

APPENDIX 'A'

GEOTECHNICAL REPORT



Quality Engineering | Valued Relationships

WSP Canada Group Ltd.

2019-2023 Henderson Highway Pavement Renewals (19-C-09)

Prepared for:

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Project Number:

1000 043 14

Date:

October 29, 2020
Final Report



Quality Engineering | Valued Relationships

October 29, 2020

Our File No. 1000 043 14

Richard Hawkins, C.E.T.
WSP Canada Group Ltd.
111-93 Lombard Avenue
Winnipeg, MB R3E 3P1

**RE: Road Investigation Report for 2019-2023 Henderson Highway Pavement Renewals
(19-C-09)**

TREK Geotechnical Inc. is pleased to submit our report for the road investigation for the 2019-2023 Henderson Highway Pavement Renewals (19-C-09) 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:

A handwritten signature in blue ink, appearing to read "Nelson John Ferreira". The signature is fluid and cursive, with a large, sweeping flourish at the end.

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	JSB	October 29, 2020	Final Report

Authorization Signatures

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1.0 Introduction

This report summarizes the results of the road investigation completed for the 2019-2023 Henderson Highway pavement renewals project. The street included Henderson Highway Southbound between Leighton Avenue and McLeod Avenue. The investigation was carried out in accordance with the City of Winnipeg public works street project requirements (Bid:156-2020).

2.0 Road Investigation

The investigation included coring of pavement at 10 locations. The WSP Canada Group Ltd. selected the investigation locations as shown on Figure 01 (attached).

The pavement coring was conducted between September 24, 2020 and September 25, 2020. The pavement (asphalt and concrete) was cored by Jashandeep Singh Bhullar 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 and asphalt and concrete pavement core photographs are included in Appendices A.

Two concrete cores were selected for concrete compressive strength breaks and the length to diameter ratio ranged between 1.01 to 1.21 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	PC20-03	52.6
2	PC20-07	60.4

The locations noted on the summary table (Appendix A) are based on the core locations relative to the nearest address, and measured distances from the edge of pavement or other permanent features. 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).

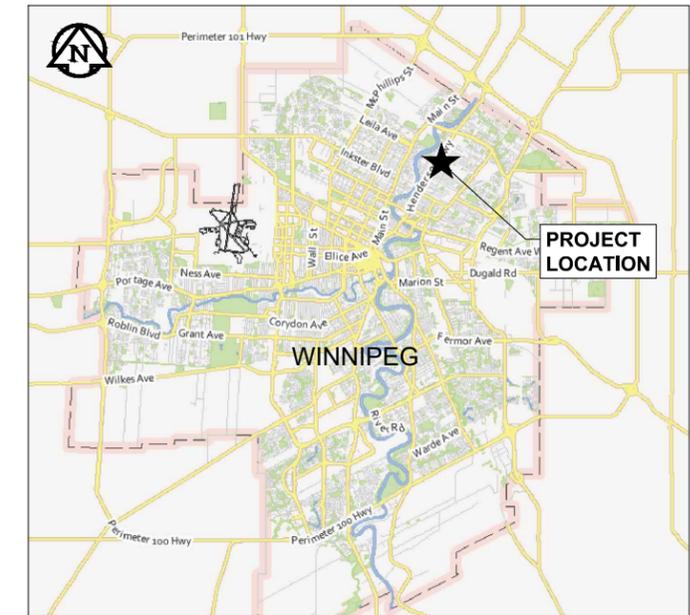
All information provided in this report is subject to our standard terms and conditions for engineering services, a copy of which is provided to each of our clients with the original scope of work, or a mutually executed standard engineering services agreement. If these conditions are not attached, and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

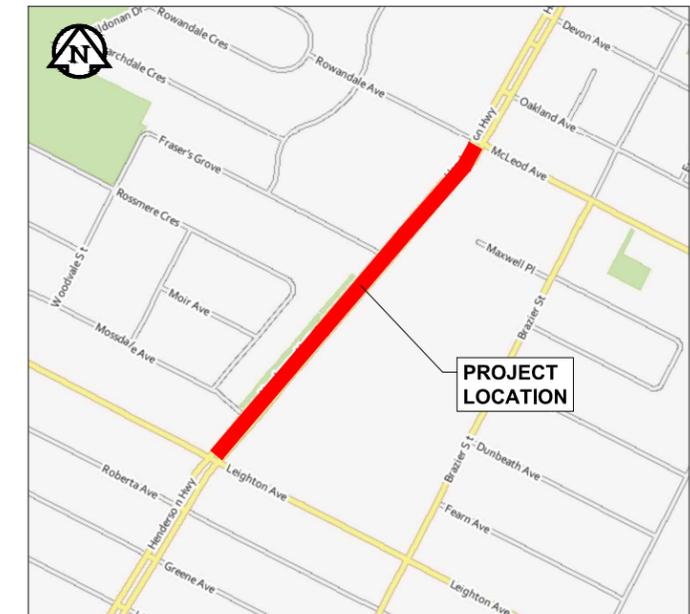
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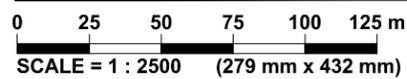
Z:\Projects\1000 Soils Lab\Projects\1000-043 WSP\1000-043-14 2019-2023 Henderson Hwy Pavement Renewals (19-C-09)\3 Survey and Dwg\3.4 CAD\3.4.3 Working Folder\1000-043-14_Henderson Test Hoies_A_CJH.dwg, 2020-10-26 8:59:21 AM



KEY PLAN
NTS



LOCATION PLAN
NTS



LEGEND: ◆ PAVEMENT CORE (TREK, 2020)

NOTES:

1. AERIAL PHOTO FROM GOOGLE EARTH (2020)
2. PAVEMENT CORE LOCATIONS OBTAINED USING HANDHELD GPS UNIT AND BY MEASURING DISTANCES OFF NEAREST ADDRESS

Figure 01
Pavement Core Location Plan

Appendix A

Summary Table and Photographs of Pavement Core Samples Henderson Highway



2019-2023 Henderson Highway Pavement Renewals (19-C-09)
Henderson Highway Southbound Lanes between McLeod Avenue and Leighton Avenue

Pavement Core No.	Pavement Core Location	Pavement Surface		Pavement Structure Material		
		Type	Thickness (mm)	Type	Thickness (mm)	Corrected Compressive Strength (Mpa)
PC20-01	UTM : 5532934 m N, 636438 m E; Located in front of house # 924 Henderson Hwy in Southbound curb lane, 1.5 m East of West curb.	Asphalt	70	Concrete	230	-
PC20-02	UTM : 5532975 m N, 636478 m E; Located on North edge of Mossdale Avenue in Southbound center lane, 5 m East of West curb.	Asphalt	85	Concrete	140	-
PC20-03	UTM : 5533005 m N, 636506 m E; Located back of house # 225 Rossmere Crescent in Southbound median lane, 1.5 m West of East curb.	Asphalt	140	Concrete	210	52.6
PC20-04	UTM : 5533056 m N, 636540 m E; Located back of house # 209 Rossmere Crescent in Southbound curb lane, 1.5 m East of West curb.	Asphalt	160	Concrete	240	-
PC20-05	UTM : 5533089 m N, 636571 m E; Located back of house # 197 Rossmere Crescent in Southbound center lane, 5 m East of West curb.	Asphalt	155	Concrete	245	-
PC20-06	UTM : 5533124 m N, 636603 m E; Located in front of Northdale Northbound bus stop stand in Southbound median lane, 5 m West of East curb turning lane.	Asphalt	55	Concrete	215	-
PC20-07	UTM : 5533171 m N, 636633 m E; Located North edge of Fraser Street South backlane in Southbound curb lane, 1.5 m East of West curb.	Asphalt	130	Concrete	170	60.4
PC20-08	UTM : 5533211 m N, 636670 m E; Located North edge of Fraser Street in Southbound center lane, 5 m East of West curb.	Asphalt	100	Concrete	200	-
PC20-09	UTM : 5533240 m N, 636697 m E; Located in front of 1030 Henderson Hwy in Southbound median curb lane, 1.5 m West of East curb.	Asphalt	190	Concrete	250	-
PC20-10	UTM : 5533307 m N, 636743 m E; Located in front of 1067 Henderson Hwy in Southbound curb lane, 1.5 m East of West curb.	Asphalt	130	Concrete	185	-

90 mm
Thick
Crumbled
Concrete



Photo 1: Pavement Core Sample at Pavement Hole PC20-01



Photo 2: Pavement Core Sample at Pavement Hole PC20-02



Photo 3: Pavement Core Sample at Pavement Hole PC20-03



Photo 4: Pavement Core Sample at Pavement Hole PC20-04



Photo 5: Pavement Core Sample at Pavement Hole PC20-05



Photo 6: Pavement Core Sample at Pavement Hole PC20-06



Photo 7: Pavement Core Sample at Pavement Hole PC20-07



Photo 8: Pavement Core Sample at Pavement Hole PC20-08



Photo 9: Pavement Core Sample at Pavement Hole PC20-09



Photo 10: Pavement Core Sample at Pavement Hole PC20-010

Appendix B

Summary Table of Concrete Core Compressive Strength

October 28, 2020

MEMORANDUM**SUBJECT: APPLICATION OF CORE CORRECTION FACTOR – Reference Core report CONC-CORE-146-2017-20-001**

The client requested that the core compressive strengths be corrected as described in the attached two pages. TABLE 1 shows each of the uncorrected core compressive strength, and each of the correction factors that were applied to determine the corrected core compressive strength.

TABLE 1.

Core ID	Uncorrected core compressive strength	L/D Correction Factor	Diameter Correction Factor	Moisture Correction Factor	Damage Correction Factor	Rebar Correction Factor	Corrected Core Compressive Strength
PC 03	50.3	0.927	0.98	1.09	1.06	N/A	52.6
PC 07	61.2	0.886	0.98	1.09	1.06	N/A	60.4

Notes:

1. The L/D factor was calculated using the formula provided in Table 3.

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 interpreta-

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

tion 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:

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

cc. 12 or cc. 15

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

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

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

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

^a Standard treatment specified in ASTM C 42/C 42M.

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

Table 6 List of comparisons between tested cores to determine.

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

- Diameter of steel bar.
- ▲ Distance of steel bar from nearly end of core.
- Number of steel bars and spacing between bars.
- ◆ Distance of steel bar from vertical axis of specimen.

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

multiple bars

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:

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

single bar

- 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 ($\Phi_r \times d$) is considered. If the bars are further apart, their combined effect is assessed by replacing the term ($\Phi_r \times r$) by ($\sum \Phi_r \times r$) as follows:

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.

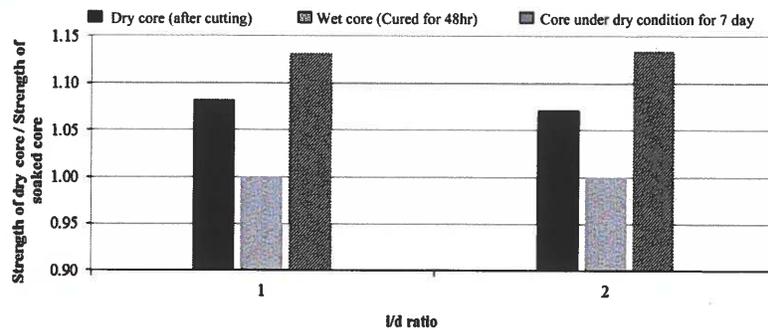


Figure 20 Effect of core moisture condition on core strength for different aspect ratios (l/d).