Amico Design Build

Geotechnical Investigation

Project Name
Proposed Apartment Building
200 Park Street West, Windsor, Ontario

Project Number
LON-00016839-BS

Prepared By:
exp Services Inc.
2199 Blackacre Drive, Unit 600
Windsor, Ontario N0R 1L0

Date Submitted
March 11, 2019

Amico Design Build

Geotechnical Investigation

Project Name:
Proposed Apartment Building
200 Park Street West, Windsor, Ontario

Project Number:
LON-00016839-BS

Prepared By:
exp
2199 Blackacre Drive, Unit 600
Windsor, Ontario N0R 1L0
Canada
T: 519-737-0588
F: 519-737-0751
www.exp.com

Brent Gusba, P. Eng., PMP
Geotechnical Engineer

Botel M. F. Chiu, M. Eng., P.Eng.
Regional Manager, Earth & Environment, Southwestern Ontario

Date Submitted:
March 11, 2019

Legal Notification

This report was prepared by EXP Services Inc. for the exclusive use of **Amico Design Build** and may not be reproduced in whole or in part, or used or relied upon in whole or in part by any party other than **Amico Design Build** for any purpose whatsoever without the express permission of **Amico Design Build** in writing.

Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. EXP Services Inc. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this project.

Table of Contents

1. Introduction

EXP Services Inc. (EXP) was retained by Amico Design Build to conduct a Geotechnical Investigation for the proposed apartment building to be constructed at 200 Park Street West, in the City of Windsor, Ontario. Authorization for EXP to proceed with the Geotechnical investigation was given by Amico Design Build via Purchase Order AD1807. In preparing this report, information provided by the client has been utilized.

1.1 Project Description

The owner of the property plans to construct an apartment building in the downtown area of the City of Windsor. It is understood that the building will be comprised of one level of underground parking, two levels of above ground parking and 11 storeys of living space.

The site is currently an asphalt surfaced parking lot situated on the north-west corner of Park Street West and Victoria Avenue. It is understood that the building footprint will be approximately 1800 square metres.

1.2 Terms of Reference

The purpose of the investigation was to examine the subsoil and groundwater conditions at the site by advancing two boreholes in the proposed footprint of the building.

The investigation was carried out in general accordance with our proposal P18-081, dated June 8, 2018 and authorization was provided by Amico Design Build on January 11, 2019.

The objective of the Geotechnical Report is to summarize the results of the investigation and provide geotechnical engineering guidelines to assist with the design and construction of the proposed work. More specifically, this report provides comments on excavation, groundwater control, foundations, seismic design, backfilling and pavement design.

This report is provided on the basis of the Terms of Reference presented above and with the assumption that the design will be in accordance with applicable codes and standards. If there are any changes in the design features relevant to the geotechnical analyses, or if any questions arise concerning the geotechnical aspects of the codes and standards, this office should be contacted to review the design.

Reference is made to **Appendix C** of this report, which contains further information necessary for the proper interpretation and use of this report.

2. Methodology

The fieldwork was conducted on February 11, 14 and 15, 2019 and consisted of advancing two (2) boreholes at the approximate locations shown on **Drawing 1**. The boreholes are designated as BH 1 and BH 2.

The boreholes were advanced using a locally subcontracted truck-mounted drilling unit equipped with continuous flight hollow stem augers, soil sampling and soil testing equipment. Borehole 1 was terminated at a depth of about 31 metres (m) below grade and BH 2 was terminated at about 15.7 m below grade.

Within the boreholes, Standard Penetration Tests (SPTs) were performed to assess the compactness or consistency of the underlying soils and to obtain representative samples. During the drilling, the soil samples obtained from the boreholes were examined and logged in the field by EXP geotechnical personnel.

Soil stratigraphy and observations pertaining to groundwater conditions in the boreholes are recorded in the borehole logs found in **Appendix A**. A temporary monitoring well for measuring groundwater levels was installed in BH 2. Upon completion of the drilling program, the monitoring well was removed and the boreholes were backfilled with the excavated materials and bentonite, to satisfy the requirements of Ontario Regulation 903.

Representative samples of the various soil strata encountered at the borehole locations were taken to our laboratory in Windsor for further examination by a geotechnical engineer. Laboratory testing for this investigation comprised of routine moisture content determinations, grain size distribution analyses and Atterberg limit testing. The laboratory results are presented on the borehole logs found in **Appendix A** and on **Figures 1 and 2** of **Appendix B**.

Samples remaining after the laboratory testing will be stored for a period of three months following the issuance of the report. After this time, they will be discarded unless prior arrangements have been made for longer storage.

3. Subsurface Conditions

3.1 Site Description

The site is located at 200 Park Street West in the City of Windsor, Ontario. The site is in the downtown area of the city and is currently an asphalt parking lot with buildings to the north and west of the property. The topography of the site is relatively flat.

3.2 Soil Stratigraphy

The detailed stratigraphy encountered in each borehole and the results of routine laboratory tests carried out on representative samples of the subsoils are presented on the borehole logs found in **Appendix A**. It must be noted that boundaries of soil indicated on the logs are inferred from non-continuous sampling and observations during drilling. These boundaries are intended to reflect transition zones for the purposes of geotechnical design and should not be interpreted as exact planes of geological change.

The pavement structure and subsurface soil conditions encountered in the boreholes are summarized as follows.

3.2.1 Pavement Structure and Fill Material

Each of the boreholes was advanced through the existing parking lot. About 100 and 200 millimetres (mm) of asphalt was encountered at BH 1 and BH 2, respectively. Below the asphalt in BH 2, about 100 mm of concrete was encountered.

Beneath the asphalt in BH 1, clayey silt fill was encountered. The thickness of the fill material was about 460 mm at the borehole location. The moisture content of a sample of the clayey silt fill material obtained was about 17 percent.

Underlying the concrete in BH 2, silty sand and gravel fill material was encountered to a depth of about 760 mm. The moisture content of a sample of the silty sand and gravel obtained was about 11 percent.

3.2.2 Silty Clay Till

Beneath the fill materials, an extensive deposit of silty clay till was encountered in the boreholes. The upper portion of the silty clay till had a mottled brown and grey colouration and was firm in consistency. Measured ‘N’ values obtained from standard penetration testing carried out in the mottled silty clay till ranged from 5 to 8 blows per 0.3 m. The moisture content of the samples of mottled silty clay till obtained varied from about 19 to 28 percent.

Underlying the mottled silty clay till, very stiff brown silty clay till was encountered. The brown silty clay till ranged in thickness from about 770 to 920 mm at the borehole locations. Two SPT ‘N’ values obtained in the brown cohesive material were 22 and 26 blows per 0.3 m. The moisture contents of the samples obtained were about 14 percent.

Beneath the brown silty clay till, very soft to stiff, grey silty clay till was encountered to a depth of about 30 m in BH 1 and to the termination depth of BH 2. Measured 'N' values obtained in the grey silty clay till ranged from 0 (weight of hammer) to 12 blows per 0.3 m. The moisture content of the samples of grey silty clay till obtained varied from about 12 to 23 percent. The results of grain size distribution analyses and Atterberg limit testing carried out on two samples of the grey silty clay till obtained from BH 1 are presented in **Figures 1 and 2**.

3.2.3 Sand

Within the deposit of grey silty clay till in BH 1, a zone of silty sand was encountered at a depth of about 3.7 m. The thickness of the silty sand was about 760 mm at the borehole location. A more extensive zone of silty sand was encountered in BH 2 at a depth of about 9.5 m. The thickness of the silty sand in BH 2 was about 2.1 m. Measured 'N' values obtained in the silty sand ranged from 9 to 19 blows per 0.3 m. The moisture content of the samples obtained varied from about 11 to 14 percent.

Underlying the grey silty clay till in BH 1, dense grey sand was encountered to the termination depth of the borehole. The sand had a gradation of fine to medium. A single SPT 'N' value obtained in the sand was 34 blows per 0.3 m and a moisture content of a sample of the sand obtained was about 19 percent.

Dynamic cone penetration testing was carried out beyond the sampling depth of BH 1 to a depth of about 37.9 m where practical refusal (presumed bedrock) was encountered. The dynamic cone penetration test values ranged from 90 to 330 blows per 0.3 m.

3.3 Groundwater

During drilling, groundwater seepage was encountered in BH 1 at the interface of the grey silty clay till and the fine to medium sand at a depth of about 30 m. In BH 2, a temporary well was installed to measure groundwater levels. On February 15, the groundwater level in the well was measured at a depth of about 2.0 m.

It is noted that the depth to the actual groundwater table may vary in response to climatic or seasonal conditions, and, as such, may differ at the time of construction, with higher levels occurring in the wet seasons.

4. Discussion and Recommendations

4.1 General

As indicated previously, the owner of the property plans to construct an apartment building in the downtown area of the City of Windsor. It is understood that the building will be comprised of one level of underground parking, two levels of above ground parking and 11 storeys of living space.

The site is currently an asphalt surfaced parking lot situated on the north-west corner of Park Street West and Victoria Avenue. It is understood that the building footprint will be approximately 1800 square metres.

The following sections of this report provide discussion and recommendations on the geotechnical aspects of the project including excavations, groundwater control, foundations, seismic design, backfilling and pavement design.

4.2 Excavations

As part of the site preparation work, the site pavements should be removed to expose the underlying granular / subgrade materials. Any existing site servicing and utility services which encroach within the proposed building location should also be removed and/or re-routed.

All excavation works must comply with the Occupational Health and Safety Act (OHSA) and Regulations for Construction Projects. The subsurface soils encountered above the anticipated founding level (approximately 4 m depth) at the site may be classified as 'Type 3' soils according to the Act.

It is understood that the building will include one level of underground parking with two levels of parking above grade. It is presumed that a raft slab foundation is being considered for the construction of the building and that the raft slab will be founded at approximately 4 m below the existing grade.

The site is bounded by existing buildings on the north and west sides, and roadways on the south and east sides. Based on the site constrictions and proposed depth of excavation, conventional open cut excavations may not be possible. Braced and sheeted excavations may need to be constructed at the building site. Various options can be considered and are discussed as follows.

4.2.1 Sheet Pile Walls

Prior to excavation, sheet pile walls comprised of steel interlocking sheets may be driven into the silty clay till materials. Some difficulty driving the sheets into the silty clay till may be encountered as the sheets approach a depth of about 2 m (and below that level) due to the material having a very stiff consistency. This aspect should be reviewed by the specialist piling contractor.

Bracing of the steel sheeting will be required in the form of wales and cross members and/or wales and rakers. Design of the bracing system should be carried out by an experienced professional engineer employed by the contractor.

4.2.2 Soldier Piles and Lagging

A soldier pile and timber lagging system may also be considered for the site. The bracing system would utilize steel H-piles (soldier piles) driven to a sufficient depth below the base of the excavation and timber lagging installed between the soldier piles. As noted above, hard driving conditions should be anticipated through the silty clay till soils.

Similar to the sheet pile wall method, cross bracing and/or rakers will be used to brace the walls.

For the sheet pile and soldier pile installations, significant vibrations from the driving of the steel piles may be imparted on the adjacent structures if difficult driving conditions are encountered. For this reason, a program of continuous vibration monitoring should be carried out during production piling. Pre-augering may be carried out to reduce vibration and to facilitate the installation of the soldier piles.

4.2.3 Secant Piles

In order to eliminate the potential for vibration during wall construction, secant piles may be considered as an alternative to conventional shoring methods. Secant piles typically employ a system of interlocking deep augered caissons to effectively build a monolithic wall around the excavation.

Construction usually consists of a guide template at the surface to ensure that the augering (construction of the caisson) is kept vertically plumb. The secant wall includes the construction of primary and secondary caissons. The primary caissons are drilled first, leaving a space in between them. These caissons are then filled with concrete and allowed to cure for a short period of time. Following this, the secondary caissons are drilled between the primary caissons in such a way that some of the adjacent concrete is removed during augering in order to achieve an overlapping effect, creating the monolithic structure. The secondary caissons are typically reinforced.

Again, cross bracing and/or rakers may be utilized to brace the walls as the excavation extends downwards.

4.2.4 Soil Parameters

Following installation of the walls, excavation for the structure may begin. As excavation proceeds, the installation of the wales and cross members (or rakers once the design level is achieved) may be carried out. The following unfactored soil parameters may be used for geotechnical design of the braced and sheeted excavation.

Soil	***φ***	***γ (kN/m³)***	K_a	K_o	K_p
Fill Materials	26	18.5	0.39	0.56	2.56
Silty Sand	30	21.0	0.33	0.50	3.0
Silty Clay Till	28	21.0	0.36	0.53	2.77

These values are provided from a preliminary standpoint. Site review by a geotechnical engineer to review the applicable soil conditions is required to verify that the values provided above are applicable to specific site conditions.

The specialist shoring contractor should review the geotechnical information provided in this report and make their own assessment of the shoring design requirements based on their knowledge of the local conditions/geology. The shoring system must be designed to not only resist the lateral earth pressures, but to also resist any hydrostatic pressures behind the wall.

4.2.5 General Considerations

Although not encountered during the drilling program, the local silty clay till soil is known to contain localized cobbles and/or boulders which may influence the progress of excavation and construction.

Care must be taken not to undermine the foundations of the existing buildings adjacent to the proposed excavation. This aspect must be considered in the design of the bracing system. To monitor potential movements, strategically placed settlement points could be set into the existing structures. These points could then be monitored by a qualified survey crew to record any movements that take place. EXP can assist with developing a settlement monitoring program for this site if required.

Once excavation is completed to the base elevation, a working slab (mud-mat) should be placed to protect the integrity of the silty clay till. The working slab should be at least 100 mm in thickness with a specified strength of 10 MPa.

4.3 Groundwater Control

The site soils are comprised of relatively low to medium permeability deposits. Although the sheeted excavation will essentially cut-off the flow of groundwater, the contractor should be prepared to install a series of sump pumps at the site.

Sump pumping techniques can be used, provided the sump pits are lined with a suitable geotextile filter fabric and the pump inlet is set in a clear stone material. Use of an unfiltered system may result in the migration of silt and sandy soil particles, thereby causing loosening of the surrounding soil deposits from their existing state of compactness, resulting in ground surface settlements.

Any collected water should be discharged a sufficient distance away from the excavated area to prevent the discharged water from returning to the excavation. Sediment control measures should be provided at the discharge point of the dewatering system. Care should also be taken to avoid any adverse impacts to the environment.

Although not anticipated for this site, it is important to mention that for any projects requiring positive groundwater control with a removal rate in excess of 50,000 litres per day, a Permit to Take Water (PTTW) will be required. PTTW applications will need to be approved by the Ministry of Environment according to Sections 34 and 98 of the Ontario Water Resources Act R.S.O. 1990 and the Water Taking and Transfer Regulation (O. Reg. 387/04). It is noted that a standard geotechnical investigation will not determine all the groundwater parameters which may be required to support the application. Accordingly, a detailed hydrogeological assessment from a quantitative point of view may be required to estimate the quantity of water to be removed. EXP can assist if the need arises.

4.4 Foundation Design

4.4.1 Raft Slab

It is understood that the structure will have one level of underground parking with two levels of parking above grade. If a raft slab (mat foundation) is proposed, it is anticipated that it would be founded in the grey silty clay till at a depth of about 4 m below grade in order to accommodate the single level of underground parking.

Settlement of the proposed building will generally govern design and the actual settlements will be based on the stress distribution at the underside of the raft foundation. On a preliminary basis, it is estimated that a uniform loading of 100 kPa on the founding soil would likely produce settlements in excess of 250 mm in the silty clay till. Depending on the actual stress distribution imparted on the founding soil, the anticipated settlements could be less, but still may be outside the tolerable serviceability limits of the structure.

To bring the settlement into a tolerable range, the building may need to incorporate light weight construction materials when considering options for exterior cladding and the like. Also, it may be prudent for the structural engineer to compare the overall weight of a building comprised of structural steel versus reinforced concrete.

A modulus of Subgrade Reaction of 15 MPa/m can be used for the preliminary design of a raft slab foundation on native silty clay till soils.

Inspection of the founding surface by the geotechnical engineer is considered imperative to confirm that the actual founding conditions are consistent with the findings presented in this report. As indicated previously, the base of the excavation should be protected with a working mat of lean concrete following approval of the founding surface by the geotechnical engineer.

In order to minimize the potential damage due to frost action, it is recommended that all exterior footings and footings in unheated areas be provided adequate protection from frost. Should construction be carried out in the winter months, care should be taken to prevent the penetration of frost beneath the partially completed structure.

If a raft slab foundation at the site is not considered feasible, alternative deep foundation options such as caissons could be considered.

4.4.2 Caissons

As an alternative to the raft foundation, the building structure could be supported on caissons (drilled piers).

For preliminary design purposes, the following unfactored soil parameters may be used for the deep foundations. The caissons would be comprised of reinforced cast-in-place concrete piles with the base founded in the grey silty clay till.

The unit skin resistance may be calculated by multiplying the undrained shear strength of the silty clay soil by the adhesion coefficient ($f_s = \alpha\ C_u$). For the silty clay till, an adhesion coefficient (α = 1.0) and a shear strength (C_u = 40 kPa) may be used for caissons constructed to a depth of about 10 m below grade.

The vertical load carrying capacity of the caissons derived from shaft resistance may be calculated using the following equation:

$$R_s = \Sigma\ f_s\ p\ L$$

In the above equation, f_s is the unit skin resistance, p is the perimeter (circumference) of the pile section and L is the length of the pile in the silty clay till.

The component of vertical load carrying capacity that may be derived from end bearing of the pile (toe resistance) in the silty clay till may be calculated using the following equation:

$$R_t = N_t\ C_u\ A_t$$

In the above equation, N_t is the bearing capacity factor (7 for piles 0.5 to 1.0 m in diameter), C_u is the undrained shear strength of the founding soil at the pile toe (30 kPa) and A_t is the cross sectional area of the pile toe.

Based on the anticipated size of the caissons and the subsurface soil conditions at the site, the capacity will be derived mainly from shaft resistance. A resistance factor of 0.4 should be applied to obtain the total factored axial resistance at Ultimate Limit States (ULS). Ongoing liaison with EXP should be carried out during the design stage to confirm the geotechnical aspects of the design and to assist with analysis of the potential settlements associated with the deep foundations (pile group).

The installation of the caissons may require a temporary steel liner in order to prevent collapse of the drilled hole if loose materials are encountered and to cut off seepage from the surrounding soil strata.

Difficulties may be encountered during augering through the very stiff silty clay till. Also, occasional cobbles and boulders may be contacted during caisson installation and this should be recognized by prospective contractors when assessing production rates.

A centering chute should be used during concrete placement. A high slump concrete (150 mm) should be used if vibration is not carried out. The mix design proposed for use should be submitted to this office for review and approval well in advance of the start of work. Sampling and testing of concrete compressive strength cylinders to the requirements of CAN/CSA A23.1 and A23.2 is recommended. At least one set of concrete cylinders should be taken for each day caissons are poured.

Prior to breaking the seal between the temporary steel liner and founding strata, the static head of the concrete should be sufficiently above the groundwater head to prevent water and caving soils from entering the hole during withdrawal of the casing. Also, concrete should be poured *above* the design cut-off level to account for the extra space to be filled during liner extraction.

It is recommended that full-time geotechnical inspection be provided during the installation of the caissons so that an accurate record of caisson sizes, locations, lengths, cut-off elevations, and installation procedures can be kept. Inspection of the bases is also required to confirm that the founding soils are suitable to support the design loads and to ensure that any disturbed soils are removed from the caisson bases.

4.5 Seismic Design

To carry out seismic analysis of a structure in accordance with the Ontario Building Code (OBC), a site class defined by the average soil/bedrock properties in the top 30 metres (100 feet) of the subsurface profile beneath the structure needs to be selected.

Table 4.1.8.4.A. 'Site Classification for Seismic Site Response' in the OBC describes the different site classifications.

For the purpose of this report, the Site Classification recommendation is based on the data obtained from the two boreholes drilled at the site. The subsurface conditions below the anticipated foundation level are assumed to generally be comprised of silty clay till underlain by sand and possible clayey silt till and limestone bedrock. The average undrained shear strength of the silty clay till would generally classify the soil as 'soft soil' according to the OBC. Based on this, a Site Class 'E' designation is recommended for preliminary design purposes, in accordance with the OBC methodology.

A seismic investigation comprising measurement of shear wave velocities to a depth of 30 m may result in a higher seismic site classification. Multichannel Analysis of Surface Waves (MASW) is a non-destructive seismic geophysical technique, and a relatively quick and economical method for this application. EXP recommends MASW services for this type of project and can provide this survey on request.

4.6 Underground Parking Level

It is understood that a single level of underground parking is proposed. Backfill material around the walls of the garage should consist of free draining granular material, such as OPSS Granular 'B', Type I, placed in maximum 300 mm thick loose lifts, uniformly compacted to at least 95 percent of standard Proctor maximum dry density (SPMDD). Provided there is perimeter drainage around the base of the structure, lateral earth pressures on the walls may be calculated using a unit weight of soil of 21 kN/m^3 and an 'at rest' lateral earth pressure coefficient of 0.43. Any applicable surcharge loads should also be considered in the design.

At the garage entrance, the subgrade should be properly insulated, or the subgrade material should consist of 1.2 m of non-frost-susceptible granular material. This will minimize frost action in this area where vertical ground movement cannot be tolerated.

Around the perimeter of the building, the ground surface should be sloped on a positive grade away from the structure to promote surface water run-off and reduce groundwater infiltration adjacent to the foundations. Subdrains around the perimeter of the garage should be provided to drain away any excess water. The purpose of the perimeter drains is to collect water that infiltrates down from ground surface and through the foundation wall backfill. The peak flow into these drains is expected to occur following heavy rainfalls or during periods of frequent precipitation.

The perimeter drains should be installed at the footing level elevation and connected to an interior pump to facilitate discharge to the storm sewer system.

4.7 Pavement Design

Prior to construction of driveways and at grade parking lots, if any, the existing asphalt, fill materials and otherwise deleterious materials should be removed from the proposed pavement area to expose competent native silty clay till.

Proof-rolling of the subgrade should be carried out with a heavy smooth drum roller. The geotechnical engineer should be called to site to witness the proof-rolling operations. Any soft areas encountered should be sub-excavated and replaced with imported Granular 'B', Type I material, placed in loose lifts of 250 mm and uniformly compacted to 98 percent of SPMDD.

It is our understanding that the driveways and parking lots will be used by heavy duty (fire/garbage trucks) and light duty vehicles (cars). The following pavement structure is recommended for light and heavy duty pavements at grade.

Recommended Pavement Structure Thicknesses			
Pavement Layer	Compaction Requirements	Light Duty Pavement Structure (Cars Only)	Heavy Duty Pavement Structure (Cars & Trucks)
Asphaltic Concrete	92.0% MRD	40 mm HL-3 50 mm HL-8	40 mm HL-3 70 mm HL-8
Granular 'A' (Base)	100% SPMDD*	350 mm	450 mm

*Notes: 1) SPMDD denotes Standard Proctor Max. Dry Density, MRD denotes Max. Relative Density
2) In-situ density testing should be carried out to confirm compaction levels.
3) The above recommendations are minimum requirements.

As noted above, the flexible pavement may consist of HL 3 surface course asphalt and HL 8 binder course asphalt. The asphalt should be produced and placed in accordance with current OPSS requirements.

Samples of the Granular 'A' aggregates should be checked for conformance to OPSS 1010 standards prior to use on site and during construction. The Granular 'A' base material should be compacted to 100 percent of SPMDD.

These recommendations on thickness design are not intended to support heavy and concentrated construction traffic, particularly where only a portion of the pavement section is installed.

If construction is undertaken under adverse weather conditions (i.e., wet or freezing conditions) subgrade preparation and granular base requirements should be reviewed by the geotechnical engineer.

Good drainage provisions will optimize pavement performance. The finished pavement surface should be free of depressions and should be sloped (preferably at a minimum grade of two percent) to provide effective surface drainage toward catch basins. Surface water should not be allowed to pond adjacent to the outside edges of pavement areas. In low areas, subdrains should be installed to intercept excess subsurface water and prevent subgrade softening. This is particularly important in heavier traffic areas at the site entrances.

4.8 Curbs and Sidewalks

The concrete for the curbs and gutters should be proportioned, mixed, placed and cured in accordance with the requirements of OPSS 353, OPSS 1350.

During cold weather, the freshly placed concrete should be covered with insulating blankets to protect against freezing. Three cylinders from each day's pour should be taken for compressive strength testing. Air entrainment, temperature, and slump tests should be made from the same batch of concrete from which test cylinders are made.

The subgrade for any sidewalks placed at the site should consist of undisturbed natural soil or well-compacted fill. A minimum 150 mm thick layer of compacted Granular 'A' material should be placed below the sidewalk slabs. The granular material should be compacted to 100 percent of SPMDD. Construction traffic should be kept off the placed curbs and sidewalks as they are not designed to withstand heavy traffic load.

4.9 Inspection and Testing Recommendations

An effective inspection and testing program is an essential part of construction monitoring. To ensure that construction is carried out in a manner consistent with the recommendations of this report and the various material and project specifications, the following should be implemented during the construction phase:

- Examination of the excavation base for the proposed raft slab to confirm that the soil conditions are consistent with the geotechnical investigation.
- Examination of the reinforcing steel for the various components of the foundation and foundation walls.
- Concrete testing (slump, air content, temperature and casting of test specimens) for the foundations to determine conformance to the project specifications.
- In-situ density testing of backfill materials to determine if appropriate levels of compaction are achieved.
- Laboratory testing (grain size analyses and Standard Proctor density tests) on the various granular materials placed at the site.
- Subgrade (proof-rolling) inspections to monitor the performance of the subgrade soil prior to the construction of any pavements at the site.

5. General Limitations

The information presented in this report is based on a limited investigation designed to provide information to support an assessment of the current geotechnical conditions within the subject property. The conclusions and recommendations presented in this report reflect site conditions existing at the time of the investigation. Consequently, during the future development of the property, conditions not observed during this investigation may become apparent. Should this occur, EXP Services Inc. should be contacted to assess the situation, and the need for additional testing and reporting. EXP has qualified personnel to provide assistance in regards to any future geotechnical and environmental issues related to this property.

Our undertaking at EXP, therefore, is to perform our work within limits prescribed by our clients, with the usual thoroughness and competence of the engineering profession. No other warranty or representation, either expressed or implied, is included or intended in this report.

The comments given in this report are intended only for the guidance of design engineers. The number of test holes required to determine the localized underground conditions between test holes affecting construction costs, techniques, sequencing, equipment, scheduling, etc. would be much greater than has been carried out for design purposes. Contractors bidding on or undertaking the works should in this light, decide on their own investigations, as well as their own interpretations of the factual borehole results, so that they may draw their own conclusions as to how the subsurface conditions may affect them.

EXP Services Inc. should be retained for a general review of the final design and specifications to verify that this report has been properly interpreted and implemented. If not afforded the privilege of making this review, EXP Services Inc. will assume no responsibility for interpretation of the recommendations in this report.

This report was prepared for the exclusive use of **Amico Design Build** and may not be reproduced in whole or in part, without the prior written consent of EXP, or used or relied upon in whole or in part by other parties for any purposes whatsoever. Any use which a third party makes of this report, or any part thereof, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. EXP Services Inc. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

We trust this report is satisfactory for your purposes. Should you have any questions, please do not hesitate to contact this office.

Drawings

-NOTES-

1. The boundaries and soil types have been established only at test hole locations. Between test holes they are assumed and may be subject to considerable error.
2. Soil samples will be retained in storage for 3 months and then destroyed unless client advises that an extended time period is required.
3. Topsoil quantities should not be established from the information provided at the test hole locations.
4. The site plan was reproduced from Google Earth Pro (2017) and should be read in conjunction with EXP Geotechnical Report LON-00016839-BS.

Geotechnical Investigation

Proposed Apartment Complex

200 Park Street West,
Windsor, Ontario

CLIENT	Amico Design Build Inc.
TITLE	Borehole Location Plan
Prepared By: M.B.	Reviewed By: B.G.
exp.	EXP Services Inc. 15701 Robin's Hill Road, London, ON, N5V 0A5

DATE	SCALE	PROJECT NO.	DWG.
MARCH 2019	NTS	LON-00016839-BS	1

Appendix A – Borehole Logs

BOREHOLE LOG

BH1

CLIENT **Amico Design Build** PROJECT NO. **LON-00016839-BS**
PROJECT **200 Park Street West Apartment Complex** DATUM **N/A**
LOCATION **Windsor, Ontario** DATES: Boring **Feb 11, 14, & 15, 2019** Water Level

Depth (m bgs)	Elevation (~m)	Strata Description	Sample Type	Sample Number	Recovery (mm)	N Value (blows)	Moisture Content (%)
0	0.10	**ASPHALT** - 100 mm					
	0.56	**FILL** - clayey silt (topsoil), occasional brick fragments, moist	AS	S1			17
1		Sandy **SILTY CLAY TILL** - mottled brown/grey, trace gravel, occasional sand pockets, firm, moist	SS	S2	380	6	20
			SS	S3	410	5	19
2	1.98	Sandy **SILTY CLAY TILL** - brown, trace gravel, very stiff, damp	SS	S4	410	22	14
3	2.90	Sandy **SILTY CLAY TILL** - grey, trace gravel, very stiff, damp	SS	S5	360	15	12
4	3.66	**SILTY SAND** - grey, some clay pockets, compact, damp	SS	S6	250	19	13
5	4.42	Sandy **SILTY CLAY TILL** - grey, trace gravel, stiff to very soft, damp to moist	SS	S7	410	10	14
6			SS	S8	460	4	13
7		- some sand seams/pockets between 5.5 m bgs and 8.5 m bgs					
8			SS	S9	460	4	19
9			SS	S10	460	2	19
10							
11			SS	S11	460	0	19

SHEAR STRENGTH: ✚ S Field Vane Test (#=Sensitivity) ▲ Penetrometer ■ Torvane — 100, 200 kPa
Atterberg Limits and Moisture: W_P W W_L
● SPT N Value × Dynamic Cone — 10, 20, 30, 40

Continued Next Page

NOTES

1) Borehole Log interpretation requires assistance by EXP before use by others. Borehole Log must be read in conjunction with EXP Report LON00016839-BS.
2) bgs denotes below ground surface.

SAMPLE LEGEND
⊠ AS Auger Sample ▨ SS Split Spoon ■ ST Shelby Tube
◫ Rock Core (eg. BQ, NQ, etc.) ◫ VN Vane Sample

OTHER TESTS
G Specific Gravity C Consolidation
H Hydrometer CD Consolidated Drained Triaxial
S Sieve Analysis CU Consolidated Undrained Triaxial
γ Unit Weight UU Unconsolidated Undrained Triaxial
P Field Permeability UC Unconfined Compression
K Lab Permeability DS Direct Shear

WATER LEVELS
▽ Apparent ▼ Measured ▲ Artesian (see Notes)

BOREHOLE LOG

CLIENT: Amico Design Build
PROJECT NO.: LON-00016839-BS
PROJECT: 200 Park Street West Apartment Complex
DATUM: N/A
LOCATION: Windsor, Ontario
DATES: Boring Feb 11, 14, & 15, 2019
Water Level:

DEPTH (m bgs)	ELEVATION (~m)	STRATA DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	RECOVERY (mm)	N VALUE (blows)	MOISTURE CONTENT (%)
12–23		Sandy **SILTY CLAY TILL** - grey, trace gravel, stiff to very soft, damp to moist - some sand seams/pockets encountered near 12.5 m bgs					
			SS	S12	460	2	18
			SS	S13	460	0	19
			SS	S14	460	2	22
			SS	S15	460	0	23

SHEAR STRENGTH: ✚ S Field Vane Test (#=Sensitivity); ▲ Penetrometer; ■ Torvane; 100, 200 kPa
Atterberg Limits and Moisture: W_P W W_L
● SPT N Value ✕ Dynamic Cone 10 20 30 40

Continued Next Page

NOTES

1) Borehole Log interpretation requires assistance by EXP before use by others. Borehole Log must be read in conjunction with EXP Report LON00016839-BS.
2) bgs denotes below ground surface.

SAMPLE LEGEND
- AS Auger Sample
- SS Split Spoon
- ST Shelby Tube
- Rock Core (eg. BQ, NQ, etc.)
- VN Vane Sample

OTHER TESTS
- G Specific Gravity
- H Hydrometer
- S Sieve Analysis
- γ Unit Weight
- P Field Permeability
- K Lab Permeability
- C Consolidation
- CD Consolidated Drained Triaxial
- CU Consolidated Undrained Triaxial
- UU Unconsolidated Undrained Triaxial
- UC Unconfined Compression
- DS Direct Shear

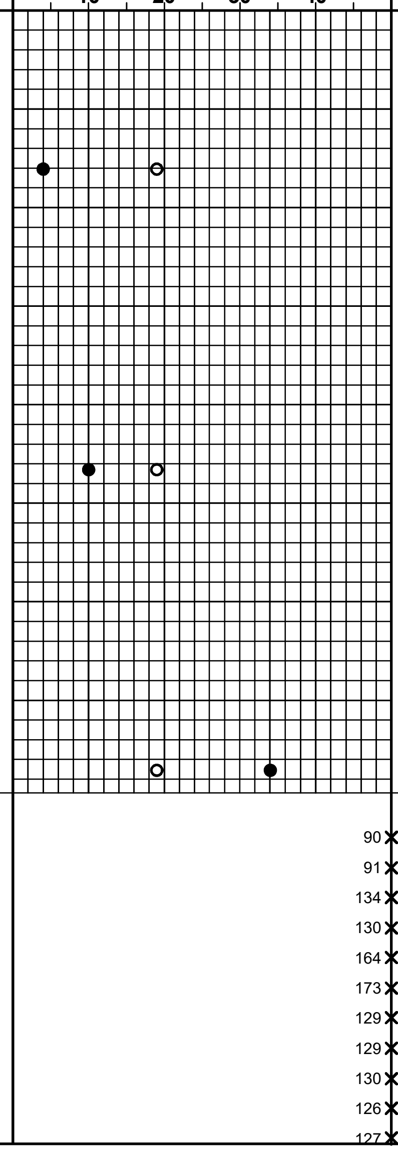
WATER LEVELS
- Apparent
- Measured
- Artesian (see Notes)

BOREHOLE LOG

CLIENT **Amico Design Build** PROJECT NO. **LON-00016839-BS**
PROJECT **200 Park Street West Apartment Complex** DATUM **N/A**
LOCATION **Windsor, Ontario** DATES: Boring **Feb 11, 14, & 15, 2019** Water Level

DEPTH (m bgs)	ELEVATION (~m)	STRATA DESCRIPTION	TYPE	NUMBER	RECOVERY (mm)	N VALUE (blows)	MOISTURE CONTENT (%)
23		Sandy **SILTY CLAY TILL** - grey, trace gravel, stiff to very soft, damp to moist					
24							
			SS	S16	410	4	19
25							
26							
27							
			SS	S17	460	10	19
28							
29							
	29.87						
30		**SAND** - grey, fine to medium grained, dense, wet					
			SS	S18	460	34	19
	30.94						
31		**End of sampling.**					
32							
33							
34							

SHEAR STRENGTH
✚ S Field Vane Test (#=Sensitivity)
▲ Penetrometer ■ Torvane
100 200 kPa
Atterberg Limits and Moisture
W_P W W_L
● SPT N Value × Dynamic Cone
10 20 30 40



Continued Next Page

NOTES
1) Borehole Log interpretation requires assistance by EXP before use by others. Borehole Log must be read in conjunction with EXP Report LON00016839-BS.
2) bgs denotes below ground surface.

SAMPLE LEGEND
⊠ AS Auger Sample ▨ SS Split Spoon ■ ST Shelby Tube
◫ Rock Core (eg. BQ, NQ, etc.) ◫ VN Vane Sample

OTHER TESTS
G Specific Gravity C Consolidation
H Hydrometer CD Consolidated Drained Triaxial
S Sieve Analysis CU Consolidated Undrained Triaxial
γ Unit Weight UU Unconsolidated Undrained Triaxial
P Field Permeability UC Unconfined Compression
K Lab Permeability DS Direct Shear

WATER LEVELS
▽ Apparent ▼ Measured ▲ Artesian (see Notes)

BOREHOLE LOG

CLIENT **Amico Design Build** PROJECT NO. **LON-00016839-BS**
PROJECT **200 Park Street West Apartment Complex** DATUM **N/A**
LOCATION **Windsor, Ontario** DATES: Boring **Feb 11, 14, & 15, 2019** Water Level

DEPTH (m bgs)	ELEVATION (~m)	STRATA DESCRIPTION	STRATA PLOT	WELL LOG	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N VALUE (blows)	MOISTURE CONTENT (%)	SHEAR STRENGTH / Atterberg Limits and Moisture / SPT N Value × Dynamic Cone
35										123, 98
36										112, 108, 115, 128
37										130, 167, 157, 160
38	37.87	Practical Refusal (assumed bedrock)								330
39										
40										
41										
42										
43										
44										
45										
46										

Shear strength legend: ✚ S Field Vane Test (#=Sensitivity); ▲ Penetrometer; ■ Torvane; scale 100, 200 kPa
Atterberg Limits and Moisture: W_P W W_L
● SPT N Value × Dynamic Cone: 10 20 30 40

NOTES

1) Borehole Log interpretation requires assistance by EXP before use by others. Borehole Log must be read in conjunction with EXP Report LON00016839-BS.
2) bgs denotes below ground surface.

SAMPLE LEGEND
☒ AS Auger Sample ▨ SS Split Spoon ■ ST Shelby Tube
◫ Rock Core (eg. BQ, NQ, etc.) ◫ VN Vane Sample

OTHER TESTS
G Specific Gravity — C Consolidation
H Hydrometer — CD Consolidated Drained Triaxial
S Sieve Analysis — CU Consolidated Undrained Triaxial
γ Unit Weight — UU Unconsolidated Undrained Triaxial
P Field Permeability — UC Unconfined Compression
K Lab Permeability — DS Direct Shear

WATER LEVELS
▽ Apparent ▼ Measured ▲ Artesian (see Notes)

BOREHOLE LOG

BH2

CLIENT **Amico Design Build** PROJECT NO. **LON-00016839-BS**
PROJECT **200 Park Street West Apartment Complex** DATUM **N/A**
LOCATION **Windsor, Ontario** DATES: Boring **February 11, 2019** Water Level **Feb 15, 2019**

DEPTH (m bgs)	ELEVATION (~m)	STRATA DESCRIPTION	TYPE	NUMBER	RECOVERY (mm)	N VALUE (blows)	MOISTURE CONTENT (%)
0	0.20	**ASPHALT** - 200 mm					
	0.30	**CONCRETE** - 100 mm					
	0.76	**FILL** - silty sand and gravel, dark grey	AS	S1			11
1		Sandy **SILTY CLAY TILL** - mottled brown and grey, trace gravel, occasional organic pockets, firm, moist	SS	S2	380	8	19
			SS	S3	410	5	28
2	2.13	Sandy **SILTY CLAY TILL** - brown, trace gravel, very stiff, damp	SS	S4	410	26	14
3	2.90	Sandy **SILTY CLAY TILL** - grey, trace gravel, some sand seams/pockets, stiff to soft, damp to moist	SS	S5	380	10	13
4			SS	S6	410	12	13
5			SS	S7	460	12	14
6			SS	S8	410	4	17
8			SS	S9	360	3	17
9	9.45		SS	S10A	360	9	21
		SILTY SAND - grey, some clay layers/pockets, trace gravel, compact, wet	SS	S10B			11
11			SS	S11	380	10	14

SHEAR STRENGTH: ✚ S Field Vane Test (#=Sensitivity); ▲ Penetrometer; ■ Torvane; 100, 200 kPa
Atterberg Limits and Moisture: W_P W W_L
● SPT N Value ✕ Dynamic Cone: 10, 20, 30, 40

Continued Next Page

NOTES

1) Borehole Log interpretation requires assistance by EXP before use by others. Borehole Log must be read in conjunction with EXP Report LON00016839-BS.
2) bgs denotes below ground surface.
3) Water Level Readings:
February 15, 2019 - 2.0 m bgs

SAMPLE LEGEND
- AS Auger Sample
- SS Split Spoon
- ST Shelby Tube
- Rock Core (eg. BQ, NQ, etc.)
- VN Vane Sample

OTHER TESTS
- G Specific Gravity
- H Hydrometer
- S Sieve Analysis
- γ Unit Weight
- P Field Permeability
- K Lab Permeability
- C Consolidation
- CD Consolidated Drained Triaxial
- CU Consolidated Undrained Triaxial
- UU Unconsolidated Undrained Triaxial
- UC Unconfined Compression
- DS Direct Shear

WATER LEVELS
- Apparent
- Measured
- Artesian (see Notes)

BOREHOLE LOG

BH2

CLIENT **Amico Design Build** PROJECT NO. **LON-00016839-BS**
PROJECT **200 Park Street West Apartment Complex** DATUM **N/A**
LOCATION **Windsor, Ontario** DATES: Boring **February 11, 2019** Water Level **Feb 15, 2019**

DEPTH (m bgs)	ELEVATION (~m)	STRATA DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	RECOVERY (mm)	N VALUE (blows)	MOISTURE CONTENT (%)
	11.58	Sandy **SILTY CLAY TILL** - grey, trace gravel, some sand seams/pockets in upper zone, firm to soft, moist					
12			SS	S12	430	5	16
13							
14			SS	S13	460	3	18
15			SS	S14	460	3	19
	15.70	**End of Borehole at 15.7 m bgs.**					
16–23							

SHEAR STRENGTH: ✚ S Field Vane Test (#=Sensitivity); ▲ Penetrometer; ■ Torvane; 100, 200 kPa
Atterberg Limits and Moisture: W_P W W_L
● SPT N Value × Dynamic Cone: 10, 20, 30, 40

NOTES
1) Borehole Log interpretation requires assistance by EXP before use by others. Borehole Log must be read in conjunction with EXP Report LON00016839-BS.
2) bgs denotes below ground surface.
3) Water Level Readings:
February 15, 2019 - 2.0 m bgs

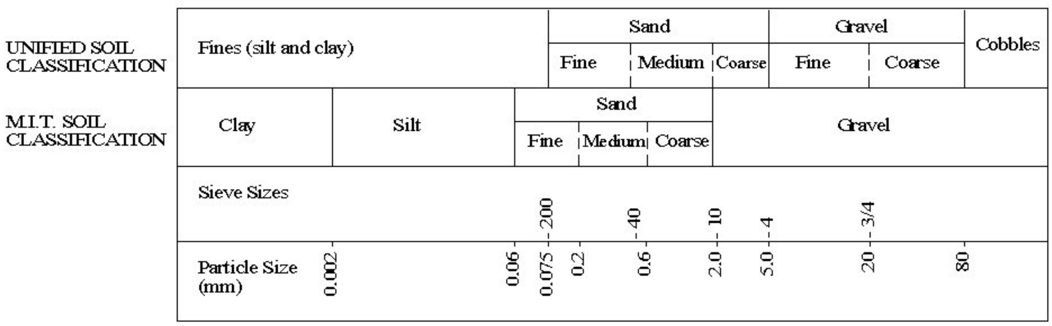
SAMPLE LEGEND
- AS Auger Sample
- SS Split Spoon
- ST Shelby Tube
- Rock Core (eg. BQ, NQ, etc.)
- VN Vane Sample

OTHER TESTS
- G Specific Gravity
- H Hydrometer
- S Sieve Analysis
- γ Unit Weight
- P Field Permeability
- K Lab Permeability
- C Consolidation
- CD Consolidated Drained Triaxial
- CU Consolidated Undrained Triaxial
- UU Unconsolidated Undrained Triaxial
- UC Unconfined Compression
- DS Direct Shear

WATER LEVELS
- Apparent
- Measured
- Artesian (see Notes)

NOTES ON SAMPLE DESCRIPTIONS

1. All descriptions included in this report follow the 'modified' Massachusetts Institute of Technology (M.I.T.) soil classification system. The laboratory grain-size analysis also follows this classification system. Others may designate the Unified Classification System as their source; a comparison of the two is shown for your information. Please note that, with the exception of those samples where the grain size analysis has been carried out, all samples are classified visually and the accuracy of the visual examination is not sufficient to differentiate between the classification systems or exact grain sizing. The M.I.T. system has been modified and the **exp** classification includes a designation for cobbles above the 75 mm size and boulders above the 200 mm size.

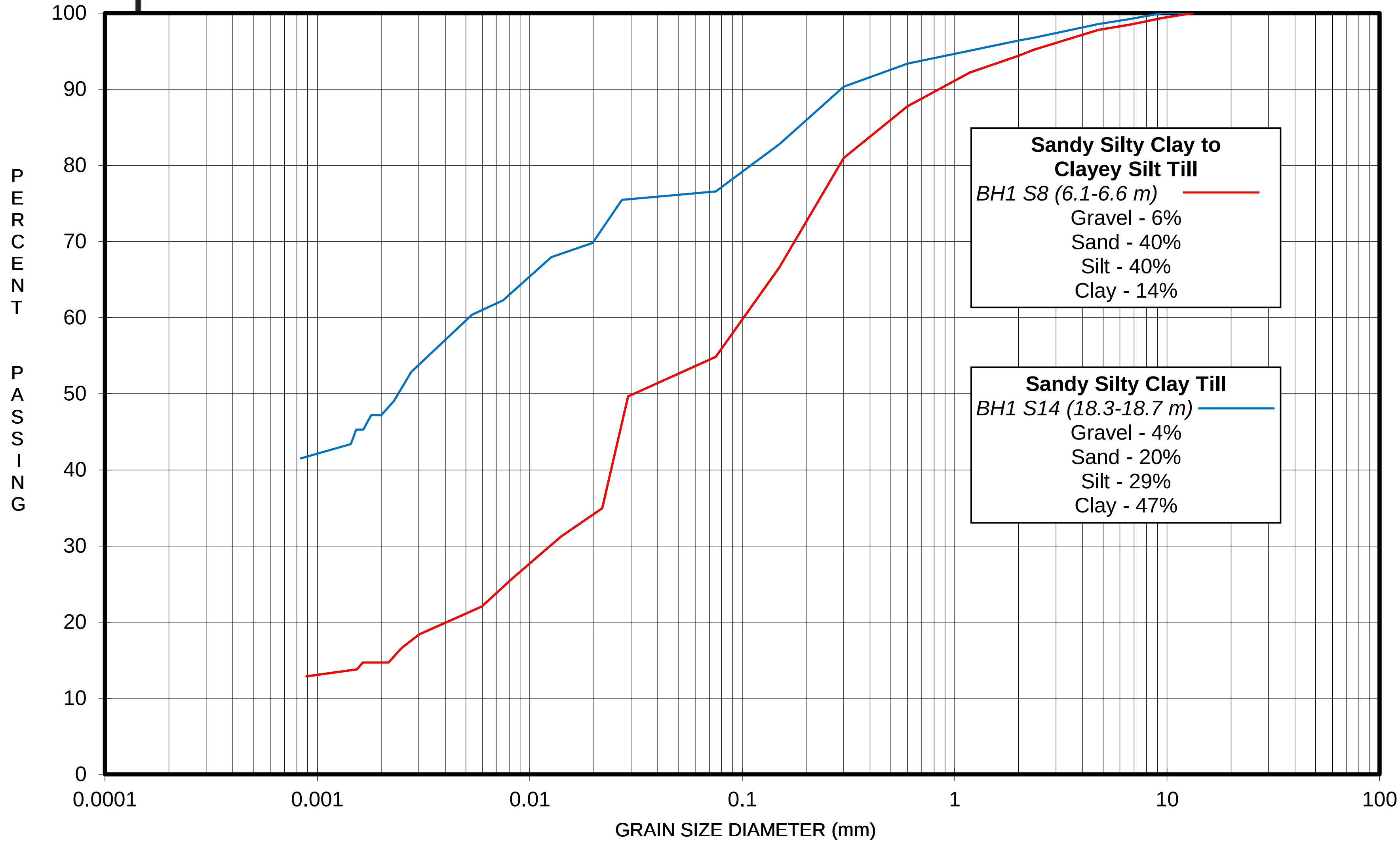


2. **Fill**: Where fill is designated on the testhole log, it is defined as indicated by the sample recovered during the boring process. The reader is cautioned that fills are heterogeneous in nature and variable in density or degree of compaction. The testhole description therefore, may not be applicable as a general description of the site fill material. All fills should be expected to contain obstructions such as large concrete pieces or subsurface basements, floors, tanks, even though none of these obstructions may have been encountered in the testhole. Since testholes cannot accurately define the contents of the fill, test pits are recommended to provide supplementary information. Despite the use of test pits, the heterogeneous nature of fill will leave some ambiguity as to the exact and correct composition of the fill. Most fills contain pockets, seams, or layers of organically contaminated soil. This organic material can result in the generation of methane gas and/or significant ongoing and future settlements. The fill at this site has **not** been monitored for the presence of methane gas. Some fill material may be contaminated by toxic waste that renders the material unacceptable for deposition in any but designated land fill sites; unless specifically stated, the fill on the site has not been tested for contaminants that may be considered hazardous. This testing and a potential hazard study can be carried out if you so request. In most residential/commercial areas undergoing reconstruction, buried oil tanks are common, but not detectable using conventional geotechnical procedures.

3. **Glacial Till**: The term till on the testhole logs indicates that the material originates from a geological process associated with glaciation. Because of this geological process, the till must be considered heterogeneous in composition and as such, may contain pockets and/or seams of material such as sand, gravel, silt or clay. Till often contains cobbles (75 to 200 mm in diameter) or boulders (greater than 200 mm diameter) and therefore, contractors may encounter them during excavation, even if they are not indicated on the testhole logs. It should be appreciated that normal sampling equipment can not differentiate the size or type of obstruction. Because of the horizontal and vertical variability of till, the sample description may be applicable to a very limited area; therefore, caution is essential when dealing with sensitive excavations or dewatering programs in till material.

Appendix B – Laboratory Test Results

MECHANICAL GRAIN SIZE ANALYSIS



CLAY	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE
	SILT			SAND			GRAVEL		
MODIFIED M.I.T. CLASSIFICATION	**Sample Description:** **Sandy Silty Clay Till**				**200 Park Street West, Windsor, ON** **Project: LON-00016839-BS**				**Figure 1**

LABORATORY TEST RESULTS

exp Services Inc.
15701 Robin's Hill Road London, Ontario N5V 0A5
tel: 519.963.3000 fax: 519.963.1152
email: london@exp.com

Project Number	LON-00016839-BS	Report Date	3/1/2019
Project Name	200 Park Streeet West, Windsor, ON		
Sample Description	BH 1 SA 8 & SA 14	Sampled By	D.B.
Sampling Date	02/15/19	Sample Source	Native
Sample Location	BH 1		
Lab Sample No.		Date Tested	3/1/2019

Atterberg Test Results	*BH1 S8 (6.1-6.6 m)*	*BH1 S14 (18.3-18.7 m)*
Liquid Limit	16.7 %	29.8 %
Plasticity Index	5.3 %	14.2 %
Plastic Limit	11.4 %	15.6 %

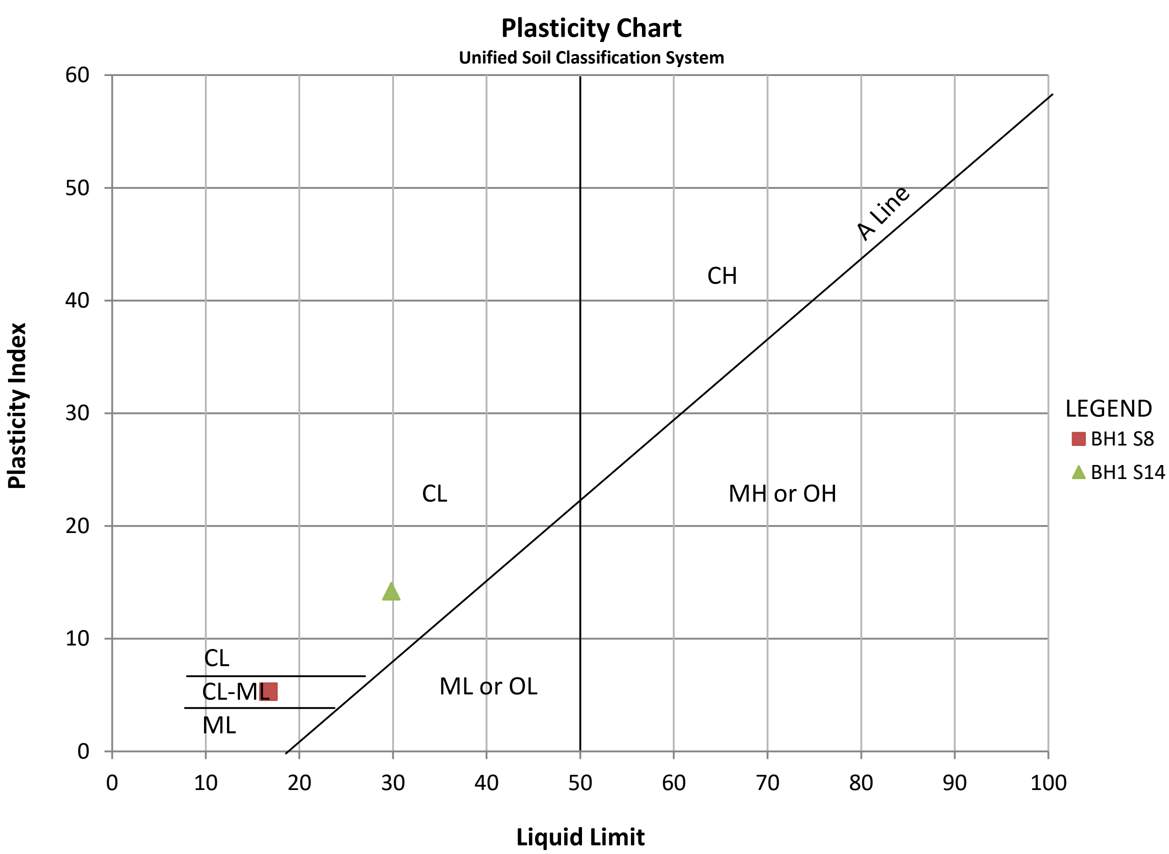


Figure 2

Appendix C – Limitations and Use of Report

LIMITATIONS AND USE OF REPORT

BASIS OF REPORT

This report ("Report") is based on site conditions known or inferred by the geotechnical investigation undertaken as of the date of the Report. Should changes occur which potentially impact the geotechnical condition of the site, or if construction is implemented more than one year following the date of the Report, the recommendations of exp may require re-evaluation.

The Report is provided solely for the guidance of design engineers and on the assumption that the design will be in accordance with applicable codes and standards. Any changes in the design features which potentially impact the geotechnical analyses or issues concerning the geotechnical aspects of applicable codes and standards will necessitate a review of the design by exp. Additional field work and reporting may also be required.

Where applicable, recommended field services are the minimum necessary to ascertain that construction is being carried out in general conformity with building code guidelines, generally accepted practices and exp's recommendations. Any reduction in the level of services recommended will result in exp providing qualified opinions regarding the adequacy of the work. exp can assist design professionals or contractors retained by the Client to review applicable plans, drawings, and specifications as they relate to the Report or to conduct field reviews during construction.

Contractors contemplating work on the site are responsible for conducting an independent investigation and interpretation of the borehole results contained in the Report. The number of boreholes necessary to determine the localized underground conditions as they impact construction costs, techniques, sequencing, equipment and scheduling may be greater than those carried out for the purpose of the Report.

Classification and identification of soils, rocks, geological units, contaminant materials, building envelopment assessments, and engineering estimates are based on investigations performed in accordance with the standard of care set out below and require the exercise of judgment. As a result, even comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations or building envelope descriptions involve an inherent risk that some conditions will not be detected. All documents or records summarizing investigations are based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated. Some conditions are subject to change over time. The Report presents the conditions at the sampled points at the time of sampling. Where special concerns exist, or the Client has special considerations or requirements, these should be disclosed to exp to allow for additional or special investigations to be undertaken not otherwise within the scope of investigation conducted for the purpose of the Report.

RELIANCE ON INFORMATION PROVIDED

The evaluation and conclusions contained in the Report are based on conditions in evidence at the time of site inspections and information provided to exp by the Client and others. The Report has been prepared for the specific site, development, building, design or building assessment objectives and purpose as communicated by the Client. exp has relied in good faith upon such representations, information and instructions and accepts no responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of any misstatements, omissions, misrepresentation or fraudulent acts of persons providing information. Unless specifically stated otherwise, the applicability and reliability of the findings, recommendations, suggestions or opinions expressed in the Report are only valid to the extent that there has been no material alteration to or variation from any of the information provided to exp.

STANDARD OF CARE

The Report has been prepared in a manner consistent with the degree of care and skill exercised by engineering consultants currently practicing under similar circumstances and locale. No other warranty, expressed or implied, is made. Unless specifically stated otherwise, the Report does not contain environmental consulting advice.

COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment form part of the Report. This material includes, but is not limited to, the terms of reference given to exp by its client ("Client"), communications between exp and the Client, other reports, proposals or documents prepared by exp for the Client in connection with the site described in the Report. In order to properly understand the suggestions, recommendations and opinions expressed in the Report, reference must be made to the Report in its entirety. exp is not responsible for use by any party of portions of the Report.