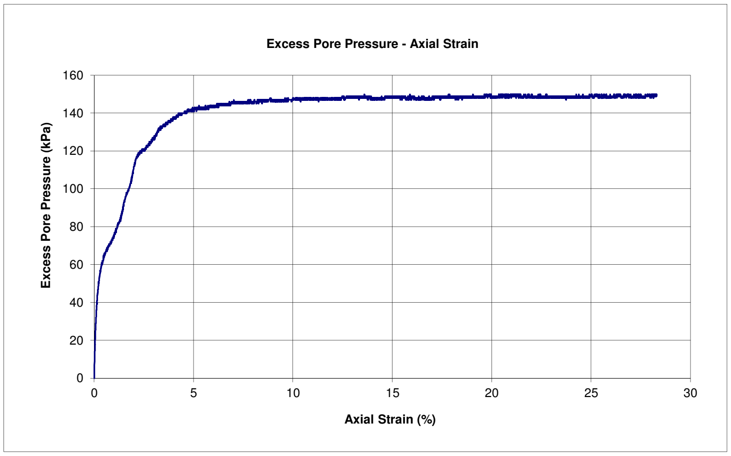
Triaxial CU Test - Charts

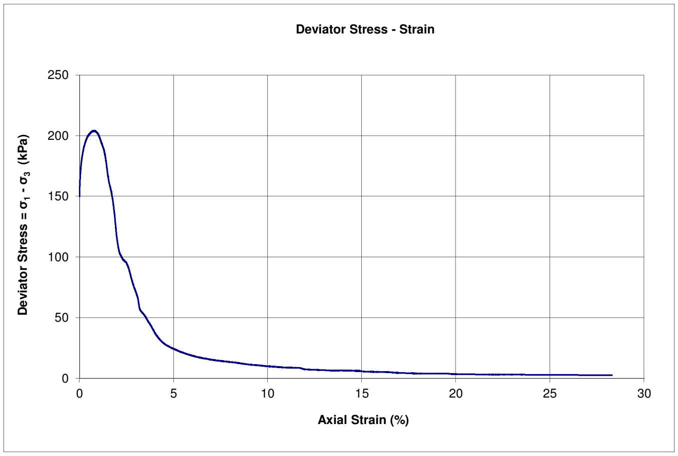
(ASTM D4767)

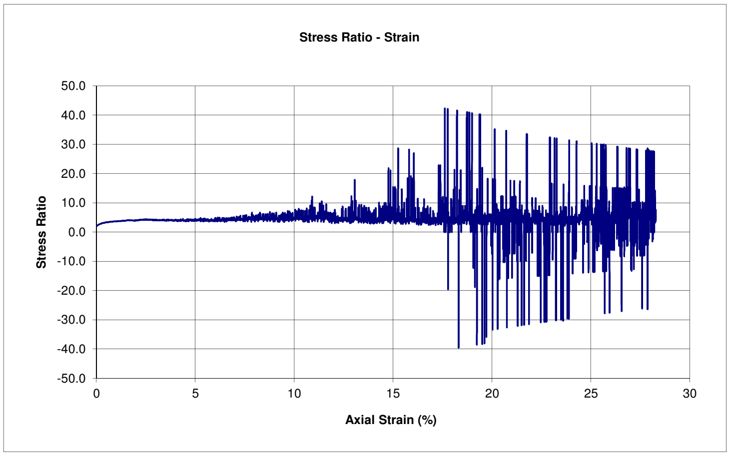
PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Coarse Gradation
Details: Anisotropic consolidation, Kc = 0.5, p' = 200 kPa, strain control

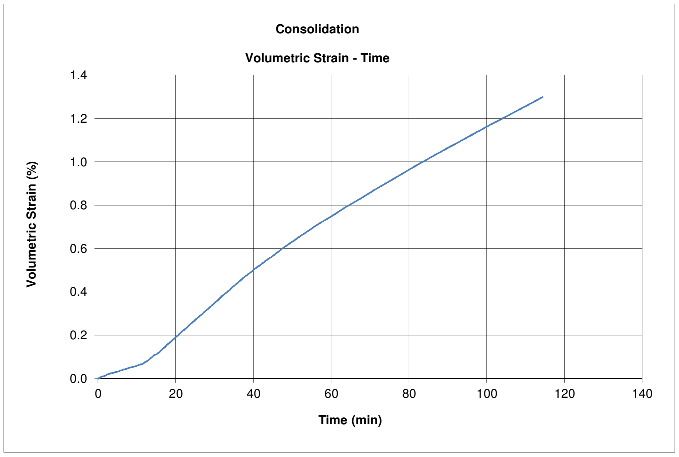
DATE : 2019-10-01
TEST BY: BY
CHECKED BY: JG


Stress Path

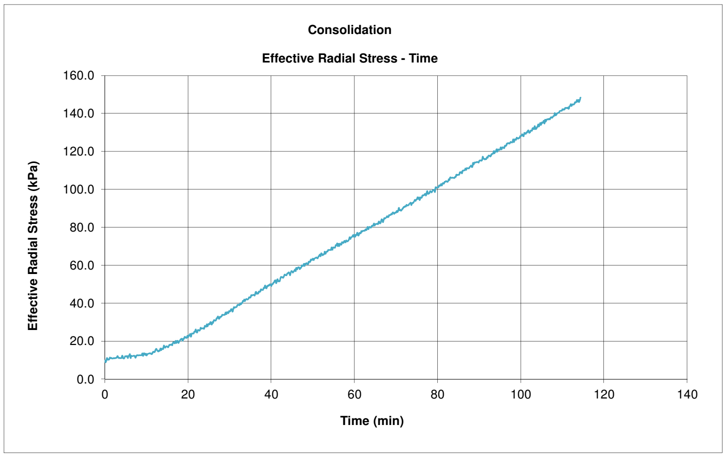

Excess Pore Pressure - Axial Strain


Deviator Stress - Strain


Stress Ratio - Strain


Consolidation

Volumetric Strain - Time


Consolidation

Effective Radial Stress - Time

Triaxial CAU Test - Summary

(ASTM D4767)

PROJECT NO. :	A03355A01	DATE :	2019-10-10
PROJECT :		TESTED BY:	BY
SAMPLE :	Fine Gradation	CHECKED BY:	JG
Details:	Anisotropic consolidation, Kc = 0.5, p' = 200 kPa, strain control		

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B-value	End of Anisotropic Consolidation*	At Maximum Deviator Stress	End of Shear		
Specimen Height	mm	139.90	139.55	139.55	139.00	137.27	136.83	97.62		
Specimen Diameter	mm	69.80	69.71	69.47	69.56	69.45	69.56	82.35		
Area	cm^2	38.26	38.17	37.90	38.00	37.88	38.00	53.26		
Volume	cm^3	535.33	532.61	528.89	528.19	519.96	519.94	519.94		
Wet Weight	g	1402.47	1402.47	1559.17	1564.54	1556.30	1556.29	1556.29		
Water Content	%	8.05	8.05	20.12	20.54	19.90	19.90	19.90		
Dry Weight	g	1297.98	1297.98	1297.98	1297.98	1297.98	1297.98	1297.98		
Wet Density	g/cm^3	2.620	2.633	2.948	2.962	2.993	2.993	2.993		
Dry Density	g/cm^3	2.425	2.437	2.454	2.457	2.496	2.496	2.496		
Specific Gravity of Solids	-	4.96	4.96	4.96	4.96	4.96	4.96	4.96		
Solids Volume	cm^3	261.690	261.690	261.690	261.690	261.690	261.690	261.690		
Void Volume	cm^3	273.636	270.921	267.201	266.501	258.268	258.253	258.253		
Water Volume	cm^3	104.488	104.488	261.188	266.554	258.321	258.306	258.306		
Void Ratio (e)	-	1.046	1.035	1.021	1.018	0.987	0.987	0.987		
Saturation Ratio (Sr)	%	38.18	38.57	97.75	100.02	100.02	100.02	100.02		
Effective Confining Stress (σ_3')	kPa					150				

** Anisotropic consolidation at 0.01%/min strain rate*

Shearing (CAU)		
Skempton's B Parameter		0.98
Back Pressure before shearing	kPa	500.0
Confining Stress (σ_3') before shearing	kPa	150
Shear Strain Rate	mm / min	0.04

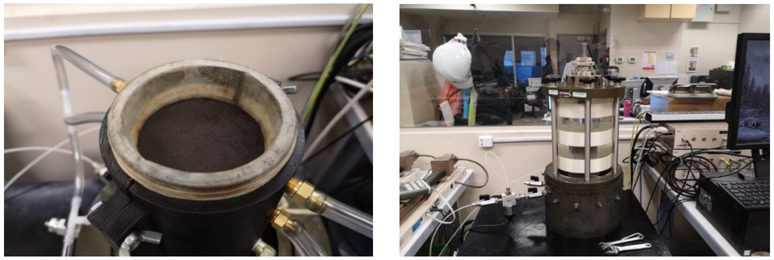
At Maximum Deviator Stress:		
Axial Stain	%	0.32
Deviator Stress	kPa	167.3
Φ '	º	28.1
c' (assumed)	kPa	0

At Maximum Stress Ratio		
Axial Stain	%	-
Deviator Stress	kPa	-
Φ '	º	-
c' (assumed)	kPa	-

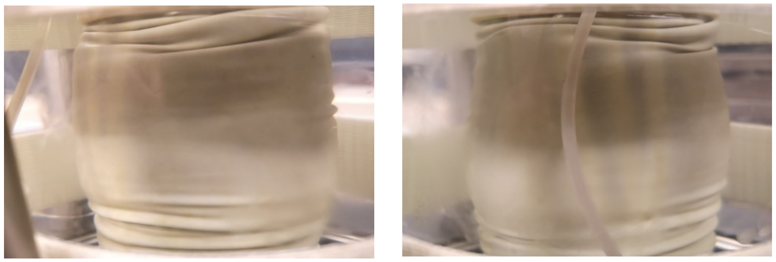
Note: *using cambridge method*

Test Photos:

Before Test



After Test

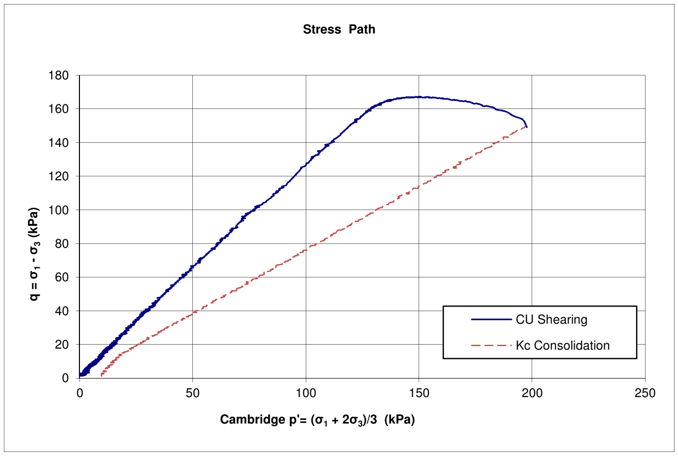


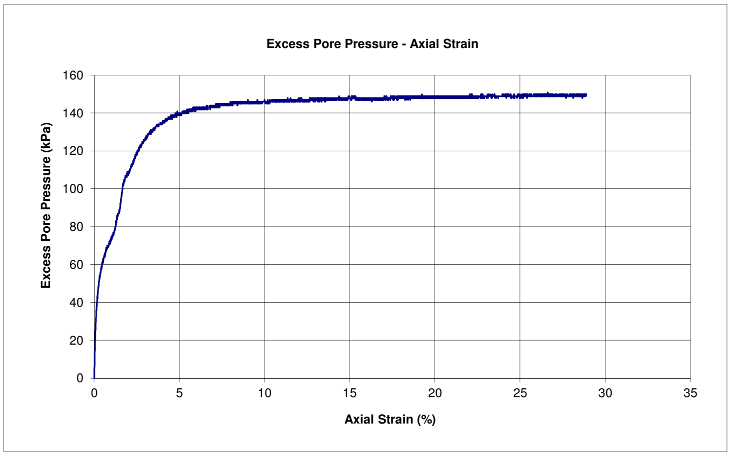
Triaxial CU Test - Charts

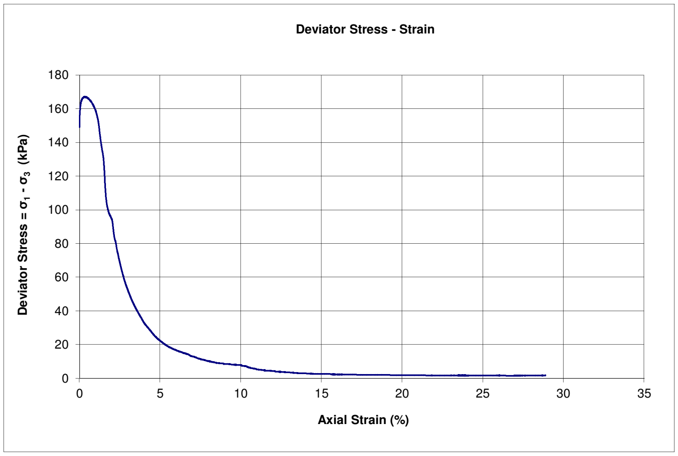
(ASTM D4767)

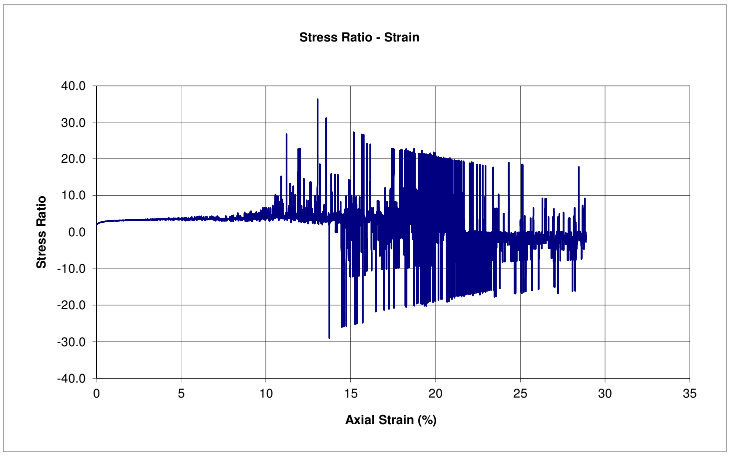
PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Fine Gradation
Details: Anisotropic consolidation, Kc = 0.5, p' = 200 kPa, strain control

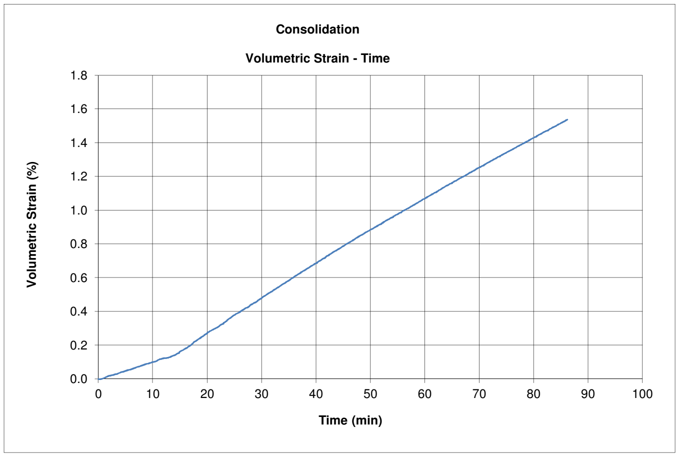
DATE : 2019-10-10
TEST BY: BY
CHECKED BY: JG


Stress Path

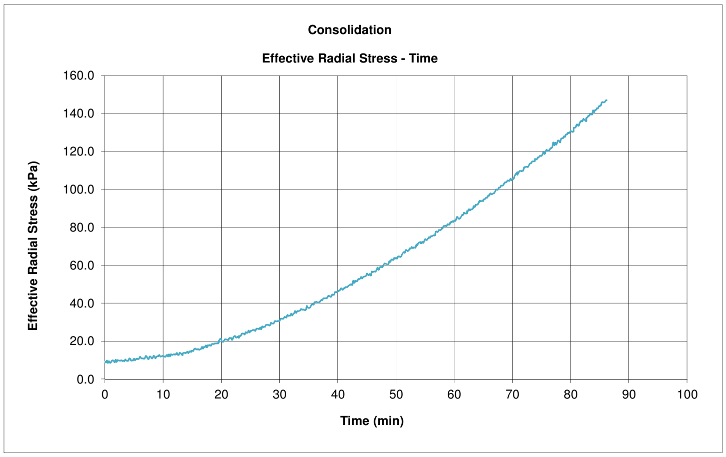

Excess Pore Pressure - Axial Strain


Deviator Stress - Strain


Stress Ratio - Strain


Consolidation

Volumetric Strain - Time


Consolidation

Effective Radial Stress - Time

Triaxial CAU Test - Summary

(ASTM D4767)

PROJECT NO. :	A03355A01	DATE :	2019-11-06
PROJECT :		TESTED BY:	BY
SAMPLE :	Fine Gradation	CHECKED BY:	JG
Details:	Anisotropic consolidation, Kc = 0.5, p' = 200 kPa, strain control		

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B-value	End of Anisotropic Consolidation*	At Maximum Deviator Stress	End of Shear		
Specimen Height	mm	140.85	140.85	140.85	140.74	139.06	99.23	99.23		
Specimen Diameter	mm	70.18	70.18	69.99	69.94	70.01	82.88	82.88		
Area	cm^2	38.68	38.68	38.47	38.41	38.49	53.94	53.94		
Volume	cm^3	544.85	544.85	541.85	540.65	535.28	535.28	535.28		
Wet Weight	g	1453.73	1453.73	1639.13	1644.27	1638.91	1638.91	1638.91		
Water Content	%	5.18	5.18	18.59	18.97	18.58	18.58	18.58		
Dry Weight	g	1382.14	1382.14	1382.14	1382.14	1382.14	1382.14	1382.14		
Wet Density	g/cm^3	2.668	2.668	3.025	3.041	3.062	3.062	3.062		
Dry Density	g/cm^3	2.537	2.537	2.551	2.556	2.582	2.582	2.582		
Specific Gravity of Solids	-	4.96	4.96	4.96	4.96	4.96	4.96	4.96		
Solids Volume	cm^3	278.656	278.656	278.656	278.656	278.656	278.656	278.656		
Void Volume	cm^3	266.189	266.189	263.189	261.989	256.626	256.625	256.625		
Water Volume	cm^3	71.595	71.595	256.995	262.137	256.774	256.773	256.773		
Void Ratio (e)	-	0.955	0.955	0.944	0.940	0.921	0.921	0.921		
Saturation Ratio (Sr)	%	26.90	26.90	97.65	100.06	100.06	100.06	100.06		
Effective Confining Stress (σ_3')	kPa					150				

** Anisotropic consolidation at 0.01%/min strain rate*

Shearing (CAU)		
Skempton's B Parameter		0.99
Back Pressure before shearing	kPa	600.0
Confining Stress (σ_3') before shearing	kPa	150
Shear Strain Rate	mm / min	0.04

At Maximum Deviator Stress:		
Axial Strain	%	2.01
Deviator Stress	kPa	408.6
Φ '	º	34.9
c' (assumed)	kPa	0

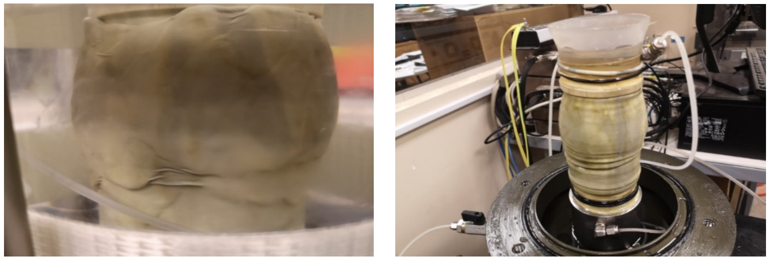
At Maximum Stress Ratio		
Axial Strain	%	6.61
Deviator Stress	kPa	358.2
Φ '	º	35.2
c' (assumed)	kPa	0

Note: *using cambridge method*

Test Photos:

Before Test

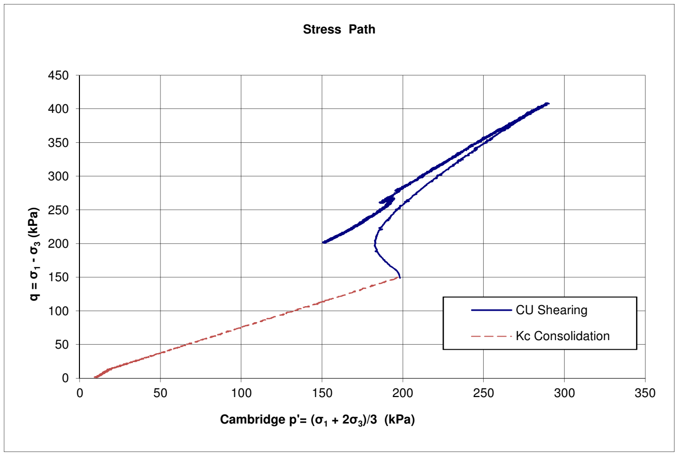
After Test

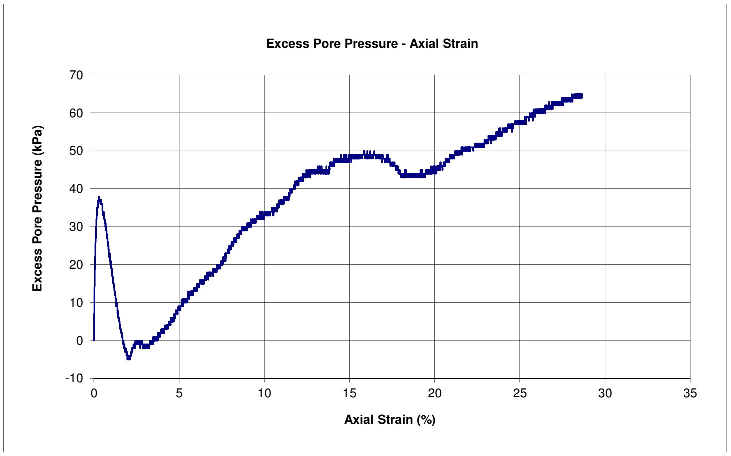


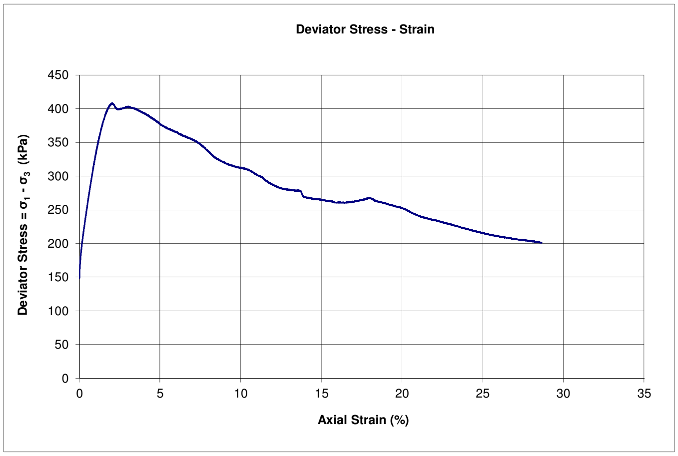
Triaxial CU Test - Charts

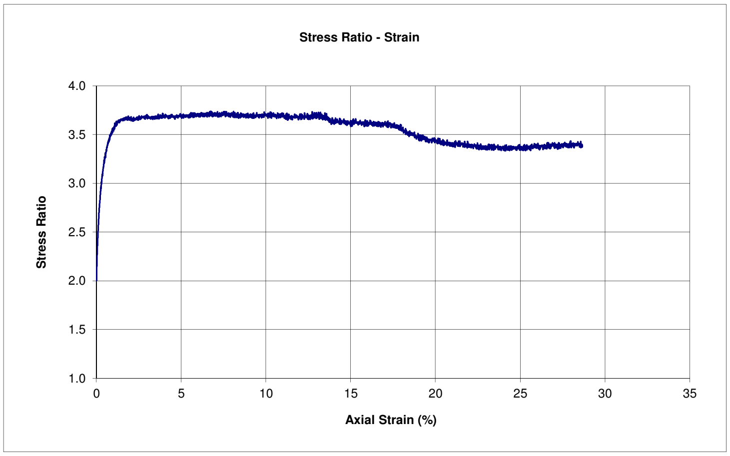
(ASTM D4767)

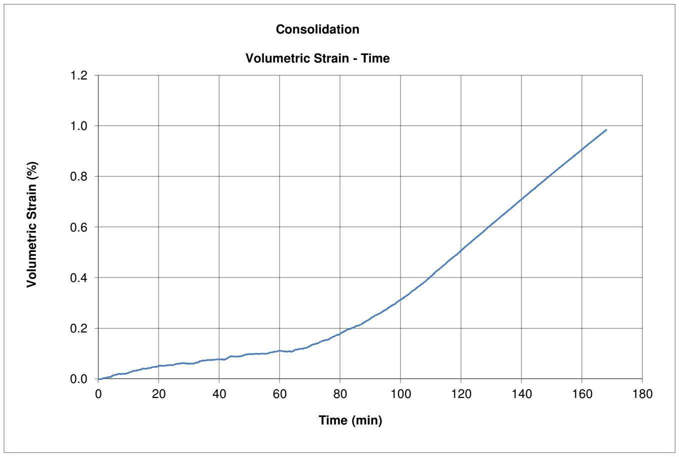
PROJECT NO. : A03355A01
DATE : 2019-11-06
PROJECT :
TEST BY: BY
SAMPLE : Fine Gradation
CHECKED BY: JG
Details: Anisotropic consolidation, Kc = 0.5, p' = 200 kPa, strain control


Stress Path

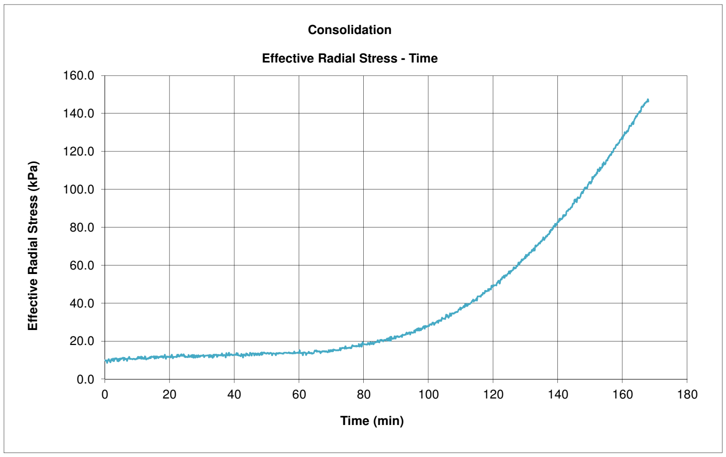

Excess Pore Pressure - Axial Strain


Deviator Stress - Strain


Stress Ratio - Strain


Consolidation

Volumetric Strain - Time


Consolidation

Effective Radial Stress - Time

Triaxial CAU Test - Summary

(ASTM D4767)

PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Fine Gradation
Details: Anisotropic consolidation, Kc = 0.5, p' = 200 kPa, strain control

DATE : 2019-11-06
TESTED BY: BY
CHECKED BY: JG

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B-value	End of Anisotropic Consolidation*	At Maximum Deviator Stress	End of Shear		
Specimen Height	mm	139.93	139.93	139.93	139.63	139.18	129.97	97.65		
Specimen Diameter	mm	70.16	70.16	70.16	70.16	70.08	72.52	83.66		
Area	cm^2	38.66	38.66	38.66	38.66	38.57	41.30	54.97		
Volume	cm^3	540.98	540.98	540.98	539.78	536.81	536.81	536.81		
Wet Weight	g	1545.07	1545.07	1708.67	1713.64	1710.67	1710.67	1710.67		
Water Content	%	5.09	5.09	16.22	16.56	16.35	16.35	16.35		
Dry Weight	g	1470.24	1470.24	1470.24	1470.24	1470.24	1470.24	1470.24		
Wet Density	g/cm^3	2.856	2.856	3.158	3.175	3.187	3.187	3.187		
Dry Density	g/cm^3	2.718	2.718	2.718	2.724	2.739	2.739	2.739		
Specific Gravity of Solids	-	4.96	4.96	4.96	4.96	4.96	4.96	4.96		
Solids Volume	cm^3	296.418	296.418	296.418	296.418	296.418	296.418	296.418		
Void Volume	cm^3	244.560	244.560	244.560	243.360	240.391	240.390	240.390		
Water Volume	cm^3	74.835	74.835	238.435	243.408	240.439	240.438	240.438		
Void Ratio (e)	-	0.825	0.825	0.825	0.821	0.811	0.811	0.811		
Saturation Ratio (Sr)	%	30.60	30.60	97.50	100.02	100.02	100.02	100.02		
Effective Confining Stress (σ_3')	kPa					150				

** Anisotropic consolidation at 0.01%/min strain rate*

Shearing (CAU)		
Skempton's B Parameter		0.99
Back Pressure before shearing	kPa	600.0
Confining Stress (σ_3') before shearing	kPa	150
Shear Strain Rate	mm / min	0.04

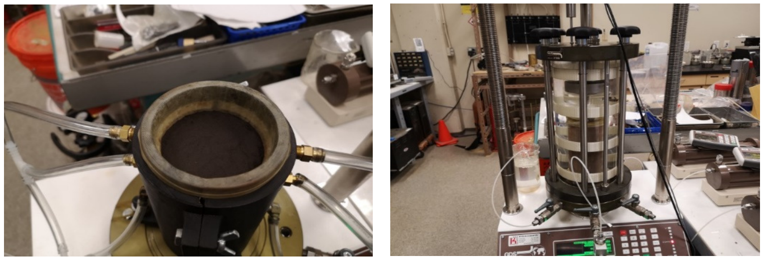
At Maximum Deviator Stress:		
Axial Stain	%	6.62
Deviator Stress	kPa	2106.0
Φ '	º	36.6
c' (assumed)	kPa	0

At Maximum Stress Ratio		
Axial Stain	%	1.54
Deviator Stress	kPa	1120.3
Φ '	º	38.9
c' (assumed)	kPa	0

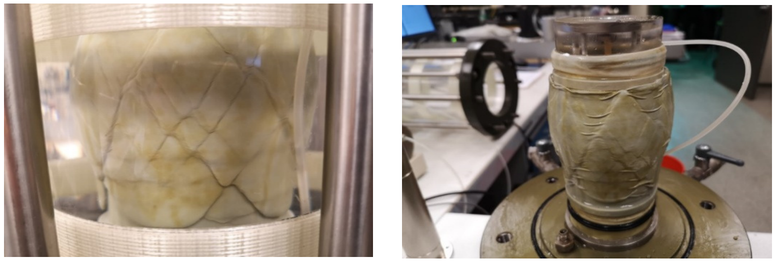
Note: *using cambridge method*

Test Photos:

Before Test



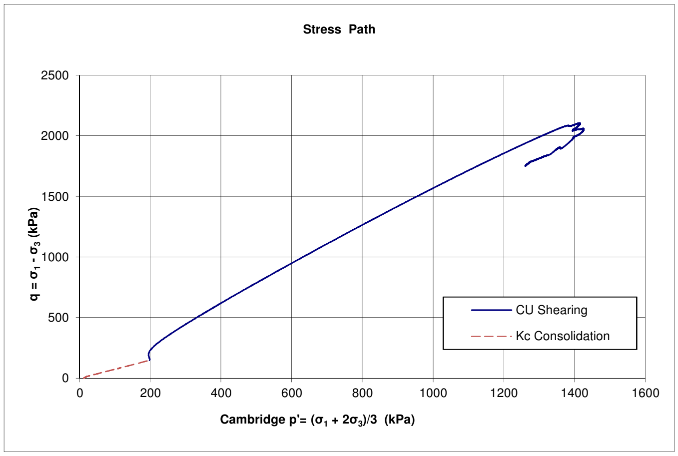
After Test

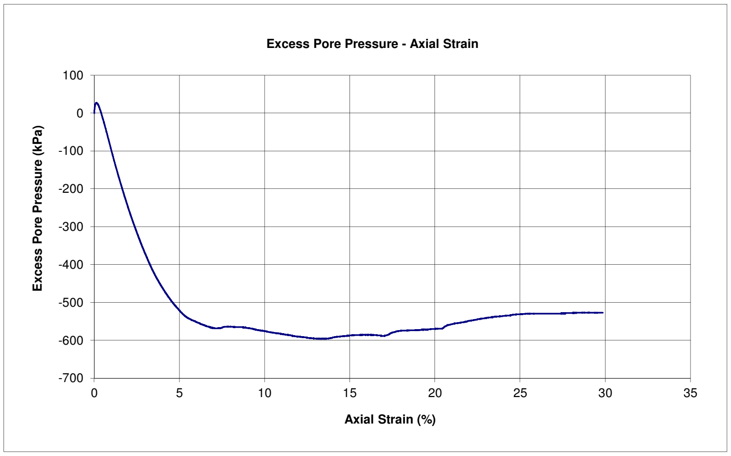


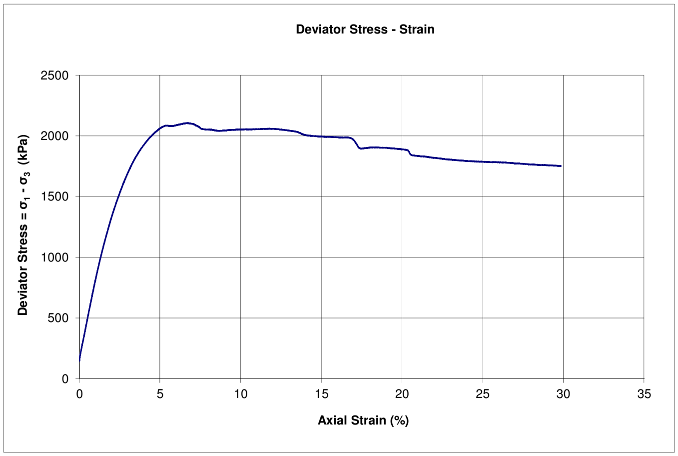
Triaxial CU Test - Charts

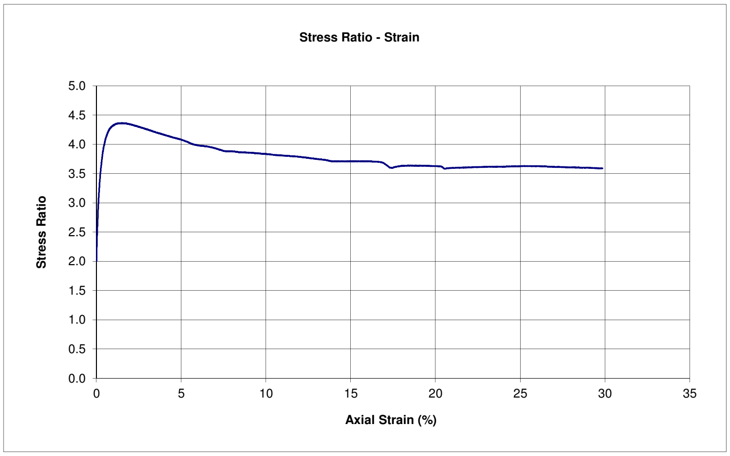
(ASTM D4767)

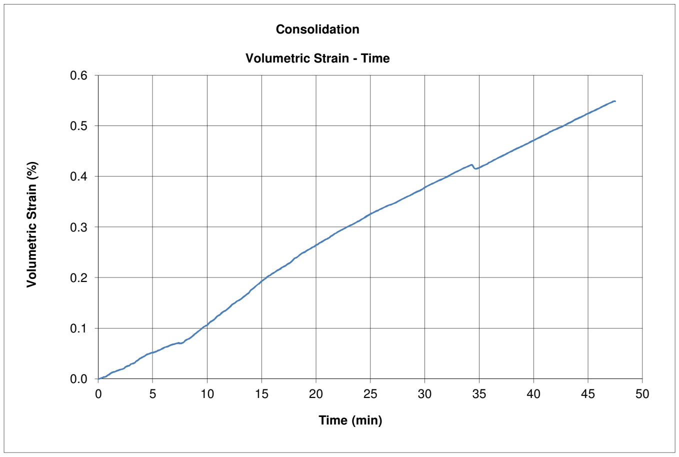
PROJECT NO. :	A03355A01	DATE :	2019-11-06
PROJECT :		TEST BY:	BY
SAMPLE :	Fine Gradation	CHECKED BY:	JG
Details:	Anisotropic consolidation, Kc = 0.5, p' = 200 kPa, strain control		

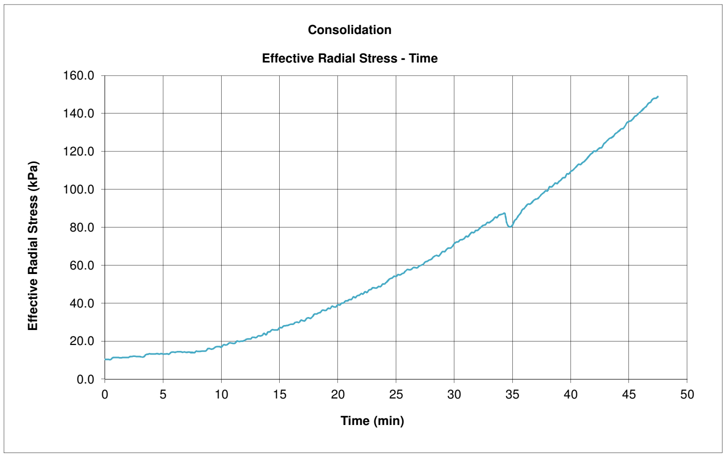












Triaxial CAU Test - Summary

(ASTM D4767)

PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Fine Gradation
Details: Anisotropic consolidation, Kc = 0.5, p' = 200 kPa, strain control

DATE : 2019-11-06
TESTED BY: BY
CHECKED BY: JG

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B-value	End of Anisotropic Consolidation*	At Maximum Deviator Stress	End of Shear		
Specimen Height	mm	140.86	140.86	140.86	140.80	140.06	133.48	95.29		
Specimen Diameter	mm	69.90	69.91	69.83	69.78	69.76	71.45	84.57		
Area	cm^2	38.37	38.39	38.29	38.24	38.22	40.10	56.17		
Volume	cm^3	540.55	540.70	539.39	538.39	535.25	535.25	535.25		
Wet Weight	g	1496.88	1496.88	1673.38	1675.61	1672.47	1672.47	1672.47		
Water Content	%	5.09	5.09	17.48	17.64	17.42	17.42	17.42		
Dry Weight	g	1424.38	1424.38	1424.38	1424.38	1424.38	1424.38	1424.38		
Wet Density	g/cm^3	2.769	2.768	3.102	3.112	3.125	3.125	3.125		
Dry Density	g/cm^3	2.635	2.634	2.641	2.646	2.661	2.661	2.661		
Specific Gravity of Solids	-	4.96	4.96	4.96	4.96	4.96	4.96	4.96		
Solids Volume	cm^3	287.173	287.173	287.173	287.173	287.173	287.173	287.173		
Void Volume	cm^3	253.372	253.527	252.217	251.217	248.079	248.079	248.079		
Water Volume	cm^3	72.501	72.501	249.001	251.230	248.093	248.092	248.092		
Void Ratio (e)	-	0.882	0.883	0.878	0.875	0.864	0.864	0.864		
Saturation Ratio (Sr)	%	28.61	28.60	98.73	100.01	100.01	100.01	100.01		
Effective Confining Stress (σ_3')	kPa					150				

** Anisotropic consolidation at 0.01%/min strain rate*

Shearing (CAU)		
Skempton's B Parameter		0.98
Back Pressure before shearing	kPa	499.7
Confining Stress (σ_3') before shearing	kPa	150
Shear Strain Rate	% / min	0.03

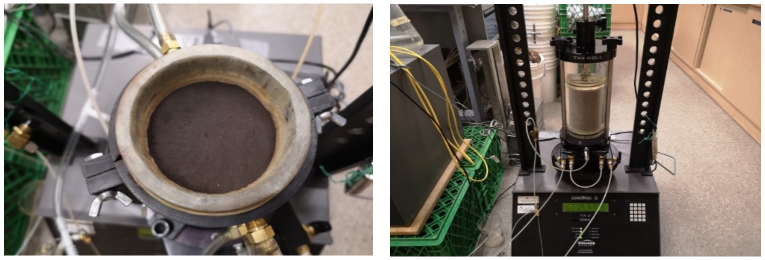
At Maximum Deviator Stress:		
Axial Stain	%	4.70
Deviator Stress	kPa	870.3
Φ '	º	36.4
c' (assumed)	kPa	0

At Maximum Stress Ratio		
Axial Stain	%	2.03
Deviator Stress	kPa	709.7
Φ '	º	37.1
c' (assumed)	kPa	0

Note: *using cambridge method*

Test Photos:

Before Test



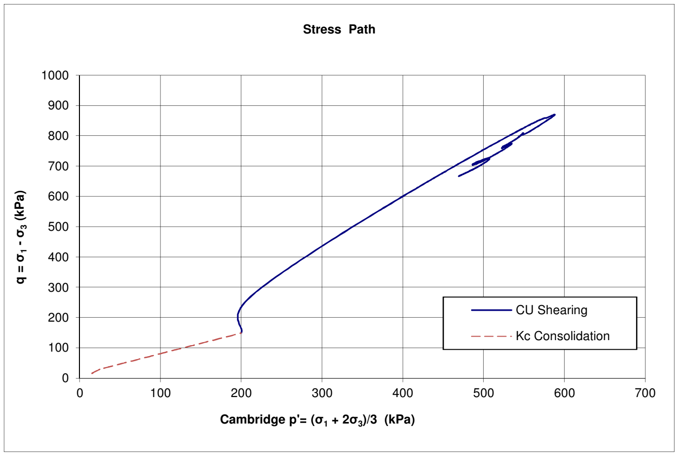
After Test

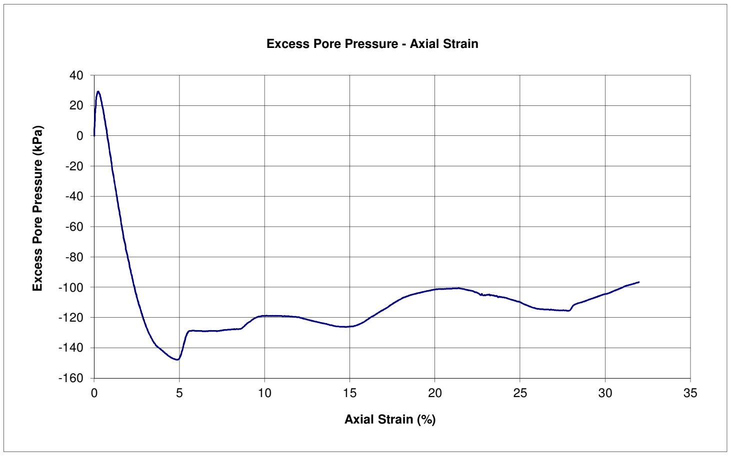
Triaxial CU Test - Charts

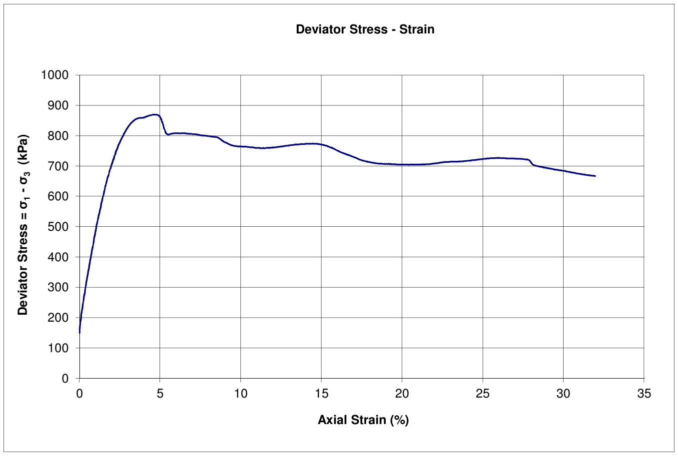
(ASTM D4767)

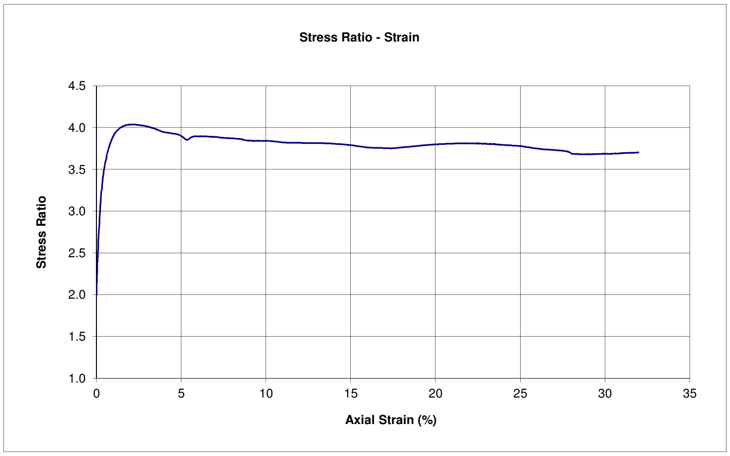
PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Fine Gradation
Details: Anisotropic consolidation, Kc = 0.5, p' = 200 kPa, strain control

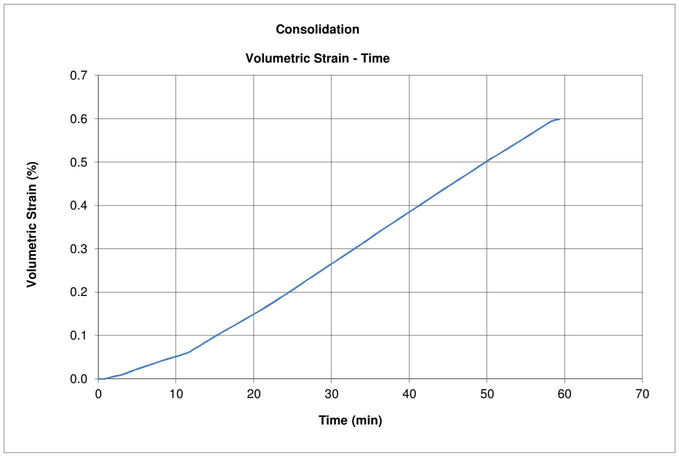
DATE : 2019-11-06
TEST BY: BY
CHECKED BY: JG

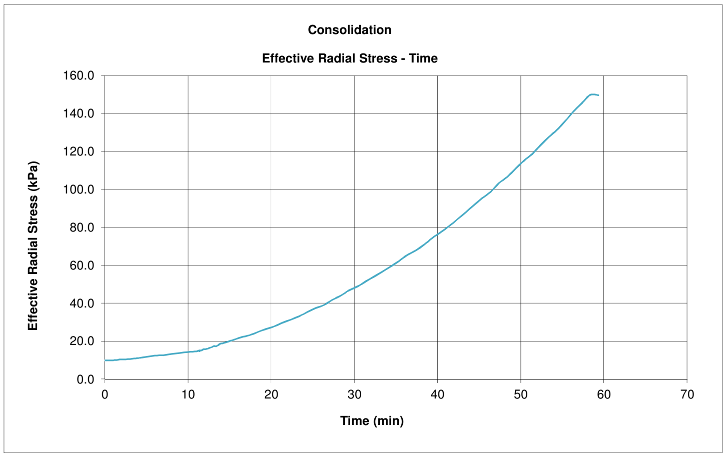












Triaxial CAU Test - Summary

(ASTM D4767)

PROJECT NO. : A03355A01 DATE : 2019-11-07

PROJECT : TESTED BY: BY

SAMPLE : Average Gradation CHECKED BY: JG

Details: Anisotropic consolidation, Kc = 0.5, p' = 200 kPa, strain control

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B-value	End of Anisotropic Consolidation*	At Maximum Deviator Stress	End of Shear		
Specimen Height	mm	140.06	140.74	140.74	140.32	139.72	132.94	96.27		
Specimen Diameter	mm	69.90	69.72	69.64	69.70	69.60	71.35	83.85		
Area	cm^2	38.37	38.18	38.09	38.16	38.05	39.99	55.22		
Volume	cm^3	537.48	537.31	536.13	535.43	531.59	531.59	531.59		
Wet Weight	g	1533.01	1533.01	1679.61	1689.12	1685.29	1685.28	1685.28		
Water Content	%	6.15	6.15	16.30	16.96	16.69	16.69	16.69		
Dry Weight	g	1444.19	1444.19	1444.19	1444.19	1444.19	1444.19	1444.19		
Wet Density	g/cm^3	2.852	2.853	3.133	3.155	3.170	3.170	3.170		
Dry Density	g/cm^3	2.687	2.688	2.694	2.697	2.717	2.717	2.717		
Specific Gravity of Solids	-	4.97	4.97	4.97	4.97	4.97	4.97	4.97		
Solids Volume	cm^3	290.582	290.582	290.582	290.582	290.582	290.582	290.582		
Void Volume	cm^3	246.893	246.725	245.545	244.845	241.012	241.006	241.006		
Water Volume	cm^3	88.818	88.818	235.418	244.930	241.097	241.091	241.091		
Void Ratio (e)	-	0.850	0.849	0.845	0.843	0.829	0.829	0.829		
Saturation Ratio (Sr)	%	35.97	36.00	95.88	100.03	100.04	100.04	100.04		
Effective Confining Stress (σ_3')	kPa					150				

** Anisotropic consolidation at 0.01%/min strain rate*

Shearing (CAU)		
Skempton's B Parameter		0.99
Back Pressure before shearing	kPa	600.0
Confining Stress (σ_3') before shearing	kPa	150
Shear Strain Rate	mm / min	0.04

At Maximum Deviator Stress:		
Axial Strain	%	4.86
Deviator Stress	kPa	692.0
Φ '	º	37.0
c' (assumed)	kPa	0

At Maximum Stress Ratio		
Axial Strain	%	1.98
Deviator Stress	kPa	623.8
Φ '	º	37.8
c' (assumed)	kPa	0

Note: *using cambridge method*

Test Photos:

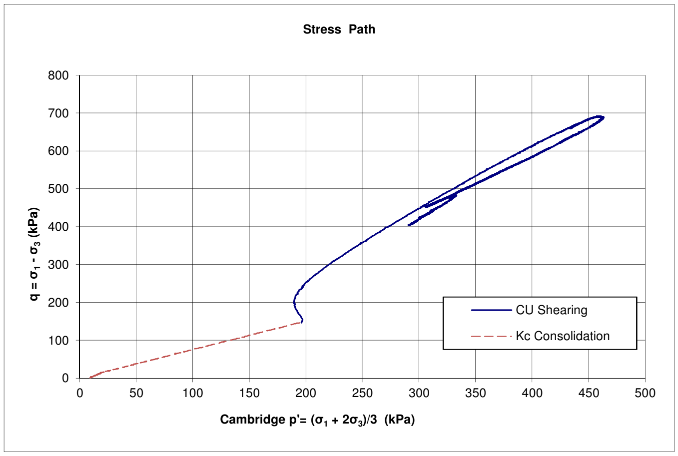
Before Test

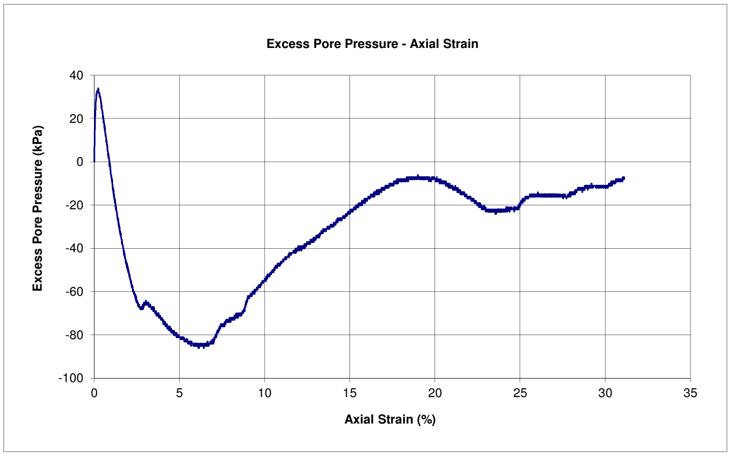
After Test `

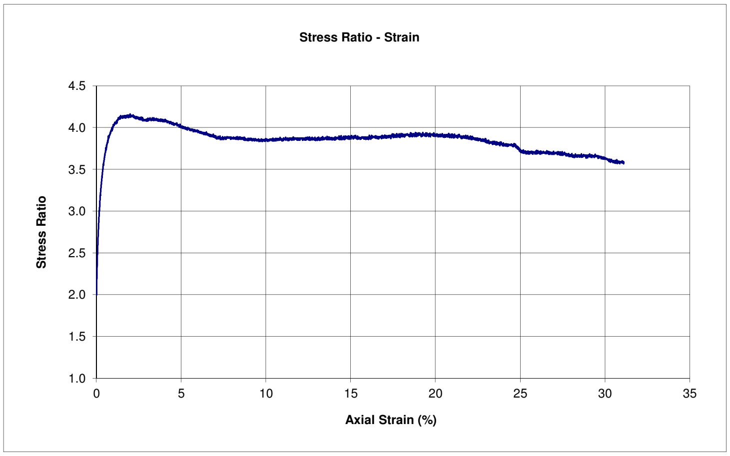
Triaxial CU Test - Charts

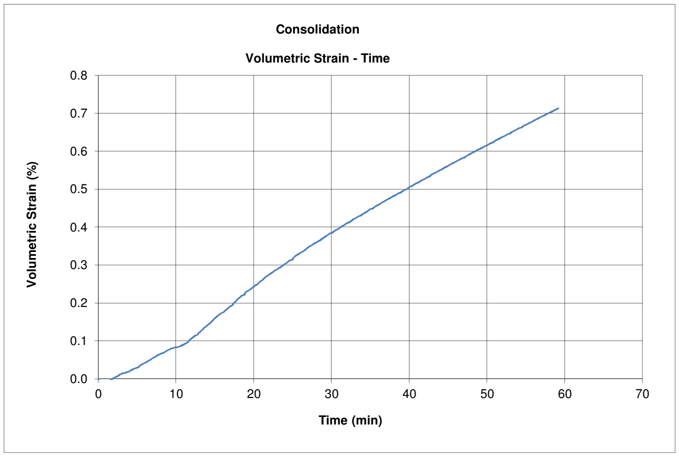
(ASTM D4767)

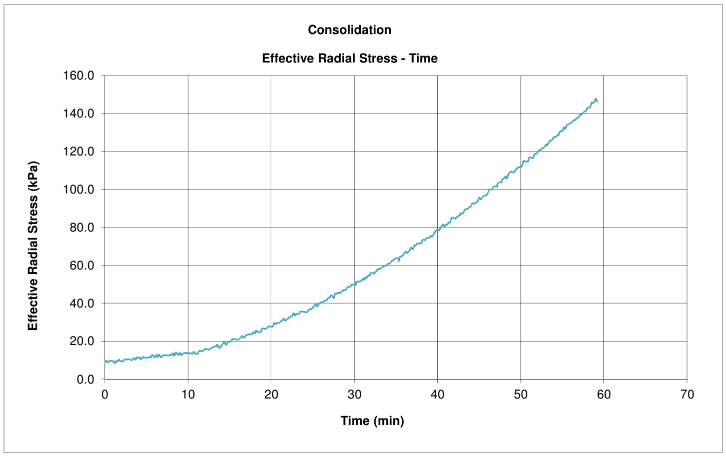
PROJECT NO. :	A03355A01	DATE :	2019-11-07
PROJECT :		TEST BY:	BY
SAMPLE :	Average Gradation	CHECKED BY:	JG
Details:	Anisotropic consolidation, Kc = 0.5, p' = 200 kPa, strain control		











Triaxial CAU Test - Summary

(ASTM D4767)

PROJECT NO. : A03355A01 DATE : 2019-11-07
PROJECT : TESTED BY: AX/BY
SAMPLE : Average Gradation CHECKED BY: JG
Details: Anisotropic consolidation, Kc = 0.5, p' = 200 kPa, strain control

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B-value	End of Anisotropic Consolidation*	At Maximum Deviator Stress	End of Shear		
Specimen Height	mm	141.94	141.94	141.94	141.93	141.37	135.08	97.08		
Specimen Diameter	mm	69.90	69.87	69.68	69.68	69.52	71.12	83.89		
Area	cm^2	38.37	38.34	38.13	38.13	37.96	39.72	55.27		
Volume	cm^3	544.69	544.22	541.22	541.22	536.57	536.57	536.57		
Wet Weight	g	1615.21	1615.21	1753.21	1762.00	1757.35	1757.35	1757.35		
Water Content	%	5.70	5.70	14.73	15.31	15.00	15.00	15.00		
Dry Weight	g	1528.11	1528.11	1528.11	1528.11	1528.11	1528.11	1528.11		
Wet Density	g/cm^3	2.965	2.968	3.239	3.256	3.275	3.275	3.275		
Dry Density	g/cm^3	2.805	2.808	2.823	2.823	2.848	2.848	2.848		
Specific Gravity of Solids	-	4.97	4.97	4.97	4.97	4.97	4.97	4.97		
Solids Volume	cm^3	307.466	307.466	307.466	307.466	307.466	307.466	307.466		
Void Volume	cm^3	237.223	236.756	233.756	233.756	229.108	229.108	229.108		
Water Volume	cm^3	87.102	87.102	225.102	233.891	229.243	229.243	229.243		
Void Ratio (e)	-	0.772	0.770	0.760	0.760	0.745	0.745	0.745		
Saturation Ratio (Sr)	%	36.72	36.79	96.30	100.06	100.06	100.06	100.06		
Effective Confining Stress (σ_3')	kPa					150				

* *Anisotropic consolidation at 0.01%/min strain rate*

Shearing (CAU)		
Skempton's B Parameter		0.99
Back Pressure before shearing	kPa	598.0
Confining Stress (σ_3') before shearing	kPa	150
Shear Strain Rate	mm / min	0.04

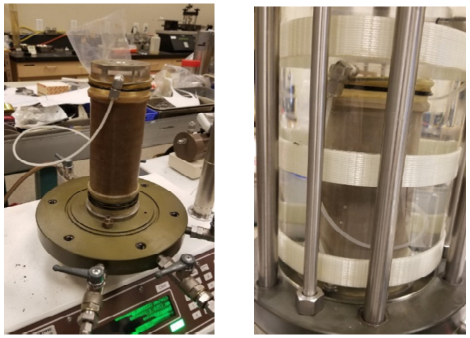
At Maximum Deviator Stress:		
Axial Stain	%	4.45
Deviator Stress	kPa	2224.6
Φ '	º	38.3
c' (assumed)	kPa	0

At Maximum Stress Ratio		
Axial Stain	%	1.74
Deviator Stress	kPa	1316.8
Φ '	º	37.3
c' (assumed)	kPa	0

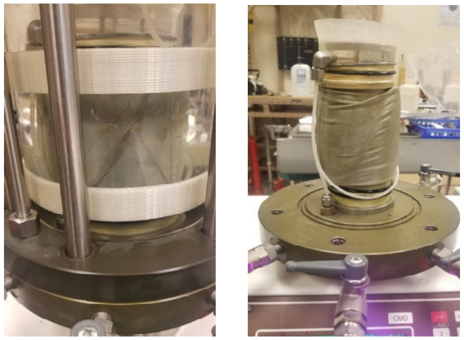
Note: *using cambridge method*

Test Photos:

Before Test



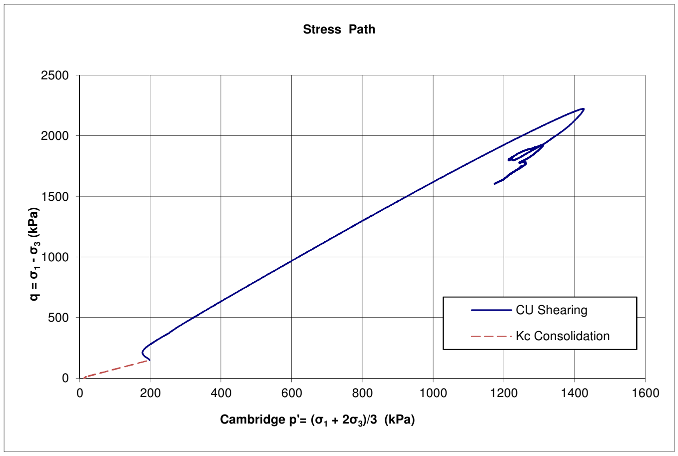
After Test

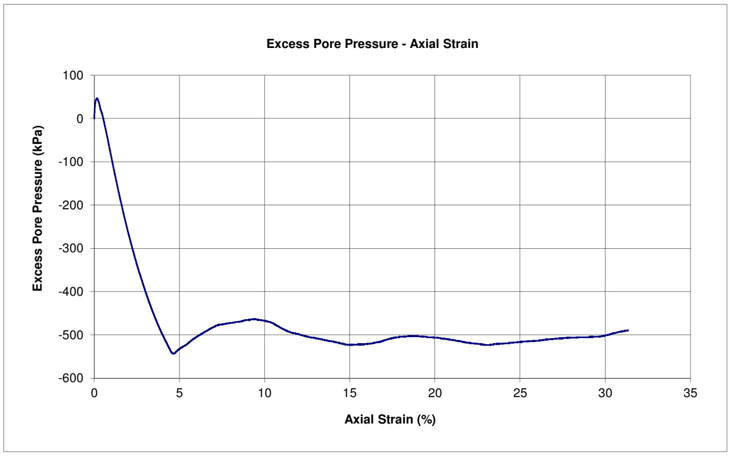


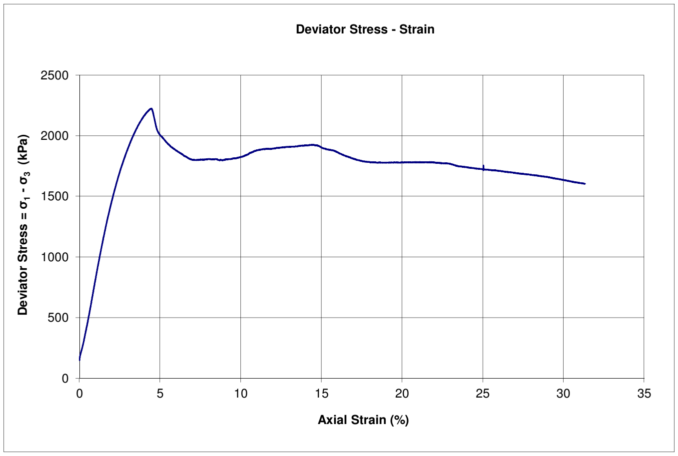
Triaxial CU Test - Charts

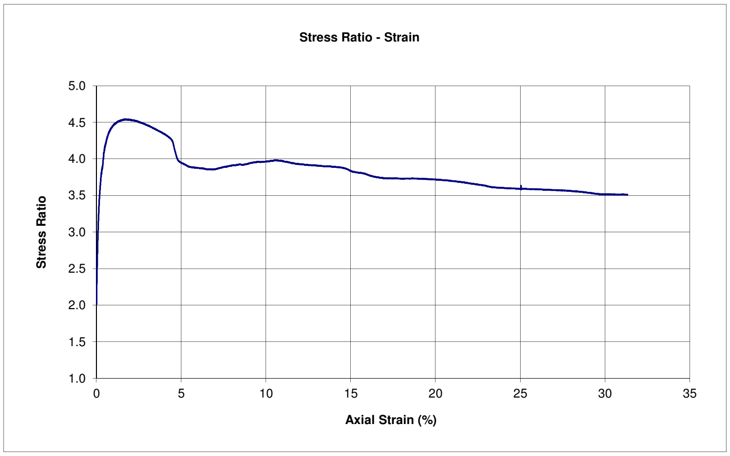
(ASTM D4767)

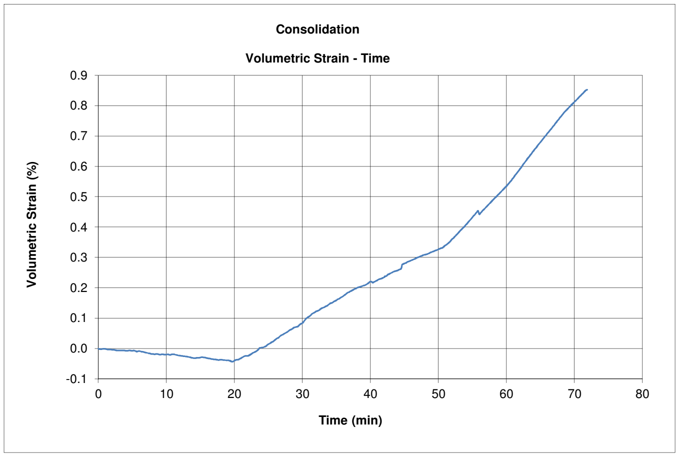
PROJECT NO. : A03355A01
DATE : 2019-11-07
PROJECT :
TEST BY: AX/BY
SAMPLE : Average Gradation
CHECKED BY: JG
Details: Anisotropic consolidation, Kc = 0.5, p' = 200 kPa, strain control

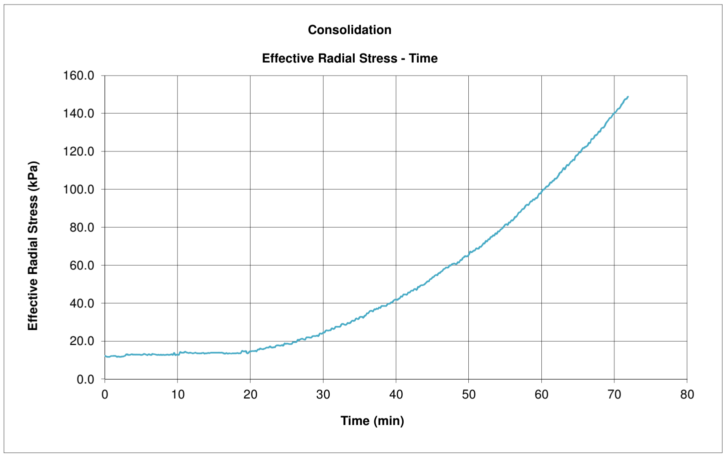












Triaxial CAU Test - Summary

(ASTM D4767)

PROJECT NO. : A03355A01 DATE : 2019-11-08
PROJECT : TESTED BY: AX / BY
SAMPLE : Average Gradation CHECKED BY: JG
Details: Anisotropic consolidation, Kc = 0.5, p' = 200 kPa, strain control

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B-value	End of Anisotropic Consolidation*	At Maximum Deviator Stress	End of Shear		
Specimen Height	mm	141.13	141.13	141.13	141.10	140.33	130.38	96.86		
Specimen Diameter	mm	69.99	69.99	69.86	69.77	69.73	72.34	83.93		
Area	cm^2	38.47	38.47	38.33	38.23	38.19	41.10	55.33		
Volume	cm^3	542.98	542.98	540.97	539.37	535.90	535.90	535.90		
Wet Weight	g	1565.99	1565.99	1723.49	1726.72	1723.25	1723.25	1723.25		
Water Content	%	5.36	5.36	15.96	16.17	15.94	15.94	15.94		
Dry Weight	g	1486.32	1486.32	1486.32	1486.32	1486.32	1486.32	1486.32		
Wet Density	g/cm^3	2.884	2.884	3.186	3.201	3.216	3.216	3.216		
Dry Density	g/cm^3	2.737	2.737	2.747	2.756	2.773	2.773	2.773		
Specific Gravity of Solids	-	4.97	4.97	4.97	4.97	4.97	4.97	4.97		
Solids Volume	cm^3	299.059	299.059	299.059	299.059	299.059	299.059	299.059		
Void Volume	cm^3	243.918	243.918	241.916	240.316	236.846	236.846	236.846		
Water Volume	cm^3	79.667	79.667	237.167	240.394	236.925	236.925	236.925		
Void Ratio (e)	-	0.816	0.816	0.809	0.804	0.792	0.792	0.792		
Saturation Ratio (Sr)	%	32.66	32.66	98.04	100.03	100.03	100.03	100.03		
Effective Confining Stress (σ_3')	kPa					150				

** Anisotropic consolidation at 0.01%/min strain rate*

Shearing (CAU)		
Skempton's B Parameter		0.98
Back Pressure before shearing	kPa	503.6
Confining Stress (σ_3') before shearing	kPa	150
Shear Strain Rate	% / min	0.03

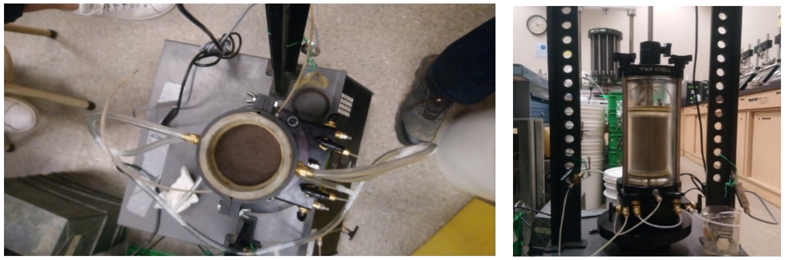
At Maximum Deviator Stress:		
Axial Stain	%	7.09
Deviator Stress	kPa	1125.8
Φ '	º	37.2
c' (assumed)	kPa	0

At Maximum Stress Ratio		
Axial Stain	%	1.70
Deviator Stress	kPa	721.5
Φ '	º	38.2
c' (assumed)	kPa	0

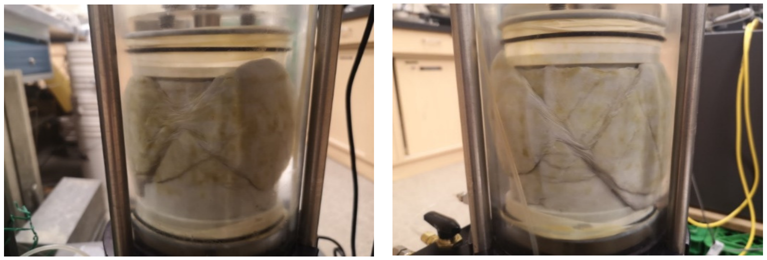
Note: *using cambridge method*

Test Photos:

Before Test



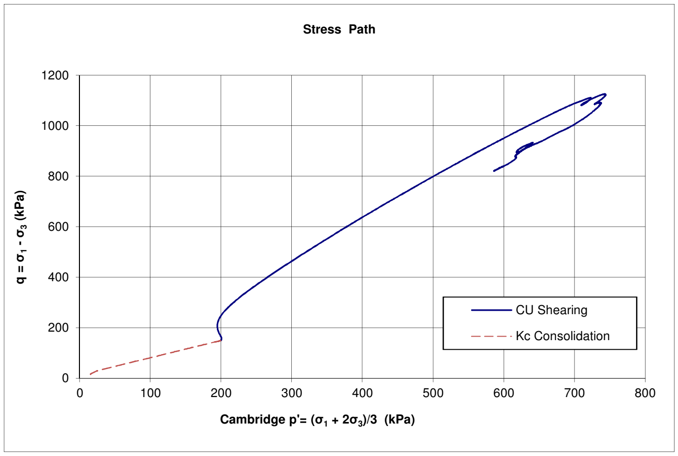
After Test

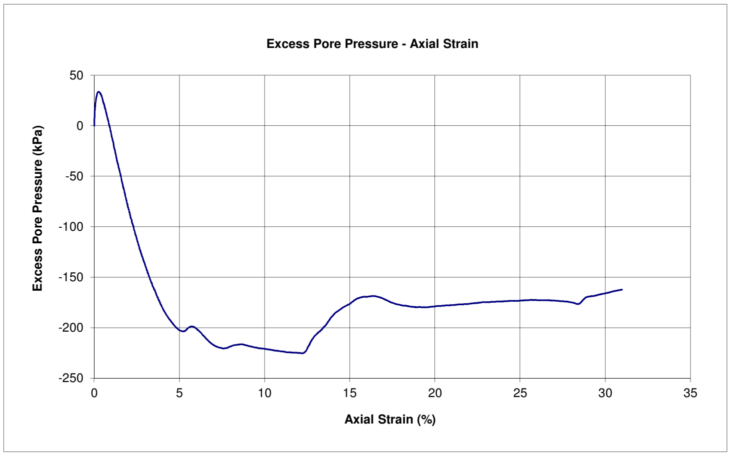


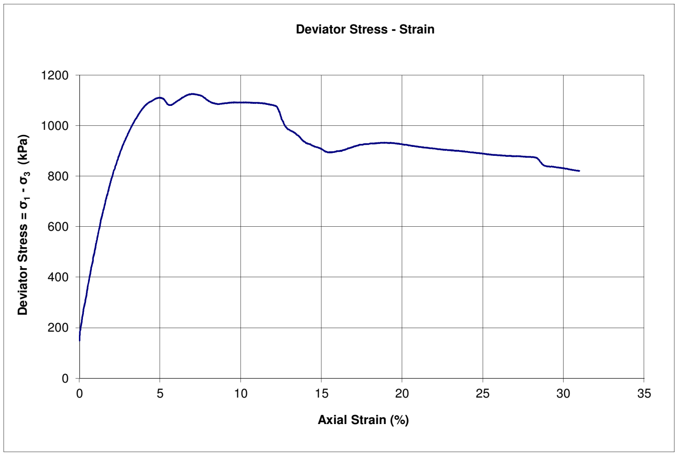
Triaxial CU Test - Charts

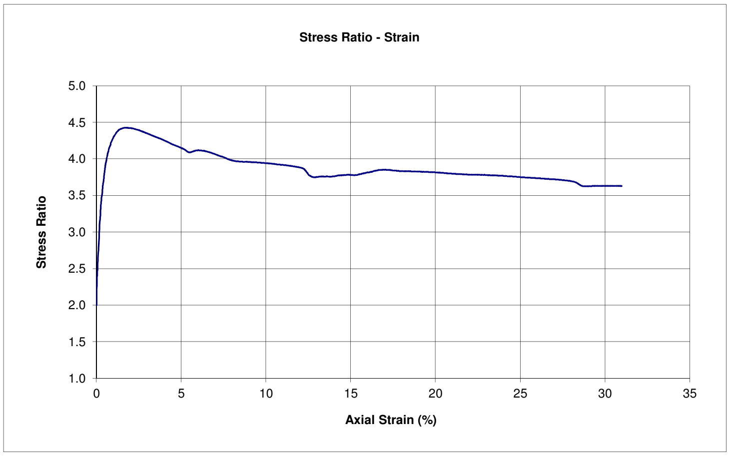
(ASTM D4767)

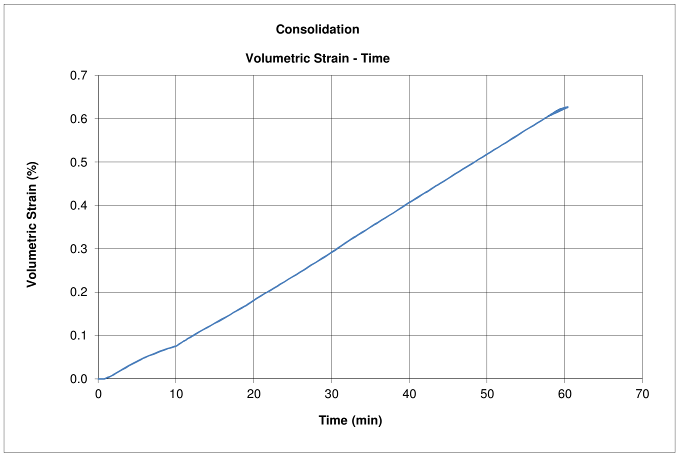
PROJECT NO. :	A03355A01	DATE :	2019-11-08
PROJECT :		TEST BY:	AX / BY
SAMPLE :	Average Gradation	CHECKED BY:	JG
Details:	Anisotropic consolidation, Kc = 0.5, p' = 200 kPa, strain control		


Stress Path

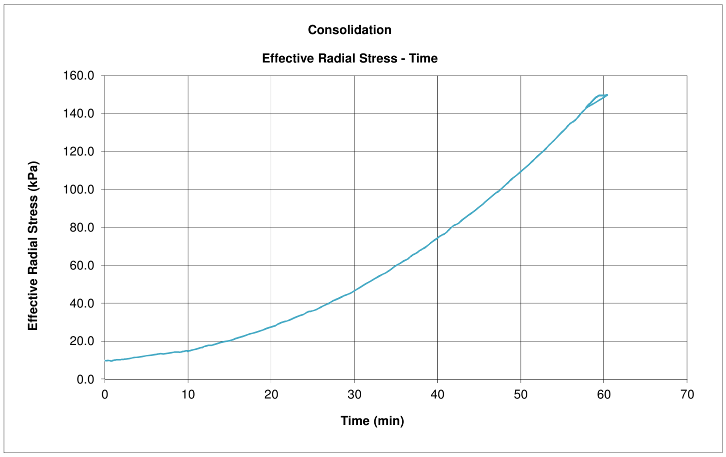

Excess Pore Pressure - Axial Strain


Deviator Stress - Strain


Stress Ratio - Strain


Consolidation

Volumetric Strain - Time


Consolidation

Effective Radial Stress - Time

Triaxial CD Test - Summary

(ASTM D7181)

PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Average
TEST NO. : TXDW01 - Anisotropic Consolidation

DATE : 2019-09-16
TESTED BY: AX/JG
CHECKED BY: JG

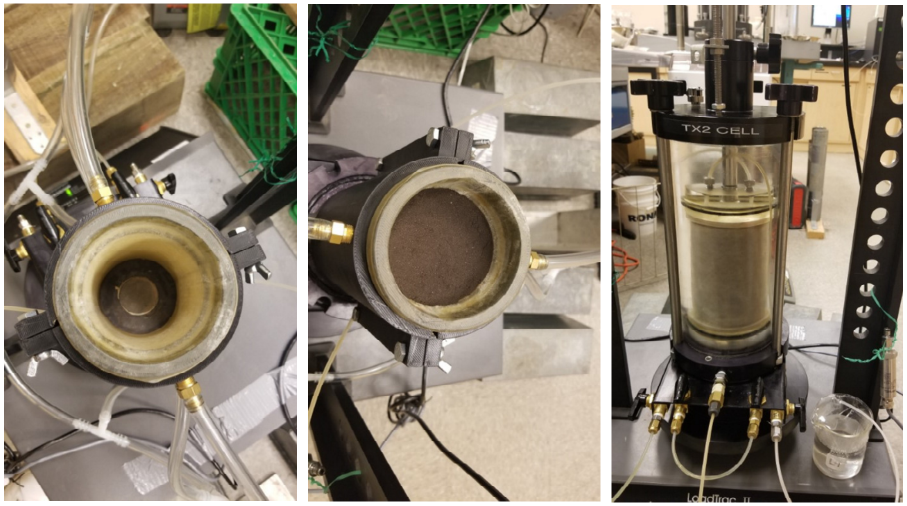
SPECIMEN INFORMATION	UNITS	Initial	vacuum	flushing	Sat/B value	1AC/End
Specimen Height	mm	140.51	140.82	140.82	140.82	132.01
Specimen Diameter	mm	69.80	69.46	69.44	69.17	70.40
Area	cm^2	38.26	37.89	37.88	37.58	38.93
Volume	cm^3	537.660	533.610	533.360	529.210	513.940
Wet Weight	g	1385.16	1385.16	1567.16	1572.73	1557.46
Water Content	%	4.85	4.85	18.63	19.05	17.89
Dry Weight	g	1321.09	1321.09	1321.09	1321.09	1321.09
Wet Density	g/cm^3	2.576	2.596	2.938	2.972	3.030
Dry Density	g/cm^3	2.457	2.476	2.477	2.496	2.571
Specific Gravity of Solids	-	4.91	4.91	4.91	4.91	4.91
Solids Volume	cm^3	269.061	269.061	269.061	269.061	269.061
Void Volume	cm^3	268.600	264.549	264.299	260.149	244.879
Water Volume	cm^3	64.073	64.073	246.073	251.638	236.368
Void Ratio (e)	-	0.998	0.983	0.982	0.967	0.910
Saturation Ratio (Sr)	%	23.85	24.22	93.10	96.73	96.52
Effective Confining Stress	kPa		Anisotropic Consolidation			p'=86KPa; q=110KPa

Stress Path*		
Skempton's B Parameter		0.98
Back Pressure before shearing	kPa	325.0
Confining Stress (s3') before shearing	kPa	6
Stress Rate	kPa / min	0.03

* one way drainage

Photos:

Before Test



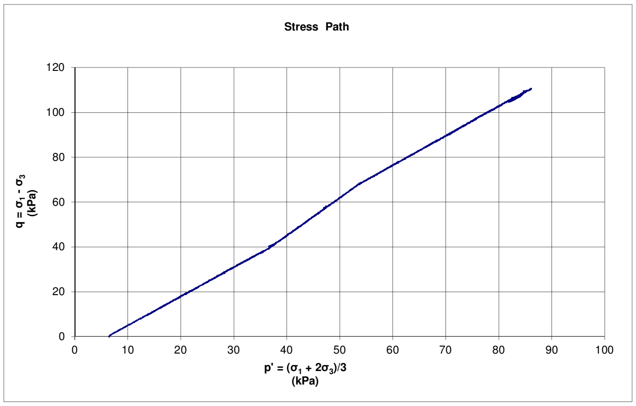
After Test

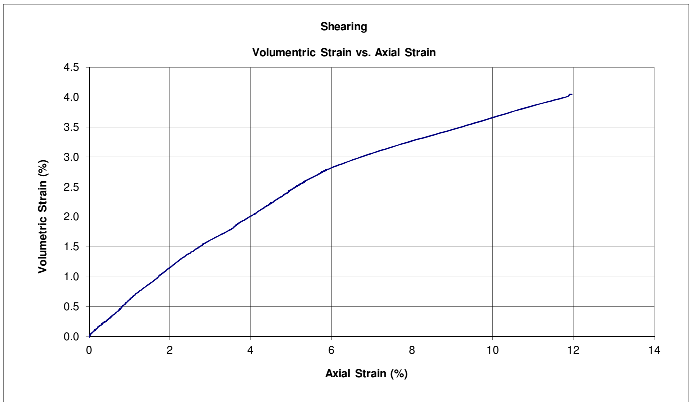
Triaxial CD Test - Charts

(ASTM D7181)

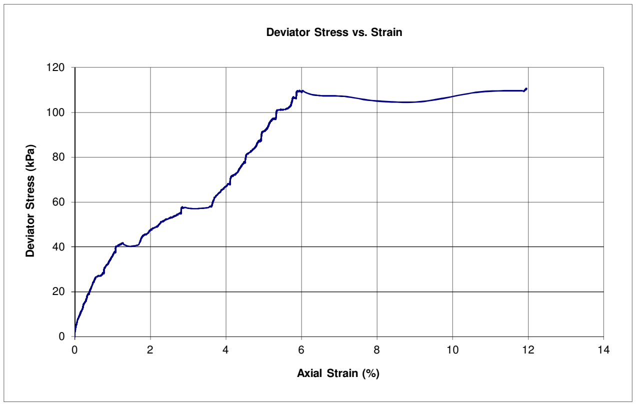
PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Average
TEST NO. : TXDW01 - Anisotropic Consolidation

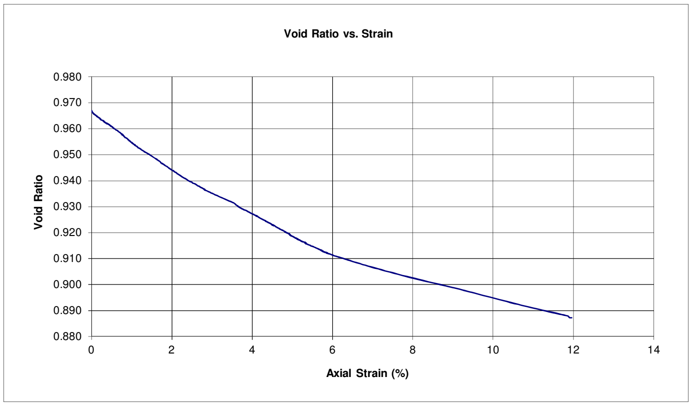
DATE : 2019-09-16
TEST BY: AX/JG
CHECKED BY: JG

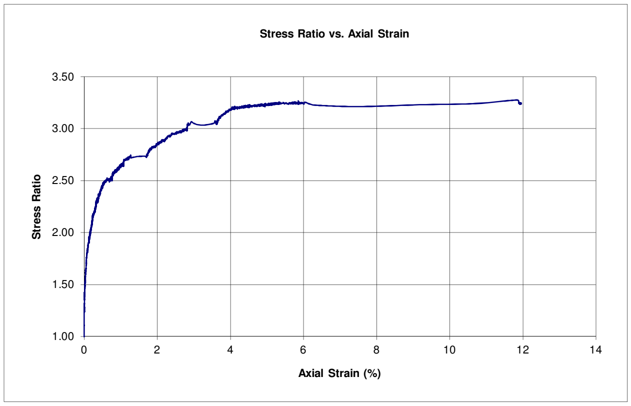

Stress Path

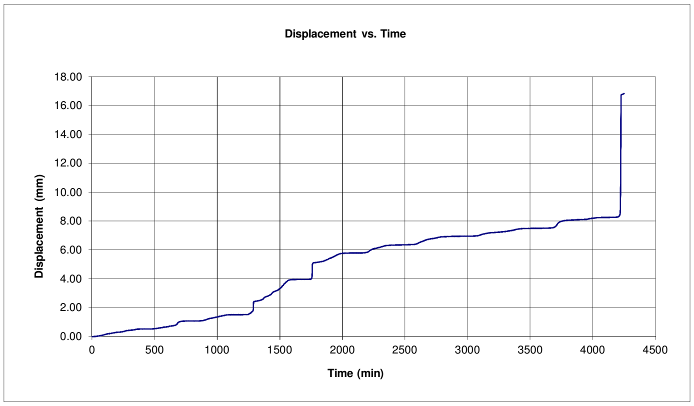

Shearing

Volumentric Strain vs. Axial Strain


Deviator Stress vs. Strain


Void Ratio vs. Strain


Stress Ratio vs. Axial Strain


Displacement vs. Time

Triaxial CAU Test - Summary

(ASTM D4767)

PROJECT NO. : A03355A01 DATE : 2019-10-02
PROJECT : TESTED BY: BY
SAMPLE : Coarse Gradation CHECKED BY: JG
Details: Anisotropic consolidation, Kc = 0.5, p' = 200 kPa, stress control

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B-value	End of Anisotropic Consolidation*	At Maximum Deviator Stress	End of Shear		
Specimen Height	mm	139.88	139.69	139.69	139.30	137.90	135.87	92.44		
Specimen Diameter	mm	69.80	69.70	69.56	69.56	69.50	70.02	84.88		
Area	cm^2	38.26	38.16	38.00	38.00	37.94	38.51	56.59		
Volume	cm^3	535.25	532.99	530.82	529.32	523.15	523.15	523.15		
Wet Weight	g	1431.48	1431.48	1611.48	1617.05	1610.88	1610.88	1610.88		
Water Content	%	4.80	4.80	17.98	18.39	17.93	17.93	17.93		
Dry Weight	g	1365.92	1365.92	1365.92	1365.92	1365.92	1365.92	1365.92		
Wet Density	g/cm^3	2.674	2.686	3.036	3.055	3.079	3.079	3.079		
Dry Density	g/cm^3	2.552	2.563	2.573	2.581	2.611	2.611	2.611		
Specific Gravity of Solids	-	4.91	4.91	4.91	4.91	4.91	4.91	4.91		
Solids Volume	cm^3	278.191	278.191	278.191	278.191	278.191	278.191	278.191		
Void Volume	cm^3	257.059	254.801	252.627	251.127	244.959	244.959	244.959		
Water Volume	cm^3	65.564	65.564	245.564	251.130	244.962	244.962	244.962		
Void Ratio (e)	-	0.924	0.916	0.908	0.903	0.881	0.881	0.881		
Saturation Ratio (Sr)	%	25.51	25.73	97.20	100.00	100.00	100.00	100.00		
Effective Confining Stress (σ_3')	kPa					150				

** Anisotropic consolidation at 0.01%/min strain rate*

Shearing (CAU)		
Skempton's B Parameter		0.98
Back Pressure before shearing	kPa	723.5
Confining Stress (σ_3') before shearing	kPa	150
Shear Stress Rate	kPa / min	<1

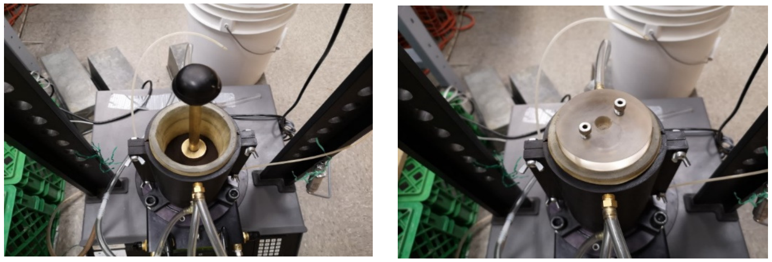
At Maximum Deviator Stress:		
Axial Stain	%	1.17
Deviator Stress	kPa	222.1
Φ '	º	35.4
c' (assumed)	kPa	0

At Maximum Stress Ratio		
Axial Stain	%	1.48
Deviator Stress	kPa	221.6
Φ '	º	36.2
c' (assumed)	kPa	0

Note: *using cambridge method*

Test Photos:

Before Test

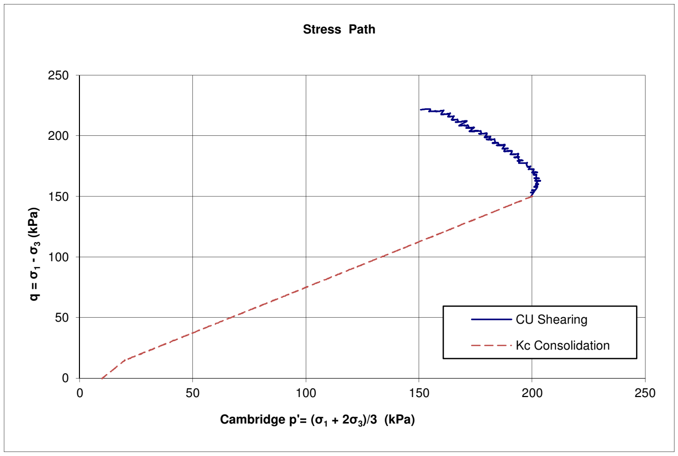


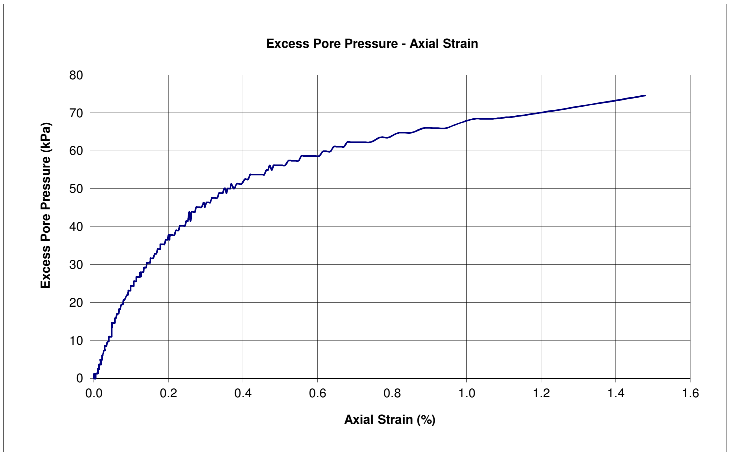
After Test

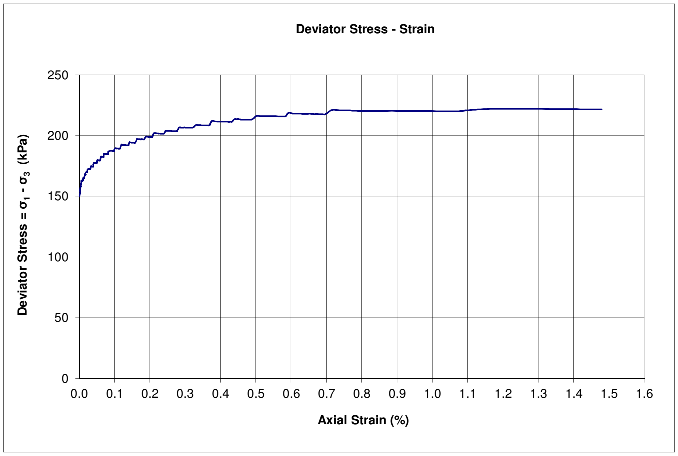
Triaxial CU Test - Charts

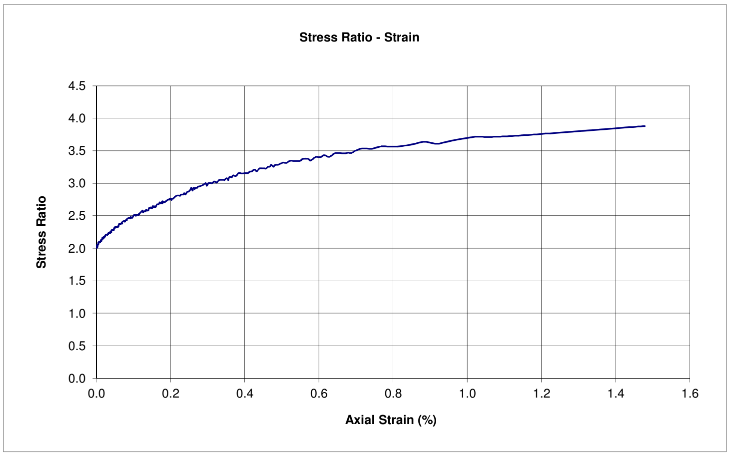
(ASTM D4767)

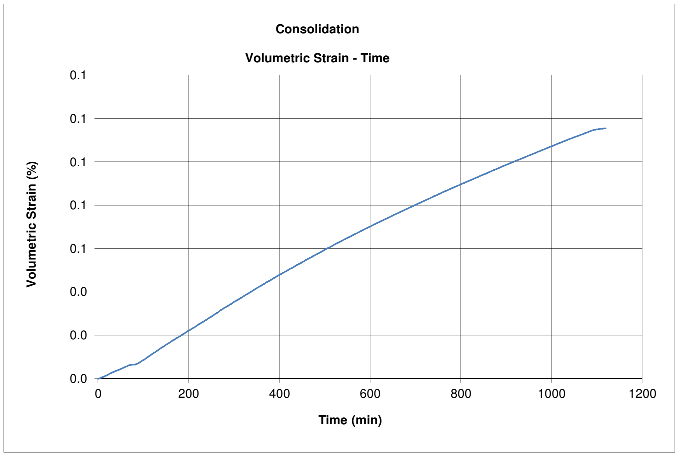
PROJECT NO. :	A03355A01	DATE :	2019-10-02
PROJECT :		TEST BY:	BY
SAMPLE :	Coarse Gradation	CHECKED BY:	JG
Details:	Anisotropic consolidation, Kc = 0.5, p' = 200 kPa, stress control		

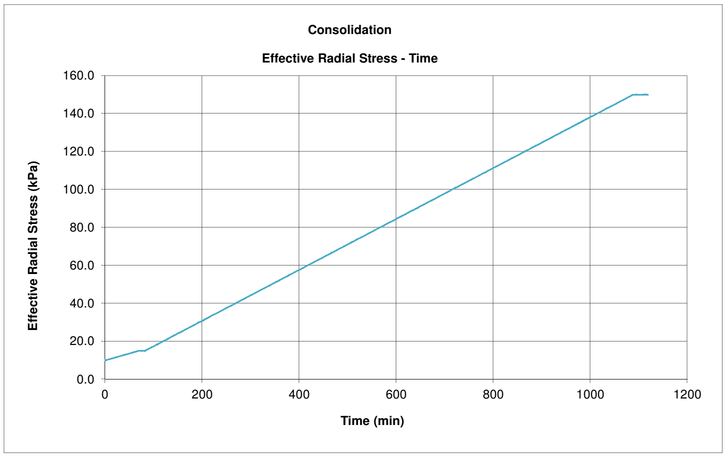












Triaxial CAU - Summary

PROJECT NO. : A03355A01 DATE : 2019-10-14
PROJECT : TESTED BY: AX / BY
SAMPLE : Coarse Gradation CHECKED BY: JG
Details: Anisotropic consolidation, Kc = 0.5, p' = 100 kPa, stress control

						Multi-Stage Anisotropic Consolidation				
SPECIMEN INFORMATION	**UNITS**	**Initial**	**Vacuum**	**Saturation**	**B-value**	**Stress Controled Consolidation***	**Constant Dead Weights Load Drained**	**Dead Weight Loading at Constant p'**	**Constant Dead Weights Load Undrained**	****Dead Weight Loading at Constant p'**
Specimen Height	mm	140.28	140.28	140.28	140.22	138.29	138.15	137.76	137.57	136.56
Specimen Diameter	mm	69.80	69.65	69.32	69.19	69.30	69.39	69.45	69.50	69.65
Area	cm^2	38.26	38.10	37.74	37.60	37.72	37.82	37.88	37.93	38.11
Volume	cm^3	536.63	534.48	529.35	527.29	521.69	522.42	521.86	521.86	520.35
Wet Weight	g	1439.57	1439.57	1609.07	1616.07	1610.47	1611.20	1610.64	1610.64	1609.13
Water Content	%	5.29	5.29	17.69	18.20	17.79	17.84	17.80	17.80	17.69
Dry Weight	g	1367.24	1367.24	1367.24	1367.24	1367.24	1367.24	1367.24	1367.24	1367.24
Wet Density	g/cm^3	2.683	2.693	3.040	3.065	3.087	3.084	3.086	3.086	3.092
Dry Density	g/cm^3	2.548	2.558	2.583	2.593	2.621	2.617	2.620	2.620	2.628
Specific Gravity of Solids	-	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91
Solids Volume	cm^3	278.461	278.461	278.461	278.461	278.461	278.461	278.461	278.461	278.461
Void Volume	cm^3	258.166	256.015	250.891	248.832	243.231	243.958	243.404	243.404	241.894
Water Volume	cm^3	72.327	72.327	241.827	248.827	243.226	243.953	243.399	243.399	241.889
Void Ratio (e)	-	0.927	0.919	0.901	0.894	0.873	0.876	0.874	0.874	0.869
Saturation Ratio (Sr)	%	28.02	28.25	96.39	100.00	100.00	100.00	100.00	100.00	100.00
Effective Confining Stress (σ3')	kPa					75	75	66	66	60
Kc (σ3' / σ1')						1.0 to 0.5	0.5	0.5 to 0.4	0.4	0.33
Skempton's B Parameter		0.98								
Back Pressure	kPa	725.0								
Stress Rate	kPa / min	~1								

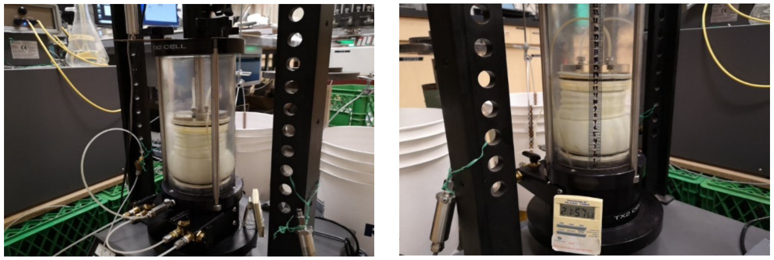
** Sample failed at Kc=0.33

Note: *using cambridge method*

Test Photos:

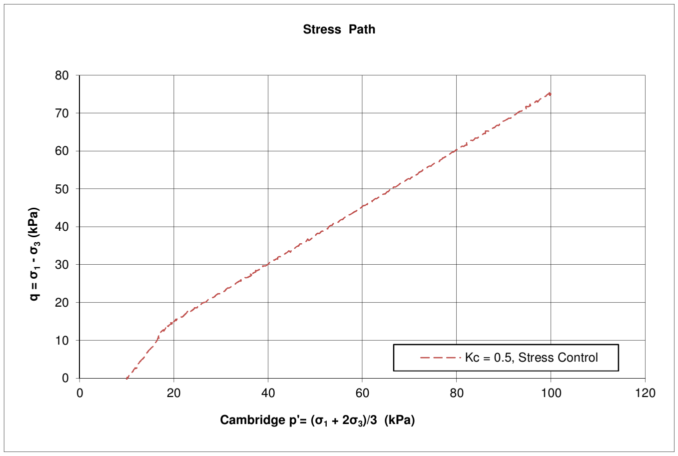
Before Test

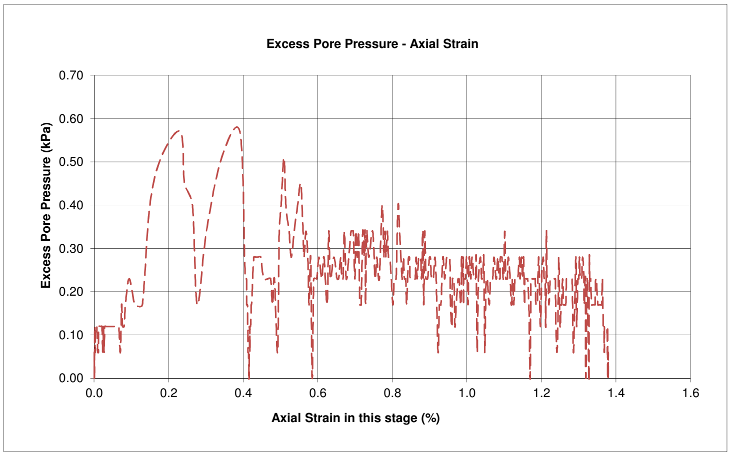
After Test `

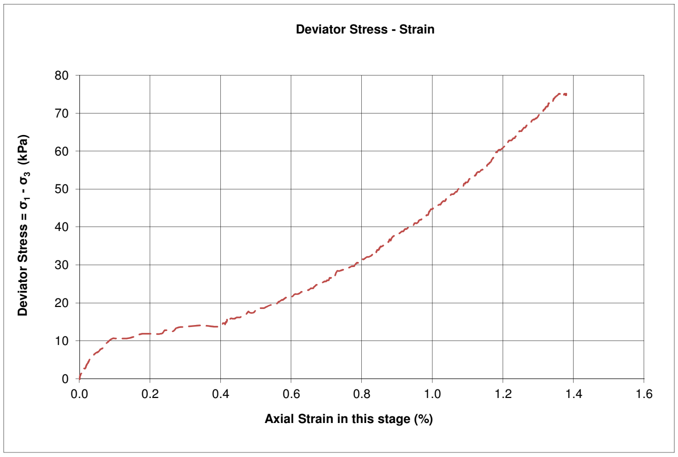


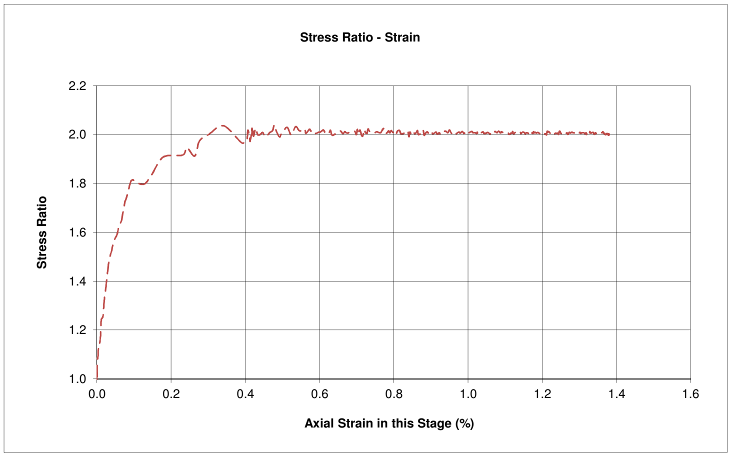
Triaxial CAU Test - Stress Control Anisotropic Consolidation, Kc = 0.5

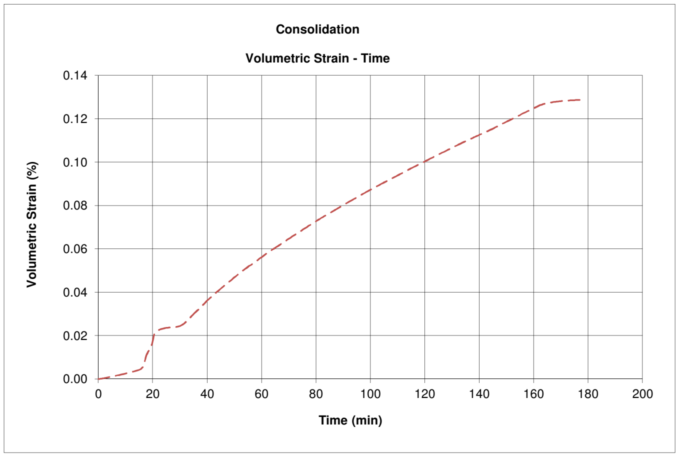
PROJECT NO. : A03355A01
DATE : 2019-10-14
PROJECT :
TEST BY: BY
SAMPLE : Coarse Gradation
CHECKED BY: JG
Details: Kc = 0.5, p' = 100 kPa, Stress rate = 1 kPa / min


Stress Path

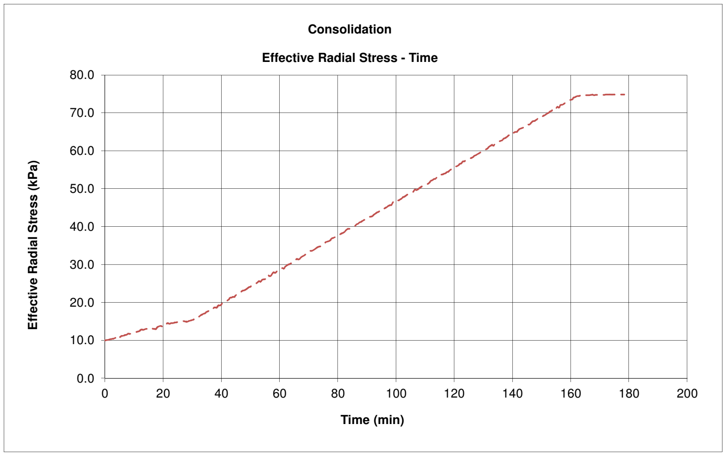

Excess Pore Pressure - Axial Strain


Deviator Stress - Strain


Stress Ratio - Strain


Consolidation

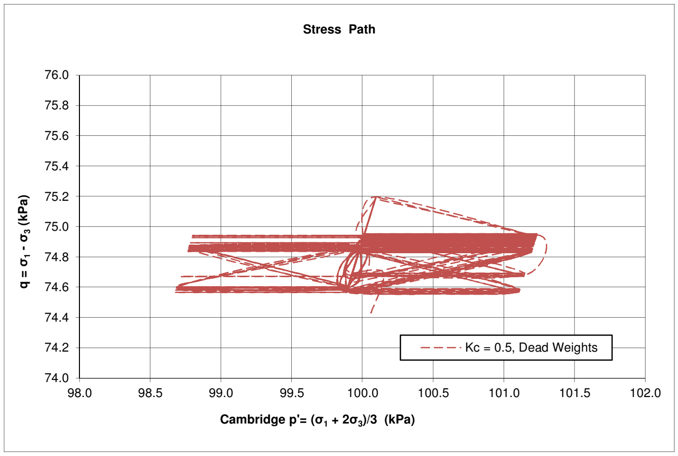
Volumetric Strain - Time

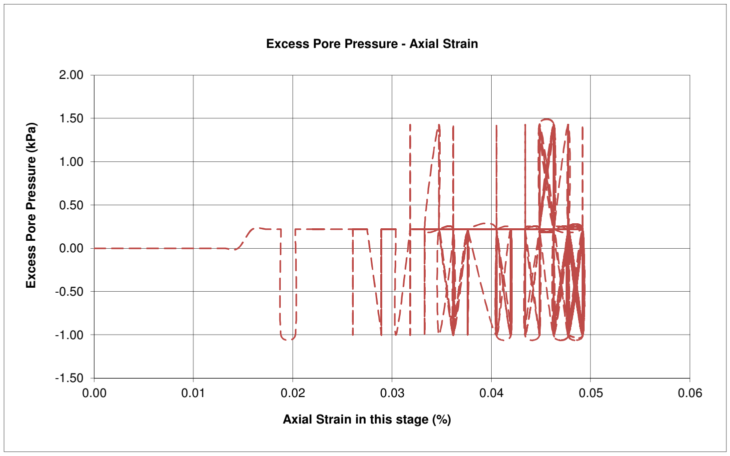

Consolidation

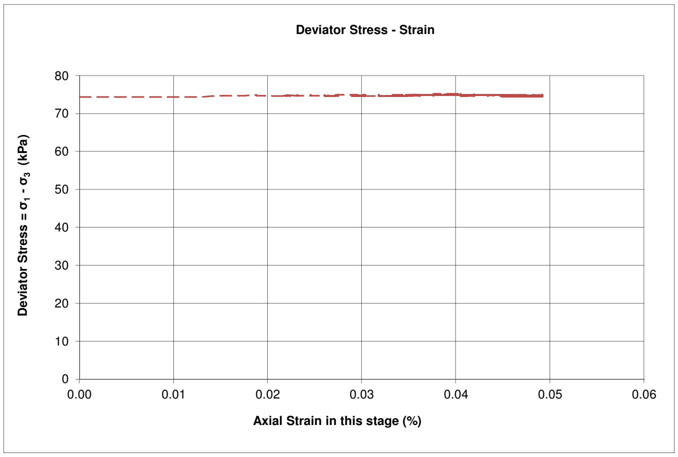
Effective Radial Stress - Time

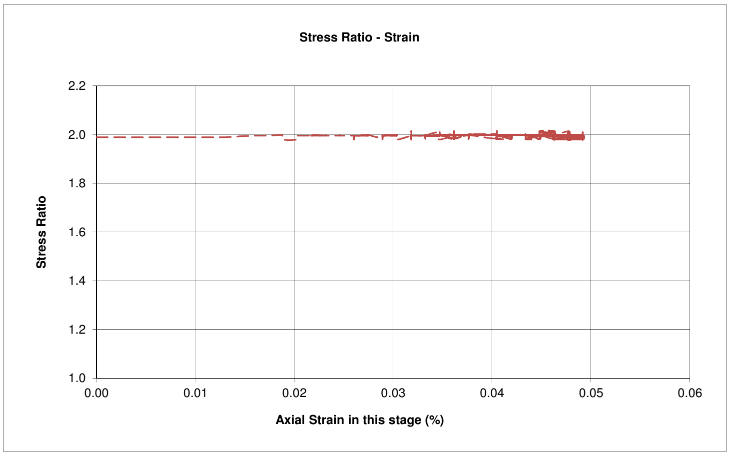
Triaxial Test - Dead Weights Constant Load at Kc = 0.5 (drained)

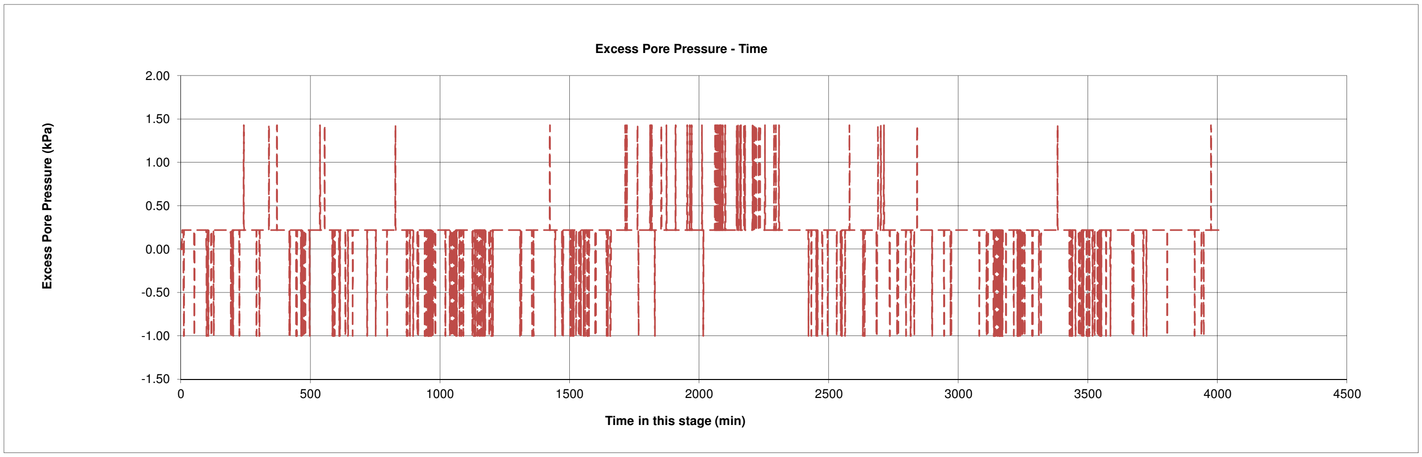
PROJECT NO. :	A03355A01	DATE :	2019-10-14
PROJECT :		TEST BY:	BY
SAMPLE :	Coarse Gradation	CHECKED BY:	JG
Details:	Anisotropic consolidation, Kc = 0.5, p' = 100 kPa, stress control		





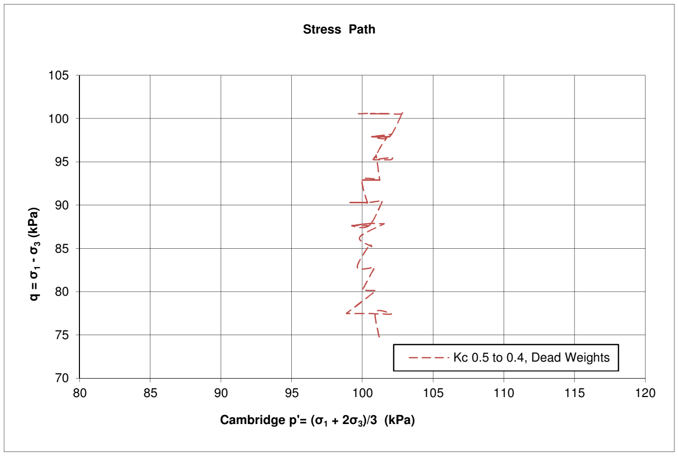


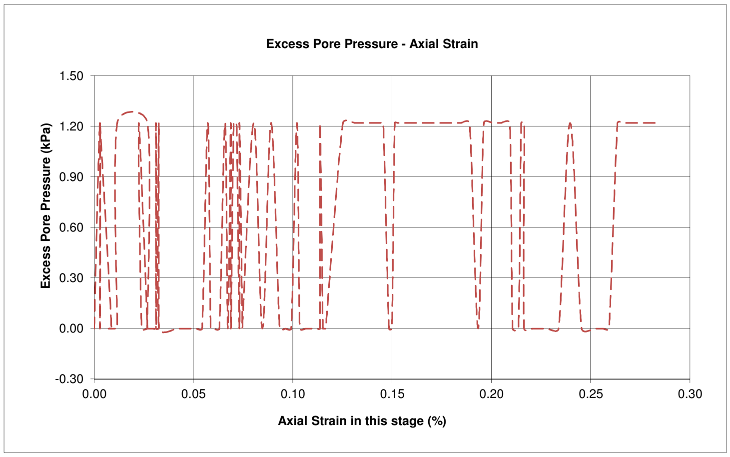


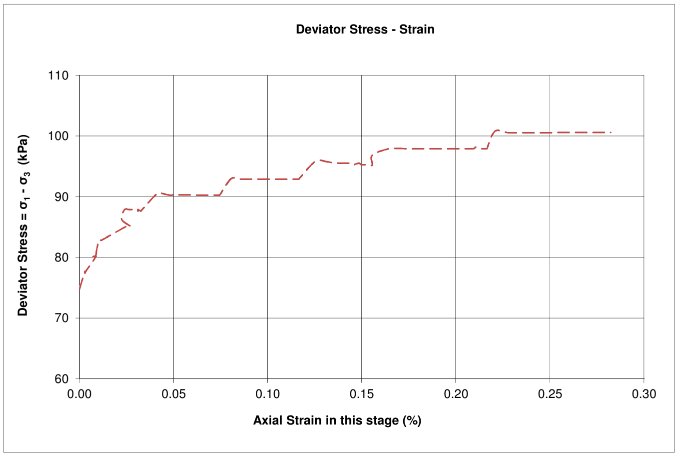


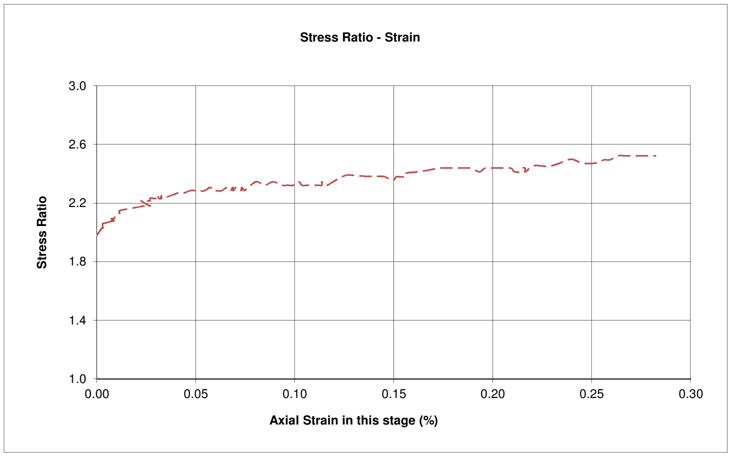
Triaxial CAU Test - Dead Weights Anisotropic Consolidation

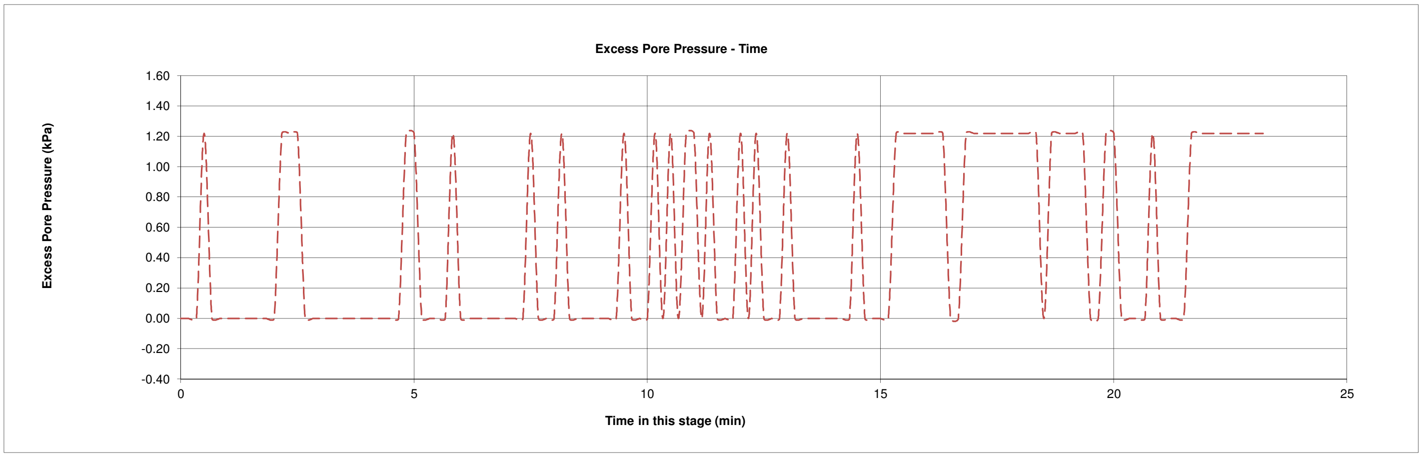
PROJECT NO. :	A03355A01	DATE :	2019-10-14
PROJECT :		TEST BY:	BY
SAMPLE :	Coarse Gradation	CHECKED BY:	JG
Details:	Dead weights loading Kc from 0.5 to 0.4, Constant p' = 100 kPa, Stress rate is around 1 kPa per minute		





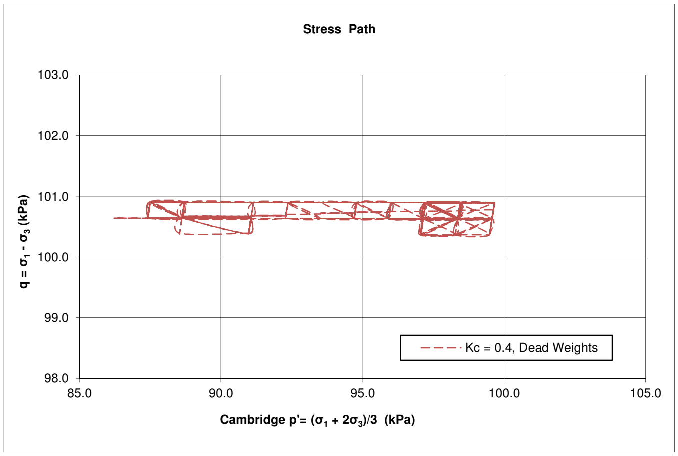


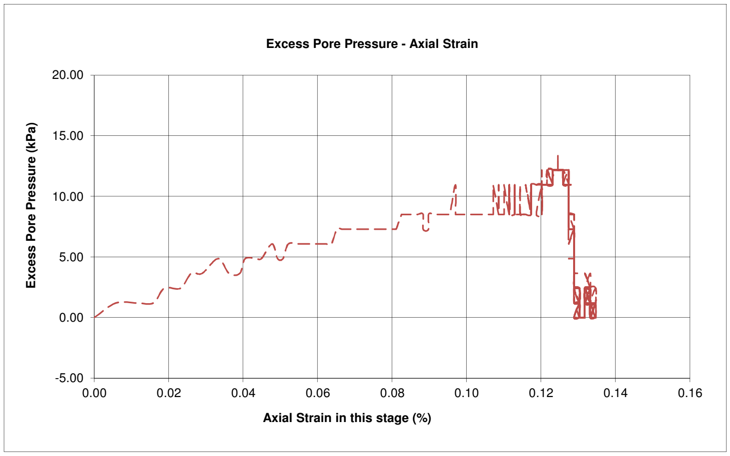


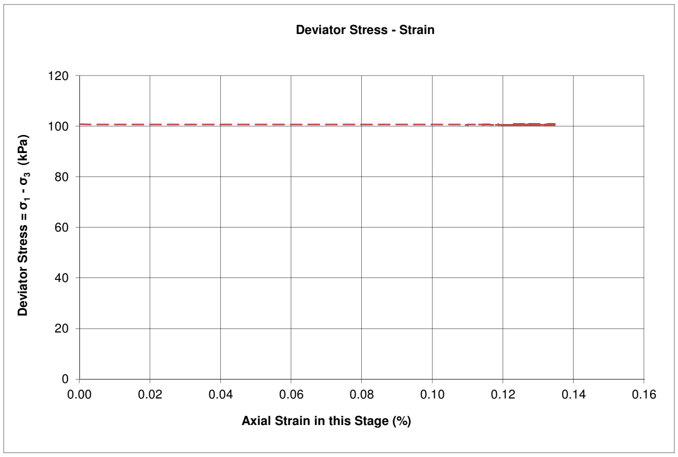


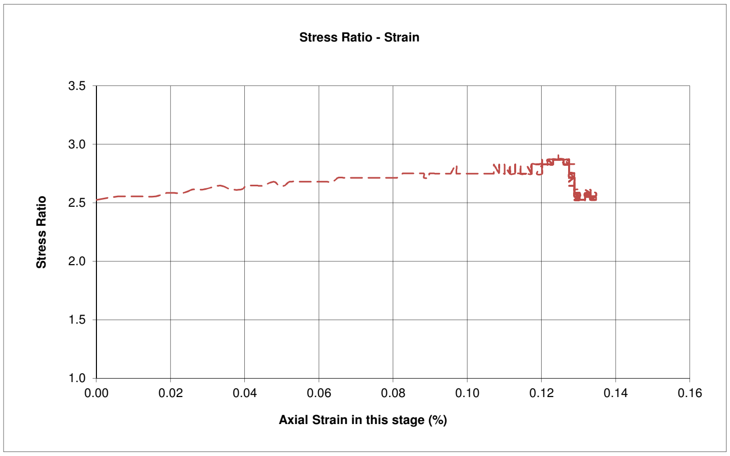
Triaxial Test - Dead Weights Constant Load at Kc = 0.4 (drained)

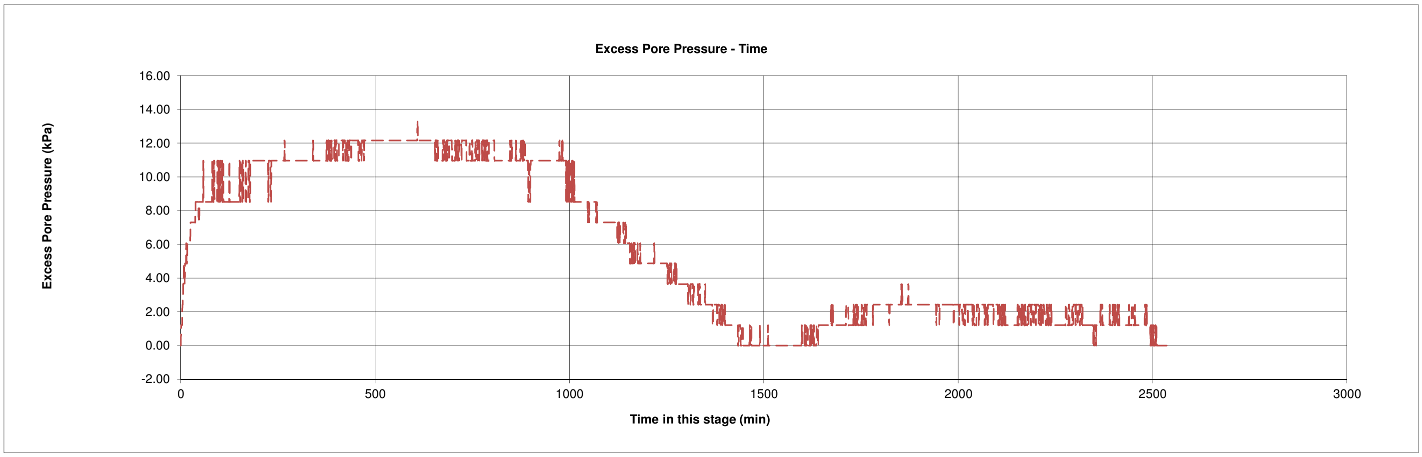
PROJECT NO. :	A03355A01	DATE :	2019-10-14
PROJECT :		TEST BY:	BY
SAMPLE :	Coarse Gradation	CHECKED BY:	JG
Details:	Kc = 0.4, constant dead weight load, undrained		







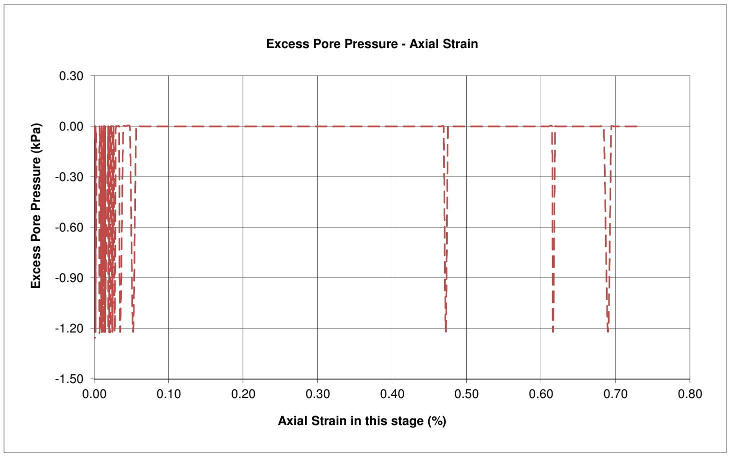


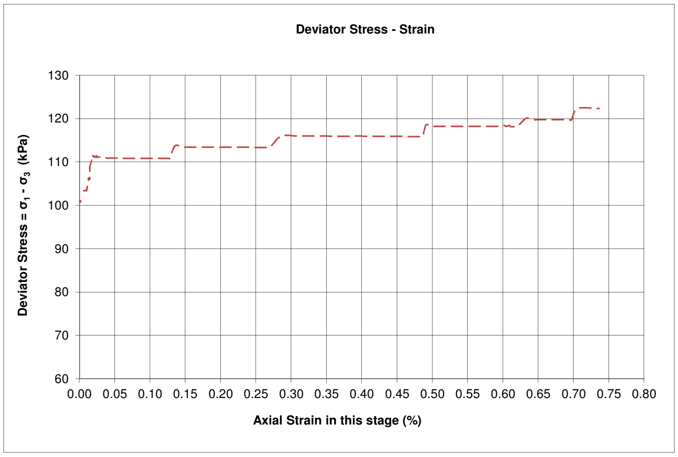


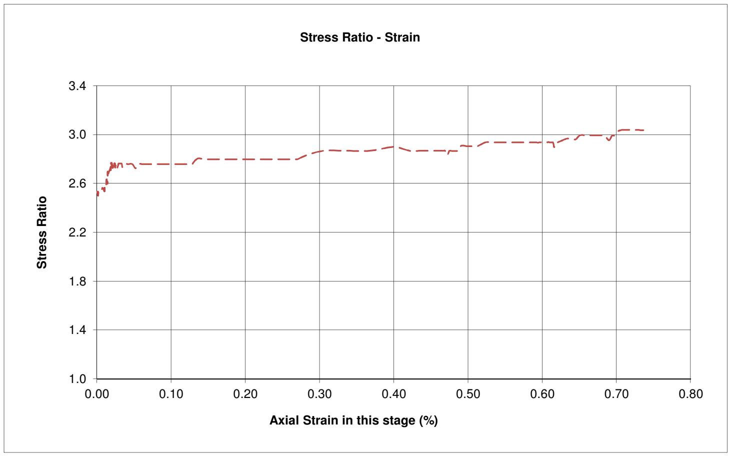
Triaxial CAU Test - Dead Weights Anisotropic Consolidation

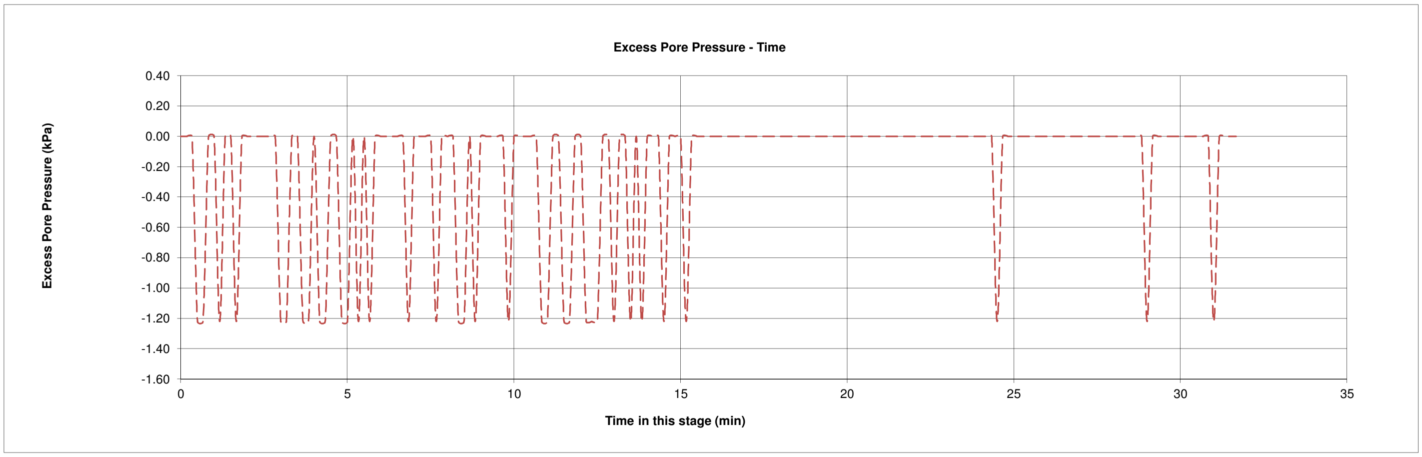
PROJECT NO. :	A03355A01	DATE :	2019-10-14
PROJECT :		TEST BY:	BY
SAMPLE :	Coarse Gradation	CHECKED BY:	JG
Details:	Dead weights loading Kc from 0.4 to 0.3, Constant p' = 100 kPa, Stress rate is around 1 kPa per minute (sample failed at Kc=0.33)		


Stress Path


Excess Pore Pressure - Axial Strain


Deviator Stress - Strain


Stress Ratio - Strain


Excess Pore Pressure - Time

Individual Bender Element Results

Triaxial Bender Element Test - Summary

PROJECT NO. A03355A01
PROJECT :
SAMPLE : Average
TEST NO. : TXBD01 e=1.2

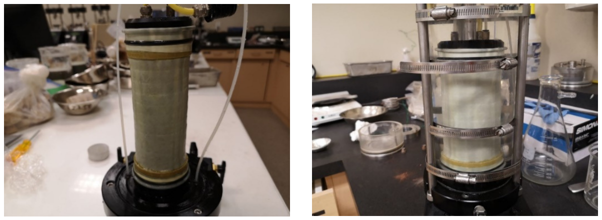
DATE : 2019-07-30
TESTED BY: BY
CHECKED BY: JG

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B value	End 1st Cons	End 2nd Cons	End 3rd Cons	End 4th Cons	End 5th Cons	End 6th Cons	End 7th Cons	End 8th Cons	End 9th Cons
Specimen Height	mm	138.93	138.93	138.93	138.38	137.62	137.18	136.66	135.95	135.47	135.02	134.75	134.45	134.10
Specimen Diameter	mm	69.80	69.65	67.81	67.84	67.37	67.09	66.79	66.48	66.27	66.14	66.02	65.90	65.77
Area	cm^2	38.26	38.10	36.12	36.15	35.64	35.35	35.04	34.71	34.50	34.36	34.23	34.11	33.97
Volume	cm^3	531.614	529.332	501.752	500.252	490.503	484.992	478.850	471.891	467.305	463.911	461.295	458.635	455.577
Wet Weight	g	1261.01	1261.01	1457.01	1458.57	1448.82	1443.31	1437.17	1430.21	1425.62	1422.23	1419.61	1416.95	1413.89
Water Content	%	5.12	5.12	21.46	21.59	20.78	20.32	19.80	19.22	18.84	18.56	18.34	18.12	17.86
Dry Weight	g	1199.59	1199.59	1199.59	1199.59	1199.59	1199.59	1199.59	1199.59	1199.59	1199.59	1199.59	1199.59	1199.59
Wet Density	g/cm^3	2.372	2.382	2.904	2.916	2.954	2.976	3.001	3.031	3.051	3.066	3.077	3.090	3.104
Dry Density	g/cm^3	2.257	2.266	2.391	2.398	2.446	2.473	2.505	2.542	2.567	2.586	2.600	2.616	2.633
Specific Gravity of Solids	-	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97
Solids Volume	cm^3	241.366	241.366	241.366	241.366	241.366	241.366	241.366	241.366	241.366	241.366	241.366	241.366	241.366
Void Volume	cm^3	290.248	287.966	260.386	258.886	249.136	243.625	237.484	230.525	225.939	222.545	219.929	217.268	214.211
Water Volume	cm^3	61.419	61.419	257.419	258.978	249.229	243.718	237.576	230.617	226.032	222.637	220.021	217.361	214.303
Void Ratio (e)	-	1.203	1.193	1.079	1.073	1.032	1.009	0.984	0.955	0.936	0.922	0.911	0.900	0.887
Saturation Ratio (Sr)	%	21.16	21.33	98.86	100.04	100.04	100.04	100.04	100.04	100.04	100.04	100.04	100.04	100.04
Effective Confining Stress	kPa					50	100	200	400	600	800	1000	1200	1500
Mean Shear Wave Velocity	m/s					**102.76**	**126.58**	**158.23**	**195.73**	**222.38**	**249.96**	**263.02**	**278.49**	**344.99**
Mean Shear Modulus	Mpa					**31.19**	**47.68**	**75.15**	**116.11**	**150.87**	**191.55**	**212.90**	**239.62**	**369.38**

Photos:

Before Test

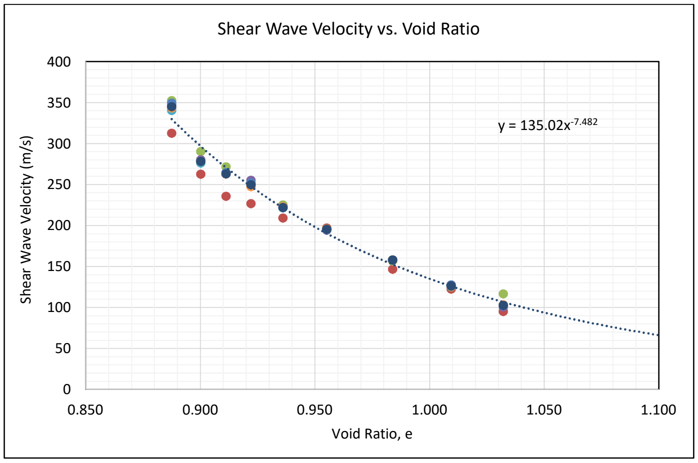
After Test

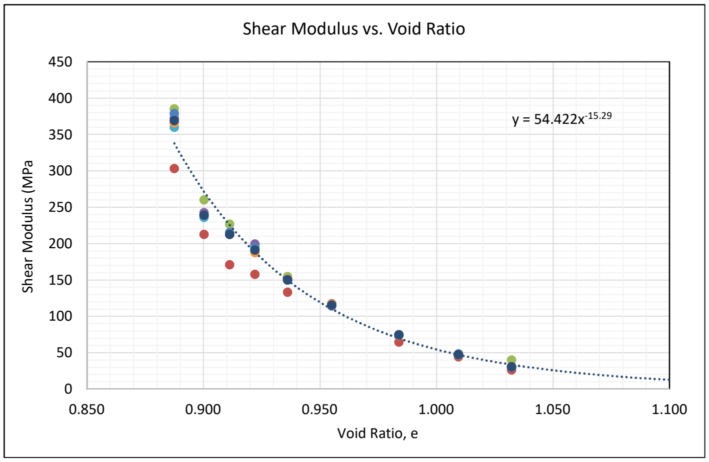


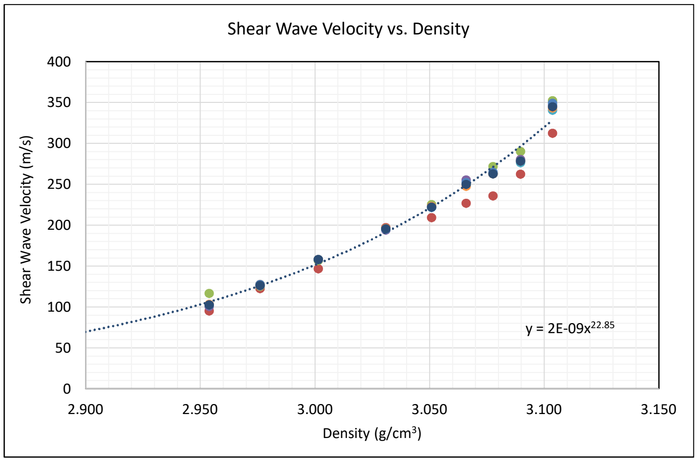
Triaxial Bender Element Test - Charts

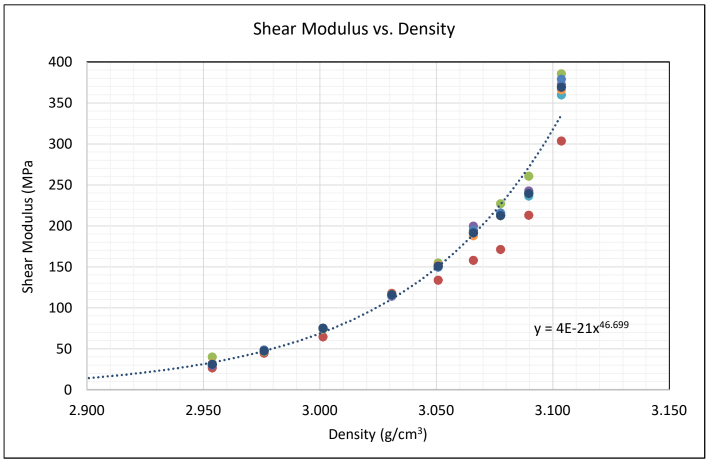
PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Average
TEST NO. : TXBD01 e=1.2

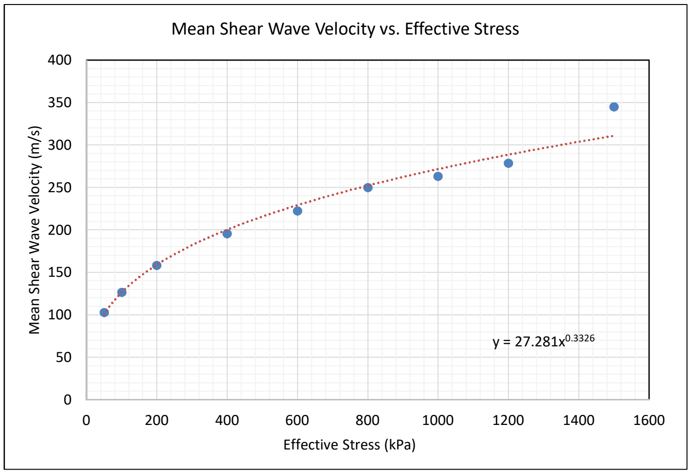
DATE : 2019-07-30
TEST BY: BY
CHECKED BY: JG

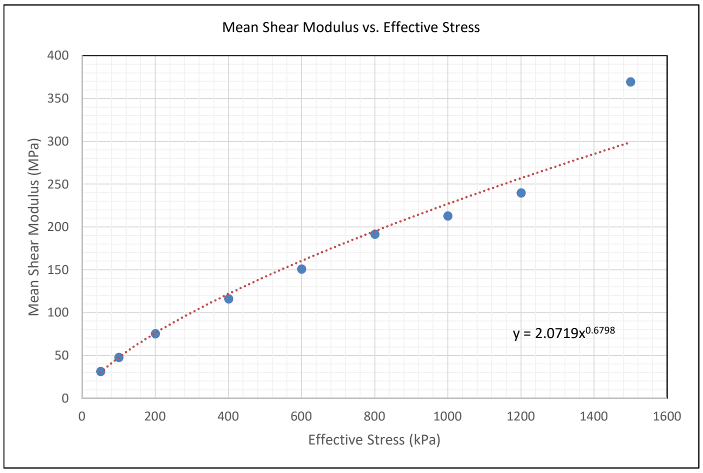












Triaxial Bender Element Test - Summary

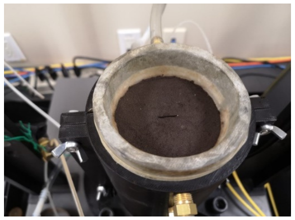
PROJECT NO. A03355A01
PROJECT :
SAMPLE : Average
TEST NO. : TXBD01 e=0.9

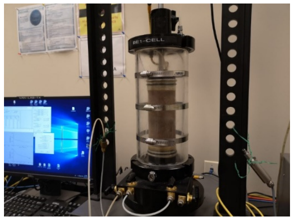
DATE : 2019-08-02
TESTED BY: BY
CHECKED BY: JG

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B value	End 1st Cons	End 2nd Cons	End 3rd Cons	End 4th Cons	End 5th Cons	End 6th Cons	End 7th Cons	End 8th Cons	End 9th Cons
Specimen Height	mm	139.14	138.96	138.96	138.91	138.91	138.85	138.75	138.58	138.45	138.33	138.22	138.13	138.00
Specimen Diameter	mm	69.90	69.90	69.84	69.85	69.78	69.73	69.65	69.54	69.45	69.38	69.32	69.26	69.17
Area	cm^2	38.37	38.37	38.31	38.32	38.24	38.18	38.10	37.98	37.88	37.80	37.74	37.67	37.58
Volume	cm^3	533.945	533.254	532.344	532.344	531.243	530.205	528.624	526.304	524.515	522.939	521.648	520.320	518.621
Wet Weight	g	1515.67	1515.67	1640.80	1647.57	1646.47	1645.43	1643.85	1641.53	1639.74	1638.17	1636.87	1635.55	1633.85
Water Content	%	8.79	8.79	17.77	18.26	18.18	18.10	17.99	17.82	17.70	17.58	17.49	17.39	17.27
Dry Weight	g	1393.21	1393.21	1393.21	1393.21	1393.21	1393.21	1393.21	1393.21	1393.21	1393.21	1393.21	1393.21	1393.21
Wet Density	g/cm^3	2.839	2.842	3.082	3.095	3.099	3.103	3.110	3.119	3.126	3.133	3.138	3.143	3.150
Dry Density	g/cm^3	2.609	2.613	2.617	2.617	2.623	2.628	2.636	2.647	2.656	2.664	2.671	2.678	2.686
Specific Gravity of Solids	-	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97
Solids Volume	cm^3	280.323	280.323	280.323	280.323	280.323	280.323	280.323	280.323	280.323	280.323	280.323	280.323	280.323
Void Volume	cm^3	253.621	252.931	252.021	252.021	250.920	249.882	248.301	245.980	244.192	242.615	241.325	239.997	238.298
Water Volume	cm^3	122.463	122.463	247.593	254.363	253.262	252.224	250.643	248.323	246.534	244.958	243.667	242.339	240.640
Void Ratio (e)	-	0.905	0.902	0.899	0.899	0.895	0.891	0.886	0.877	0.871	0.865	0.861	0.856	0.850
Saturation Ratio (Sr)	%	48.29	48.42	98.24	100.93	100.93	100.94	100.94	100.95	100.96	100.97	100.97	100.98	100.98
Effective Confining Stress	kPa					50	100	200	400	600	800	1000	1200	1500
Mean Shear Wave Velocity	m/s					**135.47**	**163.12**	**196.33**	**236.14**	**259.09**	**275.87**	**290.81**	**301.16**	**307.29**
Mean Shear Modulus	Mpa					**56.88**	**82.57**	**119.86**	**173.92**	**209.86**	**238.47**	**265.40**	**285.27**	**297.52**

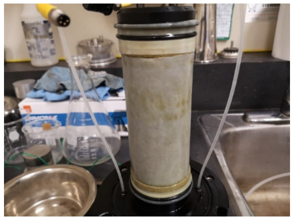
Photos:

Before Test





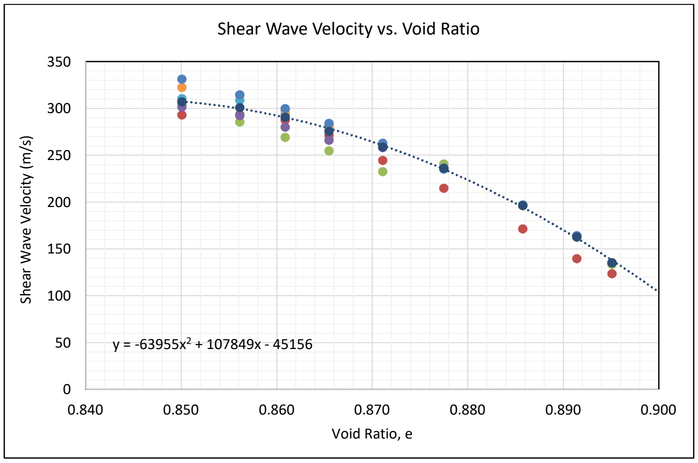
After Test

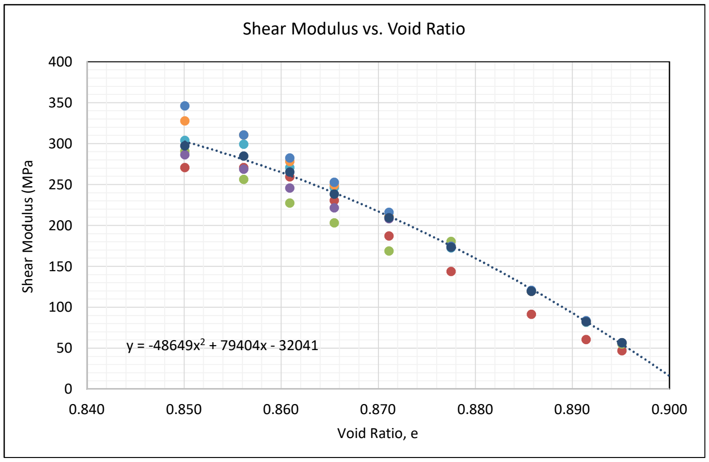


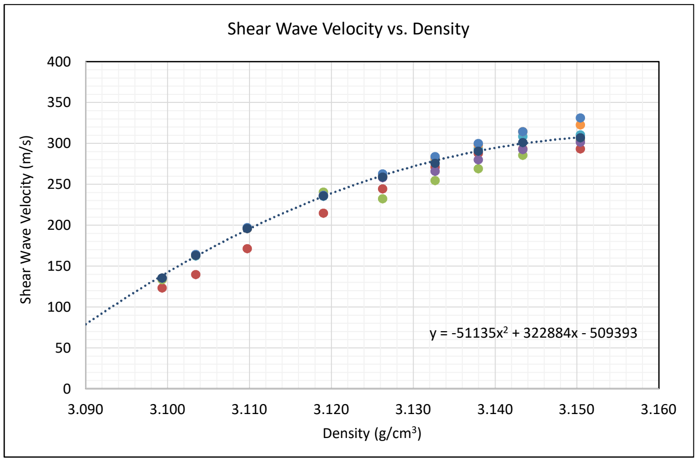
Triaxial Bender Element Test - Charts

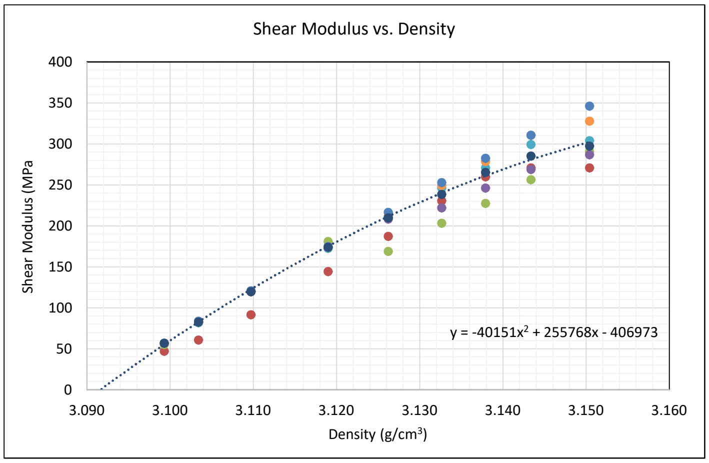
PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Average
TEST NO. : TXBD01 e=0.9

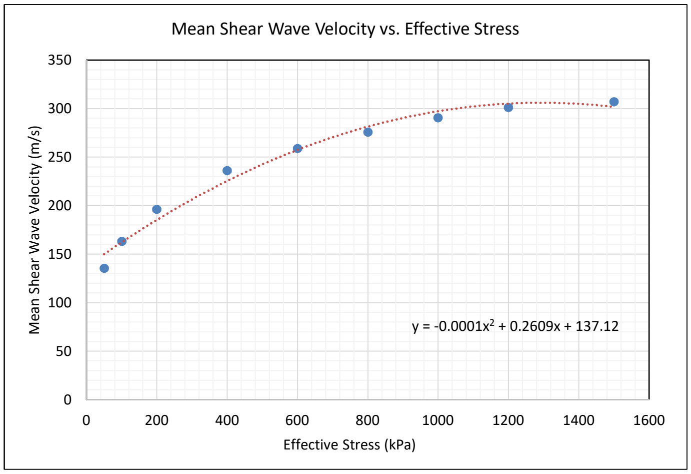
DATE : 2019-08-02
TEST BY: BY
CHECKED BY: JG

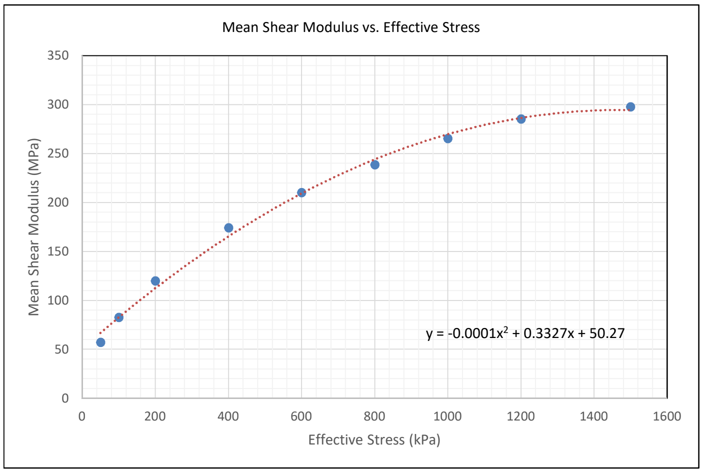












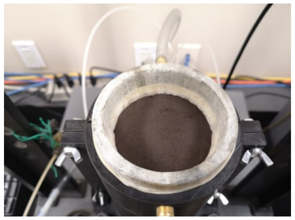
Triaxial Bender Element Test - Summary

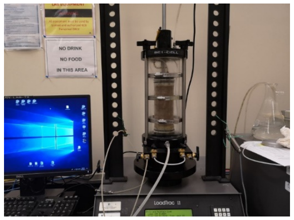
PROJECT NO.	A03355A01	DATE :	2019-08-12
PROJECT :		TESTED BY:	BY
SAMPLE :	Average	CHECKED BY:	JG
TEST NO. :	TXBD03 e=1.0		

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B value	End 1st Cons	End 2nd Cons	End 3rd Cons	End 4th Cons	End 5th Cons	End 6th Cons	End 7th Cons	End 8th Cons	End 9th Cons
Specimen Height	mm	139.17	138.92	138.92	138.83	138.79	138.66	138.45	138.14	137.89	137.64	137.46	137.27	137.02
Specimen Diameter	mm	69.80	69.66	69.50	69.53	69.49	69.39	69.24	69.04	68.89	68.75	68.64	68.55	68.41
Area	cm^2	38.26	38.11	37.94	37.97	37.93	37.81	37.66	37.44	37.27	37.12	37.00	36.90	36.75
Volume	cm^3	532.533	529.446	527.076	527.076	526.400	524.355	521.365	517.167	513.954	510.891	508.647	506.609	503.610
Wet Weight	g	1386.60	1386.60	1579.20	1587.07	1586.39	1584.35	1581.36	1577.16	1573.95	1570.89	1568.64	1566.60	1563.60
Water Content	%	4.73	4.73	19.28	19.87	19.82	19.67	19.44	19.12	18.88	18.65	18.48	18.33	18.10
Dry Weight	g	1323.98	1323.98	1323.98	1323.98	1323.98	1323.98	1323.98	1323.98	1323.98	1323.98	1323.98	1323.98	1323.98
Wet Density	g/cm^3	2.604	2.619	2.996	3.011	3.014	3.022	3.033	3.050	3.062	3.075	3.084	3.092	3.105
Dry Density	g/cm^3	2.486	2.501	2.512	2.512	2.515	2.525	2.539	2.560	2.576	2.592	2.603	2.613	2.629
Specific Gravity of Solids	-	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97
Solids Volume	cm^3	266.394	266.394	266.394	266.394	266.394	266.394	266.394	266.394	266.394	266.394	266.394	266.394	266.394
Void Volume	cm^3	266.139	263.052	260.682	260.682	260.007	257.962	254.972	250.773	247.561	244.498	242.253	240.216	237.216
Water Volume	cm^3	62.624	62.624	255.224	263.094	262.418	260.373	257.383	253.185	249.972	246.909	244.665	242.627	239.627
Void Ratio (e)	-	0.999	0.987	0.979	0.979	0.976	0.968	0.957	0.941	0.929	0.918	0.909	0.902	0.890
Saturation Ratio (Sr)	%	23.53	23.81	97.91	100.93	100.93	100.93	100.95	100.96	100.97	100.99	101.00	101.00	101.02
Effective Confining Stress	kPa					50	100	200	400	600	800	1000	1200	1500
Mean Shear Wave Velocity	m/s					**102.44**	**128.59**	**163.83**	**207.36**	**231.49**	**256.52**	**274.66**	**280.67**	**303.55**
Mean Shear Modulus	MPa					**31.62**	**49.97**	**81.41**	**131.13**	**164.10**	**202.33**	**232.65**	**243.60**	**286.08**

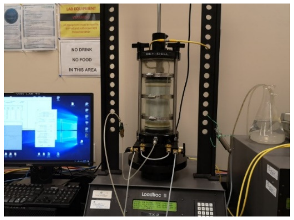
Photos:

Before Test





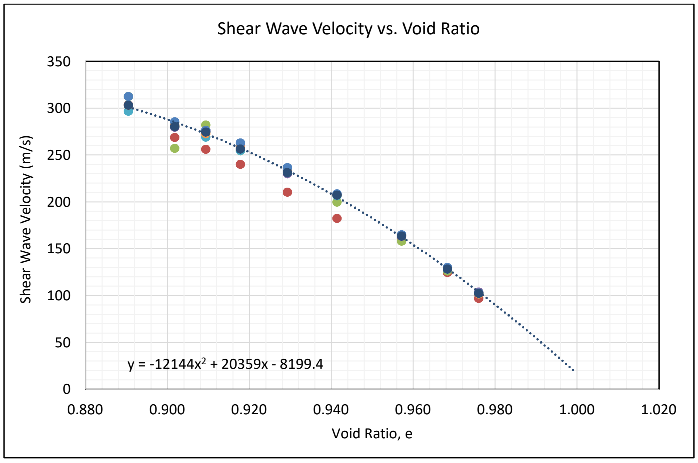
After Test

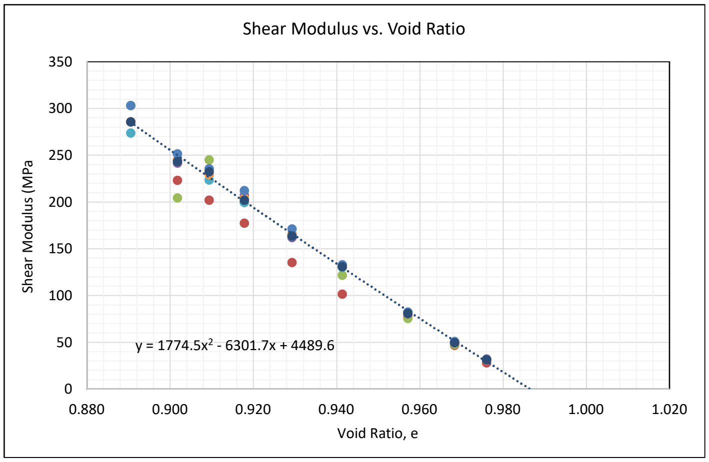


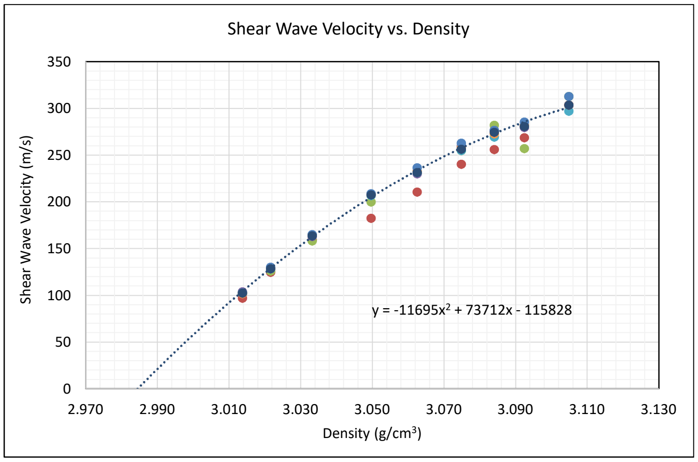
Triaxial Bender Element Test - Charts

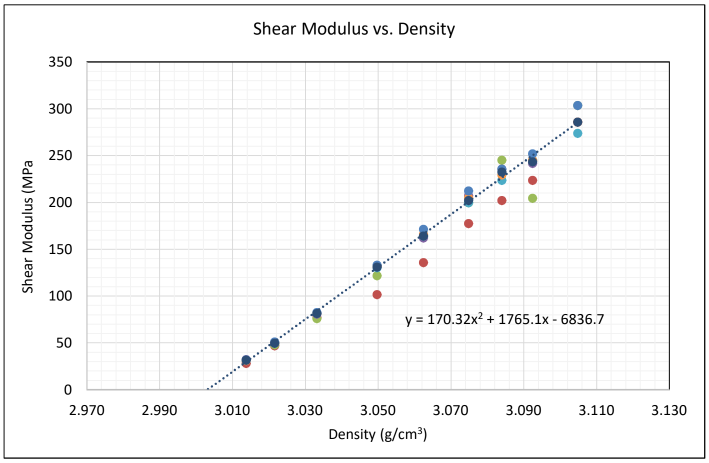
PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Average
TEST NO. : TXBD03 e=1.0

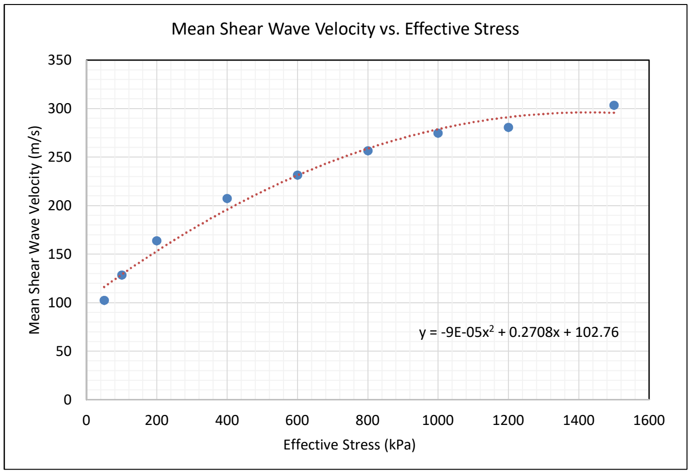
DATE : 2019-08-12
TEST BY: BY
CHECKED BY: JG

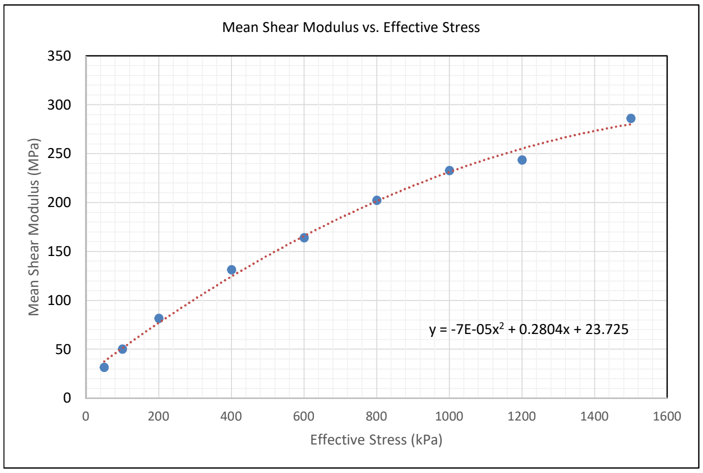












Triaxial Bender Element Test - Summary

PROJECT NO. A03355A01
PROJECT :
SAMPLE : Fine Gradation
TEST NO. : TXBD04 e=1.1

DATE : 2019-08-19
TESTED BY: BY
CHECKED BY: JG

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B value	End 1st Cons	End 2nd Cons	End 3rd Cons	End 4th Cons	End 5th Cons	End 6th Cons	End 7th Cons	End 8th Cons	End 9th Cons
Specimen Height	mm	138.53	138.2	138.20	138.18	138.18	138.07	137.87	137.52	137.27	137.01	136.83	136.63	136.39
Specimen Diameter	mm	69.80	69.90	69.73	69.73	69.62	69.46	69.27	69.05	68.88	68.76	68.64	68.53	68.40
Area	cm^2	38.26	38.37	38.18	38.19	38.07	37.90	37.69	37.45	37.27	37.13	37.00	36.89	36.74
Volume	cm^3	530.084	530.337	527.693	527.693	525.982	523.238	519.640	514.983	511.560	508.719	506.283	504.042	501.112
Wet Weight	g	1352.17	1352.17	1521.27	1529.28	1527.57	1524.83	1521.23	1516.57	1513.15	1510.31	1507.87	1505.63	1502.70
Water Content	%	7.99	7.99	21.50	22.13	22.00	21.78	21.49	21.12	20.85	20.62	20.42	20.25	20.01
Dry Weight	g	1252.13	1252.13	1252.13	1252.13	1252.13	1252.13	1252.13	1252.13	1252.13	1252.13	1252.13	1252.13	1252.13
Wet Density	g/cm^3	2.551	2.550	2.883	2.898	2.904	2.914	2.927	2.945	2.958	2.969	2.978	2.987	2.999
Dry Density	g/cm^3	2.362	2.361	2.373	2.373	2.381	2.393	2.410	2.431	2.448	2.461	2.473	2.484	2.499
Specific Gravity of Solids	-	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96
Solids Volume	cm^3	252.445	252.445	252.445	252.445	252.445	252.445	252.445	252.445	252.445	252.445	252.445	252.445	252.445
Void Volume	cm^3	277.639	277.893	275.249	275.249	273.537	270.793	267.196	262.539	259.115	256.274	253.838	251.597	248.667
Water Volume	cm^3	100.045	100.045	269.145	277.157	275.445	272.701	269.104	264.446	261.023	258.182	255.746	253.505	250.575
Void Ratio (e)	-	1.100	1.101	1.090	1.090	1.084	1.073	1.058	1.040	1.026	1.015	1.006	0.997	0.985
Saturation Ratio (Sr)	%	36.03	36.00	97.78	100.69	100.70	100.70	100.71	100.73	100.74	100.74	100.75	100.76	100.77
Effective Confining Stress	kPa					50	100	200	400	600	800	1000	1200	1500
Mean Shear Wave Velocity	m/s					**110.60**	**134.51**	**164.93**	**201.29**	**225.28**	**243.20**	**261.11**	**274.49**	**285.29**
Mean Shear Modulus	MPa					**35.52**	**52.72**	**79.63**	**119.32**	**150.12**	**175.60**	**203.06**	**225.07**	**244.12**

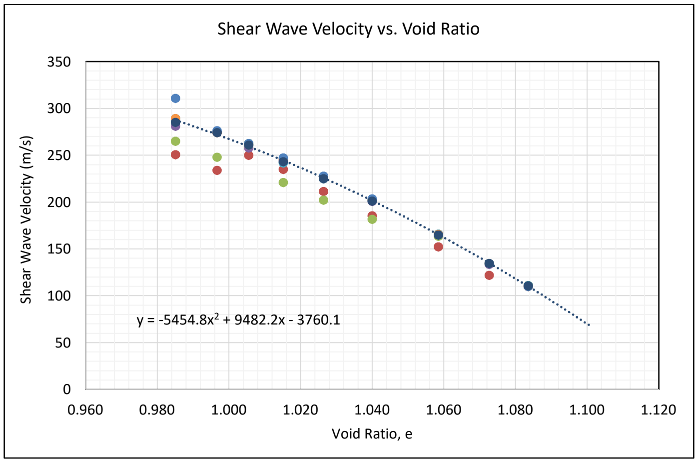
Photos:

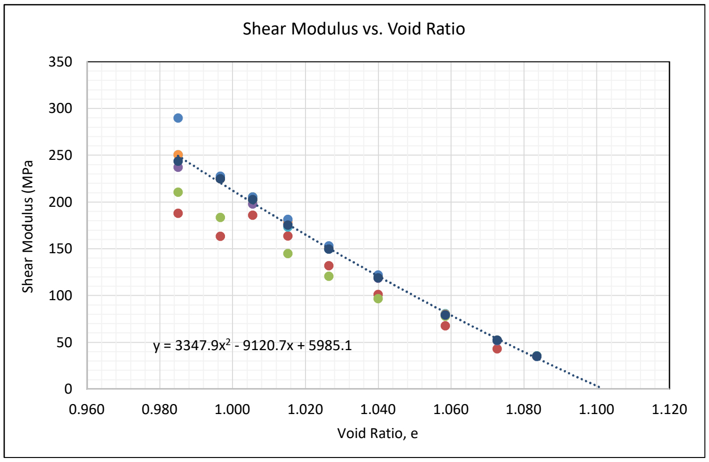
Before Test

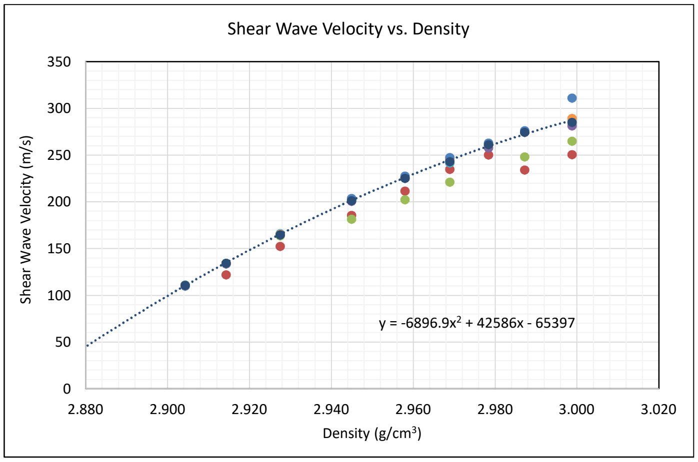
After Test

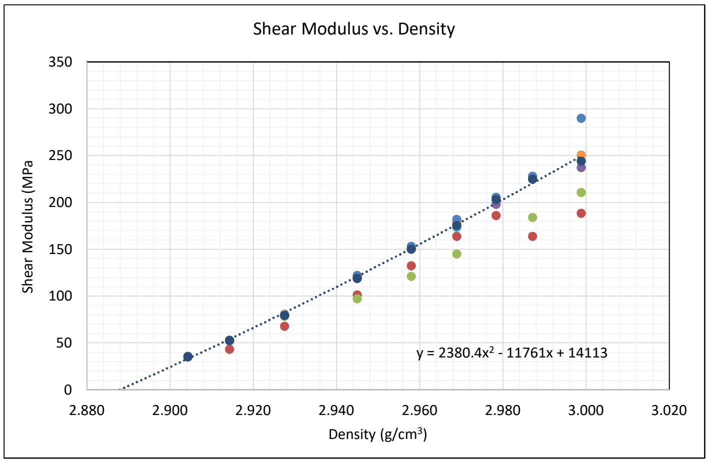
Triaxial Bender Element Test - Charts

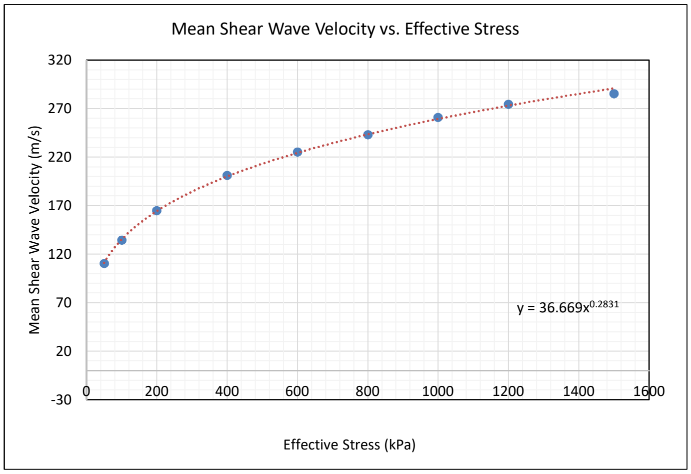
PROJECT NO. :	A03355A01	DATE :	2019-08-19
PROJECT :		TEST BY:	BY
SAMPLE :	Fine Gradation	CHECKED BY:	JG
TEST NO. :	TXBD04 e=1.1		

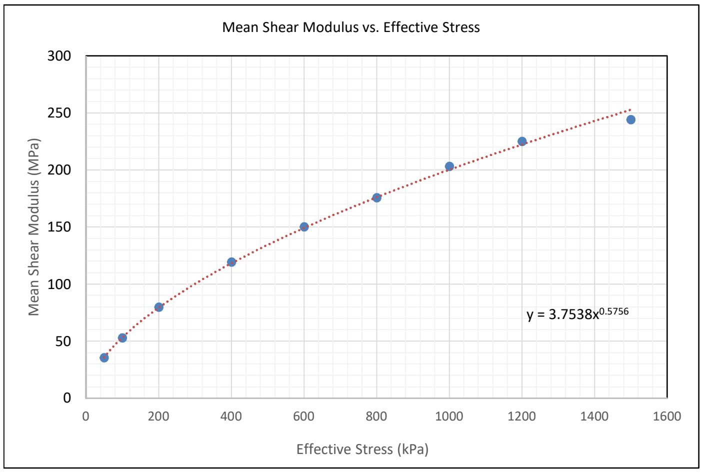












Triaxial Bender Element Test - Summary

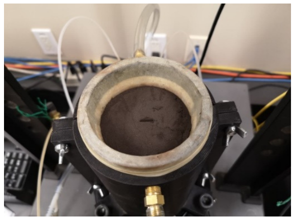
PROJECT NO. A03355A01
PROJECT :
SAMPLE : Fine Gradation
TEST NO. : TXBD05 e=0.9

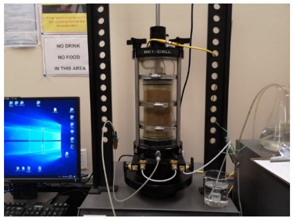
DATE : 2019-08-22
TESTED BY: BY
CHECKED BY: JG

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B value	End 1st Cons	End 2nd Cons	End 3rd Cons	End 4th Cons	End 5th Cons	End 6th Cons	End 7th Cons	End 8th Cons	End 9th Cons
Specimen Height	mm	139.08	138.72	138.72	138.68	138.62	138.55	138.42	138.31	138.19	138.10	138.01	137.91	137.82
Specimen Diameter	mm	70.15	70.15	70.12	70.13	70.07	70.02	69.96	69.87	69.81	69.75	69.71	69.66	69.60
Area	cm^2	38.65	38.65	38.62	38.63	38.57	38.51	38.44	38.35	38.28	38.21	38.16	38.12	38.04
Volume	cm^3	537.539	536.148	535.691	535.691	534.602	533.554	532.121	530.373	528.964	527.736	526.667	525.683	524.309
Wet Weight	g	1503.34	1503.34	1629.34	1650.20	1649.11	1648.06	1646.63	1644.88	1643.47	1642.24	1641.17	1640.19	1638.81
Water Content	%	7.89	7.89	16.93	18.43	18.35	18.28	18.17	18.05	17.95	17.86	17.78	17.71	17.61
Dry Weight	g	1393.40	1393.40	1393.40	1393.40	1393.40	1393.40	1393.40	1393.40	1393.40	1393.40	1393.40	1393.40	1393.40
Wet Density	g/cm^3	2.797	2.804	3.042	3.081	3.085	3.089	3.094	3.101	3.107	3.112	3.116	3.120	3.126
Dry Density	g/cm^3	2.592	2.599	2.601	2.601	2.606	2.612	2.619	2.627	2.634	2.640	2.646	2.651	2.658
Specific Gravity of Solids	-	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96
Solids Volume	cm^3	280.928	280.928	280.928	280.928	280.928	280.928	280.928	280.928	280.928	280.928	280.928	280.928	280.928
Void Volume	cm^3	256.611	255.220	254.763	254.763	253.674	252.626	251.193	249.445	248.036	246.809	245.740	244.756	243.381
Water Volume	cm^3	109.939	109.939	235.939	256.795	255.706	254.658	253.225	251.477	250.068	248.841	247.772	246.788	245.413
Void Ratio (e)	-	0.913	0.908	0.907	0.907	0.903	0.899	0.894	0.888	0.883	0.879	0.875	0.871	0.866
Saturation Ratio (Sr)	%	42.84	43.08	92.61	100.80	100.80	100.80	100.81	100.81	100.82	100.82	100.83	100.83	100.83
Effective Confining Stress	kPa					50	100	200	400	600	800	1000	1200	1500
Mean Shear Wave Velocity	m/s					**134.71**	**159.32**	**193.98**	**228.55**	**254.59**	**273.45**	**289.26**	**303.69**	**320.26**
Mean Shear Modulus	MPa					**55.98**	**78.40**	**116.43**	**161.99**	**201.38**	**232.70**	**260.74**	**287.76**	**320.58**

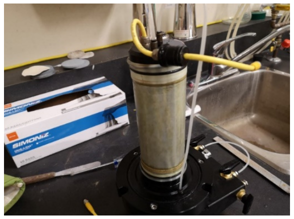
Photos:

Before Test





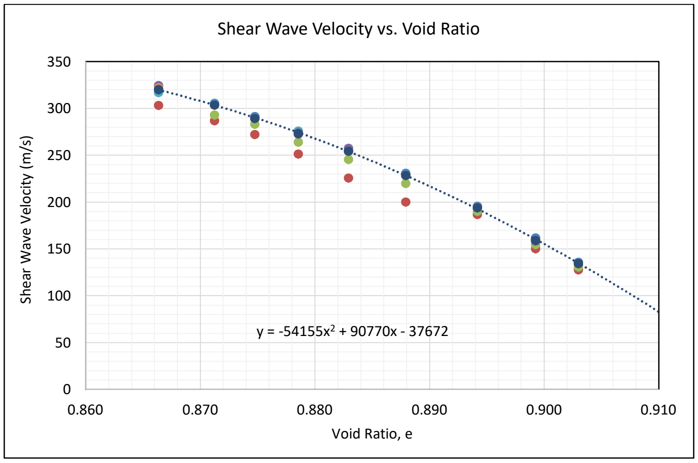
After Test

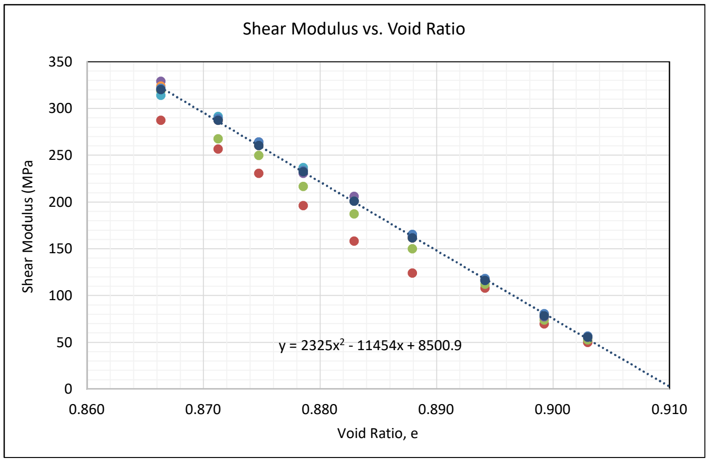


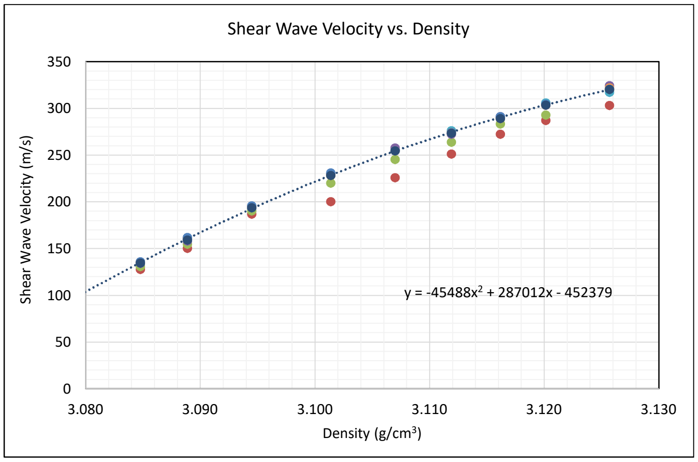
Triaxial Bender Element Test - Charts

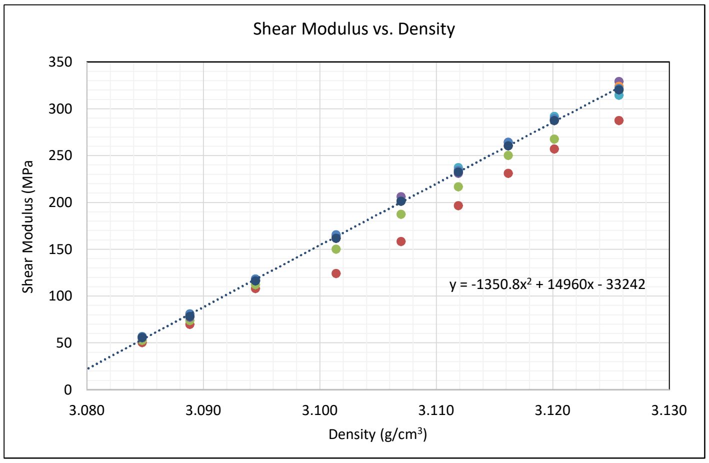
PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Fine Gradation
TEST NO. : TXBD05 e=0.9

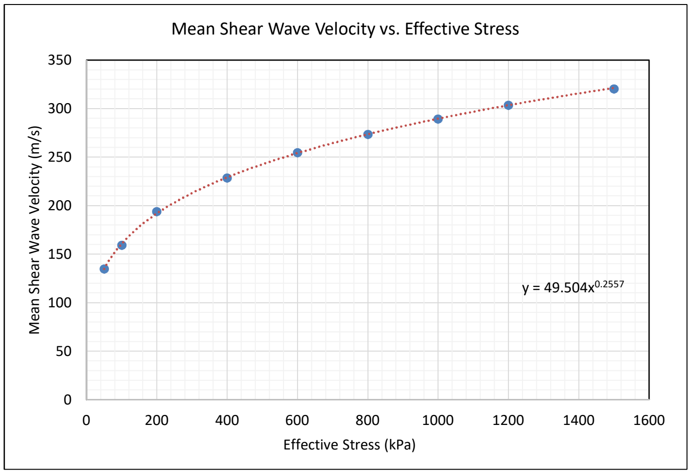
DATE : 2019-08-22
TEST BY: BY
CHECKED BY: JG

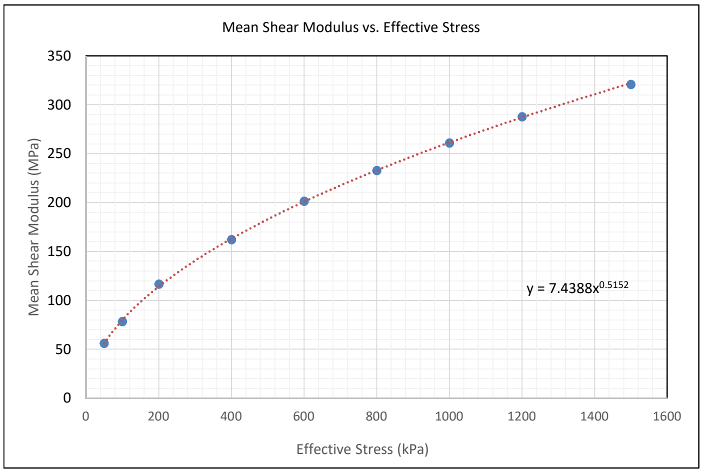












Triaxial Bender Element Test - Summary

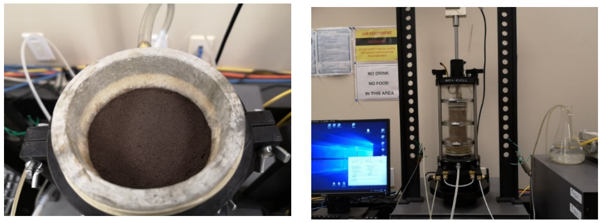
PROJECT NO. A03355A01
PROJECT :
SAMPLE : Coarse
TEST NO. : TXBD06 e=1.1

DATE : 2019-08-23
TESTED BY: BY
CHECKED BY: JG

SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B value	End 1st Cons	End 2nd Cons	End 3rd Cons	End 4th Cons	End 5th Cons	End 6th Cons	End 7th Cons	End 8th Cons	End 9th Cons
Specimen Height	mm	139.2	138.17	138.17	138.10	137.79	137.43	136.92	136.24	135.72	135.32	134.96	134.62	134.18
Specimen Diameter	mm	69.80	69.86	69.29	69.31	68.94	68.63	68.30	67.93	67.67	67.49	67.33	67.19	67.01
Area	cm^2	38.26	38.33	37.71	37.73	37.32	37.00	36.64	36.25	35.97	35.77	35.61	35.45	35.27
Volume	cm^3	532.648	529.616	521.066	521.066	514.289	508.426	501.648	493.816	488.152	484.081	480.544	477.272	473.280
Wet Weight	g	1342.27	1342.27	1509.57	1512.46	1505.68	1499.82	1493.04	1485.21	1479.55	1475.47	1471.94	1468.67	1464.67
Water Content	%	8.02	8.02	21.48	21.72	21.17	20.70	20.15	19.52	19.07	18.74	18.46	18.19	17.87
Dry Weight	g	1242.61	1242.61	1242.61	1242.61	1242.61	1242.61	1242.61	1242.61	1242.61	1242.61	1242.61	1242.61	1242.61
Wet Density	g/cm^3	2.520	2.534	2.897	2.903	2.928	2.950	2.976	3.008	3.031	3.048	3.063	3.077	3.095
Dry Density	g/cm^3	2.333	2.346	2.385	2.385	2.416	2.444	2.477	2.516	2.546	2.567	2.586	2.604	2.626
Specific Gravity of Solids	-	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91
Solids Volume	cm^3	253.078	253.078	253.078	253.078	253.078	253.078	253.078	253.078	253.078	253.078	253.078	253.078	253.078
Void Volume	cm^3	279.570	276.538	267.988	267.988	261.211	255.348	248.570	240.738	235.074	231.003	227.467	224.195	220.202
Water Volume	cm^3	99.658	99.658	266.958	269.847	263.070	257.208	250.429	242.597	236.934	232.862	229.326	226.054	222.062
Void Ratio (e)	-	1.105	1.093	1.059	1.059	1.032	1.009	0.982	0.951	0.929	0.913	0.899	0.886	0.870
Saturation Ratio (Sr)	%	35.65	36.04	99.62	100.69	100.71	100.73	100.75	100.77	100.79	100.80	100.82	100.83	100.84
Effective Confining Stress	kPa					50	100	200	400	600	800	1000	1200	1500
Mean Shear Wave Velocity	m/s					**104.77**	**129.61**	**162.32**	**203.98**	**236.33**	**252.16**	**263.61**	**283.79**	**291.98**
Mean Shear Modulus	MPa					**32.13**	**49.56**	**78.41**	**125.14**	**169.28**	**193.81**	**212.93**	**247.83**	**263.95**

Photos:

Before Test

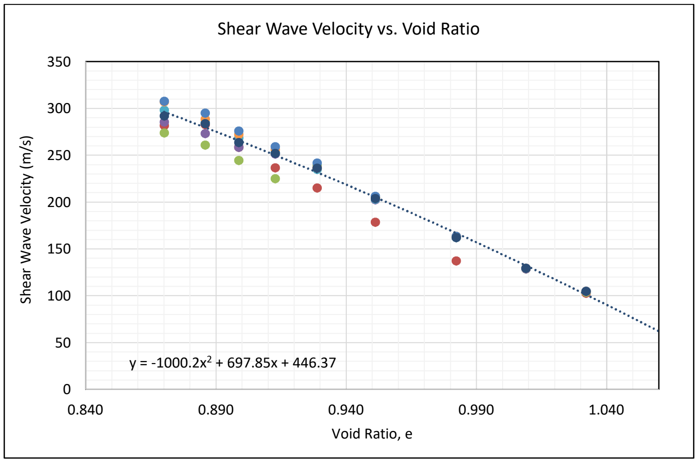


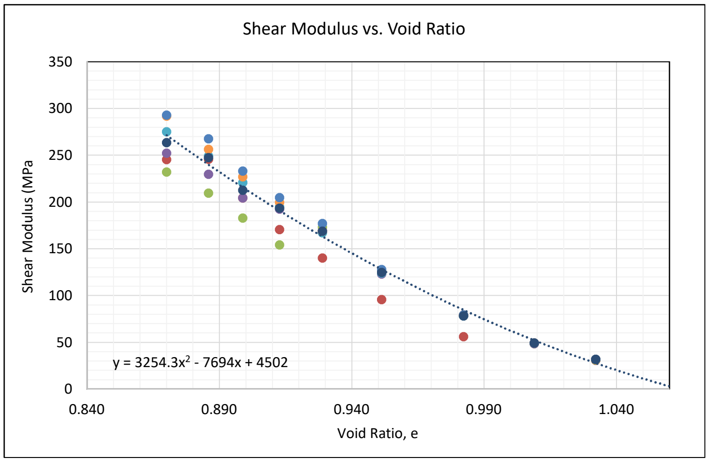
After Test

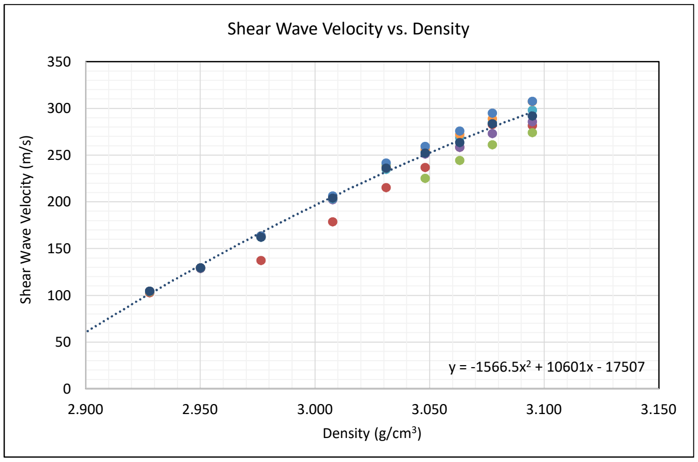
Triaxial Bender Element Test - Charts

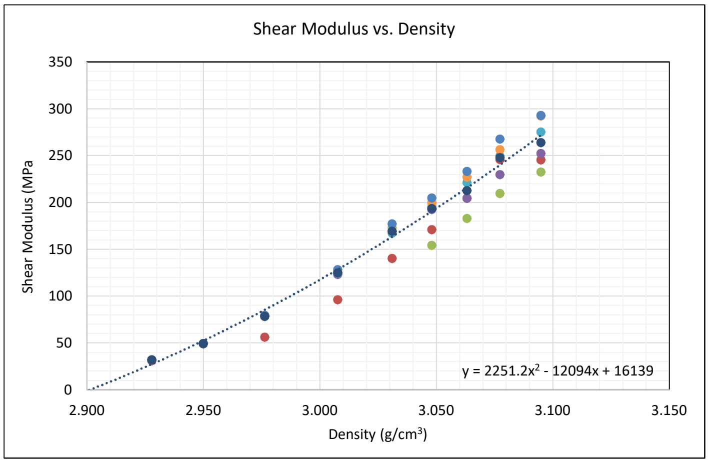
PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Coarse
TEST NO. : TXBD06 e=1.1

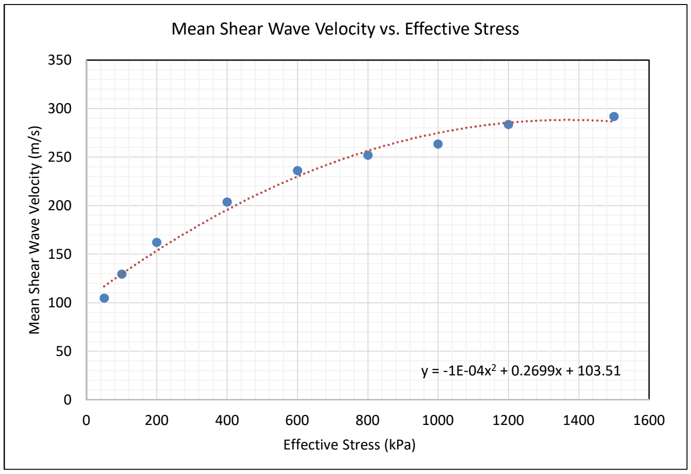
DATE : 2019-08-23
TEST BY: BY
CHECKED BY: JG

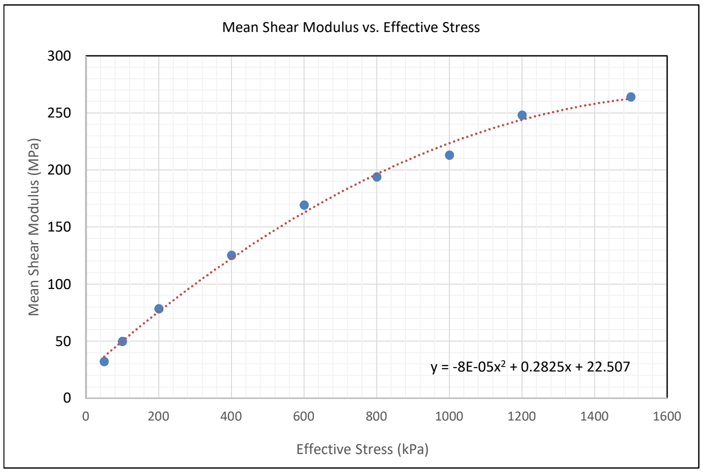












Triaxial Bender Element Test - Summary

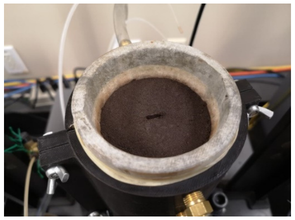
PROJECT NO. A03355A01
PROJECT :
SAMPLE : Coarse Gradation - Batch 3
TEST NO. : TXBD07 e=0.9

DATE : 2019-08-27
TESTED BY: BY
CHECKED BY: JG

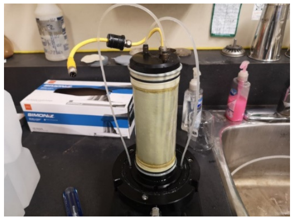
SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B value	End 1st Cons	End 2nd Cons	End 3rd Cons	End 4th Cons	End 5th Cons	End 6th Cons	End 7th Cons	End 8th Cons	End 9th Cons
Specimen Height	mm	139.06	138.51	138.51	138.45	138.45	138.40	138.27	138.09	137.95	137.77	137.67	137.53	137.36
Specimen Diameter	mm	69.90	70.04	70.04	70.05	69.97	69.89	69.78	69.63	69.51	69.41	69.32	69.24	69.13
Area	cm^2	38.37	38.53	38.53	38.54	38.46	38.36	38.25	38.08	37.95	37.84	37.75	37.66	37.53
Volume	cm^3	533.638	533.658	533.658	533.658	532.420	530.921	528.819	525.819	523.477	521.247	519.624	517.876	515.514
Wet Weight	g	1489.35	1489.35	1620.55	1633.68	1632.44	1630.94	1628.84	1625.84	1623.50	1621.27	1619.65	1617.90	1615.54
Water Content	%	8.00	8.00	17.51	18.47	18.38	18.27	18.12	17.90	17.73	17.57	17.45	17.32	17.15
Dry Weight	g	1379.03	1379.03	1379.03	1379.03	1379.03	1379.03	1379.03	1379.03	1379.03	1379.03	1379.03	1379.03	1379.03
Wet Density	g/cm^3	2.791	2.791	3.037	3.061	3.066	3.072	3.080	3.092	3.101	3.110	3.117	3.124	3.134
Dry Density	g/cm^3	2.584	2.584	2.584	2.584	2.590	2.597	2.608	2.623	2.634	2.646	2.654	2.663	2.675
Specific Gravity of Solids	-	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91
Solids Volume	cm^3	280.861	280.861	280.861	280.861	280.861	280.861	280.861	280.861	280.861	280.861	280.861	280.861	280.861
Void Volume	cm^3	252.777	252.797	252.797	252.797	251.559	250.060	247.958	244.958	242.616	240.386	238.763	237.015	234.653
Water Volume	cm^3	110.322	110.322	241.522	254.654	253.416	251.917	249.814	246.815	244.473	242.242	240.620	238.872	236.509
Void Ratio (e)	-	0.900	0.900	0.900	0.900	0.896	0.890	0.883	0.872	0.864	0.856	0.850	0.844	0.835
Saturation Ratio (Sr)	%	43.64	43.64	95.54	100.73	100.74	100.74	100.75	100.76	100.77	100.77	100.78	100.78	100.79
Effective Confining Stress	kPa					50	100	200	400	600	800	1000	1200	1500
Mean Shear Wave Velocity	m/s					**130.35**	**158.81**	**195.52**	**239.17**	**267.01**	**291.68**	**307.50**	**325.06**	**339.10**
Mean Shear Modulus	MPa					**52.10**	**77.48**	**117.75**	**176.87**	**221.11**	**264.63**	**294.72**	**330.12**	**360.36**

Photos:

Before Test

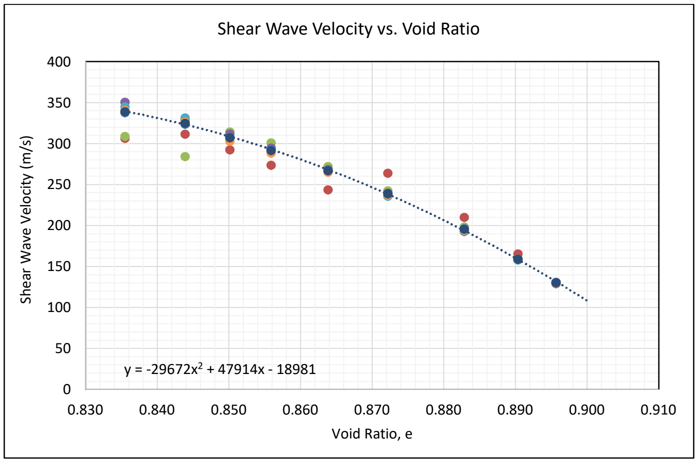


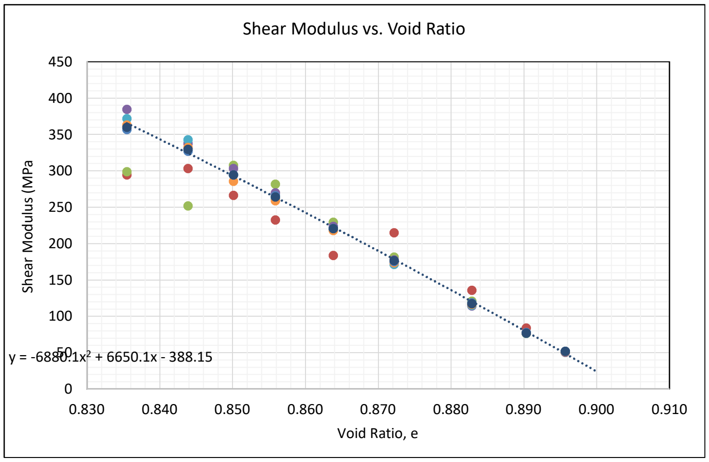
After Test

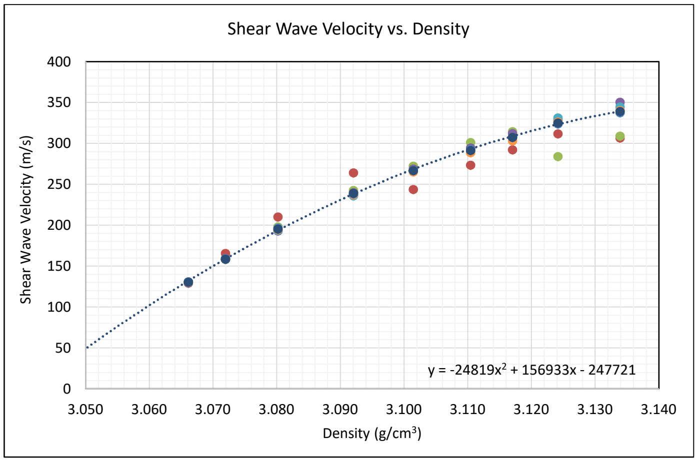


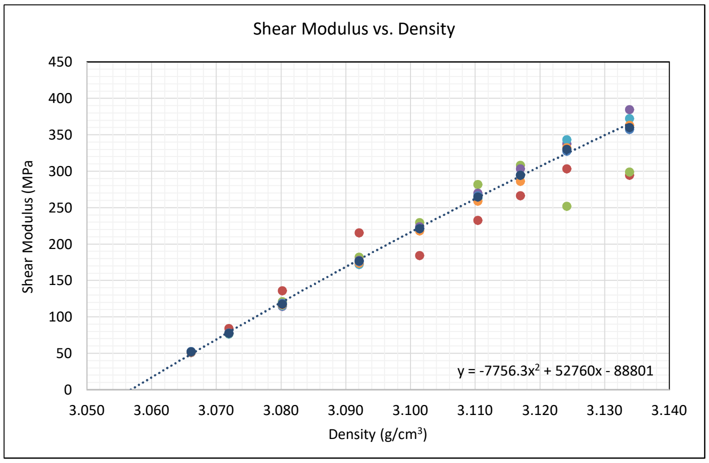
Triaxial Bender Element Test - Charts

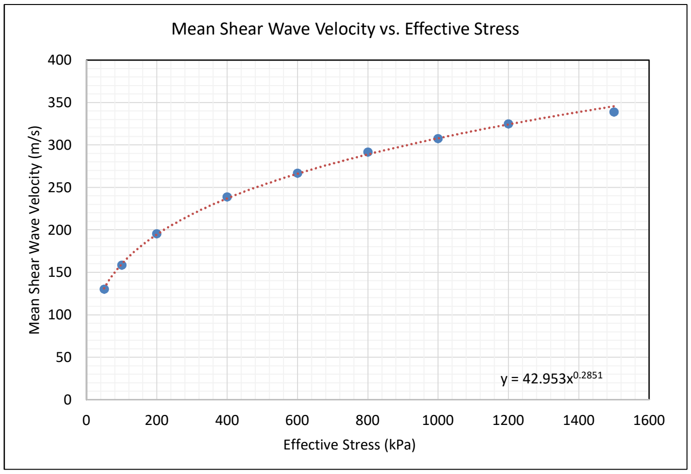
PROJECT NO. :	A03355A01	DATE :	2019-08-27
PROJECT :		TEST BY:	BY
SAMPLE :	Coarse Gradation - Batch 3	CHECKED BY:	JG
TEST NO. :	TXBD07 e=0.9		

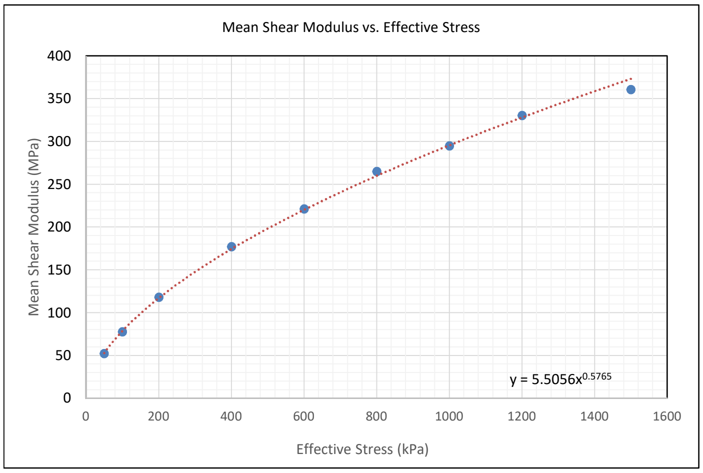












Triaxial Bender Element Test - Summary

PROJECT NO. A03355A01
PROJECT :
SAMPLE : Average
TEST NO. : TXBE08 e=0.75

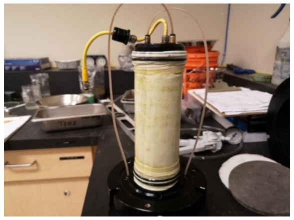
DATE : 2019-10-09
TESTED BY: BY / AX
CHECKED BY: JG

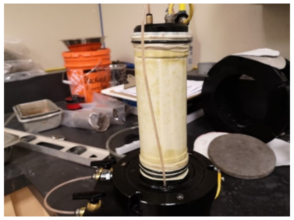
SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B value	End 1st Cons	End 2nd Cons	End 3rd Cons	End 4th Cons	End 5th Cons	End 6th Cons	End 7th Cons	End 8th Cons	End 9th Cons
Specimen Height	mm	139.67	139.67	139.67	139.55	139.49	139.42	139.29	139.08	138.96	138.85	138.76	138.68	138.59
Specimen Diameter	mm	70.27	70.27	70.09	70.09	70.05	70.01	69.95	69.89	69.84	69.81	69.78	69.74	69.66
Area	cm^2	38.78	38.78	38.58	38.59	38.54	38.49	38.43	38.37	38.31	38.27	38.24	38.20	38.11
Volume	cm^3	541.668	541.668	538.834	538.464	537.564	536.632	535.307	533.589	532.371	531.395	530.623	529.810	528.112
Wet Weight	g	1640.54	1640.54	1722.64	1753.08	1752.18	1751.25	1749.93	1748.21	1746.99	1746.02	1745.24	1744.43	1742.73
Water Content	%	7.89	7.89	13.29	15.29	15.23	15.17	15.08	14.97	14.89	14.83	14.78	14.72	14.61
Dry Weight	g	1520.57	1520.57	1520.57	1520.57	1520.57	1520.57	1520.57	1520.57	1520.57	1520.57	1520.57	1520.57	1520.57
Wet Density	g/cm^3	3.029	3.029	3.197	3.256	3.259	3.263	3.269	3.276	3.282	3.286	3.289	3.293	3.300
Dry Density	g/cm^3	2.807	2.807	2.822	2.824	2.829	2.834	2.841	2.850	2.856	2.861	2.866	2.870	2.879
Specific Gravity of Solids	-	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97
Solids Volume	cm^3	305.949	305.949	305.949	305.949	305.949	305.949	305.949	305.949	305.949	305.949	305.949	305.949	305.949
Void Volume	cm^3	235.719	235.719	232.885	232.515	231.615	230.683	229.358	227.639	226.422	225.445	224.674	223.861	222.163
Water Volume	cm^3	119.973	119.973	202.073	232.517	231.617	230.685	229.360	227.642	226.424	225.448	224.677	223.864	222.165
Void Ratio (e)	-	0.770	0.770	0.761	0.760	0.757	0.754	0.750	0.744	0.740	0.737	0.734	0.732	0.726
Saturation Ratio (Sr)	%	50.90	50.90	86.77	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Effective Confining Stress	kPa					50	100	200	400	600	800	1000	1200	1500
Mean Shear Wave Velocity	m/s					**150.10**	**173.97**	**207.36**	**233.85**	**266.81**	**292.36**	**303.71**	**311.34**	**334.56**
Mean Shear Modulus	MPa					**73.44**	**98.77**	**140.57**	**179.66**	**233.63**	**280.85**	**303.39**	**319.17**	**369.39**

Photos:

Before Test

After Test

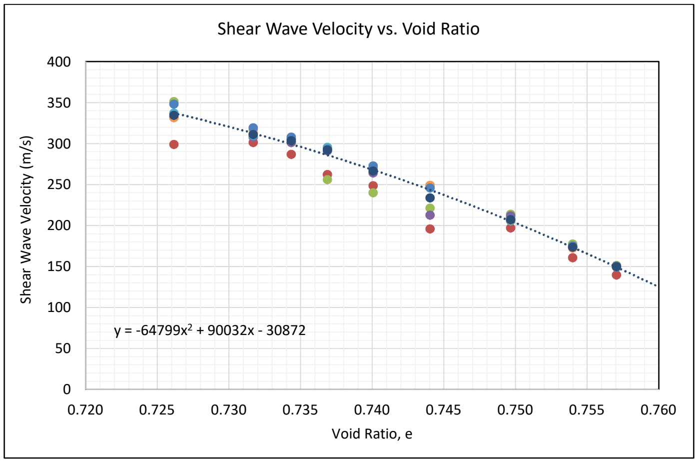


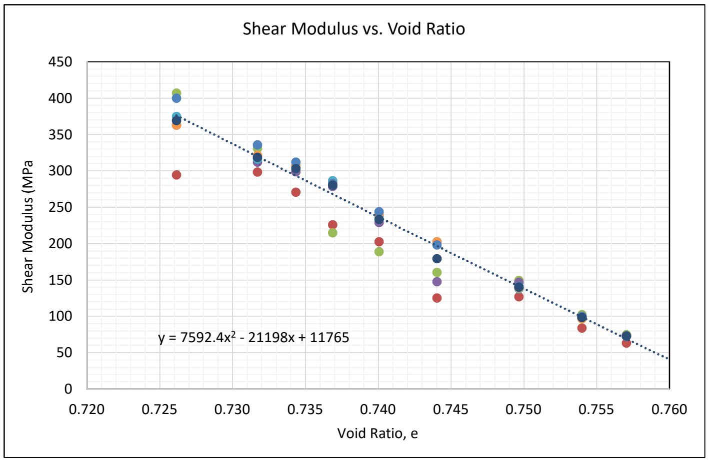


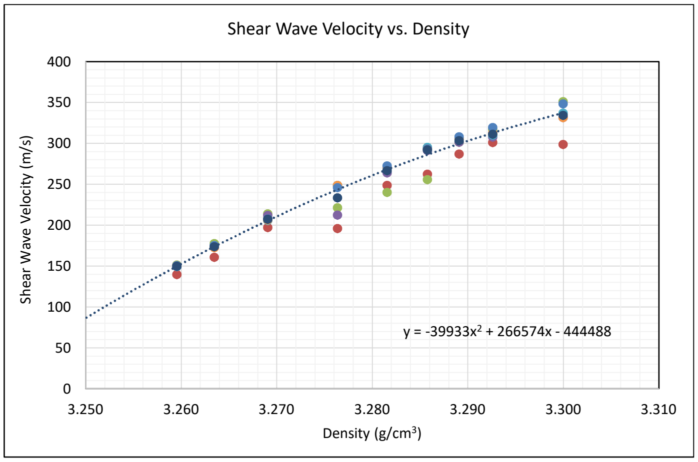
Triaxial Bender Element Test - Charts

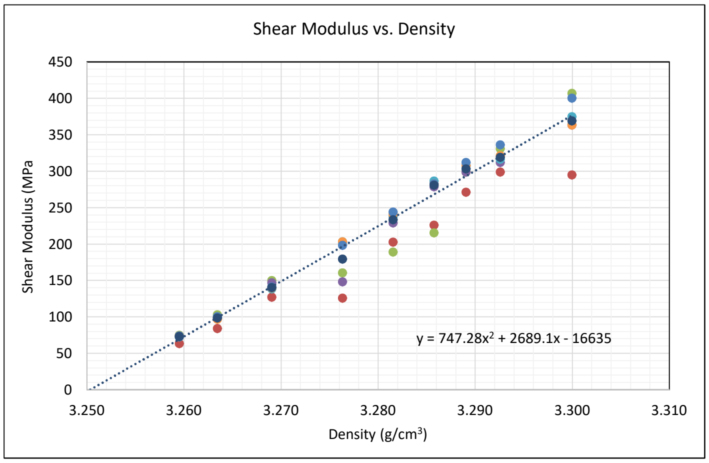
PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Average
TEST NO. : TXBE08 e=0.75

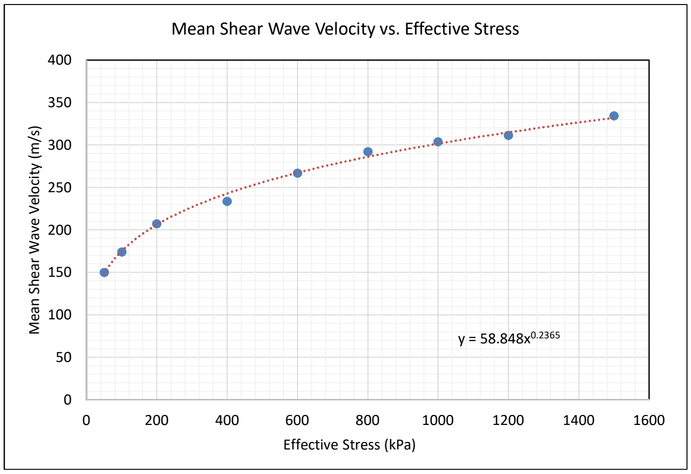
DATE : 2019-10-09
TEST BY: BY / AX
CHECKED BY: JG

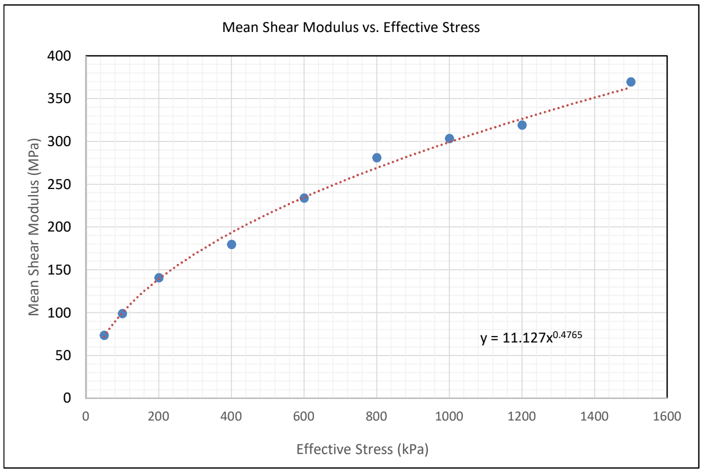

Shear Wave Velocity vs. Void Ratio


Shear Modulus vs. Void Ratio


Shear Wave Velocity vs. Density


Shear Modulus vs. Density


Mean Shear Wave Velocity vs. Effective Stress


Mean Shear Modulus vs. Effective Stress

Triaxial Bender Element Test - Summary

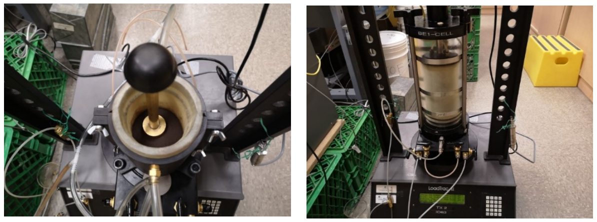
PROJECT NO. A03355A01
PROJECT :
SAMPLE : Coarse
TEST NO. : TXBD09 e=0.7

DATE : 2019-10-31
TESTED BY: BY
CHECKED BY: JG

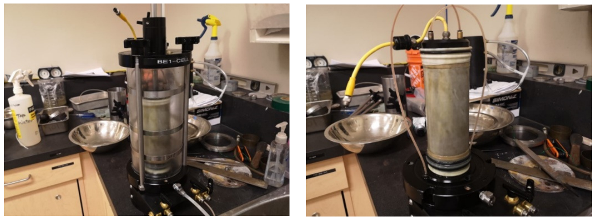
SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B value	End 1st Cons	End 2nd Cons	End 3rd Cons	End 4th Cons	End 5th Cons	End 6th Cons	End 7th Cons	End 8th Cons	End 9th Cons
Specimen Height	mm	139.06	139.06	139.06	138.99	138.96	138.89	138.83	138.71	138.61	138.53	138.45	138.38	138.28
Specimen Diameter	mm	70.11	70.11	70.05	70.07	70.03	70.00	69.94	69.87	69.82	69.79	69.75	69.71	69.67
Area	cm^2	38.61	38.61	38.54	38.56	38.52	38.48	38.42	38.34	38.29	38.25	38.21	38.17	38.12
Volume	cm^3	536.849	536.849	535.899	535.899	535.279	534.506	533.390	531.869	530.766	529.861	528.997	528.195	527.099
Wet Weight	g	1663.85	1663.85	1749.31	1762.51	1761.89	1761.12	1760.00	1758.48	1757.38	1756.47	1755.61	1754.81	1753.71
Water Content	%	8.11	8.11	13.66	14.52	14.48	14.43	14.36	14.26	14.19	14.13	14.07	14.02	13.95
Dry Weight	g	1539.03	1539.03	1539.03	1539.03	1539.03	1539.03	1539.03	1539.03	1539.03	1539.03	1539.03	1539.03	1539.03
Wet Density	g/cm^3	3.099	3.099	3.264	3.289	3.292	3.295	3.300	3.306	3.311	3.315	3.319	3.322	3.327
Dry Density	g/cm^3	2.867	2.867	2.872	2.872	2.875	2.879	2.885	2.894	2.900	2.905	2.909	2.914	2.920
Specific Gravity of Solids	-	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91	4.91
Solids Volume	cm^3	313.449	313.449	313.449	313.449	313.449	313.449	313.449	313.449	313.449	313.449	313.449	313.449	313.449
Void Volume	cm^3	223.400	223.400	222.450	222.450	221.830	221.057	219.941	218.420	217.317	216.412	215.548	214.747	213.650
Water Volume	cm^3	124.816	124.816	210.276	223.476	222.856	222.082	220.966	219.445	218.343	217.437	216.574	215.772	214.676
Void Ratio (e)	-	0.713	0.713	0.710	0.710	0.708	0.705	0.702	0.697	0.693	0.690	0.688	0.685	0.682
Saturation Ratio (Sr)	%	55.87	55.87	94.53	100.46	100.46	100.46	100.47	100.47	100.47	100.47	100.48	100.48	100.48
Effective Confining Stress	kPa					50	100	200	400	600	800	1000	1200	1500
Mean Shear Wave Velocity	m/s					**177.45**	**189.09**	**223.49**	**262.13**	**292.05**	**293.77**	**306.29**	**320.01**	**341.89**
Mean Shear Modulus	MPa					**103.96**	**117.81**	**164.82**	**227.21**	**282.69**	**286.25**	**311.45**	**340.26**	**389.00**

Photos:

Before Test



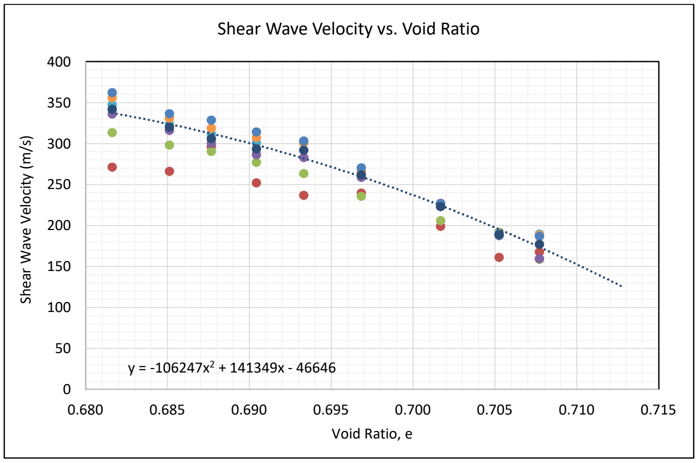
After Test

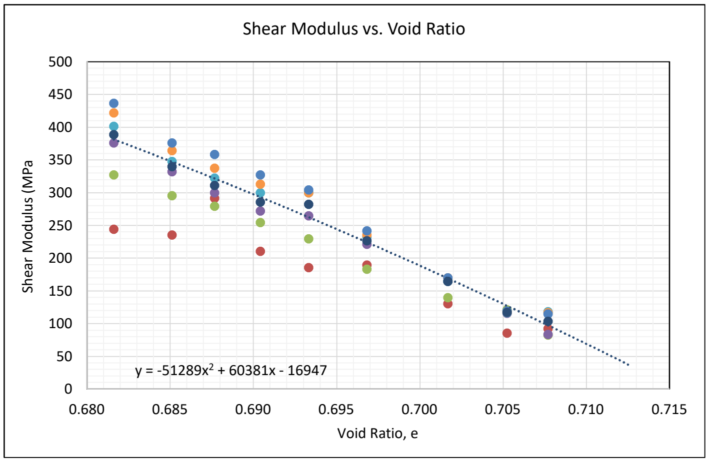


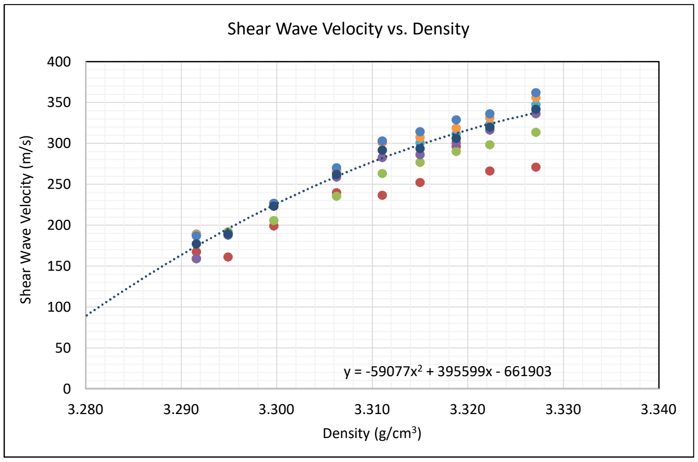
Triaxial Bender Element Test - Charts

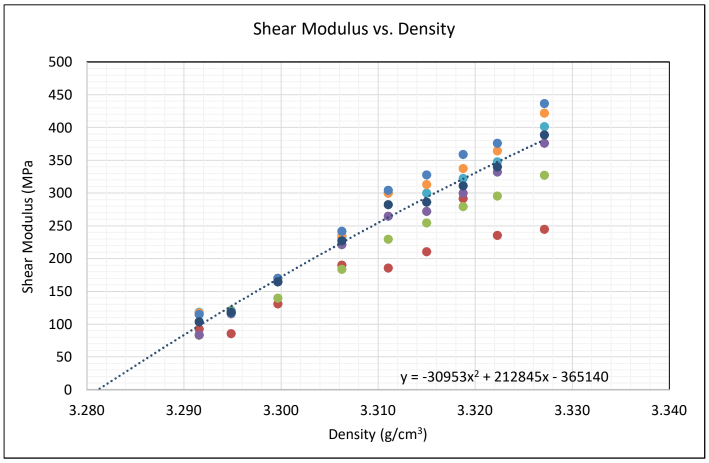
PROJECT NO. : A03355A01
PROJECT :
SAMPLE : Coarse
TEST NO. : TXBD09 e=0.7

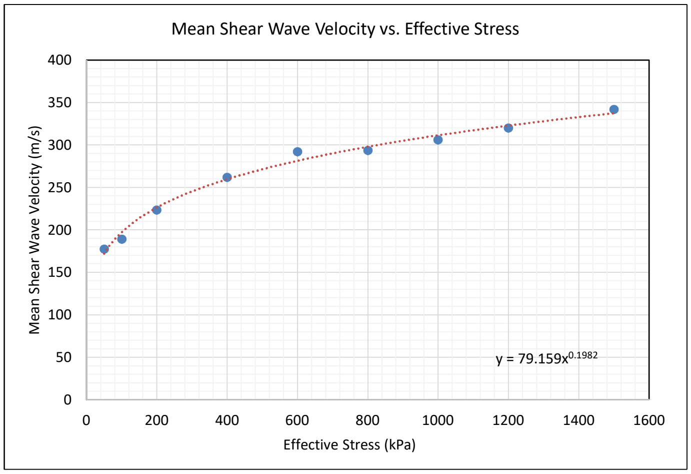
DATE : 2019-10-31
TEST BY: BY
CHECKED BY: JG

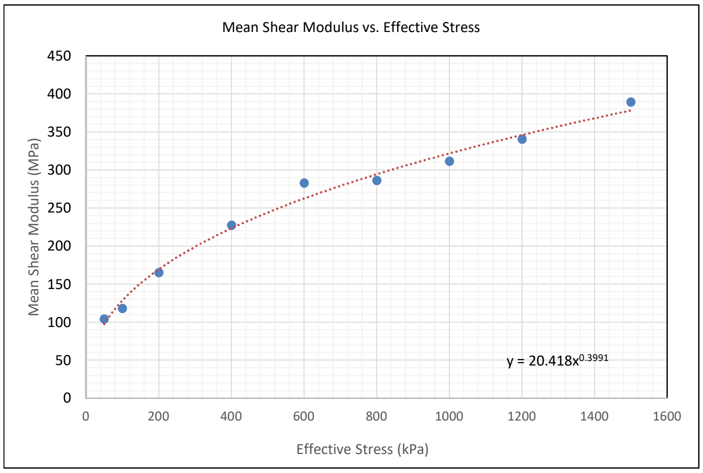

Shear Wave Velocity vs. Void Ratio


Shear Modulus vs. Void Ratio


Shear Wave Velocity vs. Density


Shear Modulus vs. Density


Mean Shear Wave Velocity vs. Effective Stress


Mean Shear Modulus vs. Effective Stress

Triaxial Bender Element Test - Summary

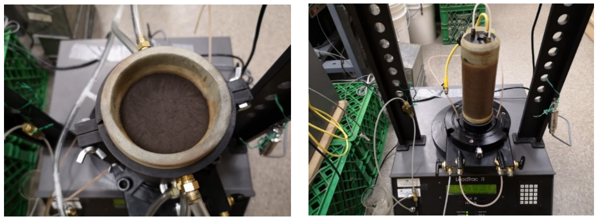
PROJECT NO. A03355A01
PROJECT :
SAMPLE : Fine Gradation
TEST NO. : TXBD10 e=0.7

DATE : 2019-11-03
TESTED BY: BY
CHECKED BY: JG

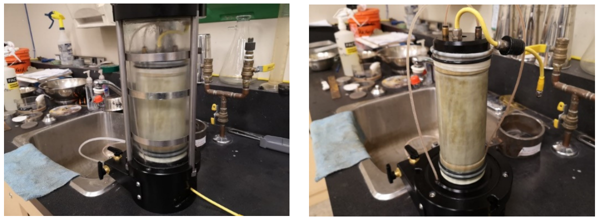
SPECIMEN INFORMATION	UNITS	Initial	Vacuum	Saturation	B value	End 1st Cons	End 2nd Cons	End 3rd Cons	End 4th Cons	End 5th Cons	End 6th Cons	End 7th Cons	End 8th Cons	End 9th Cons
Specimen Height	mm	140.51	140.51	140.51	140.41	140.37	140.31	140.22	140.13	140.04	139.97	139.92	139.86	139.80
Specimen Diameter	mm	70.23	70.23	70.23	70.22	70.18	70.15	70.12	70.07	70.03	70.00	69.97	69.95	69.91
Area	cm^2	38.74	38.74	38.74	38.73	38.68	38.65	38.62	38.56	38.52	38.49	38.46	38.43	38.39
Volume	cm^3	544.305	544.305	544.305	543.805	543.017	542.312	541.494	540.310	539.446	538.707	538.071	537.477	536.664
Wet Weight	g	1681.16	1681.16	1782.96	1787.54	1786.75	1786.05	1785.23	1784.05	1783.18	1782.44	1781.81	1781.22	1780.40
Water Content	%	8.08	8.08	14.62	14.92	14.87	14.82	14.77	14.69	14.64	14.59	14.55	14.51	14.46
Dry Weight	g	1555.48	1555.48	1555.48	1555.48	1555.48	1555.48	1555.48	1555.48	1555.48	1555.48	1555.48	1555.48	1555.48
Wet Density	g/cm^3	3.089	3.089	3.276	3.287	3.290	3.293	3.297	3.302	3.306	3.309	3.311	3.314	3.318
Dry Density	g/cm^3	2.858	2.858	2.858	2.860	2.865	2.868	2.873	2.879	2.883	2.887	2.891	2.894	2.898
Specific Gravity of Solids	-	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96
Solids Volume	cm^3	313.604	313.604	313.604	313.604	313.604	313.604	313.604	313.604	313.604	313.604	313.604	313.604	313.604
Void Volume	cm^3	230.701	230.701	230.701	230.201	229.412	228.707	227.890	226.706	225.841	225.102	224.467	223.873	223.059
Water Volume	cm^3	125.683	125.683	227.483	232.066	231.277	230.572	229.755	228.571	227.706	226.967	226.332	225.738	224.924
Void Ratio (e)	-	0.736	0.736	0.736	0.734	0.732	0.729	0.727	0.723	0.720	0.718	0.716	0.714	0.711
Saturation Ratio (Sr)	%	54.48	54.48	98.61	100.81	100.81	100.82	100.82	100.82	100.83	100.83	100.83	100.83	100.84
Effective Confining Stress	kPa					50	100	200	400	600	800	1000	1200	1500
Mean Shear Wave Velocity	m/s					**158.81**	**185.57**	**220.87**	**258.04**	**283.57**	**304.66**	**315.80**	**329.14**	**354.89**
Mean Shear Modulus	MPa					**82.99**	**113.42**	**160.84**	**219.86**	**265.80**	**307.12**	**330.27**	**359.16**	**417.83**

Photos:

Before Test

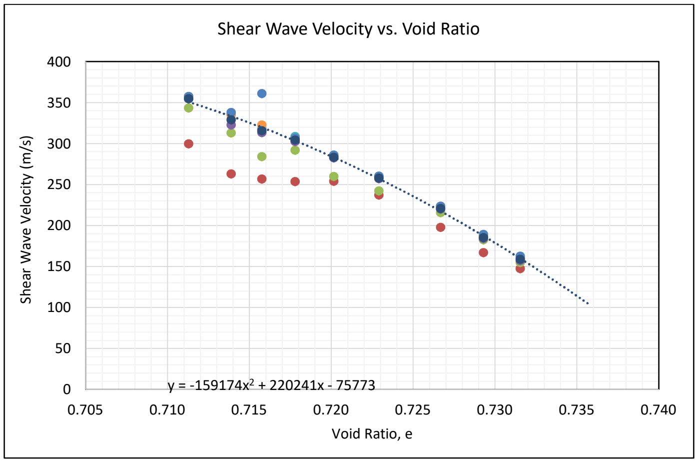


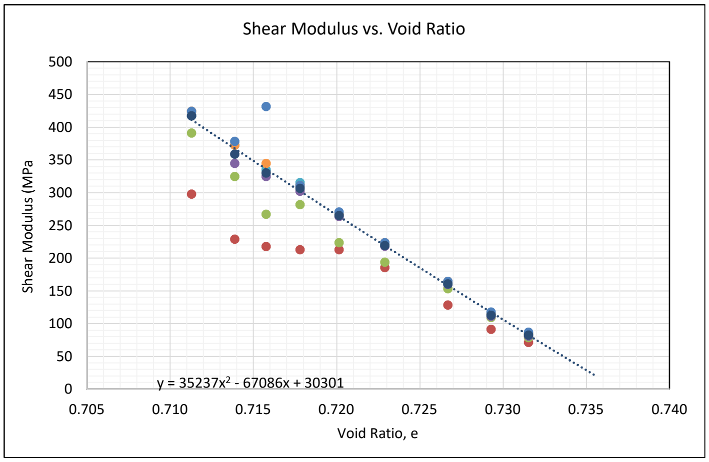
After Test

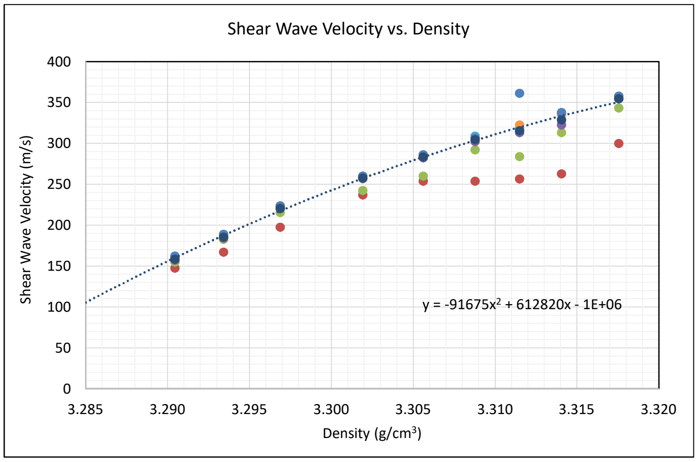


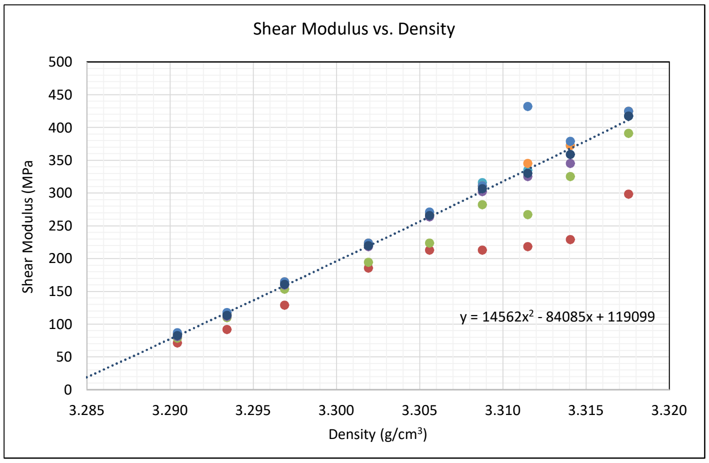
Triaxial Bender Element Test - Charts

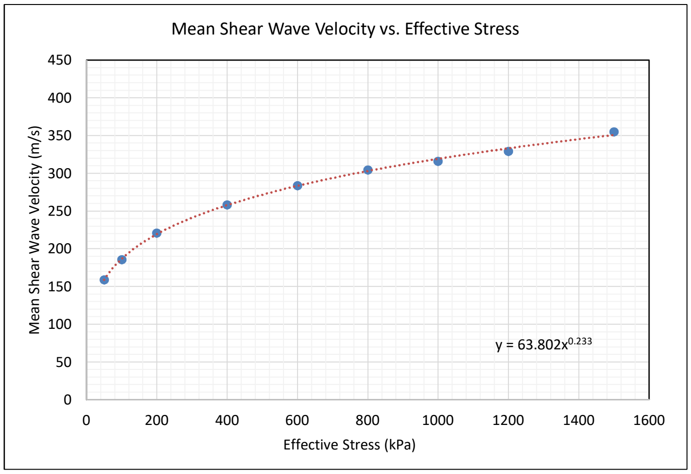
PROJECT NO. :	A03355A01	DATE :	2019-11-03
PROJECT :		TEST BY:	BY
SAMPLE :	Fine Gradation	CHECKED BY:	JG
TEST NO. :	TXBD10 e=0.7		

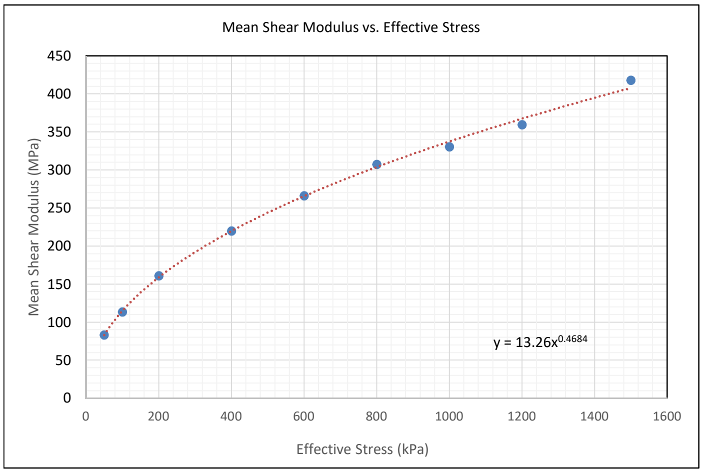




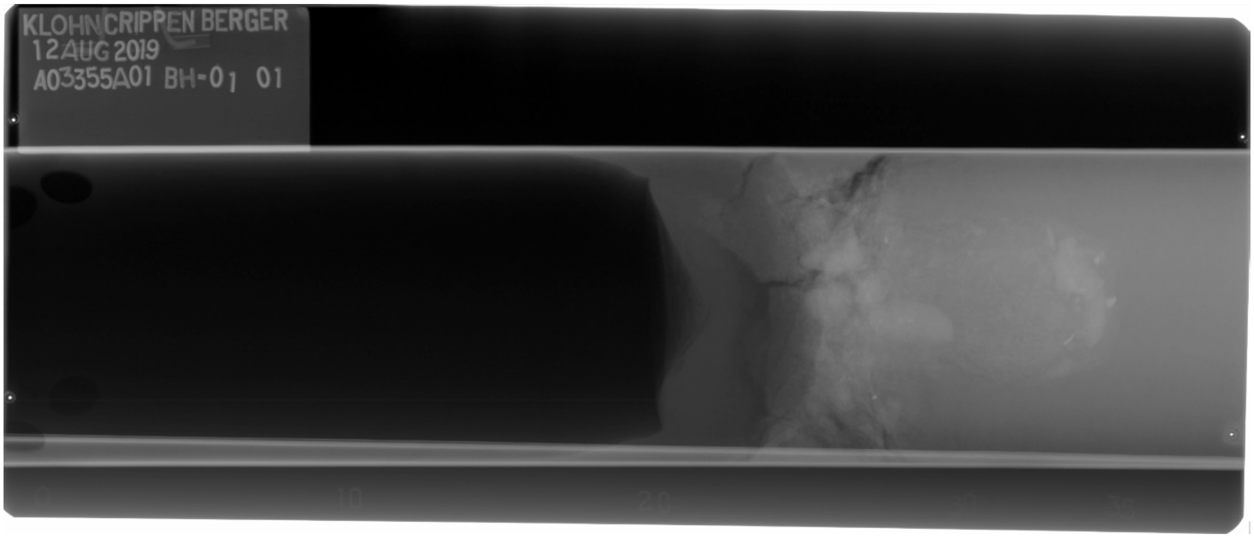


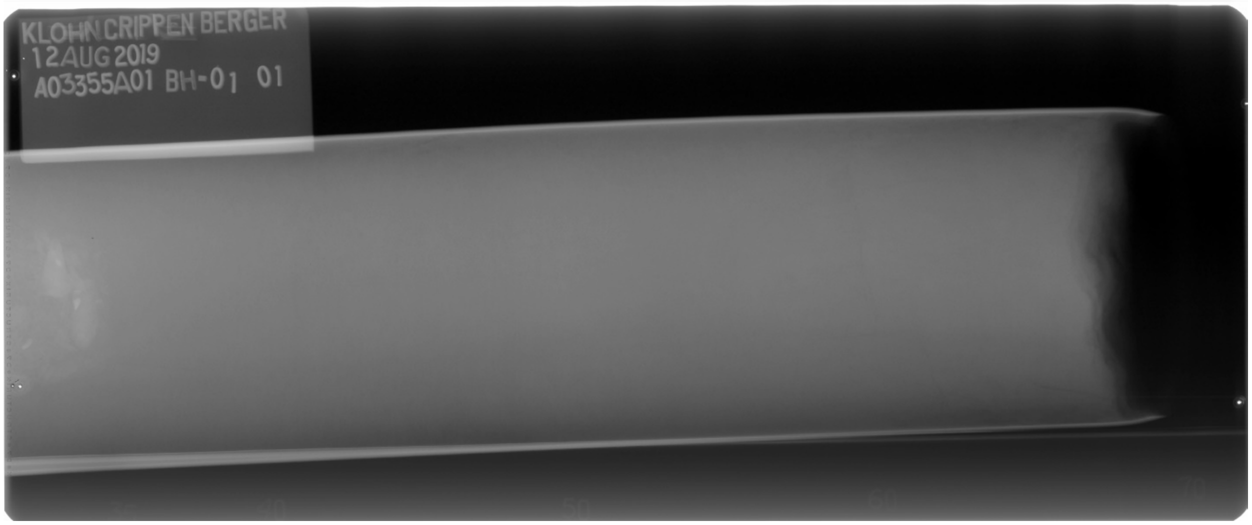


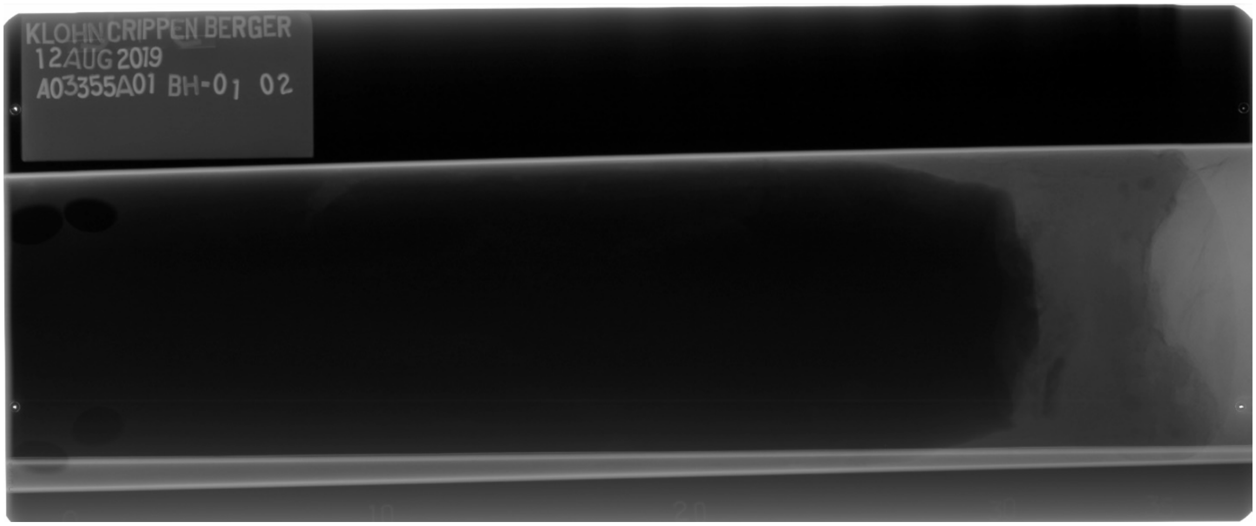




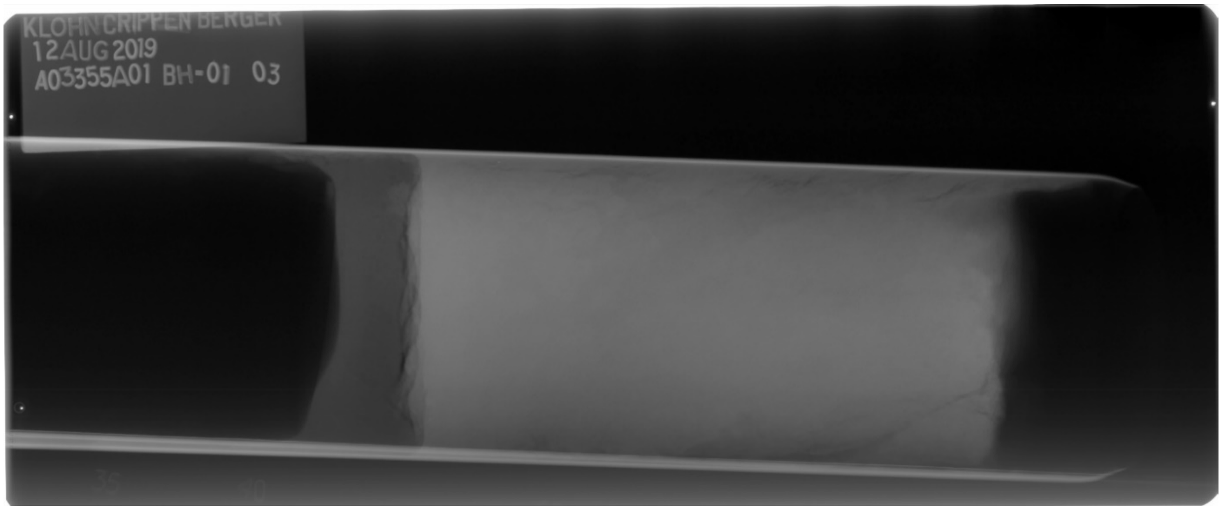
Shelby Tube X-Ray Scans

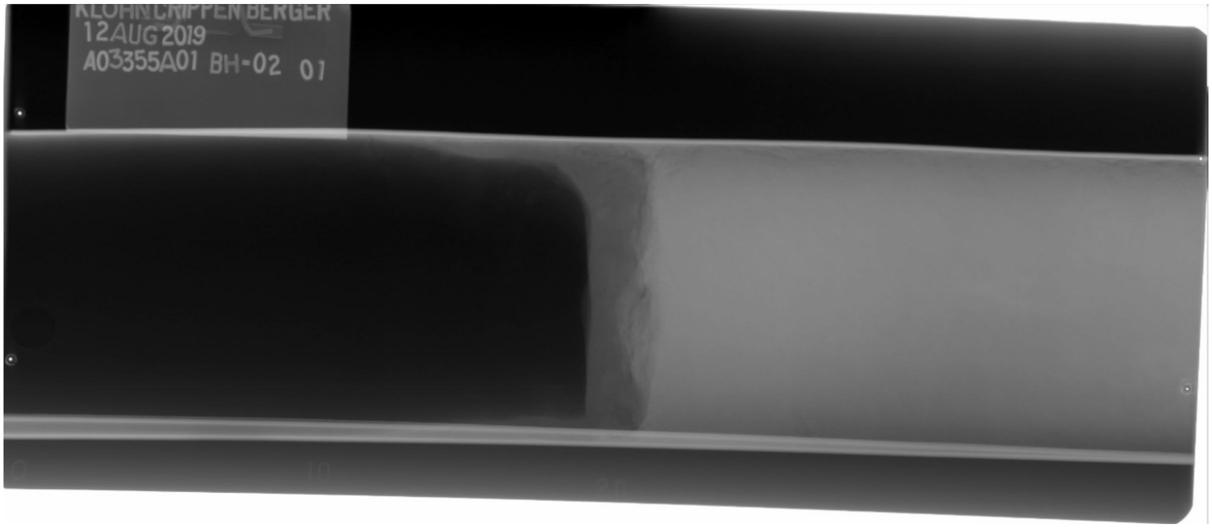

KLOHN CRIPPEN BERGER
12 AUG 2019
A03355A01 BH-01 01
0
10
20
30
36

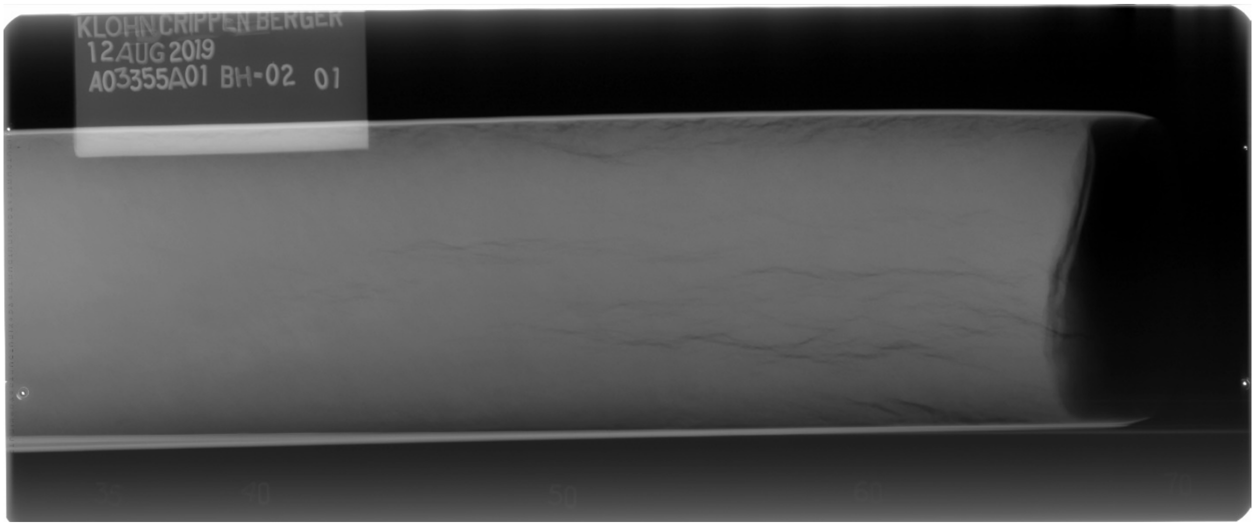

KLOHN CRIPPEN BERGER
12 AUG 2019
A03355A01 BH-01 01
35
40
50
60
70

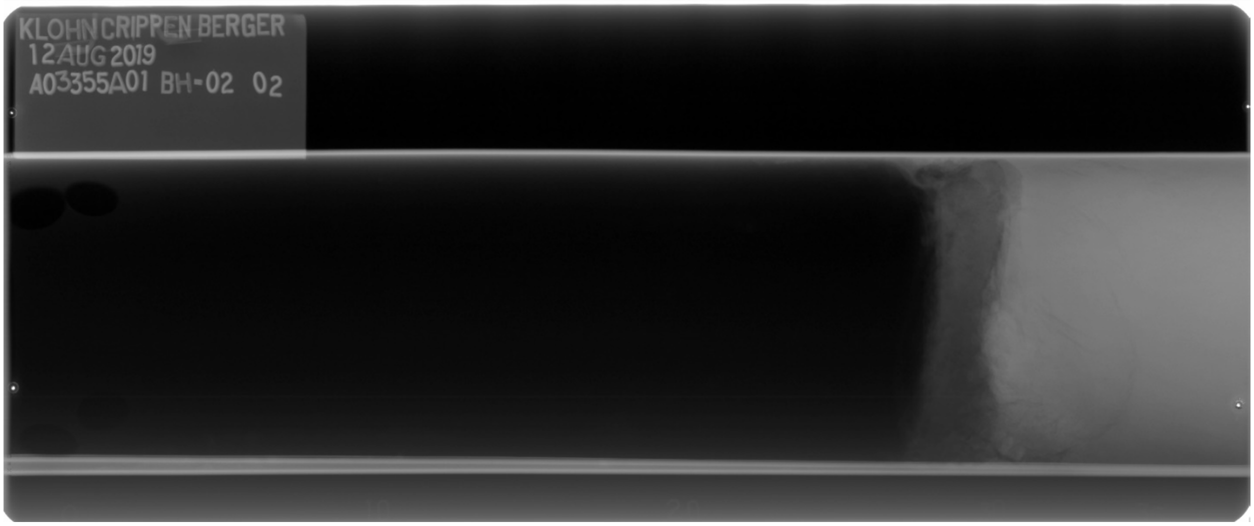

KLOHN CRIPPEN BERGER
12 AUG 2019
A03355A01 BH-01 02
0
10
20
30


KLOHN CRIPPEN BERGER
12 AUG 2019
A03355A01 BH-01 02

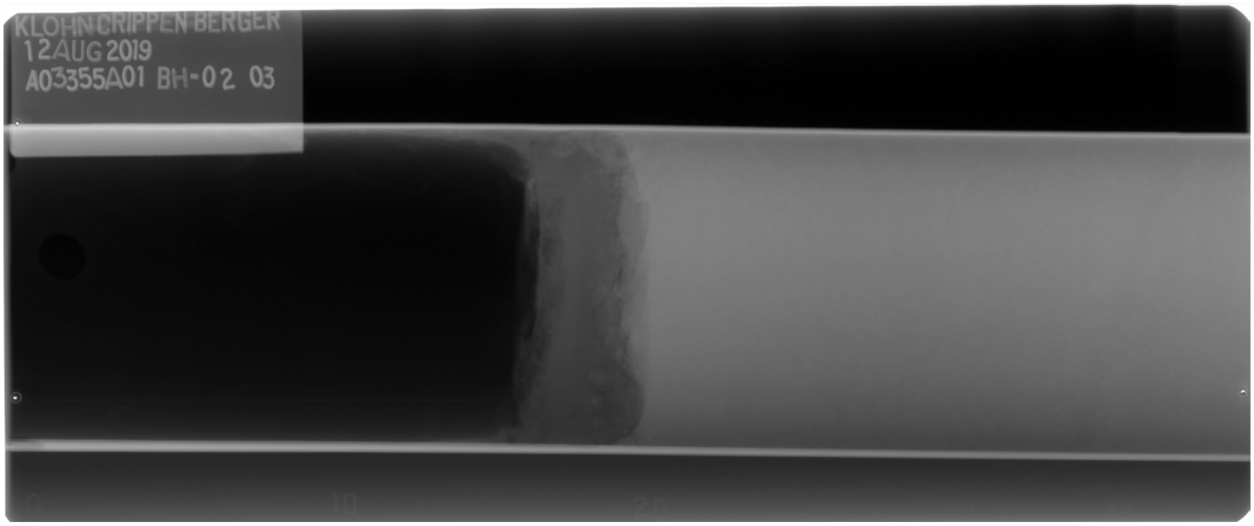

KLOHN CRIPPEN BERGER
12 AUG 2019
A03355A01 BH-01 03
35
40


KLOHN CRIPPEN BERGER
12 AUG 2019
A03355A01 BH-02 01
0
10
20

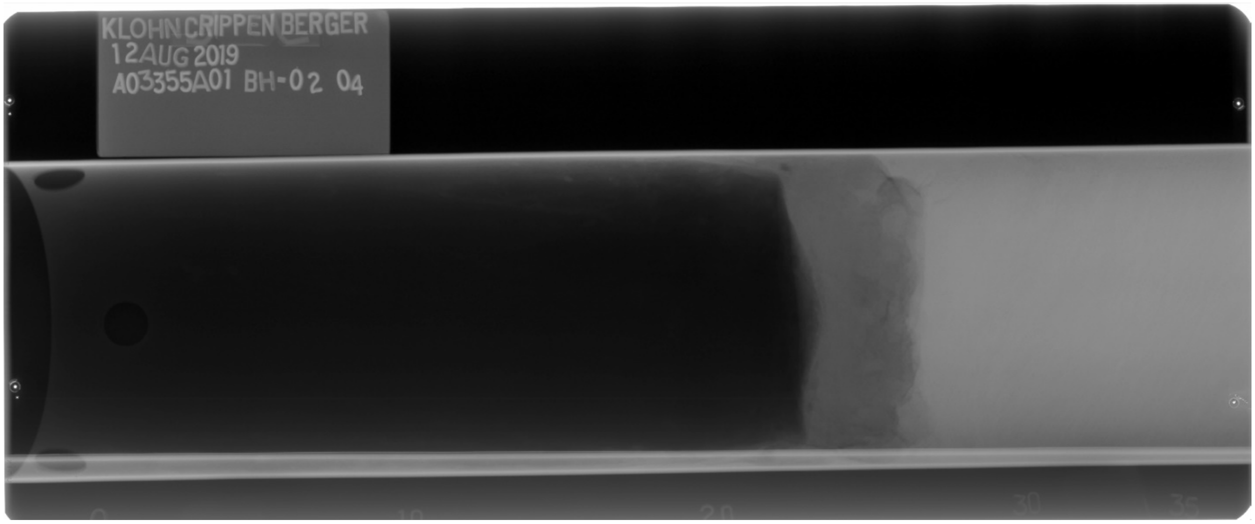

KLOHN CRIPPEN BERGER
12 AUG 2019
A03355A01 BH-02 01
35
40
50
60
70

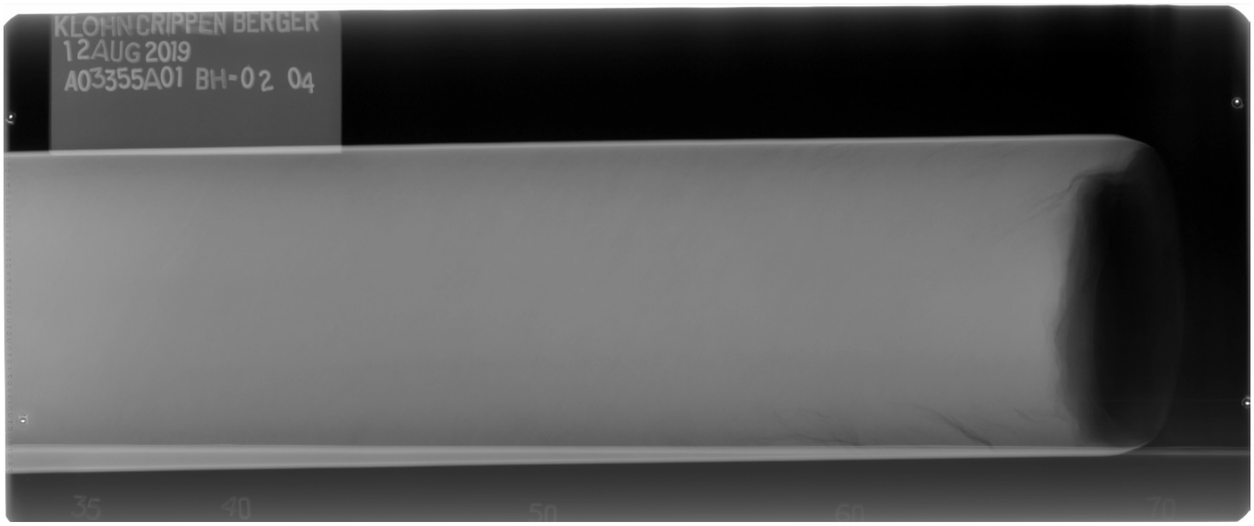

KLOHN CRIPPEN BERGER
12 AUG 2019
A03355A01 BH-02 02

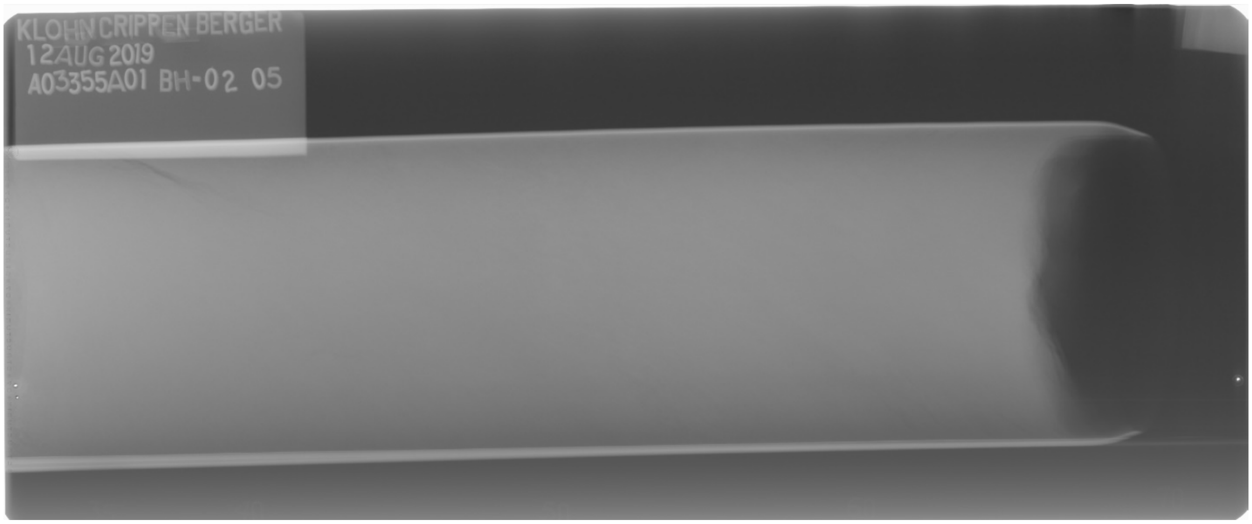

KLOHN CRIPPEN BERGER
12AUG 2019
A03355A01 BH-02 02

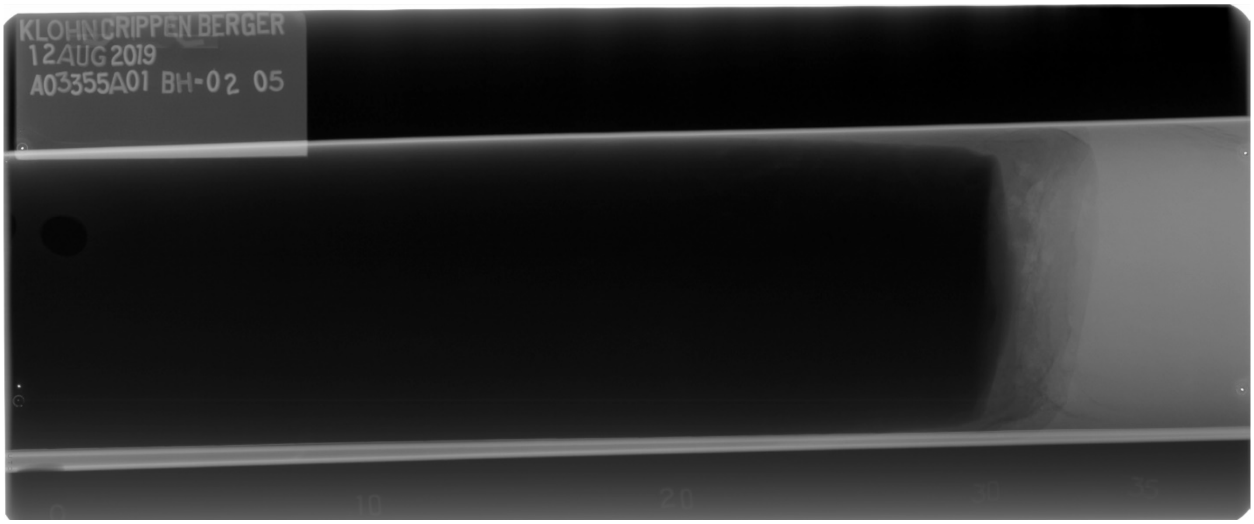

KLOHN CRIPPEN BERGER
12AUG 2019
A03355A01 BH-02 03
0
10
20

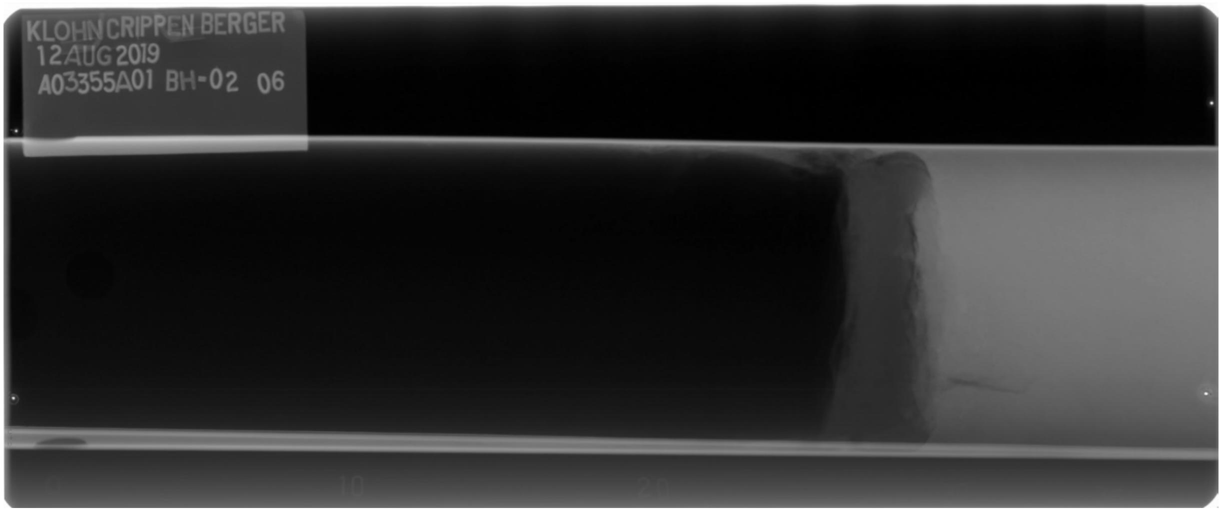

KLOHN CRIPPEN BERGER
12AUG2019
A03355A01 BH-02 03
35
40
50
60
70


KLOHN CRIPPEN BERGER
12AUG2019
A03355A01 BH-02 04
0
10
20
30
35


KLOHN CRIPPEN BERGER
12 AUG 2019
A03355A01 BH-02 04
35
40
50
60
70

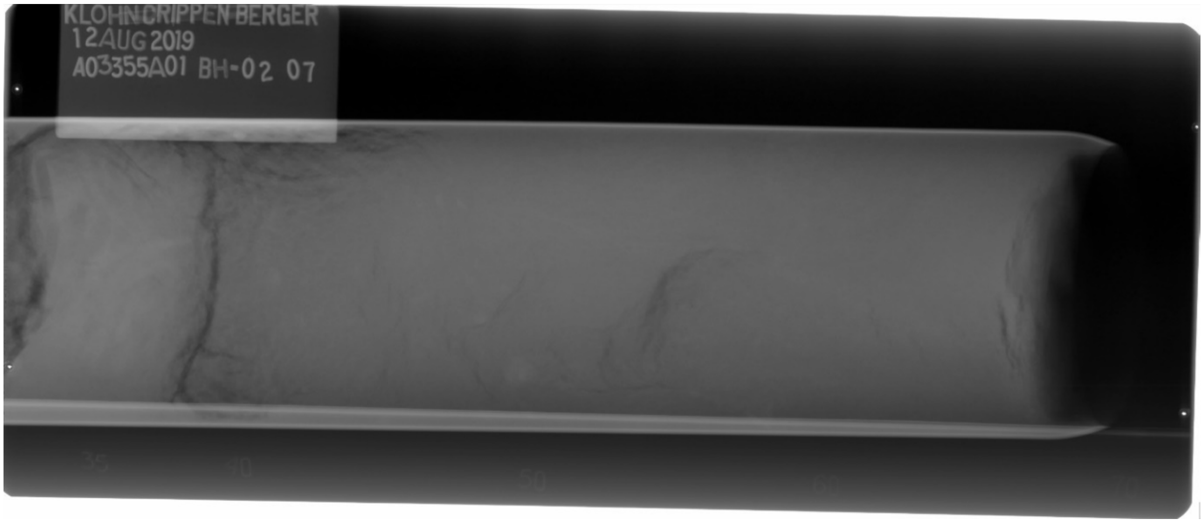

KLOHN CRIPPEN BERGER
12 AUG 2019
A03355A01 BH-02 05

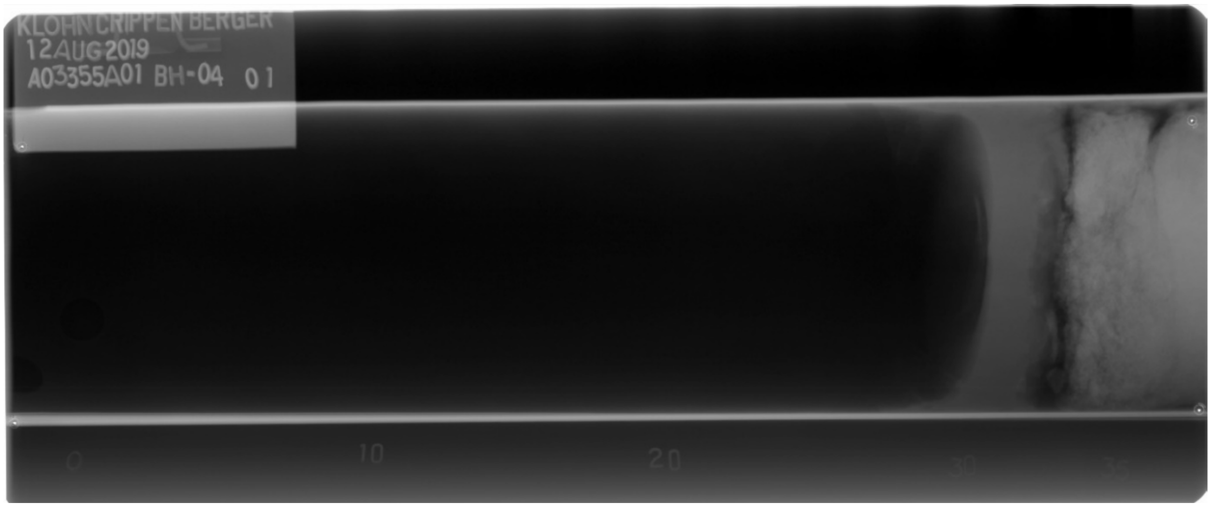

KLOHN CRIPPEN BERGER
12 AUG 2019
A03355A01 BH-02 05
0
10
20
30
35


KLOHN CRIPPEN BERGER
12 AUG 2019
A03355A01 BH-02 06
10
20

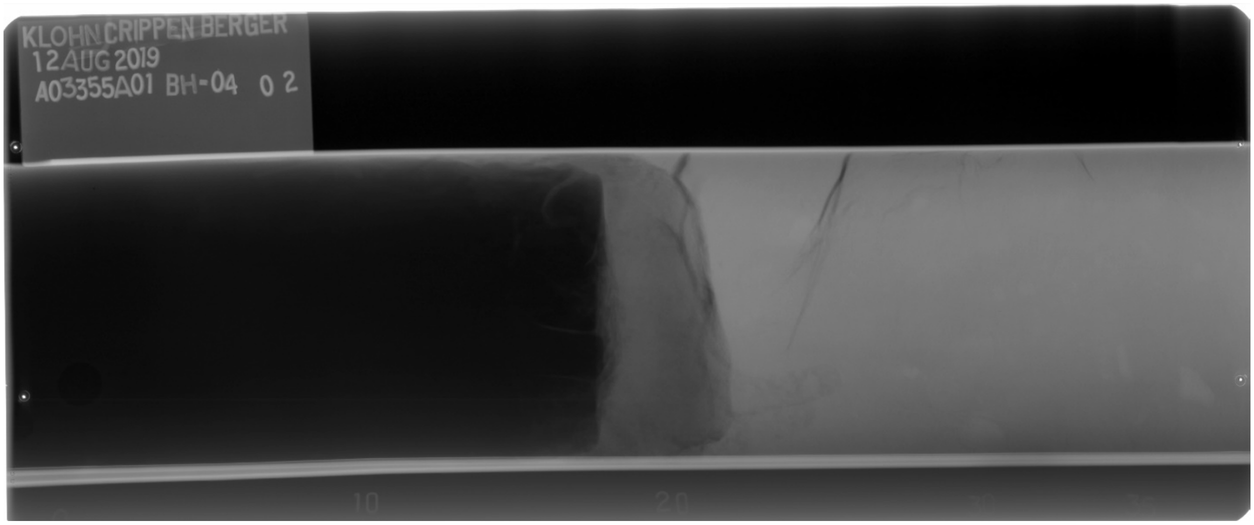

KLOHN CRIPPEN BERGER
12 AUG 2019
A03355A01 BH-02 06


KLOHN CRIPPEN BERGER
12 AUG 2019
A03355A01 BH-02 07
0
10
20


KLOHN CRIPPEN BERGER
12 AUG 2019
A03355A01 BH-02 07
35
40
50
60
70


KLOHN CRIPPEN BERGER
12 AUG 2019
A03355A01 BH-04 01
0
10
20
30


KLOHN CRIPPEN BERGER
12 AUG 2019
A03355A01 BH-04 0 1
30
40
50
60
70


KLOHN CRIPPEN BERGER
12 AUG 2019
A03355A01 BH-04 0 2
10
20
30


KLOHN CRIPPEN BERGER
12 AUG 2019
A03355A01 BH-04 0 2
35
40
50
60
70

Direct Simple Shear Test Results

Static Simple Shear Test

(ASTM D6528)

Project No.:	A03355A01	Borehole ID:	BH01
Project:		Sample ID:	Shelby1
Date:	2019-10-19	Depth:	3.50 m
Test by:	HM	Location:	Brazil
Checked by:	BY	Details:	Trimmed from Shelby Tube

Initial Sample Information		
Specimen Height	mm	23.97
Specimen Diameter	mm	70.01
Area	mm^2	3849.55
Volume	cm^3	92.27
Wet Weight	g	169.39
Water Content	%	35.49
Dry Weight	g	125.02
Wet Density	g/cm^3	1.836
Dry Density	g/cm^3	1.355
Specific Gravity (measured)	-	2.79
Void Ratio (e)	-	1.06
Saturation Ratio (Sr)	%	93.48

Static Shearing (Undrained)		
Initial Vertical Effective Stress	kPa	520
Initial Shear Stress	kPa	0.6
Shearing Rate (Shear Strain Rate)	% / hr	5.00
Peak Shear Strength	kPa	174.62
Ratio of Peak τ/σ'_v	-	0.34
Max. Excess Pore Pressure	kPa	386.33
Max. Shear Strain	%	20.0

FINAL SAMPLE INFORMATION		
Liquid Limit (test sample)		
Plastic Limit (test sample)		
Liquid Limit (shear plane)		
Plastic Limit (shear plane)		
Final Moisture Content	%	36.66
Final Moisture Content (shear plane)	%	
Final Moisture Content (outside shear plane)	%	

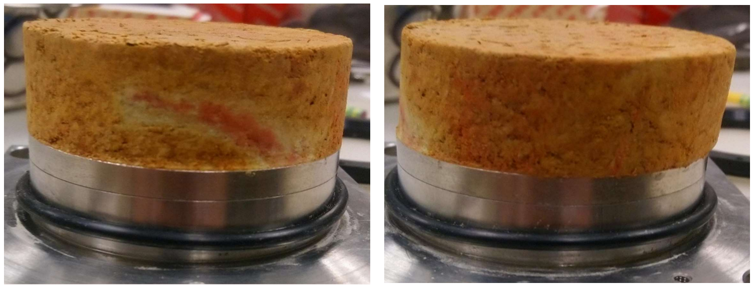
CONSOLIDATION	Stage #	1	2	3	4	5			
Vertical Effective Stress	kPa	32	65	130	260	520			
Max Load	kN	0.124	0.249	0.500	1.000	2.001			
Total Height Change	mm	0.18	0.36	0.69	1.20	1.88			
Consolidated Height	mm	23.79	23.61	23.28	22.77	22.09			
Axial Strain ^{*2}	%	0.76	1.50	2.89	5.00	7.85			
Duration	min	240	240	320	320	322			

*2 : Axial strain may differ from oedometer test result due to the sample seating system and possible lateral strain caused by the membrane.

Photos:

Before Test

After Test

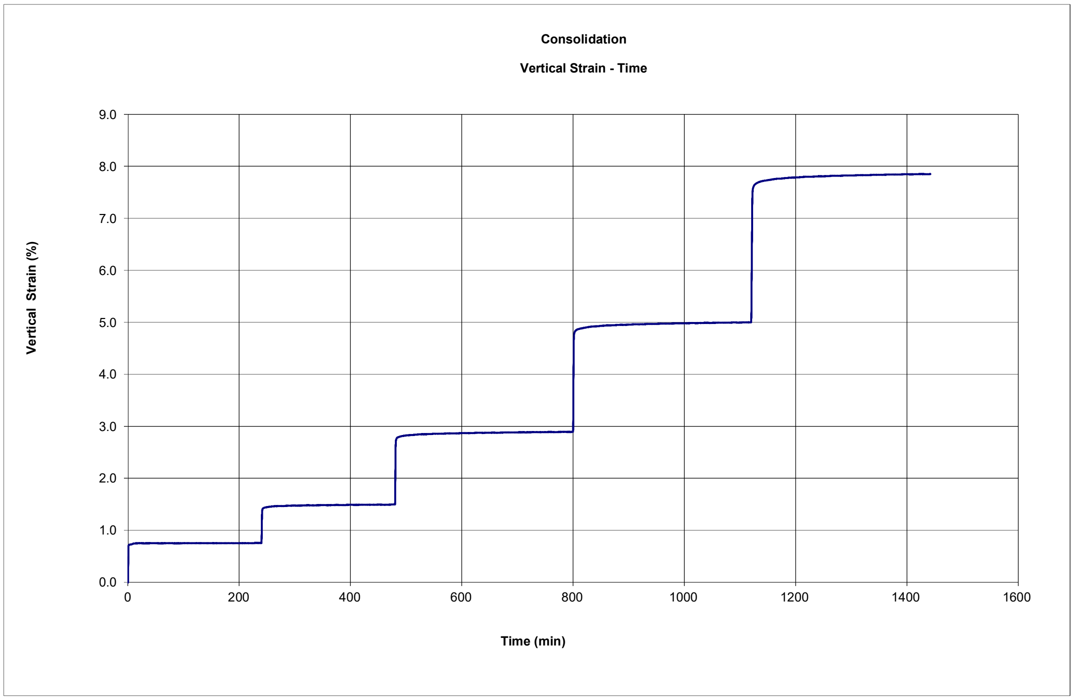


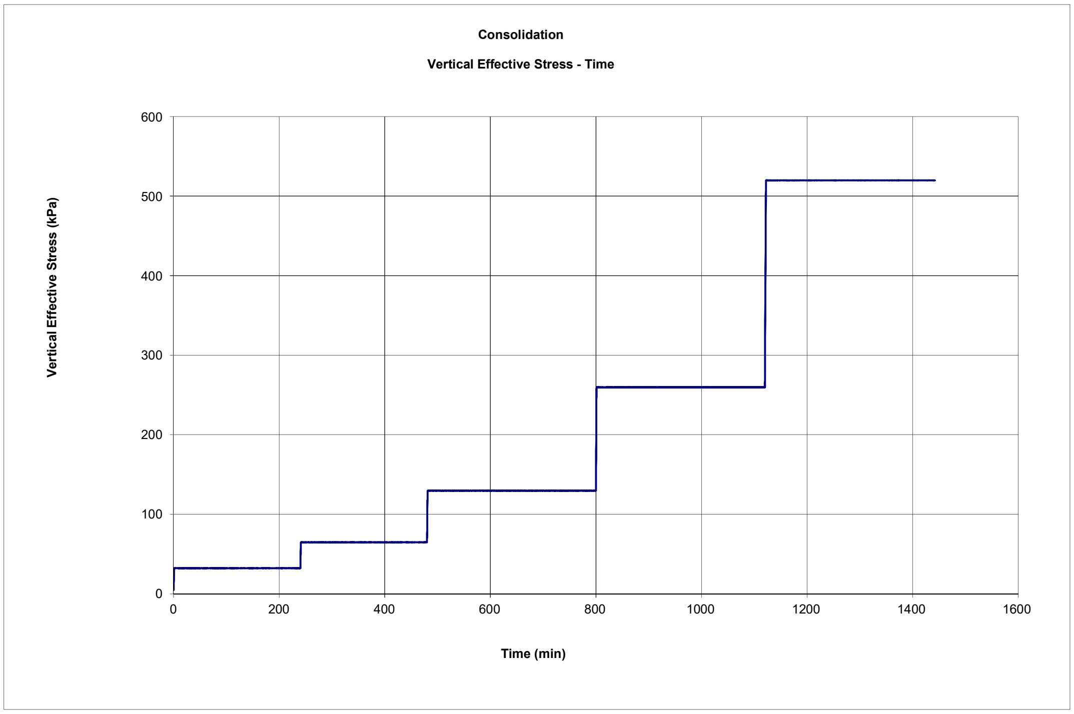
Static Simple Shear Test

(ASTM D6528)

Project No.: A03355A01
Project:
Date: 2019-10-19
Tested by: HM
Checked by: BY

Borehole ID: BH01
Sample ID: Shelby1
Depth: 3.50 m
Location: Brazil
Details: Trimmed from Shelby Tube

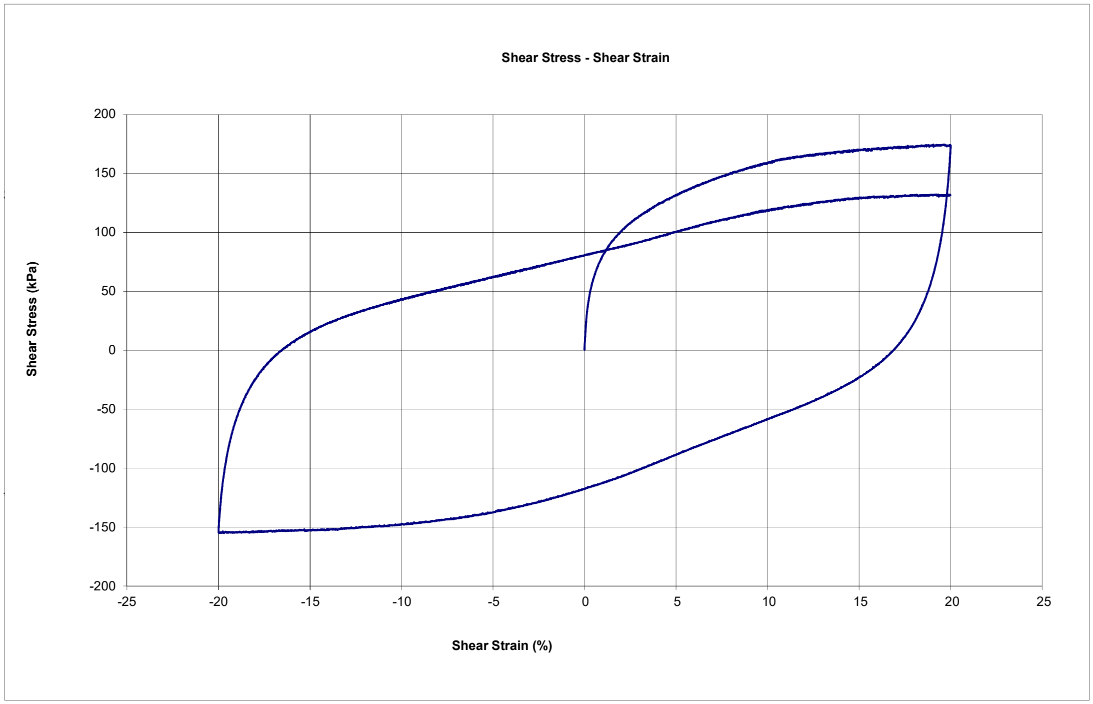


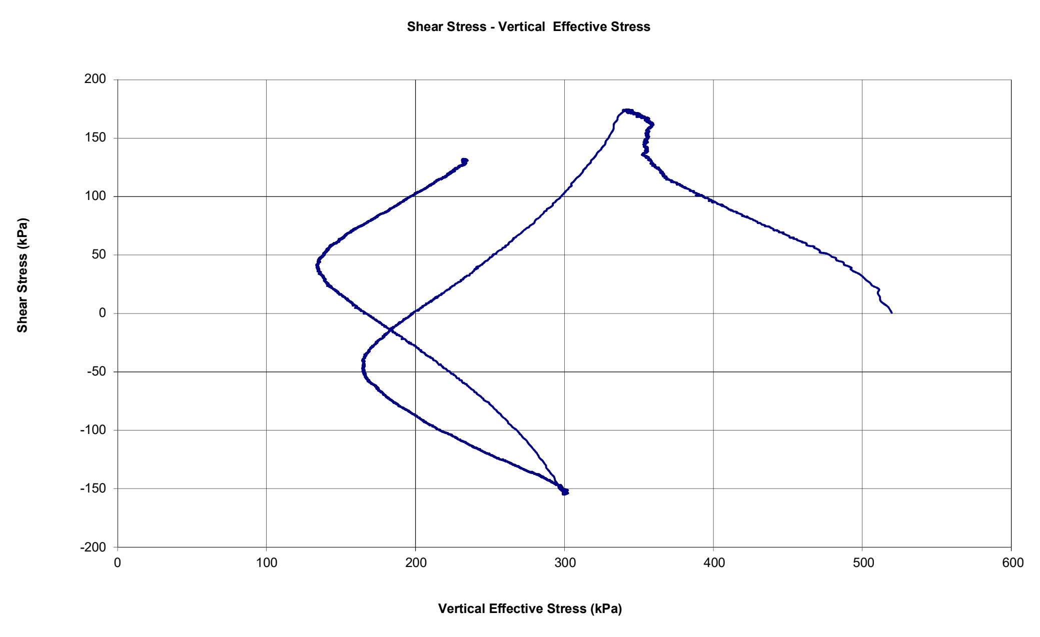


Static Simple Shear Test

(ASTM D6528)

Project No.:	A03355A01	Borehole ID:	BH01
Project:		Sample ID:	Shelby1
Date:	2019-10-19	Depth:	3.50 m
Tested by:	HM	Location:	Brazil
Checked by:	BY	Details:	Trimmed from Shelby Tube



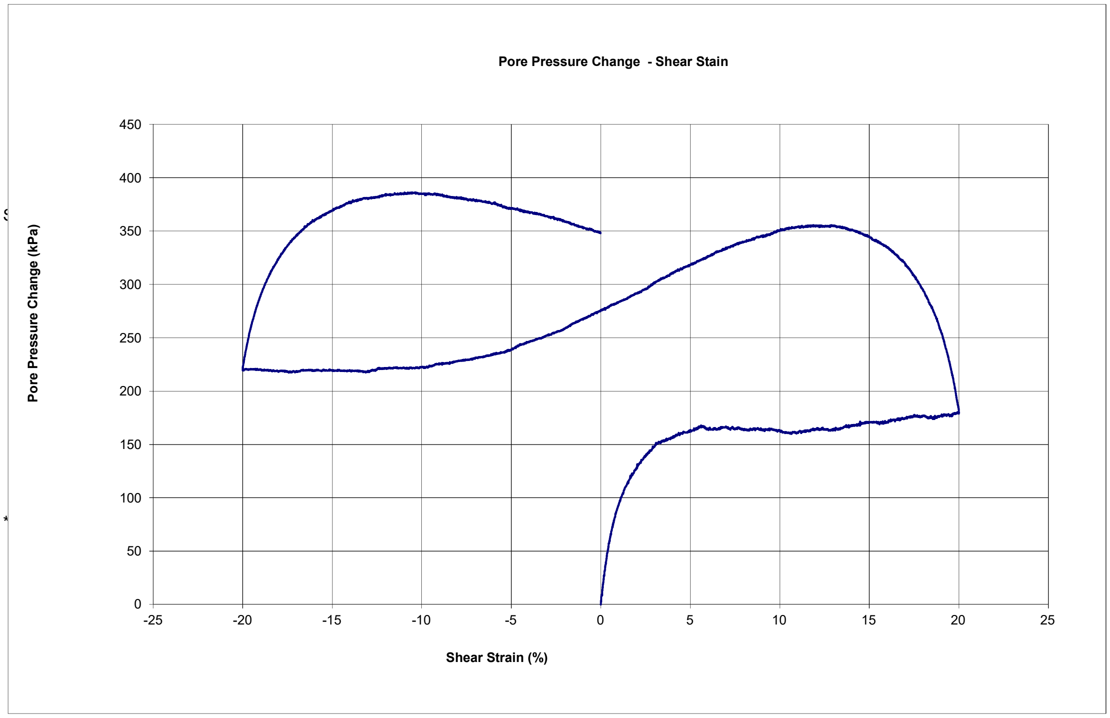


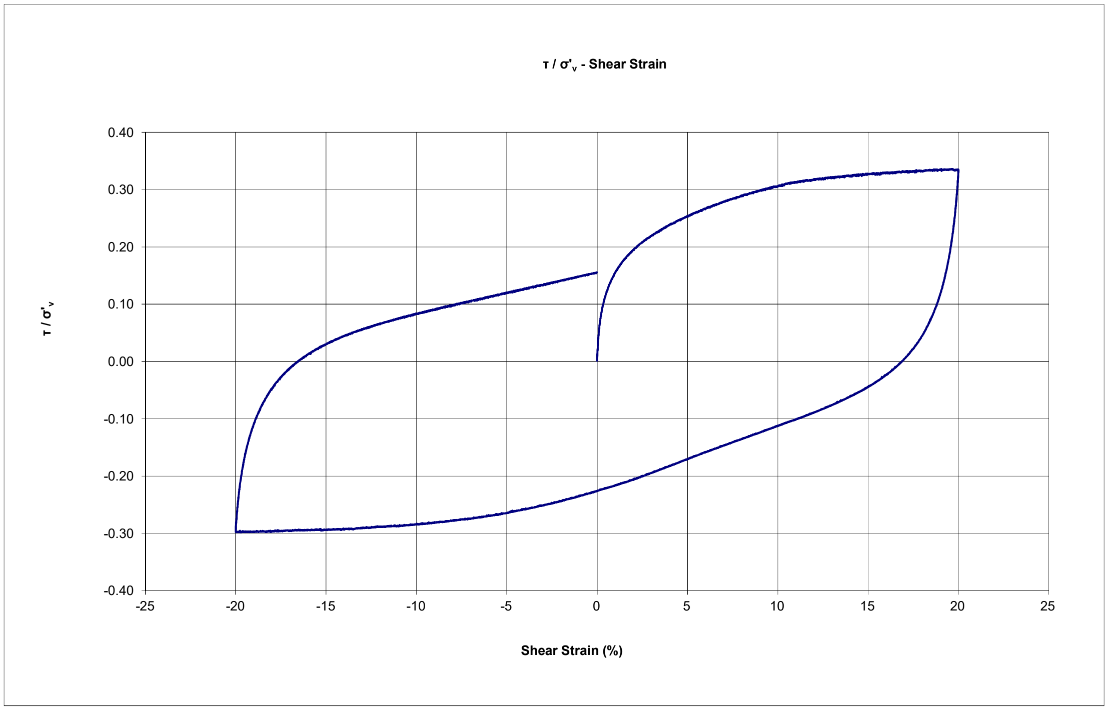
Static Simple Shear Test

(ASTM D6528)

Project No.: A03355A01
Project:
Date: 2019-10-19
Tested by: HM
Checked by: BY

Borehole ID: BH01
Sample ID: Shelby1
Depth: 3.50 m
Location: Brazil
Details: Trimmed from Shelby Tube





Static Simple Shear Test

(ASTM D6528)

Project No.: A03355A01
Project:
Date: 2019-10-17
Test by: HM
Checked by: BY

Borehole ID: BH01
Sample ID: Shelby2
Depth: 4.50 m
Location: Brazil
Details: Trimmed from Shelby Tube

Initial Sample Information		
Specimen Height	mm	23.97
Specimen Diameter	mm	70.05
Area	mm^2	3853.95
Volume	cm^3	92.38
Wet Weight	g	161.21
Water Content	%	38.31
Dry Weight	g	116.56
Wet Density	g/cm^3	1.745
Dry Density	g/cm^3	1.262
Specific Gravity (measured)	-	2.79
Void Ratio (e)	-	1.21
Saturation Ratio (Sr)	%	88.24

Static Shearing (Undrained)		
Initial Vertical Effective Stress	kPa	520
Initial Shear Stress	kPa	0.5
Shearing Rate (Shear Strain Rate)	% / hr	5.00
Peak Shear Strength	kPa	184.15
Ratio of Peak τ/σ'_v	-	0.35
Max. Excess Pore Pressure	kPa	406.05
Max. Shear Strain	%	20.0

FINAL SAMPLE INFORMATION		
Liquid Limit (test sample)		
Plastic Limit (test sample)		
Liquid Limit (shear plane)		
Plastic Limit (shear plane)		
Final Moisture Content	%	39.56
Final Moisture Content (shear plane)	%	
Final Moisture Content (outside shear plane)	%	

CONSOLIDATION	Stage #	1	2	3	4	5			
Vertical Effective Stress	kPa	32	65	130	260	520			
Max Load	kN	0.125	0.249	0.500	1.001	2.003			
Total Height Change	mm	0.23	0.40	0.66	1.00	1.60			
Consolidated Height	mm	23.74	23.57	23.31	22.97	22.37			
Axial Strain ^{*2}	%	0.97	1.69	2.73	4.17	6.69			
Duration	min	120	180	300	300	299			

*2 : Axial strain may differ from oedometer test result due to the sample seating system and possible lateral strain caused by the membrane.

Photos:

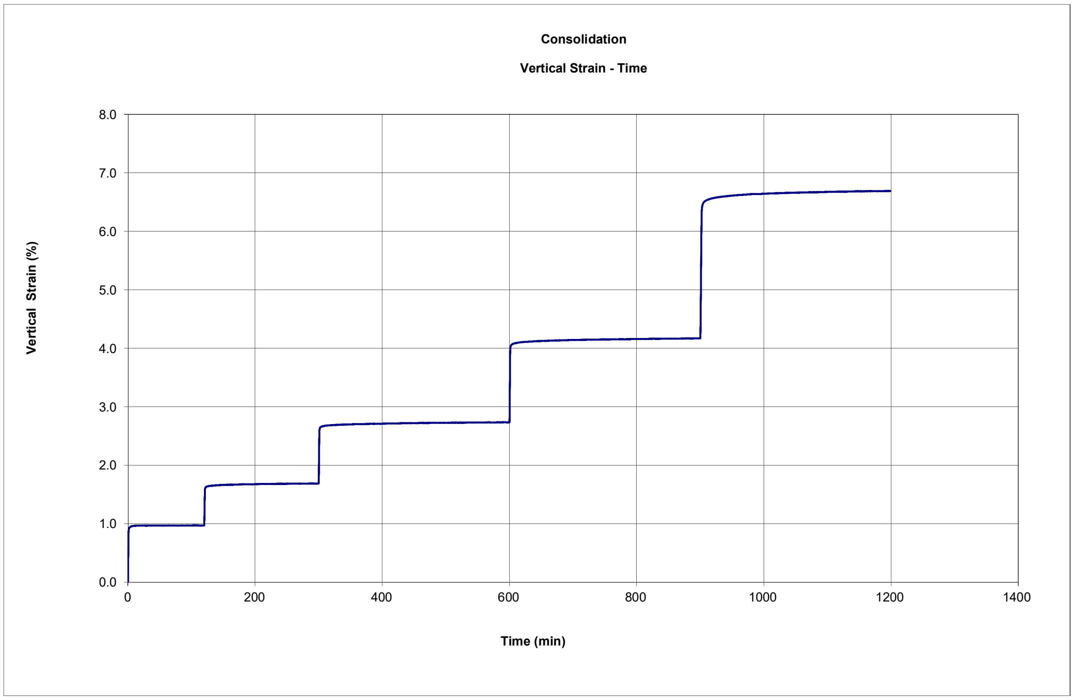
Before Test

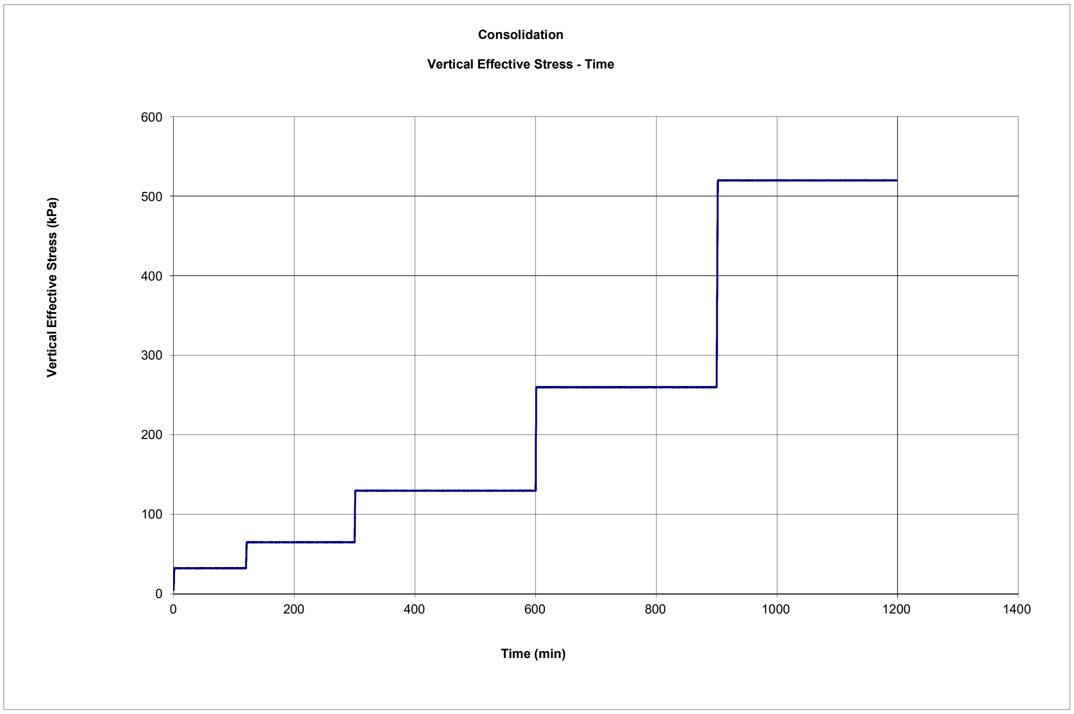
After Test

Static Simple Shear Test

(ASTM D6528)

Project No.:	A03355A01	Borehole ID:	BH01
Project:		Sample ID:	Shelby2
Date:	2019-10-17	Depth:	4.50 m
Tested by:	HM	Location:	Brazil
Checked by:	BY	Details:	Trimmed from Shelby Tube

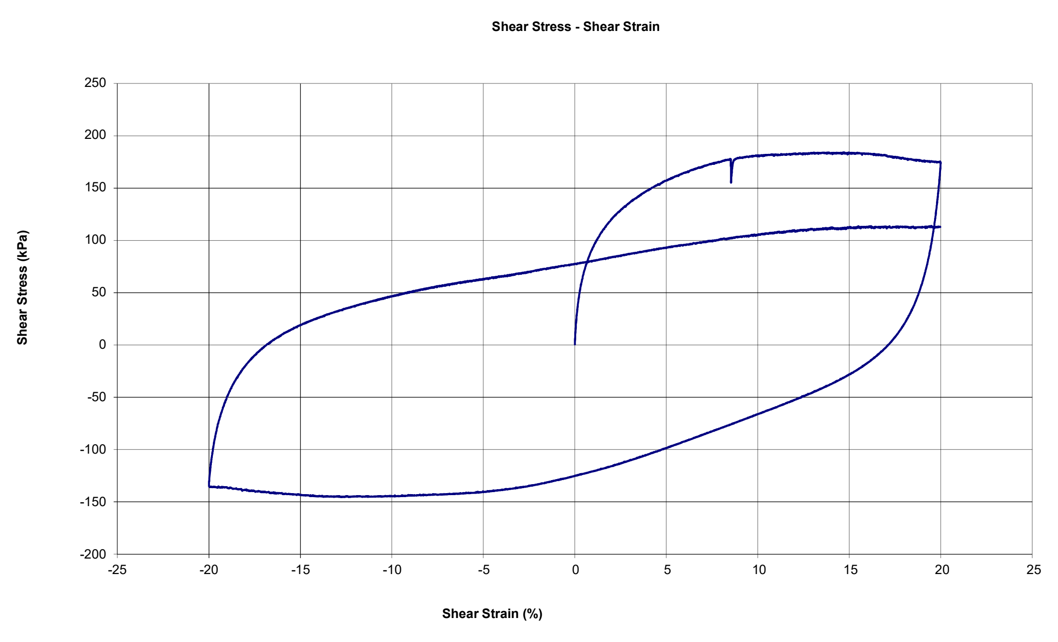


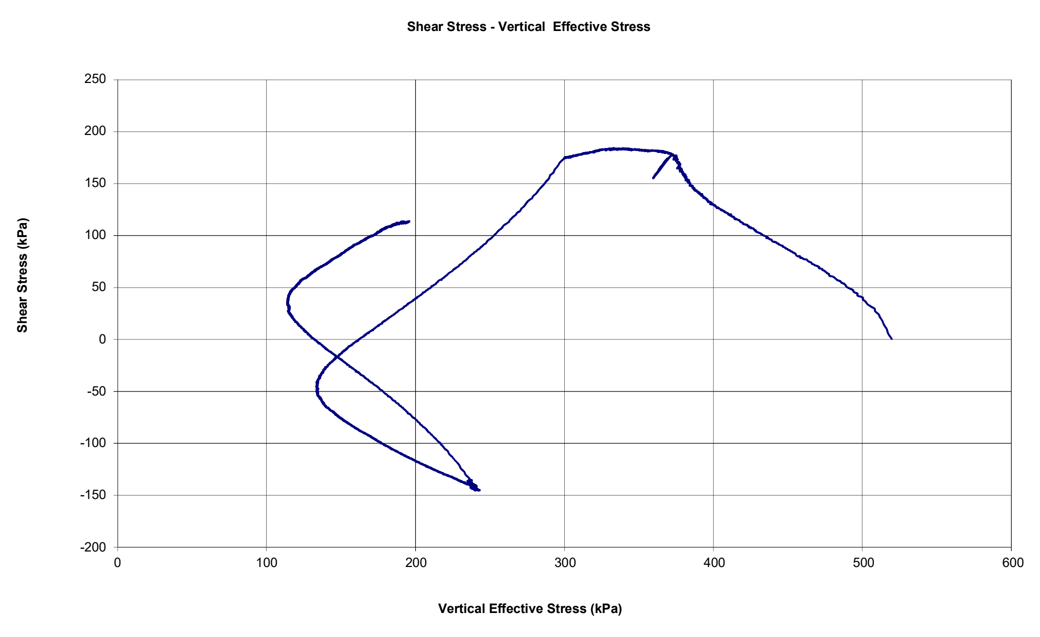


Static Simple Shear Test

(ASTM D6528)

Project No.:	A03355A01	Borehole ID:	BH01
Project:		Sample ID:	Shelby2
Date:	2019-10-17	Depth:	4.50 m
Tested by:	HM	Location:	Brazil
Checked by:	BY	Details:	Trimmed from Shelby Tube

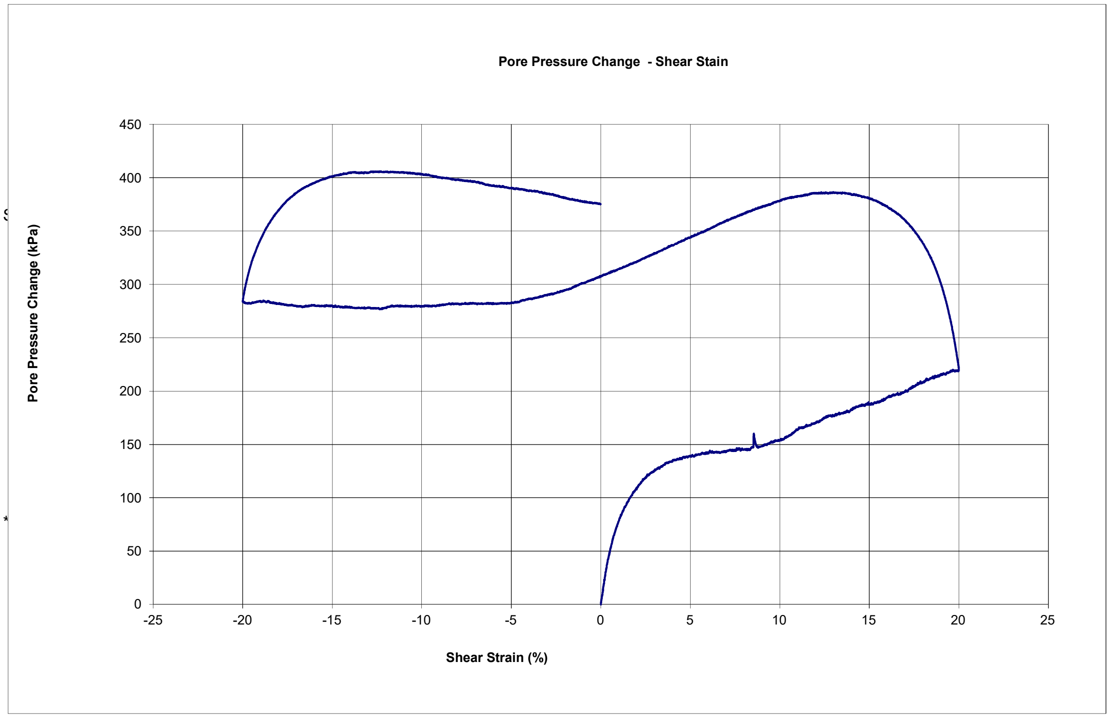


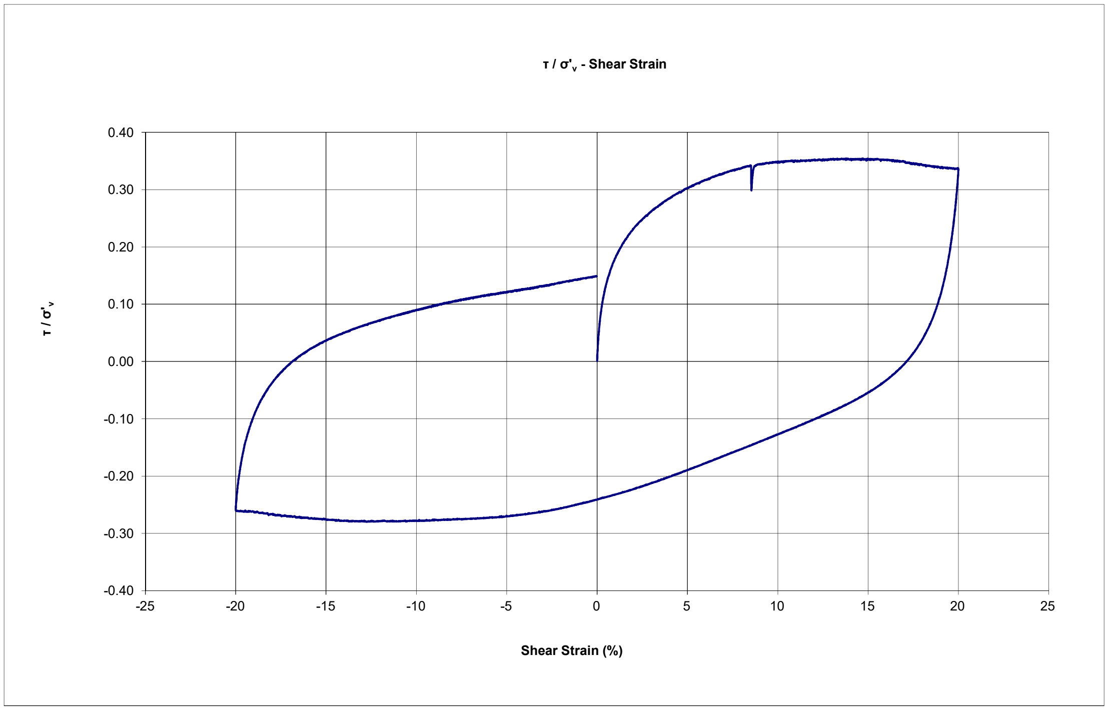


Static Simple Shear Test

(ASTM D6528)

Project No.:	A03355A01	Borehole ID:	BH01
Project:		Sample ID:	Shelby2
Date:	2019-10-17	Depth:	4.50 m
Tested by:	HM	Location:	Brazil
Checked by:	BY	Details:	Trimmed from Shelby Tube





Static Simple Shear Test

(ASTM D6528)

Project No.:	A03355A01	Borehole ID:	BH02
Project:		Sample ID:	Shelby1
Date:	2019-10-17	Depth:	3.50 m
Test by:	HM	Location:	Brazil
Checked by:	BY	Details:	Trimmed from Shelby Tube

Initial Sample Information		
Specimen Height	mm	23.98
Specimen Diameter	mm	70.02
Area	mm^2	3850.65
Volume	cm^3	92.34
Wet Weight	g	160.69
Water Content	%	43.31
Dry Weight	g	112.13
Wet Density	g/cm^3	1.740
Dry Density	g/cm^3	1.214
Specific Gravity (measured)	-	2.81
Void Ratio (e)	-	1.31
Saturation Ratio (Sr)	%	92.61

Static Shearing (Undrained)		
Initial Vertical Effective Stress	kPa	800
Initial Shear Stress	kPa	0.4
Shearing Rate (Shear Strain Rate)	% / hr	5.00
Peak Shear Strength	kPa	221.39
Ratio of Peak τ/σ'_v	-	0.28
Max. Excess Pore Pressure	kPa	656.85
Max. Shear Strain	%	20.0

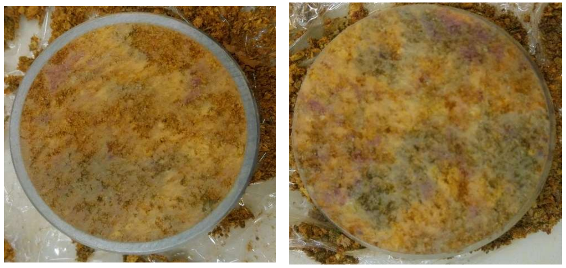
FINAL SAMPLE INFORMATION		
Liquid Limit (test sample)		
Plastic Limit (test sample)		
Liquid Limit (shear plane)		
Plastic Limit (shear plane)		
Final Moisture Content	%	43.29
Final Moisture Content (shear plane)	%	
Final Moisture Content (outside shear plane)	%	

CONSOLIDATION	Stage #	1	2	3	4	5			
Vertical Effective Stress	kPa	50	100	200	400	800			
Max Load	kN	0.191	0.384	0.769	1.539	3.080			
Total Height Change	mm	0.38	0.62	1.02	1.57	2.40			
Consolidated Height	mm	23.60	23.36	22.96	22.41	21.58			
Axial Strain *2	%	1.57	2.60	4.25	6.56	10.00			
Duration	min	280	280	280	280	393			

*2 : Axial strain may differ from oedometer test result due to the sample seating system and possible lateral strain caused by the membrane.

Photos:

Before Test

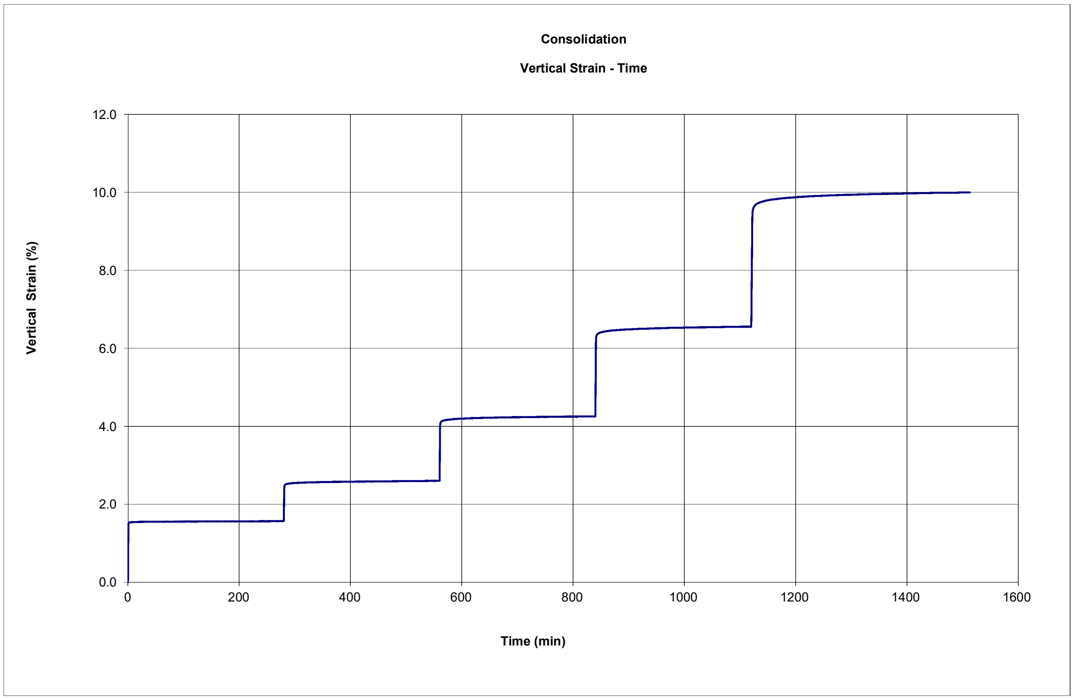


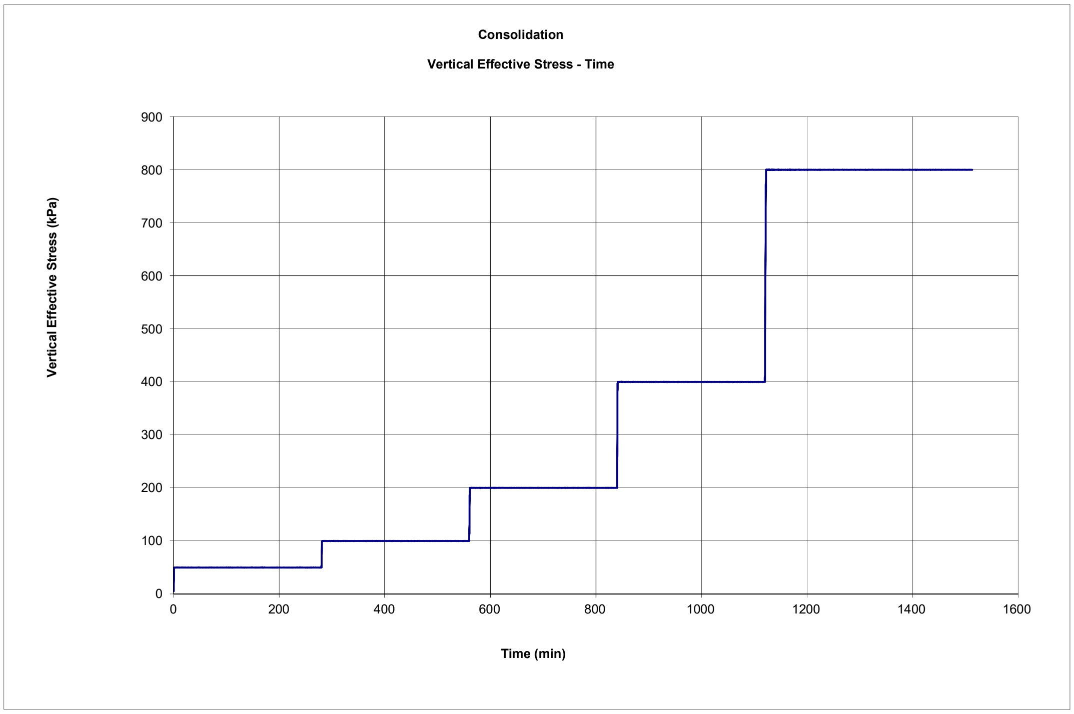
After Test

Static Simple Shear Test

(ASTM D6528)

Project No.:	A03355A01	Borehole ID:	BH02
Project:		Sample ID:	Shelby1
Date:	2019-10-17	Depth:	3.50 m
Tested by:	HM	Location:	Brazil
Checked by:	BY	Details:	Trimmed from Shelby Tube

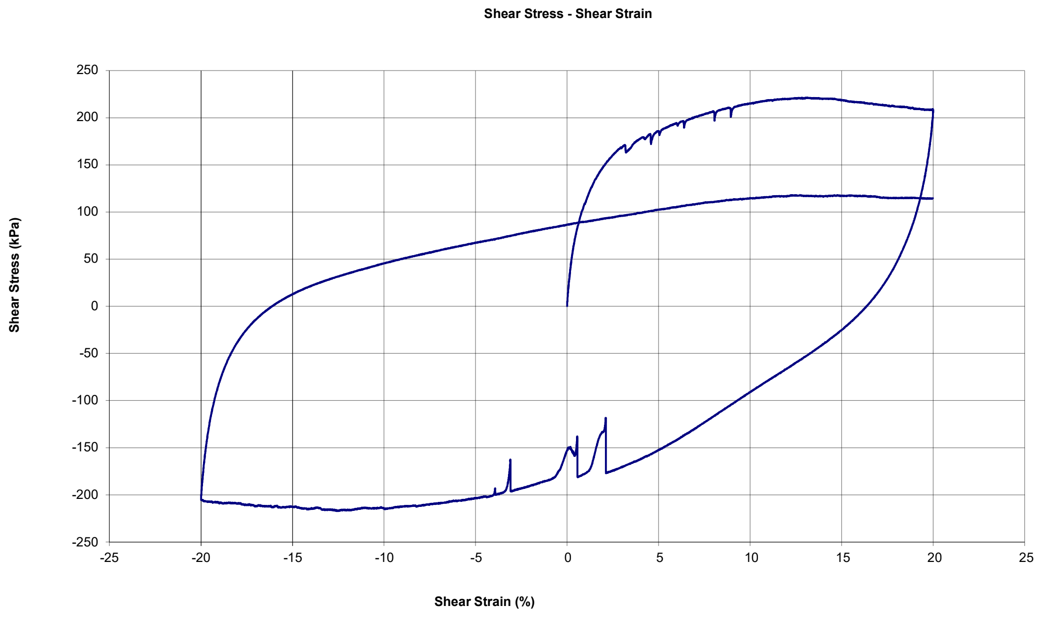


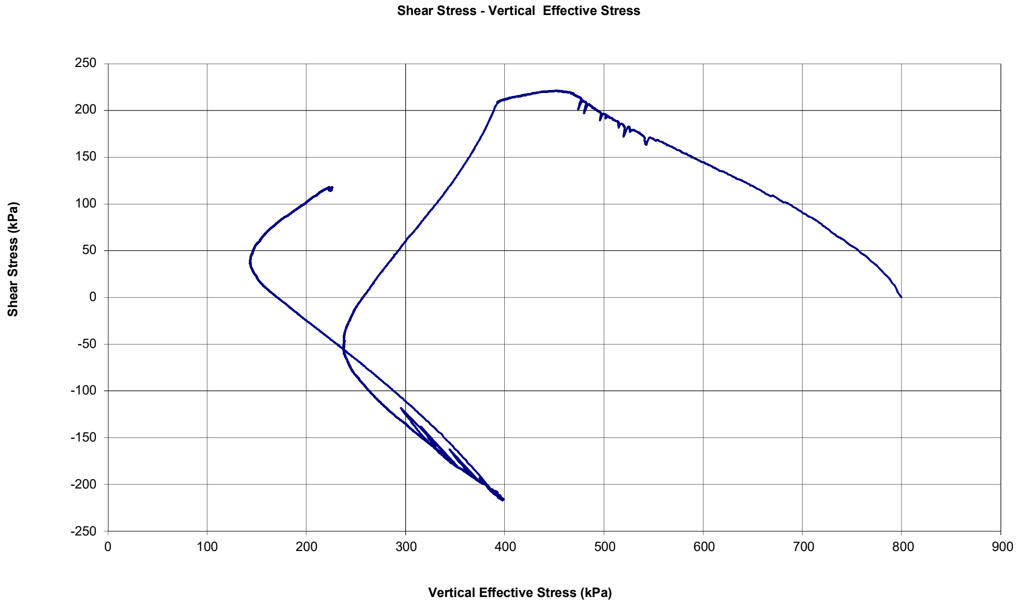


Static Simple Shear Test

(ASTM D6528)

Project No.:	A03355A01	Borehole ID:	BH02
Project:		Sample ID:	Shelby1
Date:	2019-10-17	Depth:	3.50 m
Tested by:	HM	Location:	Brazil
Checked by:	BY	Details:	Trimmed from Shelby Tube

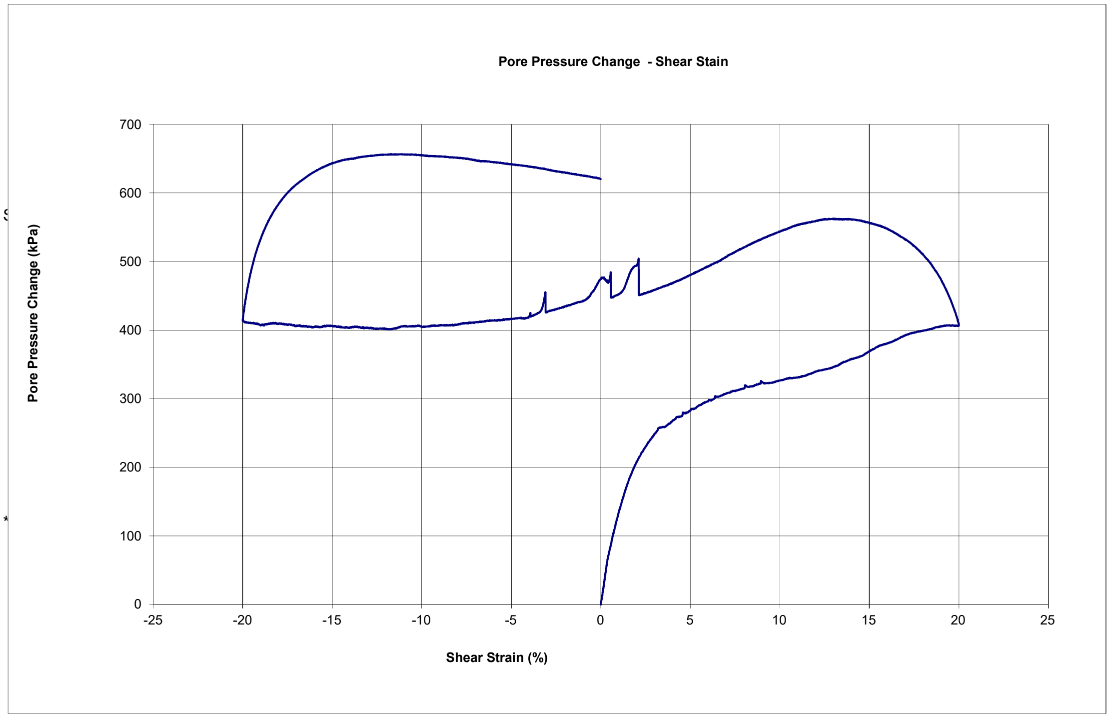


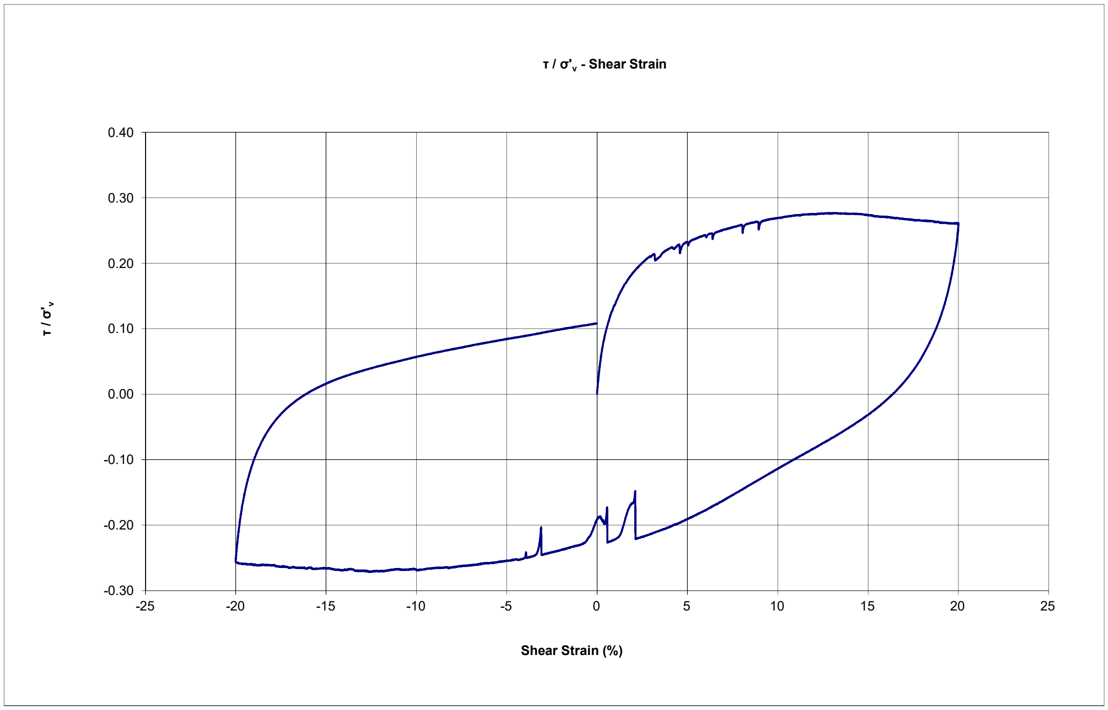


Static Simple Shear Test

(ASTM D6528)

Project No.:	A03355A01	Borehole ID:	BH02
Project:		Sample ID:	Shelby1
Date:	2019-10-17	Depth:	3.50 m
Tested by:	HM	Location:	Brazil
Checked by:	BY	Details:	Trimmed from Shelby Tube





Static Simple Shear Test
(ASTM D6528)

Project No.:	A03355A01	Borehole ID:	BH02
Project:		Sample ID:	Shelby2
Date:	2019-10-10	Depth:	
Test by:	HM	Location:	Brazil
Checked by:	BY	Details:	Trimmed from Shelby Tube

Initial Sample Information		
Specimen Height	mm	24.00
Specimen Diameter	mm	70.03
Area	mm^2	3851.75
Volume	cm^3	92.44
Wet Weight	g	170.83
Water Content	%	29.08
Dry Weight	g	132.34
Wet Density	g/cm^3	1.848
Dry Density	g/cm^3	1.432
Specific Gravity (measured)	-	2.81
Void Ratio (e)	-	0.96
Saturation Ratio (Sr)	%	84.87

Static Shearing (Undrained)		
Initial Vertical Effective Stress	kPa	800
Initial Shear Stress	kPa	0.5
Shearing Rate (Shear Strain Rate)	% / hr	5.00
Peak Shear Strength	kPa	199.00
Ratio of Peak τ/σ'_v	-	0.25
Max. Excess Pore Pressure	kPa	630.05
Max. Shear Strain	%	20.0

FINAL SAMPLE INFORMATION		
Liquid Limit (test sample)		
Plastic Limit (test sample)		
Liquid Limit (shear plane)		
Plastic Limit (shear plane)		
Final Moisture Content	%	29.17
Final Moisture Content (shear plane)	%	
Final Moisture Content (outside shear plane)	%	

CONSOLIDATION	Stage #	1	2	3	4	5			
Vertical Effective Stress	kPa	50	100	200	400	800			
Max Load	kN	0.192	0.384	0.769	1.540	3.081			
Total Height Change	mm	0.22	0.42	0.79	1.33	2.24			
Consolidated Height	mm	23.78	23.58	23.21	22.67	21.77			
Axial Strain [*2]	%	0.92	1.76	3.27	5.55	9.31			
Duration	min	360	360	360	360	1116			

*2 : Axial strain may differ from oedometer test result due to the sample seating system and possible lateral strain caused by the membrane.

Photos:

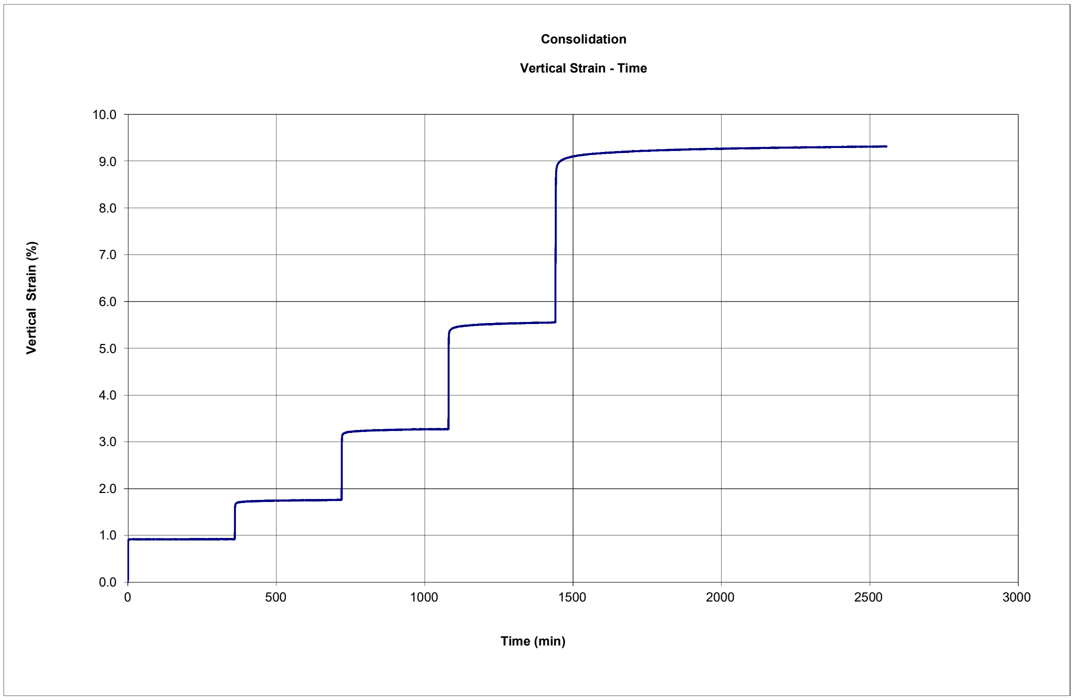
Before Test

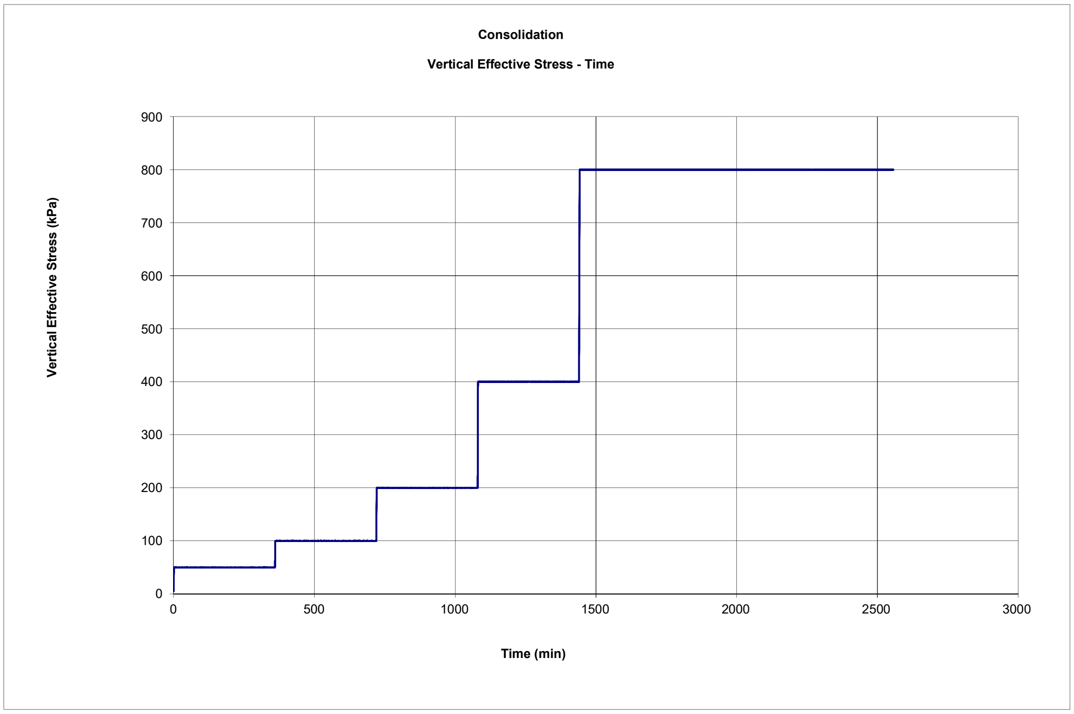
After Test

Static Simple Shear Test

(ASTM D6528)

Project No.:	A03355A01	Borehole ID:	BH02
Project:		Sample ID:	Shelby2
Date:	2019-10-10	Depth:	
Tested by:	HM	Location:	Brazil
Checked by:	BY	Details:	Trimmed from Shelby Tube

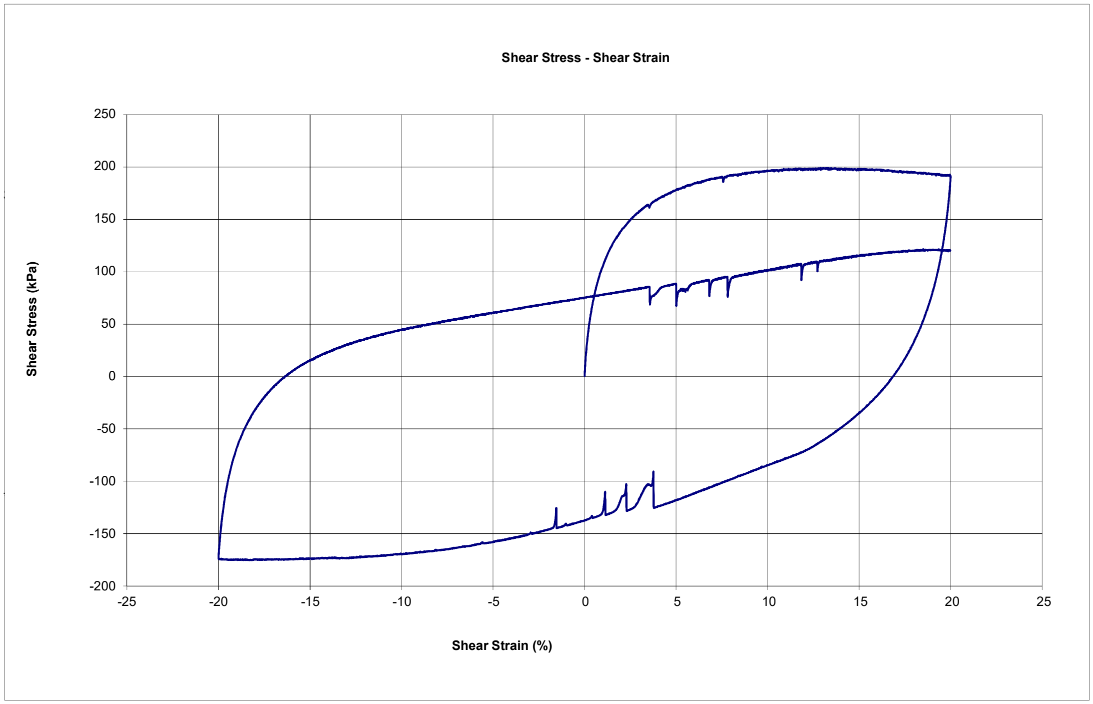


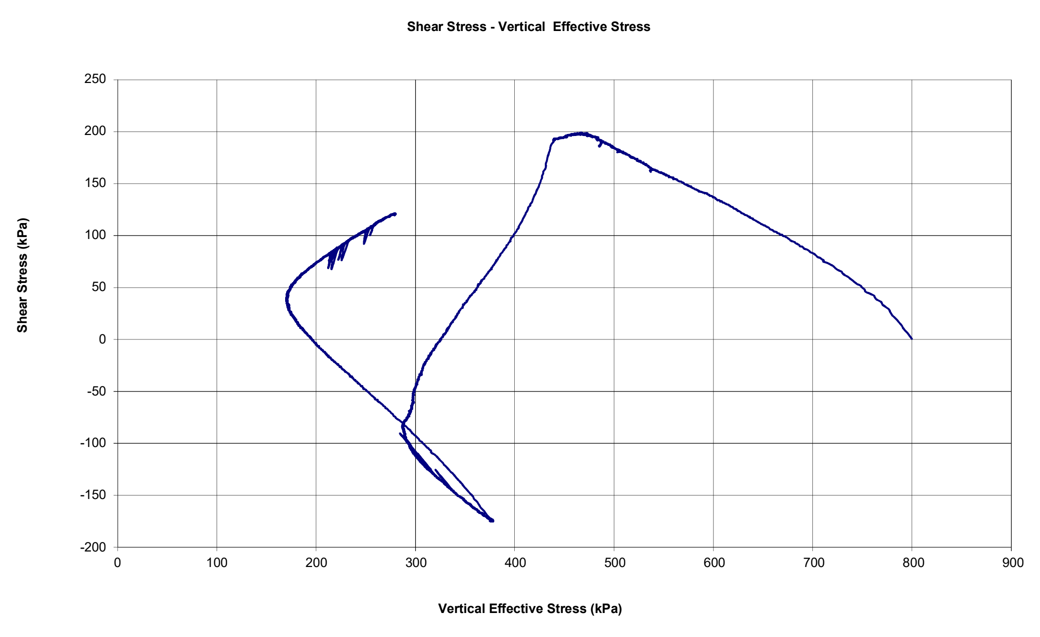


Static Simple Shear Test

(ASTM D6528)

Project No.:	A03355A01	Borehole ID:	BH02
Project:		Sample ID:	Shelby2
Date:	2019-10-10	Depth:	
Tested by:	HM	Location:	Brazil
Checked by:	BY	Details:	Trimmed from Shelby Tube



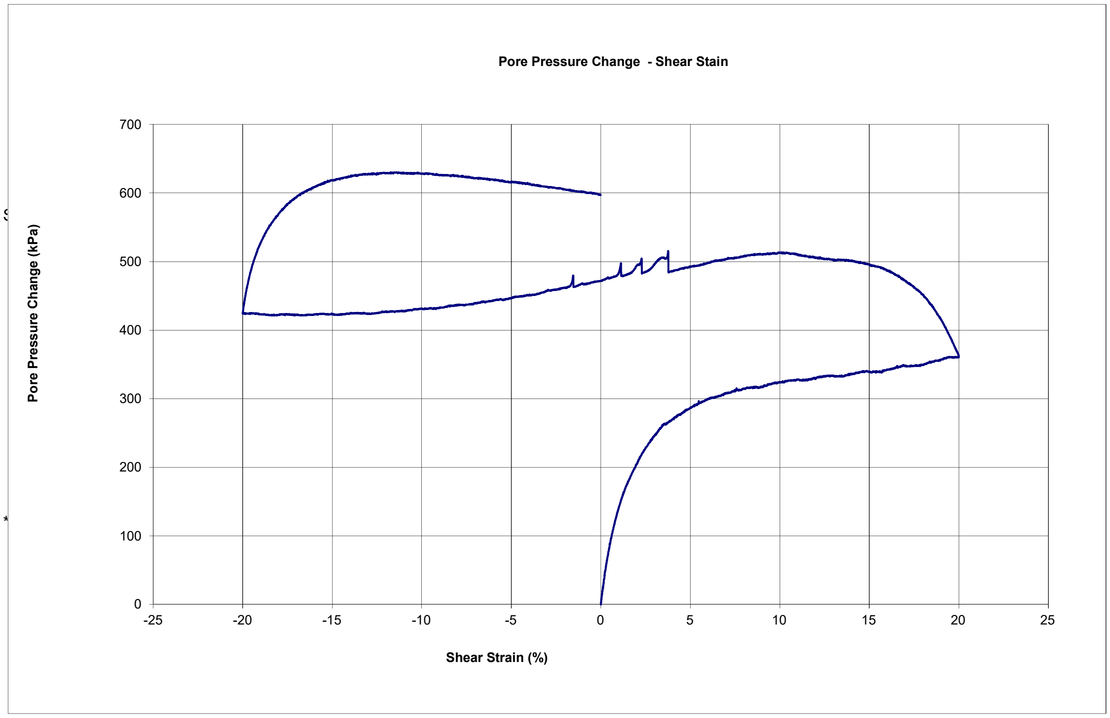


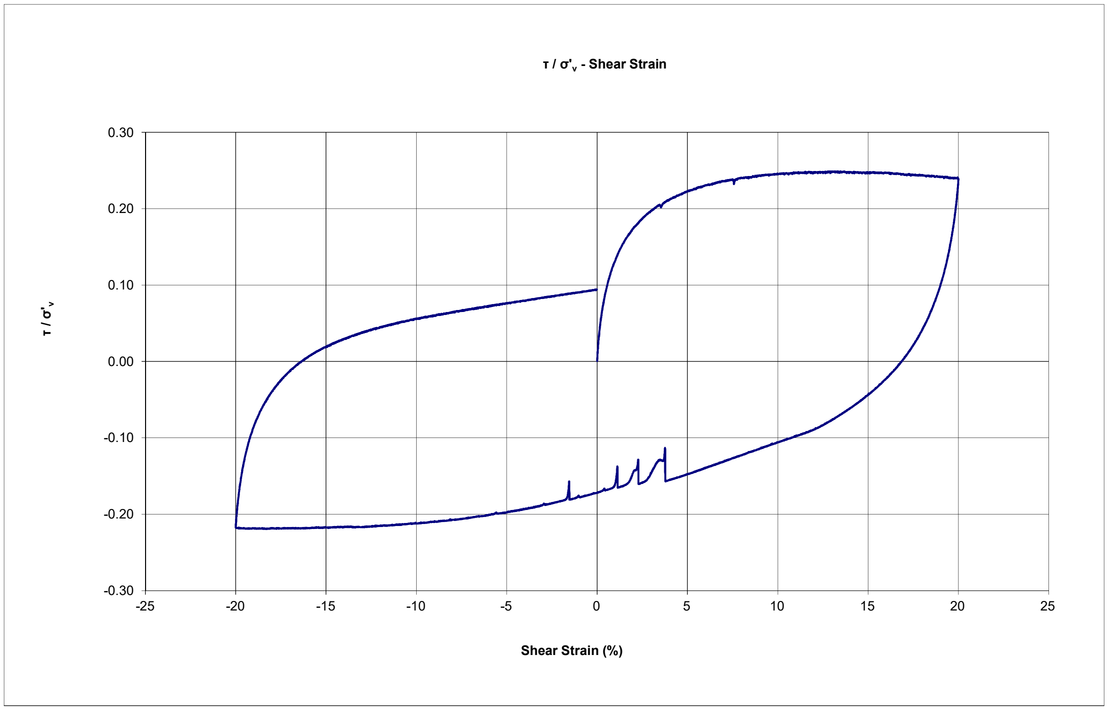
Static Simple Shear Test

(ASTM D6528)

Project No.: A03355A01
Project:
Date: 2019-10-10
Tested by: HM
Checked by: BY

Borehole ID: BH02
Sample ID: Shelby2
Depth:
Location: Brazil
Details: Trimmed from Shelby Tube





Static Simple Shear Test
(ASTM D6528)

Project No.:	A03355A01	Borehole ID:	BH04
Project:		Sample ID:	Shelby1
Date:	2019-10-10	Depth:	
Test by:	HM	Location:	Brazil
Checked by:	BY	Details:	Trimmed from Shelby Tube

Initial Sample Information		
Specimen Height	mm	23.98
Specimen Diameter	mm	70.01
Area	mm^2	3849.55
Volume	cm^3	92.31
Wet Weight	g	157.38
Water Content	%	36.13
Dry Weight	g	115.61
Wet Density	g/cm^3	1.705
Dry Density	g/cm^3	1.252
Specific Gravity (measured)	-	2.82
Void Ratio (e)	-	1.25
Saturation Ratio (Sr)	%	81.40

Static Shearing (Undrained)		
Initial Vertical Effective Stress	kPa	350
Initial Shear Stress	kPa	0.6
Shearing Rate (Shear Strain Rate)	% / hr	5.00
Peak Shear Strength	kPa	153.76
Ratio of Peak τ/σ'_v	-	0.44
Max. Excess Pore Pressure	kPa	271.85
Max. Shear Strain	%	20.0

FINAL SAMPLE INFORMATION		
Liquid Limit (test sample)		
Plastic Limit (test sample)		
Liquid Limit (shear plane)		
Plastic Limit (shear plane)		
Final Moisture Content	%	41.67
Final Moisture Content (shear plane)	%	
Final Moisture Content (outside shear plane)	%	

CONSOLIDATION	Stage #	1	2	3	4				
Vertical Effective Stress	kPa	50	100	200	350				
Max Load	kN	0.191	0.384	0.769	1.346				
Total Height Change	mm	0.26	0.46	0.78	1.13				
Consolidated Height	mm	23.72	23.52	23.20	22.85				
Axial Strain [*2]	%	1.07	1.91	3.24	4.73				
Duration	min	250	360	360	1796				

*2 : Axial strain may differ from oedometer test result due to the sample seating system and possible lateral strain caused by the membrane.

Photos:

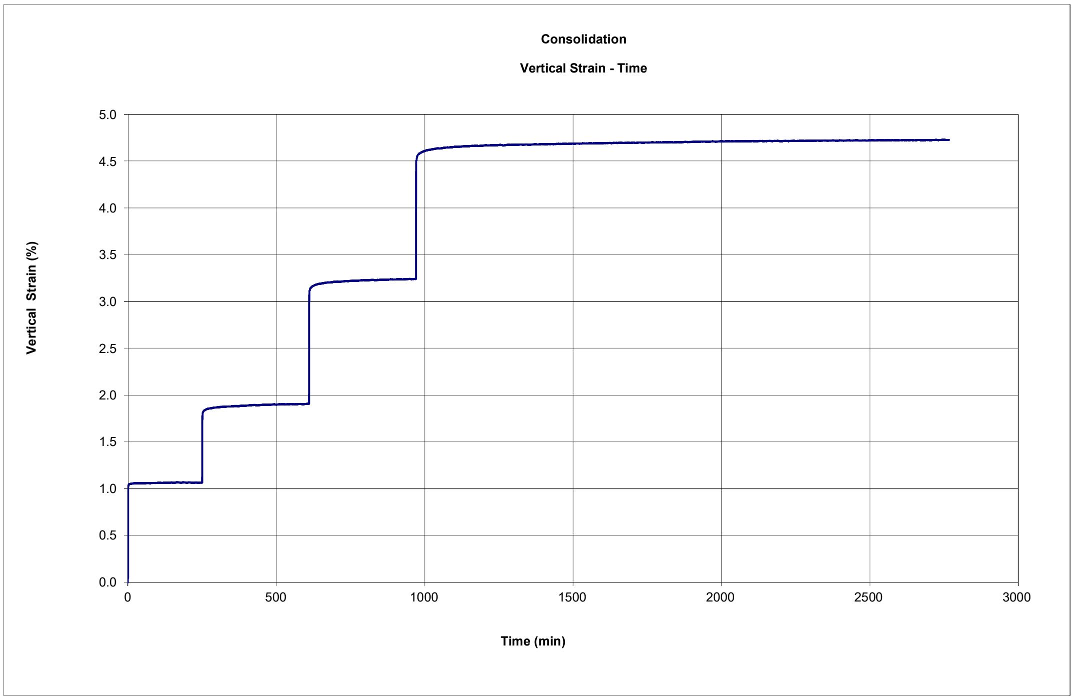
Before Test

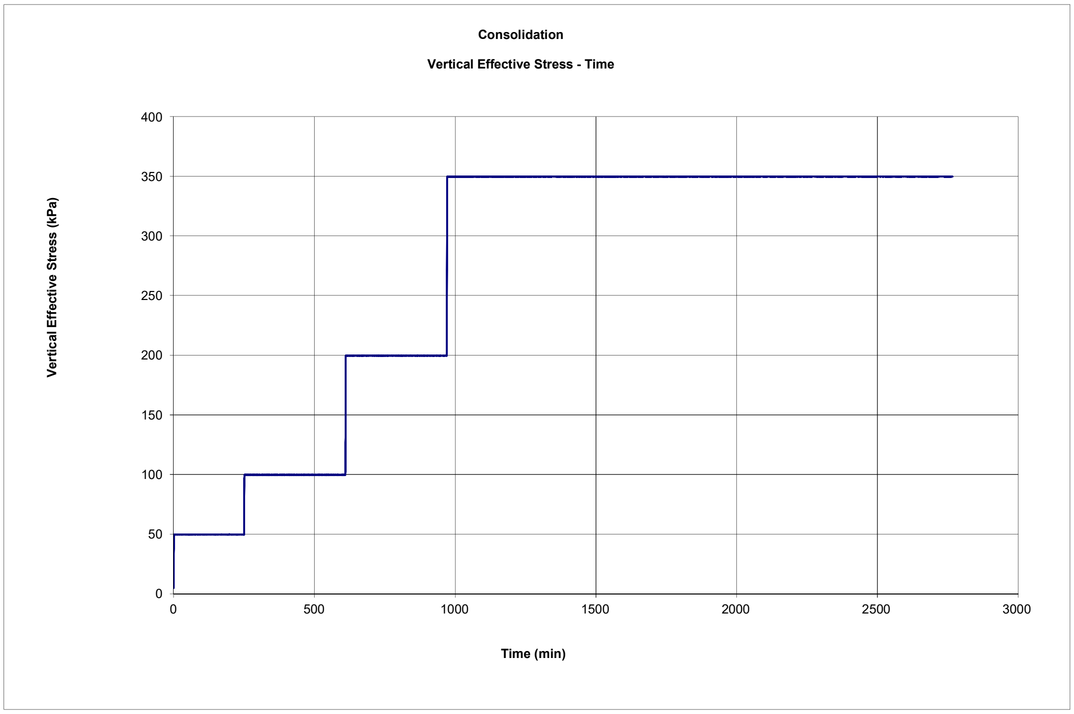
After Test

Static Simple Shear Test

(ASTM D6528)

Project No.:	A03355A01	Borehole ID:	BH04
Project:		Sample ID:	Shelby1
Date:	2019-10-10	Depth:	
Tested by:	HM	Location:	Brazil
Checked by:	BY	Details:	Trimmed from Shelby Tube

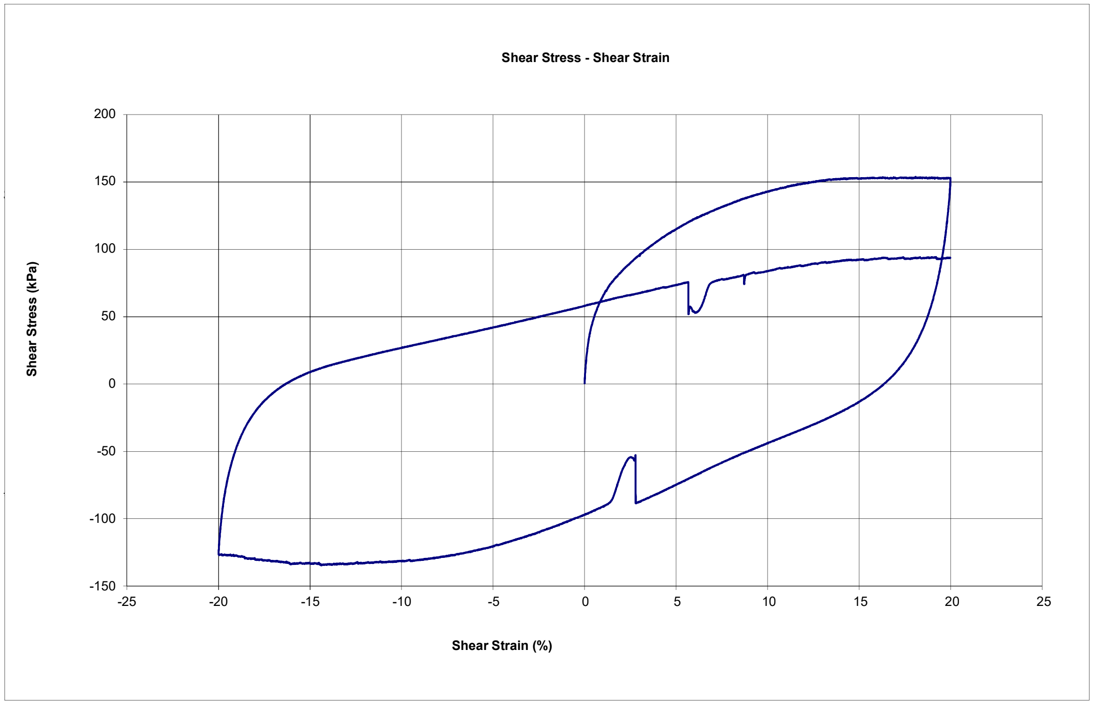


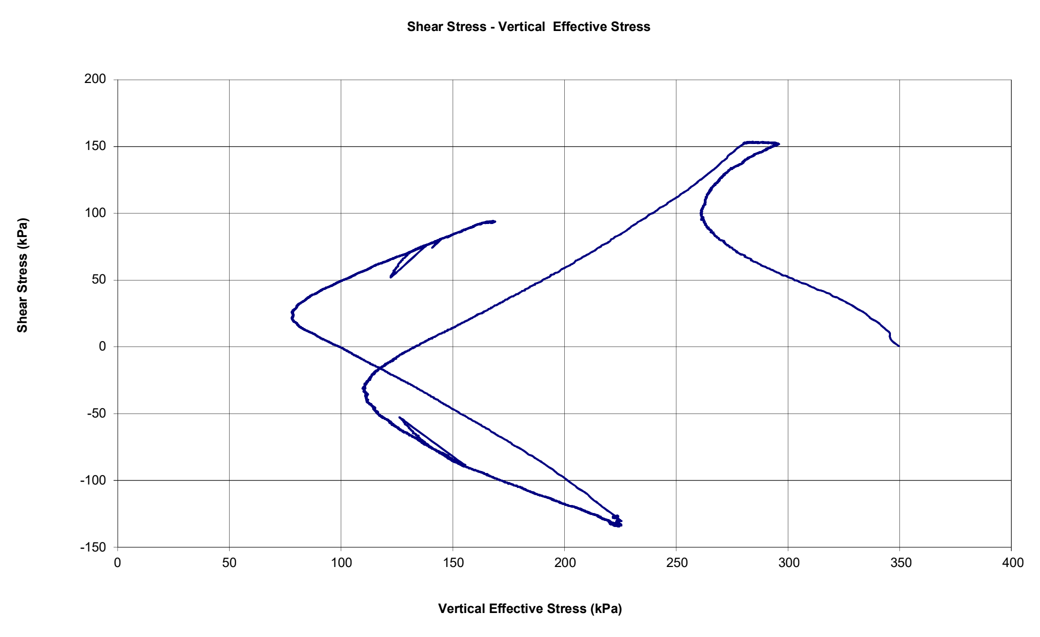


Static Simple Shear Test

(ASTM D6528)

Project No.:	A03355A01	Borehole ID:	BH04
Project:		Sample ID:	Shelby1
Date:	2019-10-10	Depth:	
Tested by:	HM	Location:	Brazil
Checked by:	BY	Details:	Trimmed from Shelby Tube

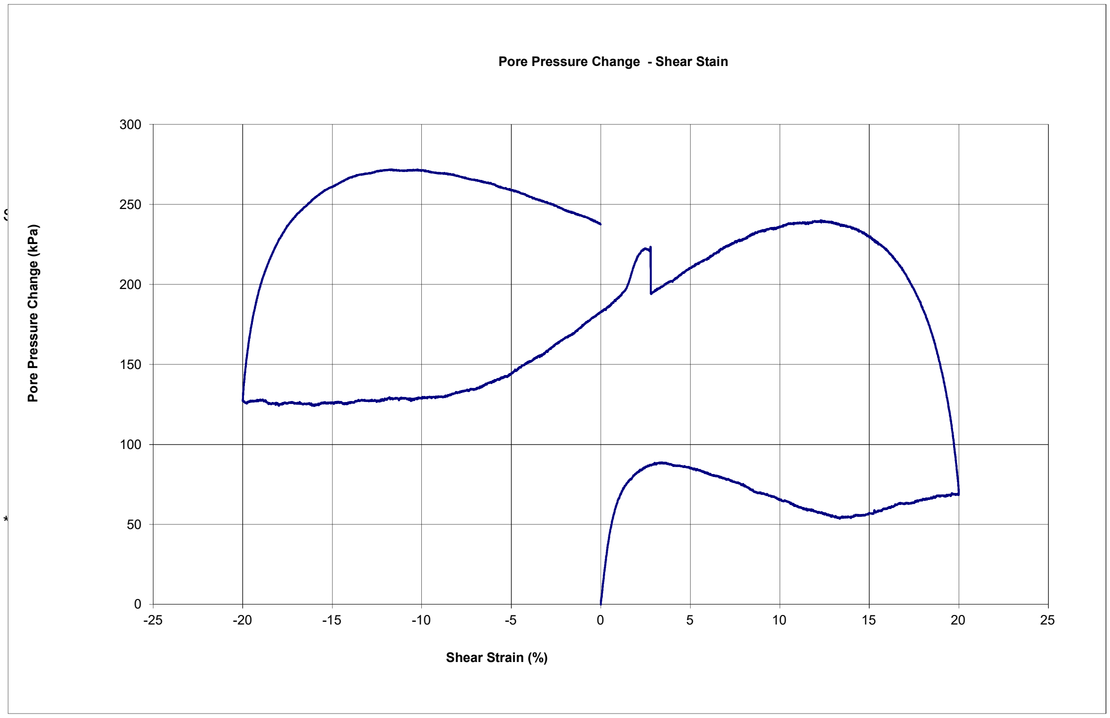


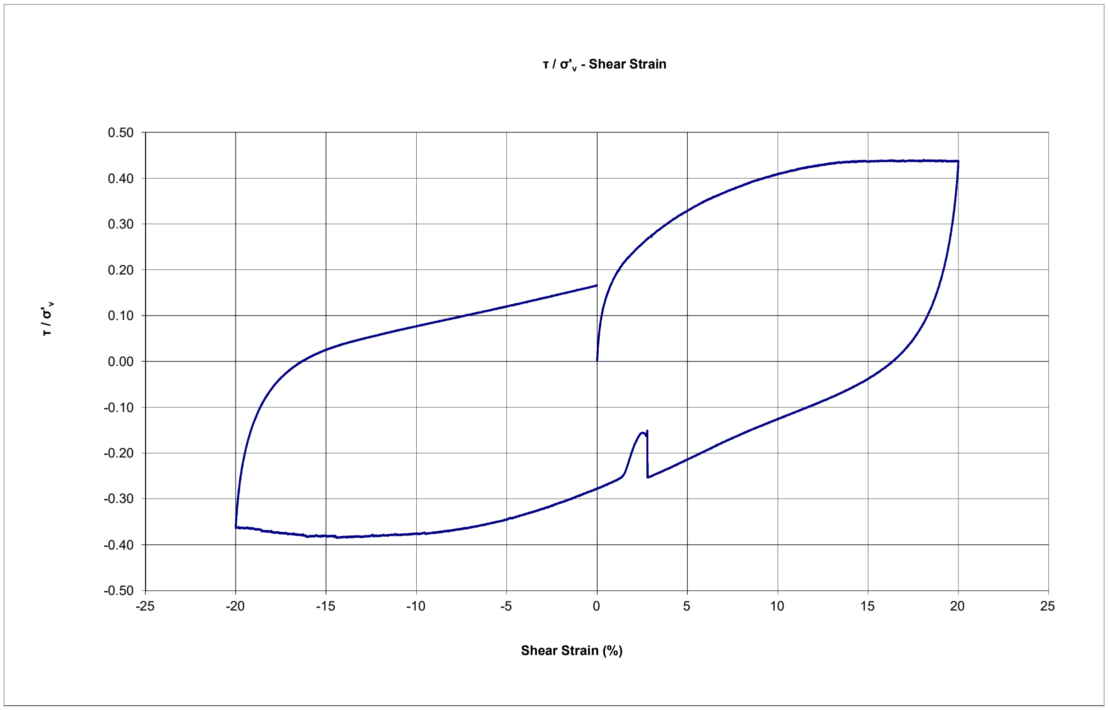


Static Simple Shear Test

(ASTM D6528)

Project No.:	A03355A01	Borehole ID:	BH04
Project:		Sample ID:	Shelby1
Date:	2019-10-10	Depth:	
Tested by:	HM	Location:	Brazil
Checked by:	BY	Details:	Trimmed from Shelby Tube





Static Simple Shear Test
(ASTM D6528)

Project No.:	A03355A01	Borehole ID:	BH04
Project:		Sample ID:	Shelby2
Date:	2019-10-15	Depth:	5.30 m
Test by:	HM	Location:	Brazil
Checked by:	BY	Details:	Trimmed from Shelby Tube

Initial Sample Information		
Specimen Height	mm	23.96
Specimen Diameter	mm	70.03
Area	mm^2	3851.75
Volume	cm^3	92.29
Wet Weight	g	174.17
Water Content	%	30.08
Dry Weight	g	133.89
Wet Density	g/cm^3	1.887
Dry Density	g/cm^3	1.451
Specific Gravity (measured)	-	2.82
Void Ratio (e)	-	0.94
Saturation Ratio (Sr)	%	89.89

Static Shearing (Undrained)		
Initial Vertical Effective Stress	kPa	370
Initial Shear Stress	kPa	0.5
Shearing Rate (Shear Strain Rate)	% / hr	5.00
Peak Shear Strength	kPa	130.56
Ratio of Peak τ/σ'_v	-	0.35
Max. Excess Pore Pressure	kPa	303.29
Max. Shear Strain	%	20.0

FINAL SAMPLE INFORMATION		
Liquid Limit (test sample)		
Plastic Limit (test sample)		
Liquid Limit (shear plane)		
Plastic Limit (shear plane)		
Final Moisture Content	%	29.90
Final Moisture Content (shear plane)	%	
Final Moisture Content (outside shear plane)	%	

CONSOLIDATION	Stage #	1	2	3	4				
Vertical Effective Stress	kPa	50	100	200	370				
Max Load	kN	0.192	0.384	0.769	1.424				
Total Height Change	mm	0.71	1.07	1.56	2.10				
Consolidated Height	mm	23.25	22.89	22.40	21.86				
Axial Strain *2	%	2.94	4.46	6.50	8.75				
Duration	min	360	360	360	591				

*2 : Axial strain may differ from oedometer test result due to the sample seating system and possible lateral strain caused by the membrane.

Photos:

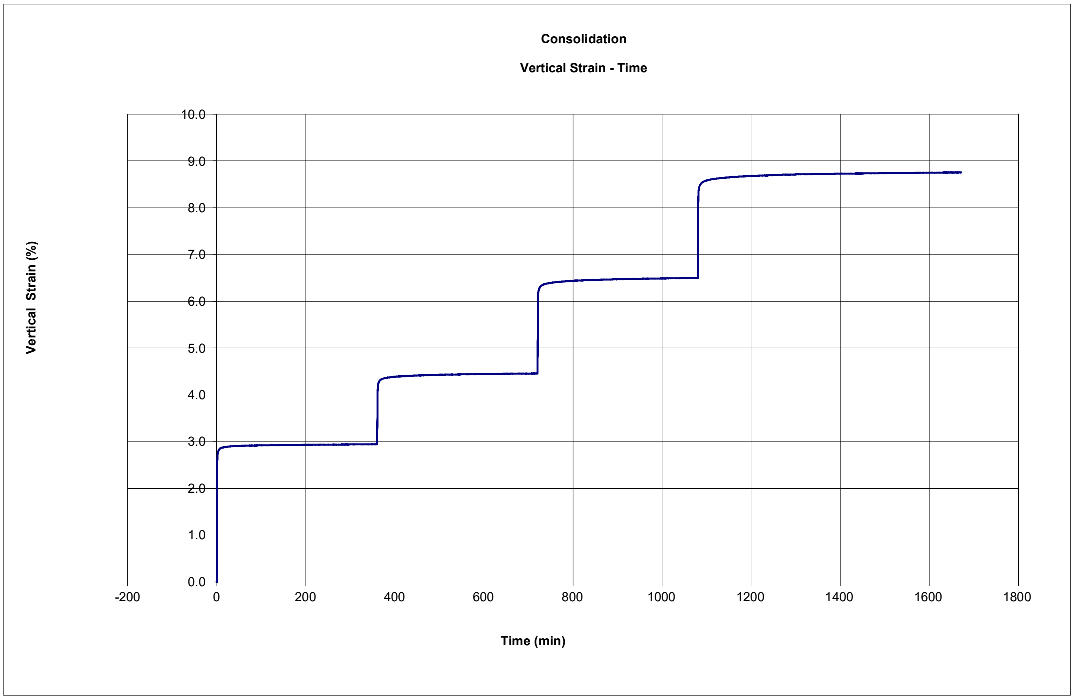
Before Test

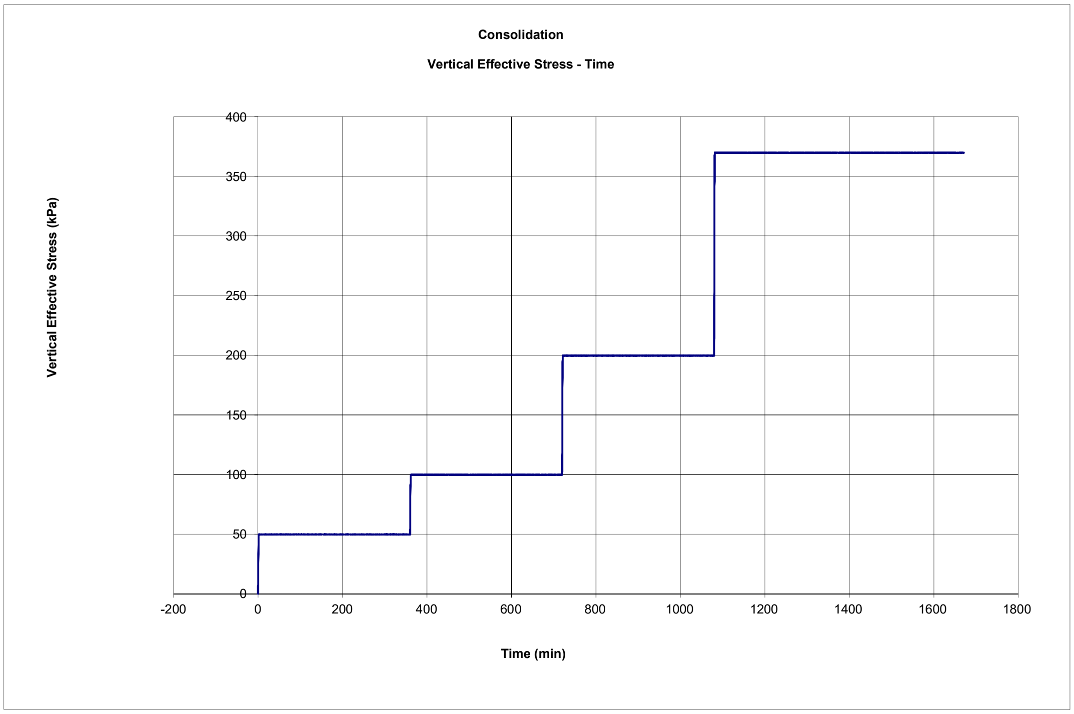
After Test

Static Simple Shear Test

(ASTM D6528)

Project No.:	A03355A01	Borehole ID:	BH04
Project:		Sample ID:	Shelby2
Date:	2019-10-15	Depth:	5.30 m
Tested by:	HM	Location:	Brazil
Checked by:	BY	Details:	Trimmed from Shelby Tube

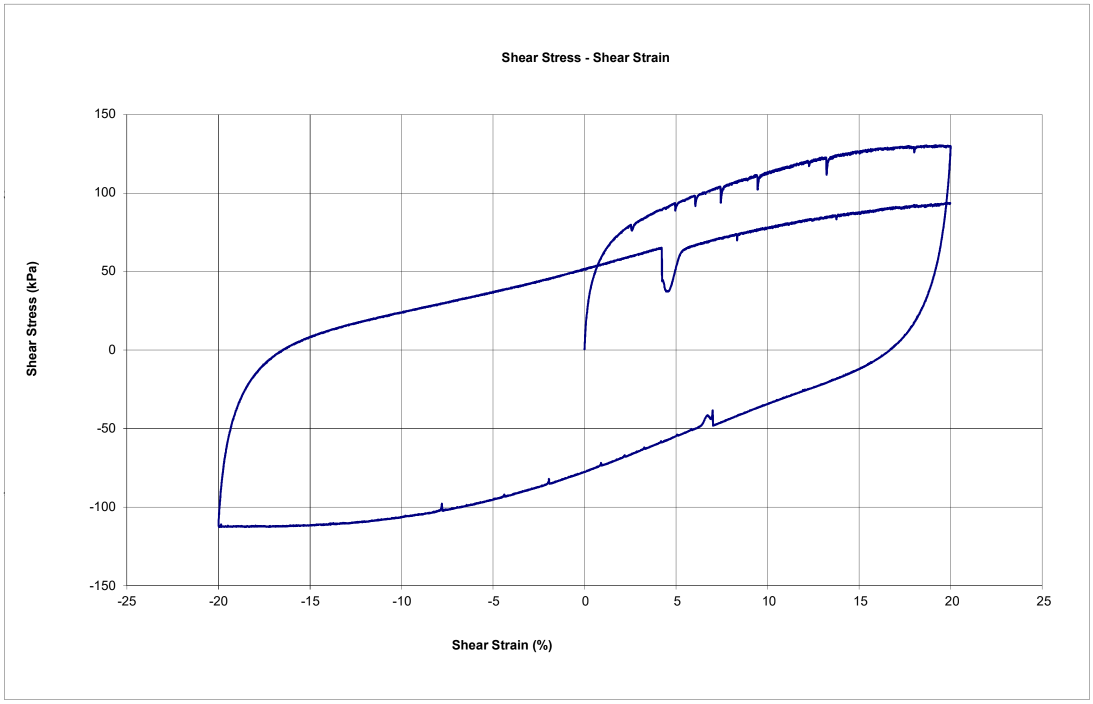


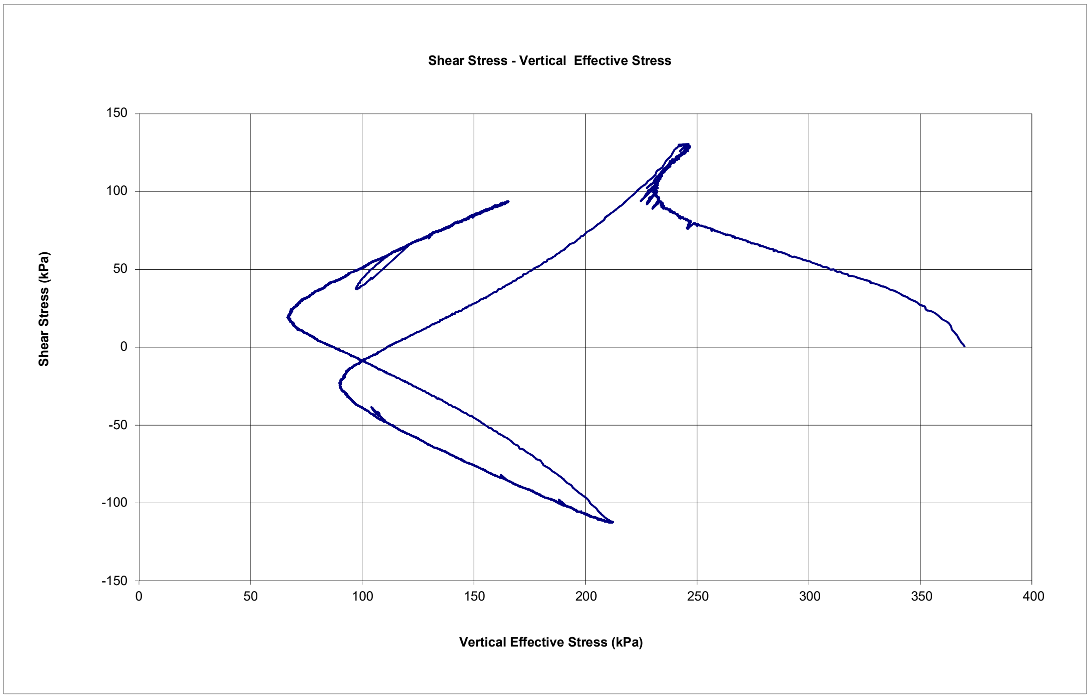


Static Simple Shear Test

(ASTM D6528)

Project No.:	A03355A01	Borehole ID:	BH04
Project:		Sample ID:	Shelby2
Date:	2019-10-15	Depth:	5.30 m
Tested by:	HM	Location:	Brazil
Checked by:	BY	Details:	Trimmed from Shelby Tube

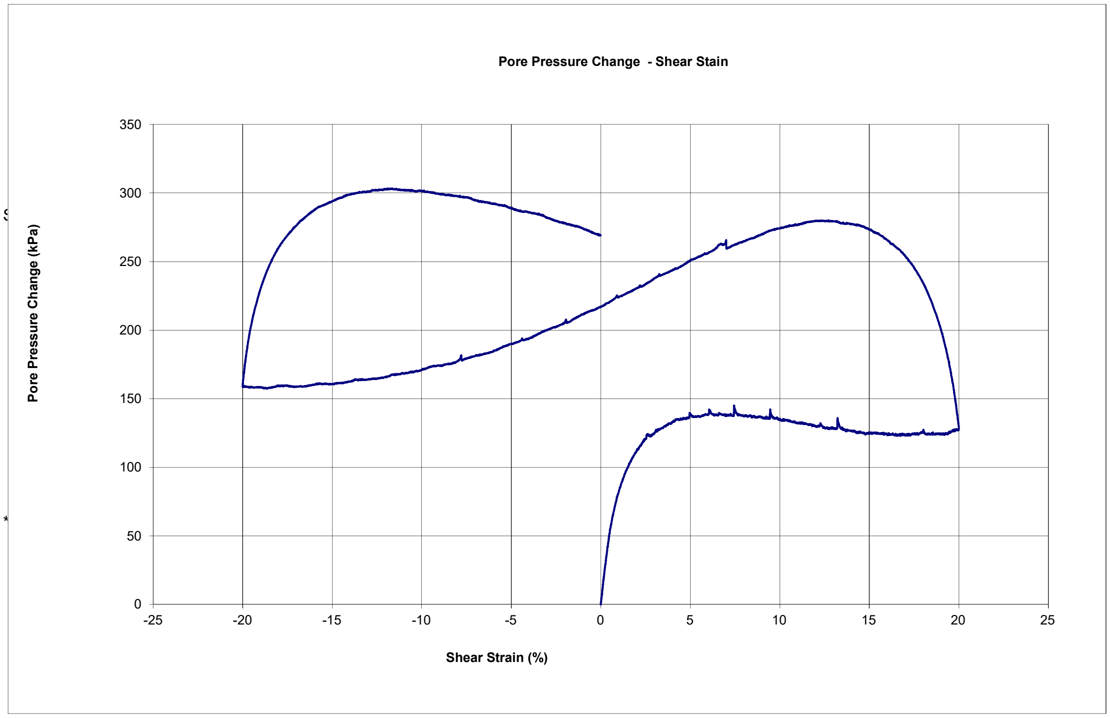


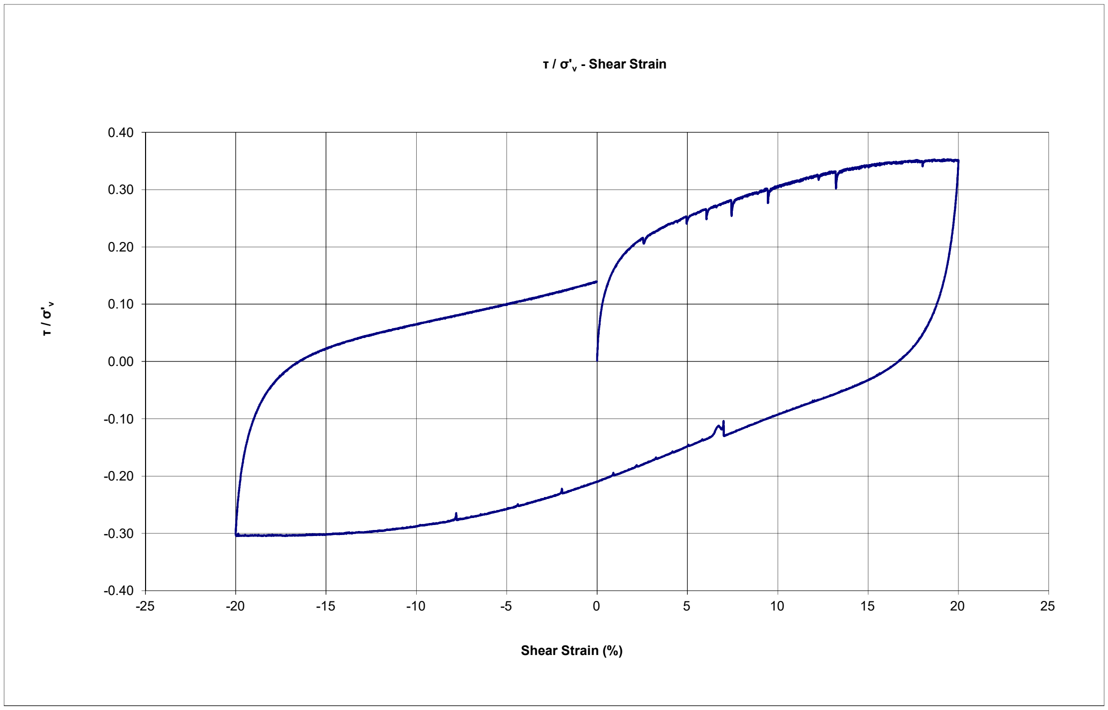


Static Simple Shear Test

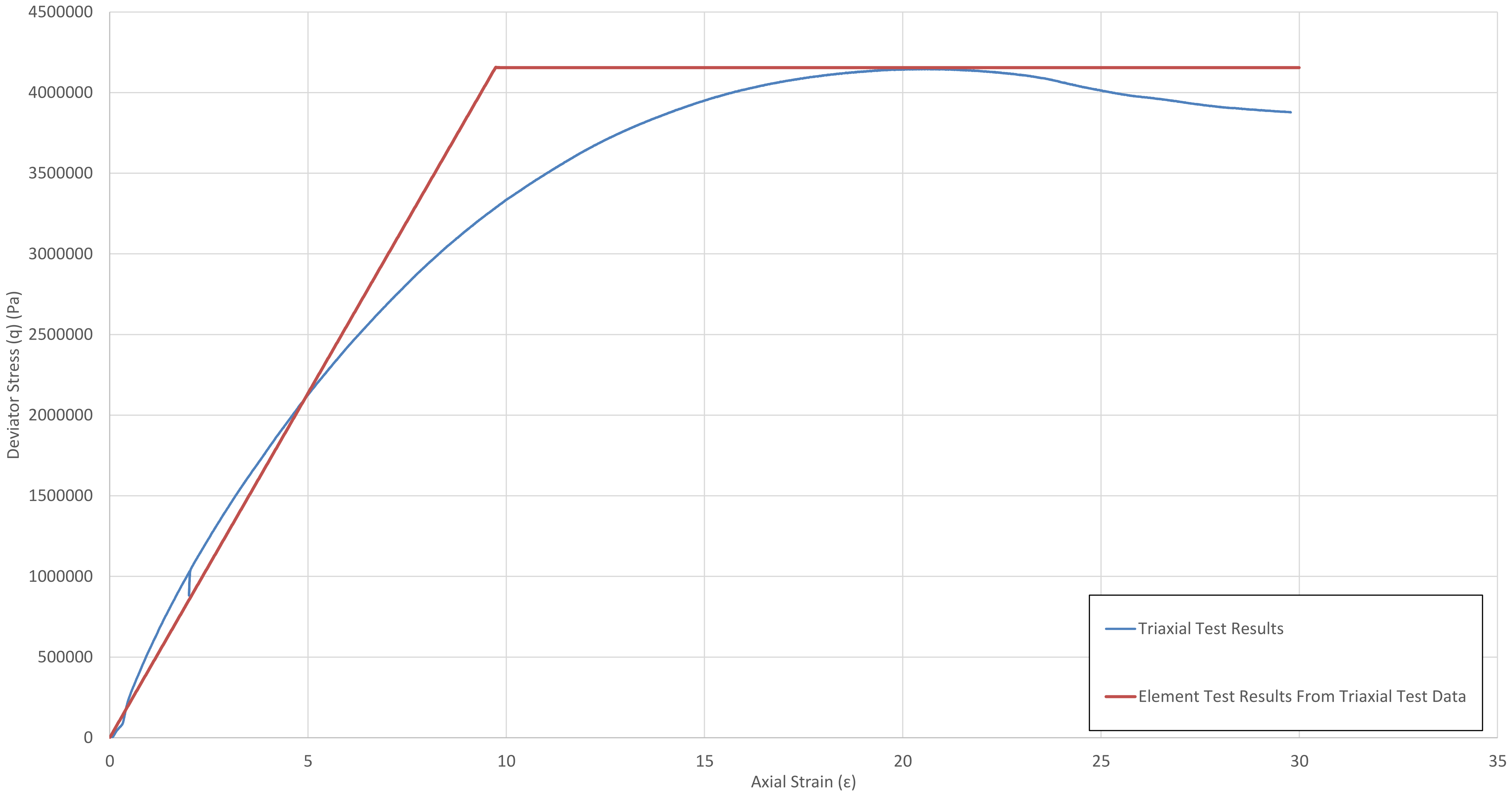
(ASTM D6528)

Project No.:	A03355A01	Borehole ID:	BH04
Project:		Sample ID:	Shelby2
Date:	2019-10-15	Depth:	5.30 m
Tested by:	HM	Location:	Brazil
Checked by:	BY	Details:	Trimmed from Shelby Tube





Mohr-Coulomb Element Tests



NOTES:

CLIENT

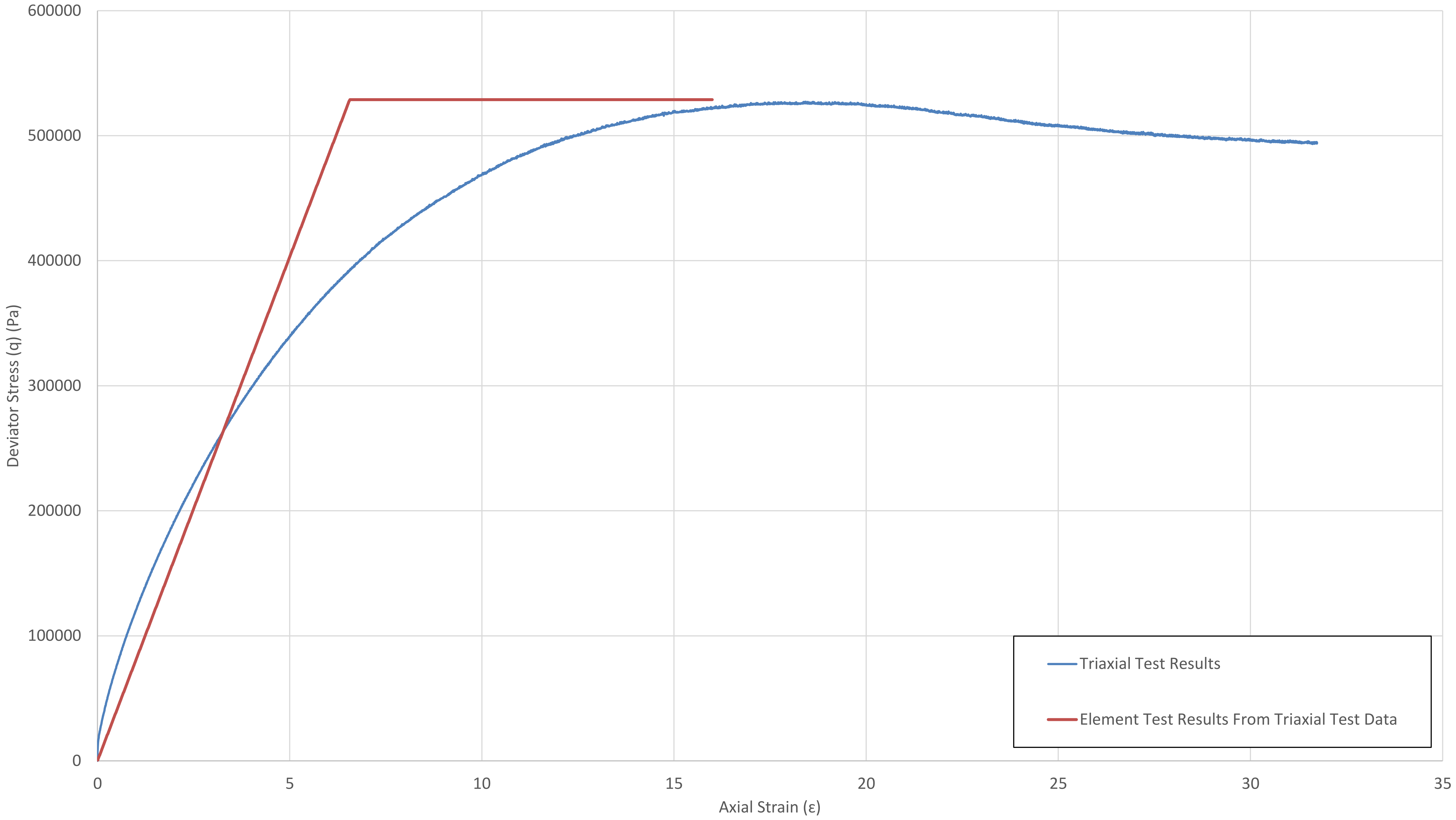
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

MOHR-COULOMB ELEMENT TEST RESULTS: DRAINED TRIAXIAL COMPRESSION TEST #01

PROJECT No. A03355A01

FIG. No. 01



NOTES:

CLIENT

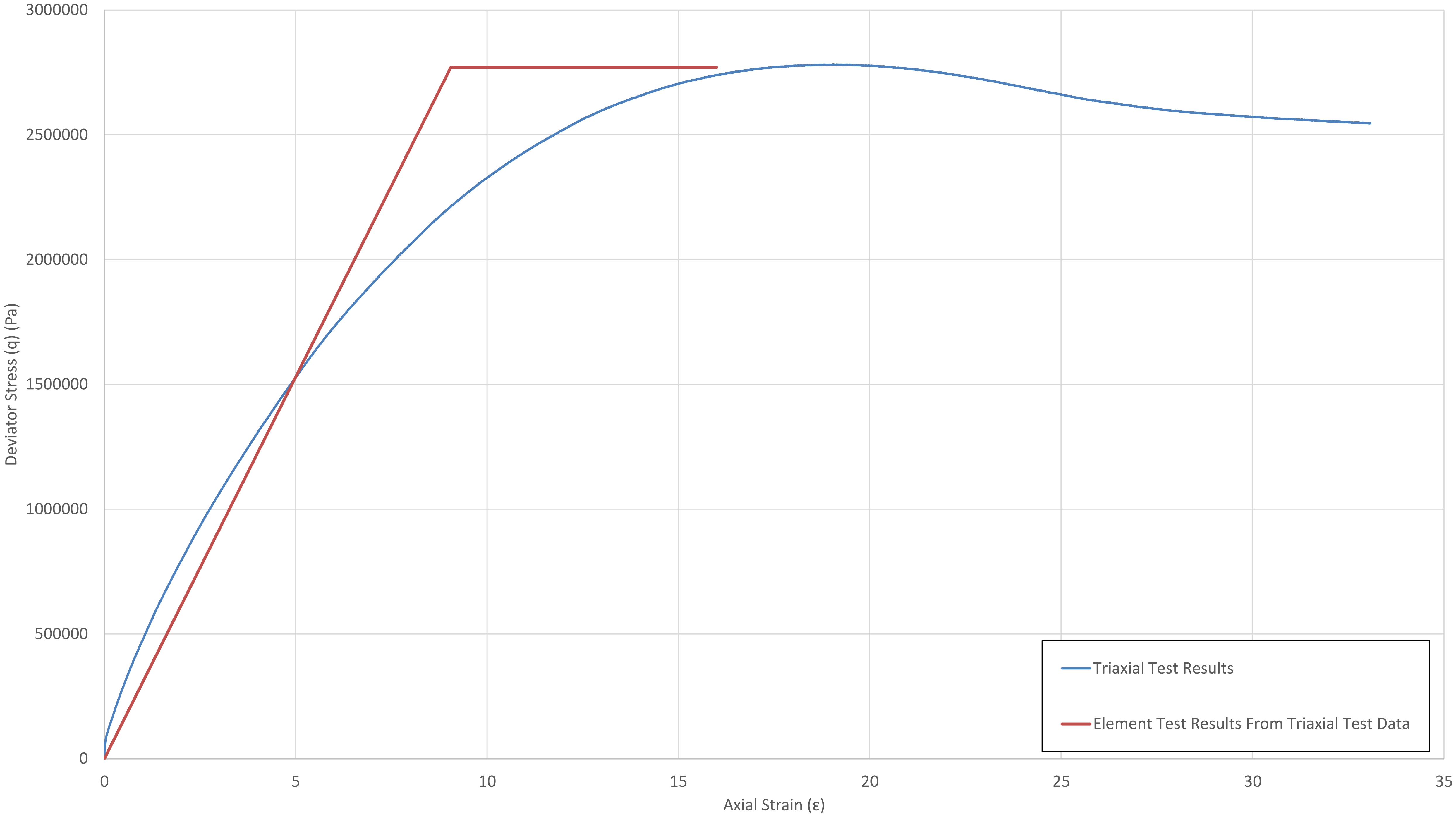
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

MOHR-COULOMB ELEMENT TEST RESULTS: DRAINED TRIAXIAL COMPRESSION TEST #02

PROJECT No.
A03355A01

FIG. No.
02



NOTES:

CLIENT

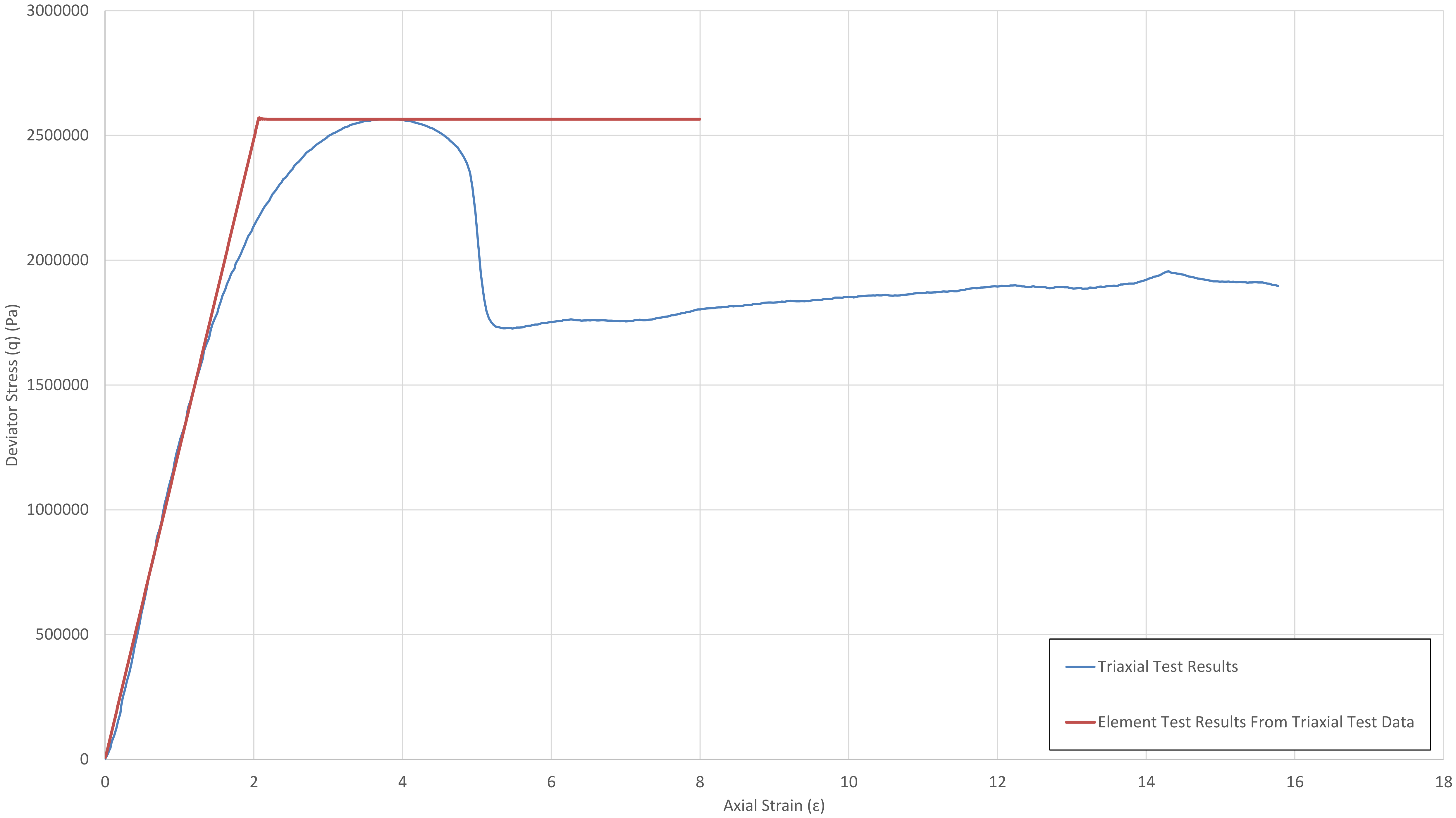
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

MOHR-COULOMB ELEMENT TEST RESULTS: DRAINED TRIAXIAL COMPRESSION TEST #03

PROJECT No. A03355A01

FIG. No. 03



NOTES:

CLIENT

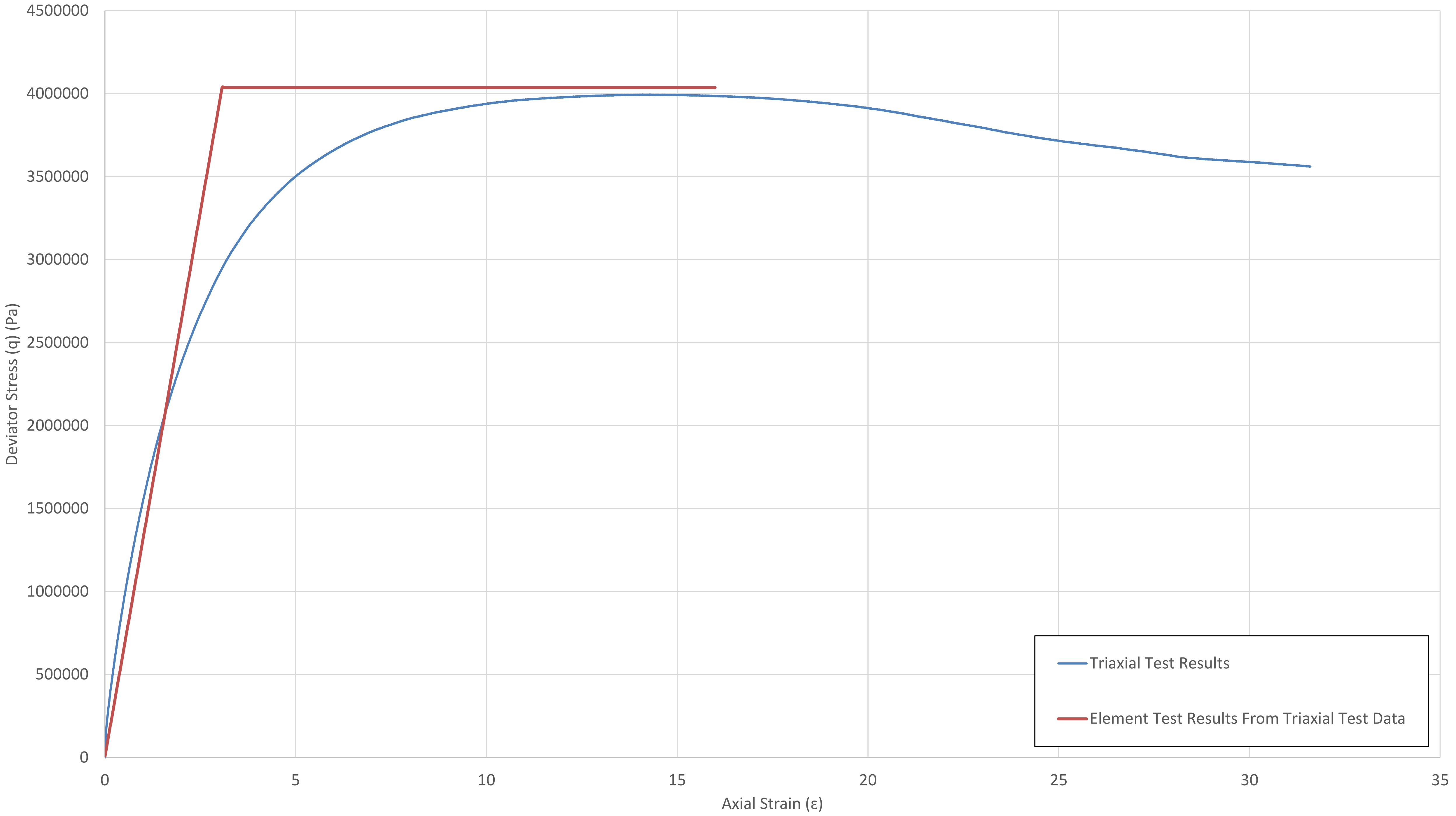
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

MOHR-COULOMB ELEMENT TEST RESULTS: DRAINED TRIAXIAL COMPRESSION TEST #05

PROJECT No. A03355A01

FIG. No. 04



NOTES:

CLIENT

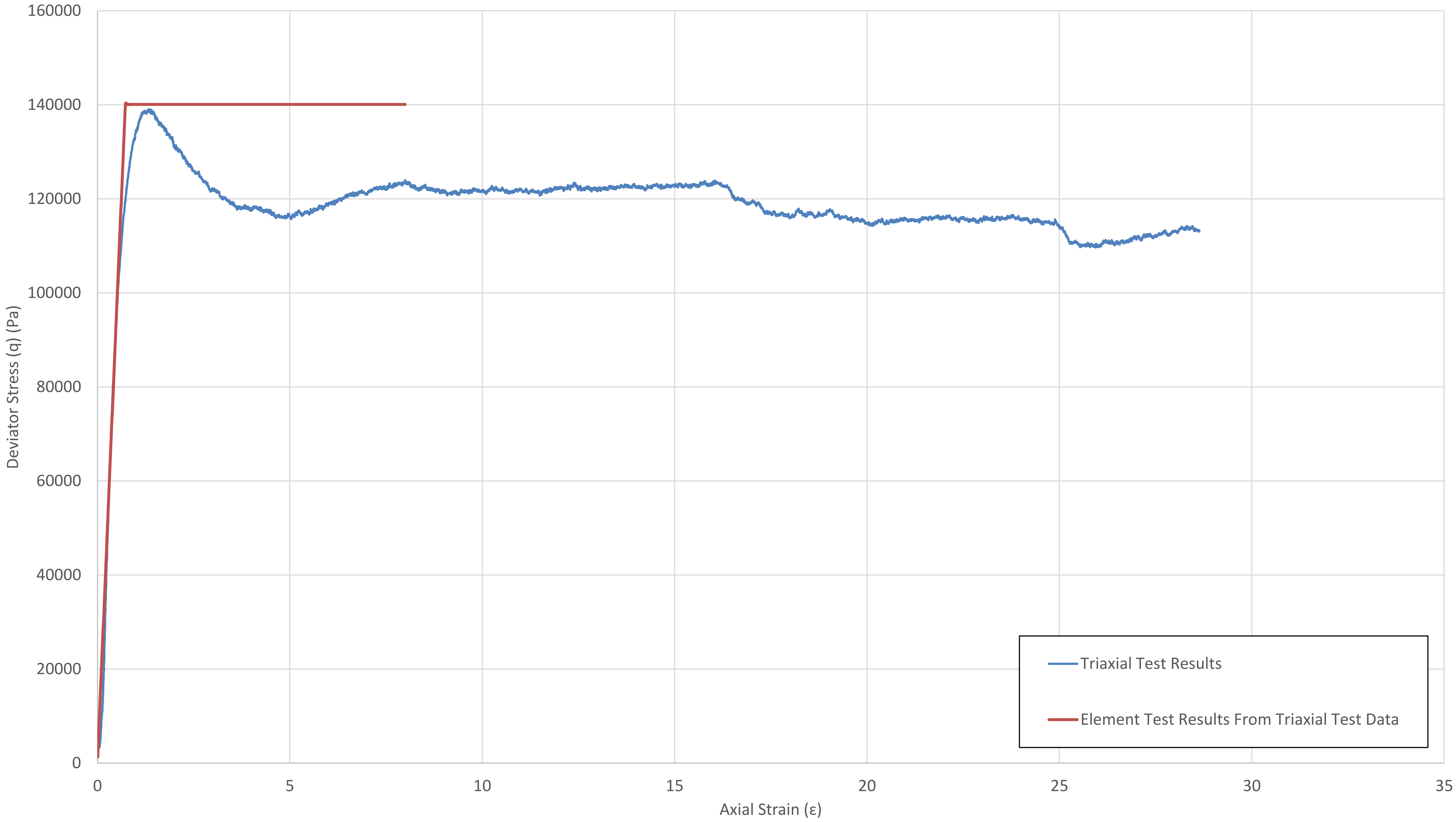
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

MOHR-COULOMB ELEMENT TEST RESULTS: DRAINED TRIAXIAL COMPRESSION TEST #06

PROJECT No. A03355A01

FIG. No. 05



NOTES:

CLIENT

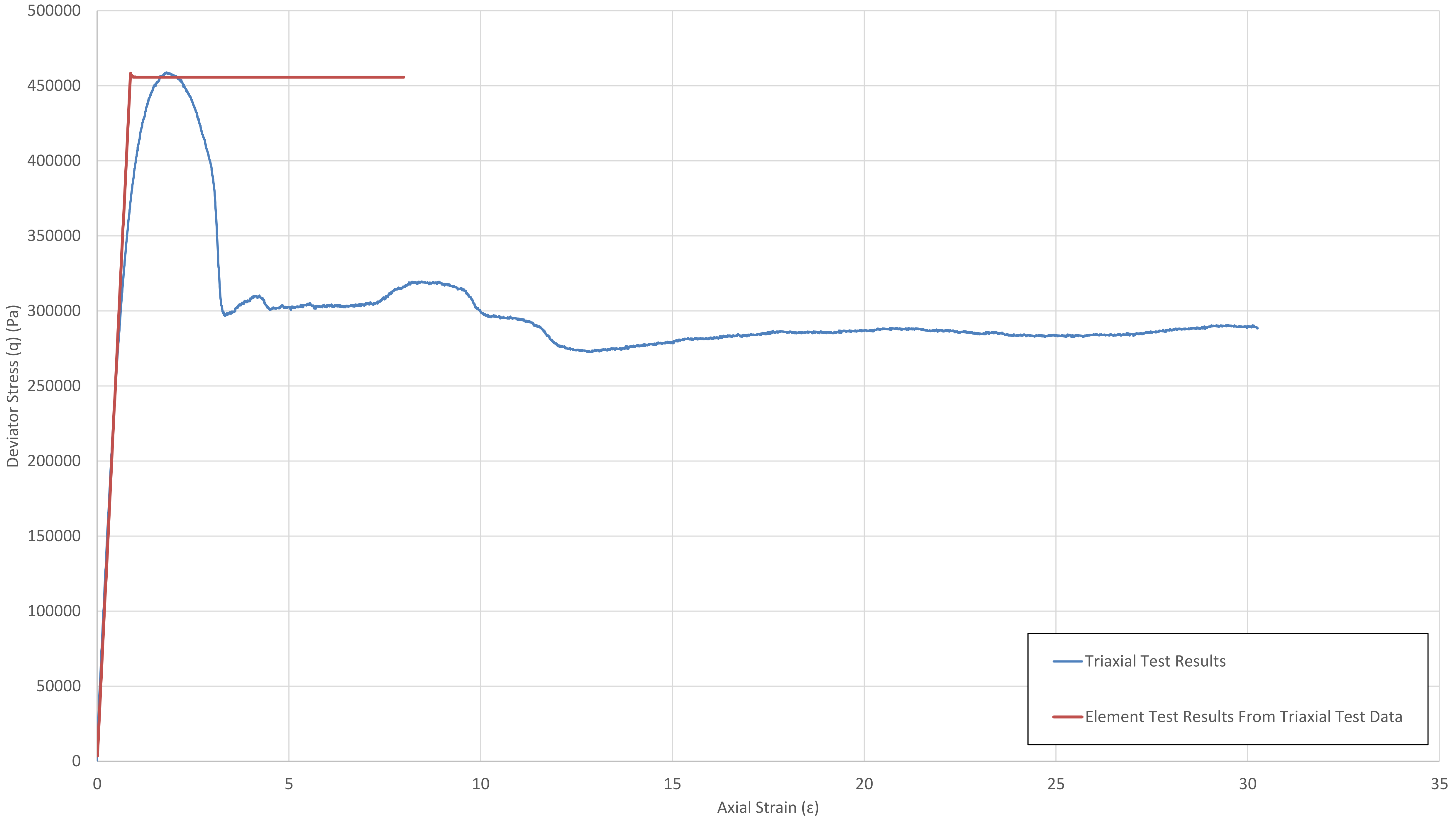
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

MOHR-COULOMB ELEMENT TEST RESULTS: DRAINED TRIAXIAL COMPRESSION TEST #08

PROJECT No.
A03355A01

FIG. No.
06



NOTES:

CLIENT

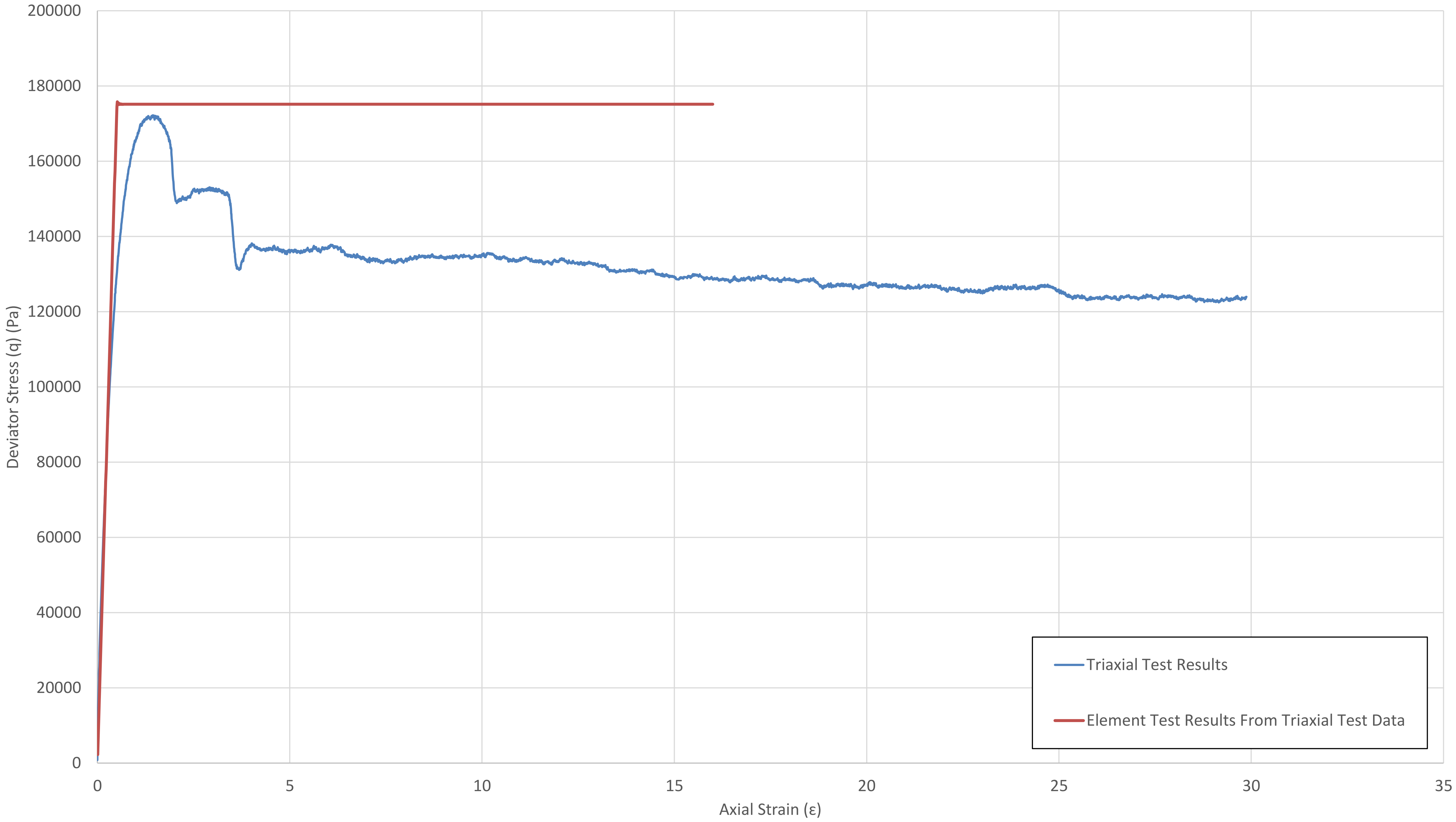
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

MOHR-COULOMB ELEMENT TEST RESULTS: DRAINED TRIAXIAL COMPRESSION TEST #09

PROJECT No.
A03355A01

FIG. No.
07



NOTES:

CLIENT

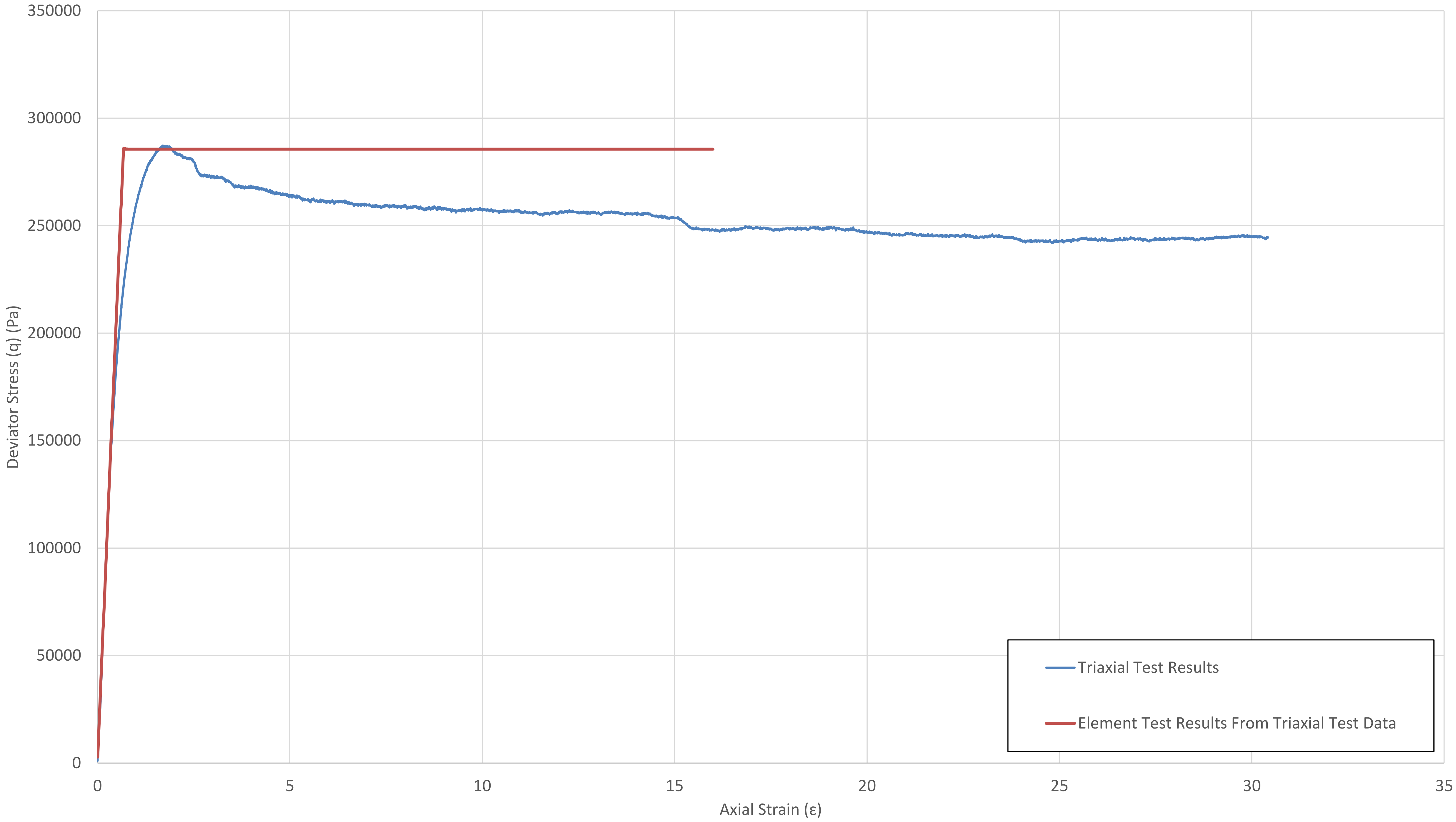
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

MOHR-COULOMB ELEMENT TEST RESULTS: DRAINED TRIAXIAL COMPRESSION TEST #10

PROJECT No. A03355A01

FIG. No. 08



NOTES:

CLIENT

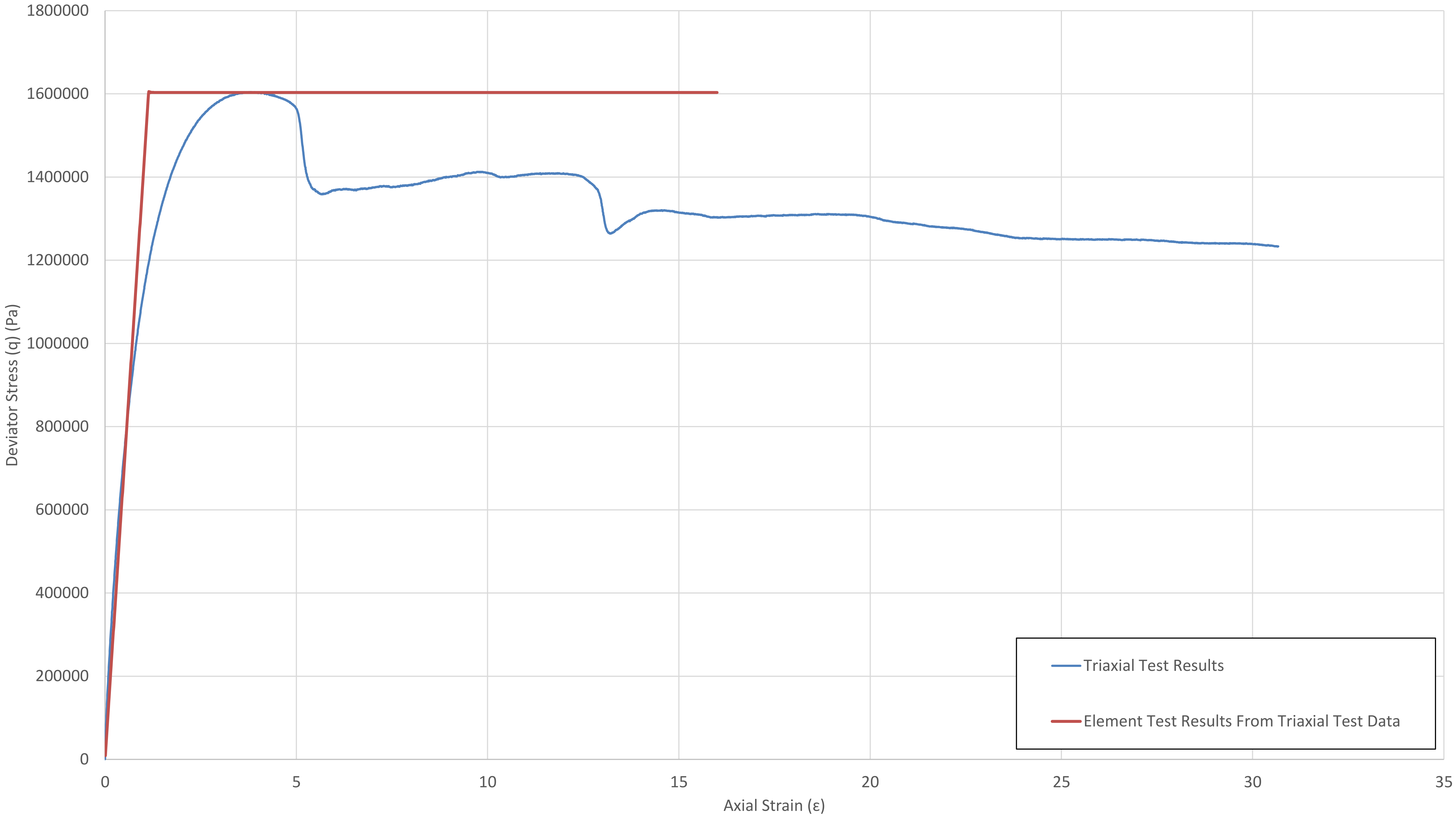
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

MOHR-COULOMB ELEMENT TEST RESULTS: DRAINED TRIAXIAL COMPRESSION TEST #11

PROJECT No.
A03355A01

FIG. No.
09



NOTES:

CLIENT

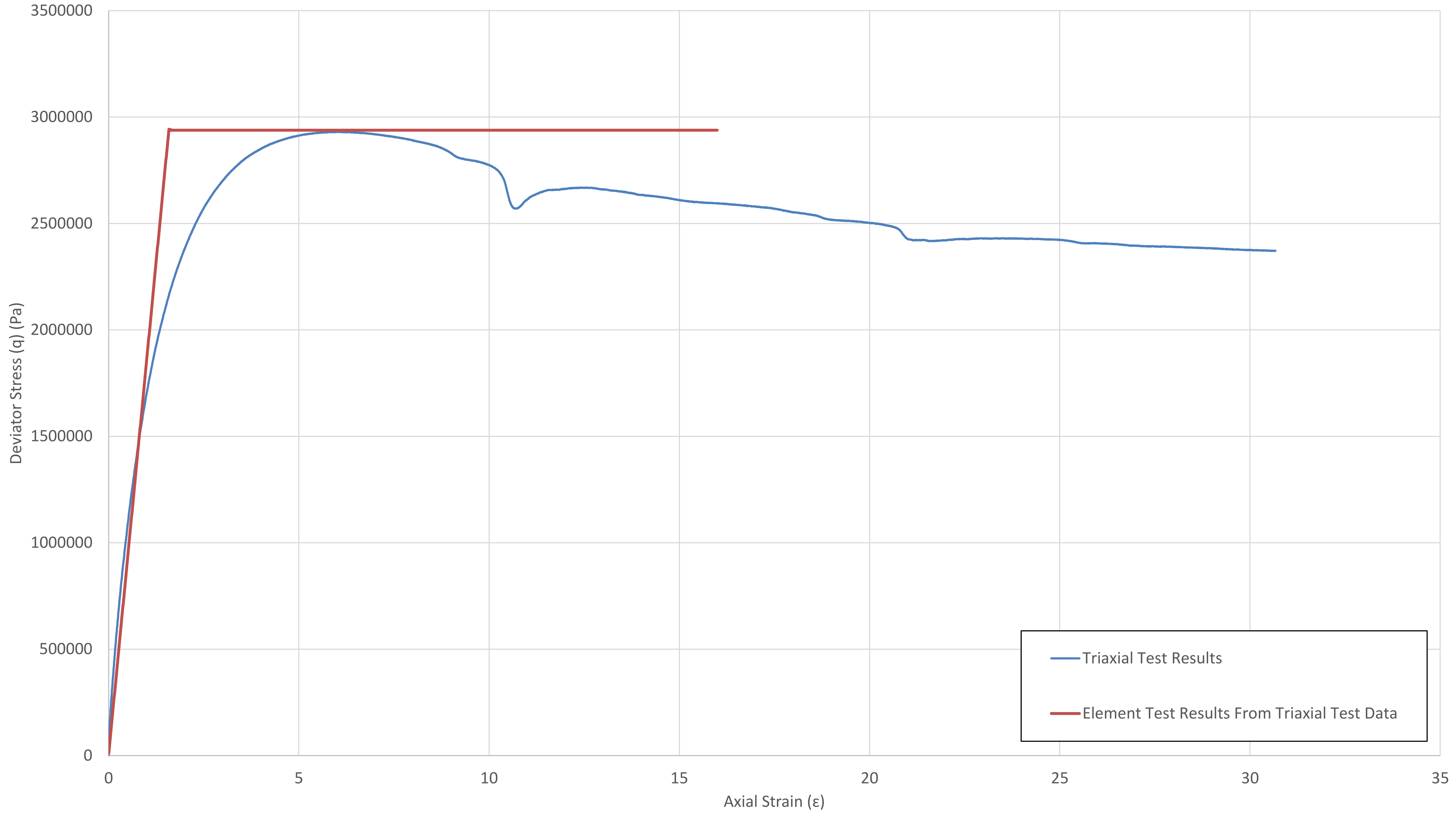
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

MOHR-COULOMB ELEMENT TEST RESULTS: DRAINED TRIAXIAL COMPRESSION TEST #12

PROJECT No. A03355A01

FIG. No. 10



NOTES:

CLIENT

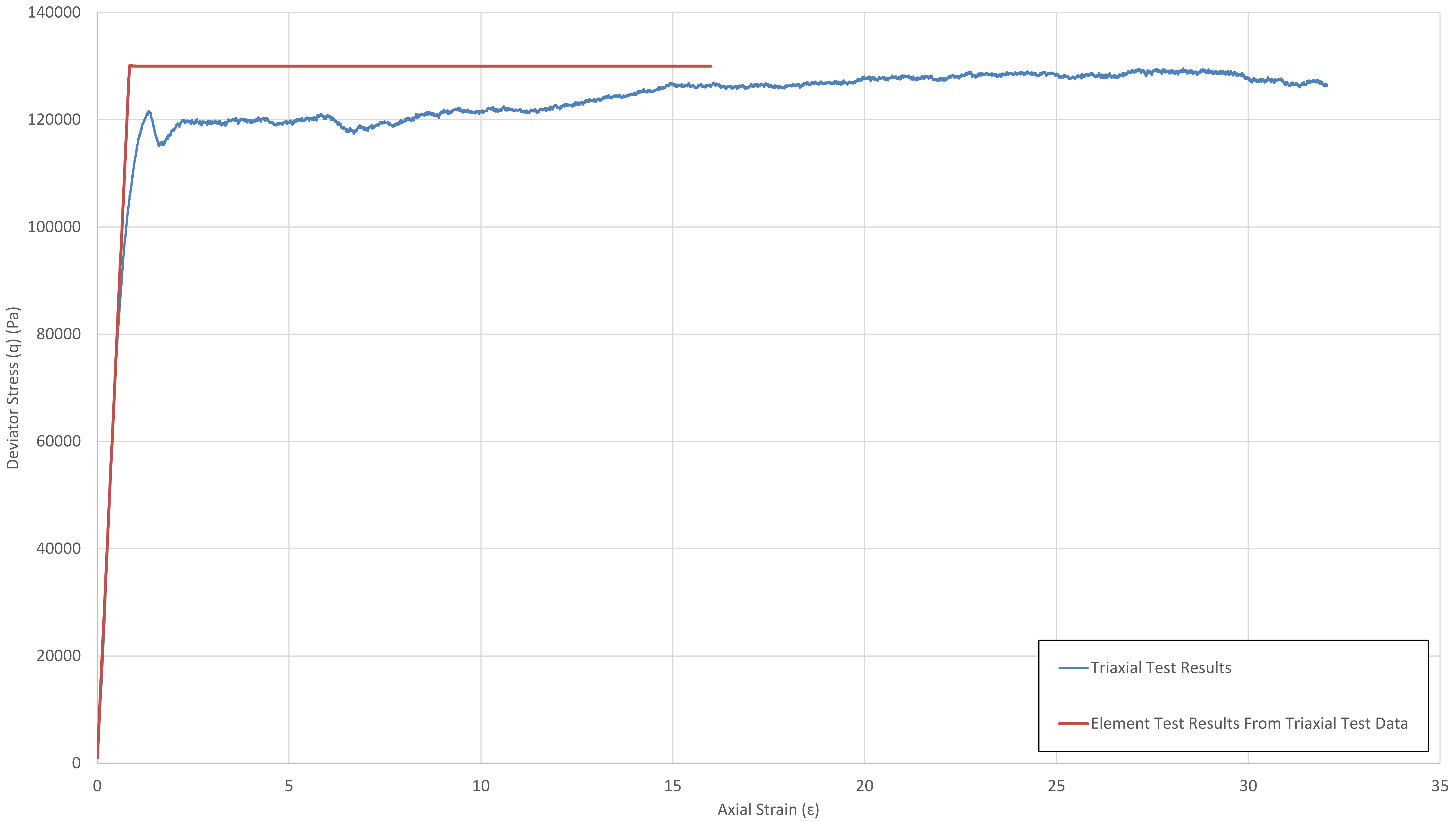
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

MOHR-COULOMB ELEMENT TEST RESULTS: DRAINED TRIAXIAL COMPRESSION TEST #13

PROJECT No. A03355A01

FIG. No. 11



NOTES:

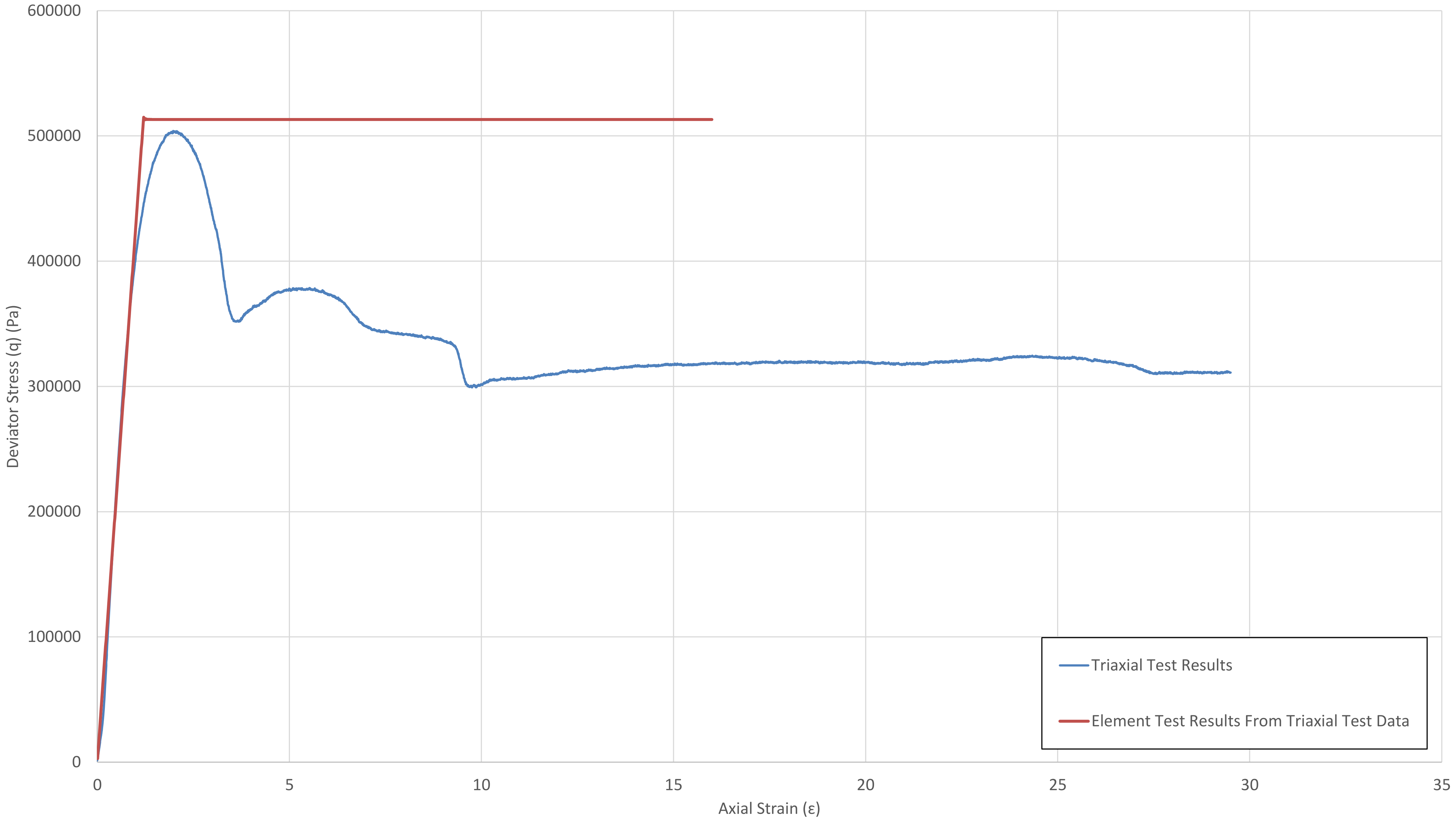
CLIENT

PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

MOHR-COULOMB ELEMENT TEST RESULTS: DRAINED TRIAXIAL COMPRESSION TEST #14

PROJECT No.	FIG. No.
A03355A01	12



NOTES:

CLIENT

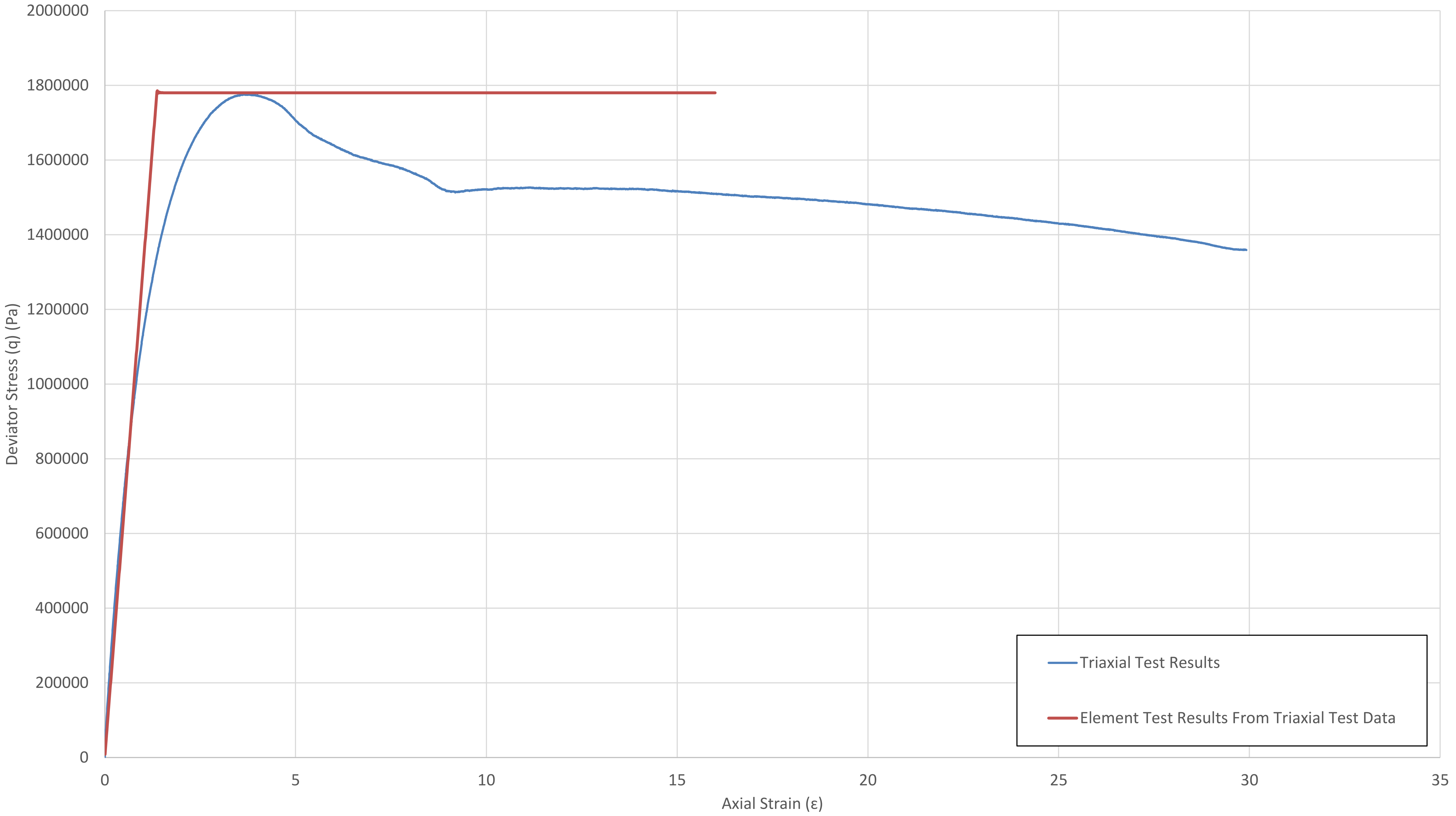
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

MOHR-COULOMB ELEMENT TEST RESULTS: DRAINED TRIAXIAL COMPRESSION TEST #15

PROJECT No.
A03355A01

FIG. No.
13



NOTES:

CLIENT

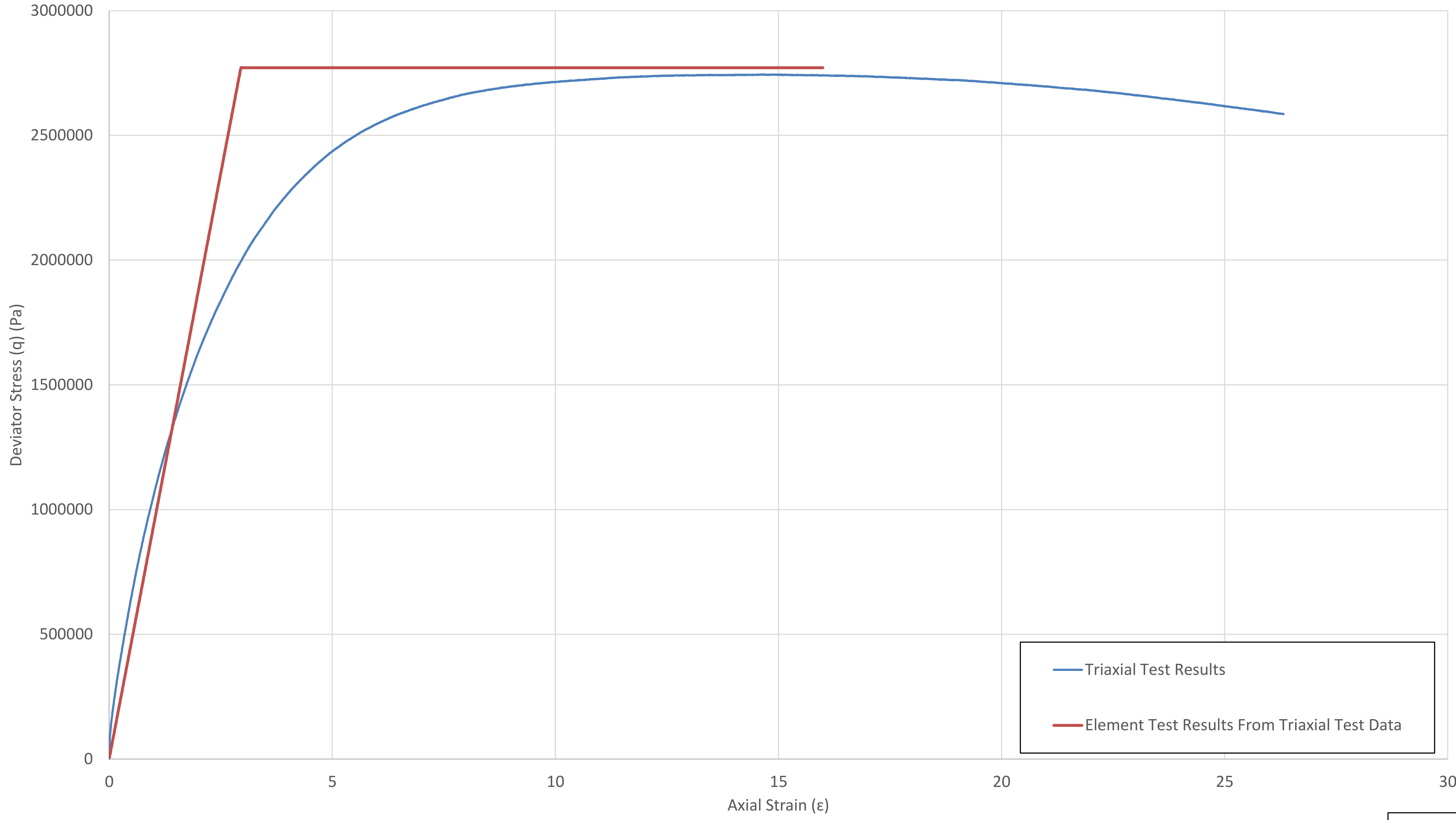
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

MOHR-COULOMB ELEMENT TEST RESULTS: DRAINED TRIAXIAL COMPRESSION TEST #16

PROJECT No. A03355A01

FIG. No. 14



NOTES:

CLIENT

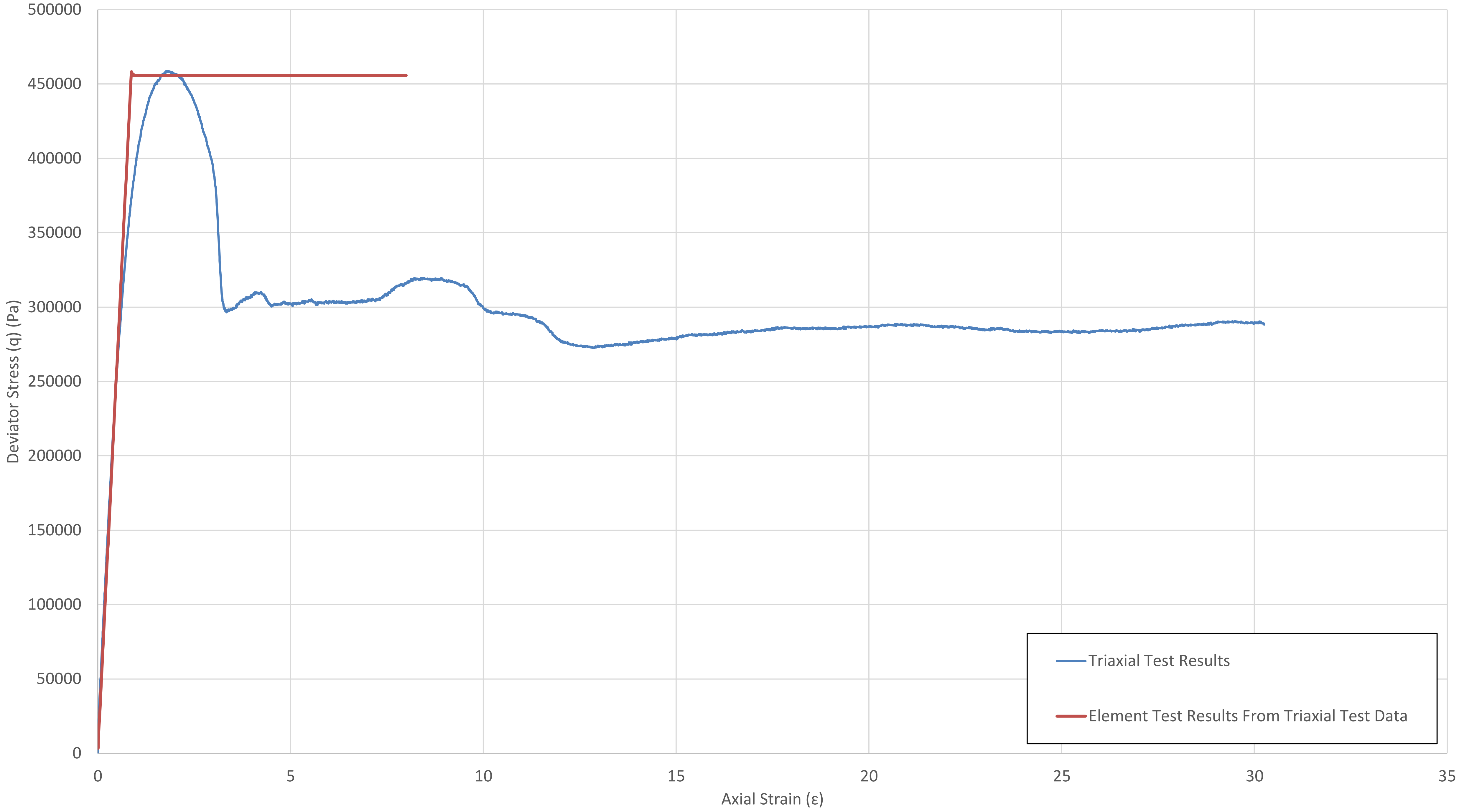
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

MOHR-COULOMB ELEMENT TEST RESULTS: DRAINED TRIAXIAL COMPRESSION TEST #17

PROJECT No. A03355A01

FIG. No. 15



NOTES:

CLIENT

PROJECT

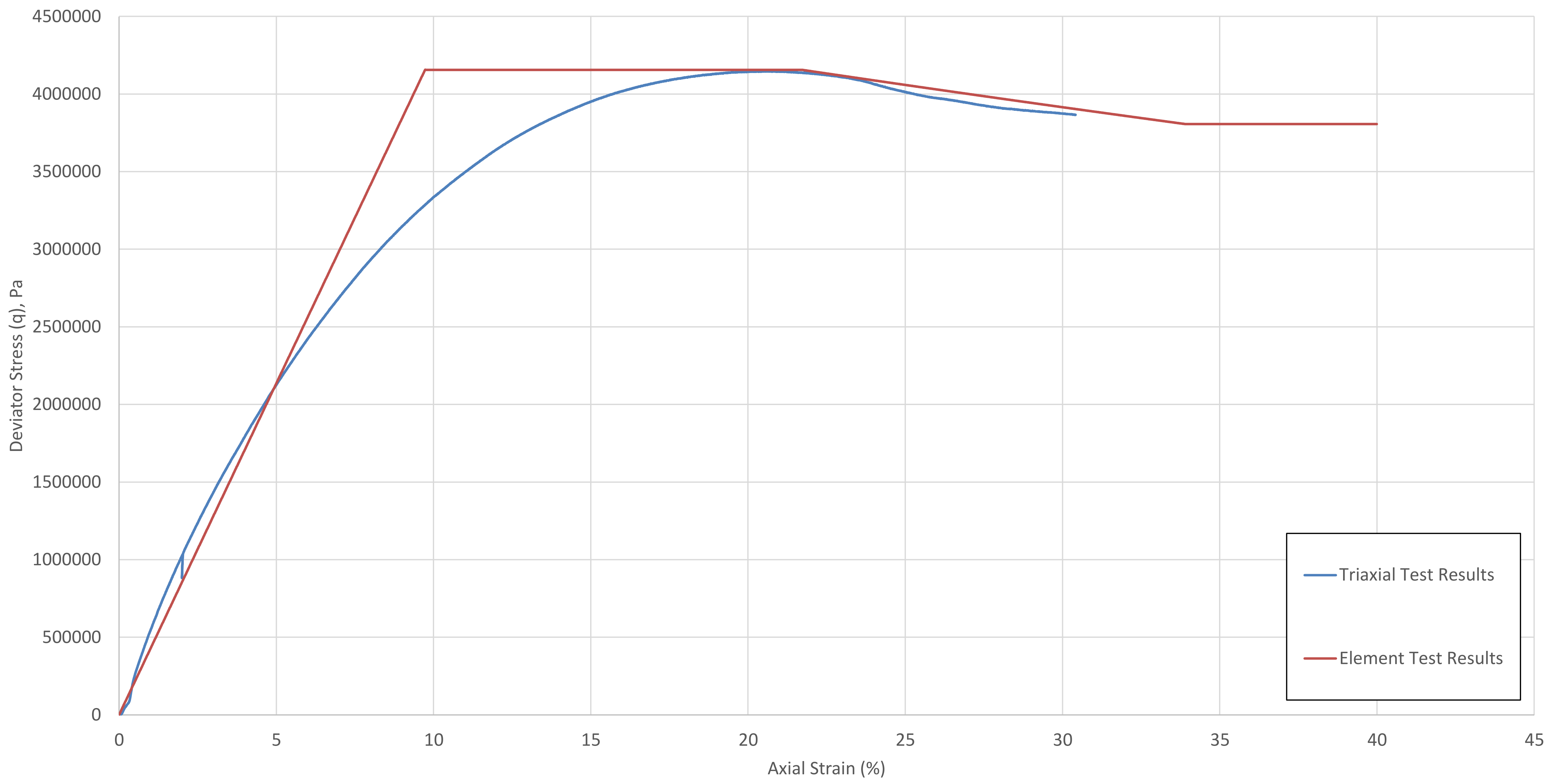
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

MOHR-COULOMB ELEMENT TEST RESULTS: DRAINED TRIAXIAL COMPRESSION TEST #18

PROJECT No. A03355A01

FIG. No. 16

Strain Weakening Element Tests - Drained



NOTES:

CLIENT

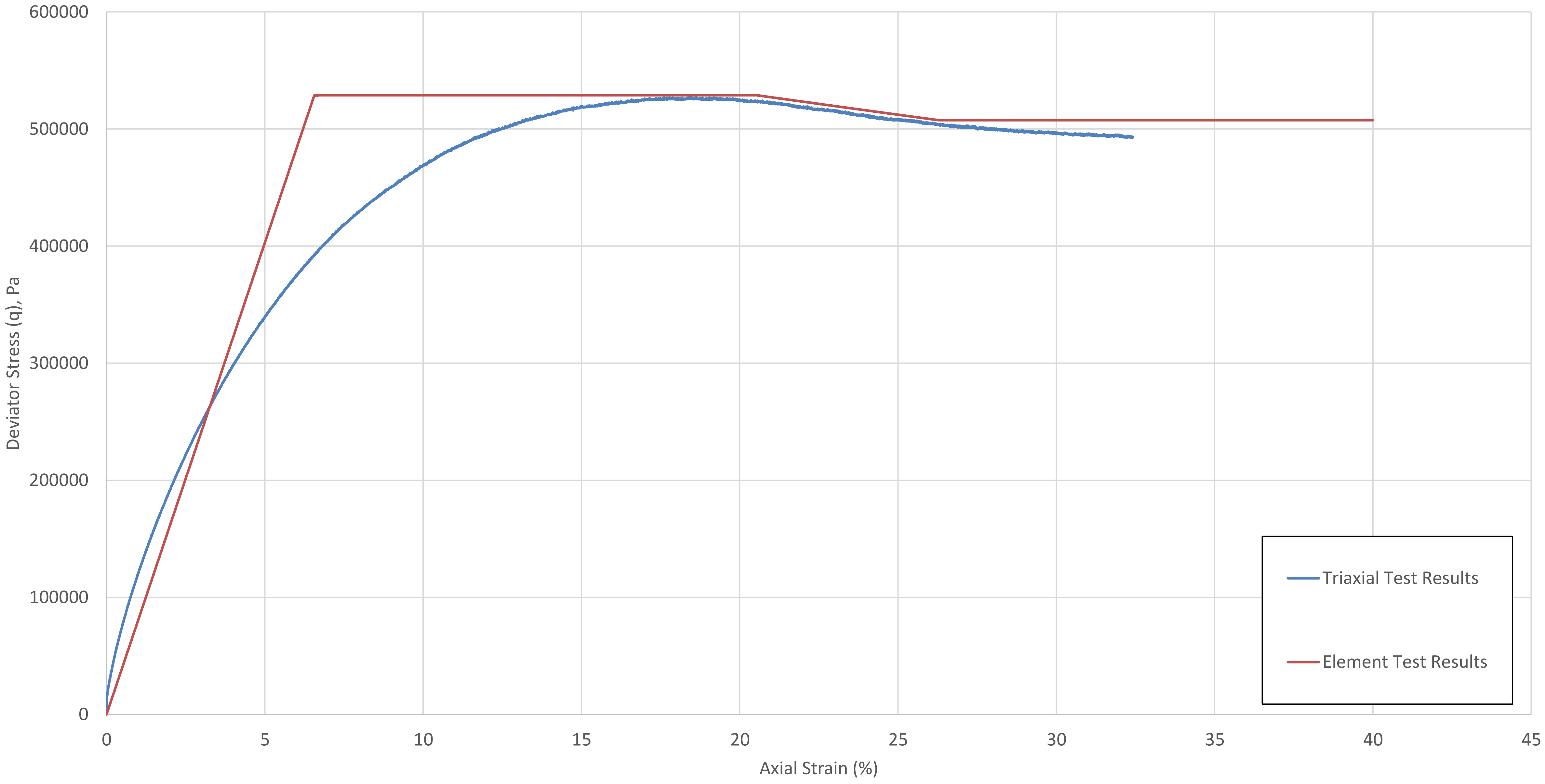
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

STRAIN WEAKENING ELEMENT TEST RESULTS: DRAINED TRIAXIAL TEST #01

PROJECT No. A03355A01

FIG. No. 17



NOTES:

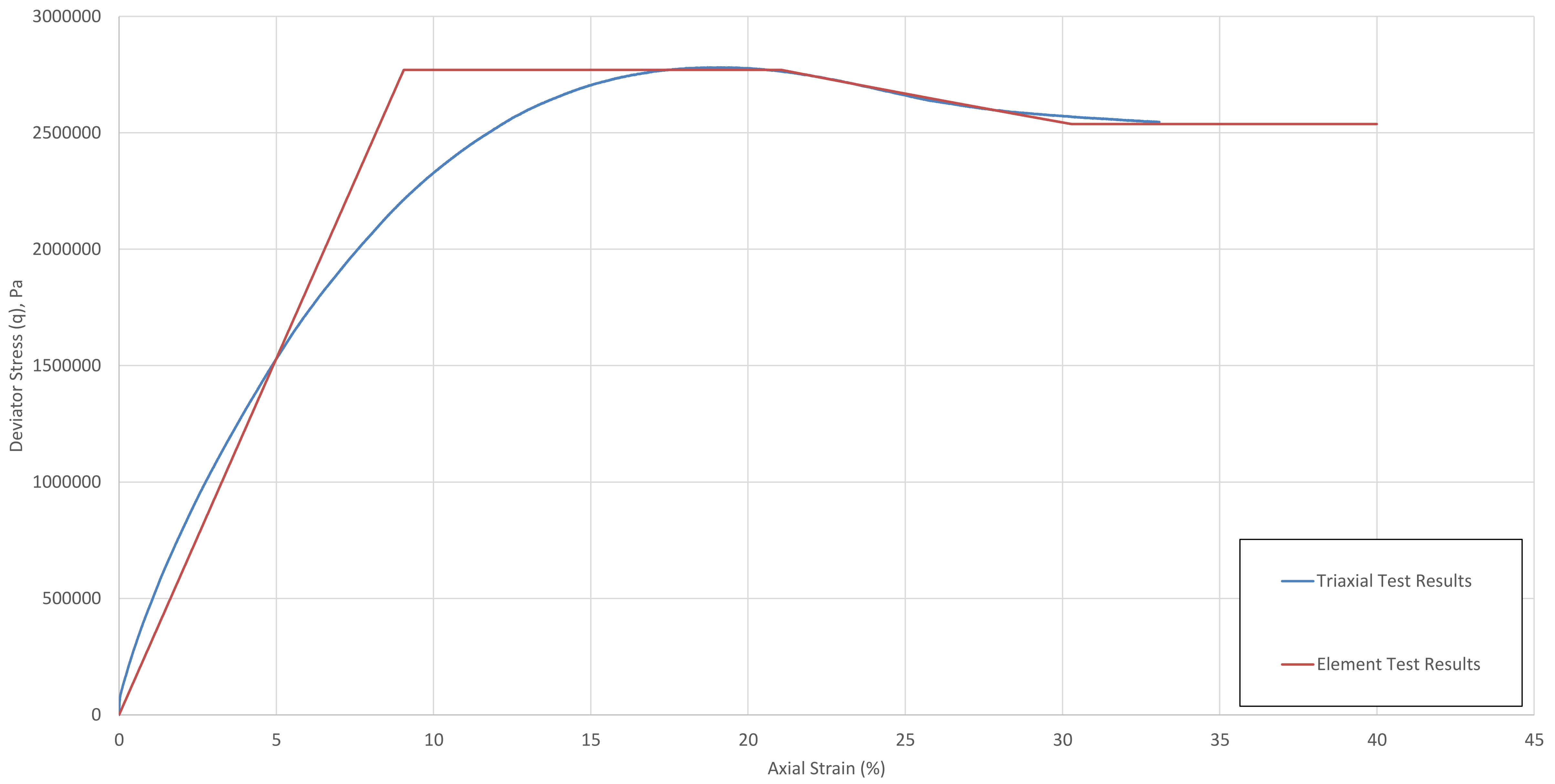
CLIENT

PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

STRAIN WEAKENING ELEMENT TEST RESULTS: DRAINED TRIAXIAL TEST #02

PROJECT No.
A03355A01

FIG. No.
18



NOTES:

CLIENT

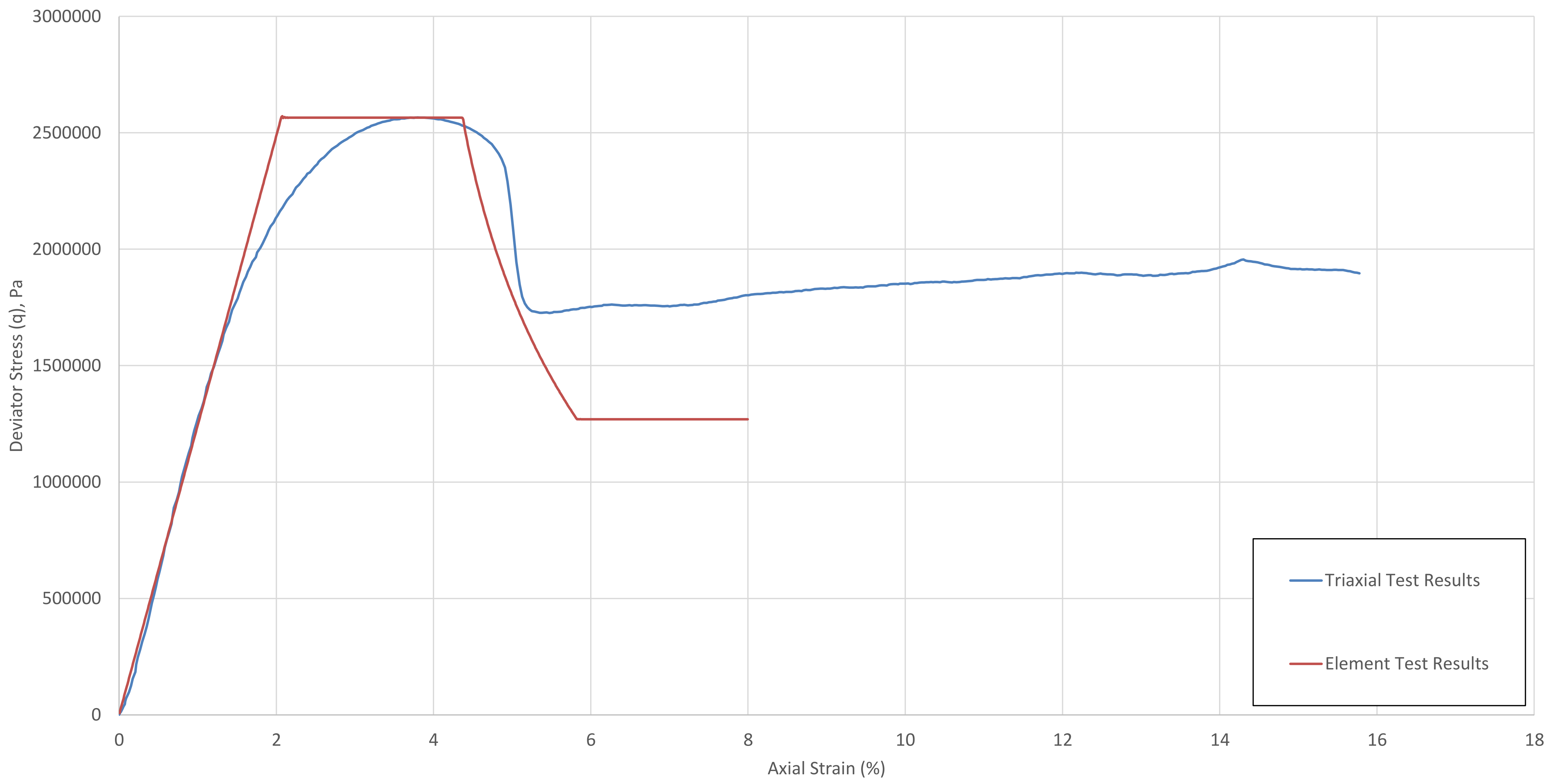
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

STRAIN WEAKENING ELEMENT TEST RESULTS: DRAINED TRIAXIAL TEST #03

PROJECT No. A03355A01

FIG. No. 19



NOTES:

CLIENT

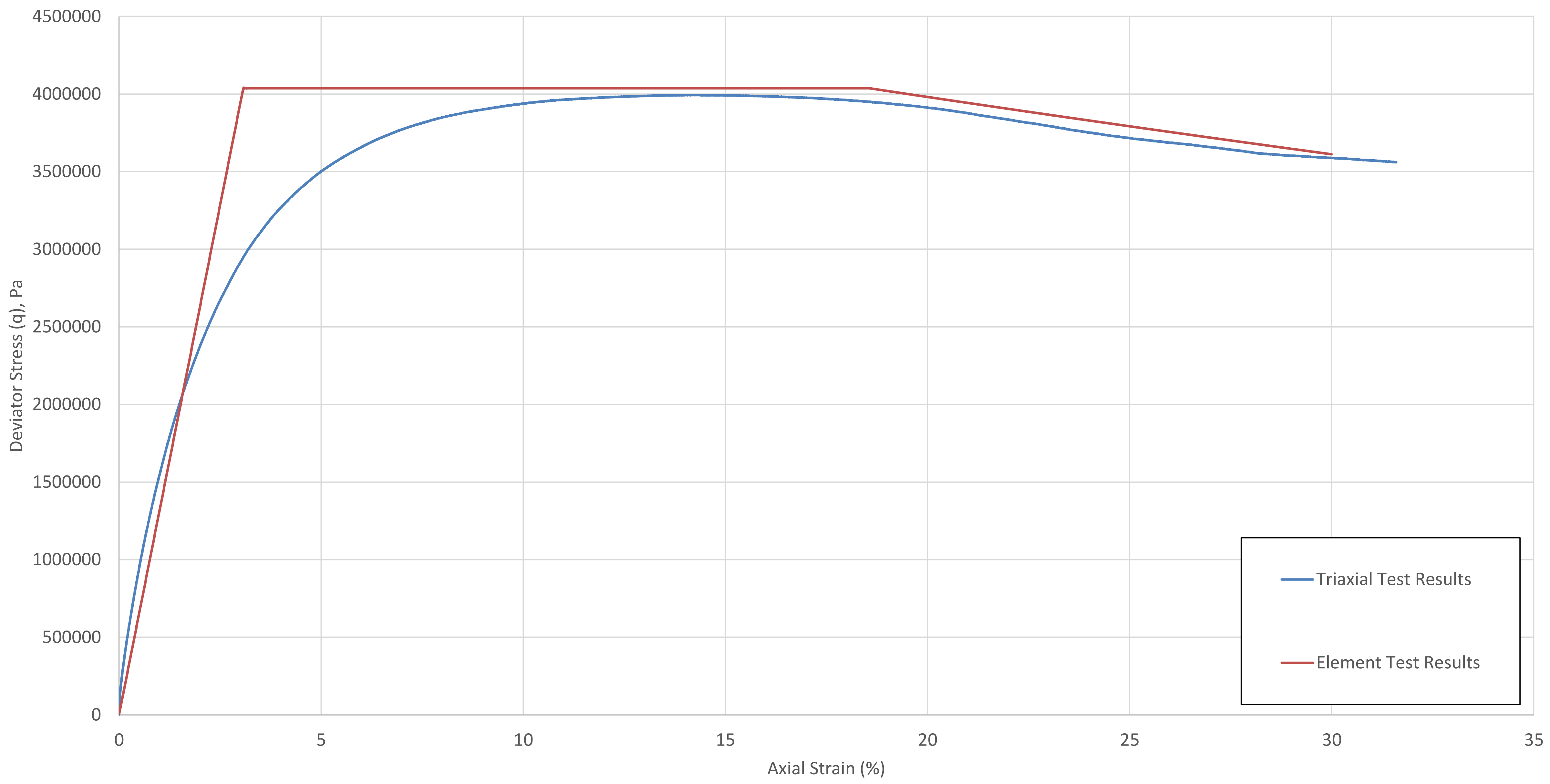
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

STRAIN WEAKENING ELEMENT TEST RESULTS: DRAINED TRIAXIAL TEST #05

PROJECT No.
A03355A01

FIG. No.
20



NOTES:

CLIENT

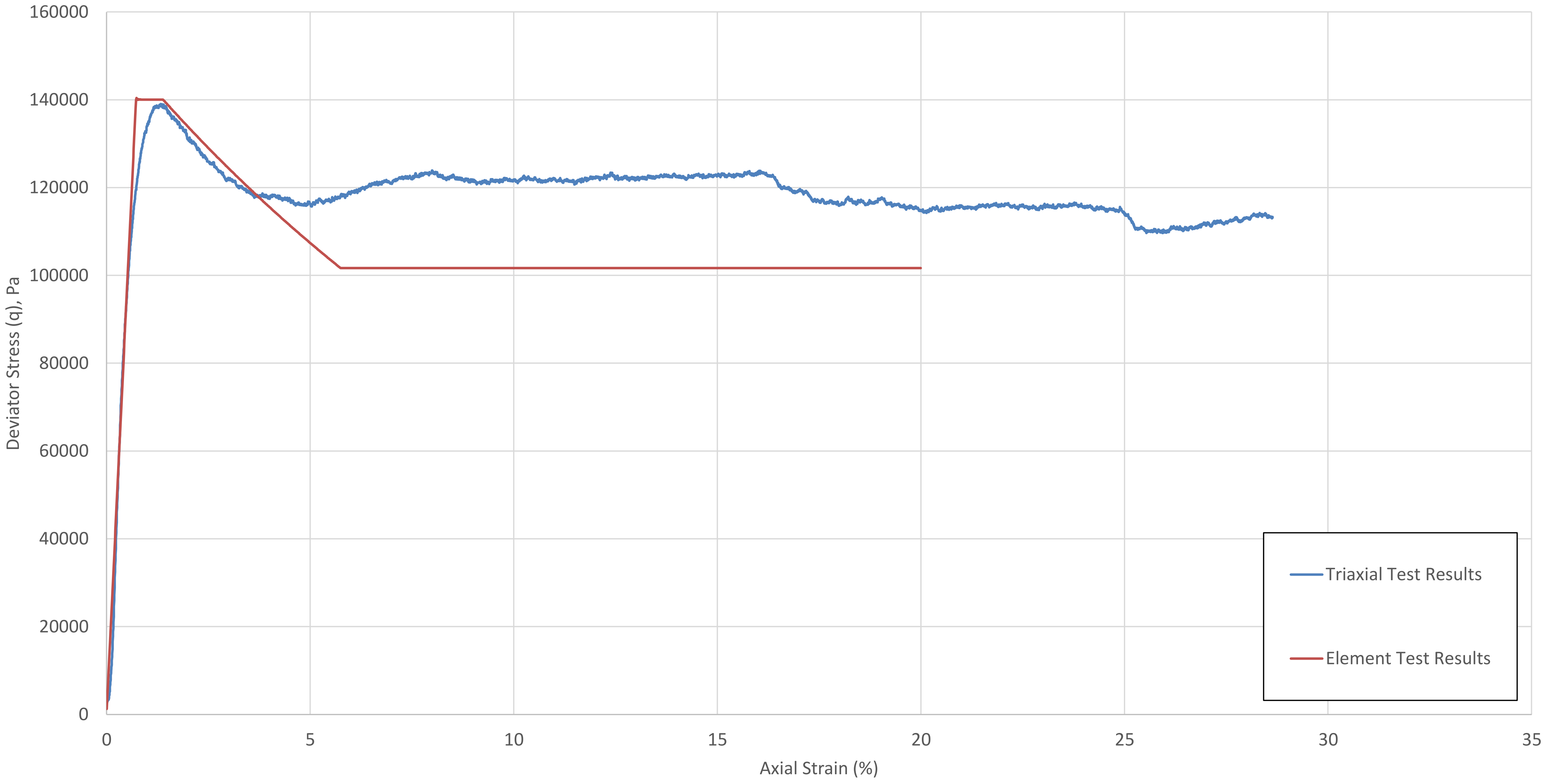
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

STRAIN WEAKENING ELEMENT TEST RESULTS: DRAINED TRIAXIAL TEST #06

PROJECT No. A03355A01

FIG. No. 21



NOTES:

CLIENT

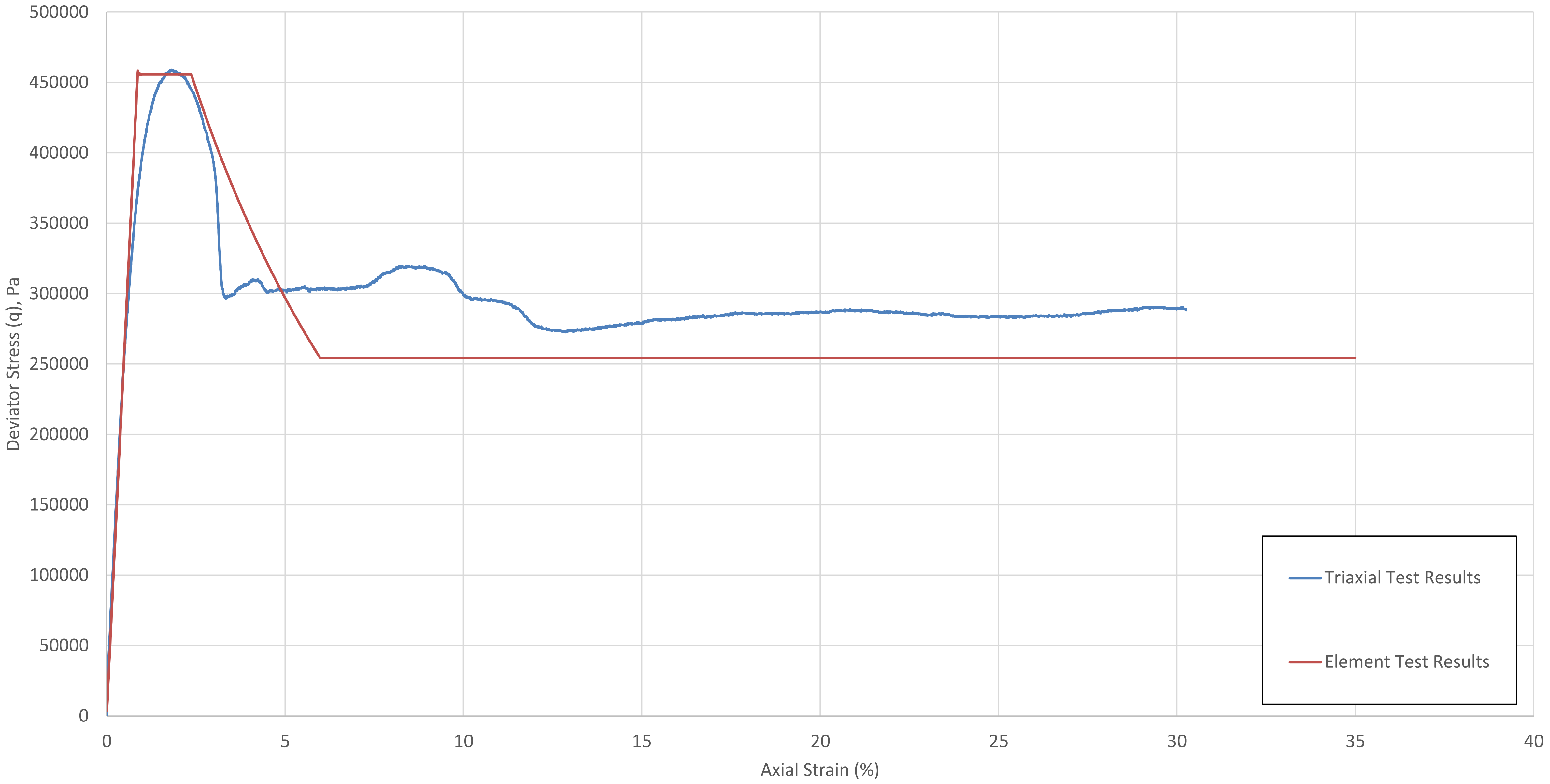
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF
THE FAILURE OF FEIJÃO DAM 1

STRAIN WEAKENING ELEMENT TEST RESULTS: DRAINED TRIAXIAL TEST #08

PROJECT No.
A03355A01

FIG. No.
22



NOTES:

CLIENT

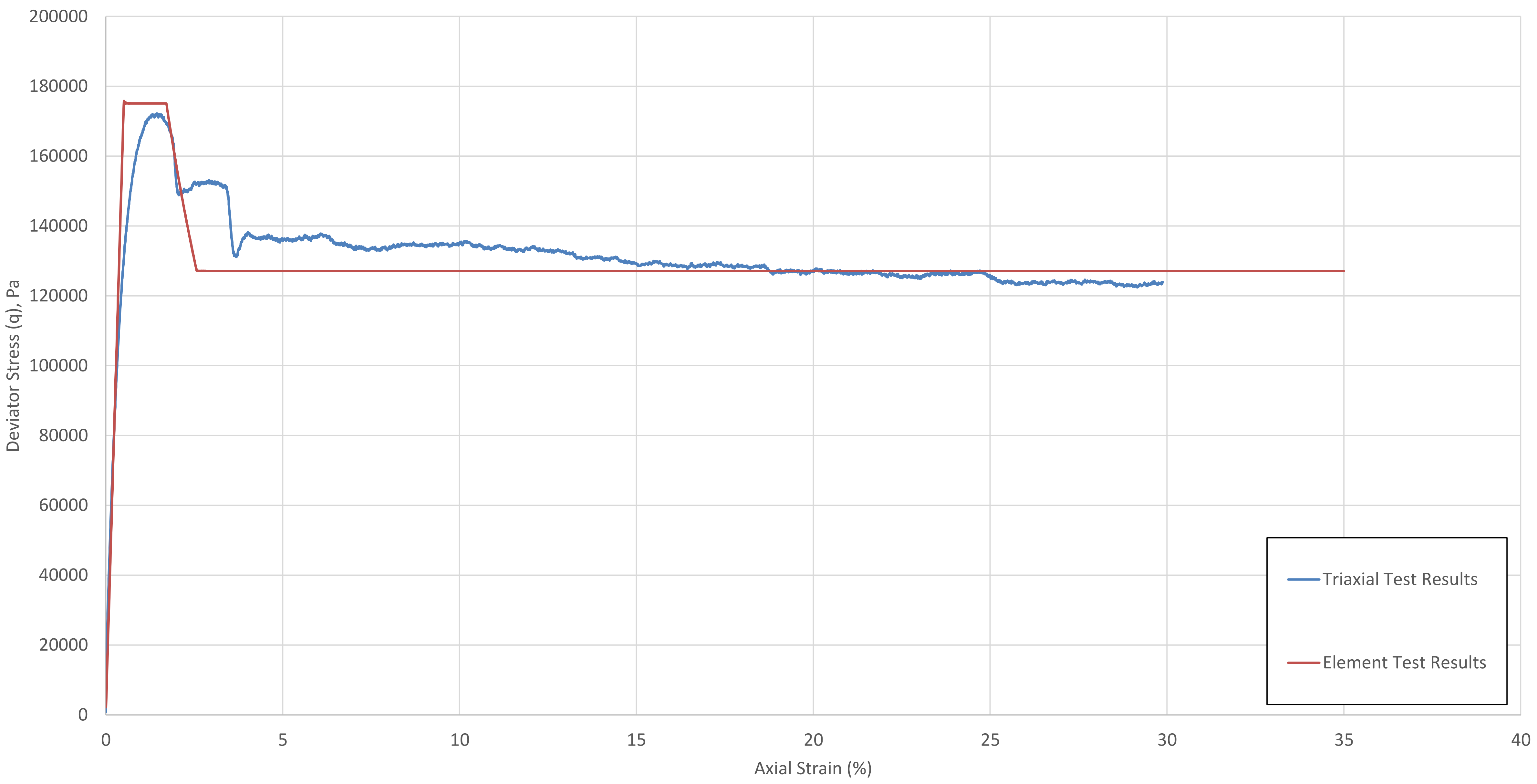
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF
THE FAILURE OF FEIJÃO DAM 1

STRAIN WEAKENING ELEMENT TEST RESULTS: DRAINED TRIAXIAL TEST #09

PROJECT No.
A03355A01

FIG. No.
23



NOTES:

CLIENT

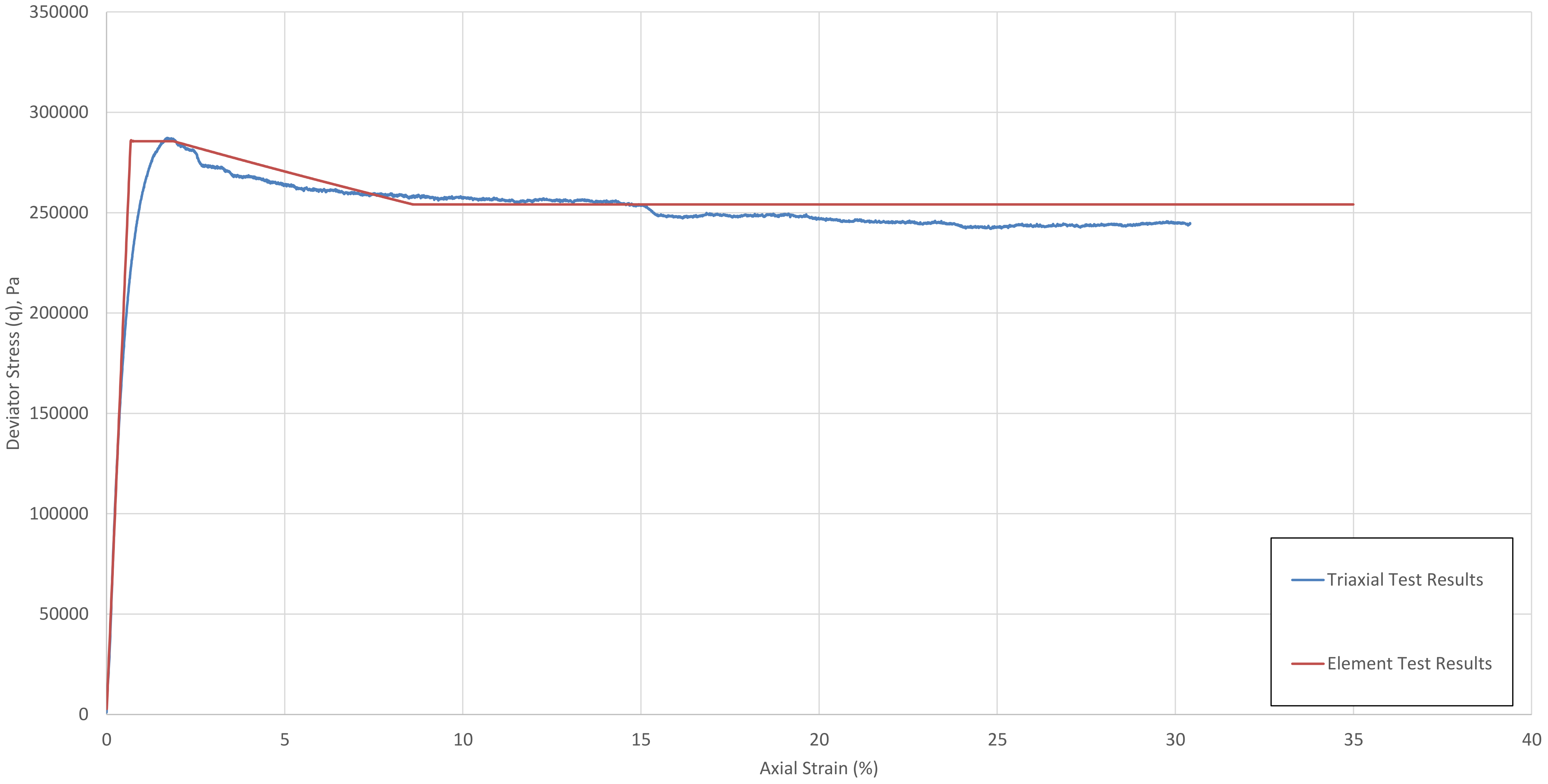
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

STRAIN WEAKENING ELEMENT TEST RESULTS: DRAINED TRIAXIAL TEST #10

PROJECT No.
A03355A01

FIG. No.
24



NOTES:

CLIENT

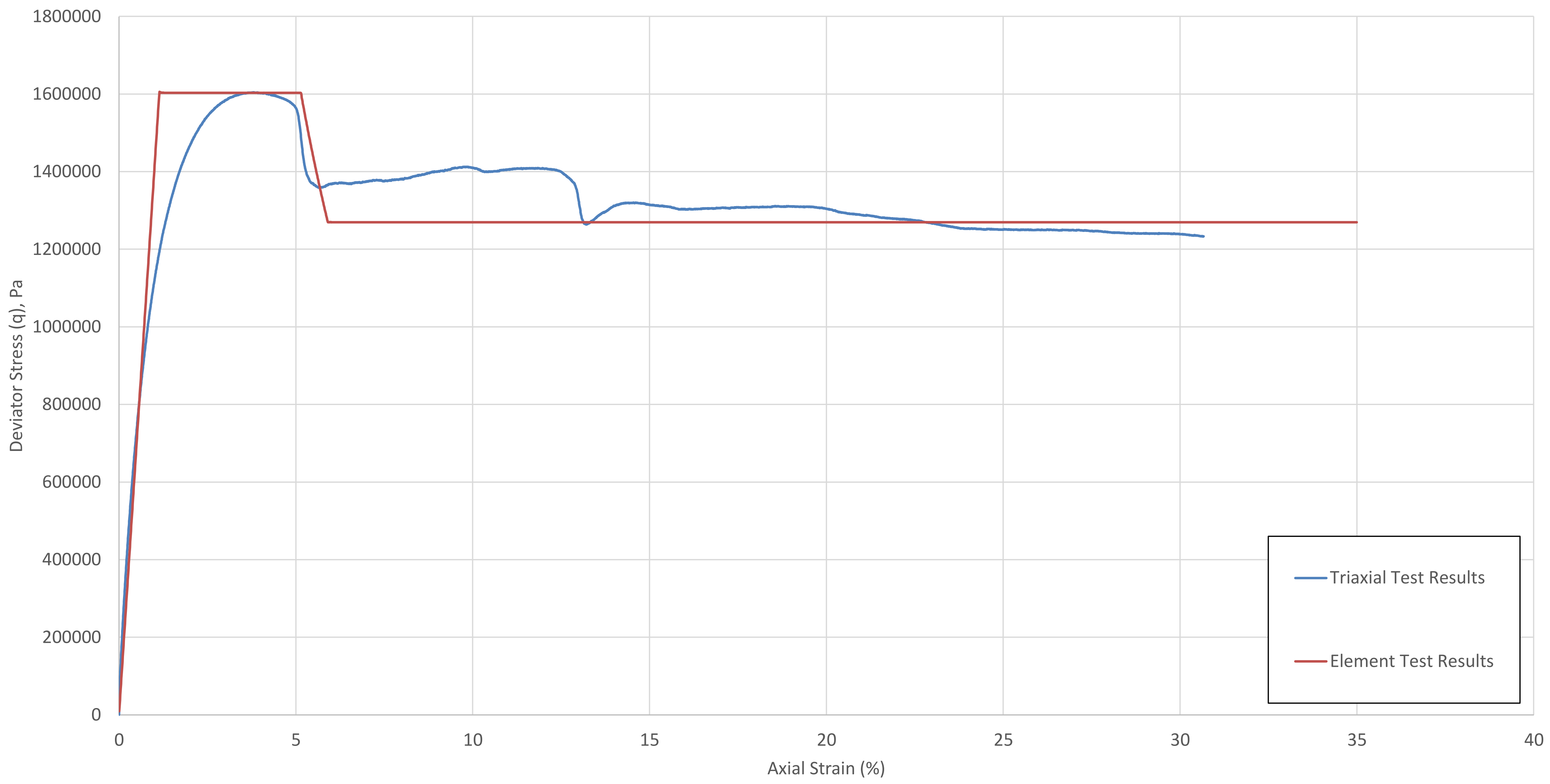
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

STRAIN WEAKENING ELEMENT TEST RESULTS: DRAINED TRIAXIAL TEST #11

PROJECT No. A03355A01

FIG. No. 25



NOTES:

CLIENT

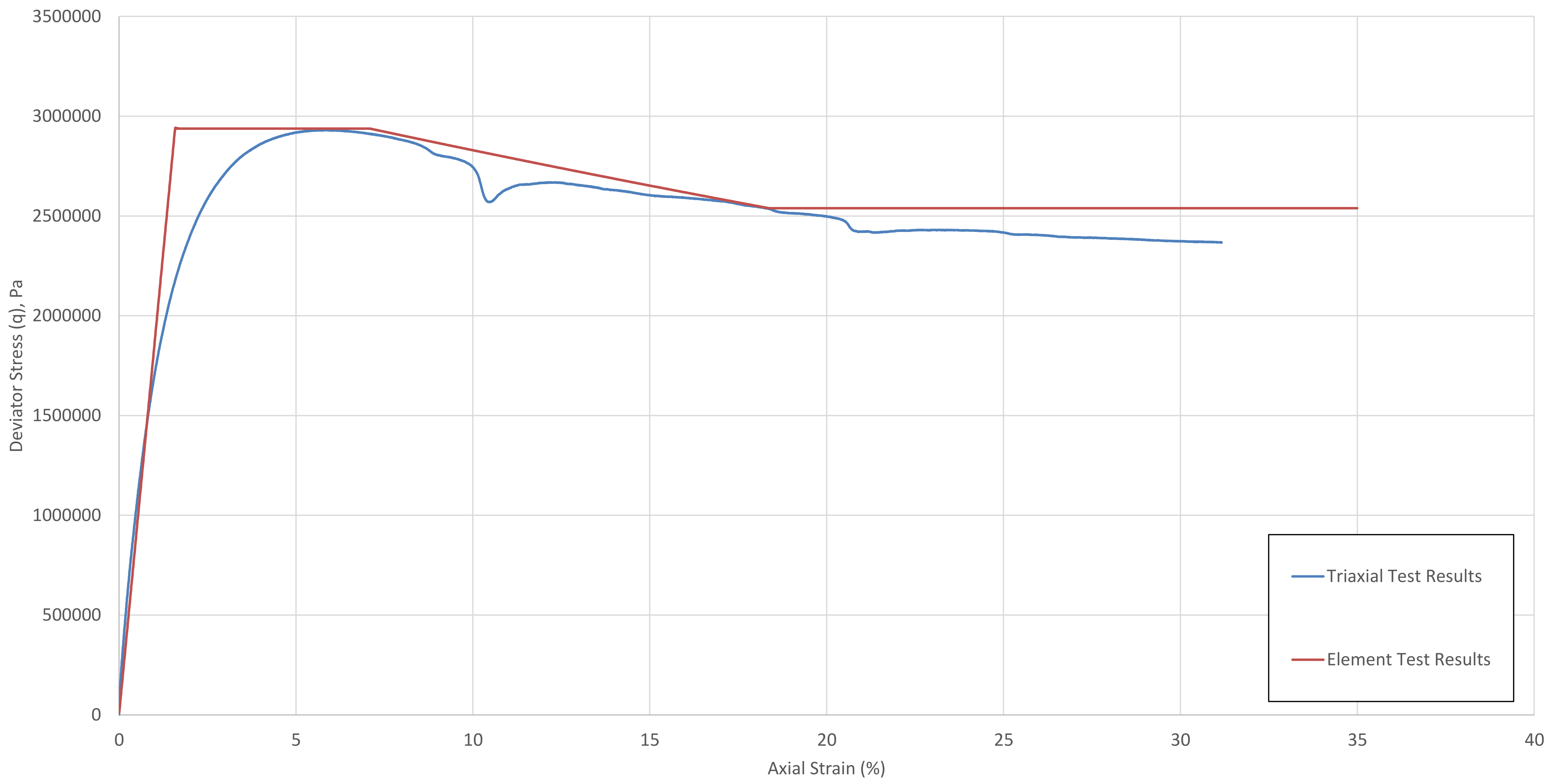
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

STRAIN WEAKENING ELEMENT TEST RESULTS: DRAINED TRIAXIAL TEST #12

PROJECT No.
A03355A01

FIG. No.
26



NOTES:

CLIENT

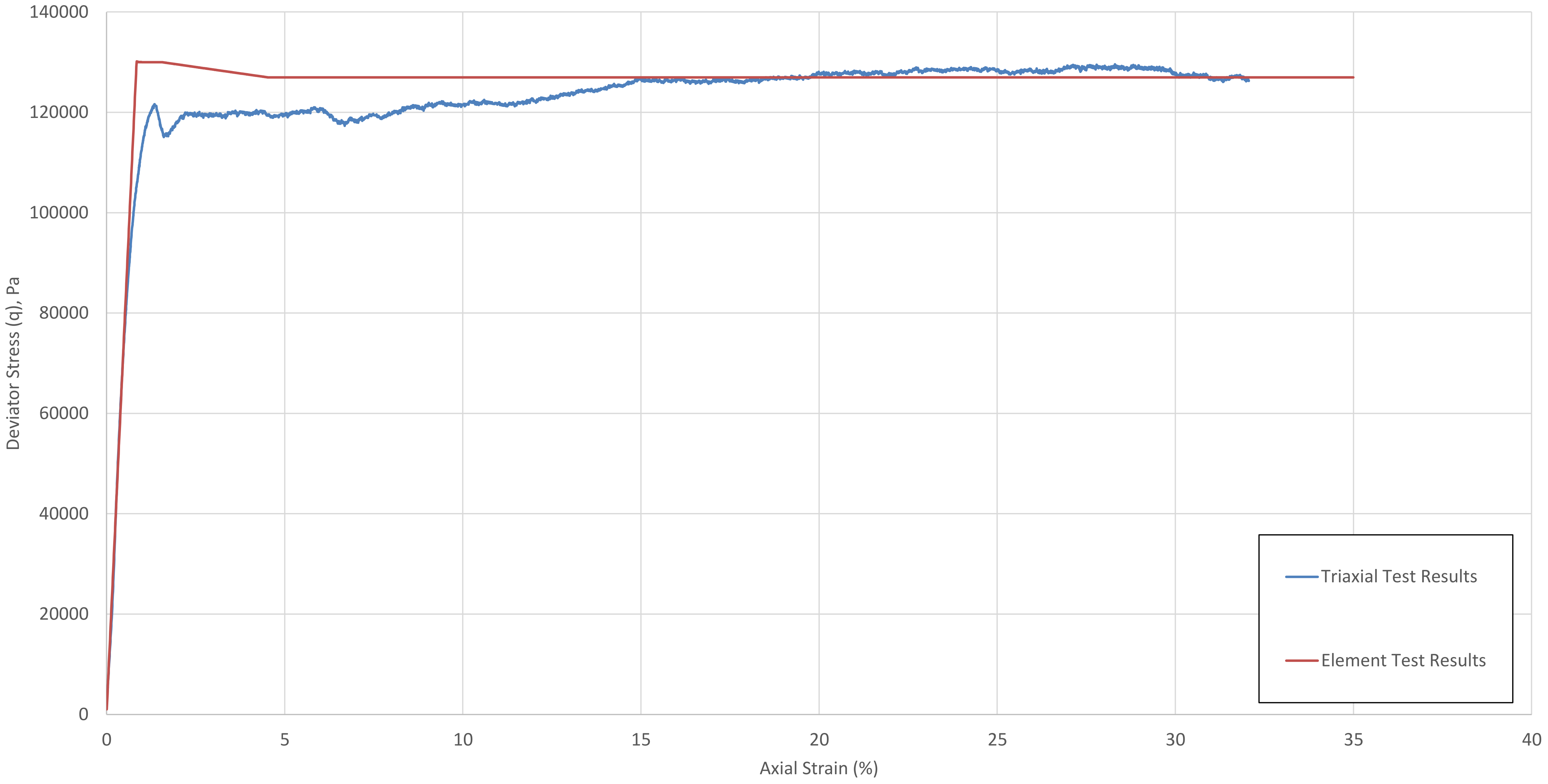
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF
THE FAILURE OF FEIJÃO DAM 1

STRAIN WEAKENING ELEMENT TEST RESULTS: DRAINED TRIAXIAL TEST #13

PROJECT No. A03355A01

FIG. No. 27



NOTES:

CLIENT

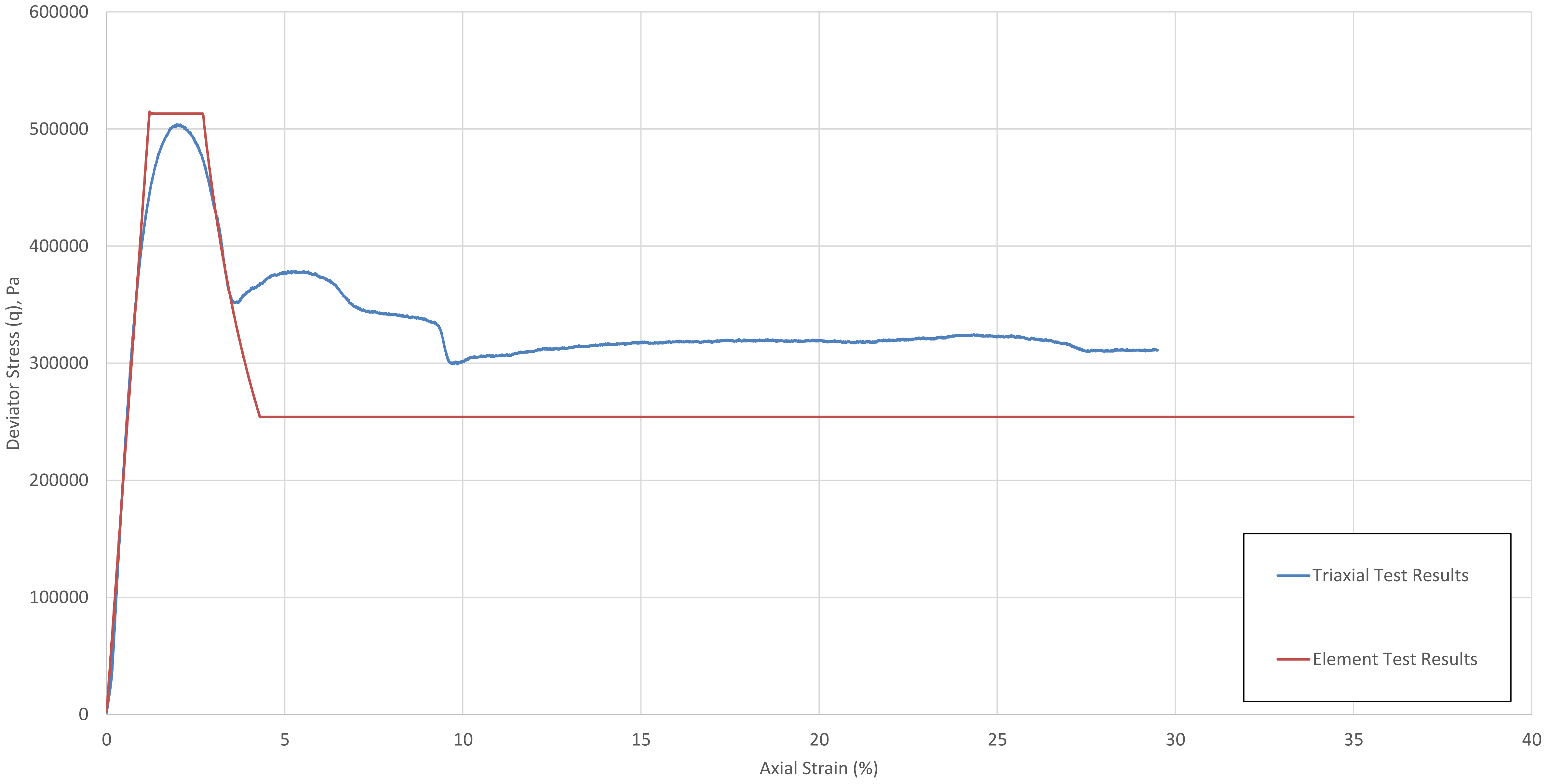
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF
THE FAILURE OF FEIJÃO DAM 1

STRAIN WEAKENING ELEMENT TEST RESULTS: DRAINED TRIAXIAL TEST #14

PROJECT No. A03355A01

FIG. No. 28



NOTES:

CLIENT

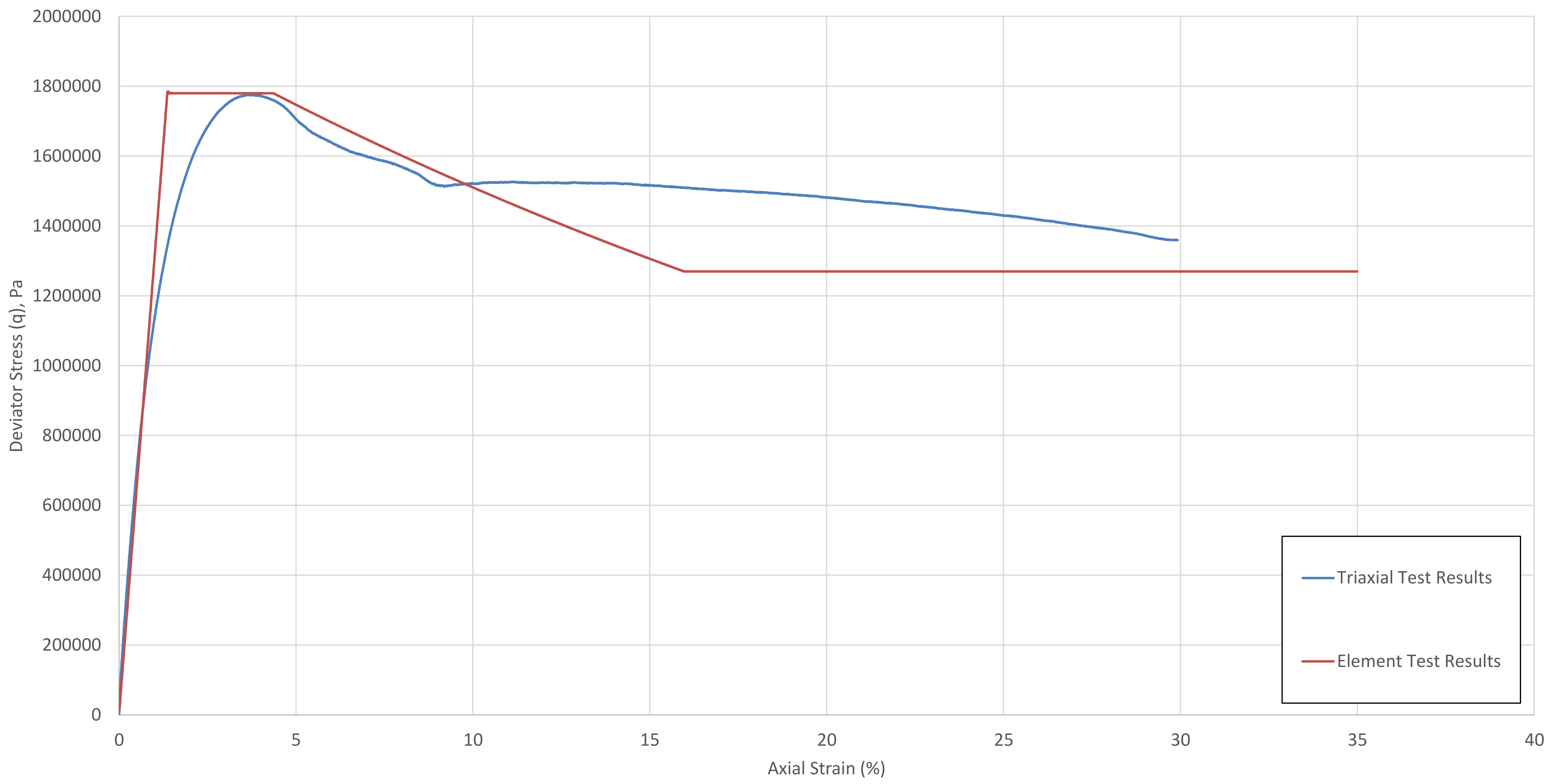
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

STRAIN WEAKENING ELEMENT TEST RESULTS: DRAINED TRIAXIAL TEST #15

PROJECT No. A03355A01

FIG. No. 29



NOTES:

CLIENT

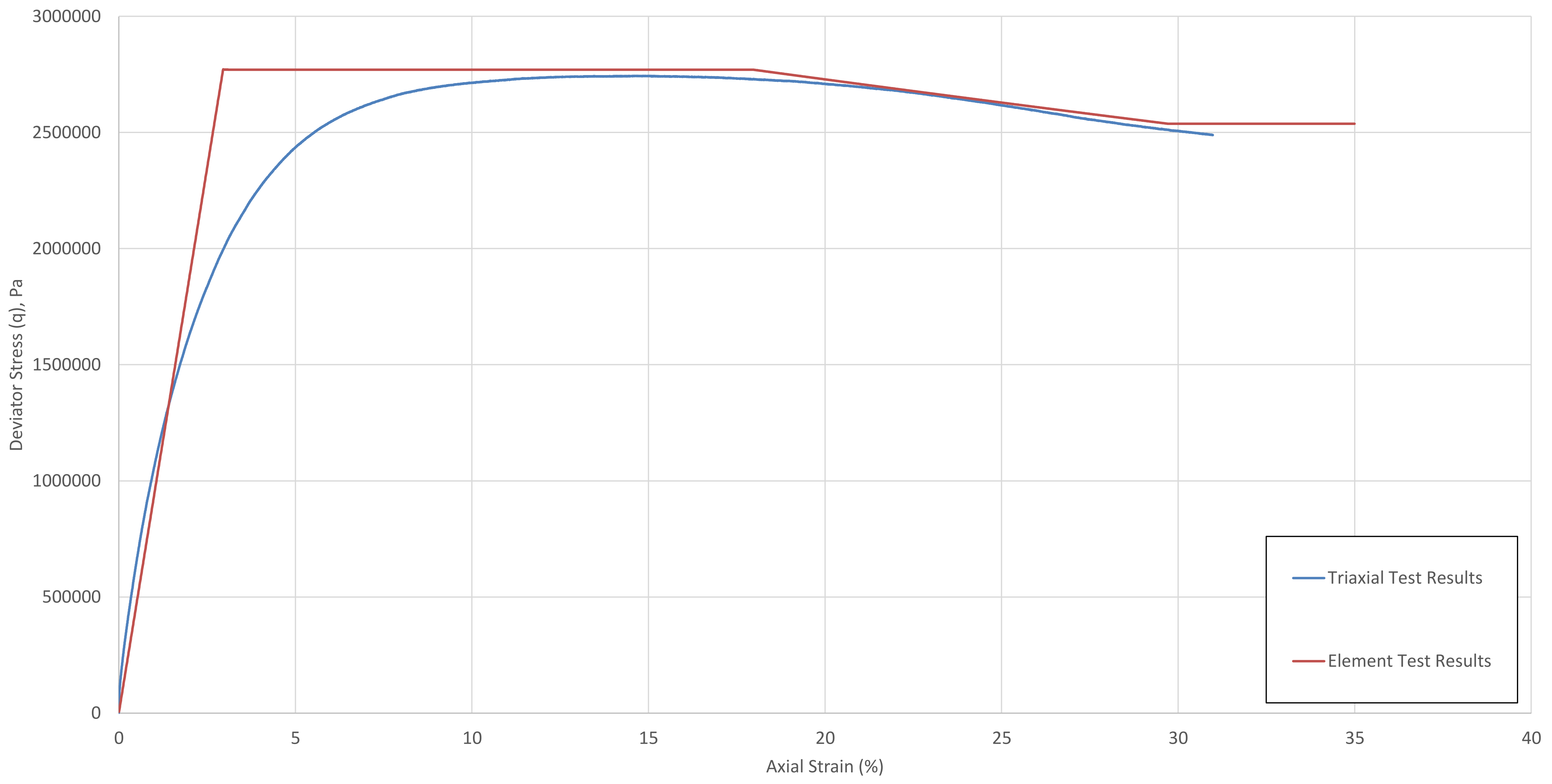
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

STRAIN WEAKENING ELEMENT TEST RESULTS: DRAINED TRIAXIAL TEST #16

PROJECT No. A03355A01

FIG. No. 30



NOTES:

CLIENT

PROJECT

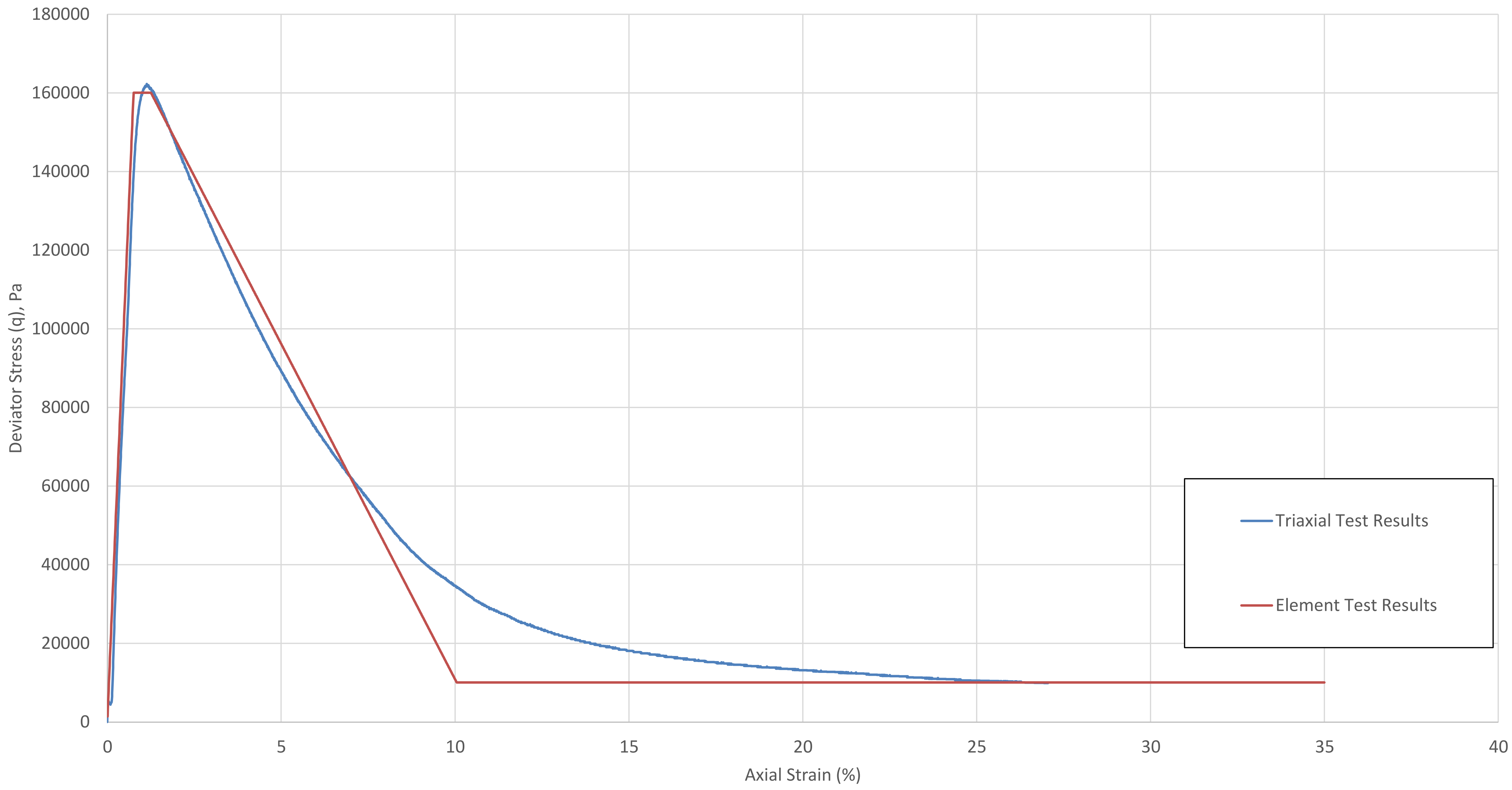
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

STRAIN WEAKENING ELEMENT TEST RESULTS: DRAINED TRIAXIAL TEST #17

PROJECT No. A03355A01

FIG. No. 31

Strain Weakening Element Tests - Undrained



NOTES:

CLIENT

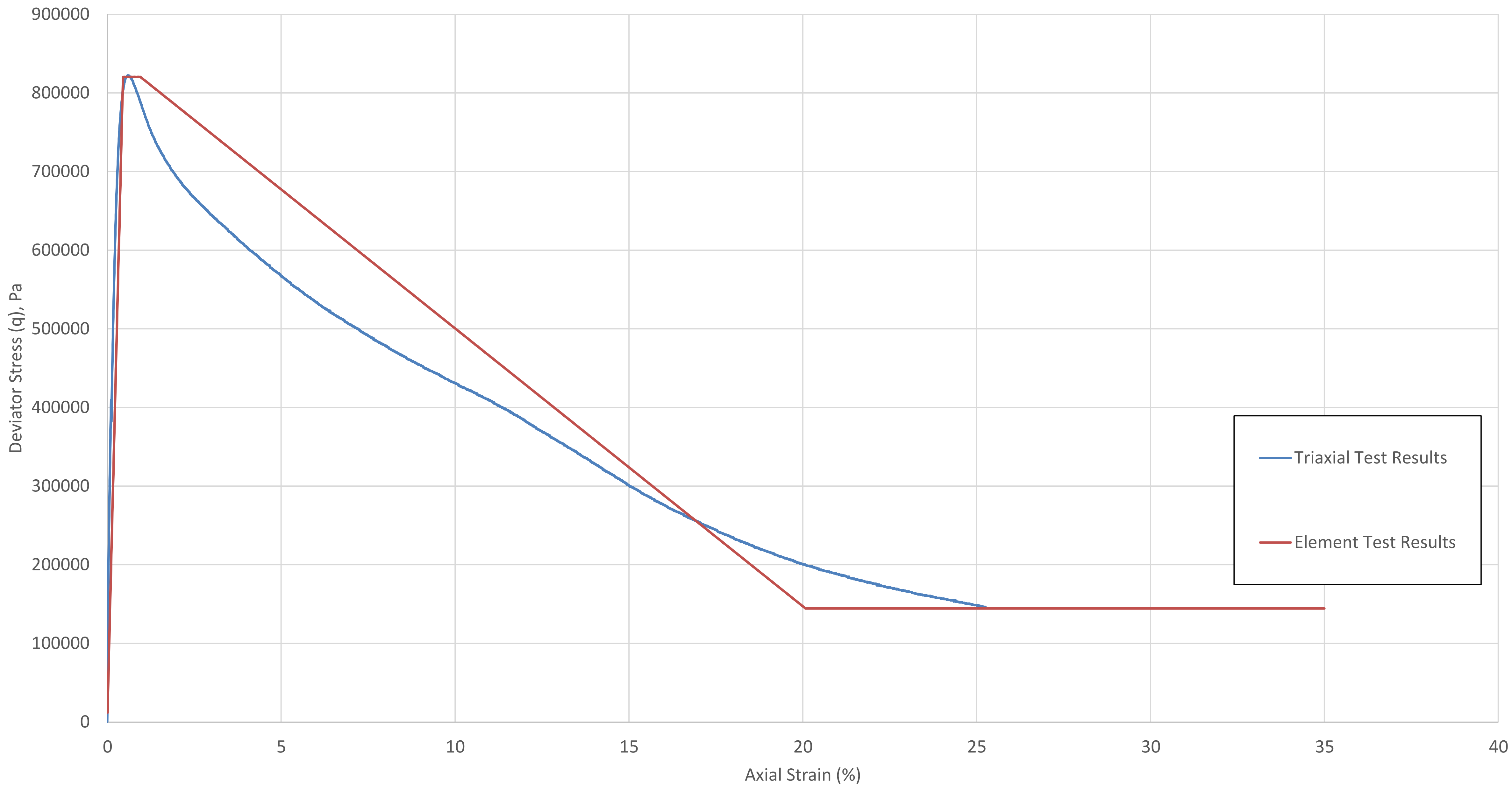
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

UNDRAINED, STRAIN WEAKENING ELEMENT TEST RESULTS: TRIAXIAL TEST #04

PROJECT No. A03355A01

FIG. No. 32



NOTES:

CLIENT

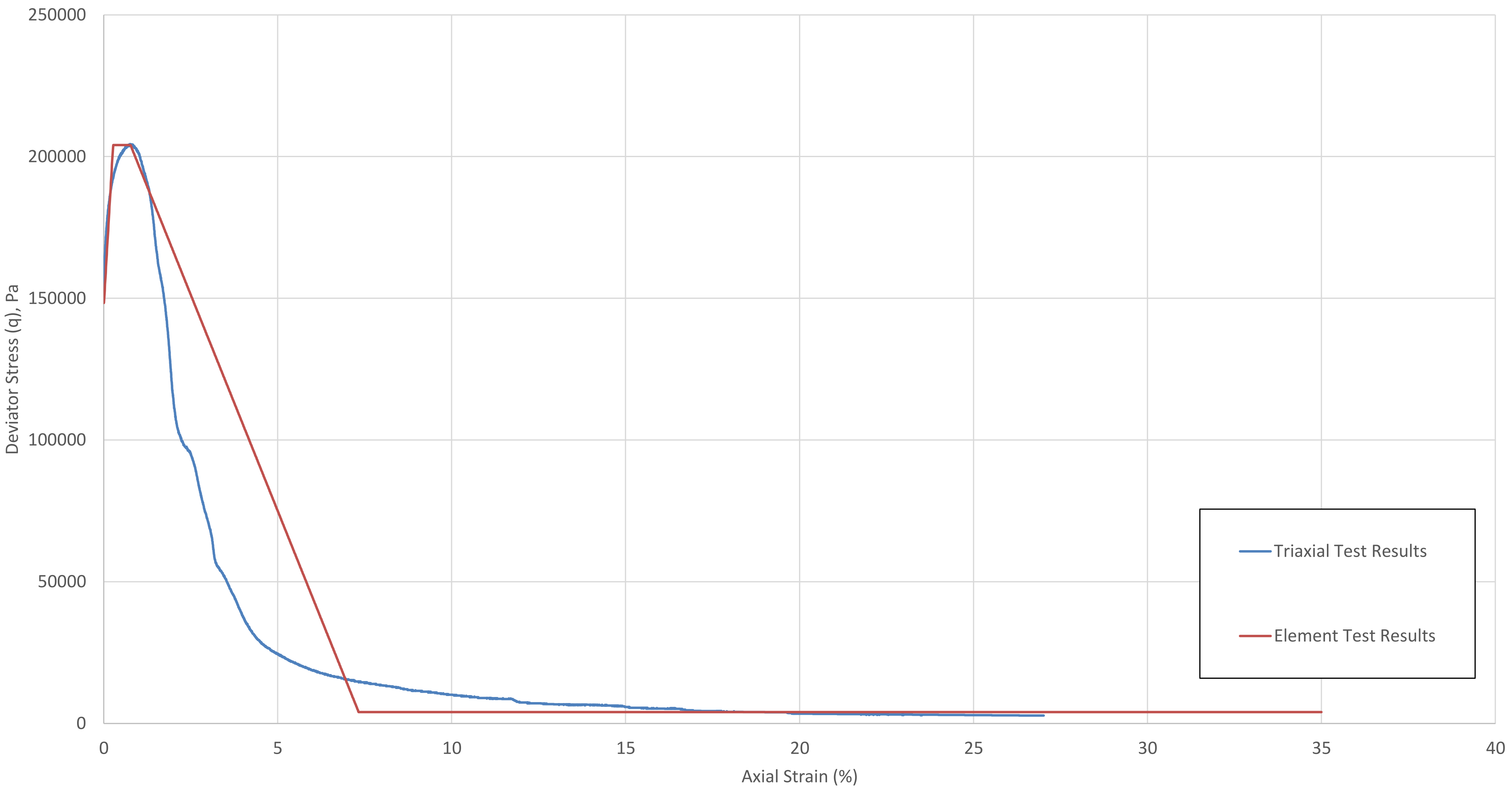
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

UNDRAINED, STRAIN WEAKENING ELEMENT TEST RESULTS: TRIAXIAL TEST #07

PROJECT No. A03355A01

FIG. No. 33



NOTES:

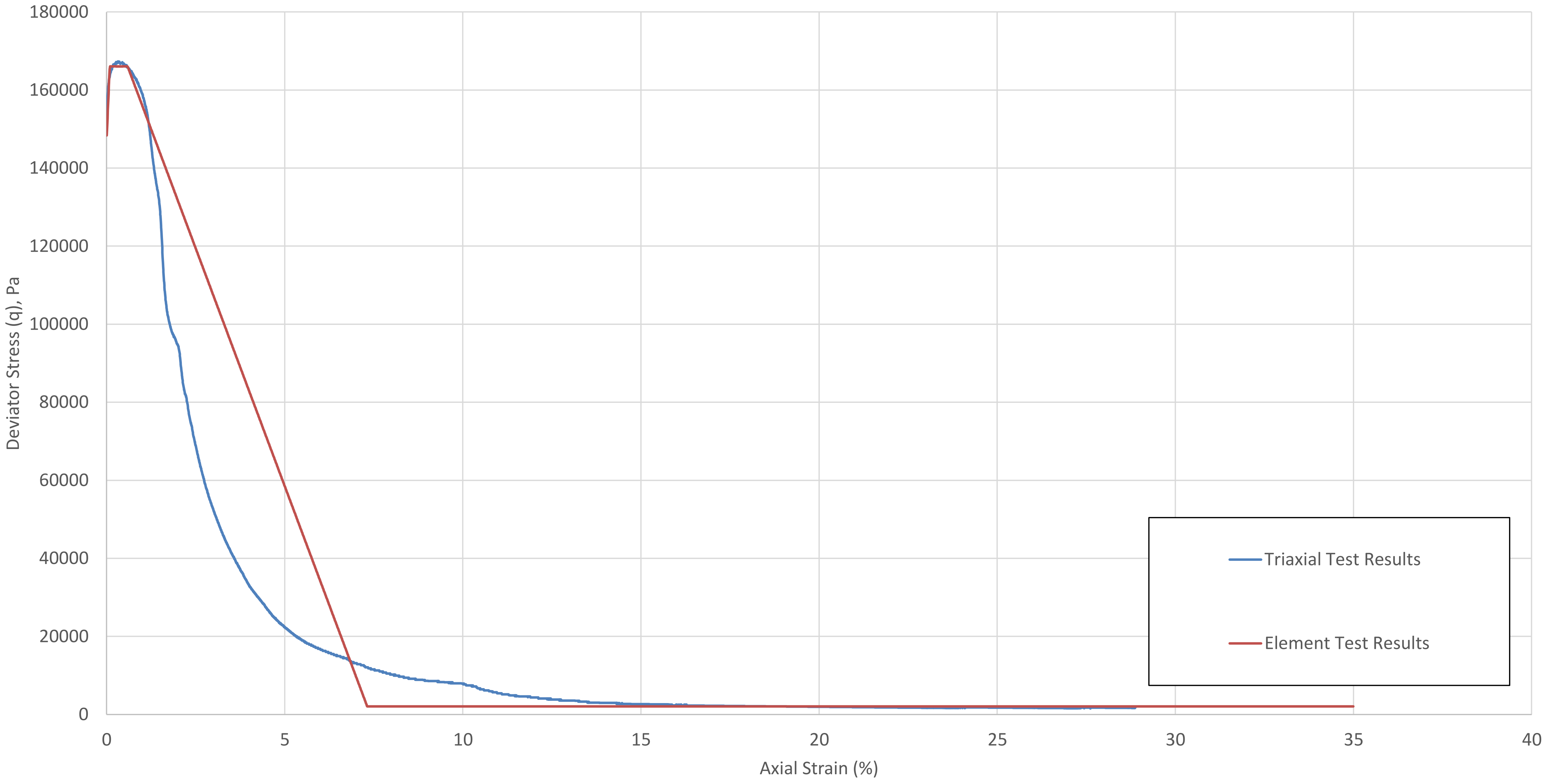
CLIENT

PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

UNDRAINED, STRAIN WEAKENING ELEMENT TEST RESULTS: TRIAXIAL TEST #25

PROJECT No.
A03355A01

FIG. No.
34



NOTES:

CLIENT

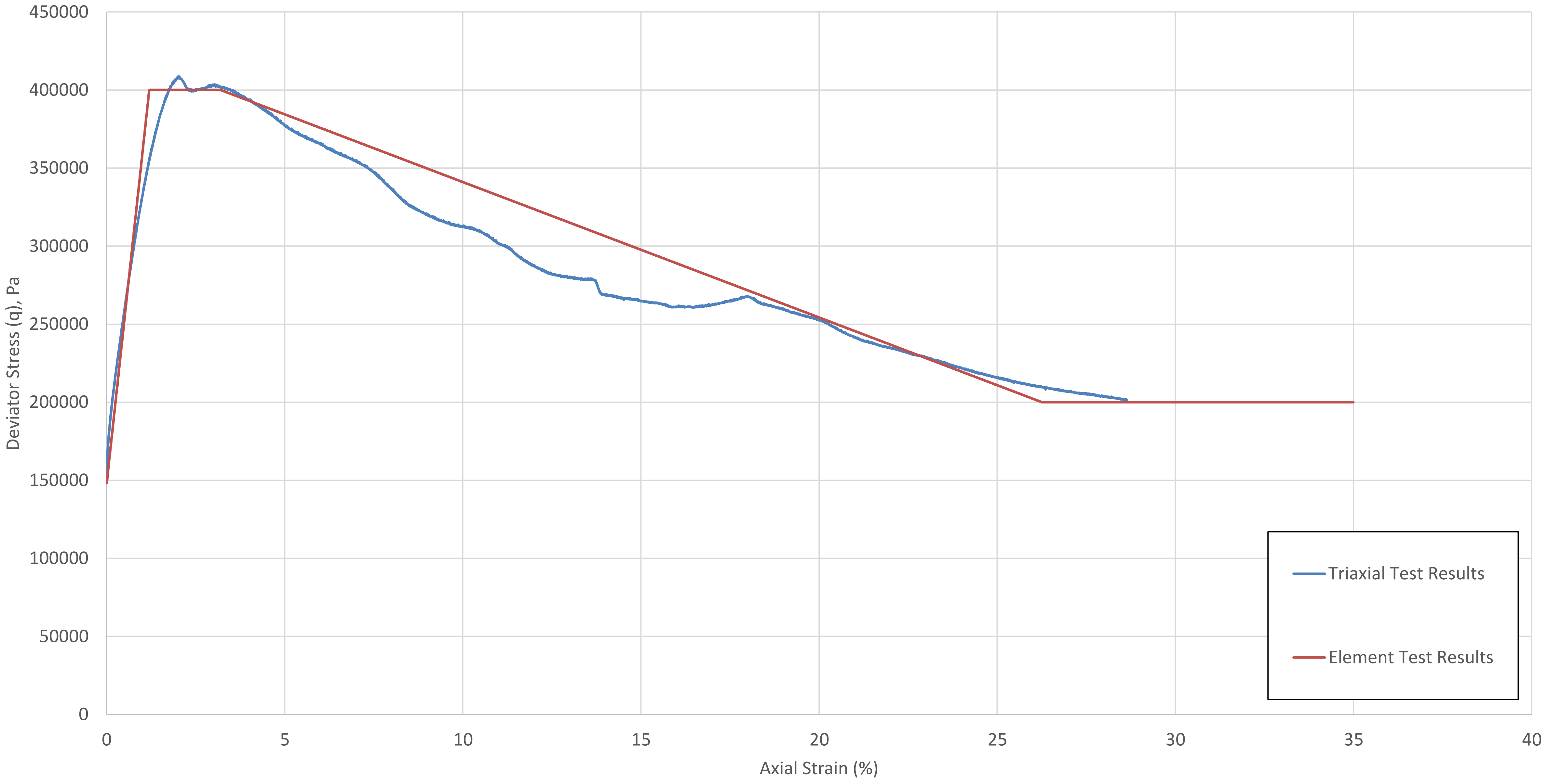
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

UNDRAINED, STRAIN WEAKENING ELEMENT TEST RESULTS: TRIAXIAL TEST #26

PROJECT No.
A03355A01

FIG. No.
35



NOTES:

CLIENT

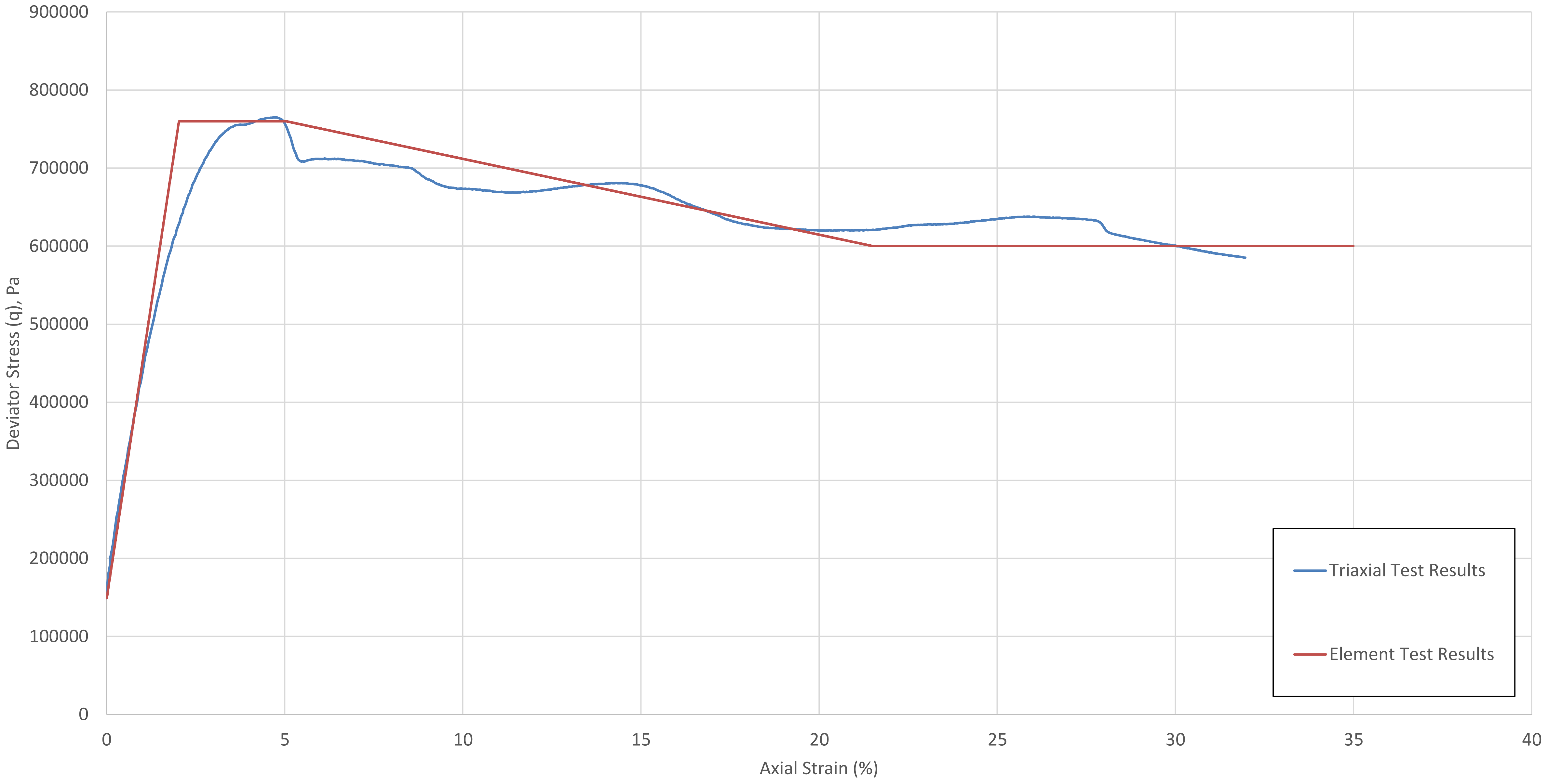
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

UNDRAINED, STRAIN WEAKENING ELEMENT TEST RESULTS: TRIAXIAL TEST #27

PROJECT No. A03355A01

FIG. No. 36



NOTES:

CLIENT

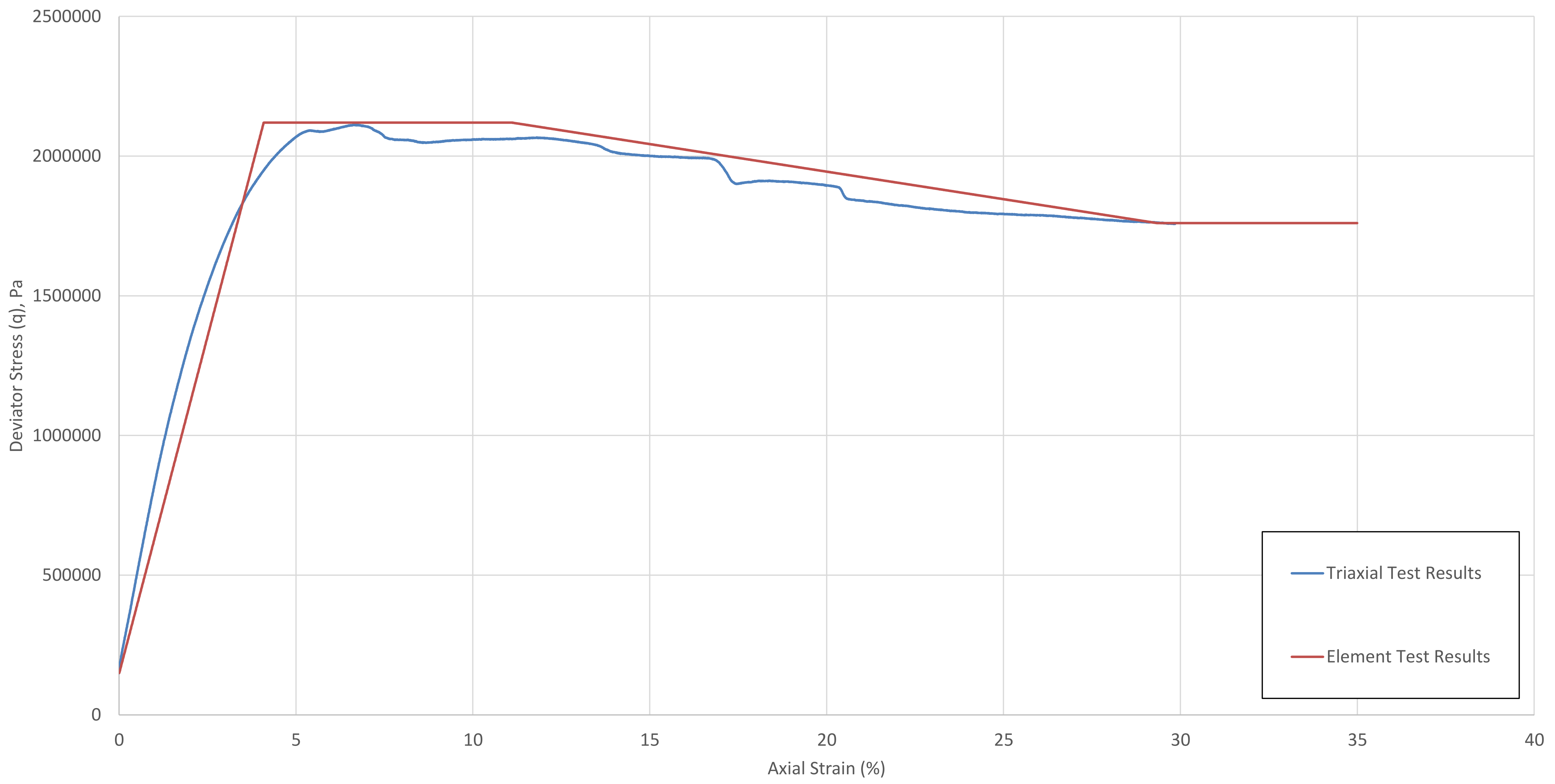
PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

UNDRAINED, STRAIN WEAKENING ELEMENT TEST RESULTS: TRIAXIAL TEST #28

PROJECT No. A03355A01

FIG. No. 37



NOTES:

AS A MUTUAL PROTECTION TO OUR CLIENT, THE PUBLIC AND OURSELVES, ALL REPORTS AND DRAWINGS ARE SUBMITTED FOR THE CONFIDENTIAL INFORMATION OF OUR CLIENT FOR A SPECIFIC PROJECT AND AUTHORIZATION FOR USE AND/OR PUBLICATION OF DATA STATEMENTS, CONCLUSIONS OR ABSTRACTS FROM OR REGARDING OUR REPORTS AND DRAWINGS IS RESERVED PENDING OUR WRITTEN APPROVAL.

CLIENT

PROJECT

REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

UNDRAINED, STRAIN WEAKENING ELEMENT TEST RESULTS: TRIAXIAL TEST #29

PROJECT No. A03355A01

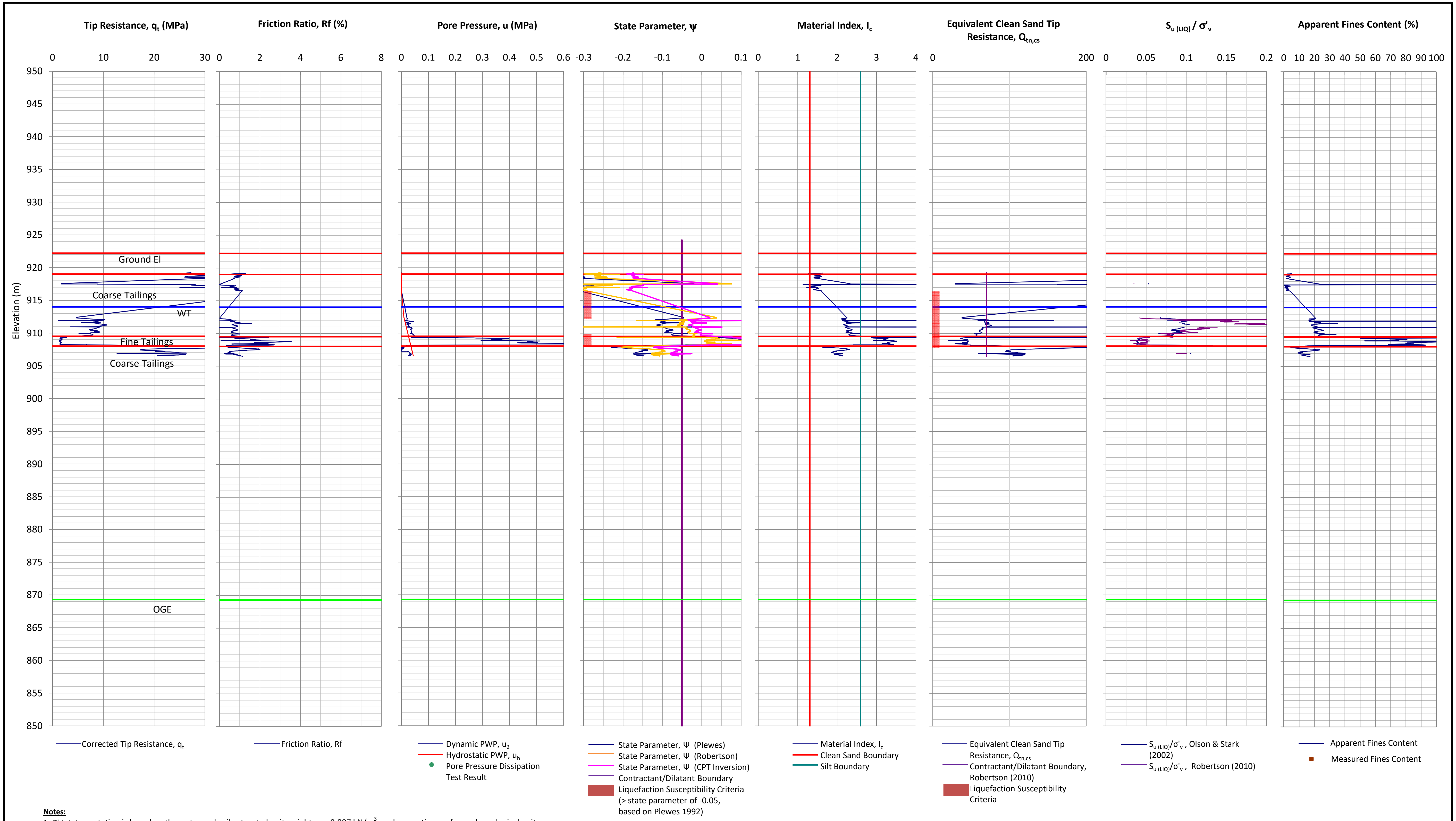
FIG. No. 38

Appendix E

Annex 9 – CPTu Plots, V_s Plots & Histogram

December 2019

CPTu & V_s Plots



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as Rf=f_s/q_t.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) calculated using Plewes, et al. (1992) and the CPT inversion method is based on an assumed K0 of 0.5.

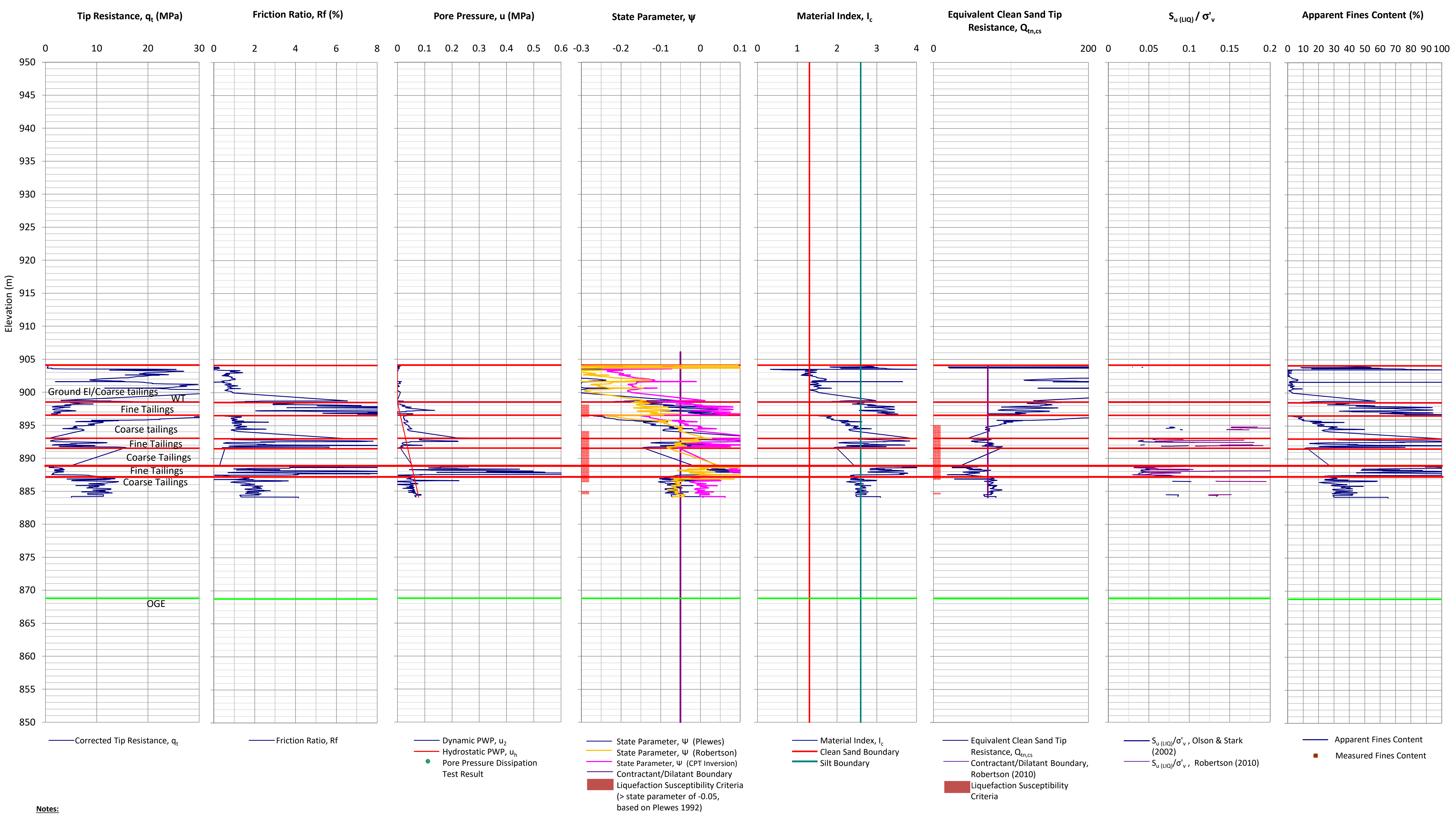
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
CONE PENETRATION TEST CPTU-05-01N_R1

N:7775122.5 E:591862.6 23-Nov-2005

PROJECT NO.
A03355A01

FIGURE NO.
1



Notes:
1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as Rf=f_s/q_t.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) is calculated using Plewes, et al. (1992) and the CPT Inversion method is based on an assumed a K0 of 0.5.

CLIENT

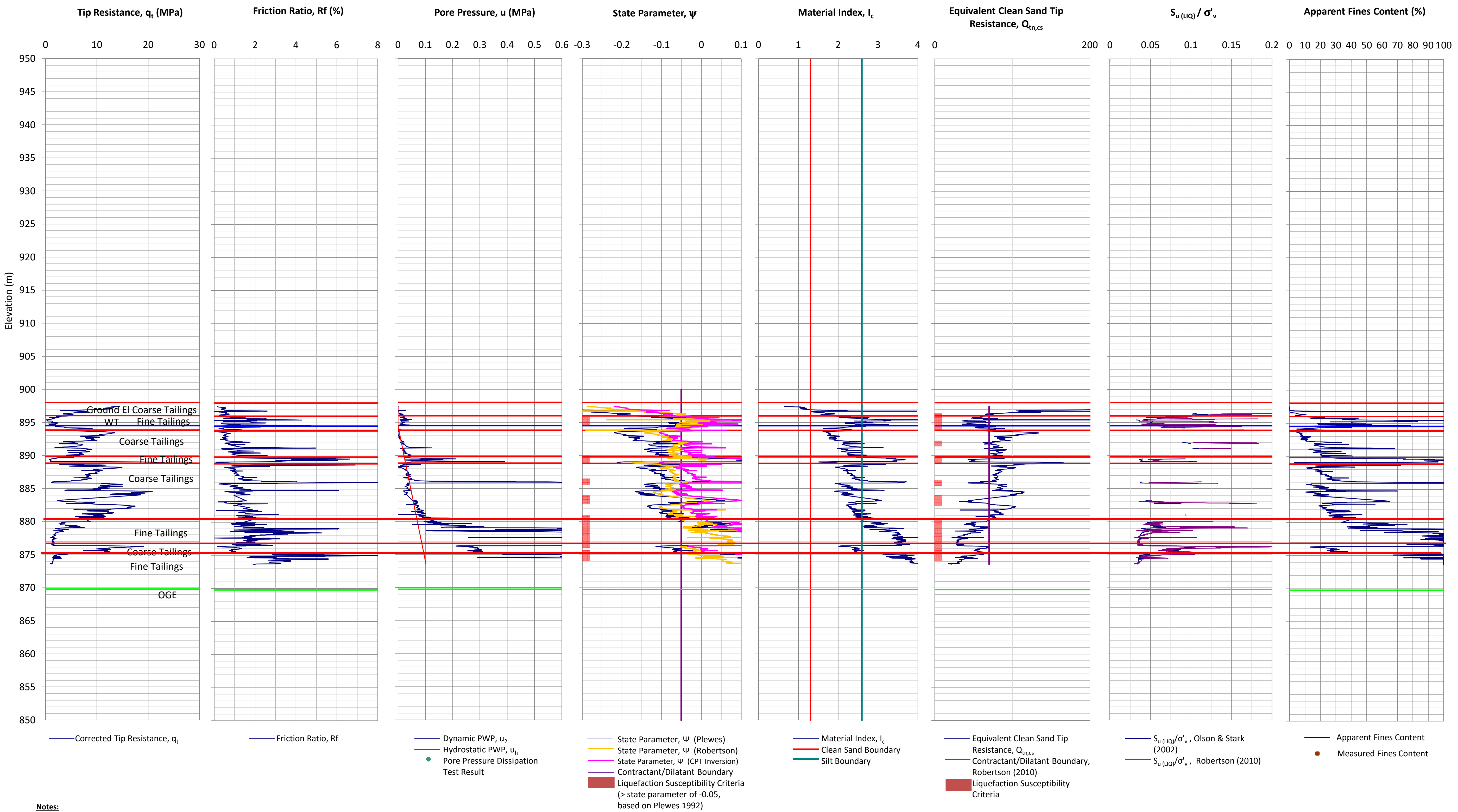
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
CONE PENETRATION TEST CPTU-05-02_R1

N:7775088.2 E:591820.6 28-Oct-2005

PROJECT NO.
A03355A01

FIGURE NO.
2



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as Rf=f_s/q_t.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) calculated using Plewes, et al. (1992) and the CPT inversion method is based on an assumed K0 of 0.5.

CLIENT

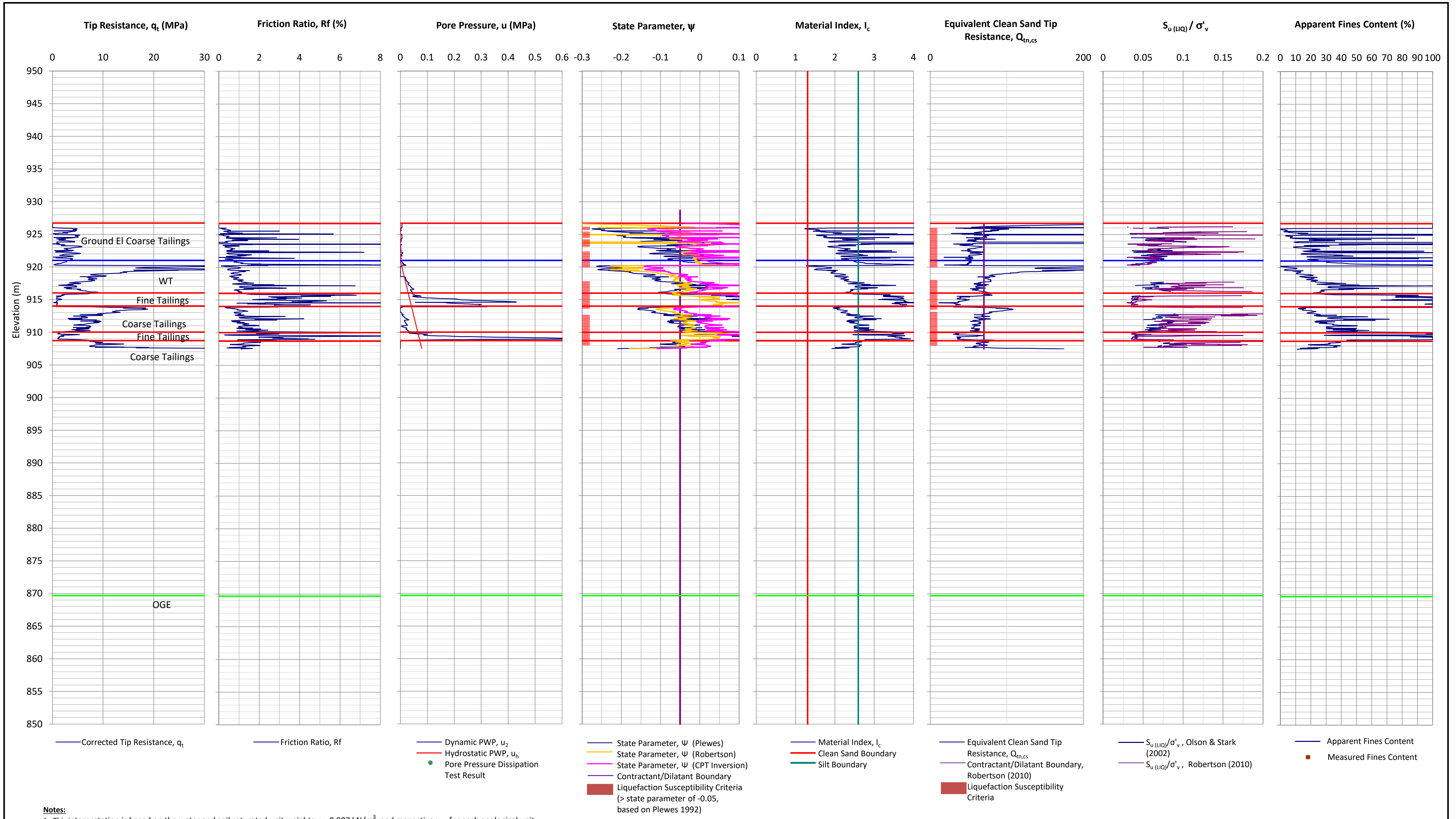
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
CONE PENETRATION TEST CPTU-05-03N_R1

N:7775072.1 E:591803 19-Oct-2005

PROJECT NO.
A03355A01

FIGURE NO.
3



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as Rf=f_s/q_t.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) calculated using Plewes, et al. (1992) and the CPT inversion method is based on an assumed K0 of 0.5.

CLIENT

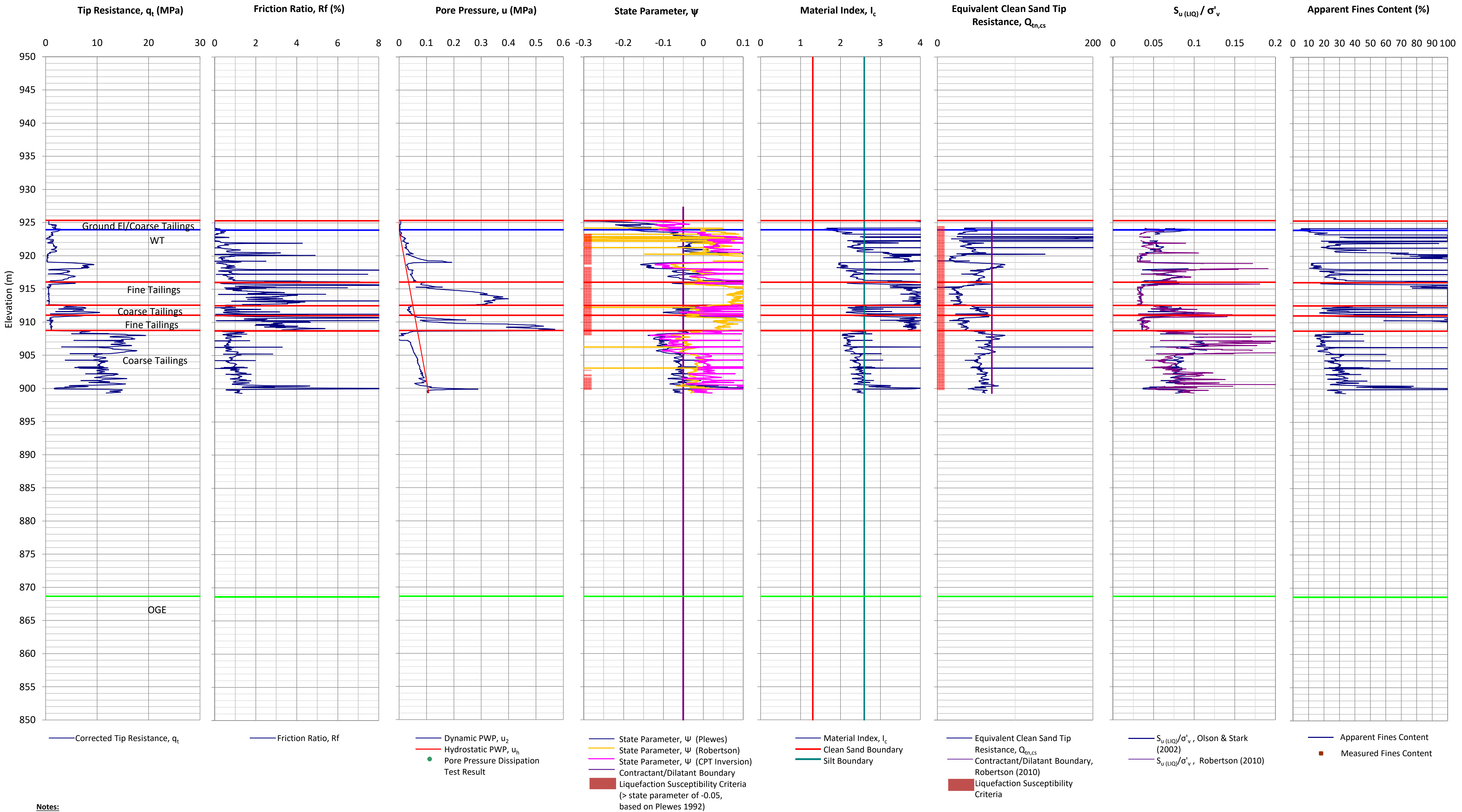
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
CONE PENETRATION TEST CPTU-05-04N_R1

N:7775144.6 E:591899.5 19-Oct-2005

PROJECT NO.
A03355A01

FIGURE NO.
4



Notes:
1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as $Rf=f_s/q_t$.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) calculated using Plewes, et al. (1992) and the CPT inversion method is based on an assumed K0 of 0.5.

CLIENT

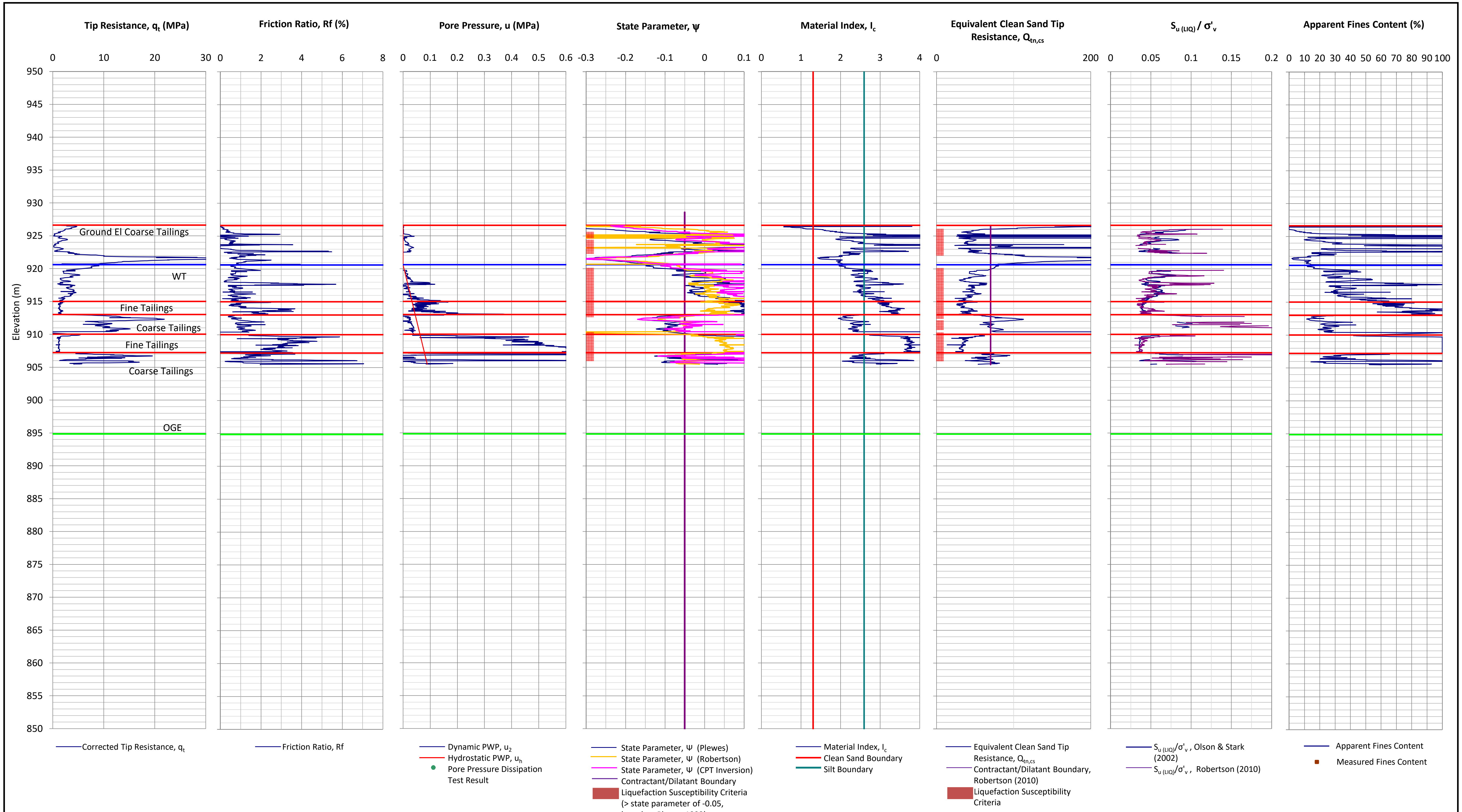
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
CONE PENETRATION TEST CPTU-05-05N_Updated

N:7775166.3 E:591940.5 2005-October-19

PROJECT NO.
A03355A01

FIGURE NO.
5



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as Rf=f_s/q_t.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) calculated using Plewes, et al. (1992) and the CPT inversion method is based on an assumed K0 of 0.5.

CLIENT

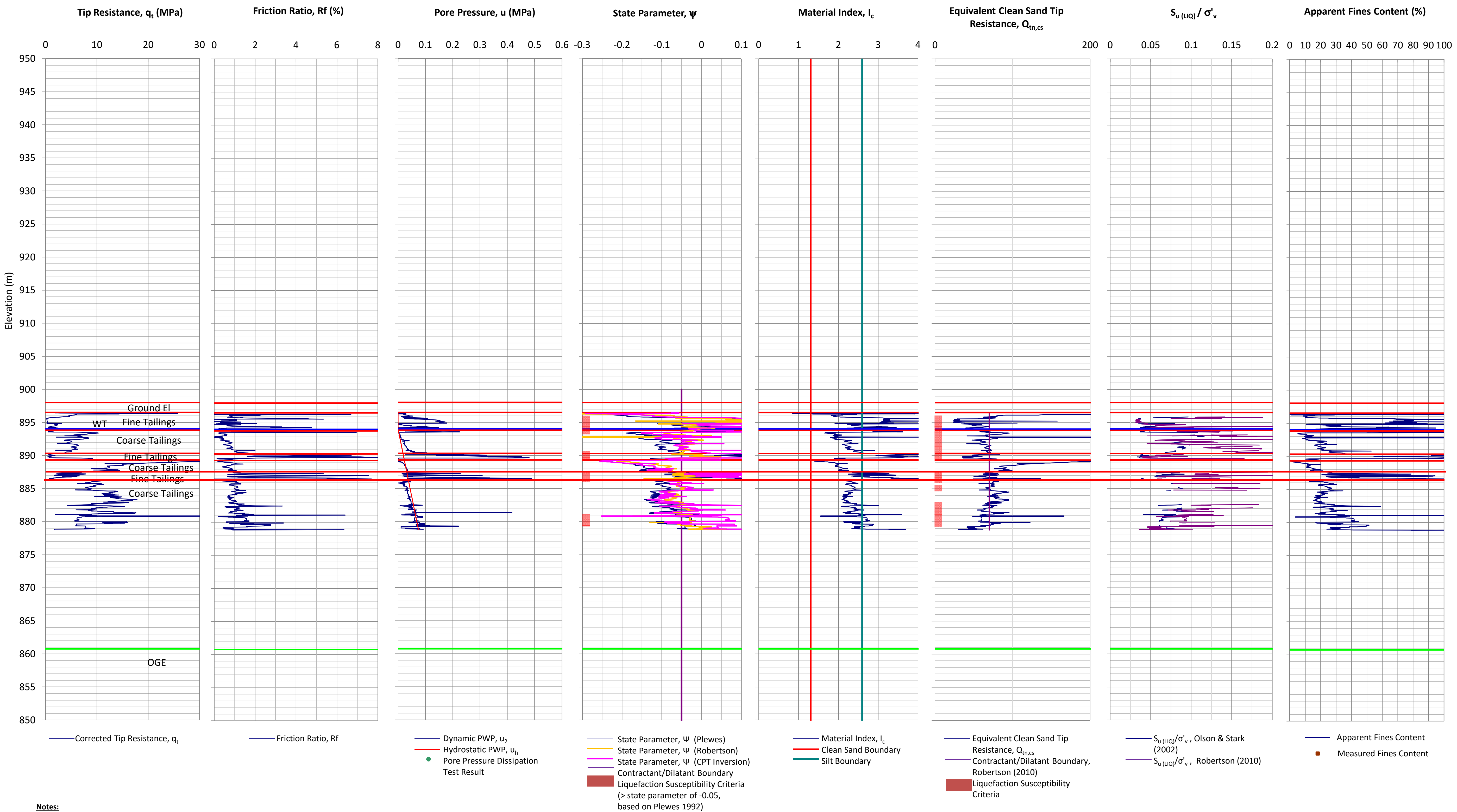
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
CONE PENETRATION TEST CPTU-05-06N_Updated

N:7774886 E:592039.5 2005-November-26

PROJECT NO.
A03355A01

FIGURE NO.
6



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as Rf=f_s/q_t.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) calculated using Plewes, et al. (1992) and the CPT inversion method is based on an assumed K0 of 0.5.

CLIENT

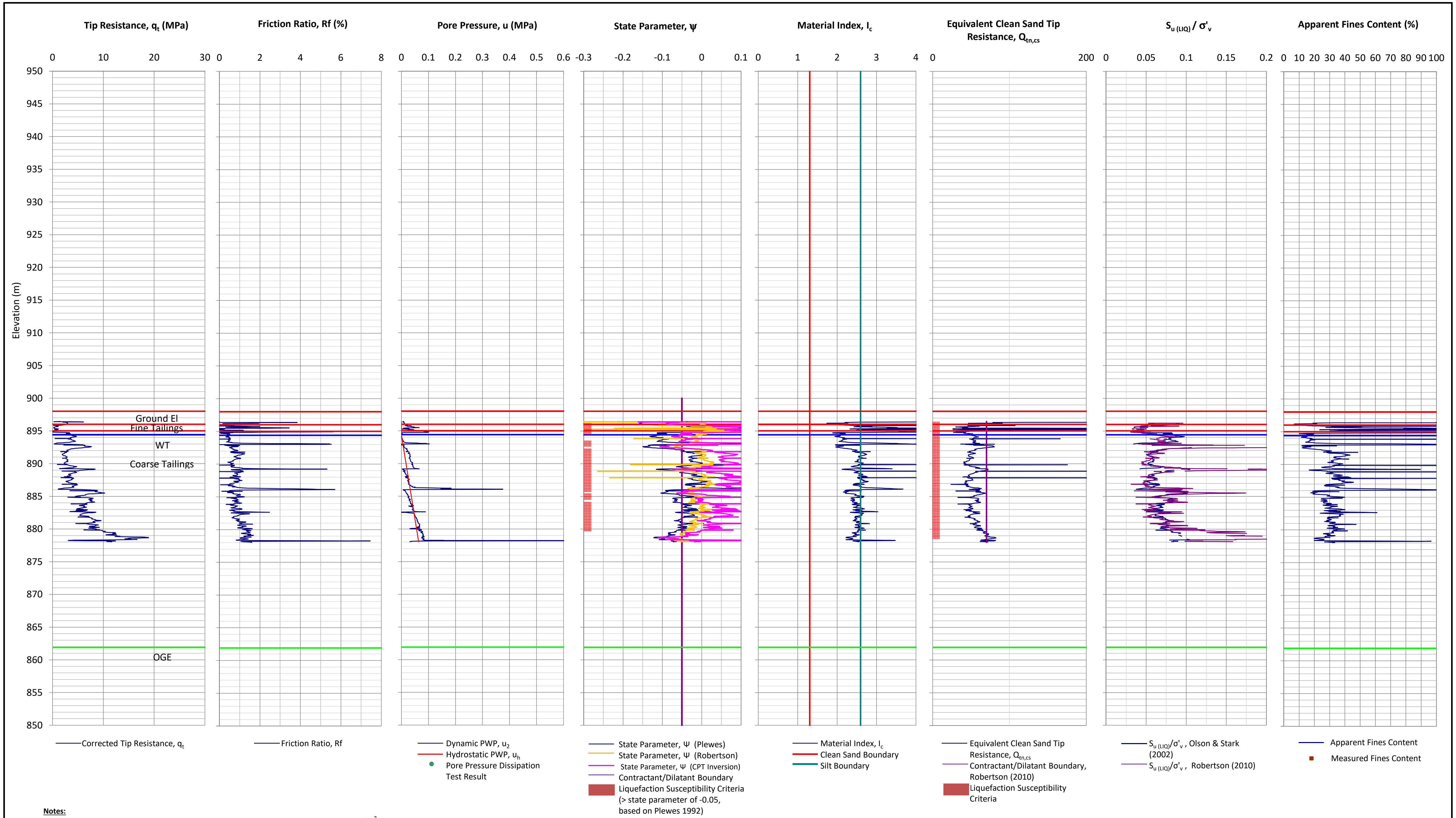
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
CONE PENETRATION TEST CPTU-05-07N_Updated

N:7775013 E:591838.4 2005-November-22

PROJECT NO.
A03355A01

FIGURE NO.
7



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as Rf=f_s/q_t.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) calculated using Plewes, et al. (1992) and the CPT inversion method is based on an assumed K0 of 0.5.

CLIENT

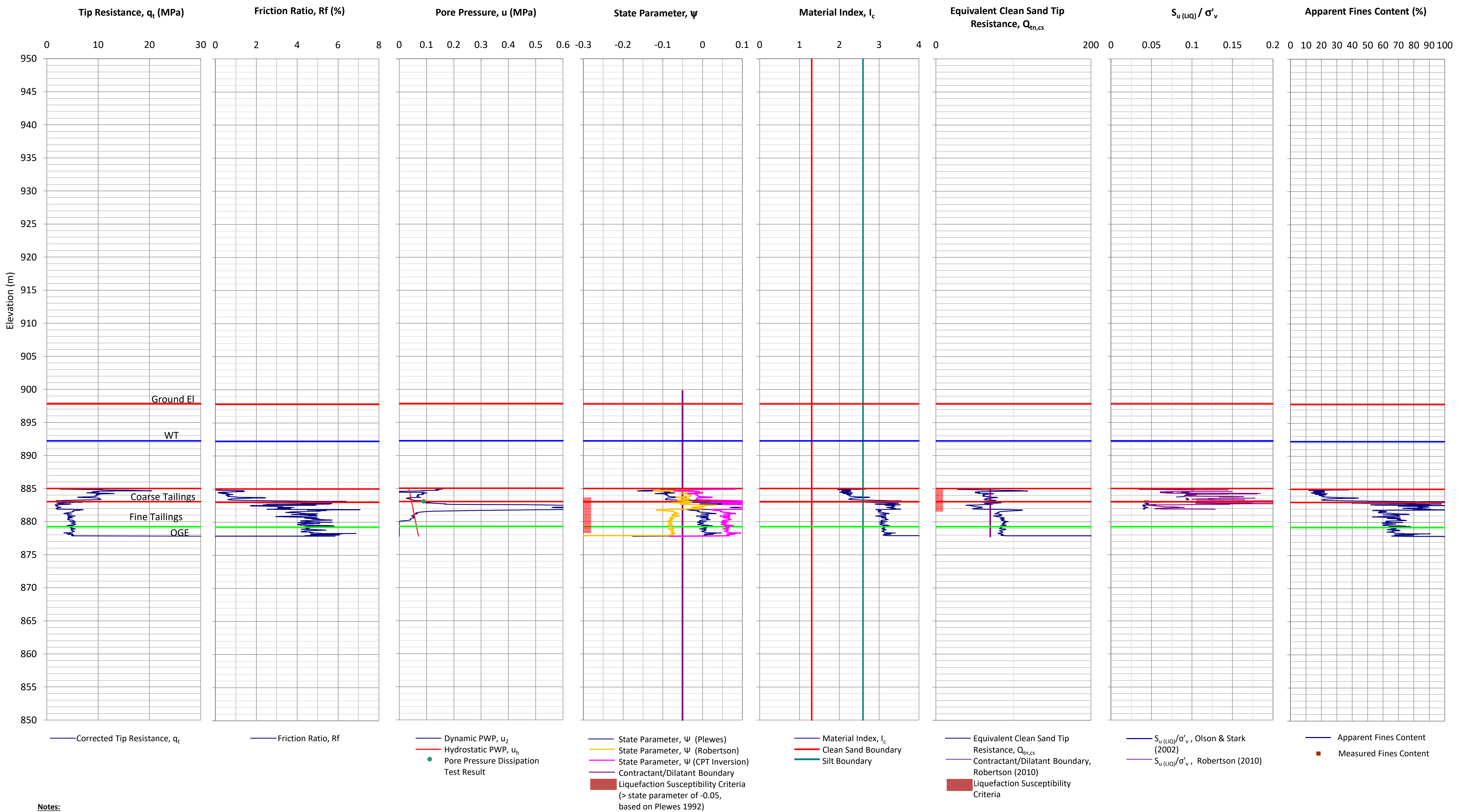
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
CONE PENETRATION TEST CPTU-05-08N_Updated

N:7774948.3 E:591874 2005-November-24

PROJECT NO.
A03355A01

FIGURE NO.
8



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as Rf=f_s/q_t.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) calculated using Plewes, et al. (1992) and the CPT inversion method is based on an assumed K0 of 0.5.

CLIENT

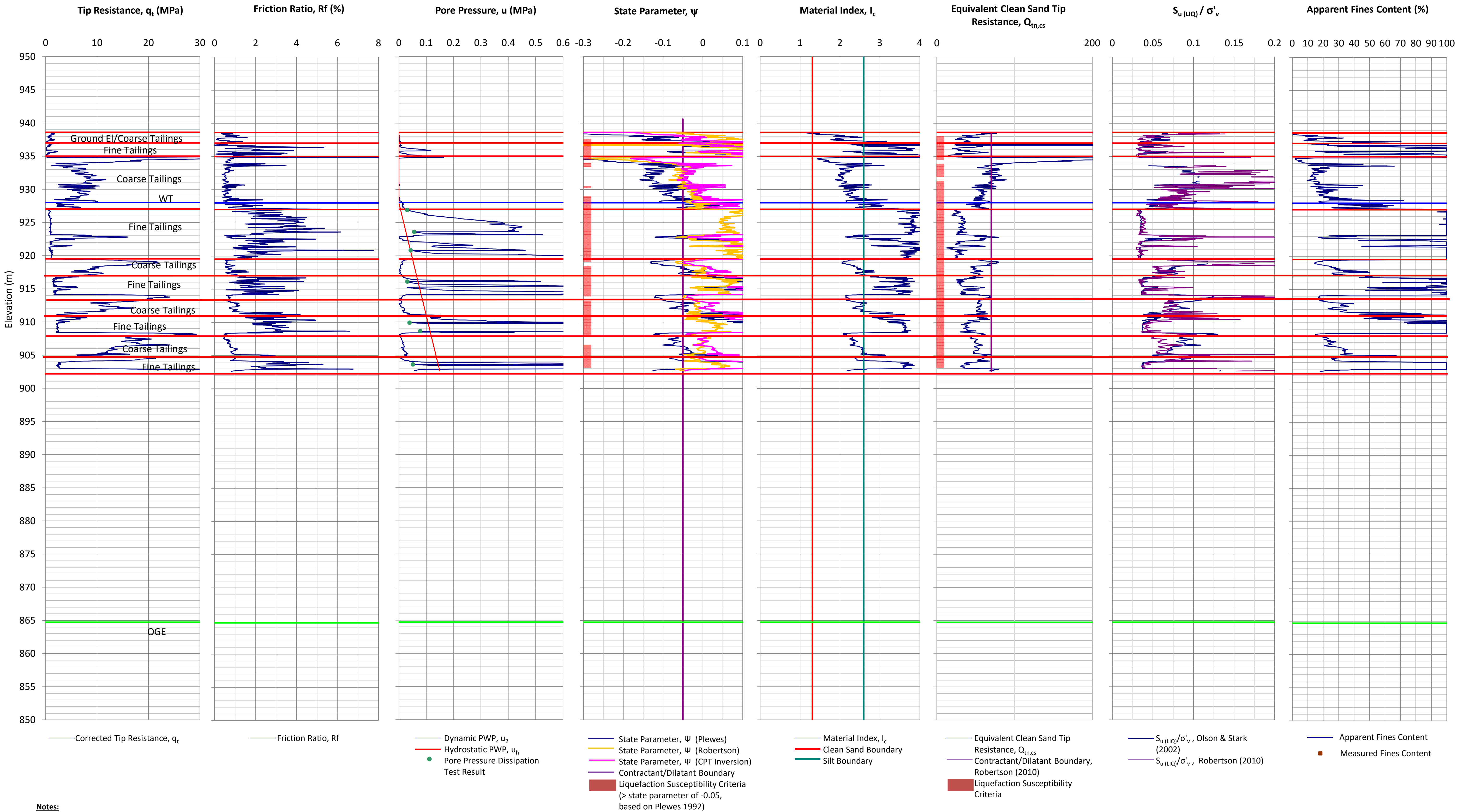
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
CONE PENETRATION TEST CPTU-16-02N_R1

N:7775122.3 E:591774.7 01-Apr-2016

PROJECT NO.
A03355A01

FIGURE NO.
9



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as $Rf=f_s/q_t$.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) calculated using Plewes, et al. (1992) and the CPT inversion method is based on an assumed K0 of 0.5.

CLIENT

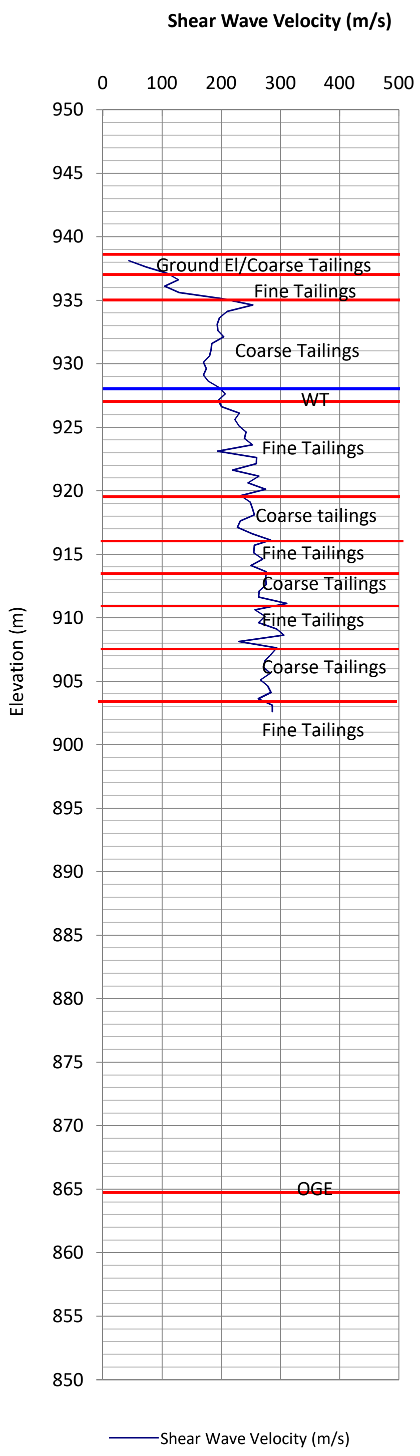
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

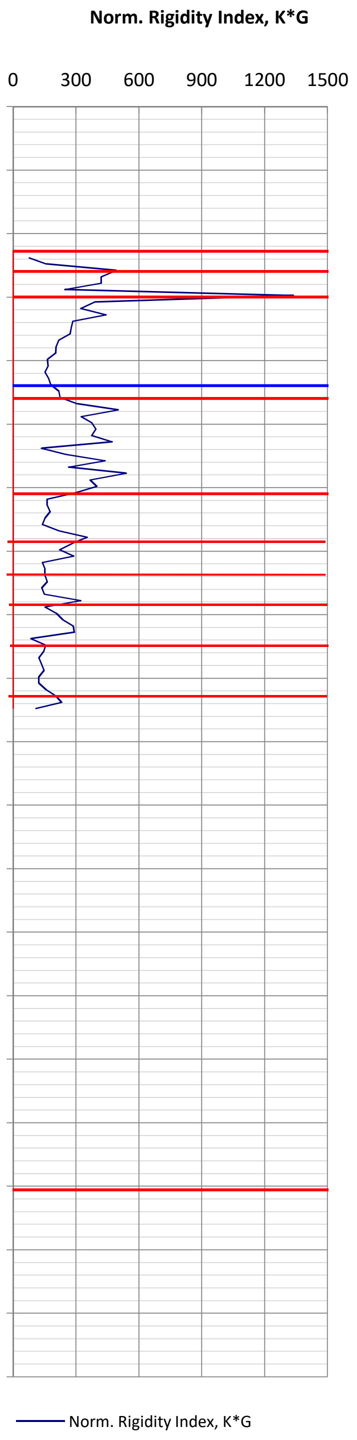
TITLE
CONE PENETRATION TEST CPTU-16-03N-R1

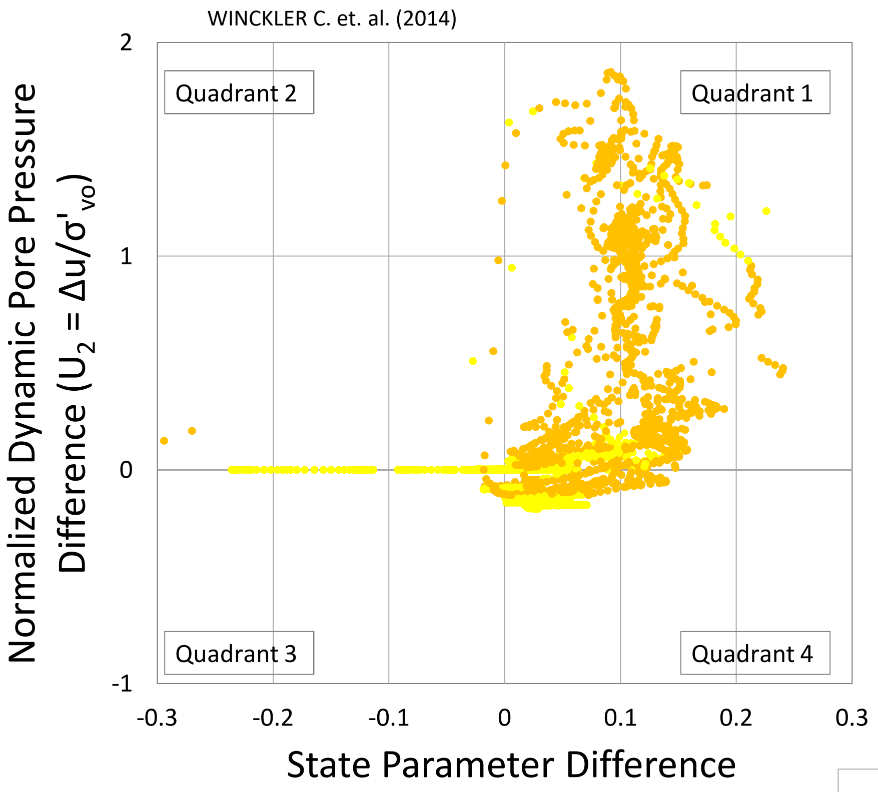
N:7775111.7 E:591977.7 12-Apr-2016

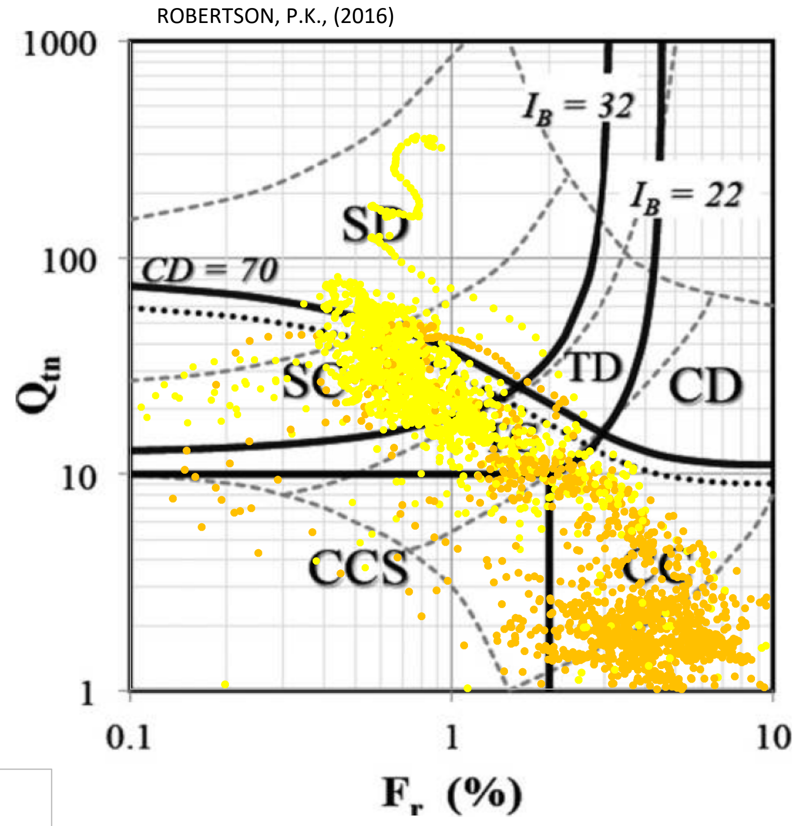
PROJECT NO.
A03355A01

FIGURE NO.
10



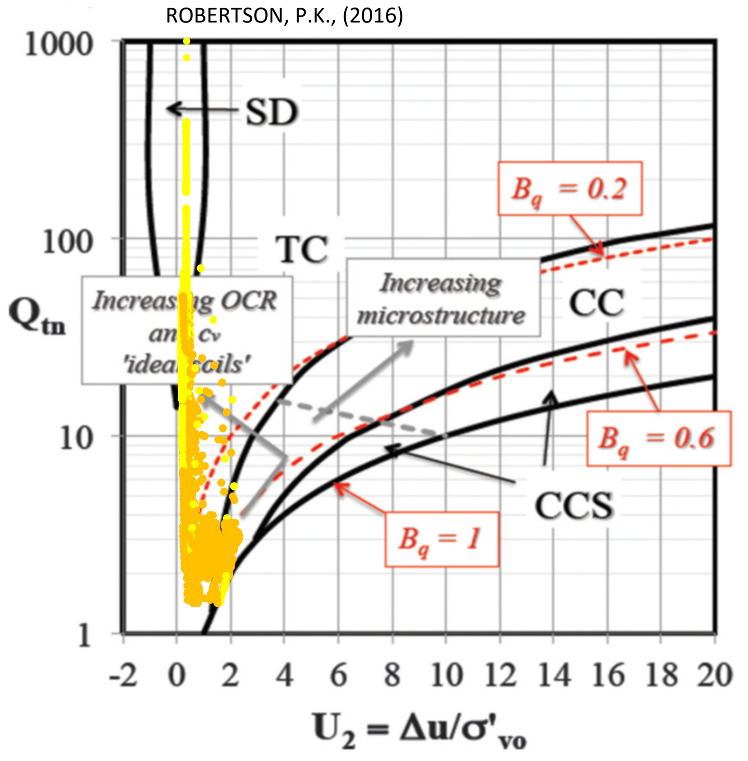


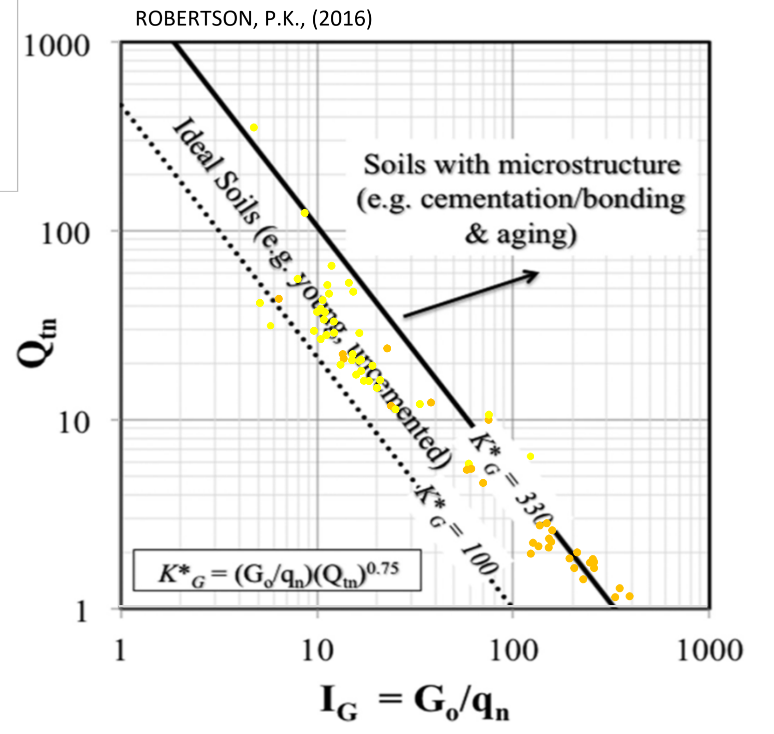




● Fine Tailings

● Coarse Tailings





Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available).
3. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
4. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.

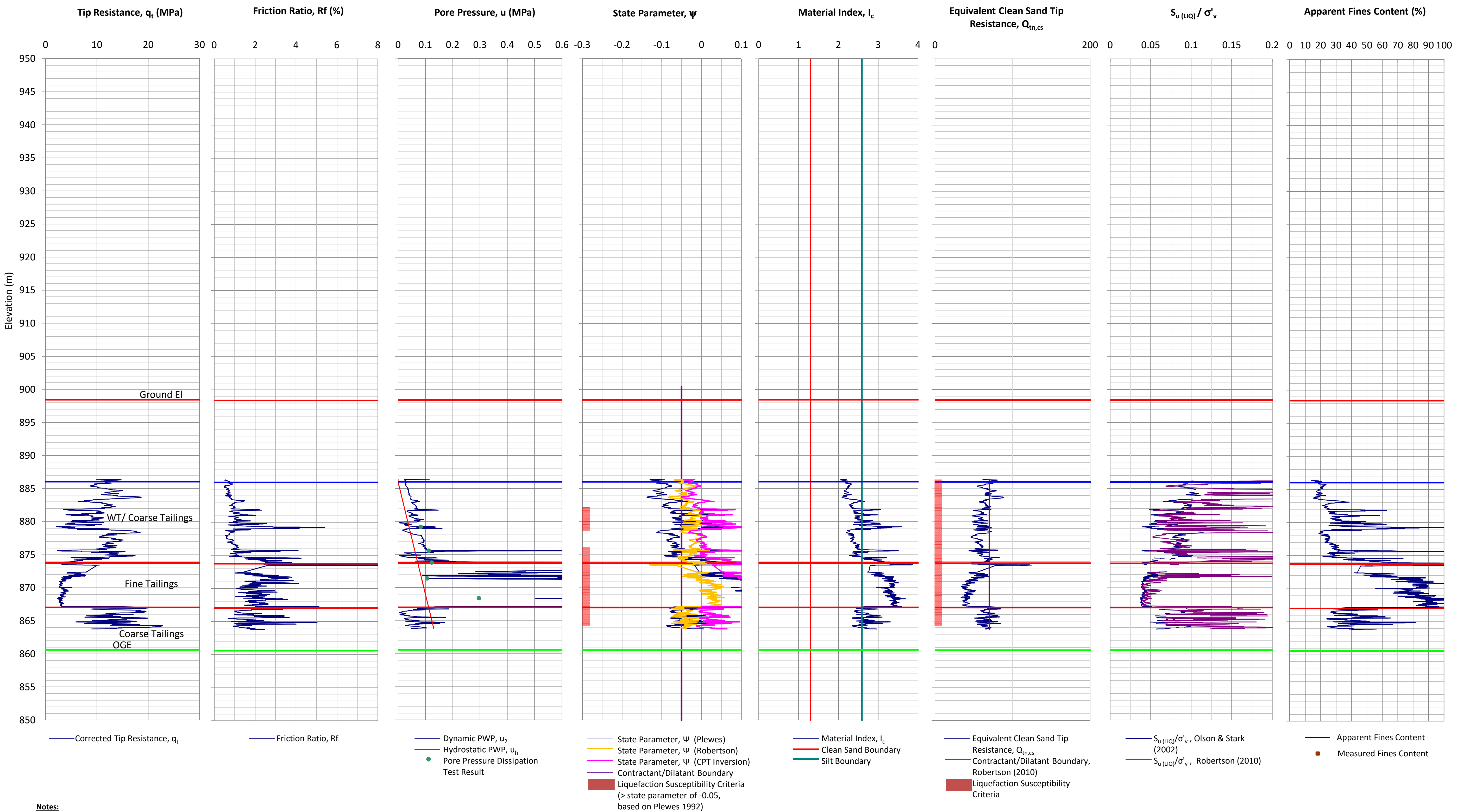
CLIENT

PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
V_s/CPT Additional Plots for CPTU-16-03N-R1
N:7775111.7 E:591977.7 12-Apr-2016

PROJECT NO.
A03355A01

FIGURE NO.
11



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as $Rf=f_s/q_t$.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) calculated using Plewes, et al. (1992) and the CPT inversion method is based on an assumed K0 of 0.5.

CLIENT

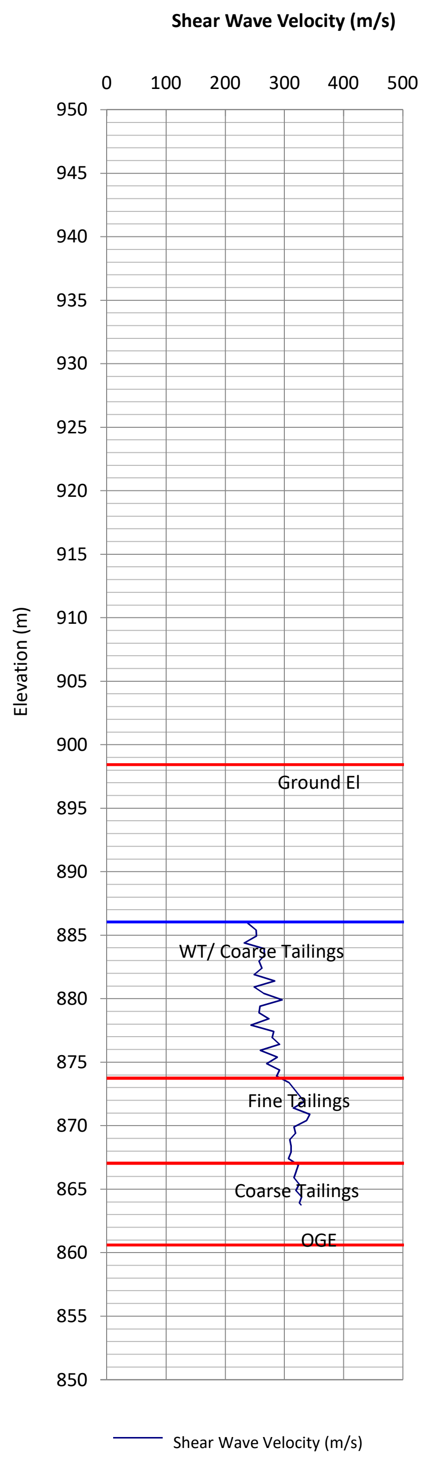
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

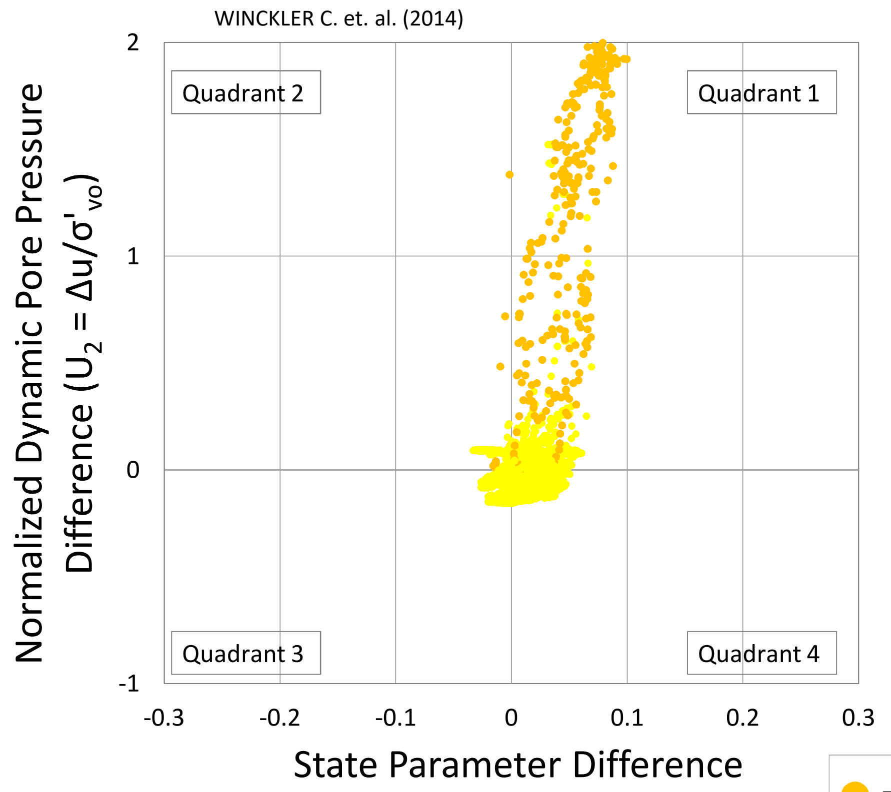
TITLE
CONE PENETRATION TEST CPTU-16-04N_R1

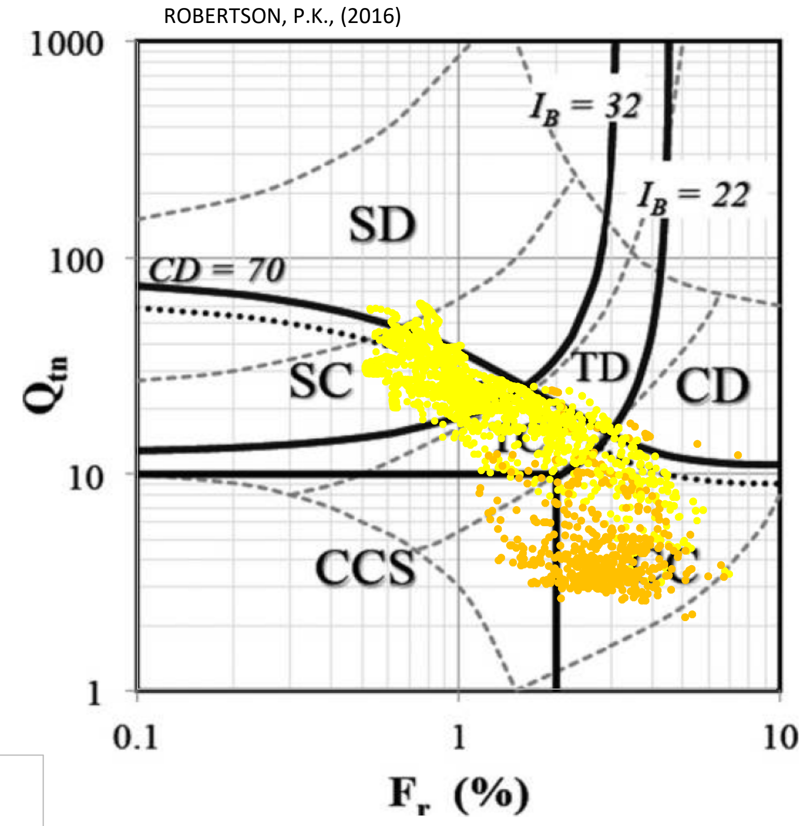
N:7775007.7 E:591838.6 31-Mar-2016

PROJECT NO.
A03355A01

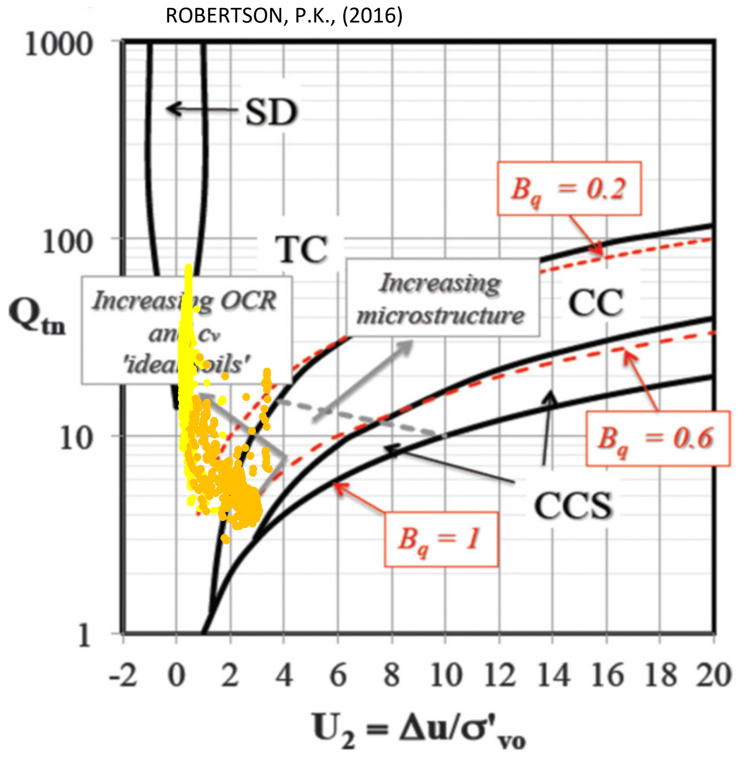
FIGURE NO.
12

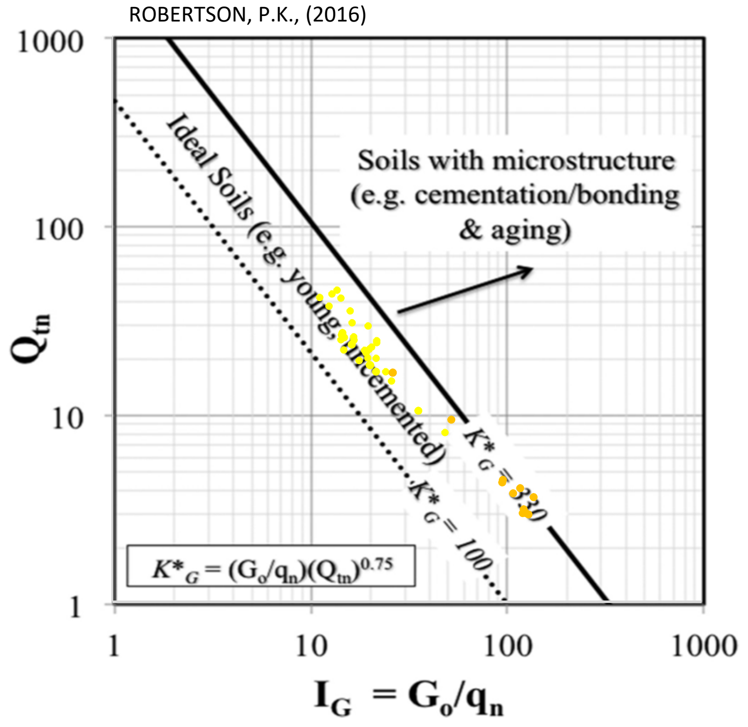






- Fine Tailings
- Coarse Tailings





Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available).
3. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
4. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.

CLIENT

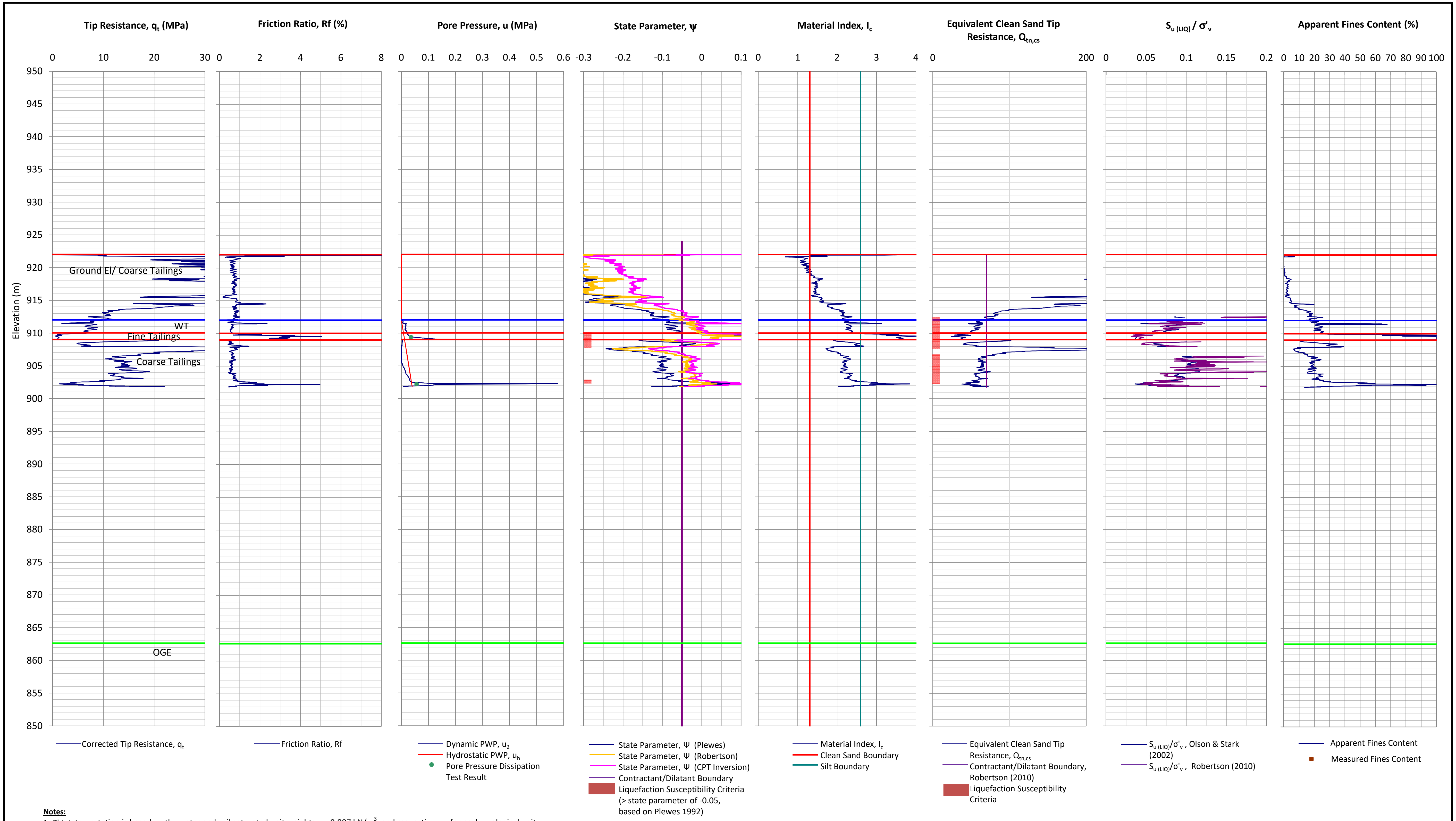
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
V_s/CPT Additional Plots for CPTU-16-04N_R1

N:7775007.7 E:591838.6 31-Mar-2016

PROJECT NO.
A03355A01

FIGURE NO.
13



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as Rf=f_s/q_t.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) calculated using Plewes, et al. (1992) and the CPT inversion method is based on an assumed K0 of 0.5.

CLIENT

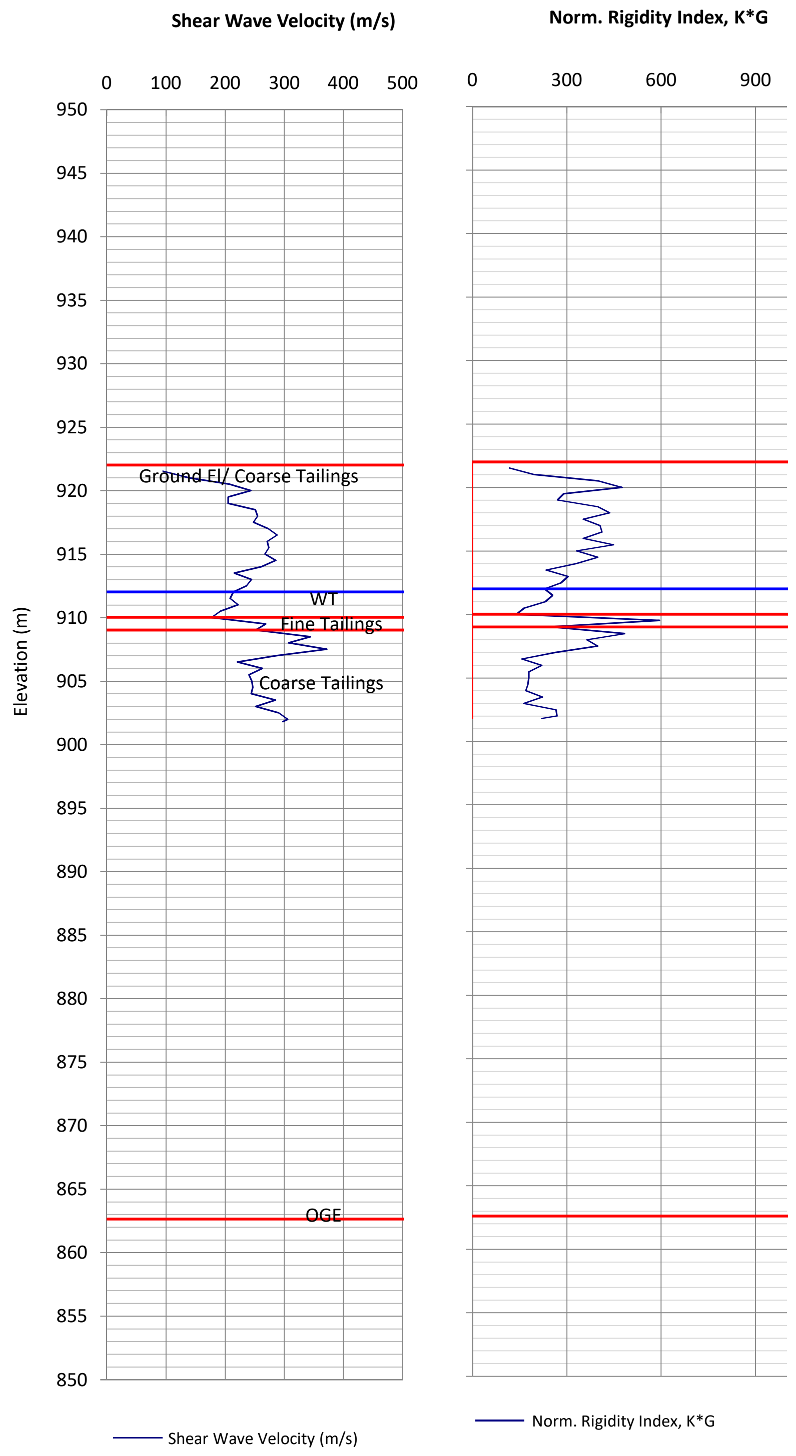
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

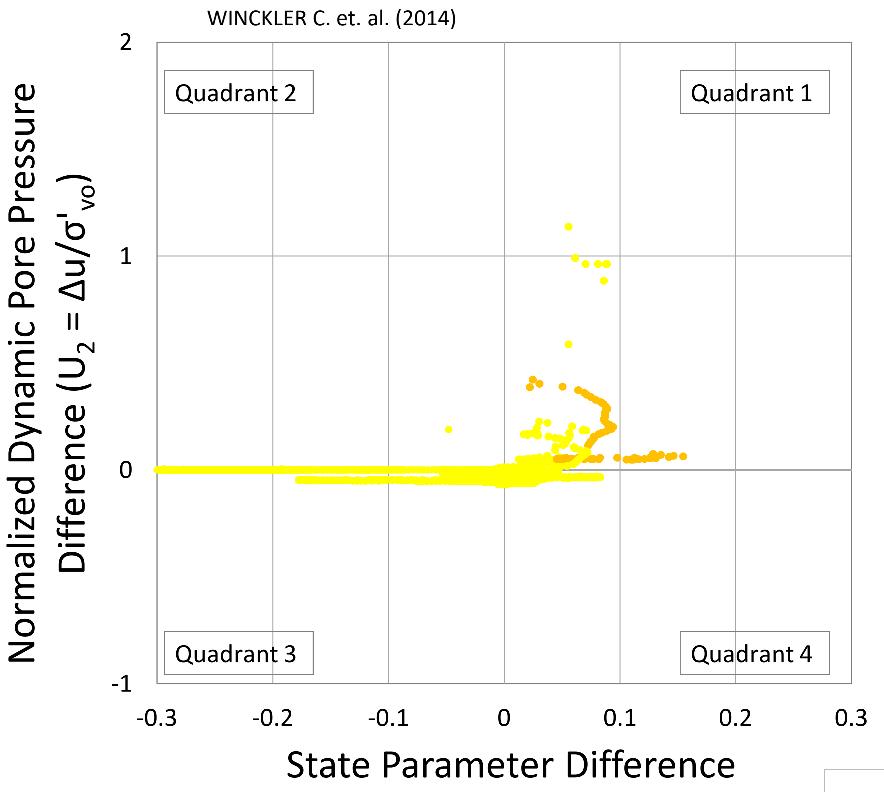
TITLE
CONE PENETRATION TEST CPTU-16-05N_R1

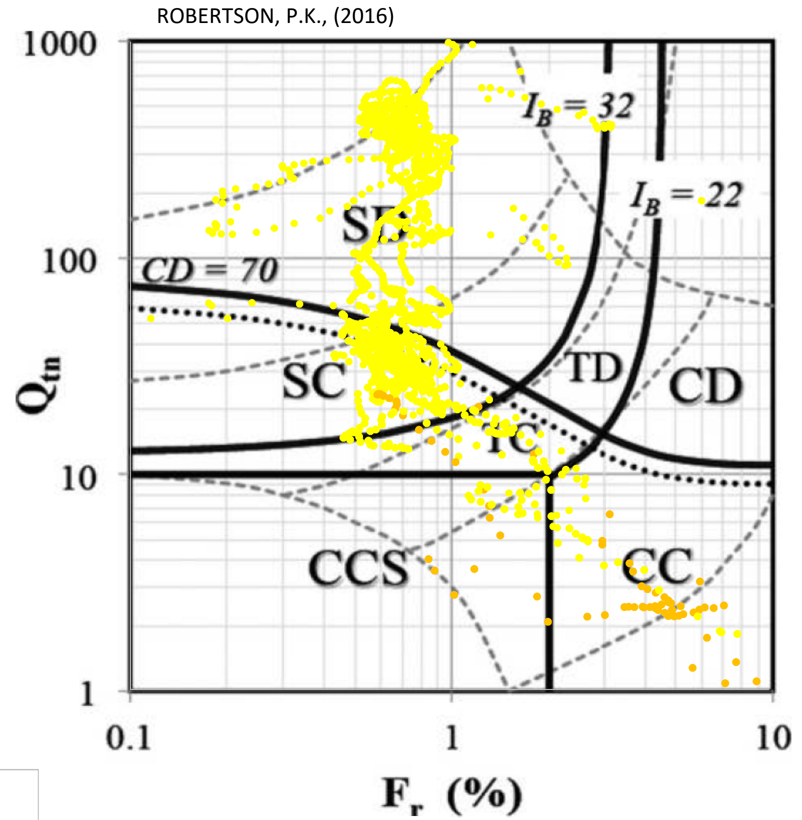
N:7775049.5 E:591901.1 8th April 2016

PROJECT NO.
A03355A01

FIGURE NO.
14

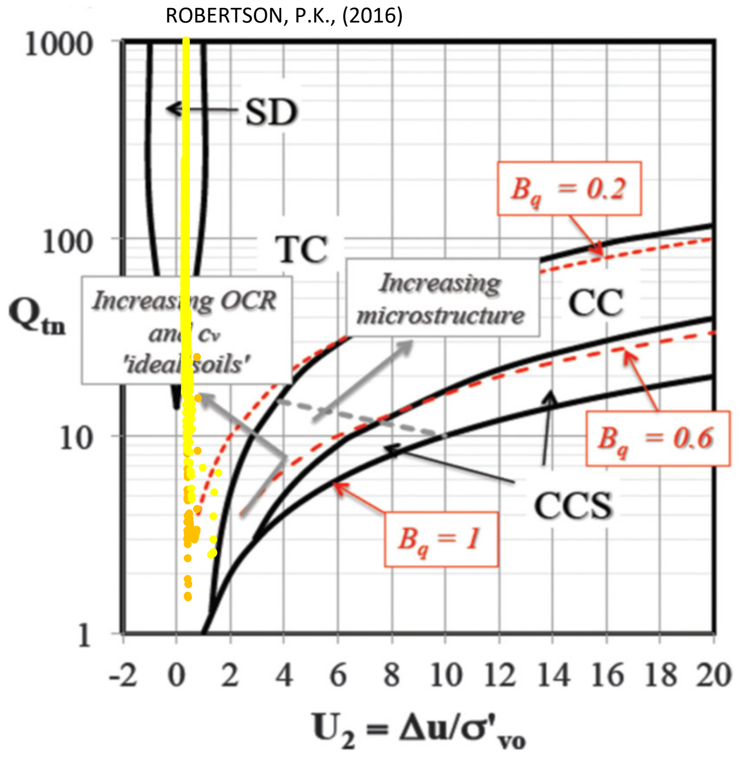


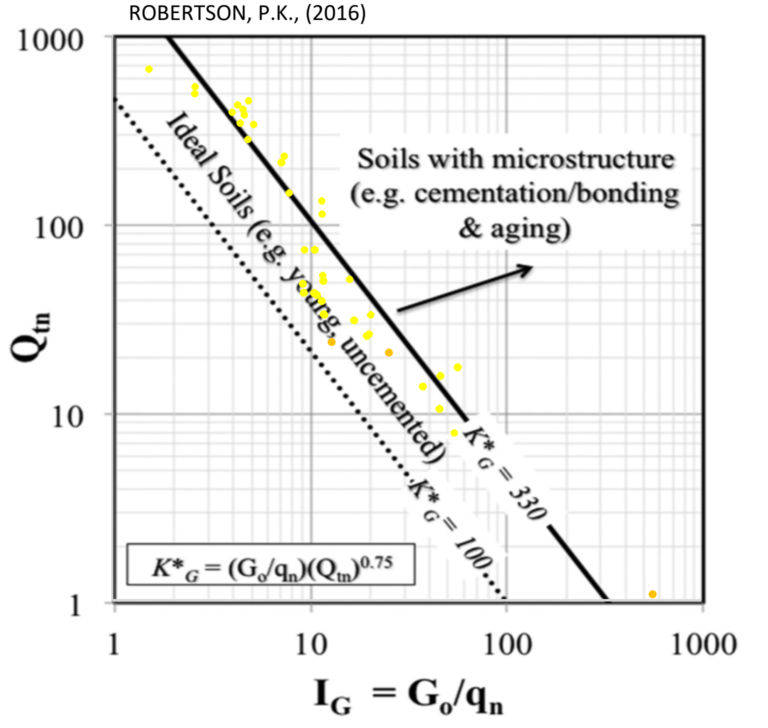




● Fine Tailings

● Coarse Tailings





Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available).
3. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
4. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.

CLIENT

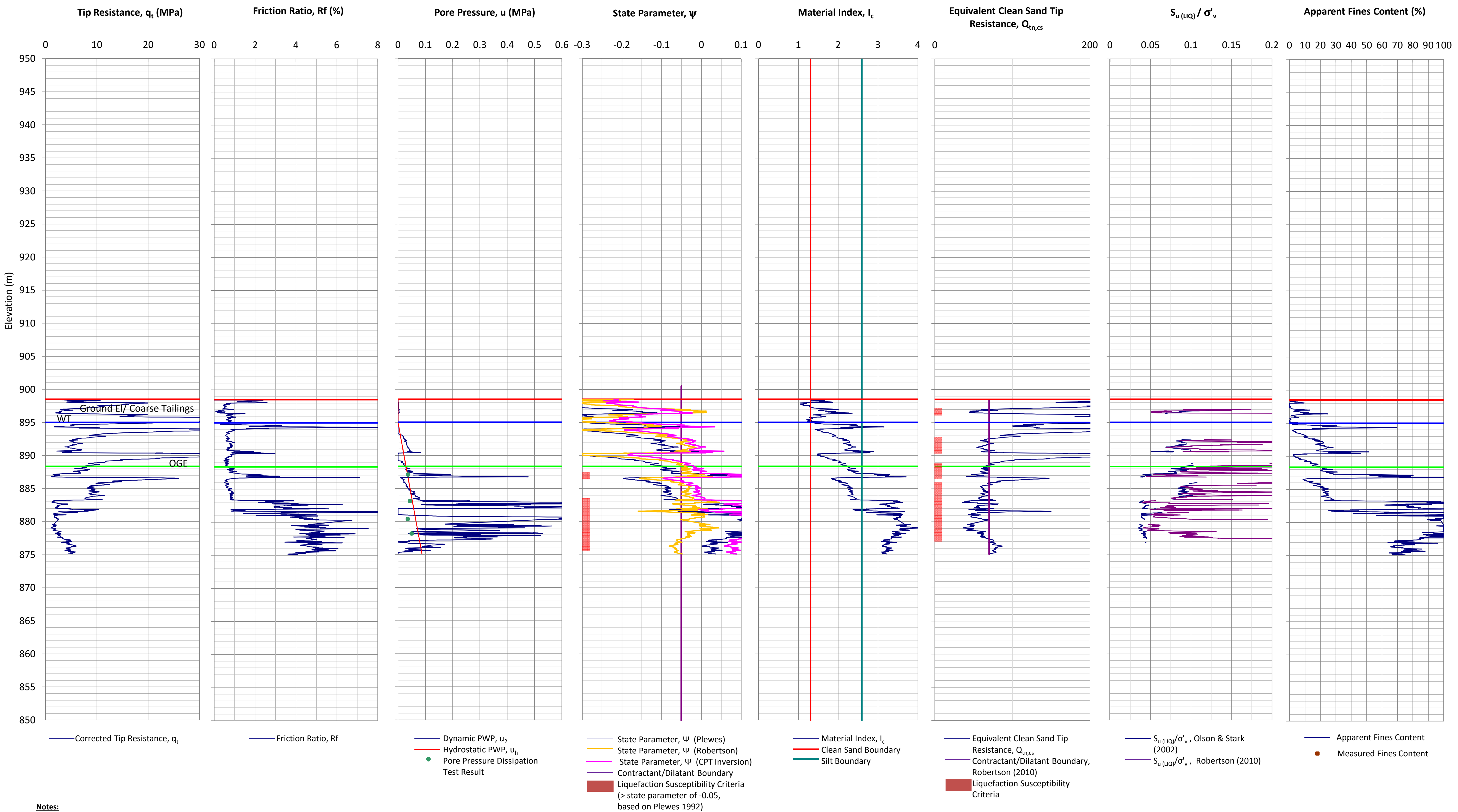
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
V_s/CPT Additional Plots for CPTU-16-05N_R1

N:7775049.5 E:591901.1 8th April 2016

PROJECT NO.
A03355A01

FIGURE NO.
15



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as Rf=f_s/q_t.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) calculated using Plewes, et al. (1992) and the CPT inversion method is based on an assumed K0 of 0.5.

CLIENT

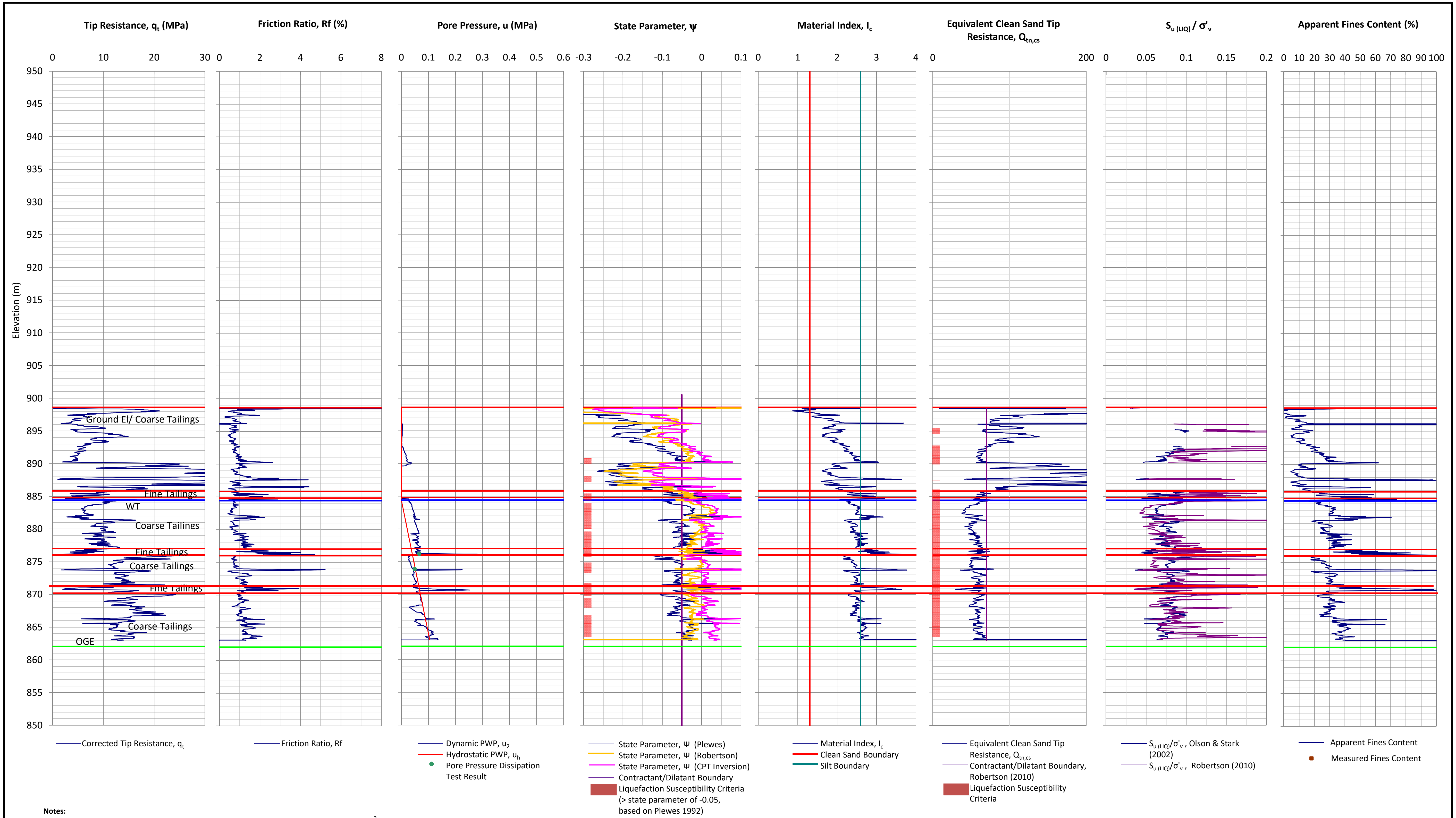
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
CONE PENETRATION TEST CPTU-16-06N_R1

N:7774824.3 E:591940.8 30th March 2016

PROJECT NO.
A03355A01

FIGURE NO.
16



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as $Rf=f_s/q_t$.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) calculated using Plewes, et al. (1992) and the CPT inversion method is based on an assumed K0 of 0.5.

CLIENT

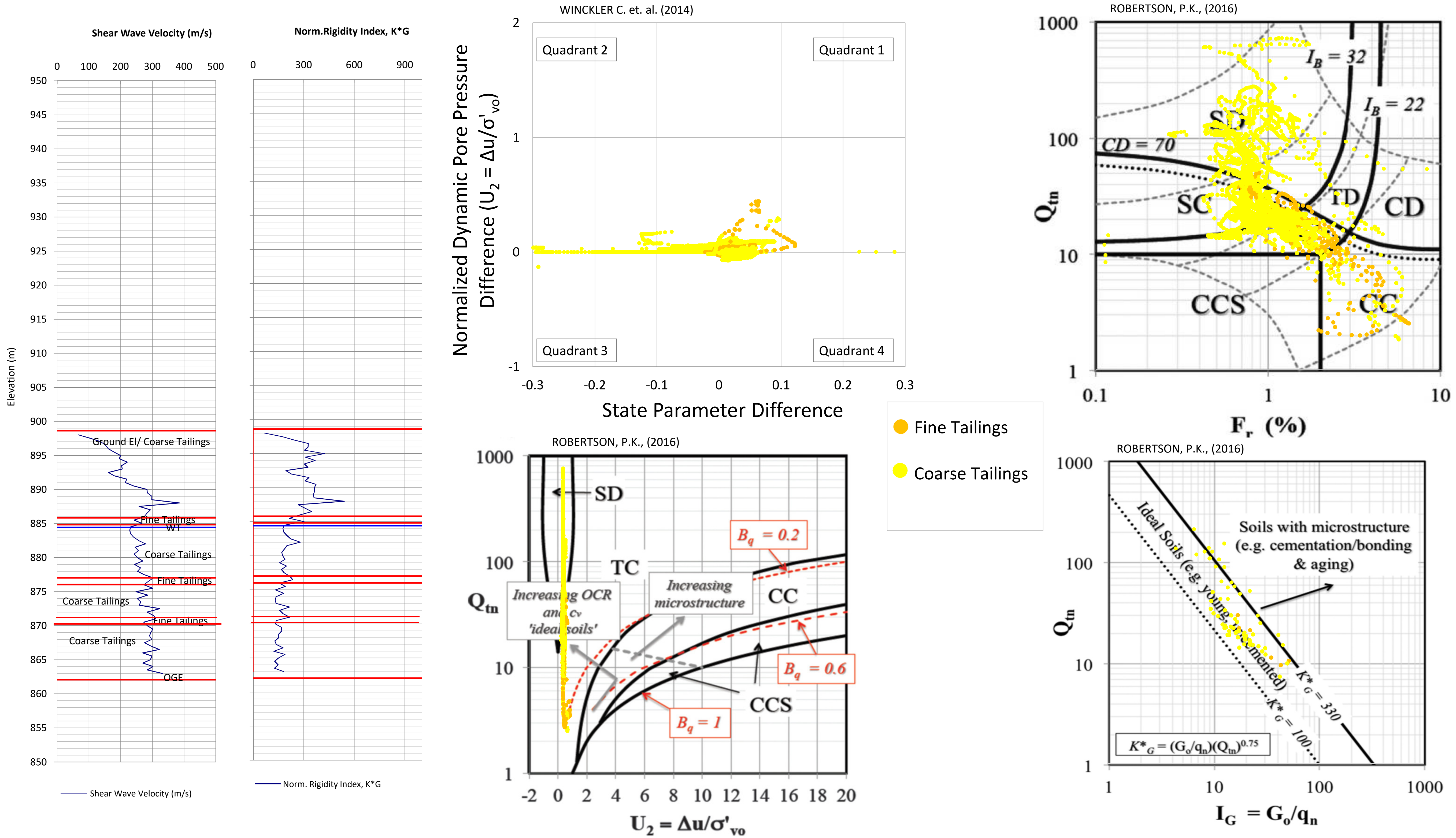
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
CONE PENETRATION TEST CPTU-16-07N_R1

N:7774990.5 E:591801.7 30-Mar-2016

PROJECT NO.
A03355A01

FIGURE NO.
17



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available).
3. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
4. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.

CLIENT

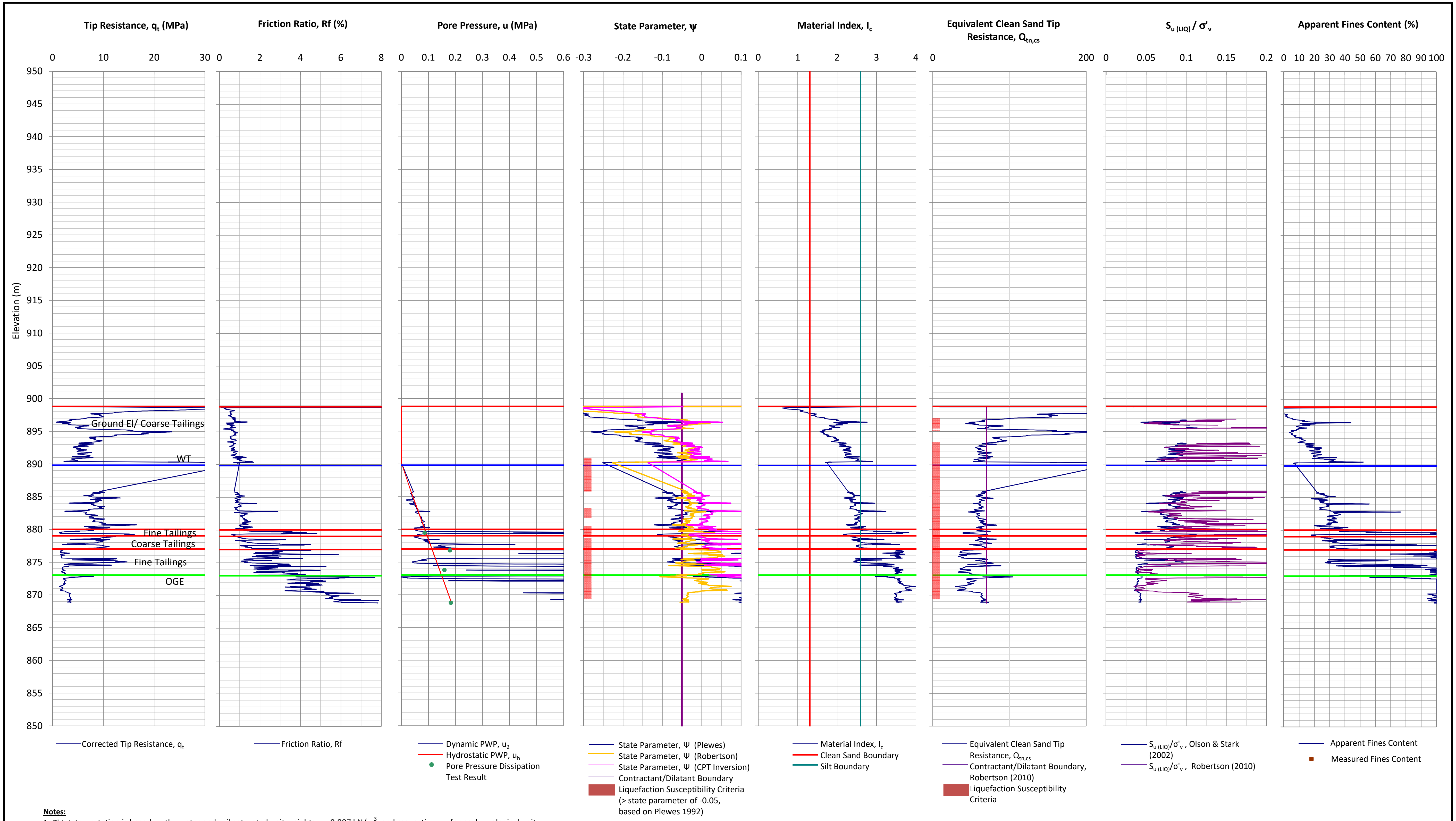
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
V_s/CPT Additional Plots for CPTU-16-07N_R1

N:7774990.5 E:591801.7 30-Mar-2016

PROJECT NO.
A03355A01

FIGURE NO.
18



Notes:
1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as Rf=f_s/q_t.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) calculated using Plewes, et al. (1992) and the CPT inversion method is based on an assumed K0 of 0.5.

CLIENT

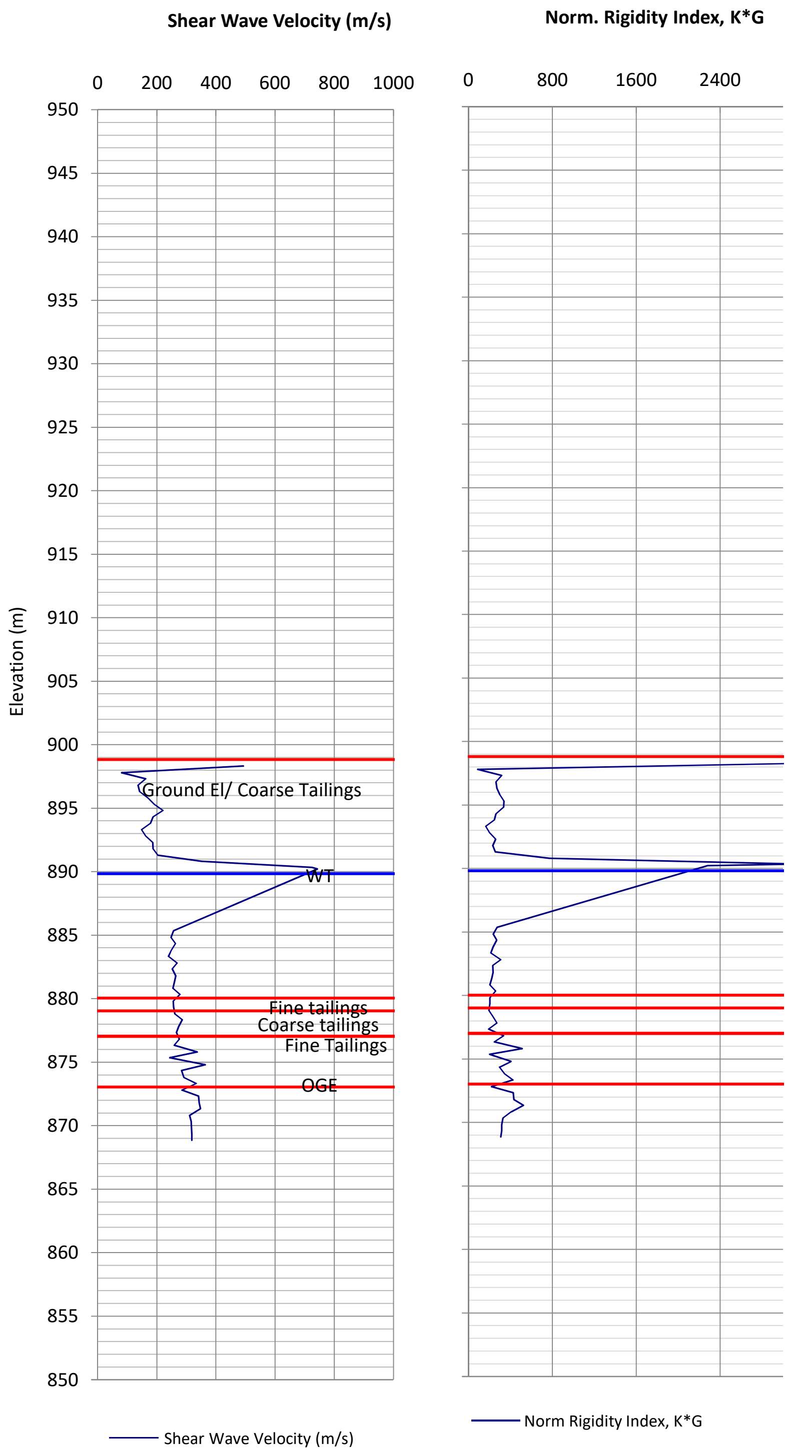
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

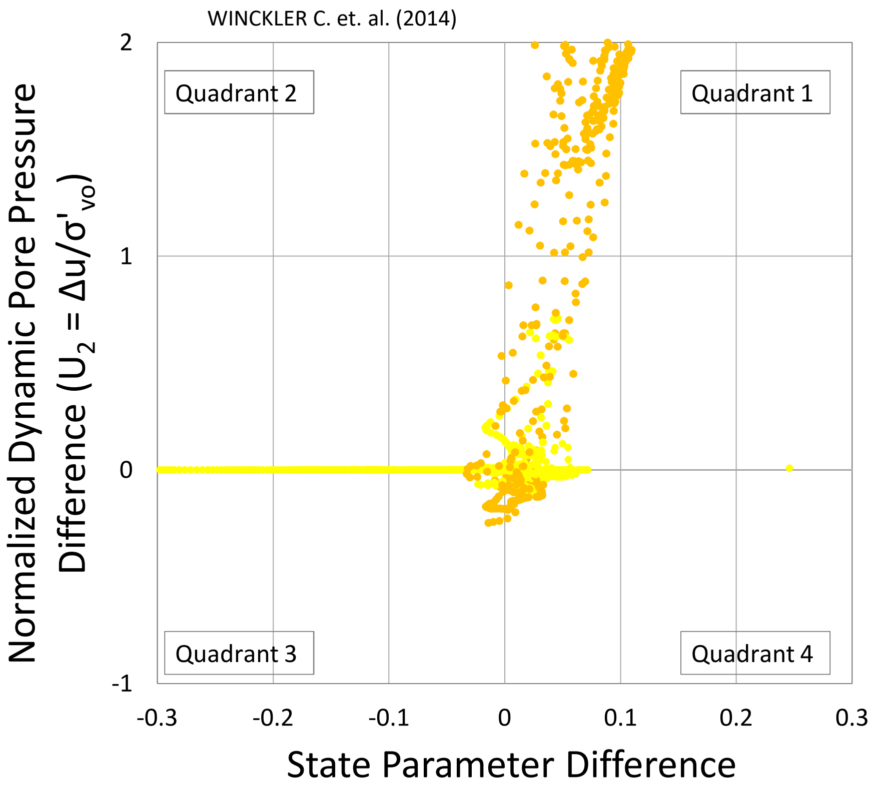
TITLE
CONE PENETRATION TEST CPTU-16-08N_R1

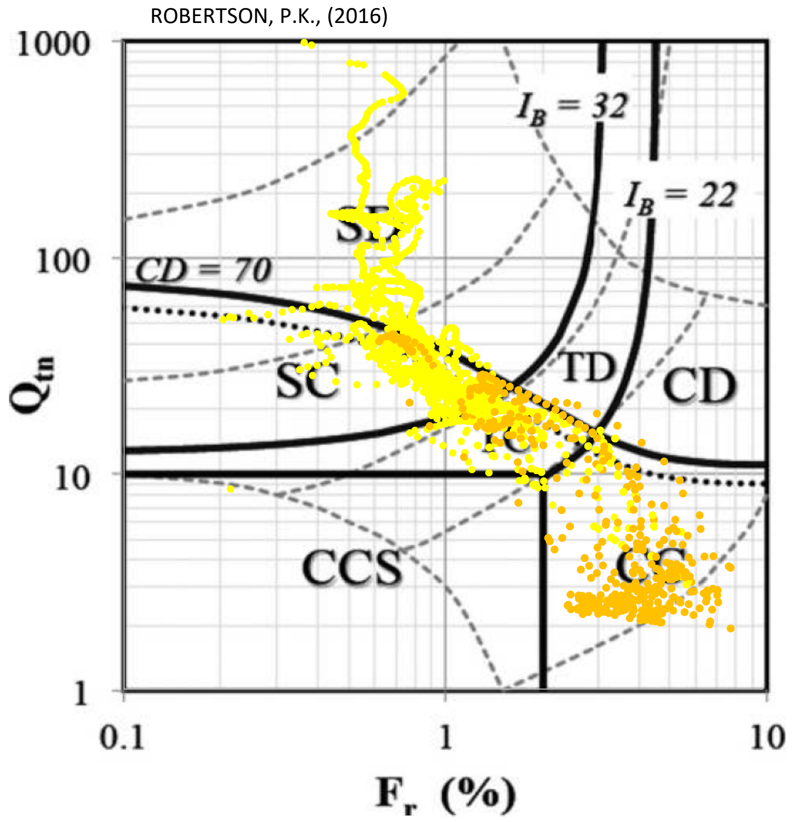
N:7775069.1 E:591776.8 4th April 2016

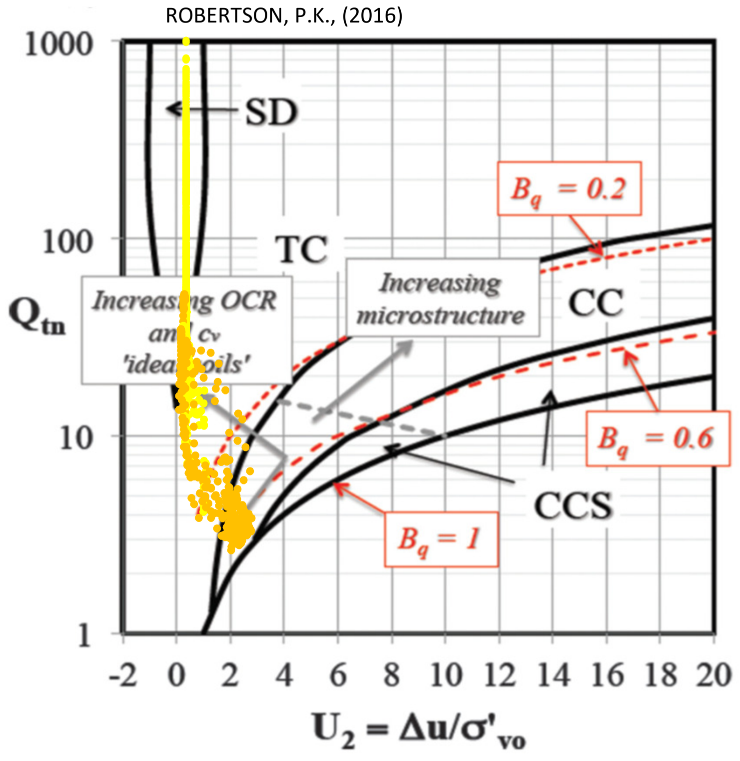
PROJECT NO.
A03355A01

FIGURE NO.
19



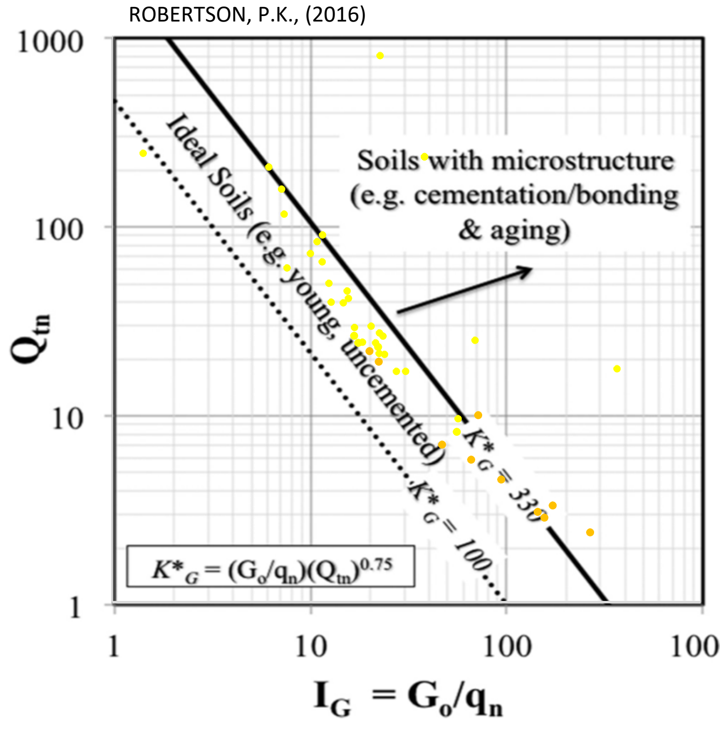

WINCKLER C. et. al. (2014)


ROBERTSON, P.K., (2016)


ROBERTSON, P.K., (2016)

● Fine Tailings

● Coarse Tailings


ROBERTSON, P.K., (2016)

Notes:
1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available).
3. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
4. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.

CLIENT

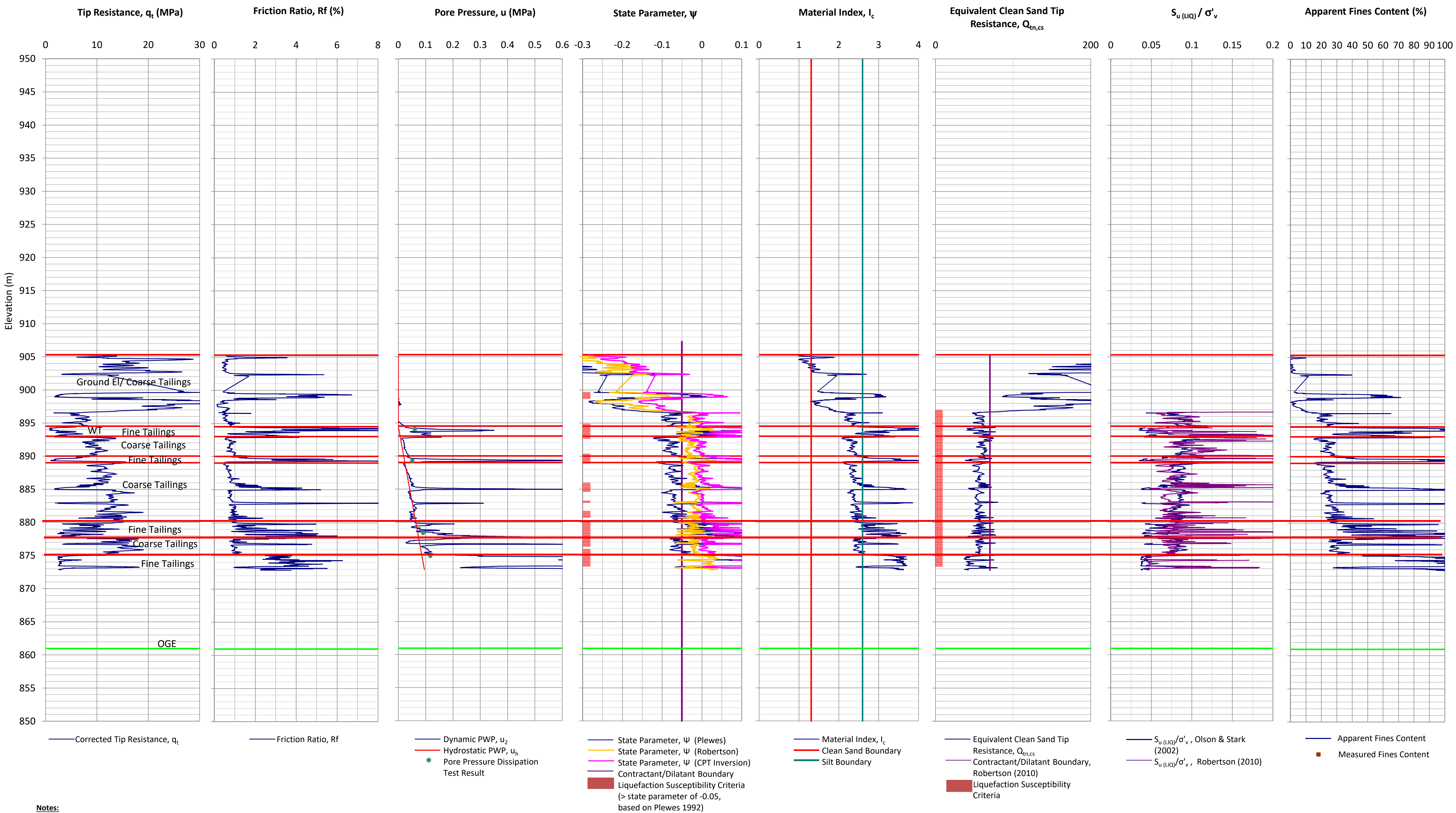
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
V_s/CPT Additional Plots for CPTU-16-08N_R1

N:7775069.1 E:591776.8 4th April 2016

PROJECT NO.
A03355A01

FIGURE NO.
20



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as $Rf=f_s/q_t$.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) calculated using Plewes, et al. (1992) and the CPT inversion method is based on an assumed K0 of 0.5.

CLIENT

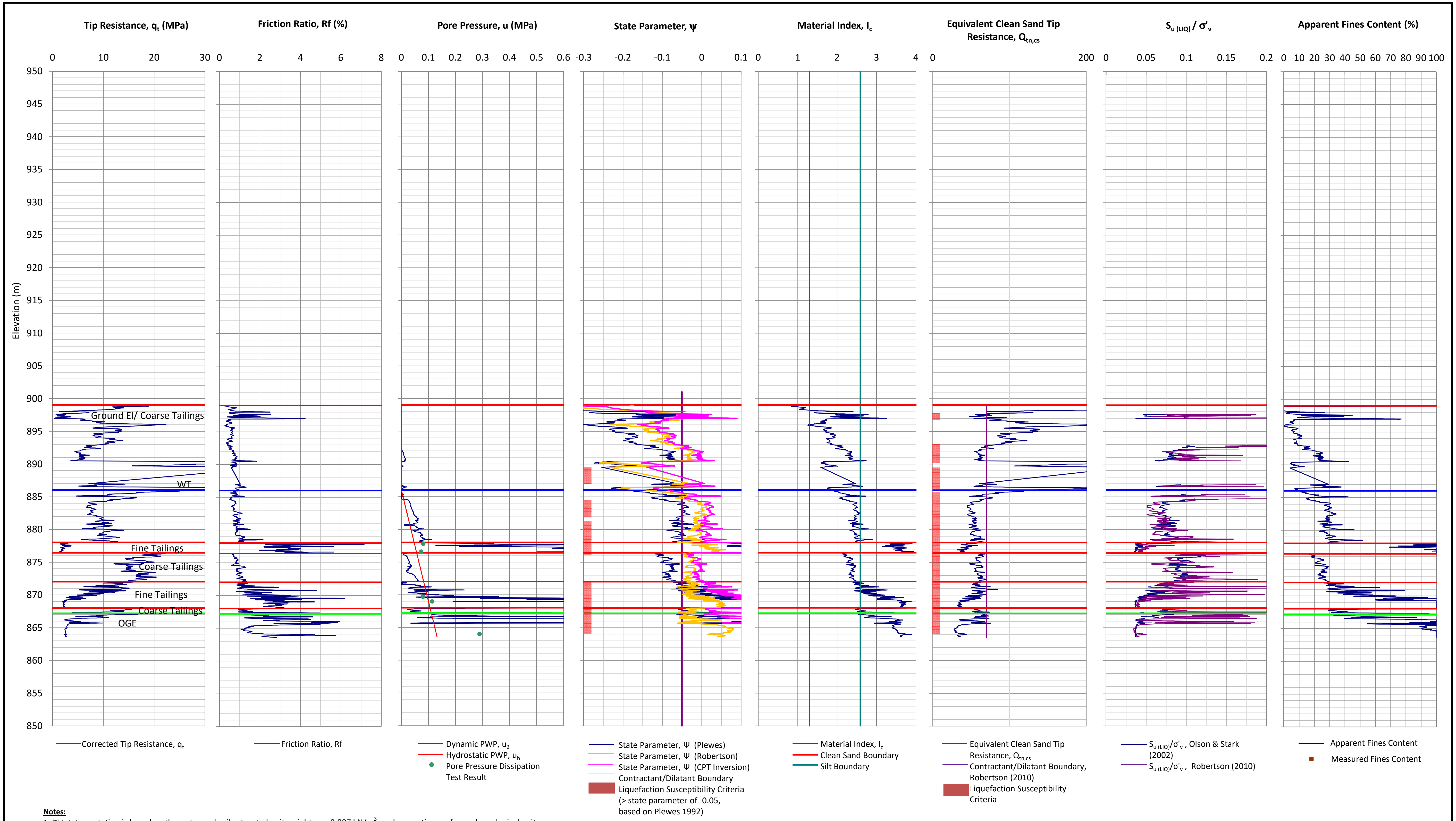
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
CONE PENETRATION TEST CPTU-16-09N_R1

N:7775029.7 E:591850 15th August 2016

PROJECT NO.
A03355A01

FIGURE NO.
21



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as Rf=f_s/q_t.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) calculated using Plewes, et al. (1992) and the CPT inversion method is based on an assumed K0 of 0.5.

CLIENT

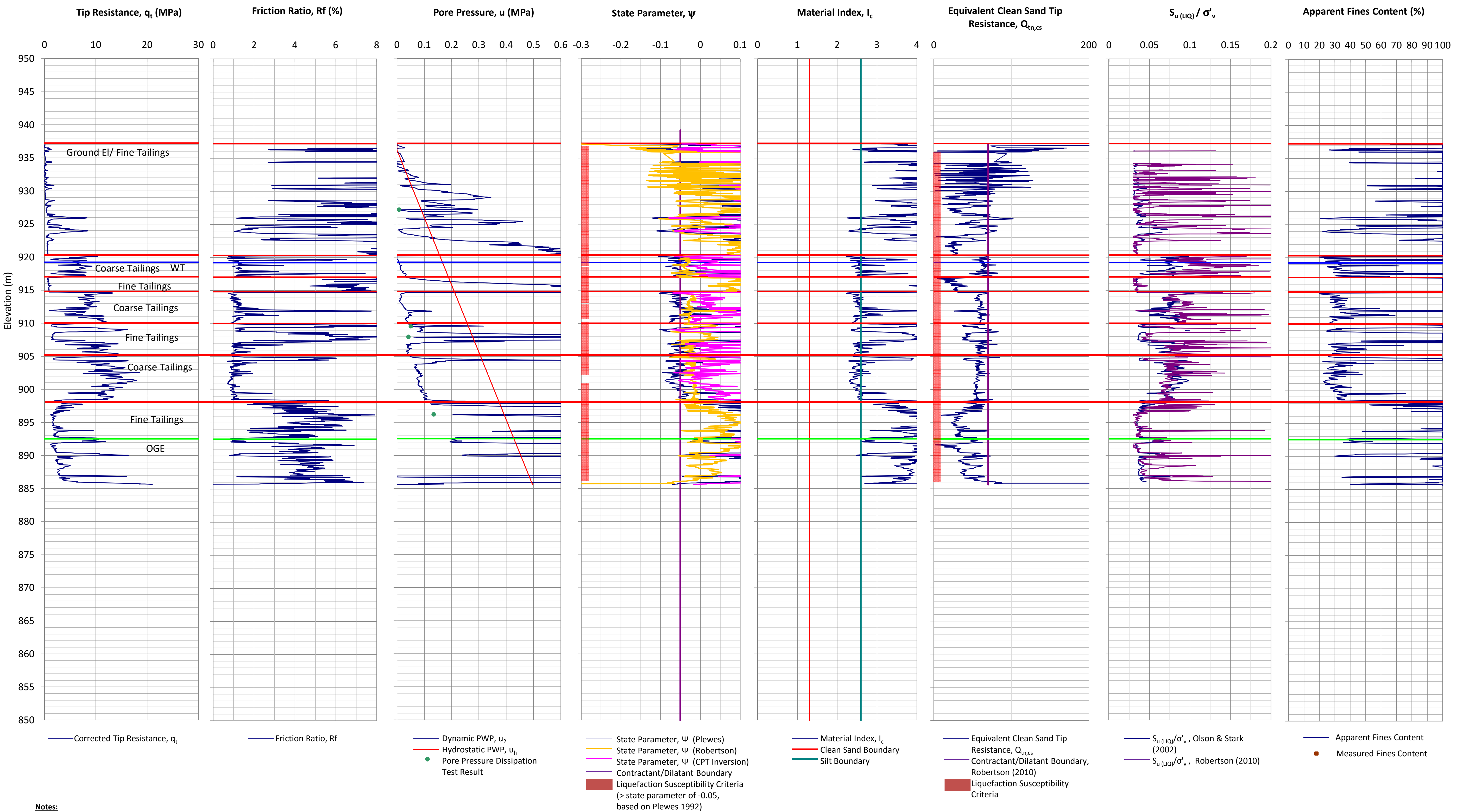
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
CONE PENETRATION TEST CPTU-16-10N_R1

N:7775014.5 E:591782 12-Aug-2016

PROJECT NO.
A03355A01

FIGURE NO.
22



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as Rf=f_s/q_t.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) calculated using Plewes, et al. (1992) and the CPT inversion method is based on an assumed K0 of 0.5.

CLIENT

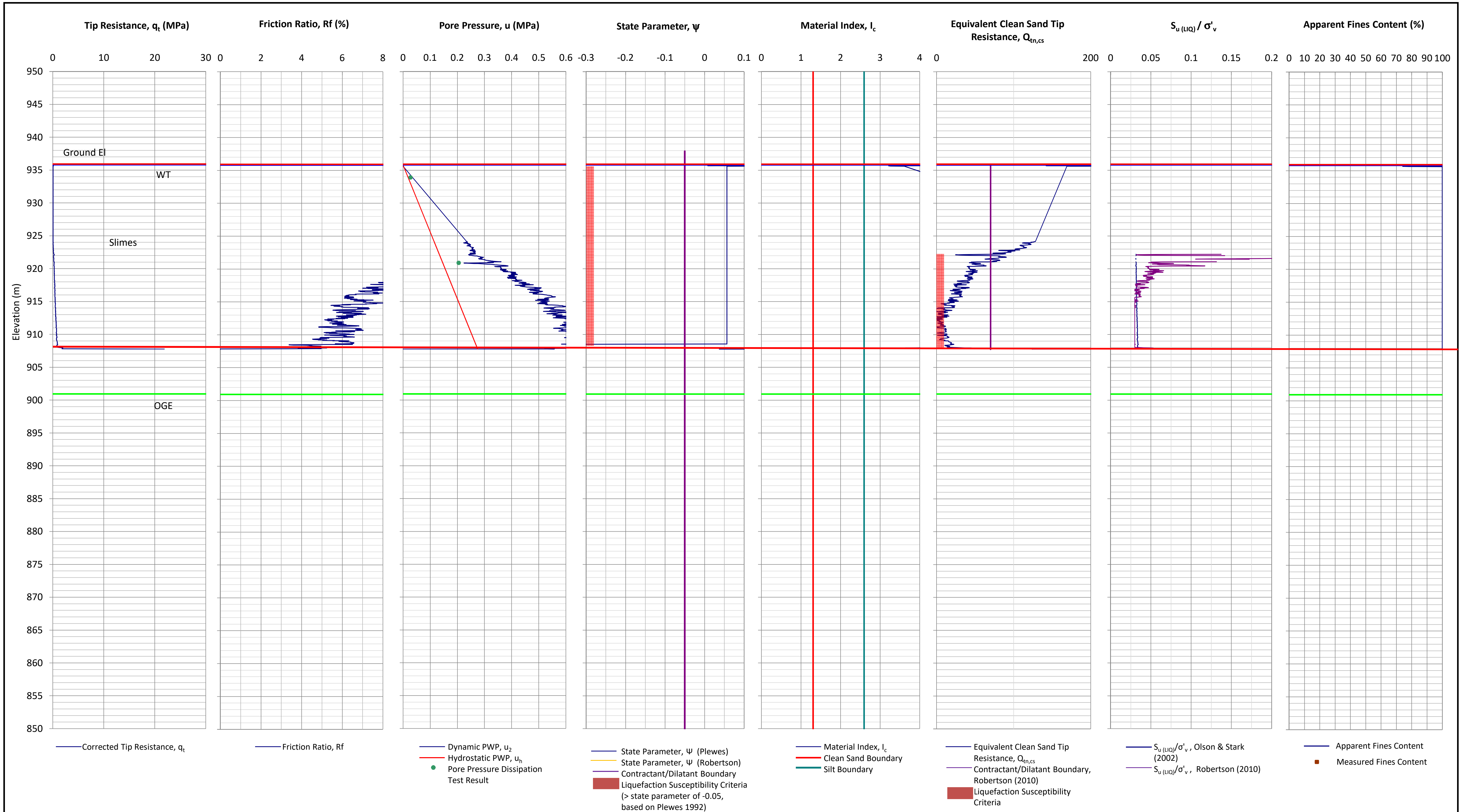
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
CONE PENETRATION TEST B1-CPTU-01_R1

N:7775132.1 E:592215.4 30-Oct-2018

PROJECT NO.
A03355A01

FIGURE NO.
23



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as Rf=f_s/q_t.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) is calculated using Plewes, et al. (1992) assuming a K0 of 0.5, and Robertson et al. (2010).

CLIENT

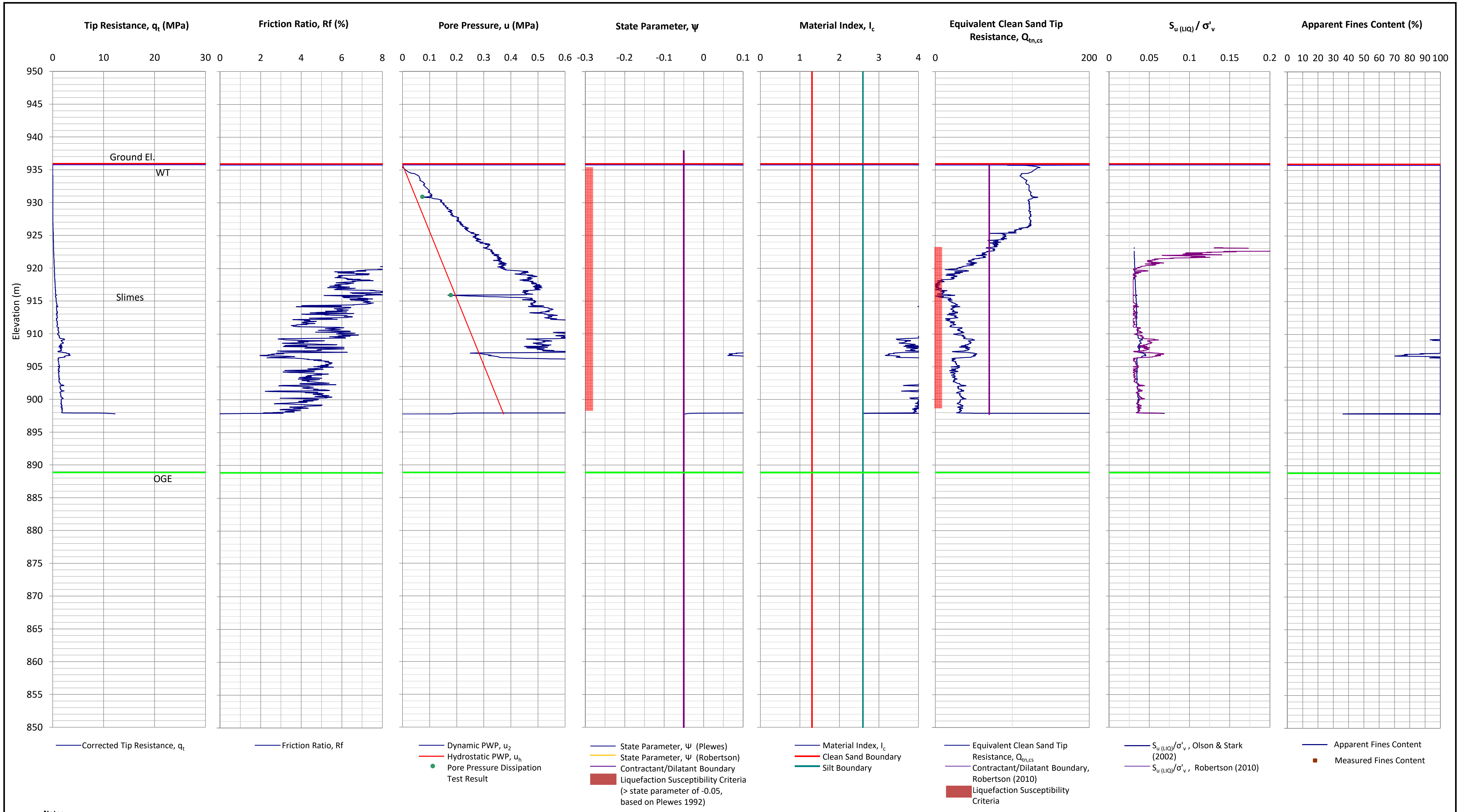
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
CONE PENETRATION TEST B1-CPTU-02M

N:7775204.4 E:592346.8 25th October 2018

PROJECT NO.
A03355A01

FIGURE NO.
24



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as Rf=f_s/q_t.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) is calculated using Plewes, et al. (1992) assuming a K0 of 0.5, and Robertson et al. (2010).

CLIENT

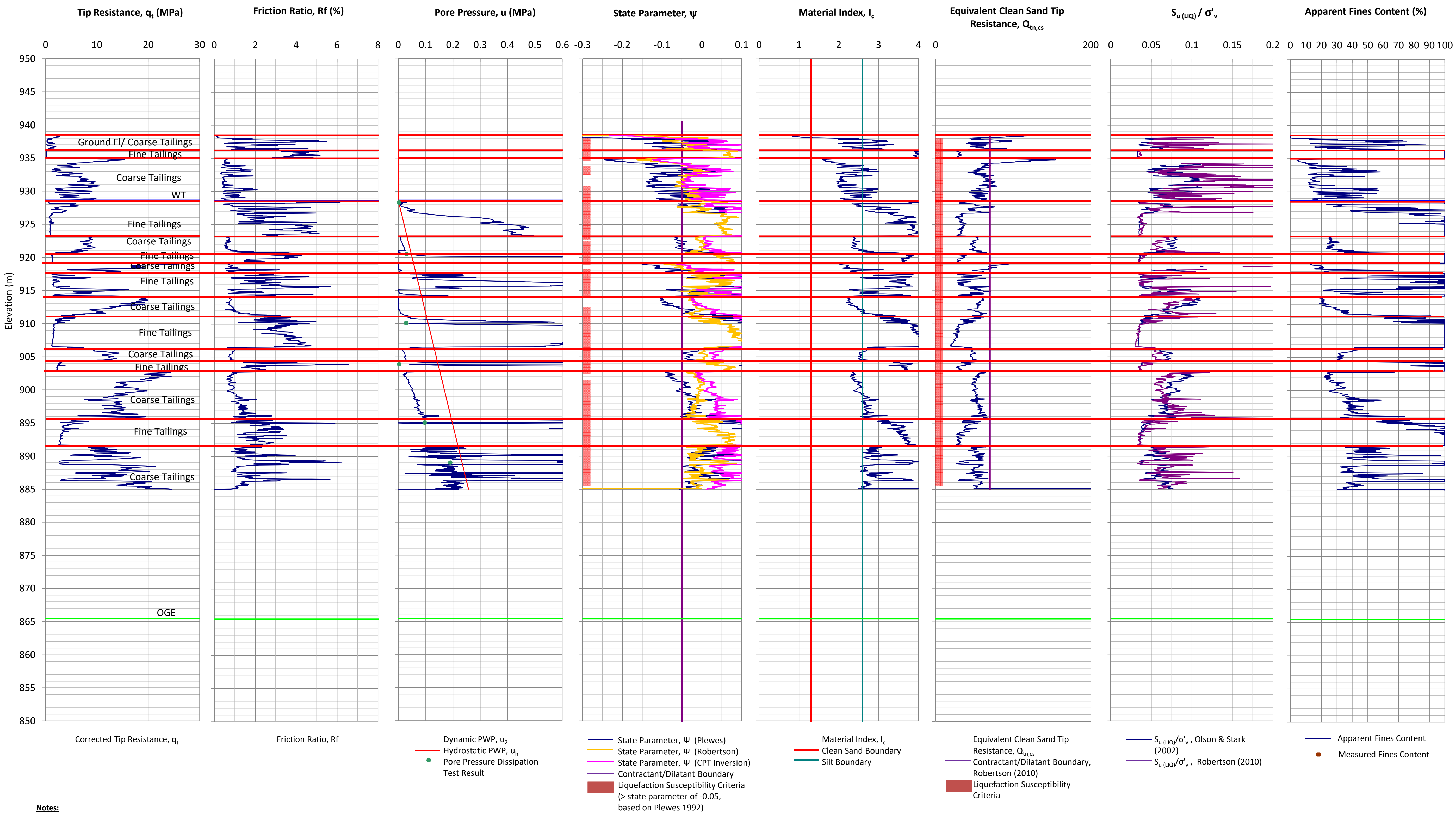
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
CONE PENETRATION TEST B1-CPTU-03_R1

N:7775253.7 E:592234.1 29-Oct-2018

PROJECT NO.
A03355A01

FIGURE NO.
25



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as Rf=f_s/q_t.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) calculated using Plewes, et al. (1992) and the CPT inversion method is based on an assumed K0 of 0.5.

CLIENT

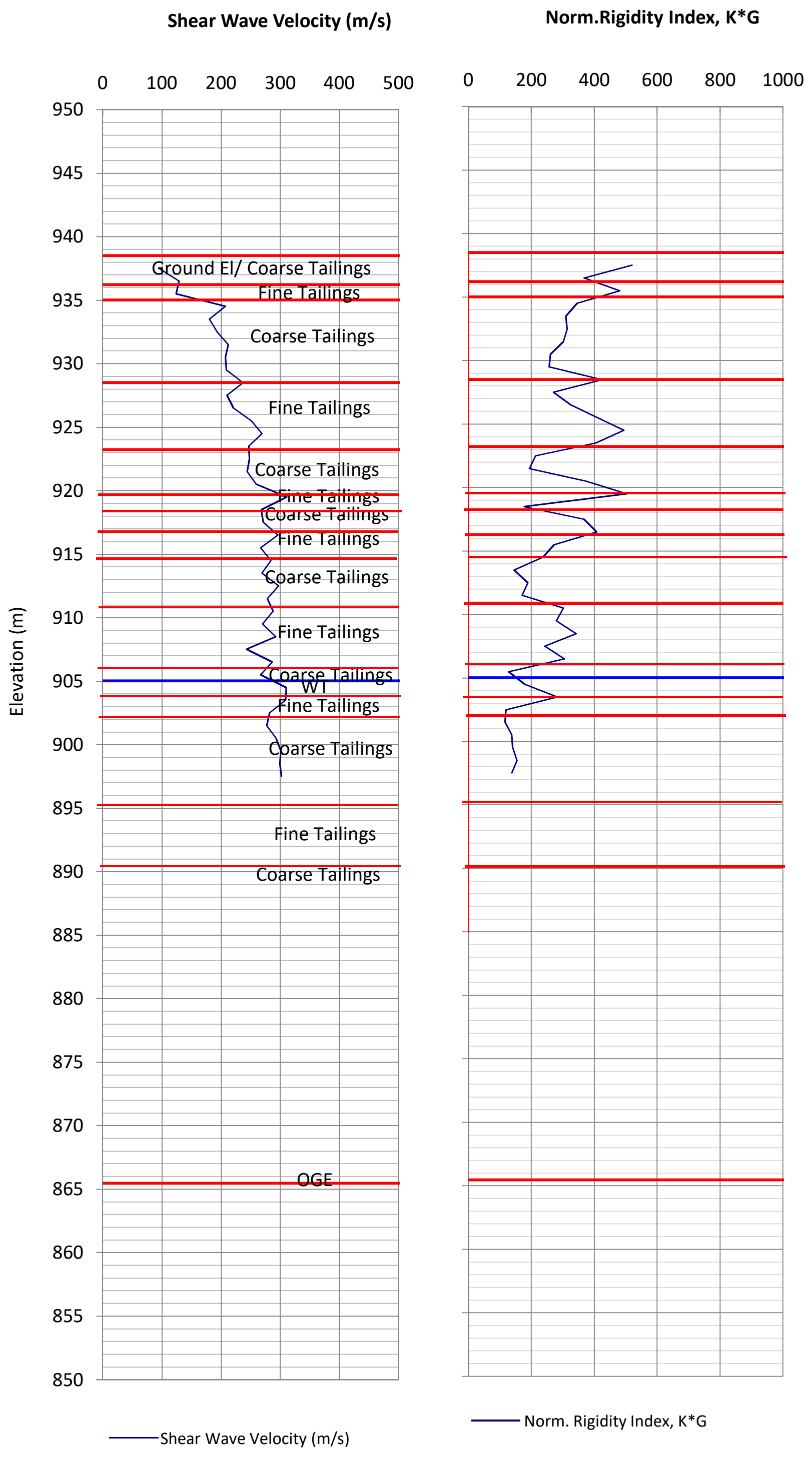
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

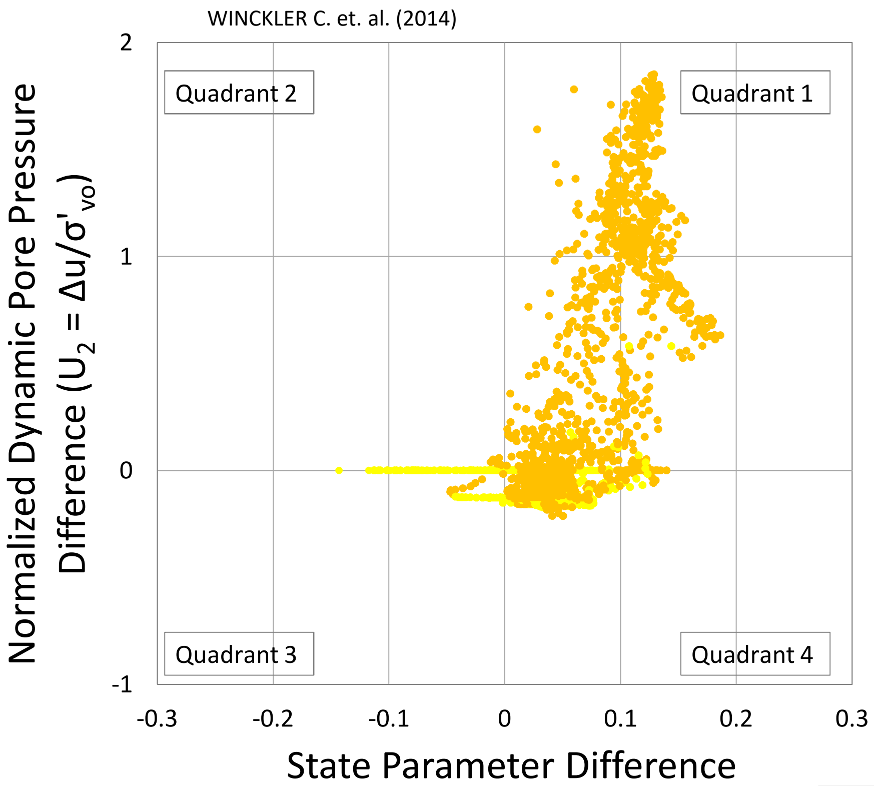
TITLE
CONE PENETRATION TEST CPTU-PZE-1-7-R1

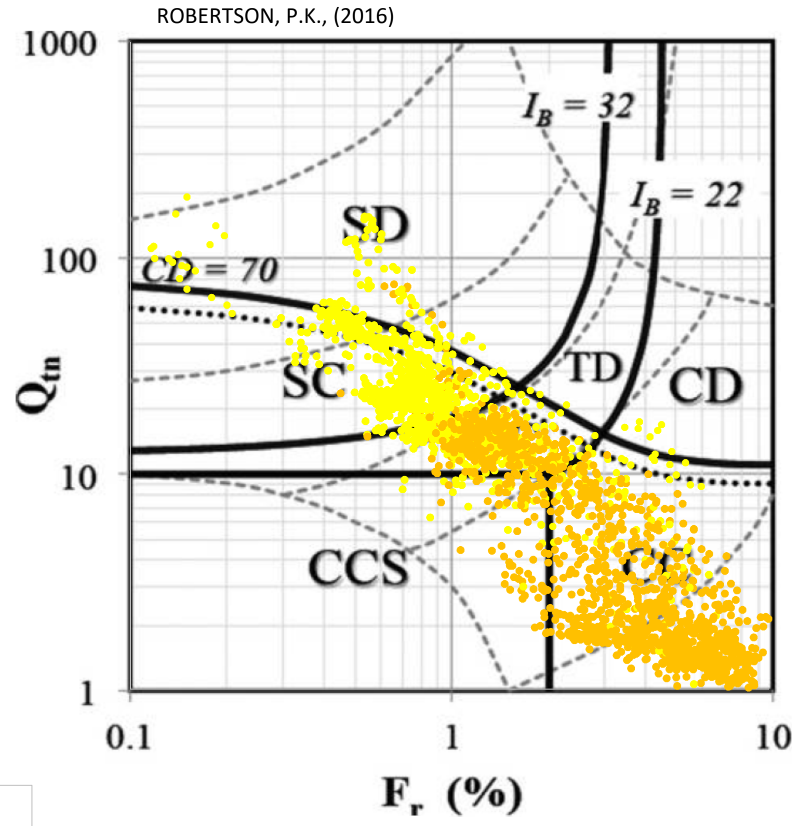
N:7775096 E:591994.9 08/10/2018

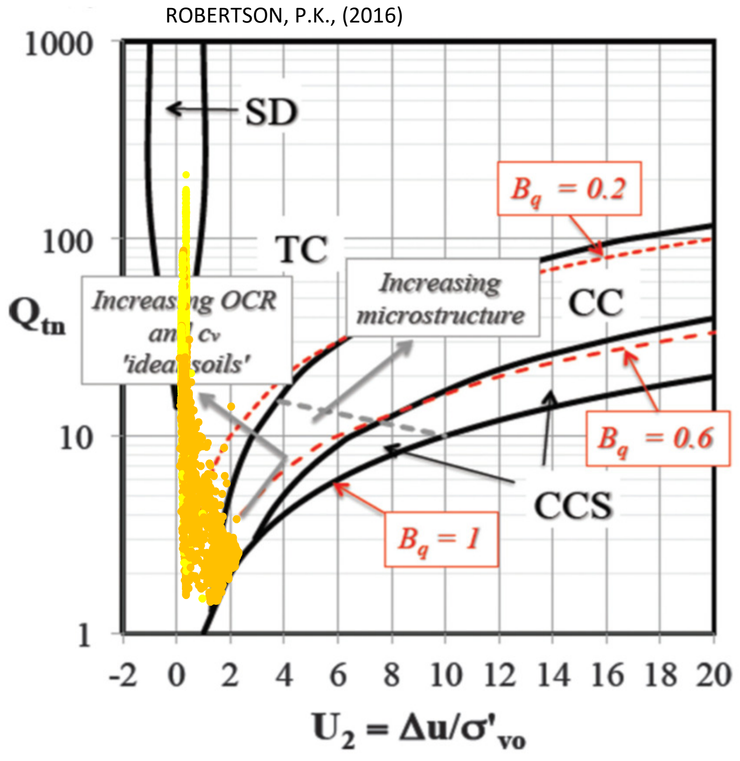
PROJECT NO.
A03355A01

FIGURE NO.
26



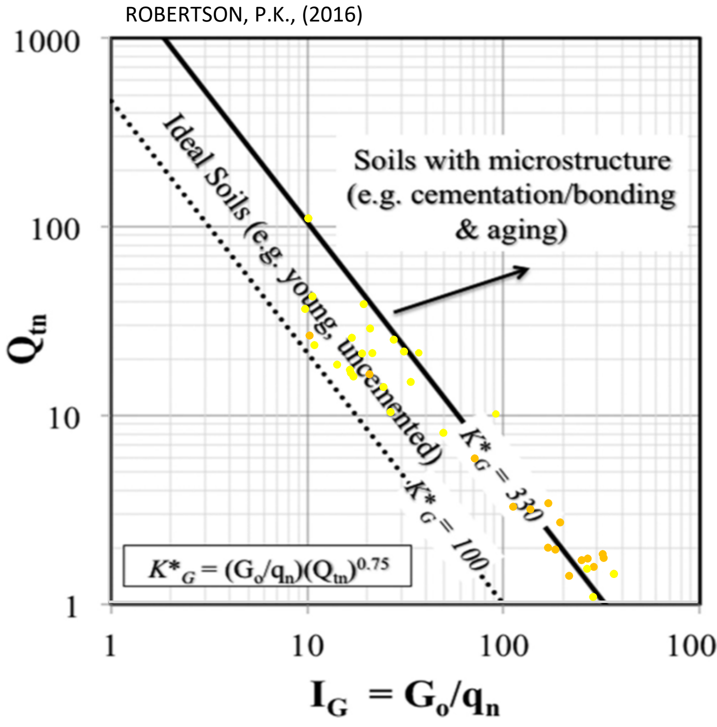






● Fine Tailings

● Coarse Tailings



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available).
3. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
4. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.

CLIENT

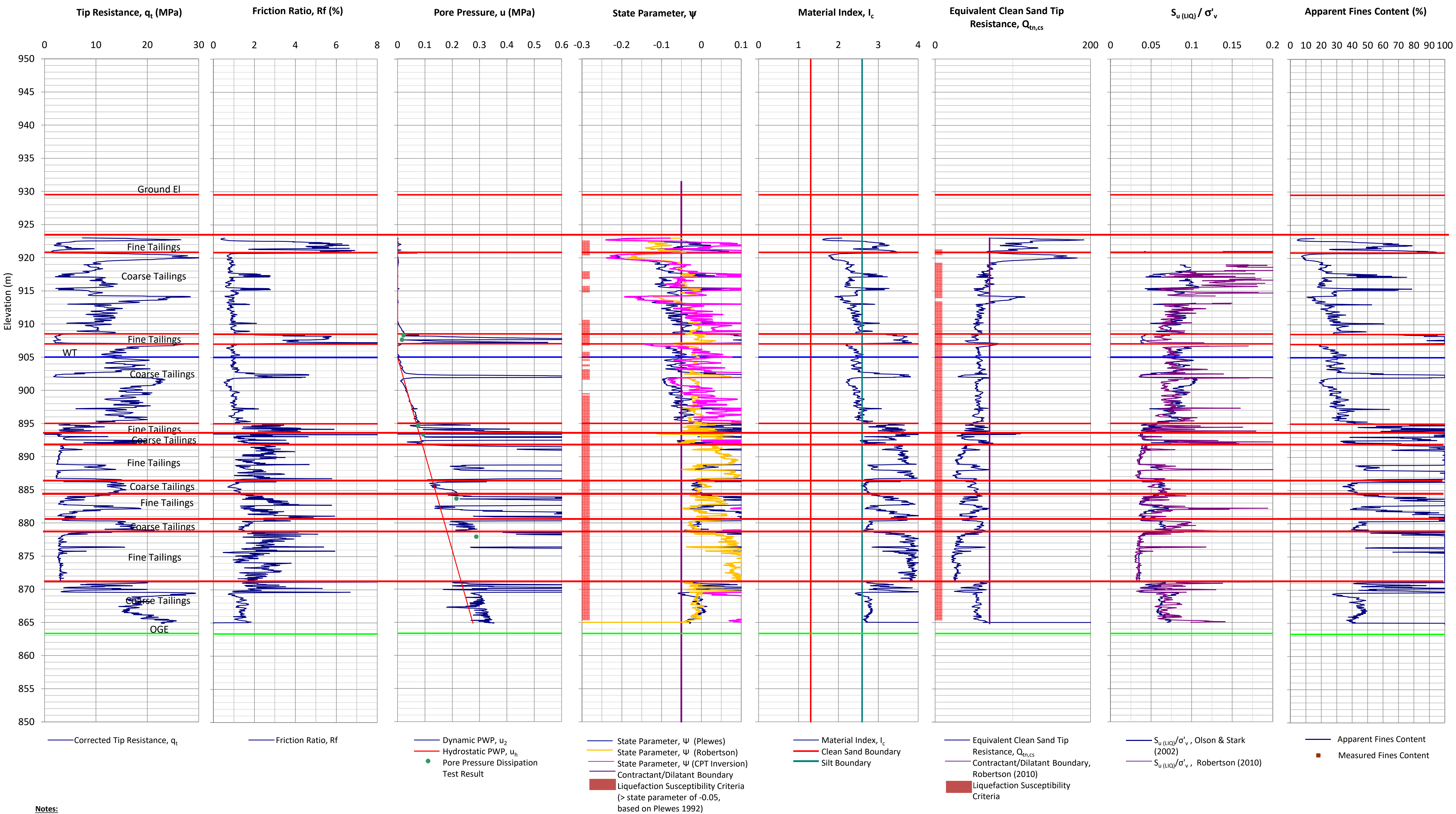
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
V_s/CPT Additional Plots for CPTU-PZE-1-7-R1

N:7775096 E:591994.9 08/10/2018

PROJECT NO.
A03355A01

FIGURE NO.
27



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as Rf=f_s/q_t.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) calculated using Plewes, et al. (1992) and the CPT inversion method is based on an assumed K0 of 0.5.

CLIENT

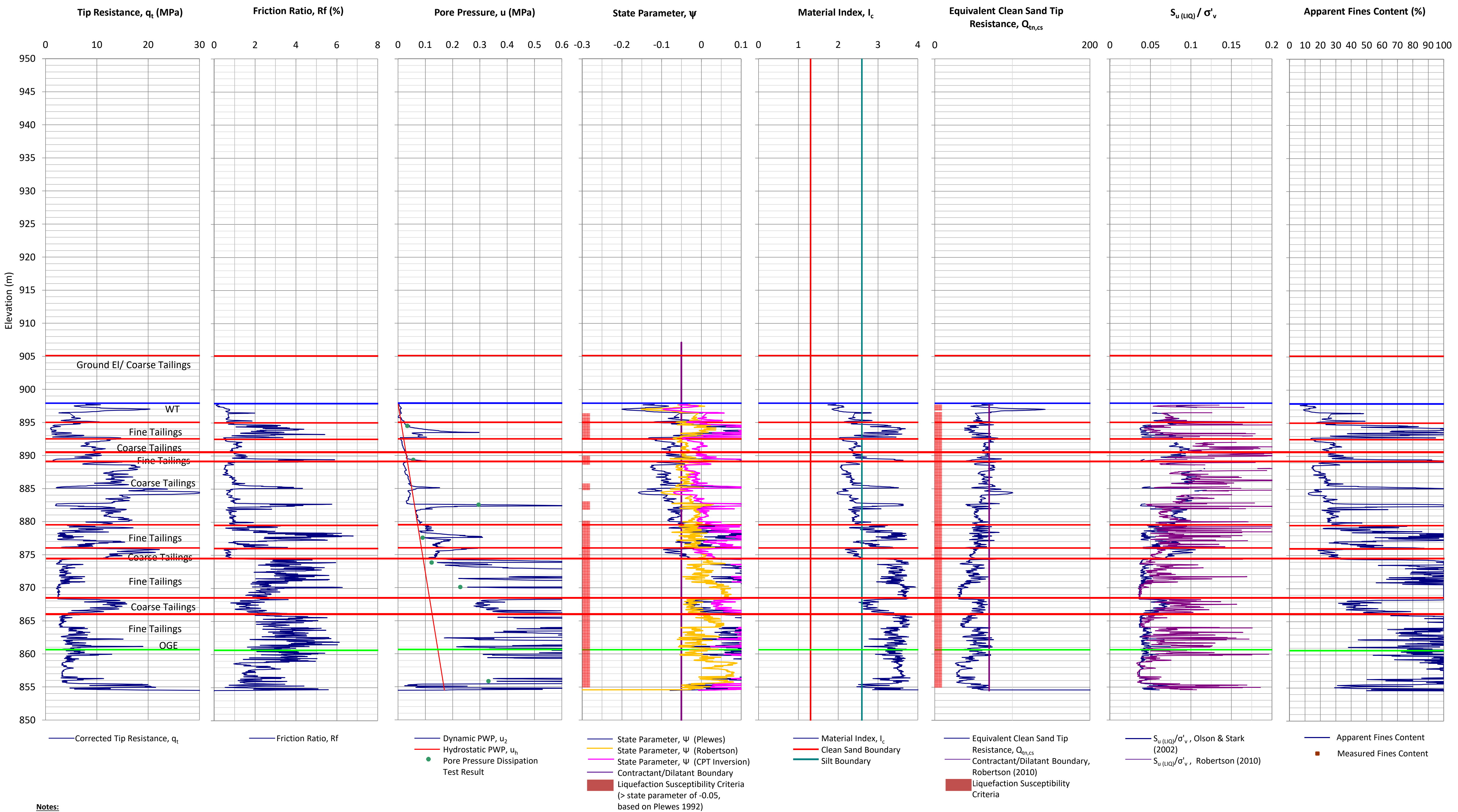
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
CONE PENETRATION TEST CPTU-PZE-09-14N_Updated

N:7775056.4 E:591924.3 2018-October-04

PROJECT NO.
A03355A01

FIGURE NO.
28



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as Rf=f_s/q_t.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) calculated using Plewes, et al. (1992) and the CPT inversion method is based on an assumed K0 of 0.5.

CLIENT

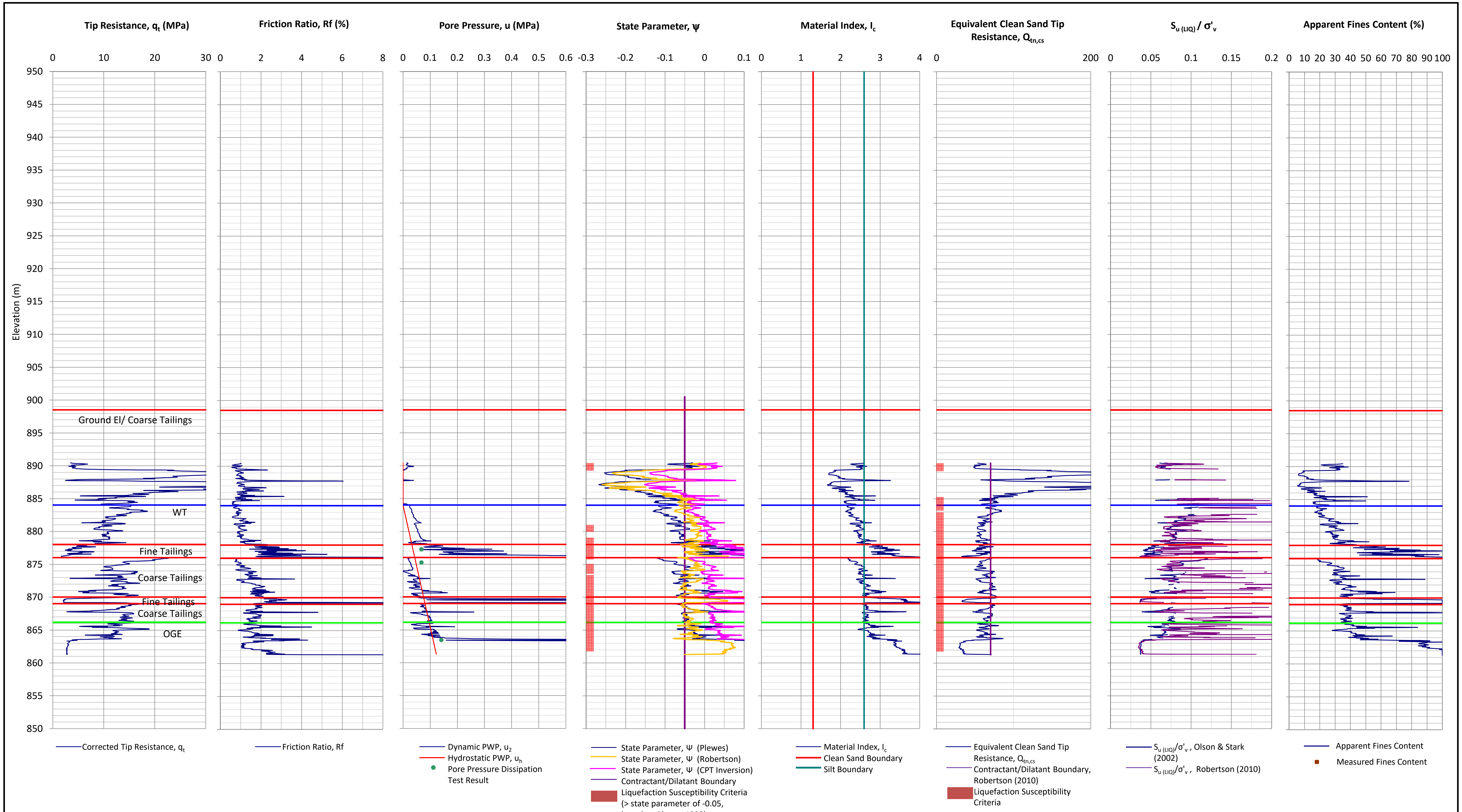
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
CONE PENETRATION TEST CPTU-PZE-15-19N_R1

N:7775018.9 E:591856.5 10/01/2018

PROJECT NO.
A03355A01

FIGURE NO.
29



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as Rf=f_s/q_t.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) calculated using Plewes, et al. (1992) and the CPT inversion method is based on an assumed K0 of 0.5.

CLIENT

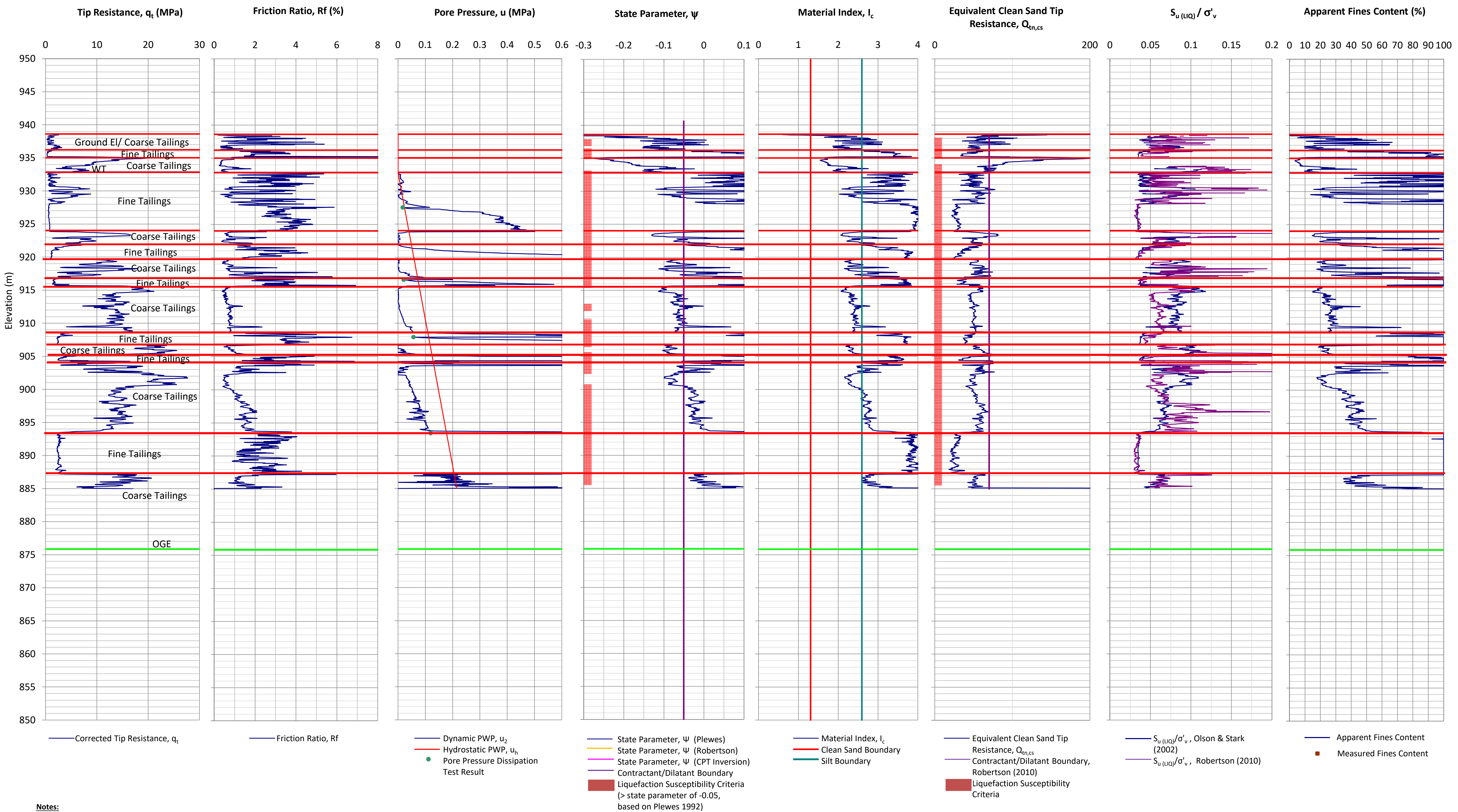
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF
THE FAILURE OF FEIJÃO DAM 1

TITLE
CONE PENETRATION TEST CPTU-PZE-20-22N-R1

N:7775010.7 E:591789.6 11/10/2018

PROJECT NO.
A03355A01

FIGURE NO.
30



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as Rf=f_s/q_t.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) calculated using Plewes, et al. (1992) and the CPT inversion method is based on an assumed K0 of 0.5.

CLIENT

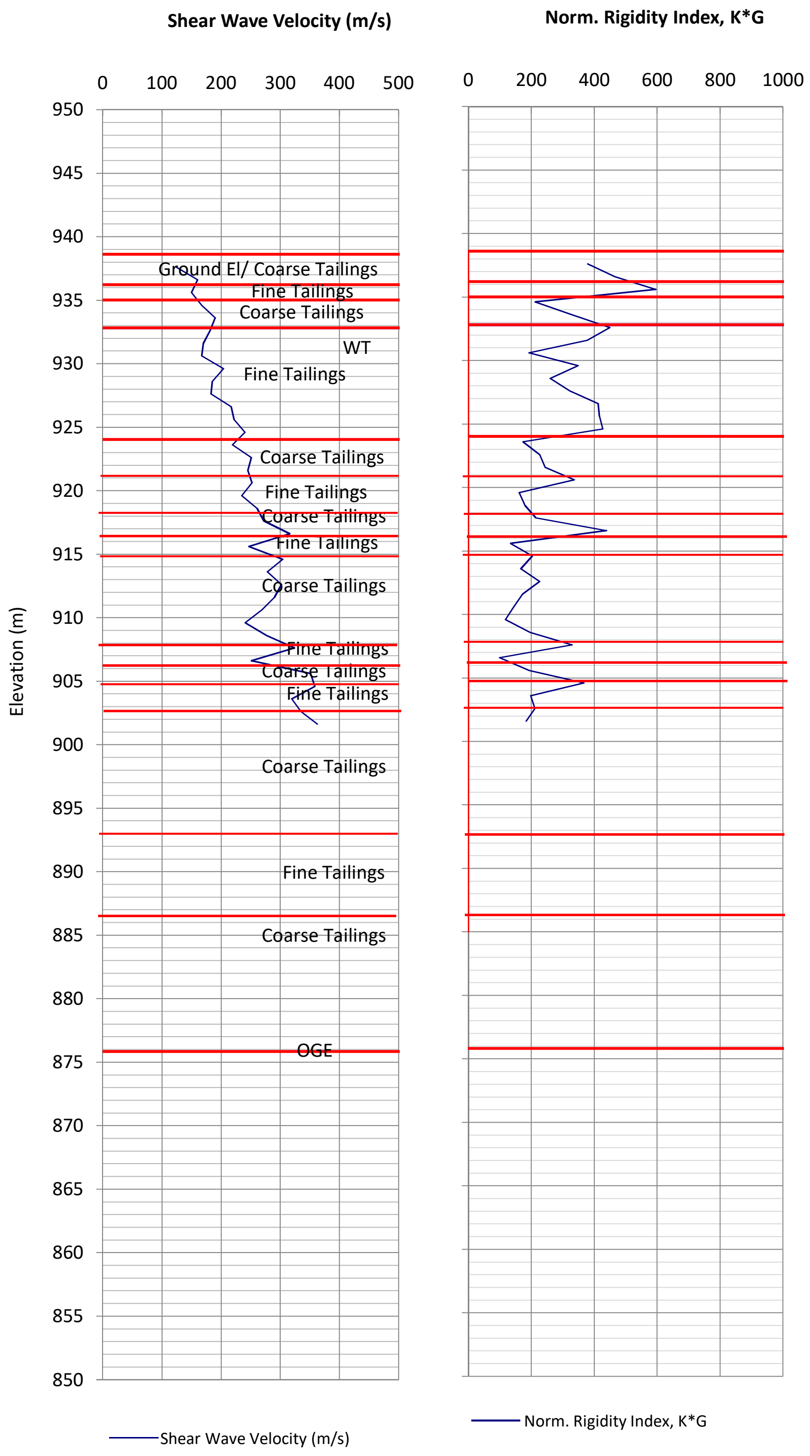
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
CONE PENETRATION TEST CPTU-PZE-23-28N_R1

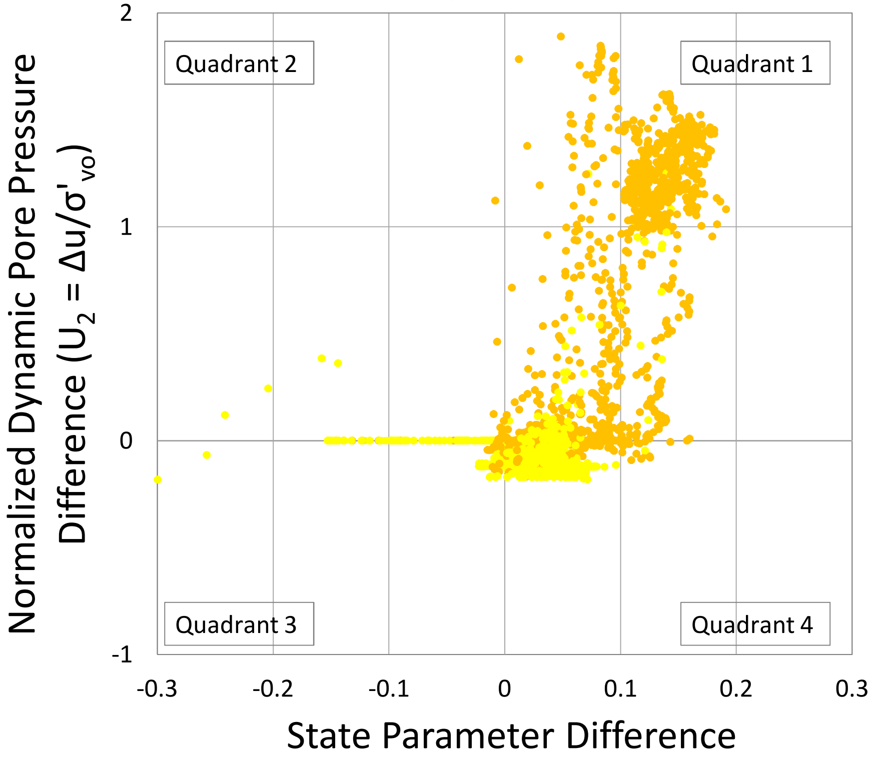
N:7775031 E:592032.5 10/11/2018

PROJECT NO.
A03355A01

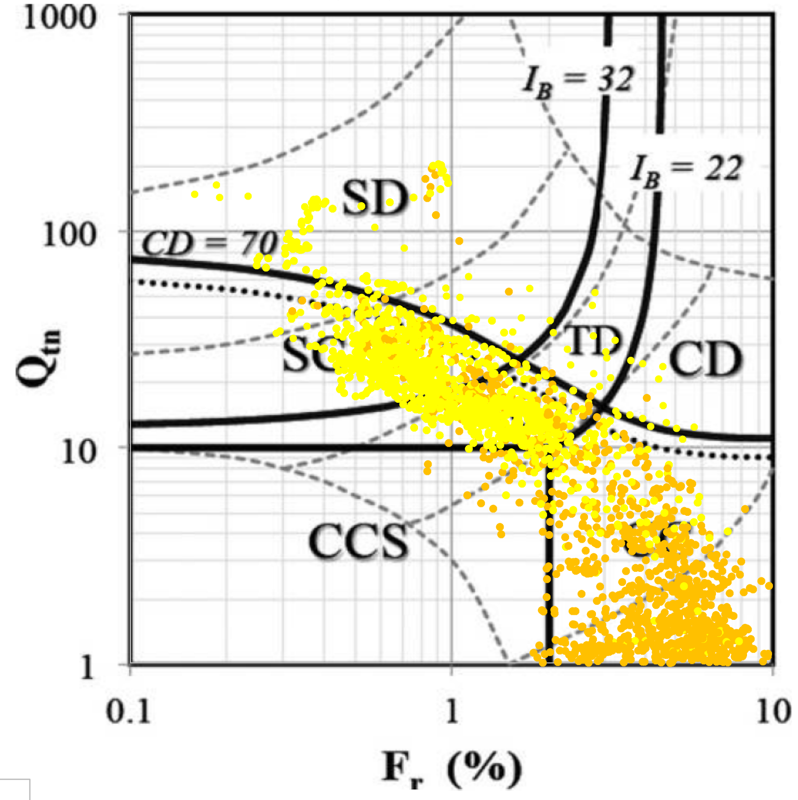
FIGURE NO.
31



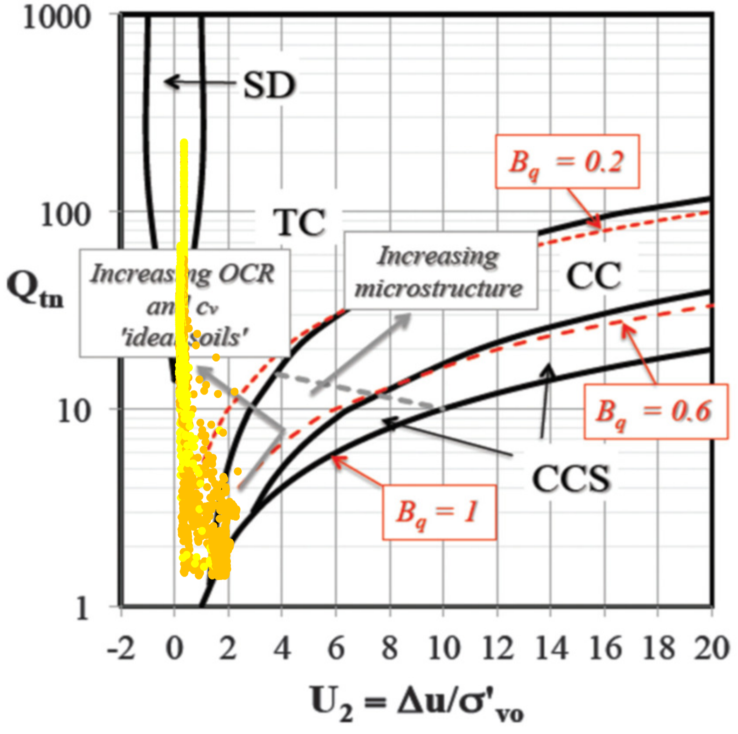
WINCKLER C. et. al. (2014)



ROBERTSON, P.K., (2016)



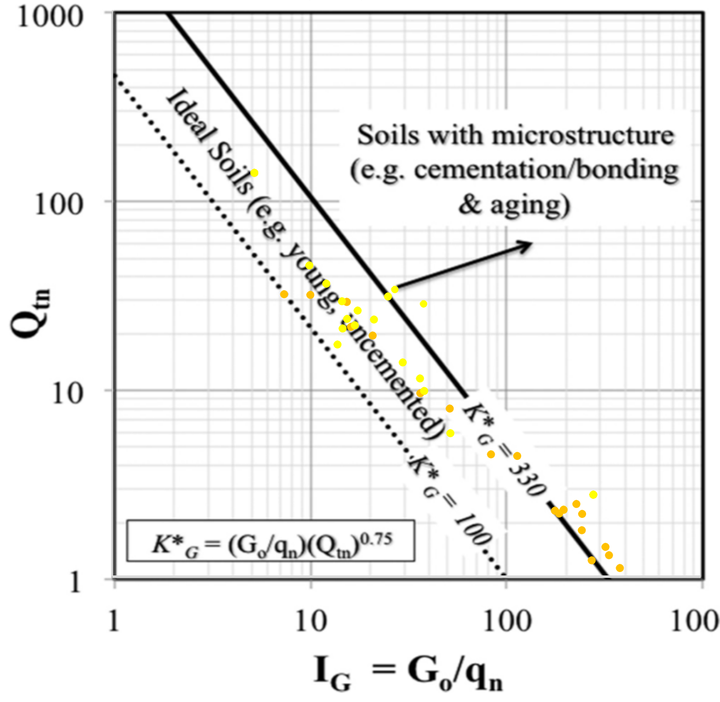
ROBERTSON, P.K., (2016)



● Fine Tailings

● Coarse Tailings

ROBERTSON, P.K., (2016)



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available).
3. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
4. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.

CLIENT

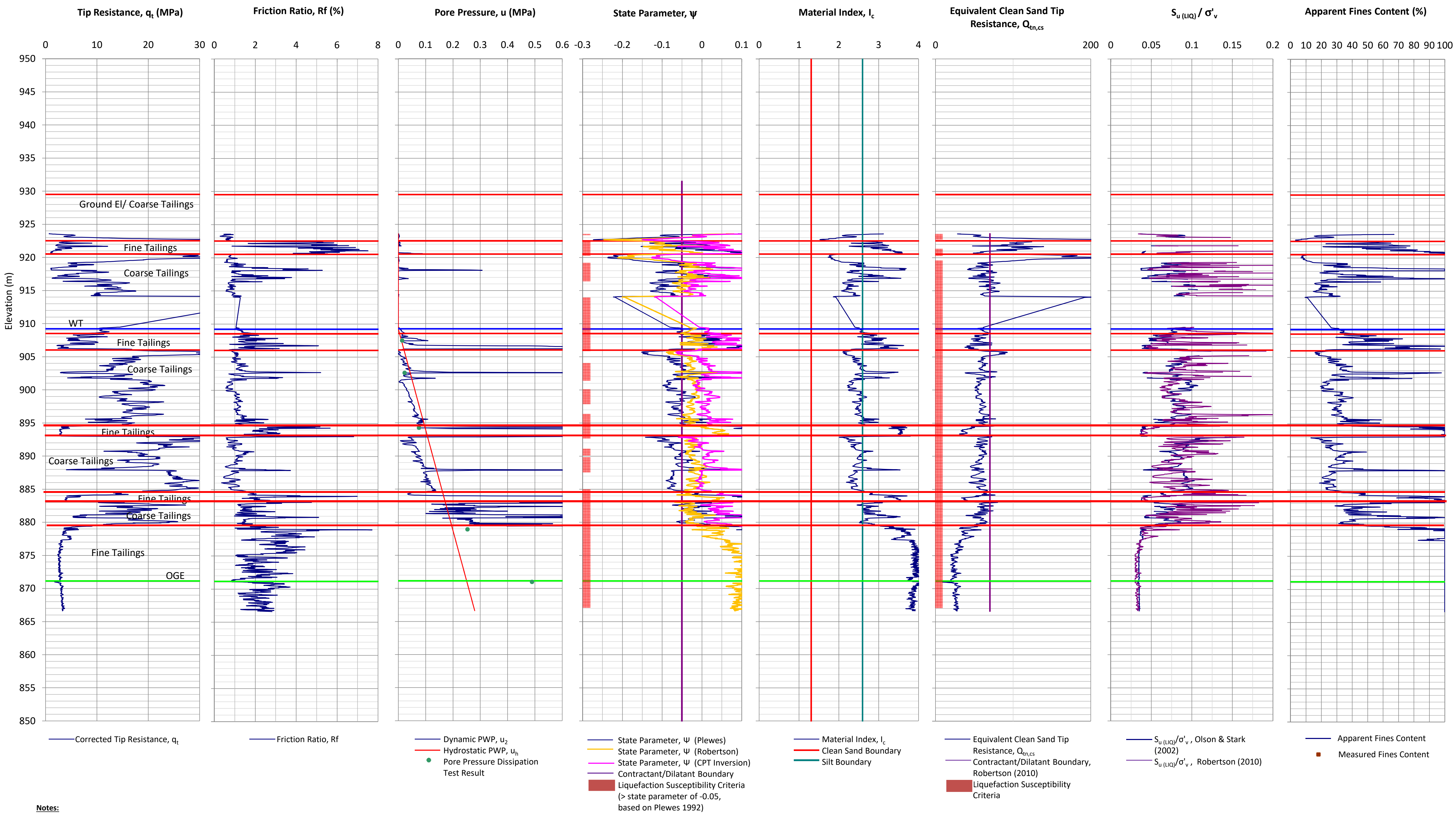
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
V_s/CPT Additional Plots for CPTU-PZE-23-28N_R1

N:7775031 E:592032.5 10/11/2018

PROJECT NO.
A03355A01

FIGURE NO.
32



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as Rf=f_s/q_t.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) calculated using Plewes, et al. (1992) and the CPT inversion method is based on an assumed K0 of 0.5.

CLIENT

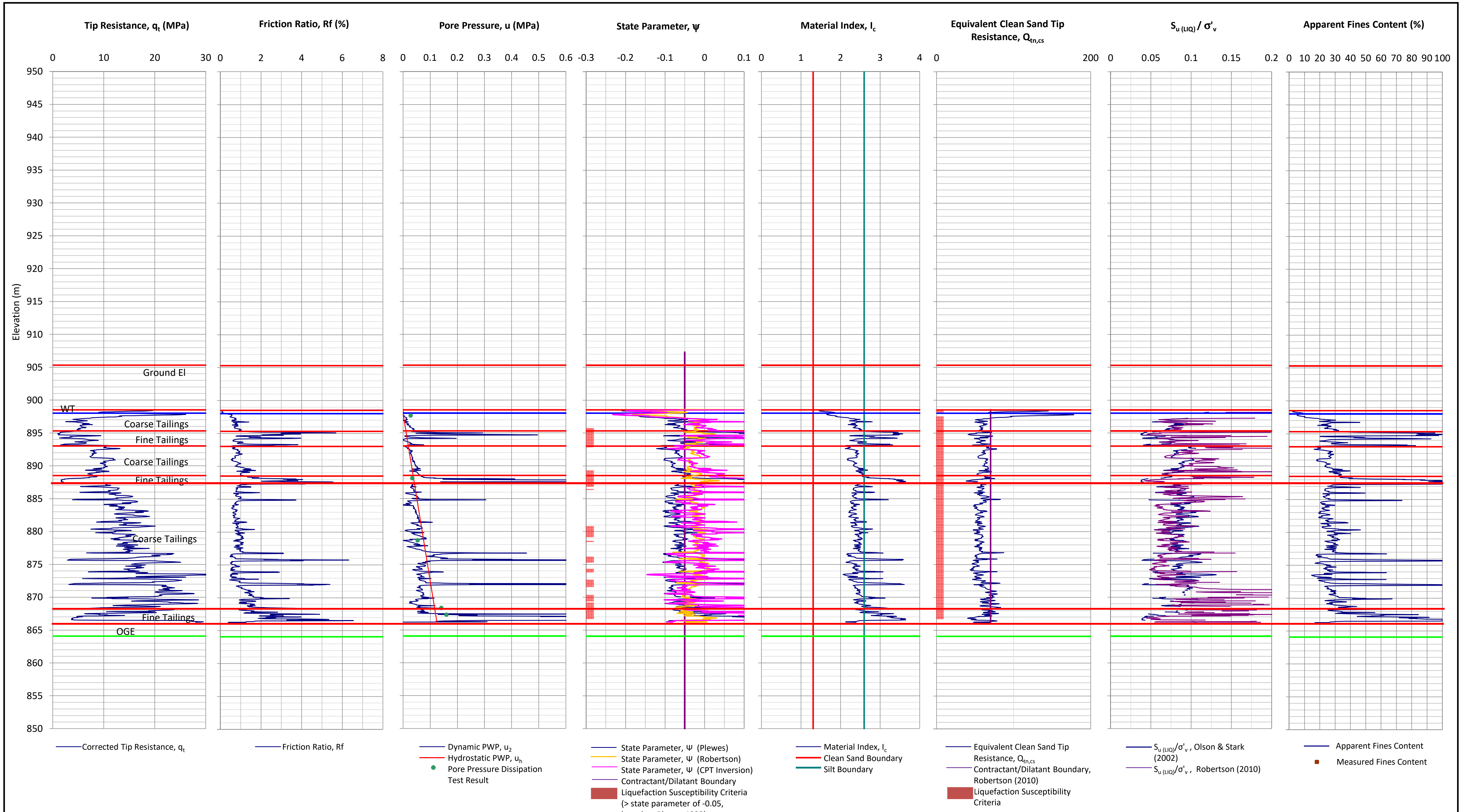
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
CONE PENETRATION TEST CPTU-PZE-29-35N_R1

N:7774991.8 E:591960.6 16/10/2018

PROJECT NO.
A03355A01

FIGURE NO.
33



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as Rf=f_s/q_t.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) calculated using Plewes, et al. (1992) and the CPT inversion method is based on an assumed K0 of 0.5.

CLIENT

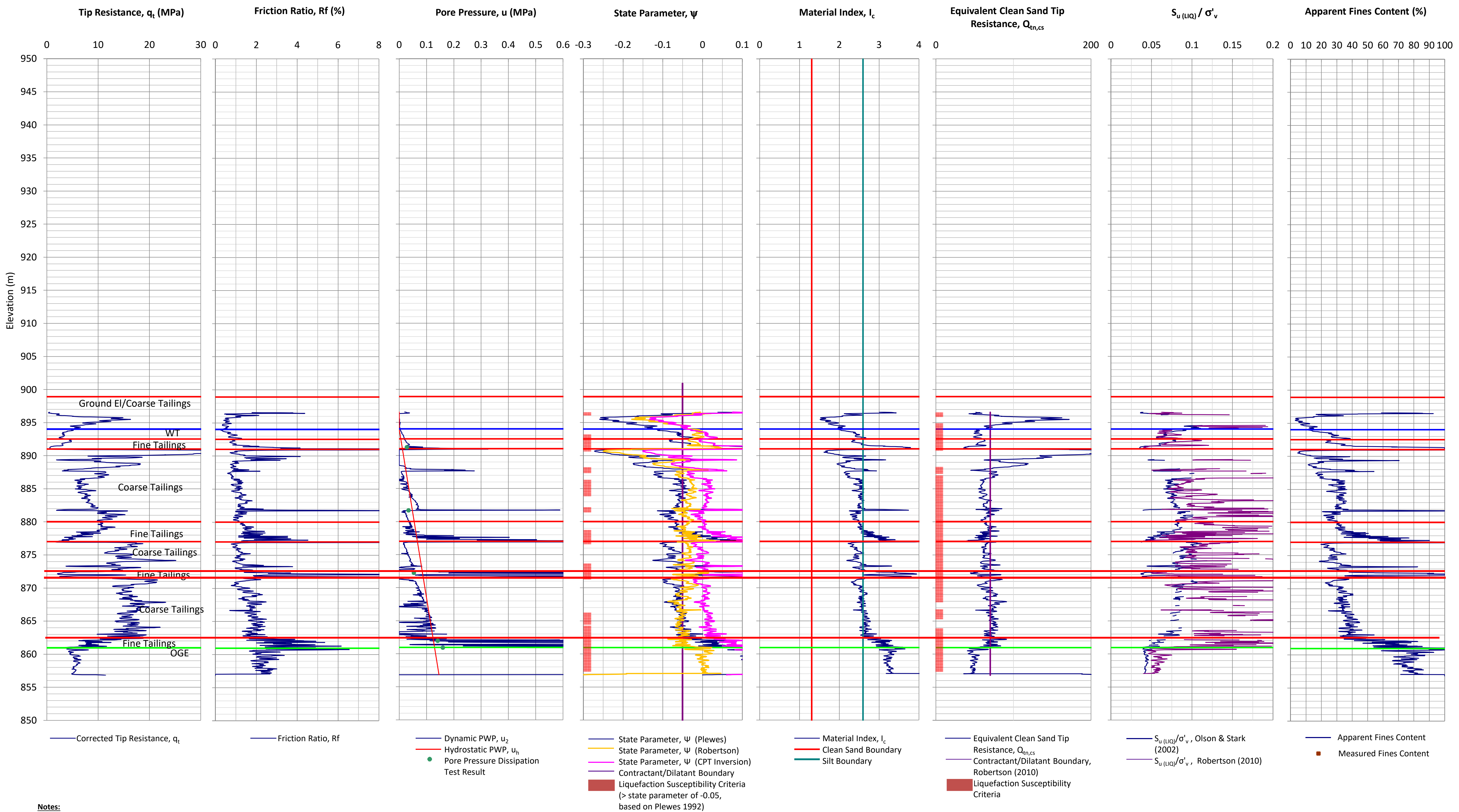
PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

TITLE
CONE PENETRATION TEST CPTU-PZE-36-40N_Updated

N:7774953.8 E:591891.7 2018-August-28

PROJECT NO.
A03355A01

FIGURE NO.
34



Notes:

1. This interpretation is based on the water and soil saturated unit weights γ_w=9.807 kN/m^3, and respective γ_{sat} for each geological unit.
2. The friction ratio Rf is calculated as Rf=f_s/q_t.
3. The hydrostatic pore pressure is calculated using the ground water level (GWL) determined from CPT pore pressure dissipation tests (where available) or dynamic pore pressure.
4. Soil boundary layers (where plotted) are based on KCB interpretation from adjacent borehole logs.
5. The data presented have been plotted to the axis limits. Data may exist beyond the axis limits shown.
6. The Material Index (I_c) boundaries are based on Robertson and Wride (1998).
7. The $Q_{tn,cs}$ contractant/dilatant boundary=70 and is based on Robertson (2010).
8. The State Parameter (Ψ) calculated using Plewes, et al. (1992) and the CPT inversion method is based on an assumed K0 of 0.5.

CLIENT

PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

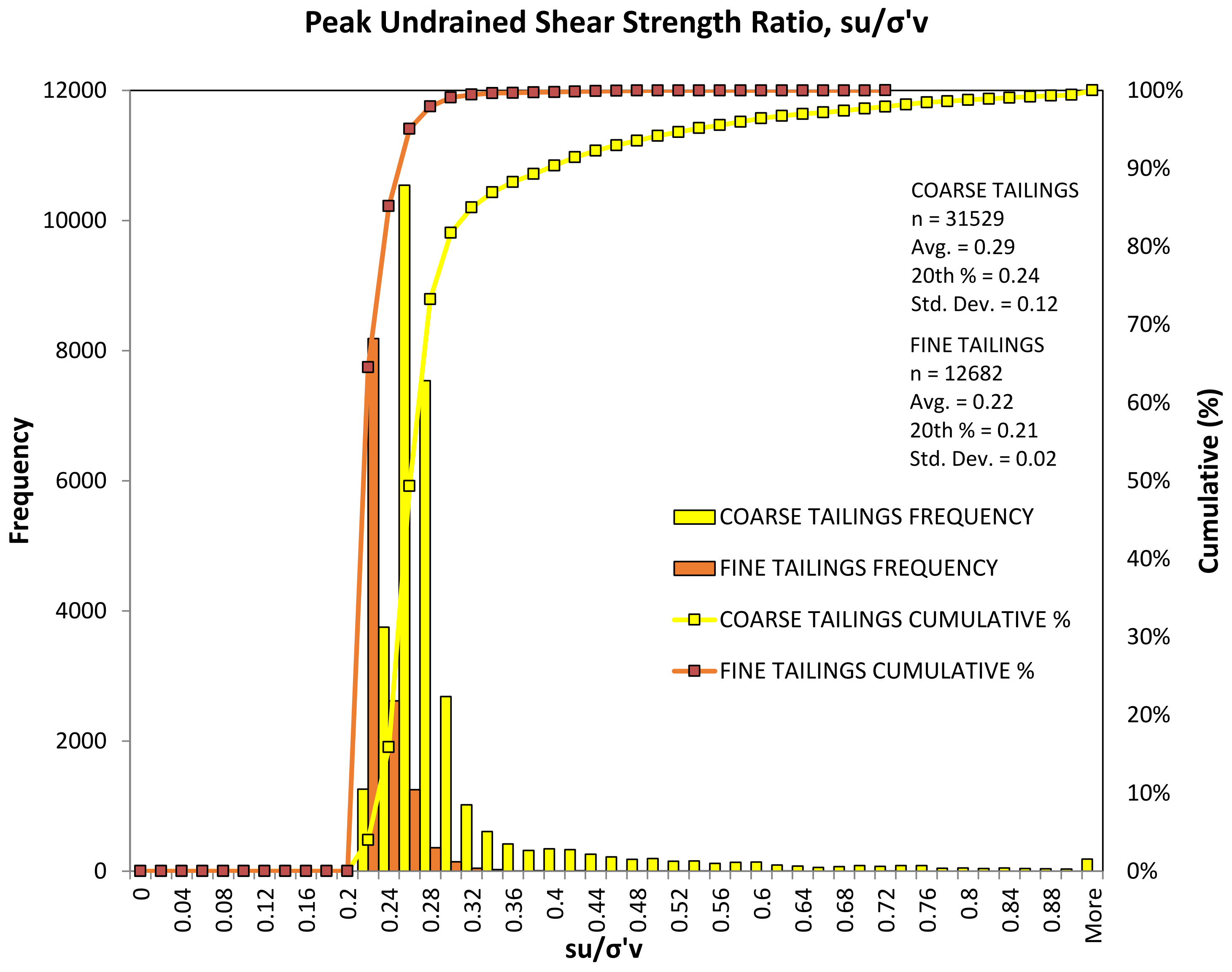
TITLE
CONE PENETRATION TEST CPTU-PZE-41-43N_R1

N:7774931.8 E:591859.6 15/10/2018

PROJECT NO.
A03355A01

FIGURE NO.
35

Calculated Strength and State Parameter Histograms



NOTES:

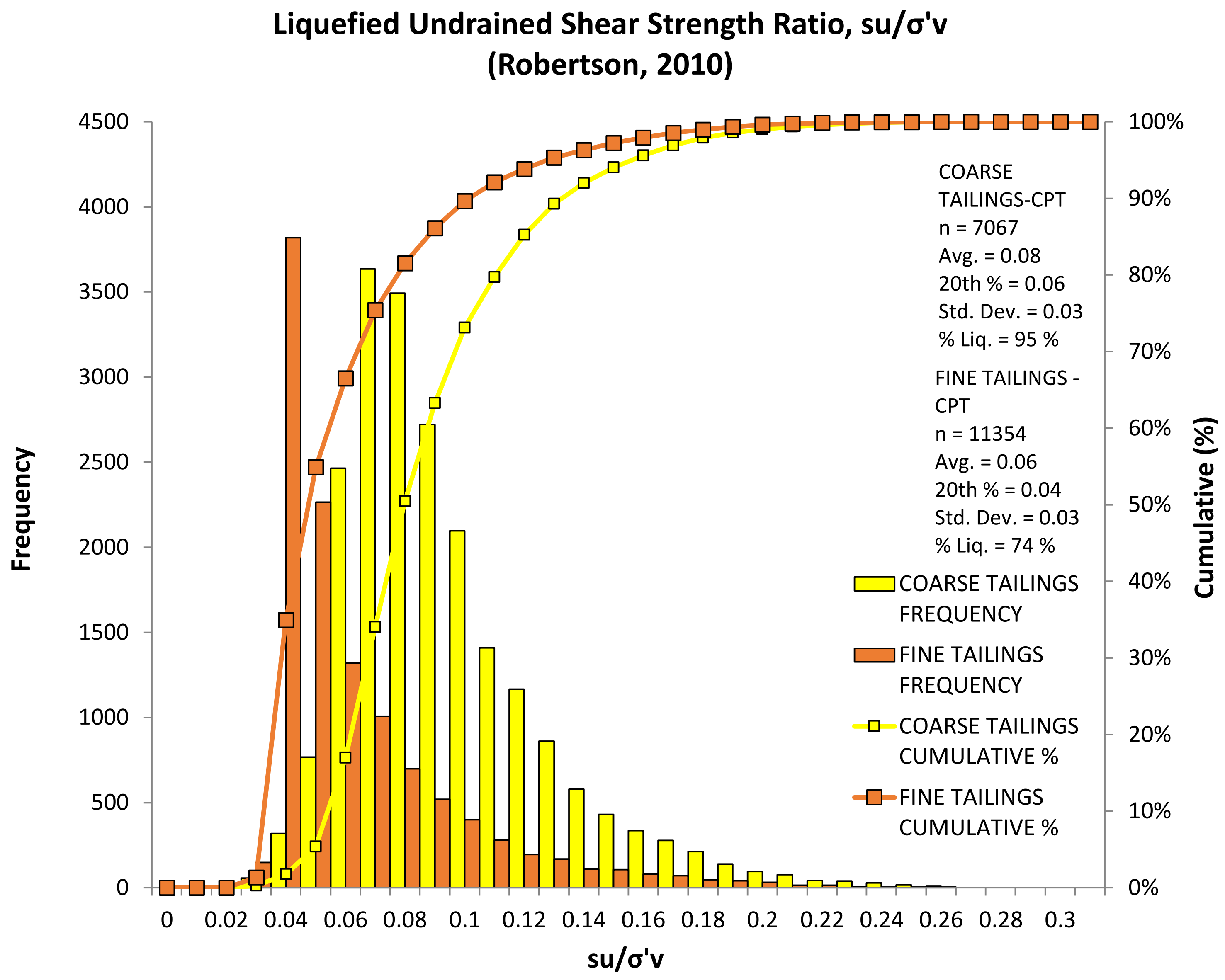
CLIENT

PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF
THE FAILURE OF FEIJÃO DAM 1

Peak Undrained Shear Strength Ratio for Fine
and Coarse Tailings Calculated from CPTu Data

PROJECT No.
A03355A01

FIG. No.
36



NOTES:

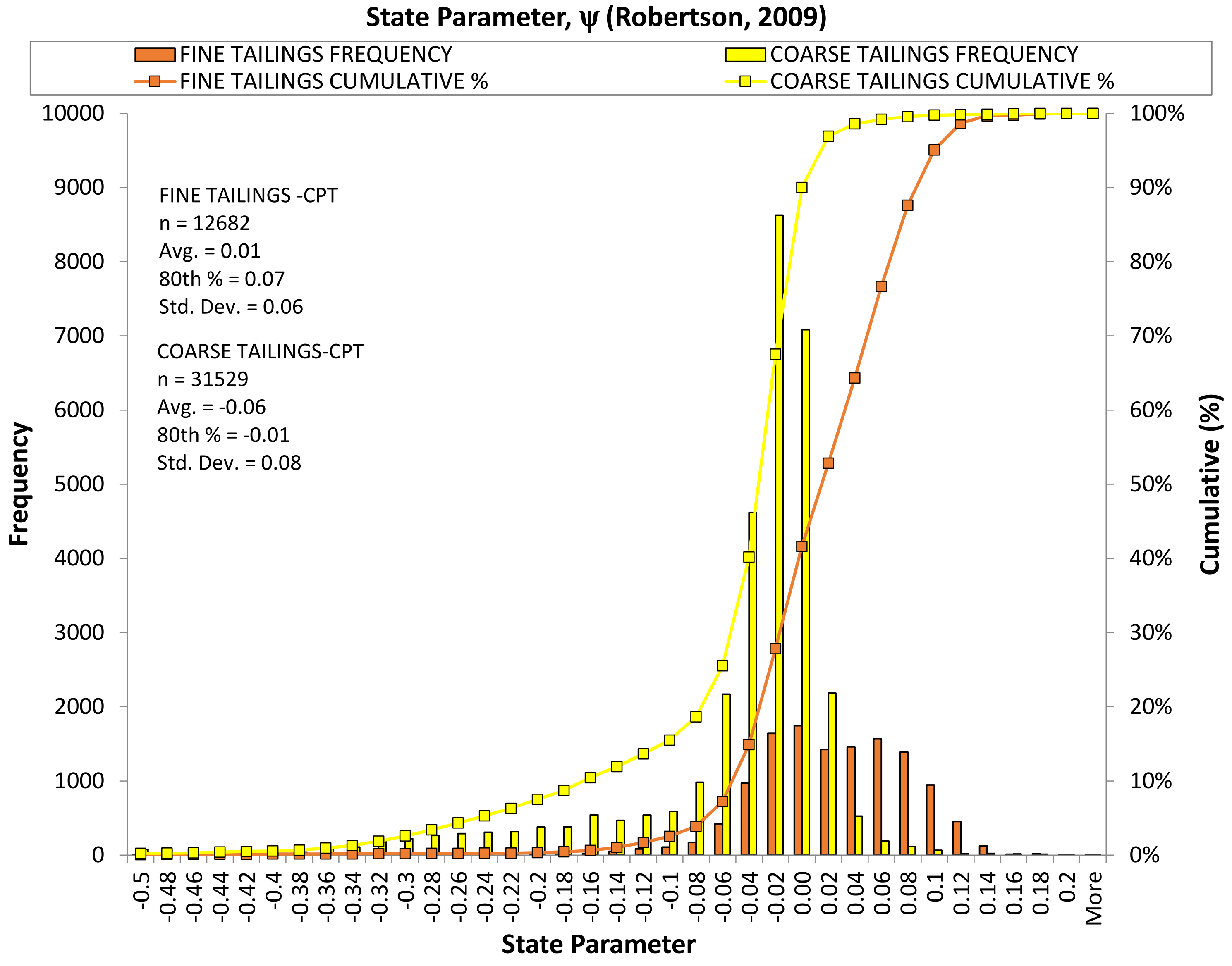
CLIENT

PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF
THE FAILURE OF FEIJÃO DAM 1

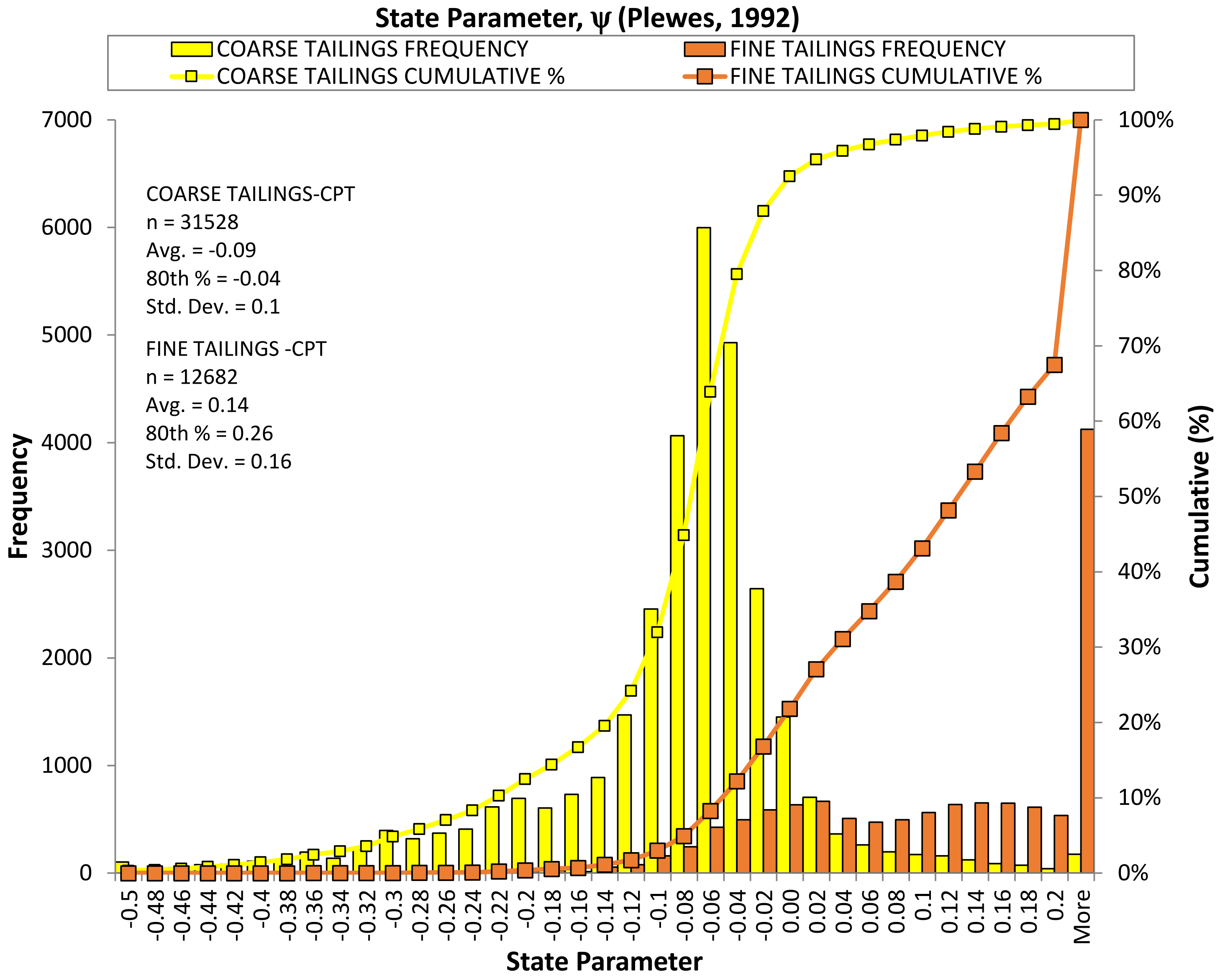
Liquefied Undrained Shear Strength Ratio for Fine and Coarse Tailings Calculated from CPTu Data

PROJECT No. A03355A01

FIG. No. 37



State Parameter, ψ (Robertson, 2009)



State Parameter, ψ (Plewes, 1992)

NOTES:

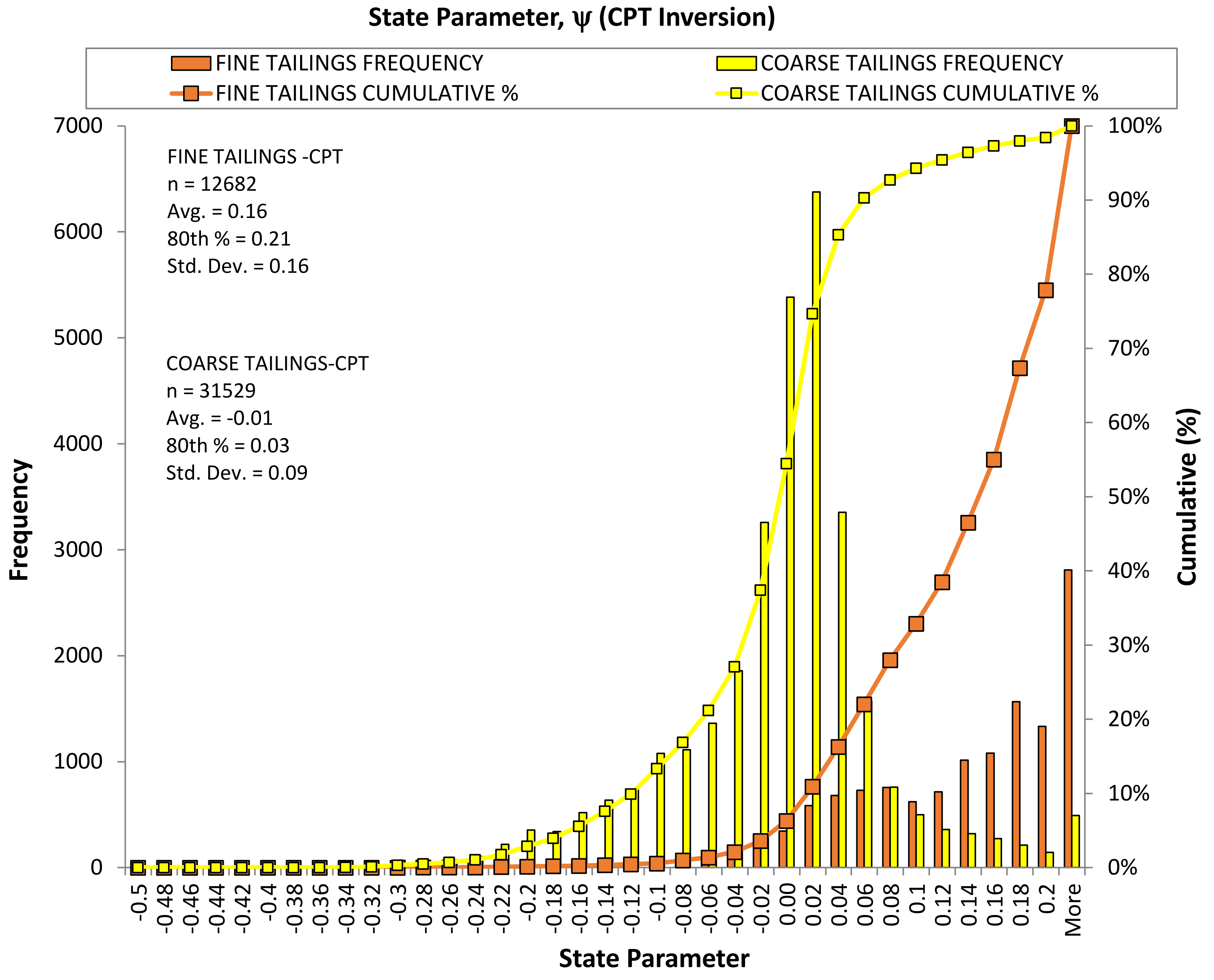
CLIENT

PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF THE FAILURE OF FEIJÃO DAM 1

Histograms Plots of State Parameter for Robertson (2009) and Plewes (1992)

PROJECT No.
A03355A01

FIG. No.
38



NOTES:

CLIENT

PROJECT
REPORT OF THE EXPERT PANEL ON THE TECHNICAL CAUSES OF
THE FAILURE OF FEIJÃO DAM 1

State Parameter Histogram Plot for CPT Inversion Method (Jefferies and Been 2016)

PROJECT No. A03355A01

FIG. No. 39