



**THURBER** ENGINEERING LTD.

## **MEMORANDUM**

To: Corinne Morden, P.Eng.,  
MTO Eastern Region P&D

Date: April 2020

From: Christopher Murray, P.Eng.  
(Reviewed by Fred Griffiths, P.Eng.)

Thurber File No.: 24726

**DRAFT**  
**INNOVATION STUDY – MEMO 1.3**  
**DETERMINATION OF STRENGTH PARAMETERS OF GRANULAR MATERIALS**  
**HIGHWAY 17 TWINNING, RENFREW AREA**  
**WP 4068-09-00 / ASSIGNMENT NO. 4018-E-0009**

This memorandum presents the results of Innovation Plan #1 for the Highway 17 Twinning project.

### **1. BACKGROUND**

The purpose of the Innovation Study is to develop project specific characteristic strength and unit weight values for use in detailed design for the granular materials local to the project site. Of particular interest are the aggregates used for structure backfill or in engineered granular pads to support shallow foundations and culverts.

Ultimately, the tender documents for highway construction will reference *OPSS.PROV 1010 Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material* which provides specifications regarding the gradation, physical properties and the source of the material that may be used for specific aggregate types. However, OPSS.PROV 1010 does not specify minimum strength parameters, the minimum unit weight or maximum unit weight of the aggregates.

Geotechnical design for lateral earth pressures (static and seismic), slope stability and bearing resistance of shallow foundations is based primarily on the soil's unit weight, the strength parameter (effective angle of internal friction,  $\phi$ ) and the geometry of the soil/structure. Since the strength parameter is not documented at the time of design, conservative design values are typically assumed. This can lead to overly conservative and less economical designs.

During this assignment, a literature review was carried out and the following two documents provided some guidance:

Scott et al. 1974. Triaxial Testing on Granular A Aggregate: this research report commissioned in part by the Ontario Ministry of Transportation, presents the results of a triaxial testing program on one quarry source and one pit source sample of Granular A acquired from the Ottawa area. It concluded that the angle of shearing resistance is inversely dependent on the confining pressure. Under a confining pressure of 34 kPa, the secant angle of shearing resistance was found to be 64° and 57° for the quarry and pit source samples respectively.

Nicks et al. 2015. Strength Characterization of Open-Graded Aggregates for Structural Backfill: this research study was based on large-scale direct shear and large-diameter triaxial tests. A total of 16 open graded aggregates were included in the testing however all samples generally have a much tighter gradation envelope than OPSS Granular A and would be considered poorly graded materials using USCS. The recommended default friction angle for the materials tested is 41°.

## 2. SCOPE

The scope of the current study was limited to the testing of OPSS Granular A (Gran A). The following table documents the extent of the testing program carried out:

**Table 2-1: Laboratory Testing Program**

Laboratory Tests	No. of Tests	Material Testing Reference	Designated Laboratory
Sieve analysis of aggregates	12	LS-602	Golder - Calgary
Moisture density relationship	12	LS-706	Golder - Calgary
Large Scale Direct Shear	12*	ASTM D3080	Golder - Calgary

Note: \* 3 samples for each test

After an extensive review of soils laboratories in Ontario, New Brunswick, Alberta and British Columbia, the Golder Laboratory in Calgary was selected to carry out the Large-Scale Direct Shear (LSDS) testing based on an assessment of equipment, availability and cost.

Golder's shear box in their Calgary laboratory is a custom-built 300 mm by 300 mm by 150 mm deep shear box. The normal force is applied via a hydraulic ram that engages a load cell and can be adjusted through flow-valves to vary load. The top box is fixed while the bottom box is on wheels that run on a track and are controlled through the horizontal hydraulic ram, Linear Variable Displacement Transducers (LVDTs) and Load cells measure the loads and displacement. A photo of the large-scale direct shear box is shown in Figure 1 below:



**Figure 1: Golder's Large-Scale Direct Shear box in Calgary, AB.**

### **3. APPROACH & METHODOLOGY**

#### **3.1 Sources and Sampling**

Thurber contacted available sources close to the Highway 17 twinning project area and obtained pit and quarry samples from those with Granular A available at the time of sampling. A plan showing the locations of the pits and quarries is appended. Samples were collected between November 19<sup>th</sup> and December 12<sup>th</sup>, 2019 in accordance with MTO Test Method LS-625, "Guidelines for Sampling of Aggregate Materials". Approximately 150 kg of each sample were acquired.

Summaries of the pit and quarry samples collected for testing are presented in Table 3-1 and Table 3-2, below:

**Table 3-1: Summary of Pit Source Granular A Samples Collected**

<b>Name</b>	<b>Identifier</b>	<b>Type</b>	<b>Source</b>
Bulk Sample 1*	BS1	Pit Source Granular A	Kluke Pit
Bulk Sample 2*	BS2	Pit Source Granular A	Kluke Pit
Bulk Sample 3	BS3	Pit Source Granular A	Nesbitt Pit
Bulk Sample 11	BS11	Pit Source Granular A	Cobus Pit

\* - Blind duplicate sample collected from the same source

**Table 3-2: Summary of Quarry Source Granular A Samples Collected**

<b>Name</b>	<b>Identifier</b>	<b>Type</b>	<b>Source</b>
Bulk Sample 4	BS4	Quarry Source Granular A	Burntlands Quarry
Bulk Sample 5	BS5	Quarry Source Granular A	Stittsville Quarry
Bulk Sample 6	BS6	Quarry Source Granular A	Packenham Quarry
Bulk Sample 7	BS7	Quarry Source Granular A	Kineburn Quarry
Bulk Sample 8	BS8	Quarry Source Granular A	Henderson Quarry
Bulk Sample 9	BS9	Quarry Source Granular A	Faught Quarry
Bulk Sample 10	BS10	Quarry Source Granular A	Haley Quarry
Bulk Sample 12	BS12	Quarry Source Granular A	Cobus Quarry





## 3.2 Testing Procedures

### 3.2.1 *Sample Preparation and Material Characterization*

Upon receipt of the samples, the samples underwent both gradation testing in accordance with LS-602 and Moisture Density Testing in accordance with LS-706. A summary of initial results is as follows:

- One of the pit source samples met the gradation requirements for Granular A.
- Three of the pit source samples were slightly high for percent passing on the 4.75 mm sieve at 56%, 56% and 58% versus the maximum acceptable value of 55% for Granular A.
- Five of the quarry source samples met the gradation requirements for Granular A.
- Three of the quarry source samples (BS6, BS7 and BS10) were low for percent passing on the 4.75 mm sieve at 32%, 31% and 25% versus the minimum acceptable value of 35% for Granular A. The same three quarry source samples are also low for percent passing on the 1.18 mm sieve at 11%, 13% and 9% versus the minimum acceptable value of 15%.

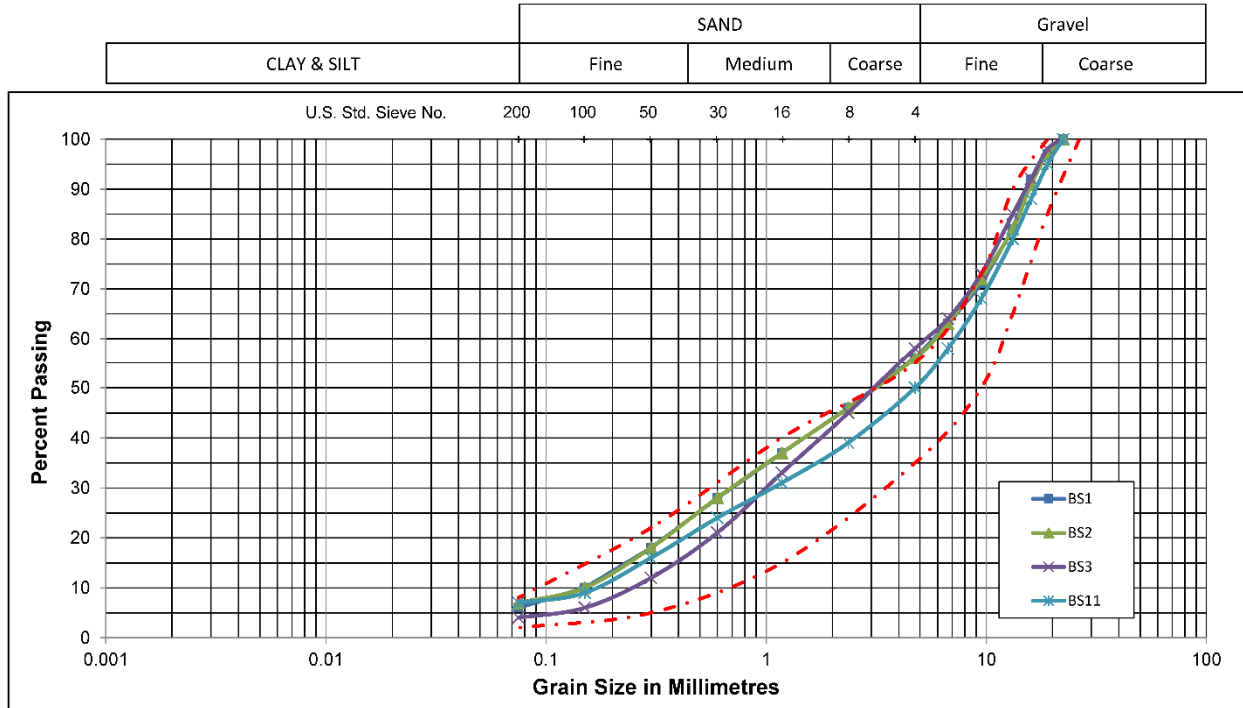
Based on these results, LSDS testing for the pit and quarry source samples which met the Granular A gradation requirements was carried out. It is noted that to meet ASTM D3080 the width of the shear box must be 10 times the maximum particle diameter, the initial thickness must be at least 6 times the maximum particle diameter and the minimum width-to-thickness ratio must be 2:1. Based on the minimum width to thickness ratio, the 300 mm x 300 mm x 150 mm shear box allows for a maximum particle size of 25 mm. Sample preparation therefore included removal of oversize particles by passing all samples through a 25 mm sieve prior to LSDS testing.

LSDS testing was also carried out on the three out-of-spec pit source samples as received since the gradations were only marginally out of spec for one sieve size. Furthermore, it was anticipated that the marginally fine gradation would have a slightly conservative effect on the shear box test results.

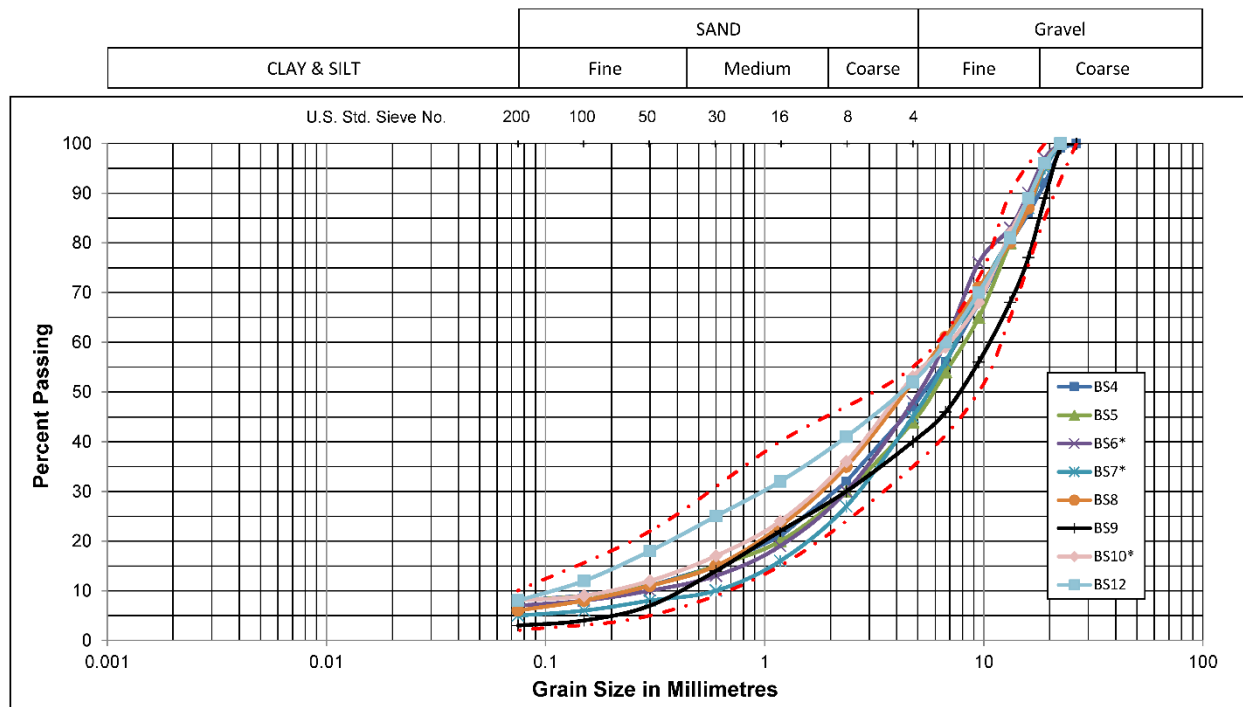
Prior to LSDS testing, the gradations of the three out-of-spec quarry samples were adjusted to generate in-spec materials by the removal of oversized material. These modified samples were re-tested to confirm gradation and establish the adjusted Moisture Density characteristics prior to completing shear box testing. It is noted that adjusted sample BS6 was marginally high for percent passing on the 9.5 mm sieve at 76% versus the maximum acceptable value of 73%. Direct shear testing on this sample was carried out as it was anticipated that the marginally fine gradation would have a slightly conservative effect on the shear box test results.

Gradation results are presented below in Figure 2 and Figure 3 and appended to this memo.

**Figure 2: Pit Source Granular A Gradation Curves with Gradation Specification Limits**



**Figure 3: Quarry Source Granular A Gradation Curves with Gradation Specification Limits**



Further material characterization resulting from the gradation and moisture density relationship testing is presented in Table 3-3 and Table 3-4 below:

**Table 3-3: Pit Source Material Characterization**

ID	% gravel	% sand	% fines	D <sub>60</sub> (mm)	D <sub>30</sub> (mm)	D <sub>10</sub> (mm)	C <sub>u</sub>	C <sub>c</sub>	γ <sub>d-max</sub> (kN/m <sup>3</sup> )	W <sub>opt</sub> (%)	USCS
BS1*	44	50	6	5.9	0.8	0.1	40.8	0.7	22.0	5.8	SP-SM
BS2*	44	49	7	5.9	0.7	0.1	41.5	0.7	21.9	5.6	SP-SM
BS3	42	54	4	5.4	1.0	0.3	21.3	0.7	21.2	5.6	SP
BS11	50	43	7	7.3	1.1	0.2	44.8	1.1	22.1**	6.0**	GW-GM

\* - Blind duplicate samples collected from the same source

\*\* - Presented values are corrected for oversize particles

**Table 3-4: Quarry Source Material Characterization**

ID	% gravel	% sand	% fines	D <sub>60</sub> (mm)	D <sub>30</sub> (mm)	D <sub>10</sub> (mm)	C <sub>u</sub>	C <sub>c</sub>	γ <sub>d-max</sub> (kN/m <sup>3</sup> )	W <sub>opt</sub> (%)	USCS
BS4	53	39	8	7.6	2.2	0.2	35.3	2.9	21.9**	5.6**	GW-GM
BS5	56	36	8	8.2	2.4	0.2	41.0	3.5	21.6	6.3	GP-GM
BS6*	52	41	7	6.6	2.4	0.3	23.1	3.0	22.0**	6.6**	GP-GM
BS7*	55	40	5	7.4	2.8	0.6	13.5	1.9	21.3**	5.3**	GW-GM
BS8	48	46	6	6.4	1.8	0.3	23.7	1.9	21.4	6.1	GW-GM
BS9	60	37	3	10.7	2.3	0.4	24.4	1.1	21.7**	4.9**	GW
BS10*	47	45	8	6.9	1.7	0.2	38.7	2.5	21.8**	6.0**	GW-GM
BS12	48	44	8	6.7	1	0.1	63.7	1.5	21.8	6.0	GW-GM

\* - Information reported for testing after gradation corrections for Samples BS6, BS7 and BS10

\*\* - Presented values are corrected for oversize particles

### 3.2.2 Direct Shear Testing

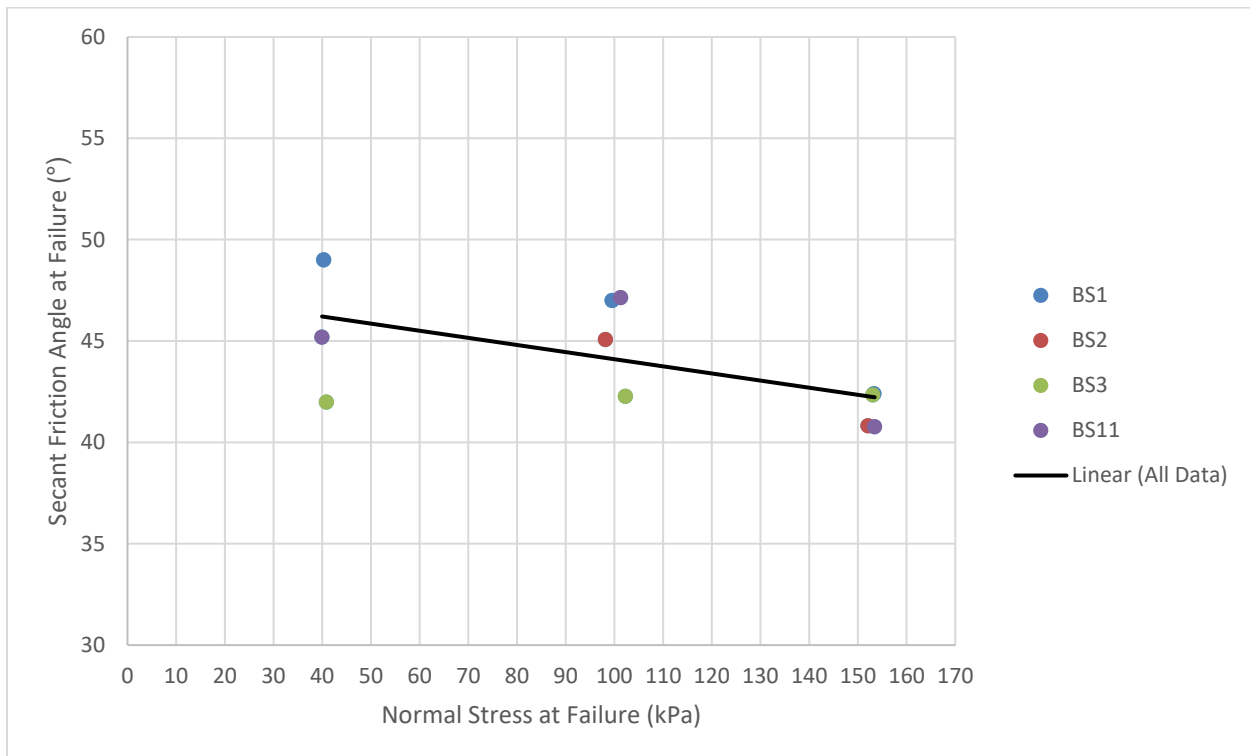
Following sample preparation, the specimens were compacted in equal lifts within the LSDS box following ASTM D3080. The shear testing was performed at 98% maximum dry density within +/- 2% of optimum moisture content to match conditions on site where the material would be used as structural backfill.

The LSDS testing was completed in accordance with ASTM D3080. Each material underwent LSDS testing at 3 normal stresses (40 kPa, 100 kPa and 150 kPa) which were selected to represent structural backfill conditions for depths ranging from approximately 1.8 m to 6.5 m. Inundation of the sample immediately followed the application of the normal stress with one-way drainage allowed to occur at the top of the box. The tests were conducted at a constant rate of horizontal displacement of 0.24 mm/min to a maximum horizontal displacement of 38 mm similar to a study performed by Bareither et al, 2008. The shear resistance due to box friction was determined using a shear load cell with an area correction related to the displacement/ movement of the box. These corrections were performed by the Golder Calgary lab, the results appended to this memo are post correction results.

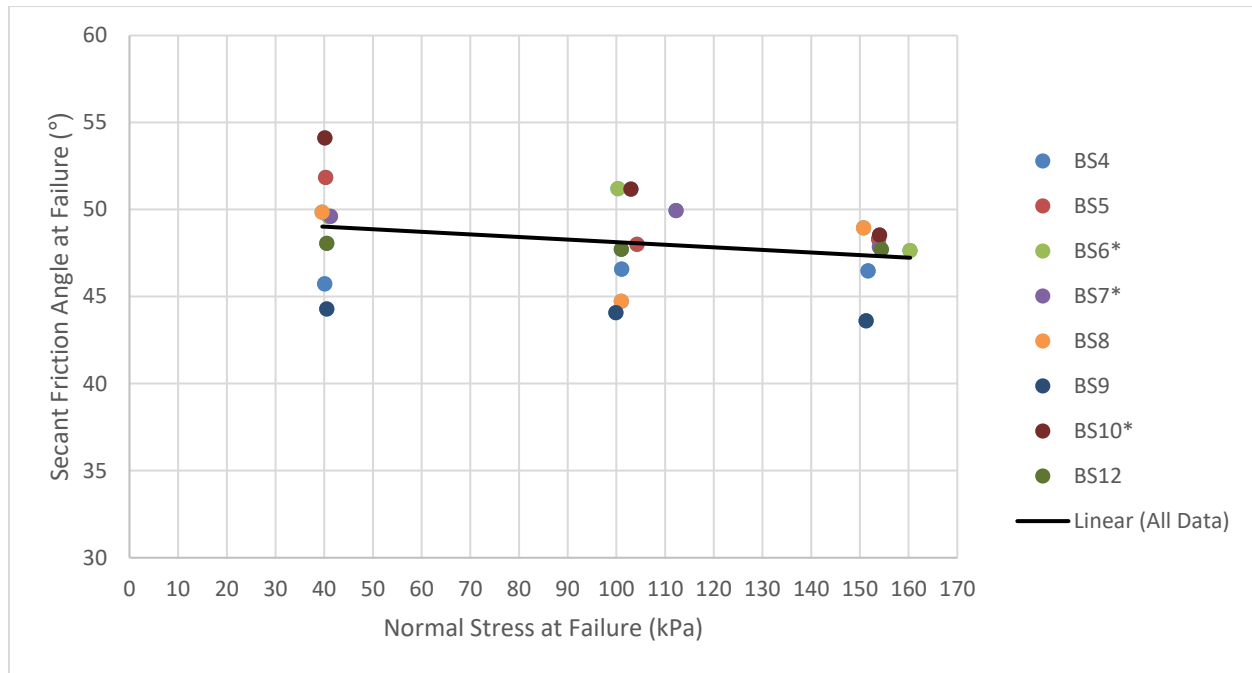
Shear failure was defined as the peak of the shear stress – relative horizontal displacement curve in tests exhibiting a distinct peak. If there was no obvious peak, the failure was defined as occurring at the maximum dilation angle closest to the plateau. Residual stress increases after the initial failure were ignored.

The results of the individual LSDS tests are appended to this memo. Initial plots of the secant friction angle at failure versus normal stress at failure were generated are shown as Figure 4 and Figure 5 below:

**Figure 4: Secant Friction Angle vs. Normal Stress at Failure for Pit Source Granular A**



**Figure 5: Secant Friction Angle vs. Normal Stress at Failure for Quarry Source Granular A**



These plots of secant friction angle at failure versus normal stress confirm the that friction angle is inversely dependent on confining pressure; i.e. the friction angle at higher normal stresses is less than that at lower normal stresses.

Based on the testing, the failure envelopes were plotted on a normal stress – shear stress plot; the slope of the Mohr-Coulomb best fit linear regression through the data points for each test was used to determine the shear strength for each sample of material for a confining pressure between 40 kPa and 150 kPa. The resulting individual sample friction angles for both pit and quarry sources are presented below in Table 3-5 and Table 3-6:

**Table 3-5: Estimated Pit Source Granular A Friction Angles**

ID	y-intercept (kPa)	$\phi'$	R <sup>2</sup>	Void ratio	$\gamma_{\text{bulk}}$ (kN/m <sup>3</sup> )
BS1*	16.4	39.7°	0.9811	0.23	22.9
BS2*	-8.3	43.8°	0.9609	0.23	22.6
BS3	-0.6	42.5°	1.0000	0.27	21.9
BS11	13.3	39.4°	0.9468	0.22	23.0
Average	5.2	41.4°	0.9722	0.24	22.6

ID	y-intercept (kPa)	$\phi'$	R <sup>2</sup>	Void ratio	$\gamma_{\text{bulk}}$ (kN/m <sup>3</sup> )
Standard Deviation	10.1	1.9°	0.0202	0.02	0.42

\* - Blind duplicate samples collected from the same source

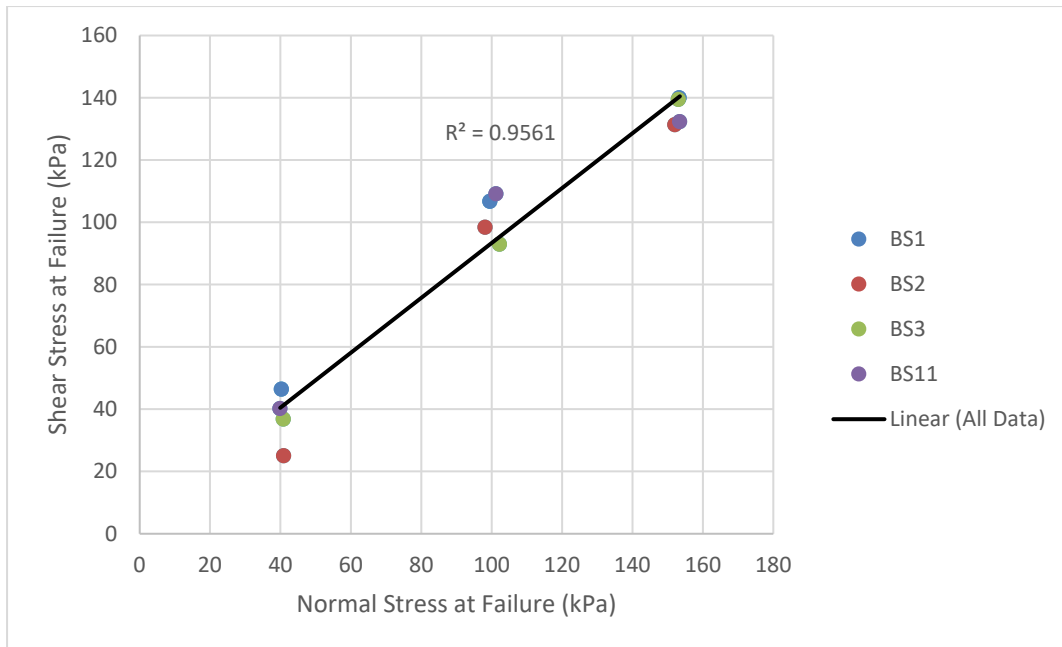
**Table 3-6: Estimated Quarry Source Granular A Friction Angles**

ID	y-intercept (kPa)	$\phi'$	R <sup>2</sup>	Void ratio	$\gamma_{\text{bulk}}$ (kN/m <sup>3</sup> )
BS4	-1.2	46.7°	0.9999	0.23	22.7
BS5	7.2	46.8°	0.9986	0.25	22.5
BS6*	8.7	46.9°	0.9861	0.23	23.0
BS7*	5.5	47.5°	0.9941	0.27	21.9
BS8	-2.5	48.3°	0.9773	0.26	22.2
BS9	1.6	43.4°	0.9998	0.24	22.3
BS10*	15.5	46.3°	0.9956	0.24	22.7
BS12	0.7	47.6°	1.0000	0.24	22.8
Average	4.4	46.7°	0.9939	0.25	22.5
Standard Deviation	5.6	1.4°	0.0077	0.01	0.34

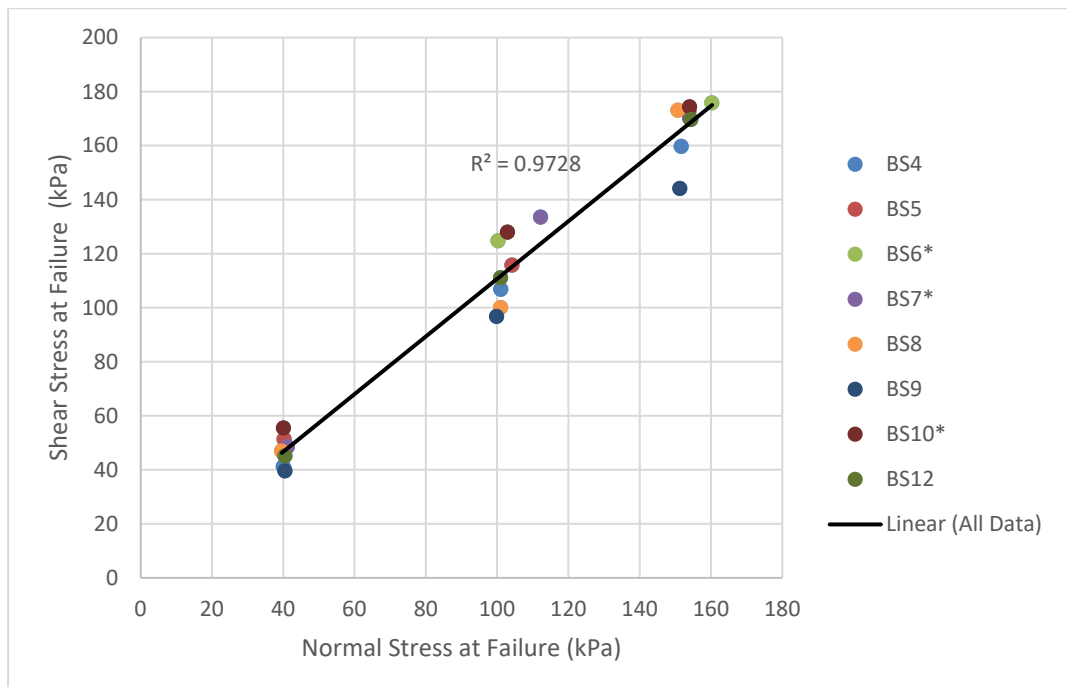
\* - Information reported for testing after gradation corrections for Samples BS6, BS7 and BS10

Alternatively, the failure shear stresses and normal stresses for each test were plotted in aggregate for both the pit and quarry source materials. These plots are shown as Figure 6 and Figure 7 below:

**Figure 6: Mohr-Coulomb Best Fit for all Pit Source Granular A LSDS Tests.**



**Figure 7: Mohr-Coulomb Best Fit for all Quarry Source Granular A LSDS Tests.**







The  $R^2$  value is shown on each plot and differed slightly from the average  $R^2$  values of the individual tests due to the increased sample size. The slope (angle of internal friction) of the linear regression analyses on the aggregate data were the same as the average slope of the individual tests. The regression analysis on the aggregate data showed the lower bound of the 99.7% confidence interval (i.e. three standard deviations below the mean) to be  $34.5^\circ$  for pit source Granular A and  $43.5^\circ$  for the quarry source Granular A.

#### 4. ENGINEERING RECOMENDATIONS

The measured friction angles range between  $39.4^\circ$  and  $43.8^\circ$  with an average of  $41.4^\circ$  for individual pit source Granular A material and  $43.4^\circ$  and  $48.3^\circ$  with an average of  $46.7^\circ$  for individual quarry source Granular A material. The results are generally within 5 percent of the average values for both pit source and quarry source materials.

It should be noted that using a linear Mohr-Coulomb interpretation results in a cohesion value for each test because the y-intercept of the best-fit approximation is not zero. It is known that these Granular A samples are not cohesive; this inconsistency is attributed to the fact that the failure envelope is nonlinear. Aggregate interlocking, particle crushing and dilation occurring during shearing (depending on the applied normal stress) also has an effect. In reality, the friction angle decreases with increased applied normal stress, see Figures 4 and 5 (FHWA-HRT-15-034, 2015).

A  $4.1^\circ$  difference was noted in the friction angles for the blind duplicate samples BS1 and BS2 despite almost identical gradation and moisture density relationships. This fact combined with the higher standard deviation and lower average  $R^2$  value highlights the variability of pit source Granular A material when compared to quarry source.

Based on the results presented above and applying a three standard deviation 99.7% confidence lower boundary of the aggregated data, the friction angle and bulk unit weight parameters recommended for the Highway 17 Twinning contract(s) are as follows:

##### Pit Source Granular A

$$\phi' = 35^\circ$$

$$\gamma = 22.8 \text{ kN/m}^3$$

##### Quarry Source Granular A

$$\phi' = 40^\circ$$

$$\gamma = 22.8 \text{ kN/m}^3$$

It is noted that the calculated 99.7% lower bound friction angle of the quarry source material is actually  $43.5^\circ$  based on the aggregated data which is in agreement with the previous papers reviewed during this study. Nonetheless, it is recommended that a lower  $40^\circ$  friction angle be used for design purposes as it allows for some additional variability and an added safety factor.

It is also noted that the testing in this study was completed at confining pressures ranging from 40 kPa and 150 kPa. During this study, it was confirmed (see Figure 4 and Figure 5) that the friction angle is inversely dependent on confining pressure. Application of the recommended friction angles to locations with a higher confining pressure is not recommended as the results will be non-conservative.



The average bulk unit weight values generated in this study are in close agreement with the 22.8 kN/m<sup>3</sup> typically assumed for Granular A materials. No adjustment to the standard practice is recommended with respect to bulk unit weight.

It is recommended that the an NSSP be included in the contract(s) for this project indicating that Granular A used as structural backfill for this assignment shall be from a quarry source. The Foundation Investigation and Design Reports will utilize the recommended friction angle presented above for quarry source Granular A in derivation of earth pressure parameters.

## 5. CONCLUSION

We trust the above provides the information you require at this time. If you have any questions regarding this memorandum, please contact the undersigned.

Regards,  
Thurber Engineering Ltd.

Christopher Murray, M.A.Sc., P.Eng.  
Geotechnical Engineer

Dr. Fred Griffiths, P.Eng.  
Senior Associate | Senior Geotechnical Engineer

P.K. Chatterji, Ph.D., P.Eng.  
Designated Foundation Engineer

Cc: Veronica Ayetan, P.Eng., MTO Foundations Group  
Tony Sangiuliano, P.Eng., MTO Foundations Group



## 6. REFERENCES

- ASTM D3080, 2011. "Standard Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions." *ASTM International*
- Bareither, C.A., 2006. "Shear strength of backfill sands in Wisconsin." M.Sc. thesis Department of Geological Engineering, University of Wisconsin-Madison, Madison, Wisconsin.
- Bareither, C.A., Benson, C.H. and Edil, T.B., 2008. "Comparison of shear strength of sand backfills measured in small-scale and large-scale direct shear tests." *Canadian Geotechnical Journal*, 45(9), pp.1224-1236.
- Nicks, J.E., Gebrenegus, T. and Adams, M.T., 2015. "Strength Characterization of Open-Graded Aggregates for Structural Backfills." US Department of Transportation FHWA-HRT-15-034.
- OPSS.PROV 1010, 2013. "Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material." *Ministry of Transportation Ontario*.
- Scott, J.D., Bauer, G.E. and Shields, D.H. 1974 (?). "Final Report on Triaxial Testing on Granular A Aggregate." Joint Transportation and Communication Research Program Project 0-1.



# Aggregate Source Location Plan

INNOVATION STUDY - MEMO 1.3  
DETERMINATION OF STRENGTH PARAMETERS OF GRANULAR MATERIALS  
HIGHWAY 17 TWINNING, RENFREW AREA  
WP 4068-09-00 / ASSIGNMENT NO. 4018-E-0009

## Legend

- Part 1A
- Part 1B
- Part 2
- Aggregate Source



Google Earth

Image Landsat / Copernicus

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## PRAIRIES AND NORTH LABORATORIES

**ATTN:** Christopher Murray, M.A.Sc., P.Eng  
Geotechnical Engineer  
Thurber Engineering Ltd.

**Received:** 10-Dec-19  
**Report Date:** 06-Mar-20  
**Version:** Final

## GEOTECHNICAL LABORATORY TEST REPORT

**Client:** Thurber Engineering Ltd.  
**Project Title:** Thurber Large Scale Direct Shear Testing - Index  
**Client Reference No.:** PROJECT 24726 HIGHWAY 17 ARNPRIOR TO HALEY  
STATION  
**Golder Billing:** 19115286.27.1  
**Lab Schedule No.:** D317

A handwritten signature in black ink, appearing to read 'M. Becker', positioned above a horizontal line.

**Matthew Becker**

Geotechnical Laboratory Manager  
Calgary Geotechnical Laboratory  
Golder Associates Ltd.

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Our liability is limited to the cost of the test requested. The test results only relate to the sample as received. No liability in whole or in part is assumed for the collection, handling or transport of the sample, application or interpretation of the test data or results.

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**Golder Associates Ltd., Bay 8, 820 28th Street NE, Calgary Alberta, Canada T2K 6K1**  
**Tel. (403) 248-6386 Fax. (403) 248-6387**

Project No.: 19115286  
 Short Title: Thurber Large Scale Direct Shear Testing - Index  
 Tested By: SP

Phase: 27.1  
 Sched: D317  
 Date: 6-Mar-20

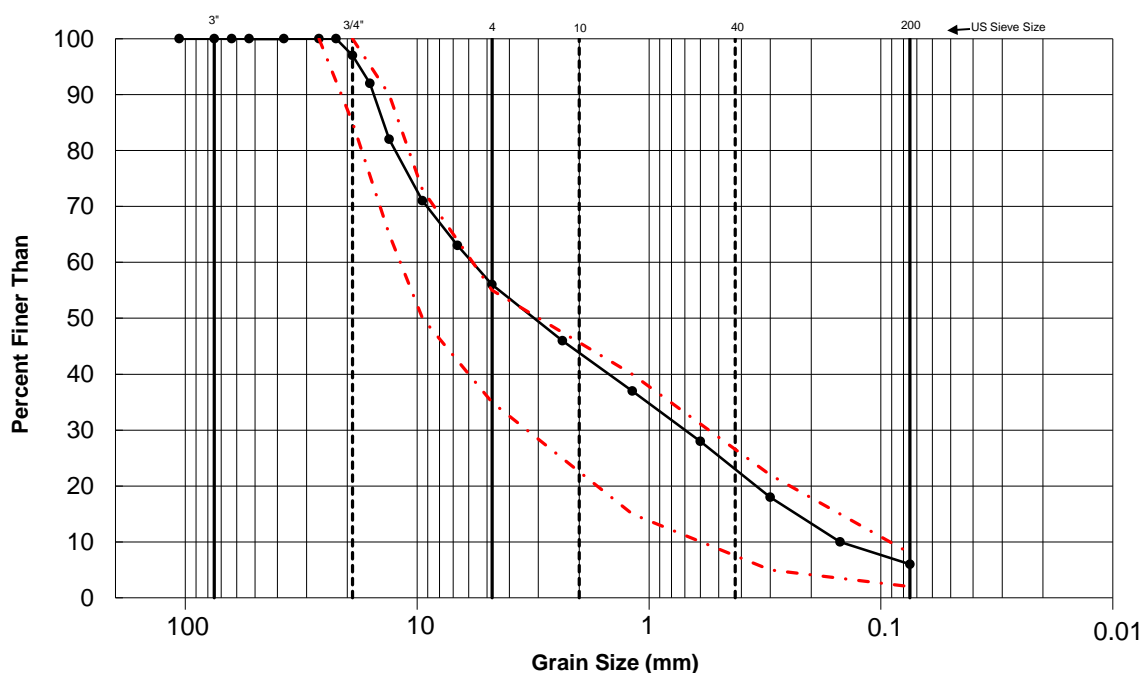
Sample Identification				Laboratory Test Results		
Bulk Sample No.	Sample	Type	Lab No.	As Received Water Content (%)	Standard Proctor Maximum Dry Density (kg/m <sup>3</sup> )	Optimum Water Content (%)
Bulk Sample #1	BS1 1-8	Pit	D317-01	4.0	2241	5.8
Bulk Sample #2	BS2 1-8	Pit	D317-02	4.5	2236	5.6
Bulk Sample #3	BS3 1-8	Pit	D317-03	3.0	2165	5.6
Bulk Sample #11	BS11 1-6	Pit	D317-04	5.4	* 2253	* 6.0
Bulk Sample #4	BS4 1-6	Quarry	D317-05	5.3	* 2236	* 5.6
Bulk Sample #5	BS5 1-6	Quarry	D317-06	3.1	2206	6.3
Bulk Sample #6	BS6 1-6	Quarry	D317-07	1.6	* 2080	* 4.5
Bulk Sample #6 (Adjusted)	BS6 1-6	Quarry	D317-07	1.6	*2245	*6.6
Bulk Sample #7	BS7 1-6	Quarry	D317-08	2.8	* 2170	* 6.0
Bulk Sample #7 (Adjusted)	BS7 1-6	Quarry	D317-08	2.8	*2171	*5.3
Bulk Sample #8	BS8 1-6	Quarry	D317-09	1.1	2184	6.1
Bulk Sample #9	BS9 1-6	Quarry	D317-10	2.5	* 2213	* 4.9
Bulk Sample #10	BS10 1-6	Quarry	D317-11	2.1	* 2035	* 6.0
Bulk Sample #10 (Adjusted)	BS10 1-6	Quarry	D317-11	2.1	*2219	*6.0
Bulk Sample #12	BS12 1-6	Quarry	D317-12	4.4	2224	6.0

Note: \* presented values are corrected for oversize

## METHOD OF TEST FOR SIEVE ANALYSIS OF AGGREGATES

(Ministry of Transportation, Ontario, Test Method LS-602 Rev. No. 33)

Project No.:	19115286	Phase:	27.1	Date:	19-Dec-19
Short Title:	Thurber Large Scale Direct Shear Testing - Index				
Sub Sampled By:	JG	Washed By:	JG	Sieved By:	JG
Field Tag No.:	-	Source:	-	Sample Type:	Pit
Lab No.:	D317-01	Northing:	-	Sample No.:	Bulk Sample #1
Sampled By:	Client	Easting:	-	Depth From:	- m
Sample Date:	-	Elevation:	- m	Depth To:	- m
Boundary Plot:	MTO Granular A - Pit	Drying Method:	Oven		
Composite Sieve:	Yes	if Yes, Split on:	4.75 mm		
Material Excluded from Sieve:	No	Describe:			
Prior Testing on Sample:	No	Describe:			



Sieve Size (mm)	Passing %
106.0	100
75.0	100
63.0	100
53.0	100
37.5	100
26.5	100
22.4	100
19.0	97
16	92
13.2	82
9.5	71
6.70	63
4.75	56
2.36	46
1.180	37
0.600	28
0.300	18
0.150	10
0.075	6

Cobbles	Coarse	Fine	Coarse	Medium	Fine	Silt and Clay Size
	Gravel Size		Sand Size			

Received Water Content (%)	Cobbles (%)	Gravel (%)	Sand (%)	Fines (%)	D60 (mm)	D30 (mm)	D10 (mm)	Cu	Cc
4.0	0	44	50	6	5.9	0.8	0.1	40.8	0.7

Sample Description: (SP-SM) fine to coarse SAND and fine angular GRAVEL, some non-plastic fines; brown; non-cohesive

USCS Classification: SP-SM

Remarks:

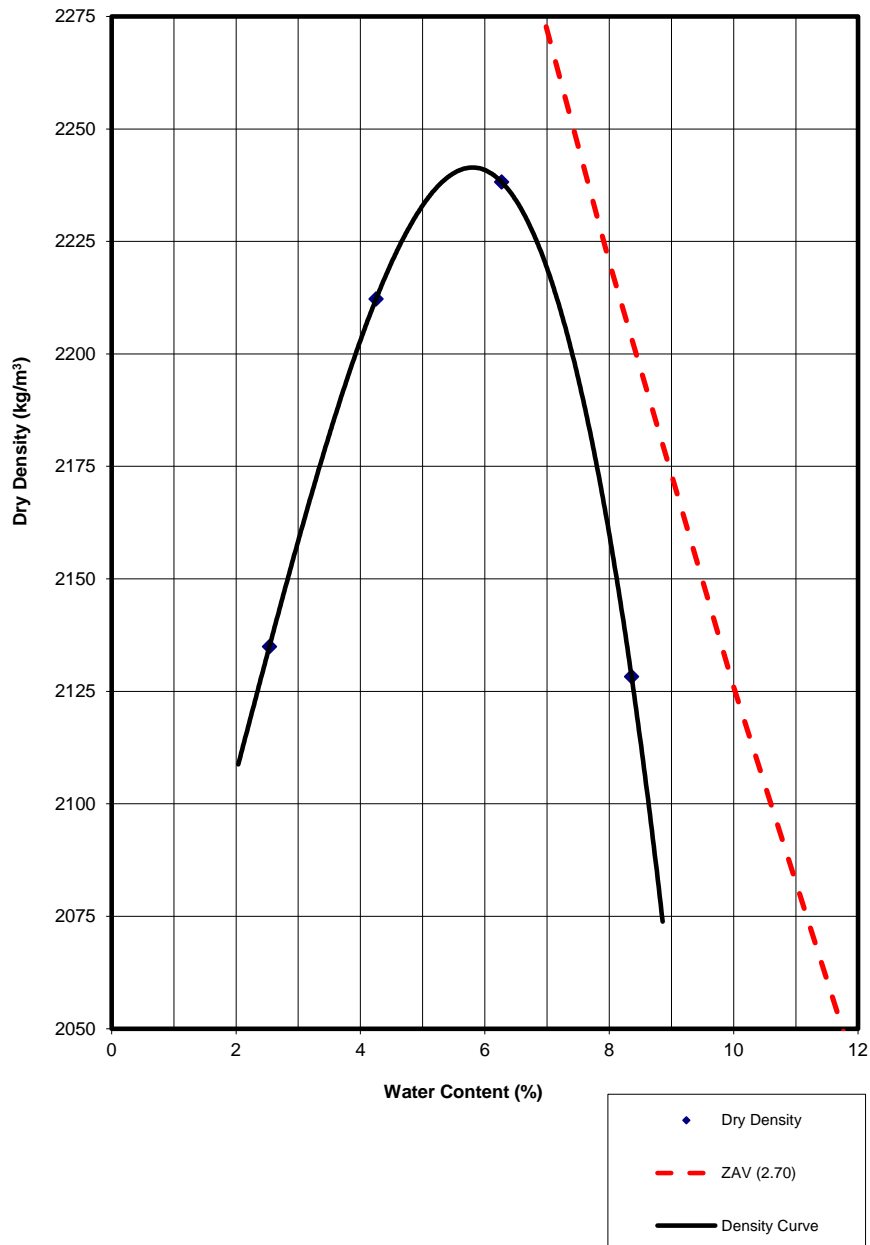


# LABORATORY COMPACTION CHARACTERISTICS OF SOIL USING STANDARD EFFORT

(Ministry of Transportation, Ontario, Test Method LS-706 Rev. No. 33/ ASTM D698)

Project No.:	19115286	Phase:	27.1
Short Title:	Thurber Large Scale Direct Shear Testing - Index	Lab No.:	D317-01
Tested By:	SP	Test Date:	17-Dec-17
Bulk Sample No.:	1	Date Sampled:	-
Sample ID:	BS1-1 to BS1-8	Sample Type:	Pit
Sampled By:	Client	Remarks:	-

## MOISTURE DENSITY RELATIONSHIP



### Maximum Dry Density

Max. Dry Density 2241 kg/m<sup>3</sup>

Optimum w 5.8 %

Method C

### Rock Correction (if required)

% Oversize \_\_\_\_\_ %

Max. Dry Density \_\_\_\_\_ kg/m<sup>3</sup> @ \_\_\_\_\_

Assumed Specific Gravity = 2.70

### Sample Description:

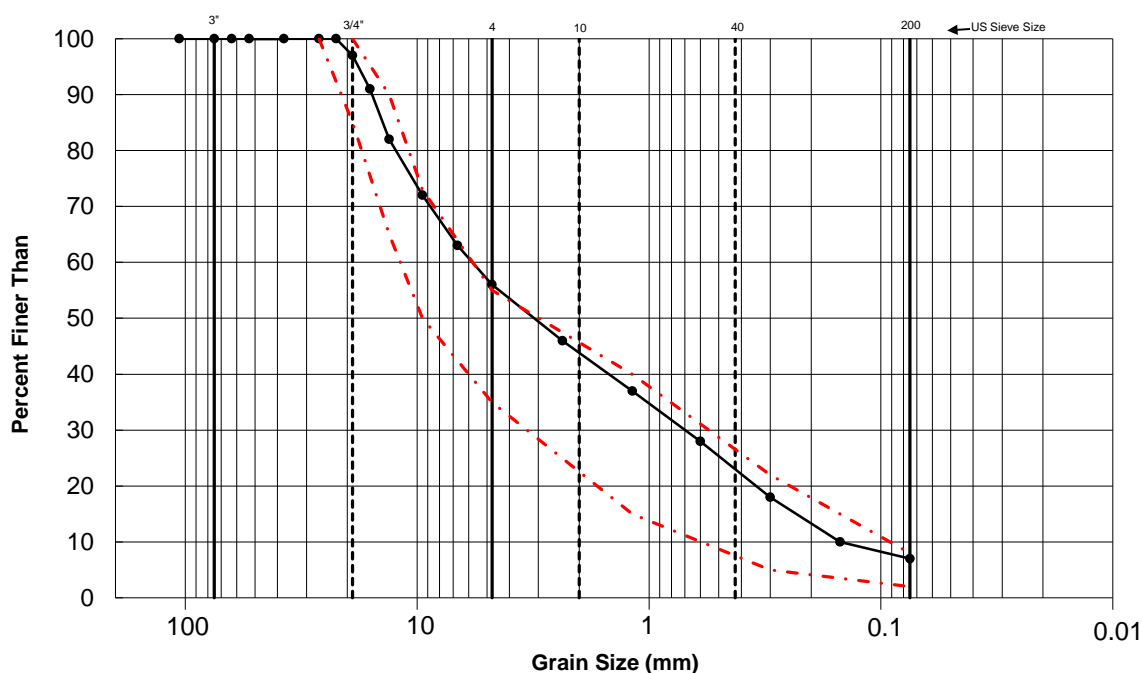
(SP-SM) fine to coarse SAND and fine angular GRAVEL, some non-plastic fines; brown; non-cohesive, moist.

As Received Water Content: 4.0%

## METHOD OF TEST FOR SIEVE ANALYSIS OF AGGREGATES

(Ministry of Transportation, Ontario, Test Method LS-602 Rev. No. 33)

Project No.:	19115286	Phase:	27.1	Date:	19-Dec-19
Short Title:	Thurber Large Scale Direct Shear Testing - Index				
Sub Sampled By:	JG	Washed By:	JG	Sieved By:	JG
Field Tag No.:	-	Source:	-	Sample Type:	Pit
Lab No.:	D317-02	Northing:	-	Sample No.:	Bulk Sample #2
Sampled By:	Client	Easting:	-	Depth From:	- m
Sample Date:	-	Elevation:	- m	Depth To:	- m
Boundary Plot:	MTO Granular A - Pit	Drying Method:	Oven		
Composite Sieve:	Yes	if Yes, Split on:	4.75 mm		
Material Excluded from Sieve:	No	Describe:			
Prior Testing on Sample:	No	Describe:			



Sieve Size (mm)	Passing %
106.0	100
75.0	100
63.0	100
53.0	100
37.5	100
26.5	100
22.4	100
19.0	97
16	91
13.2	82
9.5	72
6.70	63
4.75	56
2.36	46
1.180	37
0.600	28
0.300	18
0.150	10
0.075	7

Cobbles	Coarse	Fine	Coarse	Medium	Fine	Silt and Clay Size
	Gravel Size		Sand Size			

Received Water Content (%)	Cobbles (%)	Gravel (%)	Sand (%)	Fines (%)	D60 (mm)	D30 (mm)	D10 (mm)	Cu	Cc
4.5	0	44	49	7	5.9	0.7	0.1	41.5	0.7

Sample Description: (SP-SM) fine to coarse SAND and fine angular GRAVEL, some non-plastic fines; brown; non-cohesive

USCS Classification: SP-SM

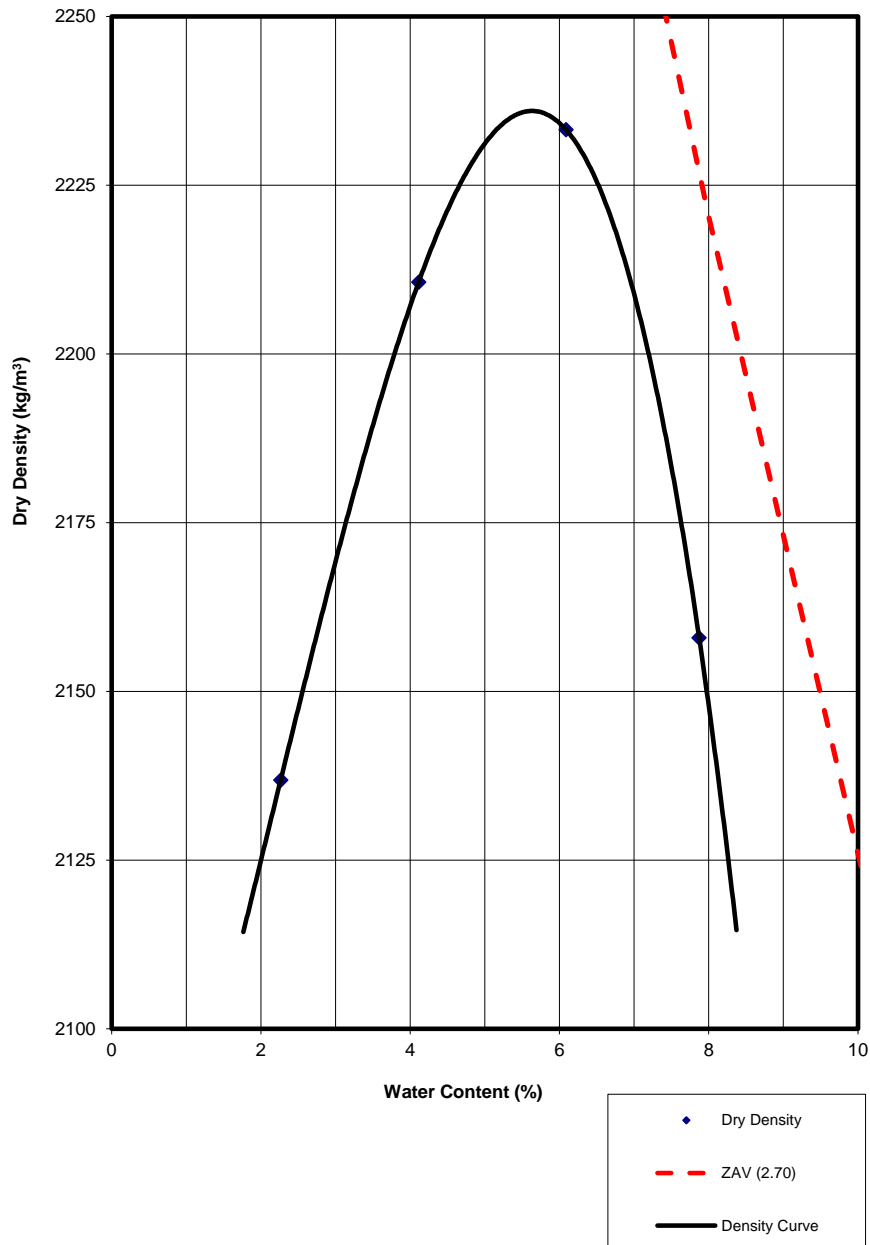
Remarks:

# LABORATORY COMPACTION CHARACTERISTICS OF SOIL USING STANDARD EFFORT

(Ministry of Transportation, Ontario, Test Method LS-706 Rev. No. 33/ ASTM D698)

Project No.:	19115286	Phase:	27.1
Short Title:	Thurber Large Scale Direct Shear Testing - Index	Lab No.:	D317-02
Tested By:	SP	Test Date:	17-Dec-17
Bulk Sample No.:	2	Date Sampled:	-
Sample ID:	BS2-1 to BS2-8	Sample Type:	Pit
Sampled By:	Client	Remarks:	-

## MOISTURE DENSITY RELATIONSHIP



### Maximum Dry Density

Max. Dry Density 2236 kg/m<sup>3</sup>

Optimum w 5.6 %

Method C

### Rock Correction (if required)

% Oversize \_\_\_\_\_ %

Max. Dry Density \_\_\_\_\_ kg/m<sup>3</sup> @ \_\_\_\_\_

Assumed Specific Gravity = 2.70

### Sample Description:

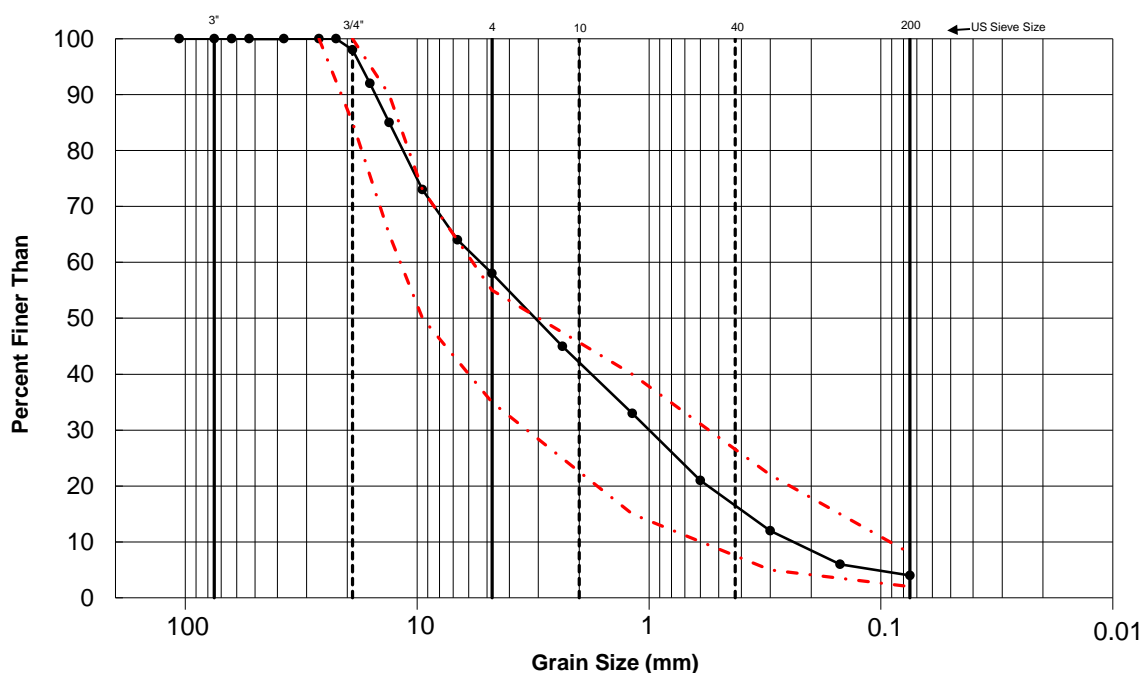
(SP-SM) fine to coarse SAND and fine angular GRAVEL, some non-plastic fines; brown; non-cohesive, moist.

As Received Water Content: 4.5%

## METHOD OF TEST FOR SIEVE ANALYSIS OF AGGREGATES

(Ministry of Transportation, Ontario, Test Method LS-602 Rev. No. 33)

Project No.:	19115286	Phase:	27.1	Date:	23-Dec-19
Short Title:	Thurber Large Scale Direct Shear Testing - Index				
Sub Sampled By:	JG	Washed By:	JG	Sieved By:	JG
Field Tag No.:	-	Source:	-	Sample Type:	Pit
Lab No.:	D317-03	Northing:	-	Sample No.:	Bulk Sample #3
Sampled By:	Client	Easting:	-	Depth From:	- m
Sample Date:	-	Elevation:	- m	Depth To:	- m
Boundary Plot:	MTO Granular A - Pit	Drying Method:	Oven		
Composite Sieve:	Yes	if Yes, Split on:	4.75 mm		
Material Excluded from Sieve:	No	Describe:			
Prior Testing on Sample:	No	Describe:			



Sieve Size (mm)	Passing %
106.0	100
75.0	100
63.0	100
53.0	100
37.5	100
26.5	100
22.4	100
19.0	98
16	92
13.2	85
9.5	73
6.70	64
4.75	58
2.36	45
1.180	33
0.600	21
0.300	12
0.150	6
0.075	4

Cobbles	Coarse	Fine	Coarse	Medium	Fine	Silt and Clay Size
	Gravel Size		Sand Size			

Received Water Content (%)	Cobbles (%)	Gravel (%)	Sand (%)	Fines (%)	D60 (mm)	D30 (mm)	D10 (mm)	Cu	Cc
3.0	0	42	54	4	5.4	1.0	0.3	21.3	0.7

Sample Description: (SP) fine to coarse SAND and fine angular GRAVEL, trace non-plastic fines; brown; non-cohesive

USCS Classification: SP

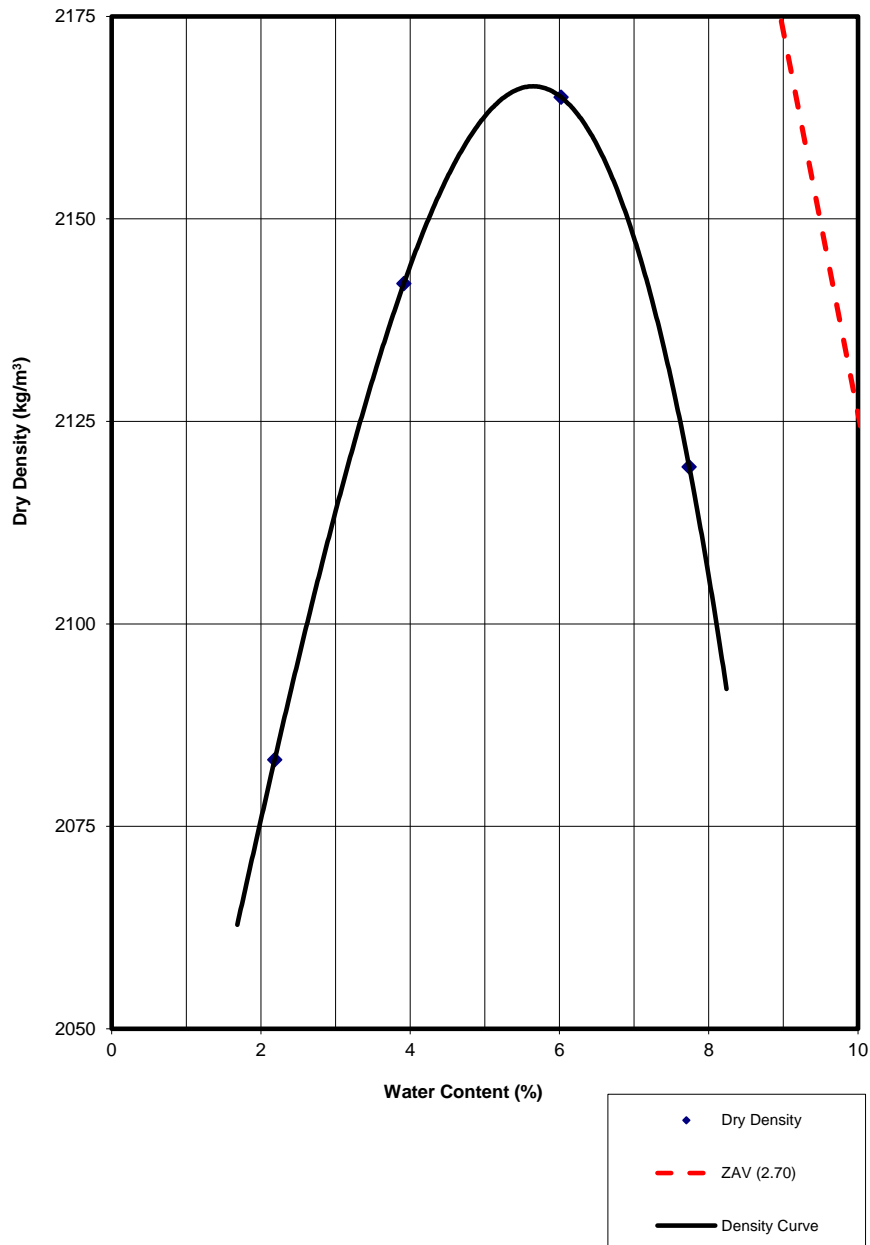
Remarks:

# LABORATORY COMPACTION CHARACTERISTICS OF SOIL USING STANDARD EFFORT

(Ministry of Transportation, Ontario, Test Method LS-706 Rev. No. 33/ ASTM D698)

Project No.:	19115286	Phase:	27.1
Short Title:	Thurber Large Scale Direct Shear Testing - Index	Lab No.:	D317-03
Tested By:	SP	Test Date:	18-Dec-17
Bulk Sample No.:	3	Date Sampled:	-
Sample ID:	BS3-1 to BS3-8	Sample Type:	Pit
Sampled By:	Client	Remarks:	-

## MOISTURE DENSITY RELATIONSHIP



### Maximum Dry Density

Max. Dry Density 2165 kg/m<sup>3</sup>

Optimum w 5.6 %

Method C

### Rock Correction (if required)

% Oversize \_\_\_\_\_ %

Max. Dry Density \_\_\_\_\_ kg/m<sup>3</sup> @ \_\_\_\_\_

Assumed Specific Gravity = 2.70

### Sample Description:

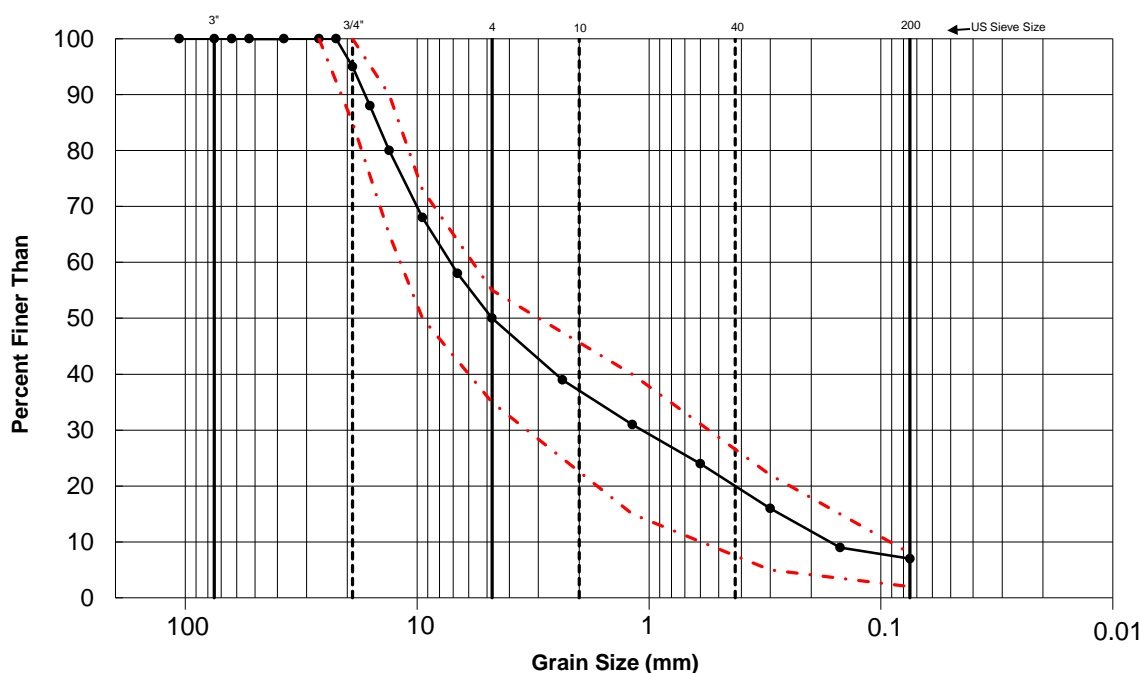
(SP) fine to coarse SAND and fine angular GRAVEL, trace non-plastic fines; brown; non-cohesive, moist

As Received Water Content: 3.0%

## METHOD OF TEST FOR SIEVE ANALYSIS OF AGGREGATES

(Ministry of Transportation, Ontario, Test Method LS-602 Rev. No. 33)

Project No.:	19115286	Phase:	27.1	Date:	24-Dec-19
Short Title:	Thurber Large Scale Direct Shear Testing - Index				
Sub Sampled By:	JG	Washed By:	JG	Sieved By:	JG
Field Tag No.:	-	Source:	-	Sample Type:	Pit
Lab No.:	D317-04	Northing:	-	Sample No.:	Bulk Sample #11
Sampled By:	Client	Easting:	-	Depth From:	- m
Sample Date:	-	Elevation:	- m	Depth To:	- m
Boundary Plot:	MTO Granular A - Pit	Drying Method:	Oven		
Composite Sieve:	Yes	if Yes, Split on:	4.75 mm		
Material Excluded from Sieve:	No	Describe:			
Prior Testing on Sample:	No	Describe:			



Sieve Size (mm)	Passing %
106.0	100
75.0	100
63.0	100
53.0	100
37.5	100
26.5	100
22.4	100
19.0	95
16	88
13.2	80
9.5	68
6.70	58
4.75	50
2.36	39
1.180	31
0.600	24
0.300	16
0.150	9
0.075	7

Cobbles	Coarse	Fine	Coarse	Medium	Fine	Silt and Clay Size
	Gravel Size		Sand Size			

Received Water Content (%)	Cobbles (%)	Gravel (%)	Sand (%)	Fines (%)	D60 (mm)	D30 (mm)	D10 (mm)	Cu	Cc
5.4	0	50	43	7	7.3	1.1	0.2	44.8	1.1

Sample Description: (GW-GM) fine angular GRAVEL and fine to coarse SAND, some non-plastic fines; brown; non-cohesive.

USCS Classification: GW-GM

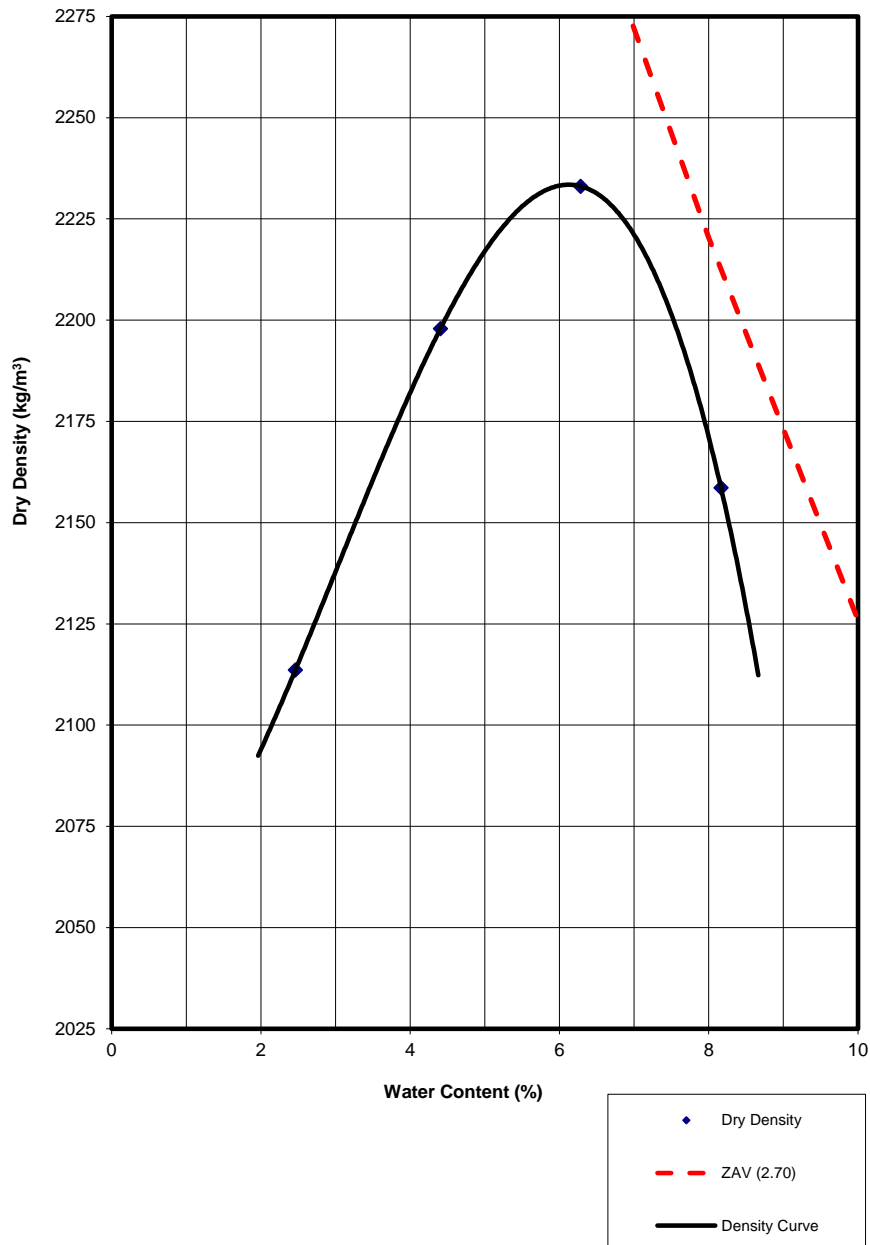
Remarks:

# LABORATORY COMPACTION CHARACTERISTICS OF SOIL USING STANDARD EFFORT

(Ministry of Transportation, Ontario, Test Method LS-706 Rev. No. 33/ ASTM D698)

Project No.:	19115286	Phase:	27.1
Short Title:	Thurber Large Scale Direct Shear Testing - Index	Lab No.:	D317-04
Tested By:	SP	Test Date:	02-Jan-20
Bulk Sample No.:	11	Date Sampled:	-
Sample ID:	BS11-1 to BS11-6	Sample Type:	Pit
Sampled By:	Client	Remarks:	-

## MOISTURE DENSITY RELATIONSHIP



### Maximum Dry Density

Max. Dry Density 2234 kg/m<sup>3</sup>

Optimum w 6.2 %

Method C

### Rock Correction (if required)

% Oversize 5 %

Max. Dry Density 2253 kg/m<sup>3</sup> @ 6.0 %

Assumed Specific Gravity = 2.70

### Sample Description:

(GW-GM) fine angular GRAVEL and fine to coarse SAND, some non-plastic fines; brown; non-cohesive.

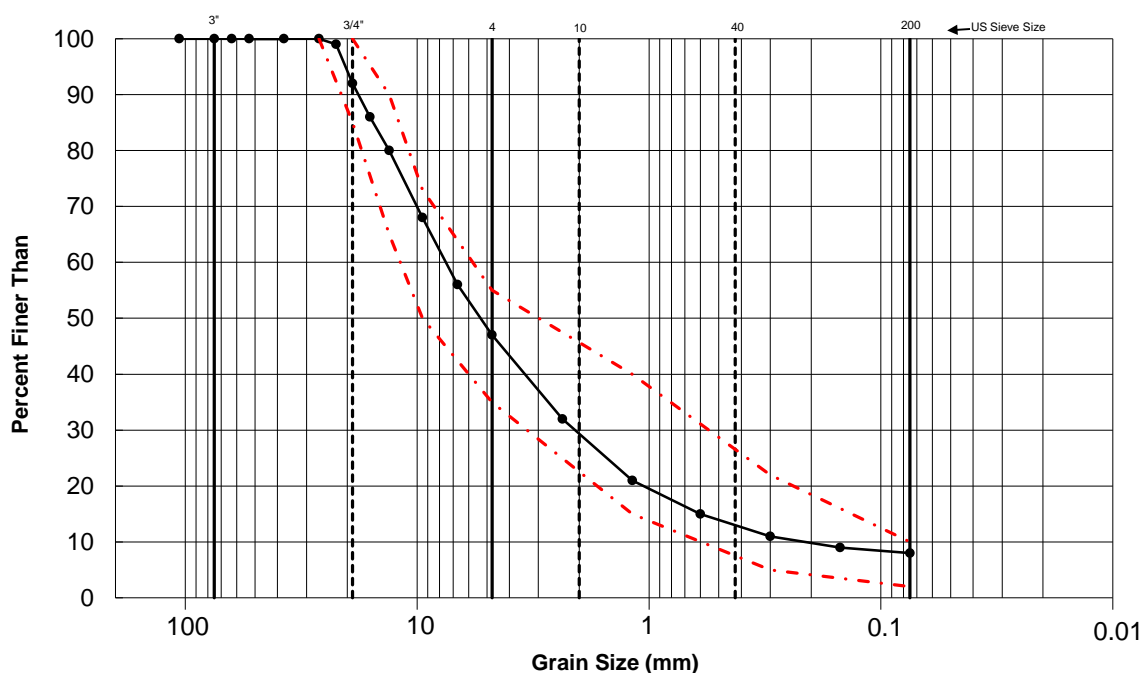
As Received Water Content: 5.4 %



## METHOD OF TEST FOR SIEVE ANALYSIS OF AGGREGATES

(Ministry of Transportation, Ontario, Test Method LS-602 Rev. No. 33)

Project No.:	19115286	Phase:	27.1	Date:	23-Dec-19
Short Title:	Thurber Large Scale Direct Shear Testing - Index				
Sub Sampled By:	JG	Washed By:	JG	Sieved By:	JG
Field Tag No.:	-	Source:	-	Sample Type:	Quarry
Lab No.:	D317-05	Northing:	-	Sample No.:	Bulk Sample #4
Sampled By:	Client	Easting:	-	Depth From:	- m
Sample Date:	-	Elevation:	- m	Depth To:	- m
Boundary Plot:	MTO Granular A-Quarry	Drying Method:	Oven		
Composite Sieve:	Yes	if Yes, Split on:	4.75 mm		
Material Excluded from Sieve:	No	Describe:			
Prior Testing on Sample:	No	Describe:			



Sieve Size (mm)	Passing %
106.0	100
75.0	100
63.0	100
53.0	100
37.5	100
26.5	100
22.4	99
19.0	92
16	86
13.2	80
9.5	68
6.70	56
4.75	47
2.36	32
1.180	21
0.600	15
0.300	11
0.150	9
0.075	8

Cobbles	Coarse	Fine	Coarse	Medium	Fine	Silt and Clay Size
	Gravel Size		Sand Size			

Received Water Content (%)	Cobbles (%)	Gravel (%)	Sand (%)	Fines (%)	D60 (mm)	D30 (mm)	D10 (mm)	Cu	Cc
5.3	0	53	39	8	7.6	2.2	0.2	35.3	2.9

Sample Description: (GW-GM) fine angular GRAVEL and fine to coarse SAND, some non-plastic fines; brown; non-cohesive

USCS Classification: GW-GM

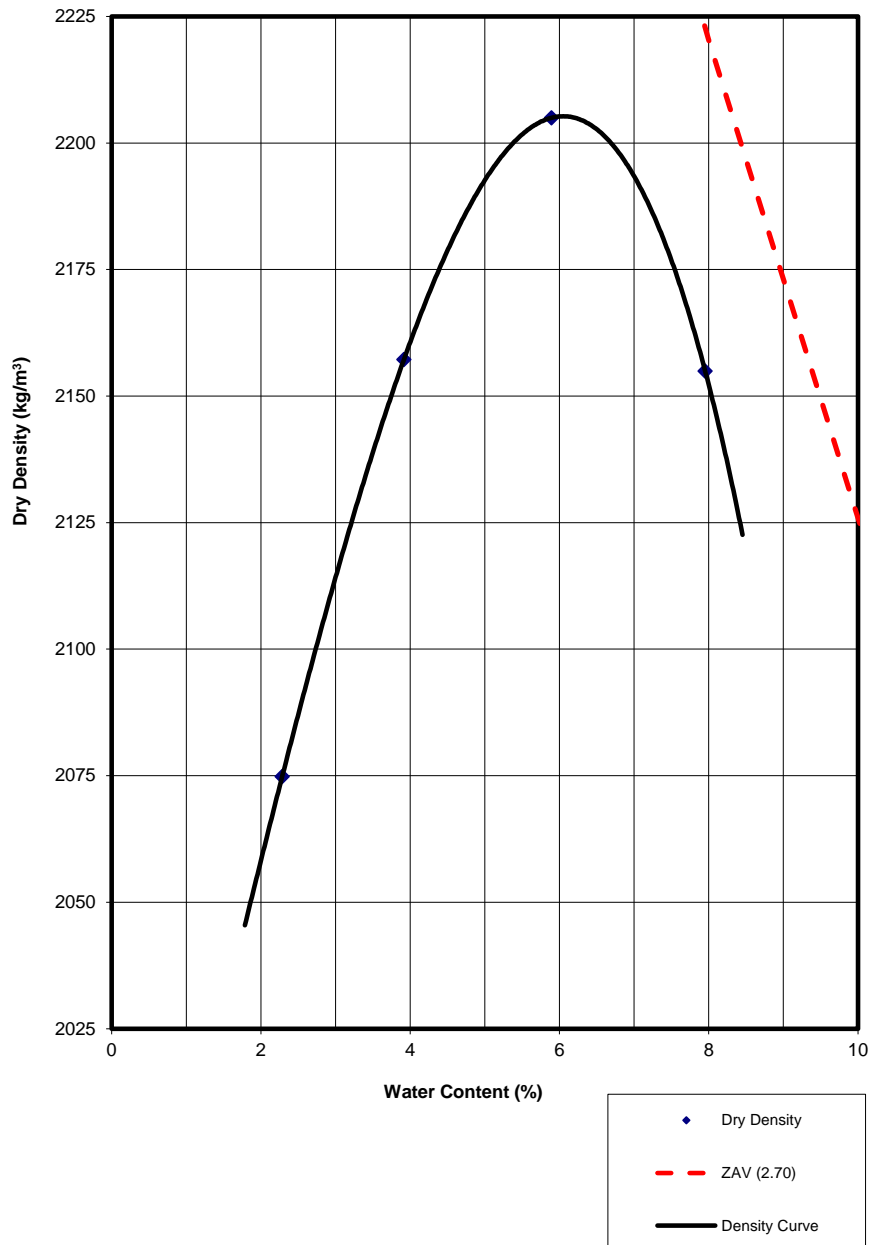
Remarks:

# LABORATORY COMPACTION CHARACTERISTICS OF SOIL USING STANDARD EFFORT

(Ministry of Transportation, Ontario, Test Method LS-706 Rev. No. 33/ ASTM D698)

Project No.:	19115286	Phase:	27.1
Short Title:	Thurber Large Scale Direct Shear Testing - Index	Lab No.:	D317-05
Tested By:	SP	Test Date:	19-Dec-17
Bulk Sample No.:	4	Date Sampled:	-
Sample ID:	BS4-1 to BS4-6	Sample Type:	Quarry
Sampled By:	Client	Remarks:	-

## MOISTURE DENSITY RELATIONSHIP



### Maximum Dry Density

Max. Dry Density 2205 kg/m<sup>3</sup>

Optimum w 5.9 %

Method C

### Rock Correction (if required)

% Oversize 8 %

Max. Dry Density 2236 kg/m<sup>3</sup> @ 5.6 %

Assumed Specific Gravity = 2.70

### Sample Description:

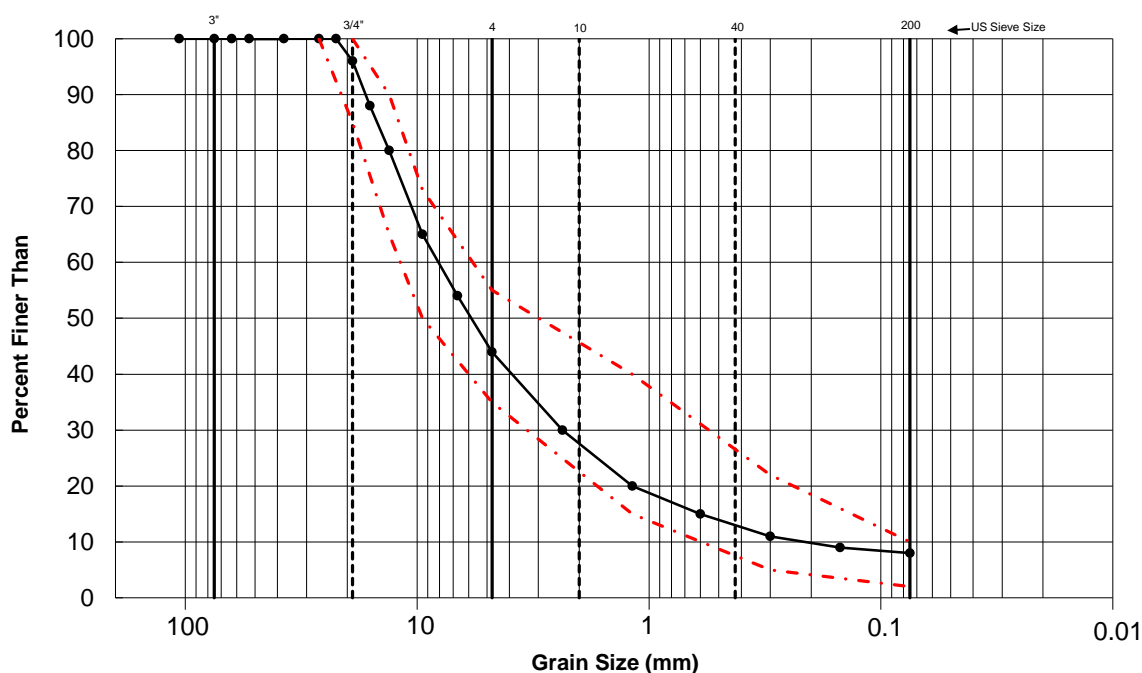
(GW-GM) fine angular GRAVEL and fine to coarse SAND, some non-plastic fines; brown; non-cohesive

As Received Water Content: 5.3 %

## METHOD OF TEST FOR SIEVE ANALYSIS OF AGGREGATES

(Ministry of Transportation, Ontario, Test Method LS-602 Rev. No. 33)

Project No.:	19115286	Phase:	27.1	Date:	26-Dec-19
Short Title:	Thurber Large Scale Direct Shear Testing - Index				
Sub Sampled By:	JG	Washed By:	JG	Sieved By:	JG
Field Tag No.:	-	Source:	-	Sample Type:	Quarry
Lab No.:	D317-06	Northing:	-	Sample No.:	Bulk Sample #5
Sampled By:	Client	Easting:	-	Depth From:	- m
Sample Date:	-	Elevation:	- m	Depth To:	- m
Boundary Plot:	MTO Granular A-Quarry	Drying Method:	Oven		
Composite Sieve:	Yes	if Yes, Split on:	4.75 mm		
Material Excluded from Sieve:	No	Describe:			
Prior Testing on Sample:	No	Describe:			



Sieve Size (mm)	Passing %
106.0	100
75.0	100
63.0	100
53.0	100
37.5	100
26.5	100
22.4	100
19.0	96
16	88
13.2	80
9.5	65
6.70	54
4.75	44
2.36	30
1.180	20
0.600	15
0.300	11
0.150	9
0.075	8

Cobbles	Coarse	Fine	Coarse	Medium	Fine	Silt and Clay Size
	Gravel Size		Sand Size			

Received Water Content (%)	Cobbles (%)	Gravel (%)	Sand (%)	Fines (%)	D60 (mm)	D30 (mm)	D10 (mm)	Cu	Cc
3.1	0	56	36	8	8.2	2.4	0.2	41.0	3.5

Sample Description: (GP-GM) fine angular GRAVEL and fine to coarse SAND, some non-plastic fines; brown; non-cohesive

USCS Classification: GP-GM

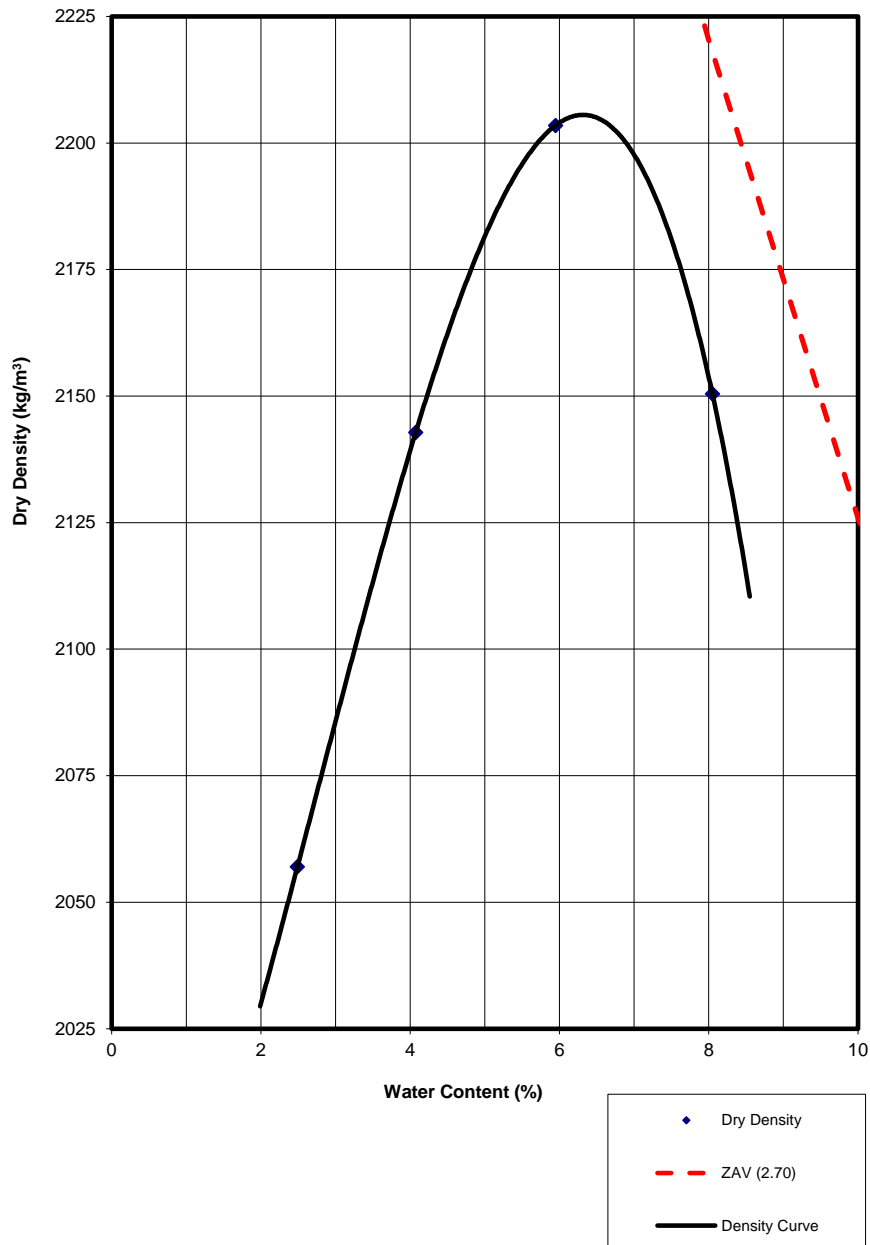
Remarks:

## LABORATORY COMPACTION CHARACTERISTICS OF SOIL USING STANDARD EFFORT

(ASTM D698)

Project No.:	19115286	Phase:	27.1
Short Title:	Thurber Large Scale Direct Shear Testing - Index	Lab No.:	D317-06
Tested By:	SP	Test Date:	20-Dec-17
Bulk Sample No.:	5	Date Sampled:	-
Sample ID:	BS5-1 to BS5-6	Sample Type:	Quarry
Sampled By:	Client	Remarks:	-

### MOISTURE DENSITY RELATIONSHIP



#### Maximum Dry Density

Max. Dry Density 2206 kg/m<sup>3</sup>

Optimum w 6.3 %

Method C

#### Rock Correction (if required)

% Oversize \_\_\_\_\_ %

Max. Dry Density \_\_\_\_\_ kg/m<sup>3</sup> @ \_\_\_\_\_

Assumed Specific Gravity = 2.70

#### Sample Description:

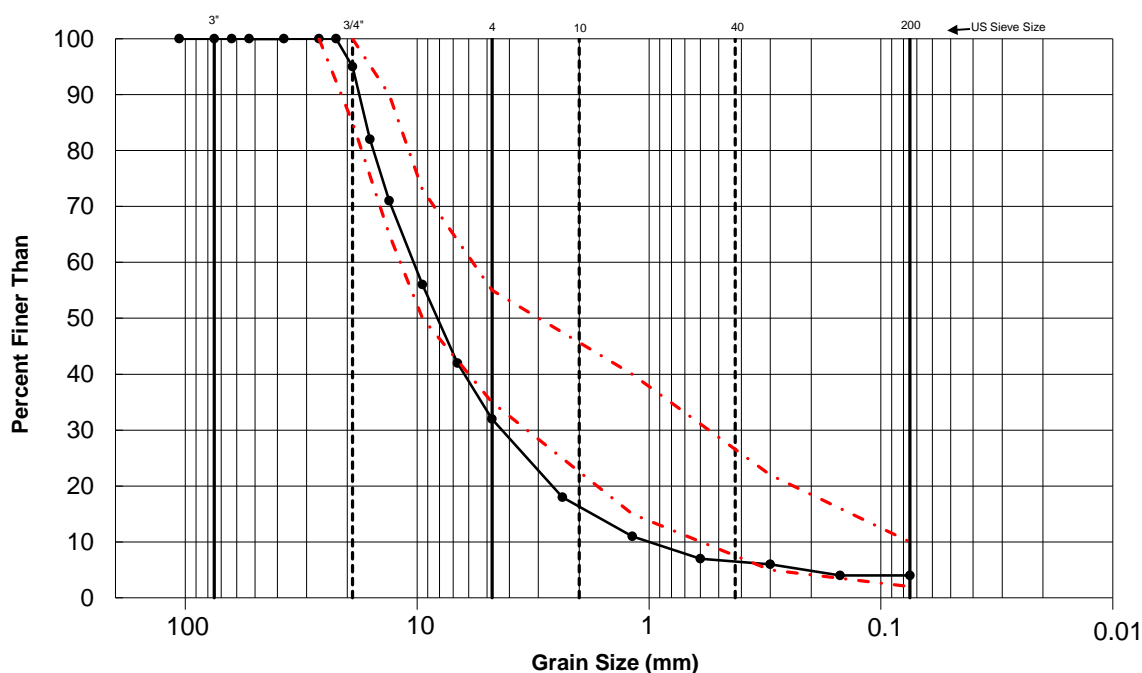
(GP-GM) fine angular GRAVEL and fine to coarse SAND, some non-plastic fines; brown; non-cohesive

As Received Water Content: 3.1%

## METHOD OF TEST FOR SIEVE ANALYSIS OF AGGREGATES

(Ministry of Transportation, Ontario, Test Method LS-602 Rev. No. 33)

Project No.:	19115286	Phase:	27.1	Date:	27-Dec-19
Short Title:	Thurber Large Scale Direct Shear Testing - Index				
Sub Sampled By:	JG	Washed By:	JG	Sieved By:	JG
Field Tag No.:	-	Source:	-	Sample Type:	Quarry
Lab No.:	D317-07	Northing:	-	Sample No.:	Bulk Sample #6
Sampled By:	Client	Easting:	-	Depth From:	- m
Sample Date:	-	Elevation:	- m	Depth To:	- m
Boundary Plot:	MTO Granular A-Quarry	Drying Method:	Oven		
Composite Sieve:	Yes	if Yes, Split on:	4.75 mm		
Material Excluded from Sieve:	No	Describe:			
Prior Testing on Sample:	No	Describe:			



Sieve Size (mm)	Passing %
106.0	100
75.0	100
63.0	100
53.0	100
37.5	100
26.5	100
22.4	100
19.0	95
16	82
13.2	71
9.5	56
6.70	42
4.75	32
2.36	18
1.180	11
0.600	7
0.300	6
0.150	4
0.075	4

Cobbles	Coarse	Fine	Coarse	Medium	Fine	Silt and Clay Size
	Gravel Size		Sand Size			

Received Water Content (%)	Cobbles (%)	Gravel (%)	Sand (%)	Fines (%)	D60 (mm)	D30 (mm)	D10 (mm)	Cu	Cc
1.6	0	68	28	4	10.5	4.4	1.1	9.9	1.8

Sample Description: (GW) sandy fine angular GRAVEL, medium to coarse SAND; brown; non-cohesive.

USCS Classification: GW

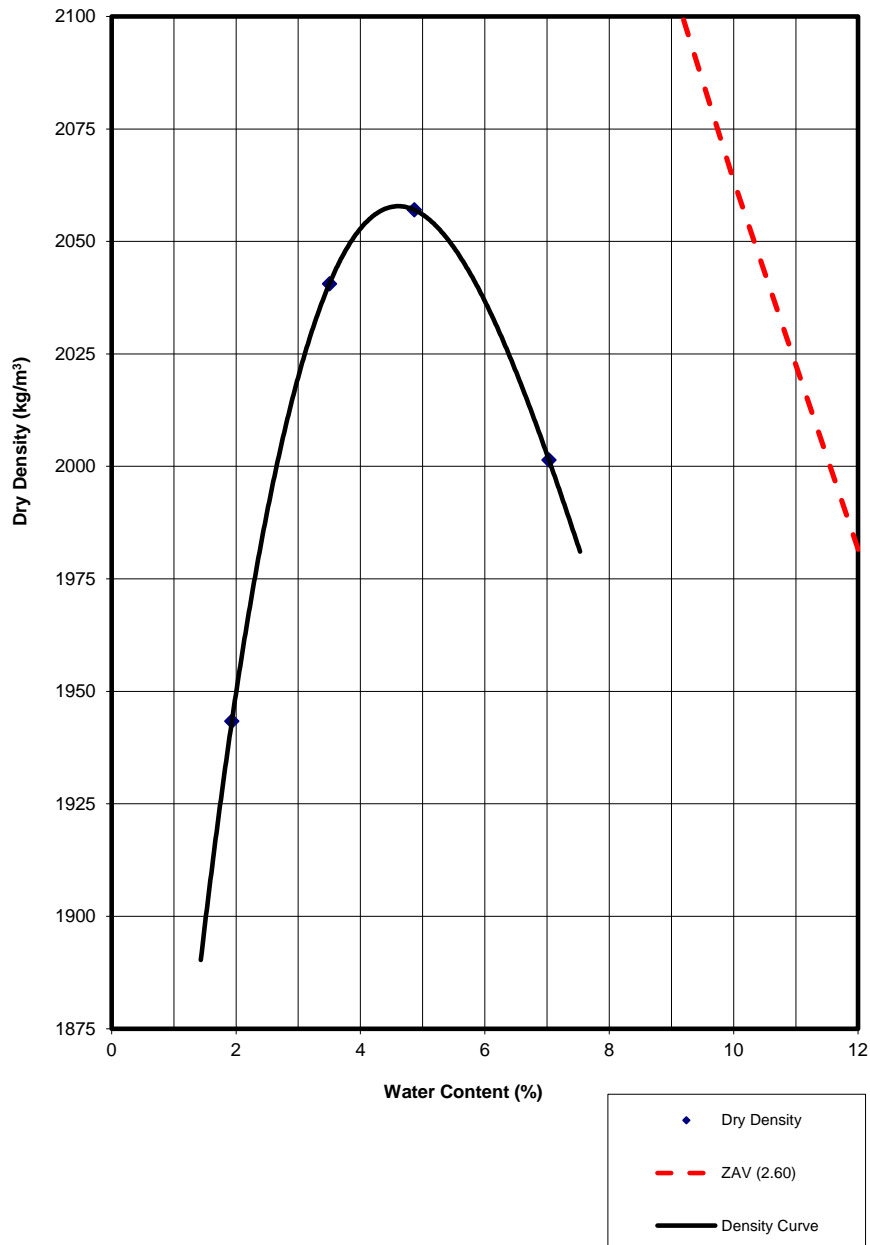
Remarks:

# LABORATORY COMPACTION CHARACTERISTICS OF SOIL USING STANDARD EFFORT

(Ministry of Transportation, Ontario, Test Method LS-706 Rev. No. 33/ ASTM D698)

Project No.:	19115286	Phase:	27.1
Short Title:	Thurber Large Scale Direct Shear Testing - Index	Lab No.:	D317-07
Tested By:	SP	Test Date:	02-Jan-20
Bulk Sample No.:	6	Date Sampled:	-
Sample ID:	BS6-1 to BS6-6	SampleType:	Quarry
Sampled By:	Client	Remarks:	-

## MOISTURE DENSITY RELATIONSHIP



### Maximum Dry Density

Max. Dry Density 2058 kg/m<sup>3</sup>

Optimum w 4.6 %

Method C

### Rock Correction (if required)

% Oversize 5 %

Max. Dry Density 2080 kg/m<sup>3</sup> @ 4.5 %

Assumed Specific Gravity = 2.60

### Sample Description:

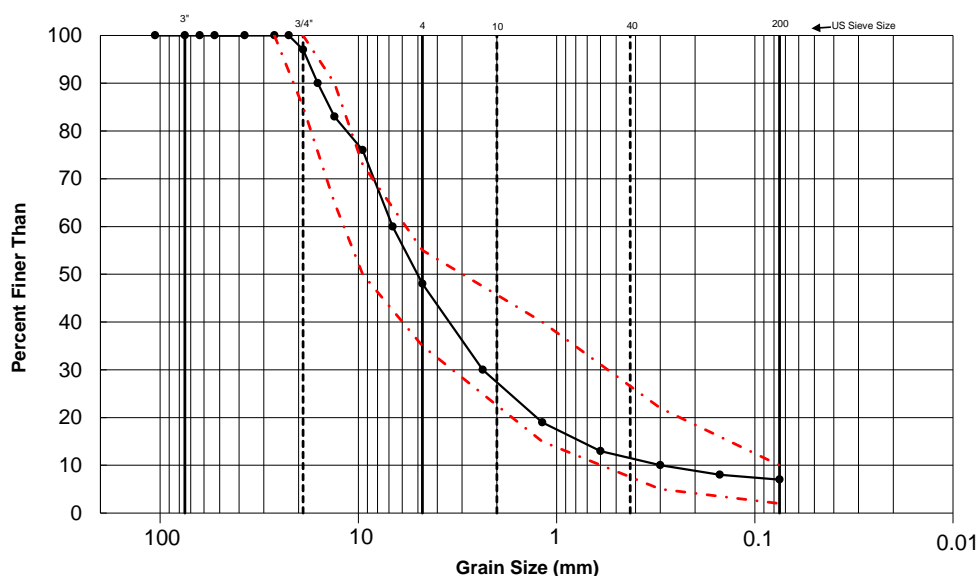
(GW) sandy fine angular GRAVEL, medium to coarse SAND; brown; non-cohesive.

As Received Water Content: 1.6 %

## METHOD OF TEST FOR SIEVE ANALYSIS OF AGGREGATES

(Ministry of Transportation, Ontario, Test Method LS-602 Rev. No. 33)

Project No.:	19115286	Phase:	27.1	Date:	11-Feb-20
Short Title:	Thurber Large Scale Direct Shear Testing - Index				
Sub Sampled By:	SP	Washed By:	SP	Sieved By:	SP
Field Tag No.:	-	Source:	-	Sample Type:	Quarry
Lab No.:	D317-07	Northing:	-	Sample No.:	Bulk Sample #6
Sampled By:	Client	Easting:	-	Depth From:	- m
Sample Date:	-	Elevation:	- m	Depth To:	- m
Boundary Plot:	MTO Granular A-Quarry	Drying Method:	Oven		
Composite Sieve:	Yes	if Yes, Split on:	4.75 mm		
Material Excluded from Sieve:	Yes	Describe:			
Prior Testing on Sample:	Yes	Describe:			



Sieve Size (mm)	Passing %
106.0	100
75.0	100
63.0	100
53.0	100
37.5	100
26.5	100
22.4	100
19.0	97
16	90
13.2	83
9.5	76
6.70	60
4.75	48
2.36	30
1.180	19
0.600	13
0.300	10
0.150	8
0.075	7

Cobbles	Coarse	Fine	Coarse	Medium	Fine	Silt and Clay Size
	Gravel Size		Sand Size			

Received Water Content (%)	Cobbles (%)	Gravel (%)	Sand (%)	Fines (%)	D60 (mm)	D30 (mm)	D10 (mm)	Cu	Cc
1.6	0	52	41	7	6.6	2.4	0.3	23.1	3.0

Sample Description: (GP-GM) fine angular GRAVEL and medium to coarse SAND, some non-plastic fines; brown; non-cohesive.

USCS Classification: GP-GM

Remarks: Material was adjusted/ modified to comply within the specified boundaries above.

The testing services reported herein have been performed in accordance with the indicated recognized standard, or in accordance with local industry practice. This report is for the sole use of the designated client. This report constitutes a testing service only and does not represent any results interpretation or opinion regarding specification compliance or material suitability. Engineering interpretation can be provided by Golder Associates Ltd. upon request.

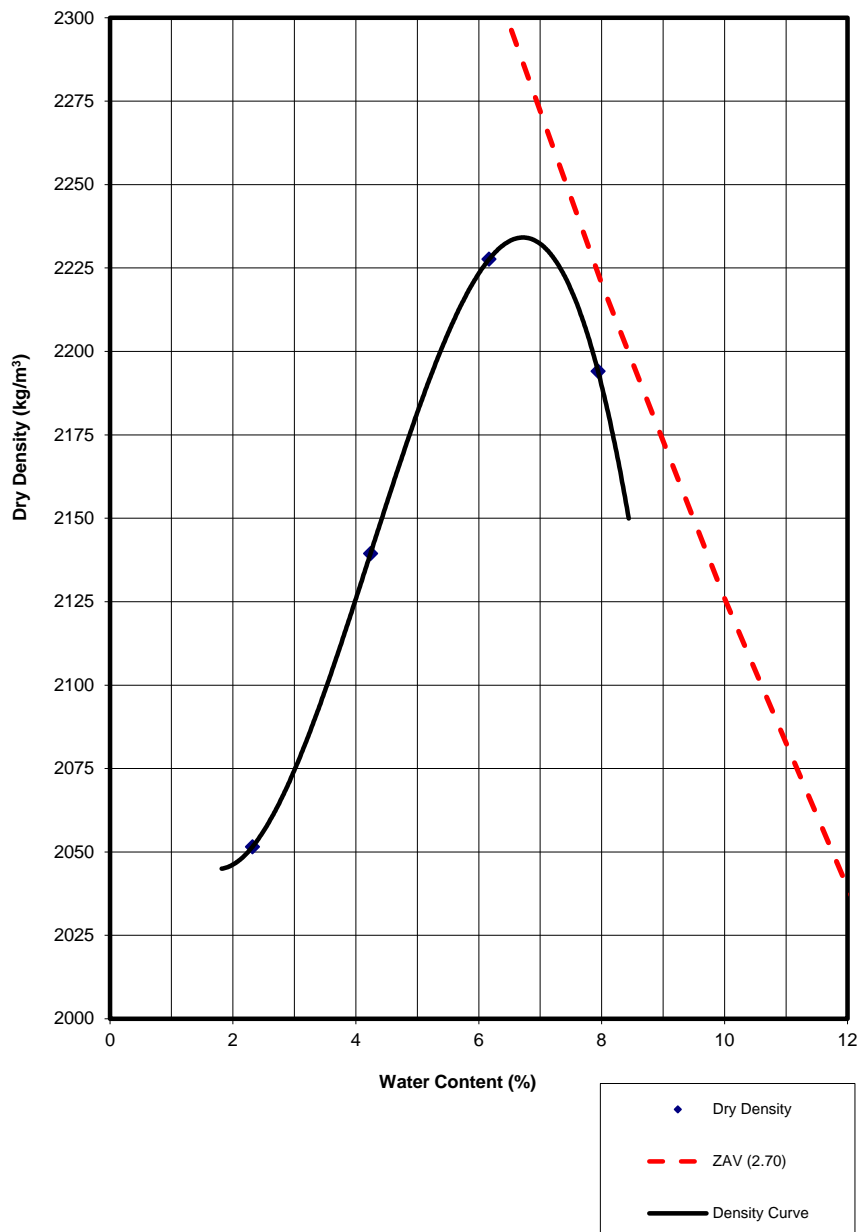


# LABORATORY COMPACTION CHARACTERISTICS OF SOIL USING STANDARD EFFORT

(Ministry of Transportation, Ontario, Test Method LS-706 Rev. No. 33/ ASTM D698)

Project No.:	19115286	Phase:	27.1
Short Title:	Thurber Large Scale Direct Shear Testing - Index	Lab No.:	D317-07
Tested By:	SP	Test Date:	02-Jan-20
Bulk Sample No.:	6	Date Sampled:	-
Sample ID:	Bulk 6	SampleType:	Quarry
Sampled By:	Client	Remarks: Sample Adjusted to meet spec.	

## MOISTURE DENSITY RELATIONSHIP



### Maximum Dry Density

Max. Dry Density 2235 kg/m<sup>3</sup>

Optimum w 6.7 %

Method C

### Rock Correction (if required)

% Oversize 3 %

Max. Dry Density 2245 kg/m<sup>3</sup> @ 6.6 %

Assumed Specific Gravity = 2.70

### Sample Description:

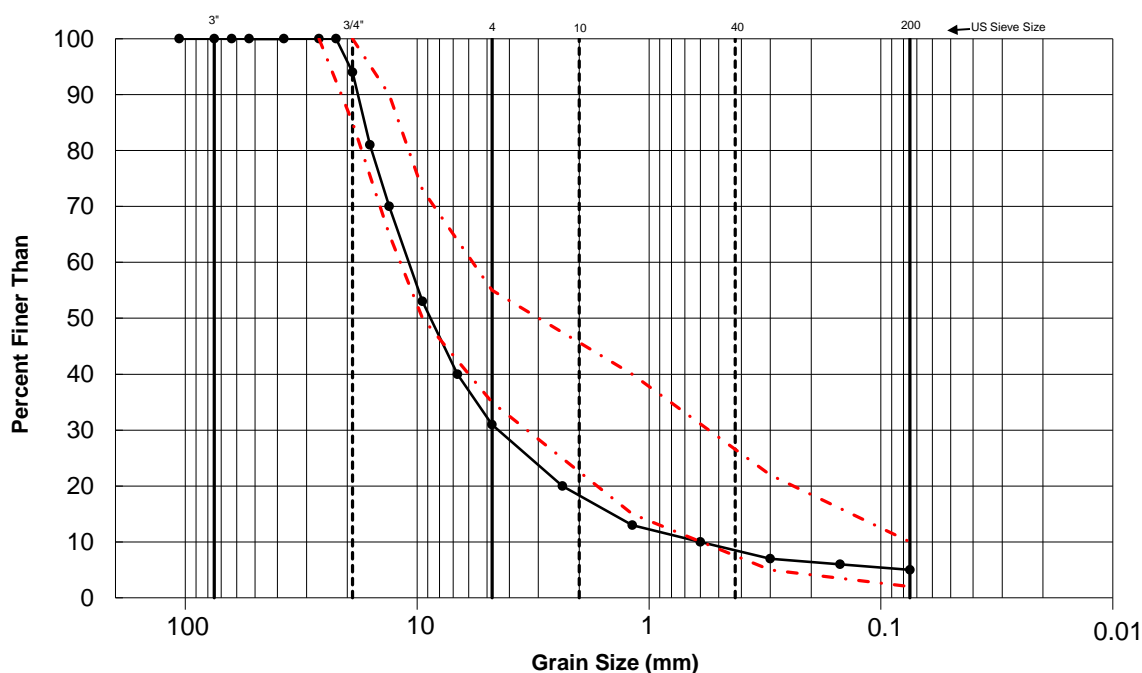
(GP-GM) fine angular GRAVEL and medium to coarse SAND, some non-plastic fines; brown; non-cohesive.

As Received Water Content: 1.6%

## METHOD OF TEST FOR SIEVE ANALYSIS OF AGGREGATES

(Ministry of Transportation, Ontario, Test Method LS-602 Rev. No. 33)

Project No.:	19115286	Phase:	27.1	Date:	26-Dec-19
Short Title:	Thurber Large Scale Direct Shear Testing - Index				
Sub Sampled By:	JG	Washed By:	JG	Sieved By:	JG
Field Tag No.:	-	Source:	-	Sample Type:	Quarry
Lab No.:	D317-08	Northing:	-	Sample No.:	Bulk Sample #7
Sampled By:	Client	Easting:	-	Depth From:	- m
Sample Date:	-	Elevation:	- m	Depth To:	- m
Boundary Plot:	MTO Granular A-Quarry	Drying Method:	Oven		
Composite Sieve:	Yes	if Yes, Split on:	4.75 mm		
Material Excluded from Sieve:	No	Describe:			
Prior Testing on Sample:	No	Describe:			



Sieve Size (mm)	Passing %
106.0	100
75.0	100
63.0	100
53.0	100
37.5	100
26.5	100
22.4	100
19.0	94
16	81
13.2	70
9.5	53
6.70	40
4.75	31
2.36	20
1.180	13
0.600	10
0.300	7
0.150	6
0.075	5

Cobbles	Coarse	Fine	Coarse	Medium	Fine	Silt and Clay Size
	Gravel Size		Sand Size			

Received Water Content (%)	Cobbles (%)	Gravel (%)	Sand (%)	Fines (%)	D60 (mm)	D30 (mm)	D10 (mm)	Cu	Cc
2.8	0	69	26	5	11.0	4.5	0.7	16.8	2.8

Sample Description: (GW) sandy fine angular GRAVEL, medium to coarse SAND; brown; non-cohesive.

USCS Classification: GW

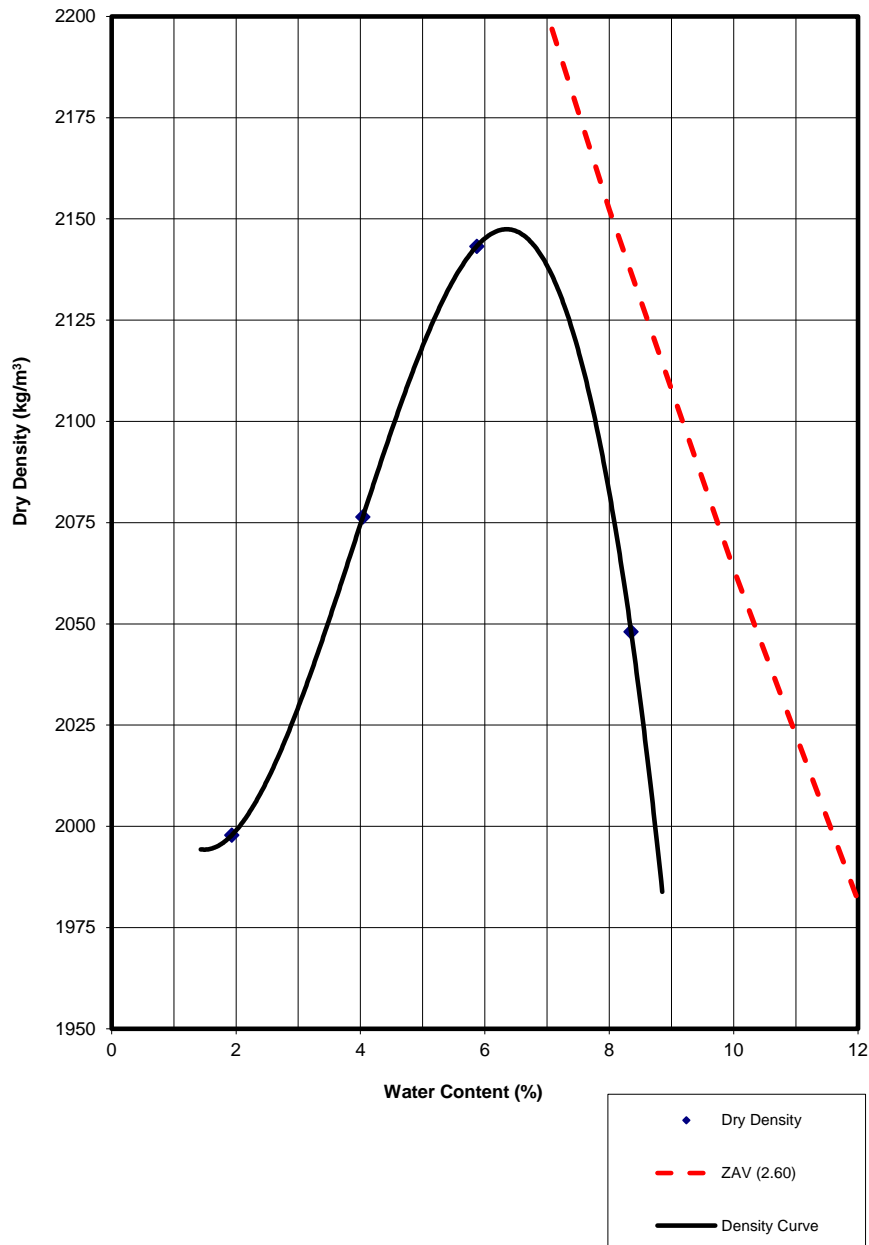
Remarks:

# LABORATORY COMPACTION CHARACTERISTICS OF SOIL USING STANDARD EFFORT

(Ministry of Transportation, Ontario, Test Method LS-706 Rev. No. 33/ ASTM D698)

Project No.:	19115286	Phase:	27.1
Short Title:	Thurber Large Scale Direct Shear Testing - Index	Lab No.:	D317-08
Tested By:	SP	Test Date:	02-Jan-20
Bulk Sample No.:	7	Date Sampled:	-
Sample ID:	BS7-1 to BS7-6	Sample Type:	Quarry
Sampled By:	Client	Remarks:	-

## MOISTURE DENSITY RELATIONSHIP



### Maximum Dry Density

Max. Dry Density 2147 kg/m<sup>3</sup>

Optimum w 6.3 %

Method C

### Rock Correction (if required)

% Oversize 6 %

Max. Dry Density 2170 kg/m<sup>3</sup> @ 6.0 %

Assumed Specific Gravity = 2.60

### Sample Description:

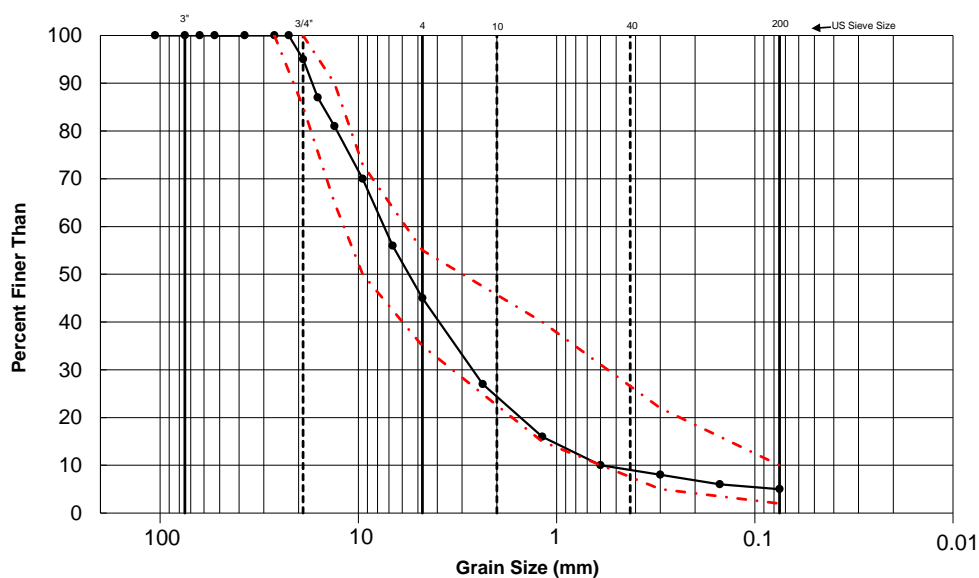
(GW) sandy fine angular GRAVEL, medium to coarse SAND; brown; non-cohesive.

As Received Water Content: 2.8 %

## METHOD OF TEST FOR SIEVE ANALYSIS OF AGGREGATES

(Ministry of Transportation, Ontario, Test Method LS-602 Rev. No. 33)

Project No.:	19115286	Phase:	27.1	Date:	13-Feb-20
Short Title:	Thurber Large Scale Direct Shear Testing - Index				
Sub Sampled By:	SP	Washed By:	SP	Sieved By:	SP
Field Tag No.:	-	Source:	-	Sample Type:	Quarry
Lab No.:	D317-08	Northing:	-	Sample No.:	Bulk Sample #7
Sampled By:	Client	Easting:	-	Depth From:	- m
Sample Date:	-	Elevation:	- m	Depth To:	- m
Boundary Plot:	MTO Granular A-Quarry	Drying Method:	Oven		
Composite Sieve:	Yes	if Yes, Split on:	4.75 mm		
Material Excluded from Sieve:	Yes	Describe:			
Prior Testing on Sample:	Yes	Describe:			



Sieve Size (mm)	Passing %
106.0	100
75.0	100
63.0	100
53.0	100
37.5	100
26.5	100
22.4	100
19.0	95
16	87
13.2	81
9.5	70
6.70	56
4.75	45
2.36	27
1.180	16
0.600	10
0.300	8
0.150	6
0.075	5

Cobbles	Coarse	Fine	Coarse	Medium	Fine	Silt and Clay Size
	Gravel Size		Sand Size			

Received Water Content (%)	Cobbles (%)	Gravel (%)	Sand (%)	Fines (%)	D60 (mm)	D30 (mm)	D10 (mm)	Cu	Cc
2.8	0	55	40	5	7.4	2.8	0.6	13.5	1.9

Sample Description: (GW-GM) fine angular GRAVEL and medium to coarse SAND, some non-plastic fines; brown; non-cohesive.

USCS Classification: GW-GM

Remarks: Material was adjusted/ modified to comply within the specified boundaries above.

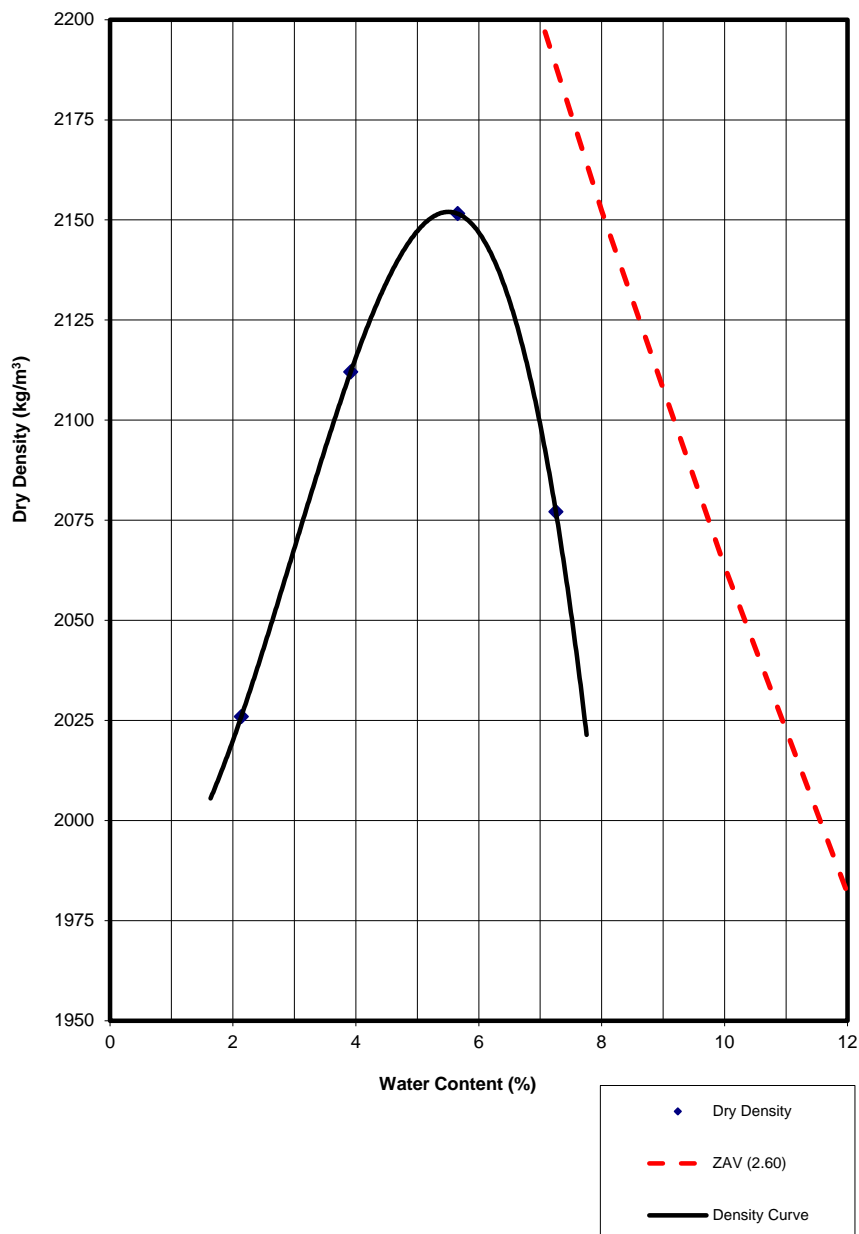
The testing services reported herein have been performed in accordance with the indicated recognized standard, or in accordance with local industry practice. This report is for the sole use of the designated client. This report constitutes a testing service only and does not represent any results interpretation or opinion regarding specification compliance or material suitability. Engineering interpretation can be provided by Golder Associates Ltd. upon request.

# LABORATORY COMPACTION CHARACTERISTICS OF SOIL USING STANDARD EFFORT

(Ministry of Transportation, Ontario, Test Method LS-706 Rev. No. 33/ ASTM D698)

Project No.:	19115286	Phase:	27.1
Short Title:	Thurber Large Scale Direct Shear Testing - Index	Lab No.:	D317-08
Tested By:	SP	Test Date:	13-Feb-20
Bulk Sample No.:	7	Date Sampled:	-
Sample ID:	Bulk 7	Sample Type:	Quarry
Sampled By:	Client	Remarks: Sample Adjusted to meet spec.	

## MOISTURE DENSITY RELATIONSHIP



### Maximum Dry Density

Max. Dry Density 2152 kg/m<sup>3</sup>

Optimum w 5.5 %

Method C

### Rock Correction (if required)

% Oversize 5 %

Max. Dry Density 2171 kg/m<sup>3</sup> @ 5.3 %

Assumed Specific Gravity = 2.60

### Sample Description:

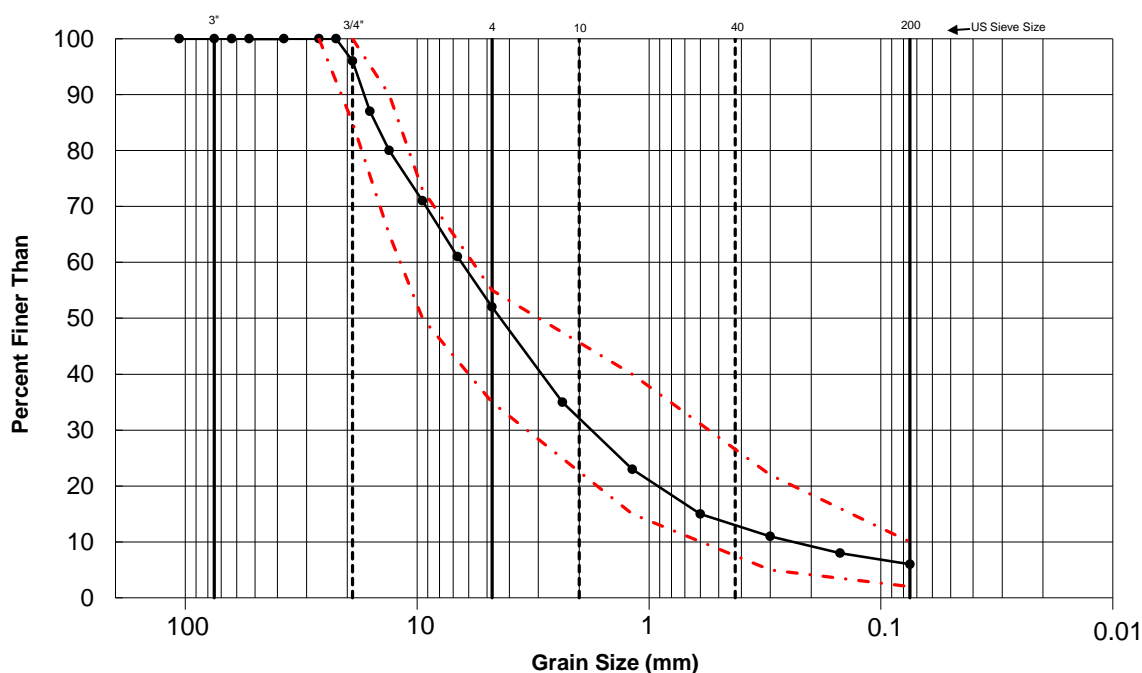
(GW-GM) fine angular GRAVEL and medium to coarse SAND, some non-plastic fines; brown; non-cohesive.

As Received Water Content: 2.8 %

## METHOD OF TEST FOR SIEVE ANALYSIS OF AGGREGATES

(Ministry of Transportation, Ontario, Test Method LS-602 Rev. No. 33)

Project No.:	19115286	Phase:	27.1	Date:	27-Dec-19
Short Title:	Thurber Large Scale Direct Shear Testing - Index				
Sub Sampled By:	JG	Washed By:	JG	Sieved By:	JG
Field Tag No.:	-	Source:	-	Sample Type:	Quarry
Lab No.:	D317-09	Northing:	-	Sample No.:	Bulk Sample #8
Sampled By:	Client	Easting:	-	Depth From:	- m
Sample Date:	-	Elevation:	- m	Depth To:	- m
Boundary Plot:	MTO Granular A-Quarry	Drying Method:	Oven		
Composite Sieve:	Yes	if Yes, Split on:	4.75 mm		
Material Excluded from Sieve:	No	Describe:			
Prior Testing on Sample:	No	Describe:			



Sieve Size (mm)	Passing %
106.0	100
75.0	100
63.0	100
53.0	100
37.5	100
26.5	100
22.4	100
19.0	96
16	87
13.2	80
9.5	71
6.70	61
4.75	52
2.36	35
1.180	23
0.600	15
0.300	11
0.150	8
0.075	6

Cobbles	Coarse	Fine	Coarse	Medium	Fine	Silt and Clay Size
	Gravel Size		Sand Size			

Received Water Content (%)	Cobbles (%)	Gravel (%)	Sand (%)	Fines (%)	D60 (mm)	D30 (mm)	D10 (mm)	Cu	Cc
1.1	0	48	46	6	6.4	1.8	0.3	23.7	1.9

Sample Description: (GW-GM) fine angular GRAVEL and fine to coarse SAND some non-plastic fines; brown; non-cohesive.

USCS Classification: GW-GM

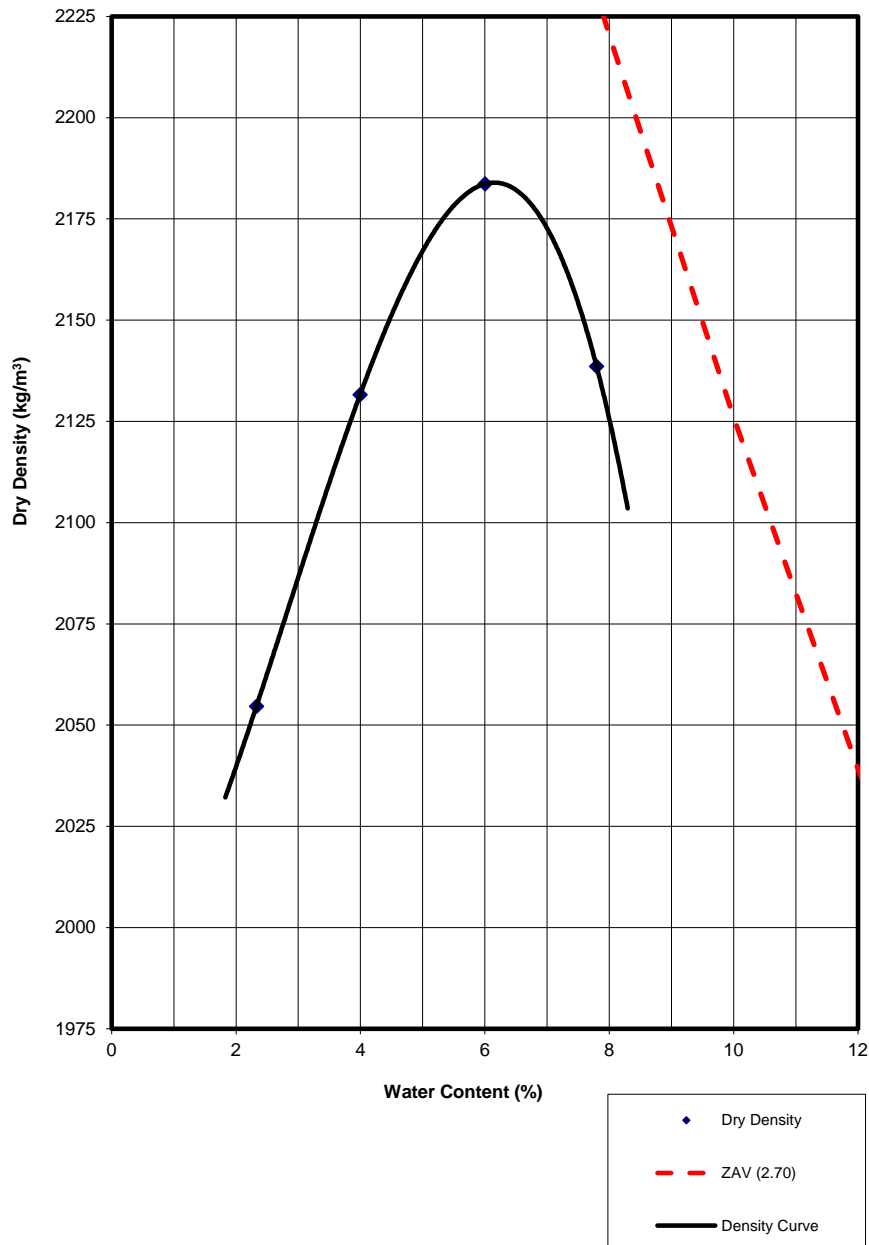
Remarks:

# LABORATORY COMPACTION CHARACTERISTICS OF SOIL USING STANDARD EFFORT

(Ministry of Transportation, Ontario, Test Method LS-706 Rev. No. 33/ ASTM D698)

Project No.:	19115286	Phase:	27.1
Short Title:	Thurber Large Scale Direct Shear Testing - Index	Lab No.:	D317-09
Tested By:	SP	Test Date:	02-Jan-20
Bulk Sample No.:	8	Date Sampled:	-
Sample ID:	BS8-1 to BS8-6	SampleType:	Quarry
Sampled By:	Client	Remarks:	-

## MOISTURE DENSITY RELATIONSHIP



### Maximum Dry Density

Max. Dry Density 2184 kg/m<sup>3</sup>

Optimum w 6.1 %

Method C

### Rock Correction (if required)

% Oversize \_\_\_\_\_ %

Max. Dry Density \_\_\_\_\_ kg/m<sup>3</sup> @ \_\_\_\_\_

Assumed Specific Gravity = 2.70

### Sample Description:

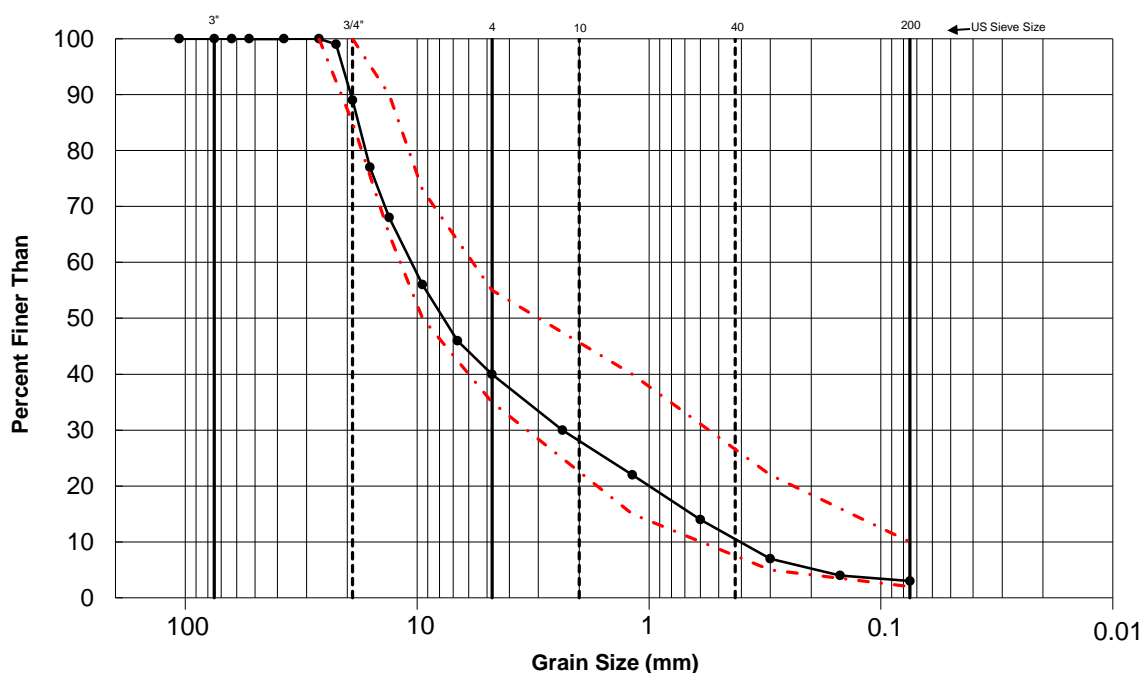
(GW-GM) fine angular GRAVEL and fine to coarse SAND some non-plastic fines; brown; non-cohesive.

As Received Water Content: 1.1%

## METHOD OF TEST FOR SIEVE ANALYSIS OF AGGREGATES

(Ministry of Transportation, Ontario, Test Method LS-602 Rev. No. 33)

Project No.:	19115286	Phase:	27.1	Date:	30-Dec-19
Short Title:	Thurber Large Scale Direct Shear Testing - Index				
Sub Sampled By:	JG	Washed By:	JG	Sieved By:	JG
Field Tag No.:	-	Source:	-	Sample Type:	Quarry
Lab No.:	D317-10	Northing:	-	Sample No.:	Bulk Sample #9
Sampled By:	Client	Easting:	-	Depth From:	- m
Sample Date:	-	Elevation:	- m	Depth To:	- m
Boundary Plot:	MTO Granular A-Quarry	Drying Method:	Oven		
Composite Sieve:	Yes	if Yes, Split on:	4.75 mm		
Material Excluded from Sieve:	No	Describe:			
Prior Testing on Sample:	No	Describe:			



Sieve Size (mm)	Passing %
106.0	100
75.0	100
63.0	100
53.0	100
37.5	100
26.5	100
22.4	99
19.0	89
16	77
13.2	68
9.5	56
6.70	46
4.75	40
2.36	30
1.180	22
0.600	14
0.300	7
0.150	4
0.075	3

Cobbles	Coarse	Fine	Coarse	Medium	Fine	Silt and Clay Size
	Gravel Size		Sand Size			

Received Water Content (%)	Cobbles (%)	Gravel (%)	Sand (%)	Fines (%)	D60 (mm)	D30 (mm)	D10 (mm)	Cu	Cc
2.5	0	60	37	3	10.7	2.3	0.4	24.4	1.1

Sample Description: (GW) fine angular GRAVEL and medium to coarse SAND; brown; non-cohesive.

USCS Classification: GW

Remarks:

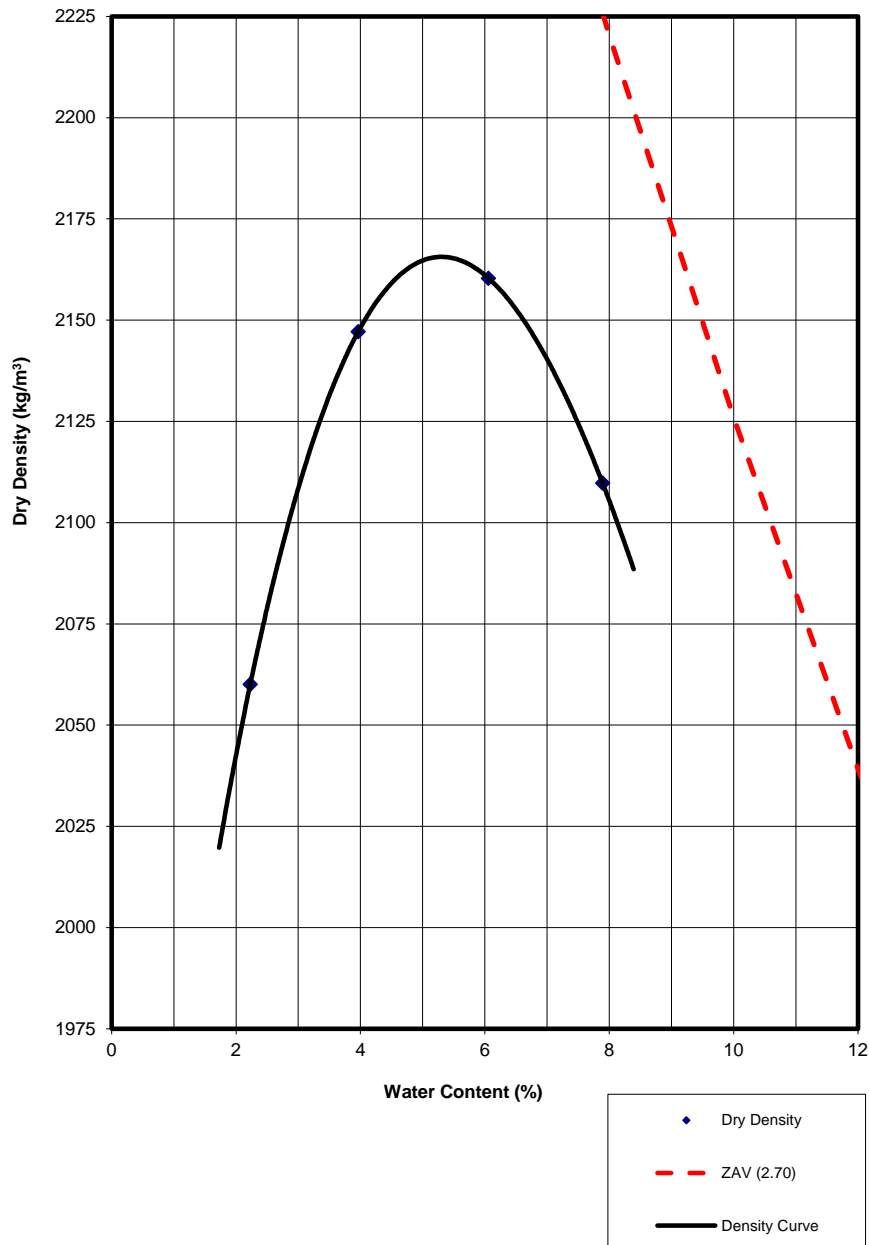


# LABORATORY COMPACTION CHARACTERISTICS OF SOIL USING STANDARD EFFORT

(Ministry of Transportation, Ontario, Test Method LS-706 Rev. No. 33/ ASTM D698)

Project No.:	19115286	Phase:	27.1
Short Title:	Thurber Large Scale Direct Shear Testing - Index	Lab No.:	D317-10
Tested By:	SP	Test Date:	02-Jan-20
Bulk Sample No.:	9	Date Sampled:	-
Sample ID:	BS9-1 to BS9-6	Sample Type:	Quarry
Sampled By:	Client	Remarks:	-

## MOISTURE DENSITY RELATIONSHIP



### Maximum Dry Density

Max. Dry Density 2165 kg/m<sup>3</sup>

Optimum w 5.3 %

Method C

### Rock Correction (if required)

% Oversize 11 %

Max. Dry Density 2213 kg/m<sup>3</sup> @ 4.9 %

Assumed Specific Gravity = 2.70

### Sample Description:

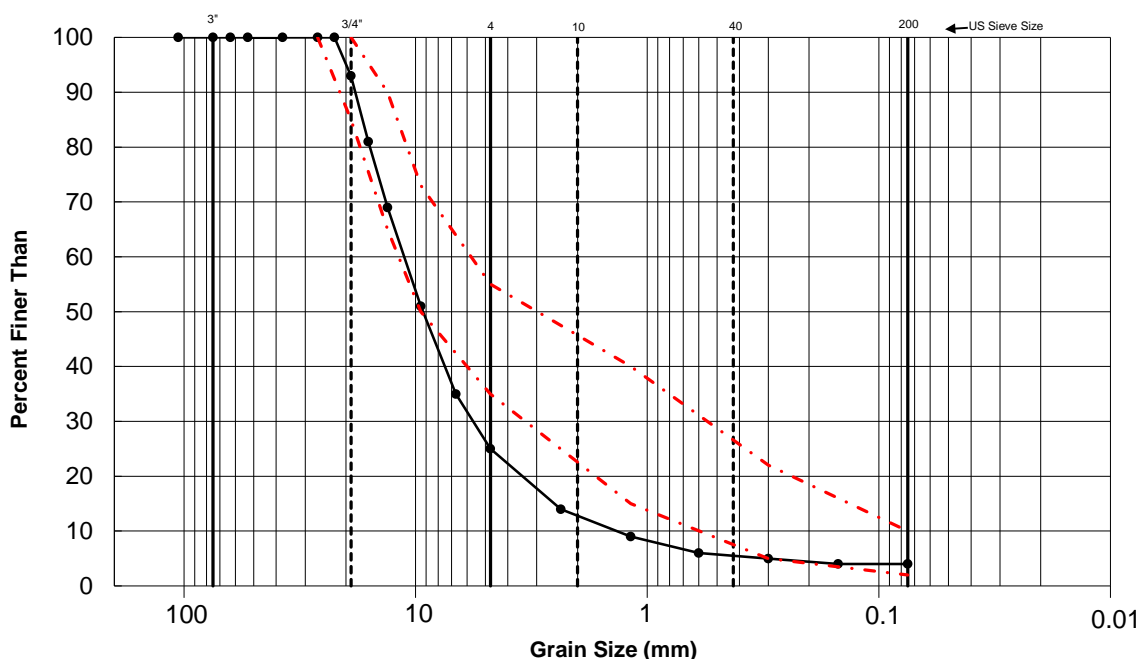
(GW) fine angular GRAVEL and medium to coarse SAND; brown; non-cohesive.

As Received Water Content: 2.5 %

## METHOD OF TEST FOR SIEVE ANALYSIS OF AGGREGATES

(Ministry of Transportation, Ontario, Test Method LS-602 Rev. No. 33)

Project No.:	19115286	Phase:	27.1	Date:	31-Dec-19
Short Title:	Thurber Large Scale Direct Shear Testing - Index				
Sub Sampled By:	JG	Washed By:	JG	Sieved By:	JG
Field Tag No.:	-	Source:	-	Sample Type:	Quarry
Lab No.:	D317-11	Northing:	-	Sample No.:	Bulk Sample #10
Sampled By:	Client	Easting:	-	Depth From:	- m
Sample Date:	-	Elevation:	- m	Depth To:	- m
Boundary Plot:	MTO Granular A-Quarry	Drying Method:	Oven		
Composite Sieve:	Yes	if Yes, Split on:	4.75 mm		
Material Excluded from Sieve:	No	Describe:			
Prior Testing on Sample:	No	Describe:			



Cobbles	Coarse	Fine	Coarse	Medium	Fine	Silt and Clay Size
	Gravel Size		Sand Size			

Received Water Content (%)	Cobbles (%)	Gravel (%)	Sand (%)	Fines (%)	D60 (mm)	D30 (mm)	D10 (mm)	Cu	Cc
2.1	0	75	21	4	11.4	5.7	1.5	7.5	1.9

Sample Description: (GW) sandy fine angular GRAVEL, medium to coarse sand; brown; non-cohesive.

USCS Classification: GW

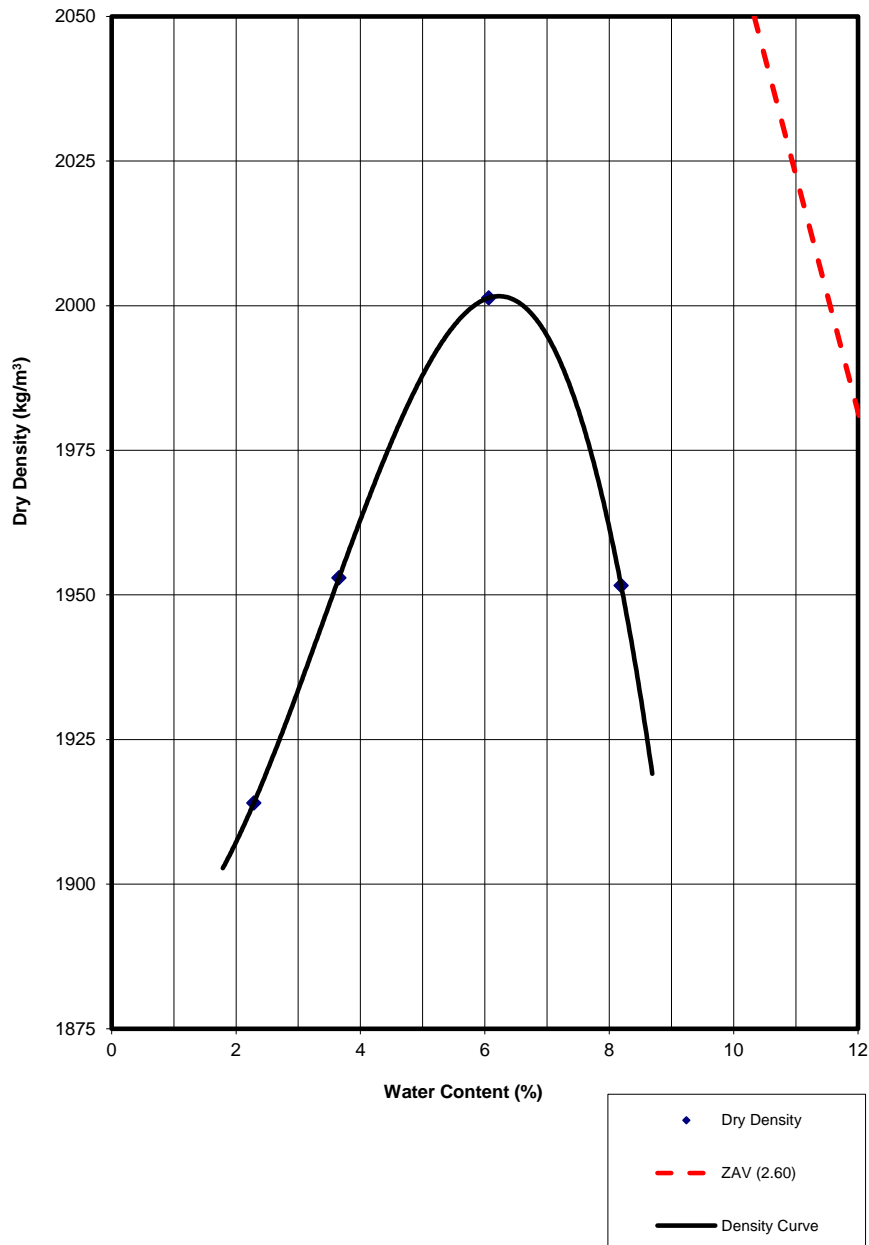
Remarks:

# LABORATORY COMPACTION CHARACTERISTICS OF SOIL USING STANDARD EFFORT

(Ministry of Transportation, Ontario, Test Method LS-706 Rev. No. 33/ ASTM D698)

Project No.:	19115286	Phase:	27.1
Short Title:	Thurber Large Scale Direct Shear Testing - Index	Lab No.:	D317-11
Tested By:	SP	Test Date:	03-Jan-20
Bulk Sample No.:	10	Date Sampled:	-
Sample ID:	BS10-1 to BS10-6	SampleType:	Quarry
Sampled By:	Client	Remarks:	-

## MOISTURE DENSITY RELATIONSHIP



### Maximum Dry Density

Max. Dry Density 2002 kg/m<sup>3</sup>

Optimum w 6.3 %

Method C

### Rock Correction (if required)

% Oversize 7 %

Max. Dry Density 2035 kg/m<sup>3</sup> @ 6.0 %

Assumed Specific Gravity = 2.60

### Sample Description:

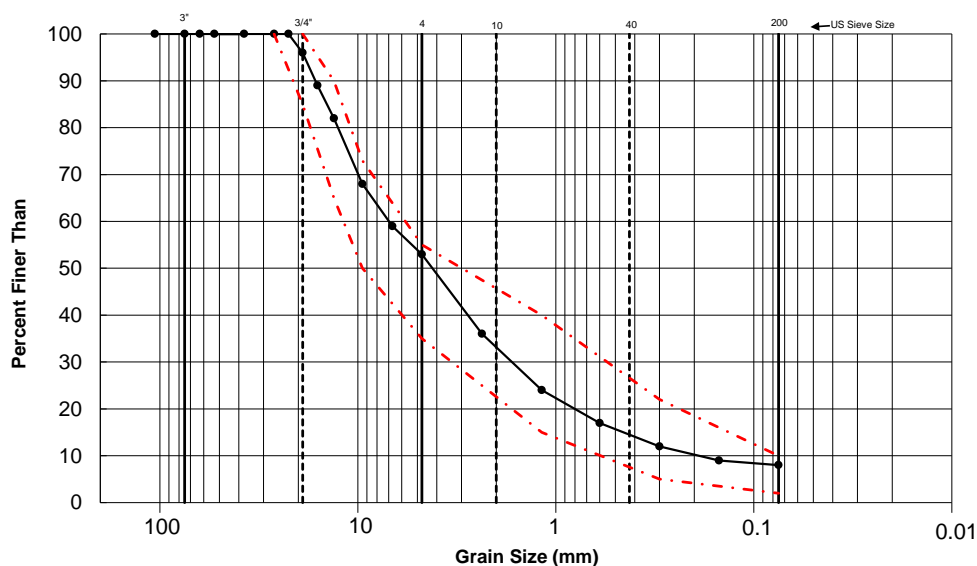
(GW) sandy fine angular GRAVEL, medium to coarse sand; brown; non-cohesive.

As Received Water Content: 2.1 %

## METHOD OF TEST FOR SIEVE ANALYSIS OF AGGREGATES

(Ministry of Transportation, Ontario, Test Method LS-602 Rev. No. 33)

Project No.:	19115286	Phase:	27.1	Date:	14-Feb-20
Short Title:	Thurber Large Scale Direct Shear Testing - Index				
Sub Sampled By:	SP	Washed By:	SP	Sieved By:	SP
Field Tag No.:	-	Source:	-	Sample Type:	Quarry
Lab No.:	D317-11	Northing:	-	Sample No.:	Bulk Sample #10
Sampled By:	Client	Easting:	-	Depth From:	- m
Sample Date:	-	Elevation:	- m	Depth To:	- m
Boundary Plot:	MTO Granular A-Quarry	Drying Method:	Oven		
Composite Sieve:	Yes	if Yes, Split on:	4.75 mm		
Material Excluded from Sieve:	Yes	Describe: Bulk 10 combined with minus 4.75mm Bulk 5 and Bulk 8			
Prior Testing on Sample:	Yes	Describe: Post LDS on minus Bulk 5 and Bulk 8			



Sieve Size (mm)	Passing %
106.0	100
75.0	100
63.0	100
53.0	100
37.5	100
26.5	100
22.4	100
19.0	96
16	89
13.2	82
9.5	68
6.70	59
4.75	53
2.36	36
1.180	24
0.600	17
0.300	12
0.150	9
0.075	8

Received Water Content (%)	Cobbles (%)	Gravel (%)	Sand (%)	Fines (%)	D60 (mm)	D30 (mm)	D10 (mm)	Cu	Cc
2.1	0	47	45	8	6.9	1.7	0.2	38.7	2.5

Sample Description: (GW-GM) fine angular GRAVEL and fine to coarse SAND, some non-plastic fines; brown; non-cohesive.

USCS Classification: GW-GM

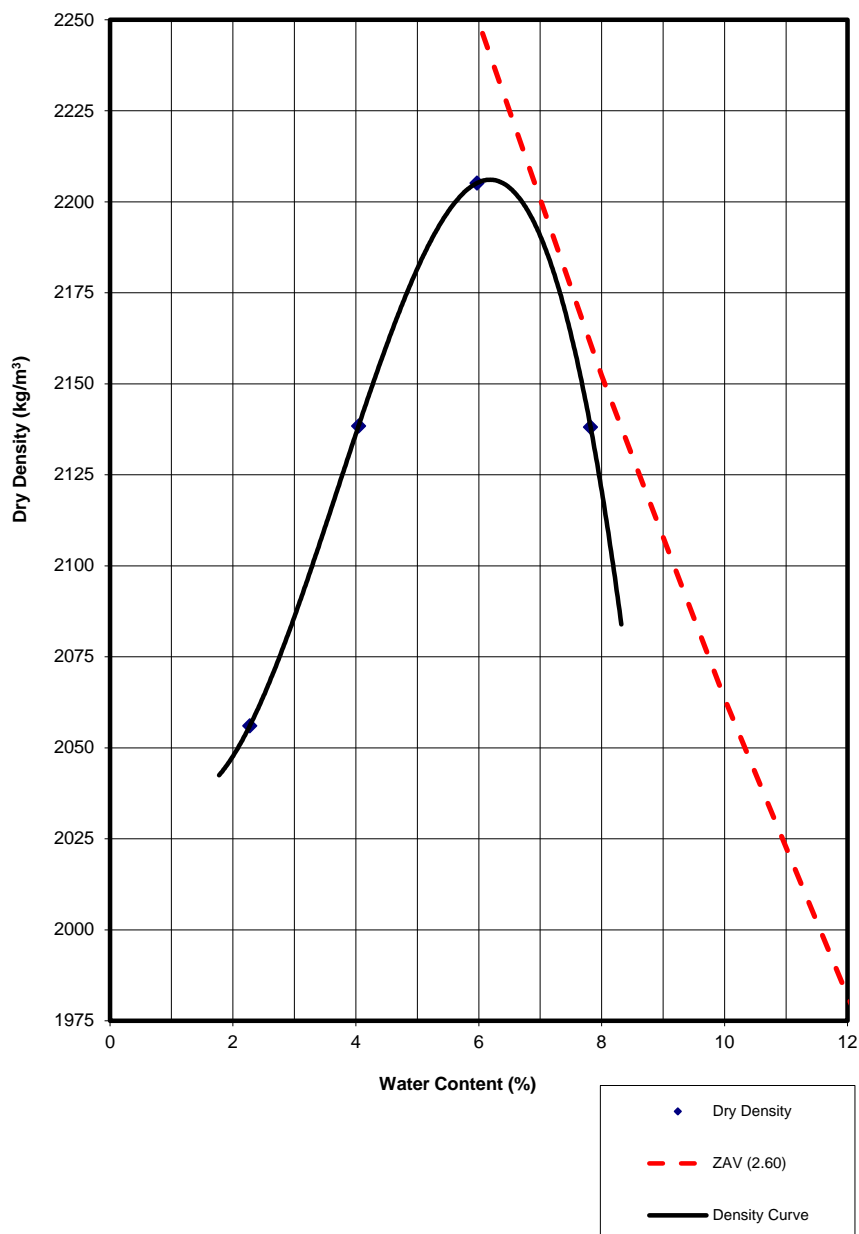
Remarks: Material was adjusted/ modified to comply within the specified boundaries above.

# LABORATORY COMPACTION CHARACTERISTICS OF SOIL USING STANDARD EFFORT

(Ministry of Transportation, Ontario, Test Method LS-706 Rev. No. 33/ ASTM D698)

Project No.:	19115286	Phase:	27.1
Short Title:	Thurber Large Scale Direct Shear Testing - Index	Lab No.:	D317-11
Tested By:	SP	Test Date:	13-Feb-20
Bulk Sample No.:	10	Date Sampled:	-
Sample ID:	Bulk 10	SampleType:	Quarry
Sampled By:	Client	Remarks: Sample Adjusted to meet spec.	

## MOISTURE DENSITY RELATIONSHIP



### Maximum Dry Density

Max. Dry Density 2206 kg/m<sup>3</sup>

Optimum w 6.2 %

Method C

### Rock Correction (if required)

% Oversize 4 %

Max. Dry Density 2219 kg/m<sup>3</sup> @ 6.0 %

Assumed Specific Gravity = 2.60

### Sample Description:

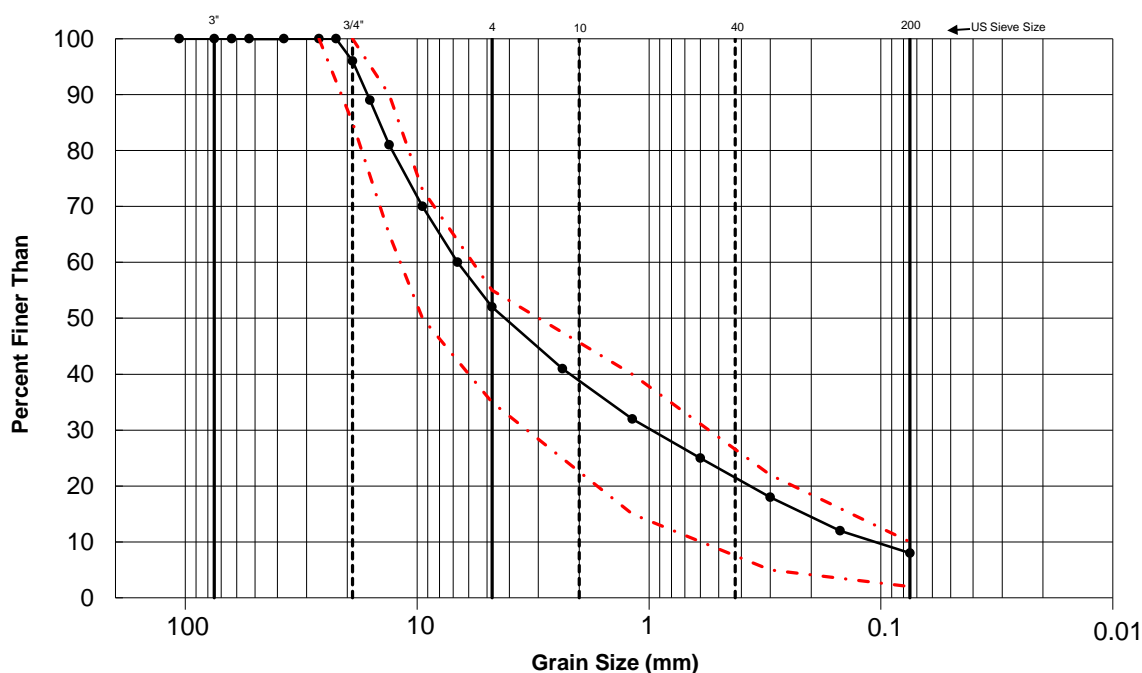
(GW-GM) fine angular GRAVEL and fine to coarse SAND, some non-plastic fines; brown; non-cohesive.

As Received Water Content: 2.1 %

## METHOD OF TEST FOR SIEVE ANALYSIS OF AGGREGATES

(Ministry of Transportation, Ontario, Test Method LS-602 Rev. No. 33)

Project No.:	19115286	Phase:	27.1	Date:	31-Dec-19
Short Title:	Thurber Large Scale Direct Shear Testing - Index				
Sub Sampled By:	JG	Washed By:	JG	Sieved By:	JG
Field Tag No.:	-	Source:	-	Sample Type:	Quarry
Lab No.:	D317-12	Northing:	-	Sample No.:	Bulk Sample #12
Sampled By:	Client	Easting:	-	Depth From:	- m
Sample Date:	-	Elevation:	- m	Depth To:	- m
Boundary Plot:	MTO Granular A-Quarry	Drying Method:	Oven		
Composite Sieve:	Yes	if Yes, Split on:	4.75 mm		
Material Excluded from Sieve:	No	Describe:			
Prior Testing on Sample:	No	Describe:			



Sieve Size (mm)	Passing %
106.0	100
75.0	100
63.0	100
53.0	100
37.5	100
26.5	100
22.4	100
19.0	96
16	89
13.2	81
9.5	70
6.7	60
4.75	52
2.36	41
1.18	32
0.600	25
0.300	18
0.150	12
0.075	8

Cobbles	Coarse	Fine	Coarse	Medium	Fine	Silt and Clay Size
	Gravel Size		Sand Size			

Received Water Content (%)	Cobbles (%)	Gravel (%)	Sand (%)	Fines (%)	D60 (mm)	D30 (mm)	D10 (mm)	Cu	Cc
4.4	0	48	44	8	6.7	1.0	0.1	63.7	1.5

Sample Description: (GW-GM) fine angular GRAVEL and fine to coarse SAND, some non-plastic fines; brown; non-cohesive.

USCS Classification: GW-GM

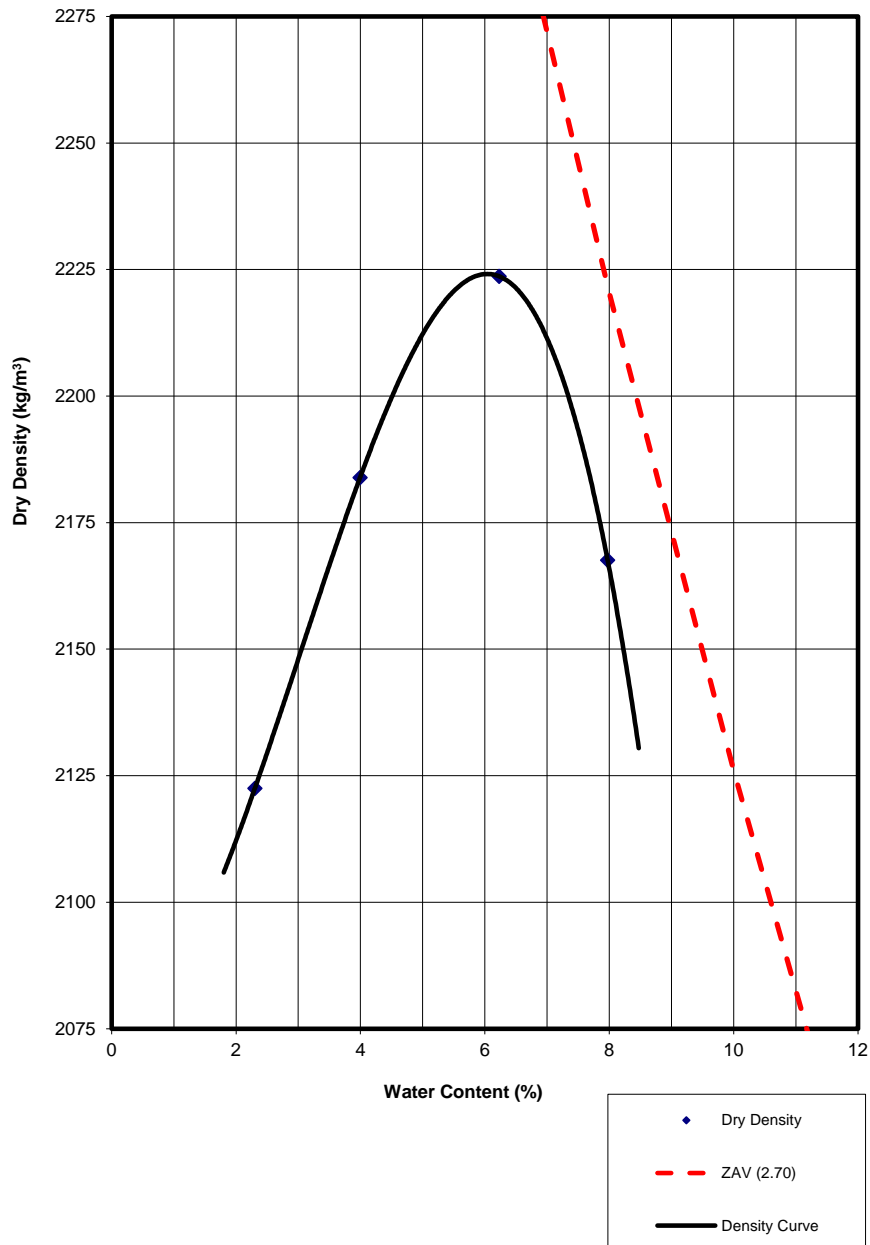
Remarks:

# LABORATORY COMPACTION CHARACTERISTICS OF SOIL USING STANDARD EFFORT

(Ministry of Transportation, Ontario, Test Method LS-706 Rev. No. 33/ ASTM D698)

Project No.:	19115286	Phase:	27.1
Short Title:	Thurber Large Scale Direct Shear Testing - Index	Lab No.:	D317-12
Tested By:	SP	Test Date:	03-Jan-20
Bulk Sample No.:	12	Date Sampled:	-
Sample ID:	BS12-1 to BS12-6	Sample Type:	Quarry
Sampled By:	Client	Remarks:	-

## MOISTURE DENSITY RELATIONSHIP



### Maximum Dry Density

Max. Dry Density 2224 kg/m<sup>3</sup>

Optimum w 6.0 %

Method C

### Rock Correction (if required)

% Oversize \_\_\_\_\_ %

Max. Dry Density \_\_\_\_\_ kg/m<sup>3</sup> @ \_\_\_\_\_

Assumed Specific Gravity = 2.70

### Sample Description:

(GW-GM) fine angular GRAVEL and fine to coarse SAND, some non-plastic fines; brown; non-cohesive.

As Received Water Content: 4.4%



## PRAIRIES AND NORTH LABORATORIES

**ATTN:** Christopher Murray, M.A.Sc., P.Eng  
Geotechnical Engineer  
Thurber Engineering Ltd.

**Received:** 10-Dec-19  
**Report Date:** 06-Mar-20  
**Version:** Final

## GEOTECHNICAL LABORATORY TEST REPORT

**Client:** Thurber Engineering Ltd.  
**Project Title:** Thurber Large Scale Direct Shear Testing - Index  
**Client Reference No.:** PROJECT 24726 HIGHWAY 17 ARNPRIOR TO HALEY  
STATION  
**Golder Billing:** 19115286.27.0  
**Lab Schedule No.:** D317

A handwritten signature in blue ink, appearing to read 'Jeff Stone', positioned above a horizontal line.

**Jeff Stone, M.Eng., P.Eng.**  
Associate, Geotechnical Engineer  
Golder Associates Ltd.

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Our liability is limited to the cost of the test requested. The test results only relate to the sample as received. No liability in whole or in part is assumed for the collection, handling or transport of the sample, application or interpretation of the test data or results.

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**Golder Associates Ltd., Bay 8, 820 28th Street NE, Calgary Alberta, Canada T2K 6K1**  
**Tel. (403) 248-6386 Fax. (403) 248-6387**



# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

## Sample Identification

Project No.:	19115286	Phase: 27.0	Test Condition: Reconstituted
Client:	Thurber Engineering Ltd.		Sample: BS1-1 to BS1-8
Project Title:	Thurber Large Scale Direct Shear Testing		
Client Ref.:	PROJECT 24726 HIGHWAY 17 ARNPRIOR TO HALEY STATION	Source: Pit	Lab No.: D317-01

## INITIAL - Sample Dimensions

Test No.	1	2	3
Shear Box Geometry	Square	Square	Square
Length, mm	302	302	302
Width, mm	302	302	302
Height, mm	159	159	159
Area, cm <sup>2</sup>	912	912	912
Volume, cm <sup>3</sup>	14501	14501	14501

## Weight Volume Relationships

Test No.	1	2	3
Sample Type	Reconstituted	Reconstituted	Reconstituted
Initial Wet Wt, kg	33.83	33.83	33.83
Initial Dry Wt, kg	31.85	31.85	31.85
Initial w, %	6.2	6.2	6.2
Final w, %	9.7	9.6	9.2
Initial $\rho_{wet}$ , kg/m <sup>3</sup>	2333	2333	2333
Initial $\rho_{dry}$ , kg/m <sup>3</sup>	2196	2196	2196
Specific Gravity (assumed)	2.70	2.70	2.70
Initial Void Ratio, e	0.23	0.23	0.23

## Equipment Description - LDS\_30S

Axial LDT	Serial #	BBD100410
Axial Load Cell	Serial #	1084597
Vertical LDT	Serial #	BBD110464
Vertical Load Cell	Serial #	978593

## Remarks

<ul style="list-style-type: none"> <li>- Three test specimens were built and sheared at 40, 100, and 150 kPa normal stresses.</li> <li>- Each specimen was placed in 3 lifts and each lift was plate-tamped to level</li> <li>- Each lift was compacted to 98% SPMDD at +/- 2% of optimum water content</li> <li>- The specimen was inundated with water followed by application of the normal stress.</li> <li>- An area correction was applied to the normal and shear stress calculations</li> </ul>	
Sample Description:	(SP-SM) fine to coarse SAND and fine angular GRAVEL, some non-plastic fines; brown; non-cohesive, moist.

Tested By: FC/SP

Date Completed: 3-Feb-20

Reviewed By: JS

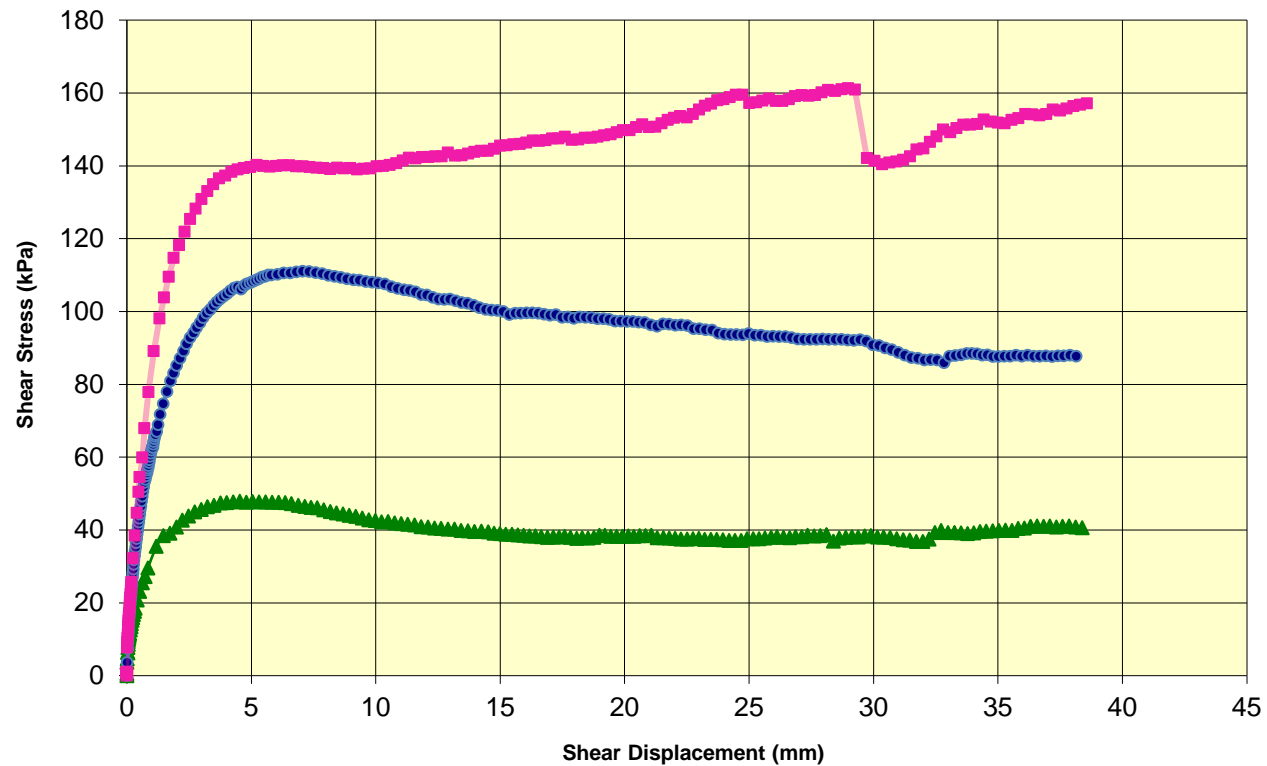
# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

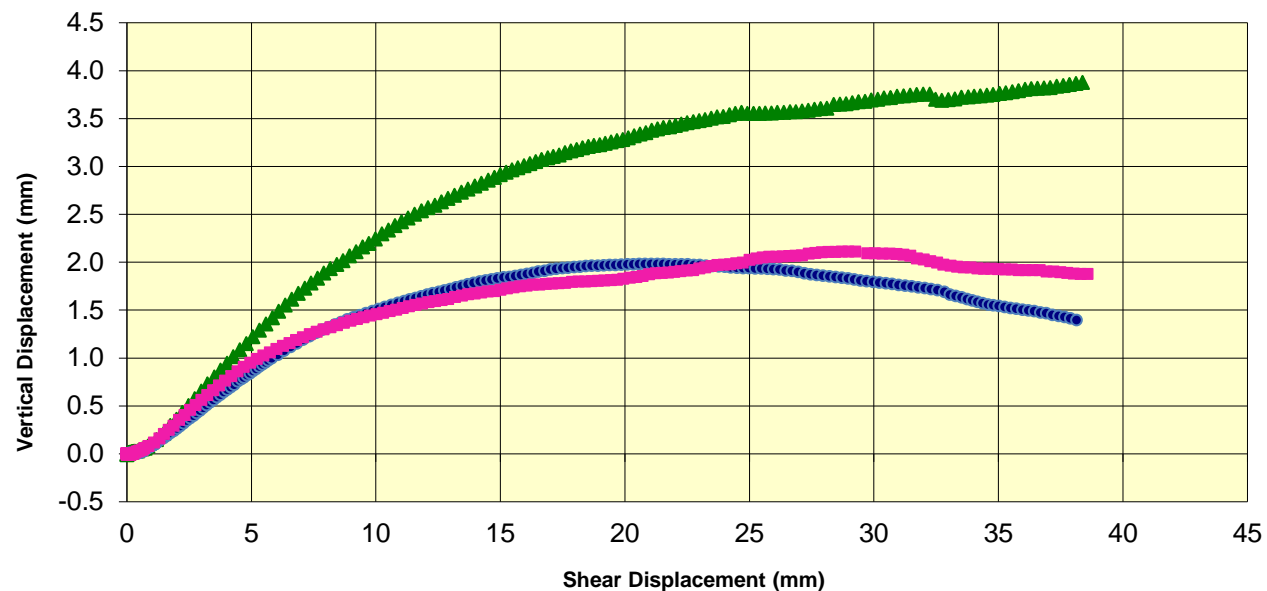
## Sample Identification

Project No.: 19115286	Phase: 27.0	Test Condition: Reconstituted
Client: Thurber Engineering Ltd.	Sample: BS1-1 to BS1-8	
Project Title: Thurber Large Scale Direct Shear		
Client Ref.: PROJECT 24726 HIGHWAY 17	Source: Pit	
ARNPRIOR TO HALEY STATION	Lab No.: D317-01	

## Peak and Residual Shear Stress vs. Displacement



—▲— 40 kPa Peak —●— 100 kPa Peak —■— 150 kPa Peak



# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

Project No.: 19115286

Phase: 27.0

Short Title: Thurber Large Scale Direct Shear Testing

Schedule No.: D317

Tested By: FC/SP

Date: 31-Jan-20

Source: Pit

Test Condition: Reconstituted

Sample: BS1-1 to BS1-8

Sample Description: (SP-SM) fine to coarse SAND and fine angular GRAVEL, some non-plastic fines; brown; non-cohesive, moist.

**Post-Test Photo - 150 kPa**





# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

## Sample Identification

Project No.:	19115286	Phase: 27.0	Test Condition: Reconstituted
Client:	Thurber Engineering Ltd.		Sample: BS2-1 to BS2-8
Project Title:	Thurber Large Scale Direct Shear Testing		
Client Ref.:	PROJECT 24726 HIGHWAY 17 ARNPRIOR TO HALEY STATION	Source: Pit	Lab No.: D317-02

## INITIAL - Sample Dimensions

Test No.	1	2	3
Shear Box Geometry	Square	Square	Square
Length, mm	302	302	302
Width, mm	302	302	302
Height, mm	159	159	159
Area, cm <sup>2</sup>	912	912	912
Volume, cm <sup>3</sup>	14501	14501	14501

## Weight Volume Relationships

Test No.	1	2	3
Sample Type	Reconstituted	Reconstituted	Reconstituted
Initial Wet Wt, kg	33.43	33.43	33.43
Initial Dry Wt, kg	31.78	31.78	31.78
Initial w, %	5.2	5.2	5.2
Final w, %	11.2	9.9	9.1
Initial $\rho_{wet}$ , kg/m <sup>3</sup>	2305	2305	2305
Initial $\rho_{dry}$ , kg/m <sup>3</sup>	2191	2191	2191
Specific Gravity (assumed)	2.70	2.70	2.70
Initial Void Ratio, e	0.23	0.23	0.23

## Equipment Description - LDS\_30S

Axial LDT	Serial #	BBD100410
Axial Load Cell	Serial #	1084597
Vertical LDT	Serial #	BBD110464
Vertical Load Cell	Serial #	978593

## Remarks

<ul style="list-style-type: none"> <li>- Three test specimens were built and sheared at 40, 100, and 150 kPa normal stresses.</li> <li>- Each specimen was placed in 3 lifts and each lift was plate-tamped to level</li> <li>- Each lift was compacted to 98% SPMDD at +/- 2% of optimum water content</li> <li>- The specimen was inundated with water followed by application of the normal stress</li> <li>- An area correction was applied to the normal and shear stress calculations</li> </ul>	
Sample Description:	(SP-SM) fine to coarse SAND and fine angular GRAVEL, some non-plastic fines; brown; non-cohesive, moist.

Tested By: FC/SP

Date Completed: 4-Feb-20

Reviewed By: JS

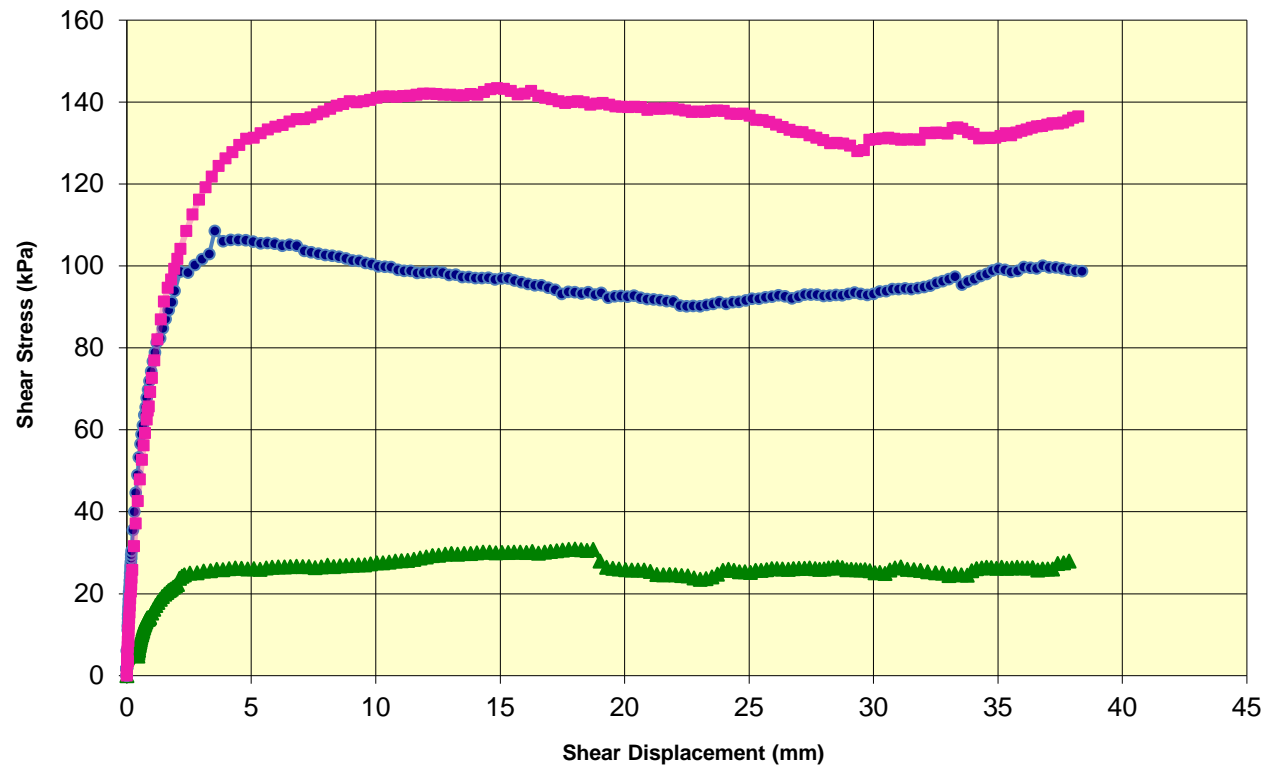
# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

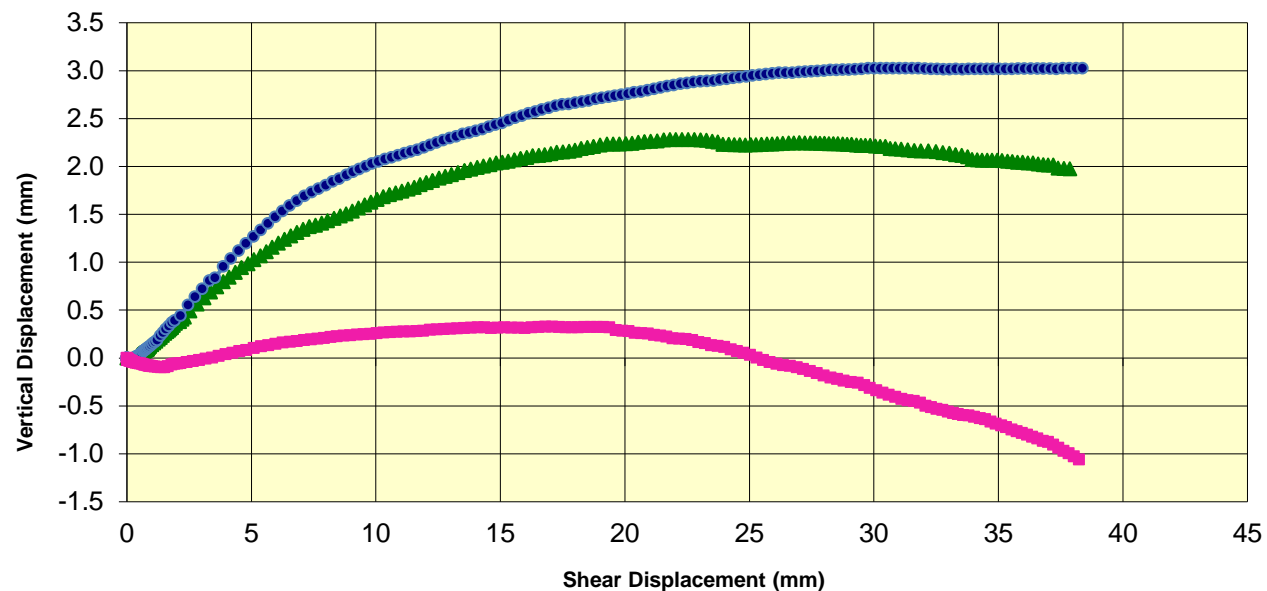
## Sample Identification

Project No.: 19115286	Phase: 27.0	Test Condition: Reconstituted
Client: Thurber Engineering Ltd.	Sample: BS2-1 to BS2-8	
Project Title: Thurber Large Scale Direct Shear		
Client Ref.: PROJECT 24726 HIGHWAY 17	Source: Pit	
ARNPRIOR TO HALEY STATION	Lab No.: D317-02	

## Peak and Residual Shear Stress vs. Displacement



—▲— 40 kPa Peak —●— 100 kPa Peak —■— 150 kPa Peak



# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

Project No.:	19115286	Phase:	27.0
Short Title:	Thurber Large Scale Direct Shear Testing	Schedule No.:	D317
Tested By:	FC/SP	Date:	04-Feb-20

Source:	Pit	Test Condition:	Reconstituted	Sample:	BS2-1 to BS2-8
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Sample Description: (SP-SM) fine to coarse SAND and fine angular GRAVEL, some non-plastic fines; brown; non-cohesive, moist.

**Post-Test Photo - 150 kPa**



# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

## Sample Identification

Project No.:	19115286	Phase: 27.0	Test Condition:	Reconstituted
Client:	Thurber Engineering Ltd.		Sample:	BS3-1 to BS3-8
Project Title:	Thurber Large Scale Direct Shear Testing			
Client Ref.:	PROJECT 24726 HIGHWAY 17 ARNPRIOR TO HALEY STATION		Source:	Pit
			Lab No.:	D317-03

## INITIAL - Sample Dimensions

Test No.	1	2	3
Shear Box Geometry	Square	Square	Square
Length, mm	302	302	302
Width, mm	302	302	302
Height, mm	159	159	159
Area, cm <sup>2</sup>	912	912	912
Volume, cm <sup>3</sup>	14501	14501	14501

## Weight Volume Relationships

Test No.	1	2	3
Sample Type	Reconstituted	Reconstituted	Reconstituted
Initial Wet Wt, kg	32.41	32.41	32.41
Initial Dry Wt, kg	30.76	30.76	30.76
Initial w, %	5.3	5.3	5.3
Final w, %	10.7	10.6	9.6
Initial $\rho_{wet}$ , kg/m <sup>3</sup>	2235	2235	2235
Initial $\rho_{dry}$ , kg/m <sup>3</sup>	2121	2121	2121
Specific Gravity (assumed)	2.70	2.70	2.70
Initial Void Ratio, e	0.27	0.27	0.27

## Equipment Description - LDS\_30S

Axial LDT	Serial #	BBD100410
Axial Load Cell	Serial #	1084597
Vertical LDT	Serial #	BBD110464
Vertical Load Cell	Serial #	978593

## Remarks

<ul style="list-style-type: none"> <li>- Three test specimens were built and sheared at 40, 100, and 150 kPa normal stresses.</li> <li>- Each specimen was placed in 3 lifts and each lift was plate-tamped to level</li> <li>- Each lift was compacted to 98% SPMDD at +/- 2% of optimum water content</li> <li>- The specimen was inundated with water followed by application of the normal stress.</li> <li>- An area correction was applied to the normal and shear stress calculations</li> </ul>	
Sample Description:	(SP) fine to coarse SAND and fine angular GRAVEL, trace non-plastic fines; brown; non-cohesive, moist

Tested By: FC/SP

Date Completed: 6-Feb-20

Reviewed By: JS



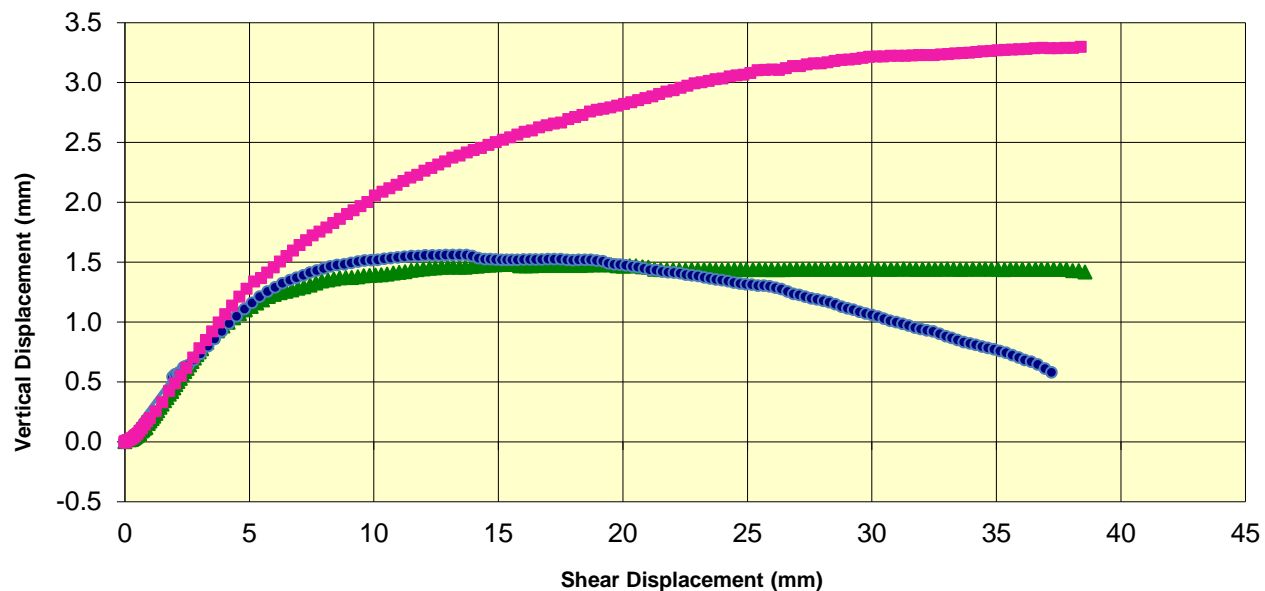
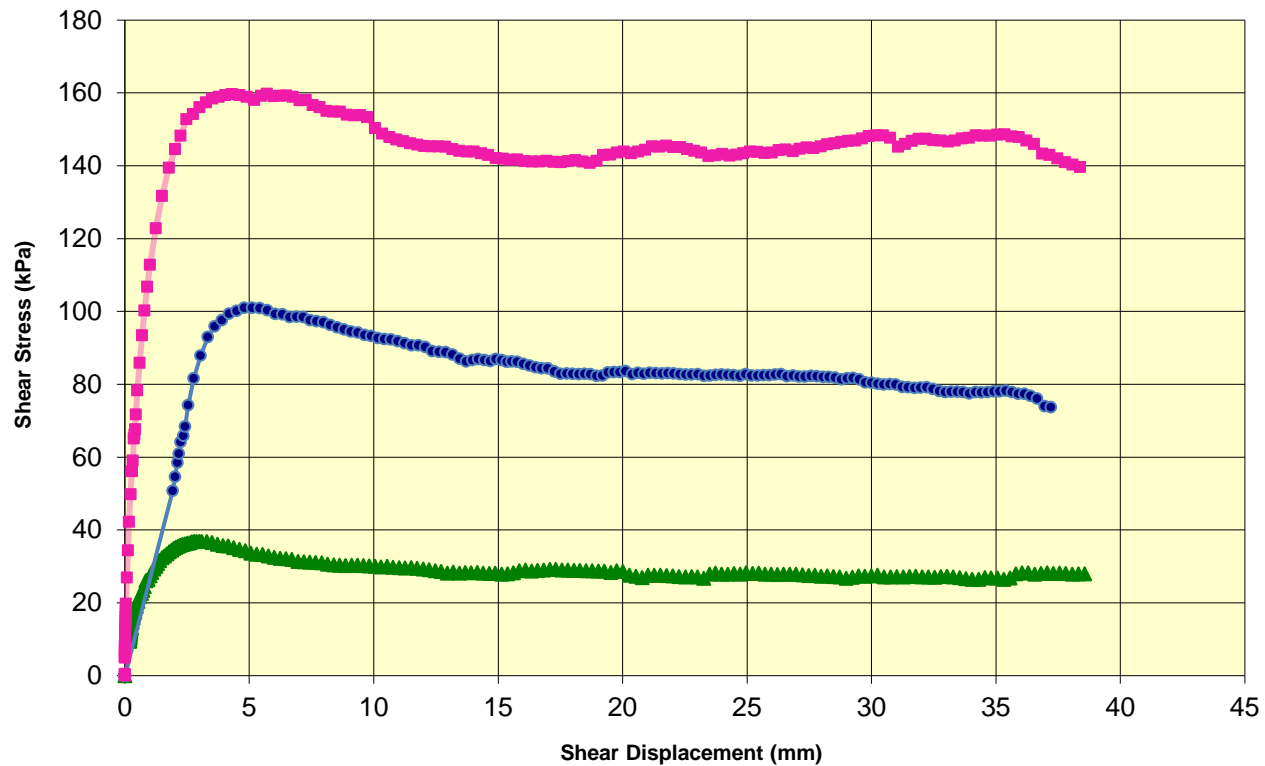
# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

## Sample Identification

Project No.: 19115286	Phase: 27.0	Test Condition: Reconstituted
Client: Thurber Engineering Ltd.	Sample: BS3-1 to BS3-8	
Project Title: Thurber Large Scale Direct Shear		
Client Ref.: PROJECT 24726 HIGHWAY 17	Source: Pit	
ARNPRIOR TO HALEY STATION	Lab No.: D317-03	

## Peak and Residual Shear Stress vs. Displacement







GOLDER

# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

Project No.: 19115286

Phase: 27.0

Short Title: Thurber Large Scale Direct Shear Testing

Schedule No.: D317

Tested By: FC/SP

Date: 06-Feb-20

Source: Pit

Test Condition: Reconstituted

Sample: BS3-1 to BS3-8

Sample Description: (SP) fine to coarse SAND and fine angular GRAVEL, trace non-plastic fines; brown; non-cohesive, moist

## Post-Test Photo - 150 kPa



The testing services reported herein have been performed in accordance with the indicated recognized standard, or in accordance with local industry practice. This report is for the sole use of the designated client. This report constitutes a testing service only and does not represent any results interpretation or opinion regarding specification compliance or material suitability. Engineering interpretation can be provided by Golder Associates Ltd. upon request.

# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

## Sample Identification

Project No.:	19115286	Phase: 27.0	Test Condition: Reconstituted
Client:	Thurber Engineering Ltd.		Sample: BS11-1 to BS11-6
Project Title:	Thurber Large Scale Direct Shear Testing		
Client Ref.:	PROJECT 24726 HIGHWAY 17 ARNPRIOR TO HALEY STATION	Source: Pit	Lab No.: D317-04

## INITIAL - Sample Dimensions

Test No.	1	2	3
Shear Box Geometry	Square	Square	Square
Length, mm	302	302	302
Width, mm	302	302	302
Height, mm	159	159	159
Area, cm <sup>2</sup>	912	912	912
Volume, cm <sup>3</sup>	14501	14501	14501

## Weight Volume Relationships

Test No.	1	2	3
Sample Type	Reconstituted	Reconstituted	Reconstituted
Initial Wet Wt, kg	34.02	34.02	34.02
Initial Dry Wt, kg	32.02	32.02	32.02
Initial w, %	6.3	6.3	6.3
Final w, %	9.7	8.6	8.8
Initial $\rho_{wet}$ , kg/m <sup>3</sup>	2346	2346	2346
Initial $\rho_{dry}$ , kg/m <sup>3</sup>	2208	2208	2208
Specific Gravity (assumed)	2.70	2.70	2.70
Initial Void Ratio, e	0.22	0.22	0.22

## Equipment Description - LDS\_30S

Axial LDT	Serial #	BBD100410
Axial Load Cell	Serial #	1084597
Vertical LDT	Serial #	BBD110464
Vertical Load Cell	Serial #	978593

## Remarks

- Three test specimens were built and sheared at 40, 100, and 150 kPa normal stresses.
- Each specimen was placed in 3 lifts and each lift was plate-tamped to level
- Each lift was compacted to 98% SPMDD at +/- 2% of optimum water content
- The specimen was inundated with water followed by application of the normal stress.
- An area correction was applied to the normal and shear stress calculations

Sample Description: (GW-GM) fine angular GRAVEL and fine to coarse SAND, some non-plastic fines; brown; non-cohesive.

Tested By: FC/SP

Date Completed: 17-Jan-20

Reviewed By: JS

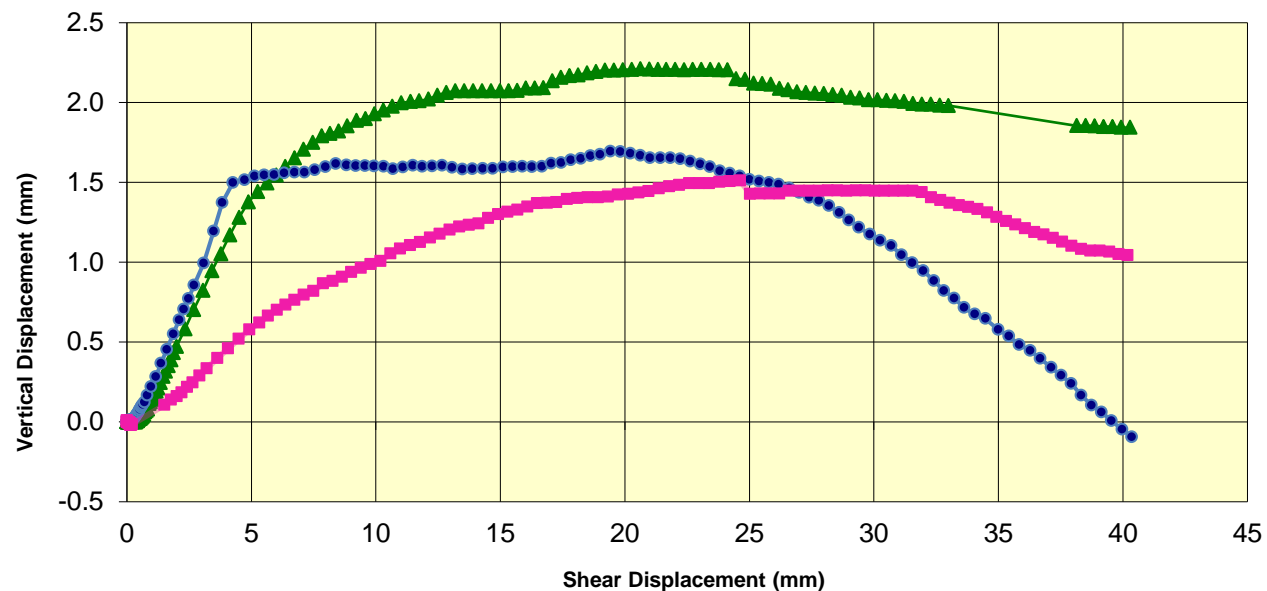
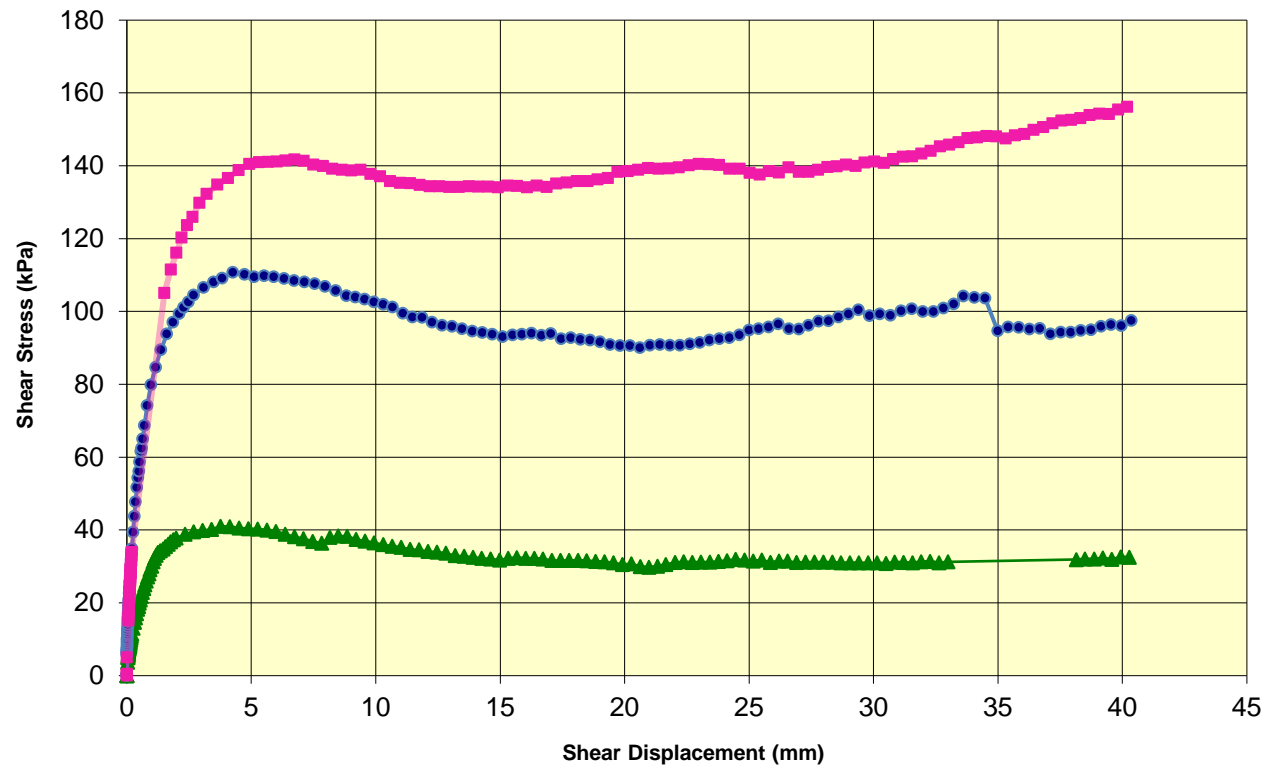
# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

## Sample Identification

Project No.: 19115286	Phase: 27.0	Test Condition: Reconstituted
Client: Thurber Engineering Ltd.	Sample: BS11-1 to BS11-6	
Project Title: Thurber Large Scale Direct Shear		
Client Ref.: PROJECT 24726 HIGHWAY 17	Source: Pit	
ARNPRIOR TO HALEY STATION	Lab No.: D317-04	

## Peak and Residual Shear Stress vs. Displacement





# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

Project No.: 19115286

Phase: 27.0

Short Title: Thurber Large Scale Direct Shear Testing

Schedule No.: D317

Tested By: FC/SP

Date: 17-Jan-20

Source: Pit

Test Condition: Reconstituted

Sample: BS11-1 to BS11-6

Sample Description: (GW-GM) fine angular GRAVEL and fine to coarse SAND, some non-plastic fines; brown; non-cohesive.

**Post-Test Photo - 100 kPa**



# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

## Sample Identification

Project No.:	19115286	Phase: 27.0	Test Condition:	Reconstituted
Client:	Thurber Engineering Ltd.		Sample:	BS4-1 to BS4-6
Project Title:	Thurber Large Scale Direct Shear Testing			
Client Ref.:	PROJECT 24726 HIGHWAY 17 ARNPRIOR TO HALEY STATION		Source:	Quarry
			Lab No.:	D317-05

## INITIAL - Sample Dimensions

Test No.	1	2	3
Shear Box Geometry	Square	Square	Square
Length, mm	302	302	302
Width, mm	302	302	302
Height, mm	159	159	159
Area, cm <sup>2</sup>	912	912	912
Volume, cm <sup>3</sup>	14501	14501	14501

## Weight Volume Relationships

Test No.	1	2	3
Sample Type	Reconstituted	Reconstituted	Reconstituted
Initial Wet Wt, kg	33.53	33.53	33.53
Initial Dry Wt, kg	31.77	31.77	31.77
Initial w, %	5.5	5.5	5.5
Final w, %	6.8	6.5	10.5
Initial $\rho_{wet}$ , kg/m <sup>3</sup>	2312	2312	2312
Initial $\rho_{dry}$ , kg/m <sup>3</sup>	2191	2191	2191
Specific Gravity (assumed)	2.70	2.70	2.70
Initial Void Ratio, e	0.23	0.23	0.23

## Equipment Description - LDS\_30S

Axial LDT	Serial #	BBD100410
Axial Load Cell	Serial #	1084597
Vertical LDT	Serial #	BBD110464
Vertical Load Cell	Serial #	978593

## Remarks

- Three test specimens were built and sheared at 40, 100, and 150 kPa normal stresses.
- Each specimen was placed in 3 lifts and each lift was plate-tamped to level
- Each lift was compacted to 98% SPMDD at +/- 2% of optimum water content
- The specimen was inundated with water followed by application of the normal stress.
- An area correction was applied to the normal and shear stress calculations

Sample Description: (GW-GM) fine angular GRAVEL and fine to coarse SAND, some non-plastic fines; brown; non-cohesive

Tested By: FC/SP

Date Completed: 13-Jan-20

Reviewed By: JS



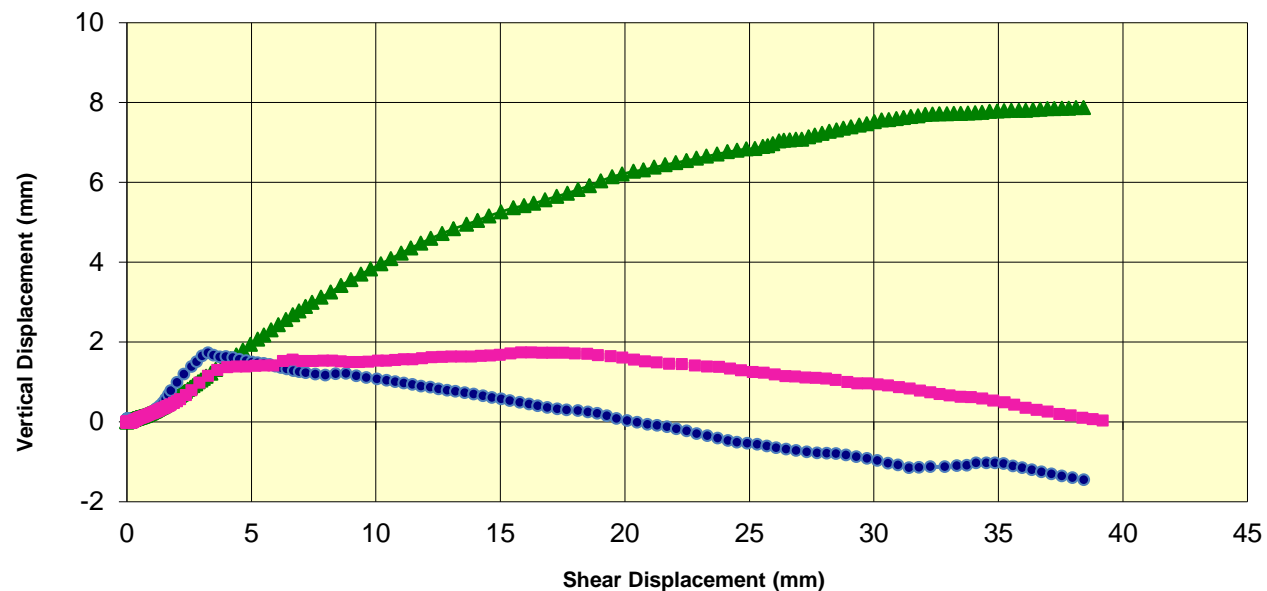
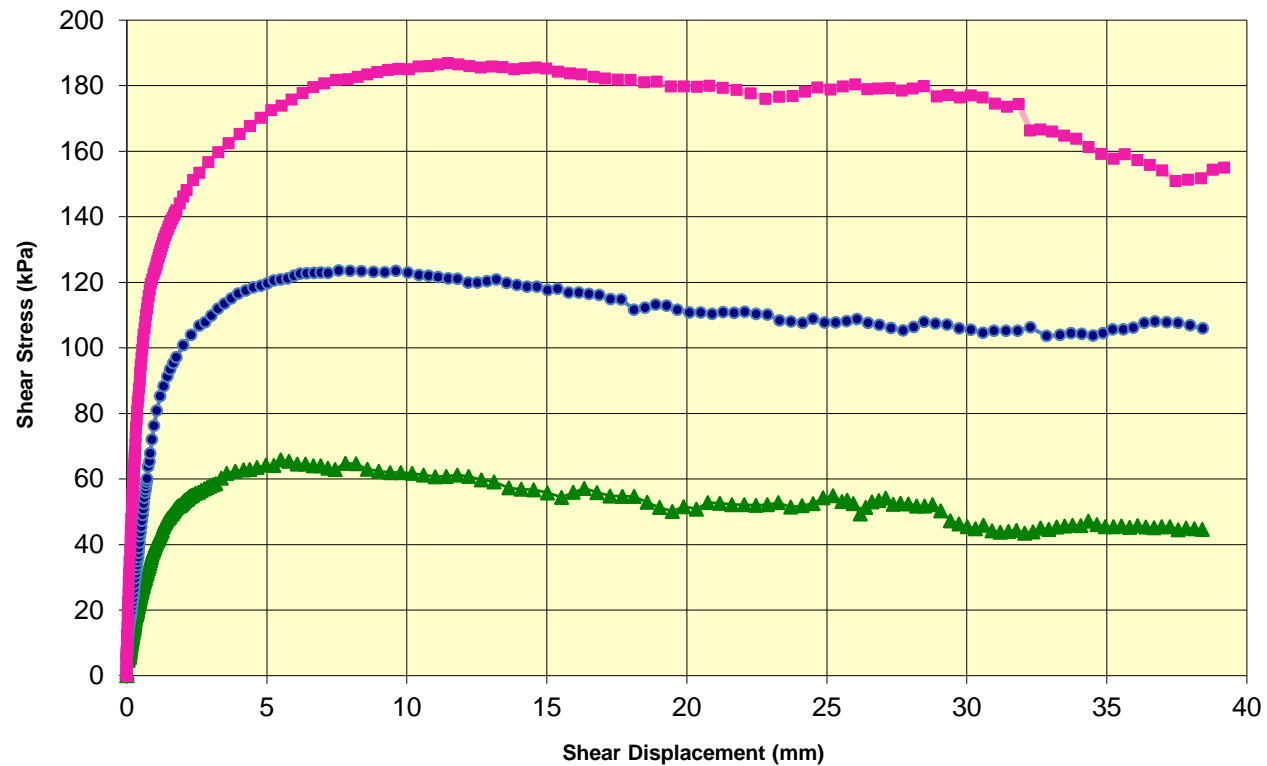
# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

## Sample Identification

Project No.: 19115286	Phase: 27.0	Test Condition: Reconstituted
Client: Thurber Engineering Ltd.	Sample: BS4-1 to BS4-6	
Project Title: Thurber Large Scale Direct Shear		
Client Ref.: PROJECT 24726 HIGHWAY 17	Source: Quarry	
ARNPRIOR TO HALEY STATION	Lab No.: D317-05	

## Peak and Residual Shear Stress vs. Displacement



# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

Project No.: 19115286

Phase: 27.0

Short Title: Thurber Large Scale Direct Shear Testing

Schedule No.: D317

Tested By: FC/SP

Date: 13-Jan-20

Source: Quarry

Test Condition: Reconstituted

Sample: BS4-1 to BS4-6

Sample Description: (GW-GM) fine angular GRAVEL and fine to coarse SAND, some non-plastic fines; brown; non-cohesive

## Post-Test Photo - 150 kPa





# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

## Sample Identification

Project No.:	19115286	Phase: 27.0	Test Condition:	Reconstituted
Client:	Thurber Engineering Ltd.		Sample:	BS5-01 to BS5-08
Project Title:	Thurber Large Scale Direct Shear Testing			
Client Ref.:	PROJECT 24726 HIGHWAY 17 ARNPRIOR TO HALEY STATION		Source:	Quarry
			Lab No.:	D317

## INITIAL - Sample Dimensions

Test No.	1	2	3
Shear Box Geometry	Square	Square	Square
Length, mm	302	302	302
Width, mm	302	302	302
Height, mm	159	159	159
Area, cm <sup>2</sup>	912	912	912
Volume, cm <sup>3</sup>	14501	14501	14501

## Weight Volume Relationships

Test No.	1	2	3
Sample Type	Reconstituted	Reconstituted	Reconstituted
Initial Wet Wt, kg	33.20	33.73	33.20
Initial Dry Wt, kg	31.35	31.85	31.35
Initial w, %	5.9	5.9	5.9
Final w, %	8.8	10.2	7.2
Initial $\rho_{wet}$ , kg/m <sup>3</sup>	2289	2326	2289
Initial $\rho_{dry}$ , kg/m <sup>3</sup>	2162	2196	2162
Specific Gravity (assumed)	2.70	2.70	2.70
Initial Void Ratio, e	0.25	0.23	0.25

## Equipment Description - LDS\_30S

Axial LDT	Serial #	BBD100410
Axial Load Cell	Serial #	1084597
Vertical LDT	Serial #	BBD110464
Vertical Load Cell	Serial #	978593

## Remarks

- Three test specimens were built and sheared at 40, 100, and 150 kPa normal stresses.
- Each specimen was placed in 3 lifts and each lift was plate-tamped to level
- Each lift was compacted to 98% SPMDD at +/- 2% of optimum water content
- The specimen was inundated with water followed by application of the normal stress.
- An area correction was applied to the normal and shear stress calculations

Sample Description: (GP-GM) fine angular GRAVEL and fine to coarse SAND, some non-plastic fines; brown; non-cohesive

Tested By: FC/SP

Date Completed: 15-Jan-20

Reviewed By: JS

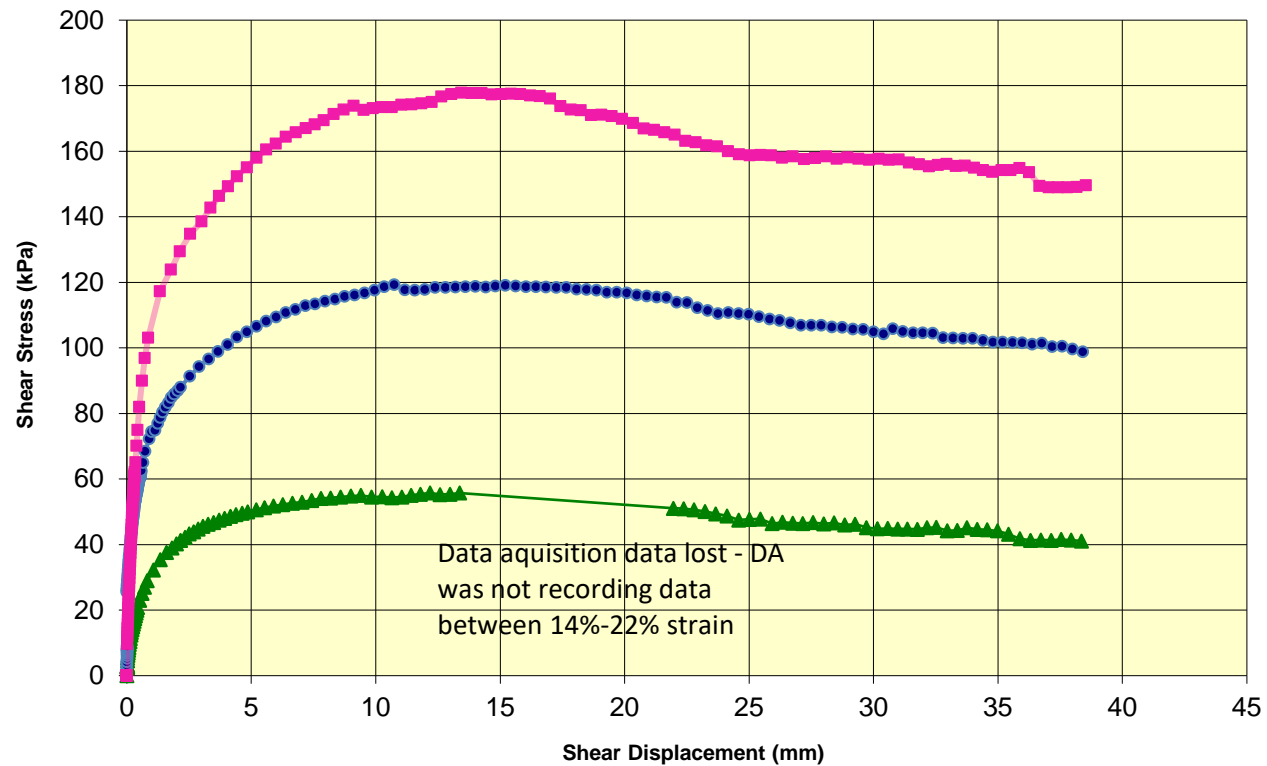
# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

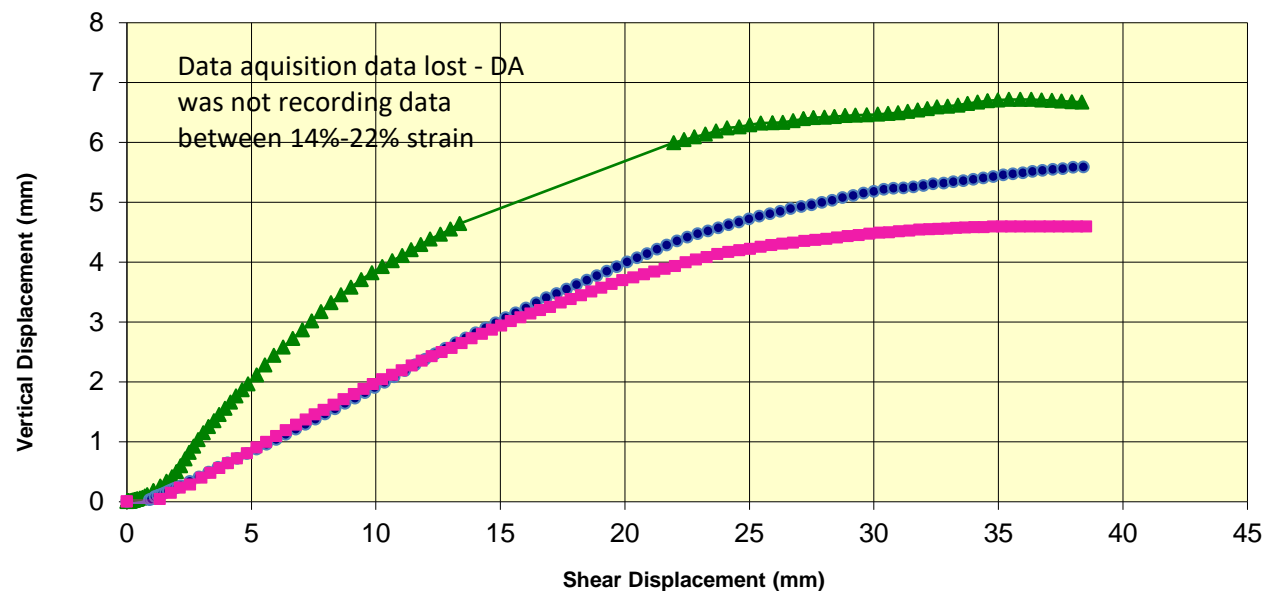
## Sample Identification

Project No.: 19115286	Phase: 27.0	Test Condition: Reconstituted
Client: Thurber Engineering Ltd.	Sample: BS5-01 to BS5-08	
Project Title: Thurber Large Scale Direct Shear		
Client Ref.: PROJECT 24726 HIGHWAY 17	Source: Quarry	
ARNPRIOR TO HALEY STATION	Lab No.: D317	

## Peak and Residual Shear Stress vs. Displacement



▲ 40 kPa Peak
 ● 100 kPa Peak
 ■ 150 kPa Peak



# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

Project No.: 19115286

Phase: 27.0

Short Title: Thurber Large Scale Direct Shear Testing

Schedule No.: D317

Tested By: FC/SP

Date: 15-Jan-20

Source: Quarry

Test Condition: Reconstituted

Sample: BS5-01 to BS5-08

Sample Description: (GP-GM) fine angular GRAVEL and fine to coarse SAND, some non-plastic fines; brown; non-cohesive

## Post-Test Photo - 150 kPa



# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

## Sample Identification

Project No.:	19115286	Phase: 27.0	Test Condition:	Reconstituted
Client:	Thurber Engineering Ltd.		Sample:	Modified BS 6 (1-6)
Project Title:	Thurber Large Scale Direct Shear Testing			
Client Ref.:	PROJECT 24726 HIGHWAY 17 ARNPRIOR TO HALEY STATION		Source:	Quarry
			Lab No.:	D317-07

## INITIAL - Sample Dimensions

Test No.	1	2	3
Shear Box Geometry	Square	Square	Square
Length, mm	302	302	302
Width, mm	302	302	302
Height, mm	159	159	159
Area, cm <sup>2</sup>	912	912	912
Volume, cm <sup>3</sup>	14501	14501	14501

## Weight Volume Relationships

Test No.	1	2	3
Sample Type	Reconstituted	Reconstituted	Reconstituted
Initial Wet Wt, kg	34.05	34.05	34.05
Initial Dry Wt, kg	31.90	31.90	31.90
Initial w, %	6.7	6.7	6.7
Final w, %	9.7	10.1	10.9
Initial $\rho_{wet}$ , kg/m <sup>3</sup>	2348	2348	2348
Initial $\rho_{dry}$ , kg/m <sup>3</sup>	2200	2200	2200
Specific Gravity (assumed)	2.70	2.70	2.70
Initial Void Ratio, e	0.23	0.23	0.23

## Equipment Description - LDS\_30S

Axial LDT	Serial #	BBD100410
Axial Load Cell	Serial #	1084597
Vertical LDT	Serial #	BBD110464
Vertical Load Cell	Serial #	978593

## Remarks

- Three test specimens were built and sheared at 40, 100, and 150 kPa normal stresses.
- Each specimen was placed in 3 lifts and each lift was plate-tamped to level
- Each lift was compacted to 98% SPMDD at +/- 2% of optimum water content
- The specimen was inundated with water followed by application of the normal stress
- An area correction was applied to the normal and shear stress calculations

Sample Description: (GW-GM) fine angular GRAVEL and fine to coarse SAND, some non-plastic fines; brown; non-cohesive.

Tested By: FC/SP

Date Completed: 18-Feb-20

Reviewed By: JS

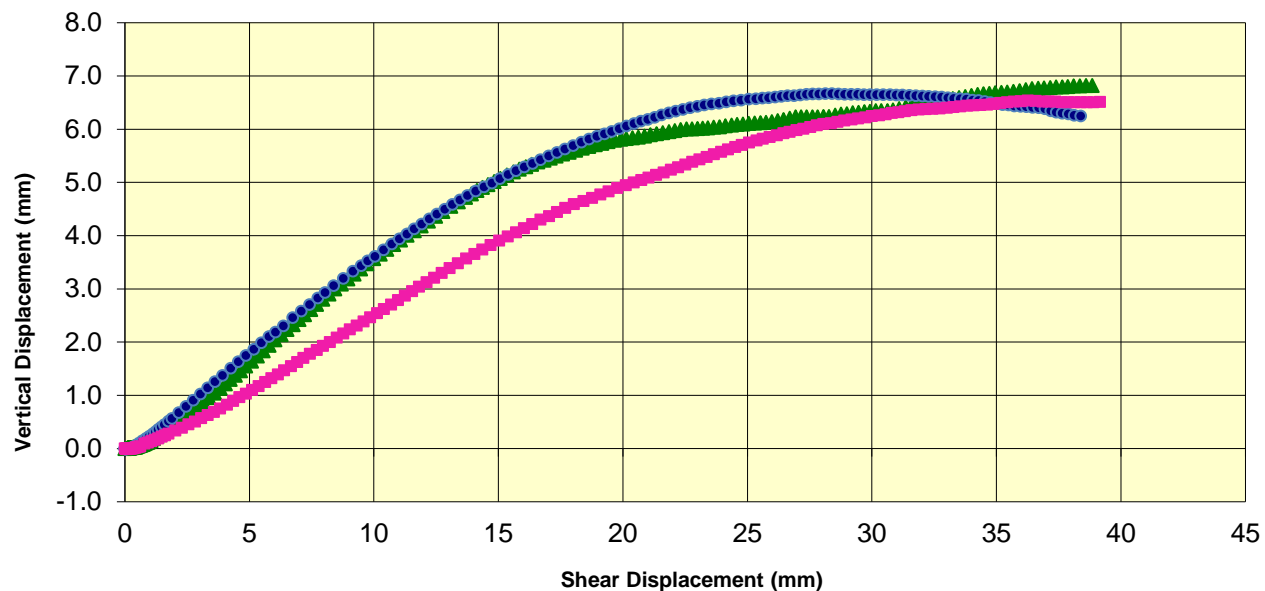
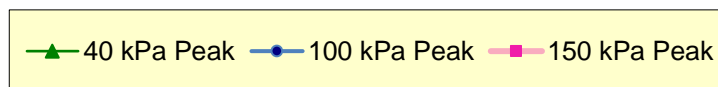
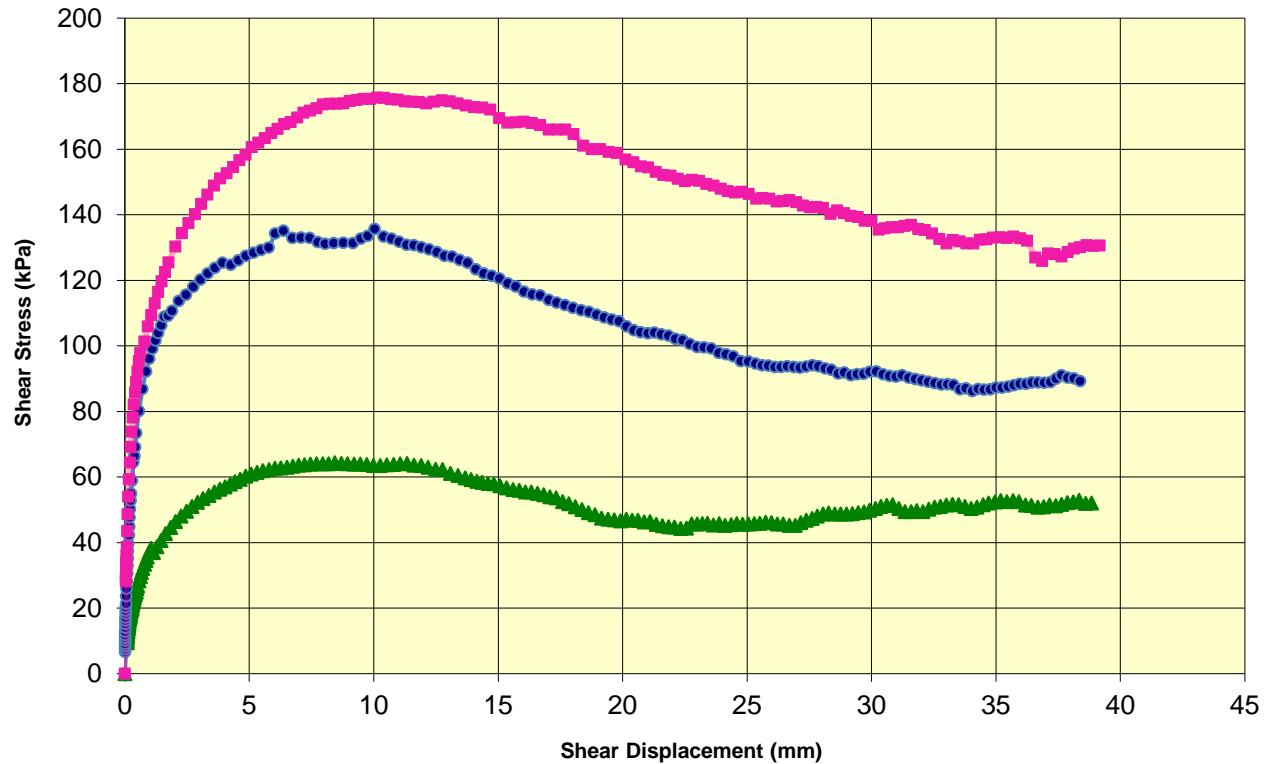
# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

## Sample Identification

Project No.: 19115286	Phase: 27.0	Test Condition: Reconstituted
Client: Thurber Engineering Ltd.		Sample: Modified BS 6 (1-6)
Project Title: Thurber Large Scale Direct Shear		
Client Ref.: PROJECT 24726 HIGHWAY 17		Source: Quarry
ARNPRIOR TO HALEY STATION		Lab No.: D317-07

## Peak and Residual Shear Stress vs. Displacement





# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

Project No.: 19115286

Phase: 27.0

Short Title: Thurber Large Scale Direct Shear Testing

Schedule No.: D317

Tested By: FC/SP

Date: 18-Feb-20

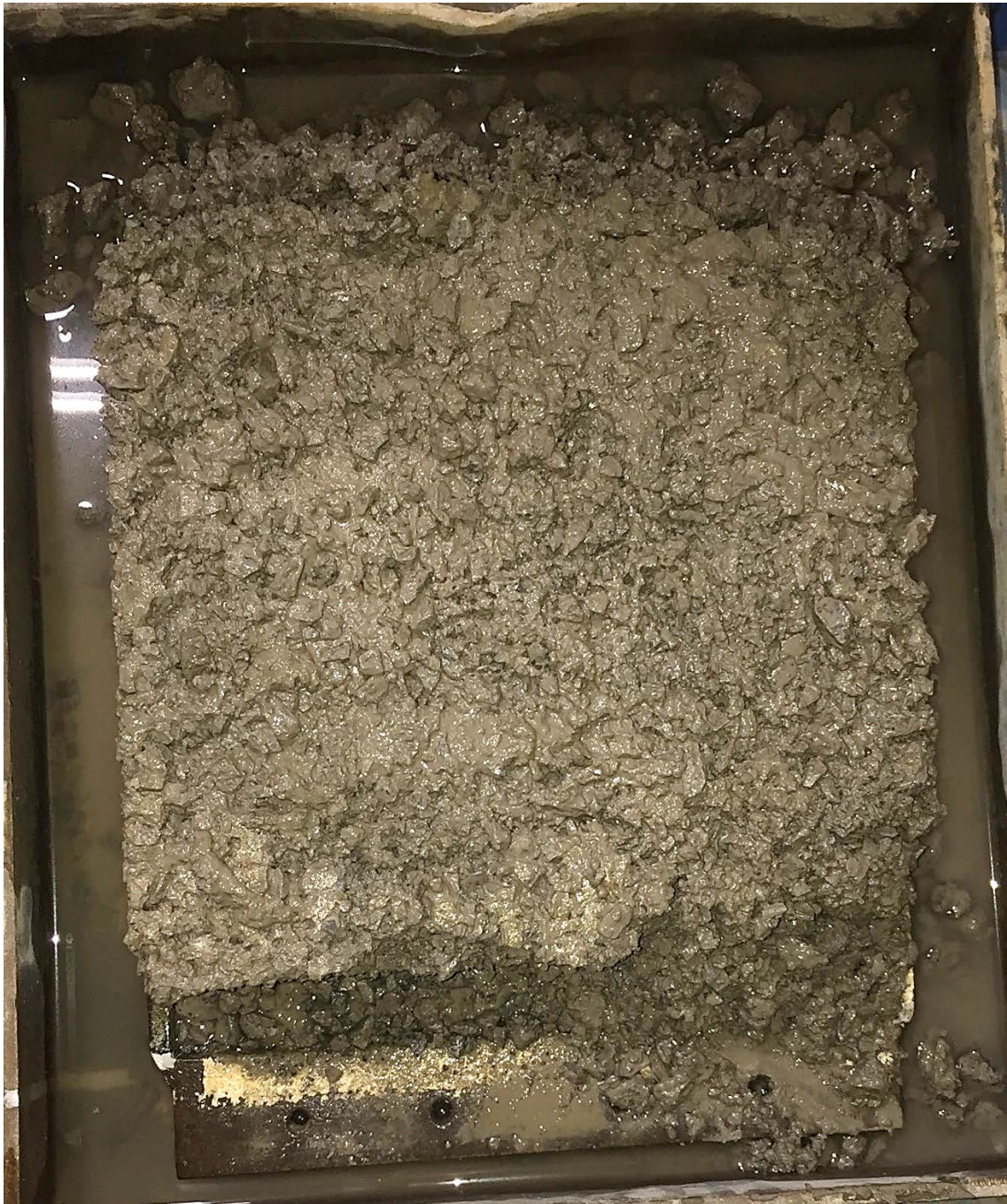
Source: Quarry

Test Condition: Reconstituted

Sample: Modified BS 6 (1-6)

Sample Description: (GW-GM) fine angular GRAVEL and fine to coarse SAND, some non-plastic fines; brown; non-cohesive.

**Post-Test Photo - 150 kPa**



# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

## Sample Identification

Project No.:	19115286	Phase: 27.0	Test Condition:	Reconstituted
Client:	Thurber Engineering Ltd.		Sample:	Modified BS 7 (1-6)
Project Title:	Thurber Large Scale Direct Shear Testing			
Client Ref.:	PROJECT 24726 HIGHWAY 17 ARNPRIOR TO HALEY STATION		Source:	Quarry
			Lab No.:	D317-08

## INITIAL - Sample Dimensions

Test No.	1	2	3
Shear Box Geometry	Square	Square	Square
Length, mm	302	302	302
Width, mm	302	302	302
Height, mm	159	159	159
Area, cm <sup>2</sup>	912	912	912
Volume, cm <sup>3</sup>	14501	14501	14501

## Weight Volume Relationships

Test No.	1	2	3
Sample Type	Reconstituted	Reconstituted	Reconstituted
Initial Wet Wt, kg	32.44	32.44	32.44
Initial Dry Wt, kg	30.85	30.85	30.85
Initial w, %	5.2	5.2	5.2
Final w, %	12.7	7.5	15.5
Initial $\rho_{wet}$ , kg/m <sup>3</sup>	2237	2237	2237
Initial $\rho_{dry}$ , kg/m <sup>3</sup>	2127	2127	2127
Specific Gravity (assumed)	2.70	2.70	2.70
Initial Void Ratio, e	0.27	0.27	0.27

## Equipment Description - LDS\_30S

Axial LDT	Serial #	BBD100410
Axial Load Cell	Serial #	1084597
Vertical LDT	Serial #	BBD110464
Vertical Load Cell	Serial #	978593

## Remarks

- Three test specimens were built and sheared at 40, 100, and 150 kPa normal stresses.
- Each specimen was placed in 3 lifts and each lift was plate-tamped to level
- Each lift was compacted to 98% SPMDD at +/- 2% of optimum water content
- The specimen was inundated with water followed by application of the normal stress
- An area correction was applied to the normal and shear stress calculations

Sample Description: (GW-GM) fine angular GRAVEL and fine to coarse SAND, some non-plastic fines; brown; non-cohesive.

Tested By: FC/SP

Date Completed: 17-Jan-20

Reviewed By: JS

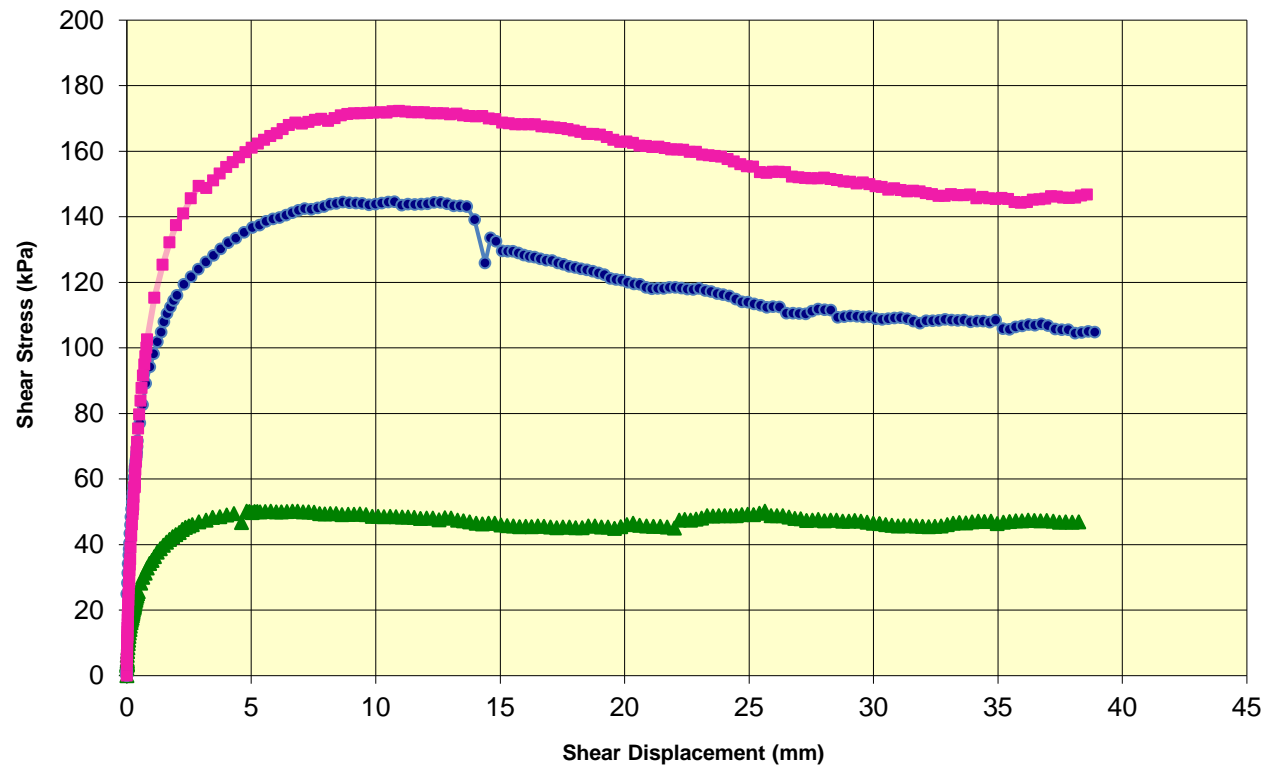
# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

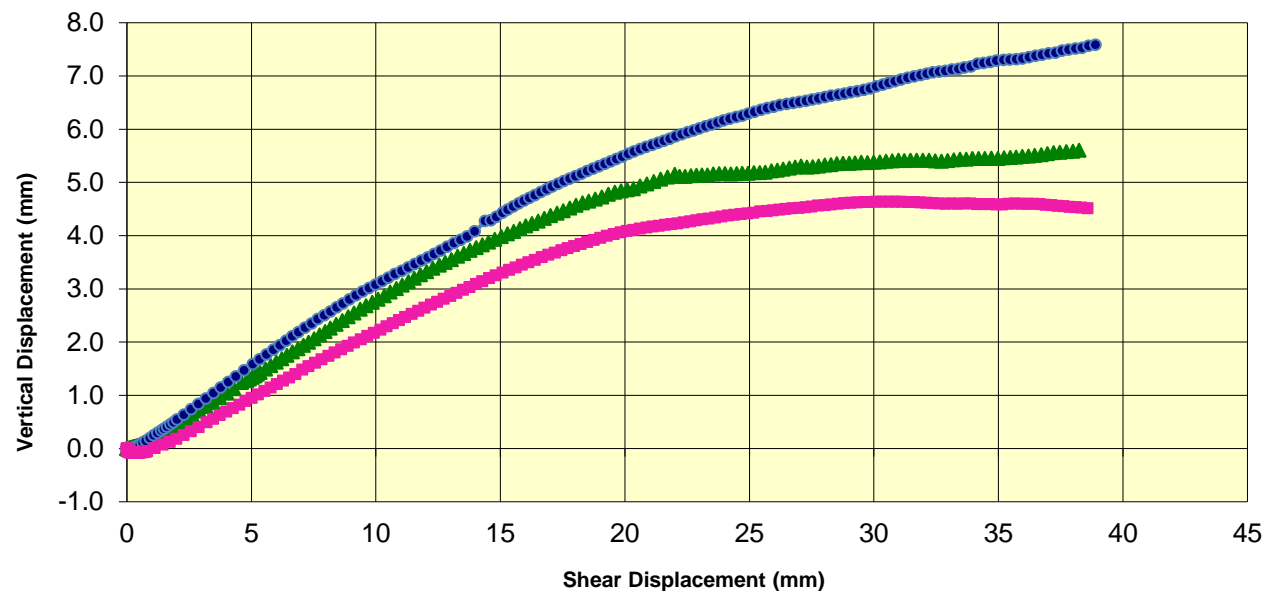
## Sample Identification

Project No.: 19115286	Phase: 27.0	Test Condition: Reconstituted
Client: Thurber Engineering Ltd.	Sample: Modified BS 7 (1-6)	
Project Title: Thurber Large Scale Direct Shear		
Client Ref.: PROJECT 24726 HIGHWAY 17	Source: Quarry	
ARNPRIOR TO HALEY STATION	Lab No.: D317-08	

## Peak and Residual Shear Stress vs. Displacement



—▲— 40 kPa Peak —●— 100 kPa Peak —■— 150 kPa Peak





# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

Project No.: 19115286

Phase: 27.0

Short Title: Thurber Large Scale Direct Shear Testing

Schedule No.: D317

Tested By: FC/SP

Date: 17-Jan-20

Source: Quarry

Test Condition: Reconstituted

Sample: Modified BS 7 (1-6)

Sample Description: (GW-GM) fine angular GRAVEL and fine to coarse SAND, some non-plastic fines; brown; non-cohesive.

**Post-Test Photo - 150 kPa**



# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

## Sample Identification

Project No.:	19115286	Phase: 27.0	Test Condition:	Reconstituted
Client:	Thurber Engineering Ltd.		Sample:	BS8-1 to BS8-6
Project Title:	Thurber Large Scale Direct Shear Testing			
Client Ref.:	PROJECT 24726 HIGHWAY 17 ARNPRIOR TO HALEY STATION		Source:	Quarry
			Lab No.:	D317-09

## INITIAL - Sample Dimensions

Test No.	1	2	3
Shear Box Geometry	Square	Square	Square
Length, mm	302	302	302
Width, mm	302	302	302
Height, mm	159	159	159
Area, cm <sup>2</sup>	912	912	912
Volume, cm <sup>3</sup>	14501	14501	14501

## Weight Volume Relationships

Test No.	1	2	3
Sample Type	Reconstituted	Reconstituted	Reconstituted
Initial Wet Wt, kg	32.81	32.81	32.81
Initial Dry Wt, kg	31.03	31.03	31.03
Initial w, %	5.7	5.7	5.7
Final w, %	10.8	10.3	10.5
Initial $\rho_{wet}$ , kg/m <sup>3</sup>	2263	2263	2263
Initial $\rho_{dry}$ , kg/m <sup>3</sup>	2140	2140	2140
Specific Gravity (assumed)	2.70	2.70	2.70
Initial Void Ratio, e	0.26	0.26	0.26

## Equipment Description - LDS\_30S

Axial LDT	Serial #	BBD100410
Axial Load Cell	Serial #	1084597
Vertical LDT	Serial #	BBD110464
Vertical Load Cell	Serial #	978593

## Remarks

- Three test specimens were built and sheared at 40, 100, and 150 kPa normal stresses.
- Each specimen was placed in 3 lifts and each lift was plate-tamped to level
- Each lift was compacted to 98% SPMDD at +/- 2% of optimum water content
- The specimen was inundated with water followed by application of the normal stress.
- An area correction was applied to the normal and shear stress calculations

Sample Description: (GW-GM) fine angular GRAVEL and fine to coarse SAND, some non-plastic fines; brown; non-cohesive.

Tested By: FC/SP

Date Completed: 21-Jan-20

Reviewed By: JS

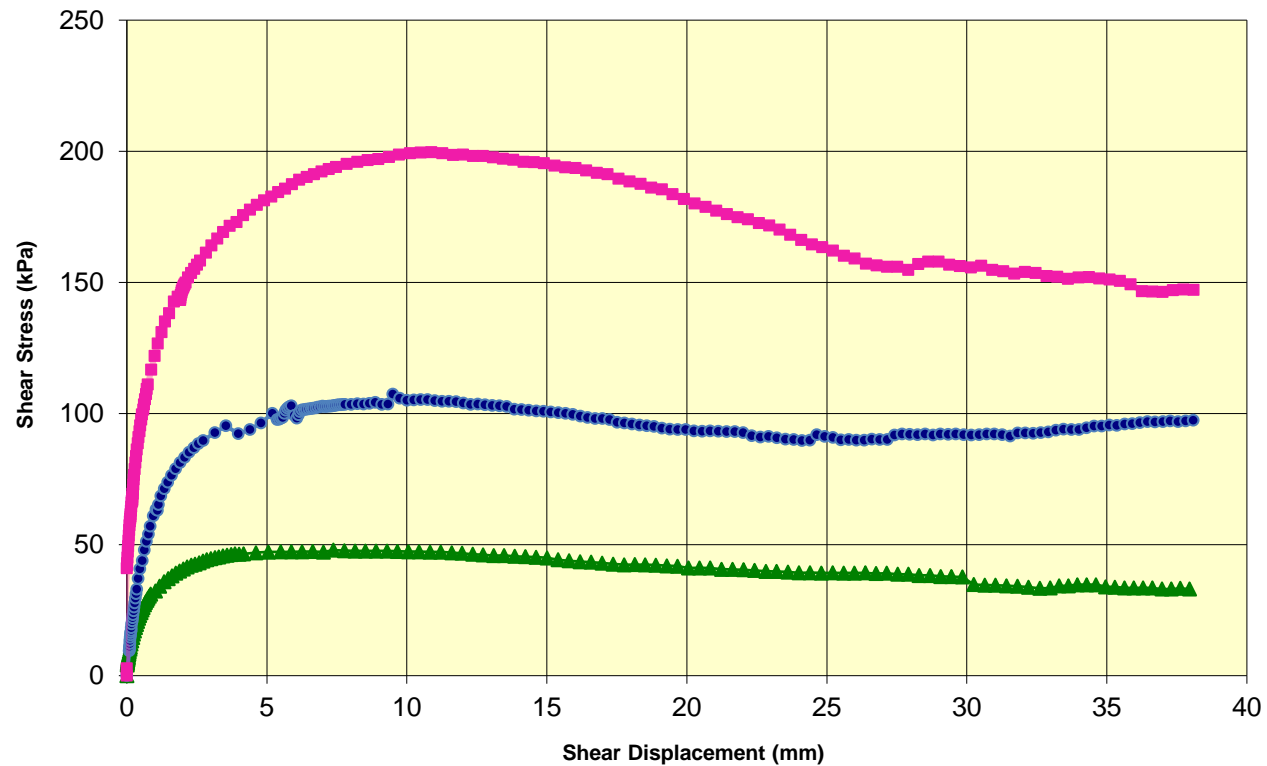
# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

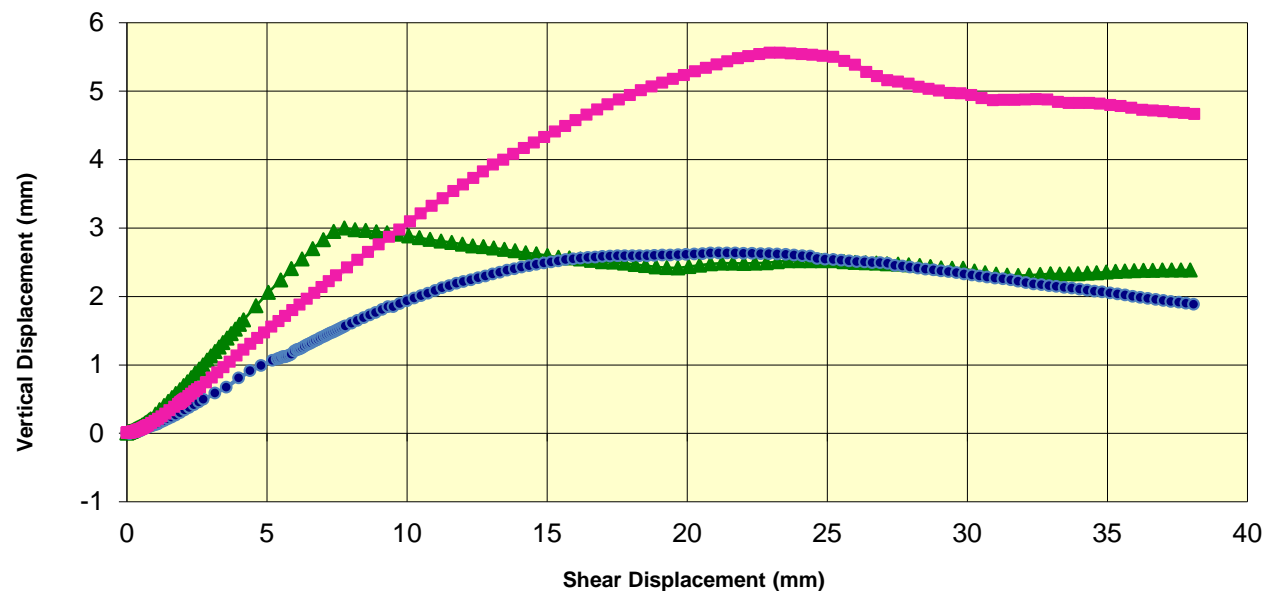
## Sample Identification

Project No.: 19115286	Phase: 27.0	Test Condition: Reconstituted
Client: Thurber Engineering Ltd.	Sample: BS8-1 to BS8-6	
Project Title: Thurber Large Scale Direct Shear		
Client Ref.: PROJECT 24726 HIGHWAY 17	Source: Quarry	
ARNPRIOR TO HALEY STATION	Lab No.: D317-09	

## Peak and Residual Shear Stress vs. Displacement



▲ 40 kPa Peak
 ● 100 kPa Peak
 ■ 150 kPa Peak





# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

Project No.: 19115286

Phase: 27.0

Short Title: Thurber Large Scale Direct Shear Testing

Schedule No.: D317

Tested By: FC/SP

Date: 21-Jan-20

Source: Quarry

Test Condition: Reconstituted

Sample: BS8-1 to BS8-6

Sample Description: (GW-GM) fine angular GRAVEL and fine to coarse SAND, some non-plastic fines; brown; non-cohesive.

## Post-Test Photo - 100 kPa



# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

## Sample Identification

Project No.:	19115286	Phase: 27.0	Test Condition: Reconstituted
Client:	Thurber Engineering Ltd.		Sample: BS9-1 to BS9-6
Project Title:	Thurber Large Scale Direct Shear Testing		
Client Ref.:	PROJECT 24726 HIGHWAY 17 ARNPRIOR TO HALEY STATION	Source: Quarry	Lab No.: D317-10

## INITIAL - Sample Dimensions

Test No.	1	2	3
Shear Box Geometry	Square	Square	Square
Length, mm	302	302	302
Width, mm	302	302	302
Height, mm	159	159	159
Area, cm <sup>2</sup>	912	912	912
Volume, cm <sup>3</sup>	14501	14501	14501

## Weight Volume Relationships

Test No.	1	2	3
Sample Type	Reconstituted	Reconstituted	Reconstituted
Initial Wet Wt, kg	32.90	32.90	32.90
Initial Dry Wt, kg	31.45	31.45	31.45
Initial w, %	4.6	4.6	4.6
Final w, %	8.0	9.3	8.6
Initial $\rho_{wet}$ , kg/m <sup>3</sup>	2269	2269	2269
Initial $\rho_{dry}$ , kg/m <sup>3</sup>	2169	2169	2169
Specific Gravity (assumed)	2.70	2.70	2.70
Initial Void Ratio, e	0.24	0.24	0.24

## Equipment Description - LDS\_30S

Axial LDT	Serial #	BBD100410
Axial Load Cell	Serial #	1084597
Vertical LDT	Serial #	BBD110464
Vertical Load Cell	Serial #	978593

## Remarks

- Three test specimens were built and sheared at 40, 100, and 150 kPa normal stresses.
- Each specimen was placed in 3 lifts and each lift was plate-tamped to level
- Each lift was compacted to 98% SPMDD at +/- 2% of optimum water content
- The specimen was inundated with water followed by application of the normal stress.
- An area correction was applied to the normal and shear stress calculations

Sample Description: (GW) fine angular GRAVEL and medium to coarse SAND; brown; non-cohesive

Tested By: FC/SP

Date Completed: 22-Jan-20

Reviewed By: JS



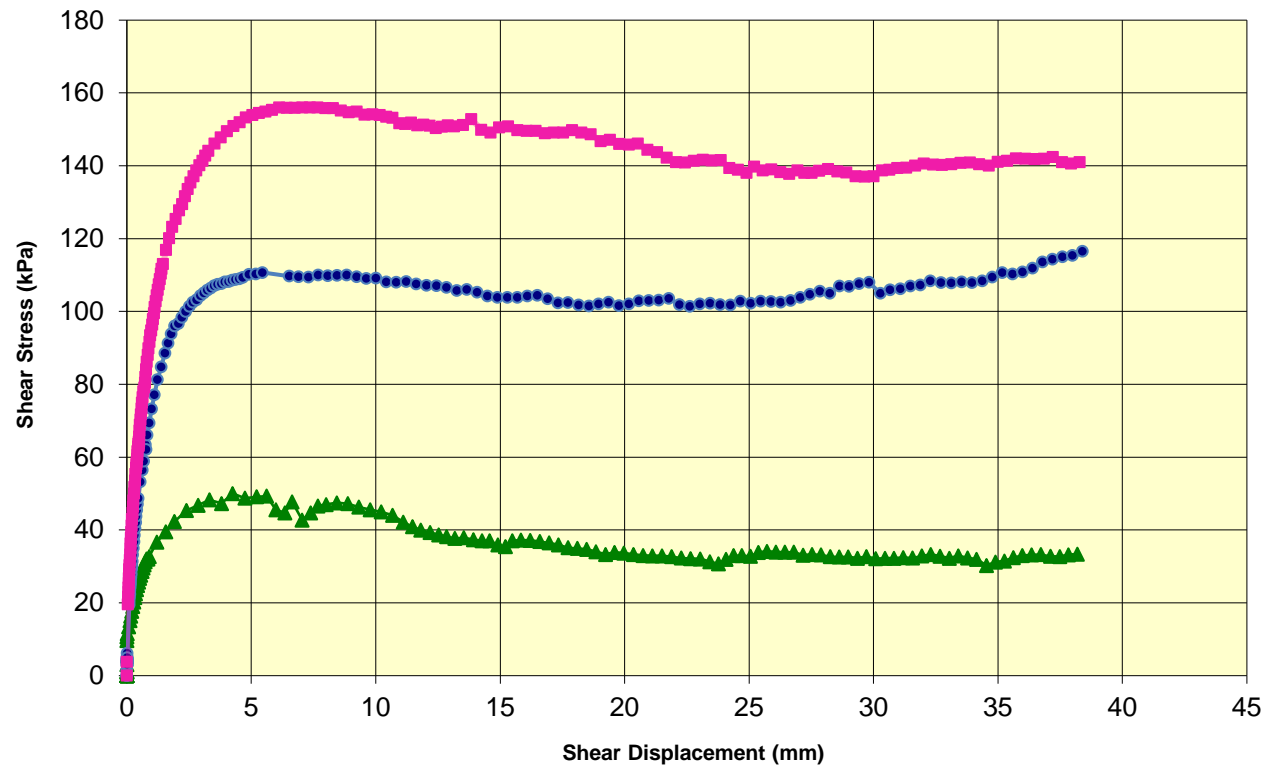
# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

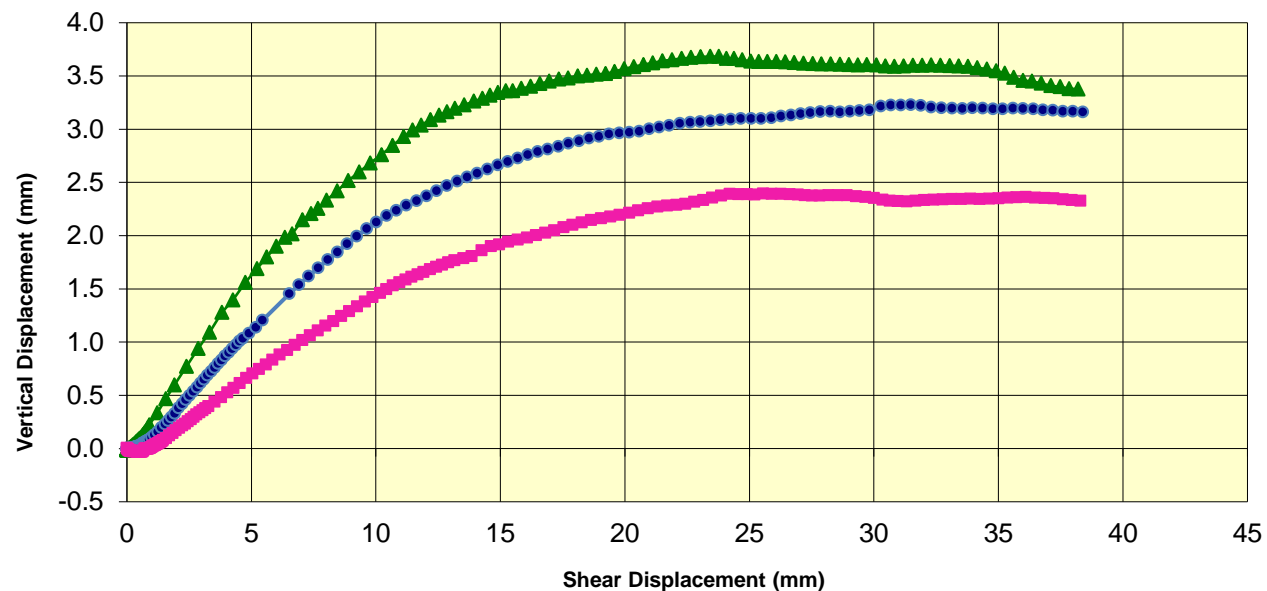
## Sample Identification

Project No.: 19115286	Phase: 27.0	Test Condition: Reconstituted
Client: Thurber Engineering Ltd.	Sample: BS9-1 to BS9-6	
Project Title: Thurber Large Scale Direct Shear		
Client Ref.: PROJECT 24726 HIGHWAY 17	Source: Quarry	
ARNPRIOR TO HALEY STATION	Lab No.: D317-10	

## Peak and Residual Shear Stress vs. Displacement



▲ 40 kPa Peak   
 ● 100 kPa Peak   
 ■ 150 kPa Peak



# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

Project No.: 19115286

Phase: 27.0

Short Title: Thurber Large Scale Direct Shear Testing

Schedule No.: D317

Tested By: FC/SP

Date: 22-Jan-20

Source: Quarry

Test Condition: Reconstituted

Sample: BS9-1 to BS9-6

Sample Description: (GW) fine angular GRAVEL and medium to coarse SAND; brown; non-cohesive

## Post-Test Photo - 150 kPa



# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

## Sample Identification

Project No.:	19115286	Phase: 27.0	Test Condition:	Reconstituted
Client:	Thurber Engineering Ltd.		Sample:	Modified BS 10 (1-6)
Project Title:	Thurber Large Scale Direct Shear Testing			
Client Ref.:	PROJECT 24726 HIGHWAY 17 ARNPRIOR TO HALEY STATION		Source:	Quarry
			Lab No.:	D317-11

## INITIAL - Sample Dimensions

Test No.	1	2	3
Shear Box Geometry	Square	Square	Square
Length, mm	302	302	302
Width, mm	302	302	302
Height, mm	159	159	159
Area, cm <sup>2</sup>	912	912	912
Volume, cm <sup>3</sup>	14501	14501	14501

## Weight Volume Relationships

Test No.	1	2	3
Sample Type	Reconstituted	Reconstituted	Reconstituted
Initial Wet Wt, kg	33.54	33.54	33.54
Initial Dry Wt, kg	31.53	31.53	31.53
Initial w, %	6.4	6.4	6.4
Final w, %	8.8	8.0	8.2
Initial $\rho_{wet}$ , kg/m <sup>3</sup>	2313	2313	2313
Initial $\rho_{dry}$ , kg/m <sup>3</sup>	2175	2175	2175
Specific Gravity (assumed)	2.70	2.70	2.70
Initial Void Ratio, e	0.24	0.24	0.24

## Equipment Description - LDS\_30S

Axial LDT	Serial #	BBD100410
Axial Load Cell	Serial #	1084597
Vertical LDT	Serial #	BBD110464
Vertical Load Cell	Serial #	978593

## Remarks

- Three test specimens were built and sheared at 40, 100, and 150 kPa normal stresses.
- Each specimen was placed in 3 lifts and each lift was plate-tamped to level
- Each lift was compacted to 98% SPMDD at +/- 2% of optimum water content
- The specimen was inundated with water followed by application of the normal stress.
- An area correction was applied to the normal and shear stress calculations

Sample Description: (GW-GM) fine angular GRAVEL and fine to coarse SAND, some non-plastic fines; brown; non-cohesive.

Tested By: FC/SP

Date Completed: 21-Feb-20

Reviewed By: JS



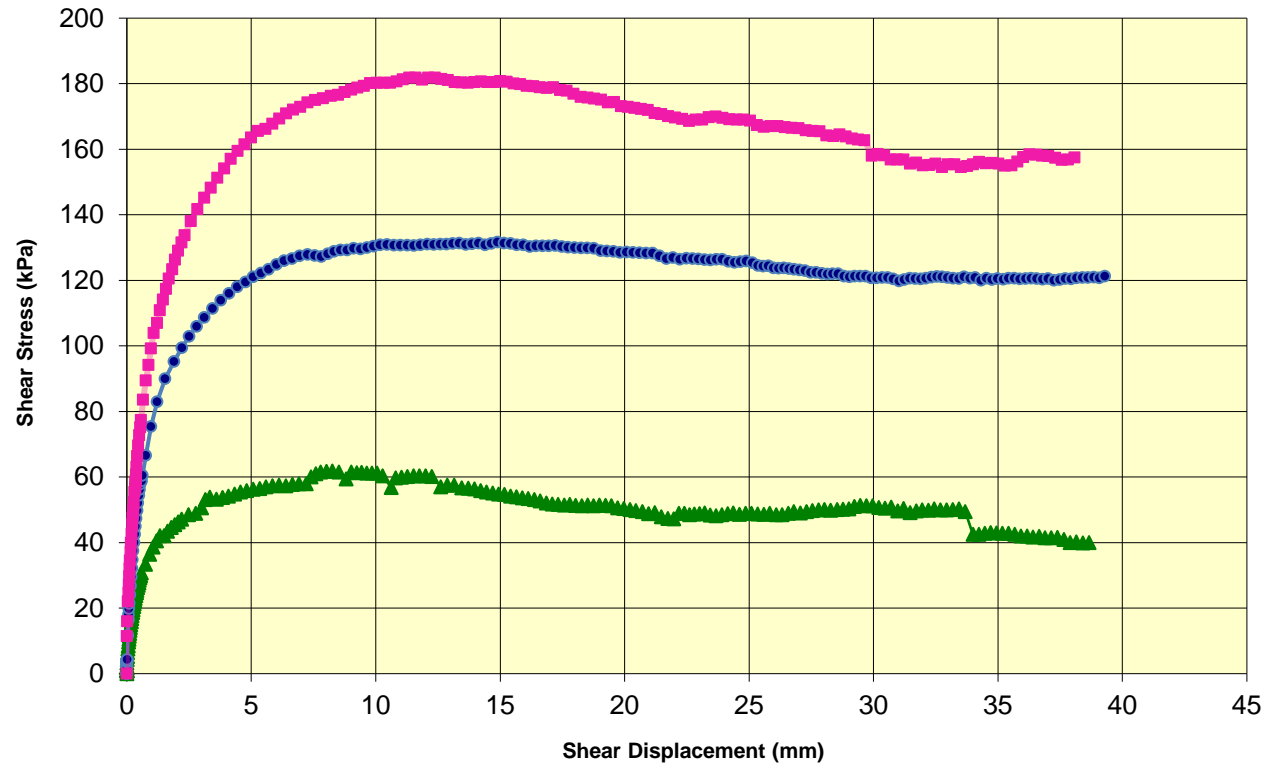
# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

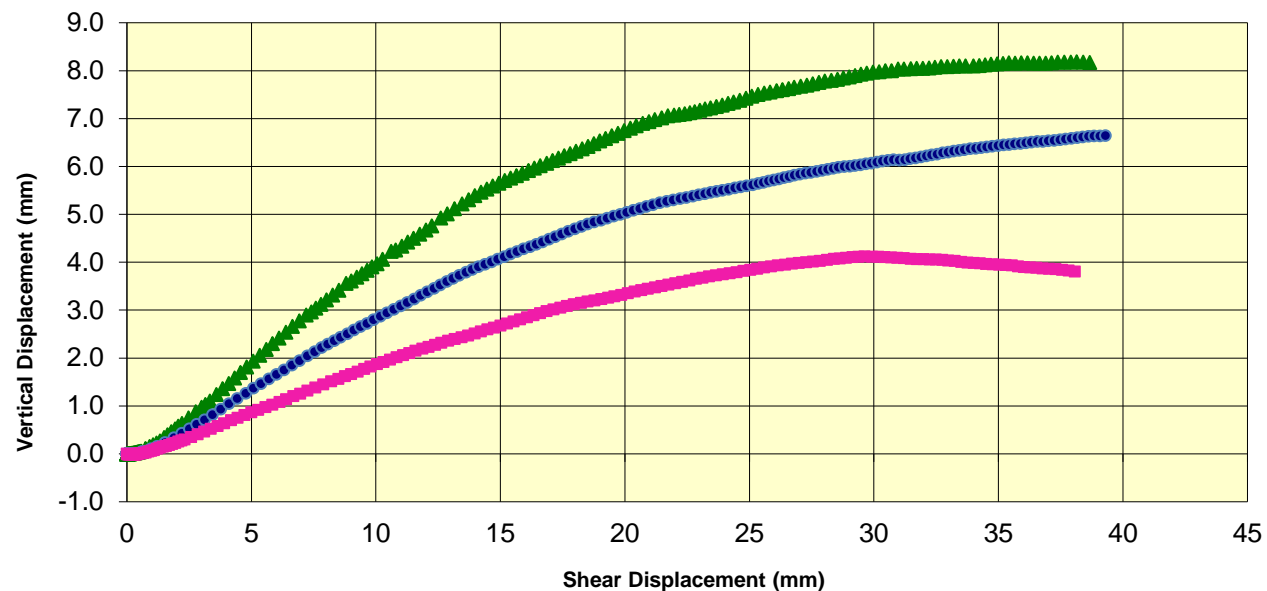
## Sample Identification

Project No.: 19115286	Phase: 27.0	Test Condition: Reconstituted
Client: Thurber Engineering Ltd.	Sample: Modified BS 10 (1-6)	
Project Title: Thurber Large Scale Direct Shear		
Client Ref.: PROJECT 24726 HIGHWAY 17	Source: Quarry	
ARNPRIOR TO HALEY STATION	Lab No.: D317-11	

## Peak and Residual Shear Stress vs. Displacement



—▲— 40 kPa Peak —●— 100 kPa Peak —■— 150 kPa Peak



# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

Project No.: 19115286

Phase: 27.0

Short Title: Thurber Large Scale Direct Shear Testing

Schedule No.: D317

Tested By: FC/SP

Date: 21-Feb-20

Source: Quarry

Test Condition: Reconstituted

Sample: Modified BS 10 (1-6)

Sample Description: (GW-GM) fine angular GRAVEL and fine to coarse SAND, some non-plastic fines; brown; non-cohesive.

**Post-Test Photo - 150 kPa**



# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

## Sample Identification

Project No.:	19115286	Phase: 27.0	Test Condition: Reconstituted
Client:	Thurber Engineering Ltd.		Sample: BS12-1 to BS12-06
Project Title:	Thurber Large Scale Direct Shear Testing		
Client Ref.:	PROJECT 24726 HIGHWAY 17 ARNPRIOR TO HALEY STATION	Source: Quarry	Lab No.: D317

## INITIAL - Sample Dimensions

Test No.	1	2	3
Shear Box Geometry	Square	Square	Square
Length, mm	302	302	302
Width, mm	302	302	302
Height, mm	159	159	159
Area, cm <sup>2</sup>	912	912	912
Volume, cm <sup>3</sup>	14501	14501	14501

## Weight Volume Relationships

Test No.	1	2	3
Sample Type	Reconstituted	Reconstituted	Reconstituted
Initial Wet Wt, kg	33.73	33.73	33.73
Initial Dry Wt, kg	31.61	31.61	31.61
Initial w, %	6.7	6.7	6.7
Final w, %	8.1	8.3	10.2
Initial $\rho_{wet}$ , kg/m <sup>3</sup>	2326	2326	2326
Initial $\rho_{dry}$ , kg/m <sup>3</sup>	2180	2180	2180
Specific Gravity (assumed)	2.70	2.70	2.70
Initial Void Ratio, e	0.24	0.24	0.24

## Equipment Description - LDS\_30S

Axial LDT	Serial #	BBD100410
Axial Load Cell	Serial #	1084597
Vertical LDT	Serial #	BBD110464
Vertical Load Cell	Serial #	978593

## Remarks

- Three test specimens were built and sheared at 40, 100, and 150 kPa normal stresses.
- Each specimen was placed in 3 lifts and each lift was plate-tamped to level
- Each lift was compacted to 98% SPMDD at +/- 2% of optimum water content
- The specimen was inundated with water followed by application of the normal stress.
- An area correction was applied to the normal and shear stress calculations

Sample Description: (GW-GM) fine angular GRAVEL and fine to coarse SAND, some non-plastic fines; brown; non-cohesive.

Tested By: FC/SP

Date Completed: 23-Jan-20

Reviewed By: JS

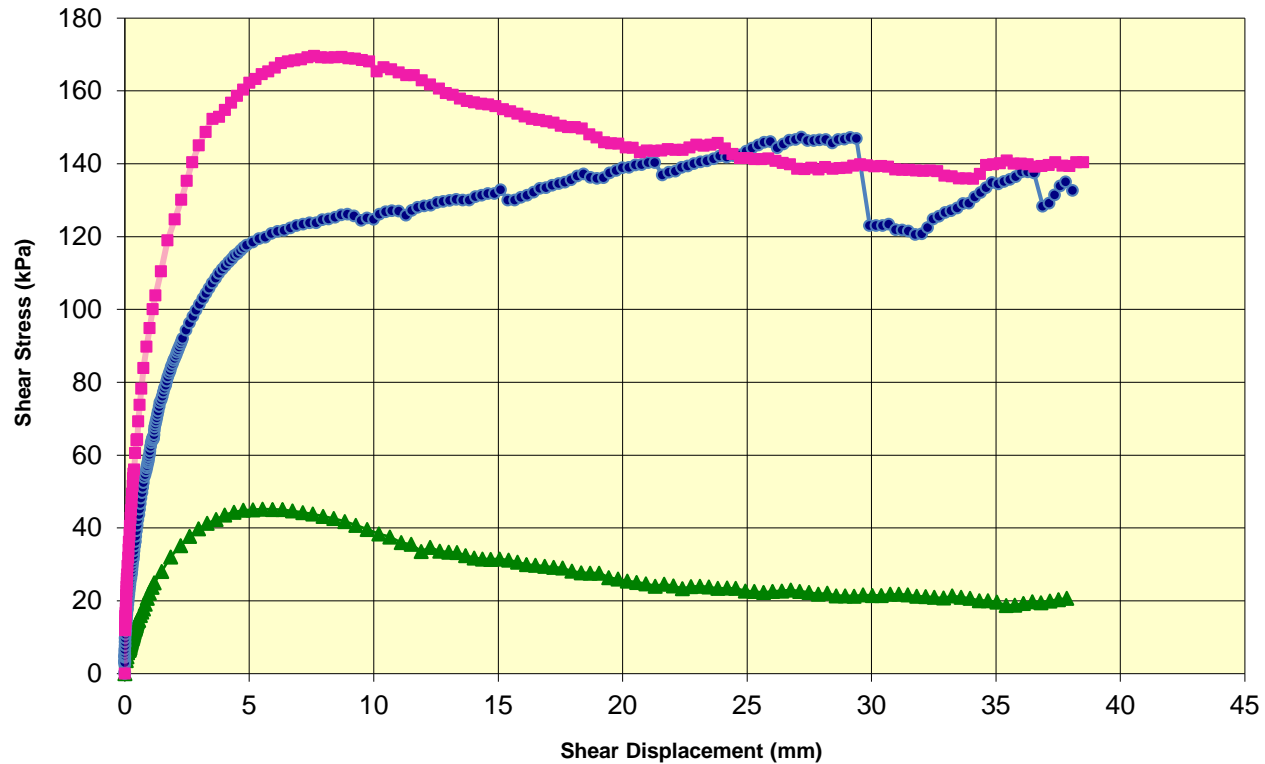
# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

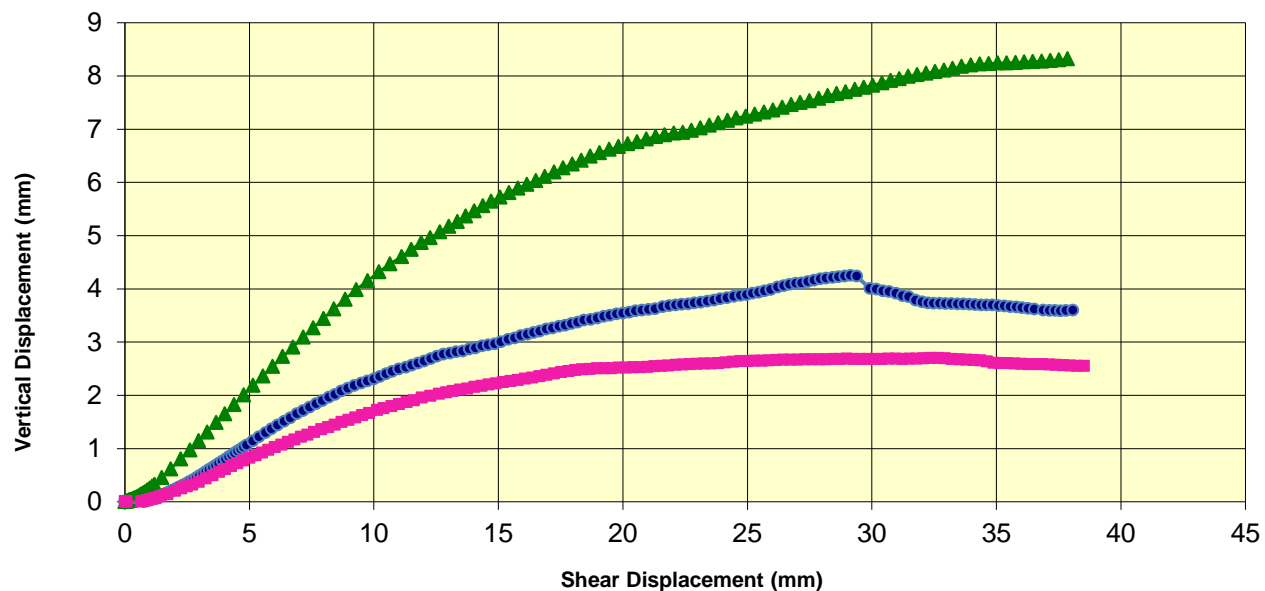
## Sample Identification

Project No.: 19115286	Phase: 27.0	Test Condition: Reconstituted
Client: Thurber Engineering Ltd.	Sample: BS12-1 to BS12-06	
Project Title: Thurber Large Scale Direct Shear		
Client Ref.: PROJECT 24726 HIGHWAY 17	Source: Quarry	
ARNPRIOR TO HALEY STATION	Lab No.: D317	

## Peak and Residual Shear Stress vs. Displacement



▲ 40 kPa Peak
 ● 100 kPa Peak
 ■ 150 kPa Peak





# DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS

(ASTM D3080/ D3080M-11)

Project No.: 19115286

Phase: 27.0

Short Title: Thurber Large Scale Direct Shear Testing

Schedule No.: D317

Tested By: FC/SP

Date: 23-Jan-20

Source: Quarry

Test Condition: Reconstituted

Sample: BS12-1 to BS12-06

Sample Description: (GW-GM) fine angular GRAVEL and fine to coarse SAND, some non-plastic fines; brown; non-cohesive.

## Post-Test Photo - 150 kPa

