

Foundation Investigation and Design Report

Variable Message and Static Overhead Signs at Dixon Road, Highway 401 Rehabilitation and Surfacing, Kipling Avenue to Keele Street, City of Toronto, Ontario, G.W.P. 2032-11-00

Submitted to:

AECOM Canada

30 Leek Crescent, 4th Floor
Richmond Hill, Ontario
L4B 4N4

Submitted by:

Golder Associates Ltd.

6925 Century Avenue, Suite #100 Mississauga, Ontario, L5N 7K2 Canada

+1 905 567 4444

GEOCREs No.: 30M11-305

Lat: 43.691899°, Long: -79.569204°

1665765 Rev. 4

February 5, 2021



Distribution List

- 1 Electronic Copy - MTO - Central Region
- 1 Electronic Copy - MTO - Foundations Section
- 1 Electronic Copy - AECOM Canada Ltd.
- 1 Electronic Copy - Golder Associates Ltd.

Table of Contents

PART A – FOUNDATION INVESTIGATION REPORT

1.0 INTRODUCTION	1
2.0 PROJECT DESCRIPTION	1
3.0 SITE DESCRIPTION	1
4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS	2
4.1 Regional Geology	2
4.2 General Overview of Subsurface Conditions	2
4.2.1 Silty Clay to Clayey Silt (Fill)	3
4.2.2 Sand (Fill)	4
4.2.3 Clayey Silt-Silt to Clayey Silt (Till)	4
4.2.4 Sandy Silt to Silty Sand (Till)	4
4.2.5 Groundwater Conditions	5
5.0 CLOSURE	6

PART B – FOUNDATION DESIGN REPORT

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS	7
6.1 General	7
6.2 Frost Penetration	7
6.3 Design of Sign Support Foundations	7
6.3.1 Site-Specific Caisson Foundation Design in Soil	8
6.4 Corrosion Assessment and Protection	10
6.5 Construction Considerations	10
6.5.1 Control of Soil and Groundwater	10
6.5.2 Obstructions	10
7.0 CLOSURE	11

REFERENCES

TABLES

Table 1 Geotechnical Design Parameters for Sign Support Foundations

DRAWINGS

Drawing 1 Borehole Location Plan

APPENDICES

APPENDIX A - Borehole Records from Previous Investigation GEOCRE 30M11-193

Borehole Nos. 193-2, 193-5, 193-6 and 193-7

APPENDIX B - Borehole Records from Previous Investigation GEOCRE 30M11-062

Borehole No. 062-3, 062-10

APPENDIX C - Non-Standard Special Provisions

NSSP Deep Foundations

NSSP Obstructions

PART A

**FOUNDATION INVESTIGATION REPORT
VARIABLE MESSAGE AND STATIC OVERHEAD SIGNS AT DIXON ROAD
HIGHWAY 401 REHABILITATION AND RESURFACING
CITY OF TORONTO, ONTARIO
G.W.P. 2032-11-00**

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AECOM Canada Ltd. (AECOM) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the proposed replacement of two variable message sign (VMS) footings and one new static overhead sign (OHS) near the Highway 401 and Dixon Road interchange, associated with the rehabilitation and resurfacing of Highway 401 from Kipling Avenue to Keele Street in Toronto, Ontario.

This report summarizes the geotechnical site conditions in the vicinity of the proposed VMS (temporary and permanent) and OHS supports at the location shown on the Key Plan on Drawing 1. The soil and groundwater information summarized in this report is based on a desktop review of the closest available GEOCREs information from the following existing foundation investigation reports:

- **MTO GEOCREs No. 30M11-193**, Boreholes 2, 5, 6 and 7 from report titled “Foundation Investigation and Design Report for High Mast Lighting at Highway 401 and Dixon Road Interchange, District No. 6, Toronto, W.P. 124-92-00”, by Ministry of Transportation Ontario – Foundation Materials Office, dated October 31, 1994.
- **MTO GEOCREs No. 30M11-062**, Borehole/Cone Penetration Hole 3 and Borehole 10 from report titled “Foundation Investigation at Proposed Intersection at the crossing of New Highway 401 and Dixon Road, County of York, Twp. Of Etobicoke, Toronto, District #6, W.J. 64-F-45 – W.P. 612-64 and W.P. 251-61-2 & 3,” by Department of Highways, Ontario, Materials & Testing Division – Foundation Section, dated August 7, 1964.

The previous investigation boreholes used in this report have been renumbered to show the MTO GEOCREs reference number followed by the original borehole designation. For example, the borehole from MTO GEOCREs Report No. 30M11-193 has been renumbered as 193-X, where X is the original borehole number.

2.0 PROJECT DESCRIPTION

It is understood that the footings of two existing VMS's located along Highway 401 on either side of the Dixon Road interchange will be replaced as part of the rehabilitation works along Highway 401, as shown on Drawing 1. The existing VMS footings were built in 2000 (westbound VMS) and 2006 (eastbound VMS) and require replacement (including foundations) to meet the latest version of the CHBDC (2019). As part of the construction staging, temporary “lollipop” VMS's will be designed and constructed within about 15 m from each existing sign location as required for 2 to 3 years during rehabilitation / reconstruction activities after removal of the existing sign footings and prior to construction of the new permanent sign footings.

An existing cantilever sign located along the westbound off-ramp to Dixon Road from Highway 401 will be also removed and a new tri-chord overhead sign is proposed to be constructed over the ramp, in advance of the bullnose that splits the ramp traffic towards Dixon Road or Martin Grove Road, as shown on Drawing 1.

3.0 SITE DESCRIPTION

The Dixon Road and Highway 401 interchange is bordered by industrial/commercial lands to the north and residential housing to the south. Near the interchange, Dixon Road is generally oriented east-west, while Highway 401 is generally oriented southwest-northeast. The Dixon Road grade ranges from approximately Elevation 161 m to Elevation 158 m, as the surrounding topography dips slightly eastward. Highway 401 is constructed as an overpass and the highway road grade climbs from approximately Elevation 160 m to Elevation 167 m as it rises over Dixon Road and the adjacent Martin Grove Road.

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

This section of Highway 401 is located within the Till Plains of the Peel Plain physiographic region, as delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, 1984)¹.

The Peel Plain physiographic region covers the central portions of the Regional Municipalities of York, Peel and Halton. The general topography of this region consists of level to gently rolling terrain, sloping gradually southward toward Lake Ontario. A surficial till sheet, which generally follows the surface topography, is present throughout much of this area. The till, which is mapped in this area as the Halton Till, typically consists of clayey silt to silty clay, with occasional sand to silt zones. Shallow, localized deposits of loose sand and silt and/or soft clay can overlie this uppermost till sheet, and these represent relatively recent deposits, formed in small glacial meltwater ponds scattered throughout the Peel Plain and concentrated near river valleys. The recent sand, silt and clay and uppermost till deposits in this area overlie and are interbedded with stratified deposits of sand, silt and clay. The study area, in the western portion of the Peel Plain, is underlain by grey shale of the Georgian Bay Formation.

4.2 General Overview of Subsurface Conditions

The relevant boreholes from the previous investigations located near each of the proposed new footing and sign locations are shown on Drawing 1. The location of each borehole was taken from the original borehole location plan provided in the GEOCRE report and converted to MTM NAD83 (Zone 10) northing and easting co-ordinates. For each proposed new sign support location, a summary of the relevant boreholes and associated ground surface elevation (geodetic datum), location (including geographic coordinates), drilled depth and approximate distance to the new sign is provided below.

Sign Support Designation	Borehole I.D.	Ground Surface Elevation (m) ¹	Northing (m) (Latitude)	Easting (m) (Longitude)	Depth of Borehole (m)	Approximate Distance to Proposed New Sign (m)
VMS#1	193-2	160.7	4,838,737.2 (43.688569)	299,013.2 (79.571785)	9.6	100
	062-3	164.1	4,838,903.8 (43.69007)	299,096.3 (-79.570756)	11.1	84
VMS#2	193-6	162.2	4,839,257.1 (43.693252)	299,360.8 (-79.567479)	7.9	60
	193-7	159.3	4,839,342.9 (43.694024)	299,316.3 (-79.568032)	9.6	50

¹Chapman, L.J. and Putnam, D.F. 1984. *The Physiography of Southern Ontario*, Ontario Geological Survey, Special Volume 2, Third Edition. Accompanied by Map P. 2715, Scale 1:600,000.

Sign Support Designation	Borehole I.D.	Ground Surface Elevation (m) ¹	Northing (m) (Latitude)	Easting (m) (Longitude)	Depth of Borehole (m)	Approximate Distance to Proposed New Sign (m)
OHS#11	193-5	166.2	4,839,207.9 (43.692808)	299,204.8 (- 79.569413)	9.6	50
	062-10	163.1	4,839,185.1 (43.692602)	299,080.4 (- 79.570956)	9.6	130

Note: 1 – The ground surface elevation is taken from the borehole record at the time of borehole advancement and may not be representative of the current ground surface elevation. Considering the 193-x series boreholes were advanced in 1994 and the 062-x series boreholes were advanced in 1964, the current ground surface elevation may have changed significantly considering construction of the highway and associated earthworks have been carried out since the boreholes were drilled.

The existing boreholes were advanced to depths ranging from about 7.9 m to 11.1 m below ground surface and sampled in general accordance with MTO procedures. The Standard Penetration Test (SPT) “N”-values from the previous investigations are reported to be in accordance with ASTM D1586 procedures, although it is inferred that “N”-values were measured using a manual hammer and the values are reported with no adjustments / corrections. In addition, the depths below ground surface in the discussion below reference the ground surface elevation on the borehole records at the time of the investigation and does not reference the current ground surface / road grade.

The detailed subsurface soil and groundwater conditions encountered in the boreholes of the previous investigations, and the results of the in situ and laboratory tests are provided on the Record of Boreholes in Appendices A and B. The results of the in-situ field tests (i.e., SPT “N”-values) as presented on the borehole records and in Section 4 are inferred to be uncorrected.

The stratigraphic boundaries shown on the borehole records are inferred from non-continuous sampling, observations of drilling progress and the results of Standard Penetration Tests. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Variation in the stratigraphic boundaries between and beyond boreholes will exist and is to be expected, however, the factual data presented on the borehole records governs any interpretation of the site conditions.

In general, the subsurface conditions as encountered in the boreholes advanced during previous investigations at the site consist of embankment fill (typically a firm to very stiff cohesive fill layer) underlain by a very stiff to hard cohesive glacial till deposit which is interlayered by a non-cohesive till deposit in some locations. Although not encountered in the previous investigations, surficial layers of asphalt, concrete and granular subbase associated with the pavement structure of Highway 401 and its associated ramps are present at this site.

A detailed description of the major soil strata encountered in the previous boreholes is provided below.

4.2.1 Silty Clay to Clayey Silt (Fill)

A 3.7 m to 5.2 m thick layer of cohesive fill was encountered at ground surface in Boreholes 193-2, 193-5, and 193-6. The fill material is described as clayey silt and silty clay to clayey silt with sand, containing some gravel and trace organics in some areas. The base of the fill layer extends to between approximately Elevations 156.3 m and 161.0 m.

The Standard Penetration Test (SPT) “N”-values measured within the cohesive fill layer range from 7 blows to 16 blows per 0.3 m of penetration, suggesting a firm to very stiff but typically stiff consistency.

4.2.2 Sand (Fill)

A 1.1 m thick sand fill layer was encountered below the cohesive fill layer in Borehole 193-2. The base of the sand fill layer extends to approximately Elevation 155.2 m.

The SPT “N”-value measured within the sand fill layer is 0 blows per 0.3 m of penetration, indicating a very loose relative density.

4.2.3 Clayey Silt-Silt to Clayey Silt (Till)

A cohesive glacial till deposit was encountered below the fill layer in Boreholes 193-2, 193-5, and 193-6 and at ground surface in Boreholes 193-7, 062-3, and 062-10. The cohesive till deposit is comprised of clayey silt-silt to clayey silt, some sand to sandy, trace to some gravel (described in the original boreholes as clayey silt to silt in Boreholes 193-2, 193-5, 193-6 and 193-7 and as a heterogenous mixture of clayey silt, sand with some gravel in Boreholes 062-3 and 062-10). Boreholes 193-2, 193-5, 193-6, 062-3 and 062-10 were terminated within the cohesive till deposit after penetrating it for lengths ranging between approximately 4.1 m and 11.1 m (corresponding to Elevations 151.1 m and 156.6 m). Although not indicated on the borehole records, cobbles/boulders are known to be present within the glacial till soils in this local region and should be anticipated to be present within this glacial till deposit.

The SPT “N” - values measured within the cohesive till deposit range from 16 blows per 0.3 m of penetration to 100 blows for 0.13 m of penetration, suggesting a very stiff to hard consistency.

Grain size distribution testing was carried out on six samples of the cohesive till deposit from Boreholes 062-3 and 062-10 and the results are shown on the corresponding record of borehole sheets in Appendix B. In summary, the results indicate the gravel content ranges from 3 to 16 per cent, sand content ranges from 18 to 35 per cent, silt content ranges from 40 to 53 per cent, and clay content ranges from 14 to 24 per cent.

Atterberg limits testing was carried out on six samples of the cohesive till deposit from Boreholes 062-3 and 062-10 and measured liquid limits ranging from about of 17 to 32 per cent, plastic limits ranging from about of 12 to 18 per cent, and corresponding plasticity indices ranging from about 5 to 15 per cent. The results are shown on the corresponding record of boreholes in Appendix B, and indicate the deposit is generally classified as clayey silt-silt to clayey silt of low plasticity.

The natural water content measured on six samples of the cohesive till deposit from Boreholes 062-3 and 062-10 ranges from about 8 to 17 per cent.

The laboratory bulk density of four samples of the cohesive till deposit from Boreholes 062-3 and 062-10 measured 17.3 to 25.0 kN/m³.

A dynamic cone penetration test (DCPT) was carried out adjacent to Borehole 062-3 from ground surface (Elevation 164.1 m) and achieved effective refusal (greater than 100 blows / 0.3 m of penetration) at approximately 3 m below ground surface (Elevation 161.1 m) within the clayey glacial till deposit.

4.2.4 Sandy Silt to Silty Sand (Till)

A non-cohesive till layer was encountered within the cohesive till deposit in Borehole 193-6 and below the cohesive till deposit in Borehole 193-7. The non-cohesive till deposit is described as consisting of wet sandy silt to silty sand,

trace gravel. In Borehole 193-6, the non-cohesive till deposit was encountered between approximately Elevation 156.4 m and 155.1 m (approximately 1.3 m thick). In Borehole 193-7, the non-cohesive till was encountered at about Elevation 152.3 m and was terminated within the sandy silt to silty sand till deposit at approximately Elevation 149.7 m, after penetrating it for approximately 2.6 m.

The SPT “N”-values measured within the non-cohesive till deposit range from 30 blows to 108 blows per 0.3 m of penetration, indicating a dense to very dense relative density.

4.2.5 Groundwater Conditions

The groundwater level recorded during drilling operations is provided on the borehole records in Appendices A and B and is summarized below.

Sign Support	Borehole No.	Ground Surface Elevation (m)	Depth to Water Level (m)	Groundwater Elevation (m)
VMS#1	193-2	160.7	3.7	157.0
	062-3	164.1	no information provided	
VMS#2	193-6	162.2	6.0	156.2
	193-7	159.3	4.4	154.9
OHS#11	193-5	166.2	dry	-
	062-10	163.1	no information provided	

The groundwater level observations at this site are not considered to represent long-term stabilized groundwater conditions. Groundwater levels will be subject to seasonal fluctuations and precipitation events; the groundwater levels should be expected to be higher during the spring season or during and following periods of heavy precipitation.

5.0 CLOSURE

This Foundation Investigation Report was prepared by Ms. Darcy Hansen, E.I.T, an engineer-in-training with Golder and reviewed by Mo'oud Nasr, P.Eng, a geotechnical engineer with Golder. Mr. Kevin Bentley, P.Eng., a MTO Foundations Designated Contact and Associate with Golder performed an independent technical and quality review of this report.

Golder Associates Ltd.



Darcy Hansen
Geotechnical Engineer-in-training



Mo'oud Nasr, P.Eng.
Geotechnical Engineer



Kevin J. Bentley, P.Eng.
MTO Foundations Designated Contact, Associate

DH/KJB/ml

Golder and the G logo are trademarks of Golder Associates Corporation

n:\canadian servers\whitby\active\2016\3 proj\1665765 aecom_2015-e-0026_hwy 401-427\fnds\6. deliverables\5. sign report (change order)\rev. 4\1665765 -r-rev4-rpt fidr 2021feb05.docx

PART B

**FOUNDATION DESIGN REPORT
VARIABLE MESSAGE AND STATIC OVERHEAD SIGNS AT DIXON ROAD
HIGHWAY 401 REHABILITATION AND RESURFACING
CITY OF TORONTO, ONTARIO
G.W.P. 2032-11-00**

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides foundation recommendations for the design of the two replacement VMS footings (designated VMS#1 and VMS#2) and the associated temporary pole-mounted variable message sign at each location, and one new overhead tri-chord sign (designated OHS#11) proposed at the Highway 401 and Dixon Road interchange (see Drawing 1). These recommendations are based on interpretation of the factual data obtained from a desktop study of existing boreholes advanced previously during subsurface investigations by others at the project site (MTO GEOCREs Nos. 30M11-193 and 30M11-062). The interpretation and recommendations presented in this report rely on the accuracy of the existing information and are intended to provide the designers with sufficient information to assess the feasible foundation alternatives and carry out detail design of the sign support foundations.

The foundation investigation report, discussion and recommendations are intended for the use of the Ministry of Transportation, Ontario (MTO) and shall not be used or relied upon for any other purpose or by any other parties including the construction or design-build Contractor. Contractors must make their own interpretation based on the factual data in Part A (Foundation Investigation) of the report. Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project, and for which special provisions may be required in the Contract Documents. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

6.2 Frost Penetration

As per Ontario Provincial Standard Drawing (OPSD) 3090.101 (*Foundation Frost Penetration Depths for Southern Ontario*), the frost penetration depth in the area is interpreted to be 1.2 m.

6.3 Design of Sign Support Foundations

Caisson foundations for sign supports should be designed in accordance with the requirements in MTO's *Sign Support Manual* (MTO, 2019). The *Sign Support Manual* includes standard caisson foundation designs for each proposed sign type as follows:

- **2 Temporary Variable Message Signs (Temporary VMS#1 and #2):** Pole Mounted VMS Supports, Section 8 and Standard Drawings SS118-3, SS118-4, and SS118-5.
- **2 Permanent Variable Message Signs (VMS#1 and #2):** VMS Overhead Truss Supports, Section 8 and Standard Drawings SS118-6, SS118-7, and SS118-8.
- **Tri-chord Sign (OHS#11):** Tri-chord Static Sign Supports, Simply Supported Type I, Section 4 and Standard Drawing SS118-3.

In the standard caisson foundation design for these sign types, the caisson lengths vary from 5 m to 6.5 m below the design frost depth (i.e. below 1.2 m) resulting in a total length of 6.2 to 7.7 m below final grade depending on the sign types and corresponding caisson diameter (i.e. 1200 mm diameter). The standard sign foundation designs presented in the MTO's *Sign Support Manual* have been developed based on the minimum soil conditions given below.

- **Case 1 (Non-Cohesive Soils):** Sand with a friction angle of 28 degrees surrounding the upper two-thirds of the portion of the caisson foundation below the frost depth, and sand with a friction angle of 30 degrees surrounding the lower third of the portion of the caisson below the design frost depth.
- **Case 2 (Cohesive Soils):** Soft clay with an undrained shear strength of 25 kPa surrounding the upper two-thirds of the portion of the caisson foundation below the frost depth, and “soft” clay with an undrained shear strength of 50 kPa surrounding the lower third of the portion of the caisson below the design frost depth.

The standard foundation design provided in MTO’s *Sign Support Manual* does not apply to sites where extensive poor fill materials or materials looser or softer than those of Case 1 or Case 2 are present. The standard foundation design is also not applicable where bedrock is encountered within the standard foundation depth. For such subsurface conditions, a site-specific design is required.

The subsurface conditions at the closest boreholes to the proposed new footing and sign locations have been compared to the standard design requirements to assess whether a standard or site-specific design is required.

Based on the available field and laboratory data, the standard sign foundation design may be applied to all five proposed new footing and sign locations: VMS#1 (footing replacement and temporary sign), VMS#2 (footing replacement and temporary sign) and OHS#11, as shown on Drawing 1.

6.3.1 Site-Specific Caisson Foundation Design in Soil

A site-specific caisson foundation design may be carried out by the structural engineer to optimize the standard foundation design or if non-standard design is required using the equations provided below and geotechnical design parameters given in Table 1 following the text of this report.

The resistance to lateral loading of caissons may be calculated using subgrade reaction theory where the coefficient of horizontal subgrade reaction (k_h in kPa/m) is determined based on the equations given below:

For cohesionless soils:

$$k_h = \frac{n_h z}{B} \quad \text{where} \quad \begin{array}{l} n_h \text{ is the constant of horizontal subgrade reaction (kPa/m);} \\ z \text{ is the depth (m); and} \\ B \text{ is the caisson diameter (m)} \end{array}$$

For cohesive soils:

$$k_h = \frac{67 S_u}{B} \quad \text{where} \quad \begin{array}{l} S_u \text{ is the undrained shear strength of the soil (kPa); and} \\ B \text{ is the caisson diameter (m)} \end{array}$$

The above equations and recommended parameters in Table 1 may be used to analyse the interaction between a caisson and the surrounding soil (i.e. for serviceability limit state design) provided that lateral displacements within the soil do not exceed about 10 mm. If deflections exceed 10 mm, a non-linear analysis method should be used to model the behaviour of the soil (e.g. p-y curves). The upper 1.2 m of soil resistance should not be included in the design to account for frost action.

The spring constant, K , for structural analysis may be obtained by the expression, $K = k_h \times L \times B$ (kN/m), where k_h is the coefficient of horizontal subgrade reaction (kPa/m), B is the buried caisson diameter (m) and L is the length (m) of the caisson segment used in the analysis.

The structural resistance of the caisson at ultimate limit state should be checked by the structural engineer and the lateral geotechnical resistance at ultimate limit state can be checked using the conventional Broms' equation (CFEM, 2006), based on the stratigraphy and geotechnical design parameters given in Table 1. Alternatively, the unfactored ultimate lateral geotechnical resistance can be calculated using passive lateral earth pressure, P_p (kPa) as defined below, distributed along the length of the caisson based on the stratigraphy and geotechnical design parameters given in Table 1.

$$P_p = K_p \gamma d_w \quad \text{above the groundwater table (kPa), and}$$

$$P_p = K_p \gamma d_w + K_p \gamma' (d - d_w) \quad \text{below the groundwater table (kPa)}$$

where K_p is the passive earth pressure coefficient;

γ is the bulk unit weight (kN/m³);

γ' is the effective unit weight below the groundwater level (kN/m³);

d is the depth below the ground surface (m); and

d_w is the depth to the groundwater level (m).

The unfactored ultimate lateral resistance, p_{ult} (kN) for non-cohesive soils should be calculated assuming an equivalent width equal to three times the caisson diameter, and an equivalent length equal to six times the caisson diameter (Section C6.8.7.1 of CHBDC (2006)), as outlined below:

$$p_{ult} = P_p A_e \text{ (kN)}$$

where A_e is the equivalent area equal to $3D \cdot 6D = 18D^2$ (m²)

D is the caisson diameter (m)

Where an undrained shear strength, S_u , is provided for a cohesive soil layer in Table 1, the undrained ultimate lateral resistance of the caisson should be checked to determine whether the drained or undrained case will govern. In this case, the lateral resistance for the length of the caisson within the cohesive soil should be calculated assuming an internal angle of friction, $\Phi' = 0$ degrees, and an unfactored passive lateral pressure distribution varying from $2 S_u$ at ground surface and increase linearly to $9 S_u$ at and below a depth equivalent to three caisson diameters, acting over the actual width of the caisson (Section C6.8.7.1 of CHBDC (2006)), as outlined below.

$$p_{ult} = P_p A_e \text{ (kN)}$$

where P_p is equal to $2 S_u$ at ground surface to $9 S_u$ at and below a depth equivalent to $3D$ (kPa)

A_e is the equivalent area equal to $L \times D$ (m²)

L is the caisson length (m)

D is the caisson diameter (m)

In accordance with CHBDC (2019), the product of the consequence factor, Ψ , and the geotechnical resistance factor, ϕ_{gu} should be applied to this unfactored lateral resistance to obtain the factored lateral geotechnical resistance at Ultimate Limit States (p_{ULS}) as shown below. A similar procedure is required to obtain the factored lateral geotechnical resistance at Serviceability Limit States using the appropriate factors in CHBDC (2019).

$$p_{ULS} = p_{ult} \cdot \Psi \cdot \phi_{gu} \text{ (kN)}$$

where $\Psi = 1$ (typical consequence factor as per Table 6.1 in CHBDC (2019))

$\phi_{gu} = 0.5$ (passive resistance factor for typical degree of understanding, as per Table 6.2 in CHBDC (2019))

Based on the drawings provided by AECOM, the sign support foundations will be constructed in areas of relatively flat ground, however, in the event that the foundations are located on an embankment slope or within about 2 caisson diameters of the crest of the slope in the direction of loading, there would be unbalanced earth pressures around the foundation due to it being located within sloping ground (assumed 2H:1V embankment). For this case, the passive earth pressure coefficient ($K_{p2:1}$), to be used in the foundation design is also included in Table 1.

6.4 Corrosion Assessment and Protection

Soil corrosivity may affect the concrete foundations and reinforcing steel and other concrete elements buried in the soil. The long-term performance and durability of the foundations are directly related to their respective corrosion resistance. Generally, the corrosivity of a structure depends on the soil resistivity, hydrogen ion concentration (pH), and salt (chloride and sulphate) concentrations. No analytical testing was carried out as part of the previous investigations however it is anticipated that road salts will have a direct impact on the foundations. It is ultimately up to the designer to determine the appropriate exposure class of concrete and to ensure that all aspects of CSA A23.1 Section 4.1.1 “Durability Requirements” are followed.

6.5 Construction Considerations

6.5.1 Control of Soil and Groundwater

The water-bearing non-cohesive layers / deposits within the fill and glacial till deposits at this site should be expected to run or flow into the caisson hole during or after drilling of the caisson foundations for the sign supports. Therefore, appropriate equipment and procedures will be required to minimize ground loss during drilling and concrete placement. This could include the use of temporary or permanent caisson liners, and/or the use of drilling mud. Foundations for the sign supports should be constructed consistent with OPSS.PROV 915 (*Sign Support Structures*). It is recommended that a Non-Standard Special Provision (NSSP) be included in the Contract Documents to warn the contractor of this condition; such an NSSP is provided in Appendix C.

6.5.2 Obstructions

The fill layers and glacial till deposits potentially contain obstructions such as cobbles and/or boulders. It is recommended that a Notice to Contractor be included in the Contract Documents to alert the Contractor of the presence of obstructions such as cobbles and/or boulders within the overburden soils; an example is provided in Appendix C.

7.0 CLOSURE

This Foundation Design Report was prepared by Ms. Darcy Hansen, E.I.T, an engineer-in-training with Golder and reviewed by Mo'oud Nasr, P.Eng, a geotechnical engineer with Golder. Mr. Kevin Bentley, P.Eng., a MTO Foundations Designated Contact and Associate with Golder performed an independent technical and quality review of this report.

Golder Associates Ltd.



Darcy Hansen
Geotechnical Engineer-in-training



Mo'oud Nasr, P.Eng.
Geotechnical Engineer



Kevin J. Bentley, P.Eng.
MTO Foundations Designated Contact, Associate

DH/KJB/ml

Golder and the G logo are trademarks of Golder Associates Corporation

n:\canadian servers\whitby\active\2016\3 proj\1665765 aecom_2015-e-0026_hwy 401-427\fnlds\6. deliverables\5. sign report (change order)\rev. 4\1665765 -r-rv4-rpt fidr 2021feb05.docx

REFERENCES

- Canadian Geotechnical Society. 2006. Canadian Foundation Engineering Manual (CFEM), 4th Edition. The Canadian Geotechnical Society, BiTech Publisher Ltd., British Columbia.
- Canadian Standards Association, 2019. Canadian Highway Bridge Design Code (CHBDC) and Commentary on CAN/CSA-S6-14. CSA Group.
- Chapman, L.J. and Putnam, D. F. 1984. The Physiography of Southern Ontario, Ontario Geological Survey, Special Volume 2, Third Edition. Accompanied by Map P.2715, Scale 1:600,000.
- CSA Group. 2014. A23.1-14/A23.2-14 - Concrete materials and methods of concrete construction / Test methods and standard practices for concrete.

ASTM International

ASTM D1586 Standard Test Method for Standard Penetration Test and Split-Barrel Sampling of Soils

Ontario Provincial Standard Drawings (OPSD)

OPSD 3090.101 Foundation Frost Penetration Depths for Southern Ontario

Ontario Provincial Standard Specification (OPSS):

OPSS 915 Construction Specification for Sign Support Structures

Ministry of Transportation, Ontario

Ministry of Transportation Ontario. Sign Support Manual. Provincial Highways Management Division, Highway Standards Branch, Bridge Office. February 2019.

Table 1: Geotechnical Design Parameters for Sign Support Foundations

Sign Support Designation	Reference Boreholes	Ground Surface Elevation at Reference Boreholes (m)		Approximate Ground Surface Elevation at Sign Location (m)	Standard or Site-Specific Foundation Design	Stratum	Estimated Depth Relative to Ground Surface at Sign Location (m) ¹	Estimated Elevation (m)	Estimated Groundwater Elevation (m)	Design Parameters						
		At time of Borehole Drilling	Current							S _u (kPa)	Φ' (degrees)	γ (kN/m ³)	γ' (kN/m ³)	n _h value (kPa/m)	K _p	K _{p2:1}
VMS#1 (Footings replacement and Temporary Sign)	193-2 / 062-3	160.7 / 164.1	163.2 / 167.6	165.8	Standard	Assumed Engineered Fill	0 – 2.5	165.8 – 163.3	157.5	-	28	19	9	4,000	2.8	1.0
						Stiff to Very Stiff Silty Clay to Clayey Silt with Sand (Fill)	2.5 - 6.9	163.3 – 158.9		60	30	19	9	--	3.0	1.1
						Very Loose Sand (Possible Fill)	6.9 – 8.0	158.9 – 157.8		--	25	20	10	2,000	2.5	0.9
						Very Stiff to Hard Clayey Silt (Till)	8.0 – 13.0	157.8 – 152.8		200	35	22	12	--	3.7	1.4
VMS#2 (Footings replacement and Temporary Sign)	193-6 / 193-7	162.2 / 159.3	162.4 / 164.0	163.8	Standard	Stiff to Very Stiff Clayey Silt (Fill)	0 – 3.0	163.8 – 160.8	156.5	60	30	19	9	--	3.0	1.1
						Very Stiff to Hard Clayey Silt-Silt to Clayey Silt (Till)	3.0 – 11.5	160.8 – 152.3		200	35	22	12	--	3.7	1.4
						Dense to Very Dense Sandy Silt to Silty Sand (Till)	11.5 – 14.1	152.3 – 149.7		--	35	22	12	10,000	3.7	1.4
OHS#11 (Permanent Tri-chord)	193-5 / 062-10	166.2 / 163.1	165.8 / 167.1	164.5 to 164.1	Standard	Firm to Stiff Clayey Silt with Sand (Fill)	0 – 4.5	164.5 – 160	157.5	50	30	19	9	--	3.0	1.1
						Very Stiff to Hard Clayey Silt-Silt to Clayey Silt (Till)	4.5 – 11.0	160 – 153.5		200	35	22	12	--	3.7	1.4

- NOTES:
1. Estimated depths are given at the existing or proposed sign support locations relative to the estimated existing ground surface. At the VMS#1 location, the existing ground surface is significantly higher than the ground surface at the time of drilling, thus, it is assumed that competent engineered fill has been placed to raise the highway embankment grade in this area. Although s_u, Φ' and K_p parameters are given for the full depth of the soil, the passive resistance in the upper 1.2 m should be neglected to account for frost action.

2. Design Parameters:

s_u = undrained shear strength (kPa);

Φ' = effective friction angle (degrees);


n_h = the constant of horizontal subgrade reaction (kPa/m)

γ = bulk unit weight (kN/m³);

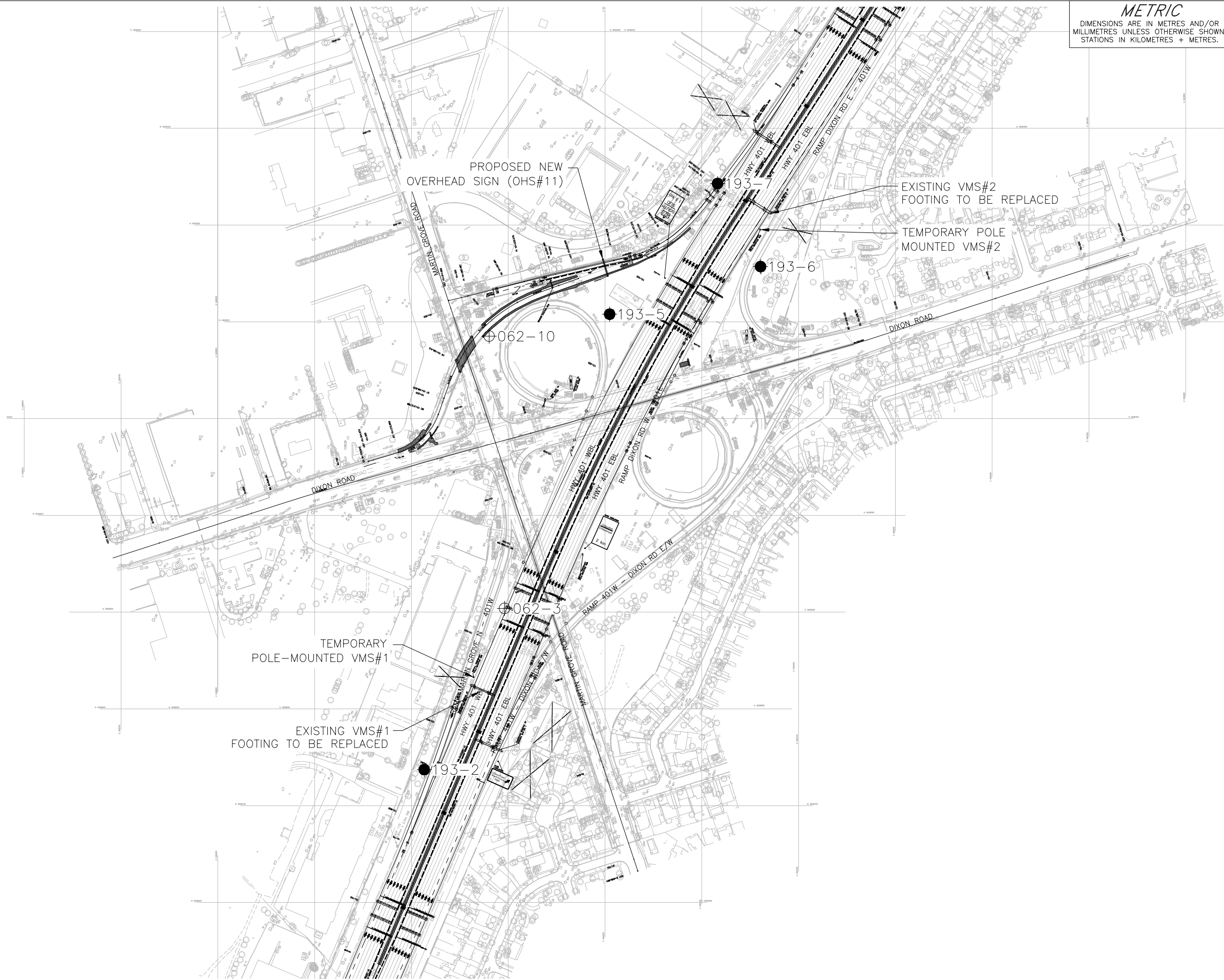
γ' = effective unit weight below the groundwater level (kN/m³);

K_p = passive earth pressure coefficient; and

K_{p2:1} = passive earth pressure coefficient for 2H:1V sloping ground surface.

3. Where both undrained shear strength and effective friction angle parameters are provided for cohesive materials, the structural assessment should be completed for both undrained and drained conditions, and the selected design should be based on the more conservative approach.
-  GOLDER

DRAWINGS

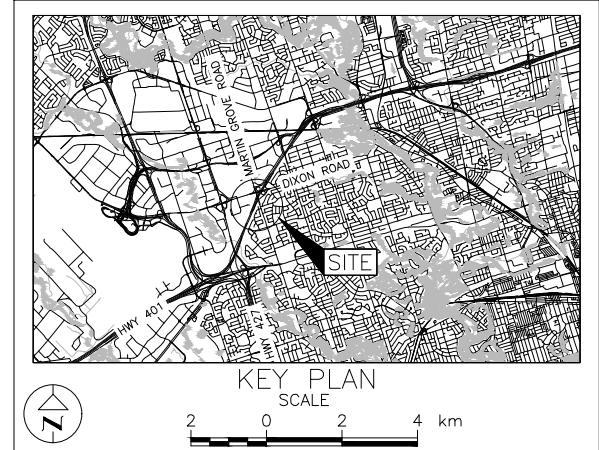


METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
WP No.

HIGHWAY 401
VMS AND OHS SIGNS LOCATIONS AT DIXON ROAD
BOREHOLE LOCATIONS PLAN

SHEET



LEGEND	
	Borehole - (GEOCRES No. 30M11-193)
	Borehole - (GEOCRES No. 30M11-062)

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
062-3	164.1	4838903.8	299096.3
062-10	163.1	4839185.1	299080.4
193-2	160.7	4838737.2	299013.2
193-5	166.2	4839207.9	299204.8
193-6	162.2	4839257.1	299360.8
193-7	159.3	4839342.9	299316.3

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

Ground surface elevations reflect the topography at the time of borehole advancement. At the VMS#1 location, the existing ground surface is significantly higher than the ground surface at the time of drilling, thus, it is assumed that competent engineered fill has been placed to raise the highway embankment grade in this area.

REFERENCE

Base plans provided in digital format by Aecom, drawing file nos. 401KM_base_C3.dwg and C3_Staging-OHS-VMS-for-Golder.dwg, received September 29, 2020.

NO.	DATE	BY	REVISION
Geocres No.			
HWY. 401		PROJECT NO. 1665765	DIST. .
SUBM'D.	CHKD. DH	DATE: 01/15/2021	SITE: .
DRAWN: DD	CHKD. .	APPD. KJB	DWG. 1

APPENDIX A

**Borehole Records from Previous Investigation
GEOCRES 30M11-193**

RECORD OF BOREHOLE No 2

1 OF 1

METRIC

W.P. 124-92-00 LOCATION Coords.: N 4 838 495.0, E 298 984.0 ORIGINATED BY KA
DIST 6 HWY 401 BOREHOLE TYPE Solid Stem Auger COMPILED BY SA
DATUM Geodetic DATE 1994 10 20 CHECKED BY KA

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100	W _p	W	W _L		
160.7	Ground Surface															
0.0																
			1	SS	8											
			2	SS	8											
	Silty Clay to Clayey Silt with Sand Stiff to V. Stiff (Fill)		3	SS	16											
			4	SS	12											
			5	SS	8											
			6	SS	0											
155.2																
5.5			7	SS	16											
			8	SS	32											
	Clayey Silt Grey, moist V. Stiff to Hard (Glacial Till)		9	SS	32											
151.1																
9.6	End of Borehole															

METRIC

+3, x5: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 6

1 OF 1

METRIC

W.P. 124-92-00 LOCATION Coords.: N 4 839 040.0, E 299 350.0 ORIGINATED BY KA
DIST 6 HWY 401 BOREHOLE TYPE Solid Stem Auger COMPILED BY SA
DATUM Geodetic DATE 1994 10 20 CHECKED BY KA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
162.2	Ground Surface																
0.0																	
			1	SS	14												
	Clayey Silt Trace of Organic Brown / Grey Stiff to V. Stiff (Fill)		2	SS	16												
			3	SS	10												
			4	SS	11												
158.5																	
3.7			5	SS	32												
	Clayey Silt to Silt with Trace of Clay Brown to Grey Hard (Glacial Till)		6	SS	38												
			7	SS	100	/13cm											
			8	SS	50	/13cm											
	Silty Sand Trace of Gravel Brown, Wet																
154.3			9	SS	58	/15cm											
7.9	End of Borehole																

RECORD OF BOREHOLE No 7

1 OF 1

METRIC

W.P. 124-92-00 LOCATION Coords.: N 4 839 155.0, E 299 300.0 ORIGINATED BY KA
DIST 6 HWY 401 BOREHOLE TYPE Solid Stem Auger COMPILED BY SA
DATUM Geodetic DATE 1994 10 19 CHECKED BY KA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
159.3	Ground Surface																
0.0	Clayey Silt Brown, Moist Trace of Gravel V. Stiff to Hard (Glacial Till)		1	SS	16												
			2	SS	19												
			3	SS	43												
			4	SS	50												
			5	SS	55												
			6	SS	57												
			7	SS	45												
			8	SS	46												
152.3	Sandy Silt to Silty Sand Grey, Wet Dense to V. Dense (Glacial Till)		9	SS	30												
7.0																	
149.7			10	SS	108												
9.6	End of Borehole																

APPENDIX B

**Borehole Records from Previous Investigation
GEOCRES 30M11-062**

Borehole No. 062-3

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & RESEARCH DIVISION

RECORD OF BOREHOLE NO. 3

FOUNDATION SECTION

64-F-45

LOCATION Hwy 401 & Martin Grove Rd

ORIGINATED BY V.K.

251-61

BORING DATE June 16, 1964.

COMPILED BY V.K.

Geodetic

BOREHOLE TYPE Penn-Drill

CHECKED BY M.D.

SOIL PROFILE		SAMPLES		ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT	Liquid Limit ——— W _p Plastic Limit ——— W _{pL} Water Content ——— W _e	BULK DENSITY P.C.F.	REMARKS
DEPTH	DESCRIPTION	STRAT PLOT	NUMBER TYPE		BLOWS / FOOT	SHEAR STRENGTH P.S.F.		
538.5	Groundlevel							
0.0	Heterogeneous mixt. of clayey silt, sand with some gravel- Glacial Till (V. stiff to hard) (Brown)		1 SS 27	240			110	Gr-8 Sa-18 Si-50 Cl-24
			2 SS 54	530				
			3 SS 65				136	Gr-3 Sa-28 Si-53 Cl-16
			4 SS 101					
523.0			5 SS 100					
15.5	(Grey)		6 SS 57	520				
			7 SS 60	460				Gr-16 Sa-30 Si-40 Cl-14
			8 SS 40					
				510				
			9 SS 68					
502.0			10 SS 130	for				
36.5	End of borehole.		6"	500				

Borehole No. 062-10

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & RESEARCH DIVISION

RECORD OF BOREHOLE NO. 10

FOUNDATION SECTION

JOB 64-F-45 LOCATION Hwy. 401 & Martin Grove Rd ORIGINATED BY V.K.
W. F. 251-61 BORING DATE June 24, 1964. COMPILED BY V.K.
DATUM Geodetic BOREHOLE TYPE Penn-Drill CHECKED BY M.D.

SOIL PROFILE		SAMPLES			ELEV SCALE	DYNAMIC PENETRATION RESISTANCE					LIQUID LIMIT ——— W _L PLASTIC LIMIT ——— W _P WATER CONTENT ——— W			BULK DENSITY P.C.F.	REMARKS	
ELEV DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE		BLOWS / FOOT	BLOWS / FOOT 20 40 60 80 100					SHEAR STRENGTH P.S.F. W _p W _c W _L				WATER CONTENT % 10 20 30
535.0	Groundlevel															
0.0	Heterogeneous mixt. of clayey silt, sand with some gravel. Glacial till Hard (Brown) (Grey)		1	SS	47	530									Gr-3	
			2	SS	59											Sa-25
			3	SS	91											Si-51
			4	SS	80											Cl-21
522.0			5	SS	62	520										Gr-3
13.0			6	SS	56											Sa-27
			7	SS	52											Si-50
			8	SS	74	510										Cl-20
503.5			9	SS	159										Gr-13	
31.5	End of borehole.					500									Sa-35	
															Si) 52	
															Cl.)	

APPENDIX C

**Non-Standard Special Provisions
(NSSP)**

DEEP FOUNDATIONS - Item No.

UNSTABLE EXCAVATIONS

Non-Standard Special Provision

Where OPSS 903 is called up by OPSS.PROV 915, OPSS 903 is amended by the following. Where conflict occurs, this NSSP shall take precedence.

The Contractor shall construct sign support foundations in conformance with the design and at the locations indicated in the Contract Documents.

The Contractor shall construct the sign support foundations against undisturbed bases and sides of excavations. The base and sides of caisson excavations shall be cleaned of loosened and/or softened materials prior to pouring concrete for the foundation. The construction methods and techniques shall be the responsibility of the contractor, but consideration could be given to using temporary liners, drilling mud and placement of concrete by tremie methods where conditions warrant.

The contractor is advised that variable subsurface conditions are anticipated to be encountered at the caisson locations for the temporary and permanent variable message signs (VMS#1 and VMS#2) and the overhead sign (OHS#11). For bidding purposes, the Contractor shall assume that the fill and glacial till deposits have zones of saturated non-cohesive (silt and sand) soil as encountered from drilling / sampling operations. The groundwater levels are anticipated to be within about 4.5 m below the ground surface. The Contractor is advised that non-cohesive soil is susceptible to disturbance and cave-in, especially under conditions of unbalanced hydrostatic head.

Basis of Payment

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.

END OF SECTION

DEEP FOUNDATIONS – Item No.

OBSTRUCTIONS

Non-Standard Special Provision

The Contractor shall be alerted to the presence of obstructions including cobbles and boulders within the native glacially derived till deposits. Details of the depths at which obstructions may be encountered are detailed in the Foundation Investigation Report and associated Record of Boreholes near each sign location. Consideration of the presence of these obstructions must be made in the selection of appropriate equipment and procedures for excavations and construction of the variable message signs and overhead sign foundations.



golder.com