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Geotechnical Engineering

Environmental Engineering

Hydrogeology

Geological Engineering

Materials Testing

Building Science

Noise and Vibration Studies

Vibration Monitoring and Control Plan

University of Ottawa Health Science Building
200 Lees Avenue
Ottawa, Ontario

Prepared For

PCL Constructors Canada Inc.

October 6, 2021

Report: PG5656-2

Paterson Group Inc.
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Contents

Appendices

Appendix 1	Proposed Monitor Location Completed Pre-Construction Survey Area
Appendix 2	Sample Vibration Monitoring Memo Soil Profile and Test Data Sheets

1.0 Introduction

Paterson Group (Paterson) was commissioned by PCL Constructors Canada Inc (PCL) to prepare a Vibration Monitoring and Control Plan (VMCP) for the proposed University of Ottawa Health Science Building to be located at 200 Lees Avenue in the City of Ottawa.

The objective of the current study was to:

- ☐ Review all available information pertaining to existing infrastructure utilities, including the OLRT Confederation Line, in the vicinity of the proposed development.

- ☐ Provide vibration monitoring procedures and criteria for construction of the proposed development.

The following report has been prepared specifically and solely for the aforementioned project which is described herein.

2.0 Background

2.1 Proposed Project

The proposed development at 200 Lees Avenue will consist of a multi-storey institutional building for the University of Ottawa Health Science department. The building will be slab-on-grade with deep foundation supports to the bedrock surface.

2.2 Site Conditions

The subject site is located on the University of Ottawa campus at 200 Lees Avenue. It was noted that three buildings were demolished at the subject site for the proposed building. The site is bordered by a university parking lot and Highway 417 to the north, two existing university buildings to the east, the Rideau River to the south and the Ottawa Light Rail Transit (OLRT) Confederation Line to the west. A proximity study completed for the OLRT Confederation Line was completed by Paterson and can be found under Paterson Group Report PG5656-1 dated June 25, 2021.

2.3 Subsurface Conditions

A drilling investigation was completed as part of a geotechnical investigation by Paterson for the subject site on June 11 and 14, 2021. Generally, the subsurface profile consisted of glacial till or grey clayey silt underlying a brown silty sand fill layer. Black shale bedrock was encountered at depths of 12.27 m to 14.45 m. The Soil Profile and Test Data Sheets from the subject site are provided in Appendix 2.

2.4 Purpose and Scope

2.4.1 Ottawa Light Rail Transit - Confederation Line

Due to the presence of the OLRT Confederation Line located to the west of the subject site, the contractor should take extra precaution to minimize vibrations resulting from pile driving and other construction activities.

It is understood the proposed building will be slab on grade with the load supported on the bedrock surface via a deep foundation system. For all caisson and piling operations, it is recommended the contractor begin at the southern portion of the site and gradually decrease the distance between the construction activities and the OLRT Confederation Line.

This will ensure that the vibrations caused by caisson or piling operations will start at minimal levels, but the magnitude of the vibrations will increase as the distance between the caisson or piling activities decrease. Utilizing this procedure will ensure the vibration intensity will be monitored and the contractor will be able to adjust and control the caisson and piling operations such that once caisson and piling operations are at the western portion of the site, they are not exceeding the vibration limits outlined in subsection 5.1.

2.4.2 Other Buildings and Structures

The contractor should take precautions to minimize the vibrations resulting from the deep foundations work and other construction activities at the pre-existing University of Ottawa buildings to the east.

☐ As previously discussed in subsection 2.4.1, it is recommended the deep foundation work begin at the south end of the site. This will allow the contractor to adjust the work such that vibration levels are not being exceeded at the university buildings as the distance between the active work and building decreases. Vibrational limits for all other buildings and structures, such as the existing university buildings, are outlined in subsection 5.1.

3.0 Regulatory Requirements and Consultation

3.1 Regulatory Requirements

The contractor should ensure all regulatory requirements, such as Transportation of Dangerous Goods, noise by-laws, etc. are met during the excavation program.

3.2 Consultation

A copy of the VMCP should be provided to all parties involved with the construction for review. A meeting between PCL, Paterson Group (Paterson) and any contractor(s) should be conducted prior to any excavation or construction of the subject site to review the following:

☐ Review the pre-condition/pre-construction survey.

☐ Control measures (i.e. vibrations, noise, dust).

☐ Vibration monitoring locations.

☐ Tracking and reporting of excavation progress.

☐ Review procedure for exceedances (i.e. vibrations, noise, dust), complaints, evaluation and corrective measures.

Any concerns or questions will be addressed prior to construction.

4.0 Vibration Assessment Criteria

4.1 References

The following reference materials were reviewed to establish the vibration criteria:

- ☐ Deutsches Institut für Normung, Germany. DIN 4150-3:1999 Structural vibration - Effects of vibration on structures.

- ☐ U.S. Bureau of Mines, Washington, D.C. USBM Report No. RI8507: Siskind D. E., M. S. Stagg, J. W. Kopp and C. H. Dowding. 1980. Structure Response and Damage Produced by Ground Vibration From Surface Mine Blasting.

- ☐ City of Toronto, By-law No. 514-2008 Section 363-3.6 Construction Vibrations.

- ☐ City of Ottawa, Noise Bylaw No.2004-253, June 2004.

4.2 Vibration Concepts

Vibration levels can be measured in terms of peak particle velocity (PPV), which is measured in millimetres per second (mm/s). Humans can sense vibrations as low as 0.1 mm/s, whereas structures can withstand much higher vibrations levels without causing structural damage. PPV is often measured during blast vibrations since PPV is well related to the stress that is experienced by buildings and structures.

4.3 Pre-construction Criteria

A preconstruction survey of the existing retaining wall along the east side of the OLRT Confederation Line was completed prior to the issuing of this report. A sketch of the inspected area has been included in Appendix 1.

The extent of the survey should be sufficient to respond to any inquiries/claims related to the construction operations. The pre-construction survey was carried out by Paterson and the recommended procedures in subsection 5.3 were followed.

A vibration test program should be implemented prior to any mass excavation. The vibration test program should involve any construction methodology the contractor may consider which could cause vibrations (pile driving, etc.). A background vibration study for the subject site is underway at the time of issuing this report. This study will confirm and establish a baseline of the vibrations experienced at the OLRT retaining wall as a result of the nearby transitways.

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5.0 Vibration Monitoring

5.1 Construction Monitoring Program

The monitoring program will incorporate real time results at the subject site. The monitoring equipment will consist of one (1) tri-axial seismograph that may be relocated throughout the construction process. It is recommended that this be installed at the retaining wall east of the OLRT Confederation Line. It is understood that the monitor will only be in place while deep foundation work such as caissons and piling are being completed. The monitor is capable of measuring vibration intensities up to 254 mm/s at a frequency response of 2 to 250 Hz. A sketch indicating the proposed location is included in Appendix 1. The monitor will be connected to a modem to provide instantaneous results through e-mail and will record vibrations continuously during the construction activities. If the modem is not able to obtain a signal due to the location of the monitor installation, an alternative location may be selected. If there is no signal at the modem at the alternative location, then an alternative program to manually download all vibration results will be required. The frequency of the site visits will be determined by the site activities and the anticipated vibration levels.

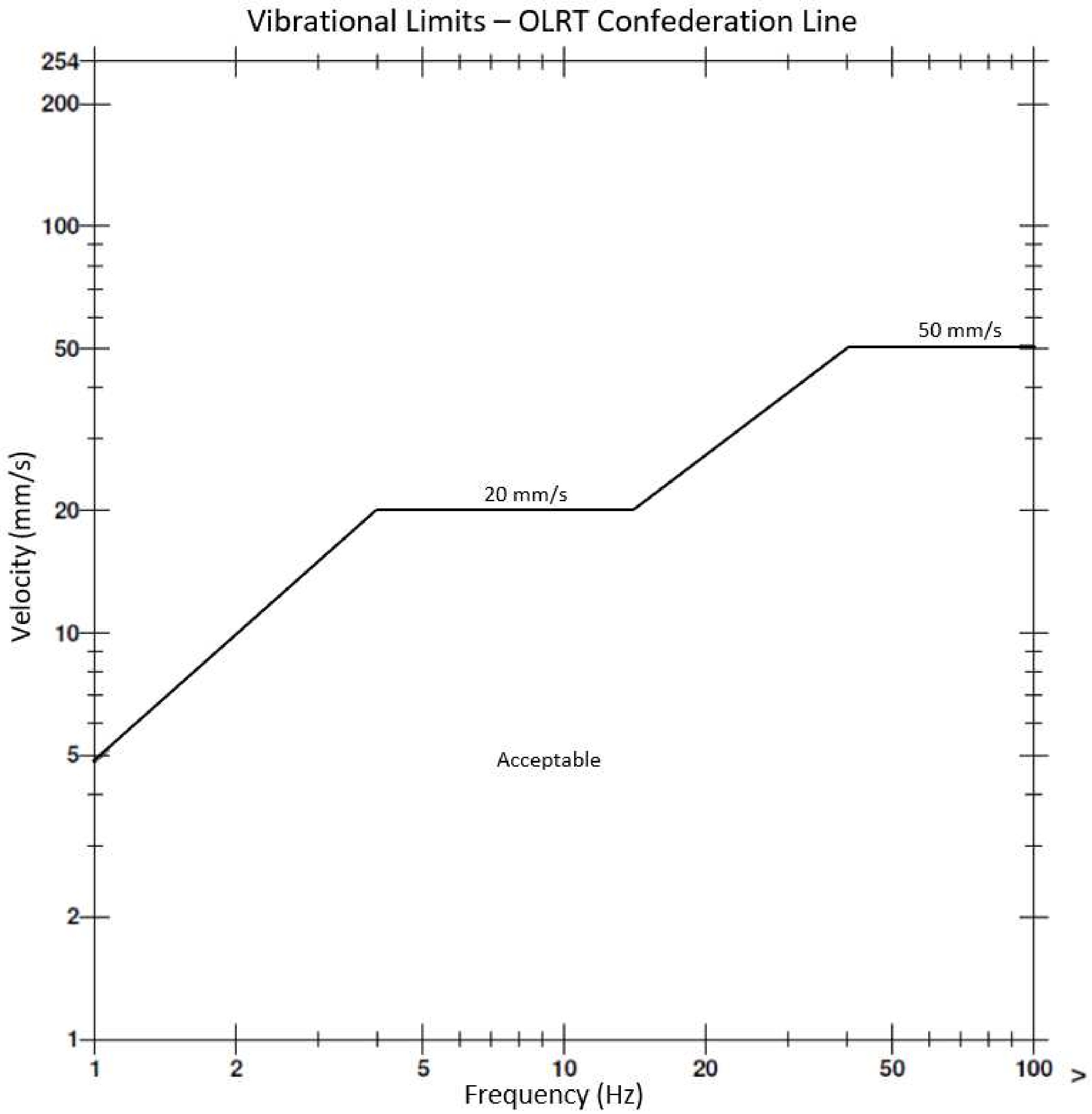
The location of the seismograph should be reviewed periodically throughout construction. As vibrations dissipate over distance, it is critical that the vibration monitor be located at the closest proximity to the construction activities. Therefore, during construction activities the vibration monitor may need to be relocated to an area that is the ‘worst case’ location for each construction activity. Monitor locations will be reviewed on a weekly basis unless directed by PCL.

As noted previously, a background vibration study is underway to determine the baseline vibration levels experienced at the site as a result of the nearby transitways.

Proposed Vibration Limits

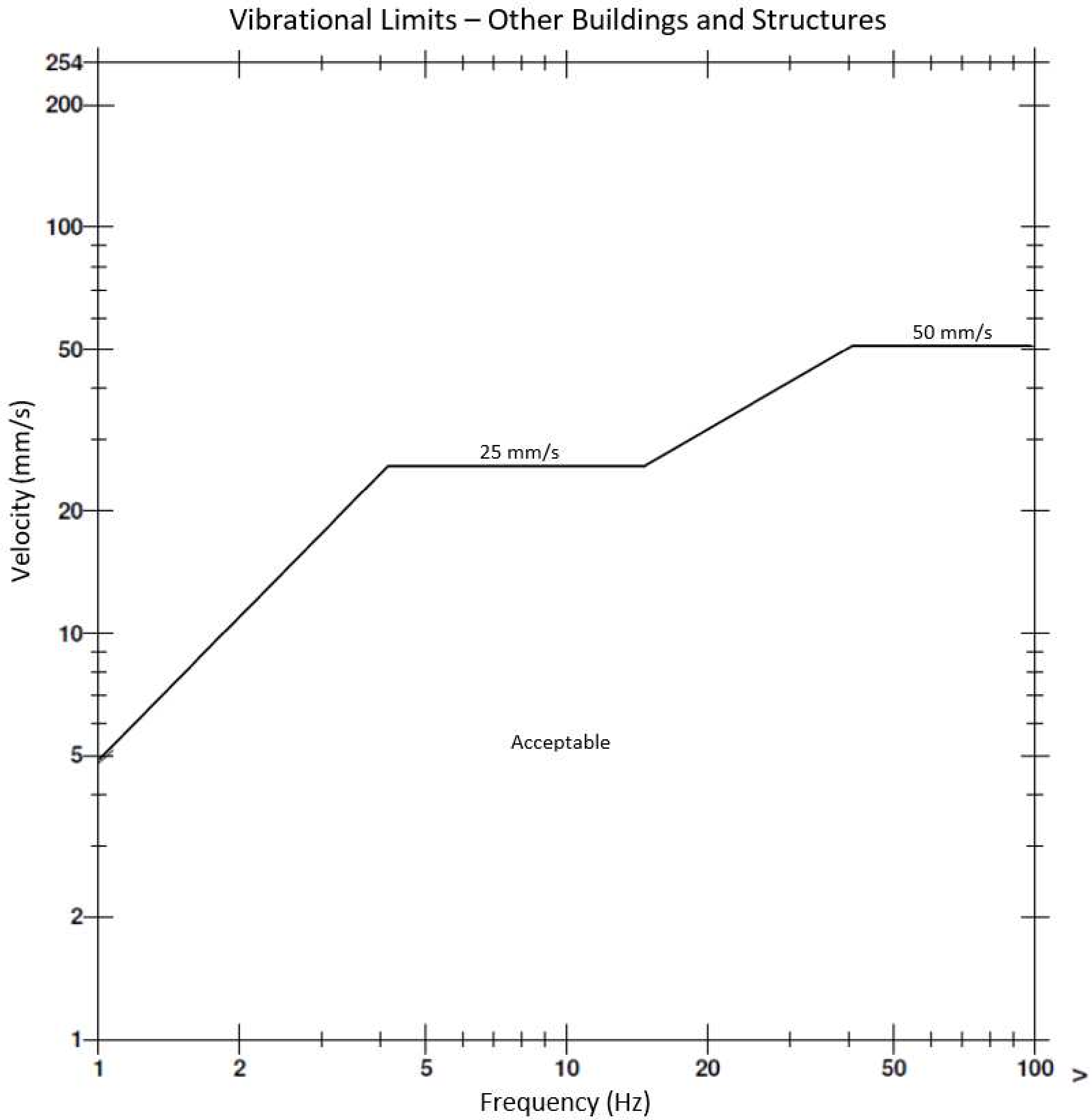
The deep foundation operations should be planned and conducted under the supervision of a licensed and experienced engineer. The following charts outline the proposed vibrational limits. Exceedances levels are found at and above the solid black line. In the event of an exceedance level event, an e-mail or phone call is made to the contractor. All triggered events recorded by the vibration monitor will be emailed to the contractor and vibration monitoring consultant.

Figure 1: Vibration limits for the OLRT Confederation Line:



- ☐ 5 to 20 mm/s for frequencies between 1 and 4 Hz, interpolated
- ☐ 20 mm/s for frequencies 4 to 15 Hz
- ☐ 20 to 50 mm/s for frequencies between 15 and 40 Hz, interpolated
- ☐ 50 mm/s for frequencies above 40 Hz

Figure 2: Vibration limits for all other buildings and structures:



- ☐ 5 to 25 mm/s for frequencies between 1 and 4 Hz, interpolated
- ☐ 25 mm/s for frequencies 4 to 15 Hz
- ☐ 25 to 50 mm/s for frequencies between 15 and 40 Hz, interpolated
- ☐ 50 mm/s for frequencies above 40 Hz

Monitoring Data

The monitoring protocol should include the following information:

- ☐ The vibration monitor is to be connected to a modem that will allow for the immediate recovery of vibration data.
- ☐ All vibrations recorded over 5 mm/s, regardless of frequency, will be emailed directly to PCL and any other required parties, such as civil contractors.

Exceedance Level Events:

- ☐ Paterson will notify all relevant parties via email immediately.
- ☐ Paterson will ensure monitors are functioning.
- ☐ Paterson will issue the vibration exceedance result.

Monitoring should be compliant will all related regulations.

5.2 Incident and Exceedance Reporting

In case an incident/exceedance occurs from construction activities, the Senior Project Management should be notified immediately and any relevant personnel. A report completed by the associated contractor should be submitted which contains the following:

- ☐ Identify the location of the vibration exceedance/incident.
- ☐ The date, time, and nature of the exceedance/incident.
- ☐ The exceedance event and current vibration criteria.
- ☐ Identify the likely cause of the exceedance/incident.
- ☐ Describe the response action that has been completed to date.
- ☐ Describe the proposed measure to address the exceedance/incident.

Based on previous exceedance reports, the contractor should implement mitigation measures for future excavation or any construction activities as necessary and provide updates on the effectiveness of the improvement. All activities that would cause excessive vibrations are to cease until a new procedure has been determined and approved by PCL. Response actions should be pre-determined prior to construction, depending on the approach provided to protect elements.

5.3 Pre-Construction/Pre-existing Condition Assessment

A pre-construction survey is a photographic or video survey of the pre-existing condition of the accessible structure (i.e. retaining wall) or the ground level and basement level interior and exterior of the building in proximity to the aforementioned site. The following pre-construction survey was completed by Paterson survey:

☐ Retaining wall and bike path along the east side of the OLRT Confederation Line. A sketch showing the area covered in this pre-construction survey is included in Appendix 1.

During the inspection, all deficiencies that were observed within the accessible areas were noted and photographed. These include, but are not limited to, cracks in the concrete slab or wall, uneven patching repairs on walls and stairs, general wear on foundation walls, concrete slabs or exterior finishes, and any staining, repairs, or structural abnormalities.

6.0 Reporting and Reviewing

6.1 Internal Reporting

A weekly report will be completed when the vibration monitors are operational regardless if there are any exceedances or not. The following will be included within the weekly report:

- ☐ Locations of vibration monitor.
- ☐ Equipment type, settings, and calibration history.
- ☐ Any exceedance correspondence, location, and reasoning.

All project files for this project are electronic, and incidents should be logged on BIM 360 Field as non-conformance. A typical example of an internal report is included in Appendix 2.

6.2 Review

The VMCP should be reviewed prior to construction with all parties involved. The review process is to reflect changes in any guidelines, technology, or operational procedures.

We trust that this information satisfies your immediate request.

Best Regards,

Paterson Group Inc.

Carly Ladd

Carly R. Ladd, B.Sc.

Stephanie A. Boisvenue, P.Eng.

Report Distribution:

- ☐ PCL Constructors (3 copies)
- ☐ Paterson Group (1 copy)

APPENDIX 1

Proposed Location of Vibration Monitor

Completed Pre-Construction Survey Area

Vibration Monitor at the retaining wall to the east of the OLRT Confederation Line

Proposed Vibration Monitor Location – PG5656 – PCL – 200 LEES AVENUE

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PRE-CONSTRUCTION AREA – PG5656 – PCL – 200 LEES AVENUE

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APPENDIX 2

Sample Vibration Monitoring Report

Soil Profile and Test Data Sheets

patersongroup **memorandum**
consulting engineers

re: **Vibration Monitoring Program - Summary of Results**
uOttawa Health Sciences Building - 200 Lees Avenue - Ottawa
to:
date:
file: PG5656-MEMO.XX

Further to your request, Paterson Group (Paterson) has reviewed the results of the vibration monitoring program implemented for the proposed development at 200 Lees Avenue in the City of Ottawa.

Instrumentation Installation

A full time continuous on-site vibration monitoring program has been implemented to monitor vibrations from the construction activities at 200 Lees for the proposed development.

The vibration monitoring program has been implemented to monitor vibrations experienced at the OLRT Confederation Line, specifically the pre-existing retaining wall at the east bike path. The monitoring instrument installed consists of an Instantel Micromate Plus tri-directional digital seismographs, which are capable of measuring vibration intensities up to 254 mm/sec at a frequency response of 2 to 250 Hz. The unit is programmed to measure all vibration levels continuously at a sampling rate of 1024 samples per second. The configuration permits continuous vibration monitoring and provides complete coverage of all vibrations, construction induced or otherwise, experienced at the monitored structure. The calibration certificate of the vibration monitor is attached to this memo.

To date, one (1) vibration monitor has been installed as part of the vibration monitoring program. The installation details can be noted below:

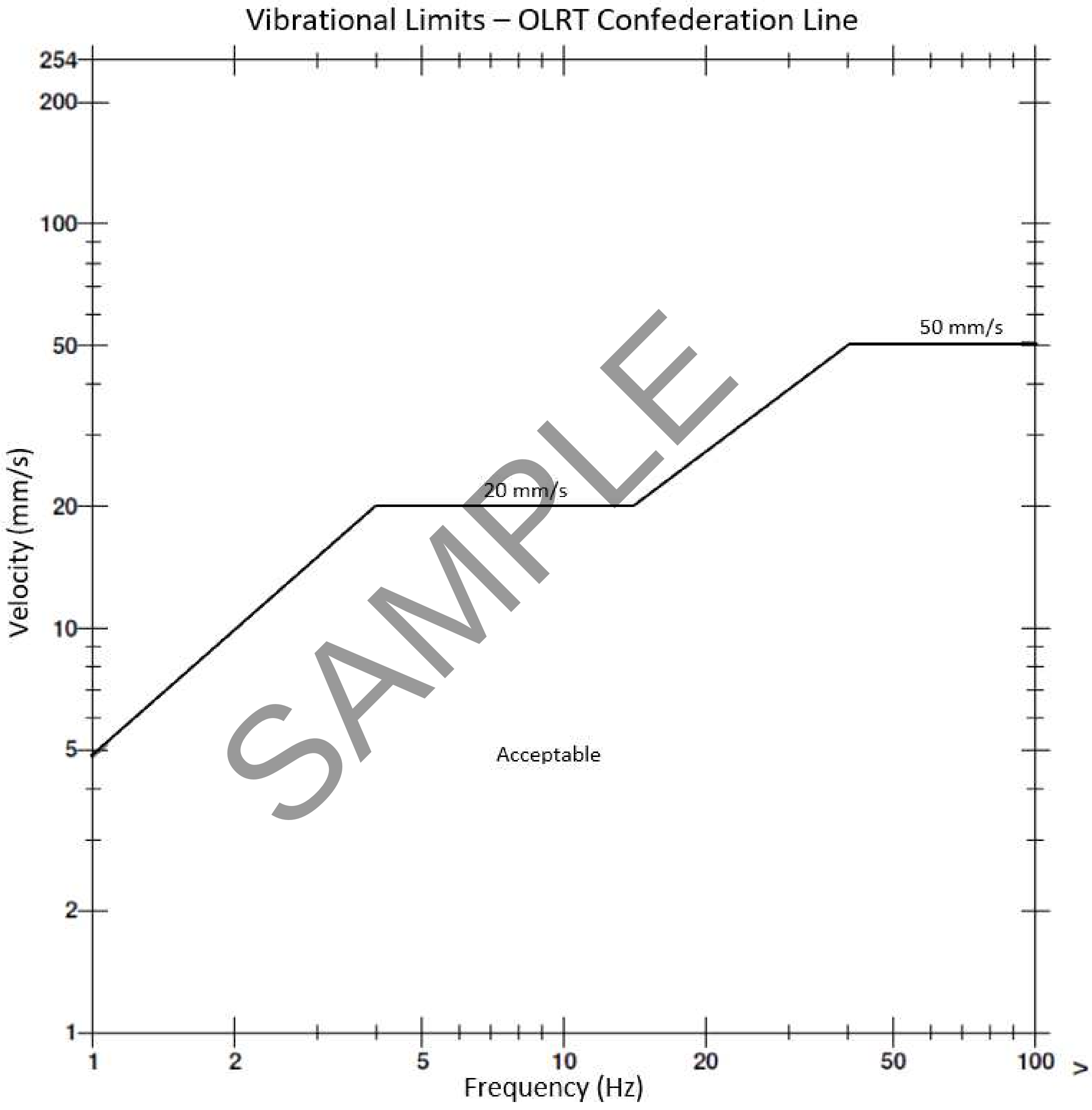
❑ UM***** installed at the retaining wall along the east bike path of the OLRT Confederation Line adjacent to 200 Lees Avenue, installed DATE.

The trigger level for all monitors are set to 5 mm/s.

The seismograph is equipped with a modem and connected to a power supply to transmit all readings through e-mail that can be reviewed immediately. A summary of the readings and relevant information, if applicable, is presented in the vibration monitoring results appended to the current report.

Construction Vibration Limits

Vibrations are monitored by peak particle velocities (PPV) of the vibration in parallel with the vibration frequencies. As a guideline to limit damage to pre-existing OLRT structure, the vibrational velocities should be limited as follows:



Humans are more perceptive to vibrations then structures are to potential damage. For instance, humans can perceive vibrations as low as 0.12 mm/s whereas a low level of vibration for a structure would be 1 mm/s. Therefore, unless vibration monitoring equipment is installed, it is difficult to determine the PPV based on human perception.

Results

There have been XX vibration events recorded that exceeded the 5 mm/s trigger between DATE 1 and DATE 2. A summary of every vibration has been attached to this letter. The full waveforms for the five largest vibrations have been attached to this letter.

Number of vibrations exceeded the limits set for this project.

We trust that this information satisfies your immediate requirements.

Best Regards,

Paterson Group Inc.

Carly R. Ladd, B.Sc. Stephanie A. Boisvenue, P.Eng.

patersongroup Consulting Engineers

154 Colonnade Road South, Ottawa, Ontario K2E 7J5

SOIL PROFILE AND TEST DATA

Geotechnical Investigation
uOttawa Faculty of Health Sciences Building
Ottawa, Ontario

DATUM Geodetic

FILE NO. PG5656

REMARKS

HOLE NO. BH 1-21

BORINGS BY CME-55 Low Clearance Drill

DATE June 14, 2021

SOIL DESCRIPTION

GROUND SURFACE

Asphaltic concrete 0.10

FILL: Brown silty sand with crushed stone and gravel
- trace asphalt by 0.6m depth 1.45

FILL: Dark brown silty sand with ash and coal 2.21

FILL: Brown to grey silty clay with topsoil, some ash and coal 2.97

GLACIAL TILL: Very stiff, brown silty clay with sand, gravel, cobbles and boulders

- grey by 4.3m depth 5.18

End of Borehole

(GWL @ 3.0m depth based on field observations)

SAMPLE

TYPE	NUMBER	% RECOVERY	N VALUE or RQD
AU	1		
SS	2	40	27
SS	3	75	19
SS	4	50	5
SS	5	75	5
SS	6	42	8
SS	7	0	11

DEPTH (m)	ELEV. (m)
0	61.95
1	60.95
2	59.95
3	58.95
4	57.95
5	56.95

Pen. Resist. Blows/0.3m
● 50 mm Dia. Cone

○ Water Content %

20 40 60 80

Piezometer Construction

∇

20 40 60 80 100

Shear Strength (kPa)

▲ Undisturbed △ Remoulded

SOIL PROFILE AND TEST DATA

Geotechnical Investigation
uOttawa Faculty of Health Sciences Building
Ottawa, Ontario

DATUM Geodetic

REMARKS

BORINGS BY CME-55 Low Clearance Drill

DATE June 14, 2021

FILE NO. PG5656

HOLE NO. BH 2-21

SOIL DESCRIPTION	STRATA PLOT	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE % RECOVERY	SAMPLE N VALUE or RQD	DEPTH (m)	ELEV. (m)	Piezometer Construction
GROUND SURFACE						0	61.94	
Asphaltic concrete 0.08		AU	1					
FILL: Brown silty sand with crushed stone and gravel 0.60		SS	2	62	9	1	60.94	
FILL: Ash and coal with brown silty sand, some gravel		SS	3	50	6	2	59.94	
		SS	4	42	4	3	58.94	
3.96		SS	5	62	1			
TOPSOIL 4.42		SS	6	42	5	4	57.94	∇
Stiff, brown **CLAYEY SILT** 5.18		SS	7	62	5	5	56.94	
End of Borehole								

Pen. Resist. Blows/0.3m
● 50 mm Dia. Cone

○ Water Content %

20 40 60 80

20 40 60 80 100
Shear Strength (kPa)
▲ Undisturbed △ Remoulded

patersongroup Consulting Engineers

154 Colonnade Road South, Ottawa, Ontario K2E 7J5

SOIL PROFILE AND TEST DATA

Geotechnical Investigation
uOttawa Faculty of Health Sciences Building
Ottawa, Ontario

DATUM Geodetic

REMARKS

BORINGS BY CME-55 Low Clearance Drill

DATE June 14, 2021

FILE NO. PG5656

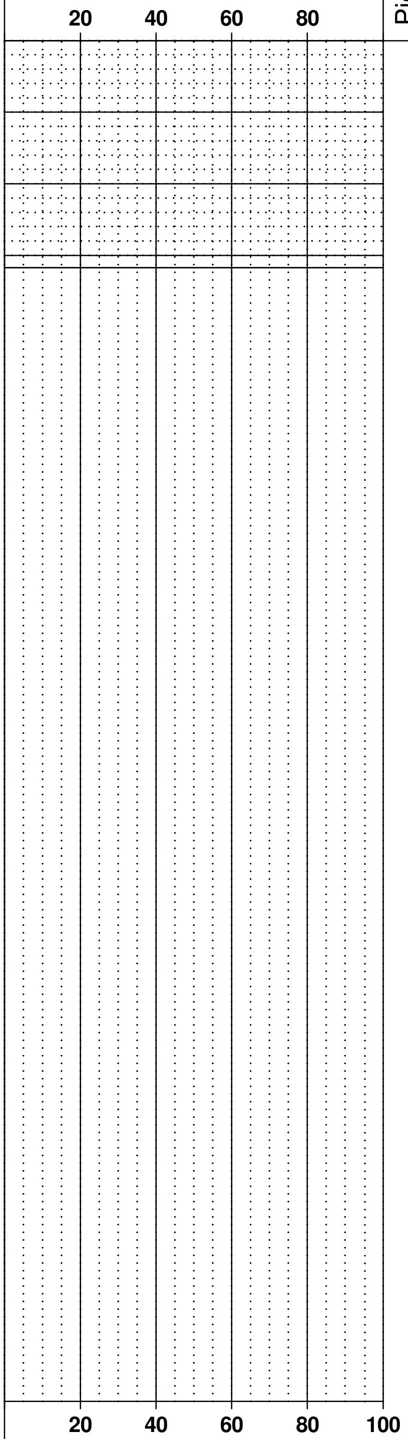
HOLE NO. BH 3-21

SOIL DESCRIPTION	STRATA PLOT	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE % RECOVERY	SAMPLE N VALUE or RQD	DEPTH (m)	ELEV. (m)	Pen. Resist. Blows/0.3m ● 50 mm Dia. Cone ○ Water Content %	Piezometer Construction
GROUND SURFACE						0	61.70		
Asphaltic concrete 0.08		AU	1						
FILL: Brown silty sand with crushed stone and gravel 0.60		SS	2	67	28	1	60.70		
FILL: Brown silty sand, some ash and coal, trace clay and gravel		SS	3	21	11	2	59.70		
		SS	4	75	12				
3.17		SS	5	0	50+	3	58.70		

End of Borehole

Practical refusal to augering at 3.17m depth.

(BH dry upon completion)



Shear Strength (kPa)

▲ Undisturbed △ Remoulded

SOIL PROFILE AND TEST DATA

Geotechnical Investigation
uOttawa Faculty of Health Sciences Building
Ottawa, Ontario

DATUM Geodetic
FILE NO. **PG5656**
REMARKS
HOLE NO. **BH 4-21**
BORINGS BY CME-55 Low Clearance Drill
DATE June 14, 2021

SOIL DESCRIPTION GROUND SURFACE	TYPE	NUMBER	% RECOVERY	N VALUE or RQD
Asphaltic concrete 0.08 **FILL:** Brown silty sand with crushed 0.60 stone and gravel, trace clay	AU	1		
	SS	2	50	15
FILL: Dark brown to black silty sand with ash and coal, some gravel 4.42	SS	3	75	14
	SS	4	17	5
	SS	5	25	4
	SS	6	58	3
Very stiff, grey **CLAYEY SILT,** tarce topsoil 5.18	SS	7	75	11
Compact, brown **CLAYEY SILT to SANDY SILT** 7.77	SS	8	67	21
Compact to very dense, grey **SILTY SAND** - trace to some gravel by 10.8m depth 14.10	SS	9	0	16
	SS	10	83	43
	SS	11	67	94
	SS	12	75	78
	SS	13	100	50+
BEDROCK: Fair to excellent quality, black shale 17.20	RC	1	100	50
	RC	2	100	73
	RC	3	100	100
End of Borehole (GWL @ 5.5m depth based on field observations)				

DEPTH (m)	ELEV. (m)
0	61.84
1	60.84
2	59.84
3	58.84
4	57.84
5	56.84
6	55.84
7	54.84
8	53.84
9	52.84
10	51.84
11	50.84
12	49.84
13	48.84
14	47.84
15	46.84
16	45.84
17	44.84

Pen. Resist. Blows/0.3m
● **50 mm Dia. Cone**
○ **Water Content %**
20 40 60 80

20 40 60 80 100
Shear Strength (kPa)
▲ Undisturbed △ Remoulded

Piezometer Construction

patersongroup Consulting Engineers
154 Colonnade Road South, Ottawa, Ontario K2E 7J5

SOIL PROFILE AND TEST DATA

Geotechnical Investigation
uOttawa Faculty of Health Sciences Building
Ottawa, Ontario

DATUM Geodetic

REMARKS

BORINGS BY CME-55 Low Clearance Drill

DATE June 11, 2021

FILE NO. PG5656

HOLE NO. BH 5-21

SOIL DESCRIPTION	STRATA PLOT	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE % RECOVERY	SAMPLE N VALUE or RQD	DEPTH (m)	ELEV. (m)
GROUND SURFACE						0	61.95
Asphaltic concrete 0.08		AU	1				
FILL: Brown silty sand with crushed stone, gravel, trace wood 0.60		SS	2	42	45	1	60.95
		SS	3	0		2	59.95
FILL: Dark brown to black silty sand, some ash, coal, wood and brick, trace gravel		SS	4	33	2	3	58.95
		SS	5	25	10		
		SS	6	42	2	4	57.95
- some clay by 4.7m depth 5.18		SS	7	42	3	5	56.95
End of Borehole							
(BH dry upon completion)							

Pen. Resist. Blows/0.3m
● **50 mm Dia. Cone**

○ **Water Content %**

20 40 60 80

Piezometer Construction

20 40 60 80 100
Shear Strength (kPa)
▲ Undisturbed △ Remoulded

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154 Colonnade Road South, Ottawa, Ontario K2E 7J5

SOIL PROFILE AND TEST DATA

Geotechnical Investigation
uOttawa Faculty of Health Sciences Building
Ottawa, Ontario

DATUM Geodetic

FILE NO. **PG5656**

REMARKS

HOLE NO. **BH 6-21**

BORINGS BY CME-55 Low Clearance Drill

DATE June 11, 2021

GROUND SURFACE

SOIL DESCRIPTION	Depth to base (m)
FILL: Organics with silty sand	0.08
FILL: Brown silty sand, trace gravel, cobbles, organics	0.43
FILL: Brown to black silty sand with ash, coal, slag, trace wood, brick and gravel	5.79
Compact, brownt o grey **CLAYEY SILT to SANDY SILT,** trace organics	7.16
GLACIAL TILL: Dense to very dense, dark grey silty sand with gravel, cobbles and boulders, trace clay	12.27
BEDROCK: Poor to excellent quality, black shale - vertical seams from 12.4 to 13.5m, 13.9 to 14.2m and from 14.4 to 15.1m depths	15.06

End of Borehole

(GWL @ 6.10m depth based on field observations)

SAMPLE

TYPE	NUMBER	% RECOVERY	N VALUE or RQD
AU	1		
SS	2	12	2
SS	3	0	3
SS	4	58	3
SS	5	33	5
SS	6	42	4
SS	7	33	4
SS	8	58	11
SS	9	54	47
SS	10	58	26
SS	11	52	106
SS	12	100	50+
RC	1	100	36
RC	2	100	92

DEPTH (m)	ELEV. (m)
0	62.05
1	61.05
2	60.05
3	59.05
4	58.05
5	57.05
6	56.05
7	55.05
8	54.05
9	53.05
10	52.05
11	51.05
12	50.05
13	49.05
14	48.05
15	47.05

Pen. Resist. Blows/0.3m
● **50 mm Dia. Cone**

○ **Water Content %**

20 40 60 80

Piezometer Construction

∇

20 40 60 80 100

Shear Strength (kPa)

▲ Undisturbed △ Remoulded

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SOIL PROFILE AND TEST DATA

Geotechnical Investigation
uOttawa Faculty of Health Sciences Building
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DATUM Geodetic

FILE NO. **PG5656**

REMARKS

HOLE NO. **BH 7-21**

BORINGS BY CME-55 Low Clearance Drill

DATE June 11, 2021

SOIL DESCRIPTION	
GROUND SURFACE	
FILL: Brown silty sand with gravel, trace cobbles and organics	0.76
FILL: Brown silty sand with ash, coal and brick, trace wood - black by 3.0m depth - reddish brown by 3.7m depth	4.88
Very stiff, brown to grey **SILTY CLAY,** trace organics	7.16
GLACIAL TILL: Dense, dark grey silty sand with gravel, cobbles and boulders, trace clay	8.70
GLACIAL TILL: Dense, dark grey silty clay with sand, gravel, cobbles, boulders and shale fragments - shale fragments increasing with depth	14.45
BEDROCK: Excellent to good quality, black shale	17.25
End of Borehole (BH dry upon completion)	

SAMPLE TYPE	NUMBER	% RECOVERY	N VALUE or RQD
AU	1		
SS	2	33	2
SS	3	21	1
SS	4	50	5
SS	5	50	3
SS	6	33	3
SS	7	0	17
SS	8	58	14
SS	9	50	47
SS	10	50	44
SS	11	62	24
SS	12	100	50+
RC	1	100	98
RC	2	100	78

DEPTH (m)	ELEV. (m)
0	61.95
1	60.95
2	59.95
3	58.95
4	57.95
5	56.95
6	55.95
7	54.95
8	53.95
9	52.95
10	51.95
11	50.95
12	49.95
13	48.95
14	47.95
15	46.95
16	45.95
17	44.95

Pen. Resist. Blows/0.3m
● **50 mm Dia. Cone**

○ **Water Content %**

20 40 60 80

Piezometer Construction

20 40 60 80 100

Shear Strength (kPa)

▲ Undisturbed △ Remoulded

SYMBOLS AND TERMS

SOIL DESCRIPTION

Behavioural properties, such as structure and strength, take precedence over particle gradation in describing soils. Terminology describing soil structure are as follows:

Desiccated	-	having visible signs of weathering by oxidation of clay minerals, shrinkage cracks, etc.
Fissured	-	having cracks, and hence a blocky structure.
Varved	-	composed of regular alternating layers of silt and clay.
Stratified	-	composed of alternating layers of different soil types, e.g. silt and sand or silt and clay.
Well-Graded	-	Having wide range in grain sizes and substantial amounts of all intermediate particle sizes (see Grain Size Distribution).
Uniformly-Graded	-	Predominantly of one grain size (see Grain Size Distribution).

The standard terminology to describe the relative strength of cohesionless soils is the compactness condition, usually inferred from the results of the Standard Penetration Test (SPT) ‘N’ value. The SPT N value is the number of blows of a 63.5 kg hammer, falling 760 mm, required to drive a 51 mm O.D. split spoon sampler 300 mm into the soil after an initial penetration of 150 mm. An SPT N value of “P” denotes that the split-spoon sampler was pushed 300 mm into the soil without the use of a falling hammer.

Compactness Condition	‘N’ Value	Relative Density %
Very Loose	<4	<15
Loose	4-10	15-35
Compact	10-30	35-65
Dense	30-50	65-85
Very Dense	>50	>85

The standard terminology to describe the strength of cohesive soils is the consistency, which is based on the undisturbed undrained shear strength as measured by the in situ or laboratory shear vane tests, unconfined compression tests, or occasionally by the Standard Penetration Test (SPT). Note that the typical correlations of undrained shear strength to SPT N value (tabulated below) tend to underestimate the consistency for sensitive silty clays, so Paterson reviews the applicable split spoon samples in the laboratory to provide a more representative consistency value based on tactile examination.

Consistency	Undrained Shear Strength (kPa)	‘N’ Value
Very Soft	<12	<2
Soft	12-25	2-4
Firm	25-50	4-8
Stiff	50-100	8-15
Very Stiff	100-200	15-30
Hard	>200	>30

SYMBOLS AND TERMS (continued)

SOIL DESCRIPTION (continued)

Cohesive soils can also be classified according to their “sensitivity”. The sensitivity, S_t, is the ratio between the undisturbed undrained shear strength and the remoulded undrained shear strength of the soil. The classes of sensitivity may be defined as follows:

Low Sensitivity: $S_t < 2$
Medium Sensitivity: $2 < S_t < 4$
Sensitive: $4 < S_t < 8$
Extra Sensitive: $8 < S_t < 16$
Quick Clay: $S_t > 16$

ROCK DESCRIPTION

The structural description of the bedrock mass is based on the Rock Quality Designation (RQD).

The RQD classification is based on a modified core recovery percentage in which all pieces of sound core over 100 mm long are counted as recovery. The smaller pieces are considered to be a result of closely-spaced discontinuities (resulting from shearing, jointing, faulting, or weathering) in the rock mass and are not counted. RQD is ideally determined from NQ or larger size core. However, it can be used on smaller core sizes, such as BQ, if the bulk of the fractures caused by drilling stresses (called “mechanical breaks”) are easily distinguishable from the normal in situ fractures.

RQD %	**ROCK QUALITY**
90-100	Excellent, intact, very sound
75-90	Good, massive, moderately jointed or sound
50-75	Fair, blocky and seamy, fractured
25-50	Poor, shattered and very seamy or blocky, severely fractured
0-25	Very poor, crushed, very severely fractured

SAMPLE TYPES

SS - Split spoon sample (obtained in conjunction with the performing of the Standard Penetration Test (SPT))
TW - Thin wall tube or Shelby tube, generally recovered using a piston sampler
G - "Grab" sample from test pit or surface materials
AU - Auger sample or bulk sample
WS - Wash sample
RC - Rock core sample (Core bit size BQ, NQ, HQ, etc.). Rock core samples are obtained with the use of standard diamond drilling bits.

SYMBOLS AND TERMS (continued)

PLASTICITY LIMITS AND GRAIN SIZE DISTRIBUTION

WC% - Natural water content or water content of sample, %
LL - Liquid Limit, % (water content above which soil behaves as a liquid)
PL - Plastic Limit, % (water content above which soil behaves plastically)
PI - Plasticity Index, % (difference between LL and PL)

Dxx - Grain size at which xx% of the soil, by weight, is of finer grain sizes
These grain size descriptions are not used below 0.075 mm grain size
D10 - Grain size at which 10% of the soil is finer (effective grain size)
D60 - Grain size at which 60% of the soil is finer

Cc - Concavity coefficient = $(D30)^2 / (D10 \times D60)$
Cu - Uniformity coefficient = D60 / D10

Cc and Cu are used to assess the grading of sands and gravels:
Well-graded gravels have: $1 < Cc < 3$ and $Cu > 4$
Well-graded sands have: $1 < Cc < 3$ and $Cu > 6$
Sands and gravels not meeting the above requirements are poorly-graded or uniformly-graded.
Cc and Cu are not applicable for the description of soils with more than 10% silt and clay (more than 10% finer than 0.075 mm or the #200 sieve)

CONSOLIDATION TEST

p'_o - Present effective overburden pressure at sample depth
p'_c - Preconsolidation pressure of (maximum past pressure on) sample
Ccr - Recompression index (in effect at pressures below p'_c)
Cc - Compression index (in effect at pressures above p'_c)

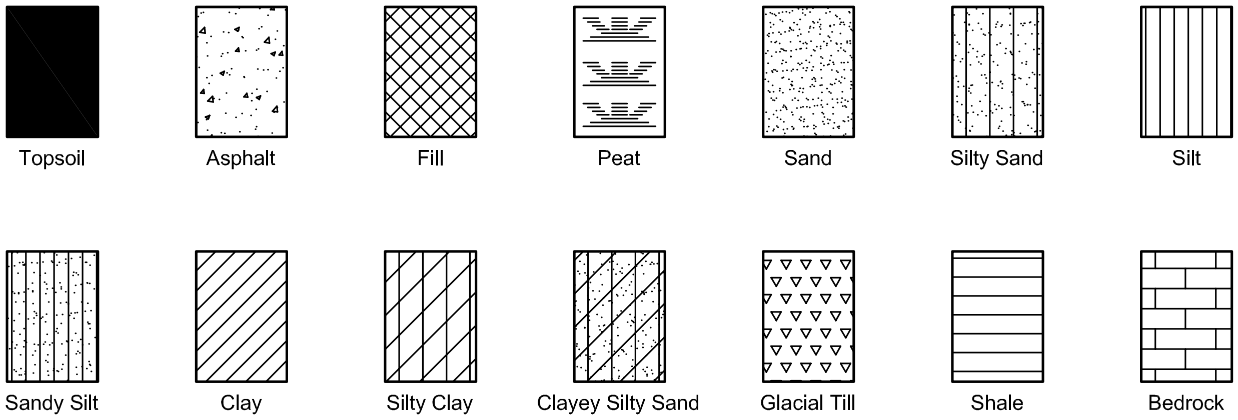
OC Ratio Overconsolidaton ratio = p'_c / p'_o
Void Ratio Initial sample void ratio = volume of voids / volume of solids
Wo - Initial water content (at start of consolidation test)

PERMEABILITY TEST

k - Coefficient of permeability or hydraulic conductivity is a measure of the ability of water to flow through the sample. The value of k is measured at a specified unit weight for (remoulded) cohesionless soil samples, because its value will vary with the unit weight or density of the sample during the test.

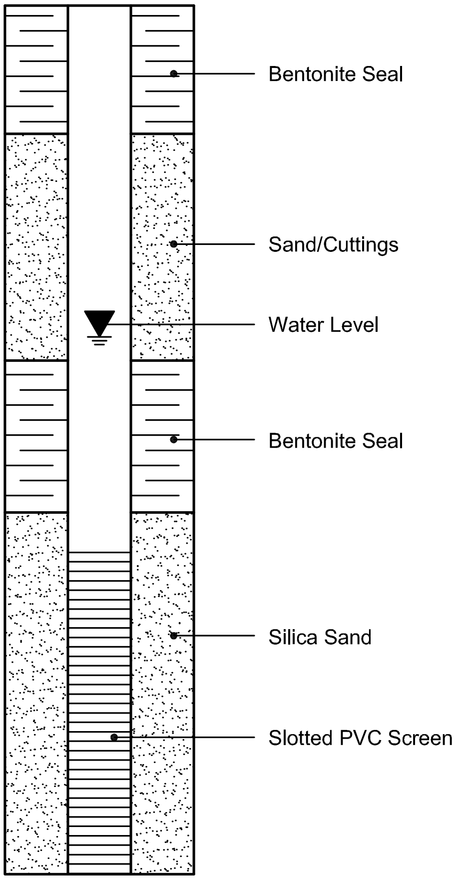
SYMBOLS AND TERMS (continued)

STRATA PLOT



MONITORING WELL AND PIEZOMETER CONSTRUCTION

MONITORING WELL CONSTRUCTION



PIEZOMETER CONSTRUCTION