APPENDIX ‘A’

GEOTECHNICAL REPORT

WSP Canada Group Ltd.

2023 Local and Industrial Streets Renewal Package (23-R-01)

Prepared for:
Mark Vogt, M.Sc., P.Eng.
WSP Canada Group Ltd.
111-93 Lombard Avenue
Winnipeg, MB
R3B 3B1

Project Number: 1000-043-21

Date: December 12, 2022

TREK GEOTECHNICAL Quality Engineering | Valued Relationships

December 12, 2022 Our File No. 1000-043-21

Mark Vogt, M.Sc., P.Eng.
WSP Canada Group Ltd.
111-93 Lombard Avenue
Winnipeg, MB
R3B 3B1

RE: 2023 Local and Industrial Streets Renewal Package (23-R-01)

TREK Geotechnical Inc. is pleased to submit our Final Report for the geotechnical investigation for 2023 Local and Industrial Streets Renewal Package (23-R-01) project.

Please contact the undersigned should you have any questions.

Sincerely,

TREK Geotechnical Inc.
Per:

Nelson John Ferreira, Ph.D., P.Eng.
Senior Geotechnical Engineer

Encl.

Revision History

Revision No.	Author	Issue Date	Description
0	AFK	December 12, 2022	Final Report

Authorization Signatures

Prepared By:

Angela Fidler-Kliewer, C.Tech.
Manager of Laboratory and Field Services

PROVINCE OF MANITOBA
N. J.
FERREIRA
Member
22892
REGISTERED PROFESSIONAL ENGINEER

Reviewed By:

Nelson John Ferreira, Ph.D., P.Eng.
Senior Geotechnical Engineer

ENGINEERS
GEOSCIENTISTS
MANITOBA
Certificate of Authorization
TREK GEOTECHNICAL INC.
No. 4877 Date: Dec 12, 2022

Table of Contents

List of Tables

List of Figures

List of Appendices

1.0 Introduction

This report summarizes the results of the road investigation completed for the Local and Industrial Streets Renewal 23-RI-01 project. The project included drilling test holes and collecting pavement cores along several streets. The test hole information collected describes the pavement structure of the existing road as well as the soil stratigraphy beneath the pavement structure. The investigation was carried out following the City of Winnipeg RFP No. 44-2022 (Appendix B – Site Investigation requirement for public works street projects).

2.0 Road Investigation

The investigation included coring of pavement at 29 locations on 11 different local streets with drilling of test holes occurring at 6 of the cored locations along three streets. The investigation locations are shown on Figures 01 to 10 (attached) and the table below summarizes the investigation program per street.

Table 1 – Road Investigation Program

23-RI-02 Pavement and Geotechnical Investigation	# of Locations	Investigation
Heaton Ave – Waterfront Dr / Argyle St	2	2 test holes to a depths of 3.0 m
Galt Ave – Lily St / Duncan St	2	2 test holes to a depths of 3.0 m
MacDonald Ave – Waterfront Dr / Gomez St	3	2 test holes to a depths of 3.0 m, 1 Core in the parking lane concrete apron
Alexander Ave – Marth St / Lily St	3	3 Cores
McDermot Ave – Myrtle St / McPhillips St	3	3 Cores
Argyle St – George Ave / Disraeli Fr	2	2 Cores
Dagmar St – William Ave / Bannatyne Ave and Bannatyne Ave / McDermot Ave	3	3 Cores
Bentall St – Mountain Ave / Redwood Ave	2	2 Cores
Wyatt Rd – Filkow By / Inkster Blvd and Mandalay Dr / Filkow By	3	3 Cores
Pacific Ave – McPhillips St / Xante St and Xante St / Arlington St	3	3 Cores
Bunting St – Inkster Blvd / Church Ave	3	3 Cores

The road investigation was conducted between November 8, 2022 and November 15, 2022. The pavement structure (asphalt/concrete) was cored by Jashandeep Bhullar of TREK Geotechnical Inc. (TREK) using a portable coring press equipped with a hollow 150 mm diameter diamond core drill bits. The test holes were drilled by by Maple Leaf Drilling Ltd.to a depth of approximately 3.0 m below road surface using a truck mounted drill rig equipped with 125 mm diameter solid stem augers except Heaton Ave which was drilled using a track mounted drill rig. The sub-surface conditions were observed during drilling and visually classified by Jashandeep Singh Bhullar of TREK. Other pertinent information such as groundwater and drilling conditions were also recorded during the drilling investigation. Disturbed (auger cuttings) samples and bulk samples retrieved during the sub-surface investigation were transported to TREK's material testing laboratory for further testing. Pavement core samples were also retrieved and logged at TREK's material testing laboratory

Core and test hole logs noted on the summary tables and test hole locations are based on UTM coordinates obtained using a hand-held GPS, and their location relative to the nearest address or intersection, measured distance from the edge of pavement, or other permanent features.

The laboratory testing program consisted of moisture content determination on all samples, as well as Atterberg Limits, and grain size analysis (mechanical sieve and hydrometer methods) on select samples between 0.9 and 1.1 m below pavement as well as Standard Proctor and CBR testing. Information gathered for each street package is included in separate appendices (Appendices A to K). The information provided in the Appendices includes test hole logs, laboratory testing summary tables and results, photos of the concrete cores, and summary of pavement compressive strength.

Three CBR's were completed on bulk samples of the soil units present below the pavement. Tests were performed on clay layers encountered within the prescribed sample depth for CBR testing and the results are shown in the table below.

Table 1: CBR Testing Summary

Soil Unit	Street	Depth (m)	SPMDD (kg/m^3)	Opt. Moisture (%)	Percent Proctor (%)	Moisture Content (%)	CBR Value at 2.54 mm	CBR Value at 5.08 mm
Clay	Heaton Ave (TH22-02)	1.1-2.7	1529	24.2	95.2	24.0	3.0%	2.4%
Clay	Galt Ave (TH22-03)	0.3-2.0	1519	24.5	95.1	24.9	0.9%	1.5%
Clay	MacDonald Ave (TH22-05)	0.3-3.0	1491	24.8	95.0	25.1	1.3%	1.2%

The test hole logs include a description of the soil units encountered during drilling and other pertinent information such as groundwater conditions and a summary of the laboratory testing results. The soils were classified in general accordance with the Unified Soil Classification System (USCS) and the

AASHTO soil classification system (American Association of state highway and transportation officials). The AASHTO system classifies soils based on laboratory testing results from Atterberg Limits and grain size testing methods (hydrometer and mechanical sieve method). Where laboratory testing was not conducted, the AASHTO classification of the soils were interpreted based on a visual assessment as indicated with a (I) on the test hole logs and attached tables. For cohesive soils, the AASHTO system uses a combination of testing results to determine the Group Index of the soils and thus, were only determined where sufficient laboratory test data was available.

Thirteen concrete cores were selected for concrete compressive strength breaks and the length to diameter ratio ranged between 1.14 to 1.50 for the cores collected. The core compressive strength tests were tested in accordance with CSA A23.2-14C – wet condition. The measured compressive strengths were also corrected based on an adapted ACI 214.4R-03 Standard to estimate the in-place concrete strengths. The table below summarizes the compressive strength results while the compressive strength testing details and the correction factor methodology are included in Appendices D to K.

Table 2: Concrete Core Compressive Strength Results

Core ID (Location)	Uncorrected Compressive Strength (MPa)	Corrected Compressive Strength (MPa)
PC-09 (Alexander Ave)	55.32	69.81
PC-10 (McDermot Ave)	61.72	67.60
PC-13 (Argyle Street)	55.85	61.89
PC-14 (Argyle Street)	52.75	63.33
PC-16 (Dagmar Street)	49.43	52.59
PC-17 (Dagmar Street)	45.35	53.34
PC-18 (Bentall Street)	58.17	63.80
PC-19 (Bentall Street)	57.34	63.14
PC-20 (Wyatt Street)	55.23	64.22
PC-22 (Wyatt Street)	58.83	63.34
PC-23 (Pacific Avenue)	57.06	66.89
PC-26 (Bunting Street)	54.65	63.39
PC-28 (Bunting Street)	62.48	66.10

3.0 Closure

The information provided in this report is in accordance with current engineering principles and practices (Standard of Practice). The findings of this report were based on information provided (field investigation, laboratory testing, geometries). Soil conditions are natural deposits that can be highly variable across a site. If sub-surface conditions are different than the conditions previously encountered on-site or those presented here, we should be notified to adjust our findings if necessary.

All information provided in this report is subject to our standard terms and conditions for engineering services, a copy of which is provided to each of our clients with the original scope of work, or a mutually executed standard engineering services agreement. If these conditions are not attached, and you are not already in possession of such terms and conditions, contact our office and you will be promptly provided with a copy.

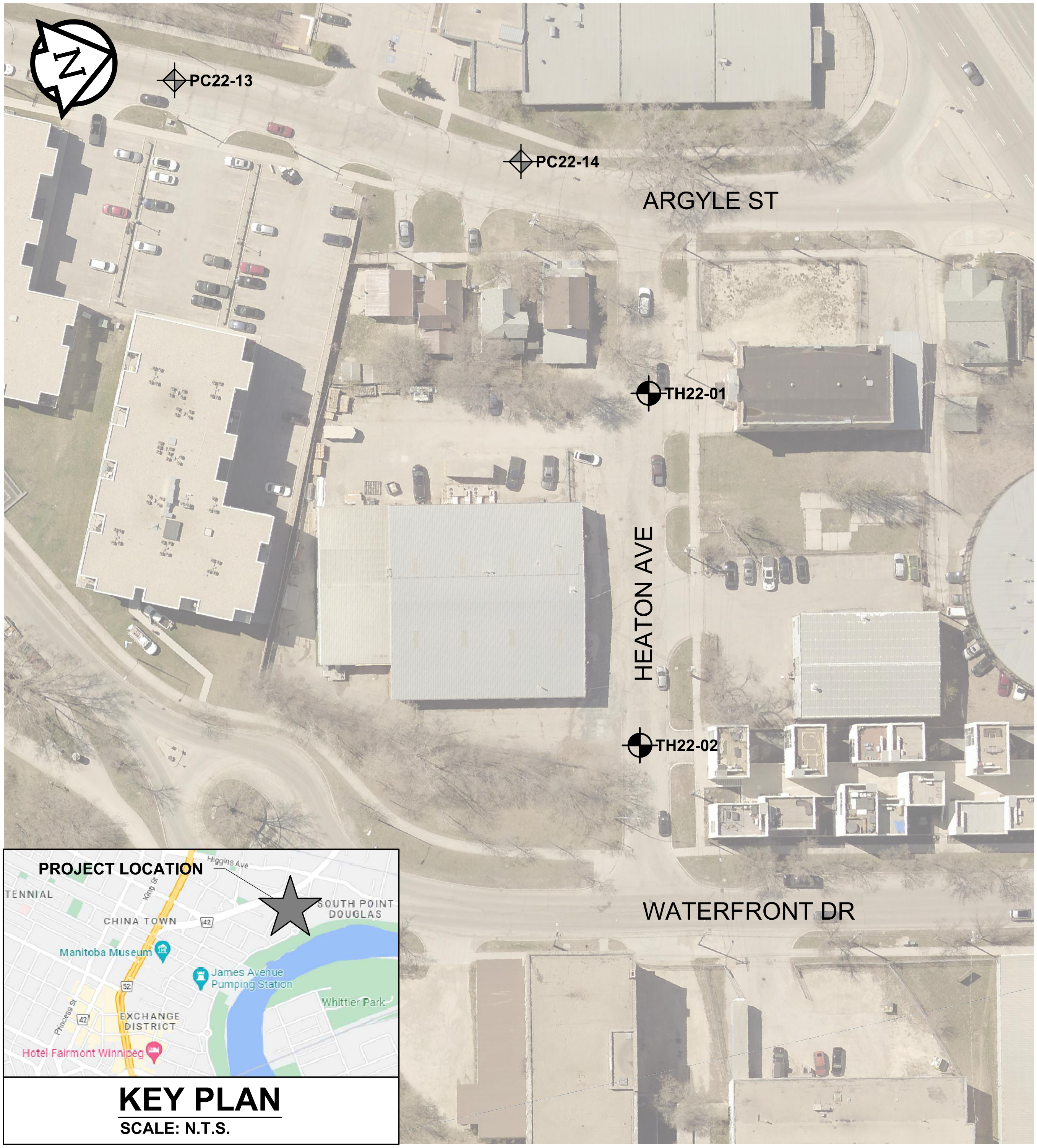
This report has been prepared by TREK Geotechnical Inc. (the Consultant) for the exclusive use of WSP Canada Group Ltd. (the Client) and their agents for the work product presented in the report. Any findings or recommendations provided in this report are not to be used or relied upon by any third parties, except as agreed to in writing by the Client and Consultant prior to use.

Figures

TREK GEOTECHNICAL

1000 043 21

WSP Canada Group Ltd.
2023 Local and Industrial Streets Renewal Package 23-RI-01



KEY PLAN
SCALE: N.T.S.

LEGEND:

⊕ **TEST HOLE (TREK, 2022)**

◈ **PAVEMENT CORE (TREK, 2022)**

NOTES:

1. **AERIAL IMAGERY FROM CITY OF WINNIPEG (2021).**

0 10 20 30 40 50 m

SCALE = 1 : 1 000 (216 mm x 279 mm)

Figure 01

Test Hole and
Pavement Core Location Plan

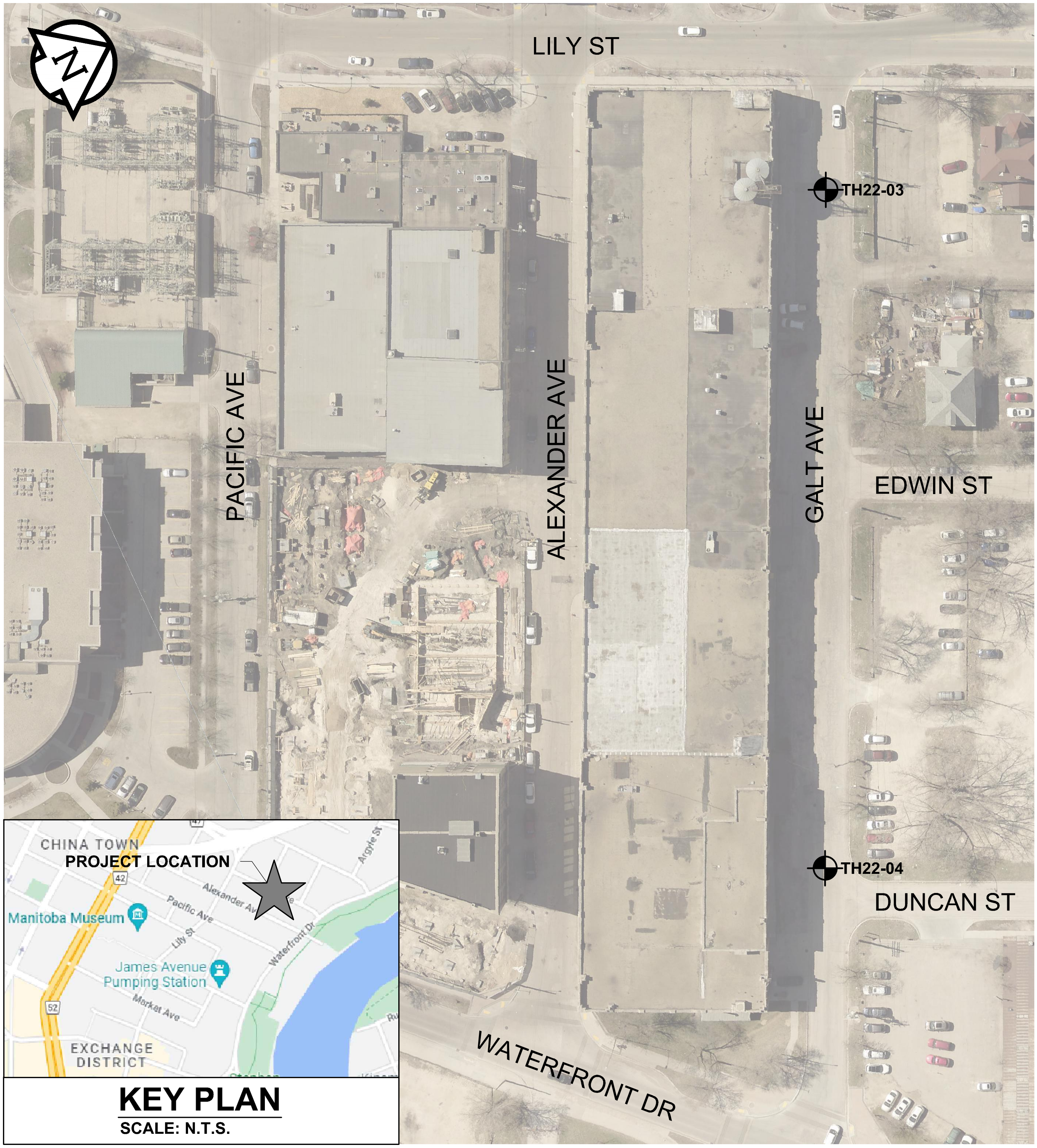
Z:\Projects\1000 Soils Lab\Lab Projects\1000 Lab Projects\1000-043 WSP\1000-043-21 2023 Local Streets Package (23-RI-01)\3 Survey and Dwg\3.4 CAD\3.4.3 Working Folder\Fig 01 2022-12-02 LSP23-RI-01 0_A 1000-043-21.dwg, 2022-12-02 10:51:53 AM

Z:\Projects\1000 Soils Lab\Lab Projects\1000 Lab Projects\1000-043 WSP\1000-043-21 2023 Local Streets Package (23-RI-01)\3 Survey and Dwg\3.4 CAD\3.4.3 Working Folder\Fig 01 2022-12-02 LSP23-RI-01 0_A 1000-043-21.dwg, 2022-12-02 10:51:32 AM

1000 043 21

WSP Canada Group Ltd.

2023 Local and Industrial Streets Renewal Package 23-RI-01



LEGEND:

⊕ TEST HOLE (TREK, 2022)

NOTES:

1. AERIAL IMAGERY FROM CITY OF WINNIPEG (2021).

0 10 20 30 40 50 m

SCALE = 1 : 1 125 (216 mm x 279 mm)

Figure 02

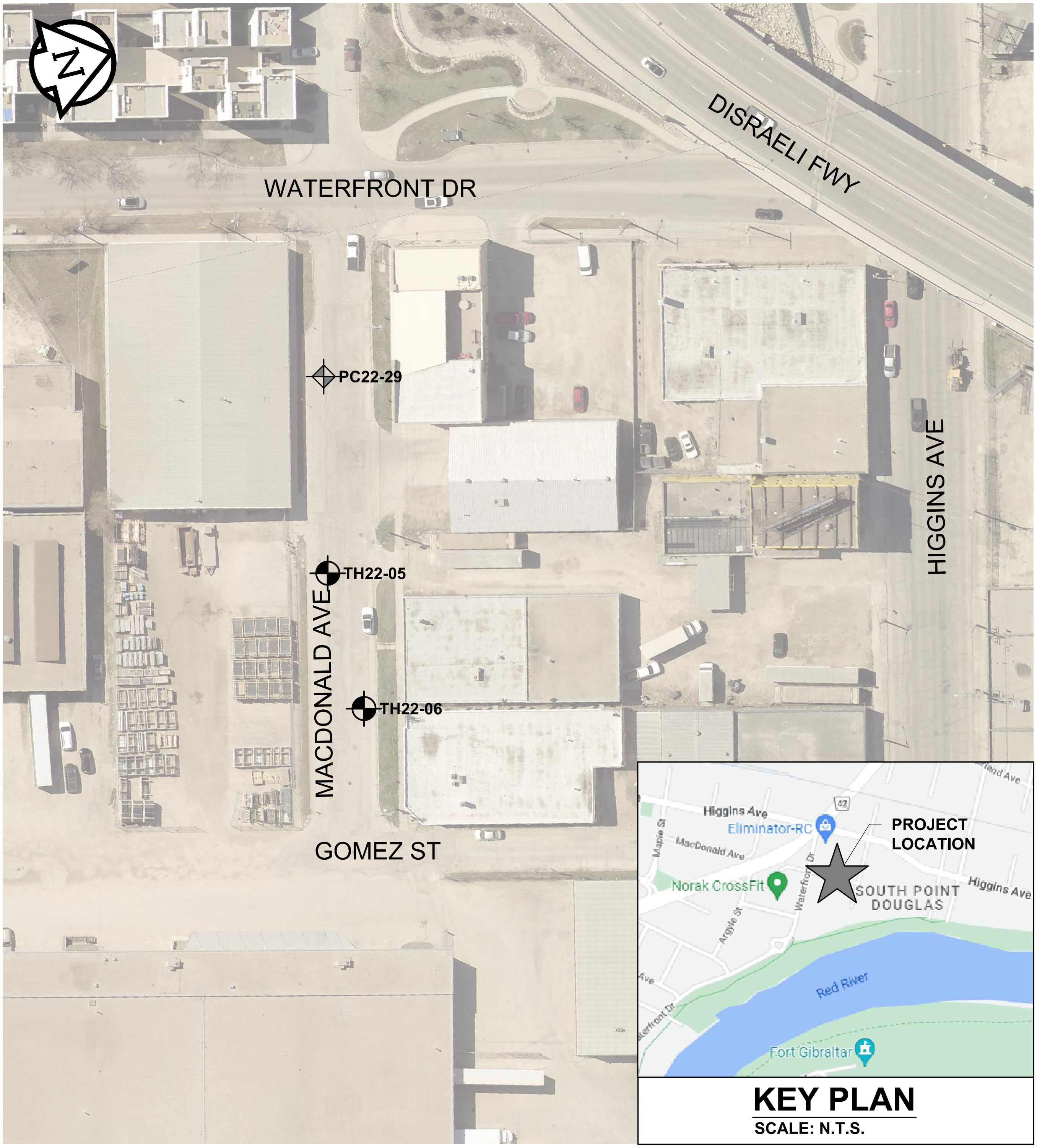
Test Hole Location Plan

Z:\Projects\1000 Soils Lab\Lab Projects\1000 Lab Projects\1000-043 WSP\1000-043-21 2023 Local Streets Package (23-RI-01)\3 Survey and Dwg\3.4 CAD\3.4.3 Working Folder\Fig 01 to 04 2022-12-05 LSP23-RI-01 0_A 1000-043-21.dwg, 2022-12-05 1:46:20 PM

1000 043 21

WSP Canada Group Ltd.

2023 Local and Industrial Streets Renewal Package 23-RI-01



LEGEND:

⊕ TEST HOLE (TREK, 2022)

⊕ PAVEMENT CORE (TREK, 2022)

NOTES:

1. AERIAL IMAGERY FROM CITY OF WINNIPEG (2021).

0 10 20 30 40 50 m

SCALE = 1 : 1 000 (216 mm x 279 mm)

Figure 03

Test Hole and

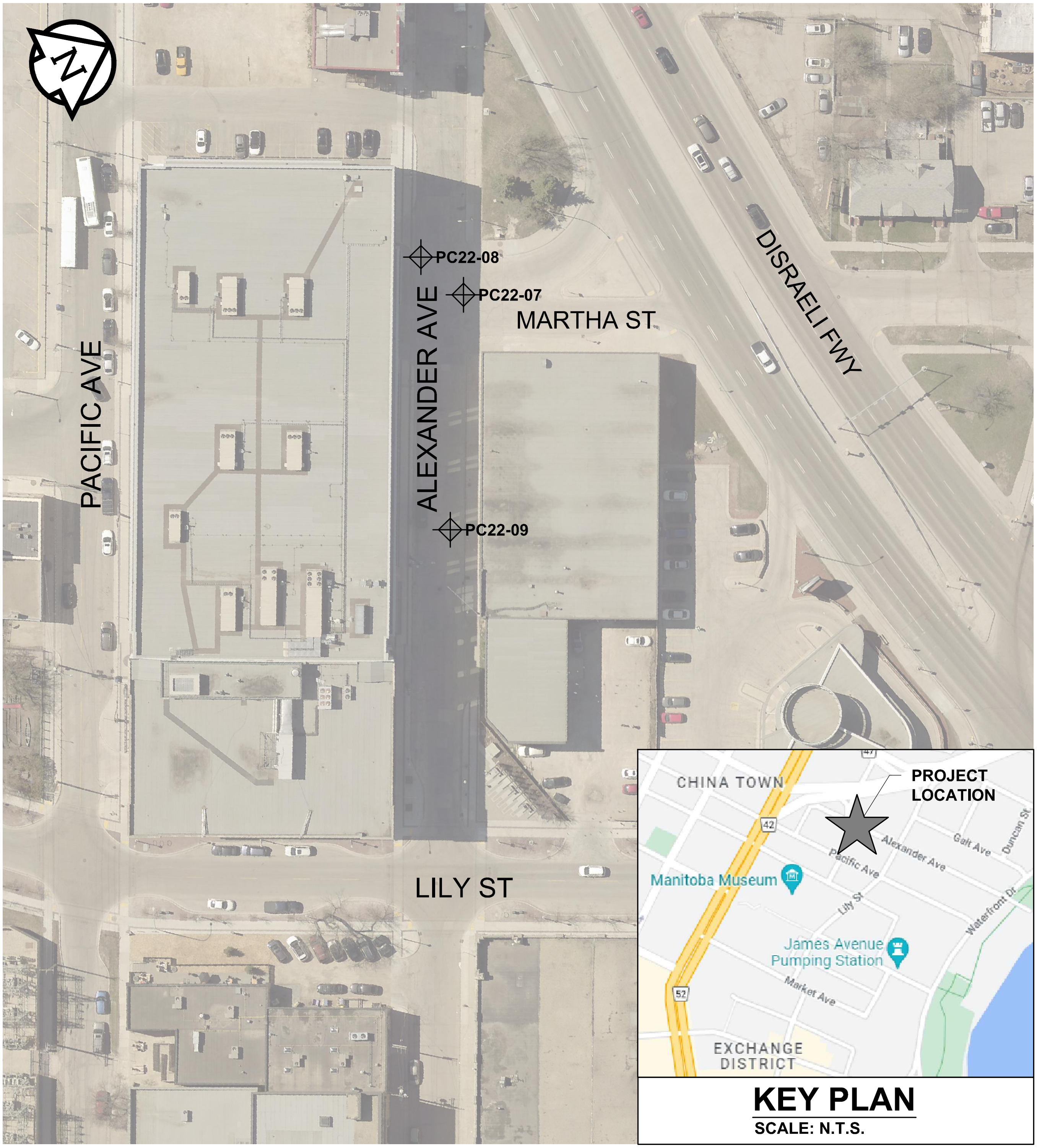
Pavement Core Location Plan

Z:\Projects\1000 Soils Lab\Lab Projects\1000 Lab Projects\1000-043 WSP\1000-043-21 2023 Local Streets Package (23-RI-01)\3 Survey and Dwg\3.4 CAD\3.4.3 Working Folder\Fig 01 2022-12-02 LSP23-RI-01 0_A 1000-043-21.dwg, 2022-12-02 11:09:20 AM

1000 043 21

WSP Canada Group Ltd.

2023 Local and Industrial Streets Renewal Package 23-RI-01



LEGEND:

⌖ PAVEMENT CORE (TREK, 2022)

NOTES:

1. AERIAL IMAGERY FROM CITY OF WINNIPEG (2021).

0 10 20 30 40 50 m

SCALE = 1 : 1 000 (216 mm x 279 mm)

Figure 04

Pavement Core Location Plan

1000 043 21

WSP Canada Group Ltd.

2023 Local and Industrial Streets Renewal Package 23-RI-01

KEY PLAN

SCALE: N.T.S.

LEGEND:

⌖ **PAVEMENT CORE (TREK, 2022)**

NOTES:

1. **AERIAL IMAGERY FROM CITY OF WINNIPEG (2021).**

0 25 50 75 m

SCALE = 1 : 1 750 (216 mm x 279 mm)

Figure 05

Pavement Core Location Plan

Z:\Projects\1000 Soils Lab\Lab Projects\1000 Lab Projects\1000-043 WSP\1000-043-21 2023 Local Streets Package (23-RI-01)\3 Survey and Dwg\3.4 CAD\3.4.3 Working Folder\Fig 05 2022-12-02 LSP23-RI-01 0_A 1000-043-21.dwg, 2022-12-02 11:42:11 AM

TREK GEOTECHNICAL

1000 043 21

WSP Canada Group Ltd.

2023 Local and Industrial Streets Renewal Package 23-RI-01

LEGEND:

PAVEMENT CORE (TREK, 2022)

NOTES:

1. AERIAL IMAGERY FROM CITY OF WINNIPEG (2021).

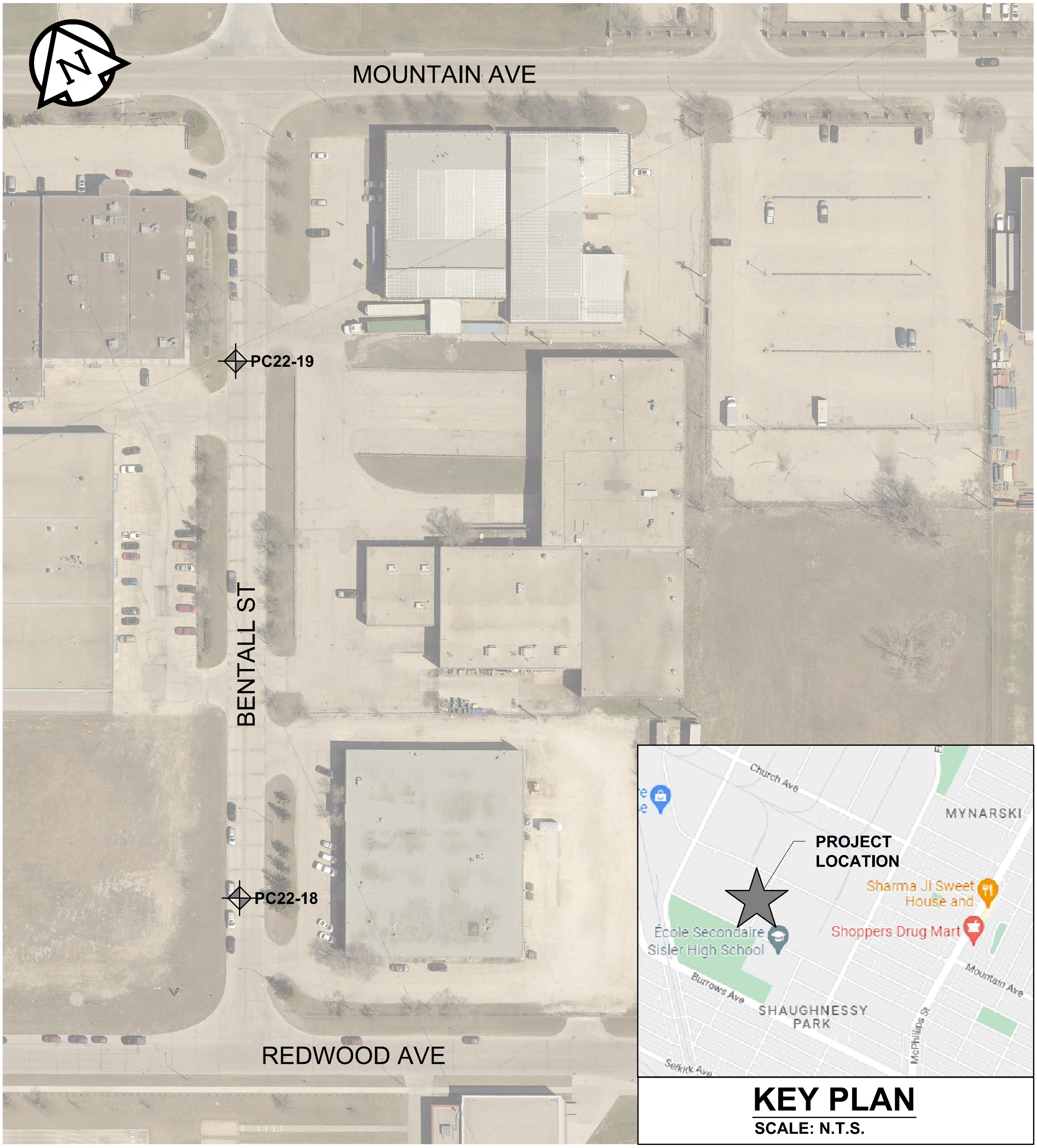
0 25 50 75 100 m

SCALE = 1 : 2 250 (216 mm x 279 mm)

Figure 06

Pavement Core Location Plan

1000 043 21
WSP Canada Group Ltd.
2023 Local and Industrial Streets Renewal Package 23-RI-01



LEGEND:

⌖ PAVEMENT CORE (TREK, 2022)

NOTES:

1. AERIAL IMAGERY FROM CITY OF WINNIPEG (2021).

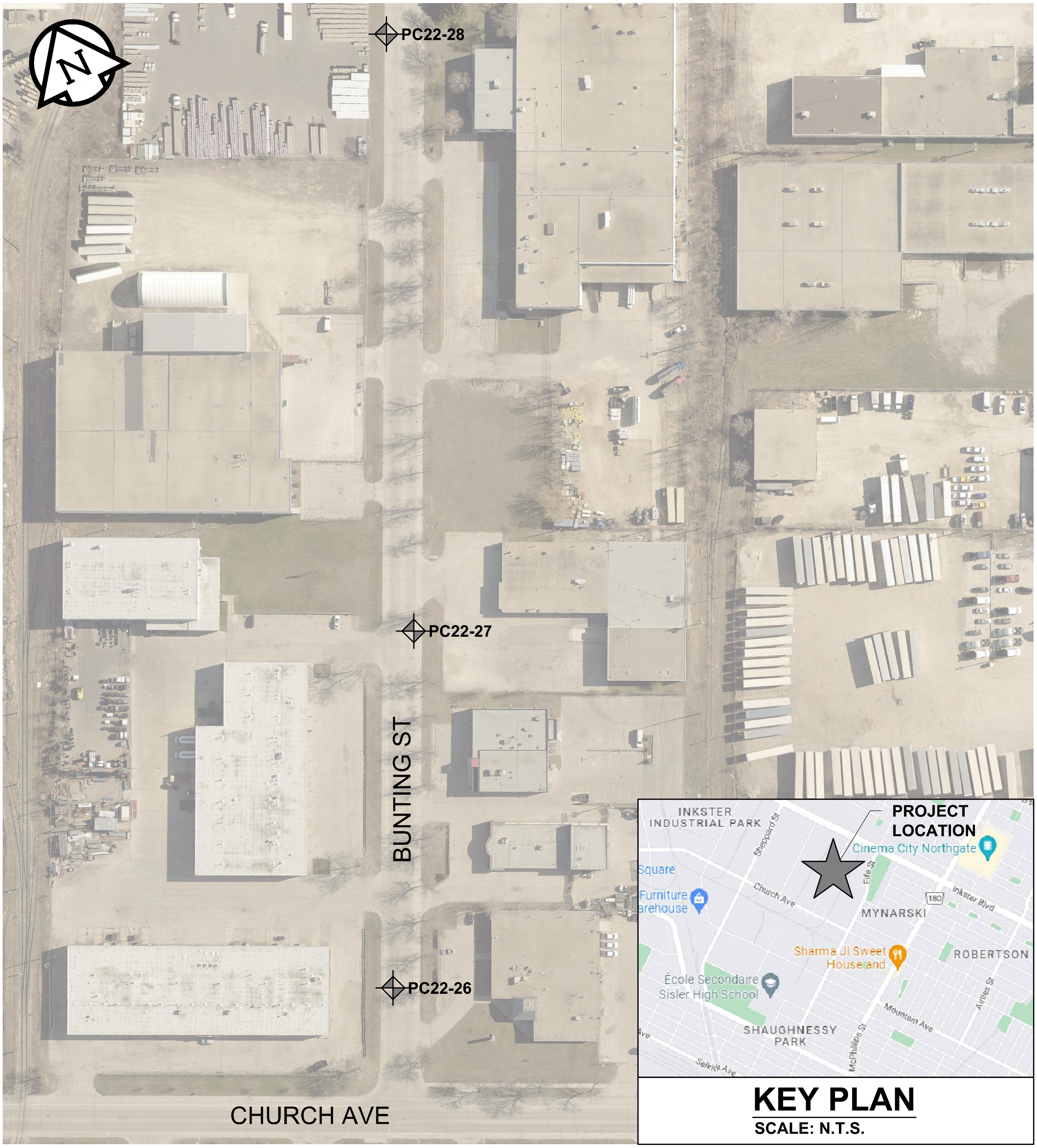
0 25 50 75 m
SCALE = 1 : 1 500 (216 mm x 279 mm)

Figure 07
Pavement Core Location Plan

Z:\Projects\1000 Soils Lab\Lab Projects\1000 Lab Projects\1000-043 WSP\1000-043-21 2023 Local Streets Package (23-RI-01)\3 Survey and Dwg\3.4 CAD\3.4.3 Working Folder\Fig 07 2022-12-02 LSP23-RI-01 0_A 1000-043-21.dwg, 2022-12-02 1:09:56 PM

TREK GEOTECHNICAL

1000 043 21
WSP Canada Group Ltd.
2023 Local and Industrial Streets Renewal Package 23-RI-01



LEGEND:

⌖ PAVEMENT CORE (TREK, 2022)

NOTES:

1. AERIAL IMAGERY FROM CITY OF WINNIPEG (2021).

0 25 50 75 100 m
SCALE = 1 : 2 000 (216 mm x 279 mm)

Figure 08
Pavement Core Location Plan

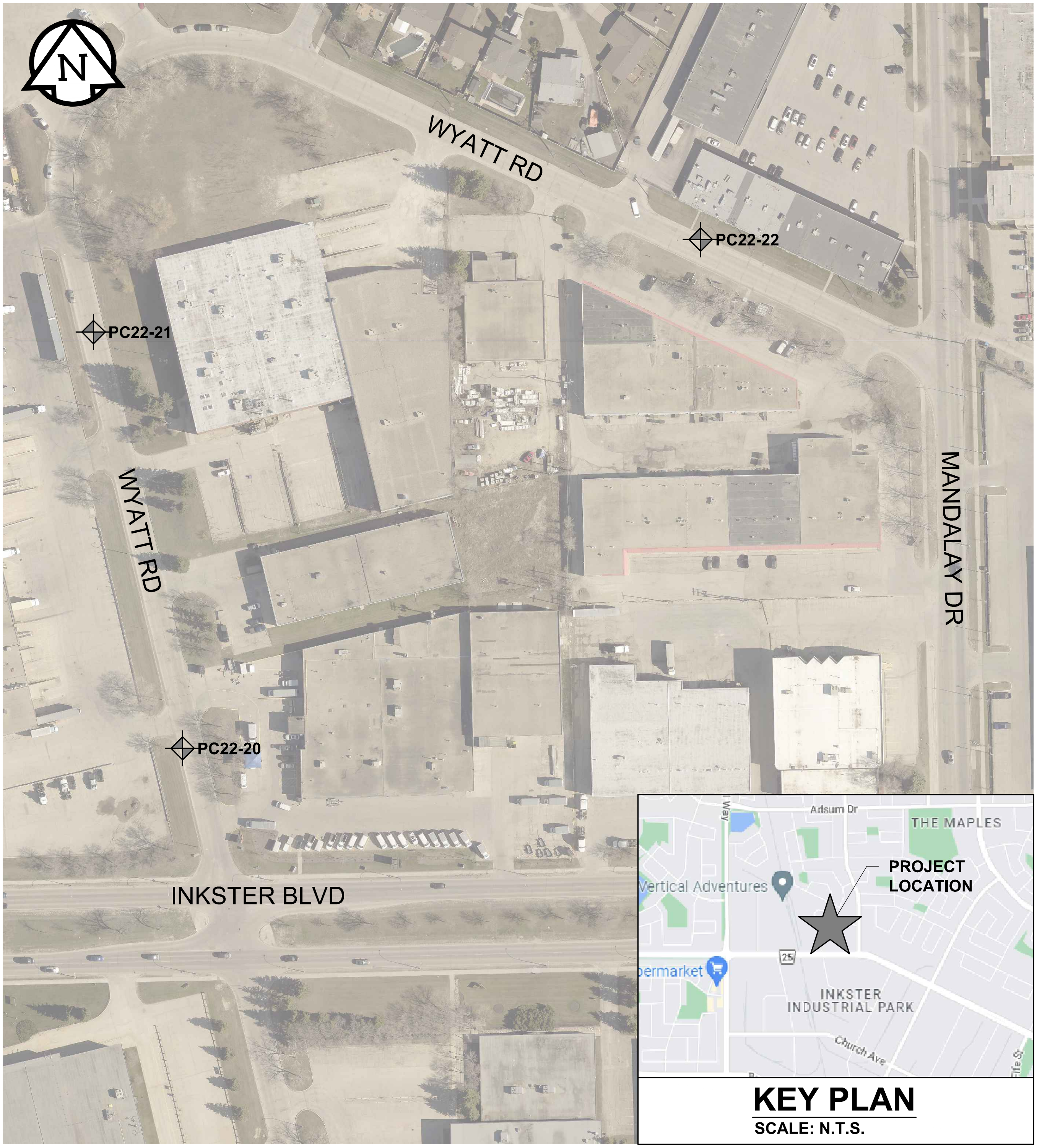
Z:\Projects\1000 Soils Lab\Lab Projects\1000 Lab Projects\1000-043 WSP\1000-043-21 2023 Local Streets Package (23-RI-01)\3 Survey and Dwg\3.4 CAD\3.4.3 Working Folder\Fig 07 to 09 2022-12-05 LSP23-RI-01 0_A 1000-043-21.dwg, 2022-12-05 2:15:22 PM

Z:\Projects\1000 Soils Lab\Lab Projects\1000 Lab Projects\1000-043 WSP\1000-043-21 2023 Local Streets Package (23-RI-01)\3 Survey and Dwg\3.4 CAD\3.4.3 Working Folder\Fig 07 2022-12-02 LSP23-RI-01 0_A 1000-043-21.dwg, 2022-12-02 1:24:17 PM

1000 043 21

WSP Canada Group Ltd.

2023 Local and Industrial Streets Renewal Package 23-RI-01



LEGEND:

⌖ PAVEMENT CORE (TREK, 2022)

NOTES:

1. AERIAL IMAGERY FROM CITY OF WINNIPEG (2021).

0 25 50 75 100 m

SCALE = 1 : 2 000 (216 mm x 279 mm)

Figure 09

Pavement Core Location Plan

LEGEND:

⌖ PAVEMENT CORE (TREK, 2022)

NOTES:

1. AERIAL IMAGERY FROM CITY OF WINNIPEG (2021).

0 10 20 30 40 50 m

SCALE = 1 : 1 250 (216 mm x 279 mm)

Figure 10
Pavement Core Location Plan

Appendix A

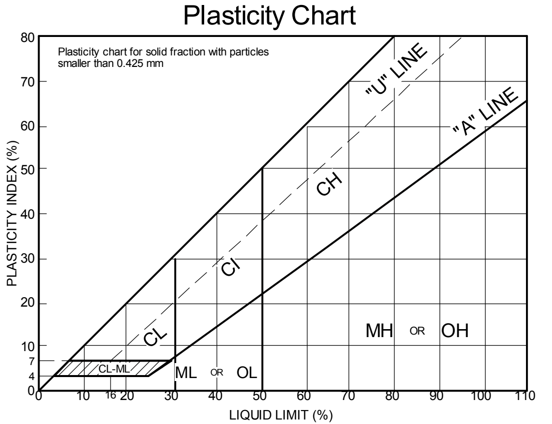
Test Hole Logs, Summary Table & Lab Testing Results and Pavement Core Photos – Heaton Ave

TREK GEOTECHNICAL

EXPLANATION OF FIELD AND LABORATORY TESTING

GENERAL NOTES

1. Classifications are based on the United Soil Classification System and include consistency, moisture, and color. Field descriptions have been modified to reflect results of laboratory tests where deemed appropriate.
2. Descriptions on these test hole logs apply only at the specific test hole locations and at the time the test holes were drilled. Variability of soil and groundwater conditions may exist between test hole locations.
3. When the following classification terms are used in this report or test hole logs, the primary and secondary soil fractions may be visually estimated.

Major Divisions			USCS Classi-fication	Symbols	Typical Names	Laboratory Classification Criteria		
Coarse-Grained soils (More than half the material is larger than No. 200 sieve size)	Gravels (More than half of coarse fraction is larger than 4.75 mm)	Clean gravel (Little or no fines)	GW	●	Well-graded gravels, gravel-sand mixtures, little or no fines	Determine percentages of sand and gravel from grain size curve, depending on percentage of fines (fraction smaller than No. 200 sieve) coarse-grained soils are classified as follows: Less than 5 percent...... GW, GP, SW, SP More than 12 percent...... GM, GC, SM, SC 6 to 12 percent...... Borderline case4s requiring dual symbols*	$C_U = \frac{D_{60}}{D_{10}}$ greater than 4; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			GP	○	Poorly-graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for GW	
		Gravel with fines (Appreciable amount of fines)	GM	◌	Silty gravels, gravel-sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are border-line cases requiring use of dual symbols
			GC	▨	Clayey gravels, gravel-sand-silt mixtures		Atterberg limits above "A" line or P.I. greater than 7	
	Sands (More than half of coarse fraction is smaller than 4.75 mm)	Clean sands (Little or no fines)	SW	∴	Well-graded sands, gravelly sands, little or no fines		$C_U = \frac{D_{60}}{D_{10}}$ greater than 6; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			SP	⁚	Poorly-graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM	▥	Silty sands, sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are border-line cases requiring use of dual symbols
			SC	▨	Clayey sands, sand-clay mixtures		Atterberg limits above "A" line or P.I. greater than 7	
Fine-Grained soils (More than half the material is smaller than No. 200 sieve size)	Silts and Clays (Liquid limit less than 50)		ML	▥	Inorganic silts and very fine sands, rock floor, silty or clayey fine sands or clayey silts with slight plasticity	Plasticity Chart 		
			CL	▨	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays			
			OL	▤	Organic silts and organic silty clays of low plasticity			
	Silts and Clays (Liquid limit greater than 50)		MH	▮	Inorganic silts, micaceous or distomaceous fine sandy or silty soils, organic silts			
			CH	▰	Inorganic clays of high plasticity, fat clays			
			OH	≈	Organic clays of medium to high plasticity, organic silts			
	Highly Organic Soils		Pt	⁂	Peat and other highly organic soils	Von Post Classification Limit	Strong colour or odour, and often fibrous texture	

Material		Particle Size mm	ASTM Sieve sizes
Sand	Coarse	2.00 to 4.75	#10 to #4
	Medium	0.425 to 2.00	#40 to #10
	Fine	0.075 to 0.425	#200 to #40
Silt or Clay		< 0.075	< #200

Material		Particle Size mm	ASTM Sieve Sizes
Boulders		> 300	> 12 in.
Cobbles		75 to 300	3 in. to 12 in.
Gravel	Coarse	19 to 75	3/4 in. to 3 in.
	Fine	4.75 to 19	#4 to 3/4 in.

* Borderline classifications used for soils possessing characteristics of two groups are designated by combinations of groups symbols. For example; GW-GC, well-graded gravel-sand mixture with clay binder.

Other Symbol Types

■	Asphalt	▨	Bedrock (undifferentiated)	○	Cobbles
⁘	Concrete	▦	Limestone Bedrock	●	Boulders and Cobbles
▩	Fill	▤	Cemented Shale	◌	Silt Till
		▨	Non-Cemented Shale	▨	Clay Till

EXPLANATION OF FIELD AND LABORATORY TESTING

LEGEND OF ABBREVIATIONS AND SYMBOLS

LL - Liquid Limit (%)
PL - Plastic Limit (%)
PI - Plasticity Index (%)
MC - Moisture Content (%)
SPT - Standard Penetration Test
RQD - Rock Quality Designation
Qu - Unconfined Compression
Su - Undrained Shear Strength
VW - Vibrating Wire Piezometer
SI - Slope Inclinometer

▽ Water Level at Time of Drilling

▼ Water Level at End of Drilling

⧨ Water Level After Drilling as Indicated on Test Hole Logs

FRACTION OF SECONDARY SOIL CONSTITUENTS ARE BASED ON THE FOLLOWING TERMINOLOGY

TERM	EXAMPLES	PERCENTAGE
and	and CLAY	35 to 50 percent
"y" or "ey"	clayey, silty	20 to 35 percent
some	some silt	10 to 20 percent
trace	trace gravel	1 to 10 percent

TERMS DESCRIBING CONSISTENCY OR COMPACTION CONDITION

The Standard Penetration Test blow count (N) of a non-cohesive soil can be related to compactness condition as follows:

Descriptive Terms	SPT (N) (Blows/300 mm)
Very loose	< 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	> 50

The Standard Penetration Test blow count (N) of a cohesive soil can be related to its consistency as follows:

Descriptive Terms	SPT (N) (Blows/300 mm)
Very soft	< 2
Soft	2 to 4
Firm	4 to 8
Stiff	8 to 15
Very stiff	15 to 30
Hard	> 30

The undrained shear strength (Su) of a cohesive soil can be related to its consistency as follows:

Descriptive Terms	Undrained Shear Strength (kPa)
Very soft	< 12
Soft	12 to 25
Firm	25 to 50
Stiff	50 to 100
Very stiff	100 to 200
Hard	> 200

Sub-Surface Log

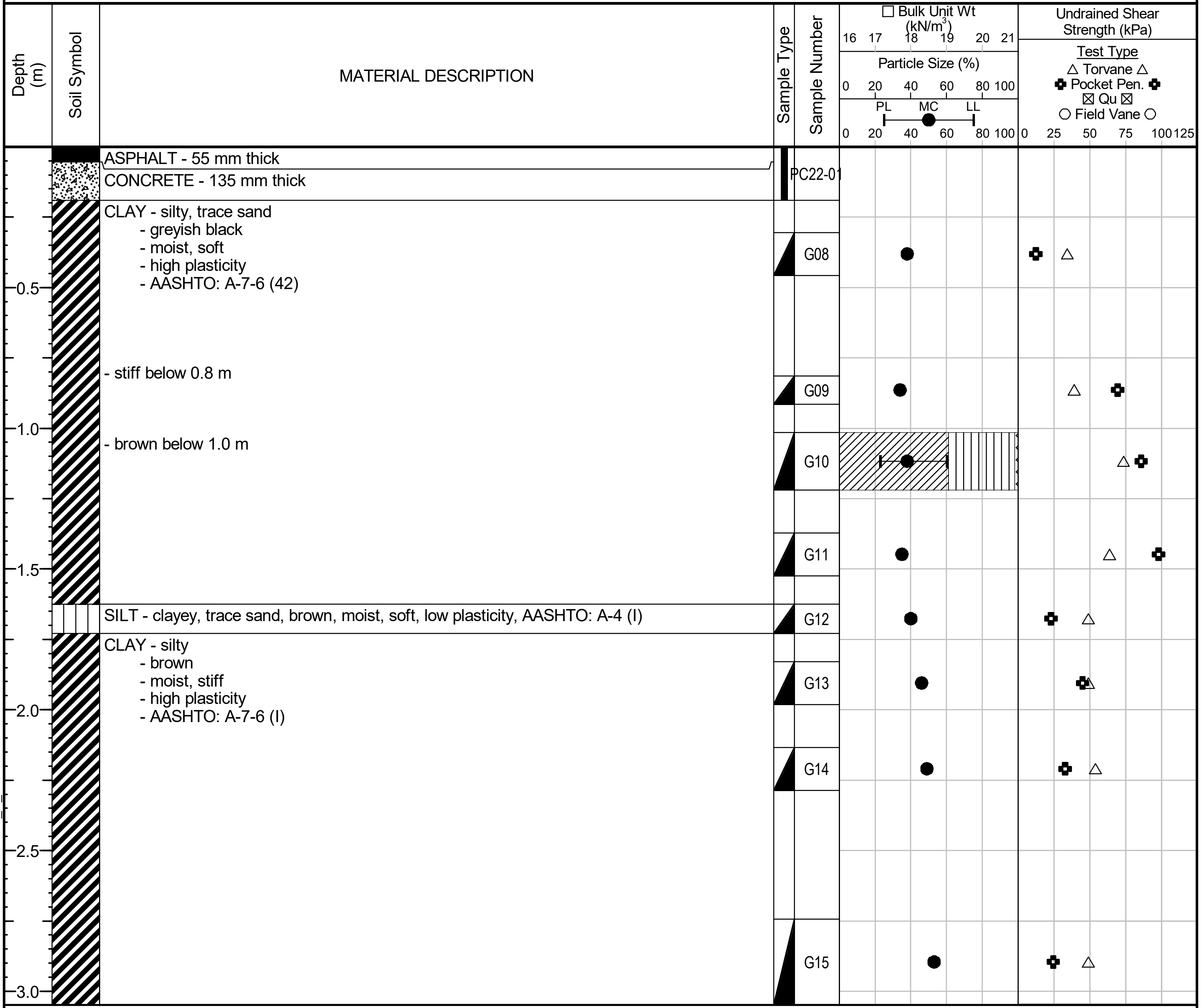
Test Hole TH22-01 (Heaton Ave)

1 of 1

Client: WSP Canada Group Ltd.
Project Name: 2023 Local and Industrial Streets Renewal Package (23-RI-01)
Contractor: Maple Leaf Drilling Ltd.
Method: 125mm Solid Stem Auger, Scout track mounted rig
Project Number: 1000-043-21
Location: UTM N-5529423, E-634385
Ground Elevation: Top of Pavement
Date Drilled: November 14, 2022

Sample Type: ◩ Grab (G) ▮ Shelby Tube (T) ☒ Split Spoon (SS) / SPT ☒ Split Barrel (SB) / LPT ▮ Core (C)

Particle Size Legend: ▦ Fines ▨ Clay ▥ Silt ⁘ Sand ● Gravel ▢ Cobbles ■ Boulders



ASPHALT - 55 mm thick

CONCRETE - 135 mm thick

CLAY - silty, trace sand
- greyish black
- moist, soft
- high plasticity
- AASHTO: A-7-6 (42)

- stiff below 0.8 m

- brown below 1.0 m

SILT - clayey, trace sand, brown, moist, soft, low plasticity, AASHTO: A-4 (I)

CLAY - silty
- brown
- moist, stiff
- high plasticity
- AASHTO: A-7-6 (I)

END OF TEST HOLE AT 3.2 m IN CLAY.
1) Seepage or sloughing not observed.
2) Test hole open to 3.2 m depth immediately after drilling.
3) Test hole backfilled with auger cuttings, bentonite chips and cold patch asphalt.
4) Test hole located in front of #61 Heaton Ave, 2.0 m South of North curb.
5) The bulk sample was collected between 0.2 m and 3.2 m depth.

Logged By: Jashandeep Singh Bhullar **Reviewed By:** Angela Fidler-Kliewer **Project Engineer:** Nelson Ferreira

TREK GEOTECHNICAL

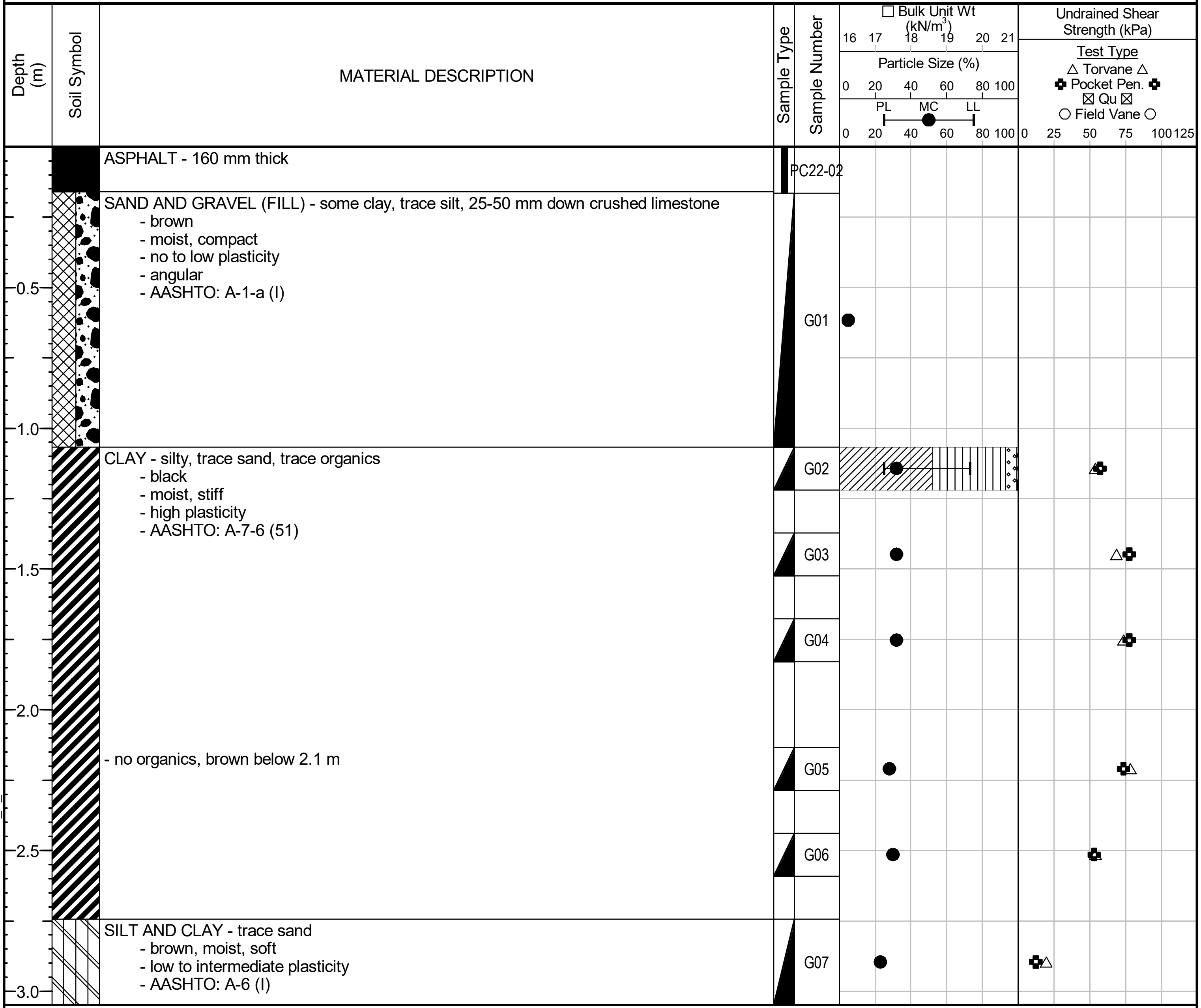
Sub-Surface Log

Test Hole TH22-02 (Heaton Ave)

Client: WSP Canada Group Ltd.
Project Number: 1000-043-21
Project Name: 2023 Local and Industrial Streets Renewal Package (23-RI-01)
Location: UTM N-5529408, E-634444
Contractor: Maple Leaf Drilling Ltd.
Ground Elevation: Top of Pavement
Method: 125mm Solid Stem Auger, Scout track mounted rig
Date Drilled: November 14, 2022

Sample Type: Grab (G) Shelby Tube (T) Split Spoon (SS) / SPT Split Barrel (SB) / LPT Core (C)

Particle Size Legend: Fines Clay Silt Sand Gravel Cobbles Boulders



ASPHALT - 160 mm thick

SAND AND GRAVEL (FILL) - some clay, trace silt, 25-50 mm down crushed limestone
- brown
- moist, compact
- no to low plasticity
- angular
- AASHTO: A-1-a (I)

CLAY - silty, trace sand, trace organics
- black
- moist, stiff
- high plasticity
- AASHTO: A-7-6 (51)

- no organics, brown below 2.1 m

SILT AND CLAY - trace sand
- brown, moist, soft
- low to intermediate plasticity
- AASHTO: A-6 (I)

END OF TEST HOLE AT 3.2 m IN SILT AND CLAY.
1) Seepage not observed.
2) Sloughing observed from top surface.
3) Test hole open to 2.7 m depth immediately after drilling.
4) Test hole backfilled with auger cuttings, bentonite chips and cold patch asphalt.
5) Test hole located in front of south face of #530 Waterfront Dr, 2.0 m North of South curb.
6) The bulk sample was collected between 1.1 m and 2.7 m depth.

Logged By: Jashandeep Singh Bhullar **Reviewed By:** Angela Fidler-Kliewer **Project Engineer:** Nelson Ferreira

2023 Local and Industrial Streets Renewal Project - 23-RI-01
Sub-Surface Investigation
Heaton Ave - Waterfront Dr / Argyle St

Test Hole No.	Test Hole Location	Pavement Surface		Pavement Structure Material		Subgrade Description	Sample Depth (m)		Moisture Content (%)	Grain Size Analysis				Atterberg Limits		
		Type	Thickness (mm)	Type	Thickness (mm)		Top (m)	Bottom (m)		Clay (%)	Silt (%)	Sand (%)	Gravel (%)	Plastic	Liquid	Plasticity Index
TH22-01	UTM: 14U 5529423 N 634385E Located in front of #61 Heaton Ave, 2.0 m South of North curb.	Asphalt	55	Concrete	135	Clay; AASHTO: A-7-6 (42)	0.3	0.5	38							
						Clay; AASHTO: A-7-6 (42)	0.8	0.9	34							
						Clay; AASHTO: A-7-6 (42)	1.0	1.2	38	61	37	2.0	0.0	23	60	38
						Clay; AASHTO: A-7-6 (42)	1.4	1.5	35							
						Silt; AASHTO: A-4 (I)	1.6	1.7	40							
						Clay; AASHTO: A-7-6 (I)	1.8	2.0	46							
						Clay; AASHTO: A-7-6 (I)	2.1	2.3	49							
						Clay; AASHTO: A-7-6 (I)	2.7	3.0	53							
TH22-02	UTM: 14U 5529408N, 634444 E Located in front of south access of #530 Waterfront Dr, 2.0 m North of South curb.	Asphalt	160	Concrete	-	Sand And Gravel (Fill); AASHTO: A-1-a (I)	0.2	1.1	5							
						Clay; AASHTO: A-7-6 (51)	1.1	1.2	32	52	41	6	1	25	73	48
						Clay; AASHTO: A-7-6 (51)	1.4	1.5	32							
						Clay; AASHTO: A-7-6 (51)	1.7	1.8	32							
						Clay; AASHTO: A-7-6 (51)	2.1	2.3	28							
						Clay; AASHTO: A-7-6 (51)	2.4	2.6	30							
						Silt and Clay; AASHTO: A-6 (I)	2.7	3.0	23							

(I) - AASHTO classification was interpreted based on visual classification.

www.trekgeotechnical.ca
1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

Moisture Content Report
ASTM D2216-10

Project No. 1000-043-21
Client WSP Canada Group LTD
Project 2023 Local and Industrial Streets Package (23-RI-01) - Heaton Ave

Sample Date 14-Nov-22
Test Date 22-Nov-22
Technician TG

Test Hole	TH22-01	TH22-01	TH22-01	TH22-01	TH22-01	TH22-01
Depth (m)	0.3 - 0.5	0.8 - 0.9	1.0 - 1.2	1.4 - 1.5	1.6 - 1.7	1.8 - 2.0
Sample #	G08	G09	G10	G11	G12	G13
Tare ID	AB08	E8	Z29	F71	E19	E60
Mass of tare	6.9	8.5	8.6	8.5	8.5	8.6
Mass wet + tare	262.5	276.0	400.0	257.5	274.5	272.9
Mass dry + tare	192.6	208.5	292.6	192.4	199.0	189.9
Mass water	69.9	67.5	107.4	65.1	75.5	83.0
Mass dry soil	185.7	200.0	284.0	183.9	190.5	181.3
Moisture %	37.6%	33.8%	37.8%	35.4%	39.6%	45.8%

Test Hole	TH22-01	TH22-01	TH22-02	TH22-02	TH22-02	TH22-02
Depth (m)	2.1 - 2.3	2.7 - 3.0	0.2 - 1.1	1.1 - 1.2	1.4 - 1.5	1.7 - 1.8
Sample #	G14	G15	G01	G02	G03	G04
Tare ID	F86	F32	W92	AB90	A17	N04
Mass of tare	8.3	8.4	8.5	6.9	8.7	8.7
Mass wet + tare	265.3	252.6	363.0	387.5	277.1	283.7
Mass dry + tare	180.7	168.1	345.5	295.0	211.6	217.1
Mass water	84.6	84.5	17.5	92.5	65.5	66.6
Mass dry soil	172.4	159.7	337.0	288.1	202.9	208.4
Moisture %	49.1%	52.9%	5.2%	32.1%	32.3%	32.0%

Test Hole	TH22-02	TH22-02	TH22-02			
Depth (m)	2.1 - 2.3	2.4 - 2.6	2.7 - 3.0			
Sample #	G05	G06	G07			
Tare ID	W04	Z132	C8			
Mass of tare	8.5	8.7	8.4			
Mass wet + tare	301.5	252.7	333.0			
Mass dry + tare	237.7	196.3	273.0			
Mass water	63.8	56.4	60.0			
Mass dry soil	229.2	187.6	264.6			
Moisture %	27.8%	30.1%	22.7%			

TREK GEOTECHNICAL
www.trekgeotechnical.ca
1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

Atterberg Limits
ASTM D4318-10e1

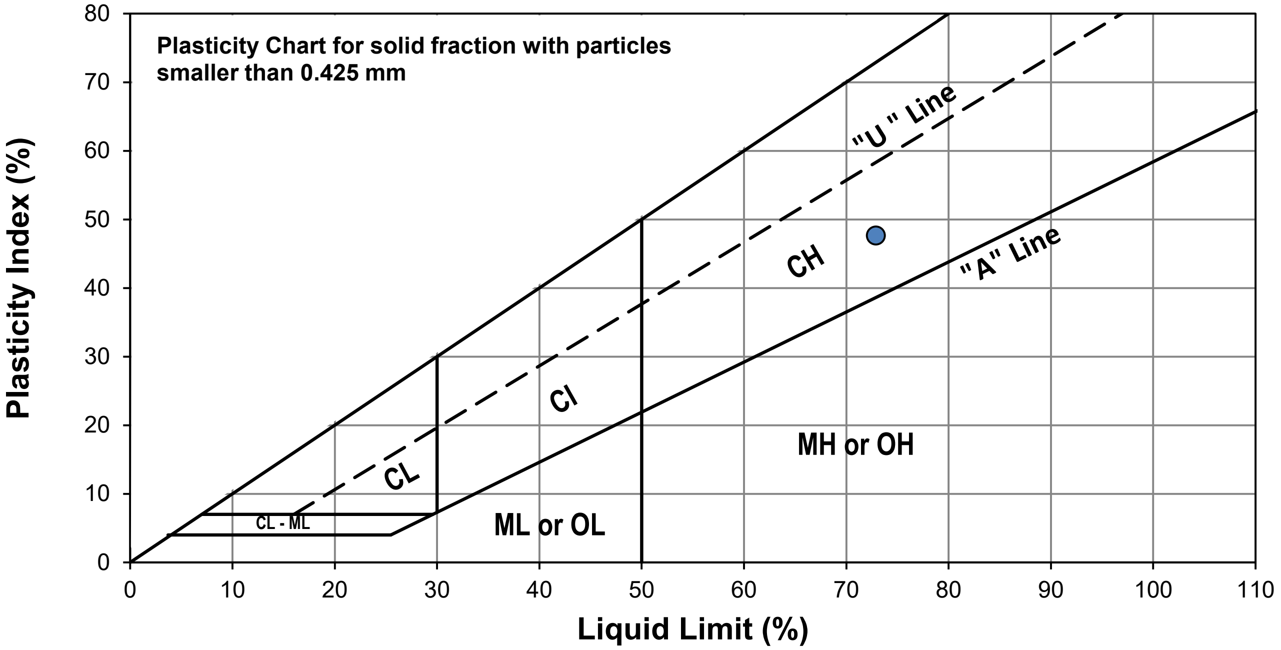
CERTIFIED BY CCIL Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

Project No.	1000-043-21
Client	WSP Canada Group LTD
Project	2023 Local and Industrial Streets Package (23-RI-01) - Heaton Ave
Test Hole	TH22-02
Sample #	G02
Depth (m)	1.1 - 1.2
Sample Date	14-Nov-22
Test Date	28-Nov-22
Technician	MT

Liquid Limit	73
Plastic Limit	25
Plasticity Index	48

Liquid Limit

Trial #	**1**	**2**	**3**		
Number of Blows (N)	15	23	34		
Mass Tare (g)	13.885	14.280	14.055		
Mass Wet Soil + Tare (g)	25.019	24.064	22.827		
Mass Dry Soil + Tare (g)	20.107	19.908	19.236		
Mass Water (g)	4.912	4.156	3.591		
Mass Dry Soil (g)	6.222	5.628	5.181		
Moisture Content (%)	78.946	73.845	69.311		



Plastic Limit

Trial #	**1**	**2**	**3**	**4**	**5**
Mass Tare (g)	13.977	14.119			
Mass Wet Soil + Tare (g)	24.505	23.871			
Mass Dry Soil + Tare (g)	22.376	21.907			
Mass Water (g)	2.129	1.964			
Mass Dry Soil (g)	8.399	7.788			
Moisture Content (%)	25.348	25.218			

Note: Additional information recorded/measured for this test is available upon request.

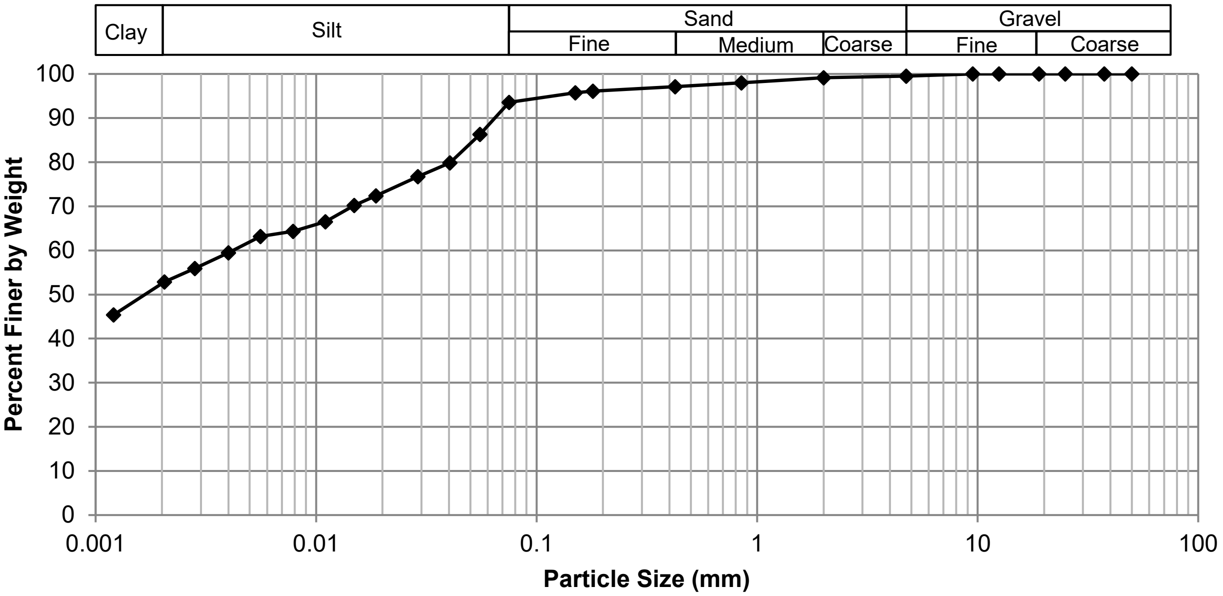
TREK GEOTECHNICAL
www.trekgeotechnical.ca
1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

Grain Size Analysis (Hydrometer Method)
AASHTO T 88

Project No.	1000-043-21
Client	WSP Canada Group LTD
Project	2023 Local and Industrial Streets Package (23-RI-01) - Heaton Ave
Test Hole	TH22-02
Sample #	G02
Depth (m)	1.1 - 1.2
Sample Date	14-Nov-22
Test Date	30-Nov-22
Technician	TG

Gravel	0.5%
Sand	5.9%
Silt	41.2%
Clay	52.4%

Particle Size Distribution Curve



Gravel		Sand		Silt and Clay	
Particle Size (mm)	**Percent Passing**	**Particle Size (mm)**	**Percent Passing**	**Particle Size (mm)**	**Percent Passing**
50.0	100.00	4.75	99.53	0.0750	93.59
37.5	100.00	2.00	99.14	0.0554	86.33
25.0	100.00	0.850	97.97	0.0404	79.82
19.0	100.00	0.425	97.11	0.0290	76.72
12.5	100.00	0.180	96.07	0.0187	72.38
9.50	100.00	0.150	95.77	0.0149	70.21
4.75	99.53	0.075	93.59	0.0110	66.49
				0.0079	64.32
				0.0056	63.15
				0.0040	59.43
				0.0028	55.95
				0.0021	52.85
				0.0012	45.38

TREK GEOTECHNICAL
www.trekgeotechnical.ca
1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

Atterberg Limits
ASTM D4318-10e1

Project No. 1000-043-21
Client WSP Canada Group LTD
Project 2023 Local and Industrial Streets Package (23-RI-01) - Heaton Ave

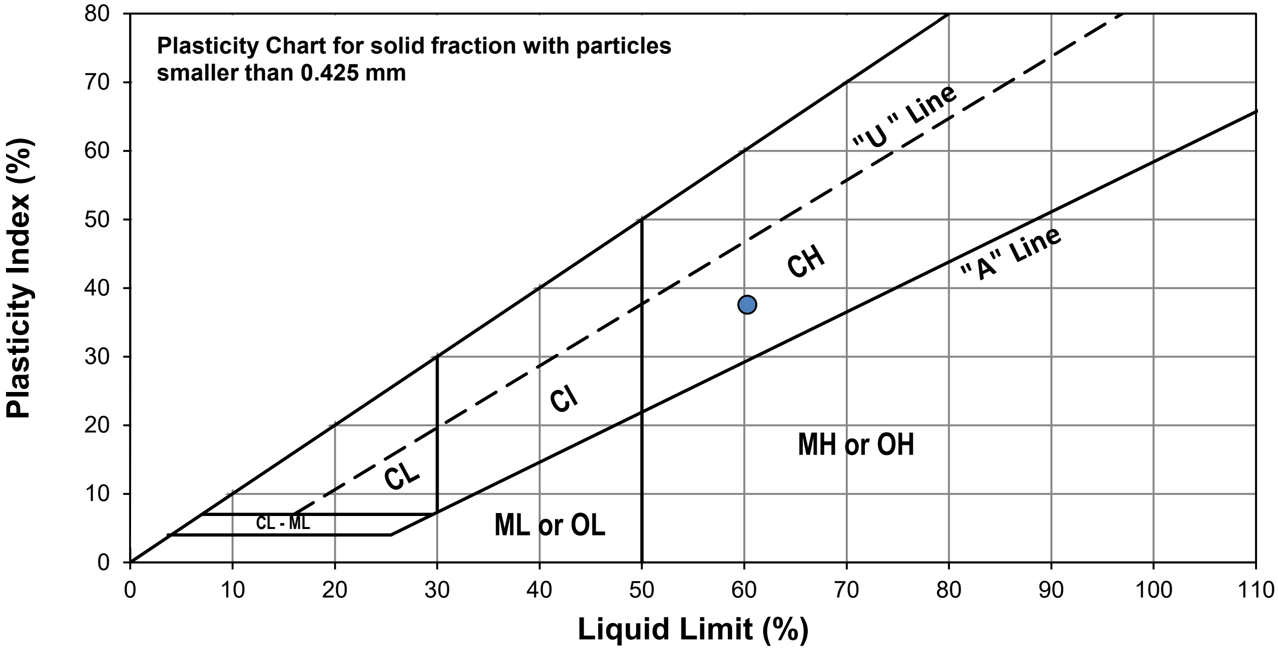
Test Hole TH22-01
Sample # G10
Depth (m) 1.0 - 1.2
Sample Date 14-Nov-22
Test Date 29-Nov-22
Technician MT

CERTIFIED BY CCIL Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

Liquid Limit	60
Plastic Limit	23
Plasticity Index	38

Liquid Limit

Trial #	**1**	**2**	**3**		
Number of Blows (N)	16	22	33		
Mass Tare (g)	14.097	14.263	13.885		
Mass Wet Soil + Tare (g)	23.728	23.518	22.791		
Mass Dry Soil + Tare (g)	19.965	19.998	19.524		
Mass Water (g)	3.763	3.520	3.267		
Mass Dry Soil (g)	5.868	5.735	5.639		
Moisture Content (%)	64.127	61.378	57.936		



Plastic Limit

Trial #	**1**	**2**	**3**	**4**	**5**
Mass Tare (g)	13.953	14.203			
Mass Wet Soil + Tare (g)	20.690	20.222			
Mass Dry Soil + Tare (g)	19.454	19.095			
Mass Water (g)	1.236	1.127			
Mass Dry Soil (g)	5.501	4.892			
Moisture Content (%)	22.469	23.038			

Note: Additional information recorded/measured for this test is available upon request.

TREK GEOTECHNICAL
www.trekgeotechnical.ca
1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

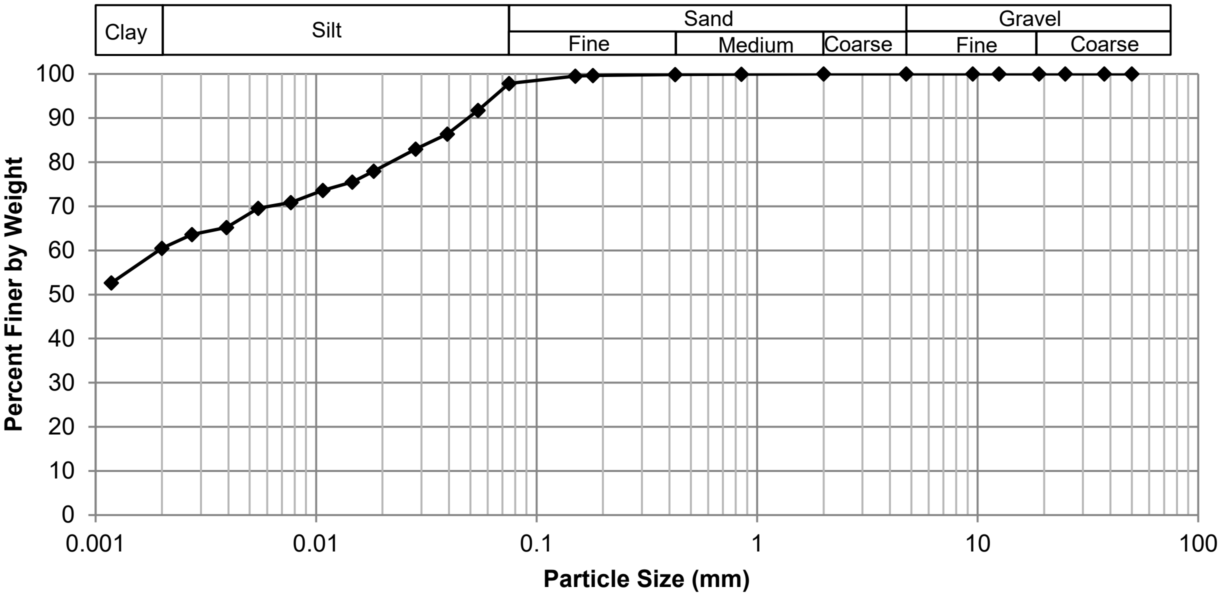
Grain Size Analysis (Hydrometer Method)
AASHTO T 88

CERTIFIED BY CCIL
Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

Project No.	1000-043-21
Client	WSP Canada Group LTD
Project	2023 Local and Industrial Streets Package (23-RI-01) - Heaton Ave
Test Hole	TH22-01
Sample #	G10
Depth (m)	1.0 - 1.2
Sample Date	14-Nov-22
Test Date	30-Nov-22
Technician	TG

Gravel	0.0%
Sand	2.2%
Silt	37.4%
Clay	60.4%

Particle Size Distribution Curve



Gravel		Sand		Silt and Clay	
Particle Size (mm)	**Percent Passing**	**Particle Size (mm)**	**Percent Passing**	**Particle Size (mm)**	**Percent Passing**
50.0	100.00	4.75	100.00	0.0750	97.81
37.5	100.00	2.00	100.00	0.0542	91.73
25.0	100.00	0.850	99.97	0.0393	86.41
19.0	100.00	0.425	99.89	0.0282	82.97
12.5	100.00	0.180	99.63	0.0183	77.97
9.50	100.00	0.150	99.51	0.0146	75.47
4.75	100.00	0.075	97.81	0.0107	73.59
				0.0077	70.82
				0.0055	69.57
				0.0039	65.19
				0.0027	63.59
				0.0020	60.46
				0.0012	52.63

TREK GEOTECHNICAL
www.trekgeotechnical.ca
1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

Standard Proctor Compaction Test

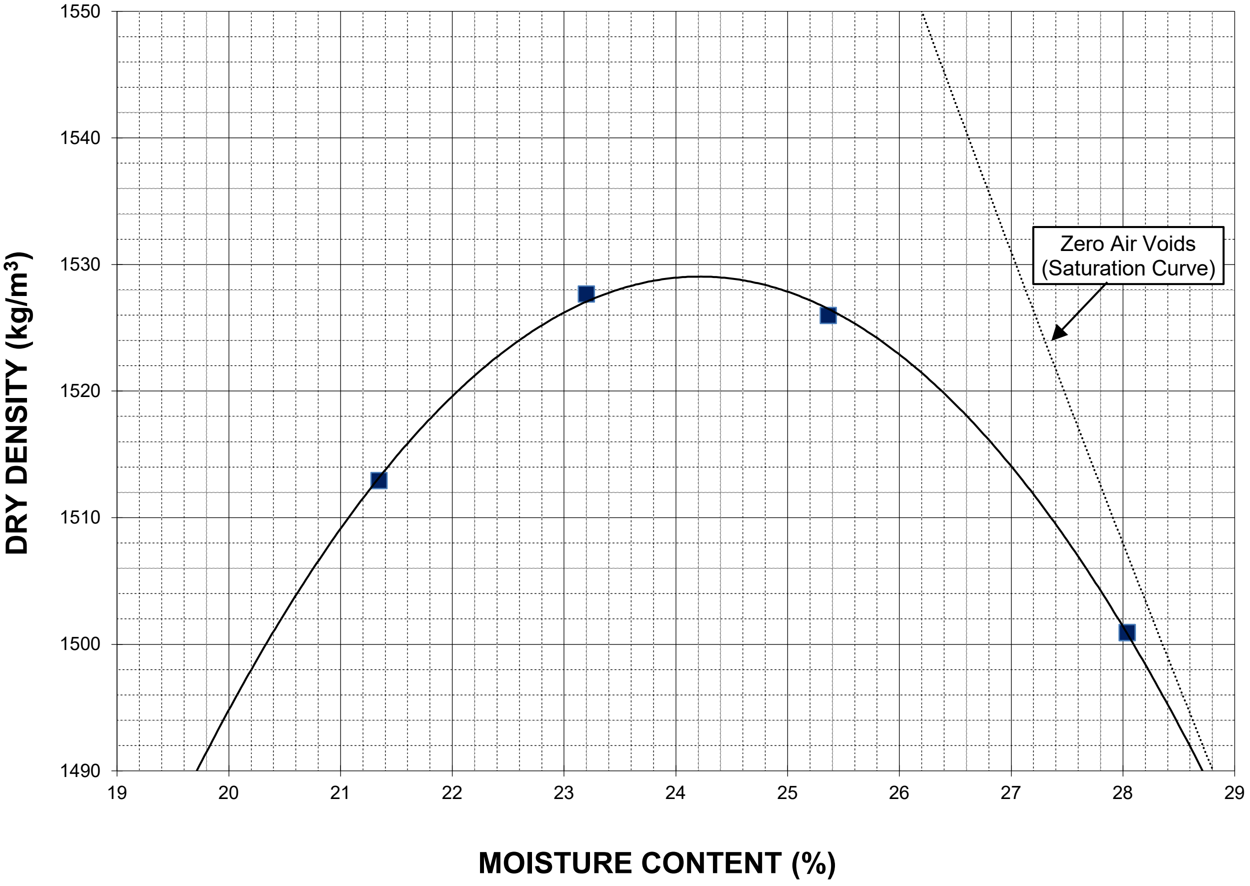
ASTM D698-12 (2021)

CERTIFIED BY CCIL
Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

Project No.	1000-043-21
Client	WSP Canada Group LTD
Project	2023 Local and Industrial Streets Package (23-RI-01)
Sample #	TH22-02
Source	Heaton Ave
Material	Clay
Sample Date	14-Nov-22
Test Date	23-Nov-22
Technician	DS

Maximum Dry Density (kg/m3)	1529
Optimum Moisture (%)	24.2

Trial Number	1	2	3	4	
Wet Density (kg/m^3)	1836	1882	1913	1922	
Dry Density (kg/m^3)	1513	1528	1526	1501	
Moisture Content (%)	21.3	23.2	25.4	28.0	



Note: Additional information recorded/measured for this test is available upon request.

www.trekgeotechnical.ca
1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

California Bearing Ratio Test Data Sheet

ASTM D1883-16

Project No.	1000-043-21	**Source**	Heaton Ave.
Client	WSP Canada Group LTD	**Material**	Clay
Project	2023 Local Streets (23-RI-01)	**Sample Date**	2022-11-14
Sample #	TH22-02	**Test Date**	2022-11-25
		Technician	DS

Proctor Results (ASTM D698)

Maximum Dry Density	1529	kg/m3
Optimum Moisture Content	24.2	%
Material Retained on 19 mm Sieve	0.0	%

CBR Sample Compaction

Dry Density	1456	kg/m3
Initial Moisture Content	24.0	%
Relative Density	95.2	% SPMDD

Soaking Results

Surcharge	4.54	kg
Swell	1.6	%
Moisture Content in top 25 mm	33.3	%
Immersion Period	96	h

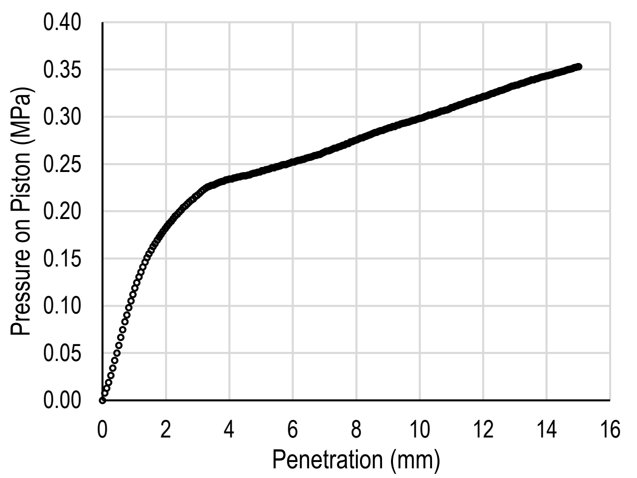
CBR Results

CBR at 2.54 mm	3.0	%
CBR at 5.08 mm	2.4	%
Zero Correction	0	mm

Test Data

Penetration (mm)	Measured Pressure (MPa)	Corrected Pressure (MPa)
0.64	0.08	0.08
1.27	0.14	0.14
1.91	0.18	0.18
2.54	0.20	0.20
3.18	0.22	0.22
3.81	0.23	0.23
4.45	0.24	0.24
5.08	0.24	0.24
7.62	0.27	0.27
10.16	0.30	0.30
12.70	0.33	0.33

Load/Penetration Curve



Comments:

Template Rev. B - 2018-04-07

Appendix B

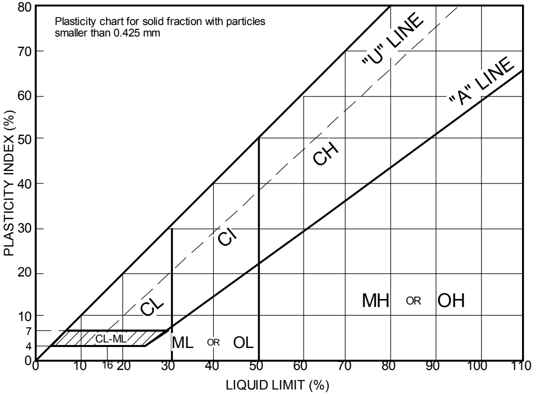
Test Hole Logs, Summary Table & Lab Testing Results and Pavement Core Photos – Galt Ave

TREK GEOTECHNICAL

EXPLANATION OF FIELD AND LABORATORY TESTING

GENERAL NOTES

1. Classifications are based on the United Soil Classification System and include consistency, moisture, and color. Field descriptions have been modified to reflect results of laboratory tests where deemed appropriate.
2. Descriptions on these test hole logs apply only at the specific test hole locations and at the time the test holes were drilled. Variability of soil and groundwater conditions may exist between test hole locations.
3. When the following classification terms are used in this report or test hole logs, the primary and secondary soil fractions may be visually estimated.

Major Divisions			USCS Classification	Symbols	Typical Names	Laboratory Classification Criteria		
Coarse-Grained soils (More than half the material is larger than No. 200 sieve size)	Gravels (More than half of coarse fraction is larger than 4.75 mm)	Clean gravel (Little or no fines)	GW	●	Well-graded gravels, gravel-sand mixtures, little or no fines	Determine percentages of sand and gravel from grain size curve, depending on percentage of fines (fraction smaller than No. 200 sieve) coarse-grained soils are classified as follows: Less than 5 percent...... GW, GP, SW, SP More than 12 percent...... GM, GC, SM, SC 6 to 12 percent...... Borderline case4s requiring dual symbols*	$C_U = \frac{D_{60}}{D_{10}}$ greater than 4; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			GP	◌	Poorly-graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for GW	
		Gravel with fines (Appreciable amount of fines)	GM	◌	Silty gravels, gravel-sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are border-line cases requiring use of dual symbols
			GC	▨	Clayey gravels, gravel-sand-silt mixtures		Atterberg limits above "A" line or P.I. greater than 7	
	Sands (More than half of coarse fraction is smaller than 4.75 mm)	Clean sands (Little or no fines)	SW	∴	Well-graded sands, gravelly sands, little or no fines		$C_U = \frac{D_{60}}{D_{10}}$ greater than 6; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			SP	⁚	Poorly-graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM	▥	Silty sands, sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are border-line cases requiring use of dual symbols
			SC	▨	Clayey sands, sand-clay mixtures		Atterberg limits above "A" line or P.I. greater than 7	
Fine-Grained soils (More than half the material is smaller than No. 200 sieve size)	Silts and Clays (Liquid limit less than 50)		ML	▥	Inorganic silts and very fine sands, rock floor, silty or clayey fine sands or clayey silts with slight plasticity	Plasticity Chart  		
			CL	▨	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays			
			OL	☰	Organic silts and organic silty clays of low plasticity			
	Silts and Clays (Liquid limit greater than 50)		MH	▥	Inorganic silts, micaceous or distomaceous fine sandy or silty soils, organic silts			
			CH	▰	Inorganic clays of high plasticity, fat clays			
			OH	≋	Organic clays of medium to high plasticity, organic silts			
	Highly Organic Soils		Pt	⁂	Peat and other highly organic soils	Von Post Classification Limit	Strong colour or odour, and often fibrous texture	

Material		Particle Size mm	Particle Size ASTM Sieve sizes
Sand	Coarse	2.00 to 4.75	#10 to #4
	Medium	0.425 to 2.00	#40 to #10
	Fine	0.075 to 0.425	#200 to #40
Silt or Clay		< 0.075	< #200

Material		Particle Size mm	Particle Size ASTM Sieve Sizes
Boulders		> 300	> 12 in.
Cobbles		75 to 300	3 in. to 12 in.
Gravel	Coarse	19 to 75	3/4 in. to 3 in.
	Fine	4.75 to 19	#4 to 3/4 in.

* Borderline classifications used for soils possessing characteristics of two groups are designated by combinations of groups symbols. For example; GW-GC, well-graded gravel-sand mixture with clay binder.

Other Symbol Types

■	Asphalt	▧	Bedrock (undifferentiated)	◌	Cobbles
░	Concrete	⊞	Limestone Bedrock	▚	Boulders and Cobbles
▩	Fill	☰	Cemented Shale	▥	Silt Till
		▤	Non-Cemented Shale	▨	Clay Till

EXPLANATION OF FIELD AND LABORATORY TESTING

LEGEND OF ABBREVIATIONS AND SYMBOLS

LL - Liquid Limit (%)
PL - Plastic Limit (%)
PI - Plasticity Index (%)
MC - Moisture Content (%)
SPT - Standard Penetration Test
RQD - Rock Quality Designation
Qu - Unconfined Compression
Su - Undrained Shear Strength
VW - Vibrating Wire Piezometer
SI - Slope Inclinometer

▽ Water Level at Time of Drilling

▼ Water Level at End of Drilling

⧩ Water Level After Drilling as Indicated on Test Hole Logs

FRACTION OF SECONDARY SOIL CONSTITUENTS ARE BASED ON THE FOLLOWING TERMINOLOGY

TERM	EXAMPLES	PERCENTAGE
and	and CLAY	35 to 50 percent
"y" or "ey"	clayey, silty	20 to 35 percent
some	some silt	10 to 20 percent
trace	trace gravel	1 to 10 percent

TERMS DESCRIBING CONSISTENCY OR COMPACTION CONDITION

The Standard Penetration Test blow count (N) of a non-cohesive soil can be related to compactness condition as follows:

Descriptive Terms	SPT (N) (Blows/300 mm)
Very loose	< 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	> 50

The Standard Penetration Test blow count (N) of a cohesive soil can be related to its consistency as follows:

Descriptive Terms	SPT (N) (Blows/300 mm)
Very soft	< 2
Soft	2 to 4
Firm	4 to 8
Stiff	8 to 15
Very stiff	15 to 30
Hard	> 30

The undrained shear strength (Su) of a cohesive soil can be related to its consistency as follows:

Descriptive Terms	Undrained Shear Strength (kPa)
Very soft	< 12
Soft	12 to 25
Firm	25 to 50
Stiff	50 to 100
Very stiff	100 to 200
Hard	> 200

Sub-Surface Log

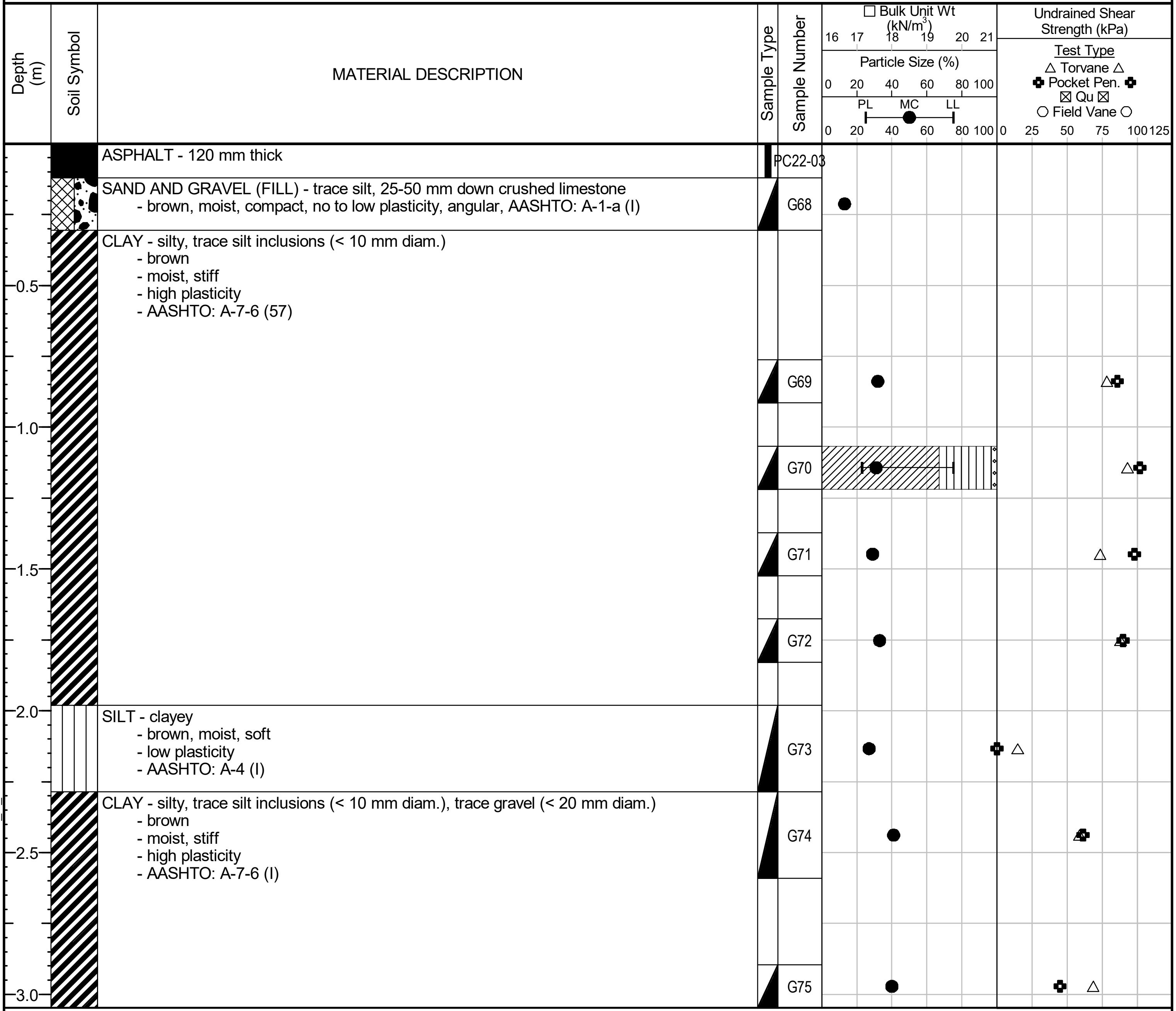
Test Hole TH22-03 (Galt Ave)

1 of 1

Client: WSP Canada Group Ltd.
Project Name: 2023 Local and Industrial Streets Renewal Package (23-RI-01)
Contractor: Maple Leaf Drilling Ltd.
Method: 125mm Solid Stem Auger, B40 Mobile Truck Mount
Project Number: 1000-043-21
Location: UTM N-5529304, E-634057
Ground Elevation: Top of Pavement
Date Drilled: November 15, 2022

Sample Type: Grab (G) Shelby Tube (T) Split Spoon (SS) / SPT Split Barrel (SB) / LPT Core (C)

Particle Size Legend: ▥ Fines ▨ Clay ▥ Silt ▒ Sand Gravel Cobbles Boulders



ASPHALT - 120 mm thick

SAND AND GRAVEL (FILL) - trace silt, 25-50 mm down crushed limestone
- brown, moist, compact, no to low plasticity, angular, AASHTO: A-1-a (I)

CLAY - silty, trace silt inclusions (< 10 mm diam.)
- brown
- moist, stiff
- high plasticity
- AASHTO: A-7-6 (57)

SILT - clayey
- brown, moist, soft
- low plasticity
- AASHTO: A-4 (I)

CLAY - silty, trace silt inclusions (< 10 mm diam.), trace gravel (< 20 mm diam.)
- brown
- moist, stiff
- high plasticity
- AASHTO: A-7-6 (I)

END OF TEST HOLE AT 3.2 m IN CLAY.
1) Seepage or sloughing not observed.
2) Test hole open to 3.2 m depth immediately after drilling.
3) Test hole backfilled with auger cuttings, bentonite chips and cold patch asphalt.
4) Test hole located in front of #18 Galt Ave, 1.2 m North of South edge of road.
5) The bulk sample was collected between 0.3 to 2.0 m and 2.3 to 3.0 m depth.

Logged By: Jashandeep Singh Bhullar **Reviewed By:** Angela Fidler-Kliewer **Project Engineer:** Nelson Ferreira

Test Hole TH22-04 (Galt Ave)

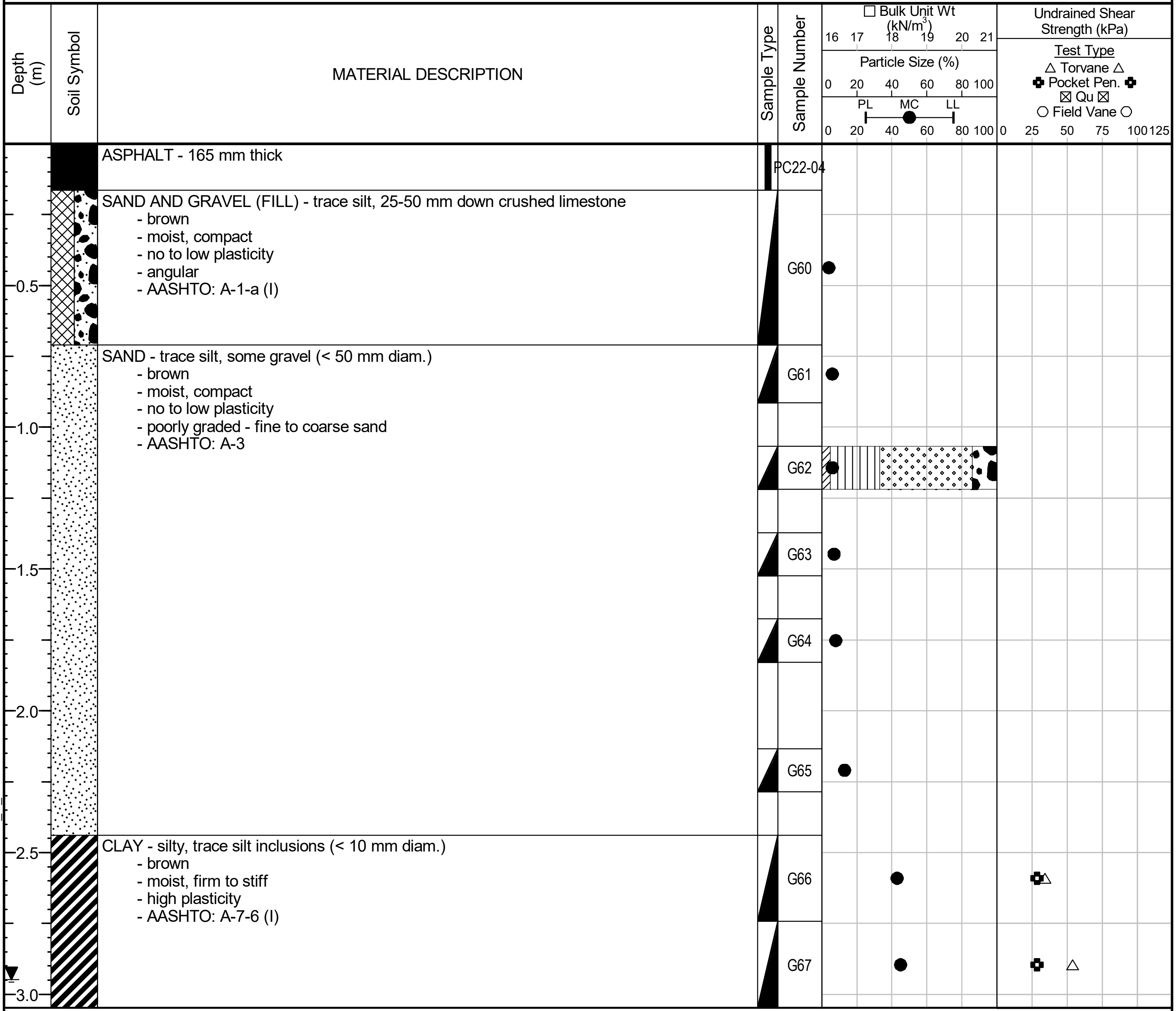
1 of 1

Sub-Surface Log

Client: WSP Canada Group Ltd.
Project Number: 1000-043-21
Project Name: 2023 Local and Industrial Streets Renewal Package (23-RI-01)
Location: UTM N-5529249, E-634177
Contractor: Maple Leaf Drilling Ltd.
Ground Elevation: Top of Pavement
Method: 125mm Solid Stem Auger, B40 Mobile Truck Mount
Date Drilled: November 15, 2022

Sample Type: Grab (G) Shelby Tube (T) Split Spoon (SS) / SPT Split Barrel (SB) / LPT Core (C)

Particle Size Legend: Fines Clay Silt Sand Gravel Cobbles Boulders



ASPHALT - 165 mm thick

SAND AND GRAVEL (FILL) - trace silt, 25-50 mm down crushed limestone
- brown
- moist, compact
- no to low plasticity
- angular
- AASHTO: A-1-a (I)

SAND - trace silt, some gravel (< 50 mm diam.)
- brown
- moist, compact
- no to low plasticity
- poorly graded - fine to coarse sand
- AASHTO: A-3

CLAY - silty, trace silt inclusions (< 10 mm diam.)
- brown
- moist, firm to stiff
- high plasticity
- AASHTO: A-7-6 (I)

END OF TEST HOLE AT 3.2 m IN CLAY.
1) Seepage observed below 1.5 m depth.
2) Sloughing not observed.
3) Test hole open to 3.2 m depth and water level at 2.9 m depth immediately after drilling.
4) Test hole backfilled with auger cuttings, bentonite chips and cold patch asphalt.
5) Test hole located in front of #130 Galt Ave, 0.9 m North of South edge of road.

Logged By: Jashandeep Singh Bhullar
Reviewed By: Angela Fidler-Kliewer
Project Engineer: Nelson Ferreira

2023 Local and Industrial Streets Renewal Project - 23-RI-01
Sub-Surface Investigation
Galt Ave - Lily St / Ducan St

Test Hole No.	Test Hole Location	Pavement Surface		Pavement Structure Material		Subgrade Description	Sample Depth (m)		Moisture Content (%)	Grain Size Analysis				Atterberg Limits		
		Type	Thickness (mm)	Type	Thickness (mm)		Top (m)	Bottom (m)		Clay (%)	Silt (%)	Sand (%)	Gravel (%)	Plastic	Liquid	Plasticity Index
TH22-03	UTM: 14U 5529304 N 634057E Located in front of #18 Galt Ave, 1.2 m North of South edge of road.	Asphalt	120	Concrete	-	Sand and Gravel (Fill); AASHTO: A-1-a (I)	0.2	0.3	13							
						Clay; AASHTO: A-7-6 (57)	0.8	0.9	32							
						Clay; AASHTO: A-7-6 (57)	1.1	1.2	31	67	30	3.0	0.0	23	75	52
						Clay; AASHTO: A-7-6 (57)	1.4	1.5	29							
						Clay; AASHTO: A-7-6 (57)	1.7	1.8	33							
						Silt; AASHTO: A-4 (I)	2.0	2.3	27							
						Clay; AASHTO: A-7-6 (I)	2.3	2.6	41							
						Clay; AASHTO: A-7-6 (I)	2.9	3.0	40							
TH22-04	UTM: 14U 5529249N, 634177 E Located in front of #130 Galt Ave, 0.9 m North of South edge of road.	Asphalt	165	Concrete	-	Sand and Gravel (Fill); AASHTO: A-1-a (I)	0.2	0.7	4							
						Sand; AASHTO: A-3	0.7	0.9	6							
						Sand; AASHTO: A-3	1.1	1.2	6	5	28	53	14	-	-	NP
						Sand; AASHTO: A-3	1.4	1.5	7							
						Sand; AASHTO: A-3	1.7	1.8	8							
						Sand; AASHTO: A-3	2.1	2.3	13							
						Clay; AASHTO: A-7-6 (I)	2.4	2.7	43							
						Clay; AASHTO: A-7-6 (I)	2.7	3.0	45							

(I) - AASHTO classification was interpreted based on visual classification.

TREK GEOTECHNICAL
www.trekgeotechnical.ca
1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

Moisture Content Report
ASTM D2216-10

Project No. 1000-043-21
Client WSP Canada Group LTD
Project 2023 Local and Industrial Streets Package (23-RI-01) - Galt Ave

Sample Date 14-Nov-22
Test Date 22-Nov-22
Technician TG

Test Hole	TH22-03	TH22-03	TH22-03	TH22-03	TH22-03	TH22-03
Depth (m)	0.2 - 0.3	0.8 - 0.9	1.1 - 1.2	1.4 - 1.5	1.7 - 1.8	2.0 - 2.3
Sample #	G68	G69	G70	G71	G72	G73
Tare ID	W15	N72	E38	Z63	H03	N12
Mass of tare	8.4	8.9	8.5	8.5	8.6	8.7
Mass wet + tare	398.5	265.0	401.4	243.3	283.4	291.0
Mass dry + tare	355.0	203.2	309.1	190.5	214.9	231.8
Mass water	43.5	61.8	92.3	52.8	68.5	59.2
Mass dry soil	346.6	194.3	300.6	182.0	206.3	223.1
Moisture %	12.6%	31.8%	30.7%	29.0%	33.2%	26.5%

Test Hole	TH22-03	TH22-03	TH22-04	TH22-04	TH22-04	TH22-04
Depth (m)	2.3 - 2.6	2.9 - 3.0	0.2 - 0.7	0.7 - 0.9	1.1 - 1.2	1.4 - 1.5
Sample #	G74	G75	G60	G61	G62	G63
Tare ID	F52	N58	E141	AA19	W77	E470
Mass of tare	8.5	8.4	8.7	6.8	8.6	8.6
Mass wet + tare	251.9	277.2	324.3	338.6	524.5	321.9
Mass dry + tare	180.8	200.3	312.7	320.1	494.6	301.3
Mass water	71.1	76.9	11.6	18.5	29.9	20.6
Mass dry soil	172.3	191.9	304.0	313.3	486.0	292.7
Moisture %	41.3%	40.1%	3.8%	5.9%	6.2%	7.0%

Test Hole	TH22-04	TH22-04	TH22-04	TH22-04		
Depth (m)	1.7 - 1.8	2.1 - 2.3	2.4 - 2.7	2.7 - 3.0		
Sample #	G64	G65	G66	G67		
Tare ID	W79	Z101	P21	W94		
Mass of tare	8.7	8.4	8.5	8.5		
Mass wet + tare	348.9	402.6	270.8	282.7		
Mass dry + tare	323.0	357.6	191.6	197.9		
Mass water	25.9	45.0	79.2	84.8		
Mass dry soil	314.3	349.2	183.1	189.4		
Moisture %	8.2%	12.9%	43.3%	44.8%		

TREK GEOTECHNICAL
www.trekgeotechnical.ca
1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

Atterberg Limits
ASTM D4318-17e1

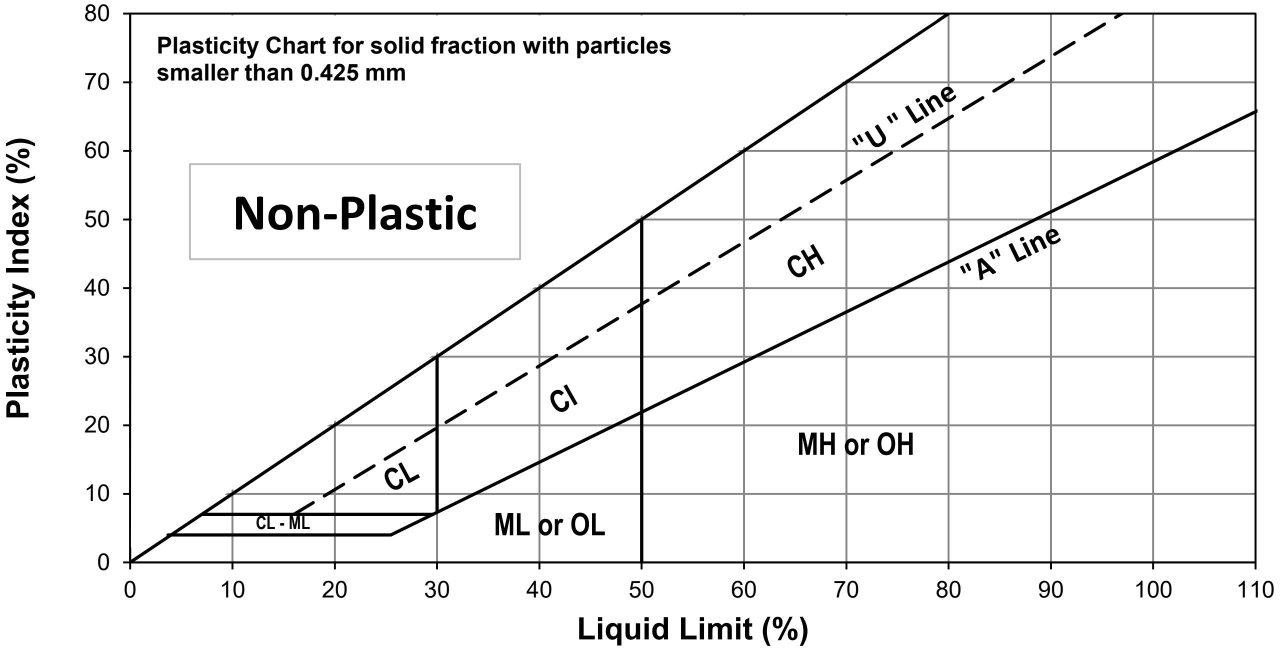
Project No.	1000-043-21
Client	WSP Canada Group LTD
Project	2023 Local and Industrial Streets Package (23-RI-01) - Galt Ave
Test Hole	TH22-04
Sample #	G62
Depth	1.1 - 1.2
Sample Date	15-Nov-22
Test Date	24-Nov-22
Technician	SL

CERTIFIED BY CCIL Canadian Council of Independent Laboratories For specific tests as listed on www.ccil.com

Liquid Limit	-
Plastic Limit	-
Plasticity Index	NP

Liquid Limit

Trial #	1	2	3	4	5
Number of Blows (N)	11				
Mass Tare (g)	14.208				
Mass Wet Soil + Tare (g)	32.448				
Mass Dry Soil + Tare (g)	30.306				
Mass Water (g)	2.142				
Mass Dry Soil (g)	16.098				
Moisture Content (%)	13.306				



Plastic Limit

Trial #	1	2	3	4	5
Mass Tare (g)					
Mass Wet Soil + Tare (g)					
Mass Dry Soil + Tare (g)					
Mass Water (g)					
Mass Dry Soil (g)					
Moisture Content (%)					

Note: Additional information recorded/measured for this test is available upon request.

TREK GEOTECHNICAL
www.trekgeotechnical.ca
1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

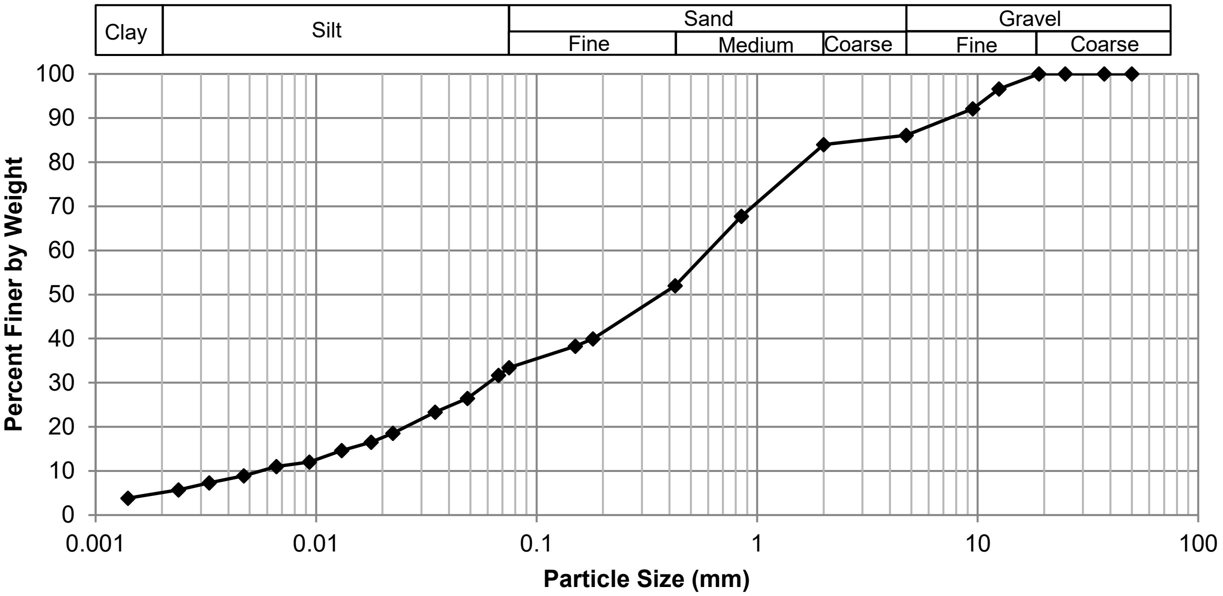
Grain Size Analysis (Hydrometer Method)
AASHTO T 88

CERTIFIED BY CCIL Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

Project No.	1000-043-21
Client	WSP Canada Group LTD
Project	2023 Local and Industrial Streets Package (23-RI-01) - Galt Ave
Test Hole	TH22-04
Sample #	G62
Depth (m)	1.1 - 1.2
Sample Date	14-Nov-22
Test Date	29-Nov-22
Technician	TG

Gravel	13.9%
Sand	52.7%
Silt	28.4%
Clay	5.0%

Particle Size Distribution Curve



Gravel		Sand		Silt and Clay	
Particle Size (mm)	**Percent Passing**	**Particle Size (mm)**	**Percent Passing**	**Particle Size (mm)**	**Percent Passing**
50.0	100.00	4.75	86.12	0.0750	33.43
37.5	100.00	2.00	83.98	0.0673	31.72
25.0	100.00	0.850	67.70	0.0485	26.47
19.0	100.00	0.425	52.00	0.0347	23.32
12.5	96.61	0.180	39.99	0.0223	18.59
9.50	92.11	0.150	38.32	0.0178	16.49
4.75	86.12	0.075	33.43	0.0131	14.65
				0.0093	12.03
				0.0066	10.98
				0.0047	8.90
				0.0033	7.33
				0.0024	5.73
				0.0014	3.84

Atterberg Limits
ASTM D4318-10e1

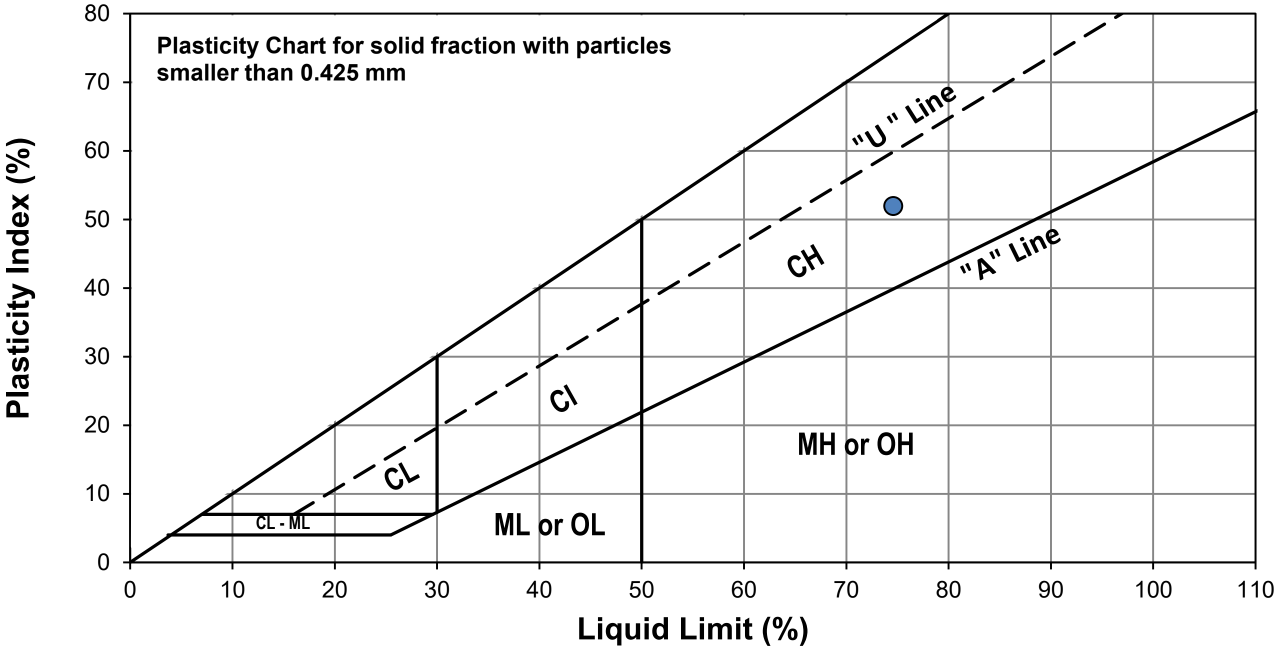
CERTIFIED BY CCIL Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

Project No.	1000-043-21
Client	WSP Canada Group LTD
Project	2023 Local and Industrial Streets Package (23-RI-01) - Galt Ave
Test Hole	TH22-03
Sample #	G70
Depth (m)	1.1 - 1.2
Sample Date	15-Nov-22
Test Date	28-Nov-22
Technician	MT

Liquid Limit	75
Plastic Limit	23
Plasticity Index	52

Liquid Limit

Trial #	**1**	**2**	**3**		
Number of Blows (N)	16	20	34		
Mass Tare (g)	14.127	14.081	13.982		
Mass Wet Soil + Tare (g)	23.455	24.523	24.901		
Mass Dry Soil + Tare (g)	19.314	20.003	20.348		
Mass Water (g)	4.141	4.520	4.553		
Mass Dry Soil (g)	5.187	5.922	6.366		
Moisture Content (%)	79.834	76.326	71.521		



Plastic Limit

Trial #	**1**	**2**	**3**	**4**	**5**
Mass Tare (g)	14.103	14.119			
Mass Wet Soil + Tare (g)	22.980	24.572			
Mass Dry Soil + Tare (g)	21.328	22.652			
Mass Water (g)	1.652	1.920			
Mass Dry Soil (g)	7.225	8.533			
Moisture Content (%)	22.865	22.501			

Note: Additional information recorded/measured for this test is available upon request.

TREK GEOTECHNICAL
www.trekgeotechnical.ca
1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

Grain Size Analysis (Hydrometer Method)
AASHTO T 88

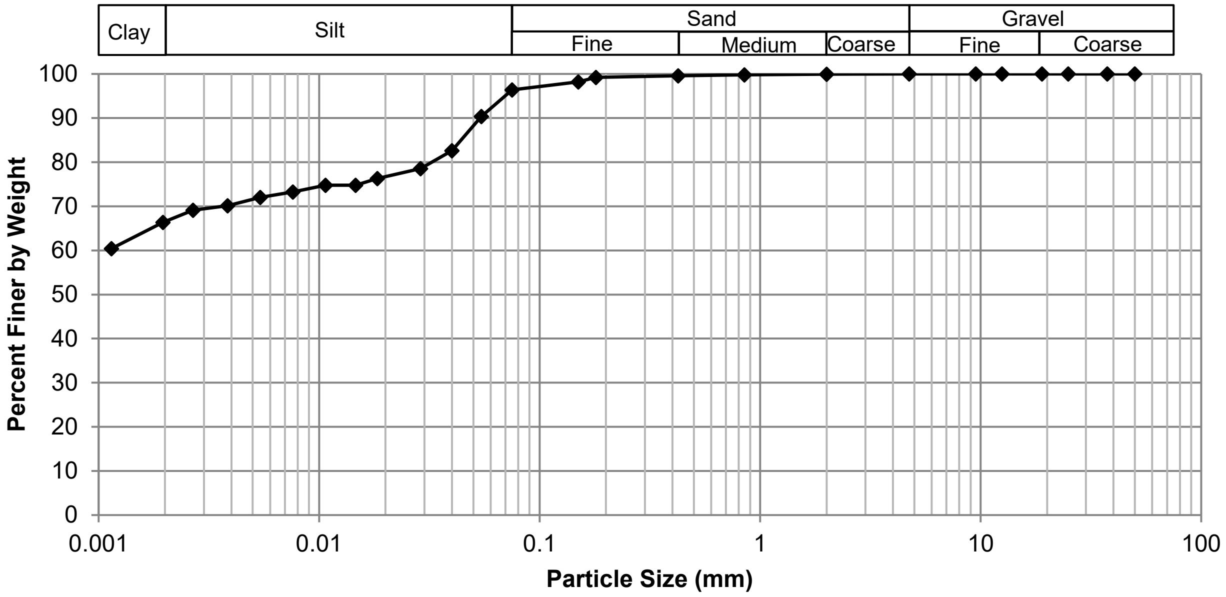
CERTIFIED BY CCIL
Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

Project No. 1000-043-21
Client WSP Canada Group LTD
Project 2023 Local and Industrial Streets Package (23-RI-01) - Galt Ave

Test Hole TH22-03
Sample # G70
Depth (m) 1.1 - 1.2
Sample Date 14-Nov-22
Test Date 29-Nov-22
Technician TG

Gravel	0.0%
Sand	3.6%
Silt	29.9%
Clay	66.5%

Particle Size Distribution Curve



Gravel		Sand		Silt and Clay	
Particle Size (mm)	**Percent Passing**	**Particle Size (mm)**	**Percent Passing**	**Particle Size (mm)**	**Percent Passing**
50.0	100.00	4.75	100.00	0.0750	96.37
37.5	100.00	2.00	99.96	0.0545	90.39
25.0	100.00	0.850	99.83	0.0400	82.58
19.0	100.00	0.425	99.57	0.0288	78.51
12.5	100.00	0.180	99.20	0.0184	76.33
9.50	100.00	0.150	98.21	0.0146	74.76
4.75	100.00	0.075	96.37	0.0107	74.76
				0.0076	73.24
				0.0054	71.99
				0.0038	70.12
				0.0027	69.14
				0.0020	66.33
				0.0011	60.42

TREK GEOTECHNICAL
www.trekgeotechnical.ca
1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

Standard Proctor Compaction Test

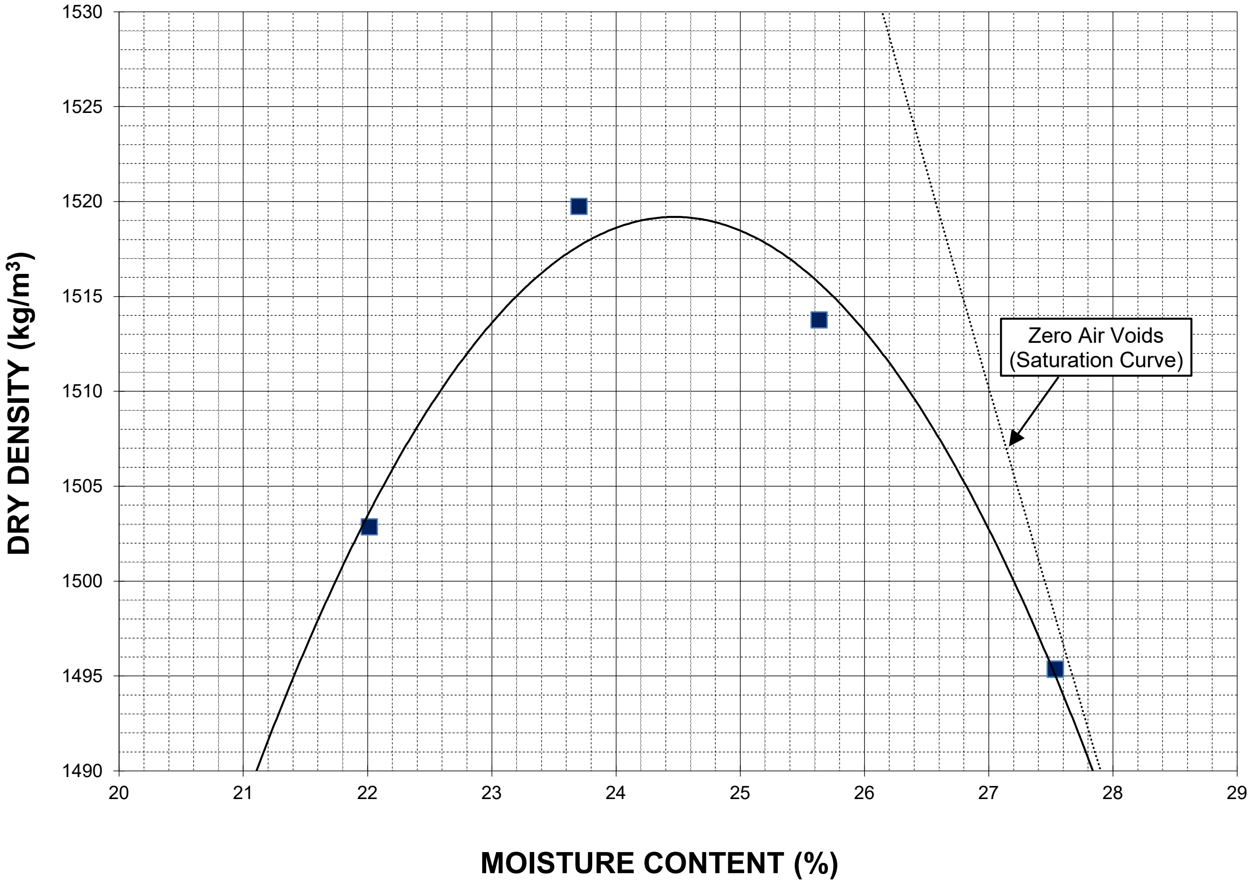
ASTM D698-12 (2021)

CERTIFIED BY CCIL
Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

Project No.	1000-043-21
Client	WSP Canada Group LTD
Project	2023 Local and Industrial Streets Package (23-RI-01)
Sample #	TH22-03
Source	Galt Ave.
Material	Clay
Sample Date	15-Nov-22
Test Date	24-Nov-22
Technician	DS

Maximum Dry Density (kg/m3)	1519
Optimum Moisture (%)	24.5

Trial Number	1	2	3	4	
Wet Density (kg/m^3)	1834	1880	1902	1907	
Dry Density (kg/m^3)	1503	1520	1514	1495	
Moisture Content (%)	22.0	23.7	25.6	27.5	



Note: Additional information recorded/measured for this test is available upon request.

TREK GEOTECHNICAL
www.trekgeotechnical.ca
1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

California Bearing Ratio Test Data Sheet

ASTM D1883-16

Project No.	1000-043-21	**Source**	Galt Ave.
Client	WSP Canada Group Ltd.	**Material**	Clay
Project	2023 Local Streets Package (23-RI-01)	**Sample Date**	2022-11-15
Sample #	TH22-03	**Test Date**	2022-11-28
		Technician	DS

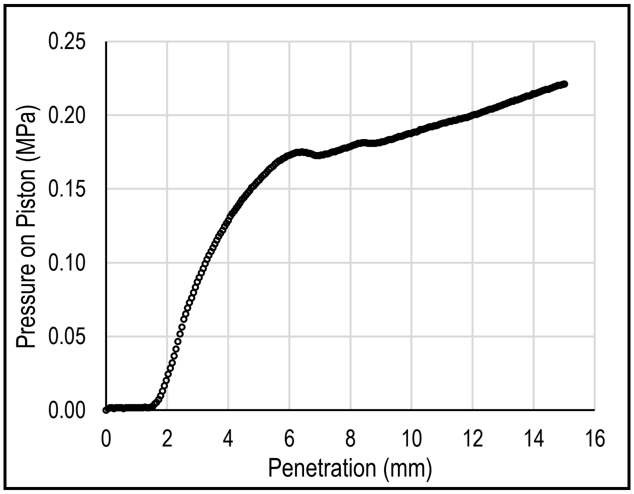
Proctor Results (ASTM D698)			**CBR Sample Compaction**		
Maximum Dry Density	1519	kg/m3	Dry Density	1445	kg/m3
Optimum Moisture Content	24.5	%	Initial Moisture Content	24.9	%
Material Retained on 19 mm Sieve	0.0	%	Relative Density	95.1	% SPMDD

Soaking Results			**CBR Results**		
Surcharge	4.54	kg	CBR at 2.54 mm	0.9	%
Swell	2.3	%	CBR at 5.08 mm	1.5	%
Moisture Content in top 25 mm	38.1	%	Zero Correction	0	mm
Immersion Period	96	h			

Test Data

Penetration (mm)	Measured Pressure (MPa)	Corrected Pressure (MPa)
0.64	0.00	0.00
1.27	0.00	0.00
1.91	0.02	0.02
2.54	0.06	0.06
3.18	0.10	0.10
3.81	0.12	0.12
4.45	0.14	0.14
5.08	0.16	0.16
7.62	0.18	0.18
10.16	0.19	0.19
12.70	0.20	0.20

Load/Penetration Curve



Comments:

Appendix C

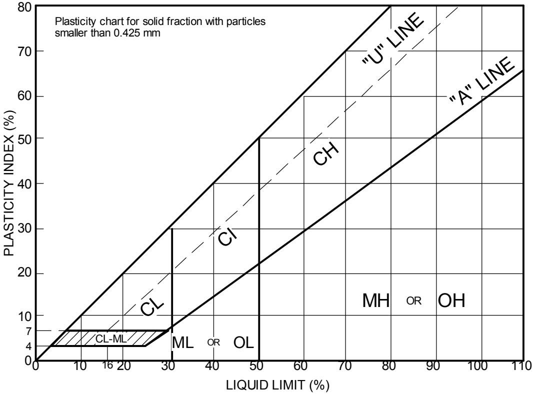
Test Hole Logs, Summary Table & Lab Testing Results and Pavement Core Photos – MacDonald Ave

TREK GEOTECHNICAL

EXPLANATION OF FIELD AND LABORATORY TESTING

GENERAL NOTES

1. Classifications are based on the United Soil Classification System and include consistency, moisture, and color. Field descriptions have been modified to reflect results of laboratory tests where deemed appropriate.
2. Descriptions on these test hole logs apply only at the specific test hole locations and at the time the test holes were drilled. Variability of soil and groundwater conditions may exist between test hole locations.
3. When the following classification terms are used in this report or test hole logs, the primary and secondary soil fractions may be visually estimated.

Major Divisions			USCS Classification	Symbols	Typical Names	Laboratory Classification Criteria		
Coarse-Grained soils (More than half the material is larger than No. 200 sieve size)	Gravels (More than half of coarse fraction is larger than 4.75 mm)	Clean gravel (Little or no fines)	GW	●	Well-graded gravels, gravel-sand mixtures, little or no fines	Determine percentages of sand and gravel from grain size curve, depending on percentage of fines (fraction smaller than No. 200 sieve) coarse-grained soils are classified as follows: Less than 5 percent...... GW, GP, SW, SP More than 12 percent...... GM, GC, SM, SC 6 to 12 percent...... Borderline case4s requiring dual symbols*	$C_U = \frac{D_{60}}{D_{10}}$ greater than 4; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			GP	○	Poorly-graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for GW	
		Gravel with fines (Appreciable amount of fines)	GM	▦	Silty gravels, gravel-sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are border-line cases requiring use of dual symbols
			GC	▧	Clayey gravels, gravel-sand-silt mixtures		Atterberg limits above "A" line or P.I. greater than 7	
	Sands (More than half of coarse fraction is smaller than 4.75 mm)	Clean sands (Little or no fines)	SW	∴	Well-graded sands, gravelly sands, little or no fines		$C_U = \frac{D_{60}}{D_{10}}$ greater than 6; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			SP	⋯	Poorly-graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM	▥	Silty sands, sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are border-line cases requiring use of dual symbols
			SC	▨	Clayey sands, sand-clay mixtures		Atterberg limits above "A" line or P.I. greater than 7	
Fine-Grained soils (More than half the material is smaller than No. 200 sieve size)	Silts and Clays (Liquid limit less than 50)		ML	▥	Inorganic silts and very fine sands, rock floor, silty or clayey fine sands or clayey silts with slight plasticity	Plasticity Chart 		
			CL	▨	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays			
			OL	☰	Organic silts and organic silty clays of low plasticity			
	Silts and Clays (Liquid limit greater than 50)		MH	▮	Inorganic silts, micaceous or distomaceous fine sandy or silty soils, organic silts			
			CH	▧	Inorganic clays of high plasticity, fat clays			
			OH	≋	Organic clays of medium to high plasticity, organic silts			
	Highly Organic Soils		Pt	⁂	Peat and other highly organic soils	Von Post Classification Limit	Strong colour or odour, and often fibrous texture	

Material		Particle Size	
		mm	ASTM Sieve sizes
Sand	Coarse	2.00 to 4.75	#10 to #4
	Medium	0.425 to 2.00	#40 to #10
	Fine	0.075 to 0.425	#200 to #40
Silt or Clay		< 0.075	< #200

Material		Particle Size	
		mm	ASTM Sieve Sizes
Boulders		> 300	> 12 in.
Cobbles		75 to 300	3 in. to 12 in.
Gravel	Coarse	19 to 75	3/4 in. to 3 in.
	Fine	4.75 to 19	#4 to 3/4 in.

* Borderline classifications used for soils possessing characteristics of two groups are designated by combinations of groups symbols. For example; GW-GC, well-graded gravel-sand mixture with clay binder.

Other Symbol Types

■	Asphalt	▧	Bedrock (undifferentiated)	○	Cobbles
⁘	Concrete	▦	Limestone Bedrock	●	Boulders and Cobbles
▩	Fill	☰	Cemented Shale	▥	Silt Till
		▤	Non-Cemented Shale	▨	Clay Till

EXPLANATION OF FIELD AND LABORATORY TESTING

LEGEND OF ABBREVIATIONS AND SYMBOLS

LL - Liquid Limit (%)
PL - Plastic Limit (%)
PI - Plasticity Index (%)
MC - Moisture Content (%)
SPT - Standard Penetration Test
RQD - Rock Quality Designation
Qu - Unconfined Compression
Su - Undrained Shear Strength
VW - Vibrating Wire Piezometer
SI - Slope Inclinometer

▽ Water Level at Time of Drilling
▼ Water Level at End of Drilling
⧨ Water Level After Drilling as Indicated on Test Hole Logs

FRACTION OF SECONDARY SOIL CONSTITUENTS ARE BASED ON THE FOLLOWING TERMINOLOGY

TERM	EXAMPLES	PERCENTAGE
and	and CLAY	35 to 50 percent
"y" or "ey"	clayey, silty	20 to 35 percent
some	some silt	10 to 20 percent
trace	trace gravel	1 to 10 percent

TERMS DESCRIBING CONSISTENCY OR COMPACTION CONDITION

The Standard Penetration Test blow count (N) of a non-cohesive soil can be related to compactness condition as follows:

Descriptive Terms	SPT (N) (Blows/300 mm)
Very loose	< 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	> 50

The Standard Penetration Test blow count (N) of a cohesive soil can be related to its consistency as follows:

Descriptive Terms	SPT (N) (Blows/300 mm)
Very soft	< 2
Soft	2 to 4
Firm	4 to 8
Stiff	8 to 15
Very stiff	15 to 30
Hard	> 30

The undrained shear strength (Su) of a cohesive soil can be related to its consistency as follows:

Descriptive Terms	Undrained Shear Strength (kPa)
Very soft	< 12
Soft	12 to 25
Firm	25 to 50
Stiff	50 to 100
Very stiff	100 to 200
Hard	> 200

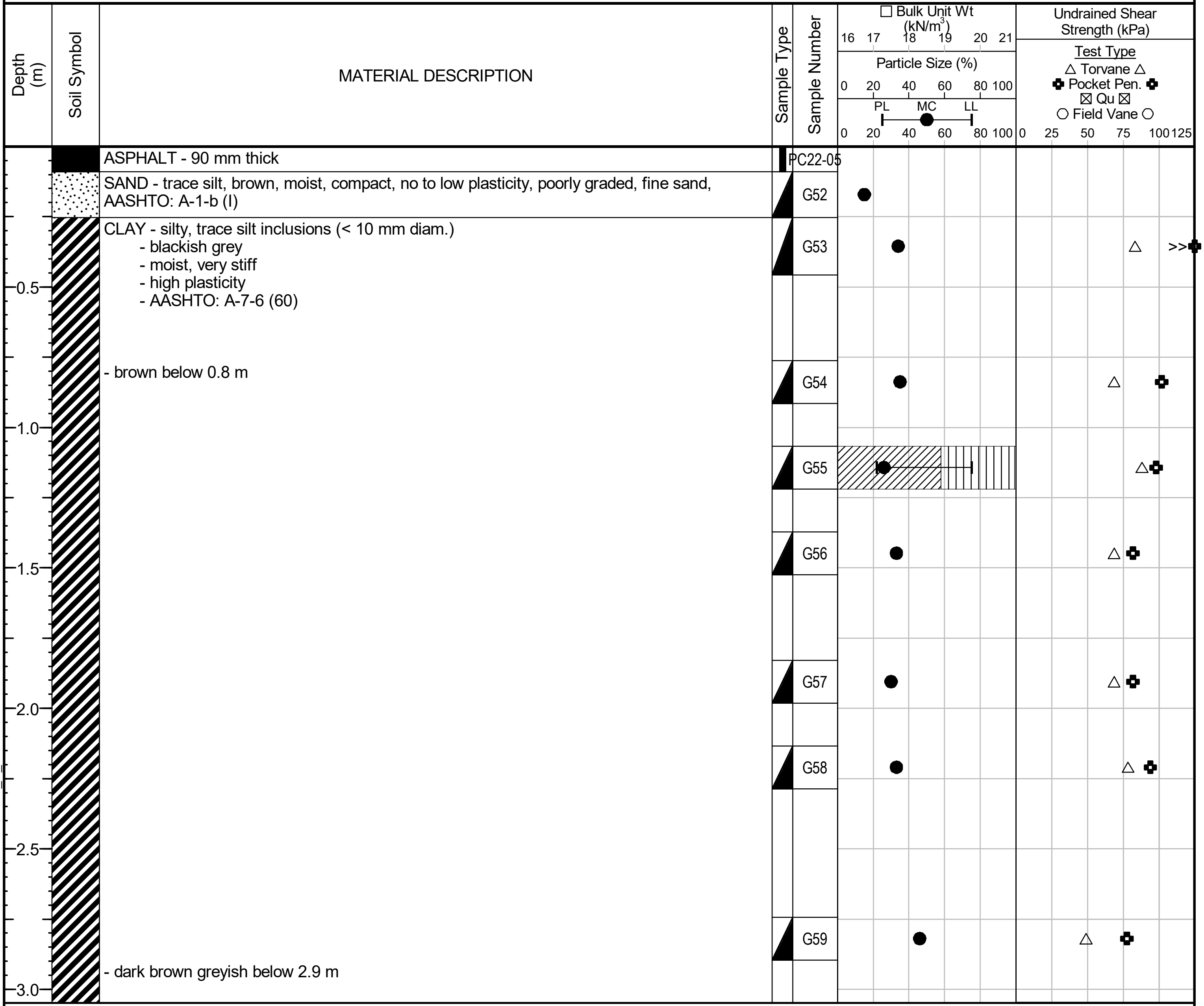
Sub-Surface Log

Test Hole TH22-05 (MacDonald Ave)

Client: WSP Canada Group Ltd.
Project Name: 2023 Local and Industrial Streets Renewal Package (23-RI-01)
Contractor: Maple Leaf Drilling Ltd.
Method: 125mm Solid Stem Auger, B40 Mobile Truck Mount
Project Number: 1000-043-21
Location: UTM N-5529488, E-634558
Ground Elevation: Top of Pavement
Date Drilled: November 15, 2022

Sample Type: ◩ Grab (G) ◨ Shelby Tube (T) ☒ Split Spoon (SS) / SPT ☒ Split Barrel (SB) / LPT ◨ Core (C)

Particle Size Legend: ▦ Fines ▨ Clay ▥ Silt ⛆ Sand ● Gravel ○ Cobbles ■ Boulders



ASPHALT - 90 mm thick

SAND - trace silt, brown, moist, compact, no to low plasticity, poorly graded, fine sand, AASHTO: A-1-b (I)

CLAY - silty, trace silt inclusions (< 10 mm diam.)
- blackish grey
- moist, very stiff
- high plasticity
- AASHTO: A-7-6 (60)

- brown below 0.8 m

- dark brown greyish below 2.9 m

END OF TEST HOLE AT 3.2 m IN CLAY.
1) Seepage or sloughing not observed.
2) Test hole open to 3.2 m depth immediately after drilling.
3) Test hole backfilled with auger cuttings, bentonite chips and cold patch asphalt.
4) Test hole located in front of #15 MacDonald Ave, 4.6 m North of South curb.
5) The bulk sample was collected between 0.3 m and 3.2 m depth.

Logged By: Jashandeep Singh Bhullar **Reviewed By:** Angela Fidler-Kliewer **Project Engineer:** Nelson Ferreira

TREK GEOTECHNICAL

Test Hole TH22-06 (MacDonald Ave)

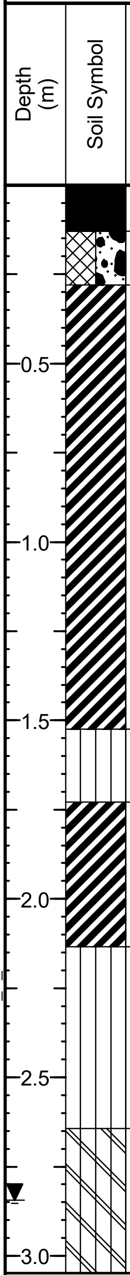
Sub-Surface Log

1 of 1

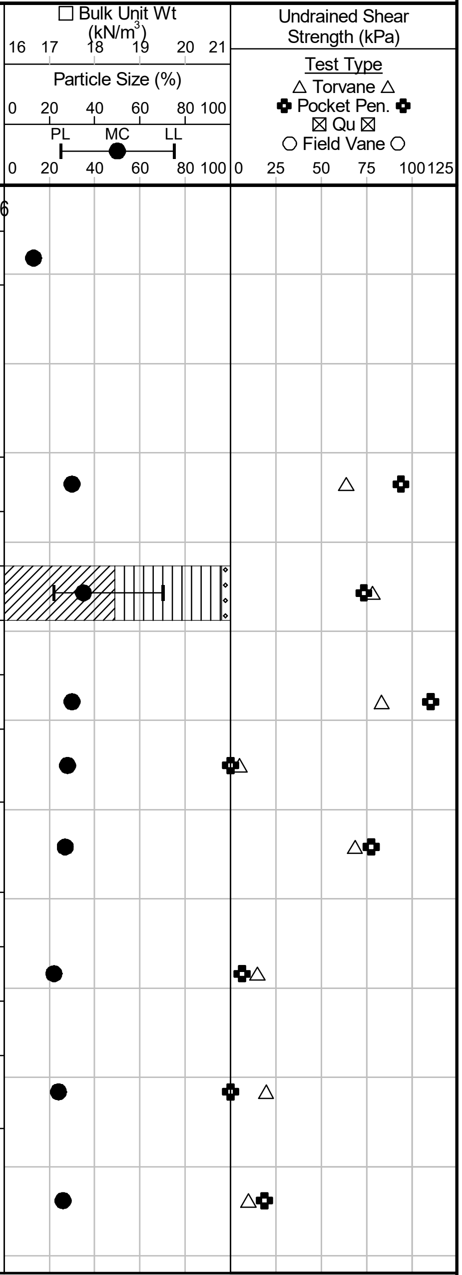
Client:	WSP Canada Group Ltd.	**Project Number:**	1000-043-21
Project Name:	2023 Local and Industrial Streets Renewal Package (23-RI-01)	**Location:**	UTM N-5529488, E-634582
Contractor:	Maple Leaf Drilling Ltd.	**Ground Elevation:**	Top of Pavement
Method:	125mm Solid Stem Auger, B40 Mobile Truck Mount	**Date Drilled:**	November 15, 2022

Sample Type: Grab (G) Shelby Tube (T) ☒ Split Spoon (SS) / SPT Split Barrel (SB) / LPT Core (C)

Particle Size Legend: Fines Clay Silt Sand Gravel Cobbles Boulders



MATERIAL DESCRIPTION	Sample Type	Sample Number
ASPHALT - 130 mm thick		PC22-06
SAND AND GRAVEL (FILL) - trace clay, some silt, 50 mm dowm crushed limestone - brown, moist, compact, no to low plasticity, angular, AASHTO: A-1-b (I)	G	G43
CLAY - silty, trace silt inclusions (< 20 mm diam.) - brown - moist, stiff - high plasticity - AASHTO: A-7-6 (52)	G	G44 G45 G46
SILT - clayey - light brown, moist, soft - low plasticity, AASHTO: A-4 (I)	G	G47
CLAY - silty, trace silt inclusions (< 10 mm diam.) - black - moist, stiff - high plasticity - AASHTO: A-7-6 (I)	G	G48
SILT - clayey - brown, moist, soft - low plasticity - AASHTO: A-4 (I)	G	G49 G50
SILT AND CLAY - trace sand - brown - moist, soft to firm - intermediate plasticity - AASHTO: A-6 (I)	G	G51



END OF TEST HOLE AT 3.2 m IN SILT AND CLAY.
1) Seepage observed below 2.1 m depth.
2) Sloughing not observed.
3) Test hole open to 3.2 m depth and water level at 2.8 m depth immediately after drilling.
4) Test hole backfilled with auger cuttings, bentonite chips and cold patch asphalt.
5) Test hole located in front of south face of #11 MacDonald Ave, 1.8 m South of North curb.
6) The bulk sample was collected between 0.2 to 1.5 m and 1.7 to 2.1 m depth.

Logged By: Jashandeep Singh Bhullar **Reviewed By:** Angela Fidler-Kliewer **Project Engineer:** Nelson Ferreira

SUB-SURFACE LOG LOGS 2022-12-09 MACDONALD AVE 23-R-01 0_D_JSB 1000 043 21.GPJ TREK.GDT 12/9/22

TREK GEOTECHNICAL

2023 Local and Industrial Streets Renewal Project - 23-RI-01
Sub-Surface Investigation
MacDonald Ave - Waterfront Dr / Gomez St

Test Hole No.	Test Hole Location	Pavement Surface		Pavement Structure Material		Subgrade Description	Sample Depth (m)		Moisture Content (%)	Grain Size Analysis				Atterberg Limits		
		Type	Thickness (mm)	Type	Thickness (mm)		Top (m)	Bottom (m)		Clay (%)	Silt (%)	Sand (%)	Gravel (%)	Plastic	Liquid	Plasticity Index
TH22-05	UTM: 14U 5529488 N 634558 E Located in front of #15 MacDonald Ave, 4.6 m North of South curb.	Asphalt	90	Concrete	-	Sand; AASHTO: A-1-b (I)	0.1	0.3	15							
						Clay; AASHTO: A-7-6 (60)	0.3	0.5	34							
						Clay; AASHTO: A-7-6 (60)	0.8	0.9	35							
						Clay; AASHTO: A-7-6 (60)	1.1	1.2	26	58	41	1	0	22	75	53
						Clay; AASHTO: A-7-6 (60)	1.4	1.5	33							
						Clay; AASHTO: A-7-6 (60)	1.8	2.0	30							
						Clay; AASHTO: A-7-6 (60)	2.1	2.3	33							
						Clay; AASHTO: A-7-6 (60)	2.7	2.9	46							
TH22-06	UTM: 14U 5529488 N, 634582 E Located in front of #11 MacDonald Ave, 1.8 m South of North curb.	Asphalt	130	Concrete	-	Sand And Gravel (Fill); AASHTO: A-1-b (I)	0.1	0.3	13							
						Clay; AASHTO: A-7-6 (52)	0.8	0.9	30							
						Clay; AASHTO: A-7-6 (52)	1.1	1.2	35	49	47	4	0	22	70	48
						Clay; AASHTO: A-7-6 (52)	1.4	1.5	30							
						Silt; AASHTO: A-4 (I)	1.5	1.7	28							
						Clay; AASHTO: A-7-6 (I)	1.7	2.0	27							
						Silt; AASHTO: A-4 (I)	2.1	2.3	22							
						Silt; AASHTO: A-4 (I)	2.4	2.6	24							
						Silt and Clay; AASHTO: A-6 (I)	2.6	3.0	26							

(I) - AASHTO classification was interpreted based on visual classification.

TREK GEOTECHNICAL
www.trekgeotechnical.ca
1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

Moisture Content Report
ASTM D2216-10

Project No. 1000-043-21
Client WSP Canada Group LTD
Project 2023 Local and Industrial Streets Package (23-RI-01) - MacDonald Ave

Sample Date 15-Nov-22
Test Date 22-Nov-22
Technician TG

Test Hole	TH22-05	TH22-05	TH22-05	TH22-05	TH22-05	TH22-05
Depth (m)	0.1 - 0.2	0.2 - 0.5	0.8 - 0.9	1.1 - 1.2	1.4 - 1.5	1.8 - 2.0
Sample #	G52	G53	G54	G55	G56	G57
Tare ID	N59	N06	H72	A39	W53	N111
Mass of tare	8.4	8.6	9.0	8.3	8.6	8.8
Mass wet + tare	256.4	279.4	316.9	426.1	251.7	285.4
Mass dry + tare	223.3	211.3	237.3	340.7	191.7	222.4
Mass water	33.1	68.1	79.6	85.4	60.0	63.0
Mass dry soil	214.9	202.7	228.3	332.4	183.1	213.6
Moisture %	15.4%	33.6%	34.9%	25.7%	32.8%	29.5%

Test Hole	TH22-05	TH22-05	TH22-06	TH22-06	TH22-06	TH22-06
Depth (m)	2.1 - 2.3	2.7 - 2.9	0.1 - 0.3	0.8 - 0.9	1.1 - 1.2	1.4 - 1.5
Sample #	G58	G59	G43	G44	G45	G46
Tare ID	E94	N76	F100	H4	P37	F26
Mass of tare	8.5	8.6	8.5	8.7	8.5	8.5
Mass wet + tare	337.7	253.9	479.9	269.5	440.9	307.3
Mass dry + tare	255.5	176.3	426.2	209.4	328.0	238.1
Mass water	82.2	77.6	53.7	60.1	112.9	69.2
Mass dry soil	247.0	167.7	417.7	200.7	319.5	229.6
Moisture %	33.3%	46.3%	12.9%	29.9%	35.3%	30.1%

Test Hole	TH22-06	TH22-06	TH22-06	TH22-06	TH22-06	
Depth (m)	1.5 - 1.7	1.7 - 2.0	2.1 - 2.3	2.4 - 2.7	2.7 - 3.0	
Sample #	G47	G48	G49	G50	G51	
Tare ID	C2	F108	W34	Z67	AB62	
Mass of tare	8.5	8.4	8.6	8.6	6.7	
Mass wet + tare	290.1	320.0	406.7	348.2	361.2	
Mass dry + tare	229.0	253.2	334.3	281.6	288.0	
Mass water	61.1	66.8	72.4	66.6	73.2	
Mass dry soil	220.5	244.8	325.7	273.0	281.3	
Moisture %	27.7%	27.3%	22.2%	24.4%	26.0%	

TREK GEOTECHNICAL
www.trekgeotechnical.ca
1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

Atterberg Limits
ASTM D4318-10e1

Project No. 1000-043-21
Client WSP Canada Group LTD
Project 2023 Local and Industrial Streets Package (23-RI-01) - MacDonald Ave

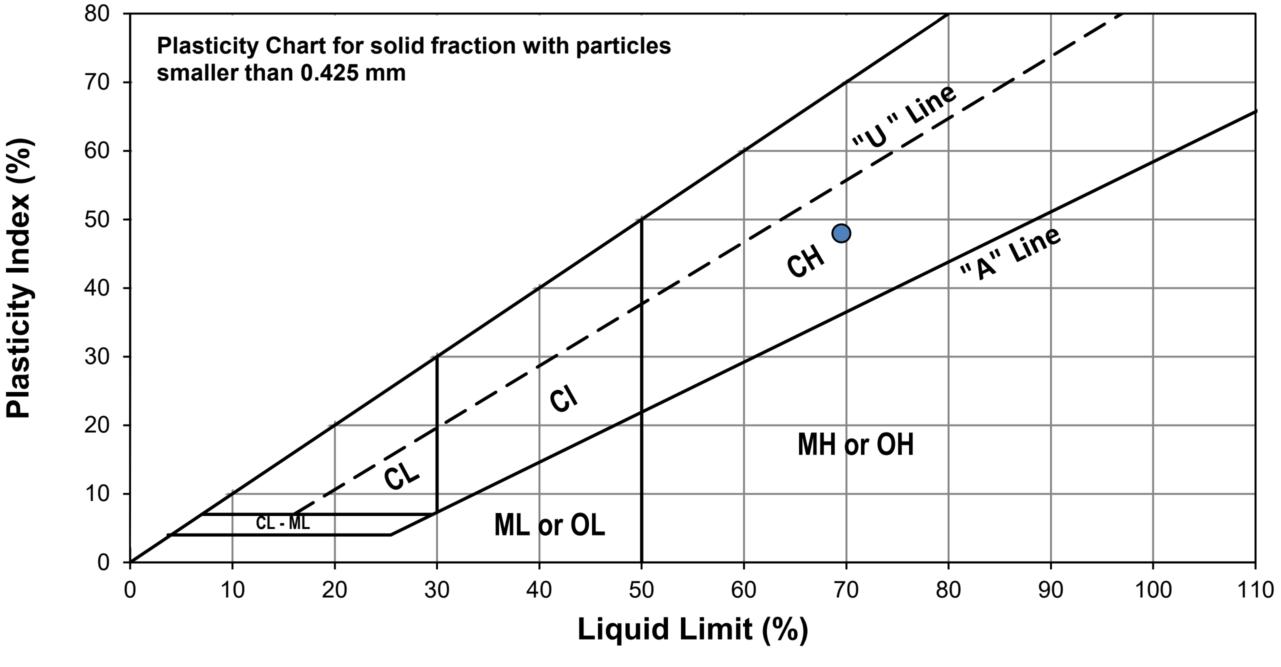
CERTIFIED BY CCIL Canadian Council of Independent Laboratories For specific tests as listed on www.ccil.com

Test Hole TH22-06
Sample # G45
Depth (m) 1.1 - 1.2
Sample Date 15-Nov-22
Test Date 29-Nov-22
Technician SL

Liquid Limit	70
Plastic Limit	22
Plasticity Index	48

Liquid Limit

Trial #	1	2	3		
Number of Blows (N)	16	28	34		
Mass Tare (g)	14.017	14.064	14.119		
Mass Wet Soil + Tare (g)	19.829	20.707	20.682		
Mass Dry Soil + Tare (g)	17.395	18.001	18.028		
Mass Water (g)	2.434	2.706	2.654		
Mass Dry Soil (g)	3.378	3.937	3.909		
Moisture Content (%)	72.054	68.733	67.895		



Plastic Limit

Trial #	1	2	3	4	5
Mass Tare (g)	14.111	14.219			
Mass Wet Soil + Tare (g)	20.272	20.784			
Mass Dry Soil + Tare (g)	19.177	19.622			
Mass Water (g)	1.095	1.162			
Mass Dry Soil (g)	5.066	5.403			
Moisture Content (%)	21.615	21.507			

Note: Additional information recorded/measured for this test is available upon request.

www.trekgeotechnical.ca
1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

Grain Size Analysis (Hydrometer Method)
AASHTO T 88

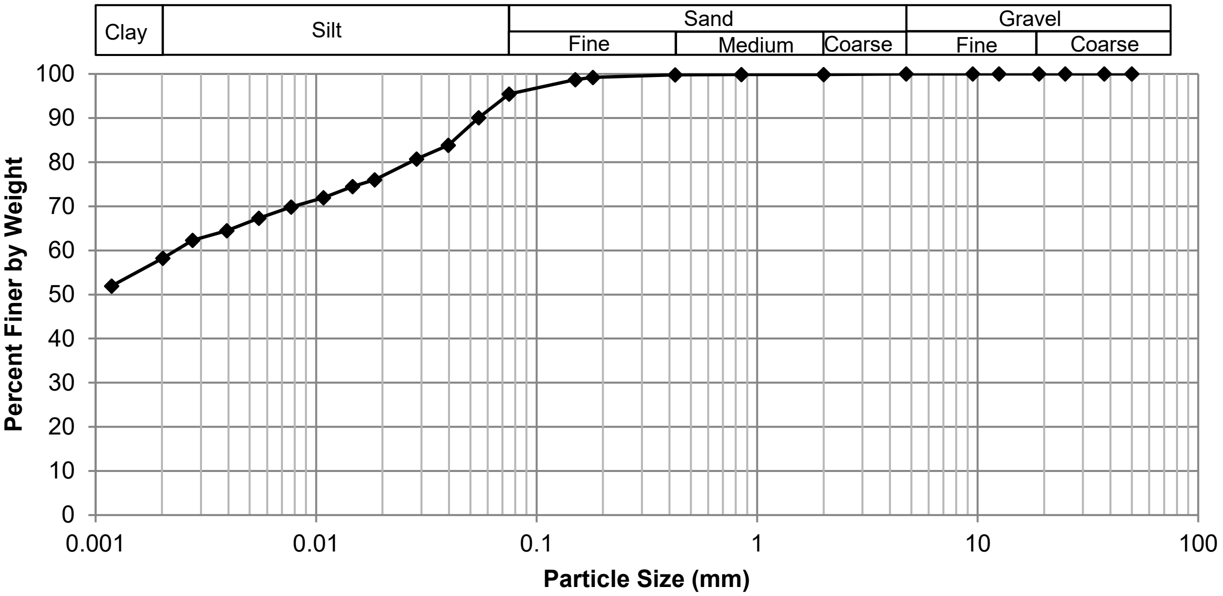
CERTIFIED BY CCIL Canadian Council of Independent Laboratories For specific tests as listed on www.ccil.com

Project No. 1000-043-21
Client WSP Canada Group LTD
Project 2023 Local and Industrial Streets Package (23-RI-01) - MacDonald Ave

Test Hole TH22-06
Sample # G45
Depth (m) 1.1 - 1.2
Sample Date 15-Nov-22
Test Date 29-Nov-22
Technician TG

Gravel	0.0%
Sand	4.5%
Silt	47.0%
Clay	48.5%

Particle Size Distribution Curve



Gravel		Sand		Silt and Clay	
Particle Size (mm)	**Percent Passing**	**Particle Size (mm)**	**Percent Passing**	**Particle Size (mm)**	**Percent Passing**
50.0	100.00	4.75	100.00	0.0750	95.45
37.5	100.00	2.00	99.90	0.0546	90.07
25.0	100.00	0.850	99.87	0.0398	83.83
19.0	100.00	0.425	99.79	0.0285	80.70
12.5	100.00	0.180	99.20	0.0184	76.02
9.50	100.00	0.150	98.72	0.0147	74.46
4.75	100.00	0.075	95.45	0.0108	71.96
				0.0077	69.81
				0.0055	67.31
				0.0039	64.50
				0.0028	62.28
				0.0020	58.22
				0.0012	51.95

Atterberg Limits
ASTM D4318-10e1

CERTIFIED BY CCIL Canadian Council of Independent Laboratories For specific tests as listed on www.ccil.com

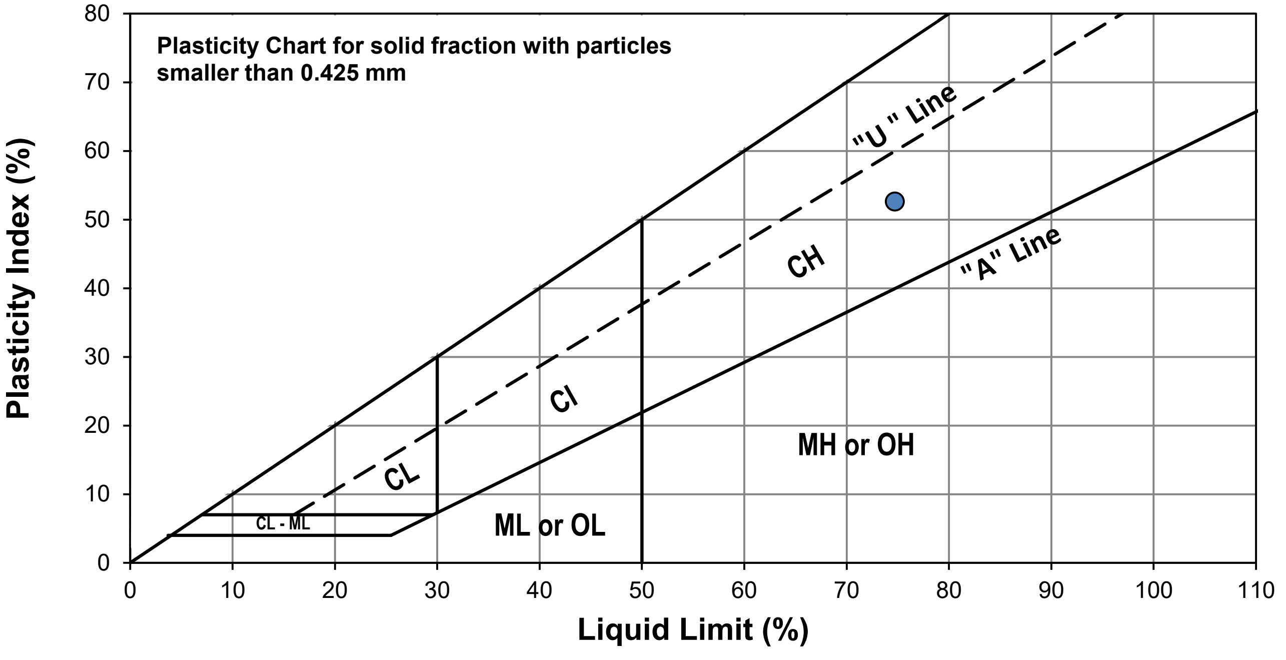
Project No. 1000-043-21
Client WSP Canada Group LTD
Project 2023 Local and Industrial Streets Package (23-RI-01) - MacDonald Ave

Test Hole TH22-05
Sample # G55
Depth (m) 1.1 - 1.2
Sample Date 15-Nov-22
Test Date 29-Nov-22
Technician MT

Liquid Limit	75
Plastic Limit	22
Plasticity Index	53

Liquid Limit

Trial #	**1**	**2**	**3**		
Number of Blows (N)	22	28	33		
Mass Tare (g)	13.975	13.927	14.033		
Mass Wet Soil + Tare (g)	20.903	19.915	21.208		
Mass Dry Soil + Tare (g)	17.900	17.389	18.225		
Mass Water (g)	3.003	2.526	2.983		
Mass Dry Soil (g)	3.925	3.462	4.192		
Moisture Content (%)	76.510	72.964	71.159		



Plastic Limit

Trial #	**1**	**2**	**3**	**4**	**5**
Mass Tare (g)	14.111	14.093			
Mass Wet Soil + Tare (g)	24.007	24.681			
Mass Dry Soil + Tare (g)	22.222	22.760			
Mass Water (g)	1.785	1.921			
Mass Dry Soil (g)	8.111	8.667			
Moisture Content (%)	22.007	22.165			

Note: Additional information recorded/measured for this test is available upon request.

TREK GEOTECHNICAL
www.trekgeotechnical.ca
1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

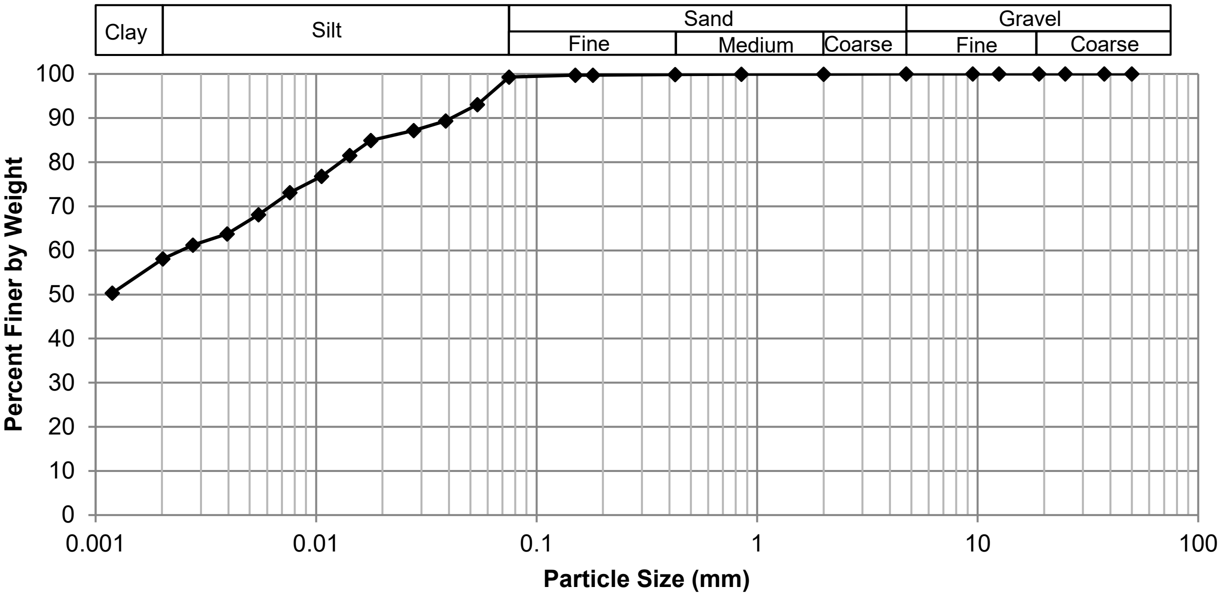
Grain Size Analysis (Hydrometer Method)
AASHTO T 88

CERTIFIED BY CCIL
Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

Project No.	1000-043-21
Client	WSP Canada Group LTD
Project	2023 Local and Industrial Streets Package (23-RI-01) - MacDonald Ave
Test Hole	TH22-05
Sample #	G55
Depth (m)	1.1 - 1.2
Sample Date	15-Nov-22
Test Date	29-Nov-22
Technician	TG

Gravel	0.0%
Sand	0.7%
Silt	41.4%
Clay	57.9%

Particle Size Distribution Curve



Gravel		Sand		Silt and Clay	
Particle Size (mm)	**Percent Passing**	**Particle Size (mm)**	**Percent Passing**	**Particle Size (mm)**	**Percent Passing**
50.0	100.00	4.75	100.00	0.0750	99.32
37.5	100.00	2.00	99.97	0.0538	93.08
25.0	100.00	0.850	99.95	0.0388	89.33
19.0	100.00	0.425	99.89	0.0277	87.14
12.5	100.00	0.180	99.76	0.0177	84.96
9.50	100.00	0.150	99.73	0.0142	81.52
4.75	100.00	0.075	99.32	0.0106	76.83
				0.0076	73.13
				0.0055	68.13
				0.0039	63.75
				0.0028	61.20
				0.0020	58.07
				0.0012	50.31

TREK GEOTECHNICAL
www.trekgeotechnical.ca
1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

Standard Proctor Compaction Test

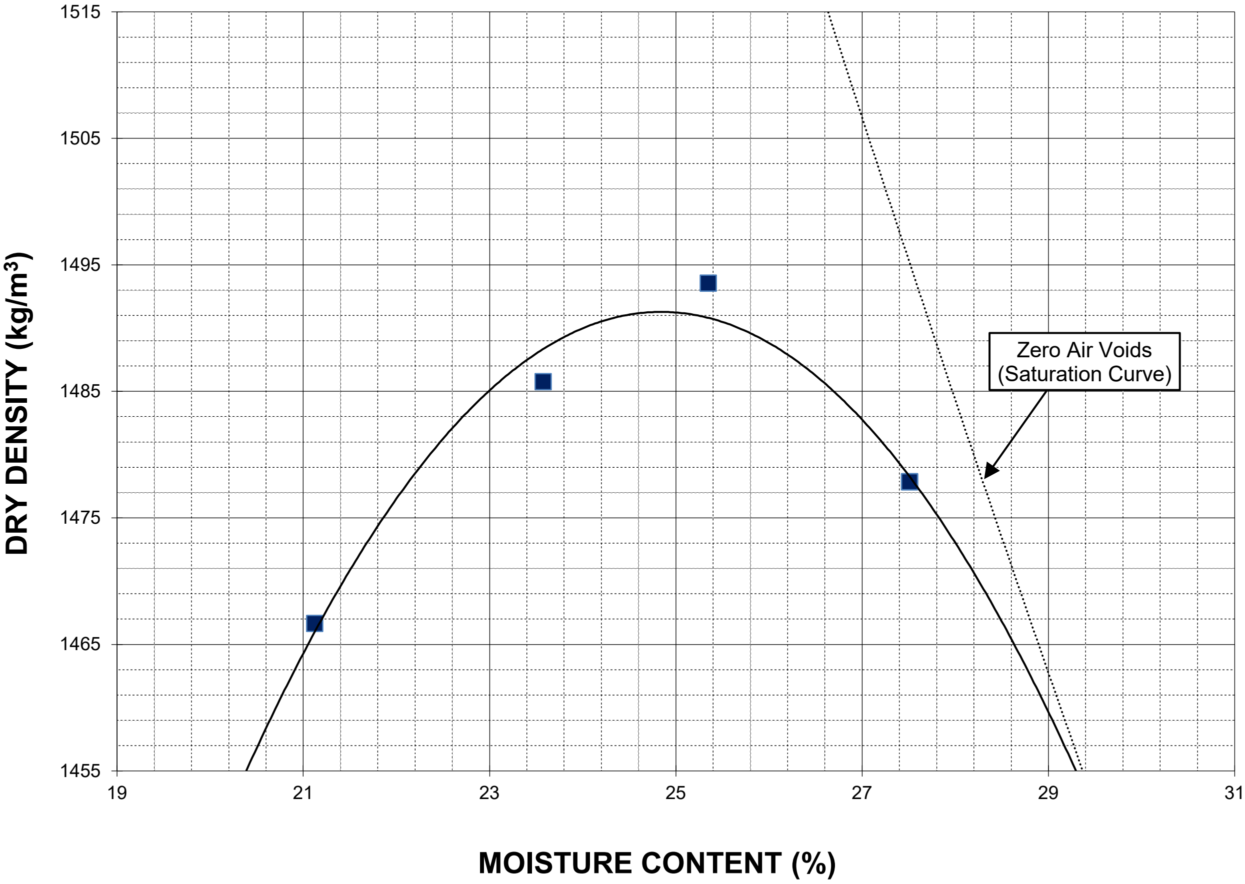
ASTM D698-12 (2021)

CERTIFIED BY CCIL Canadian Council of Independent Laboratories For specific tests as listed on www.ccil.com

Project No.	1000-043-21
Client	WSP Canada Group LTD
Project	2023 Local and Industrial Streets Package (23-RI-01)
Sample #	TH22-05
Source	MacDonald Ave.
Material	Clay
Sample Date	15-Nov-22
Test Date	24-Nov-22
Technician	DS

Maximum Dry Density (kg/m3)	1491
Optimum Moisture (%)	24.8

Trial Number	1	2	3	4	
Wet Density (kg/m^3)	1776	1836	1872	1884	
Dry Density (kg/m^3)	1467	1486	1494	1478	
Moisture Content (%)	21.1	23.6	25.3	27.5	



Note: Additional information recorded/measured for this test is available upon request.

Appendix D

Summary Table and Pavement Core Photos – Alexander Ave

TREK GEOTECHNICAL

2023 Local and Industrial Streets Renewal Package - 23-RI-01

Alexander Ave - Marth St / Lily St

Pavement Core No.	Pavement Core Location	Pavement Surface		Pavement Structure Material		
		Type	Thickness (mm)	Type	Thickness (mm)	Corrected Compressive Strength (Mpa)
PC22-07	UTM : 5529314 m N, 633918 m E; Located in front of north entrance of #145 Pacific Ave, 1.5 m South of North Curb.	Asphalt	70	Concrete	220	-
PC22-08	UTM : 5529310 m N, 633909 m E; Located in front of north entrance of #145 Pacific Ave, 2.3 m North of South Curb.	Asphalt	80	Concrete	-	-
PC22-09	UTM : 5529295 m N, 633954 m E; Located in front of #155 Alexander Ave, 1.4 m South of North Curb.	Asphalt	-	Concrete	225	69.81

1712 St. James Street
Winnipeg, Manitoba R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435
www.trekgeotechnical.ca

Project 1000-043-21
Location Alexander Ave (23-RI-01)
Hole No. PC-07 Sample No. PC-07
Depth 290 mm
Technician TG/JJB Date Nov 9/22

Photo 1: Pavement Core Sample PC-07

1712 St. James Street
Winnipeg, Manitoba R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435
www.trekgeotechnical.ca

Project 1000-043-21
Location Alexander Ave (23-RI-01)
Hole No. PC-08 Sample No. PC-08
Depth 80 mm
Technician TG/JJB Date Nov 9/22

Photo 2: Pavement Core Sample PC-08

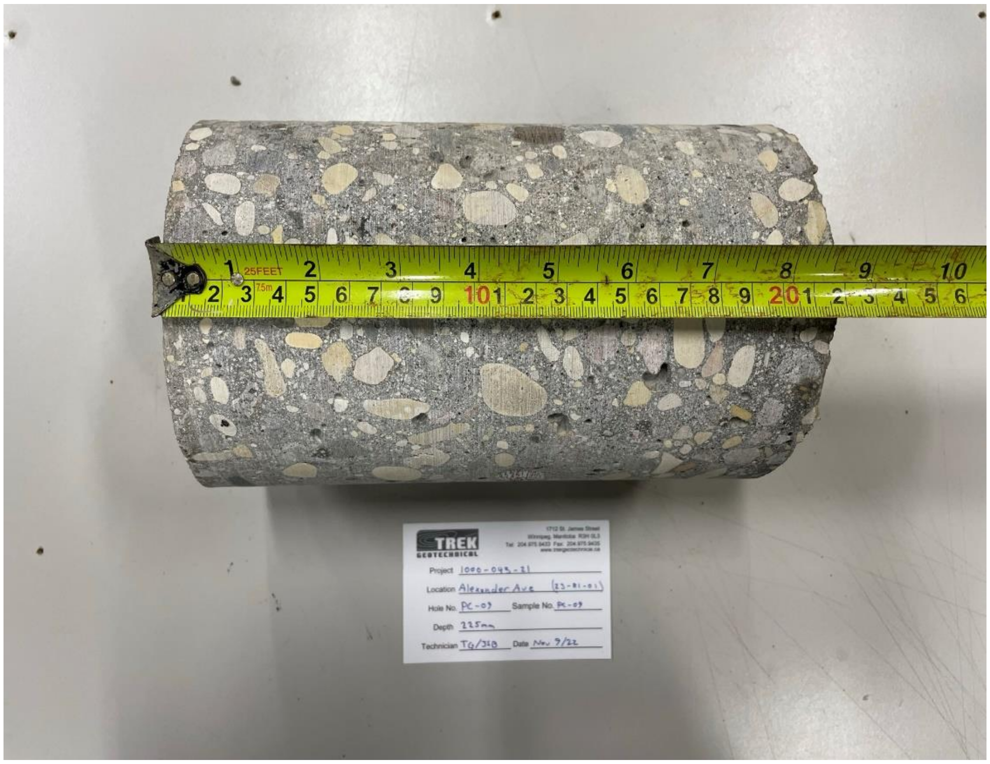


Photo 3: Pavement Core Sample PC-09

TREK GEOTECHNICAL
www.trekgeotechnical.ca
1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

Concrete Core Compressive Strength Report

CSA A23.2-14C

Project No. 1000-043-21

Project 2023 Local Streets Package - 23-R1-01

Client WSP Group Canada Inc.

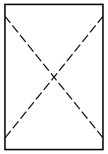
Date December 7, 2022

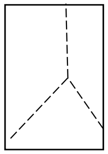
Technician KM

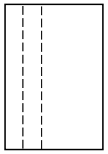
Core Location	Core ID	Date Received	Date of Break	Age at Break	Diam. (mm)	Length (mm)	Moisture Conditioning	Compressive Strength (MPa)		Break Type	Correction Factors*				
								Uncorrected f_{conc}	Corrected* f_c		$F_{l/d}$	F_{dia}	F_{mc}	F_D	F_{reinf}
Alexander Avenue	PC-09	Nov.9th/22	2022-12-07	-	146	220	Soaked 48 h	55.32	69.81	1	0.9773	0.9801	1.0900	1.0600	1.1403

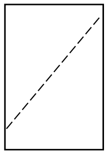
Comments

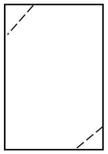
*Correction factors $F_{l/d}$, F_{dia}, F_{mc}, and F_D calculated as per ACI 214.4R-03, and correction factor F_{reinf} calculated as per Khoury et al. (2014): $f_c = f_{conc}F_{l/d}F_{dia}F_{mc}F_DF_{reinf}$

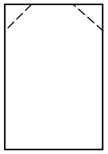

Type 1


Type 2


Type 3


Type 4


Type 5


Type 6

Reviewed by (print): Angela Fidler-Kliewer, C.Tech.

Signature: Angela Fidler-Kliewer

Table 1 Factors involved in interpretation of core results by different codes.

List	Code/standard	Edition	Factors Considered					
			Aspect ratio	Diameter	Reinforcing	Moisture	Damage	Direction
1	Egyptian Code/Standard Specification	2008	✓		✓			✓
2	British Code/Standard Specification	2003	✓		✓			✓
3	American Concrete Institute ACI	1998	✓					
		2012	✓	✓		✓	✓	
4	European Standard Specification	1998	✓	✓	✓		✓	
		2009	✓		✓			
5	Japanese Standard	1998	✓					
6	Concrete Society	1987	✓		✓		✓	✓

In addition, for core specimen containing two bars no further apart than the diameter of the larger bar, only the bar corresponding to the higher value of ($\Phi_r * d$) is considered. If the bars are further apart, their combined effect should be assessed by replacing the term ($\Phi_r * d$) by the term ($\sum \Phi_r * d$).

It should be pointed out that above equations used to interpret the core concrete strength to the in-situ concrete cube strength have been developed based on a set of assumptions and through many converting process. It is also of interest to note that the damage effect is considered in the development of the formulas in indirect way. The subject derivation and detailed formulas may be seen elsewhere [14].

3.2. American Concrete Institute (ACI)

3.2.1. Former ACI Code (2002) & Current ASTM (2009)

The methodology of core interpretation given in the former ACI code was remained without changes for decades and up to Year (2003). The in-place strength of concrete cylinder at the location from which a core test specimen was extracted can be computed using the equation:

$$f_{cy} = F_{l/d} \cdot f_{core} \qquad (4)$$

where f_{cy} is the equivalent in-place concrete cylinder strength, f_{core} is concrete core strength, and $F_{l/d}$ is the strength correction factor for aspect ratio.

The former ACI code does not include any equation to calculate the correction factor ($F_{l/d}$); however, the code gives different values for this term that is associated with different aspect ratios (l/d) as given in Table 2. It should also be noted that the approach of current ASTM is similar to that mentioned above. The only considered variable is the aspect ratio (l/d). It should be noted that identical approach to that mentioned above is still effective in ASTM C42/C42M-03 [10].

3.2.2. Current ACI Code (2012) [15]

Starting from Year 2003, significant changes have been made to the relevant ACI Code provisions regarding the interpretation of core strength test results. New factors have been considered. These include core diameter, moisture content of core sample, core damage associated with drilling, in addition to the effect of aspect ratio that was previously considered in the former ACI edition (1998). According to the ACI 214.4R-03, the in-place concrete strength can be computed using the equation:

← eq. 12

$$f_c = F_{l/d} \cdot F_{dia} \cdot F_{mc} \cdot F_D \cdot f_{core} \cdot F_{reinf} \qquad (5)$$

or eq. 15

where f_c is the equivalent in-place concrete cylinder strength, f_{core} is concrete core strength, $F_{l/d}$ is strength correction factor for aspect ratio, F_{dia} is strength correction factors for diameter, F_{mc} is strength correction factor for moisture condition of core sample, and F_D is the strength correction factor that accounts for effect of damage sustained during core drilling including micro-cracking and undulations at the drilled surface and cutting through coarse-aggregate particles that may subsequently pop out during testing.

The ACI committee considered the correction factors presented in Table 3 for converting core strengths into equivalent in-place strengths based on the work reported by Bartlett and MacGregor [6]. It should be noted that the magnitude of

Table 2 Mean values for factor $F_{l/d}$ according to ACI Code (1998) and ASTM.

	Specimen length-to-diameter ratio, l/d			
	1.00	1.25	1.50	1.75
$F_{l/d}$	0.87	0.93	0.96	0.98

Table 3 Strength correction factors according to ACI 214.4R-03.

List	Factors	Mean values
(1)[b]	$F_{l/d}$:l/d ratio	
	As-received	$1 - \{0.130 - \alpha f_{core}\}(2 - \frac{l}{d})^2$
	Soaked 48 h	$1 - \{0.117 - \alpha f_{core}\}\ (2 - \frac{l}{d})^2$
	Air dried[a]	$1 - \{0.144 - \alpha f_{core}\}(2 - \frac{l}{d})^2$
(2)	F_{dia}: core diameter	
	50 mm	1.06
	100 mm	1.00
	150 mm	0.98
(3)	F_{mc}: core moisture content	
	As-received	1.00
	Soaked 48 h	1.09
	Air dried[a]	0.96
(4)	F_D: damage due to drilling	1.06

[a] Standard treatment specified in ASTM C 42/C 42M.

[b] Constant α equals $4.3(10^{-4})$ 1/MPa for f_{core} in MPa.

Table 6 List of comparisons between tested cores to determine.

	A18	A17	A16	A15	A14	A13	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1
A1	♦●	●	♦●	■●	■●		●				●			▲	▲	■	▲	
A2																		
A3						■●				■●								
A4																		
A5																		
A6								■▲●	■▲●			■▲						
A7								■▲●	■▲●									
A8		●	♦	●	●													
A9																		
A10								■▲●										
A11																		
A12		●		●	●													
A13																		
A14		●		●														
A15		●																
A16	●♦																	
A17	♦																	
A18																		

● Diameter of steel bar.
▲ Distance of steel bar from nearly end of core.
■ Number of steel bars and spacing between bars.
♦ Distance of steel bar from vertical axis of specimen.

This brief review indicated that the various proposed relationships for correction factors are all nonlinear. It should be noted that the equations given by the Egyptian Code takes into account most variables that may affect the interpretation of the results; however, the code ignores the deterioration of steel–concrete bond that may occur and also the position of the reinforcement from vertical axis of core specimens.

Weighted nonlinear regression analysis has been performed to determine the factor (F_{reinf}) with the use of the software "SAS" package and "Data Fit." This shows that the correction factor for reinforcement (F_{reinf}) is given by the following expression:

- For cores containing a single bar:

single bar

$$F_{\mathrm{reinf}} = \left[1 + 1.5\frac{[\Phi_r \times r + \Phi_r \times (S/10)]}{\Phi_c * L}\right] \times \frac{1.13}{f_{\mathrm{core}}^{0.015}} \quad (12)$$

- For core specimen containing two bars no further apart than the diameter of the larger bar, only the bar corresponding to the higher value of ($\Phi_r * d$) is considered. If the bars are further apart, their combined effect is assessed by replacing the term ($\Phi_r * r$) by ($\sum \Phi_r * r$ as follows:

multiple bars

$$F_{\mathrm{reinf}} = \left[1 + 1.5\frac{\sum[\Phi_r \times r + \Phi_r \times (S/10)]}{\Phi_c * L}\right] \times \frac{1.13}{f_{\mathrm{core}}^{0.015}} \quad (13)$$

where F_{reinf} is the correction factor for reinforcement, Φ_r is the diameter of the reinforcement, Φ_c is the diameter of the concrete specimen, r is the distance of axis of bar from nearer end of specimen, S is the distance of axis of bar from axis of core specimen, L is the length of the specimen after end preparation by grinding or capping, and f_{core} is the concrete core strength (kg/cm^2).

6.1.6. *Effect of moisture condition of core*

Results of about 100 cores indicate that the strength of cores left to dry in air for 7 days is on average 13% greater than that of cores soaked at least 40 h before testing. The strength of cores with negligible moisture gradient and tested after cutting is found to be 7–9% larger than that of soaked cores as shown in Fig. 20. The authors strongly recommend to use a correction factor accounting for moisture condition (F_m) equals to 1.09 and 0.96, respectively, for cores tested after 48 h soaked in water and for those tested after 7 days dry in air.

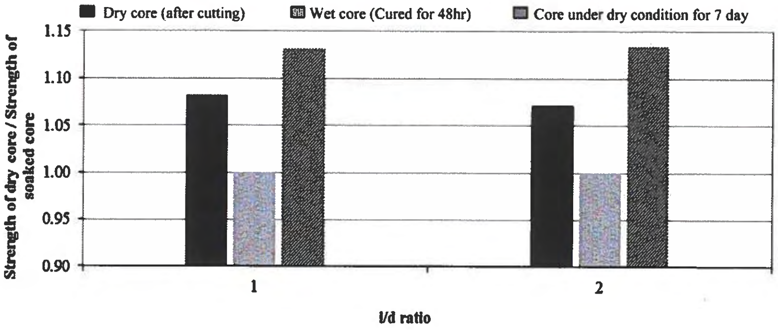


Figure 20 Effect of core moisture condition on core strength for different aspect ratios (l/d).

Appendix E

Summary Table and Pavement Core Photos – McDermot Ave

2023 Local and Industrial Streets Renewal Package - 23-RI-01

McDermot Ave - Myrtle St / McPhillips St

Pavement Core No.	Pavement Core Location	Pavement Surface		Pavement Structure Material		
		Type	Thickness (mm)	Type	Thickness (mm)	Corrected Compressive Strength (Mpa)
PC22-10	UTM : 5530064 m N, 631055 m E; Located in front of #1139 McDermot Ave, 3.8 m South of North Curb.	Asphalt	-	Concrete	220	67.6
PC22-11	UTM : 5530008 m N, 631160 m E; Located in front of #1-1090 McDermot Ave, 2.9 m North of South Curb.	Asphalt	-	Concrete	250	-
PC22-12	UTM : 5529968 m N, 631260 m E; Located in front of South wall of #100 McPhillips St, 3.0 m South of North edge of road.	Asphalt	-	Concrete	225	-

1712 St. James Street
Winnipeg, Manitoba R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435
www.trekgeotechnical.ca

Project 1000-043-21
Location McDermot Ave (23-RI-01)
Hole No. PC-10 Sample No. PC-10
Depth 210mm
Technician TG Date Nov 14/22

Photo 1: Pavement Core Sample PC-10

1712 St. James Street
Winnipeg, Manitoba R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435
www.trekgeotechnical.ca

Project 1000-043-21
Location McDermot Ave (23-RI-01)
Hole No. PC-11 Sample No. PC-11
Depth 250mm
Technician TG Date Nov. 14/22

Photo 2: Pavement Core Sample PC-11

Project 1000-043-21
Location McDermot Ave (23-RI-01)
Hole No. PC-12 Sample No. PC-12
Depth 250mm
Technician TG Date Nov14/22

Photo 3: Pavement Core Sample PC-12

www.trekgeotechnical.ca
1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

Concrete Core Compressive Strength Report

CSA A23.2-14C

Project No. 1000-043-21

Project 2023 Local Streets Package - 23-R1-01

Client WSP Group Canada Inc.

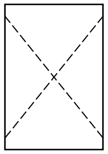
Date December 7, 2022

Technician KM

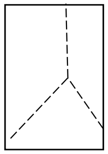
Core Location	Core ID	Date Received	Date of Break	Age at Break	Diam. (mm)	Length (mm)	Moisture Conditioning	Compressive Strength (MPa)		Break Type	Correction Factors*				
								Uncorrected f_{conc}	Corrected* f_c		$F_{l/d}$	F_{dia}	F_{mc}	F_D	F_{reinf}
McDermot Avenue	PC-10	2022-11-14	2022-12-07	-	146	204	Soaked 48 h	61.72	67.60	1	0.9671	0.9801	1.0900	1.0600	1.0000

Comments

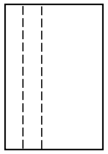
*Correction factors $F_{l/d}$, F_{dia}, F_{mc}, and F_D calculated as per ACI 214.4R-03, and correction factor F_{reinf} calculated as per Khoury et al. (2014): $f_c = f_{conc}F_{l/d}F_{dia}F_{mc}F_DF_{reinf}$



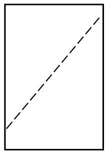
Type 1



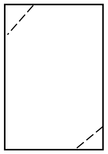
Type 2



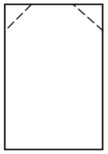
Type 3



Type 4



Type 5



Type 6

Reviewed by (print): Angela Fidler-Kliewer,C.Tech.

Signature: Angela Fidler-Kliewer

Table 1 Factors involved in interpretation of core results by different codes.

List	Code/standard	Edition	Factors Considered					
			Aspect ratio	Diameter	Reinforcing	Moisture	Damage	Direction
1	Egyptian Code/Standard Specification	2008	√		√			√
2	British Code/Standard Specification	2003	√		√			√
3	American Concrete Institute ACI	1998	√					
		2012	√	√		√	√	
4	European Standard Specification	1998	√	√	√		√	
		2009	√		√			
5	Japanese Standard	1998	√					
6	Concrete Society	1987	√		√		√	√

In addition, for core specimen containing two bars no further apart than the diameter of the larger bar, only the bar corresponding to the higher value of ($\Phi_r * d$) is considered. If the bars are further apart, their combined effect should be assessed by replacing the term ($\Phi_r * d$) by the term ($\sum \Phi_r * d$).

It should be pointed out that above equations used to interpret the core concrete strength to the in-situ concrete cube strength have been developed based on a set of assumptions and through many converting process. It is also of interest to note that the damage effect is considered in the development of the formulas in indirect way. The subject derivation and detailed formulas may be seen elsewhere [14].

3.2. American Concrete Institute (ACI)

3.2.1. Former ACI Code (2002) & Current ASTM (2009)

The methodology of core interpretation given in the former ACI code was remained without changes for decades and up to Year (2003). The in-place strength of concrete cylinder at the location from which a core test specimen was extracted can be computed using the equation:

$$f_{cy} = F_{l/d} \cdot f_{core} \tag{4}$$

where f_{cy} is the equivalent in-place concrete cylinder strength, f_{core} is concrete core strength, and $F_{l/d}$ is the strength correction factor for aspect ratio.

The former ACI code does not include any equation to calculate the correction factor ($F_{l/d}$); however, the code gives different values for this term that is associated with different aspect ratios (l/d) as given in Table 2. It should also be noted that the approach of current ASTM is similar to that mentioned above. The only considered variable is the aspect ratio (l/d). It should be noted that identical approach to that mentioned above is still effective in ASTM C42/C42M-03 [10].

3.2.2. Current ACI Code (2012) [15]

Starting from Year 2003, significant changes have been made to the relevant ACI Code provisions regarding the interpretation of core strength test results. New factors have been considered. These include core diameter, moisture content of core sample, core damage associated with drilling, in addition to the effect of aspect ratio that was previously considered in the former ACI edition (1998). According to the ACI 214.4R-03, the in-place concrete strength can be computed using the equation:

eq. 12

$$f_c = F_{l/d} \cdot F_{dia} \cdot F_{mc} \cdot F_D \cdot f_{core} \cdot F_{reinf} \tag{5}$$

or eq. 15

where f_c is the equivalent in-place concrete cylinder strength, f_{core} is concrete core strength, $F_{l/d}$ is strength correction factor for aspect ratio, F_{dia} is strength correction factors for diameter, F_{mc} is strength correction factor for moisture condition of core sample, and F_D is the strength correction factor that accounts for effect of damage sustained during core drilling including micro-cracking and undulations at the drilled surface and cutting through coarse-aggregate particles that may subsequently pop out during testing.

The ACI committee considered the correction factors presented in Table 3 for converting core strengths into equivalent in-place strengths based on the work reported by Bartlett and MacGregor [6]. It should be noted that the magnitude of

Table 2 Mean values for factor $F_{l/d}$ according to ACI Code (1998) and ASTM.

	Specimen length-to-diameter ratio, l/d			
	1.00	1.25	1.50	1.75
$F_{l/d}$	0.87	0.93	0.96	0.98

Table 3 Strength correction factors according to ACI 214.4R-03.

List	Factors	Mean values
(1)[b]	$F_{l/d}$:l/d ratio	
	As-received	$1 - \{0.130 - \alpha f_{core}\}(2 - \frac{l}{d})^2$
	Soaked 48 h	$1 - \{0.117 - \alpha f_{core}\}\ (2 - \frac{l}{d})^2$
	Air dried[a]	$1 - \{0.144 - \alpha f_{core}\}(2 - \frac{l}{d})^2$
(2)	F_{dia}: core diameter	
	50 mm	1.06
	100 mm	1.00
	150 mm	0.98
(3)	F_{mc}: core moisture content	
	As-received	1.00
	Soaked 48 h	1.09
	Air dried[a]	0.96
(4)	F_D: damage due to drilling	1.06

[a] Standard treatment specified in ASTM C 42/C 42M.

[b] Constant α equals $4.3(10^{-4})$ 1/MPa for f_{core} in MPa.

Table 6 List of comparisons between tested cores to determine.

	A18	A17	A16	A15	A14	A13	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1
A1	♦●	●	♦●	■●	■●		●				●			▲	▲	■	▲	
A2																		
A3						■●				■●								
A4																		
A5																		
A6								■▲●	■▲●			■▲						
A7								■▲●	■▲●									
A8		●	♦	●	●													
A9																		
A10								■▲●										
A11																		
A12		●		●	●													
A13																		
A14		●		●														
A15		●																
A16	●♦																	
A17	♦																	
A18																		

● Diameter of steel bar.
▲ Distance of steel bar from nearly end of core.
■ Number of steel bars and spacing between bars.
♦ Distance of steel bar from vertical axis of specimen.

This brief review indicated that the various proposed relationships for correction factors are all nonlinear. It should be noted that the equations given by the Egyptian Code takes into account most variables that may affect the interpretation of the results; however, the code ignores the deterioration of steel–concrete bond that may occur and also the position of the reinforcement from vertical axis of core specimens.

Weighted nonlinear regression analysis has been performed to determine the factor (F_{reinf}) with the use of the software "SAS" package and "Data Fit." This shows that the correction factor for reinforcement (F_{reinf}) is given by the following expression:

single bar

- For cores containing a single bar:

$$F_{\text{reinf}} = \left[1 + 1.5\frac{[\Phi_r \times r + \Phi_r \times (S/10)]}{\Phi_c * L}\right] \times \frac{1.13}{f_{\text{core}}^{0.015}} \quad (12)$$

- For core specimen containing two bars no further apart than the diameter of the larger bar, only the bar corresponding to the higher value of ($\Phi_r * d$) is considered. If the bars are further apart, their combined effect is assessed by replacing the term ($\Phi_r * r$) by ($\sum \Phi_r * r$ as follows:

multiple bars

$$F_{\text{reinf}} = \left[1 + 1.5\frac{\sum[\Phi_r \times r + \Phi_r \times (S/10)]}{\Phi_c * L}\right] \times \frac{1.13}{f_{\text{core}}^{0.015}} \quad (13)$$

where F_{reinf} is the correction factor for reinforcement, Φ_r is the diameter of the reinforcement, Φ_c is the diameter of the concrete specimen, r is the distance of axis of bar from nearer end of specimen, S is the distance of axis of bar from axis of core specimen, L is the length of the specimen after end preparation by grinding or capping, and f_{core} is the concrete core strength (kg/cm^2).

6.1.6. *Effect of moisture condition of core*

Results of about 100 cores indicate that the strength of cores left to dry in air for 7 days is on average 13% greater than that of cores soaked at least 40 h before testing. The strength of cores with negligible moisture gradient and tested after cutting is found to be 7–9% larger than that of soaked cores as shown in Fig. 20. The authors strongly recommend to use a correction factor accounting for moisture condition (F_m) equals to 1.09 and 0.96, respectively, for cores tested after 48 h soaked in water and for those tested after 7 days dry in air.

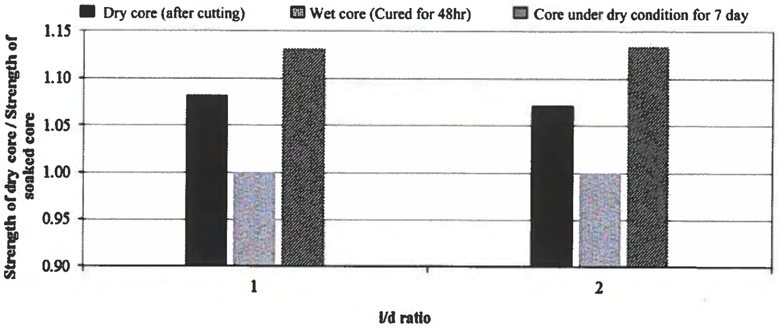


Figure 20 Effect of core moisture condition on core strength for different aspect ratios (l/d).

Appendix F

Summary Table and Pavement Core Photos – Argyle St

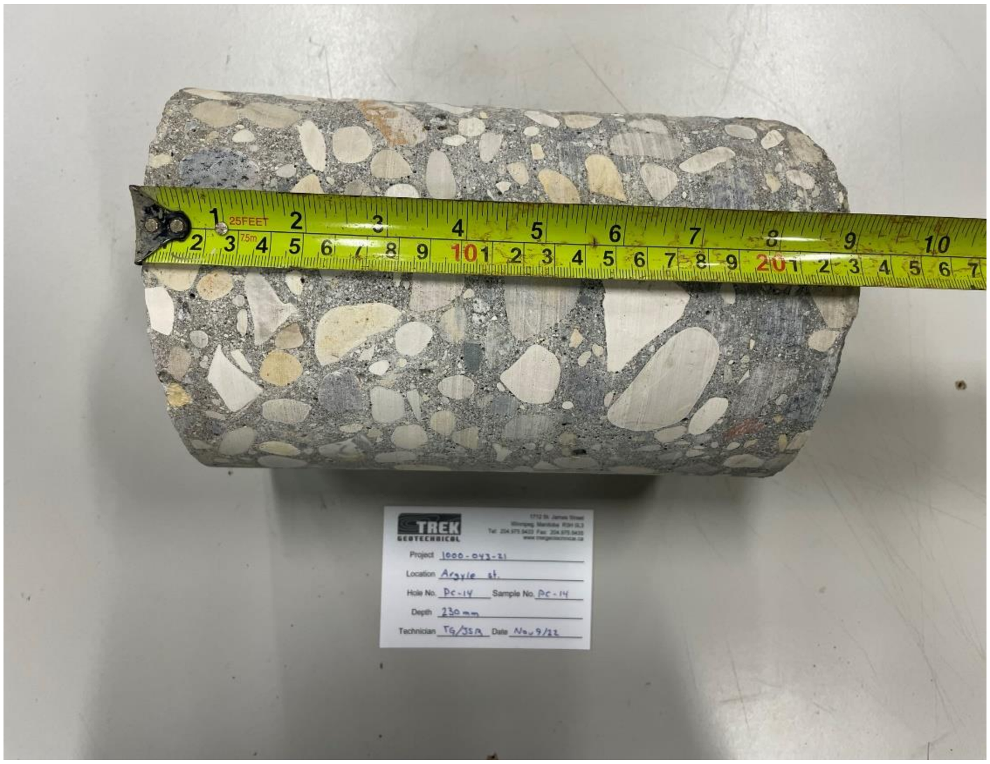
2023 Local and Industrial Streets Renewal Package - 23-RI-01

Argyle St - George Av / Disraeli Fr

Pavement Core No.	Pavement Core Location	Pavement Surface		Pavement Structure Material		
		Type	Thickness (mm)	Type	Thickness (mm)	Corrected Compressive Strength (Mpa)
PC22-13	UTM : 5529355 m N, 634314 m E; Located in front of West emtrance of #500 Waterfront Dr, 2.0 m West of East Curb.	Asphalt	-	Concrete	230	61.89
PC22-14	UTM : 5529411 m N, 634338 m E; Located in front of #19 Argyle St, 1.2 East of West Curb.	Asphalt	-	Concrete	230	63.33

Project 1000-043-21
Location Argyle st.
Hole No. PC-13 Sample No. PC-13
Depth 230 mm
Technician TG/JSB Date Nov 9/22

Photo 1: Pavement Core Sample PC-13



Project 1000-043-21
Location Argyle st.
Hole No. PC-14 Sample No. PC-14
Depth 230 mm
Technician TG/JSB Date Nov 9/22

Photo 2: Pavement Core Sample PC-14

www.trekgeotechnical.ca
1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

Concrete Core Compressive Strength Report

CSA A23.2-14C

Project No. 1000-043-21

Project 2023 Local Streets Package - 23-R1-01

Client WSP Group Canada Inc.

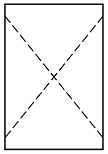
Date December 7, 2022

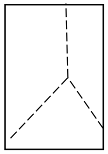
Technician KM

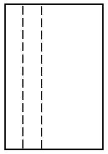
Core Location	Core ID	Date Received	Date of Break	Age at Break	Diam. (mm)	Length (mm)	Moisture Conditioning	Compressive Strength (MPa)		Break Type	Correction Factors*				
								Uncorrected f_{conc}	Corrected* f_c		$F_{l/d}$	F_{dia}	F_{mc}	F_D	F_{reinf}
Argyle Street	PC-13	2022-11-09	2022-12-07	-	146	222	Soaked 48 h	55.85	61.89	1	0.9786	0.9801	1.0900	1.0600	1.0000
Argyle Street	PC-14	2022-11-09	2022-12-07	-	146	217	Soaked 48 h	52.75	63.33	1	0.9751	0.9801	1.0900	1.0600	1.0872

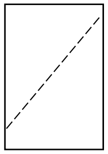
Comments

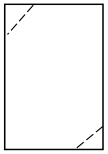
*Correction factors $F_{l/d}$, F_{dia}, F_{mc}, and F_D calculated as per ACI 214.4R-03, and correction factor F_{reinf} calculated as per Khoury et al. (2014): $f_c = f_{conc}F_{l/d}F_{dia}F_{mc}F_DF_{reinf}$

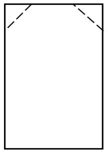

Type 1


Type 2


Type 3


Type 4


Type 5


Type 6

Reviewed by (print): Angela Fidler-Kliewer, C.Tech.

Signature: Angela Fidler-Kliewer

Table 1 Factors involved in interpretation of core results by different codes.

List	Code/standard	Edition	Factors Considered					
			Aspect ratio	Diameter	Reinforcing	Moisture	Damage	Direction
1	Egyptian Code/Standard Specification	2008	√		√			√
2	British Code/Standard Specification	2003	√		√			√
3	American Concrete Institute ACI	1998	√					
		2012	√	√		√	√	
4	European Standard Specification	1998	√	√	√		√	
		2009	√		√			
5	Japanese Standard	1998	√					
6	Concrete Society	1987	√		√		√	√

In addition, for core specimen containing two bars no further apart than the diameter of the larger bar, only the bar corresponding to the higher value of ($\Phi_r * d$) is considered. If the bars are further apart, their combined effect should be assessed by replacing the term ($\Phi_r * d$) by the term ($\sum \Phi_r * d$).

It should be pointed out that above equations used to interpret the core concrete strength to the in-situ concrete cube strength have been developed based on a set of assumptions and through many converting process. It is also of interest to note that the damage effect is considered in the development of the formulas in indirect way. The subject derivation and detailed formulas may be seen elsewhere [14].

3.2. American Concrete Institute (ACI)

3.2.1. Former ACI Code (2002) & Current ASTM (2009)

The methodology of core interpretation given in the former ACI code was remained without changes for decades and up to Year (2003). The in-place strength of concrete cylinder at the location from which a core test specimen was extracted can be computed using the equation:

$$f_{cy} = F_{l/d} \cdot f_{core} \tag{4}$$

where f_{cy} is the equivalent in-place concrete cylinder strength, f_{core} is concrete core strength, and $F_{l/d}$ is the strength correction factor for aspect ratio.

The former ACI code does not include any equation to calculate the correction factor ($F_{l/d}$); however, the code gives different values for this term that is associated with different aspect ratios (l/d) as given in Table 2. It should also be noted that the approach of current ASTM is similar to that mentioned above. The only considered variable is the aspect ratio (l/d). It should be noted that identical approach to that mentioned above is still effective in ASTM C42/C42M-03 [10].

3.2.2. Current ACI Code (2012) [15]

Starting from Year 2003, significant changes have been made to the relevant ACI Code provisions regarding the interpretation of core strength test results. New factors have been considered. These include core diameter, moisture content of core sample, core damage associated with drilling, in addition to the effect of aspect ratio that was previously considered in the former ACI edition (1998). According to the ACI 214.4R-03, the in-place concrete strength can be computed using the equation:

Table 2 Mean values for factor $F_{l/d}$ according to ACI Code (1998) and ASTM.

	Specimen length-to-diameter ratio, l/d			
	1.00	1.25	1.50	1.75
$F_{l/d}$	0.87	0.93	0.96	0.98

$$f_c = F_{l/d} \cdot F_{dia} \cdot F_{mc} \cdot F_D \cdot f_{core} \tag{5}$$

• Fpoint ← eq. 12 or eq. 15

where f_c is the equivalent in-place concrete cylinder strength, f_{core} is concrete core strength, $F_{l/d}$ is strength correction factor for aspect ratio, F_{dia} is strength correction factors for diameter, F_{mc} is strength correction factor for moisture condition of core sample, and F_D is the strength correction factor that accounts for effect of damage sustained during core drilling including micro-cracking and undulations at the drilled surface and cutting through coarse-aggregate particles that may subsequently pop out during testing.

The ACI committee considered the correction factors presented in Table 3 for converting core strengths into equivalent in-place strengths based on the work reported by Bartlett and MacGregor [6]. It should be noted that the magnitude of

Table 3 Strength correction factors according to ACI 214.4R-03.

List	Factors	Mean values
(1)[b]	$F_{l/d}$:l/d ratio	
	As-received	$1 - \{0.130 - \alpha f_{core}\}(2 - \frac{l}{d})^2$
	Soaked 48 h	$1 - \{0.117 - \alpha f_{core}\}\ (2 - \frac{l}{d})^2$
	Air dried[a]	$1 - \{0.144 - \alpha f_{core}\}(2 - \frac{l}{d})^2$
(2)	F_{dia}: core diameter	
	50 mm	1.06
	100 mm	1.00
	150 mm	0.98
(3)	F_{mc}: core moisture content	
	As-received	1.00
	Soaked 48 h	1.09
	Air dried[a]	0.96
(4)	F_D: damage due to drilling	1.06

[a] Standard treatment specified in ASTM C 42/C 42M.

[b] Constant α equals $4.3(10^{-4})$ 1/MPa for f_{core} in MPa.

Table 6 List of comparisons between tested cores to determine.

	A18	A17	A16	A15	A14	A13	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1
A1	♦●	●	♦●	■●	■●		●				●			▲	▲	■	▲	
A2																		
A3						■●				■●								
A4																		
A5																		
A6								■▲●	■▲●			■▲						
A7								■▲●	■▲●									
A8		●	♦	●	●													
A9																		
A10								■▲●										
A11																		
A12		●		●	●													
A13																		
A14		●		●														
A15		●																
A16	●♦																	
A17	♦																	
A18																		

● Diameter of steel bar.
▲ Distance of steel bar from nearly end of core.
■ Number of steel bars and spacing between bars.
♦ Distance of steel bar from vertical axis of specimen.

This brief review indicated that the various proposed relationships for correction factors are all nonlinear. It should be noted that the equations given by the Egyptian Code takes into account most variables that may affect the interpretation of the results; however, the code ignores the deterioration of steel–concrete bond that may occur and also the position of the reinforcement from vertical axis of core specimens.

Weighted nonlinear regression analysis has been performed to determine the factor (F_{reinf}) with the use of the software "SAS" package and "Data Fit." This shows that the correction factor for reinforcement (F_{reinf}) is given by the following expression:

- For cores containing a single bar:

single bar

$$F_{\text{reinf}} = \left[1 + 1.5\frac{[\Phi_r \times r + \Phi_r \times (S/10)]}{\Phi_c * L}\right] \times \frac{1.13}{f_{\text{core}}^{0.015}} \quad (12)$$

- For core specimen containing two bars no further apart than the diameter of the larger bar, only the bar corresponding to the higher value of ($\Phi_r * d$) is considered. If the bars are further apart, their combined effect is assessed by replacing the term ($\Phi_r * r$) by ($\sum \Phi_r * r$ as follows:

multiple bars

$$F_{\text{reinf}} = \left[1 + 1.5\frac{\sum[\Phi_r \times r + \Phi_r \times (S/10)]}{\Phi_c * L}\right] \times \frac{1.13}{f_{\text{core}}^{0.015}} \quad (13)$$

where F_{reinf} is the correction factor for reinforcement, Φ_r is the diameter of the reinforcement, Φ_c is the diameter of the concrete specimen, r is the distance of axis of bar from nearer end of specimen, S is the distance of axis of bar from axis of core specimen, L is the length of the specimen after end preparation by grinding or capping, and f_{core} is the concrete core strength (kg/cm^2).

6.1.6. *Effect of moisture condition of core*

Results of about 100 cores indicate that the strength of cores left to dry in air for 7 days is on average 13% greater than that of cores soaked at least 40 h before testing. The strength of cores with negligible moisture gradient and tested after cutting is found to be 7–9% larger than that of soaked cores as shown in Fig. 20. The authors strongly recommend to use a correction factor accounting for moisture condition (F_m) equals to 1.09 and 0.96, respectively, for cores tested after 48 h soaked in water and for those tested after 7 days dry in air.

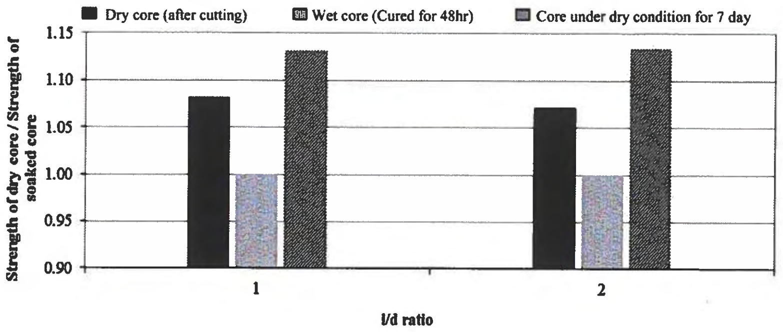


Figure 20 Effect of core moisture condition on core strength for different aspect ratios (*l*/*d*).

Appendix H

Summary Table and Pavement Core Photos – Bentall St

2023 Local and Industrial Streets Renewal Package - 23-RI-01

Bentall St - Mountain Ave / Redwood Ave

Pavement Core No.	Pavement Core Location	Pavement Surface		Pavement Structure Material		
		Type	Thickness (mm)	Type	Thickness (mm)	Corrected Compressive Strength (Mpa)
PC22-18	UTM : 5532770 m N, 630721 m E; Located in front of #21 Bentall Ave, 1.2 m West of East Curb.	Asphalt	-	Concrete	220	63.80
PC22-19	UTM : 5532899 m N, 630774 m E; Located in front of East side of #1410 Mountain Ave, 1.5 m East of West Curb.	Asphalt	-	Concrete	220	63.14

Photo 1: Pavement Core Sample PC-18

Photo 2: Pavement Core Sample PC-19

TREK GEOTECHNICAL
www.trekgeotechnical.ca
1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

Concrete Core Compressive Strength Report

CSA A23.2-14C

Project No. 1000-043-21

Project 2023 Local Streets Package - 23-R1-01

Client WSP Group Canada Inc.

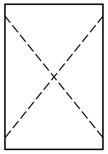
Date December 7, 2022

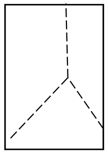
Technician KM

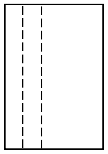
Core Location	Core ID	Date Received	Date of Break	Age at Break	Diam. (mm)	Length (mm)	Moisture Conditioning	Compressive Strength (MPa)		Break Type	Correction Factors*				
								Uncorrected f_{conc}	Corrected* f_c		$F_{l/d}$	F_{dia}	F_{mc}	F_D	F_{reinf}
Bentall Street	PC-18	2022-11-07	2022-12-07	-	146	209	Soaked 48 h	58.07	63.80	1	0.9703	0.9801	1.0900	1.0600	1.0000
Bentall Street	PC-19	2022-11-07	2022-12-07	-	146	212	Soaked 48 h	57.34	63.14	1	0.9723	0.9801	1.0900	1.0600	1.0000

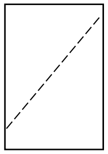
Comments

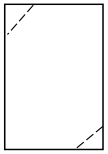
*Correction factors $F_{l/d}$, F_{dia}, F_{mc}, and F_D calculated as per ACI 214.4R-03, and correction factor F_{reinf} calculated as per Khoury et al. (2014): $f_c = f_{conc}F_{l/d}F_{dia}F_{mc}F_DF_{reinf}$

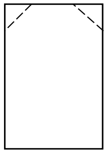

Type 1


Type 2


Type 3


Type 4


Type 5


Type 6

Reviewed by (print): Angela Fidler-Kliewer, C.Tech.

Signature: Angela Fidler-Kliewer

Table 1 Factors involved in interpretation of core results by different codes.

List	Code/standard	Edition	Factors Considered					
			Aspect ratio	Diameter	Reinforcing	Moisture	Damage	Direction
1	Egyptian Code/Standard Specification	2008	√		√			√
2	British Code/Standard Specification	2003	√		√			√
3	American Concrete Institute ACI	1998	√					
		2012	√	√		√	√	
4	European Standard Specification	1998	√	√	√		√	
		2009	√		√			
5	Japanese Standard	1998	√					
6	Concrete Society	1987	√		√		√	√

In addition, for core specimen containing two bars no further apart than the diameter of the larger bar, only the bar corresponding to the higher value of ($\Phi_r * d$) is considered. If the bars are further apart, their combined effect should be assessed by replacing the term ($\Phi_r * d$) by the term ($\sum \Phi_r * d$).

It should be pointed out that above equations used to interpret the core concrete strength to the in-situ concrete cube strength have been developed based on a set of assumptions and through many converting process. It is also of interest to note that the damage effect is considered in the development of the formulas in indirect way. The subject derivation and detailed formulas may be seen elsewhere [14].

3.2. American Concrete Institute (ACI)

3.2.1. Former ACI Code (2002) & Current ASTM (2009)

The methodology of core interpretation given in the former ACI code was remained without changes for decades and up to Year (2003). The in-place strength of concrete cylinder at the location from which a core test specimen was extracted can be computed using the equation:

$$f_{cy} = F_{l/d} \cdot f_{core} \quad (4)$$

where f_{cy} is the equivalent in-place concrete cylinder strength, f_{core} is concrete core strength, and $F_{l/d}$ is the strength correction factor for aspect ratio.

The former ACI code does not include any equation to calculate the correction factor ($F_{l/d}$); however, the code gives different values for this term that is associated with different aspect ratios (l/d) as given in Table 2. It should also be noted that the approach of current ASTM is similar to that mentioned above. The only considered variable is the aspect ratio (l/d). It should be noted that identical approach to that mentioned above is still effective in ASTM C42/C42M-03 [10].

3.2.2. Current ACI Code (2012) [15]

Starting from Year 2003, significant changes have been made to the relevant ACI Code provisions regarding the interpretation of core strength test results. New factors have been considered. These include core diameter, moisture content of core sample, core damage associated with drilling, in addition to the effect of aspect ratio that was previously considered in the former ACI edition (1998). According to the ACI 214.4R-03, the in-place concrete strength can be computed using the equation:

← eq. 12

$$f_c = F_{l/d} \cdot F_{dia} \cdot F_{mc} \cdot F_D \cdot f_{core} \cdot F_{rent} \quad (5)$$

or eq. 15

where f_c is the equivalent in-place concrete cylinder strength, f_{core} is concrete core strength, $F_{l/d}$ is strength correction factor for aspect ratio, F_{dia} is strength correction factors for diameter, F_{mc} is strength correction factor for moisture condition of core sample, and F_D is the strength correction factor that accounts for effect of damage sustained during core drilling including micro-cracking and undulations at the drilled surface and cutting through coarse-aggregate particles that may subsequently pop out during testing.

The ACI committee considered the correction factors presented in Table 3 for converting core strengths into equivalent in-place strengths based on the work reported by Bartlett and MacGregor [6]. It should be noted that the magnitude of

Table 2 Mean values for factor $F_{l/d}$ according to ACI Code (1998) and ASTM.

	Specimen length-to-diameter ratio, l/d			
	1.00	1.25	1.50	1.75
$F_{l/d}$	0.87	0.93	0.96	0.98

Table 3 Strength correction factors according to ACI 214.4R-03.

List	Factors	Mean values
(1)[b]	$F_{l/d}$:l/d ratio	
	As-received	$1 - \{0.130 - \alpha f_{core}\}(2 - \frac{l}{d})^2$
	Soaked 48 h	$1 - \{0.117 - \alpha f_{core}\}(2 - \frac{l}{d})^2$
	Air dried[a]	$1 - \{0.144 - \alpha f_{core}\}(2 - \frac{l}{d})^2$
(2)	F_{dia}: core diameter	
	50 mm	1.06
	100 mm	1.00
	150 mm	0.98
(3)	F_{mc}: core moisture content	
	As-received	1.00
	Soaked 48 h	1.09
	Air dried[a]	0.96
(4)	F_D: damage due to drilling	1.06

[a] Standard treatment specified in ASTM C 42/C 42M.
[b] Constant α equals $4.3(10^{-4})$ 1/MPa for f_{core} in MPa.

Table 6 List of comparisons between tested cores to determine.

	A18	A17	A16	A15	A14	A13	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1
A1	♦●	●	♦●	■●	■●		●				●			▲	▲	■	▲	
A2																		
A3						■●				■●								
A4																		
A5																		
A6								■▲●	■▲●			■▲						
A7								■▲●	■▲●									
A8		●	♦	●	●													
A9																		
A10								■▲●										
A11																		
A12		●		●	●													
A13																		
A14		●		●														
A15		●																
A16	●♦																	
A17	♦																	
A18																		

● Diameter of steel bar.
▲ Distance of steel bar from nearly end of core.
■ Number of steel bars and spacing between bars.
♦ Distance of steel bar from vertical axis of specimen.

This brief review indicated that the various proposed relationships for correction factors are all nonlinear. It should be noted that the equations given by the Egyptian Code takes into account most variables that may affect the interpretation of the results; however, the code ignores the deterioration of steel–concrete bond that may occur and also the position of the reinforcement from vertical axis of core specimens.

Weighted nonlinear regression analysis has been performed to determine the factor (F_{reinf}) with the use of the software "SAS" package and "Data Fit." This shows that the correction factor for reinforcement (F_{reinf}) is given by the following expression:

single bar

- For cores containing a single bar:

$$F_{\text{reinf}} = \left[1 + 1.5\frac{[\Phi_r \times r + \Phi_r \times (S/10)]}{\Phi_c * L}\right] \times \frac{1.13}{f_{\text{core}}^{0.015}} \tag{12}$$

- For core specimen containing two bars no further apart than the diameter of the larger bar, only the bar corresponding to the higher value of ($\Phi_r * d$) is considered. If the bars are further apart, their combined effect is assessed by replacing the term ($\Phi_r * r$) by ($\sum \Phi_r * r$ as follows:

multiple bars

$$F_{\text{reinf}} = \left[1 + 1.5\frac{\sum[\Phi_r \times r + \Phi_r \times (S/10)]}{\Phi_c * L}\right] \times \frac{1.13}{f_{\text{core}}^{0.015}} \tag{13}$$

where F_{reinf} is the correction factor for reinforcement, Φ_r is the diameter of the reinforcement, Φ_c is the diameter of the concrete specimen, r is the distance of axis of bar from nearer end of specimen, S is the distance of axis of bar from axis of core specimen, L is the length of the specimen after end preparation by grinding or capping, and f_{core} is the concrete core strength (kg/cm^2).

6.1.6. *Effect of moisture condition of core*

Results of about 100 cores indicate that the strength of cores left to dry in air for 7 days is on average 13% greater than that of cores soaked at least 40 h before testing. The strength of cores with negligible moisture gradient and tested after cutting is found to be 7–9% larger than that of soaked cores as shown in Fig. 20. The authors strongly recommend to use a correction factor accounting for moisture condition (F_m) equals to 1.09 and 0.96, respectively, for cores tested after 48 h soaked in water and for those tested after 7 days dry in air.

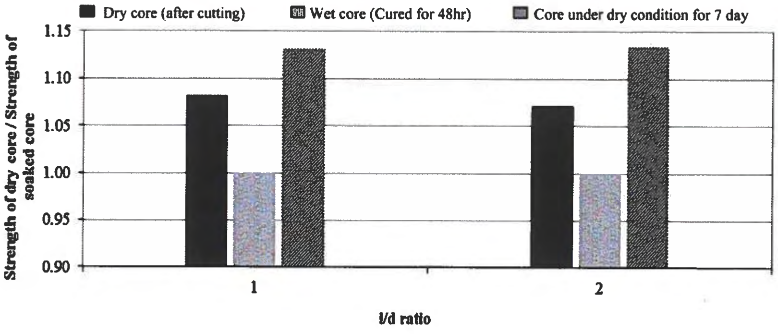


Figure 20 Effect of core moisture condition on core strength for different aspect ratios (l/d).

Appendix I

Summary Table and Pavement Core Photos – Wyatt Rd

2023 Local and Industrial Streets Renewal Package - 23-RI-01

Wyatt Rd - Filkow By / Inkster Blvd and Mandalay Dr / Filkow By

Pavement Core No.	Pavement Core Location	Pavement Surface		Pavement Structure Material		
		Type	Thickness (mm)	Type	Thickness (mm)	Corrected Compressive Strength (Mpa)
PC22-20	UTM : 5534259 m N, 630120 m E; Located 8 m south of the South-East entrance of #1771 Inkster Blvd, 2.0 m East of West Curb.	Asphalt	-	Concrete	200	64.22
PC22-21	UTM : 5534403 m N, 630092 m E; Located in front of #1725 Inkster Blvd, 1.2 m West of East Curb.	Asphalt	100	Concrete	140	-
PC22-22	UTM : 5534435 m N, 630302 m E; Located in front of #174 Wyatt Rd, 2.0 m South of North Curb.	Asphalt	-	Concrete	195	63.34

Photo 1: Pavement Core Sample PC-20

Photo 2: Pavement Core Sample PC-21

Photo 3: Pavement Core Sample PC-22

TREK GEOTECHNICAL
www.trekgeotechnical.ca
1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

Concrete Core Compressive Strength Report

CSA A23.2-14C

Project No. 1000-043-21

Project 2023 Local Streets Package - 23-R1-01

Client WSP Group Canada Inc.

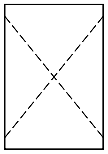
Date December 7, 2022

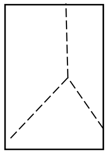
Technician KM

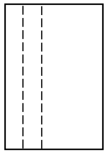
Core Location	Core ID	Date Received	Date of Break	Age at Break	Diam. (mm)	Length (mm)	Moisture Conditioning	Compressive Strength (MPa)		Break Type	Correction Factors*				
								Uncorrected f_{conc}	Corrected* f_c		$F_{l/d}$	F_{dia}	F_{mc}	F_D	F_{reinf}
Wyatt Street	PC-20	2022-11-07	2022-12-07	-	145	186	Soaked 48 h	55.23	64.22	1	0.9520	0.9802	1.0900	1.0600	1.0785
Wyatt Street	PC-22	2022-11-07	2022-12-07	-	146	185	Soaked 48 h	58.83	63.34	1	0.9507	0.9801	1.0900	1.0600	1.0000

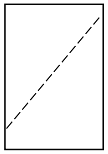
Comments

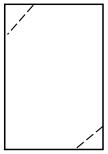
*Correction factors $F_{l/d}$, F_{dia}, F_{mc}, and F_D calculated as per ACI 214.4R-03, and correction factor F_{reinf} calculated as per Khoury et al. (2014): $f_c = f_{conc}F_{l/d}F_{dia}F_{mc}F_DF_{reinf}$

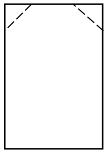

Type 1


Type 2


Type 3


Type 4


Type 5


Type 6

Reviewed by (print): Angela Fidler-Kliewer, C.Tech.

Signature: Angela Fidler-Kliewer

Table 1 Factors involved in interpretation of core results by different codes.

List	Code/standard	Edition	Factors Considered					
			Aspect ratio	Diameter	Reinforcing	Moisture	Damage	Direction
1	Egyptian Code/Standard Specification	2008	√		√			√
2	British Code/Standard Specification	2003	√		√			√
3	American Concrete Institute ACI	1998	√					
		2012	√	√		√	√	
4	European Standard Specification	1998	√	√	√		√	
		2009	√		√			
5	Japanese Standard	1998	√					
6	Concrete Society	1987	√		√		√	√

In addition, for core specimen containing two bars no further apart than the diameter of the larger bar, only the bar corresponding to the higher value of ($\Phi_r * d$) is considered. If the bars are further apart, their combined effect should be assessed by replacing the term ($\Phi_r * d$) by the term ($\sum \Phi_r * d$).

It should be pointed out that above equations used to interpret the core concrete strength to the in-situ concrete cube strength have been developed based on a set of assumptions and through many converting process. It is also of interest to note that the damage effect is considered in the development of the formulas in indirect way. The subject derivation and detailed formulas may be seen elsewhere [14].

3.2. American Concrete Institute (ACI)

3.2.1. Former ACI Code (2002) & Current ASTM (2009)

The methodology of core interpretation given in the former ACI code was remained without changes for decades and up to Year (2003). The in-place strength of concrete cylinder at the location from which a core test specimen was extracted can be computed using the equation:

$$f_{cy} = F_{l/d} \cdot f_{core} \tag{4}$$

where f_{cy} is the equivalent in-place concrete cylinder strength, f_{core} is concrete core strength, and $F_{l/d}$ is the strength correction factor for aspect ratio.

The former ACI code does not include any equation to calculate the correction factor ($F_{l/d}$); however, the code gives different values for this term that is associated with different aspect ratios (l/d) as given in Table 2. It should also be noted that the approach of current ASTM is similar to that mentioned above. The only considered variable is the aspect ratio (l/d). It should be noted that identical approach to that mentioned above is still effective in ASTM C42/C42M-03 [10].

Table 2 Mean values for factor $F_{l/d}$ according to ACI Code (1998) and ASTM.

	Specimen length-to-diameter ratio, l/d			
	1.00	1.25	1.50	1.75
$F_{l/d}$	0.87	0.93	0.96	0.98

3.2.2. Current ACI Code (2012) [15]

Starting from Year 2003, significant changes have been made to the relevant ACI Code provisions regarding the interpretation of core strength test results. New factors have been considered. These include core diameter, moisture content of core sample, core damage associated with drilling, in addition to the effect of aspect ratio that was previously considered in the former ACI edition (1998). According to the ACI 214.4R-03, the in-place concrete strength can be computed using the equation:

← eq. 12

$$f_c = F_{l/d} \cdot F_{dia} \cdot F_{mc} \cdot F_D \cdot f_{core} \cdot \text{Front} \tag{5}$$

or eq. 15

where f_c is the equivalent in-place concrete cylinder strength, f_{core} is concrete core strength, $F_{l/d}$ is strength correction factor for aspect ratio, F_{dia} is strength correction factors for diameter, F_{mc} is strength correction factor for moisture condition of core sample, and F_D is the strength correction factor that accounts for effect of damage sustained during core drilling including micro-cracking and undulations at the drilled surface and cutting through coarse-aggregate particles that may subsequently pop out during testing.

The ACI committee considered the correction factors presented in Table 3 for converting core strengths into equivalent in-place strengths based on the work reported by Bartlett and MacGregor [6]. It should be noted that the magnitude of

Table 3 Strength correction factors according to ACI 214.4R-03.

List	Factors	Mean values
(1)[b]	$F_{l/d}$:l/d ratio	
	As-received	$1 - \{0.130 - \alpha f_{core}\}(2 - \frac{l}{d})^2$
	Soaked 48 h	$1 - \{0.117 - \alpha f_{core}\}\ (2 - \frac{l}{d})^2$
	Air dried[a]	$1 - \{0.144 - \alpha f_{core}\}(2 - \frac{l}{d})^2$
(2)	F_{dia}: core diameter	
	50 mm	1.06
	100 mm	1.00
	150 mm	0.98
(3)	F_{mc}: core moisture content	
	As-received	1.00
	Soaked 48 h	1.09
	Air dried[a]	0.96
(4)	F_D: damage due to drilling	1.06

[a] Standard treatment specified in ASTM C 42/C 42M.
[b] Constant α equals $4.3(10^{-4})$ 1/MPa for f_{core} in MPa.

Table 6 List of comparisons between tested cores to determine.

	A18	A17	A16	A15	A14	A13	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1
A1	♦●	●	♦●	■●	■●		●				●			▲	▲	■	▲	
A2																		
A3						■●				■●								
A4																		
A5																		
A6								■▲●	■▲●			■▲						
A7								■▲●	■▲●									
A8		●	♦	●	●													
A9																		
A10								■▲●										
A11																		
A12		●		●	●													
A13																		
A14		●		●														
A15		●																
A16	●♦																	
A17	♦																	
A18																		

● Diameter of steel bar.
▲ Distance of steel bar from nearly end of core.
■ Number of steel bars and spacing between bars.
♦ Distance of steel bar from vertical axis of specimen.

This brief review indicated that the various proposed relationships for correction factors are all nonlinear. It should be noted that the equations given by the Egyptian Code takes into account most variables that may affect the interpretation of the results; however, the code ignores the deterioration of steel–concrete bond that may occur and also the position of the reinforcement from vertical axis of core specimens.

Weighted nonlinear regression analysis has been performed to determine the factor (F_{reinf}) with the use of the software "SAS" package and "Data Fit." This shows that the correction factor for reinforcement (F_{reinf}) is given by the following expression:

- For cores containing a single bar:

single bar

$$F_{\text{reinf}} = \left[1 + 1.5\frac{[\Phi_r \times r + \Phi_r \times (S/10)]}{\Phi_c * L}\right] \times \frac{1.13}{f_{\text{core}}^{0.015}} \quad (12)$$

- For core specimen containing two bars no further apart than the diameter of the larger bar, only the bar corresponding to the higher value of ($\Phi_r * d$) is considered. If the bars are further apart, their combined effect is assessed by replacing the term ($\Phi_r * r$) by ($\sum \Phi_r * r$ as follows:

multiple bars

$$F_{\text{reinf}} = \left[1 + 1.5\frac{\sum[\Phi_r \times r + \Phi_r \times (S/10)]}{\Phi_c * L}\right] \times \frac{1.13}{f_{\text{core}}^{0.015}} \quad (13)$$

where F_{reinf} is the correction factor for reinforcement, Φ_r is the diameter of the reinforcement, Φ_c is the diameter of the concrete specimen, r is the distance of axis of bar from nearer end of specimen, S is the distance of axis of bar from axis of core specimen, L is the length of the specimen after end preparation by grinding or capping, and f_{core} is the concrete core strength (kg/cm^2).

6.1.6. *Effect of moisture condition of core*

Results of about 100 cores indicate that the strength of cores left to dry in air for 7 days is on average 13% greater than that of cores soaked at least 40 h before testing. The strength of cores with negligible moisture gradient and tested after cutting is found to be 7–9% larger than that of soaked cores as shown in Fig. 20. The authors strongly recommend to use a correction factor accounting for moisture condition (F_m) equals to 1.09 and 0.96, respectively, for cores tested after 48 h soaked in water and for those tested after 7 days dry in air.

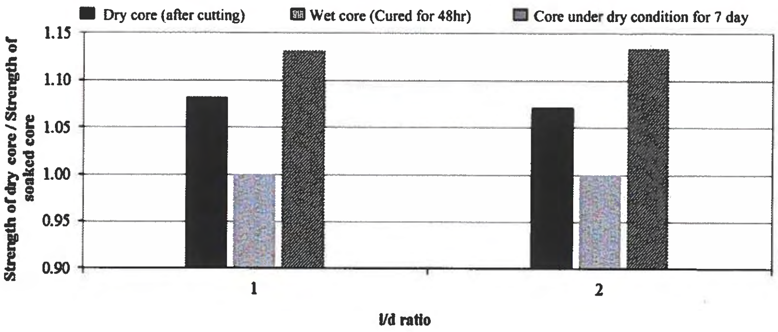


Figure 20 Effect of core moisture condition on core strength for different aspect ratios (*l*/*d*).

Appendix J

Summary Table and Pavement Core Photos – Pacific Ave

2023 Local and Industrial Streets Renewal Package - 23-RI-01

Pacific Ave - McPhillips St / Xante St and Xante St/ Arlington St

Pavement Core No.	Pavement Core Location	Pavement Surface		Pavement Structure Material		
		Type	Thickness (mm)	Type	Thickness (mm)	Corrected Compressive Strength (Mpa)
PC22-23	UTM : 5530380 m N, 631479 m E; Located in front of #1021 Pacific Ave, 2.1 m South of North Curb.	Asphalt	-	Concrete	180	66.89
PC22-24	UTM : 5530289 m N, 631667 m E; Located in front of #965 Pacific Ave, 1.8 m South of North Curb.	Asphalt	65	Concrete	180	-
PC22-25	UTM : 5530240 m N, 631769 m E; Located in front of South face of #1070 Arlington St, 1.5 m North of South Curb.	Asphalt	55	Concrete	225	-

1712 St. James Street
Winnipeg, Manitoba R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435
www.trekgeotechnical.ca

Project 1000-043-21
Location Pacific Ave (23-RI-01)
Hole No. PC-23 Sample No. PC-23
Depth 180mm
Technician TG Date Nov 14/22

Photo 1: Pavement Core Sample PC-23

1712 St. James Street
Winnipeg, Manitoba R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435
www.trekgeotechnical.ca

Project 1000-043-21
Location Pacific Ave (23-RI-01)
Hole No. PC-24 Sample No. PC-24
Depth 245mm
Technician TG Date Nov-14/22

Photo 2: Pavement Core Sample PC-24

Project 1000-043-21

Location Pacific Ave (23-RI-01)

Hole No. PC-25 Sample No. PC-25

Depth 280mm

Technician TG Date Nov 14/22

Photo 3: Pavement Core Sample PC-25

TREK GEOTECHNICAL
www.trekgeotechnical.ca
1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

Concrete Core Compressive Strength Report

CSA A23.2-14C

Project No. 1000-043-21

Project 2023 Local Streets Package - 23-R1-01

Client WSP Group Canada Inc.

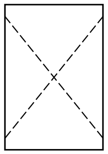
Date December 7, 2022

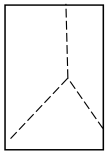
Technician KM

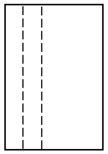
Core Location	Core ID	Date Received	Date of Break	Age at Break	Diam. (mm)	Length (mm)	Moisture Conditioning	Compressive Strength (MPa)		Break Type	Correction Factors*				
								Uncorrected f_{conc}	Corrected* f_c		$F_{l/d}$	F_{dia}	F_{mc}	F_D	F_{reinf}
Pacific Avenue	PC-23	2022-11-14	2022-12-07	-	146	171	Soaked 48 h	57.06	66.89	1	0.9365	0.9801	1.0900	1.0600	1.1054

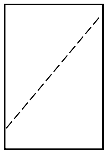
Comments

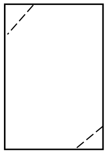
*Correction factors $F_{l/d}$, F_{dia}, F_{mc}, and F_D calculated as per ACI 214.4R-03, and correction factor F_{reinf} calculated as per Khoury et al. (2014): $f_c = f_{conc}F_{l/d}F_{dia}F_{mc}F_DF_{reinf}$

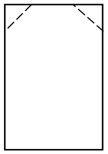

Type 1


Type 2


Type 3


Type 4


Type 5


Type 6

Reviewed by (print): Angela Fidler-Kliewer, C.Tech.

Signature: Angela Fidler-Kliewer

Table 1 Factors involved in interpretation of core results by different codes.

List	Code/standard	Edition	Factors Considered					
			Aspect ratio	Diameter	Reinforcing	Moisture	Damage	Direction
1	Egyptian Code/Standard Specification	2008	√		√			√
2	British Code/Standard Specification	2003	√		√			√
3	American Concrete Institute ACI	1998	√					
		2012	√	√		√	√	
4	European Standard Specification	1998	√	√	√		√	
		2009	√		√			
5	Japanese Standard	1998	√					
6	Concrete Society	1987	√		√		√	√

In addition, for core specimen containing two bars no further apart than the diameter of the larger bar, only the bar corresponding to the higher value of $(\Phi_r * d)$ is considered. If the bars are further apart, their combined effect should be assessed by replacing the term $(\Phi_r * d)$ by the term $(\sum \Phi_r * d)$.

It should be pointed out that above equations used to interpret the core concrete strength to the in-situ concrete cube strength have been developed based on a set of assumptions and through many converting process. It is also of interest to note that the damage effect is considered in the development of the formulas in indirect way. The subject derivation and detailed formulas may be seen elsewhere [14].

3.2. American Concrete Institute (ACI)

3.2.1. Former ACI Code (2002) & Current ASTM (2009)

The methodology of core interpretation given in the former ACI code was remained without changes for decades and up to Year (2003). The in-place strength of concrete cylinder at the location from which a core test specimen was extracted can be computed using the equation:

$$f_{cy} = F_{l/d} \cdot f_{core} \tag{4}$$

where f_{cy} is the equivalent in-place concrete cylinder strength, f_{core} is concrete core strength, and $F_{l/d}$ is the strength correction factor for aspect ratio.

The former ACI code does not include any equation to calculate the correction factor $(F_{l/d})$; however, the code gives different values for this term that is associated with different aspect ratios (l/d) as given in Table 2. It should also be noted that the approach of current ASTM is similar to that mentioned above. The only considered variable is the aspect ratio (l/d). It should be noted that identical approach to that mentioned above is still effective in ASTM C42/C42M-03 [10].

3.2.2. Current ACI Code (2012) [15]

Starting from Year 2003, significant changes have been made to the relevant ACI Code provisions regarding the interpretation of core strength test results. New factors have been considered. These include core diameter, moisture content of core sample, core damage associated with drilling, in addition to the effect of aspect ratio that was previously considered in the former ACI edition (1998). According to the ACI 214.4R-03, the in-place concrete strength can be computed using the equation:

Table 2 Mean values for factor $F_{l/d}$ according to ACI Code (1998) and ASTM.

	Specimen length-to-diameter ratio, l/d			
	1.00	1.25	1.50	1.75
$F_{l/d}$	0.87	0.93	0.96	0.98

$$f_c = F_{l/d} \cdot F_{dia} \cdot F_{mc} \cdot F_D \cdot f_{core} \cdot F_{reinf} \tag{5}$$

← Eq. 12 or Eq. 15

where f_c is the equivalent in-place concrete cylinder strength, f_{core} is concrete core strength, $F_{l/d}$ is strength correction factor for aspect ratio, F_{dia} is strength correction factors for diameter, F_{mc} is strength correction factor for moisture condition of core sample, and F_D is the strength correction factor that accounts for effect of damage sustained during core drilling including micro-cracking and undulations at the drilled surface and cutting through coarse-aggregate particles that may subsequently pop out during testing.

The ACI committee considered the correction factors presented in Table 3 for converting core strengths into equivalent in-place strengths based on the work reported by Bartlett and MacGregor [6]. It should be noted that the magnitude of

Table 3 Strength correction factors according to ACI 214.4R-03.

List	Factors	Mean values
(1)[b]	$F_{l/d}$:l/d ratio	
	As-received	$1 - \{0.130 - \alpha f_{core}\}(2 - \frac{l}{d})^2$
	Soaked 48 h	$1 - \{0.117 - \alpha f_{core}\}(2 - \frac{l}{d})^2$
	Air dried[a]	$1 - \{0.144 - \alpha f_{core}\}(2 - \frac{l}{d})^2$
(2)	F_{dia}: core diameter	
	50 mm	1.06
	100 mm	1.00
	150 mm	0.98
(3)	F_{mc}: core moisture content	
	As-received	1.00
	Soaked 48 h	1.09
	Air dried[a]	0.96
(4)	F_D: damage due to drilling	1.06

[a] Standard treatment specified in ASTM C 42/C 42M.
[b] Constant α equals $4.3(10^{-4})$ 1/MPa for f_{core} in MPa.

Table 6 List of comparisons between tested cores to determine.

	A18	A17	A16	A15	A14	A13	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1
A1	♦●	●	♦●	■●	■●		●				●			▲	▲	■	▲	
A2																		
A3						■●				■●								
A4																		
A5																		
A6								■▲●	■▲●			■▲						
A7								■▲●	■▲●									
A8		●	♦	●	●													
A9																		
A10								■▲●										
A11																		
A12		●		●	●													
A13																		
A14		●		●														
A15		●																
A16	●♦																	
A17	♦																	
A18																		

● Diameter of steel bar.
▲ Distance of steel bar from nearly end of core.
■ Number of steel bars and spacing between bars.
♦ Distance of steel bar from vertical axis of specimen.

This brief review indicated that the various proposed relationships for correction factors are all nonlinear. It should be noted that the equations given by the Egyptian Code takes into account most variables that may affect the interpretation of the results; however, the code ignores the deterioration of steel–concrete bond that may occur and also the position of the reinforcement from vertical axis of core specimens.

Weighted nonlinear regression analysis has been performed to determine the factor (F_{reinf}) with the use of the software "SAS" package and "Data Fit." This shows that the correction factor for reinforcement (F_{reinf}) is given by the following expression:

- For cores containing a single bar:

single bar

$$F_{\text{reinf}} = \left[1 + 1.5\frac{[\Phi_r \times r + \Phi_r \times (S/10)]}{\Phi_c * L}\right] \times \frac{1.13}{f_{\text{core}}^{0.015}} \tag{12}$$

- For core specimen containing two bars no further apart than the diameter of the larger bar, only the bar corresponding to the higher value of ($\Phi_r * d$) is considered. If the bars are further apart, their combined effect is assessed by replacing the term ($\Phi_r * r$) by ($\sum \Phi_r * r$ as follows:

multiple bars

$$F_{\text{reinf}} = \left[1 + 1.5\frac{\sum[\Phi_r \times r + \Phi_r \times (S/10)]}{\Phi_c * L}\right] \times \frac{1.13}{f_{\text{core}}^{0.015}} \tag{13}$$

where F_{reinf} is the correction factor for reinforcement, Φ_r is the diameter of the reinforcement, Φ_c is the diameter of the concrete specimen, r is the distance of axis of bar from nearer end of specimen, S is the distance of axis of bar from axis of core specimen, L is the length of the specimen after end preparation by grinding or capping, and f_{core} is the concrete core strength (kg/cm^2).

6.1.6. *Effect of moisture condition of core*

Results of about 100 cores indicate that the strength of cores left to dry in air for 7 days is on average 13% greater than that of cores soaked at least 40 h before testing. The strength of cores with negligible moisture gradient and tested after cutting is found to be 7–9% larger than that of soaked cores as shown in Fig. 20. The authors strongly recommend to use a correction factor accounting for moisture condition (F_m) equals to 1.09 and 0.96, respectively, for cores tested after 48 h soaked in water and for those tested after 7 days dry in air.

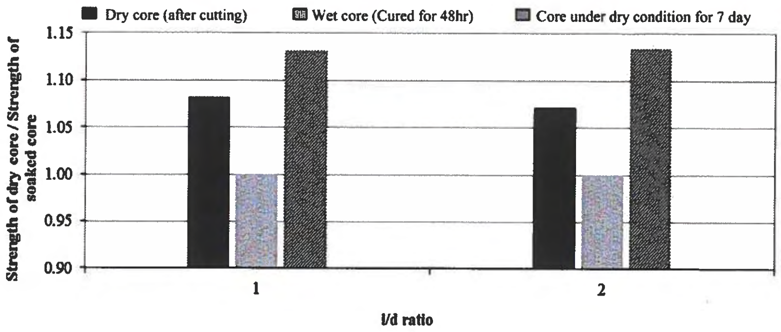


Figure 20 Effect of core moisture condition on core strength for different aspect ratios (l/d).

Appendix K

Summary Table and Pavement Core Photos – Bunting St

TREK GEOTECHNICAL

2023 Local and Industrial Streets Renewal Package - 23-RI-01

Bunting St - Inkster Blvd / Church Ave

Pavement Core No.	Pavement Core Location	Pavement Surface		Pavement Structure Material		
		Type	Thickness (mm)	Type	Thickness (mm)	Corrected Compressive Strength (Mpa)
PC22-26	UTM : 5533274 m N, 631130 m E; Located in front of #12 Bunting St, 1.8 m West of East Curb.	Asphalt	-	Concrete	180	63.39
PC22-27	UTM : 5533386 m N, 631182 m E; Located in front of #34 Bunting St, 2.2 m West of East Curb.	Asphalt	65	Concrete	180	-
PC22-28	UTM : 5533576 m N, 631263 m E; Located in front of #89 Bunting St, 1.5 m East of West Curb.	Asphalt	55	Concrete	225	66.10

Project 1000-043-21
Location Bunting st (23-RI-01)
Hole No. PC-26 Sample No. PC-26
Depth 210mm
Technician KM/JSB Date Nov 7/22

Photo 1: Pavement Core Sample PC-26

Project 1000-043-21
Location Bunting st. (23-RI-01)
Hole No. PC-27 Sample No. PC-27
Depth 205mm
Technician KM/JSB Date Nov 7/22

Photo 2: Pavement Core Sample PC-27

Project 1000-043-21
Location Bunting st. (23RI-01)
Hole No. PC-28 Sample No. PC-28
Depth 215mm
Technician KM/JSB Date Nov 7/22

Photo 3: Pavement Core Sample PC-28

TREK GEOTECHNICAL
www.trekgeotechnical.ca
1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

Concrete Core Compressive Strength Report

CSA A23.2-14C

Project No. 1000-043-21

Project 2023 Local Streets Package - 23-R1-01

Client WSP Group Canada Inc.

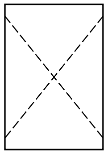
Date December 7, 2022

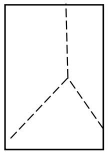
Technician KM

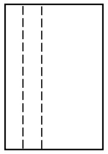
Core Location	Core ID	Date Received	Date of Break	Age at Break	Diam. (mm)	Length (mm)	Moisture Conditioning	Compressive Strength (MPa)		Break Type	Correction Factors*				
								Uncorrected f_{conc}	Corrected* f_c		$F_{l/d}$	F_{dia}	F_{mc}	F_D	F_{reinf}
Bunting Street	PC-26	2022-11-07	2022-12-07	-	145	205	Soaked 48 h	54.65	63.39	1	0.9679	0.9802	1.0900	1.0600	1.0581
Bunting Street	PC-28	2022-11-07	2022-12-07	-	145	166	Soaked 48 h	62.48	66.10	1	0.9341	0.9802	1.0900	1.0600	1.0000

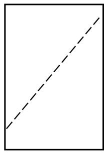
Comments

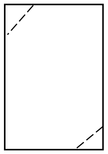
*Correction factors $F_{l/d}$, F_{dia}, F_{mc}, and F_D calculated as per ACI 214.4R-03, and correction factor F_{reinf} calculated as per Khoury et al. (2014): $f_c = f_{conc}F_{l/d}F_{dia}F_{mc}F_DF_{reinf}$

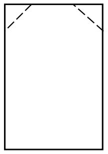

Type 1


Type 2


Type 3


Type 4


Type 5


Type 6

Reviewed by (print): Angela Fidler-Kliewer, C.Tech.

Signature: Angela Fidler-Kliewer

Table 1 Factors involved in interpretation of core results by different codes.

List	Code/standard	Edition	Factors Considered					
			Aspect ratio	Diameter	Reinforcing	Moisture	Damage	Direction
1	Egyptian Code/Standard Specification	2008	√		√			√
2	British Code/Standard Specification	2003	√		√			√
3	American Concrete Institute ACI	1998	√					
		2012	√	√		√	√	
4	European Standard Specification	1998	√	√	√		√	
		2009	√		√			
5	Japanese Standard	1998	√					
6	Concrete Society	1987	√		√		√	√

In addition, for core specimen containing two bars no further apart than the diameter of the larger bar, only the bar corresponding to the higher value of ($\Phi_r * d$) is considered. If the bars are further apart, their combined effect should be assessed by replacing the term ($\Phi_r * d$) by the term ($\sum \Phi_r * d$).

It should be pointed out that above equations used to interpret the core concrete strength to the in-situ concrete cube strength have been developed based on a set of assumptions and through many converting process. It is also of interest to note that the damage effect is considered in the development of the formulas in indirect way. The subject derivation and detailed formulas may be seen elsewhere [14].

3.2. American Concrete Institute (ACI)

3.2.1. Former ACI Code (2002) & Current ASTM (2009)

The methodology of core interpretation given in the former ACI code was remained without changes for decades and up to Year (2003). The in-place strength of concrete cylinder at the location from which a core test specimen was extracted can be computed using the equation:

$$f_{cy} = F_{l/d} \cdot f_{core} \tag{4}$$

where f_{cy} is the equivalent in-place concrete cylinder strength, f_{core} is concrete core strength, and $F_{l/d}$ is the strength correction factor for aspect ratio.

The former ACI code does not include any equation to calculate the correction factor ($F_{l/d}$); however, the code gives different values for this term that is associated with different aspect ratios (l/d) as given in Table 2. It should also be noted that the approach of current ASTM is similar to that mentioned above. The only considered variable is the aspect ratio (l/d). It should be noted that identical approach to that mentioned above is still effective in ASTM C42/C42M-03 [10].

3.2.2. Current ACI Code (2012) [15]

Starting from Year 2003, significant changes have been made to the relevant ACI Code provisions regarding the interpretation of core strength test results. New factors have been considered. These include core diameter, moisture content of core sample, core damage associated with drilling, in addition to the effect of aspect ratio that was previously considered in the former ACI edition (1998). According to the ACI 214.4R-03, the in-place concrete strength can be computed using the equation:

eq. 12

$$f_c = F_{l/d} \cdot F_{dia} \cdot F_{mc} \cdot F_D \cdot f_{core} \cdot F_{reinf} \tag{5}$$

or

eq. 15

where f_c is the equivalent in-place concrete cylinder strength, f_{core} is concrete core strength, $F_{l/d}$ is strength correction factor for aspect ratio, F_{dia} is strength correction factors for diameter, F_{mc} is strength correction factor for moisture condition of core sample, and F_D is the strength correction factor that accounts for effect of damage sustained during core drilling including micro-cracking and undulations at the drilled surface and cutting through coarse-aggregate particles that may subsequently pop out during testing.

The ACI committee considered the correction factors presented in Table 3 for converting core strengths into equivalent in-place strengths based on the work reported by Bartlett and MacGregor [6]. It should be noted that the magnitude of

Table 2 Mean values for factor $F_{l/d}$ according to ACI Code (1998) and ASTM.

	Specimen length-to-diameter ratio, l/d			
	1.00	1.25	1.50	1.75
$F_{l/d}$	0.87	0.93	0.96	0.98

Table 3 Strength correction factors according to ACI 214.4R-03.

List	Factors	Mean values
(1)[b]	$F_{l/d}$:l/d ratio	
	As-received	$1 - \{0.130 - \alpha f_{core}\}(2 - \frac{l}{d})^2$
	Soaked 48 h	$1 - \{0.117 - \alpha f_{core}\}\ (2 - \frac{l}{d})^2$
	Air dried[a]	$1 - \{0.144 - \alpha f_{core}\}(2 - \frac{l}{d})^2$
(2)	F_{dia}: core diameter	
	50 mm	1.06
	100 mm	1.00
	150 mm	0.98
(3)	F_{mc}: core moisture content	
	As-received	1.00
	Soaked 48 h	1.09
	Air dried[a]	0.96
(4)	F_D: damage due to drilling	1.06

[a] Standard treatment specified in ASTM C 42/C 42M.

[b] Constant α equals $4.3(10^{-4})$ 1/MPa for f_{core} in MPa.

Table 6 List of comparisons between tested cores to determine.

	A18	A17	A16	A15	A14	A13	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1
A1	♦●	●	♦●	■●	■●		●				●			▲	▲	■	▲	
A2																		
A3						■●				■●								
A4																		
A5																		
A6								■▲●	■▲●			■▲						
A7								■▲●	■▲●									
A8		●	♦	●	●													
A9																		
A10								■▲●										
A11																		
A12		●		●	●													
A13																		
A14		●		●														
A15		●																
A16	●♦																	
A17	♦																	
A18																		

● Diameter of steel bar.
▲ Distance of steel bar from nearly end of core.
■ Number of steel bars and spacing between bars.
♦ Distance of steel bar from vertical axis of specimen.

This brief review indicated that the various proposed relationships for correction factors are all nonlinear. It should be noted that the equations given by the Egyptian Code takes into account most variables that may affect the interpretation of the results; however, the code ignores the deterioration of steel–concrete bond that may occur and also the position of the reinforcement from vertical axis of core specimens.

Weighted nonlinear regression analysis has been performed to determine the factor (F_{reinf}) with the use of the software "SAS" package and "Data Fit." This shows that the correction factor for reinforcement (F_{reinf}) is given by the following expression:

single bar

- For cores containing a single bar:

$$F_{\text{reinf}} = \left[1 + 1.5\frac{[\Phi_r \times r + \Phi_r \times (S/10)]}{\Phi_c * L}\right] \times \frac{1.13}{f_{\text{core}}^{0.015}} \quad (12)$$

- For core specimen containing two bars no further apart than the diameter of the larger bar, only the bar corresponding to the higher value of ($\Phi_r * d$) is considered. If the bars are further apart, their combined effect is assessed by replacing the term ($\Phi_r * r$) by ($\sum \Phi_r * r$ as follows:

multiple bars

$$F_{\text{reinf}} = \left[1 + 1.5\frac{\sum[\Phi_r \times r + \Phi_r \times (S/10)]}{\Phi_c * L}\right] \times \frac{1.13}{f_{\text{core}}^{0.015}} \quad (13)$$

where F_{reinf} is the correction factor for reinforcement, Φ_r is the diameter of the reinforcement, Φ_c is the diameter of the concrete specimen, r is the distance of axis of bar from nearer end of specimen, S is the distance of axis of bar from axis of core specimen, L is the length of the specimen after end preparation by grinding or capping, and f_{core} is the concrete core strength (kg/cm^2).

6.1.6. *Effect of moisture condition of core*

Results of about 100 cores indicate that the strength of cores left to dry in air for 7 days is on average 13% greater than that of cores soaked at least 40 h before testing. The strength of cores with negligible moisture gradient and tested after cutting is found to be 7–9% larger than that of soaked cores as shown in Fig. 20. The authors strongly recommend to use a correction factor accounting for moisture condition (F_m) equals to 1.09 and 0.96, respectively, for cores tested after 48 h soaked in water and for those tested after 7 days dry in air.

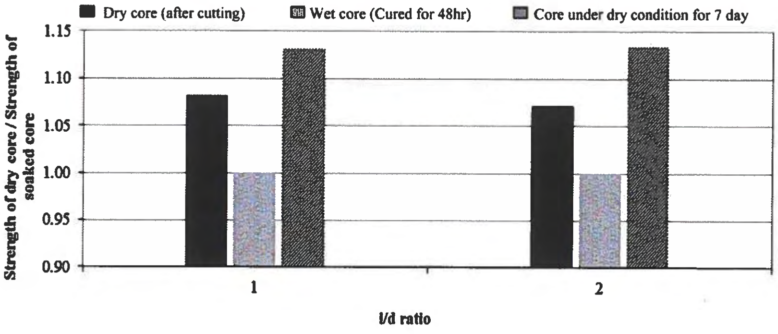


Figure 20 Effect of core moisture condition on core strength for different aspect ratios (l/d).