APPENDIX ‘A’

GEOTECHNICAL REPORT

WSP Canada Group Ltd.

2022 Local Streets Package 22-R-03

Prepared for:
Lissa Van Dorp
WSP Canada Group Ltd.
111-93 Lombard Avenue
Winnipeg, MB
R3B 3B1

Project Number: 1000-043-18

Date: February 2, 2022

TREK GEOTECHNICAL Quality Engineering | Valued Relationships

February 2, 2022 Our File No. 1000-043-18

Lissa Van Dorp
WSP Canada Group Ltd.
111-93 Lombard Avenue
Winnipeg, MB
R3B 3B1

RE: 2022 Local Streets Package 22-R-03

TREK Geotechnical Inc. is pleased to submit our Final Report for the geotechnical investigation for 2022 Local Streets Package (22-R-03) 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	AD	February 2, 2022	Final Report

Authorization Signatures

Prepared By:

Prepared By: Asad Dustmamatov C.E.T.
Geotechnical Engineering Technologist

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

N.J. FERREIRA
Member
22892
Feb. 2, 20

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

ENGINEERS
GEOSCIENTISTS
MANITOBA
Certificate of Authorization
TREK GEOTECHNICAL INC.
No. 4877 Date: Feb. 2, 2022

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Appendix E Summary Table, Pavement Core Photos, and Summary of Pavement Compressive Strength – Wardlaw Avenue

1.0 Introduction

This report summarizes the results of the road investigation completed for the Local Streets Package 22-R-03 project. The project included drilling test holes along Waterford Avenue, and collecting pavement cores along Gerard Street, Oakenwald Avenue, Roslyn Road, Wardlaw Avenue and Waterford Avenue. 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. 476-2021 (Appendix B – Site Investigation requirement for public works street projects).

2.0 Road Investigation

The investigation included coring of pavement at 29 locations on 5 different local streets with drilling of test holes at 5 locations along one street. WSP selected the investigation locations as shown on Figures 01 to 04 (attached) and the table below summarizes the investigation program per street.

Table 1: Road Investigation Program

Street	# of Locations	Investigation
Waterford Avenue (Between Pembina Hwy and Lyon St.)	5	Pavement Cores and Test Holes
Gerard Street (Between River Ave to End)	3	Pavement Core
Oakenwald Avenue (Between Wicklow S.t and Point Rd.)	8	Pavement Cores
Roslyn Road (Between Osbourne St. and Roslyn Cr.)	4	Pavement Cores
Wardlaw Avenue (Between Donald St. and Osborne St.)	9	Pavement Cores

The road investigation was conducted between January 16th and 20th, 2022. The pavement structure (asphalt/concrete) was cored by Naimu Mujyambere and Asad Dustmamatov of TREK Geotechnical Inc. (TREK) using a portable coring press equipped with a hollow 100 mm and 150 mm diameter diamond core drill bits. The test holes were drilled by Asad Dustmamatov to a depth of 2.0 m below road surface by Maple Leaf Drilling Ltd. using a truck mounted drill rig equipped with 125 mm diameter solid stem augers. The sub-surface conditions were observed during drilling and visually classified by Asad Dustmamatov 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. 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 (hydrometer methods) on select samples between 0.6 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 E). The information provided in the Appendices includes test hole logs, laboratory testing summary tables and results, and photos of the concrete cores.

One CBR was completed on bulk samples of the soil units present below the pavement. Only silt and clay were encountered within the prescribed sample depth for CBR testing and the results are shown in the table below.

Table 2: CBR Testing Summary

Sample Description	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	Waterford Ave	0.3-1.5	1568	23.1	94.2	23.8	3.5%	3.0%

* Testing completed on combining grab samples from the top 1.5 m of each test hole.

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.

Twelve concrete cores were selected for concrete compressive strength breaks and the length to diameter ratio ranged between 1.52 to 1.98 for the cores collected. The core compressive strength tests were tested in accordance with CSA A23.2-14C – wet dried 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 Appendix B, D and E.

Table 3: Concrete Core Compressive Strength Results

Core ID	Uncorrected Compressive Strength (MPa)	Rebar Corr. Factor	Corrected Compressive Strength (MPa)
PC-01	65.92	-	76.42
PC-02	72.46	-	83.10
PC-03	61.97	-	71.88
PC-05	62.18	-	72.11
PC-07	60.12	-	69.47
PC-09	60.31	-	69.63
PC-18	66.81	-	75.91
PC-24	74.51	1.08	92.30
PC-25	65.07	-	75.48
PC-26	61.02	-	70.80
PC-27	61.00	-	70.65
PC-28	59.04	-	68.40

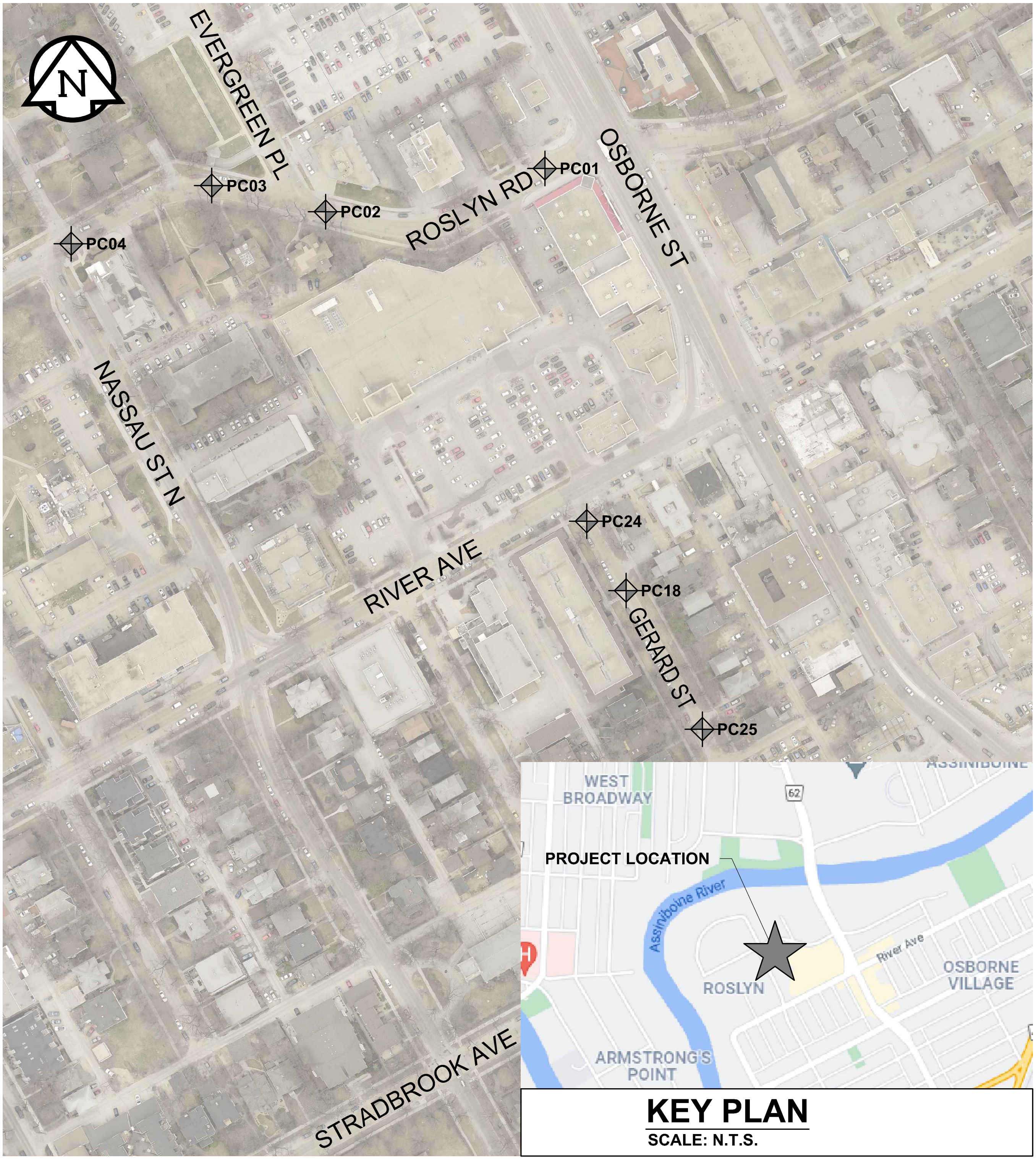
3.0 Closure

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



KEY PLAN
SCALE: N.T.S.

LEGEND:

⌖ PAVEMENT CORE (TREK 2021)

NOTES:

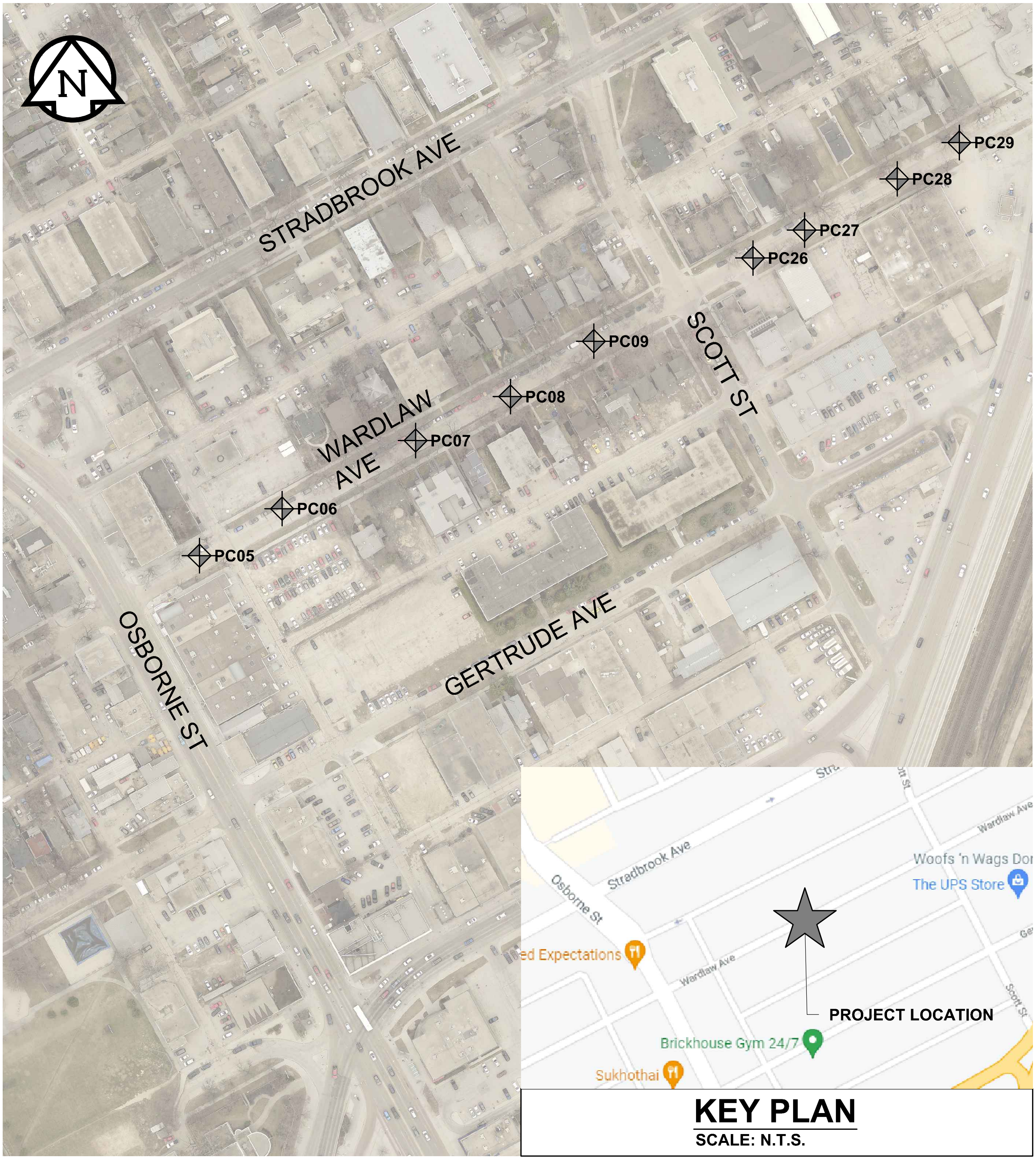
1. AERIAL IMAGERY FROM CITY OF WINNIPEG (2016).

0 50 100 150 m
SCALE = 1 : 2 500 (216 mm x 279 mm)

Figure 01
Pavement Core Location Plan

TREK GEOTECHNICAL

1000 043 18
WSP
2022 Local Streets Package (22-R-03)



LEGEND:

⌖ PAVEMENT CORE (TREK 2021)

NOTES:

1. AERIAL IMAGERY FROM CITY OF WINNIPEG (2016).

0 50 100 150 m
SCALE = 1 : 2 500 (216 mm x 279 mm)

Figure 02
Pavement Core Location Plan

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1000 043 18
WSP
2022 Local Streets Package (22-R-03)

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LEGEND:

⌖ **PAVEMENT CORE (TREK 2021)**

NOTES:

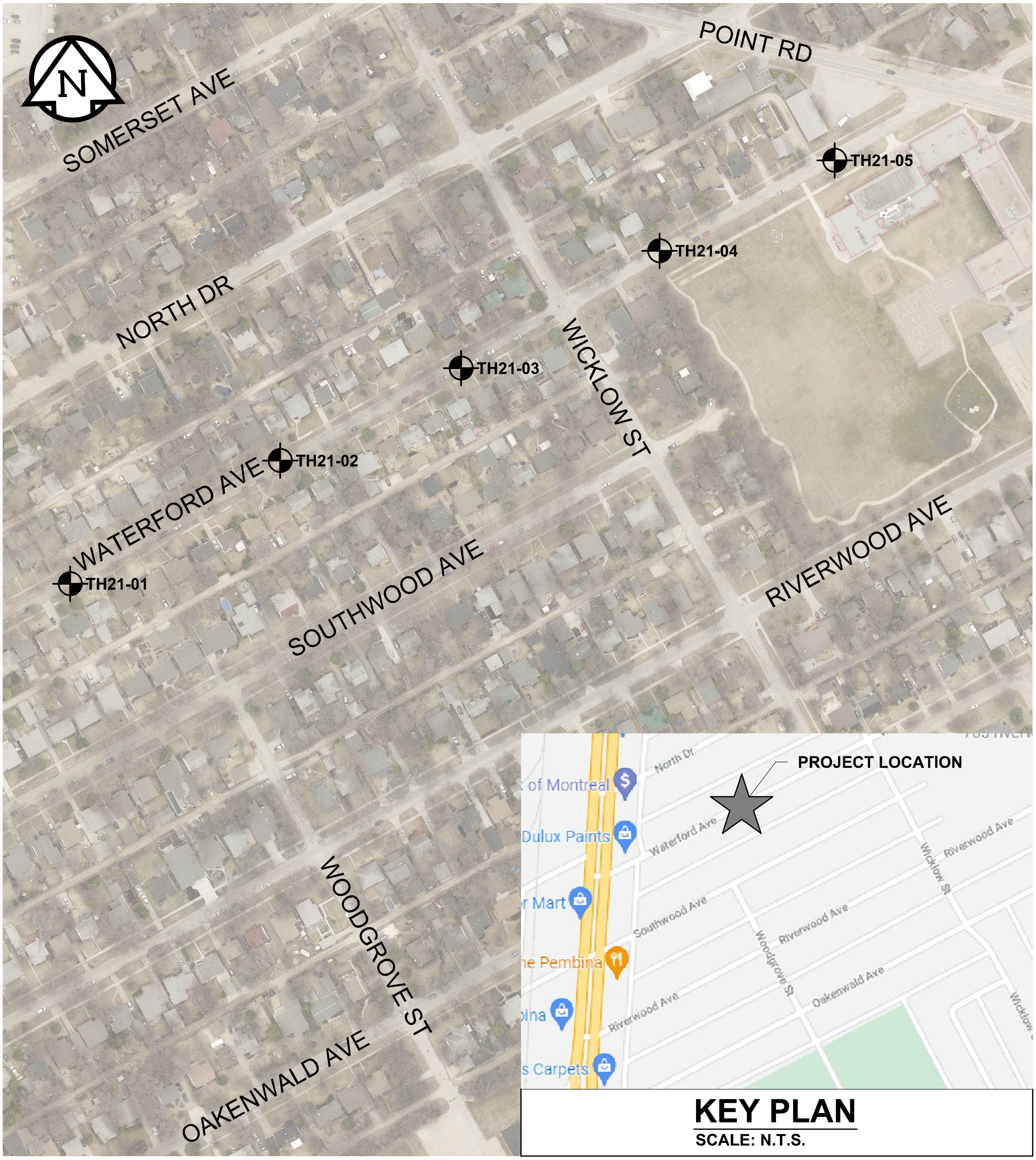
1. **AERIAL IMAGERY FROM CITY OF WINNIPEG (2016).**

0 50 100 150 m
SCALE = 1 : 3 000 (216 mm x 279 mm)

Figure 03
Pavement Core Location Plan

TREK GEOTECHNICAL

1000 043 18
WSP
2022 Local Streets Package (22-R-03)



LEGEND:

⊕ TEST HOLE (TREK, 2021)

NOTES:

1. AERIAL IMAGERY FROM CITY OF WINNIPEG (2016).

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0 50 100 150 m

SCALE = 1 : 3 000 (216 mm x 279 mm)

Figure 04

Test Hole Location Plan

TREK GEOTECHNICAL

1000 043 18
WSP
2022 Local Streets Package (22-R-03)

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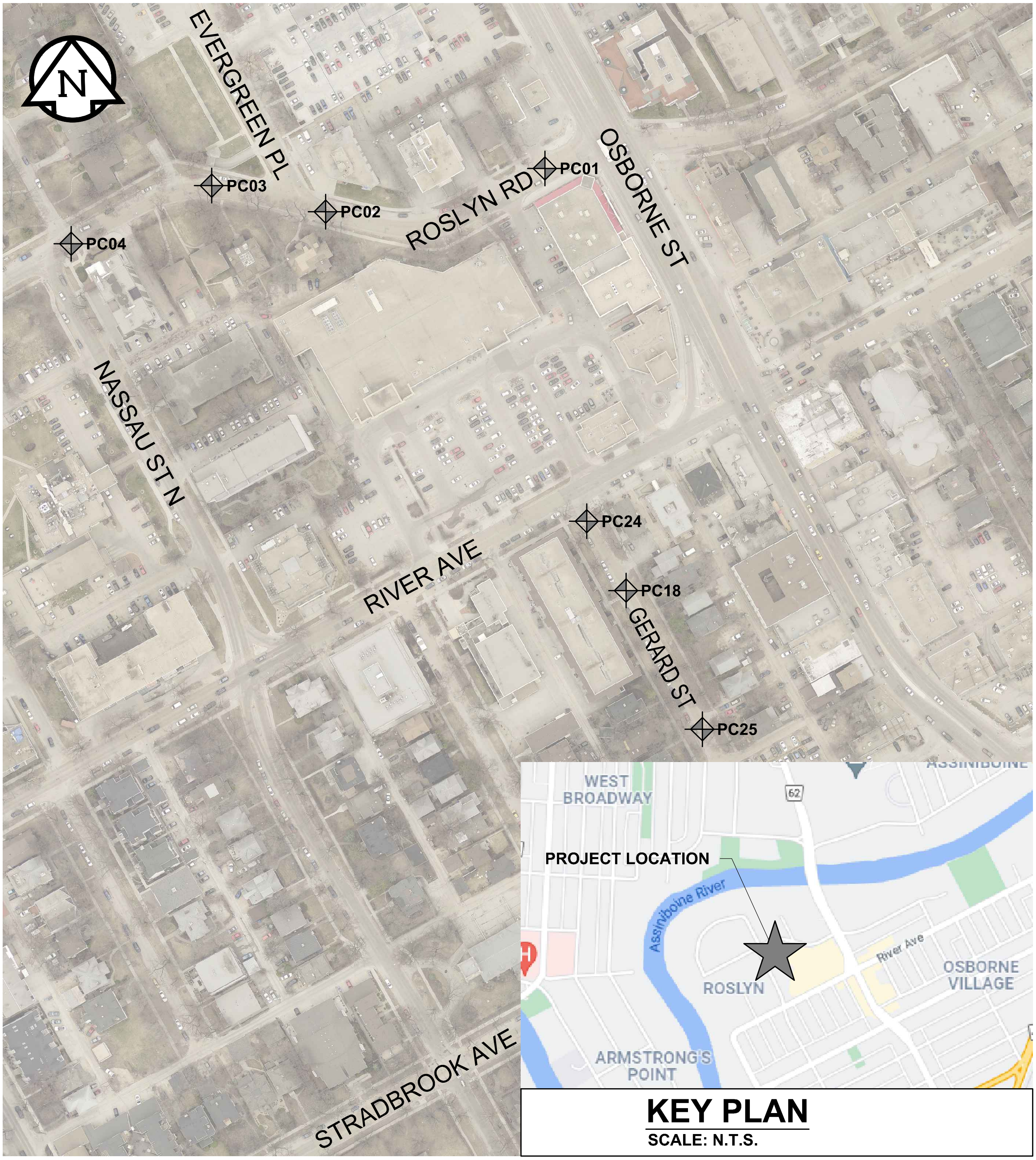


LEGEND:

⌖ PAVEMENT CORE (TREK 2021)

NOTES:

1. AERIAL IMAGERY FROM CITY OF WINNIPEG (2016).

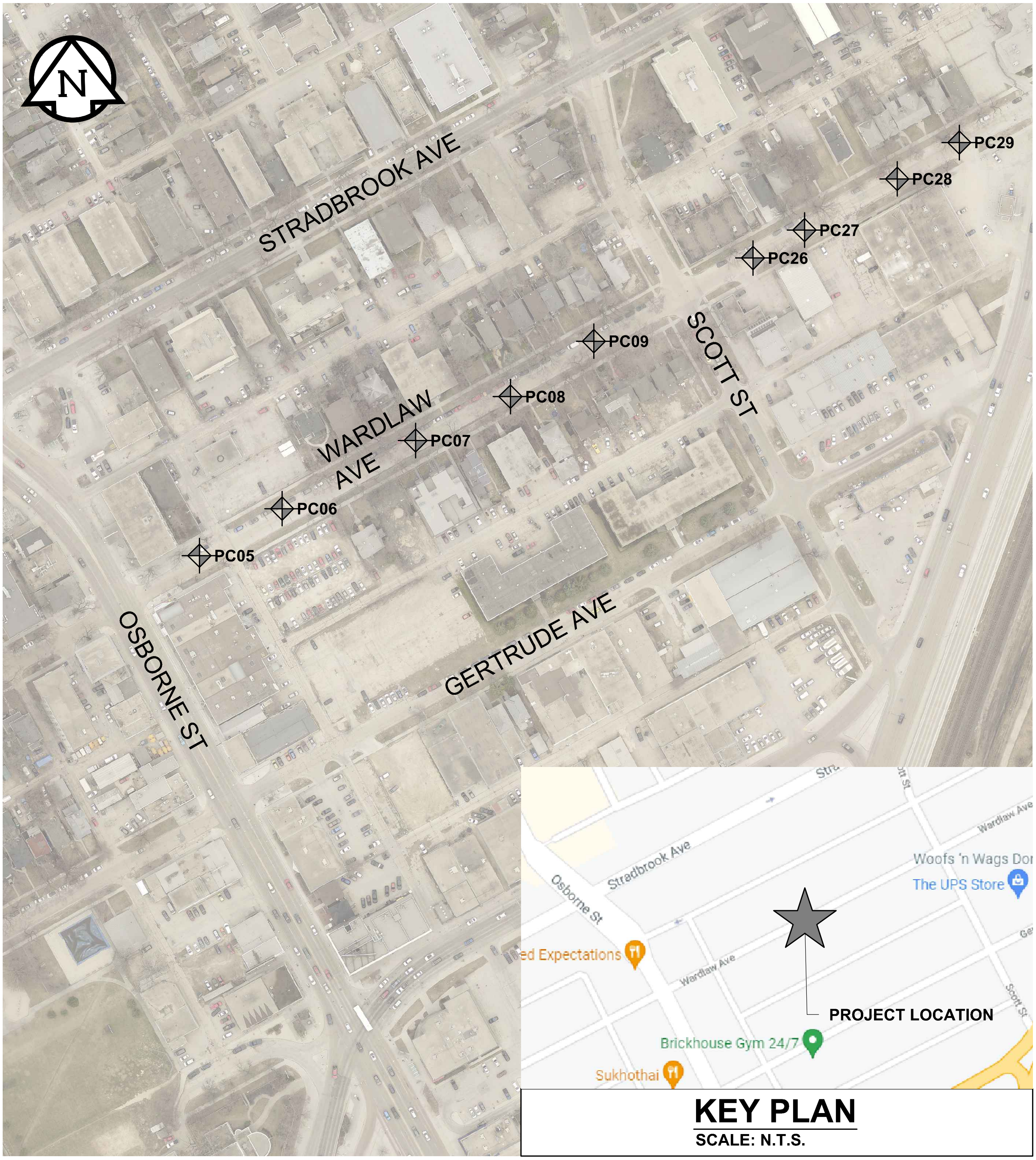
0 50 100 150 m

SCALE = 1 : 2 500 (216 mm x 279 mm)

Figure 01
Pavement Core Location Plan

TREK GEOTECHNICAL

1000 043 18
WSP
2022 Local Streets Package (22-R-03)



KEY PLAN
SCALE: N.T.S.

LEGEND:

⌖ **PAVEMENT CORE (TREK 2021)**

NOTES:

1. **AERIAL IMAGERY FROM CITY OF WINNIPEG (2016).**

0 50 100 150 m
SCALE = 1 : 2 500 (216 mm x 279 mm)

Figure 02
Pavement Core Location Plan

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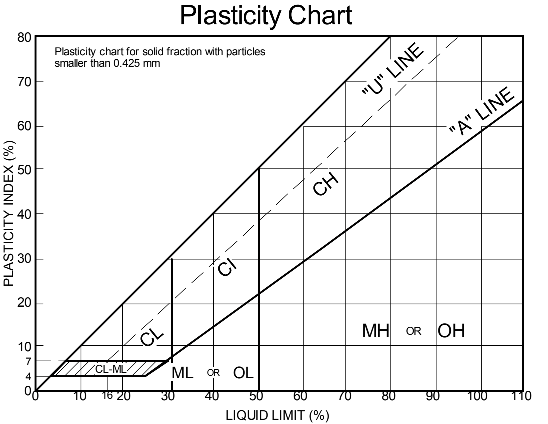
Appendix A

Test Hole Logs, Summary Table & Lab Testing Results and Pavement Core Photos – Waterford Avenue

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			
			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 TH22-01

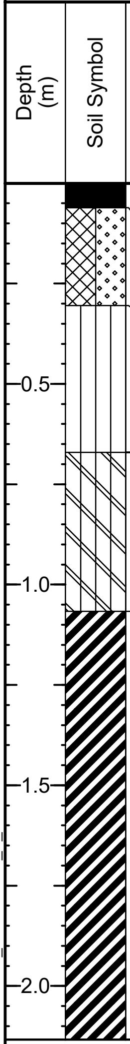
1 of 1

Client: City of Winnipeg
Project Name: Local Street Package 22-R-03 - Waterford Ave
Contractor: Maple Leaf Drilling Ltd.
Method: 125mm Solid Stem Auger, B40 Mobile Truck Mount

Project Number: 1000-043-18
Location: UTM N-5523011, E-632876
Ground Elevation: Top of Pavement
Date Drilled: January 20, 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

ASPHALT - 60 mm thick

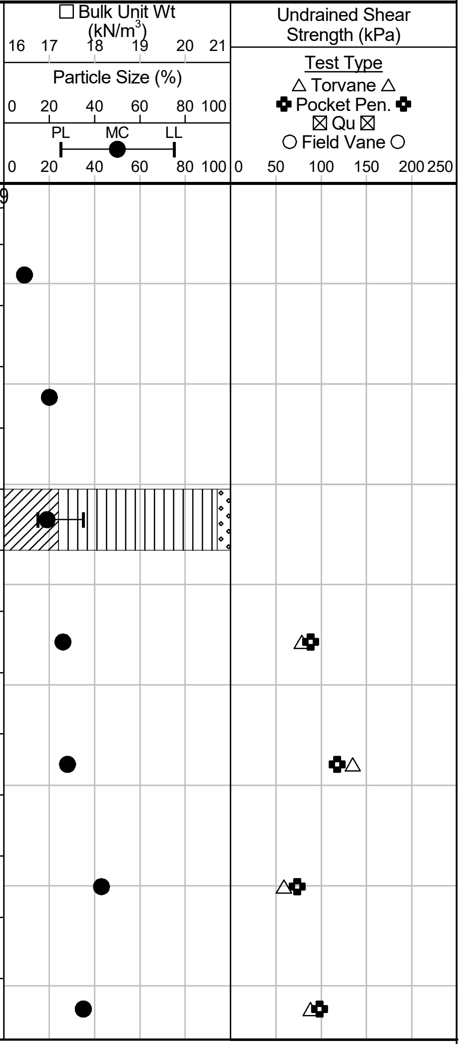
SAND (FILL) - some silt to silty, some gravel (<20 mm diam.), trace clay
- reddish brown
- dry to moist, compact to dense, poorly graded, rounded to sub-angular
- AASHTO: A-1-b (I)

SILT - trace to some clay, trace sand, trace organics
- light brown
- frozen, moist and soft when thawed
- low to intermediate plasticity
- AASHTO: A-4 (I)

- CLAY and SILT - trace sand, trace organics
- grey
- frozen, moist and soft to firm when thawed
- intermediate plasticity
- AASHTO: A-6 (17)

CLAY - silty
- grey
- frozen to 1.5 m depth, moist and stiff to very stiff when thawed
- high plasticity
- AASHTO: A-7-6 (I)

Sample Type	Sample Number
Core	PC22-19
Grab	G01
Grab	G02
Grab	G03
Grab	G04
Grab	G05
Grab	G06
Grab	G07



END OF TEST HOLE AT 2.1 m IN CLAY
1) No seepage or sloughing observed.
2) Test hole open to 2.1 m immediately after drilling.
3) Test hole backfilled with auger cuttings, granular fill and cold patch asphalt.
4) Test hole located 2 m East of West corner of #967 Waterford ave, Eastbound lane, 1.5 m North of South curb.

Logged By: Asad Dustmamatov
Reviewed By: Angela Fidler-Kliewer
Project Engineer: Nelson Ferreira

Sub-Surface Log

Test Hole TH22-02

1 of 1

Client: City of Winnipeg

Project Number: 1000-043-18

Project Name: Local Street Package 22-R-03 - Waterford Ave

Location: UTM N-5523075, E-632985

Contractor: Maple Leaf Drilling Ltd.

Ground Elevation: Top of Pavement

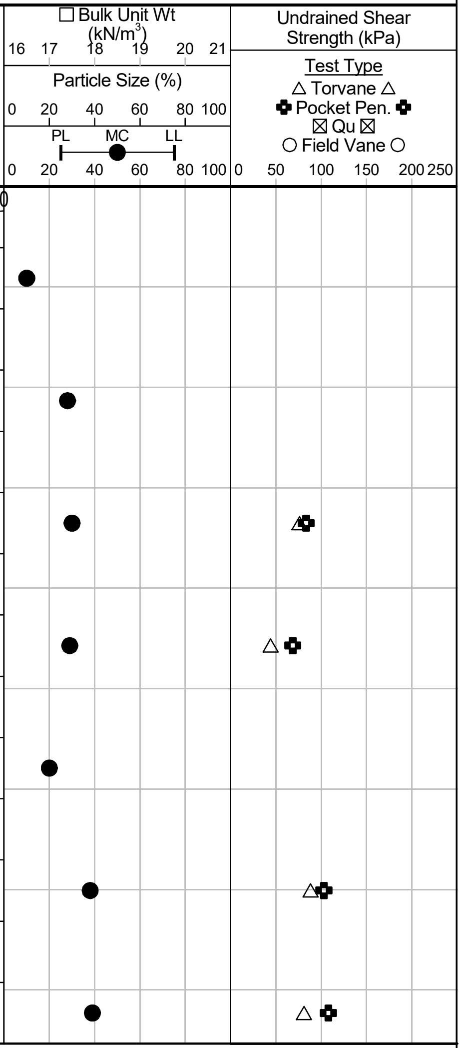
Method: 125mm Solid Stem Auger, B40 Mobile Truck Mount

Date Drilled: January 20, 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

Depth (m)	Soil Symbol	MATERIAL DESCRIPTION	Sample Type	Sample Number
		ASPHALT - 70 mm thick	Core (C)	PC22-20
		SAND (FILL) - some silt to silty, some gravel (<20 mm diam.), trace clay - reddish brown - dry to moist, compact to dense, poorly graded, rounded to sub-angular - AASHTO: A-1-b (I)	Grab (G)	G08
0.5		CLAY - silty, trace sand, trace organics - black - frozen, moist and firm to stiff when thawed - high plasticity - AASHTO: A-7-6 (I)	Grab (G)	G09
			Grab (G)	G10
1.0		- grey, no organics below 1.1 m	Grab (G)	G11
1.5		CLAY and SILT - trace sand - light brown - frozen to 1.5 m depth, moist and soft to firm when thawed - intermediate plasticity - AASHTO: A-6 (I)	Grab (G)	G12
		CLAY - silty - brown - moist, stiff to very stiff - high plasticity - AASHTO: A-7-6 (I)	Grab (G)	G13
2.0			Grab (G)	G14



END OF TEST HOLE AT 2.1 m IN CLAY
1) No seepage or sloughing observed.
2) Test hole open to 2.1 m immediately after drilling.
3) Test hole backfilled with auger cuttings, granular fill and cold patch asphalt.
4) Test hole located 2 m East of East corner of #941 Waterford ave, Westbound lane, 1.5 m South of North curb.

Logged By: Asad Dustmamatov **Reviewed By:** Angela Fidler-Kliewer **Project Engineer:** Nelson Ferreira

TREK GEOTECHNICAL

Sub-Surface Log

Test Hole TH22-03

Client: City of Winnipeg

Project Name: Local Street Package 22-R-03 - Waterford Ave

Contractor: Maple Leaf Drilling Ltd.

Method: 125mm Solid Stem Auger, B40 Mobile Truck Mount

Project Number: 1000-043-18

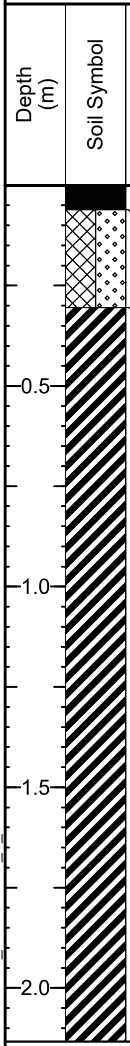
Location: UTM N-5523123, E-633079

Ground Elevation: Top of Pavement

Date Drilled: January 20, 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

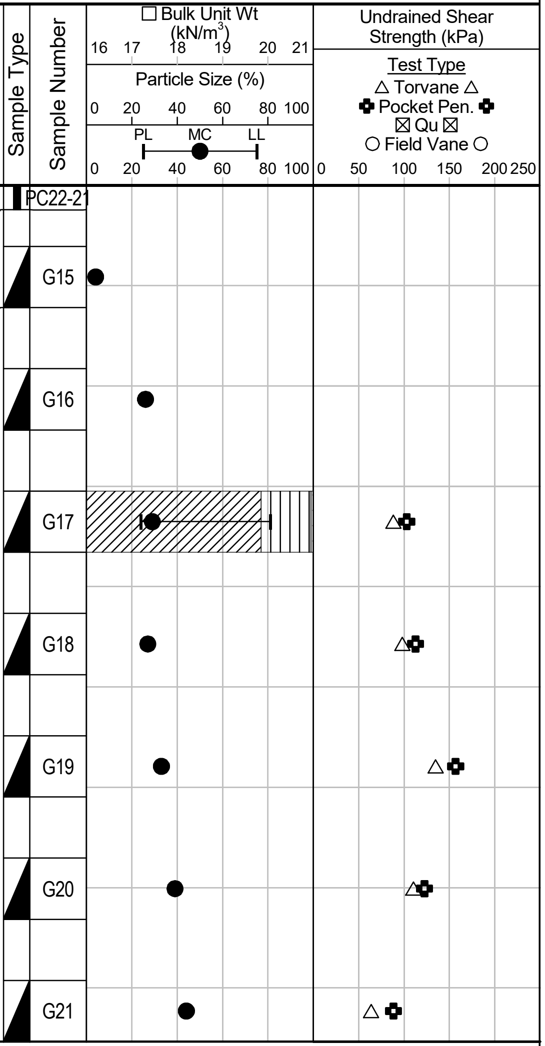


MATERIAL DESCRIPTION

ASPHALT - 60 mm thick

SAND (FILL) - some silt to silty, some gravel (<20 mm diam.), trace clay
- reddish brown
- dry to moist, compact to dense, poorly graded, rounded to sub-angular
- AASHTO: A-1-b (I)

CLAY - silty, trace sand
- grey
- frozen to 1.5 m depth, moist and stiff to very stiff when thawed
- high plasticity
- AASHTO: A-7-6 (64)



END OF TEST HOLE AT 2.1 m IN CLAY
1) No seepage or sloughing observed.
2) Test hole open to 2.1 m immediately after drilling.
3) Test hole backfilled with auger cuttings, granular fill and cold patch asphalt.
4) Test hole located 2 m East of West corner of #912 Waterford ave, Eastbound lane, 2 m North of South curb.

Logged By: Asad Dustmamatov

Reviewed By: Angela Fidler-Kliewer

Project Engineer: Nelson Ferreira

Sub-Surface Log

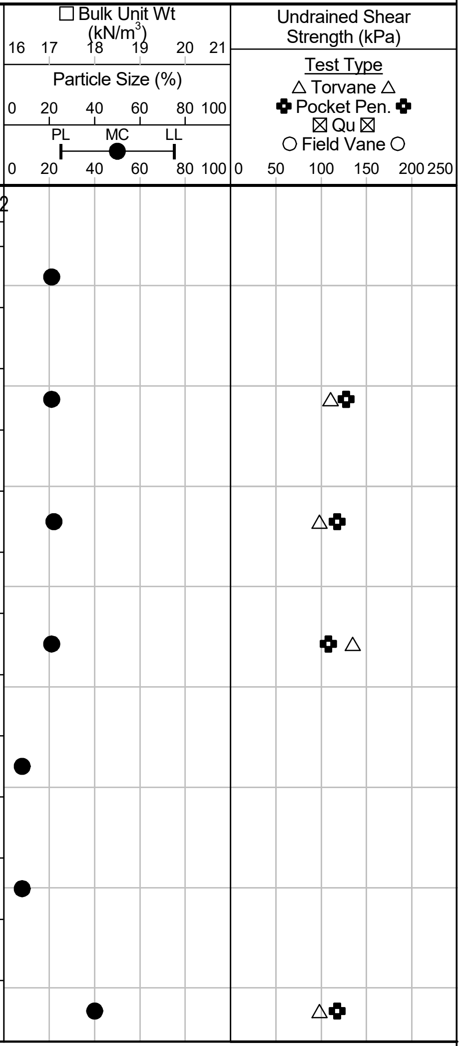
Test Hole TH22-04

Client: City of Winnipeg
Project Number: 1000-043-18
Project Name: Local Street Package 22-R-03 - Waterford Ave
Location: UTM N-5523184, E-633182
Contractor: Maple Leaf Drilling Ltd.
Ground Elevation: Top of Pavement
Method: 125mm Solid Stem Auger, B40 Mobile Truck Mount
Date Drilled: January 20, 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

Depth (m)	Soil Symbol	MATERIAL DESCRIPTION	Sample Type	Sample Number
	■	ASPHALT - 100 mm thick	▮	PC22-22
0.5 1.0	▨	CLAY - silty, trace sand - grey - frozen, moist and stiff to very stiff when thawed - high plasticity - AASHTO: A-7-6 (I)	◪ ◪ ◪ ◪	G22 G23 G24 G25
1.5	▥	SILT - trace to some clay, trace sand - light brown - frozen to 1.5 m depth, moist and soft when thawed - low to intermediate plasticity - AASHTO: A-4 (I)	◪ ◪	G26 G27
2.0	▨	CLAY - silty - grey - moist, stiff to very stiff - high plasticity - AASHTO: A-7-6 (I)	◪	G28



END OF TEST HOLE AT 2.1 m IN CLAY
1) No seepage or sloughing observed.
2) Test hole open to 2.1 m immediately after drilling.
3) Test hole backfilled with auger cuttings, granular fill and cold patch asphalt.
4) Test hole located 1 m West of East corner of #861 Waterford ave, Westbound lane, 1.5 m South of North curb.

Logged By: Asad Dustmamatov
Reviewed By: Angela Fidler-Kliewer
Project Engineer: Nelson Ferreira

TREK GEOTECHNICAL

Sub-Surface Log

Test Hole TH22-05

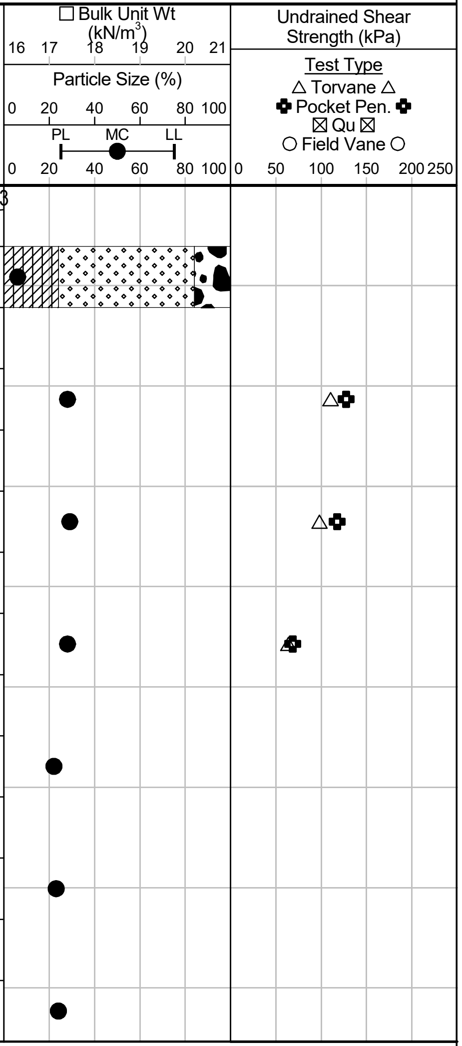
1 of 1

Client: City of Winnipeg
Project Name: Local Street Package 22-R-03 - Waterford Ave
Contractor: Maple Leaf Drilling Ltd.
Method: 125mm Solid Stem Auger, B40 Mobile Truck Mount
Project Number: 1000-043-18
Location: UTM N-5523231, E-633273
Ground Elevation: Top of Pavement
Date Drilled: January 20, 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

Depth (m)	MATERIAL DESCRIPTION	Sample Type	Sample Number
	ASPHALT - 70 mm thick	▮	PC22-23
	SAND (FILL) - some silt to silty, some gravel (<20 mm diam.), trace clay - reddish brown - dry to moist, compact to dense, poorly graded, rounded to sub-angular - AASHTO: A-1-b	◪	G29
0.5	CLAY - silty, trace sand - brown - frozen, moist and stiff to very stiff when thawed - high plasticity - AASHTO: A-7-6 (I)	◪	G30
		◪	G31
1.0		◪	G32
	SILT - trace to some clay, trace sand - light brown - frozen to 1.5 m depth, moist and soft when thawed - low to intermediate plasticity - AASHTO: A-4 (I)	◪	G33
1.5		◪	G34
2.0		◪	G35



END OF TEST HOLE AT 2.1 m IN SILT
1) No seepage or sloughing observed.
2) Test hole open to 2.1 m immediately after drilling.
3) Test hole backfilled with auger cuttings, granular fill and cold patch asphalt.
4) Test hole located 20 m East of East corner of #835 Waterford ave, Eastbound lane, 1.5 m North of South curb.

Logged By: Asad Dustmamatov **Reviewed By:** Angela Fidler-Kliewer **Project Engineer:** Nelson Ferreira

TREK GEOTECHNICAL

2022 Local Street Package - 22-R-03
Sub-Surface Investigation
Waterford Avenue: between Pembina Highway and Lyon Street

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 5523011 N, 632876 E Located 2 m East of West corner of #967 Waterford ave, Eastbound lane, 1.5 m North of South curb.	Asphalt	60	Concrete	-	Sand; AASHTO: A-1-b (I)	0.2	0.3	9							
						Silt; AASHTO: A-6 (17)	0.5	0.6	20							
						Silt; AASHTO: A-6 (17)	0.8	0.9	19	24	70	6	0	15	35	19
						Clay; AASHTO: A-7-6 (I)	1.1	1.2	26							
						Clay; AASHTO: A-7-6 (I)	1.4	1.5	28							
						Clay; AASHTO: A-7-6 (I)	1.7	1.8	43							
						Clay; AASHTO: A-7-6 (I)	2.0	2.1	35							
TH22-02	UTM : 14U 5523075 N, 632985 E Located 2 m East of East corner of #941 Waterford ave, Westbound lane, 1.5 m South of North curb.	Asphalt	70	Concrete	-	Sand; AASHTO: A-1-b (I)	0.2	0.3	10							
						Clay; AASHTO: A-7-6 (I)	0.5	0.6	28							
						Clay; AASHTO: A-7-6 (I)	0.8	0.9	30							
						Clay; AASHTO: A-7-6 (I)	1.1	1.2	29							
						Silt; AASHTO: A-6 (I)	1.4	1.5	20							
						Clay; AASHTO: A-7-6 (I)	1.7	1.8	38							
						Clay; AASHTO: A-7-6 (I)	2.0	2.1	39							
TH22-03	UTM : 14U 5523123 N, 633079 E Located 2 m East of West corner of #912 Waterford ave, Eastbound lane, 2 m North of South curb.	Asphalt	60	Concrete	-	Sand; AASHTO: A-1-B (I)	0.2	0.3	4							
						Clay; AASHTO: A-7-6 (64)	0.5	0.6	26							
						Clay; AASHTO: A-7-6 (64)	0.8	0.9	29	77	22	1	0	24	81	56
						Clay; AASHTO: A-7-6 (64)	1.1	1.2	27							
						Clay; AASHTO: A-7-6 (64)	1.4	1.5	33							
						Clay; AASHTO: A-7-6 (64)	1.7	1.8	39							
						Clay; AASHTO: A-7-6 (64)	2.0	2.1	44							

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

2022 Local Street Package - 22-R-03
Sub-Surface Investigation
Waterford Avenue: between Pembina Highway and Lyon Street

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
TH22-04	UTM : 14U 5523184 N, 633182 E Located 1 m West of East corner of #861 Waterford ave, Westbound lane, 1.5 m South of North curb.	Asphalt	100	Concrete	-	Clay; AASHTO: A-7-6 (I)	0.2	0.3	21							
						Clay; AASHTO: A-7-6 (I)	0.5	0.6	21							
						Clay; AASHTO: A-7-6 (I)	0.8	0.9	22							
						Clay; AASHTO: A-7-6 (I)	1.1	1.2	21							
						Silt; AASHTO: A-6 (I)	1.4	1.5	8							
						Silt; AASHTO: A-6 (I)	1.7	1.8	8							
						Clay; AASHTO: A-7-6 (I)	2.0	2.1	40							
TH22-05	UTM : 14U 5523231 N, 633273 E Located 20 m East of East corner of #835 Waterford ave, Eastbound lane, 1.5 m North of South curb.	Asphalt	70	Concrete	-	Sand; AASHTO: A-1-b	0.2	0.3	6	24.0		60.0	16.0			
						Clay; AASHTO: A-7-6 (I)	0.5	0.6	28							
						Clay; AASHTO: A-7-6 (I)	0.8	0.9	29							
						Clay; AASHTO: A-7-6 (I)	1.1	1.2	28							
						Silt; AASHTO: A-6 (I)	1.4	1.5	22							
						Silt; AASHTO: A-6 (I)	1.7	1.8	23							
						Silt; AASHTO: A-6 (I)	2.0	2.1	24							

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

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Moisture Content Report
ASTM D2216-10

Project No.	1000-043-18
Client	WSP Canada Inc
Project	Local Street Package 22-R-03
Sample Date	20-Jan-22
Test Date	24-Jan-22
Technician	AD

Test Hole	TH22-01	TH22-01	TH22-01	TH22-01	TH22-01	TH22-01
Depth (m)	0.2 - 0.3	0.5 - 0.6	0.8 - 0.9	1.1 - 1.2	1.4 - 1.5	1.7 - 1.8
Sample #	G01	G02	G03	G04	G05	G06
Tare ID	P24	F95	F54	P29	N115	E67
Mass of tare	8.7	8.3	8.6	8.4	8.6	9.1
Mass wet + tare	163.9	273.5	406.5	242.5	196.1	393.7
Mass dry + tare	151.3	228.6	343.6	194.1	154.7	277.6
Mass water	12.6	44.9	62.9	48.4	41.4	116.1
Mass dry soil	142.6	220.3	335.0	185.7	146.1	268.5
Moisture %	8.8%	20.4%	18.8%	26.1%	28.3%	43.2%

Test Hole	TH22-01	TH22-02	TH22-02	TH22-02	TH22-02	TH22-02
Depth (m)	2.0 - 2.1	0.2 - 0.3	0.5 - 0.6	0.8 - 0.9	1.1 - 1.2	1.4 - 1.5
Sample #	G07	G08	G09	G10	G11	G12
Tare ID	W83	C18	A28	AC03	AB94	AB47
Mass of tare	8.5	8.7	8.2	6.8	6.8	6.8
Mass wet + tare	323.4	248.0	139.9	252.7	337.4	286.2
Mass dry + tare	242.1	226.6	111.1	196.5	262.5	239.3
Mass water	81.3	21.4	28.8	56.2	74.9	46.9
Mass dry soil	233.6	217.9	102.9	189.7	255.7	232.5
Moisture %	34.8%	9.8%	28.0%	29.6%	29.3%	20.2%

Test Hole	TH22-02	TH22-02	TH22-03	TH22-03	TH22-03	TH22-03
Depth (m)	1.7 - 1.8	2.0 - 2.1	0.2 - 0.3	0.5 - 0.6	0.8 - 0.9	1.1 - 1.2
Sample #	G13	G14	G15	G16	G17	G18
Tare ID	H45	AB49	AB01	Z54	Z86	F87
Mass of tare	8.5	7.0	6.7	8.5	8.5	8.5
Mass wet + tare	285.1	337.2	433.1	282.5	421.6	298.8
Mass dry + tare	208.4	244.3	417.5	225.3	328.4	236.9
Mass water	76.7	92.9	15.6	57.2	93.2	61.9
Mass dry soil	199.9	237.3	410.8	216.8	319.9	228.4
Moisture %	38.4%	39.1%	3.8%	26.4%	29.1%	27.1%

Moisture Content Report
ASTM D2216-10

Project No. 1000-043-18
Client WSP Canada Inc
Project Local Street Package 22-R-03

Sample Date 20-Jan-22
Test Date 24-Jan-22
Technician AD

Test Hole	TH22-03	TH22-03	TH22-03	TH22-04	TH22-04	TH22-04
Depth (m)	1.4 - 1.5	1.7 - 1.8	2.0 - 2.1	0.2 - 0.3	0.5 - 0.6	0.8 - 0.9
Sample #	G19	G20	G21	G22	G23	G24
Tare ID	E83	AB27	F112	P08	W48	N72
Mass of tare	8.8	6.7	8.2	8.6	8.4	8.7
Mass wet + tare	286.1	341.7	359.8	243.4	313.9	251.3
Mass dry + tare	218.1	247.7	251.9	202.9	260.3	208.2
Mass water	68.0	94.0	107.9	40.5	53.6	43.1
Mass dry soil	209.3	241.0	243.7	194.3	251.9	199.5
Moisture %	32.5%	39.0%	44.3%	20.8%	21.3%	21.6%

Test Hole	TH22-04	TH22-04	TH22-04	TH22-04	TH22-05	TH22-05
Depth (m)	1.1 - 1.2	1.4 - 1.5	1.7 - 1.8	2.0 - 2.1	0.2 - 0.3	0.5 - 0.6
Sample #	G25	G26	G27	G28	G29	G30
Tare ID	W80	AB10	N07	E69	BBW	AB30
Mass of tare	8.5	6.8	8.6	8.7	242.1	6.8
Mass wet + tare	223.4	249.1	212.5	280.9	1160.9	342.3
Mass dry + tare	185.7	231.9	196.9	203.8	1111.9	268.7
Mass water	37.7	17.2	15.6	77.1	49.0	73.6
Mass dry soil	177.2	225.1	188.3	195.1	869.8	261.9
Moisture %	21.3%	7.6%	8.3%	39.5%	5.6%	28.1%

Test Hole	TH22-05	TH22-05	TH22-05	TH22-05	TH22-05	
Depth (m)	0.8 - 0.9	1.1 - 1.2	1.4 - 1.5	1.7 - 1.8	2.0 - 2.1	
Sample #	G31	G32	G33	G34	G35	
Tare ID	D12	E33	A8	W87	N36	
Mass of tare	8.4	8.5	8.1	8.4	8.4	
Mass wet + tare	325.2	371.6	214.5	388.8	370.3	
Mass dry + tare	255.0	293.0	177.2	318.8	301.4	
Mass water	70.2	78.6	37.3	70.0	68.9	
Mass dry soil	246.6	284.5	169.1	310.4	293.0	
Moisture %	28.5%	27.6%	22.1%	22.6%	23.5%	

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Atterberg Limits
ASTM D4318-10e1

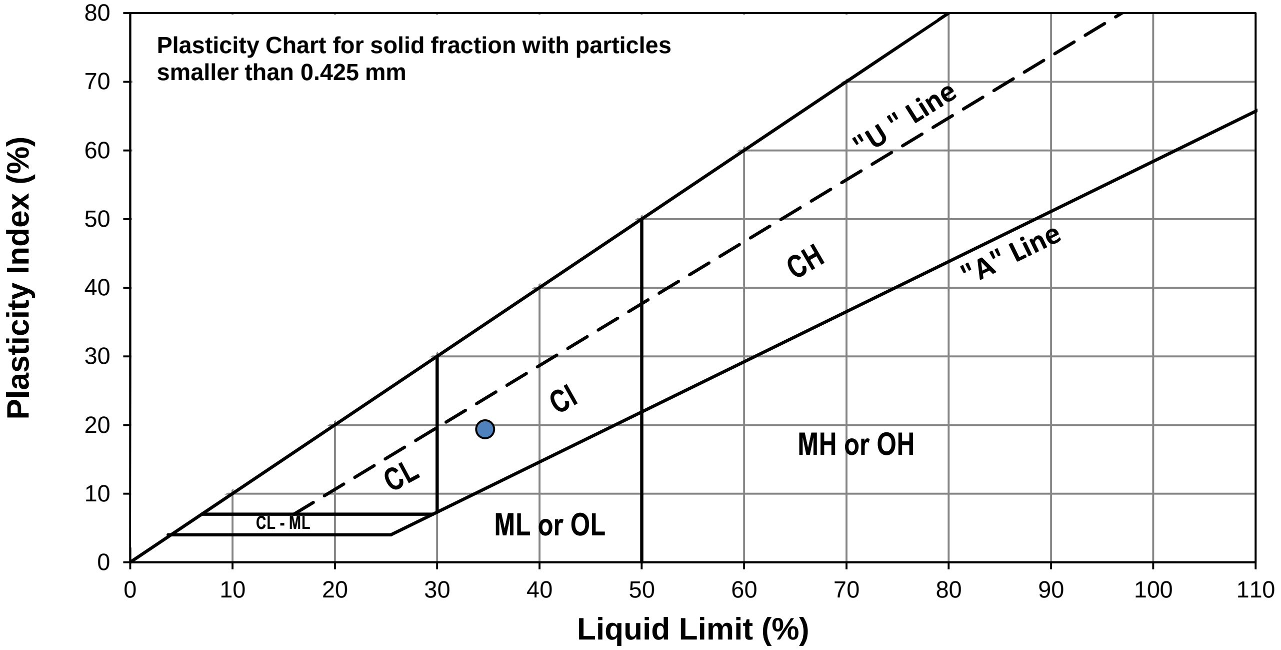
Project No. 1000-043-18
Client City of Winnipeg
Project Local Street Package 22-R-03

Test Hole TH22-01
Sample # G03
Depth (m) 0.8 - 0.9
Sample Date 20-Jan-22
Test Date 26-Jan-22
Technician DS

Liquid Limit	35
Plastic Limit	15
Plasticity Index	19

Liquid Limit

Trial #	1	2	3		
Number of Blows (N)	17	23	30		
Mass Tare (g)	14.055	14.212	14.045		
Mass Wet Soil + Tare (g)	26.869	27.073	27.966		
Mass Dry Soil + Tare (g)	23.436	23.727	24.453		
Mass Water (g)	3.433	3.346	3.513		
Mass Dry Soil (g)	9.381	9.515	10.408		
Moisture Content (%)	36.595	35.166	33.753		



Plastic Limit

Trial #	1	2	3	4	5
Mass Tare (g)	13.975	13.933			
Mass Wet Soil + Tare (g)	21.012	22.072			
Mass Dry Soil + Tare (g)	20.080	20.985			
Mass Water (g)	0.932	1.087			
Mass Dry Soil (g)	6.105	7.052			
Moisture Content (%)	15.266	15.414			

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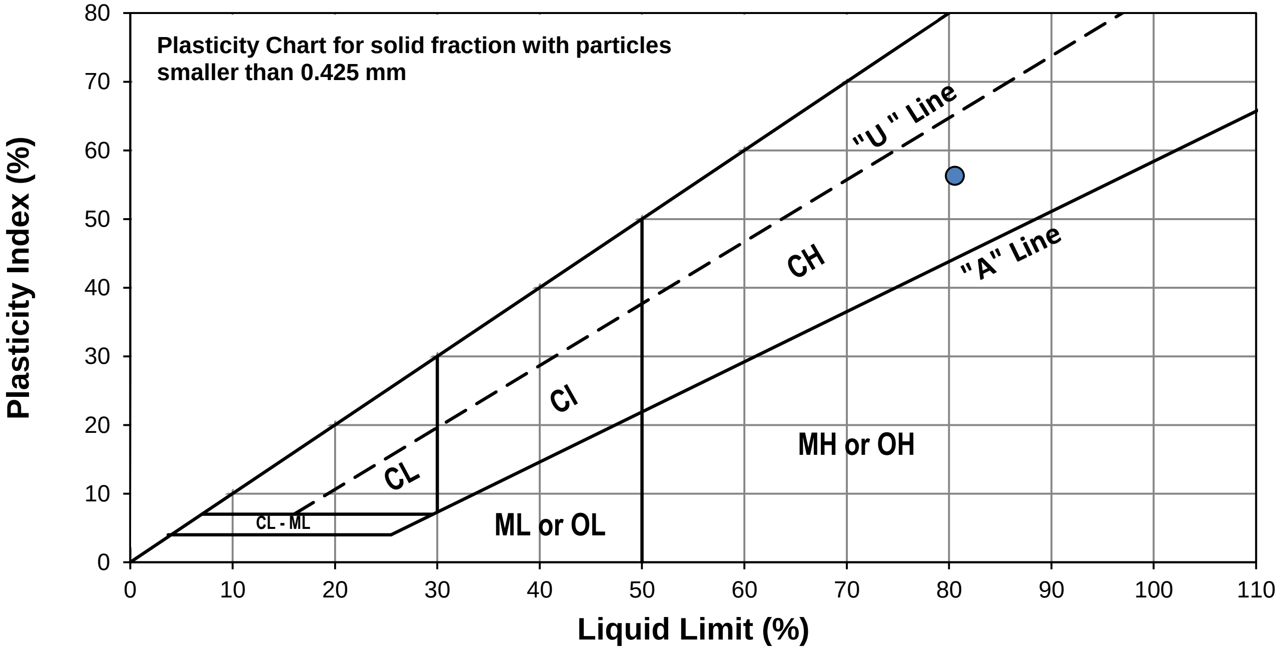
Atterberg Limits
ASTM D4318-10e1

Project No.	1000-043-18
Client	City of Winnipeg
Project	Local Street Package 22-R-03
Test Hole	TH22-03
Sample #	G17
Depth (m)	0.8 - 0.9
Sample Date	20-Jan-22
Test Date	26-Jan-22
Technician	DS

Liquid Limit	81
Plastic Limit	24
Plasticity Index	56

Liquid Limit

Trial #	1	2	3		
Number of Blows (N)	18	22	32		
Mass Tare (g)	13.991	14.071	14.104		
Mass Wet Soil + Tare (g)	23.614	25.180	23.661		
Mass Dry Soil + Tare (g)	19.252	20.191	19.449		
Mass Water (g)	4.362	4.989	4.212		
Mass Dry Soil (g)	5.261	6.120	5.345		
Moisture Content (%)	82.912	81.520	78.803		



Plastic Limit

Trial #	1	2	3	4	5
Mass Tare (g)	14.068	13.881			
Mass Wet Soil + Tare (g)	20.969	21.678			
Mass Dry Soil + Tare (g)	19.610	20.165			
Mass Water (g)	1.359	1.513			
Mass Dry Soil (g)	5.542	6.284			
Moisture Content (%)	24.522	24.077			

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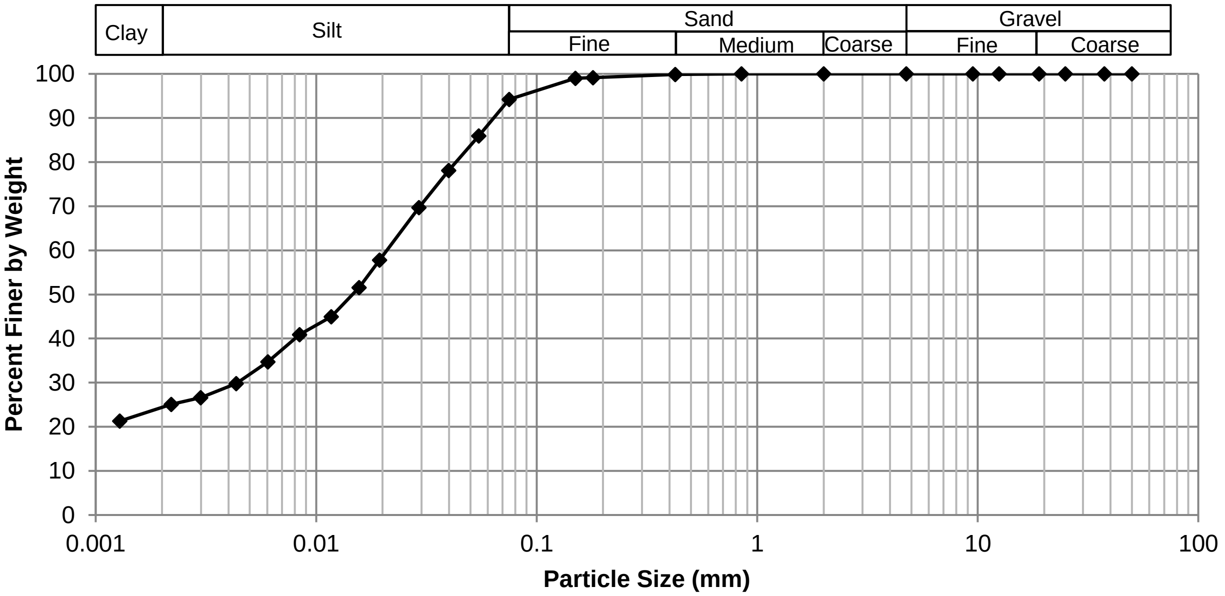
Grain Size Analysis (Hydrometer Method)
AASHTO T 88

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

Project No.	1000-043-18
Client	WSP Canada Inc
Project	Local Street Package 22-R-03
Test Hole	TH22-01
Sample #	G03
Depth (m)	0.8 - 0.9
Sample Date	20-Jan-22
Test Date	25-Jan-22
Technician	AD

Gravel	0.0%
Sand	5.8%
Silt	70.0%
Clay	24.3%

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	94.23
37.5	100.00	2.00	100.00	0.0545	85.95
25.0	100.00	0.850	100.00	0.0399	78.13
19.0	100.00	0.425	99.88	0.0293	69.69
12.5	100.00	0.180	99.17	0.0194	57.81
9.50	100.00	0.150	98.98	0.0157	51.56
4.75	100.00	0.075	94.23	0.0117	44.99
				0.0084	40.93
				0.0060	34.73
				0.0043	29.79
				0.0030	26.60
				0.0022	25.10
				0.0013	21.29

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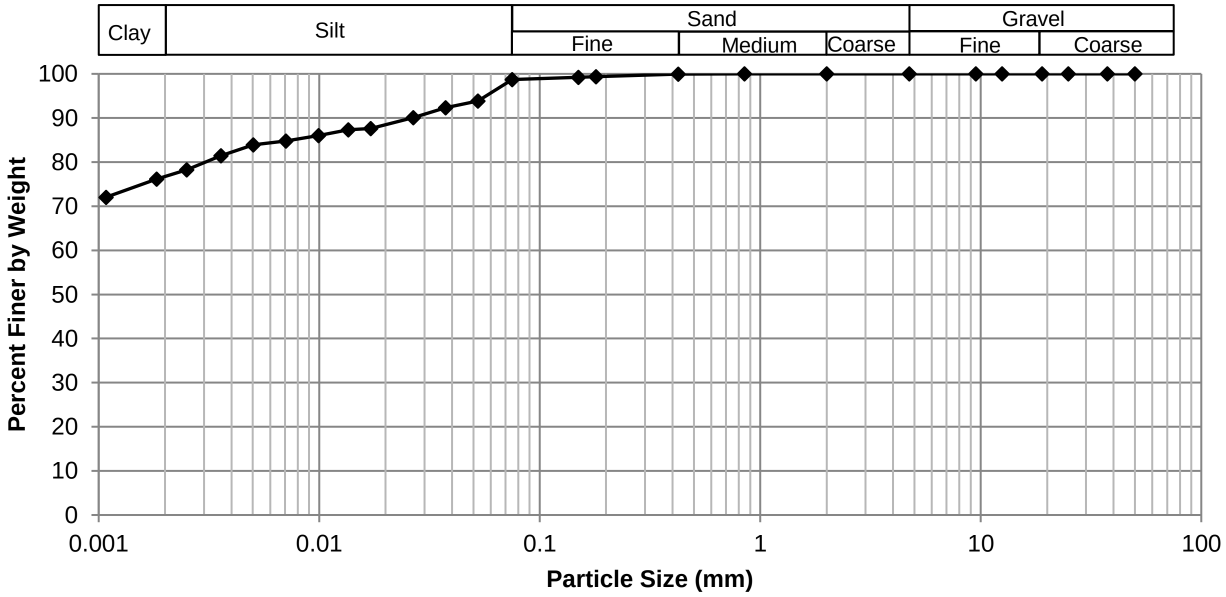
Grain Size Analysis (Hydrometer Method)
AASHTO T 88

Project No.	1000-043-18
Client	WSP Canada Inc
Project	Local Street Package 22-R-03
Test Hole	TH22-03
Sample #	G17
Depth (m)	0.8 - 0.9
Sample Date	20-Jan-22
Test Date	25-Jan-22
Technician	AD

Gravel	0.0%
Sand	1.3%
Silt	22.0%
Clay	76.7%

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	98.71
37.5	100.00	2.00	100.00	0.0525	93.86
25.0	100.00	0.850	100.00	0.0374	92.30
19.0	100.00	0.425	99.92	0.0267	90.11
12.5	100.00	0.180	99.34	0.0171	87.61
9.50	100.00	0.150	99.23	0.0135	87.30
4.75	100.00	0.075	98.71	0.0100	86.05
				0.0071	84.79
				0.0050	83.92
				0.0036	81.47
				0.0025	78.29
				0.0018	76.16
				0.0011	72.03

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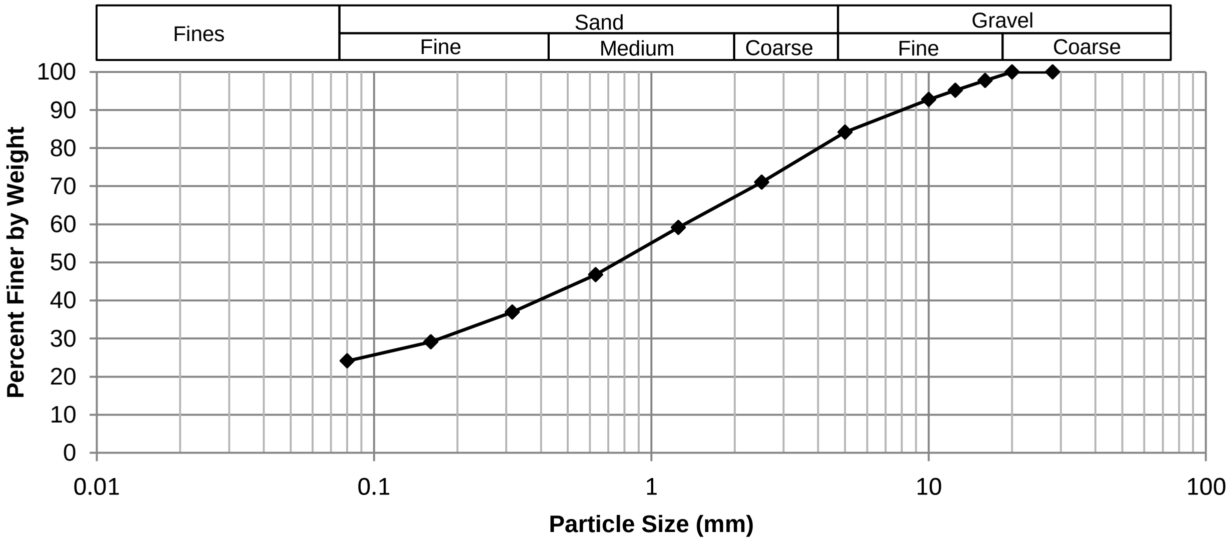
Grain Size Analysis (Sieve Method)
ASTM C136-06

Project No.	1000-043-18
Client	WSP Canada Inc
Project	Local Street Package 22-R-03

Test Hole	TH22-05
Sample #	G29
Depth	0.2-0.3
Date Sampled	20-Jan-22
Date Tested	25-Jan-22
Technician	AD

Total Weight (g)	869.8
Gravel %	15.8
Sand %	60.1
Fines %	24.1

Particle Size Distribution Curve



Sieve Opening (mm)	Percent Passing	Specification (Min-Max)
20.0	100	-
16.0	98	-
12.5	95	-
10.0	93	-
5.0	84	-
2.50	71	-
1.25	59	-
0.630	47	-
0.315	37	-
0.160	29	-
0.080	24	-

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Standard Proctor Compaction Test

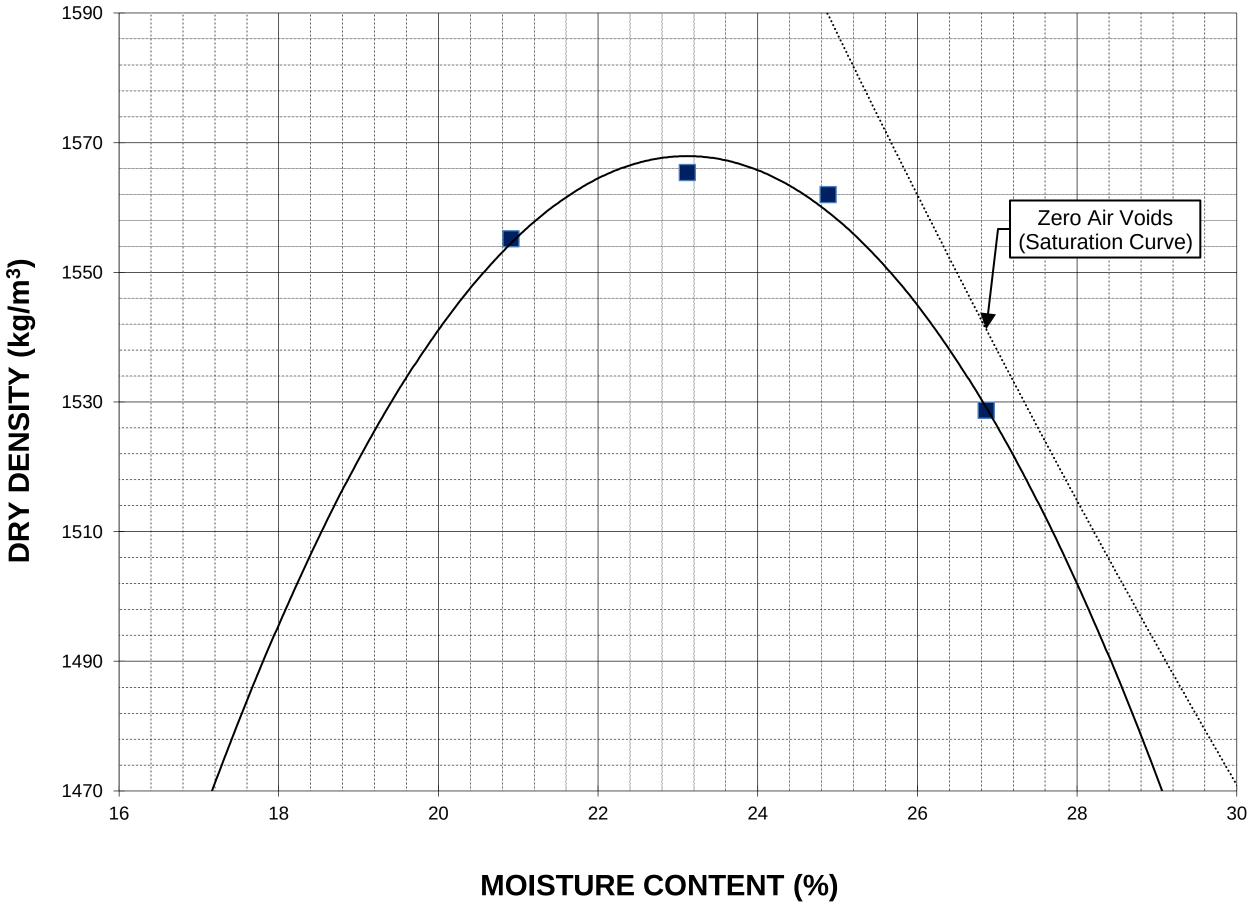
ASTM D698-12e2

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

Project No.	1000-043-18
Client	WSP Canada Inc
Project	Local Street Package 22-R-03
Sample #	R22-014
Source	TH21-02, 03, 04 and 05
Material	Clay Sub-grade Material
Sample Date	20-Jan-22
Test Date	24-Jan-22
Technician	AD

Maximum Dry Density (kg/m3)	1568
Optimum Moisture (%)	23.1

Trial Number	1	2	3	4	
Wet Density (kg/m^3)	1880	1927	1951	1939	
Dry Density (kg/m^3)	1555	1565	1562	1529	
Moisture Content (%)	20.9	23.1	24.9	26.9	



California Bearing Ratio Test Data Sheet

ASTM D1883-16

Project No.	1000-043-18	**Source**	TH21-02,03,04 and 05
Client	WSP Group Canada Inc.	**Material**	Clay
Project	Local Streets Package 22-R-03	**Sample Date**	2022-01-20
Sample #	R22-014 (Waterford Ave)	**Test Date**	2021-01-27
		Technician	AD

Proctor Results (ASTM D698)

Maximum Dry Density	1568	kg/m3
Optimum Moisture Content	23.1	%
Material Retained on 19 mm Sieve	0.0	%

CBR Sample Compaction

Dry Density	1477	kg/m3
Initial Moisture Content	24.3	%
Relative Density	94.2	% SPMDD

Soaking Results

Surcharge	4.54	kg
Swell	1.3	%
Moisture Content in top 25 mm	32.0	%
Immersion Period	96	h

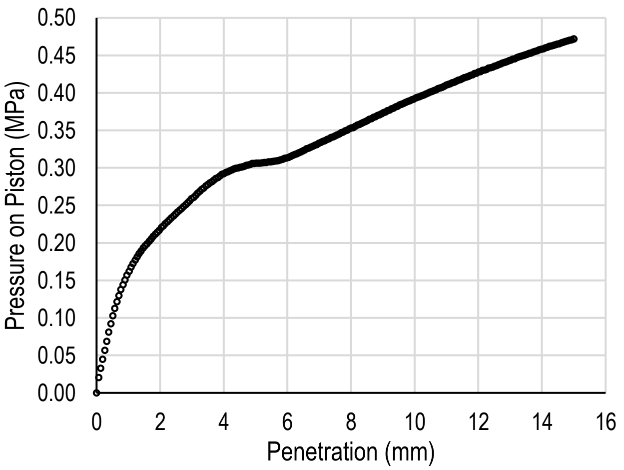
CBR Results

CBR at 2.54 mm	3.5	%
CBR at 5.08 mm	3.0	%
Zero Correction	0	mm

Test Data

Penetration (mm)	Measured Pressure (MPa)	Corrected Pressure (MPa)
0.64	0.12	0.12
1.27	0.18	0.18
1.91	0.21	0.21
2.54	0.24	0.24
3.18	0.27	0.27
3.81	0.29	0.29
4.45	0.30	0.30
5.08	0.31	0.31
7.62	0.35	0.35
10.16	0.40	0.40
12.70	0.44	0.44

Load/Penetration Curve



Comments:

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Project 1000-043-18
Location WATERFORD AVE (22-R-03)
Hole No. TH22-01 Sample No. PC 19
Depth 60 MM
Technician AD Date JAN 19, 2022

Photo 1: Pavement Core Sample at Test Hole TH22-01

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Project 1000-043-18
Location WATERFORD AVE (22-R-03)
Hole No. TH22-02 Sample No. PC 20
Depth 70 mm
Technician AD Date JAN 19, 2022

Photo 2: Pavement Core Sample at Test Hole TH22-02

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Project 1000-043-18
Location WATERFORD AVE (22-R-03)
Hole No. TH22-03 Sample No. PC 21
Depth 60 mm
Technician AD Date JAN 19, 2022

Photo 3: Pavement Core Sample at Test Hole TH22-03

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Project 1000-043-18
Location WATERFORD AVE (22-R-03)
Hole No. TH22-04 Sample No. PC 22
Depth 100 MM
Technician AD Date JAN 19, 2022

Photo 4: Pavement Core Sample at Test Hole TH22-04

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Project 1000-043-18
Location WATERFORD AVE (22-R-03)
Hole No. TH22-05 Sample No. PC23
Depth 70 mm
Technician AD Date JAN 19, 2022

Photo 5: Pavement Core Sample at Test Hole TH22-05

Appendix B

Summary Table, Pavement Core Photos, and Summary of Pavement Compressive Strength – Gerard Street

2022 Local Street Package - 22-R-03

Gerard Street: River Avenue to end

Pavement Core No.	Pavement Core Location	Pavement Surface		Pavement Structure Material		
		Type	Thickness (mm)	Type	Thickness (mm)	Corrected Compressive Strength (Mpa)
PC22-18	UTM : 5526760 m N, 633118 m E; Located in front of #102 Gerard St, Southbound lane, 2 m East of West curb.	Asphalt	-	Concrete	150	75.91
PC22-24	UTM : 5526790 m N, 633101 m E; Located 14 m South of Gerard St and River Ave intersection, Northbound lane, 1.5 m West of East curb.	Asphalt	-	Concrete	170	87.24
PC22-25	UTM : 5526700 m N, 633151 m E; Located 137 m South of Gerard St and River Ave intersection, Northbound lane, 1.5 m West of East curb.	Asphalt	-	Concrete	220	75.48

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Project 1000-043-18
Location GERARD St (22-R-03)
Hole No. PC22-18 Sample No. PC 18
Depth 150 mm
Technician AD Date JAN 17, 2022

Photo 1: Pavement Core Sample at PC22-18

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Project 1000-043-18
Location GERARD St (22-R-03)
Hole No. PC22-24 Sample No. PC24
Depth 170 mm
Technician NM Date JAN 20, 2022

Photo 2: Pavement Core Sample at PC22-24

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Project 1000-043-18

Location GERARD St (22-R-03)

Hole No. PC22-25 Sample No. PC25

Depth 220 mm

Technician NM Date JAN 20, 2022

Photo 3: Pavement Core Sample at PC22-25

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Concrete Core Compressive Strength Report

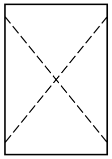
CSA A23.2-14C

Project No. 1000-043-18
Date January 31, 2022
Project 2022 Local Street Package - 22-R-03
Technician AD
Client WSP Group Canada Inc.

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}
Gerard Street	PC18	2022-01-17	2022-01-29	-	95	144	Soaked 48 h	66.81	75.91	1	0.98	1.00	1.09	1.06	1.00
Gerard Street	PC24	2022-01-20	2022-01-29	-	95	152	Soaked 48 h	74.51	92.30	1	0.99	1.00	1.09	1.06	1.08
Gerard Street	PC25	2022-01-20	2022-01-29	-	95	185	Soaked 48 h	65.07	75.48	1	1.00	1.00	1.09	1.06	1.00

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): $f_c = f_{conc}F_{l/d}F_{dia}F_{mc}F_DF_{reinf}$



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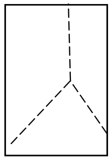

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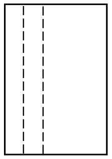

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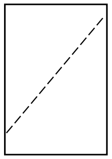

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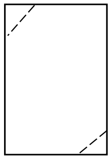

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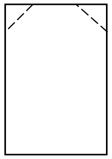

Type 6

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

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.

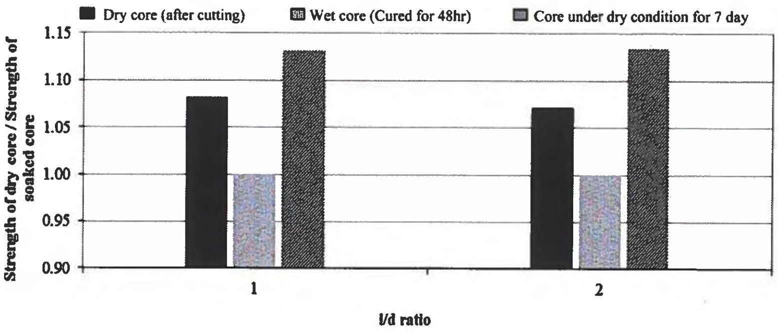

Figure 20 Effect of core moisture condition on core strength for different aspect ratios (l/d).

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

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

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.

Appendix C

Summary Table, Pavement Core Photos – Oakenwald Avenue

2022 Local Street Package - 22-R-03

Oakenwald Avenue: between Wicklow Street and Point Road

Pavement Core No.	Pavement Core Location	Pavement Surface		Pavement Structure Material		
		Type	Thickness (mm)	Type	Thickness (mm)	Corrected Compressive Strength (Mpa)
PC22-10	UTM : 5522932 m N, 633308 m E; Located in front of #761 Oakenwald Ave, Eastbound lane, 1.5 m North of South curb.	Asphalt	80	Concrete	-	-
PC22-11	UTM : 5522965 m N, 633363 m E; Located 3 m West of Ruttan Bay and Oakenwald Ave intersection, Westbound lane, 1.5 m South of North curb.	Asphalt	80	Concrete	-	-
PC22-12	UTM : 5522991 m N, 633418 m E; Located in front of #727 Oakenwald Ave, Eastbound lane, 1.8 m North of South curb.	Asphalt	130	Concrete	-	-
PC22-13	UTM : 5523037 m N, 633492 m E; Located 2 m East of East corner of #705 Oakenwald Ave, Westbound lane, 1.5 m South of North curb.	Asphalt	90	Concrete	-	-
PC22-14	UTM : 5523066 m N, 633547 m E; Located 14 m East of Lyon St and Oakenward Ave intersection, Eastbound lane, 1.8 m North of South curb.	Asphalt	50	Concrete	-	-
PC22-15	UTM : 5523096 m N, 633602 m E; Located in front of #671 Oakenward Ave, Westbound lane, 2 m South of North curb.	Asphalt	130	Concrete	-	-
PC22-16	UTM : 5523129 m N, 633664 m E; Located 1 m East of West corner of #661 Oakenwald Ave, Eastbound lane, 1.5 m North of South curb.	Asphalt	120	Concrete	-	-
PC22-17	UTM : 5523164 m N, 633721 m E; Located 25 m West of Point Rd and Oakenwald Ave intersection, Westbound lane, 1.5 m South of North curb.	Asphalt	120	Concrete	-	-

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Project 1000-043-18
Location OAKENWALD AVE
Hole No. PC22-10 Sample No. PC10
Depth 80 mm
Technician AD Date JAN 17, 2022

Photo 1: Pavement Core Sample at PC22-10

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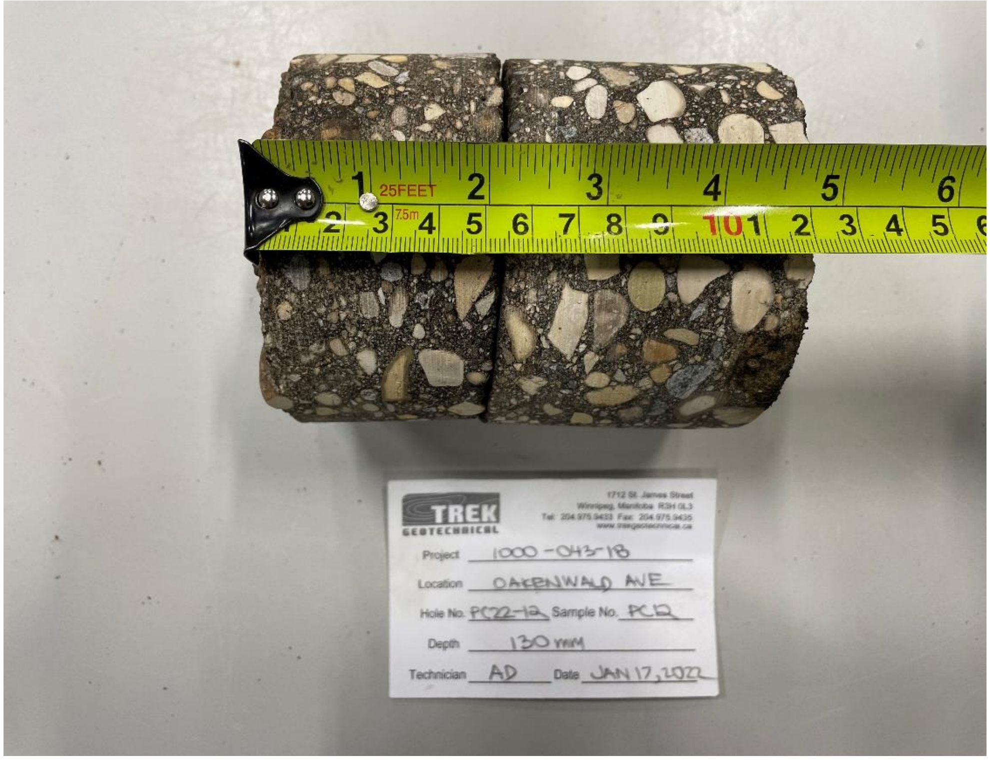
Project 1000-043-18
Location OAKENWALD AVE
Hole No. PC22-11 Sample No. PC11
Depth 80 mm
Technician AD Date JAN 17, 2022

Photo 2: Pavement Core Sample at PC22-11



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Project 1000-043-18
Location OAKENWALD AVE
Hole No. PC22-12 Sample No. PC12
Depth 130 MM
Technician AD Date JAN 17, 2022

Photo 3: Pavement Core Sample at PC22-12

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Project 1000-043-18
Location OAKENWALD AVE
Hole No. PC22-13 Sample No. PC13
Depth 90MM
Technician AD Date JAN 17, 2022

Photo 4: Pavement Core Sample at PC22-13

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Project 1000-043-18
Location OAKENWALD AVE
Hole No. PC22-14 Sample No. PC14
Depth 50 mm
Technician AD Date JAN 17, 2022

Photo 5: Pavement Core Sample at PC22-14

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Project 1000-043-18
Location OAKENWALD AVE
Hole No. PC22-15 Sample No. PC15
Depth 130mm
Technician AD Date JAN 17, 2022

Photo 6: Pavement Core Sample at PC22-15

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Project 1000-043-18
Location OAKENWALD AVE
Hole No. PC22-16 Sample No. PC16
Depth 120 mm
Technician AD Date JAN 17, 2022

Photo 7: Pavement Core Sample at PC22-16

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Project 1000-043-18
Location OAKENWALD AVE
Hole No. PC22-17 Sample No. PC17
Depth 120 MM
Technician AD Date JAN 17, 2022

Photo 8: Pavement Core Sample at PC22-17

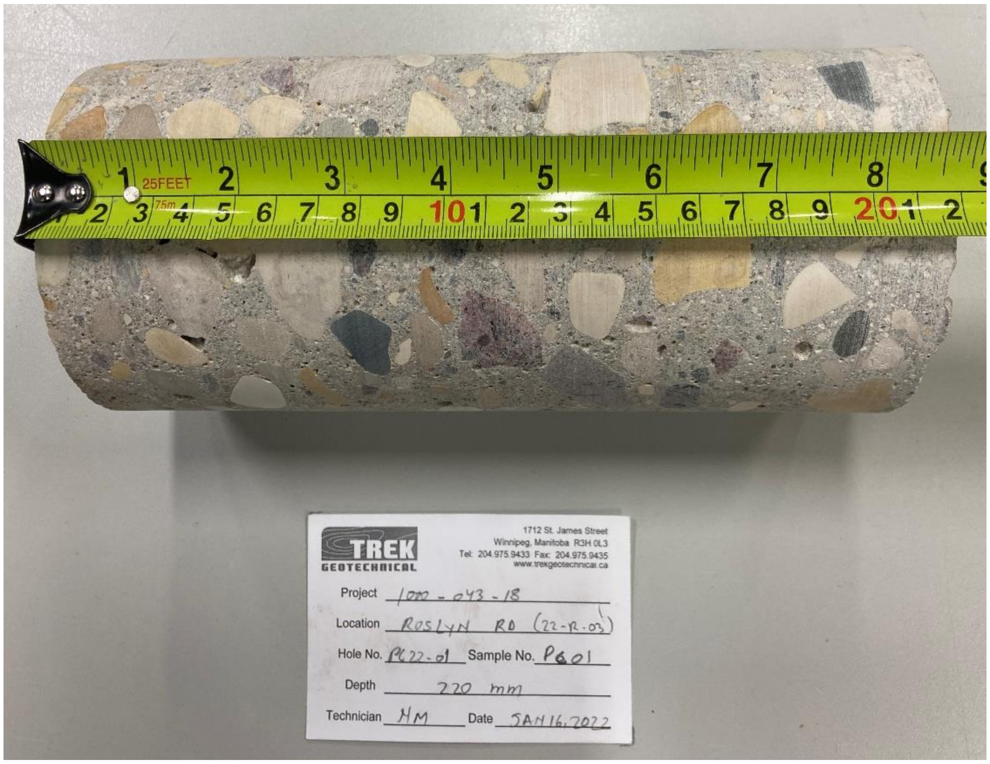
Appendix D

Summary Table, Pavement Core Photos, and Summary of Pavement Compressive Strength – Roslyn Road

2022 Local Street Package - 22-R-03

Roslyn Road: between Osbourne Street and Roslyn Crescent

Pavement Core No.	Pavement Core Location	Pavement Surface		Pavement Structure Material		
		Type	Thickness (mm)	Type	Thickness (mm)	Corrected Compressive Strength (Mpa)
PC22-01	UTM : 5526939 m N, 633086 m E; Located 24 m West of Osbourne St and Roslyn Rd intersection, Westbound lane, 1.5 m South of North curb.	Asphalt	-	Concrete	220	76.42
PC22-02	UTM : 5526924 m N, 632988 m E; Located 7 m East of Roslyn Rd and Evergreen Pl intersection, Eastbound lane, 1.5 m North of South curb.	Asphalt	-	Concrete	220	83.10
PC22-03	UTM : 5526943 m N, 632934 m E; Located 42 m West of Roslyn Rd and Evergreen Pl intersection, Westbound lane, 1.5 m South of North curb.	Asphalt	-	Concrete	210	71.88
PC22-04	UTM : 5526908 m N, 632882 m E; Located 4 m East of Roslyn Cres and Roslyn Rd intersection, Eastbound lane, 2 m North of South curb.	Asphalt	80	Concrete	220	-



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Project 1000-043-18

Location ROSLYN RD (22-R-03)

Hole No. PC22-01 Sample No. PC01

Depth 220 mm

Technician HM Date JAN 16, 2022

Photo 1: Pavement Core Sample at PC22-01

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Project 1000-043-18

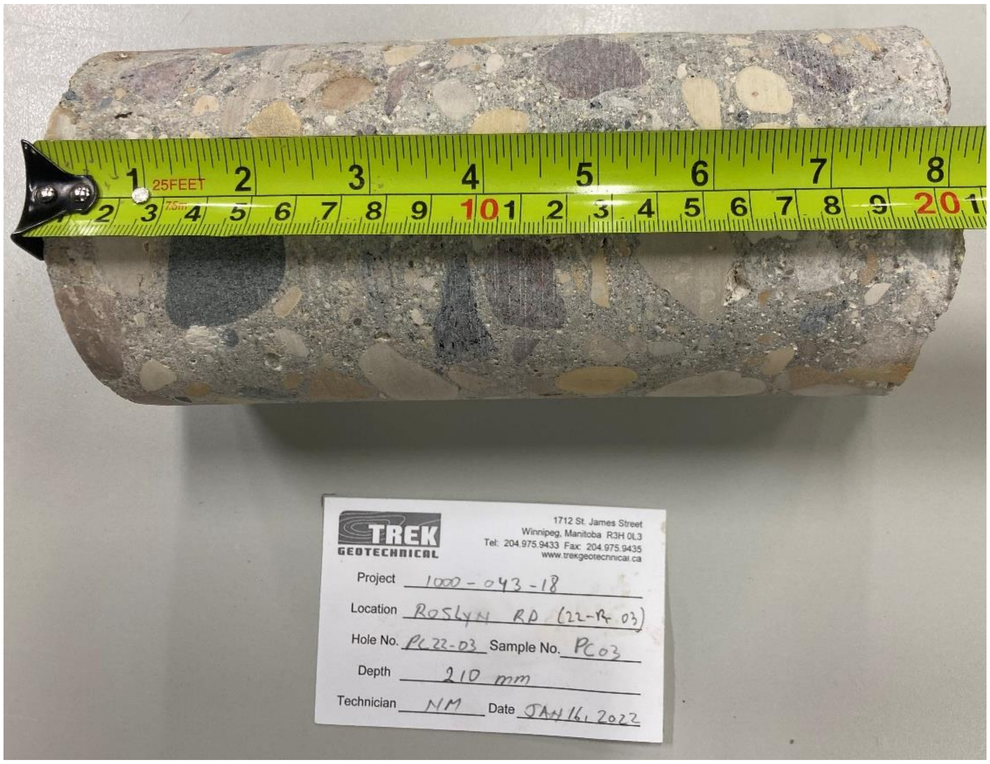
Location ROSLYN RD (22-R-03)

Hole No. PC22-02 Sample No. PC02

Depth 290 mm

Technician NM Date JAN 16, 2022

Photo 2: Pavement Core Sample at PC22-02



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Project 1000 - 043 - 18

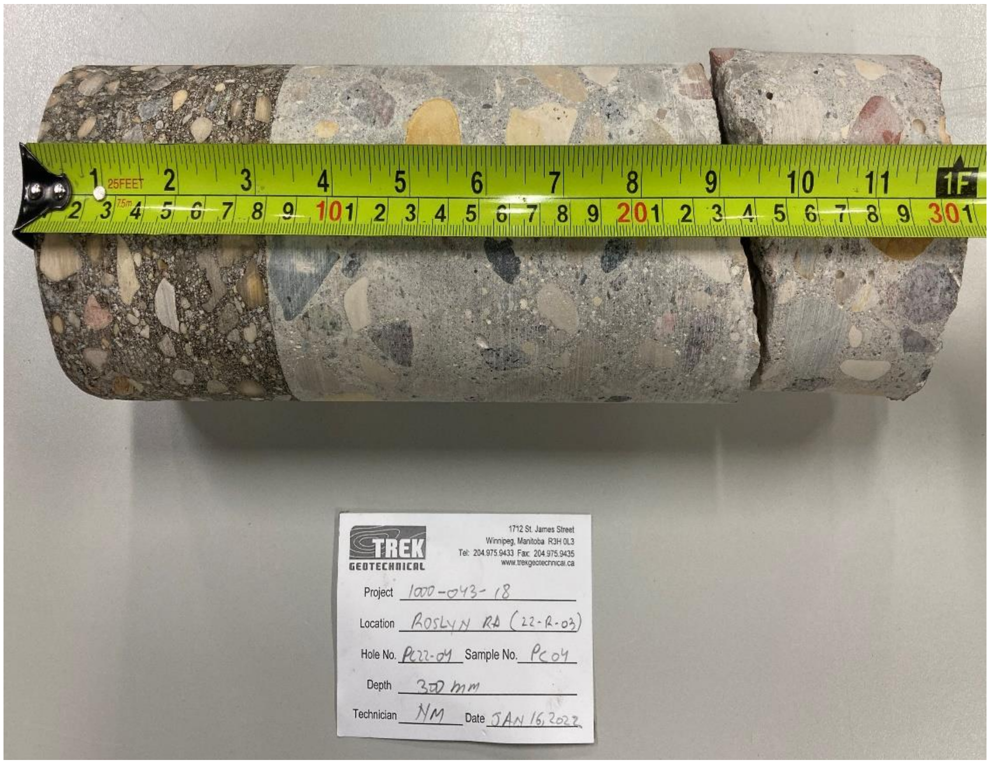
Location ROSLYN RD (22-R 03)

Hole No. PC22-03 Sample No. PC03

Depth 210 mm

Technician NM Date JAN 16, 2022

Photo 03: Pavement Core Sample at PC22-03



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Project 1000-043- 18

Location ROSLYN RD (22-R-03)

Hole No. PC22-04 Sample No. PC04

Depth 300 mm

Technician NM Date JAN 16, 2022

Photo 04: Pavement Core Sample at PC22-04

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Concrete Core Compressive Strength Report

CSA A23.2-14C

Project No. 1000-043-18

Date January 31, 2022

Project 2022 Local Street Package - 22-R-03

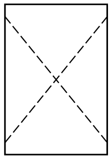
Technician AD

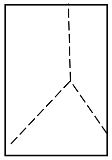
Client WSP Group Canada Inc.

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}
Roslyn Road	PC01	2022-01-16	2022-01-29	-	95	181	Soaked 48 h	65.92	76.42	1	1.00	1.00	1.09	1.06	1.00
Roslyn Road	PC02	2022-01-16	2022-01-29	-	95	155	Soaked 48 h	72.46	83.10	1	0.99	1.00	1.09	1.06	1.00
Roslyn Road	PC03	2022-01-16	2022-01-29	-	95	185	Soaked 48 h	61.97	71.88	1	1.00	1.00	1.09	1.06	1.00

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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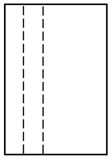
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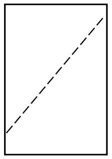
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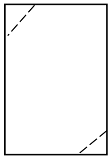
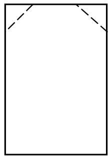

Type 5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Reviewed by (print): Angela Fidler-Kliewer,C.Tech. Signature: Angela Fidler-Kliewer

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:

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

- 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

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

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.

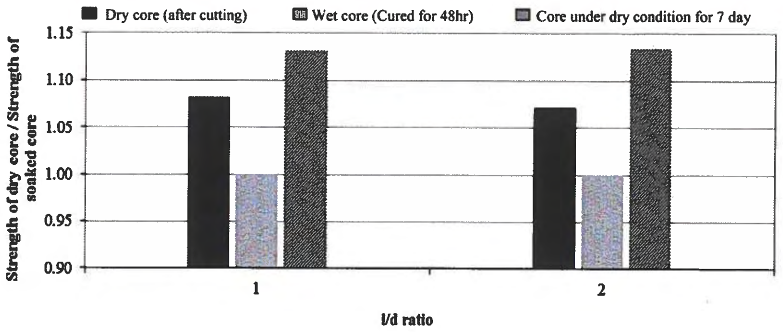


Figure 20 Effect of core moisture condition on core strength for different aspect ratios (l/d).

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

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

• Freinf

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.

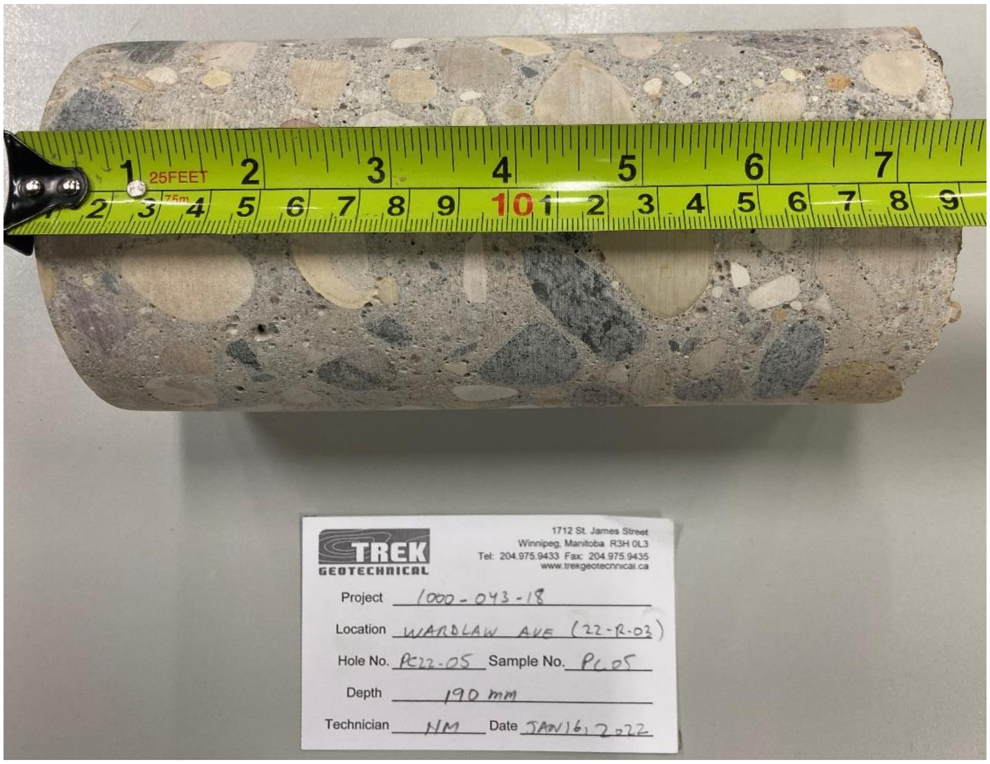
Appendix E

Summary Table, Pavement Core Photos, and Summary of Pavement Compressive Strength – Wardlaw Avenue

2022 Local Street Package - 22-R-03

Wardlaw Avenue: between Osbourne Street and Donald Street

Pavement Core No.	Pavement Core Location	Pavement Surface		Pavement Structure Material		
		Type	Thickness (mm)	Type	Thickness (mm)	Corrected Compressive Strength (Mpa)
PC22-05	UTM : 5526628 m N, 633386 m E; Located 39 m East of Osbourne St and Wardlaw Ave intersection, Westbound lane, 2 m South of North curb.	Asphalt	-	Concrete	190	72.11
PC22-06	UTM : 5526646 m N, 633423 m E; Located 86 m East of Osbourne St and Wardlaw Ave intersection, Eastbound lane, 1.5 m North of South curb.	Asphalt	-	Concrete	220	-
PC22-07	UTM : 5526674 m N, 633482 m E; Located 163 m East of Osbourne St and Wardlaw Ave intersection, Westbound lane, 1.5 m South of North curb.	Asphalt	-	Concrete	180	69.47
PC22-08	UTM : 5526693 m N, 633523 m E; Located 86 m West of Scott St and Wardlaw Ave intersection, Eastbound lane, 1.5 m North of South curb.	Asphalt	-	Concrete	210	-
PC22-09	UTM : 5526712 m N, 633562 m E; Located 42 m West of Scott St and Wardlaw Ave intersection, Westbound lane, 1.5 m South of North curb.	Asphalt	-	Concrete	180	69.63
PC22-26	UTM : 5526753 m N, 633628 m E; Located 40 m East of Scotts St and Wardlaw Ave intersection, Eastbound lane, 1.5 m North of South curb.	Asphalt	-	Concrete	210	70.80
PC22-27	UTM : 5526763 m N, 633652 m E; Located 72 m East of Scotts St and Wardlaw Ave intersection, Westbound lane, 5 m South of North curb.	Asphalt	-	Concrete	200	70.65
PC22-28	UTM : 5526797 m N, 633685 m E; Located 76 m West of Donald St and Wardlaw Ave intersection, Eastbound lane, 1.5 m North of South curb.	Asphalt	-	Concrete	210	68.40
PC22-29	UTM : 5526806 m N, 633715 m E; Located 53 m West of Donald St and Wardlaw Ave intersection, Westbound lane, 5 m South of North curb.	Asphalt	-	Concrete	190	-



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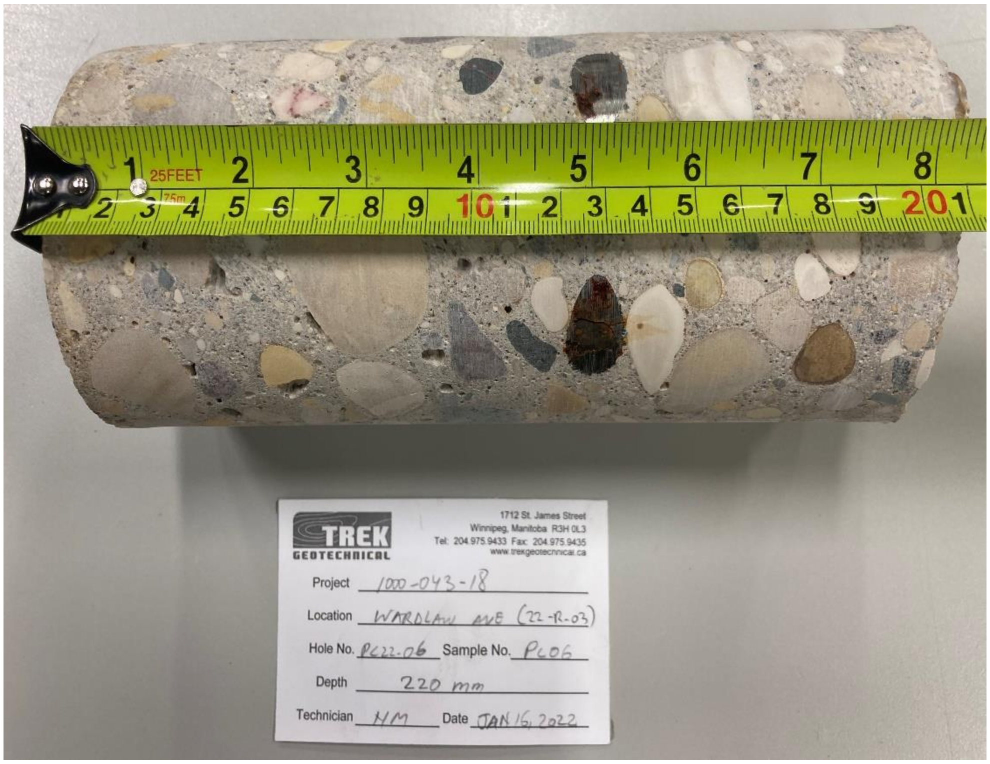
Project 1000-043-18
Location WARDLAW AVE (22-R-03)
Hole No. PC22-05 Sample No. PC05
Depth 190 mm
Technician NM Date JAN 16, 2022

Photo 1: Pavement Core Sample at PC22-05



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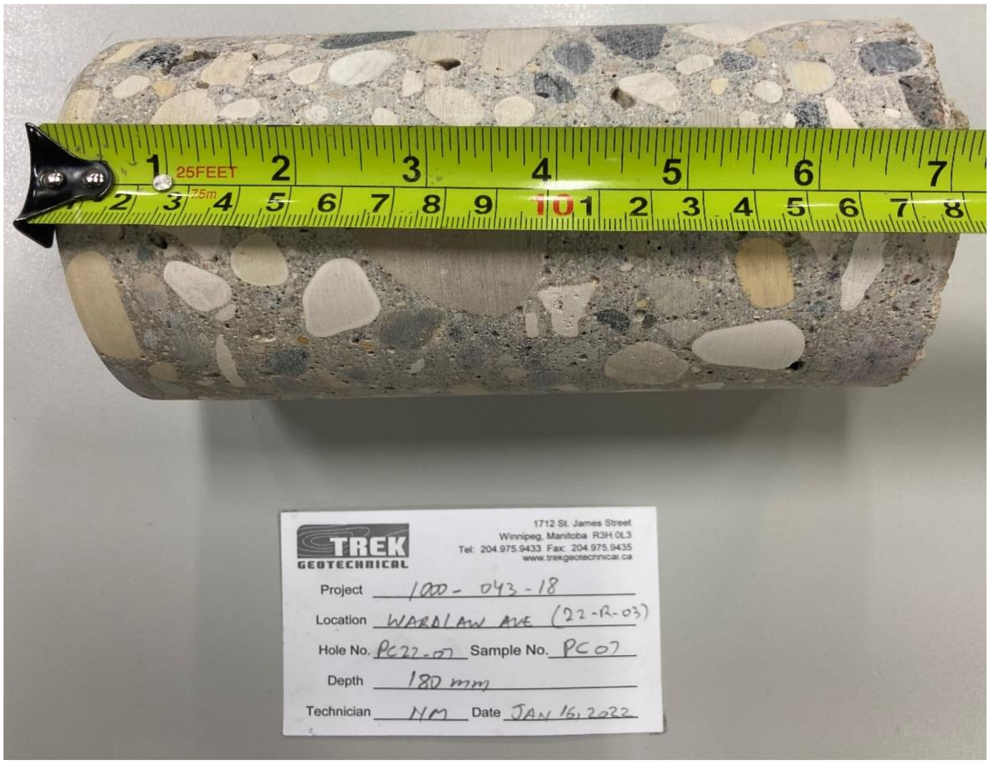
Project 1000-043-18
Location WARDLAW AVE (22-R-03)
Hole No. PC22-06 Sample No. PC06
Depth 220 mm
Technician NM Date JAN 16, 2022

Photo 2: Pavement Core Sample at PC22-06



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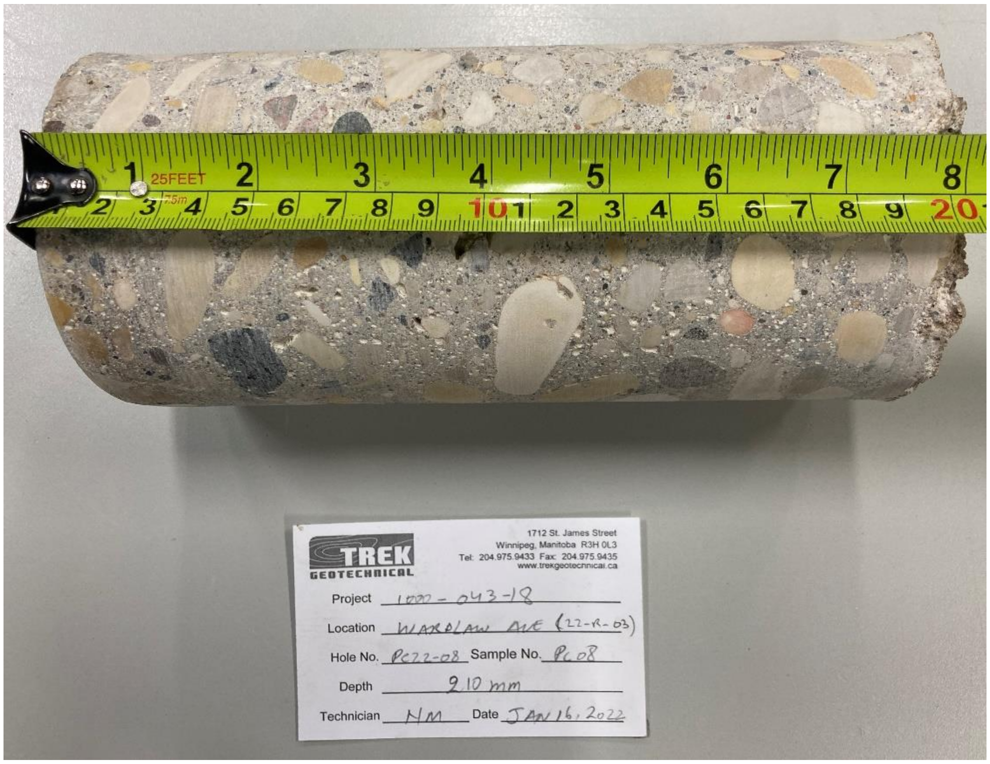
Project 1000-043-18
Location WARDLAW AVE (22-R-03)
Hole No. PC22-07 Sample No. PC07
Depth 180 mm
Technician NM Date JAN 16, 2022

Photo 3: Pavement Core Sample at PC22-07



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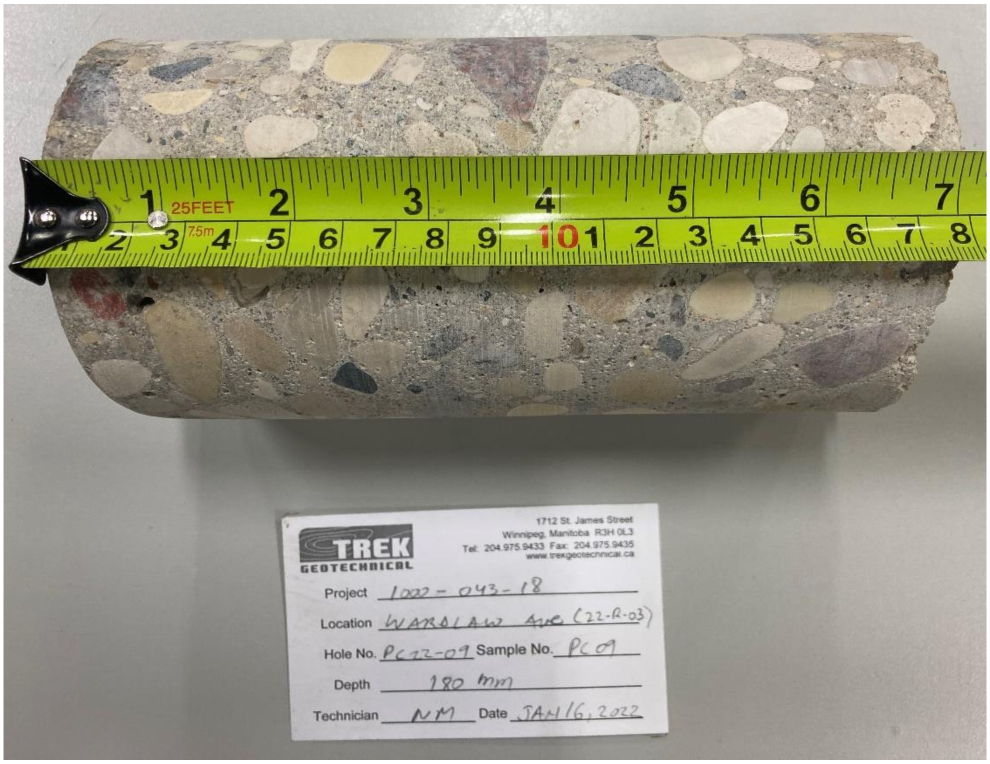
Project 1000-043-18
Location WARDLAW AVE (22-R-03)
Hole No. PC22-08 Sample No. PC08
Depth 210 mm
Technician NM Date JAN 16, 2022

Photo 4: Pavement Core Sample at PC22-08



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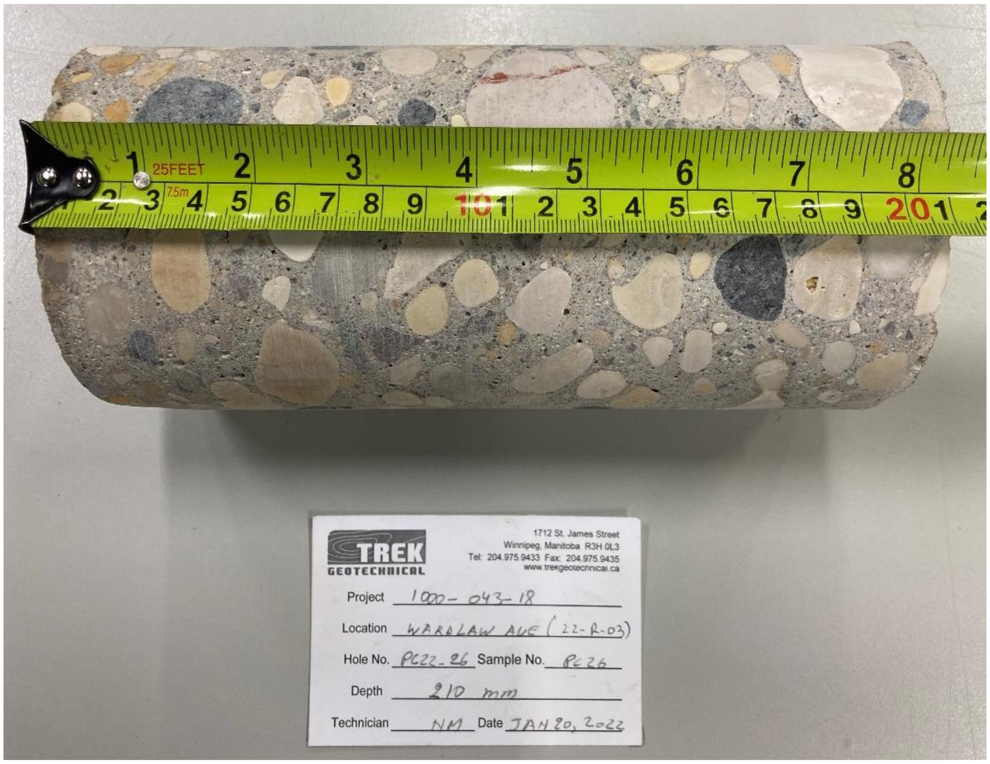
Project 1000-043-18
Location WARDLAW Ave (22-R-03)
Hole No. PC22-09 Sample No. PC09
Depth 180 mm
Technician NM Date JAN 16, 2022

Photo 5: Pavement Core Sample at PC22-09



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Project 1000-043-18
Location WARDLAW AVE (22-R-03)
Hole No. PC22-26 Sample No. PC26
Depth 210 mm
Technician NM Date JAN 20, 2022

Photo 6: Pavement Core Sample at PC22-26

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Project 1000-043-18

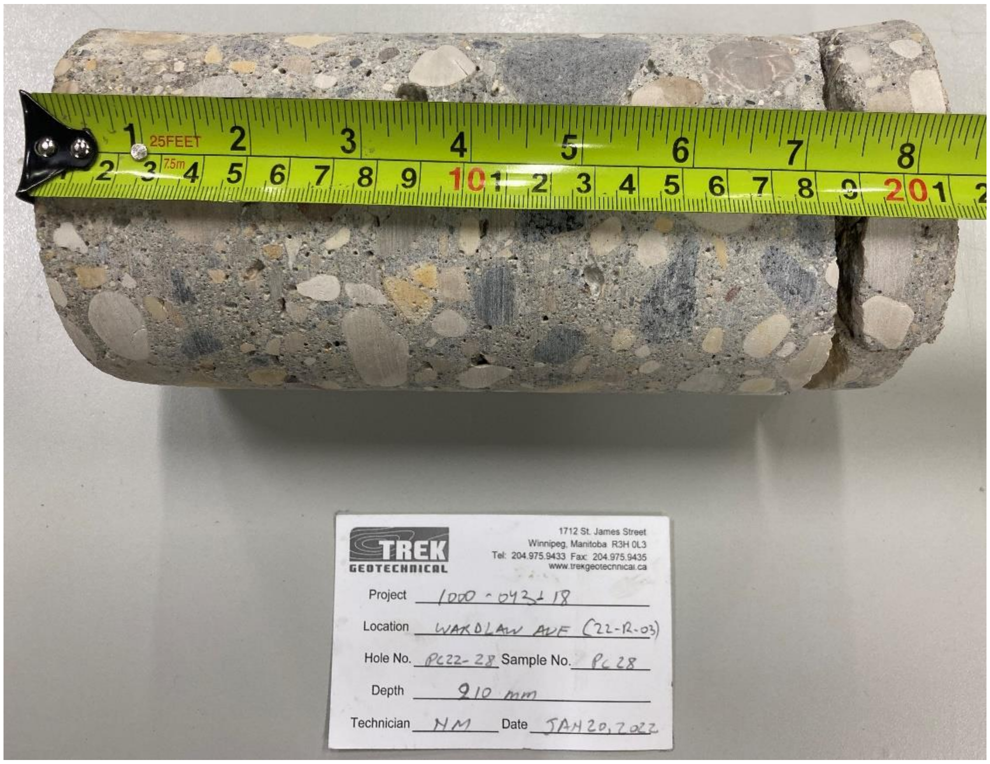
Location WARDLAW AVE (22-R-03)

Hole No. PC22-27 Sample No. PC27

Depth 200 mm

Technician HM Date JAN 20, 2022

Photo 7: Pavement Core Sample at PC22-27



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Project 1000-043-18

Location WARDLAW AVE (22-R-03)

Hole No. PC22-28 Sample No. PC28

Depth 210 mm

Technician HM Date JAN 20, 2022

Photo 8: Pavement Core Sample at PC22-28

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Project 1000-043-18
Location WARDLAW AVE (22-R-03)
Hole No. PC22-29 Sample No. PC 29
Depth 190 mm
Technician NM Date JAN 20, 2022

Photo 9: Pavement Core Sample at PC22-29

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Concrete Core Compressive Strength Report

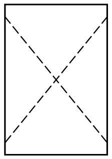
CSA A23.2-14C

Project No. 1000-043-18
Date January 31, 2022
Project 2022 Local Street Package - 22-R-03
Technician AD
Client WSP Group Canada Inc.

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}
Wardlaw Avenue	PC05	2022-01-16	2022-01-29	-	95	183	Soaked 48 h	62.18	72.11	1	1.00	1.00	1.09	1.06	1.00
Wardlaw Avenue	PC07	2022-01-16	2022-01-29	-	95	170	Soaked 48 h	60.12	69.47	1	1.00	1.00	1.09	1.06	1.00
Wardlaw Avenue	PC09	2022-01-16	2022-01-29	-	95	168	Soaked 48 h	60.31	69.63	1	1.00	1.00	1.09	1.06	1.00
Wardlaw Avenue	PC26	2022-01-20	2022-01-29	-	95	188	Soaked 48 h	61.02	70.80	1	1.00	1.00	1.09	1.06	1.00
Wardlaw Avenue	PC27	2022-01-20	2022-01-29	-	95	177	Soaked 48 h	61.00	70.65	1	1.00	1.00	1.09	1.06	1.00
Wardlaw Avenue	PC28	2022-01-20	2022-01-29	-	95	178	Soaked 48 h	59.04	68.40	1	1.00	1.00	1.09	1.06	1.00

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): $f_c = f_{conc}F_{l/d}F_{dia}F_{mc}F_DF_{reinf}$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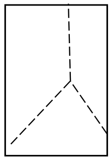
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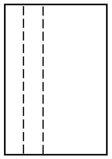
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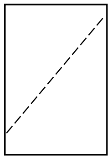
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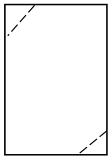
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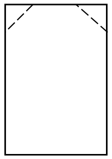
Type 6

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

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.

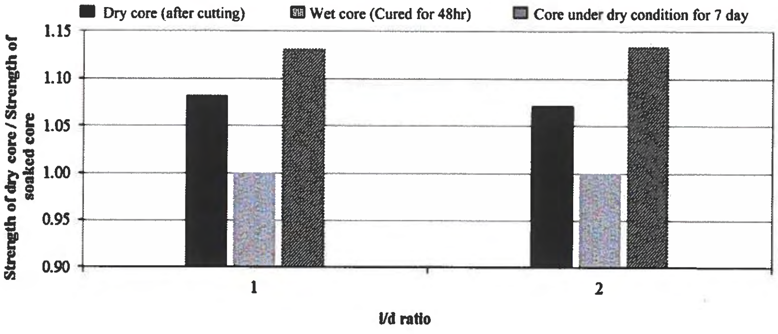

Figure 20 Effect of core moisture condition on core strength for different aspect ratios (l/d).

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:

$$f_c = F_{l/d} \cdot F_{dia} \cdot F_{mc} \cdot F_D \cdot f_{core} \quad \cdot F_{reinf} \qquad \leftarrow \text{eq. 12 or eq. 15} \tag{5}$$

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.