FOUNDATION INVESTIGATION AND DESIGN REPORT

FRENCH LINE ROAD OVERPASS EMBANKMENTS

HIGHWAY 401 RECONSTRUCTION

GWP 63-00-00, AGREEMENT NO. 3004-E-0006

MINISTRY OF TRANSPORTATION - SOUTHWESTERN REGION

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PART A

FOUNDATION INVESTIGATION REPORT

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introduction

Golder Associates Ltd. (Golder Associates) has been retained by Dillon Consulting Limited on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundations engineering services as part of the detail design work for the section of Highway 401 described by GWP 63-00-00. This section of Highway 401 is some 9.9 kilometres in length and extends from 2.5 kilometres east of Essex Road 27 easterly to 1.2 kilometres west of Highway 77 in the Township of Lakeshore, County of Essex, Ontario.

The purpose of this portion of the foundation investigation was to determine the subsurface conditions for the grade raise and widening of the Highway 401 - French Line Road overpass embankments by drilling boreholes, carrying out in-situ tests and laboratory tests on selected samples. The terms of reference for the scope of work are outlined in the MTO's request for proposal, Golder Associates proposal P41-3106, dated December 24, 2004 and letter dated June 27, 2005. The work was carried out in accordance with our Quality Control Plan for Foundation Engineering Detail Design Services dated March 9, 2005.

site description

General

GWP 63-00-00 comprises the reconstruction and widening of some 9.9 kilometres of Highway 401 extending from 2.5 kilometres east of Essex Road 27 in the Township of Rochester easterly to 1.2 kilometres west of Highway 77 in the Township of Tilbury West, County of Essex, Ontario. The location of the project is shown on the Key Plan, Figure 1. The project chainage extends from Highway 401 Station 13+000, Township of Rochester to Station 12+700, Township of Tilbury West.

This report addresses the subsurface conditions for the grade raise and widening of the French Line Road overpass embankments. The location of the overpass is shown on the Key Plan, Figure 1.

This section of Highway 401 is currently a four lane divided freeway with a depressed grass median. In each direction, two 3.35 metre wide lanes with 3.58 metre outer shoulders and 4.57 metre wide inner shoulders are present. French Line Road within the project limits is a two lane roadway. The existing French Line Road/Highway 401 interchange consists of four ramps, one in each of the four quadrants.

The topography in the area of the site is generally flat with the existing embankment fills at the French Line overpass rising as much as 6 metres above the general level of the adjacent lands. The existing embankment side slopes are typically at inclinations of 2.3 to 2.8 horizontal to one vertical. The areas outside of the paved surfaces are well vegetated with grasses. The primary land use in the area is agricultural with some residential areas along French Line Road.

Site Geology

The project lies within the Essex Clay Plain, a subregion of the physiographic region of southern Ontario known as the St. Clair Clay Plains, identified in “The Physiography of Southern Ontario” by Chapman and Putnam (1984). The clay plain is described as a till plain that has been smoothed by shallow deposits of lacustrine clay which settled in the depressions of the till. The prevailing soil type is reportedly the Brookston clay.

Based on the Ontario Department of Mines and Northern Affairs Preliminary Maps P.749 and P.750 entitled “Quaternary Geology of the Windsor-Essex Area” Western and Eastern Parts, respectively, the project area is reportedly located in predominantly clayey silt till.

Based on the available bedrock geology mapping, the subcropping bedrock consists of limestone of the Dundee formation of Middle Devonian age.

investigation procedures

The field work for this investigation was carried out between July 27 and 28, 2005 at which time six boreholes were drilled at the locations indicated on Drawing 1.

The as-drilled borehole locations, ground surface elevations and borehole depths are as follows:

BOREHOLE	LOCATIONS (m) Northing	Easting	GROUND SURFACE ELEVATION (m)	BOREHOLE DEPTH (m)
101	4677046.0	293548.0	182.53	8.08
102	4677114.0	293412.0	182.43	8.08
103	4677072.0	293364.0	188.11	14.17
104	4677067.0	293459.0	188.78	9.60
105	4677065.0	293493.0	188.78	9.60
106	4677086.0	293603.0	188.01	14.17

The soil stratigraphy encountered in the boreholes is shown on the attached Record of Borehole sheets and on Drawing 1.

The boreholes were advanced using an all terrain vehicle mounted power auger supplied and operated by a specialist drilling contractor. Samples of the overburden were obtained at suitable intervals of depth using 50 millimetre outside diameter split spoon sampling equipment in accordance with the standard penetration test (SPT) procedures. In addition, dynamic cone penetration testing was carried out adjacent to borehole 105. In situ vane testing was carried out, where feasible, within the cohesive strata. Groundwater conditions were observed in the boreholes throughout the drilling operations. All of the boreholes were backfilled in accordance with current regulations and MTO recommended procedures.

The field work was supervised on a full-time basis by experienced members of our engineering staff who arranged for underground utility locates, directed the drilling, sampling and in situ testing operations, logged the boreholes and cared for the samples obtained. The soil samples were identified in the field, placed in labeled containers and transported to Golder Associates' London laboratory for further examination and routine testing. Index and classification tests consisting of water content determinations, grain size distribution analyses and Atterberg limits determinations were carried out on selected samples. The results of the field and laboratory testing are given on the Record of Borehole sheets and in Appendix A.

Temporary traffic control was provided by a specialist contractor in accordance with the Ontario Traffic Manual, Book 7, dated March 2001.

In addition, the results from boreholes 87-1 and 87-6 from Report No. 01TF073G by Peto MacCallum Ltd. entitled "Foundation Investigation and Design Report for St. Joachim Road Overpass, G.W.P. 60-00-00, Site 6-87, Highway 401, Town of Lakeshore, Ontario", dated November 2002, MTO Geocres No. 4052-53 have been included and the Record of Boreholes are attached in Appendix B.

The locations of the boreholes are indicated on the Record of Borehole sheets and are shown on Drawing 1, attached.

subsurface conditions

Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of the in situ and laboratory testing are provided on the attached Record of Borehole sheets following the text of this report and in Appendix A. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling and observations of drilling resistance and may represent transitions between soil types rather than exact planes of geological change. Further, the subsurface conditions may vary significantly between and beyond the borehole locations.

In summary, the boreholes drilled for the Highway 401 French Line Road overpass embankments grade raise and widening encountered topsoil and fill materials overlying silty clay till.

A detailed description of the subsurface conditions encountered in the boreholes is provided on the Record of Borehole sheets and is summarized in the following sections.

Topsoil and Fill Materials

Topsoil was encountered at ground surface in boreholes 101, 102, 87-1 and 87-6. The topsoil was 0.1 to 0.3 metres thick at the borehole locations.

The French Line Road pavement structure was encountered in boreholes 103 to 106, inclusive. The pavement structure consisted of 90 to 200 millimetres of asphalt and 210 to 250 millimetres of granular base. Beneath the granular base in boreholes 104 and 105, 560 to 790 millimetres of granular subbase was present.

Beneath the pavement structure, boreholes 103 to 106 encountered the embankment fill materials. The fill materials consisted primarily of silty clay with occasional clayey silt layers. However, some 3.7 metres of sand fill was encountered in borehole 105. The fill was 4.7 to 5.2 metres thick at the other borehole locations. The granular fill materials were loose with N values, as determined in the standard penetration testing, of 4 to 7 blows per 0.3 metres. The clayey fill materials had N values of generally 8 to 22 blows per 0.3 metres. In borehole 103, a driving resistance of 50 blows for 150 millimetres penetration was recorded at the surface of the clayey fill, on an obstruction. The clayey fill had in situ water contents of 4 to 28 per cent with an average water content of about 16 per cent. The clayey fill materials had corresponding average plastic and liquid limits of 19 and 41 per cent, respectively, based on three Atterberg limits determinations. The Atterberg limits data are provided on the Plasticity Chart, Figure A-5 and indicate an inorganic clay of low to intermediate plasticity.

Grain size distribution curves for samples of the granular and cohesive fill materials recovered from the standard penetration testing are provided on Figures A-1 and A-2, respectively.

Silty Clay Till

Beneath the surficial topsoil or fill materials, all of the boreholes encountered and were terminated in firm to hard silty clay till. The silty clay till was explored for 3.1 to 9.0 metres prior to terminating the boreholes. Boreholes put down for the bridge foundations indicates that the silty clay till is underlain by limestone bedrock at about elevation 150 metres, about 32 metres below original ground level. The silty clay till had N values of 6 to 42 blows per 0.3 metres. In situ vane testing carried out in the boreholes indicated undrained shear strengths of 114 to greater than 144 kilopascals (kPa) with vane sensitivities of about 2. The silty clay till samples recovered during the current investigation had natural water contents of 13 to 27 per cent with an average water content of about 20 per cent and corresponding average plastic and liquid limits of 18 and 35 per cent, respectively, based on seven Atterberg limits determinations. The Atterberg limits data are provided on the Plasticity Chart, Figure A-5 and indicate an inorganic clay of low to intermediate plasticity.

Grain size distribution curves for samples of the silty clay till are provided on Figures A-3 and A-4.

Groundwater Conditions

Groundwater conditions were observed in the boreholes during drilling. Groundwater was encountered in borehole 101 about 3.9 metres below ground surface or at elevation 178.6 metres during drilling on July 27, 2005. The remainder of the boreholes were dry during drilling. This information is summarized below:

BOREHOLE	GROUND SURFACE ELEVATION (m)	ENCOUNTERED GROUNDWATER ELEVATION (m)
101	182.53	178.6
102	182.43	Dry
103	188.11	Dry
104	188.78	Dry
105	188.78	Dry
106	188.01	Dry
87-1	182.39	Dry
87-6	182.15	Dry

MISCELLANEOUS

This investigation was carried out using equipment supplied and operated by Lantech Drilling Services Inc., an Ontario Ministry of Environment licensed well contractor. The field operations were supervised by Mr. Michael Arthur and Mr. Dan Babcock under the direction of Mr. David J. Mitchell. The laboratory testing was carried out at Golder Associates' London laboratory under the direction of Mr. Chris M. Sewell. The laboratory is an accredited participant in the MTO Soil and Aggregate Proficiency Program and is certified by the Canadian Council of Independent Laboratories for testing Types C and D aggregates. This report was prepared by Mr. Michael E. Beadle, P. Eng. under the direction of the Project Manager, Mr. Philip R. Bedell, P. Eng. This report was reviewed by Mr. Fintan J. Heffernan, P. Eng., the Designated MTO Contact and Quality Control Auditor for this assignment.

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PART B

FOUNDATION DESIGN REPORT

FRENCH LINE ROAD OVERPASS EMBANKMENTS

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engineering recommendations

General

This section of the report provides our recommendations on the foundation aspects of the design of the proposed grade raise and widening of the existing French Line Road overpass embankments. The recommendations are based on our interpretation of the factual information obtained during the investigation. 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 which could affect the design of the project. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

Overpass Embankment Grade Raise and Widening

Highway 401 will also be widened as part of this project. The widening will facilitate three lanes of Highway 401 traffic in each direction. The lane configurations will consist of 3.75 metre wide outer and centre lanes, a 3.5 metre wide median lane and 3.0 metre wide outer and median shoulders in each direction. The total finished crest widths will be about 36 metres. In addition, the existing overpass structure is to be reconstructed and the clear span lengthened from 12 to 31 metres.

Based on the information provided, it is understood that the existing French Line Road overpass approach embankments will be raised as much as 2 metres between Station 16+240 and Station 17+200. The existing embankments are as much as 6 metres above the general level of the adjacent lands with side slope inclinations of 2.3 to 2.8 horizontal to 1 vertical. The crests of the existing embankments are about 31 metres wide.

Based on the subsurface conditions encountered in the boreholes, typically firm to very stiff clayey fill materials are present within the existing embankment. Beneath the fill, an extensive stratum of firm to hard silty clay till is present.

Settlement

Based on the information provided, an approximately 2 metre high grade raise and 6 metre widenings of the existing approach embankments are proposed together with the overpass structure replacement. Settlement analyses were carried out for the approach embankments based on the borehole and in-situ vane shear strength data obtained during the investigation and the proposed modifications. In addition, the results of oedometer testing carried out on samples

obtained from other components of the project were considered. The following parameters were used in the analysis:

SOIL UNIT	RECOMPRESSION INDEX, C_r (over consolidated crust)	COMPRESSION INDEX, C_c' (normally consolidated zone)	INITIAL VOID RATIO, e_o
Silty Clay Till	0.06	0.23	0.63

The embankment fill loads were modeled both as a rectangular wedge having the dimensions of the existing and proposed fill as well as an infinitely long embankment. Based on the results of the analyses, it is considered that no discernable settlements will occur within 15 metres of the new abutments because of the unloading effect of removing fill due to the lengthened bridge. Beyond this point, it is estimated that as much as 250 millimetres of total settlement of the completed embankments will occur at about 25 to 50 metres behind the new abutments. Further, it is estimated that 50 per cent of this settlement will occur in the first year and that 90 per cent of this settlement will have taken place after about 5 years. These settlements may require periodic padding of the approach embankments.

Alternatively, if lightweight fill were utilized for the embankment and widening, the total settlements could be reduced to about 100 to 140 millimetres depending on the configuration and nature of the lightweight fill.

Stability

Stability analyses were carried out for completed embankments. The analyses considered the effects of the loads applied at the top of the bank together with the interaction between the stiffer crust and the underlying softer silty clay soils as well as variations in the subsurface conditions at the various borehole locations. Based on the results of the analyses, embankments constructed with side slopes inclined at 2 horizontal to 1 vertical or flatter have a factor of safety of greater than 1.3.

Subgrade Preparation and Embankment Construction

All surficial topsoil, fill, and otherwise deleterious materials should be stripped from the area of the embankment widening. The exposed subgrade should then be proofrolled prior to fill

placement under the direction of qualified geotechnical personnel. In addition, all surficial topsoil and deleterious fill materials should be removed from the existing embankment slope.

The embankment widening should be constructed using Granular B, Type I, an approved granular borrow such as Select Subgrade Material (SSM) or approved earth borrow. The purpose for considering granular fill materials is to provide a material that is capable of providing enhanced drainage for the existing embankment due to the presence of pockets and layers of sandy fill materials, particularly at the location of borehole 105. Should a less permeable material be utilized, pore pressure may elevate behind the widened portion, which could potentially adversely impact embankment stability unless proper drainage is provided.

The embankment fill material should be placed in maximum 300 millimetre thick loose lifts properly benching into the existing embankment as per Ontario Provincial Standard Drawing (OPSD) 208.010 and compacted. Upon completion of filling to proposed subgrade level, the embankment side slopes should be trimmed to a final inclination of two horizontal to one vertical or flatter. Two metre wide benches should be provided at mid height whenever the embankment height exceeds 8 metres.

Excavations and Temporary Cut Slopes

The temporary excavation support system(s), should be designed and constructed in accordance with MTO's Special Provision 539S01. The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in SP 539S01. It should be noted that the embankment fill materials are variable consisting of both cohesive and granular materials and that additional granular fill materials may be encountered adjacent to the existing bridge abutments.

The support systems may be designed using the following parameters:

SOIL TYPE	COEFFICIENT OF EARTH PRESSURE			INTERNAL ANGLE OF FRICTION (degrees)	UNIT WEIGHT (Mg/m^3)
	Active, K_a	At Rest, K_o	Passive, K_p		
Clayey Fill	0.41	0.58	2.5	25	2.0
Granular Fill	0.38	0.55	2.7	27	2.1
Silty Clay Till	0.33	0.50	3.0	30	2.0

All excavations should be carried out in accordance with the guidelines outlined in the latest edition of the Ontario Occupational Health and Safety Act and Regulations For Construction Projects. The fill materials at this site would be classified as Type 3 soils and the underlying native cohesive soils deposits would be classified as Type 2 soils.

miscellaneous

This report was prepared by Mr. Michael E. Beadle, P.Eng. under the direction of the Project Manager, Mr. Philip R. Bedell, P.Eng. This report was reviewed by Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment.

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APPENDIX A

LABORATORY TEST DATA (FIGURES A-1 TO A-5)

APPENDIX B

RECORD OF BOREHOLES

FROM PETO MACCALLUM LTD. REPORT NO. 01TF073G

DATED NOVEMBER 2002