Specialised Testing Laboratory (Pty) Ltd
Asphalt | Aggregate | Bitumen | Geotechnical
Quality | Excellence | On Time

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Gerrie | 082 309 4448 | gerrie@stlab.co.za
www.stlab.co.za

Client Name: Epoch Resources
Project Name: Tharisa - TSF2 - Phase 01
Job Number: EPO-57
Date: 2023-08-07
Method: SANS 3001 GR1, GR3, GR10 GR12 & BS 1377 (where applicable)

FOUNDATION INDICATOR

Sheet Reference: R-STL-011 Rev02

Grading & Hydrometer Analysis (Particle Size (mm) & % Passing)				Atterberg Limits & Classification			
Sample	Inner Wall	Penstock	Representative Sample	Sample	Inner Wall	Penstock	Representative Sample
Lab No	EPO-57-461	EPO-57-462	EPO-57-463	Lab No	EPO-57-461	EPO-57-462	EPO-57-463
53.0	**100**	**100**	**100**	Liquid Limit (%)	-	-	-
37.5	**100**	**100**	**100**	Plastic Limit (%)	-	-	-
26.5	**100**	**100**	**100**	Plasticity Index (%)	**NP**	**NP**	**NP**
19.0	**100**	**100**	**100**	Linear Shrinkage (%)	**0.0**	**0.0**	**0.0**
13.2	**100**	**100**	**100**	PI of whole sample	-	-	-
9.5	**100**	**100**	**100**				
6.7	**100**	**100**	**100**	% Gravel	**0**	**0**	**0**
4.75	**100**	**100**	**100**	% Sand	**80**	**32**	**36**
2.00	**100**	**100**	**100**	% Silt	**19**	**60**	**57**
1.00	**100**	**100**	**100**	% Clay	**1**	**8**	**7**
0.425	**99**	**100**	**100**	Activity	**0.0**	**0.0**	**0.0**
0.250	**88**	**100**	**97**				
0.150	**60**	**93**	**87**	% Soil Mortar	**100**	**100**	**100**
0.075	**28**	**76**	**70**				
0.060	**20**	**68**	**64**	Grading Modulus	**0.73**	**0.24**	**0.30**
0.050	**15**	**63**	**59**	Moisture Content (%)	**N / T**	**N / T**	**N / T**
0.035	**9**	**52**	**47**	Relative Density (SG)*	**3.468**	**3.265**	**3.253**
0.020	**6**	**35**	**33**				
0.006	**3**	**18**	**17**	Unified (ASTM D2487)	**SM**	**ML**	**ML**
0.002	**1**	**8**	**7**	AASHTO (M145-91)	**A - 2 - 4**	**A - 4**	**A - 4**

Remarks: *: Determined
N / T: Not Tested

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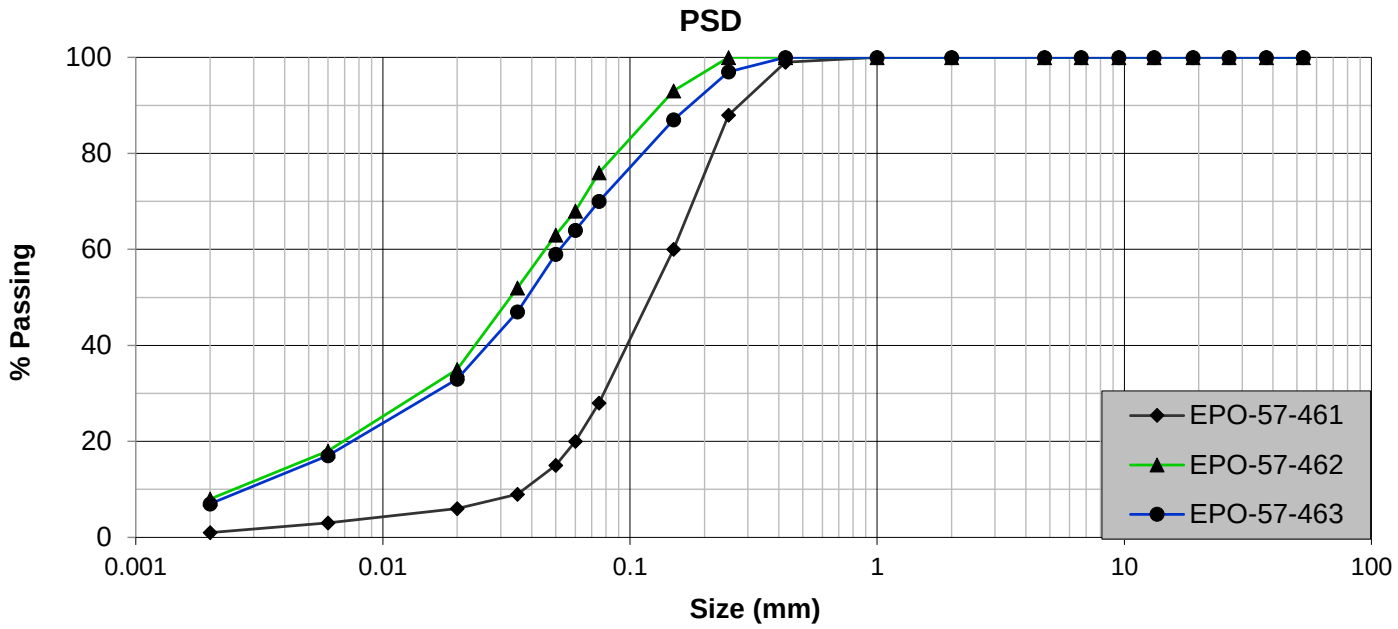
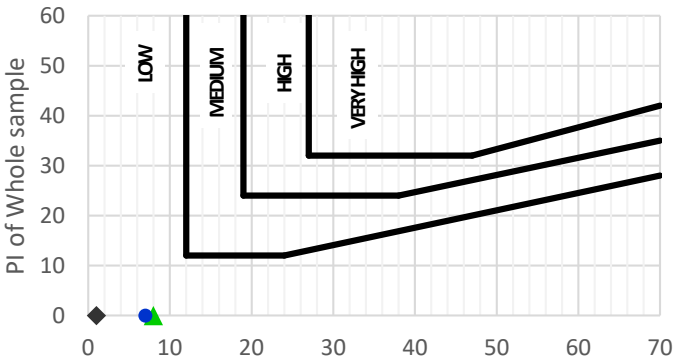
Sheet Reference: R-STL-011 Rev02

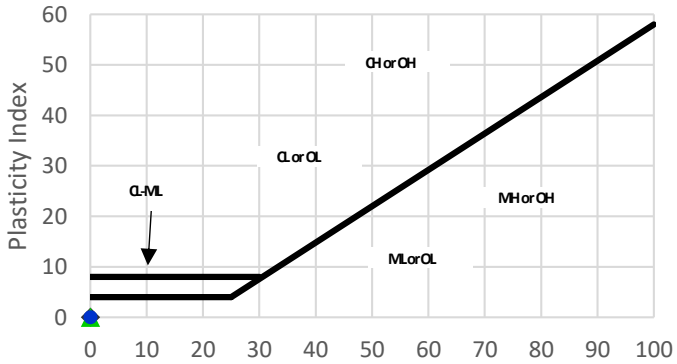


Potential Expansiveness



◆ EPO-57-461 ▲ EPO-57-462 ● EPO-57-463

Casagrande Plasticity Chart



◆ EPO-57-461 ▲ EPO-57-462 ● EPO-57-463

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Client Name: Epoch Resources
Project Name: Tharisa - TSF2 - Phase 01
Sample: Inner Wall
Depth: (m) -

Job Number: EPO-57
Lab Number: EPO-57-461
Date: 07-Aug-23

CONSTANT HEAD PERMEABILITY TEST

General Test Data		
Type of Sample:	-	Remoulded to a Void Ratio of 1.0 (supplied by client)
MDD:	g/cm³	-
OMC:	%	-

Initial Specimen Details		
Diameter	mm	50.8
Length	mm	91.1
Area	mm²	2026.8
Volume	cm³	184.5
Moisture Content	%	4.5
Dry Density	g/cm³	1.680
Void Ratio	-	1.064
Degree of Saturation	%	14.5
Particle Density (SG)	-	3.468 - Determined

Permeability Details

Coefficient of Permeability		Flow Rate (Q) (m^3/s)	Coefficient of Permeability ($k_{T)}$
Run 1	m/s	9.09E-08	2.04E-06
Run 2		8.33E-08	1.87E-06
Run 3		5.88E-08	1.32E-06
Run 4		5.88E-08	1.32E-06
Run 5		5.00E-08	1.12E-06
Run 6		4.00E-08	8.98E-07
Run 7		4.00E-08	8.98E-07
Run 8		4.00E-08	8.98E-07
Run 9		3.23E-08	7.25E-07
Run 10		2.70E-08	6.07E-07

Coefficient of Permeability k_{T20}	**Min.**	**m/s**	**6.05E-07**
	Max.		**2.04E-06**
	Ave.		**1.17E-06**

Remarks:

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Client Name: Epoch Resources
Project Name: Tharisa - TSF2 - Phase 01
Sample: Penstock
Depth: (m) -

Job Number: EPO-57
Lab Number: EPO-57-462
Date: 07-Aug-23

CONSTANT HEAD PERMEABILITY TEST

General Test Data		
Type of Sample:	-	Remoulded to a Void Ratio of 1.0 (supplied by client)
MDD:	g/cm³	-
OMC:	%	-

Initial Specimen Details		
Diameter	mm	50.8
Length	mm	90.8
Area	mm²	2026.8
Volume	cm³	184.1
Moisture Content	%	9.7
Dry Density	g/cm³	1.586
Void Ratio	-	1.058
Degree of Saturation	%	29.8
Particle Density (SG)	-	3.265 - Determined

Permeability Details

Coefficient of Permeability		Flow Rate (Q) (m^3/s)	Coefficient of Permeability ($k_{T)}$
Run 1	m/s	1.92E-09	4.31E-08
Run 2		1.23E-09	2.77E-08
Run 3		1.03E-09	2.30E-08
Run 4		1.25E-09	2.81E-08
Run 5		1.15E-09	2.58E-08
Run 6		1.13E-09	2.54E-08
Run 7		1.34E-09	3.01E-08
Run 8		1.39E-09	3.10E-08
Run 9		1.45E-09	3.24E-08
Run 10		1.15E-09	2.58E-08

Coefficient of Permeability k_{T20}	**Min.**	**m/s**	**2.29E-08**
	Max.		**4.30E-08**
	Ave.		**2.92E-08**

Remarks:

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Client Name:	Epoch Resources	**Job Number:**	EPO-57
Project Name:	Tharisa - TSF2 - Phase 01	**Lab Number:**	EPO-57-463
Sample:	Representative Sample	**Date:**	07-Aug-23
Depth: (m)	-		

CONSTANT HEAD PERMEABILITY TEST

General Test Data		
Type of Sample:	-	Remoulded to a Void Ratio of 1.0 (supplied by client)
MDD:	g/cm³	-
OMC:	%	-

Initial Specimen Details		
Diameter	mm	50.8
Length	mm	91.7
Area	mm²	2026.8
Volume	cm³	185.8
Moisture Content	%	9.7
Dry Density	g/cm³	1.564
Void Ratio	-	1.079
Degree of Saturation	%	29.2
Particle Density (SG)	-	3.253 - Determined

Permeability Details

Coefficient of Permeability		Flow Rate (Q) (m^3/s)	Coefficient of Permeability ($k_{T)}$
Run 1	m/s	5.49E-09	1.24E-07
Run 2		5.26E-09	1.19E-07
Run 3		7.25E-09	1.64E-07
Run 4		4.67E-09	1.06E-07
Run 5		6.41E-09	1.45E-07
Run 6		5.43E-09	1.23E-07
Run 7		7.81E-09	1.77E-07
Run 8		9.26E-09	2.09E-07
Run 9		4.59E-09	1.04E-07
Run 10		4.50E-09	1.02E-07

Coefficient of Permeability k_{T20}	**Min.**	**m/s**	**1.02E-07**
	Max.		**2.09E-07**
	Ave.		**1.37E-07**

Remarks:

Epoch Resources

THARISA TAILINGS RHEOLOGY TESTS

Test Work Report

Report Number: EPO-THA-8980 R01 Rev 0

19 April 2022

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Vietti Slurrytec (Pty) Ltd. Reg No: 2005/0087/52/07
VAT No: 4590220515

CONTENTS

1. INTRODUCTION

A request was received from Epoch Resources for Vietti Slurrytec (Pty) Ltd to conduct rheology test work on ONE (1) tailings sample originating from the Tharisa Minerals Project in South Africa

The purpose of this test campaign is to characterise the flow behaviour of the tailings material and to determine the sheared yield stress and viscosity as a function of slurry solids concentration of the sample over a client specified range of five (5) different solids concentrations. The rheological parameters will be used for a dam breach study by the client.

This document details the test results and findings of the analysis.

2. SAMPLE DESCRIPTION AND PREPARATION

One slurry sample in a 25L container (55.8%m solids) was delivered to the Vietti Slurrytec laboratory facility in Johannesburg, South Africa. The sample was allowed to settle and the clear supernatant was siphoned off. The presence of grits necessitated the screening of the slurry sample to 500 micron

3. TEST WORK SCOPE

Vietti Slurrytec carried out the following test work programme scope:

- Material Property tests
    - Specific Gravity
    - Particle size distribution
    - Solids concentration
- Rotational Viscometer Tests

4. RESULTS

4.1 Material Property Tests

The raw data of the material property tests are presented in Appendix A.

4.1.1 Particle Specific Gravity

The particle specific gravity of the Tharisa Tailings sample was measured by Helium stereopycnometer method and presented in Table I.

Table I: Slurry Solids Concentration (by mass)

Tharisa	Particle Specific Gravity (g/cm^3)
Platinum Tailings	3.213

4.1.2 Particle Size Distribution

The particle size distribution of the Tharisa tailings sample was determined by laser diffraction method and is presented in Figure 1. The presence of grits necessitated the screening of the Tharisa tailings samples to 500 µm. The +500 µm fraction was determined to consist of only 1.91%m of the total sample as presented in Table II.

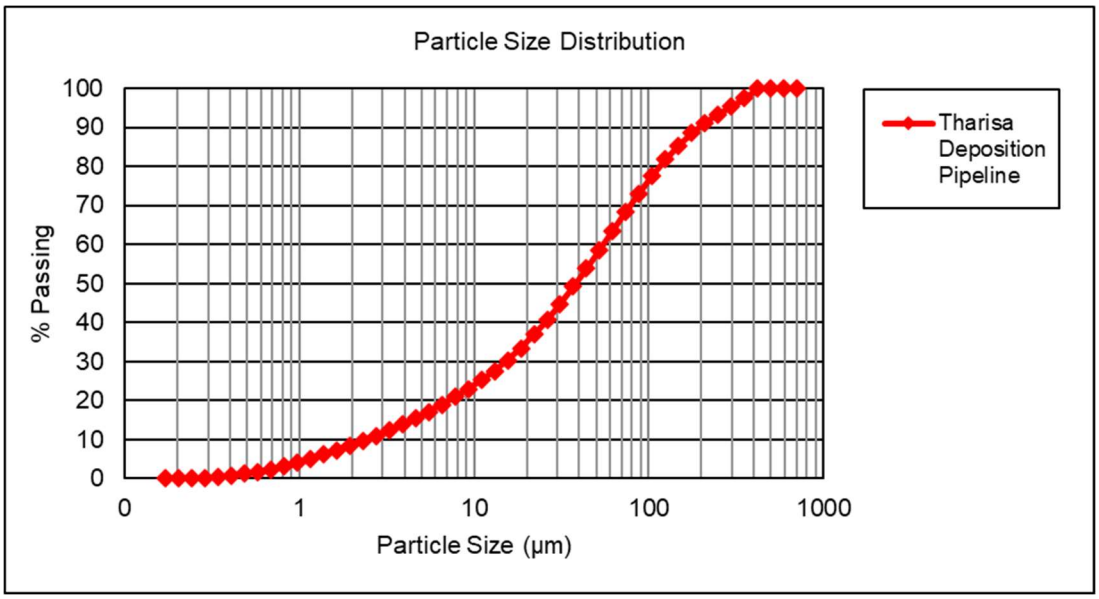


Figure 1 Laser Particle Size Distribution

Table II: Particle Size Distribution Summary

Particle size parameter	Tharisa tailings sample (µm)
$\mathbf{d_{20}}$	7.2
$\mathbf{d_{50}}$	38.2
$\mathbf{d_{80}}$	115.5
+500µm (%m)	1.9

4.1.3 Solids Concentration

The rheology tests for the Tharisa tailings sample was conducted on the minus 500 micron fraction as the rheological characteristics of a slurry is determined by the fines fraction. The plus 500 micron grits particles do not contribute to the rheological flow behaviour of the slurry and are merely transported by the fines vehicle part of the slurry. The slurry density of the minus 500 micron slurry was measured through oven drying and the total slurry density (including grits) were calculated based on the grits to fines ratio presented in Table II

The viscosity of the Tharisa tailings sample was measured at five different solids concentrations covering the range of 74%m to 79%m. The highest solids concentration was achieved by centrifuge. Settling began to occur within the rheometer cup in the slurries below 74%m solids concentration. The high particle specific gravity (3.2 g/cm^3) was the main contributor to the settling nature of the sample at lower solids concentrations. The actual solids concentrations at which the viscosity was measured was determined through oven drying and is presented in Table III

Table III Slurry Solids Concentration (by mass)

Sample	**Tharisa Tailings**	
	Measured Slurry Solids Conc. (%m)	
Rheology Test No.	-500 micron	Total
1	78.9 (Centrifuge)	79.2
2	78.1	78.5
3	77.7	78.1
4	76.5	76.8
5	73.7	74.1

4.2 Rotational Viscometer Tests

The objective of these tests is to determine a rheogram which is a plot of shear stress against shear rate for a range of mass solids concentrations. The rheogram is used to characterise the rheological flow behaviour of the slurry through model fitting.

An Anton Paar Rheolab QC rotational viscometer (RheolabQC SN80429371; FW1.22) with a Bob & Cup measuring system was used for the test work.

4.2.1 Test Data

Appendix B presents the rotational viscometer test data which contains the following:

- Measured values of torque, speed and calculated values of shear stress and shear rate.

Figure 2 shows the rheogram data for the Tharisa tailings sample for mass solids concentrations from 74 %m to 79 %m. Each sample was analysed over a shear rate range of 1 to 500 1/s.

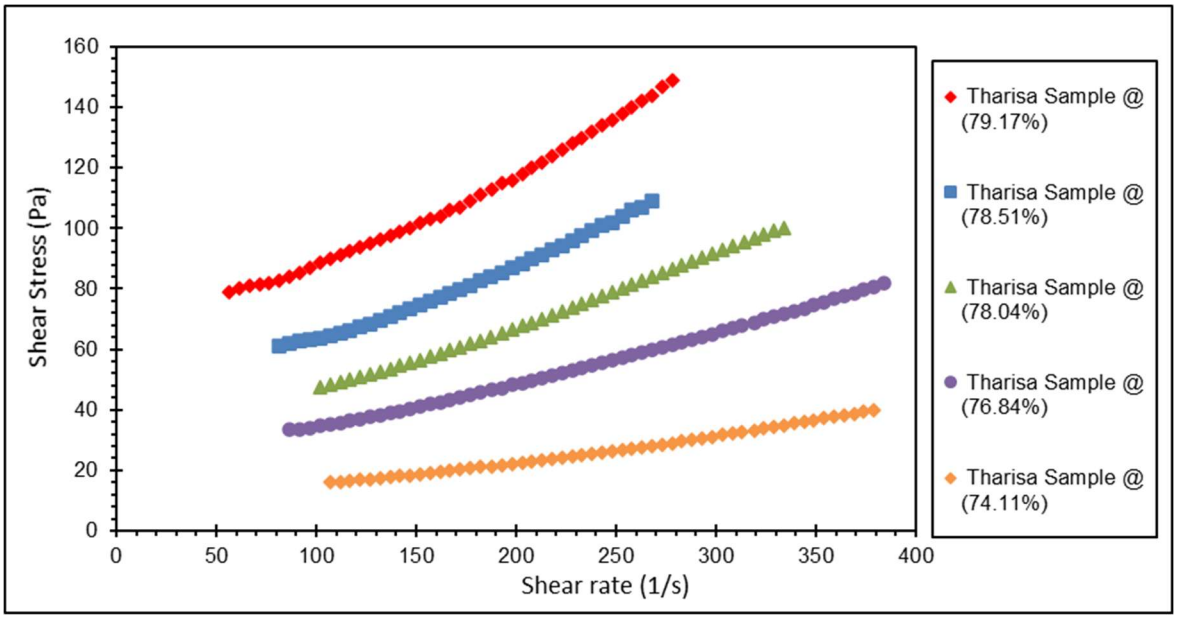


Figure 2: Rheogram Data – Tharisa Tailing Sample

4.3 Rheological characterisation

4.3.1 *Bingham Plastic model*

The Bingham model was used to model the flow behaviour of the sample. The Bingham model is a two parameter rheological model, i.e.:

$$y = a + bx$$

Where: y = shear stress (Pa)
a = Bingham plastic yield stress (Pa)
b = Bingham plastic viscosity (Pa.s)
x = shear rate (s^{-1})

The **apparent viscosity** is defined as the slope of a line drawn from the origin to a point on the rheogram corresponding to a specific shear rate. For a Bingham mixture, the apparent viscosity decreases with increasing shear rate.

Shear thinning refers to a decrease in the apparent viscosity with an increase in shear rate, while **shear thickening** refers to an increase in the apparent viscosity with an increase in shear rate.

The rheogram data was analysed by fitting the Bingham plastic model. The model data for the Bingham plastic model as generated by the RHEOPLUS/32 V3.31 software is presented in Appendix C.

Figure 3 and Figure 4 show the sheared yield stress and plastic viscosity as a function of mass solids concentration for the Tharisa Tailings samples.

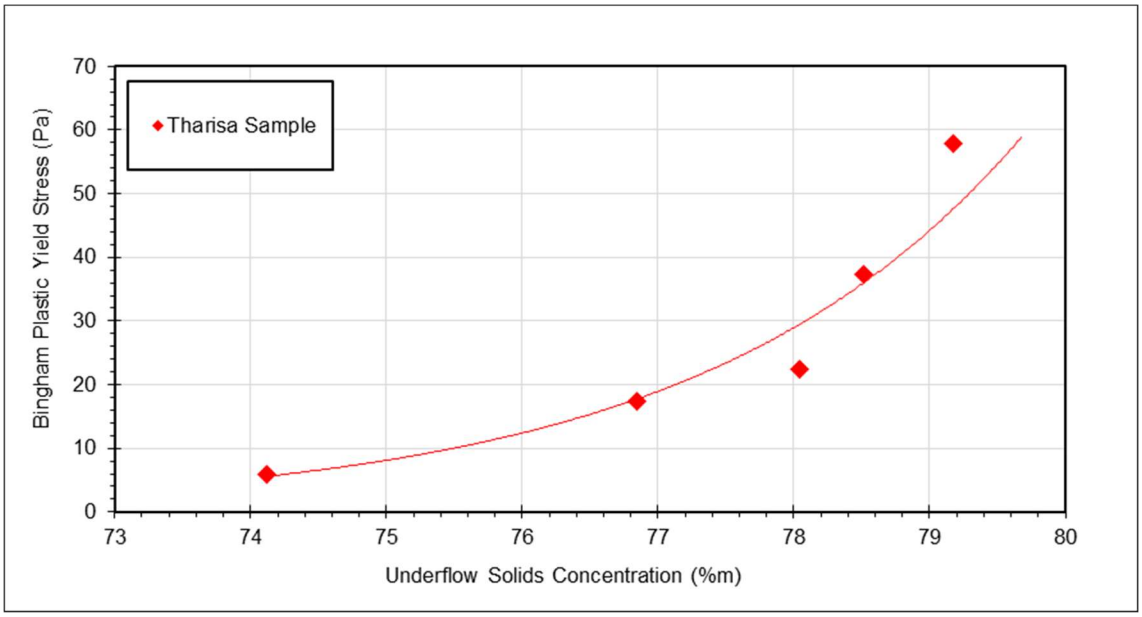


Figure 3: Sheared Yield Stress versus Mass Solids concentration

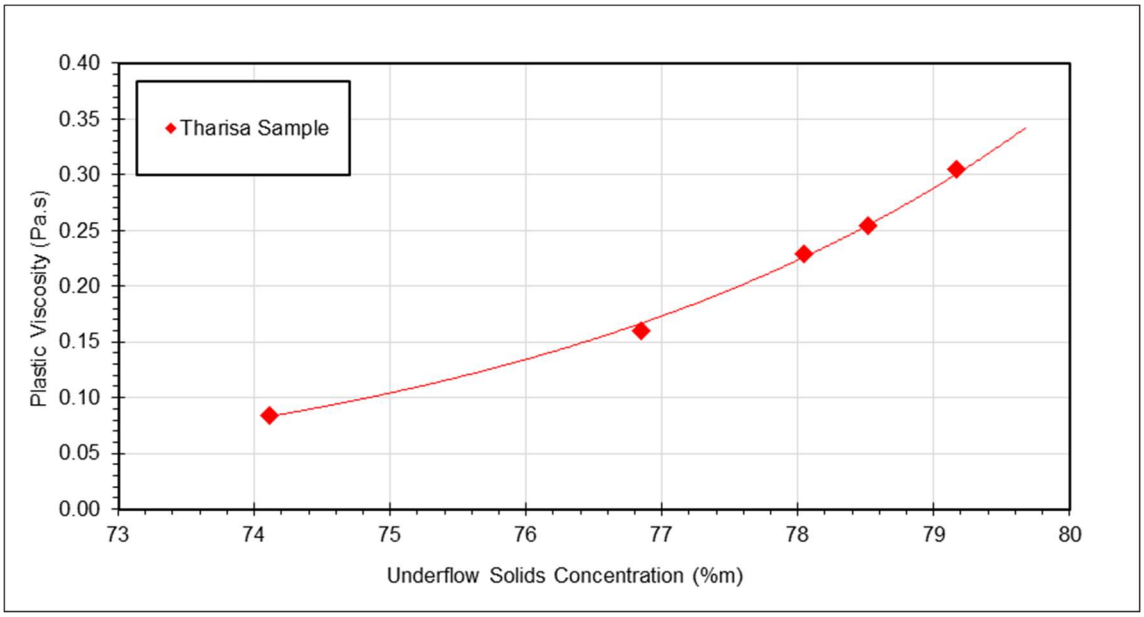


Figure 4: Plastic Viscosity versus Mass Solids concentration

4.4 Rheological Correlation

Table IV presents the correlations used to calculate the plastic viscosity (b) and Bingham yield stress (a) as a function of mass solids concentration (C):

Table IV: Rheological correlations

Tharisa Tailings	**Bingham Plastic Model**	
	Bingham Yield Stress	Plastic Viscosity
	Applicable Mass Solids Concentration (C) Range: 73.7%m – 78.9%m	
	$a = (1x10^{-13})e^{0.4239C}$	$b = (5x10^{-10})e^{0.2543C}$
	$R^2 = 0.93$	$R^2 = 0.99$

5. SUMMARY

The following conclusions are made from the rheology test work results of the Tharisa Tailings samples:

(1) The particle specific gravity of the Tharisa tailings material averaged to 3.2 g/cm^3.

(2) The particle size distribution of the Tharisa tailings material as determined by laser diffraction method, the analysis showed a particle d_{80} – 115.5µm and d_{50} – 38.2µm, with a proportion of particles larger than 500 µm of 1.91%m.

(3) The rheological flow behaviour of the Tharisa tailings material was analysed by applying the Bingham Plastic model to the rheogram data. A good model fit was obtained. Table IV presents the exponential rheological correlations as a function of slurry solids concentration by mass.

(4) The yield stress values calculated from a flow behaviour model depends on the model fit. Even though good model fits were obtained, Vietti Slurrytec recommends that if more accurate yield stress values are required a direct vane measurement is used instead of the bob & cup measurement.

Christopher van der Linde
Laboratory Scientist

19 April 2022

APPENDIX A – MATERIAL PROPERTIES RAW DATA

Particle Specific Gravity

VIETTI Slurrytec
Understanding slurry™

SG - DENSITY DATA WORKSHEET

STEREOPYCNOMETER

TRUE POWDER DENSITY

Sample ID: - EPO-THA-8980
Source: - Tharisa Deposition Pipeline
Tare weight: - 21.3584 g
Total weight: - 138.5406 g

Date: - 06/04/2022
Operator: - HM

DATA

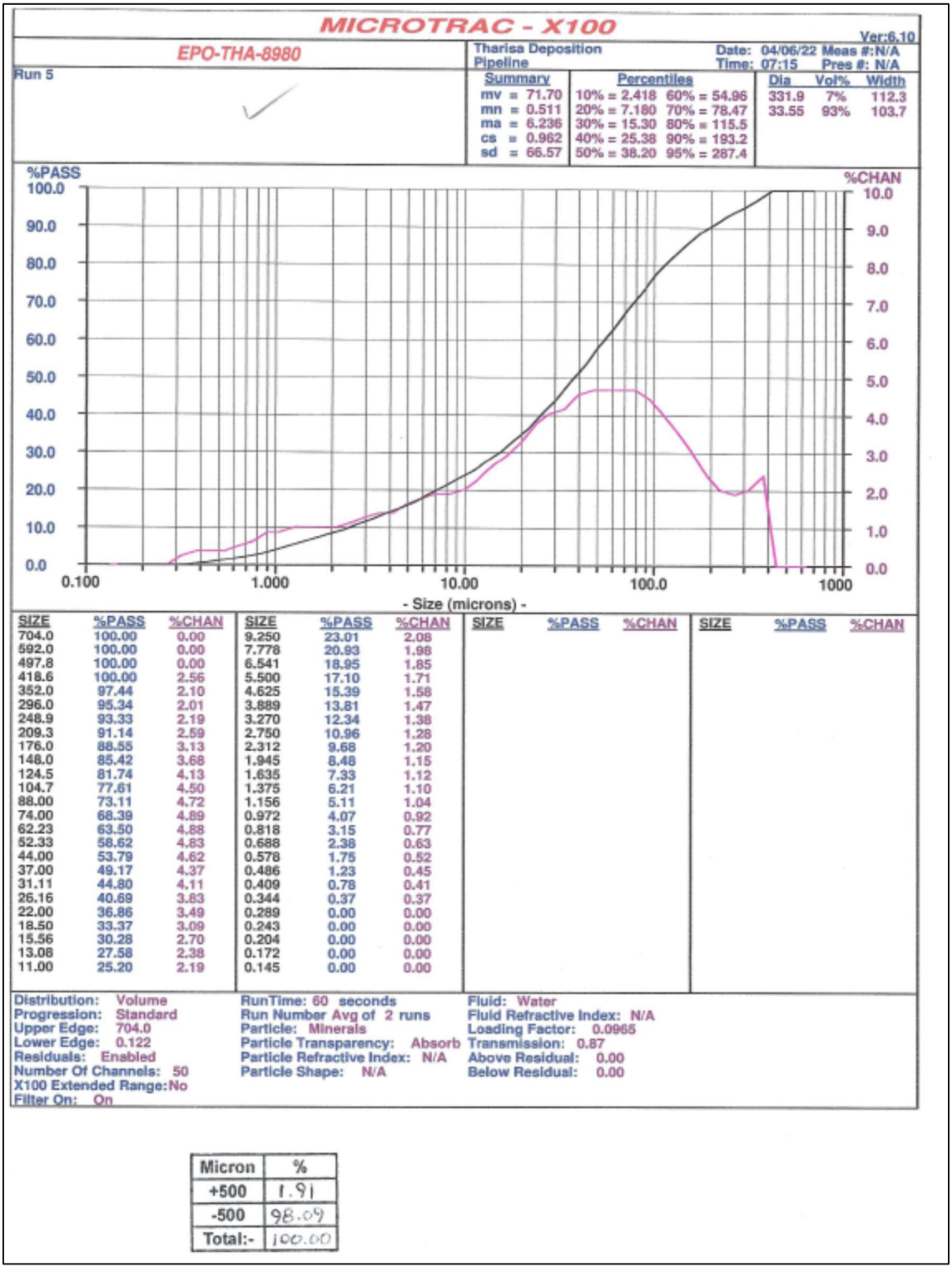
	Run 1		Run 2		Run 3	
P2	17.056		17.035		17.040	
P3	9.865		9.855		9.858	
Density	3.215	g/cc	3.221	g/cc	3.221	g/cc

Avg SG: - 3.219

P2 = Pressure reading after pressurizing cell

P3 = Pressure reading after added V A

Particle Size Distribution



MICROTRAC - X100 Ver:6.10

EPO-THA-8980

Tharisa Deposition Pipeline

Date: 04/06/22 Meas #:N/A
Time: 07:15 Pres #: N/A

Run 5

Summary		Percentiles		Dia	Vol%	Width
mv = 71.70		10% = 2.418	60% = 54.96	331.9	7%	112.3
mn = 0.511		20% = 7.180	70% = 78.47	33.55	93%	103.7
ma = 6.236		30% = 15.30	80% = 115.5			
cs = 0.962		40% = 25.38	90% = 193.2			
sd = 66.57		50% = 38.20	95% = 287.4			

%PASS 100.0 90.0 80.0 70.0 60.0 50.0 40.0 30.0 20.0 10.0 0.0

%CHAN 10.0 9.0 8.0 7.0 6.0 5.0 4.0 3.0 2.0 1.0 0.0

0.100 1.000 10.00 100.0 1000

- Size (microns) -

SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	23.01	2.08						
592.0	100.00	0.00	7.778	20.93	1.98						
497.8	100.00	0.00	6.541	18.95	1.85						
418.6	100.00	2.56	5.500	17.10	1.71						
352.0	97.44	2.10	4.625	15.39	1.58						
296.0	95.34	2.01	3.889	13.81	1.47						
248.9	93.33	2.19	3.270	12.34	1.38						
209.3	91.14	2.59	2.750	10.96	1.28						
176.0	88.55	3.13	2.312	9.68	1.20						
148.0	85.42	3.68	1.945	8.48	1.15						
124.5	81.74	4.13	1.635	7.33	1.12						
104.7	77.61	4.50	1.375	6.21	1.10						
88.00	73.11	4.72	1.156	5.11	1.04						
74.00	68.39	4.89	0.972	4.07	0.92						
62.23	63.50	4.88	0.818	3.15	0.77						
52.33	58.62	4.83	0.688	2.38	0.63						
44.00	53.79	4.62	0.578	1.75	0.52						
37.00	49.17	4.37	0.486	1.23	0.45						
31.11	44.80	4.11	0.409	0.78	0.41						
26.16	40.69	3.83	0.344	0.37	0.37						
22.00	36.86	3.49	0.289	0.00	0.00						
18.50	33.37	3.09	0.243	0.00	0.00						
15.56	30.28	2.70	0.204	0.00	0.00						
13.08	27.58	2.38	0.172	0.00	0.00						
11.00	25.20	2.19	0.145	0.00	0.00						

Distribution: Volume
Progression: Standard
Upper Edge: 704.0
Lower Edge: 0.122
Residuals: Enabled
Number Of Channels: 50
X100 Extended Range: No
Filter On: On

RunTime: 60 seconds
Run Number Avg of 2 runs
Particle: Minerals
Particle Transparency: Absorb
Particle Refractive Index: N/A
Particle Shape: N/A

Fluid: Water
Fluid Refractive Index: N/A
Loading Factor: 0.0965
Transmission: 0.87
Above Residual: 0.00
Below Residual: 0.00

Micron	%
+500	1.91
-500	98.09
Total:-	100.00

APPENDIX B – ROTATIONAL VISCOMETER TEST DATA

Refer to attached excel spreadsheet for data (EPO-THA-8980 (Raw & Model Data))

APPENDIX C – BINGHAM PLASTIC MODEL DATA

Refer to attached excel spreadsheet for data (EPO-THA-8980 (Raw & Model Data)