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**FOUNDATION INVESTIGATION AND DESIGN REPORT
PROPOSED CHANGEABLE MESSAGE SIGNS (CMS)
HIGHWAY 401 CMS UPGRADE AND EXPANSION
DIXON ROAD/MARTINGROVE ROAD TO ALLEN ROAD
TORONTO, ONTARIO
G.W.P. 04-20003**

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September 2004

04-1111-023



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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by IBI Group on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation design recommendations for nine proposed changeable message signs along Highways 401, 400, 409 and Allen Road in Toronto, Ontario.

The subsurface information and geotechnical recommendations provided in this report are based on a review of geotechnical data available from MTO's GEOCREs system for previous geotechnical investigations in the vicinity of each of the proposed signs. The following table lists the locations of the proposed signs under this work project, and the GEOCREs data that has been referenced to determine the subsurface conditions and geotechnical engineering recommendations.

<i>Site No.</i>	<i>Sign Location</i>	<i>Reference</i>
1	Highway 401 Eastbound Express East of Dixon Road (Station 13+526)	GEOCREs No. 30M11-193: Foundation Investigation for High Mast Light Poles at Highway 401-Dixon Road Interchange, W.P. No. 124-92-00, Contract No. 95-36
2	Highway 409 Eastbound West of Kipling Avenue (Station 13+602)	Job No. 63-F-68: Foundation Investigation for Extension of Underpass Carrying Kipling Avenue over Highway 401, W.P. No. 250-61 Job No. 65-F-230: Foundation Investigation for Kipling Avenue Underpass at Proposed CNR Subway, W.P. No. 308-65-1
5	Highway 400 Southbound South of Sheppard Avenue (Station 14+849)	GEOCREs No. 30M11-191: Foundation Investigation for High Mast Light Poles on Highway 400 Between Highway 401 and Steeles Avenue, W.P. No. 149-87-00(A)
6	Highway 401 Westbound Collector West of Keele Street (Station 14+478)	Job No. 64-F-42: Department of Highways Borrow Area, W.P. No. 85-59-3
7	Highway 401 Westbound Express East of Keele Street (Station 14+770)	Job No. 63-F-87: Foundation Investigation for Keele Street Underpass, W.P. No. 231-60
8	Highway 401 Eastbound Express West of Dufferin Street (Station 16+267)	Job No. 63-F-24: Foundation Investigation for Spadina Expressway Bridges 1, 2 and 3, W.P. No. 229-60, 233-61-2-1 and 233-61-2-2
9	Allen Road Northbound South of Ranee Avenue	Job No. 62-F-220-C, Foundation Investigation for Highway 401 and Spadina Road Interchange, W.P. No. 233-61-03
10	Allen Road S-W Ramp	Job No. 62-F-220-C, Foundation Investigation for Highway 401 and Spadina Road Interchange, W.P. No. 233-61-03
New	Highway 400 Northbound South of Finch Avenue (Station 17+298)	GEOCREs No. 30M11-191: Foundation Investigation for High Mast Light Poles on Highway 400 Between Highway 401 and Steeles Avenue, W.P. No. 149-87-00(A)

2.0 SUBSURFACE CONDITIONS

The following subsections provide a summary of the subsurface conditions at each of the proposed changeable message sign (CMS) locations, based on the available subsurface information in the vicinity of the sites as obtained from MTO's GEOCREST system.

2.1 Site 1 – Highway 401 Eastbound Express, East of Dixon Road

Appendix A contains a borehole location plan and the records for Boreholes 6 and 7, which were advanced in the vicinity of the proposed CMS sign at this site as part of a 1994 investigation for high mast light poles at the Highway 401 – Dixon Road interchange.

In Borehole 6, a surficial layer of clayey silt fill was encountered above Elevation 158.5 m (approximately 3.7 m depth). This fill contains trace organic matter and is stiff to very stiff, based on measured Standard Penetration Test (SPT) "N" values of 10 to 16 blows per 0.3 m of penetration.

A deposit of glacial till is present below the fill in Borehole 6, and from ground surface (about Elevation 159.3 m) in Borehole 7. The glacial till ranges in composition from clayey silt with sand to silty sand containing trace clay; the till was noted to contain an approximately 1 m thick interlayer of wet silty sand in Borehole 6, below about Elevation 156.5 m. The measured SPT "N" values in the glacial till range from 16 to greater than 100 blows per 0.3 m of penetration, but are typically above 30 blows per 0.3 m of penetration, indicating that the deposit is generally hard / dense to very dense. The lower SPT "N" values of 16 and 19 blows per 0.3 m of penetration were encountered in the upper portion of the glacial till deposit encountered in Borehole 7; based on these results, this portion of the deposit has a very stiff consistency.

The water level in these two boreholes, and in other boreholes advanced in this area of the site, was measured between Elevations 155 m and 156.5 m on completion of drilling.

2.2 Site 2 – Highway 409 Eastbound, West of Kipling Avenue

Appendix B contains borehole location plans and records for the following selected boreholes:

- Boreholes 3 (1963) and 4 (1963), which were advanced as part of a 1963 investigation for the Highway 401 – Kipling Avenue structure.
- Boreholes 4 (1965) and 5 (1965), which were advanced as part of a 1965 investigation for the CN Rail subway; these boreholes are located immediately north of Belfield Road, which is just north of Highway 409.

These boreholes encountered a glacial till deposit extending from ground surface, which was at about Elevation 151.5 m to 152.5 m at the Highway 401 – Kipling Avenue structure site, and at about Elevation 156.5 m to 157.5 m at the Kipling Avenue – CN Rail structure site. The glacial till is described as a clayey silt containing some sand and gravel at Highway 401, and as a silt till at CN Rail. The measured SPT “N” values in the upper 1 m of the deposit are between 15 and 25 blows per 0.3 m of penetration, indicating that the upper portion of the deposit is very stiff / compact. Below this, the glacial till is generally hard or dense to very dense, based on measured SPT “N” values of about 30 to greater than 100 blows per 0.3 m of penetration.

The water level in the boreholes was encountered at about Elevation 150 m at the Highway 401 site, and between Elevations 151.3 m and 152 m at the CN Rail site.

2.3 Site 5 – Highway 400 Southbound, South of Sheppard Avenue

Appendix C contains a borehole location plan and records for selected boreholes (Boreholes 5, 6 and 8), which were advanced at Sheppard Avenue as part of a 1989 foundations investigation.

In all three boreholes, a surficial deposit of clayey silt to silty clay, containing sand seams, was encountered extending from ground surface (about Elevation 147.0 m) in Borehole 5 and below approximately 1.2 m of fill in Borehole 6. The base of this deposit was encountered at approximately Elevation 140 m in the two boreholes that fully penetrated the clayey silt. The surficial clayey silt to silty clay is generally stiff to very stiff, based on measured SPT “N” values of 13 to 27 blows per 0.3 m of penetration. However, measured SPT “N” values of 4 and 8 blows per 0.3 m of penetration were measured near the base of the deposit in Boreholes 5 and 8, respectively. An in situ vane shear test was carried out at about the same level in Borehole 6, and an undrained shear strength of greater than 100 kPa was measured. One Atterberg limits test was carried out on a sample of this material, and the plastic limit was 19 per cent, the liquid limit 39 per cent, and the plasticity index 20 per cent.

Below about Elevation 140 m, Boreholes 5 and 6 encountered a glacial till deposit consisting of a “heterogeneous mixture of clayey silt, sand and gravel”. The upper approximately 2 m to 3 m of this deposit is stiff to very stiff, based on measured SPT “N” values of about 12 and 15 blows per 0.3 m of penetration. Below about Elevation 137 m, the glacial till is hard, based on measured SPT “N” values of 41 to greater than 100 blows per 0.3 m of penetration.

2.4 Site 6 – Highway 401 Westbound Collector, West of Keele Street

Appendix D contains a borehole location plan and the record for Borehole 1, which was advanced as part of a 1964 investigation in the southwest quadrant of the Highway 401 – Keele Street interchange.

Borehole 1 (as well as the other boreholes in this area) encountered a deposit of clayey silt containing some sand and trace gravel, extending from ground surface to a depth of about 10 m. This deposit is interpreted to be a glacial till, based on the relative proportions of material types indicated on the borehole record, the relatively hard consistency as indicated by the SPT “N” values, and the geological history of the area. An SPT “N” value of 11 blows per 0.3 m of penetration was measured in the upper 2 m of the glacial till encountered in Borehole 1, indicating that the upper portion of the deposit is stiff. Below this, the deposit is very stiff to hard, based on SPT “N” values ranging from 20 to 46 blows per 0.3 m of penetration. Atterberg limits testing conducted on four samples from Borehole 1 measured plastic limits of 11 to 19 per cent, liquid limits of 20 to 29 per cent, and plasticity indices of about 9 to 10 per cent; these results indicate that the clayey silt is of low plasticity.

It is noted that a boulder is recorded on the log for Borehole 1; an SPT “N” value of 115 blows per 0.3 m of penetration is interpreted to be due to the presence of the boulder at this depth, and not to the consistency of the till material itself.

2.5 Site 7 – Highway 401 Westbound Express, East of Keele Street

Appendix E contains a borehole location plan and the records for Boreholes 1 and 2, which were advanced as part of a 1963 investigation for the Keele Street underpass structure.

Boreholes 1 and 2 encountered a deposit of glacial till extending from about Elevation 178.5 m to the maximum investigated depth of about 16 m. The glacial till consists of clayey silt containing some sand and gravel. The deposit is very stiff to hard, based on measured SPT “N” values ranging from 25 to 56 blows per 0.3 m of penetration. Atterberg limits testing conducted on ten samples from these boreholes measured plastic limits of about 11 to 15 per cent, liquid limits of about 15 to 27 per cent, and plasticity indices of about 5 to 12 per cent; these results indicate that the clayey silt till is of low plasticity.

The water level was encountered in Boreholes 1 and 2 at Elevations 169.4 m and 168.3 m, respectively.

2.6 Site 8 – Highway 401 Eastbound Express, West of Dufferin Street

Appendix F contains a borehole location plan and the records for a selected borehole (Borehole 4A) that was advanced in the vicinity of the proposed CMS location at this site as part of a 1963 investigation for the Dufferin Street bridges.

Borehole 4A encountered a glacial till deposit extending from about Elevation 191 m to Elevation 178.8 m. The glacial till consists of clayey silt to silty clay, containing trace sand and gravel. The till is very stiff to hard, based on measured SPT “N” values ranging from 23 to 62 blows per

0.3 m of penetration. A deposit of very dense silt / hard clayey silt was encountered below the glacial till, below about Elevation 178.8 m. The measured SPT “N” values in this deposit were greater than 100 blows per 0.3 m of penetration.

The water level was encountered in the borehole at about Elevation 187.6 m.

2.7 Sites 9 and 10 – Allen Road Northbound, and Allen Road S-W Ramp

Appendix G contains a borehole location plan and the records of selected boreholes (Boreholes 113, 115 and 116) that were advanced in the vicinity of the proposed CMS signs at these sites as part of a 1962 investigation for the Highway 401 – Allen Road interchange structures. Borehole 115 is located approximately at the proposed CMS location on the S-W Ramp, and Boreholes 113 and 116 are located at the Ranee Street structure that is approximately 20 m north of the proposed CMS on northbound Allen Road.

At CMS Site 9 on the S-W Ramp, Borehole 115 encountered a “silty till” extending from ground surface (at about Elevation 189.3 m) down to about Elevation 181.6 m. This till deposit has a dense to very dense relative density, based on measured SPT “N” values of 32 to greater than 100 blows per 0.3 m of penetration. Below Elevation 181.6 m, a deposit of stratified sand and silt was encountered; this deposit is very dense, based on measured SPT “N” values greater than 100 blows per 0.3 m of penetration. This borehole was dry two days following completion of drilling.

At CMS Site 10, Boreholes 113 and 116 encountered a “silty till” extending from ground surface (at about Elevation 187.5 m) to the maximum depth of investigation, at about Elevation 170.8 m. The till deposit has a compact to very dense relative density, based on measured SPT “N” values of 16 to greater than 100 blows; however, the SPT “N” values are typically in the range of about 30 to 60 blows per 0.3 m of penetration, indicative of a generally dense to very dense relative density. Both of these boreholes were dry following completion.

2.8 Site “New” – Highway 400 Northbound, South of Finch Avenue

Appendix H contains a borehole location plan and records for selected boreholes (Boreholes 11 and 12), which were advanced at Finch Avenue as part of a 1965 foundations investigation.

Boreholes 11 and 12 encountered glacial till from ground surface (about Elevations 171.1 m and 168.0 m, respectively) to about 10 m depth. The glacial till consists of “a heterogeneous mixture of clayey silt, sand and gravel”. SPT “N” values of 10 to 20 blows per 0.3 m of penetration were measured in the upper 1.5 m to 2 m of the deposit, and this portion of the glacial till has a stiff to very stiff consistency. Below 1.5 m to 2 m depth, the glacial till is generally hard, based on measured SPT “N” values of 34 to greater than 100 blows per 0.3 m of penetration; however, an SPT “N” value of 18 blows per 0.3 m of penetration was measured on one sample, at about 4 m

depth in one of the boreholes, indicating that a very stiff zone is present within the hard clayey silt till. Atterberg limits testing carried out on several samples of the till measured plastic limits of about 14 to 21 per cent (but typically 14 to 17 per cent), liquid limits of about 21 to 30 per cent, and plasticity indices of about 7 to 13 per cent.

The water level in these two boreholes was encountered between Elevations 165 m and 166.5 m following completion of drilling.

3.0 GEOTECHNICAL DESIGN RECOMMENDATIONS

3.1 General

This section provides recommendations for the geotechnical design of the proposed CMS foundations, based on interpretation of the geotechnical information available from MTO'S GEOCREs system. It should be noted that the interpretation and recommendations are intended for use only by the design engineer. Where comments are made on construction, they are provided only in order to highlight those aspects of construction that could affect the design of the project. Contractors bidding on or undertaking work at the site should examine the factual data, satisfy themselves as to the adequacy of the information for construction, and make their own interpretation of the factual data as it affects their proposed construction techniques, schedule, equipment capabilities, costs, sequencing and the like.

The professional services for this assignment address only the geotechnical (physical) aspects of the subsurface conditions at the sign sites. The geo-environmental (chemical) aspects, including consequences of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources, are outside the terms of reference for this report and have been neither investigated nor addressed by Golder.

3.2 Caisson Foundation Design

Caisson foundations for overhead changeable message signs are typically designed in accordance with the standard design methods for Tri-Chord Static Sign Supports, contained in Section 4 and Standard Drawings SS118-3, SS118-4 and SS118-5 of MTO's *Sign Support Manual*. In the standard design, the caissons are extended 5 m below the design frost depth (i.e. a total length of 6.2 m below the ground surface). This standard design was developed based on the following minimum soil conditions:

- **Case 1 (Cohesionless 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 fill materials or materials softer than those of Case 2 are present. For such subsurface conditions, a site-specific design is required.

Based on the review of the available subsurface information, the subsurface soils at all but one of the proposed CMS sites have friction angles and/or undrained shear strengths that exceed the input parameters used in the modelling of the standard caisson foundations and, therefore, the standard caisson foundation design is suitable for these sites. The following table summarizes those sites for which the standard foundation design applies, and the site for which site-specific foundation design will be required.

<i>Site No.</i>	<i>Sign Location</i>	<i>Standard Foundation Design</i>	<i>Site-Specific Foundation Design</i>
1	Highway 401 Eastbound Express East of Dixon Road	✓	
2	Highway 409 Eastbound West of Kipling Avenue	✓	
5	Highway 400 Southbound South of Sheppard Avenue		✓
6	Highway 401 Westbound Collector West of Keele Street	✓	
7	Highway 401 Westbound Express East of Keele Street	✓	
8	Highway 401 Eastbound Express West of Dufferin Street	✓	
9	Allen Road Northbound South of Ranee Street	✓	
10	Allen Road S-W Ramp	✓	
New	Highway 400 Northbound South of Finch Avenue	✓	

For Site No. 5, where a site-specific foundation design is required, the unfactored passive lateral earth pressure, P_p , at any depth, d (in metres), along the caisson foundations may be calculated using the following equation, and the geotechnical design parameters given in the table on the following page:

$$P_p = K_p \gamma d \quad \text{above the groundwater table, and}$$

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

where K_p is the passive earth pressure coefficient;
 γ is the bulk unit weight (kN/m^3);
 γ' is the effective unit weight below the water level (kN/m^3);
 d is the depth below the ground surface (m); and
 d_w is the depth to the groundwater level.

The unfactored lateral resistance should be calculated assuming an equivalent pile width equal to three times the caisson diameter.

The undrained capacity of the caisson should also be checked to establish whether the drained or the undrained case will govern. For the undrained case, the capacity for the length of the caisson within the cohesive soils should be calculated assuming an unfactored passive lateral pressure distribution equivalent to twice the undrained shear strength (i.e. $P_p = 2 c_u$), also over an equivalent width of three times the caisson diameter.

A resistance factor of 0.5 should be applied to the lateral resistance as calculated from the above noted methods to obtain the factored lateral geotechnical resistance at ULS. The passive resistance in front of the caisson within the upper 1.2 m below ground surface should be neglected in the design of the foundations to account for frost action.

Based on the available geotechnical information, the following table provides a summary of the simplified subsurface stratigraphy and geotechnical design parameters that may be used in confirming the design of the proposed CMS at Site 5.

GEOTECHNICAL DESIGN PARAMETERS FOR CMS SITE 5

<i>Stratum</i>	<i>Depth (m)</i>	<i>Groundwater Depth</i>	<i>Design Parameters</i>				
			c_u	ϕ'	γ	γ'	K_p
Very stiff clayey silt to silty clay	0.0 – 3.0	1.0 m	100	28	20	10	2.8
Soft to firm clayey silt to silty clay	3.0 – 7.0		30	28	20	10	2.8
Stiff to very stiff clayey silt till	7.0 – 10.0		–	32	22	12	3.3
Hard clayey silt till	Below 10.0		–	35	22	12	3.7

NOTES:

c_u = undrained shear strength (kPa)
 ϕ' = effective friction angle (degrees)
 γ = bulk unit weight (kN/m^3)
 γ' = effective unit weight below the groundwater level (kN/m^3)
 K_p = passive earth pressure coefficient

3.3 Caisson Installation Considerations

The installation of CMS foundations at this site will require caissons to be extended through surficial fill materials and glacial till deposits. The foundation contractor should include provision for encountering and removing obstructions such as rubble and debris materials within the fill, and cobbles and/or boulders within the glacial till.

The majority of the CMS foundations will be installed in glacial till, which will generally behave as a cohesive material. However, lenses or interlayers of cohesionless soil should be anticipated within the glacial till (as have been encountered at CMS Site 9, for example), and “perched” groundwater should be anticipated at the base of any cohesionless fill materials atop the glacial till. Where cohesionless interlayers are encountered below the water level, and where “perched” groundwater is encountered atop the glacial till, the cohesionless soils should be expected to flow into unsupported auger holes. Where such zones of saturated cohesionless soil are encountered during caisson installation, a temporary liner will be required to prevent groundwater seepage and loss of ground into the auger hole.

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