APPENDIX 'A'

GEOTECHNICAL REPORT

Morrison Hershfield
Sturgeon Road Coring Program (RFP No. 437-2021)

Prepared for:

Ron Bruce, P. Eng
Morrison Hershfield
1-59 Scurfield Boulevard
Winnipeg, MB R3Y 1V2

Project Number:
1000 001 26

Date:
October 27, 2021
Final Report

Quality Engineering | Valued Relationships

October 27, 2021

Our File No. 1000 001 26

Mr. Ron Bruce, P. Eng
Morrison Hershfield
1-59 Scurfield Boulevard
Winnipeg, Manitoba, R3Y 1V2

RE: 2021 Regional Street Renewal (RFP No. 437-2021) Sturgeon Road Coring Program

TREK Geotechnical Inc. is pleased to submit our report for the road investigation for the Sturgeon Road Coring Program 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	NM	October 26, 2021	Final Report

Authorization Signatures

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Geotechnical Engineer

ENGINEERS GEOSCIENTISTS MANITOBA
Certificate of Authorization
TREK GEOTECHNICAL INC.
No. 4877 Date: Oct. 26, 2021

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1.0 Introduction

This report summarizes the results of the road investigation completed for the Sturgeon Road Coring Program project which included obtaining pavement cores between Booth Dr and Ness Avenue. The information collected describes the asphalt and concrete pavement structure of the existing road. The investigation was carried out in accordance with the City of Winnipeg public works street project requirements.

2.0 Road Investigation

The investigation included coring of pavement at 4 locations on Sturgeon Road. Morrison Hershfield selected the investigation locations as shown on Figure 01 (attached) and the table below summarizes the investigation program.

Road Investigation Program

Street	# of Locations	Investigation
Sturgeon Road – Booth Drive to Ness Ave	4	Pavement Cores

Pavement coring was completed on October 1st, 2021. The pavement was cored by Naimu Mujyambere of TREK Geotechnical Inc. (TREK) using a portable coring press equipped with a hollow 150 mm diameter diamond core drill bit. 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 Appendix A.

Four concrete cores were tested for concrete compressive strength breaks and the length to diameter ratio ranged between 1.00 to 1.34 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 Appendix B.

Concrete Core Compressive Strength Results

Core #	Core Location	Corrected Compressive Strength (MPa)
1	PC21-01	59.6
2	PC21-02	54.1
3	PC21-03	61.2
4	PC21-04	60.1

The locations noted on the summary table (Appendix A) is 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 Morrison Hershfield (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

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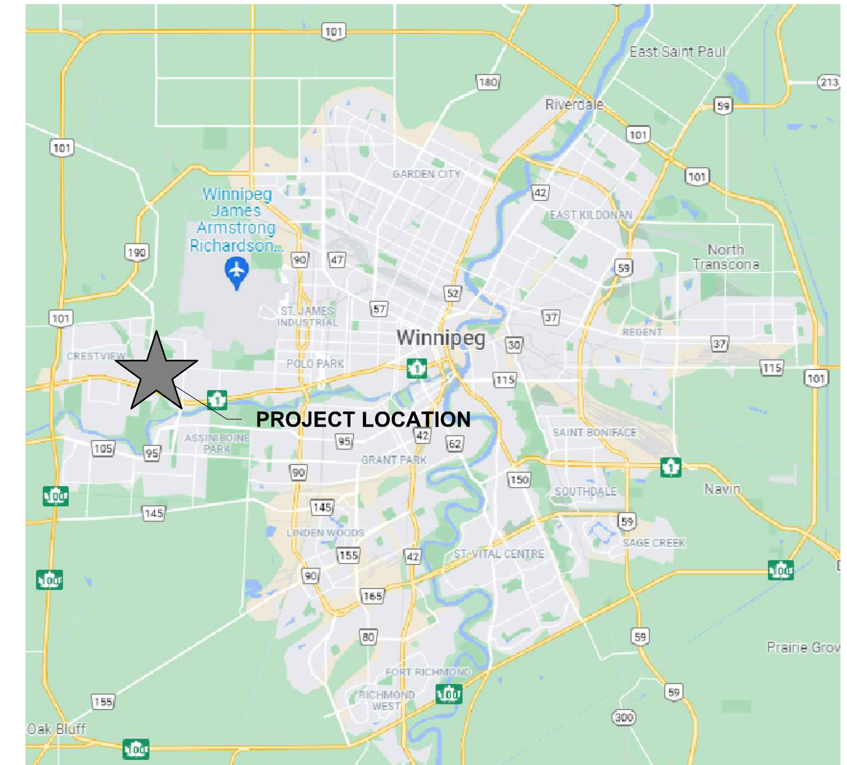
TREK GEOTECHNICAL

1000 001 26
Morrison Hershfield
Sturgeon Road Coring Program



KEY PLAN
SCALE: N.T.S.

0 50 100 150 m
SCALE = 1 : 2 500 (279 mm x 432 mm)

LEGEND: PAVEMENT CORE (TREK, 2021)

NOTES:
1. AERIAL IMAGERY FROM CITY OF WINNIPEG, (2016).

Figure 01
Pavement Core Location Plan

Appendix A

Summary Table and Photographs of Pavement Core Samples
Sturgeon Road – Ness Avenue and Booth Dr

Sturgeon Road Coring Program

Sturgeon Road Northbound and Southbound Lanes - Booth Drive to Ness Ave

Pavement Core No.	Pavement Core Location	Pavement Surface		Pavement Structure Material		
		Type	Thickness (mm)	Type	Thickness (mm)	Corrected Compressive Strength (Mpa)
PC21-01	UTM : 5527161 m N, 0623648 m E; : Located 2 m East of West curb, in front of south edge of #738 Sturgeon Road.	Asphalt	40	Concrete	230	59.6
PC21-02	UTM : 5527278 m N, 0623669 m E; : Located 2 m West of East curb, in front of south edge of #759 Sturgeon Road.	Asphalt	65	Concrete	140	54.1
PC21-03	UTM : 5527397 m N, 0623673 m E; : Located 2 m West of East curb, in front of North edge of #791 Sturgeon Road.	Asphalt	50	Concrete	210	61.2
PC21-04	UTM : 5527444 m N, 0623658 m E; : Located 2 m East of West curb, in front of North edge of #798 Sturgeon Road.	Asphalt	40	Concrete	240	60.1

Photo 1: Pavement Core Sample at PC21-01

Photo 2: Pavement Core Sample at PC21-02

Photo 3: Pavement Core Sample at PC21-03

Photo 4: Pavement Core Sample at PC21-04

Appendix B

Summary of Pavement Core Compressive Strength

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Concrete Core Compressive Strength Report

CSA A23.2-14C

Project No. 1000-001-26 **Date** October 22, 2021

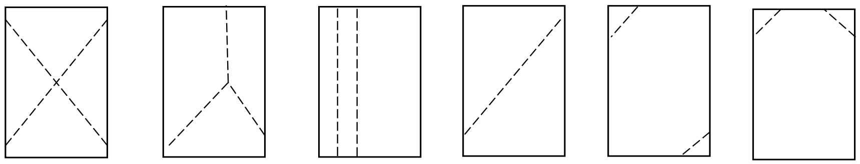
Project Sturgeon Road Coring Program **Technician** IA

Client Morrison Hershfield

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}
PC21-01	C01	2021-10-20	2021-10-22	-	144.6	145.1	Soaked 48 h	58.24	59.94	1	0.91	0.98	1.09	1.06	1.00
PC21-02	C02	2021-10-20	2021-10-22	-	144.6	195.2	Soaked 48 h	46.93	54.48	1	0.96	0.98	1.09	1.06	1.07
PC21-03	C03	2021-10-20	2021-10-22	-	144.6	183.2	Soaked 48 h	57.21	61.58	1	0.95	0.98	1.09	1.06	1.00
PC21-04	C04	2021-10-20	2021-10-22	-	144.6	186	Soaked 48 h	52.34	60.47	1	0.95	0.98	1.09	1.06	1.07

Comments

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



Type 1 Type 2 Type 3 Type 4 Type 5 Type 6

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

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

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

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

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

3.2. American Concrete Institute (ACI)

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

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

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

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

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

3.2.2. Current ACI Code (2012) [15]

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

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

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								■▲●	■▲●			■▲						
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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.

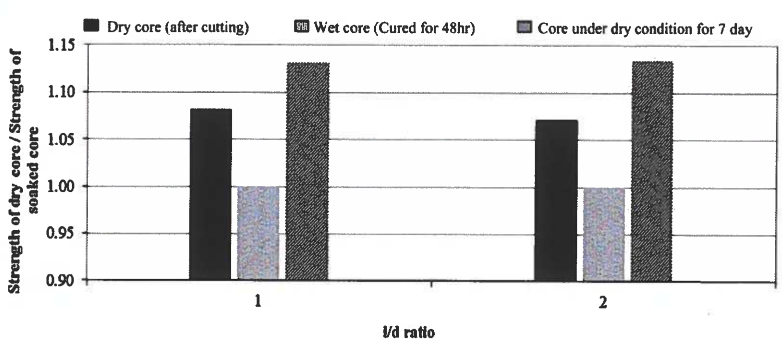

Figure 20 Effect of core moisture condition on core strength for different aspect ratios (l/d).