APPENDIX 'A'

GEOTECHNICAL REPORT

WSP Canada Group Ltd.

2022 Local Streets Package (21-R-06)

Prepared for:

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

Project Number:
1000 043 20

Date:
February 2, 2022
Final Report

February 2, 2022 Our File No. 1000 043 20

Lissa Van Dorp
WSP Canada Group Ltd.
111-93 Lombard Avenue
Winnipeg, MB R3E 3P1

RE: Road Investigation Report for 2022 Local Streets Package (22-R-06)

TREK Geotechnical Inc. is pleased to submit our report for the road investigation for the 2022 Local Streets Package (22-R-03) project.

Please contact the undersigned if you have any questions. Thank you for the opportunity to serve you on this assignment.

Sincerely,

TREK Geotechnical Inc.
Per:

Nelson John Ferreira, Ph.D., P. Eng.
Geotechnical Engineer, Principal
Tel: 204.975.9433 ext. 103

cc: Angela Fidler-Kliewer C.Tech. (TREK Geotechnical)

Revision History

Revision No.	Author	Issue Date	Description
0	AD	February 2, 2022	Final Report

Authorization Signatures

Prepared By:

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Reviewed By:

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Geotechnical Engineer

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

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1.0 Introduction

This report summarizes the results of the road investigation completed for the 2022 Local Streets Package 22-R-06. The investigation was carried out along Dubuc Street, Harvard Ave E., Lawndale Ave, Victoria Ave E., Widlake Street, Winona Street and Youville Street. Information collected describes the asphalt and concrete pavement structure of the existing roads. The investigation was carried out in accordance with the City of Winnipeg RFP No. 476-2021.

2.0 Road Investigation

The investigation included coring of pavement at 36 locations on 7 different local streets. WSP selected the investigation locations as shown on Figures 01 to 06 (attached) and the table below summarizes the investigation program.

Table 1: Road Investigation Program

Street	# of Locations	Investigation
Dubuc Street (Between Enfield Cresc and Des Meurons St.)	6	Pavement Cores
Harvard Avenue E. (Between Roanoke Str. and Leola St.)	3	Pavement Cores
Lawndale Avenue (Between Lyndale Dr. and Highfield St.)	6	Pavement Cores
Victoria Avenue E. (Between Roanoke Str. and Leola St.)	3	Pavement Cores
Widlake Street (Between Kildare Ave E. and Victoria Ave E.)	6	Pavement Cores
Winona Street (Between Kildare Ave W. and Regent Ave W.)	8	Pavement Cores
Youville Street (Between Marion St. and Eugenie St.)	4	Pavement Cores

Pavement coring was completed between January 11th and 20th, 2022. The pavement was cored by Naimu Mujyambere and Asad Dustmamatov of TREK Geotechnical Inc. (TREK) using a portable coring press equipped with a hollow 100 and 150 mm diameter diamond core drill bits. Core samples were also retrieved and logged at TREK's material testing laboratory. A summary table of the concrete pavement cores and photographs of the cores are included in Appendices A to G

Nineteen concrete cores were selected for concrete compressive strength breaks and the length to diameter ratio ranged between 1.16 to 1.91 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 A to G.

Table 2: Concrete Core Compressive Strength Results

Core ID	Uncorrected Compressive Strength (MPa)	Corrected Compressive Strength (MPa)
PC-01	55.39	63.21
PC-05	60.15	69.73
PC-06	48.83	56.53
PC-07	65.58	75.27
PC-08	44.95	51.20
PC-09	53.83	60.49
PC-14	44.50	48.05
PC-19	43.63	50.16
PC-22	41.52	47.53
PC-23	34.48	39.59
PC-25	51.19	58.49
PC-26	66.54	74.83
PC-27	50.67	57.99
PC-28	68.35	78.70
PC-29	76.63	87.59
PC-31	59.15	67.57
PC-34	53.56	61.11
PC-35	43.99	50.58
PC-36	53.44	60.58

The locations noted on the summary tables (Appendices A to G) are based on the core locations relative to the nearest address or intersection, and measured distances from the edge of pavement. UTM coordinates measured using a handheld GPS unit are also provided.

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).

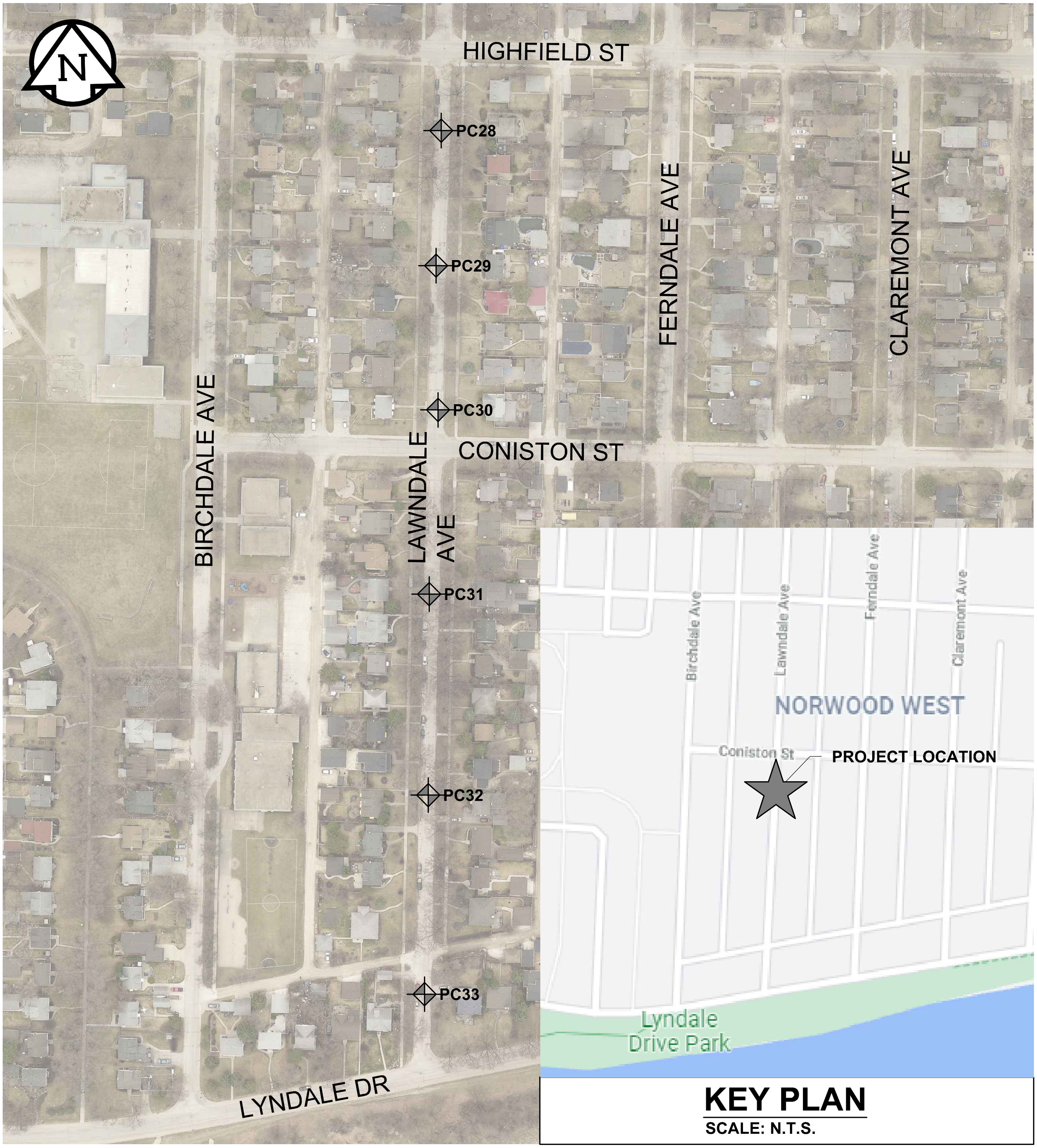
All information provided in this report is subject to our standard terms and conditions for engineering services, a copy of which is provided to each of our clients with the original scope of work, or a mutually executed standard engineering services agreement. If these conditions are not attached, and 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 Group of Canada (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 20
WSP
2022 Local Streets Package (22-R-06)



KEY PLAN

SCALE: N.T.S.

LEGEND:

PAVEMENT CORE (TREK 2021)

NOTES:

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

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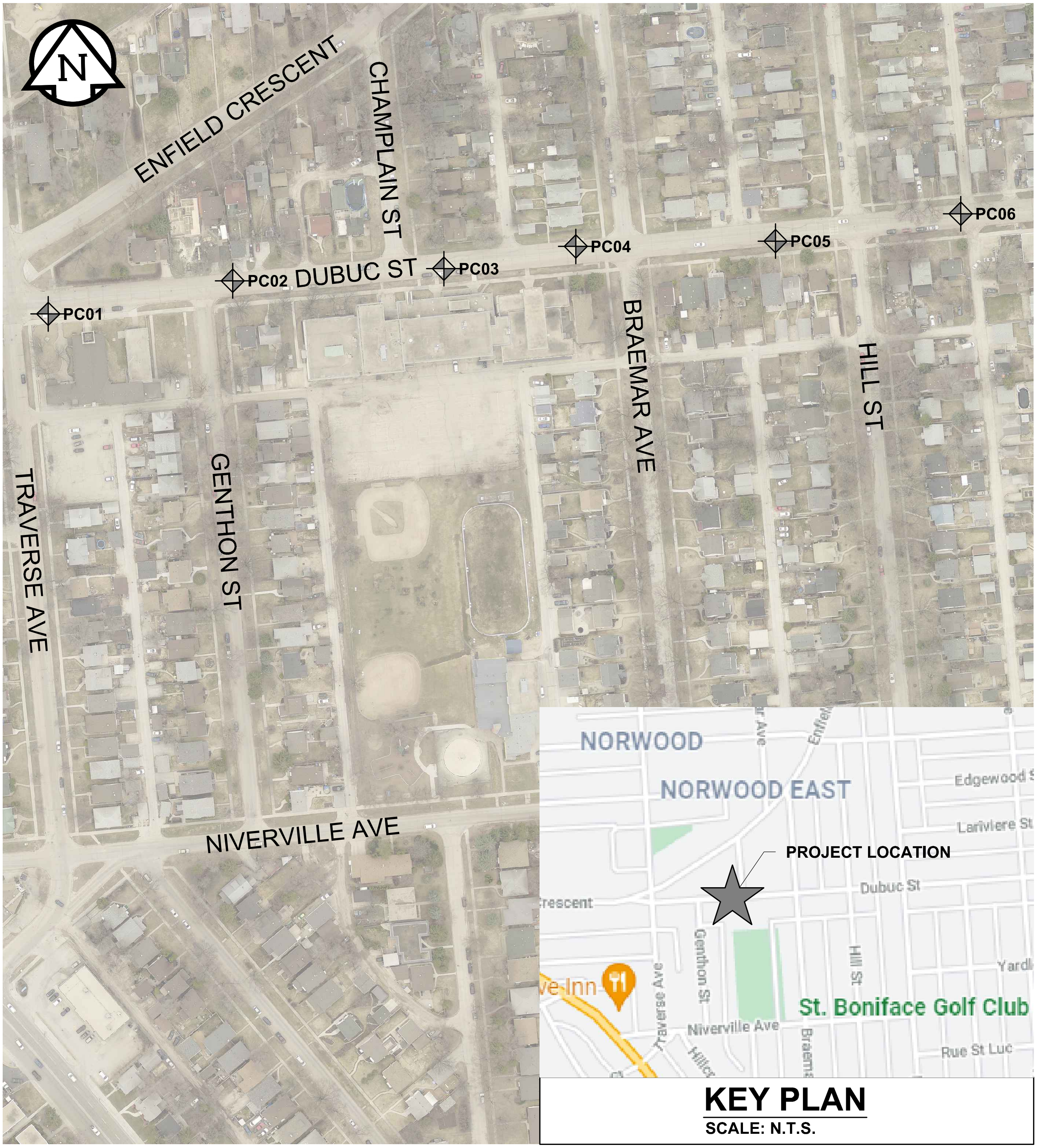
0 50 100 150 m

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

Figure 01

Pavement Core Location Plan



LEGEND:

PAVEMENT CORE (TREK 2021)

NOTES:

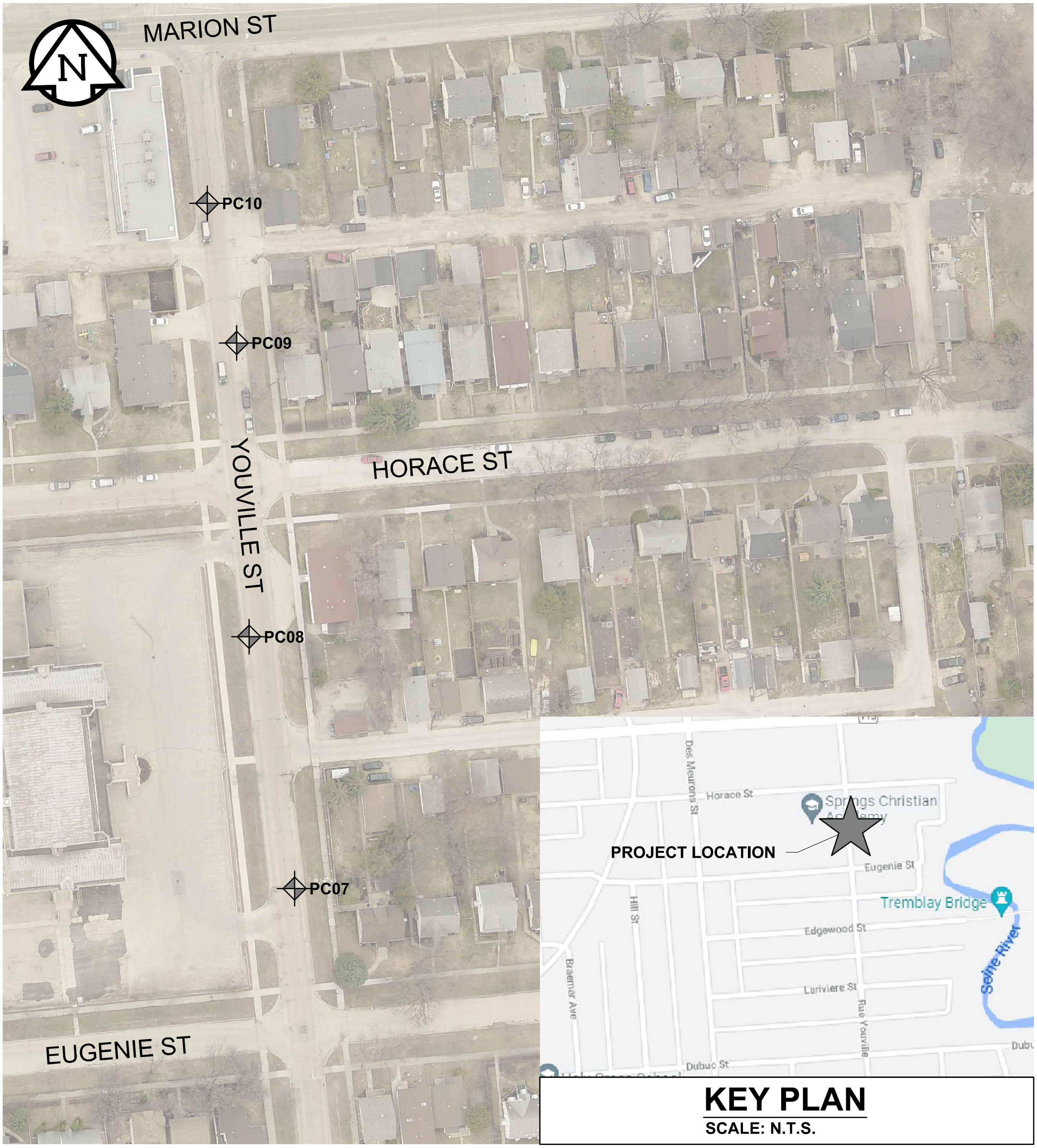
1. AERIAL IMAGERY FROM CITY OF WINNIPEG (2016).

0 50 100 150 m

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

Figure 02

Pavement Core Location Plan



LEGEND:

PAVEMENT CORE (TREK 2021)

NOTES:

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

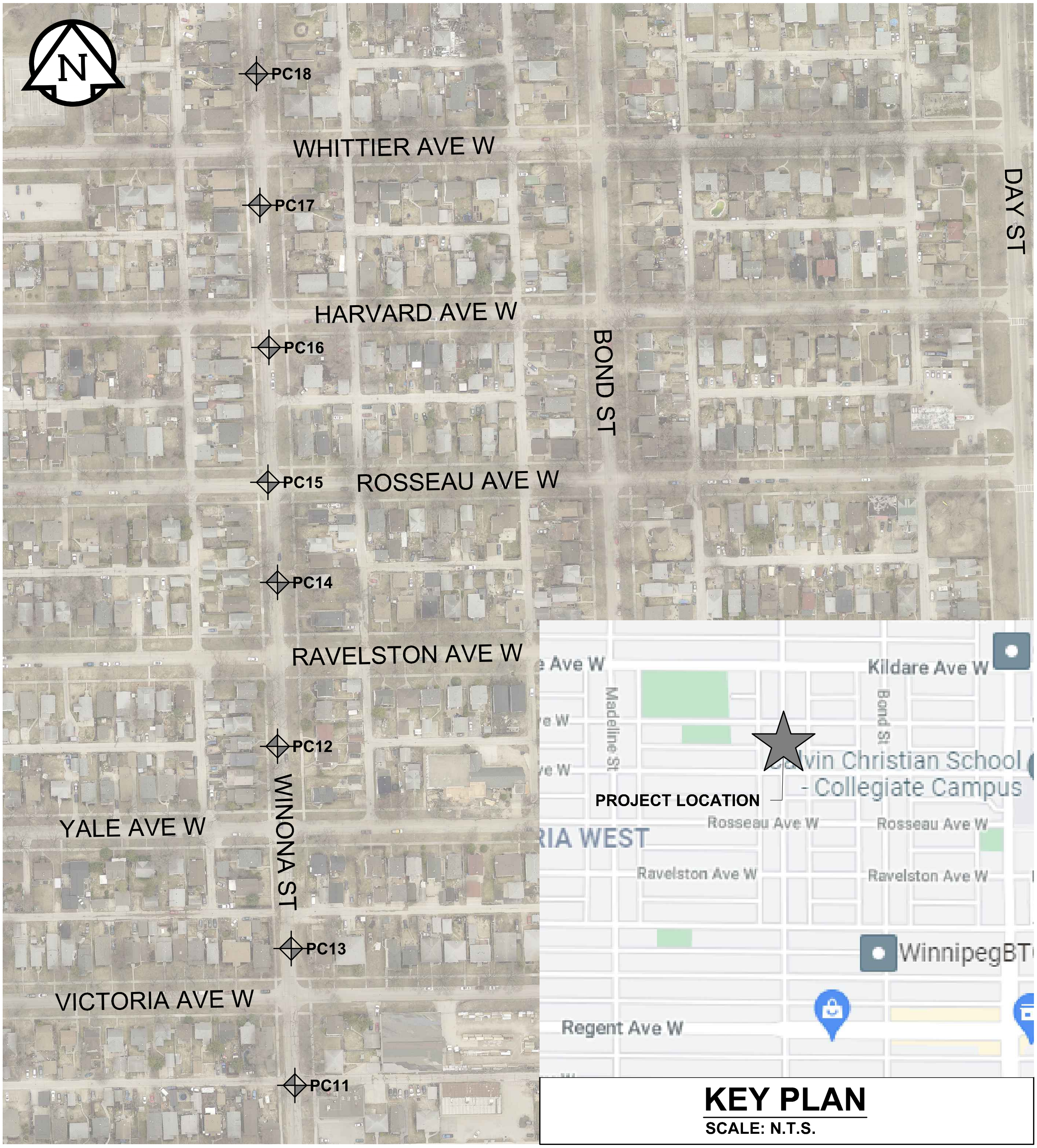
Z:\Projects\1000 Soils Lab\Lab Projects\1000 Lab Projects\1000-043 WSP\1000-043-20 2022 Local Streets Package (22-R-06)\3 Survey and Dwg\3.4 CAD\3.4.3 Working Folder, 2022-01-31 1:56:20 PM ANSI full bleed A (8.50 x 11.00 Inches)

0 10 20 30 40 50 m

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

Figure 03

Pavement Core Location Plan



LEGEND:

PAVEMENT CORE (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

Pavement Core Location Plan

LEGEND:

PAVEMENT CORE (TREK 2021)

NOTES:

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

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0 50 100 150 m

SCALE = 1 : 2 750 (216 mm x 279 mm)

Figure 05

Pavement Core Location Plan

1000 043 20
WSP
2022 Local Streets Package (22-R-06)

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 06
Pavement Core Location Plan

Appendix A

Summary Table, Pavement Core Compressive Strength and Photographs of Pavement Core Samples - Dubuc St

2022 Local Street Package - 22-R-06

Dubuc Street: between Enfield Crescent and Des Meurons Street

Pavement Core No.	Pavement Core Location	Pavement Surface		Pavement Structure Material		
		Type	Thickness (mm)	Type	Thickness (mm)	Corrected Compressive Strength (Mpa)
PC22-01	UTM : 5526678 m N, 635314 m E; Located 10 m East of Traverse Ave and Dubuc St intersection, Eastbound lane, 1.5 m North of South curb.	Asphalt	90	Concrete	190	63.21
PC22-02	UTM : 5526693 m N, 635399 m E; Located 12 m East of Genthon St and Dubuc St intersection, Westbound lane, 1.5 m South of North curb.	Asphalt	50	Concrete	200	-
PC22-03	UTM : 5526695 m N, 635487 m E; Located 20 m East of Champlain St and Dubuc St intersection, Eastbound lane, 1.5 m North of South curb.	Asphalt	50	Concrete	200	-
PC22-04	UTM : 5526704 m N, 635544 m E; Located 23 m West of Braemar Ave and Dubuc St intersection, Westbound lane, 1.5 m South of North curb.	Asphalt	50	Concrete	190	-
PC22-05	UTM : 5526717 m N, 635630 m E; Located 30 m West of Hill St and Dubuc St intersection, Eastbound lane, 1.5 m North of South curb.	Asphalt	60	Concrete	200	69.73
PC22-06	UTM : 5526718 m N, 635711 m E; Located 61 m West of Des Meurons St and Dubuc St intersection, Westbound lane, 1.5 m South of North curb.	Asphalt	60	Concrete	190	56.53

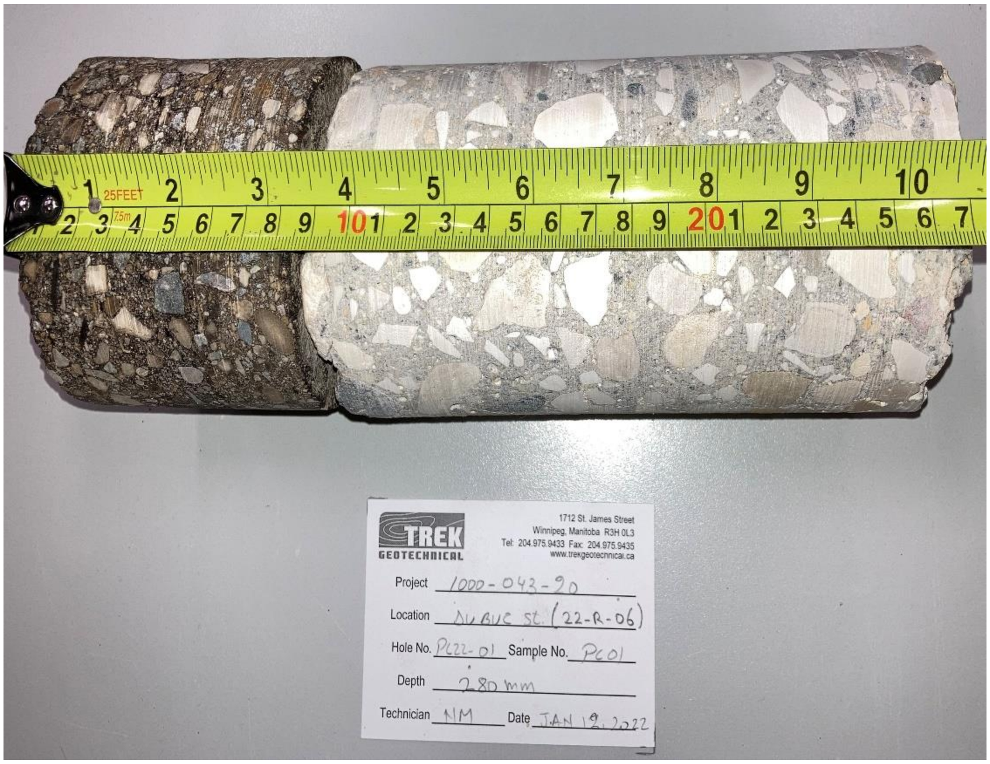

Photo 1: Pavement Core Sample at PC22-01

Photo 2: Pavement Core Sample at PC22-02

Photo 3: Pavement Core Sample at PC22-03

Photo 4: Pavement Core Sample at PC22-04

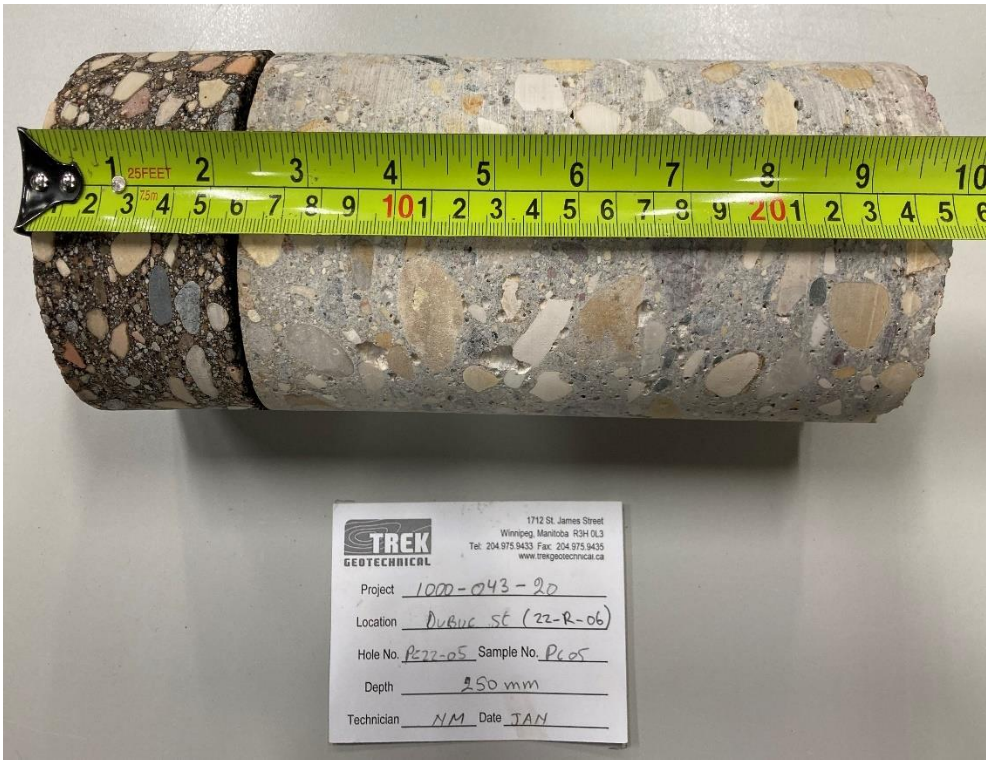

Photo 5: Pavement Core Sample at PC22-05

Photo 6: Pavement Core Sample at PC22-06

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Concrete Core Compressive Strength Report

CSA A23.2-14C

Project No. 1000-043-20 **Date** January 28, 2022

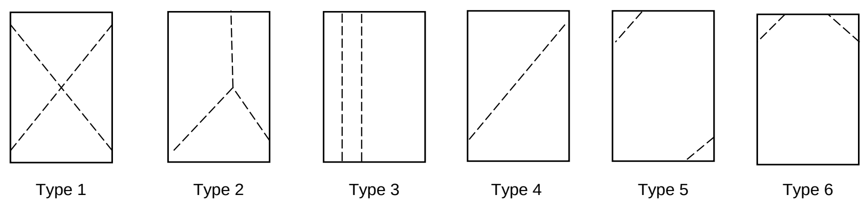
Project 2022 Local Street Package - 22-R-06 **Technician** NM

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}
Dubuc Street	PC01	2022-01-13	2022-01-26	-	95	150	Soaked 48 h	55.39	63.21	1	0.98	1.00	1.09	1.06	1.00
Dubuc Street	PC05	2022-01-13	2022-01-26	-	95	181	Soaked 48 h	60.15	69.73	1	1.00	1.00	1.09	1.06	1.00
Dubuc Street	PC06	2022-01-13	2022-01-26	-	95	176	Soaked 48 h	48.83	56.53	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): $f_c = f_{conc}F_{l/d}F_{dia}F_{mc}F_DF_{reinf}$



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:

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

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.

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:

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

- 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:

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

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.

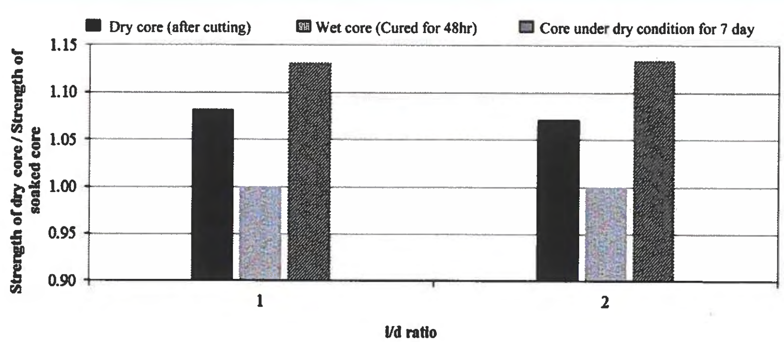


Figure 20 Effect of core moisture condition on core strength for different aspect ratios (l/d).

Appendix B

Summary Table, Pavement Core Compressive Strength and Photographs of Pavement Core Samples - Harvard Ave E.

2022 Local Street Package - 22-R-06

Harvard Avenue East: between Roanoke Street and Leola Street

Pavement Core No.	Pavement Core Location	Pavement Surface		Pavement Structure Material		
		Type	Thickness (mm)	Type	Thickness (mm)	Corrected Compressive Strength (Mpa)
PC22-25	UTM : 5529342 m N, 644071 m E; Located 26 m West of Harvard Ave E and Leola St intersection, Westbound lane, 1.5 m South of North curb.	Asphalt	-	Concrete	170	58.49
PC22-26	UTM : 5529339 m N, 644002 m E; Located in front of #427 Harvard Ave E, Eastbound lane, 1.5 m North of South curb.	Asphalt	-	Concrete	160	74.83
PC22-27	UTM : 5529339 m N, 643949 m E; Located 11 m West of West corner of #421 Harvard Ave E, Westbound lane, 1.5 m South of North curb.	Asphalt	-	Concrete	170	57.99

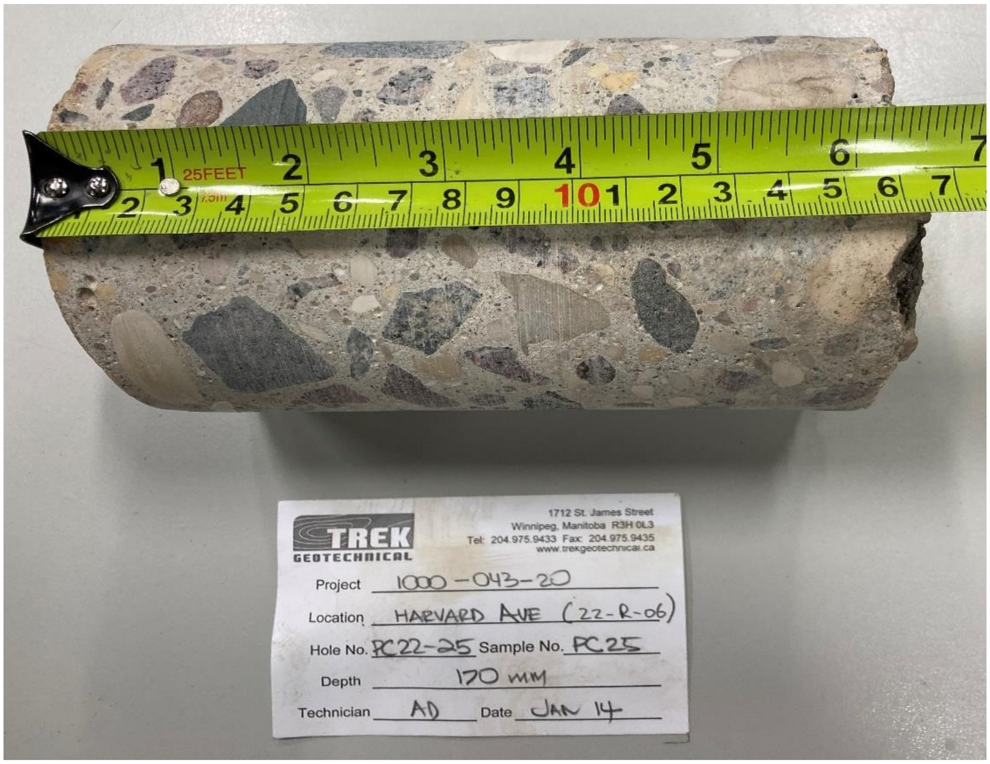


Photo 1: Pavement Core Sample at PC22-25

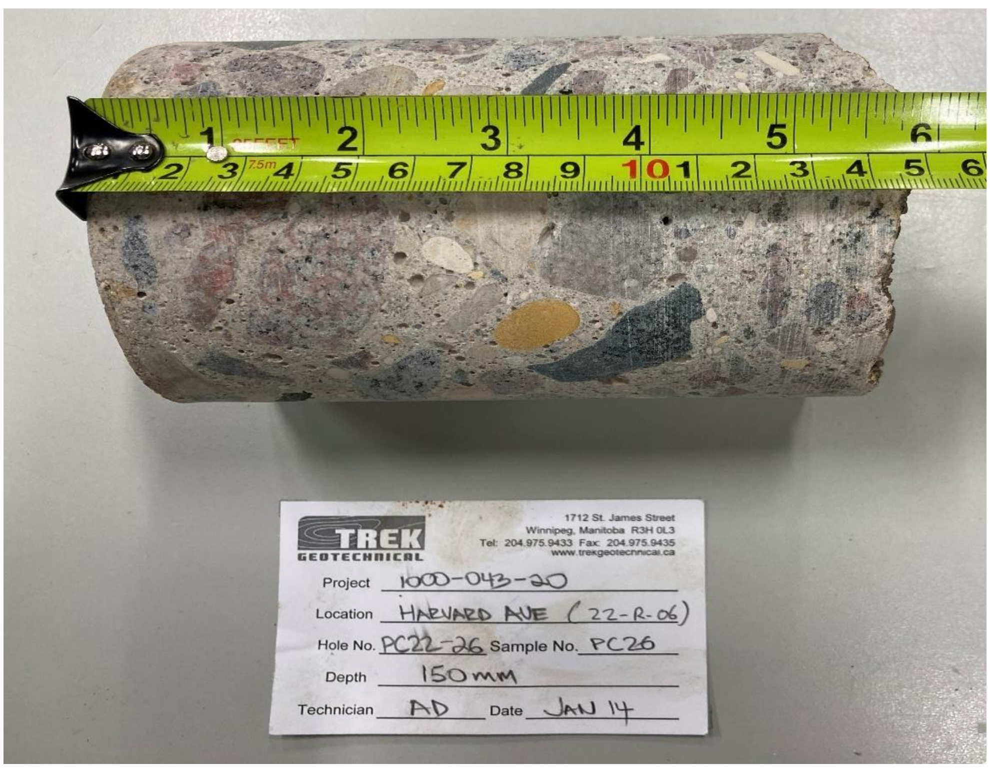


Photo 2: Pavement Core Sample at PC22-26

Photo 3: Pavement Core Sample at PC22-27

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Concrete Core Compressive Strength Report

CSA A23.2-14C

Project No. 1000-043-20 **Date** January 28, 2022

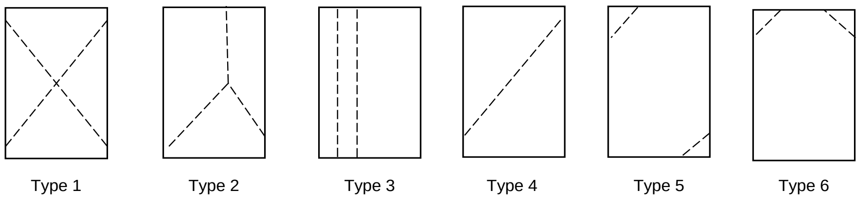
Project 2022 Local Street Package - 22-R-06 **Technician** NM

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}
Harvard Avenue East	PC25	2022-01-14	2022-01-27	-	95	152	Soaked 48 h	51.19	58.49	1	0.98	1.00	1.09	1.06	1.00
Harvard Avenue East	PC26	2022-01-14	2022-01-27	-	95	134	Soaked 48 h	66.54	74.83	1	0.97	1.00	1.09	1.06	1.00
Harvard Avenue East	PC27	2022-01-14	2022-01-27	-	95	154	Soaked 48 h	50.67	57.99	1	0.99	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): $f_c = f_{conc}F_{l/d}F_{dia}F_{mc}F_DF_{reinf}$



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:

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

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.

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:

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

- 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:

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

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.

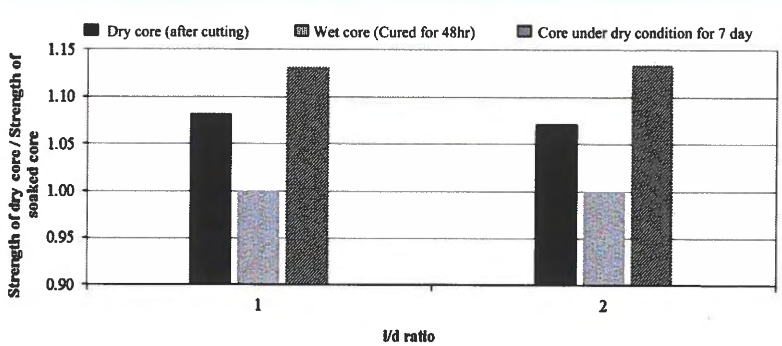


Figure 20 Effect of core moisture condition on core strength for different aspect ratios (l/d).

Appendix C

Summary Table, Pavement Core Compressive Strength and Photographs of Pavement Core Samples - Lawndale Ave

2022 Local Street Package - 22-R-06

Lawndale Avenue: between Lyndale Drive and Highfield Street

Pavement Core No.	Pavement Core Location	Pavement Surface		Pavement Structure Material		
		Type	Thickness (mm)	Type	Thickness (mm)	Corrected Compressive Strength (Mpa)
PC22-28	UTM : 5526432 m N, 634448 m E; Located 36 m South of Lawndale Ave and Highfield St intersection, Northbound lane, 1.5 m West of East curb.	Asphalt	-	Concrete	170	78.70
PC22-29	UTM : 5526368 m N, 634451 m E; Located 105 m South of Lawndale Ave and Highfield St intersection, Southbound lane, 1.5 m East of West curb.	Asphalt	-	Concrete	160	87.59
PC22-30	UTM : 5526308 m N, 634447 m E; Located 15 m North of Coniston St and Lawndale Ave intersection, Northbound lane, 1.5 m West of East curb.	Asphalt	10	Concrete	160	-
PC22-31	UTM : 5526226 m N, 634448 m E; Located 71 m South of Coniston St and Lawndale Ave intersection, Southbound lane, 1.5 m East of West curb.	Asphalt	-	Concrete	160	67.57
PC22-32	UTM : 5526141 m N, 634443 m E; Located 169 m South of Coniston St and Lawndale Ave intersection, Northbound lane, 1.5 m West of East curb.	Asphalt	-	Concrete	150	-
PC22-33	UTM : 5526053 m N, 634446 m E; Located 27 m North of Lyndale Dr and Lawndale Ave intersection, Southbound lane, 1.5 m East of West curb.	Asphalt	-	Concrete	150	-

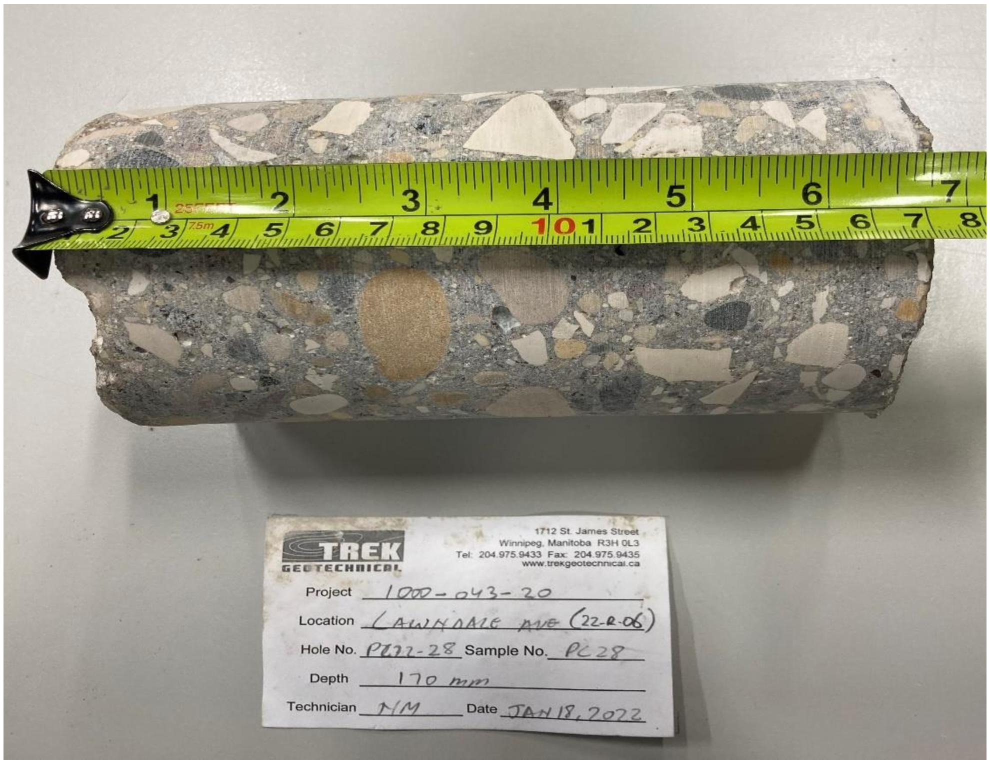


Photo 1: Pavement Core Sample at PC22-28

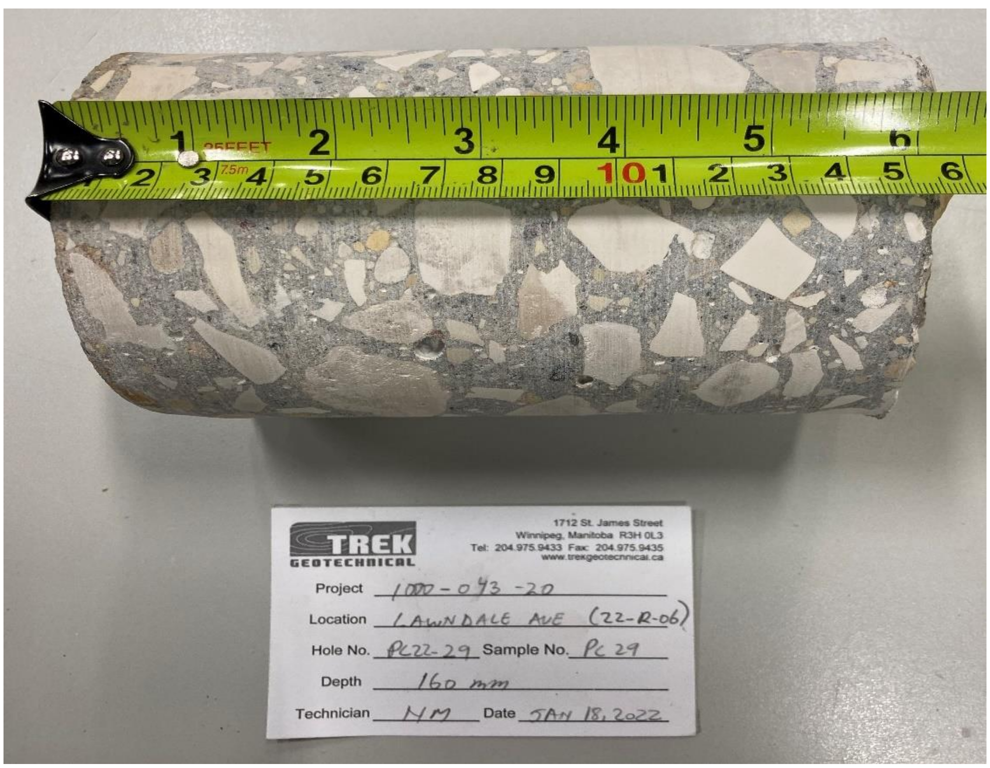


Photo 2: Pavement Core Sample at PC22-29

Photo 3: Pavement Core Sample at PC22-30

Photo 4: Pavement Core Sample at PC22-31

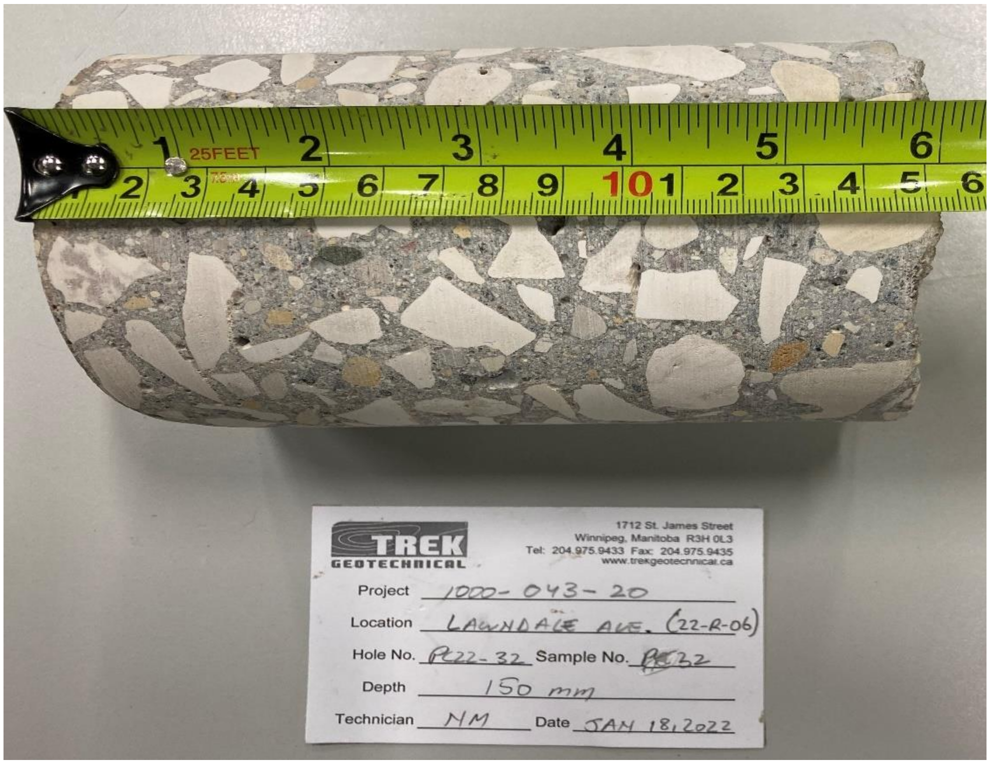


Photo 5: Pavement Core Sample at PC22-32

Photo 6: Pavement Core Sample at PC22-33

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Concrete Core Compressive Strength Report

CSA A23.2-14C

Project No. 1000-043-20 **Date** January 28, 2022

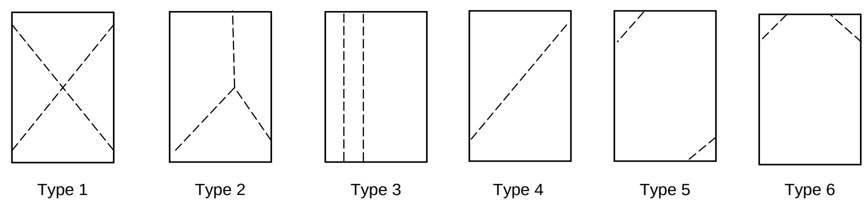
Project 2022 Local Street Package - 22-R-06 **Technician** NM

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}
Lawndale Avenue	PC28	2022-01-18	2022-01-27	-	95	162	Soaked 48 h	68.35	78.70	1	0.99	1.00	1.09	1.06	1.00
Lawndale Avenue	PC29	2022-01-18	2022-01-27	-	95	150	Soaked 48 h	76.63	87.59	1	0.99	1.00	1.09	1.06	1.00
Lawndale Avenue	PC31	2022-01-18	2022-01-27	-	95	151	Soaked 48 h	59.15	67.57	1	0.98	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): $f_c = f_{conc} F_{l/d} F_{dia} F_{mc} F_D F_{reinf}$



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	√		√			√
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3	American Concrete Institute ACI	1998	√					
		2012	√	√		√	√	
4	European Standard Specification	1998	√	√	√		√	
		2009	√		√			
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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].

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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:

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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:

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	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.
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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		●		●	●													
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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.

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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).

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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.

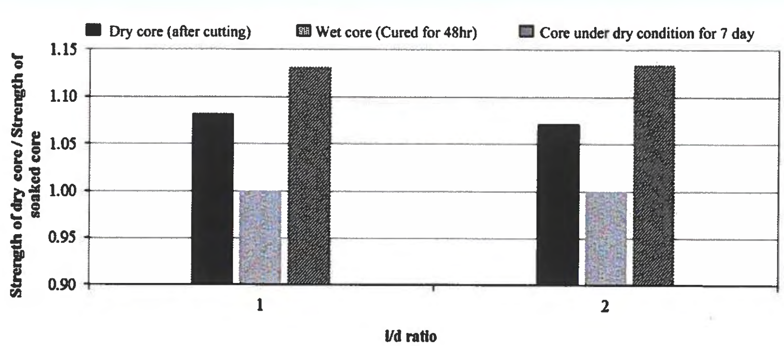

Figure 20 Effect of core moisture condition on core strength for different aspect ratios (l/d).

Appendix D

Summary Table, Pavement Core Compressive Strength and Photographs of Pavement Core Samples – Victoria Ave E.

TREK GEOTECHNICAL

2022 Local Street Package - 22-R-06

Victoria Avenue East: between Roanoke Street and Leola Street

Pavement Core No.	Pavement Core Location	Pavement Surface		Pavement Structure Material		
		Type	Thickness (mm)	Type	Thickness (mm)	Corrected Compressive Strength (Mpa)
PC22-34	UTM : 5528992 m N, 644064 m E; Located 45 m West of Victoria Ave East and Leola St intersection, Westbound lane, 1.5 m South of North curb.	Asphalt	-	Concrete	160	61.11
PC22-35	UTM : 5528986 m N, 644017 m E; Located 99 m West of Victoria Ave East and Leola St intersection, Eastbound lane, 1.5 m North of South curb.	Asphalt	-	Concrete	180	50.58
PC22-36	UTM : 5528985 m N, 643982 m E; Located 35 m East of Victoria Ave East and Roanoke St intersection, Westbound lane, 1.5 m South of North curb.	Asphalt	-	Concrete	150	60.58

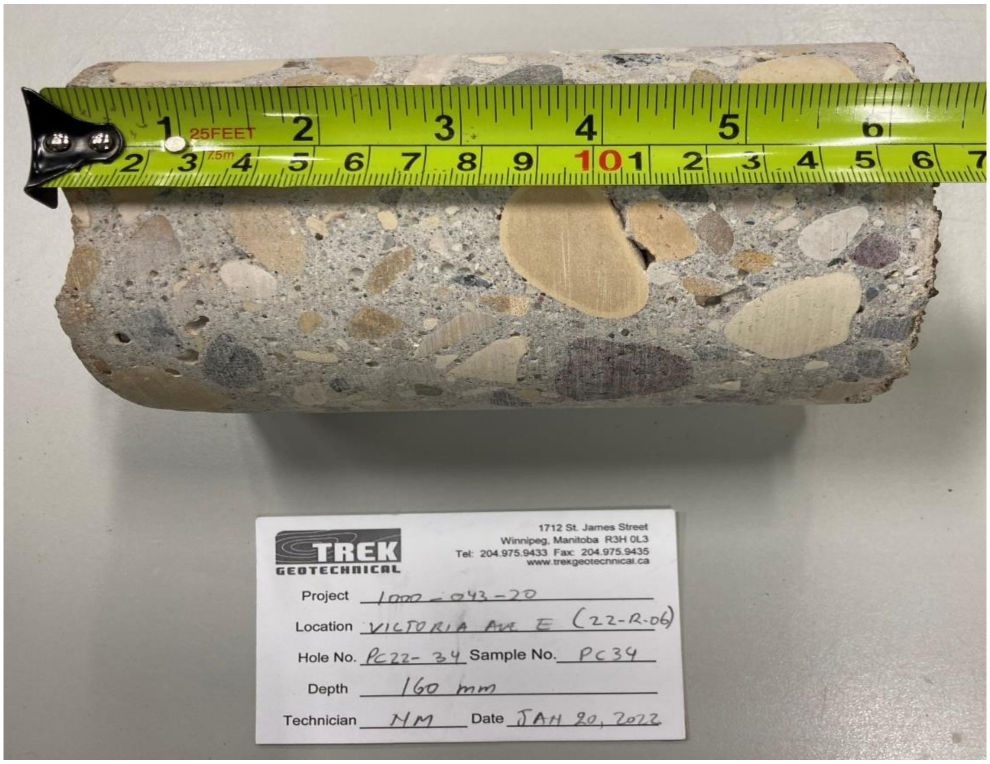

Photo 1: Pavement Core Sample at PC22-34

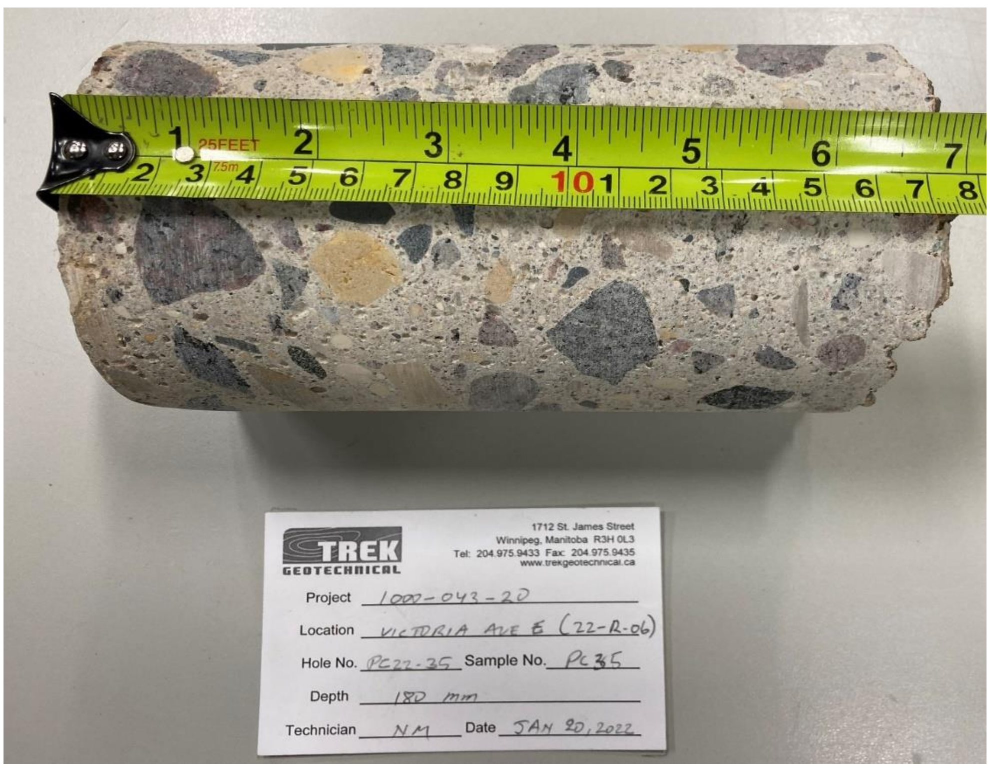

Photo 2: Pavement Core Sample at PC22-35

Photo 3: Pavement Core Sample at PC22-36

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Concrete Core Compressive Strength Report

CSA A23.2-14C

Project No. 1000-043-20 **Date** January 28, 2022

Project 2022 Local Street Package - 22-R-06 **Technician** NM

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}
Victoria Avenue East	PC34	2022-01-20	2022-01-27	-	95	150	Soaked 48 h	53.56	61.11	1	0.98	1.00	1.09	1.06	1.00
Victoria Avenue East	PC35	2022-01-20	2022-01-26	-	95	161	Soaked 48 h	43.99	50.58	1	0.99	1.00	1.09	1.06	1.00
Victoria Avenue East	PC36	2022-01-20	2022-01-26	-	95	143	Soaked 48 h	53.44	60.58	1	0.98	1.00	1.09	1.06	1.00

Comments

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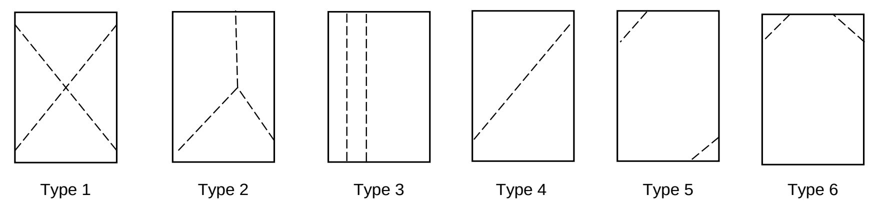

Reviewed by (print): Angela Fidler-Kliewer,C.Tech. Signature: Angela Fidler-Kliewer

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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 $(\sum \Phi_r * d)$.

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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:

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

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.

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:

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

- 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:

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

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.

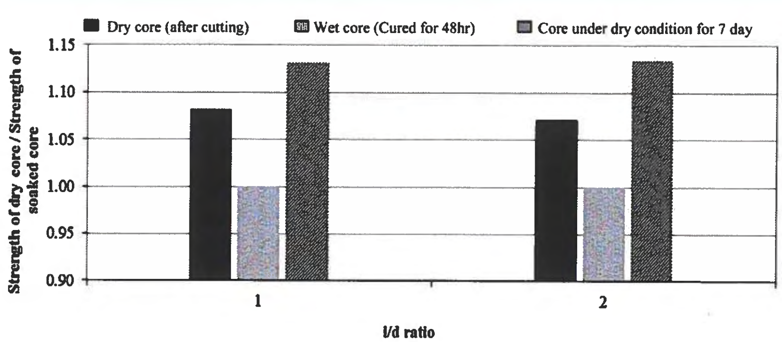

Figure 20 Effect of core moisture condition on core strength for different aspect ratios (l/d).

Appendix E

Summary Table, Pavement Core Compressive Strength and Photographs of Pavement Core Samples - Widlake St

2022 Local Street Package - 22-R-06

Widlake Street: between Kildare Avenue West and Victoria Avenue East

Pavement Core No.	Pavement Core Location	Pavement Surface		Pavement Structure Material		
		Type	Thickness (mm)	Type	Thickness (mm)	Corrected Compressive Strength (Mpa)
PC22-19	UTM : 5529491m N, 644789 m E; Located 68 m South of Kildare Ave E and Widlake St intersection, Northbound lane, 1.5 m West of East curb.	Asphalt	110	Concrete	170	50.16
PC22-20	UTM : 5529242 m N, 644793 m E; Located 19 m South of Coldstream Ave and Widlake St intersection, Southbound lane, 1.5 m East of West curb.	Asphalt	-	Concrete	170	-
PC22-21	UTM : 5529142 m N, 644800 m E; Located in front of #431 Widlake Ave, Northbound lane, 1.5 m West of East curb.	Asphalt	80	Concrete	160	-
PC22-22	UTM : 5529052 m N, 644798 m E; Located in front of #407 Widlake Ave, Southbound lane, 2 m East of West curb.	Asphalt	70	Concrete	160	47.53
PC22-23	UTM : 5529335 m N, 644788 m E; Located in front of #483 Widlake St, Northbound lane, 2.5 m West of East curb.	Asphalt	80	Concrete	170	39.59
PC22-24	UTM : 5529444 m N, 644790 m E; Located 23 m North of North corner of #503 Midlake St, Southbound lane, 1.5 m West of East curb.	Asphalt	50	Concrete	180	-

Photo 1: Pavement Core Sample at PC22-19

Photo 2: Pavement Core Sample at PC22-20

Photo 3: Pavement Core Sample at PC22-21

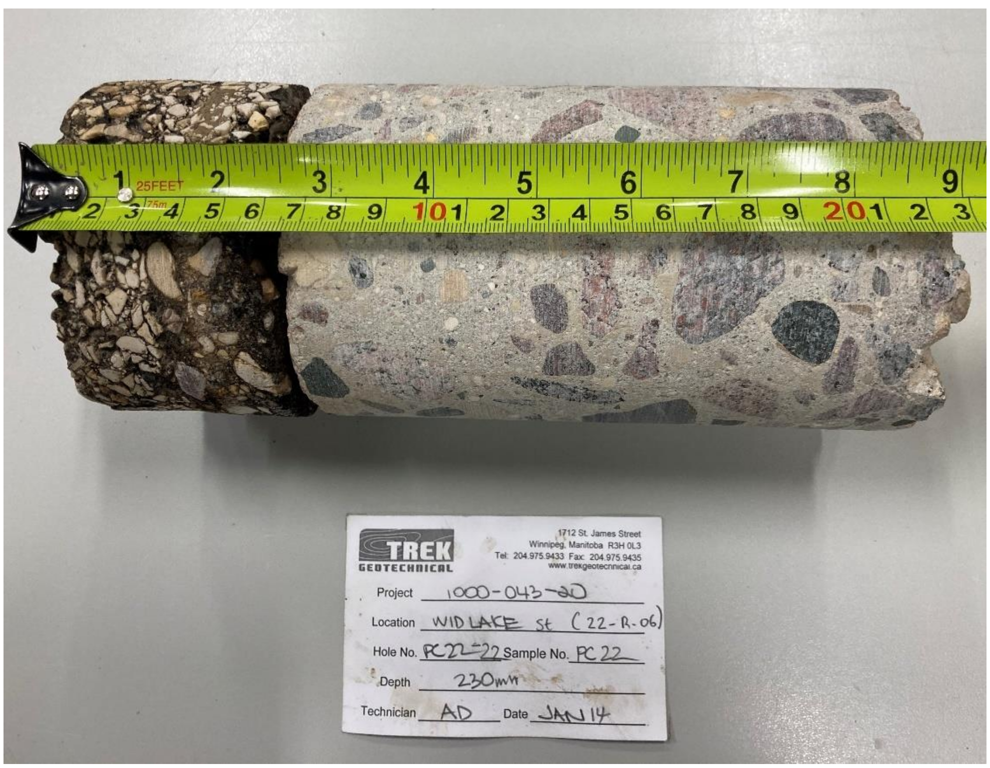

Photo 4: Pavement Core Sample at PC22-22

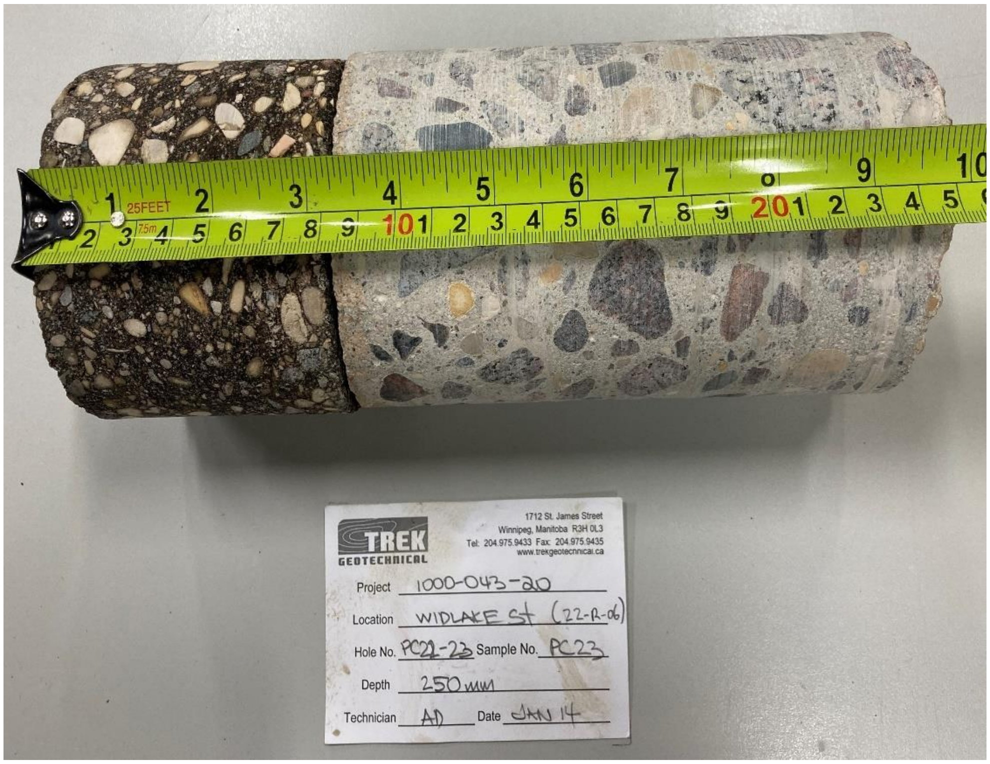

Photo 5: Pavement Core Sample at PC22-23

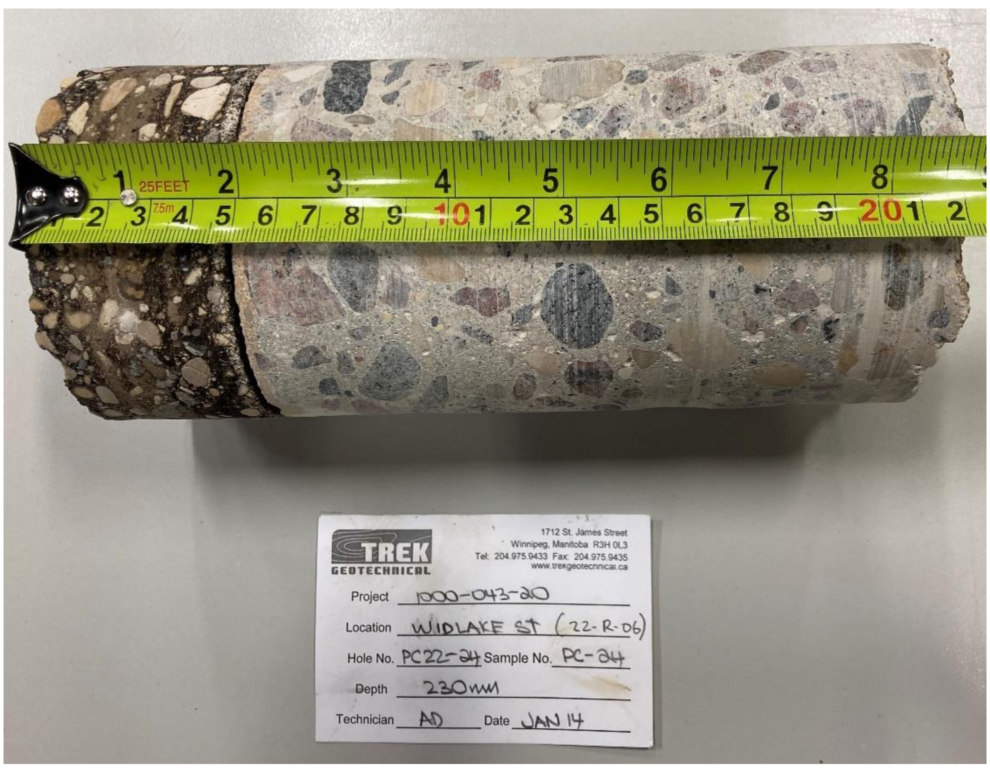

Photo 6: Pavement Core Sample at PC22-24

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Concrete Core Compressive Strength Report

CSA A23.2-14C

Project No. 1000-043-20 **Date** January 28, 2022

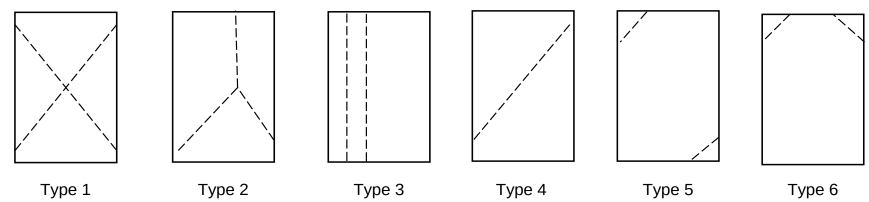
Project 2022 Local Street Package - 22-R-06 **Technician** NM

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}
Widlake Street	PC19	2022-01-14	2022-01-26	-	95	161	Soaked 48 h	43.63	50.16	1	0.99	1.00	1.09	1.06	1.00
Widlake Street	PC22	2022-01-14	2022-01-26	-	95	155	Soaked 48 h	41.52	47.53	1	0.99	1.00	1.09	1.06	1.00
Widlake Street	PC23	2022-01-14	2022-01-26	-	95	160	Soaked 48 h	34.48	39.59	1	0.99	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): $f_c = f_{conc}F_{l/d}F_{dia}F_{mc}F_DF_{reinf}$



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:

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

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.

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:

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

- 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:

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

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.

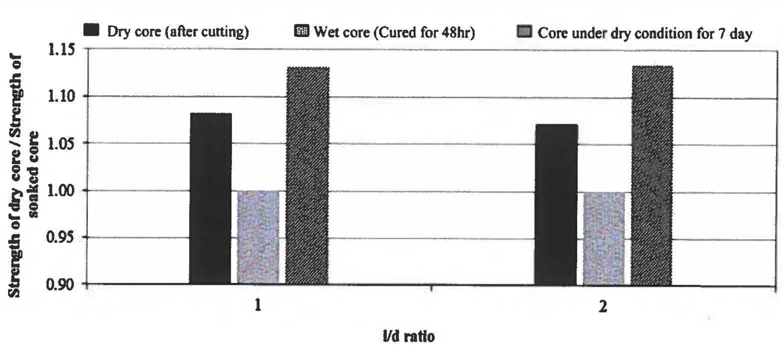


Figure 20 Effect of core moisture condition on core strength for different aspect ratios (l/d).

Appendix F

Summary Table, Pavement Core Compressive Strength and Photographs of Pavement Core Samples – Winona St

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2022 Local Street Package - 22-R-06

Winona Street: between Kildare Avenue West and Regent Avenue West

Pavement Core No.	Pavement Core Location	Pavement Surface		Pavement Structure Material		
		Type	Thickness (mm)	Type	Thickness (mm)	Corrected Compressive Strength (Mpa)
PC22-11	UTM : 5528915 m N, 643071 m E; Located 42 m North of Regent Ave and Winona St intersection, Southbound lane, 1 m West of East curb.	Asphalt	40	Concrete	140	-
PC22-12	UTM : 5529091 m N, 643062 m E; Located 38 m North of Yale Ave W and Winona St intersection, Southbound lane, 1.5 m East of West curb.	Asphalt	50	Concrete	140	-
PC22-13	UTM : 5528986 m N, 643069 m E; Located 26 m North of Victoria Ave W and Winona St intersection, Northbound lane, 1.5 m West of East curb.	Asphalt	40	Concrete	140	-
PC22-14	UTM : 5529176 m N, 6430062 m E; Located 36 m North of Ravelston Ave W and Winona St intersection, Northbound lane, 1.5 m West of East curb.	Asphalt	40	Concrete	130	48.05
PC22-15	UTM : 5529228 m N, 643057 m E; Located at Rosseau Ave W and Winona st intersection, Southbound lane, 1.5 m East of West curb.	Asphalt	30	Concrete	160	-
PC22-16	UTM : 5529295 m N, 643055 m E; Located in front of #170 Winona St, Northbound lane, 1.5 m West of East curb.	Asphalt	50	Concrete	150	-
PC22-17	UTM : 5529369 m N, 643050 m E; Located 2 m North of South corner of #807 Winona St, Southbound lane, 1.5 m East of West curb.	Asphalt	70	Concrete	160	-
PC22-18	UTM : 5529440 m N, 643051 m E; Located in front of #905 Winona St, Northbound lane, 2 m West of East curb.	Asphalt	60	Concrete	160	-

Photo 1: Pavement Core Sample at PC22-11

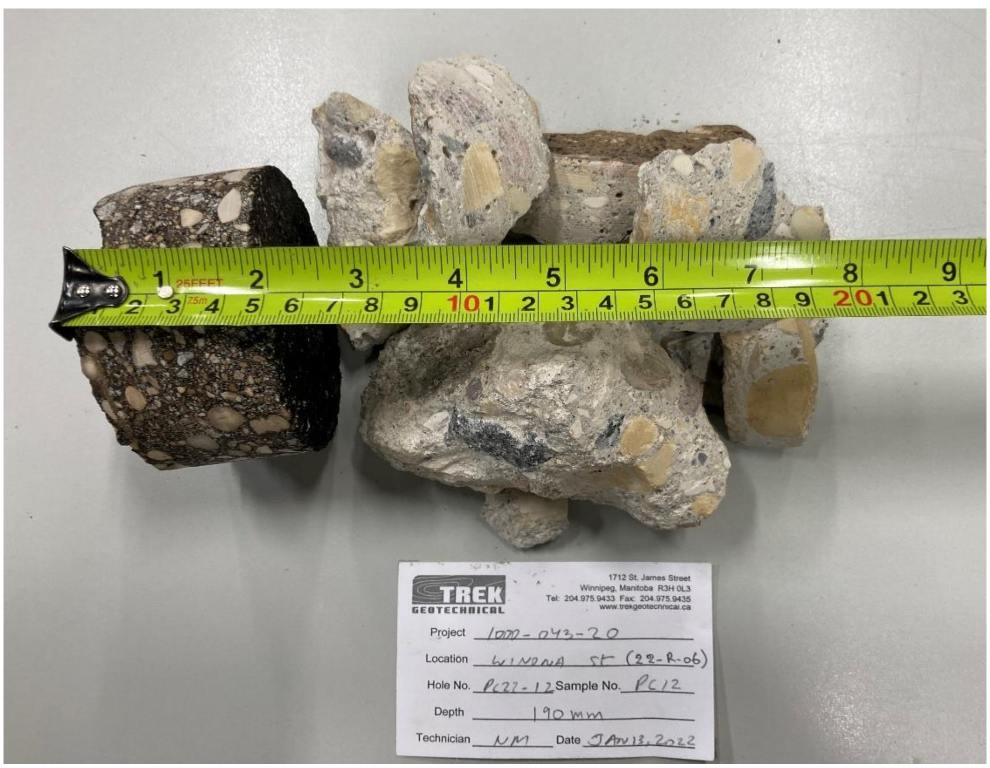

Photo 2: Pavement Core Sample at PC22-12

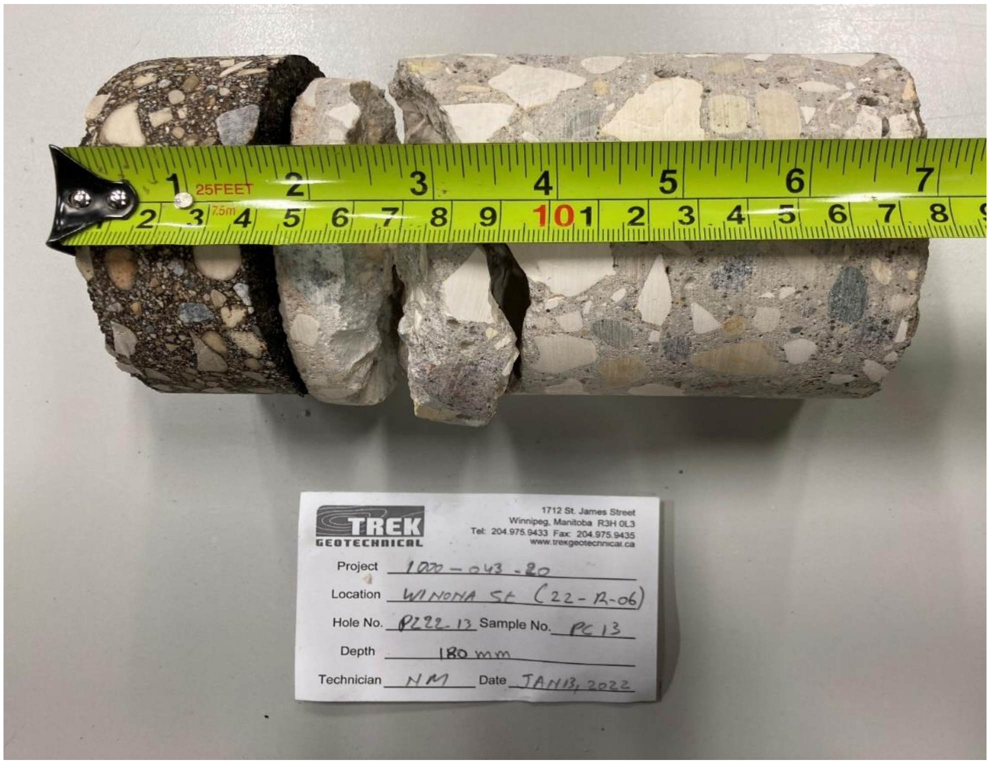

Photo 3: Pavement Core Sample at PC22-13

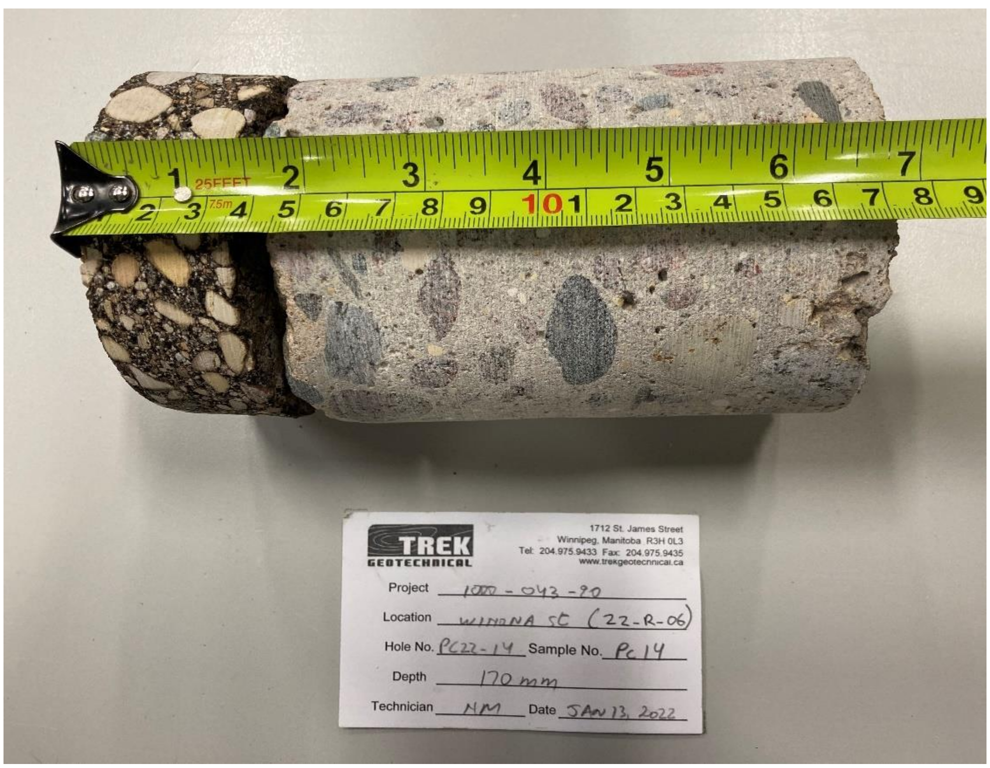

Photo 4: Pavement Core Sample at PC22-14

Photo 5: Pavement Core Sample at PC22-15

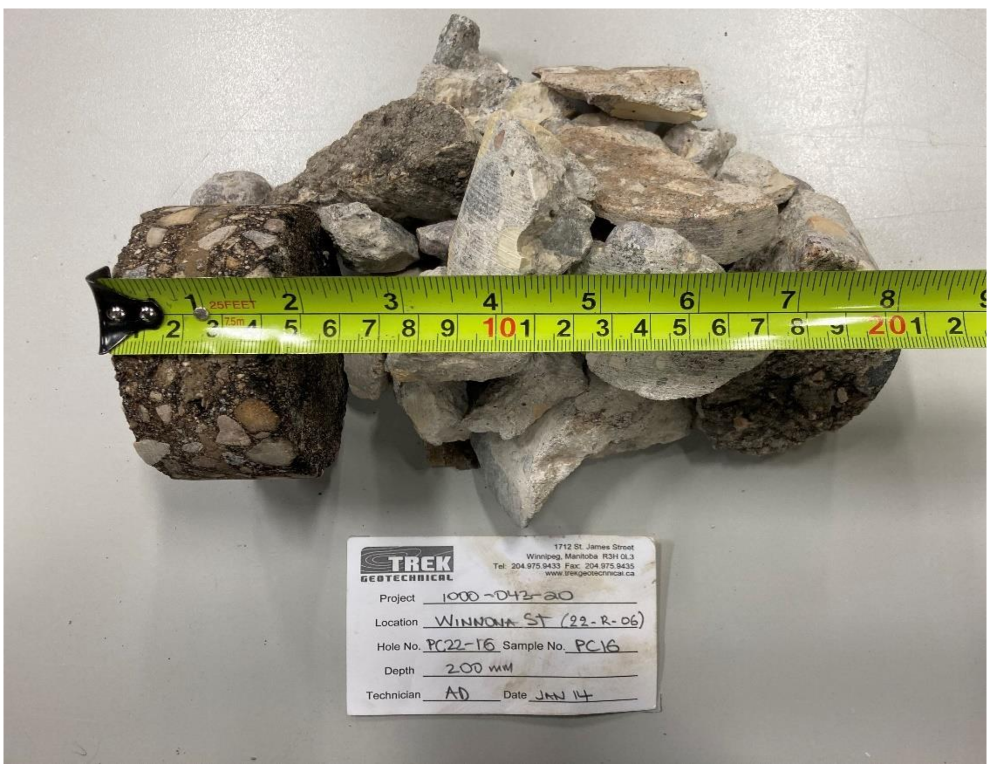

Photo 6: Pavement Core Sample at PC22-16

Photo 7: Pavement Core Sample at PC22-17

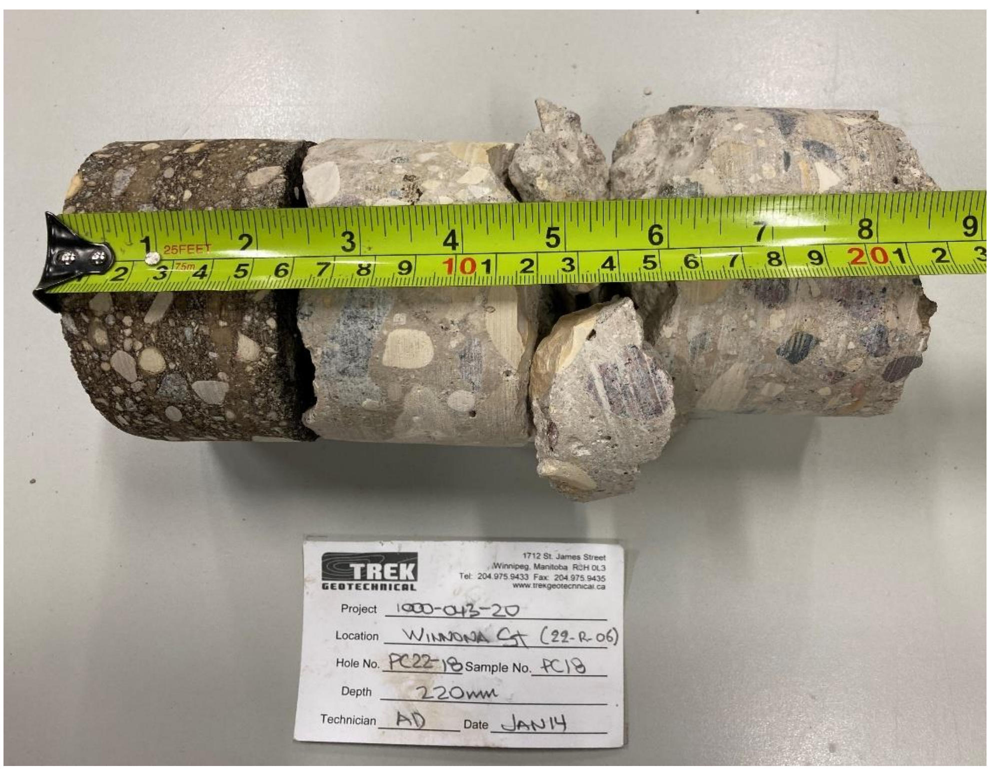

Photo 8: Pavement Core Sample at PC22-18

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Concrete Core Compressive Strength Report

CSA A23.2-14C

Project No. 1000-043-20 **Date** January 28, 2022

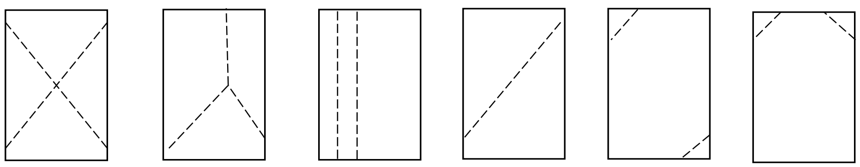
Project 2022 Local Street Package - 22-R-06 **Technician** NM

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}
Winona Street	PC14	2022-01-13	2022-01-27	-	95	110	Soaked 48 h	44.50	48.05	1	0.93	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 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 $(\sum \Phi_r * d)$.

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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 or Eq. 15

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

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.

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:

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

- 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:

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

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.

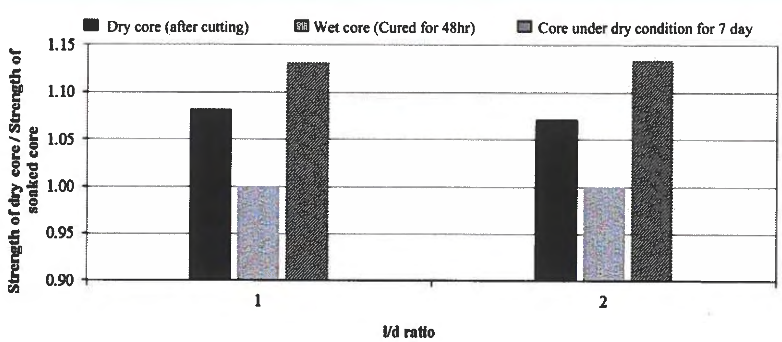

Figure 20 Effect of core moisture condition on core strength for different aspect ratios (l/d).

Appendix G

Summary Table, Pavement Core Compressive Strength and Photographs of Pavement Core Samples - Youville Street

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2022 Local Street Package - 22-R-06

Youville Street: between Marion Street and Eugenie Street

Pavement Core No.	Pavement Core Location	Pavement Surface		Pavement Structure Material		
		Type	Thickness (mm)	Type	Thickness (mm)	Corrected Compressive Strength (Mpa)
PC22-07	UTM : 5527040 m N, 635952 m E; Located 29 m North of Youville St and Eugenie St intersection, Northbound lane, 1.5 m West of East curb.	Asphalt	-	Concrete	160	75.27
PC22-08	UTM : 5527097 m N, 635944 m E; Located 40 m South of Horace St and Youville St intersection, Southbound lane, 1.5 m East of West curb.	Asphalt	-	Concrete	160	51.20
PC22-09	UTM : 5527161 m N, 635939 m E; Located 30 m North of Youville St and Horace St intersection, Northbound lane, 1.5 m West of East curb.	Asphalt	-	Concrete	150	60.49
PC22-10	UTM : 5527188 m N, 635928 m E; Located 43 m South of Marion St and Youville St intersection, Southbound lane, 1.5 m East of West curb.	Asphalt	-	Concrete	150	-

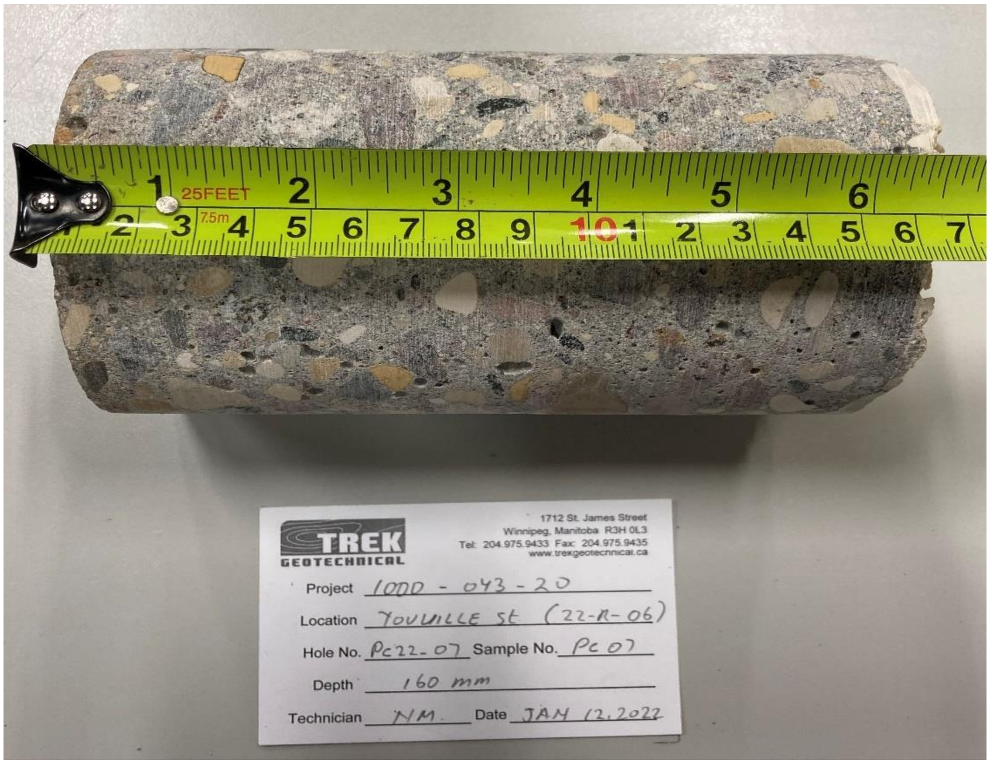


Photo 1: Pavement Core Sample at PC22-07

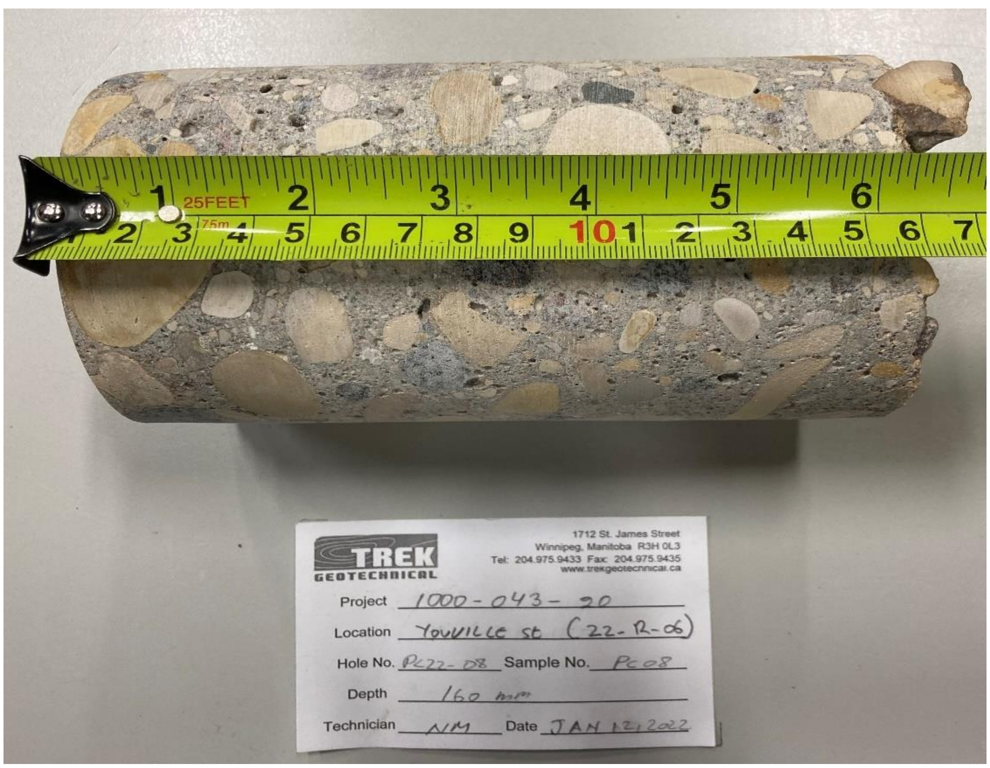


Photo 2: Pavement Core Sample at PC22-08

Photo 3: Pavement Core Sample at PC22-09

Photo 4: Pavement Core Sample at PC22-10

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. 1000-043-20 **Date** January 28, 2022

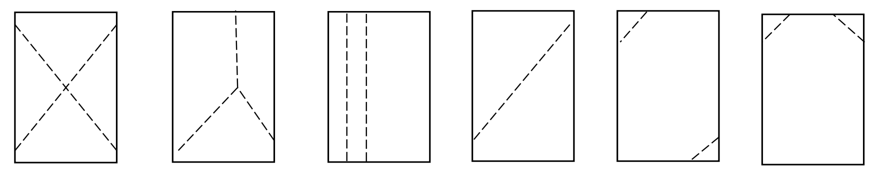
Project 2022 Local Street Package - 22-R-06 **Technician** NM

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}
Youville Street	PC07	2022-01-12	2022-01-27	-	95	157	Soaked 48 h	65.58	75.27	1	0.99	1.00	1.09	1.06	1.00
Youville Street	PC08	2022-01-12	2022-01-27	-	95	149	Soaked 48 h	44.95	51.20	1	0.98	1.00	1.09	1.06	1.00
Youville Street	PC09	2022-01-12	2022-01-27	-	95	135	Soaked 48 h	53.83	60.49	1	0.97	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 Type 2 Type 3 Type 4 Type 5 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																		
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● Diameter of steel bar.
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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:

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

- 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:

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

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.

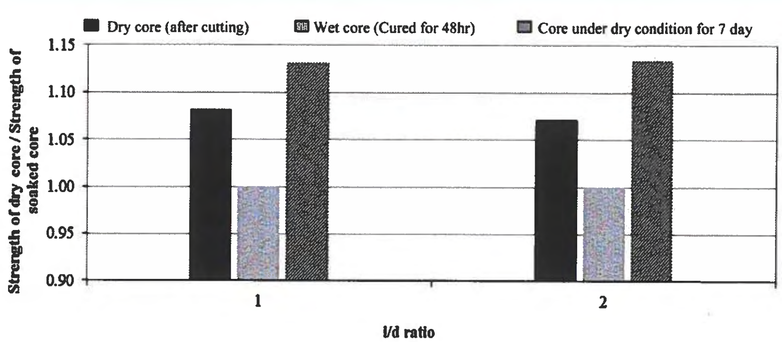

Figure 20 Effect of core moisture condition on core strength for different aspect ratios (l/d).

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:

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

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.

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WSP Canada Group Ltd.

2022 Local Streets Package 22-R-06 Additional Investigation

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

Project Number: 1000-043-20

Date: March 18, 2022

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March 18, 2022

Our File No. 1000-043-20

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

RE: 2022 Local Streets Package 22-R-06 Additional Investigation

TREK Geotechnical Inc. is pleased to submit our Final Report for the additional geotechnical investigation along Victoria avenue for 2022 Local Streets Package (22-R-06) 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	March 18, 2022	Final Report

Authorization Signatures

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

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

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Senior Geotechnical Engineer

ENGINEERS GEOSCIENTISTS MANITOBA
Certificate of Authorization
TREK GEOTECHNICAL INC.
No. 4877 Date: Mar 18, 2022

Table of Contents

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1.0 Introduction

This report summarizes the results of the additional road investigation completed for the Local Streets Package 22-R-06 project. The project included collecting pavement cores and drilling test holes along Victoria avenue E. 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 and drilling of test holes at 3 locations along Victoria avenue. WSP selected the investigation locations as shown on Figures 01 (attached). The road investigation was conducted on March 7th, 2022. The pavement structure (asphalt/concrete) was cored by Asad Dustmamatov 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 Asad Dustmamatov to a depth of 2.3 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

Pavement core and test hole locations noted on the summary tables and test hole logs 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 method) on select samples between 0.6 and 0.9 m below pavement as well as Standard Proctor and CBR testing. Information gathered in Appendix A 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 clay was encountered within the prescribed sample depth for CBR testing and the results are shown in the table below.

Table 1: 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	Victoria Ave E (TH22-01, 02, 03)	0.3-1.5	1536	25.2	95.4	25.5	3.4%	2.6%

* 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 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.

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

1000-043-20
WSP
2022 Local Streets Package (22-R-06)

LEGEND:

TEST HOLE (TREK, 2022)

NOTES:

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

0 10 20 30 40 50 m
SCALE = 1 : 1 000 (216 mm x 279 mm)

Figure 01
Test Hole Location Plan

Appendix A

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

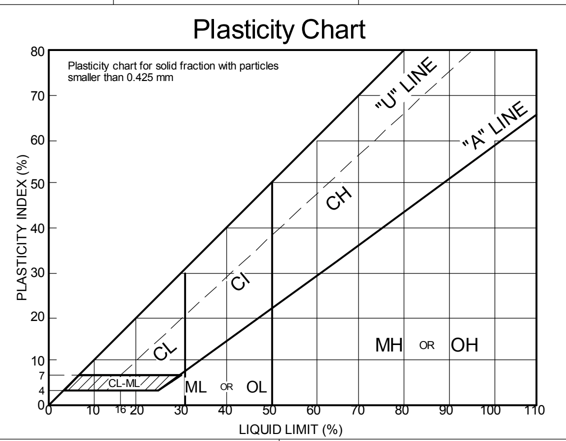
TREK GEOTECHNICAL

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	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

TREK GEOTECHNICAL

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

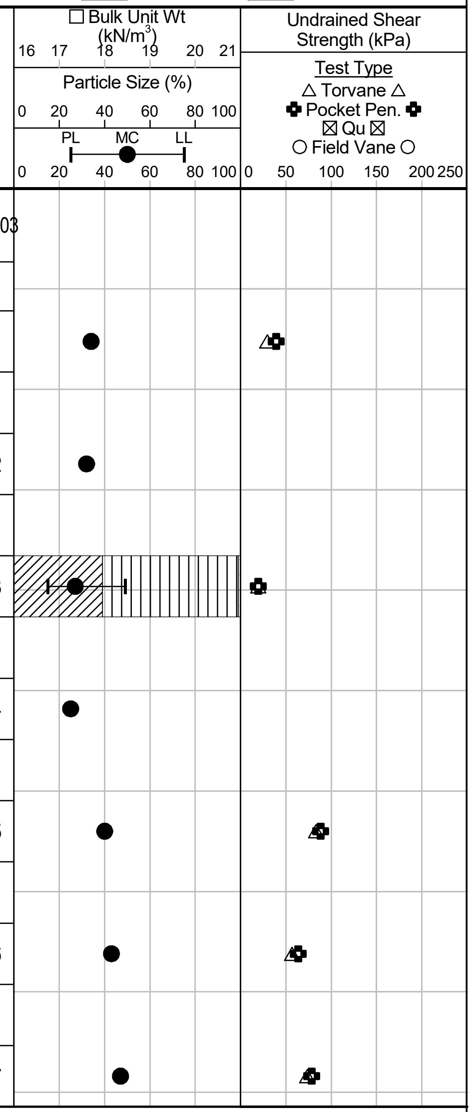
Sub-Surface Log

Client:	WSP Canada Inc	**Project Number:**	1000-043-20
Project Name:	Local Street Package 22-R-06	**Location:**	UTM N-5528990, E-643970 (Victoria Ave E)
Contractor:	Maple Leaf Drilling Ltd.	**Ground Elevation:**	Top of Pavement
Method:	125mm Solid Stem Auger, B40 Mobile Truck Mount	**Date Drilled:**	March 7, 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
0.0	CONCRETE - 160 mm thick	Core	PC22-03
	CLAY - silty, trace sand - grey - frozen, moist and soft to firm when thawed - high plasticity - AASHTO: A-7-6 (I)	Grab	G01
0.5		Grab	G02
	SILT and CLAY - trace sand - brown - frozen to 1.5 m depth, moist and soft when thawed - intermediate plasticity - AASHTO: A-7-6 (35)		
1.0		Grab	G03
		Grab	G04
1.5	CLAY - silty - brown - moist, stiff - high plasticity - AASHTO: A-7-6 (I)	Grab	G05
		Grab	G06
2.0		Grab	G07



END OF TEST HOLE AT 2.3 m IN CLAY
1) No seepage or sloughing observed.
2) Test hole open to 2.3 m immediately after drilling.
3) Test hole backfilled with auger cuttings, granular fill and cold patch asphalt.
4) Test hole located in front of #403 Victoria ave E, Westbound lane, 1.5 m South of North curb.
5) The bulk sample was collected between 0.3 m and 1.5 m depth.

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

Sub-Surface Log

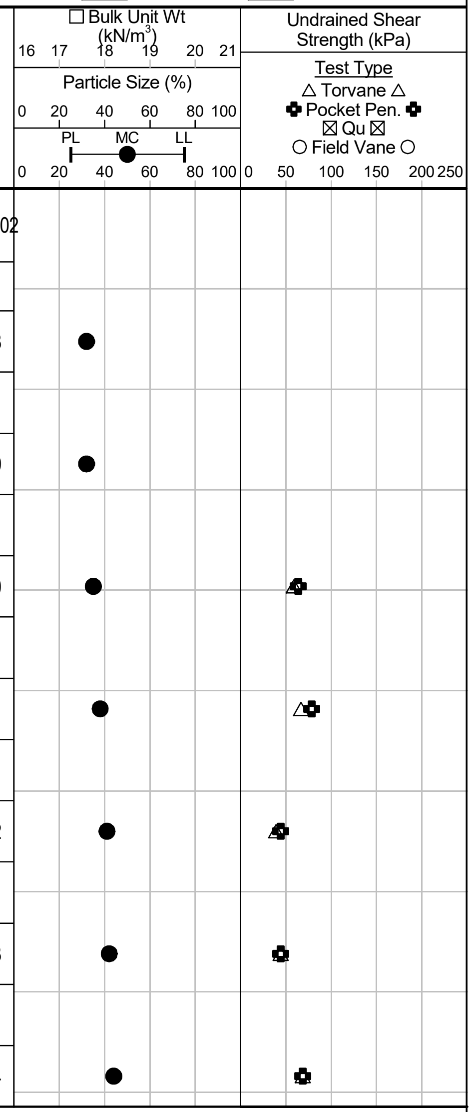
TREK GEOTECHNICAL

Client:	WSP Canada Inc	**Project Number:**	1000-043-20
Project Name:	Local Street Package 22-R-06	**Location:**	UTM N-5528989, E-644022 (Victoria Ave E)
Contractor:	Maple Leaf Drilling Ltd.	**Ground Elevation:**	Top of Pavement
Method:	125mm Solid Stem Auger, B40 Mobile Truck Mount	**Date Drilled:**	March 7, 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
		CONCRETE - 160 mm thick		PC22-02
		CLAY - silty, trace sand - grey - frozen to 1.5 m depth, moist and firm to stiff when thawed - high plasticity - AASHTO: A-7-6 (I)	Grab	G08
0.5			Grab	G09
1.0			Grab	G10
			Grab	G11
1.5		- brown below 1.5 m	Grab	G12
2.0			Grab	G13
			Grab	G14



END OF TEST HOLE AT 2.3 m IN CLAY
1) No seepage or sloughing observed.
2) Test hole open to 2.3 m immediately after drilling.
3) Test hole backfilled with auger cuttings, granular fill and cold patch asphalt.
4) Test hole located in front of #412 Victoria ave E, Eastbound lane, 1.5 m North of South curb.
5) The bulk sample was collected between 0.3 m and 1.5 m depth.

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

TREK GEOTECHNICAL

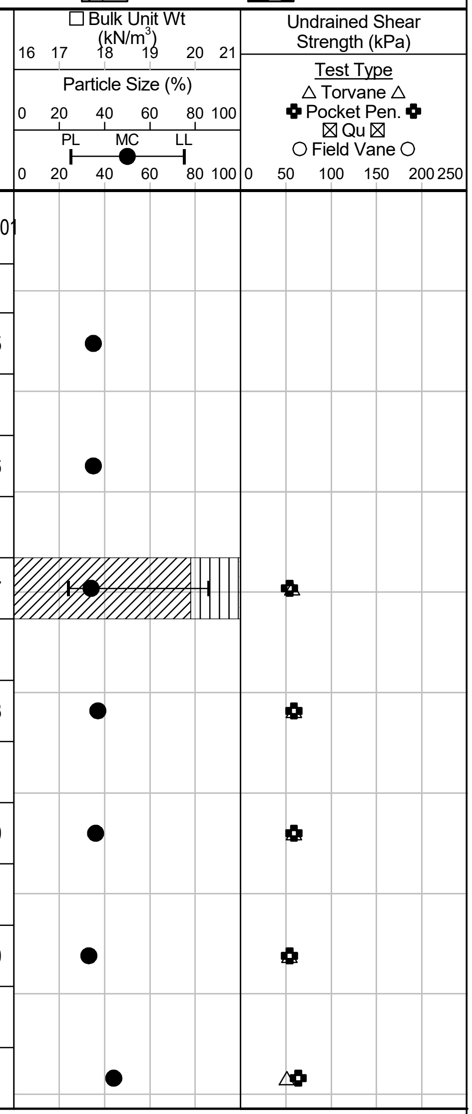
Sub-Surface Log

Client:	WSP Canada Inc	**Project Number:**	1000-043-20
Project Name:	Local Street Package 22-R-06	**Location:**	UTM N-5528992, E-644069 (Victoria Ave E)
Contractor:	Maple Leaf Drilling Ltd.	**Ground Elevation:**	Top of Pavement
Method:	125mm Solid Stem Auger, B40 Mobile Truck Mount	**Date Drilled:**	March 7, 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
	CONCRETE - 145 mm thick		PC22-01
	CLAY - silty, trace sand - grey - frozen to 1.5 m depth, moist and stiff when thawed - high plasticity - AASHTO: A-7-6 (71)	Grab	G15
0.5		Grab	G16
1.0		Grab	G17
		Grab	G18
1.5		Grab	G19
	- brown below 1.8 m	Grab	G20
2.0		Grab	G21



END OF TEST HOLE AT 2.3 m IN CLAY
1) No seepage or sloughing observed.
2) Test hole open to 2.3 m immediately after drilling.
3) Test hole backfilled with auger cuttings, granular fill and cold patch asphalt.
4) Test hole located in front of #423 Victoria ave E, Westbound lane, 1.5 m South of North curb.
5) The bulk sample was collected between 0.3 m and 1.5 m depth.

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

2022 Local Street Package - 22-R-06
Sub-Surface Investigation
Victoria Avenue East : between Roanoke Street and Leola 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 5528990 N, 643970 E Located in front of #403 Victoria Ave E, Westbound lane, 1.5 m South of North curb.	Asphalt	-	Concrete	145	Clay; AASHTO: A-7-6 (I)	0.3	0.5	34							
						Clay; AASHTO: A-7-6 (I)	0.6	0.8	32							
						Silt and Clay; AASHTO: A-7-6 (35)	0.9	1.1	27	39	60	1		15	49	33
						Silt and Clay; AASHTO: A-7-6 (35)	1.2	1.4	25							
						Clay; AASHTO: A-7-6 (I)	1.5	1.7	40							
						Clay; AASHTO: A-7-6 (I)	1.8	2.0	43							
						Clay; AASHTO: A-7-6 (I)	2.1	2.3	47							
TH22-02	UTM : 14U 5528989 N, 644022 E Located in front of #412 Victoria Ave E, Eastbound lane, 1.5 m North of South curb.	Asphalt	-	Concrete	160	Clay; AASHTO: A-7-6 (I)	0.3	0.5	32							
						Clay; AASHTO: A-7-6 (I)	0.6	0.8	32							
						Clay; AASHTO: A-7-6 (I)	0.9	1.1	35							
						Clay; AASHTO: A-7-6 (I)	1.2	1.4	38							
						Clay; AASHTO: A-7-6 (I)	1.5	1.7	41							
						Clay; AASHTO: A-7-6 (I)	1.8	2.0	42							
						Clay; AASHTO: A-7-6 (I)	2.1	2.3	44							
TH22-03	UTM : 14U 5528992 N, 644069 E Located in front of #423 Victoria Ave E, Westbound lane, 1.5 m South of North curb.	Asphalt	-	Concrete	155	Clay; AASHTO: A-7-6 (71)	0.3	0.5	35							
						Clay; AASHTO: A-7-6 (71)	0.6	0.8	35							
						Clay; AASHTO: A-7-6 (71)	0.9	1.1	34	78	21	1		24	86	62
						Clay; AASHTO: A-7-6 (71)	1.2	1.4	37							
						Clay; AASHTO: A-7-6 (71)	1.5	1.7	36							
						Clay; AASHTO: A-7-6 (71)	1.8	2.0	33							
						Clay; AASHTO: A-7-6 (71)	2.1	2.3	44							

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

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Winnipeg, MB R3H 0L3
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Moisture Content Report
ASTM D2216-10

Project No. 1000-043-20
Client WSP Canada Inc.
Project Local Street Package 22-R-06

Sample Date 07-Mar-22
Test Date 08-Mar-22
Technician AD

Test Hole	TH22-01	TH22-01	TH22-01	TH22-01	TH22-01	TH22-01
Depth (m)	0.3 - 0.5	0.6 - 0.8	0.9 - 1.1	1.2 - 1.4	1.5 - 1.7	1.8 - 2.0
Sample #	G01	G02	G03	G04	G05	G06
Tare ID	AC25	P28	W08	AC16	E94	A103
Mass of tare	6.8	8.7	8.5	7.0	8.6	8.7
Mass wet + tare	222.1	251.1	397.6	230.3	235.2	233.8
Mass dry + tare	168.0	192.6	315.3	185.2	170.8	165.9
Mass water	54.1	58.5	82.3	45.1	64.4	67.9
Mass dry soil	161.2	183.9	306.8	178.2	162.2	157.2
Moisture %	33.6%	31.8%	26.8%	25.3%	39.7%	43.2%

Test Hole	TH22-01	TH22-02	TH22-02	TH22-02	TH22-02	TH22-02
Depth (m)	2.1 - 2.3	0.3 - 0.5	0.6 - 0.8	0.9 - 1.1	1.2 - 1.4	1.5 - 1.7
Sample #	G07	G08	G09	G10	G11	G12
Tare ID	H41	N28	D17	AB01	E69	N07
Mass of tare	8.8	8.5	8.7	6.9	8.7	8.7
Mass wet + tare	213.9	225.6	251.5	260.0	236.8	266.5
Mass dry + tare	147.9	172.6	192.1	193.9	174.0	191.4
Mass water	66.0	53.0	59.4	66.1	62.8	75.1
Mass dry soil	139.1	164.1	183.4	187.0	165.3	182.7
Moisture %	47.4%	32.3%	32.4%	35.3%	38.0%	41.1%

Test Hole	TH22-02	TH22-02	TH22-03	TH22-03	TH22-03	TH22-03
Depth (m)	1.8 - 2.0	2.1 - 2.3	0.3 - 0.5	0.6 - 0.8	0.9 - 1.1	1.2 - 1.4
Sample #	G13	G14	G15	G16	G17	G18
Tare ID	AB10	W80	A19	F41	E88	AB33
Mass of tare	6.9	8.6	8.6	8.5	8.5	6.7
Mass wet + tare	197.1	229.7	240.9	168.5	406.3	161.7
Mass dry + tare	141.0	162.6	181.3	126.9	304.6	119.9
Mass water	56.1	67.1	59.6	41.6	101.7	41.8
Mass dry soil	134.1	154.0	172.7	118.4	296.1	113.2
Moisture %	41.8%	43.6%	34.5%	35.1%	34.3%	36.9%

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Moisture Content Report
ASTM D2216-10

Project No. 1000-043-20
Client WSP Canada Inc.
Project Local Street Package 22-R-06

Sample Date 07-Mar-22
Test Date 08-Mar-22
Technician AD

Test Hole	TH22-03	TH22-03	TH22-03			
Depth (m)	1.5 - 1.7	1.8 - 2.0	2.1 - 2.3			
Sample #	G19	G20	G21			
Tare ID	A105	W55	F21			
Mass of tare	8.5	8.5	8.9			
Mass wet + tare	195.2	157.7	224.1			
Mass dry + tare	146.1	121.0	158.8			
Mass water	49.1	36.7	65.3			
Mass dry soil	137.6	112.5	149.9			
Moisture %	35.7%	32.6%	43.6%			

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Atterberg Limits
ASTM D4318-10e1

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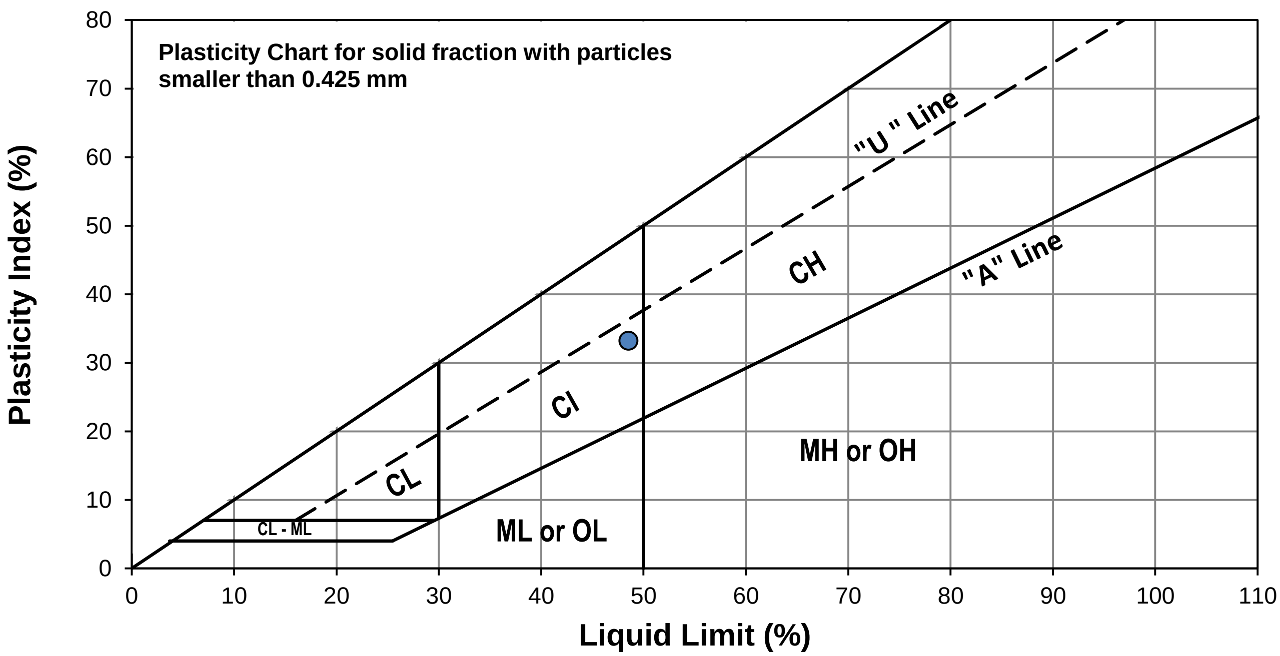
For specific tests as listed on www.ccil.com

Project No.	1000-043-20
Client	WSP Canada Inc.
Project	Local Street Package 22-R-06
Test Hole	TH22-01
Sample #	G03
Depth (m)	0.9 - 1.1
Sample Date	07-Mar-22
Test Date	10-Mar-22
Technician	AD

Liquid Limit	49
Plastic Limit	15
Plasticity Index	33

Liquid Limit

Trial #	**1**	**2**	**3**		
Number of Blows (N)	17	24	30		
Mass Tare (g)	14.108	14.316	14.086		
Mass Wet Soil + Tare (g)	25.955	25.152	24.486		
Mass Dry Soil + Tare (g)	21.968	21.599	21.139		
Mass Water (g)	3.987	3.553	3.347		
Mass Dry Soil (g)	7.860	7.283	7.053		
Moisture Content (%)	50.725	48.785	47.455		



Plastic Limit

Trial #	**1**	**2**	**3**	**4**	**5**
Mass Tare (g)	14.006	14.089			
Mass Wet Soil + Tare (g)	21.525	20.530			
Mass Dry Soil + Tare (g)	20.541	19.663			
Mass Water (g)	0.984	0.867			
Mass Dry Soil (g)	6.535	5.574			
Moisture Content (%)	15.057	15.554			

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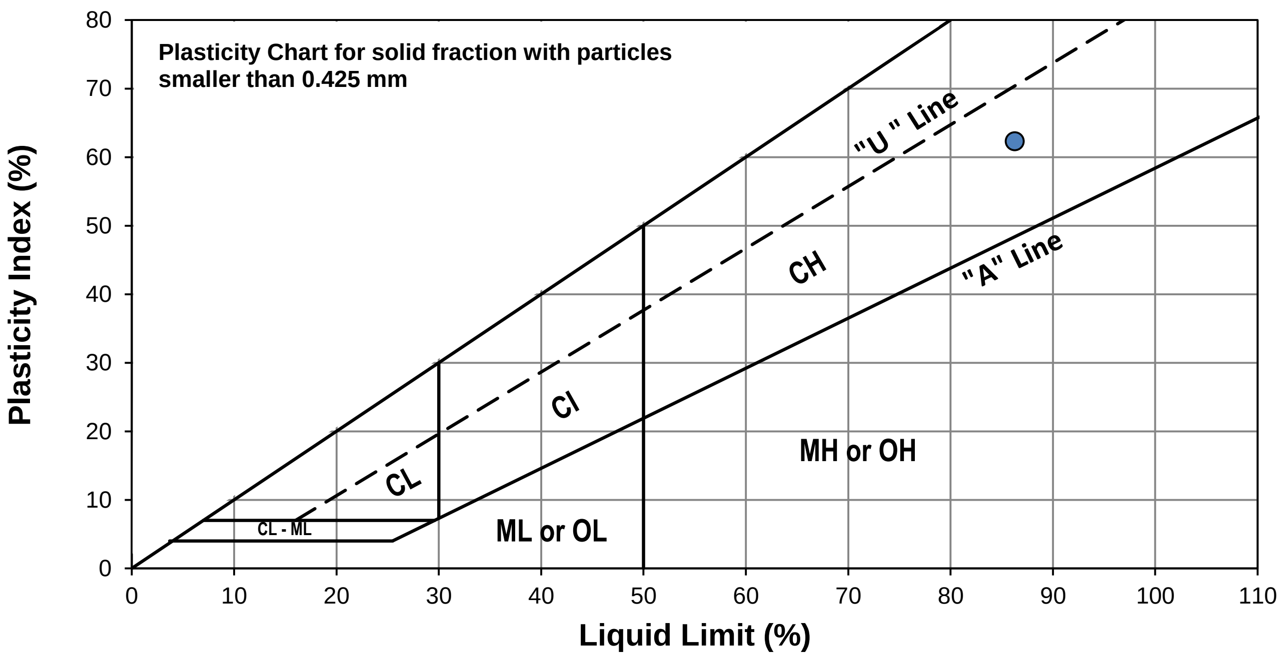
Atterberg Limits
ASTM D4318-10e1

Project No.	1000-043-20
Client	WSP Canada Inc.
Project	Local Street Package 22-R-06
Test Hole	TH22-03
Sample #	G17
Depth (m)	0.9 - 1.1
Sample Date	07-Mar-22
Test Date	10-Mar-22
Technician	AD

Liquid Limit	86
Plastic Limit	24
Plasticity Index	62

Liquid Limit

Trial #	**1**	**2**	**3**		
Number of Blows (N)	24	29	32		
Mass Tare (g)	14.060	13.940	14.058		
Mass Wet Soil + Tare (g)	26.231	23.984	23.647		
Mass Dry Soil + Tare (g)	20.581	19.371	19.271		
Mass Water (g)	5.650	4.613	4.376		
Mass Dry Soil (g)	6.521	5.431	5.213		
Moisture Content (%)	86.643	84.938	83.944		



Plastic Limit

Trial #	**1**	**2**	**3**	**4**	**5**
Mass Tare (g)	13.871	13.944			
Mass Wet Soil + Tare (g)	20.515	20.186			
Mass Dry Soil + Tare (g)	19.233	18.974			
Mass Water (g)	1.282	1.212			
Mass Dry Soil (g)	5.362	5.030			
Moisture Content (%)	23.909	24.095			

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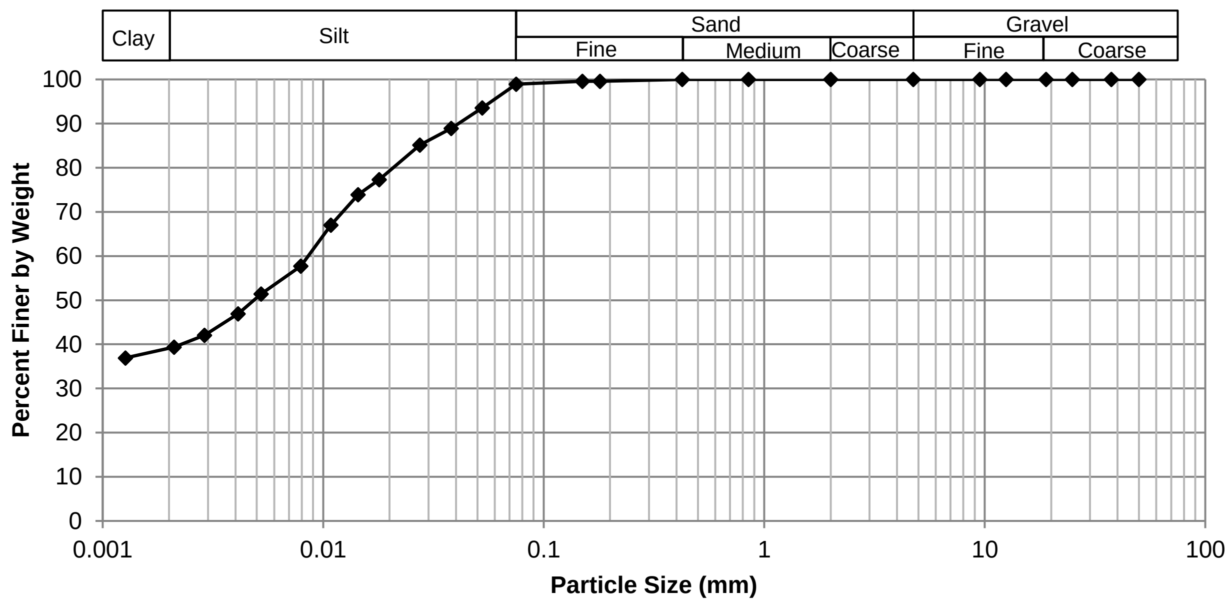
Grain Size Analysis (Hydrometer Method)
AASHTO T 88

Project No.	1000-043-20
Client	WSP Canada Inc
Project	Local Street Package 22-R-06
Test Hole	TH22-01
Sample #	G03
Depth (m)	0.9 - 1.1
Sample Date	7-Mar-22
Test Date	10-Mar-22
Technician	AD

Gravel	0.0%
Sand	1.1%
Silt	59.8%
Clay	39.1%

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	98.92
37.5	100.00	2.00	100.00	0.0527	93.58
25.0	100.00	0.850	100.00	0.0381	88.89
19.0	100.00	0.425	100.00	0.0274	85.13
12.5	100.00	0.180	99.61	0.0180	77.32
9.50	100.00	0.150	99.61	0.0144	73.88
4.75	100.00	0.075	98.92	0.0108	67.00
				0.0079	57.69
				0.0052	51.44
				0.0041	46.90
				0.0029	42.06
				0.0021	39.40
				0.0013	36.93

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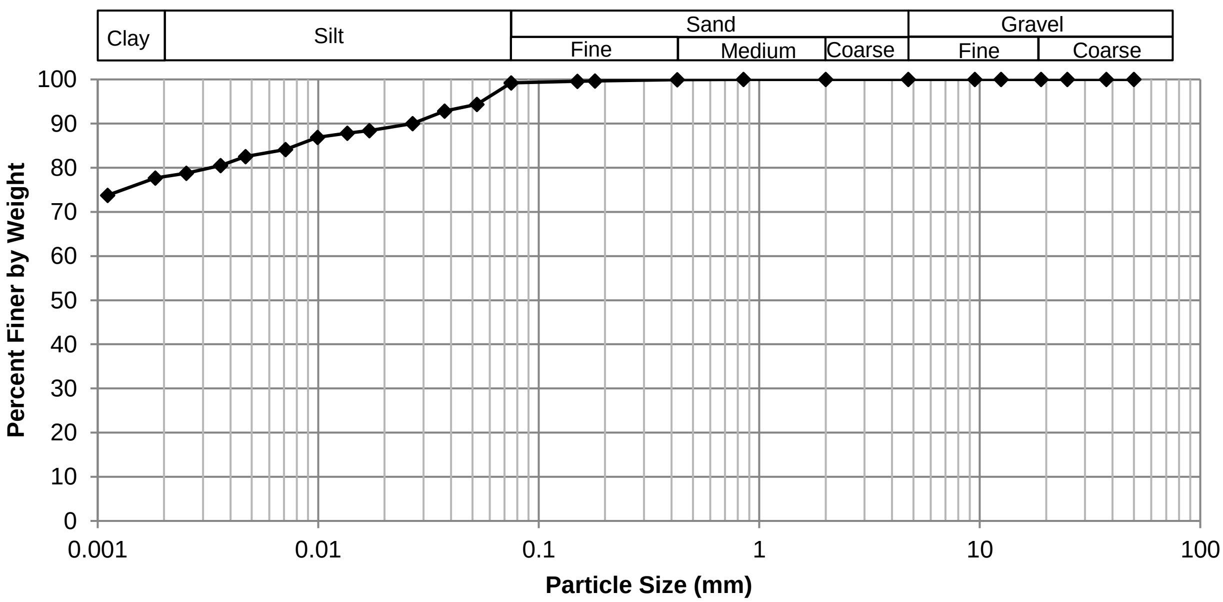
Grain Size Analysis (Hydrometer Method)
AASHTO T 88

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

Project No.	1000-043-20
Client	WSP Canada Inc
Project	Local Street Package 22-R-06
Test Hole	TH22-03
Sample #	G17
Depth (m)	0.9 - 1.1
Sample Date	7-Mar-22
Test Date	10-Mar-22
Technician	AD

Gravel	0.0%
Sand	0.8%
Silt	21.3%
Clay	77.9%

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	99.24
37.5	100.00	2.00	100.00	0.0525	94.37
25.0	100.00	0.850	100.00	0.0374	92.81
19.0	100.00	0.425	99.98	0.0268	89.99
12.5	100.00	0.180	99.63	0.0171	88.43
9.50	100.00	0.150	99.55	0.0135	87.80
4.75	100.00	0.075	99.24	0.0099	86.87
				0.0071	84.11
				0.0047	82.55
				0.0036	80.48
				0.0025	78.79
				0.0018	77.66
				0.0011	73.77

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Standard Proctor Compaction Test

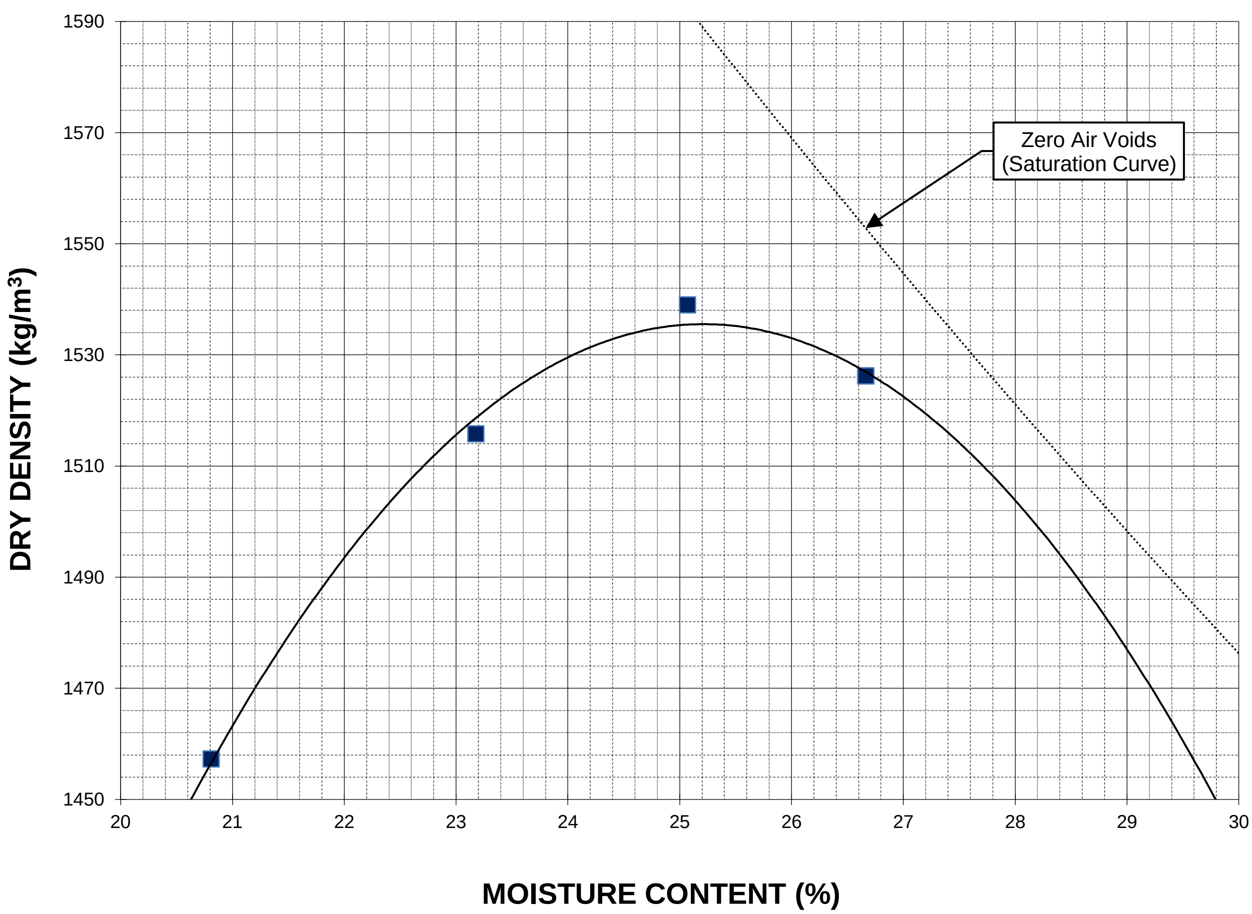
ASTM D698-12e2

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

Project No.	1000-043-20
Client	WSP Canada Inc.
Project	Local Street Package 22-R-06
Sample #	Combined bulk samples
Source	TH22-01, 02, 03
Material	Clay
Sample Date	07-Mar-22
Test Date	09-Mar-22
Technician	AD

Maximum Dry Density (kg/m3)	1536
Optimum Moisture (%)	25.2

Trial Number	1	2	3	4	
Wet Density (kg/m^3)	1761	1867	1925	1933	
Dry Density (kg/m^3)	1457	1516	1539	1526	
Moisture Content (%)	20.8	23.2	25.1	26.7	



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California Bearing Ratio Test Data Sheet

ASTM D1883-16

Project No.	1000-043-20	**Source**	TH22-01, 02, 03
Client	WSP Canada Inc.	**Material**	Clay
Project	Local Street Package 22-R-06	**Sample Date**	2022-03-07
Sample #	Combined bulk samples	**Test Date**	2022-03-10
		Technician	AD

Proctor Results (ASTM D698)

Maximum Dry Density	1536	kg/m3
Optimum Moisture Content	25.2	%
Material Retained on 19 mm Sieve	0.0	%

CBR Sample Compaction

Dry Density	1465	kg/m3
Initial Moisture Content	25.5	%
Relative Density	95.4	% SPMDD

Soaking Results

Surcharge	4.54	kg
Swell	1.6	%
Moisture Content in top 25 mm	33.7	%
Immersion Period	96	h

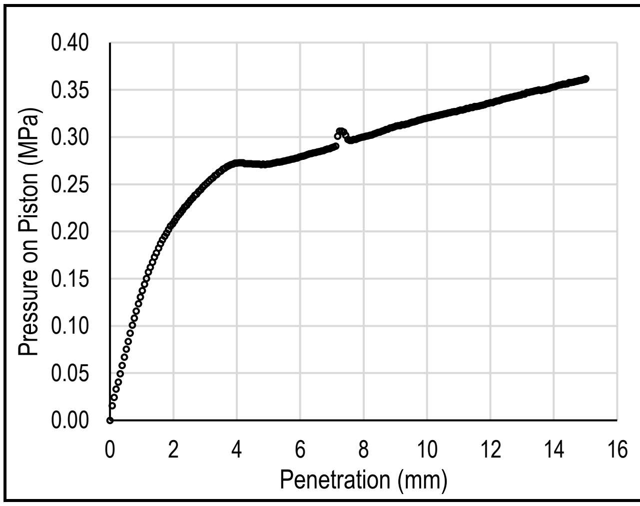
CBR Results

CBR at 2.54 mm	3.4	%
CBR at 5.08 mm	2.6	%
Zero Correction	0	mm

Test Data

Penetration (mm)	Measured Pressure (MPa)	Corrected Pressure (MPa)
0.64	0.09	0.09
1.27	0.16	0.16
1.91	0.21	0.21
2.54	0.23	0.23
3.18	0.26	0.26
3.81	0.27	0.27
4.45	0.27	0.27
5.08	0.27	0.27
7.62	0.30	0.30
10.16	0.32	0.32
12.70	0.34	0.34

Load/Penetration Curve



Comments:

Template Rev. B - 2018-04-07

Photo 1: Pavement Core Sample at TH22-01

Photo 2: Pavement Core Sample at TH22-02

Photo 3: Pavement Core Sample at TH22-03