# APPENDIX B: PAVEMENT CORE REPORT

GEOTECHNICAL Quality Engineering | Valued Relationships

Tetra Tech Inc.

# Lagimodiere Twin Overpasses and Pavement Renewal (Concordia Avenue & CPKC Keewatin) Pavement Coring Investigation

**Prepared for:**

Jeff Crang, P.Eng.
Tetra Tech Inc.
400-161 Portage Ave East
Winnipeg, Manitoba
R3B 0Y4

**Project Number:**
0002-130-01

**Date:**
September 20, 2024

September 20, 2024 Our File No. 0002-130-01

Jeff Crang, P.Eng.
Tetra Tech Inc.
400-161 Portage Ave East
Winnipeg, Manitoba
R3B 0Y4

**RE: Lagimodiere Twin Overpasses and Pavement Renewal (Concordia Avenue & CPKC Keewatin) Pavement Coring Investigation**

TREK Geotechnical Inc. is pleased to submit our final report for the above noted 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

# Revision History

| Revision No. | Author | Issue Date | Description |
|---|---|---|---|
| 0 | TG | September 20, 2024 | Final Report |

# Authorization Signatures

**Prepared By:** ______________________
Tyler Green

PROVINCE OF MANITOBA
2024/09/20
M.D. KLYMOCHKO
Member
37605
REGISTERED PROFESSIONAL ENGINEER

ENGINEERS GEOSCIENTISTS MANITOBA
Certificate of Authorization
TREK GEOTECHNICAL INC.
No. 4877

**Reviewed By**: ______________________
Matt Klymochko, P.Eng.
Geotechnical Engineer

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

**Table of Contents**



## List of Tables



## List of Figures



## List of Appendices

# 1.0 Introduction

This report summarizes the results of the road investigation completed for the Lagimodiere Twin Overpasses and Pavement Renewal (Concordia & CPKC Keewatin). The investigation was carried out along Lagimodiere Boulevard between Grassie Boulevard and Reenders Drive, and along Concordia Avenue between Panet Road and Peguis Street. Information collected describes the asphalt and concrete pavement structure. 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 34 locations. Tetra Tech selected the investigation locations as shown on Figures 01 to 09 (attached).

Pavement coring was completed between September 9th and 14th, 2024. The pavement was cored by Tyler Green of TREK Geotechnical Inc. (TREK) using a portable coring press equipped with a hollow 150 mm and 100 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 selected for concrete compressive strength breaks. The length to diameter ratio for the cores collected ranged between 1.73 to 2.00. 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 A.

**Table 01: Concrete Core Compressive Strength Results**

| Core ID | Uncorrected Compressive Strength (MPa) | Corrected Compressive Strength (MPa) |
|---|---|---|
| PC24-17 | 49.40 | 64.50 |
| PC24-21 | 38.22 | 44.01 |
| PC24-22 | 45.74 | 52.98 |
| PC24-30 | 38.14 | 49.17 |

The locations noted on the summary tables in Appendix A are based on the core locations relative to 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 Tetra Tech (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.

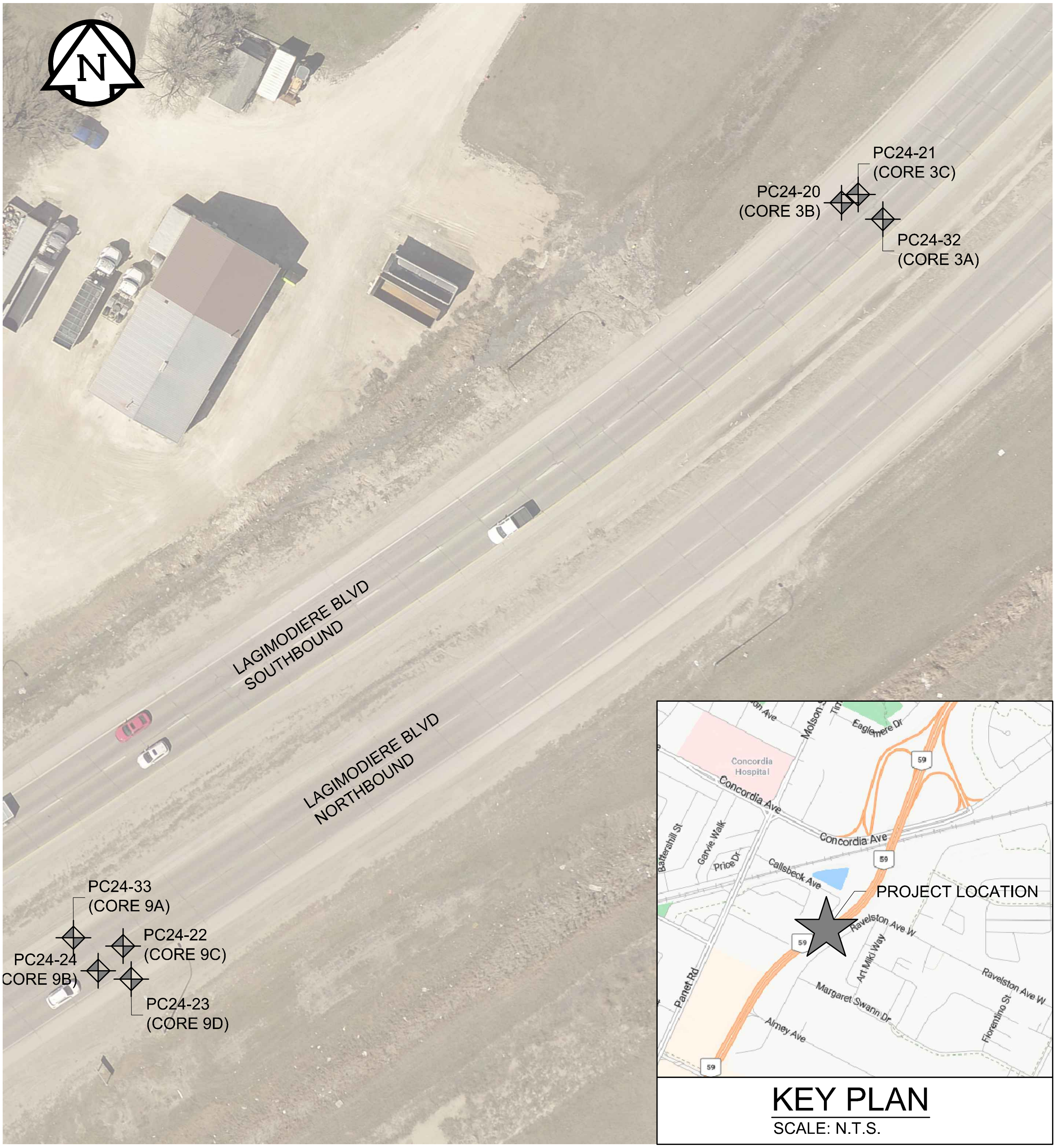
# Figures

TREK GEOTECHNICAL

**0002 130 01**

Tetra Tech Inc.

Lagimodiere Twin Overpasses and Pavement Renewal (Concordia Avenue & CPKC Keewatin)




KEY PLAN

SCALE: N.T.S.

LEGEND:

PAVEMENT CORE (TREK, 2024)

NOTES:

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

Z:\Projects\0002 Tetra Tech\0002 130 01 Lag Overpass DD & Cons\3 Survey and Dwg\3.4 CAD\3.4.3 Working Folder\PC\Fig 01 2024-09-17 Lagimodiere Twin Overpasses 0_A 0002-130-01.dwg, 2024-09-18 4:05:46 PM

0 10 20 30 m

SCALE = 1 : 700 (216 mm x 279 mm)

**Figure 01**

Pavement Core Location Plan

**0002 130 01**
Tetra Tech Inc.
Lagimodiere Twin Overpasses and Pavement Renewal (Concordia Avenue & CPKC Keewatin)


## LEGEND:

PAVEMENT CORE (TREK, 2024)

## NOTES:

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

0 10 20 30 m

SCALE = 1 : 700 (216 mm x 279 mm)

**Figure 02**
Pavement Core Location Plan


LEGEND:

PAVEMENT CORE (TREK, 2024)

NOTES:

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

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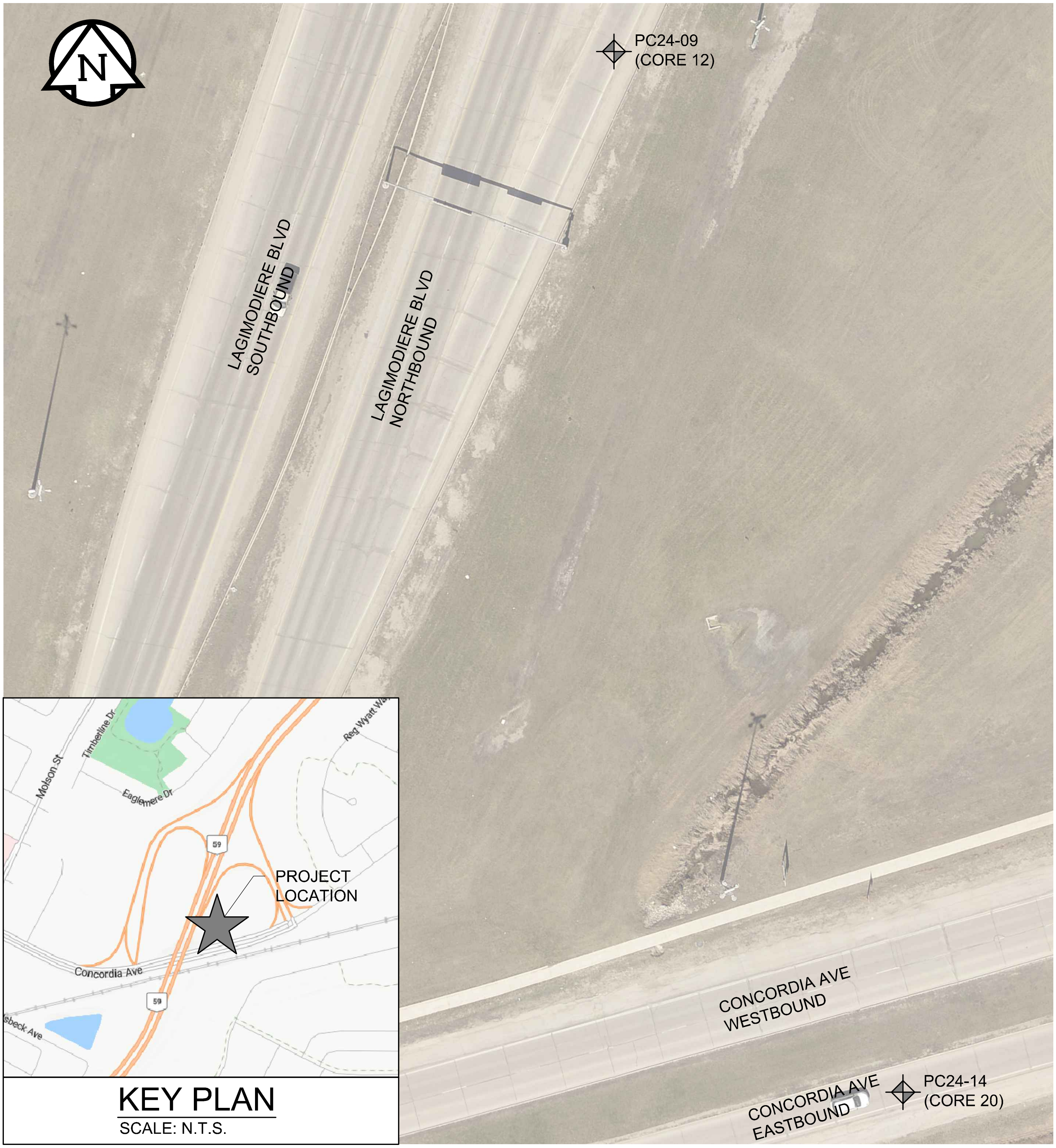
SCALE = 1 : 700 (216 mm x 279 mm)

**Figure 03**

Pavement Core Location Plan




KEY PLAN
SCALE: N.T.S.

LEGEND:

PAVEMENT CORE (TREK, 2024)

NOTES:

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

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0 10 20 30 m
SCALE = 1 : 700 (216 mm x 279 mm)

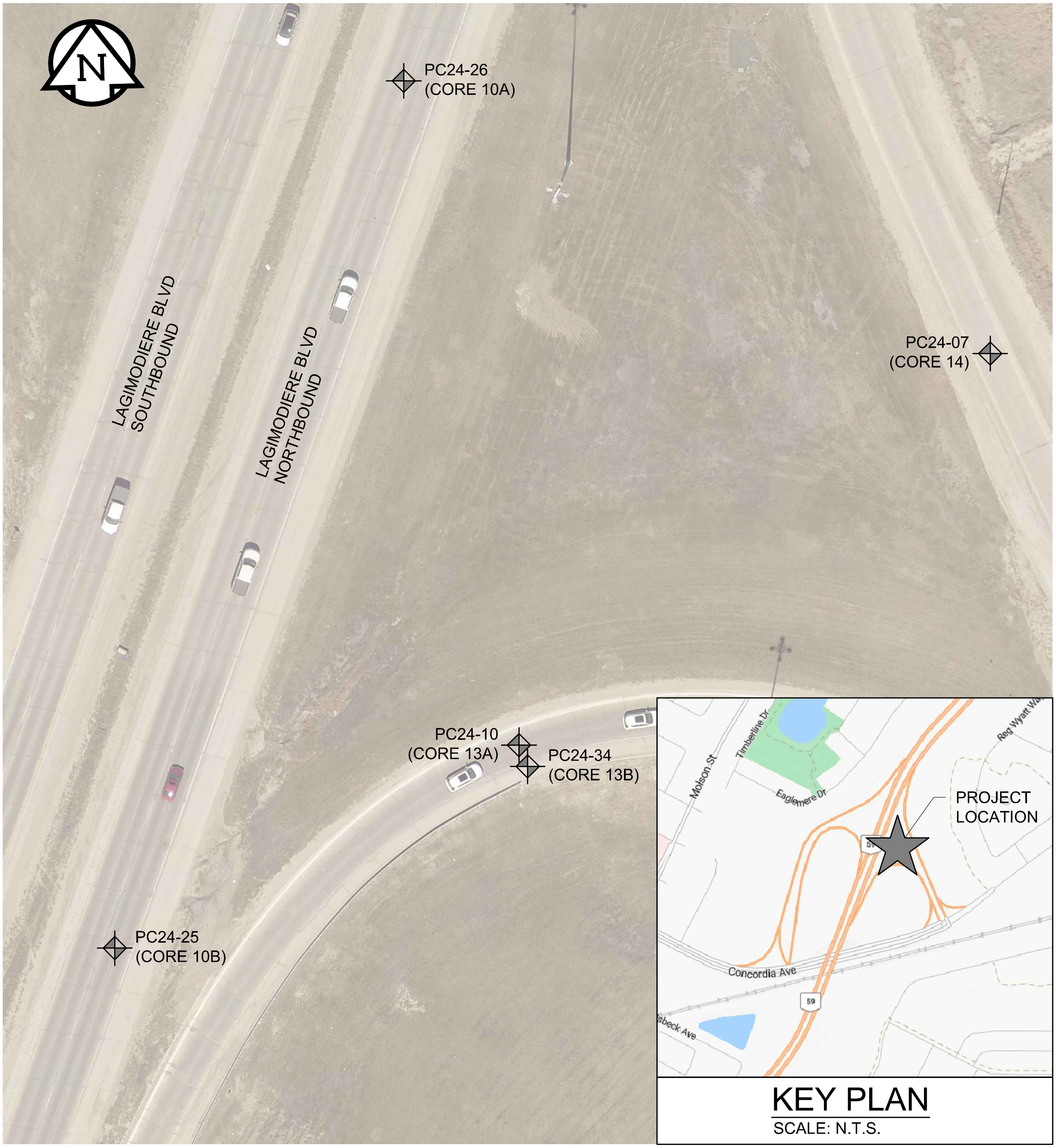
**Figure 04**
Pavement Core Location Plan

0002 130 01

Tetra Tech Inc.

TREK GEOTECHNICAL

Lagimodiere Twin Overpasses and Pavement Renewal (Concordia Avenue & CPKC Keewatin)




LEGEND:

PAVEMENT CORE (TREK, 2024)

NOTES:

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

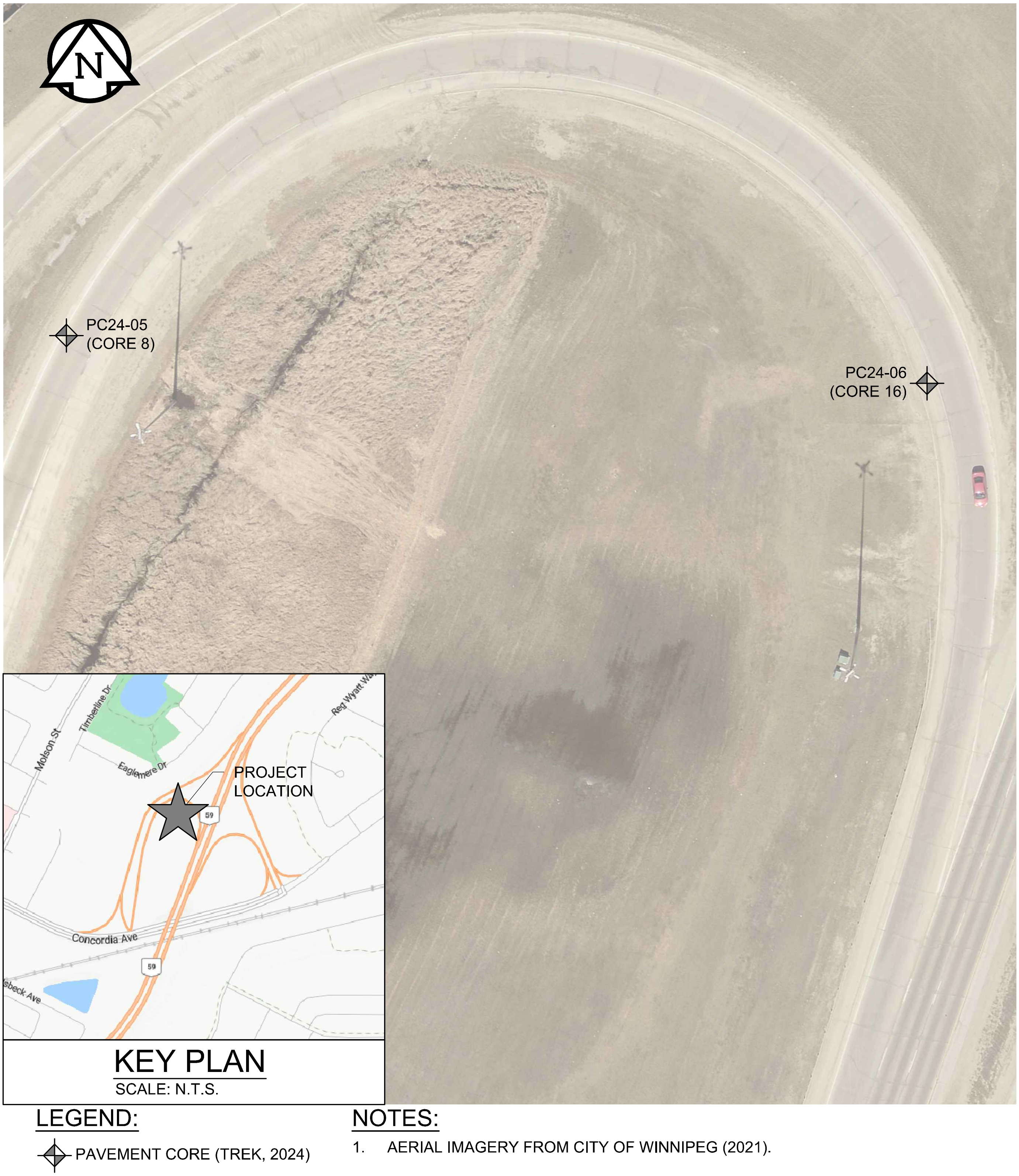
0 10 20 30 m

SCALE = 1 : 700 (216 mm x 279 mm)

**Figure 05**

Pavement Core Location Plan

**0002 130 01**
Tetra Tech Inc.
Lagimodiere Twin Overpasses and Pavement Renewal (Concordia Avenue & CPKC Keewatin)




## LEGEND:

PAVEMENT CORE (TREK, 2024)

## NOTES:

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

Z:\Projects\0002 Tetra Tech\0002 130 01 Lag Overpass DD & Cons\3 Survey and Dwg\3.4 CAD\3.4.3 Working Folder\PC\Fig 06 2024-09-17 Lagimodiere Twin Overpasses 0_A 0002-130-01.dwg, 2024-09-18 4:00:37 PM

0 10 20 30 m
SCALE = 1 : 700 (216 mm x 279 mm)

**Figure 06**
Pavement Core Location Plan

**0002 130 01**

Tetra Tech Inc.

TREK GEOTECHNICAL

Lagimodiere Twin Overpasses and Pavement Renewal (Concordia Avenue & CPKC Keewatin)


## LEGEND:

PAVEMENT CORE (TREK, 2024)

## NOTES:

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

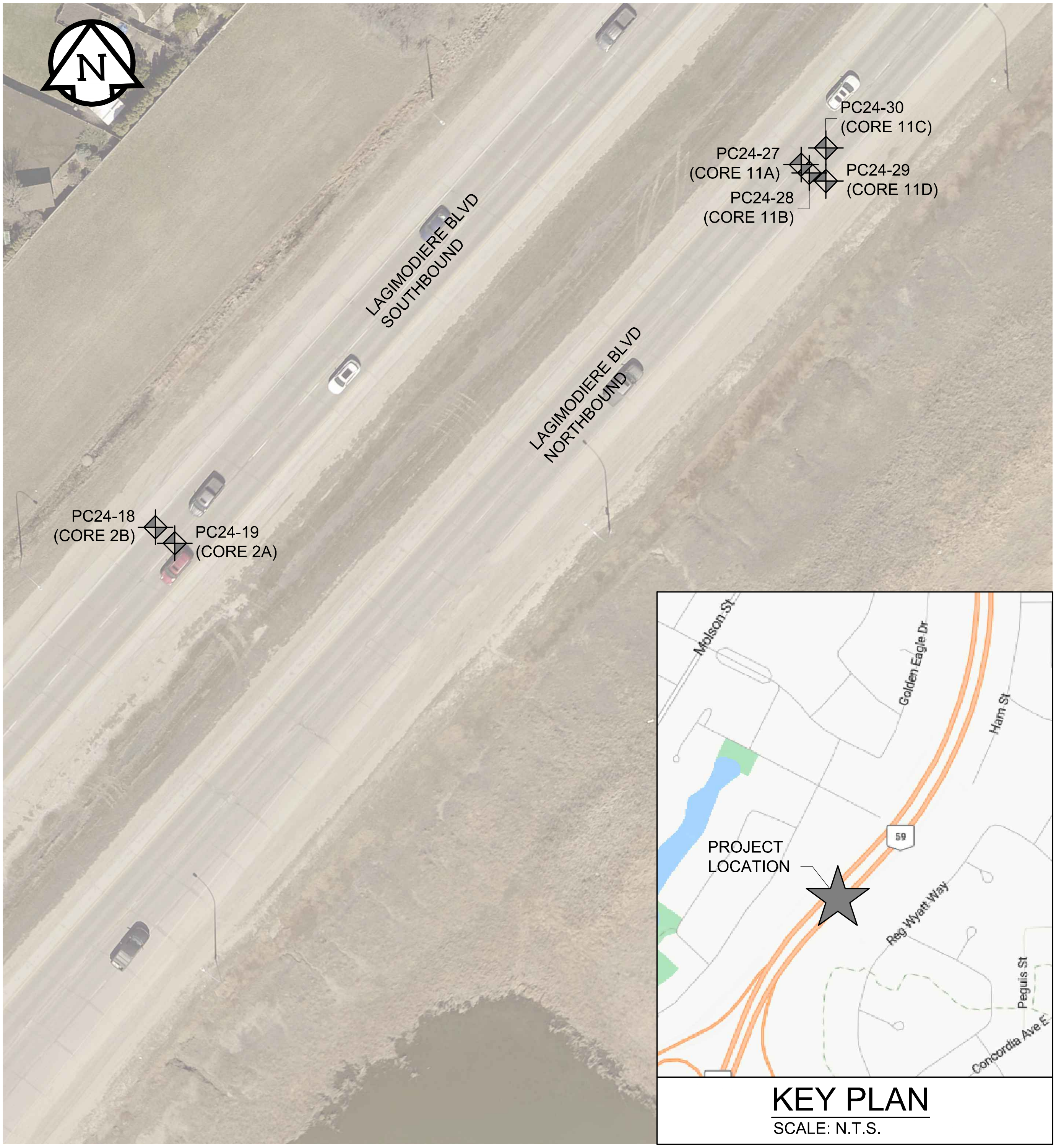
Z:\Projects\0002 Tetra Tech\0002 130 01 Lag Overpass DD & Cons\3 Survey and Dwg\3.4 CAD\3.4.3 Working Folder\PC\Fig 07 2024-09-17 Lagimodiere Twin Overpasses 0_A 0002-130-01.dwg, 2024-09-18 4:00:53 PM

0 10 20 30 m

SCALE = 1 : 700 (216 mm x 279 mm)

**Figure 07**

Pavement Core Location Plan




KEY PLAN

SCALE: N.T.S.

## LEGEND:

PAVEMENT CORE (TREK, 2024)

## NOTES:

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

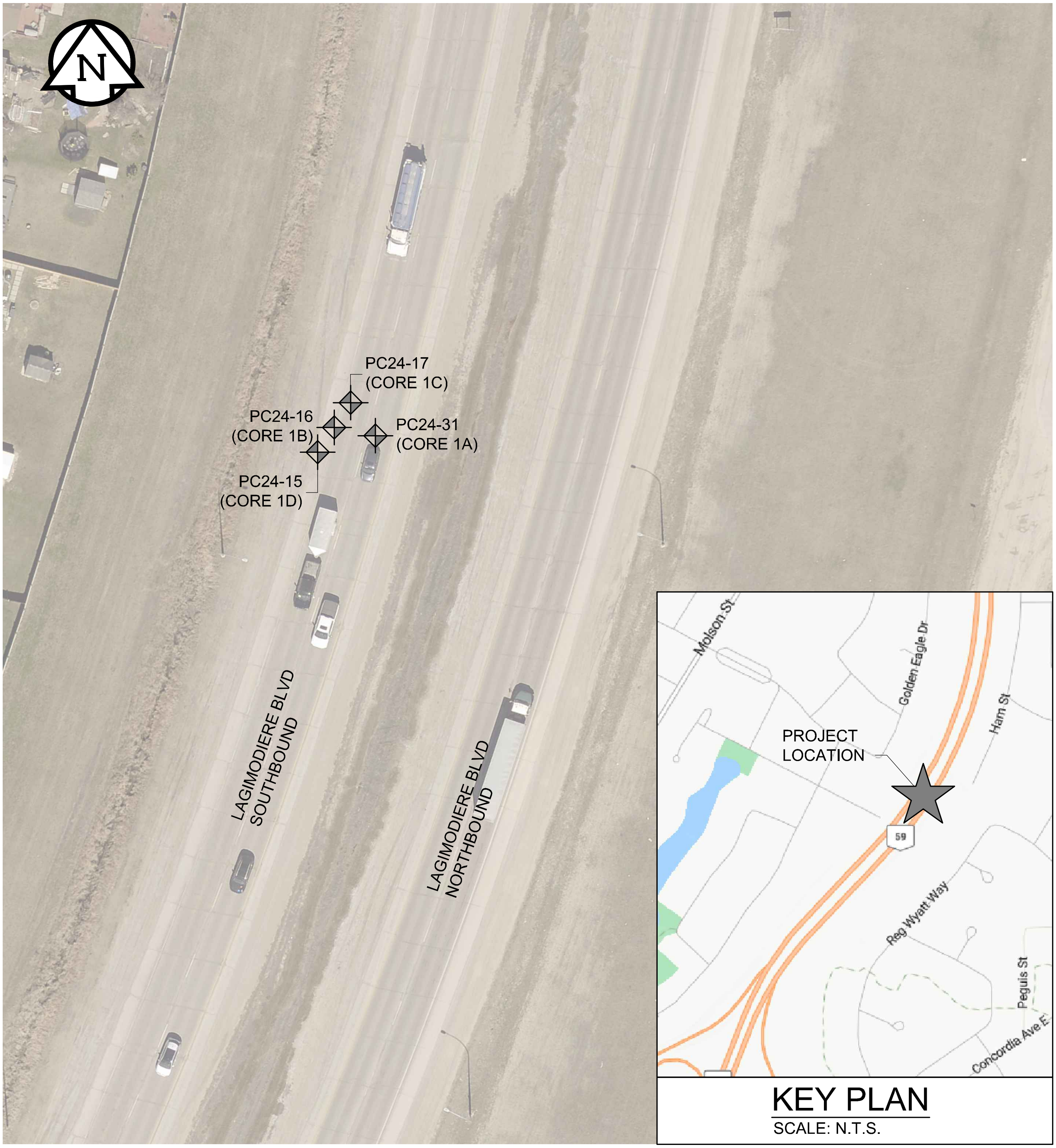


0 10 20 30 m

SCALE = 1 : 700 (216 mm x 279 mm)

**Figure 08**

Pavement Core Location Plan




LEGEND:

PAVEMENT CORE (TREK, 2024)

NOTES:

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

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0 10 20 30 m

SCALE = 1 : 700 (216 mm x 279 mm)

**Figure 09**

Pavement Core Location Plan

# Appendix A

## Summary Table, Lab Testing Results and Photographs of Pavement Core Samples
## Northbound/Southbound Lagimodiere Boulevard and Eastbound Concordia Avenue

**Lagimodiere Twin Overpasses and Pavement Renewal**

**Concordia Aveneue & CPKC Keewatin**

| Pavement Core No. | Pavement Core Location | Pavement Surface | | Pavement Structure Material | | |
|---|---|---|---|---|---|---|
| | | Type | Thickness (mm) | Type | Thickness (mm) | Corrected Compressive Strength (MPa) |
| PC24-01 | UTM : 5530940 m N, 639652 m E; Sta 3+655, Core Location 4. 1.0 m East of pavement edge | Asphalt | - | Concrete | 190 | |
| PC24-02 | UTM : 5530919 m N, 639628 m E; Sta 3+625, Core Location 5, 1.1 m East of pavement edge | Asphalt | - | Concrete | 200 | |
| PC24-03 | UTM : 5530608 m N, 639421 m E; Sta 3+324, Core Location 6, 1.0 m East of pavement edge | Asphalt | - | Concrete | 180 | |
| PC24-04 | UTM : 5530597 m N, 639456 m E; Sta 4+076, Core Location 7, 1.0 m East of pavement edge | Asphalt | 90 (Joint Repair) | Concrete | 90 | |
| PC24-05 | UTM : 5530821 m N, 639501 m E; Sta 4+303, Core Location 8, 1.0 m East of pavement edge | Asphalt | 80 (Joint Repair) | Concrete | 170 | |
| PC24-06 | UTM : 5530815 m N, 639609 m E; Sta 4+440, Core Location 16, 0.2 m East of pavement edge | Asphalt | 110 | Concrete | n/a | |
| PC24-07 | UTM : 5530816 m N, 639739 m E; Sta 1+168, Core Location 14, 1.1 m West of pavement edge | Asphalt | 25 (Joint Repair) | Concrete | 200 | |
| PC24-08 | UTM : 5530890 m N, 639714 m E; : Sta 1+272, Core Location 15, 1.0 m West of shoulder line | Asphalt | 40 (Joint Repair) | Concrete | 170 | |
| PC24-09 | UTM : 5530689 m N, 639624 m E; Sta 2+096, Core Location 12, 1.0 m East of shoulder line | Asphalt | 50 | Concrete | 230 | |
| PC24-10 | UTM : 5530766 m N, 639683 m E; Sta 2+196, Core Location 13, 1.1 m North of shoulder line | Asphalt | 40 (Joint Repair) | Concrete | 190 | |
| PC24-11 | UTM : 5530537 m N, 639219 m E; Sta 5+153, Core Location 18A, 3.5 m North of pavement edge | Asphalt | 80 | Concrete | 250 | |
| PC24-12 | UTM : 5530534 m N, 639218 m E; Sta 5+153, Core Location 18B, 1.3 m North of pavement edge | Asphalt | 65 | Concrete | 225 | |
| PC24-13 | UTM : 5530525 m N, 639520 m E; Sta 5+454, Core Location 19, 1.0 m North of pavement edge | Asphalt | 80 | Concrete | 190 | |
| PC24-14 | UTM : 5530563 m N, 639659 m E; Sta 5+601, Core Location 20, 1.1 m North of pavement edge | Asphalt | 110 | Concrete | 160 | |
| PC24-15 | UTM : 5531521 m N, 640051 m E; Sta 32+409, Core Location 1D, 0.3 m East of pavement edge | Asphalt | 80 | Concrete | n/a | |
| PC24-16 | UTM : 5531524 m N, 640053 m E; Sta 32+409, Core Location 1B, 1.2 m East of shoulder line | Asphalt | 90 | Concrete | 170 | |

**Lagimodiere Twin Overpasses and Pavement Renewal**

**Concordia Aveneue & CPKC Keewatin**

| Pavement Core No. | Pavement Core Location | Pavement Surface | | Pavement Structure Material | | |
|---|---|---|---|---|---|---|
| | | Type | Thickness (mm) | Type | Thickness (mm) | Corrected Compressive Strength (MPa) |
| PC24-17 | UTM : 5531527 m N, 640055 m E; Sta 32+409, Core Location 1C, 1.5 m East of shoulder line | Asphalt | 125 | Concrete | 195 | 64.50 |
| PC24-18 | UTM : 5531145 m N, 639811 m E; Sta 3+642, Core Location 2B, 1.1 m East of shoulder line | Asphalt | 100 | Concrete | 190 | |
| PC24-19 | UTM : 5531143 m N, 639814 m E; Sta 3+642, Core Location 2A, 3.5 m North of shoulder line | Asphalt | 90 | Concrete | 220 | |
| PC24-20 | UTM : 5530235 m N, 639375 m E; Sta 30+932, Core Location 3B, 1.2 m East of shoulder line | Asphalt | 80 | Concrete | 190 | |
| PC24-21 | UTM : 5530236 m N, 639377 m E; Sta 30+932, Core Location 3C, 1.7 m East of shoulder line | Asphalt | 90 | Concrete | 180 | 44.01 |
| PC24-22 | UTM : 5530145 m N, 639288 m E; Sta 20+794, Core Location 9C, 1.8 m West of shoulder line | Asphalt | 75 | Concrete | 210 | 53.06 |
| PC24-23 | UTM : 5530141 m N, 639289 m E; Sta 20+794, Core Location 9D. 0.3 m West of pavement edge | Asphalt | 75 | Concrete | n/a | |
| PC24-24 | UTM : 5530142 m N, 639285 m E; Sta 20+794, Core Location 9B. 0.9 m West of shoulder line | Asphalt | 60 | Concrete | 210 | |
| PC24-25 | UTM : 5530774 m N, 639633 m E; Sta 2+072, Core Location 10B, 1.2 m West of shoulder line | Asphalt | 60 | Concrete | 200 | |
| PC24-26 | UTM : 5530849 m N, 639668 m E; Sta 21+600, Core Location 10A, 3.5 m West of shoulder line | Asphalt | 90 | Concrete | 160 | |
| PC24-27 | UTM : 5531190 m N, 639888 m E; Sta 22+061, Core Location 11A, 3.7 m West of shoulder line | Asphalt | 90 | Concrete | 220 | |
| PC24-28 | UTM : 5531189 m N, 639889 m E; Sta 22+061, Core Location 11B, 1.1 m West of shoulder line | Asphalt | 70 | Concrete | 220 | |
| PC24-29 | UTM : 5531188 m N, 639891 m E; Sta 22+061, Core Location 11D, 0.3 m West of pavement edge | Asphalt | 90 | Concrete | n/a | |
| PC24-30 | UTM : 5531192 m N, 639891 m E; Sta 22+061, Core Location 11C, 1.7 m West of shoulder line | Asphalt | 110 | Concrete | 190 | 49.08 |
| PC24-31 | UTM : 5531523 m N, 640058 m E; Sta 32+409, Core Location 1A, 1.2 m West of shoulder line | Asphalt | 70 | Concrete | 190 | |
| PC24-32 | UTM : 5530233 m N, 639380 m E; Sta 30+932, Core Location 3A, 1.1 m West of shoulder line | Asphalt | 75 | Concrete | 190 | |

**Lagimodiere Twin Overpasses and Pavement Renewal**

**Concordia Aveneue & CPKC Keewatin**

| Pavement Core No. | Pavement Core Location | Pavement Surface | | Pavement Structure Material | | |
|---|---|---|---|---|---|---|
| | | Type | Thickness (mm) | Type | Thickness (mm) | Corrected Compressive Strength (MPa) |
| PC24-33 | UTM : 5530146 m N, 639282 m E; Sta 20+744, Core Location 9A, 1.0 m East of shoulder line | Asphalt | 90 | Concrete | 170 | |
| | | | | | | |
| PC24-34 | UTM : 5530761 m N, 639689 m E; Sta 2+196, Core Location 13B, 0.4 m North of pavement edge | Asphalt | 135 | Concrete | n/a | |
| | | | | | | |


Photo 1: Pavement Core Sample PC24-01


Photo 2: Pavement Core Sample PC24-02


Photo 3: Pavement Core Sample PC24-03


Photo 4: Pavement Core Sample PC24-04


Photo 5: Pavement Core Sample PC24-05


Photo 6: Pavement Core Sample PC24-06

Photo 7: Pavement Core Sample PC24-07

Photo 8: Pavement Core Sample PC24-08


Photo 9: Pavement Core Sample PC24-09


Photo 10: Pavement Core Sample PC24-10


Photo 11: Pavement Core Sample PC24-11


Photo 12: Pavement Core Sample PC24-12


Photo 13: Pavement Core Sample PC24-13


Photo 14: Pavement Core Sample PC24-14

Photo 15: Pavement Core Sample PC24-15

Photo 16: Pavement Core Sample PC24-16

Photo 17: Pavement Core Sample PC24-17

Photo 18: Pavement Core Sample PC24-18

Photo 19: Pavement Core Sample PC24-19

Photo 20: Pavement Core Sample PC24-20


Photo 21: Pavement Core Sample PC24-21


Photo 22: Pavement Core Sample PC24-22


Photo 23: Pavement Core Sample PC24-23


Photo 24: Pavement Core Sample PC24-24

Photo 25: Pavement Core Sample PC24-25

Photo 26: Pavement Core Sample PC24-26

Photo 27: Pavement Core Sample PC24-27

Photo 28: Pavement Core Sample PC24-28


Photo 29: Pavement Core Sample PC24-29


Photo 30: Pavement Core Sample PC24-30

Photo 31: Pavement Core Sample PC24-31

Photo 32: Pavement Core Sample PC24-32


Photo 33: Pavement Core Sample PC24-33


Photo 34: Pavement Core Sample PC24-34

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# Concrete Core Compressive Strength Report

*CSA A23.2-14C*

**Project No.** 0002-130-01

**Project** Lagimodiere Twin Overpass and Pavement Renewal

**Client** Tetra Tech Inc.

**Date** September 16, 2024

**Technician** T. Green

| 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* $f_c$ | | $F_{l/d}$ | $F_{dia}$ | $F_{mc}$ | $F_D$ | $F_{reinf}$ |
| UTM : 5531527 m N, 640055 m E (Core 1C) | PC24-17 | 2024-09-11 | 2024-09-16 | - | 95 | 188 | Soaked 48 h | 49.40 | 64.50 | 1 | 1.0000 | 1.0042 | 1.0900 | 1.0600 | 1.1254 |
| UTM : 5530236 m N, 639377 m E (Core 3C) | PC24-21 | 2024-09-11 | 2024-09-16 | - | 95 | 164 | Soaked 48 h | 38.22 | 44.01 | 1 | 0.9925 | 1.0042 | 1.0900 | 1.0600 | 1.0000 |
| UTM : 5530145 m N, 639288 m E (Core 9C) | PC24-22 | 2024-09-12 | 2024-09-16 | - | 95 | 190 | Soaked 48 h | 45.74 | 53.06 | 1 | 1.0000 | 1.0042 | 1.0900 | 1.0600 | 1.0000 |
| UTM : 5531192 m N, 639891 m E (Core 11C) | PC24-30 | 2024-09-13 | 2024-09-16 | - | 95 | 188 | Soaked 48 h | 38.14 | 49.08 | 1 | 1.0000 | 1.0042 | 1.0900 | 1.0600 | 1.1091 |
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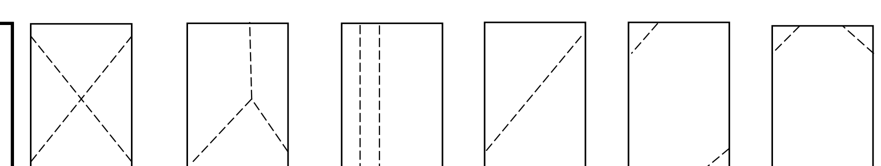
Comments

*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): ____________________ Signature: ____________________

**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 $\alpha$ 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, $\Phi_r$ is the diameter of the reinforcement, $\Phi_c$ 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.

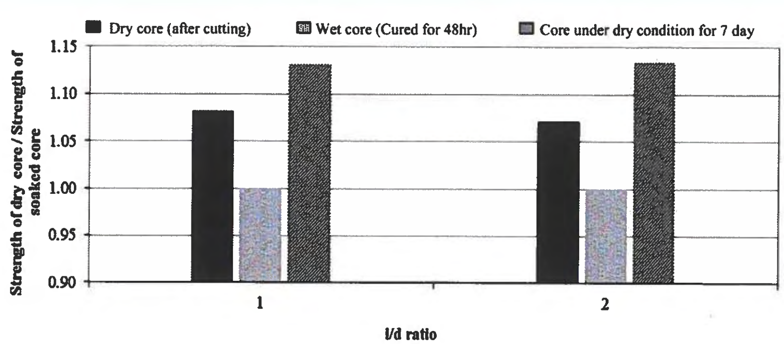



**Figure 20** Effect of core moisture condition on core strength for different aspect ratios ($l/d$).