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Attention: Mark Bortolotti

Geotechnical Investigation

Type of Document:
Final

Project Name:
Proposed Addition to Apartment Building
173-177 Preston Street
Ottawa, Ontario

Project Number:
OTT-00216595-A0

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Executive Summary

A geotechnical investigation was undertaken at the site of the proposed apartment building to be located at 173-177 Preston Street in the City of Ottawa, Ontario. This work was authorized by Pat and Dom Carrozza on December 11, 2013. The proposed building will comprise of a four-storey structure with one basement level. It will be founded at a depth of 3 m approximately below the existing ground surface.

The investigation comprised the drilling of two boreholes at the site to a depth ranging between 8.7 m and 10.9 m. Standard penetration tests were performed in the boreholes at 0.75 m to 1.5 m depth intervals and soil samples retrieved. In addition, washboring and core drilling techniques were used to advance one of the boreholes beyond the refusal depth. Monitoring wells were installed in both boreholes to monitor and sample the groundwater table from the site.

The investigation revealed that the pavement structure is underlain by silty sand and gravel fill, which extends to 1.6 m depth. The fill is underlain by compact to loose silty sand till to depths of approximately 3.9 m, which is underlain by bouldery sand and gravel deposit which extends to the maximum depth investigated of 10.9 m in Borehole No. 1 and by compact to loose sand extending to the maximum auger depth of 7.2 m in Borehole No. 2. The loose sand in Borehole No. 2 is underlain by limestone bedrock which extends to the maximum depth investigated of 8.5 m. The groundwater table was measured at depths of 3.6 m to 4.1 m below the existing ground surface.

The investigation has revealed that the loose sand below the groundwater table (Borehole No. 2) is susceptible to liquefaction during a seismic event and that the structure could experience 65 mm of settlement. This magnitude of settlement is not tolerable by a structure founded on spread and strip footings. Possible choices of foundation are a flexible raft with a framed superstructure, a rigid raft foundation, which may experience some tilt during a seismic event but the superstructure will not experience any damage, or on piled foundations with a structural slab also supported on piles. The floor slab of the proposed structure should be constructed as per the recommendation of the report. Perimeter as well as underfloor drainage systems should be provided for the proposed residences.

Excavations for construction of the apartment building will extend to a maximum depth of 3 to 3.5 m. These excavations may be undertaken as 'open cut' provided they are cut back at 45 degrees above the groundwater table. Below the groundwater table, the excavation sides are expected to slough and will eventually stabilize at a slope of 2H:1V to 3H:1V. If space restrictions prevent open-cut excavation, the excavation should be shored. It is noted that the existing building is located at a higher level in close proximity of the proposed new building. Care should be exercised during construction to ensure that the existing building is not undermined.

Seepage of surface and sub-surface water into the excavations should be anticipated. However, it should be possible to remove the water entering the excavations by collecting it in perimeter ditches and pumping from sumps. In service trenches, the water may be collected at low points and removed by pumping.
Backfill against subsurface walls and in footing and service trenches inside the building should consist of free draining granular material preferably conforming to Ontario Provincial Standard Specifications (OPSS) for Granular ‘B’, Type II’. The backfill in service trenches outside the building should be compactible. All backfill should be compacted to 95 percent of standard Proctor maximum dry density.

The soil to be excavated and suitable from use as backfill is expected to be of limited quantity. It is recommended that any fill to be imported for backfilling service trenches and for road subgrade should conform to OPSS 1010 for Granular ‘B’, material.

The pavement structure thickness for the pavement to be re-instated may consist of 65 mm of asphaltic concrete underlain by 150 mm of Granular ‘A’ base and 400 mm of Granular ‘B’ sub-base.

General Use (GU) Portland cement may be used in the subsurface concrete at this site.

Based on the results of the investigation, the site has been classified as Class ‘E’ for seismic site response in accordance with requirements of Table 4.1.8.4A of the Ontario Building Code, 2012 for the foundation options recommended in the report.

The above and other related issues have been discussed in greater detail in the report.
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1 Introduction

A geotechnical investigation was undertaken at the site of the apartment building to be located at 173-177 Preston Street. This work was authorized by Pat and Dom Carrozza on December 11, 2013.

It is proposed to construct a four-storey apartment building with one basement level. It will be located north west of the existing building, approximately 1.3 m to 1.8 m away. Available information indicates that the footings of the existing building are at a depth of 2m. Plans call for founding the proposed building at a depth of 3 m approximately below the existing ground surface.

The investigation was undertaken to:

1.) Establish the geotechnical and ground water profile at the site at the locations of the boreholes;
2.) Discuss grade raise restriction at the site (if any);
3.) Make recommendations regarding the most suitable type of foundations, founding depth and Serviceability Limited State (SLS) bearing pressure and factored geotechnical resistance at Ultimate Limit State (ULS);
4.) Discuss earth pressure against subsurface walls;
5.) Comment on excavation conditions;
6.) Discuss backfilling requirements and suitability of onsite soils for backfilling purposes;
7.) Discuss liquefaction potential of the on-site soils during a seismic event;
8.) Classify the site for seismic site response in accordance with Table 4.1.8.4A of 2012 edition of Ontario Building Code;
9.) Recommend pavement structure thickness for the pavement to be re-instated;
10.) Comment on subsurface concrete requirements.

The comments and recommendations given in this report are based on the assumption that the above-described design concept will proceed to construction. If changes are made either in the design phase or during construction, this office must be retained to review these modifications. The result of this review may be a modification of our recommendations or it may require additional field or laboratory work to check whether the changes are acceptable from a geotechnical viewpoint.
2 Procedure

The fieldwork for this investigation was undertaken with truck mounted CME-55 drill rig equipped with continuous flight hollow stem augers and core drilling facilities. It was supervised on a full-time basis by a representative of exp. The fieldwork was undertaken on January 17 and February 3rd, 2014 and consisted of drilling a total of two boreholes to 8.7 m and 10.9 m depths.

Standard penetration tests were performed in the boreholes at 0.75 m to 1.5 m depth intervals and soil samples retrieved by split barrel sampler. In addition, washboring and core drilling techniques were used to advance one of the boreholes below the refusal depth. Monitoring wells comprising of 50 mm PVC pipes were installed in both boreholes for long-term monitoring and sampling of the groundwater table at the site.

The locations of the boreholes were established in the field by representatives of exp and are shown on Site Plan, Figure No. 1.

All the boreholes were logged in the field. The retrieved soil samples were visually examined for textural classification, preserved in plastic bags and identified. Similarly, the rock cores were visually examined, logged, placed in core boxes and identified. On completion of the fieldwork, all the soil and rock samples were transported to the exp Laboratory in the City of Ottawa, Ontario where they were visually examined by a geotechnical engineer and borehole logs prepared. The engineer also assigned the laboratory testing which consisted of performing natural moisture content, grain-size analyses and pH and sulphate tests on selected soil samples.
3 Site and Soil Description

The site of the proposed development is located in the north east quadrant of the intersection of Preston Street and Poplar Street in the City of Ottawa, Ontario. The site is currently occupied by a two storey multi-unit apartment building with one basement level.

A detailed description of the geotechnical conditions encountered in the two boreholes drilled at the site is given on Borehole Logs, Figures 2 and 3. The borehole logs and related information depict subsurface conditions only at the specific locations and times indicated. Subsurface conditions and water levels at other locations may differ from conditions at the locations where sampling was conducted. The passage of time also may result in changes in the conditions interpreted to exist at the locations where sampling was conducted. Boreholes were drilled to provide representation of subsurface conditions as part of a geotechnical exploration program and are not intended to provide evidence of potential environmental conditions.

A review of Figures 2 and 3 (Borehole Logs 1 and 2) inclusive indicates that beneath 50 mm of asphaltic concrete, fill was encountered in both boreholes and extends 1.6 m depths. The fill consists of sand and gravel to crusher-run limestone in the upper levels and becomes silty sand with gravel and some organics with depth. It is dense to compact and has a natural moisture content ranging between 4 and 20 percent.

The fill is underlain by silty sand till which extends 3.9 m depth. The till is compact to loose as indicated by the standard penetration SPT N value of 7 to 28. The natural moisture content of the till is 8 to 12 percent. A grain-size analysis performed on a sample from this stratum revealed a soil composition of 32 percent gravel, 33 percent sand and 35 percent silt and clay (Figure 4).

The till in Borehole No. 1 is underlain by granular deposit comprising of sand and gravel to bouldery sand and gravel with seams of medium to coarse sand which extends to the maximum auger depth of 10.9 m in this borehole. This stratum is water bearing and is compact to very dense as indicated by 'N' value which were likely affected by the presence of boulders and cobbles within this matrix. The natural moisture content of this stratum varies from 8 to 14 percent. A grain-size analysis performed on a sample from this stratum indicates a soil composition of 34 percent gravel, 52 percent sand and 14 percent silt and clay (Figure 5).

The till in Borehole No. 2 is underlain by medium to coarse sand which extends to the maximum auger depth of 8.7 m in this borehole. This stratum is water bearing and is loose as indicated by 'N' value. The natural moisture content of this stratum varies from 6 to 21 percent. A grain-size analysis performed on a sample from this stratum indicates a soil composition of 16 percent gravel, 74 percent sand and 10 percent silt and clay (Figure 6).

Water level observations were made in all the boreholes during drilling and in monitoring wells installed in the boreholes subsequent to completion of the fieldwork. These observations indicate that the groundwater table at the site was located at a depth of 3.6 m (for BH-1) and 4.5 m (for BH-2), upon
completion of the drilling program. After 28 days, the depth to the groundwater at BH-1 was 4.1 m below grade. Access to BH-2 was not available due to ice cover.

Water levels were measured in the exploratory boreholes at the times and under the conditions stated in the scope of services. These data were reviewed and exp's interpretation of them discussed in the text of the report. Note that fluctuations in the level of the groundwater may occur due to seasonal variation such as precipitation, snowmelt, rainfall activities, and other factors not evident at the time of measurement and therefore may be at a higher level during wet weather periods.
4 Site Re-grading

Based on the proposed development, the grades at the site are not expected to be raised. Since cohesive soils were not encountered, there are no grade raise restrictions at the site.
5 Liquefaction Potential of On-site Soils

Very loose to loose sand was encountered in Borehole No. 2 between 3.9 m and 7.2 m depths. The majority of this sand is below the groundwater table. Therefore, a liquefaction analysis was undertaken. The results are presented in Appendix A. The analysis revealed that the sand below the groundwater table is susceptible to liquefaction during a seismic event. The analysis also revealed that the liquefaction settlements of the sand will be 65 mm.

Therefore, it is recommended that the proposed structure should be founded on Beam on Elastic Foundation or on drilled piles.
6 Foundation Considerations

As indicated previously, the very loose to loose sand is subject to liquefaction during an earthquake. Therefore, spread and strip footing foundations are not feasible. However, the proposed structure may be constructed using one of the following alternatives:

- Raft Foundations:
  - a.) A flexible raft supported on beams or elastic foundation provided that the structure is designed as a framed structure; or
  - b.) Rigid raft, which may tilt during a seismic event, but the superstructure will not experience any cracking;

- Geopiers

- Augercast Piles

6.1 Raft Foundation

The building foundation may be constructed as a flexible (Beam on Elastic Foundation) or rigid mat foundation bearing on compact silty sand till subgrade at a depth of 3 m approximately below the existing ground surface and designed for a geotechnical reaction at SLS of 125 kPa, and a factored geotechnical resistance at ULS of 185 kPa, subject to confirmation of the quality of subgrade during construction. A modulus of subgrade reaction of 15,000 kN/ m³ may be used in the design.

For supporting the building on a mat foundation, the subgrade should be compacted in place to a dense, unyielding condition. With the parameters discussed above, we estimate settlements in the range of 25 to 40 mm. Most settlements are expected to occur during construction.

6.2 Geopiers

Geo-piers or rammed aggregate piers can also be used in the existing loose sand to establish support for conventional spread footings. This procedure consists of creating a highly densified column of graded aggregate that would extend through the loose sand into the underlying bedrock. Due to the method used to construct the piers, some improvement of the adjacent soils is also realized. Once constructed, conventional spread footing foundations can be designed to bear immediately above the Geo-pier locations.

This ground improvement technique is typically completed on a design/build approach with both design and construction completed by a specialty contractor. We can assist in contacting and selecting the specialty contractor, if desired.
6.3 Auger Cast Piles

Another alternative is to found the proposed structure on augercast piles to bedrock. Augercast piles of 500 mm and 750 mm in diameter advanced to the bedrock would have the following available capacities:

<table>
<thead>
<tr>
<th>Pile Size (mm)</th>
<th>ULS End Bearing (kN)</th>
<th>SLS End Bearing (kN)</th>
<th>ULS Uplift (kN)</th>
<th>SLS Uplift (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>900</td>
<td>625</td>
<td>500</td>
<td>300</td>
</tr>
<tr>
<td>750</td>
<td>1,700</td>
<td>1,100</td>
<td>750</td>
<td>500</td>
</tr>
</tbody>
</table>

Pile settlements are expected to be less than 6 mm, most of which should occur as loads are applied. Full single pile capacities can be used provided pile spacing is at least three pile diameters. For closer spacing, there will be a slight reduction in the allowable single pile capacity due to group effects. The amount of this reduction will depend on the number of piles in the grouping and their spacing. We should be contacted to provide this information, if required.

The pressure used to inject the grout and construct the pile column will compress the soils immediately adjacent to the pile. As a result, the amount of grout needed to form the pile will be greater than the computed volume for the particular pile diameter. The contractor will need to take this into consideration in estimating grout volumes.

The installation sequence should be such that piles are constructed at a minimum clear spacing of five pile diameters. Installation between these locations can be completed once the grout has achieved its initial set, usually in 24 hours.

The auger should be extracted slowly and uniformly below a sufficient and consistent head of grout. If the auger is extracted too quickly, the pile may neck down and the soil may collapse into the pile, reducing its structural integrity. The injection line should be equipped with a pressure gauge to monitor the grout pressure during construction. A means for determining the amount of grout used in forming the piles should also be provided.

6.4 Lateral Pile Capacity

The resistance to lateral loading in front of a vertical pile may be calculated using subgrade reaction theory where the coefficient of horizontal subgrade reaction, Kh (kPa/m), is based on the equation for cohesionless soils as follows:
Kh = nhZ/B (Silty sand)

Where: nh = The constant of horizontal subgrade reaction (kPa/m)
         = 1300 kPa/m (very loose to compact sand)

  Z = The depth (m)

  B = the pile diameter or width (m)

The upper 1.5x B metric length of the piles should be neglected in the calculation of lateral resistance of the pile due to disturbance during installation. Group action for lateral loading should be considered when the pile spacing in the direction of loading is less than eight pile diameters.

<table>
<thead>
<tr>
<th>Pile Spacing in Direction of Loading (d= Pile Diameter)</th>
<th>Subgrade Reaction Reduction Factor*</th>
</tr>
</thead>
<tbody>
<tr>
<td>8d</td>
<td>1.0</td>
</tr>
<tr>
<td>6d</td>
<td>0.70</td>
</tr>
<tr>
<td>4d</td>
<td>0.40</td>
</tr>
<tr>
<td>3d</td>
<td>0.25</td>
</tr>
</tbody>
</table>

* NAVFAC DM – 7.2
7 Floor Slab and Drainage Requirements

The lowest level floor of the proposed building should be constructed as a structural slab supported on pile, if piles foundation is used. It should be set on a bed of well compacted 19 mm clear stone at least 200 mm thick placed on the natural soil or on well compacted fill. The clear stone would prevent the capillary rise of moisture from the sub-soil to the floor slab. Any underfloor fill required should conform to OPSS Granular ‘B’ and should be placed in 300 mm lift thickness and each lift compacted to at least 95 percent of the Standard Proctor Dry Density.

It is recommended that perimeter as well as underfloor drains should be provided for the proposed structure. The underfloor drainage system may consist of 100 mm diameter perforated pipe or equivalent placed in parallel rows at 5 m to 6 m centres and at least 300 mm below the underside of the floor slab. The drains should be set on 100 mm of pea-gravel and covered on top and sides with 150 mm of pea-gravel and 300 mm of CSA Fine Concrete Aggregate (Figure No. 7). The perimeter drains may also consist of 100 mm diameter of perforated pipe set on the footings and surrounded with 150 mm of pea-gravel and 300 mm of CSA Concrete Aggregate. The perimeter and underfloor drains should preferably be connected to separate sumps so that at least one system would be operations should the other fail.

The finished exterior grade should be sloped away from the buildings to prevent surface ponding close to the exterior walls.
8 Lateral Earth Pressure

The subsurface walls of the proposed structure will be subjected to lateral static earth pressure as well as lateral dynamic earth pressure during a seismic event. The lateral static earth pressure that the subsurface walls would be subjected to may be computed from the following equation:

\[ P_A = K_a H (q + \frac{1}{2} \gamma H) \]

where

- \( P_A \) = lateral earth force, kN/m
- \( K_a \) = earth pressure coefficient = 0.4
- \( \gamma \) = unit weight of backfill = 22 kN/m³
- \( H \) = height of wall, (m)
- \( q \) = surcharge load, kPa

The lateral force per units length of the wall due to seismic loading may be computed from the equation given below:

\[ \Delta P_E = (a_h/g).F_p \cdot \gamma H^2 = 0.15 \gamma H^2 \]

where

- \( \Delta P_E \) = resultant force due to seismic activity; kN/m
- \( a_h \) = pseudo-static horizontal acceleration, \( a_h=0.16 \) g (Ottawa).
- \( \gamma \) = unit weight of free draining granular backfill; Granular B Type II = 22 kN/m³
- \( H \) = height of backfill behind wall, (m)

The \( \Delta P_E \) value does not take into account the surcharge load. The seismic load should be assumed to act at 0.6 \( H \) from the bottom of the wall.
9 Excavations

Excavation for construction of apartment building is expected to extend to a depth of 3.0 m below the existing ground surface. The depth to which excavations would be undertaken for installation of services is not known. These excavations will terminate in the silty sand till. They are expected to be above the groundwater table. Depending on the depth of installation of the services, the excavations for services may extend below the groundwater table in some areas. Excavations below the groundwater table will be susceptible to a ‘base-heave’ type of failure of the excavation. Therefore, if excavations below the groundwater table are to be undertaken, dewatering of the site to below the excavation depth will be required prior to commencement of the excavation.

Excavation at the site for the building may be undertaken as open cut provided space permits since ‘base-heave’ type of failure of the excavation is not anticipated. The excavation should comply at all times with Ontario Occupational Health and Safety Act, Ontario Regulation 213/91. Excavation above the groundwater table is expected to be stable for the construction period when cut back at 45 degrees. Excavations in the granular soils below the groundwater table are expected to slough and will eventually stabilize at a slope of 2H:1V to 3H:1V. It is noted that along the north side, the excavation will extend up to the property boundary. On the south side, the excavation will extend within 1.3 m to 1.8 m of the existing building and will be lower by approximately 1 m. It is therefore anticipated that the north face of the excavation would have to be shored. Depending on the site conditions, shoring of the south face may also be required to prevent undermining of the existing building. This office should be contacted to provide geotechnical design parameter if shoring is to be used. Excavations for installation of the services may be undertaken within the confines of a prefabricated support system, such as a trench box designed and installed in accordance OHSA 213/91. Dewatering of the service trenches may be undertaken by pumping from sumps located at low points.

Seepage of the surface and subsurface water into the excavations is anticipated. However, it should be possible to collect any water entering the excavations in perimeter ditches and to remove it by pumping from sumps. Although this investigation has estimated the groundwater levels at the time of the field work, and commented on dewatering and general construction problems, conditions may be present which are difficult to establish from standard boring techniques and which may affect the type and nature of dewatering procedures used by the contractor in practice. These conditions include local and seasonal fluctuations in the groundwater table, erratic changes in the soil profile, thin layers of soil with large or small permeabilities compared with the soil mass, etc. Only carefully controlled tests using pumped wells and observation wells will yield the quantitative data on groundwater volumes and pressures that are necessary to adequately engineer construction dewatering systems. Permit to take water may be required from Ontario Ministry of the Environment.

Many geologic materials deteriorate rapidly upon exposure to meteorological elements. Unless otherwise specifically indicated in this report, walls and floors of excavations must be protected from moisture, desiccation, and frost action throughout the course of construction.
10 Backfilling Requirements and Suitability of On-site Soils for Backfilling Purposes

The backfill against subsurface walls and in footing and service trenches inside the building should consist of free draining material preferably conforming to Ontario Provincial Standard Specifications for Granular ‘B’. The backfill in service trenches outside the building should be compactible i.e. free of organics and debris and with natural moisture content which is within 2 percent of the optimum moisture content. All backfill should be compacted to 95 percent standard Proctor maximum dry density.

The soils to be excavated during construction are fill and silty sand till. These materials are non-free draining and therefore not suitable for backfilling in the interior or exterior of the building. They may be used however as fill in the landscaped areas.

It is anticipated that the majority of the material required for backfilling purposes for the project would need to be imported and should preferably conform to the following specification:

- Backfill against subsurface walls - OPSS 1010 Granular ‘B’, Type I;
- Underfloor Fill and Backfill of footing Trenches (interior and exterior) – OPSS 1010 Granular ‘B’ Type I; and,
- Trench backfill and subgrade fill for access roadways – OPSS 1010 Select Subgrade Material (SSM).
11 Pavement Design

It is understood that surface parking is to be provided on the north side of the proposed addition. The following pavement structure is recommended for the parking areas to be used by light automobile traffic.

<table>
<thead>
<tr>
<th>Pavement Layer</th>
<th>Compaction Requirements</th>
<th>Computed Pavement Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalitc Concrete (PG 58-34)</td>
<td>92-96% Maximum Relative Density</td>
<td>65 SC</td>
</tr>
<tr>
<td>OPSS Granular ‘A’ Base (crushed limestone)</td>
<td>100% SPMDD*</td>
<td>150</td>
</tr>
<tr>
<td>OPSS Granular ‘B’ II Sub-base</td>
<td>100% SPMDD*</td>
<td>300</td>
</tr>
</tbody>
</table>

Notes:
1. SPMDD denotes standard Proctor maximum dry density, ASTM, D-698
2. Any subgrade fill must be compacted to 98% SPMDD for at least the upper 300 mm
3. SC Denotes Surface course asphalt and may comprise of Superpave OPSS 1151 SP 12.5 mm Mix (Category C).

Procedure for construction of the pavements is discussed below.

After all the underground services have been installed, backfilled and satisfactorily compacted, the entire road should be excavated to the subgrade level. It should then be proof rolled with a heavy roller. Any soft areas which become evident should be sub-excavated and replaced with approved native fill with moisture content within +/- 2 percent of the optimum value or free draining granular material. All subgrade fill should be placed in maximum 300 mm lifts and compacted to 98 percent of standard Proctor maximum dry density. In-place density tests should be performed at regular intervals to ensure that the specified degree of compaction is being achieved.

Additional comments on construction of the roadways are as follows:

1.) The finished pavement surface should be free of depressions and should be sloped (preferably at a minimum cross fall of 2 percent) to provide effective surface drainage towards catch basins. Surface water should not be allowed to pond adjacent to the outside edges of paved areas.

2.) The granular materials used for pavement construction should conform to Ontario Provincial Standard Specifications (OPSS) for Granular ‘A’ and Granular ‘B’, Type II and should be compacted to 100 percent of the standard Proctor maximum dry density. The asphaltic concrete used and its placement should meet OPSS requirements. It should be compacted to 92 to 96.5 Maximum Relative Density.
It is recommended that a geotechnical engineer be retained to review the final pavement structure design and drainage plans prior to construction to ensure that they are consistent with the recommendations of this report.
12 Seismic Site Classification

The investigation has revealed that some of the soils at the site are susceptible to liquefaction during a seismic event. Therefore, the site classification would be Class F. However, it has been recommended that the proposed structure should be founded on pile foundations or a raft foundation or piled foundation to mitigate the effect of liquefaction of the sand.

We understand that the structural period is less than 0.5. Based on liquefaction analysis and the assumption that the proposed building will be founded on silty sand till underlain by loose sand, the Site Class for these structure is deemed to be Class "E". Therefore, the ground accelerations calculated above need to be adjusted to the site specific conditions as described by Finn and Wightman (2003).

From the 2012 NBCC, the respective short- and long- period amplification factors Fa and Fv for Site Class “E” are 1.24 and 2.06, respectively. Therefore based on these factors and reference spectral accelerations given above for Site Class "E", the specific-site spectral accelerations for this project are adjusted to: Sa(0.2)=0.787g, Sa(0.5)=0.634g, Sa(1.0)=0.282g, Sa(2.0)=0.095g and PGA=0.665g.
14 General Comments

The comments given in this report are intended only for the guidance of design engineers. The number of boreholes required to determine the localized underground conditions between boreholes affecting construction costs, techniques, sequencing, equipment, scheduling, etc., would be much greater than has been carried out for the 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.

The information contained in this report is not intended to reflect on environmental aspects of the soils. Should specific information be required, including for example, the presence of pollutants, contaminants or other hazards in the soil, additional testing may be required.

We trust that the information contained in this report will be satisfactory for your purposes. Should you have any questions, please do not hesitate to contact this office.
Figures
LEGEND

- BH2

GEOTECHNICAL BOREHOLE LOCATION & NUMBER (EXP 2014)

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exp

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Notes On Sample Descriptions

1. All sample descriptions included in this report follow the Canadian Foundations Engineering Manual soil classification system. This system follows the standard proposed by the International Society for Soil Mechanics and Foundation Engineering. Laboratory grain size analyses provided by exp Services Inc also follow the same system. Different classification systems may be used by others; one such system is the Unified Soil Classification. Please note that, with the exception of those samples where a grain size analysis has been made, all samples are classified visually. Visual classification is not sufficiently accurate to provide exact grain sizing or precise differentiation between size classification systems.

<table>
<thead>
<tr>
<th>ISMFE Soil Classification</th>
<th>Clay</th>
<th>Silts (CL)</th>
<th>Sand</th>
<th>Gravel</th>
<th>Cobble</th>
<th>Boulders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Coarse</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Fine</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Medium</td>
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</tr>
<tr>
<td>Coarse</td>
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<table>
<thead>
<tr>
<th>EQUIVALENT GRAIN DIAMETER IN MILLIMETRES</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.002</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unified Soil Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay (Plastic):</td>
</tr>
<tr>
<td>Fine</td>
</tr>
<tr>
<td>Medium</td>
</tr>
<tr>
<td>Coarse</td>
</tr>
</tbody>
</table>

2. Fill: Where fill is designated on the borehole 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 borehole description may therefore not be applicable as a general description of site fill materials. All fills should be expected to contain obstruction such as wood, large concrete pieces or subsurface basements, floors, tanks, etc., none of these may have been encountered in the boreholes. Since boreholes 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 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. Fill at this site may have been monitored for the presence of methane gas and, if so, the results are given on the borehole logs. The monitoring process does not indicate the volume of gas that can be potentially generated nor does it pinpoint the source of the gas. These readings are to advise of the presence of gas only, and a detailed study is recommended for sites where any explosive gas/methane is detected. Some fill material may be contaminated by toxic/hazardous waste that renders it unacceptable for deposition in any but designated land fill sites; unless specifically stated the fill on this site has not been tested for contaminants that may be considered toxic or hazardous. This testing and a potential hazard study can be undertaken if requested. In most residential/commercial areas undergoing reconstruction, buried oil tanks are common and are generally not detected in a conventional geotechnical site investigation.

3. Till: The term till on the borehole 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 (60 to 200 mm) or boulders (over 200 mm). Contractors may therefore encounter cobbles and boulders during excavation, even if they are not indicated by the borings. It should be appreciated that normal sampling equipment cannot differentiate the size or type of any obstruction. Because of the horizontal and vertical variability of till, the sample description may be applicable to a very limited zone; caution is therefore essential when dealing with sensitive excavations or dewatering programs in till materials.
### Log of Borehole

**Project No:** OTT-000216595-AO  
**Project:** Geotechnical Investigation - Proposed Residential Building Addition  
**Location:** 173-175 Preston Street, City of Ottawa, Ontario  
**Date Drilled:** January 17, 2014  
**Drill Type:** CME-75 (Truck Mount)  
**Datum:** Depth Below Grade  
**Logged by:** MD  
**Checked by:** IMT

#### SOIL DESCRIPTION

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ASPHALTIC CONCRETE ~45 mm</strong></td>
<td>Crusher-run limestone to sand and gravel fill, some silt, grey (frozen)</td>
</tr>
<tr>
<td><strong>FILL</strong></td>
<td>Trace gravel, dark brown to black, some limestone chips, moist, (dense)</td>
</tr>
<tr>
<td><strong>SILTY SAND FILL</strong></td>
<td>Some Gravel, trace clay, brown, moist (compact to loose)</td>
</tr>
<tr>
<td><strong>SAND AND GRAVEL</strong></td>
<td>Medium to coarse grained, occasional boulders and cobbles and shale pieces, some coarse sand layers or seams, brown to grey, wet to very wet (compact to very dense)</td>
</tr>
</tbody>
</table>

#### Refusal to Augers @ 10.9M Depth

- Natural Moisture Content
- Atterberg Limits
- Undrained Triaxial at % Strain at Failure
- Shear Strength by Penetrometer Test

#### Table: Standard Penetration Test N Value

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>N Value (kN/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>50/125mm</td>
</tr>
<tr>
<td>1</td>
<td>52</td>
</tr>
<tr>
<td>2</td>
<td>28</td>
</tr>
<tr>
<td>3</td>
<td>28</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
</tr>
<tr>
<td>5</td>
<td>56250mm</td>
</tr>
<tr>
<td>6</td>
<td>77/280mm</td>
</tr>
<tr>
<td>7</td>
<td>Sank first 150mm</td>
</tr>
<tr>
<td>8</td>
<td>50/125mm</td>
</tr>
</tbody>
</table>

#### Table: Combustible Vapour Reading

- Combustible Vapour Reading (ppm)  
- Natural Moisture Content %  
- Atterberg Limits (% Dry Weight)

<table>
<thead>
<tr>
<th>Date Drilled:</th>
<th>Drill Type:</th>
<th>Datum:</th>
<th>Logged by:</th>
<th>Checked by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>January 17, 2014</td>
<td>CME-75 (Truck Mount)</td>
<td>Depth Below Grade</td>
<td>MD</td>
<td>IMT</td>
</tr>
</tbody>
</table>

### Notes:
1. Borehole data requires interpretation by exp. before use by others
2. A monitoring well with a 45 mm diameter PVC pipe was installed in the borehole upon completion
3. Field work supervised by an exp. representative.
4. See Notes on Sample Descriptions
5. This Figure is to read with exp. Services Inc. report OTT-000216595-AO

### WATER LEVEL RECORDS

<table>
<thead>
<tr>
<th>Run No.</th>
<th>Depth (m)</th>
<th>% Rec.</th>
<th>RQD %</th>
</tr>
</thead>
</table>

### CORE DRILLING RECORD

<table>
<thead>
<tr>
<th>Run No.</th>
<th>Depth (m)</th>
<th>% Rec.</th>
<th>RQD %</th>
</tr>
</thead>
</table>
### Log of Borehole 2

**Project No:** OTT-000216595-AO  
**Project:** Geotechnical Investigation - Proposed Residential Building Addition  
**Location:** 173-175 Preston Street, City of Ottawa, Ontario  
**Date Drilled:** January 17 and February 3, 2014  
**Drill Type:** CME-75 (Truck Mount)  
**Datum:** Depth Below Grade  
**Logged by:** MD  
**Checked by:** IMT

#### SOIL DESCRIPTION

<table>
<thead>
<tr>
<th>Depth Below Grade m</th>
<th>Soil Description</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>ASPHALTIC CONCRETE ~45 mm FILL</td>
</tr>
<tr>
<td>-1.0</td>
<td>Crusher-run limestone to sand and gravel fill, some silt, grey (frozen)</td>
</tr>
<tr>
<td>-1.6</td>
<td>SILTY SAND FILL</td>
</tr>
<tr>
<td>Trace gravel, organic topsoil seams or pockets, dark brown, moist, (dense to compact)</td>
<td></td>
</tr>
<tr>
<td>-3.9</td>
<td>SILTY SAND TILL</td>
</tr>
<tr>
<td>Some Gravel, trace clay, slightly cohesive, brown to grey, moist to wet (compact to loose)</td>
<td></td>
</tr>
<tr>
<td>-4.5</td>
<td>SAND</td>
</tr>
<tr>
<td>Medium to coarse grained, some fine gravel to gravelly, red brown in the upper levels to brown, wet to very wet (compact to very loose)</td>
<td></td>
</tr>
<tr>
<td>-7.2</td>
<td>LIMESTONE BEDROCK</td>
</tr>
<tr>
<td>Some shale partings, grey (Good quality)</td>
<td></td>
</tr>
</tbody>
</table>

**Terminated @ 8.5M Depth**

### WATER LEVEL RECORDS

<table>
<thead>
<tr>
<th>Run No.</th>
<th>Depth (m)</th>
<th>% Rec.</th>
<th>RQD %</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>7.2 - 8.5</td>
<td>100</td>
<td>73</td>
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### CORE DRILLING RECORD

#### Standard Penetration Test N Value

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<tbody>
<tr>
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<td>43</td>
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<tr>
<td>1</td>
<td>17</td>
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<tr>
<td>2</td>
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<td>4</td>
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<tr>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>8</td>
<td>5</td>
</tr>
</tbody>
</table>

#### Natural Moisture Content %

### Combustible Vapour Reading

<table>
<thead>
<tr>
<th>Depth</th>
<th>ppm</th>
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</thead>
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</tr>
<tr>
<td>1</td>
<td>500</td>
</tr>
<tr>
<td>2</td>
<td>750</td>
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### Shear Strength by Penetrometer Test

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<th>kPa</th>
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<tbody>
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<td>-</td>
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<tr>
<td>2</td>
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<td>3</td>
<td>-</td>
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<td>4</td>
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<td>7</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>-</td>
</tr>
</tbody>
</table>

### Notes:

1. Borehole data requires interpretation by exp. before use by others.
2. A monitoring well with a 45 mm diameter PVC pipe was installed in the borehole upon completion.
3. Field work supervised by an exp. representative.
4. See Notes on Sample Descriptions.
5. This Figure is to be read with exp. Services Inc. report OTT-000216595-AO.
Method of Test for Sieve Analysis of Aggregate
ASTM C-136 (LS-602)

Grain Size Distribution Curve

<table>
<thead>
<tr>
<th>CLAY</th>
<th>Fine</th>
<th>Medium</th>
<th>Coarse</th>
<th>Fine</th>
<th>Medium</th>
<th>Coarse</th>
<th>Fine</th>
<th>Medium</th>
<th>Coarse</th>
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</thead>
<tbody>
<tr>
<td>SILT</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAND</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GRAVEL</td>
<td></td>
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</tr>
</tbody>
</table>

Modified M.I.T. Classification

Exp Project No.: OTT-00216595-A0
Client: Padom Holdings
Date Sampled: January 17, 2014
Sample Description: Silty and Gravel, Some Silt

Project Name: Geotechnical Investigation, Proposed Apartment Building Addition
Project Location: 175-177 Preston Street, Ottawa, Ontario
Sample Type: BOREHOLE
Sample Number: 2
Sample Subdivision: SSS
Depth (m): 3.0 - 3.6
Figure: 4
Method of Test for Sieve Analysis of Aggregate
ASTM C-136 (LS-602)

Grain Size Distribution Curve

<table>
<thead>
<tr>
<th>CLAY</th>
<th>Fine</th>
<th>Medium</th>
<th>Coarse</th>
<th>SILT</th>
<th>Fine</th>
<th>Medium</th>
<th>Coarse</th>
<th>SAND</th>
<th>Fine</th>
<th>Medium</th>
<th>Coarse</th>
<th>GRAVEL</th>
</tr>
</thead>
<tbody>
<tr>
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Modified M.I.T. Classification

Exp Project No.: OTT-00216595-A0
Project Name: Geotechnical Investigation, Proposed Apartment Building Addition
Client: Padom Holdings
Project Location: 175-177 Preston Street, Ottawa, Ontario
Date Sampled: January 17, 2014
BOREHOLE 1 SAMPLE SS6+SS7 Depth (m): 3.7-5.2
Sample Description: Sand, Some Silt and Gravel

www.exp.com
Method of Test for Sieve Analysis of Aggregate
ASTM C-136 (LS-602)

Grain Size Distribution Curve

<table>
<thead>
<tr>
<th>CLAY</th>
<th>Fine</th>
<th>Medium</th>
<th>Coarse</th>
<th>Fine</th>
<th>Medium</th>
<th>Coarse</th>
<th>Fine</th>
<th>Medium</th>
<th>Coarse</th>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SILT</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>SAND</td>
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<tr>
<td>GRAVEL</td>
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Modified M.I.T. Classification

Exp Project No.: OTT-00216595-A0
Project Name: Geotechnical Investigation, Proposed Apartment Building Addition
Client: Padom Holdings
Project Location: 175-177 Preston Street, Ottawa, Ontario
Date Sampled: January 17, 2014
BOREHOLE 2 SAMPLE SS8
Depth (m): 5.3-5.9
Sample Description: Silty Sand and Gravel
Figure: 6

www.exp.com
NOTES

OPTION A - GRANULAR BACKFILL

1. Drainage tile to consist of 100mm (4 in.) diameter weeping tile or equivalent perforated pipe leading to a positive sump or outlet. Invert to be minimum of 150mm (6 in.) below underside of floor slab.

2. Pea gravel 150mm (6 in.) top and sides of drain. If drain is not on footing, place 100mm (4 in.) of pea gravel below drain. 20mm (3/4 in.) clear stone may be used provided it is covered by an approved porous geotextile membrane (Terrafil 270R or equivalent).

3. CSA fine concrete aggregate to act as filter material. Minimum 300mm (12 in.) top and sides of drain. This may be replaced by an approved porous geotextile membrane (Terrafil 270R or equivalent).

4. Free-draining backfill - OPSS Granular B or equivalent compacted to 93 to 95 (maximum) percent Standard Proctor density. Do not compact closer than 1.8m (6 ft.) from wall with heavy equipment. Use handheld light compaction equipment within 1.8m (6 ft.) of wall.

5. Impermeable backfill seal of compacted clay, clayey silt or equivalent. If original soil is free-draining seal may be omitted.

6. Do not backfill until wall is supported by basement and floor slabs or adequate bracing.

7. Moisture barrier to consist of compacted 20mm (3/4 in.) clear stone or equivalent free-draining material. Layer to be 200mm (8 in.) minimum thickness.

8. Basement walls to be damp-proofed.

9. Exterior grade to slope away from wall.

10. Slab-on-grade should not be structurally connected to wall or footing.

11. Underfloor drain invert to be a least 300mm (12 in.) below underside of floor slab. Drainage tile placed in parallel rows 6 to 8m (20 to 25ft) centres one way. Place drain on 100mm (4 in.) of pea gravel with 150mm (6 in.) of pea gravel top and sides. CSA fine concrete aggregate to be provided as filter material or an approved geotextile membrane (as in 2 above) may be used.

12. Do not connect the underfloor drains to perimeter drains.

13. If the 20mm (3/4 in.) clear stone requires surface binding, use 6mm (1/4 in.) clear stone chips.

NOTE: A) Underfloor drainage can be deleted where not required (see report).

OPTION B - CORE DRAIN

Prefabricated continuous wall drain ② may be installed and Zone 4 backfilled with an alternate material compacted to 93 - 95% Proctor. Further cost savings may result by placing the wall drains at equal distance strips no greater than 2.5m spacing but the risk of water leakage must be assessed and then assumed by the client.

1. Wall drain option ② may increase the lateral pressures above those of the conventional detail.

2. The use of waterproofing details at construction and expansion joints may also be required.

3. For block walls or unreinforced cast in place concrete, the granular backfill option is recommended

Note: If water table exists above the floor slab, then options of granular in combinations with the wall drain should be reviewed.
Appendix A: Liquefaction Analysis
Memorandum

To: Mark Bortolotti, Padom Holdings Ltd.  

Date: February 27, 2014  
Project No.: OTT-00216595-A0  
Subject: Liquefaction Analysis for Updated Geotechnical Investigation Report, Proposed Addition to Apartment Building, 173-177 Preston Street, Ottawa, Ontario  
Distribution:

At your request, exp Services Inc. (exp), has analyzed the liquefaction potential at the Proposed Residential Building Addition at 173-177 Preston Street, City of Ottawa. For the analyses, we have reviewed the following document:


Data and Assumptions

Design ground accelerations for the project site were determined from the Earthquakes Canada Website (NRCan) by interpolating the 2010 National Building Code of Canada (NBCC) Seismic Hazard values. From the NBCC seismic calculation, the damped reference spectral accelerations for the project site are Sa(0.2)=0.635g, Sa(0.5)=0.308g, Sa(1.0)=0.137g, Sa(2.0)=0.046g and the reference peak ground acceleration (PGA) is 0.323g (g=acceleration due to gravity - 9.81 m/s²). These values are associated with an earthquake having 2 percent probability of exceedance in a 50-year period, or 0.000404 per annum probability of occurrence for the 2010 NBCC Soil Class "C" (very dense soil and soft rock).

Basic information included soil strata from Borehole No.2 data. Existing groundwater was encountered at a depth approximately 4.5 m at the time of exploratory boring.
Liquefaction Potential Assessment

Liquefaction is a phenomenon where there is a reduction or complete loss of soil strength due to an increase in pore water pressure induced by vibrations. Liquefaction mainly affects loose deposits of fine-grained silt and/or sands that are below the groundwater table. During an earthquake event, the soil deposit temporarily behaves as a viscous fluid; porewater pressure rises and the shear strength of the deposit is greatly diminished. Liquefaction is often accompanied by sand boils, lateral spread, and post-liquefaction settlement as the pore water pressure dissipates. Liquefiable soils typically consist of cohesionless sands and silts that are loose to medium dense, and saturated. Fine grained soils (Silt & Clay) which are not highly sensitive do not liquefy because surface tension holds the water-coated flakes together, and therefore the fine grained soils is not at risk to densification by shaking.

Liquefaction analysis was carried out as per ‘Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils, Edited by T. L. Youd and I. M. Idriss NCEER – 97 -0022’. Liquefaction analyses were carried out using a commercially available computer program NovLiq developed by NovoTech, Canada.

Liquefaction layers can be identified when the resistance to liquefaction is less than the induced stress. Our analysis indicates that saturated loose sand at depth below 4.5 m may liquefied subjected to ground motions from an earthquake magnitude 7.0 or higher seismic events. The analysis results are shown in Appendix A.

Site Class

We understand that the structural period is less than 0.5. Based on liquefaction analysis and the assumption that the proposed building will be founded on silty sand till underlain by loose sand, the Site Class for these structure is deemed to be Class “E”. Therefore, the ground accelerations calculated above need to be adjusted to the site specific conditions as described by Finn and Wightman (2003)

From the 2012 NBCC, the respective short- and long- period amplification factors Fa and Fv for Site Class “E” are 1.24 and 2.06, respectively. Therefore based on these factors and reference spectral accelerations given above for Site Class “E”, the specific-site spectral accelerations for this project are adjusted to: Sa(0.2)=0.787g, Sa(0.5)=0.634g, Sa(1.0)=0.282g, Sa(2.0)=0.095g and PGA=0.665g.

Foundation

Based on the liquefaction analysis, the ground floor slab can be expected to settle during a seismic Magnitude 7 event with 1 in 2,500 year return. A total settlement of 65 mm can be expected. Therefore, the proposed building addition can be supported by mat foundation (Flexible, if the structure is framed) or (Rigid, if the structure is not framed structure), Geopier, or Augercast Pile.
exp Services Inc.

Memorandum

Re: Liquefaction Analysis for Updated Geotechnical Investigation Report,
Proposed Addition to Apartment Building, 173-177 Preston Street, Ottawa, Ontario
February 27, 2014

We trust that the above comments are satisfactory. Should you have any questions or comments, please do not hesitate to contact this office.

Yours truly,
exp Services Inc.

Thein Aung, M. Sc., P. Eng., FGS
Sr. Geotechnical Engineer, Geotechnical Services
Earth and Environment

Ismail Taki, M. Eng., P. Eng.
Manager, Geotechnical Services
Earth and Environment
# Liquefaction Analysis Results

**Job Title:** Liquefaction Analysis  
**Job No.:** OTT-216595  
**Client:** Padam Holding  
**Address:** 173-175 Preston Street Ottawa  
**Calculated By:** Thein Aung, M. Sc., P. Eng., FGS  
**Reviewed By:** Z = 0

### Input Assumptions

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### CRR Formula

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<td>NCEER Workshop (1997)</td>
<td>True</td>
</tr>
<tr>
<td>Boulanger &amp; Idriss (2004)</td>
<td>False</td>
</tr>
<tr>
<td>Vancouver Task Force (2007)</td>
<td>False</td>
</tr>
<tr>
<td>Cetin et al. (2004)</td>
<td>False</td>
</tr>
<tr>
<td>Chinese Code</td>
<td>False</td>
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<tr>
<td>Seed et al. (1983)</td>
<td>False</td>
</tr>
<tr>
<td>Japanese Highway Bridge Code</td>
<td>False</td>
</tr>
<tr>
<td>Tokimatsu &amp; Yoshimi (1983)</td>
<td>False</td>
</tr>
<tr>
<td>Shibata (1981)</td>
<td>False</td>
</tr>
<tr>
<td>Kokusho et al. (1983)</td>
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</table>

### Depth (m) to SPT Slow Counts (N)

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>SPT Slow Counts (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>43</td>
</tr>
<tr>
<td>0.76</td>
<td>17</td>
</tr>
<tr>
<td>1.5</td>
<td>18</td>
</tr>
<tr>
<td>2.28</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>3.8</td>
<td>7</td>
</tr>
<tr>
<td>4.57</td>
<td>4</td>
</tr>
<tr>
<td>5.33</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
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</table>

### Layer Details

<table>
<thead>
<tr>
<th>Layer Thickness (m)</th>
<th>Soil Type</th>
<th>Unit Weight (kN/m³)</th>
<th>Fines Content (%)</th>
<th>D50 (mm)</th>
<th>Prone to Liquefaction?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gravel</td>
<td>22</td>
<td>30</td>
<td>4</td>
<td>True</td>
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<tr>
<td>0.6</td>
<td>Sand</td>
<td>21</td>
<td>15</td>
<td>0.7</td>
<td>True</td>
</tr>
<tr>
<td>2.3</td>
<td>Sand</td>
<td>21</td>
<td>15</td>
<td>0.7</td>
<td>True</td>
</tr>
<tr>
<td>3.3</td>
<td>Sand</td>
<td>20</td>
<td>10</td>
<td>0.8</td>
<td>True</td>
</tr>
</tbody>
</table>
Liquefaction Analysis Results

Job Title: Liquefaction Analysis
Job No.: OTT-216595
Client: Padom Holding
Address: 173-175 Preston Street Ottawa
Calculated By: Thein Aung, M.Sc., P.Eng., FGS

Borehole: BH-2
Coordinates:
X = 0
Y = 0
Reviewed By: Z = 0
Liquefaction Analysis Results

Job Title: Liquefaction Analysis
Job No.: OTT-216595
Client: Padom Holding
Address: 173-175 Preston Street Ottawa
Calculated By: Thein Aung, M. Sc., P. Eng., FGS

Borehole: BH-2
Coordinates:
X = 0
Y = 0
Reviewed By: Z = 0
National Building Code ground motions:
2% probability of exceedance in 50 years (0.000404 per annum)

<table>
<thead>
<tr>
<th></th>
<th>Sa(0.2)</th>
<th>Sa(0.5)</th>
<th>Sa(1.0)</th>
<th>Sa(2.0)</th>
<th>PGA</th>
</tr>
</thead>
<tbody>
<tr>
<td>ground</td>
<td>0.635</td>
<td>0.308</td>
<td>0.137</td>
<td>0.046</td>
<td>0.323</td>
</tr>
</tbody>
</table>

Notes. Spectral and peak hazard values are determined for firm ground (NBCC 2010 soil class C - average shear wave velocity 360-750 m/s). Median (50th percentile) values are given in units of g. 5% damped spectral acceleration (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are tabulated. Only 2 significant figures are to be used. **These values have been interpolated from a 10 km spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the calculated values.**

Ground motions for other probabilities:

<table>
<thead>
<tr>
<th>Probability of exceedance per annum</th>
<th>0.010</th>
<th>0.0021</th>
<th>0.001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability of exceedance in 50 years</td>
<td>40%</td>
<td>10%</td>
<td>5%</td>
</tr>
<tr>
<td>Sa(0.2)</td>
<td>0.089</td>
<td>0.249</td>
<td>0.386</td>
</tr>
<tr>
<td>Sa(0.5)</td>
<td>0.043</td>
<td>0.122</td>
<td>0.186</td>
</tr>
<tr>
<td>Sa(1.0)</td>
<td>0.017</td>
<td>0.056</td>
<td>0.087</td>
</tr>
<tr>
<td>Sa(2.0)</td>
<td>0.006</td>
<td>0.018</td>
<td>0.028</td>
</tr>
<tr>
<td>PGA</td>
<td>0.039</td>
<td>0.122</td>
<td>0.201</td>
</tr>
</tbody>
</table>

References

National Building Code of Canada 2010 NRCC no. 53301; sections 4.1.8, 9.20.1.2, 9.23.10.2, 9.31.6.2, and 6.2.1.3
Appendix C: Climatic Information for Building Design in Canada - table in Appendix C starting on page C-11 of Division B, volume 2

Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File xxxx
Fourth generation seismic hazard maps of Canada: Maps and grid values to be used with the 2010 National Building Code of Canada (in preparation)

See the websites www.EarthquakesCanada.ca and www.nationalcodes.ca for more information

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