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Geotechnical Engineering Report
Construction of New Industrial Facilities
Barette-Chapais Lumber Mill

Project No.: 7001420

Distribution: Mr. Christopher Amey, (PDF)
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GROUPE QUALITAS INC. May 13, 2014

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This report numbers 58 pages including appendices and must not be partially reproduced without the authorization of Groupe Qualitas Inc.

1.0 INTRODUCTION

Groupe Qualitas Inc. (referred to as Qualitas hereafter) was mandated by Rentech to carry out a site investigation for the construction project of new industrial facilities at the Barette-Chapais Lumber Mill, in the Nord-Du-Québec region.

This report presents our geotechnical investigation pertaining to this project. The terms of reference of the report are in general accordance with our proposal dated April 17th, 2014 (Proposal No. 14-00971). The field works and recommendation have been carried out considering the project is at the feasibility stage.. The objective of the investigation is to give a geotechnical overlook of the site geology to provide general construction recommendations, to identify and review key geotechnical issues, and to provide a basis to develop construction cost estimates.

The report encloses in order of appearance: site and project description, investigation methodology, ground conditions, geotechnical recommendations and bearing capacity of soil and rock.

This geotechnical report was written for Rentech and the project engineering consultants in order to achieve the previously described objectives. Qualitas will have to be informed of any significant modification to the project in order to revalidate the recommendations stated in this report.

2.0 SITE AND PROJECT DESCRIPTION

The Barette-Chapais Lumber Mill is located near the town of Chapais, in Quebec (Figure 1). The site is bounded to the north by a CN railway and to the south by a partially backfilled area. An existing warehouse is located at the northwest corner of the site. The ground surface is generally inclined to the east and is irregular because of the presence of rock outcrops and some backfilled areas.. The investigated site has approximately 16 500 sq. m. of area.

This project plans for the construction of a plant and a storage building. The latter will be adjacent to the existing warehouse. Based on the information communicated by the design engineer, the plant is to be located on the eastern side of the site (boreholes B-01 to B-04, B-07 and B-08), while the new storage building is to be located on the northwest portion of the site (boreholes B-05, B-06, B-09, B-10 and B-11).

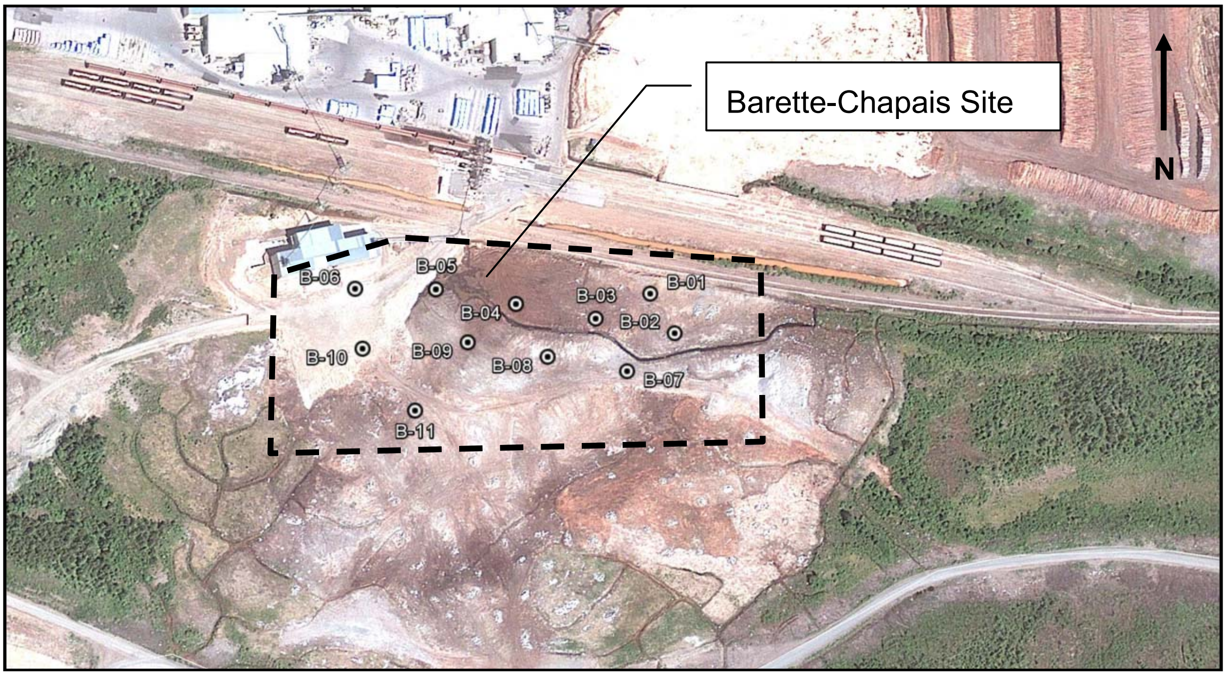

Figure 1 – Location Map

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3.0 GEOTECHNICAL INVESTIGATION SUMMARY

3.1 GEOTECHNICAL FIELD WORK

The field work was conducted from May 2th to May 7th, 2014. The scope of work originally included 11 boreholes. However, because of access difficulties, only 7 of the original 11 boreholes (B-05 to B-11) were completed using a rotary drill rig (Longyear model L-34, mounted on a trailer). The boreholes B-02 to B-04 were carried out with an Acker Lighweight Motorized hoist and a portable Aluminium Derrick (Acker tripod). At the location of those 3 boreholes, the depth to bedrock was further defined using a Pionjar percussion rock drill. At the location of B-01, the bedrock was encountered near the surface (approximately 1.6 meter deep) using the Pionjar drill. The field work was carried out under the supervision of a qualified geotechnical technician.

Boreholes B-02 to B-11 were advanced using NW flush joint casings. In each borehole, Standard Penetration Tests (SPT) were performed as per ASTM D1586. At the same time SPT testing was conducted, disturbed soil samples were recovered using a standardized split-spoon sampler (outside diameter of 51 mm and length of 610 mm). SPT testing and soil sampling was carried at intervals of 0.75 m between the ground surface and 6.0 m of depth (or refusal on bedrock).

In boreholes B-05 to B-11, the rock was cored until 3 m of fair quality rock (RQD > 50%) or 6.0 m of total core length was recovered at each location . Rock core samples were recovered using NQ-caliber diamond core barrels. A general description of the rock was noted by the technician/geologist and *Recuperation* and *Rock Quality Designation* (RQD) were measured for each core run. *Solid Core Recovery* (SCR) was also determined for most core samples.

Table 1 shows the depth reached in each borehole as well as the elevation of the bedrock.

TABLE 1 : Depths reached in the boreholes					
Borehole	**Date**	**Surface elevation (m)**	**Bedrock elevation (m)**	**End of borehole elevation (m)**	**Depth of borehole (m)**
B-01	2014-05-07	384.70	383.70	383.70	1.6
B-02	2014-05-07	382.94	380.01	380.01	2.93
B-03	2014-05-07	382.76	380.78	380.78	1.98
B-04	2014-05-07	382.21	377.38	377.38	4.83
B-05	2014-05-07	384.61	378.82	375.32	9.29
B-06	2014-05-02	386.40	383.22	380.33	6.07
B-07	2014-05-05	384.22	378.96	376.07	8.15
B-08	2014-05-05	384.11	378.83	375.95	8.16
B-09	2014-05-06	385.53	380.48	377.13	8.40
B-10	2014-05-02	385.86	384.51	381.01	4.85
B-11	2014-05-05	385.14	378.94	378.94	6.20

The borehole logs are provided in Appendix 2, at the end of the report.

3.2 INSTRUMENTATION

Casagrande standpipe piezometers were installed in boreholes B-05 to B-11 to measure the groundwater levels in the overburden. The water level inside B-02 to B-04 was measured from within the casing as those boreholes were done last and were located beside a temporary lake maintained by thawing snow. The piezometers consist of a 19-mm diameter polyvinyl chloride plastic (PVC) pipe with a 300-mm long porous Casagrande tip at the bottom of the installation. The porous tip is surrounded by a silica sand filter pack. A bentonite plug is placed above the sand filter and around the PVC standpipe to provide a seal and the rest of the hole is backfilled with cuttings.

3.3 SURVEYING

The borehole locations were designated by the consultant engineer and surveyed on the field by Qualitas with a Trimble Pathfinder ProXRT GPS receiver. Wood survey stakes were left at the true location of every hole for the as-realized survey (to be carried out by others if required). The survey was done in the UTM NAD83 system. Elevations are geodetic and were established using a benchmark anchored in a nearby rock outcrop. The benchmark location and elevation is found on drawing 7001420-01 of appendix 4.

The location of every borehole is shown on the overall site plan (drawing No. 7001420-01) in Appendix 4.

3.4 LABORATORY TESTING

All soil samples and rock core samples were brought back to Qualitas laboratory in Jonquiere (Quebec), to be described and classified. Laboratory tests were performed on selected samples. The complete laboratory testing program is presented in Table 2.

Table 2 : Laboratory tests		
Tests	**Standard**	**Quantity**
Grain Size Analysis of Retained and Passing Material on 5 mm Sieve with Washing of the 80 µm Sieve	LC 21-040	4
Uniaxial Compressive strength	ASTM D2938	2

The unused samples will be stored for a period of one year after the publication date of this report. Unless otherwise specified by Rentech, the samples will be destroyed once this time period has elapsed.

4.0 GROUND CONDITIONS

4.1 GENERAL

Subsurface conditions encountered at specific locations are shown on the borehole logs enclosed in Appendix 2 and discussed below. The general soil profiles observed in the boreholes are reasonably similar, with expected variations in soil composition and unit thickness.

In the following sections, the soil description has been interpreted and simplified to major strata for the purpose of geotechnical analysis. The soil profile is presented in descending order, from the shallowest unit to the deepest.

4.2 SURFICIAL LAYERS

Surficial layer may vary between boreholes locations, from topsoil, to fill materials to organic soil. Table 3 shows the depth at which these layers were encountered as well as their thickness.

The topsoil layer was observed in boreholes B-02, B-03, B-04 and B-08. Generally the topsoil layer, composed of moss, roots and other organics at various stages of decomposition, is less than 0.85 m thick. In borehole B-02, a 0,70 m thick loose sand and silt layer underlies the topsoil layer.

Fill material composed of sand with some silt overlies organic matter in boreholes B-06 and B-09 from the surface to 2,50 m deep, approximately. The organic layer is 0,6 m thick.

Table 3: Thickness of topsoil, fill and organic soil encountered at boreholes				
Borehole	Depth (m)		Thickness (m)	Description
	From	To		
B-02	0.00	0.95	0.25	Topsoil
B-02	0.25	0.95	0.70	Loose sand and silt
B-03	0.00	0.30	0.30	Topsoil
B-04	0.00	0.85	0.85	Topsoil
B-06	0.00	2.55	2.55	Fill: Sand with some silt and gravel
B-06	2.55	3.10	0.55	Organic soil
B-08	0.00	0.09	0.09	Fill: Silty sand
B-08	0.09	0.30	0.21	Topsoil
B-09	0.00	2.25	2.25	Fill: Sand with some silt and traces of gravel
B-09	2.25	2.50	0.25	Fill: Sand with some gravel, presence of wood chips.
B-09	2.50	3.10	0.60	Organic soil

4.3 GLACIAL DEPOSIT (TILL)

The surficial layers overlies a till deposit 1.35 to 5.79 m thick (except at borehole B-06, in which it is 0.08 m thick). The till is mostly composed of silty sand, with some gravel. It also contains cobbles and boulders.

In boreholes B-04 and B-05, a 1.4 m thick, very loose to loose sand and silt layer (SPT N values between 3 to 9), included in the till deposit was encountered at depths of 2.2 m and 4.4 m respectively.

Grain size distribution curves, presented in Appendix 3, show gravel contents between 12% and 33%, sand contents between 45.6% and 62.8% and silt contents between 13.6% and 25.2%. The very loose to loose sand and silt layer encountered in borehole B-04 and B-05 has 1%, 57.2 % and 41.8 % of gravel, sand and silt, respectively.

SPT N values obtained from the till deposit (except boreholes B-04 and B-05 sand and silt layer) vary from 14 to 80 blows per 300 mm indicating compactness ranging from compact to very dense. On average, the N values approximated a blow count of 30 which indicate a compact layer.

Table 4 shows the depth at which the till deposit was encountered and its thickness.

Table 4: Thickness of till layer encountered at boreholes

Borehole	Depth (m)		Thickness (m)	Description
	From	To		
B-02	0.95	2.93	1.98	Sand, some silt and gravel
B-03	0.30	1.98	1.68	Silty sand, some gravel
B-04	0.85	4.83	3.98	Silty sand, some gravel
B-04*	2.2	3.60	1.4	Sand and silt
B-05	0.00	4.4	4.4	Silty sand, trace of gravel
B-05*	4.4	5.79	1.39	Sand and silt
B-06	3.10	3.18	0.08	Sand
B-07	0.00	5.26	5.26	Silty sand, some gravel, trace of cobbles
B-08	0.30	5.28	4.98	Silty sand, some gravel and cobbles, trace of boulders
B-09	3.10	5.05	1.95	Silty sand, some gravel
B-10	0.00	1.35	1.35	Silty sand, trace of gravel
B-11	0.00	1.68	1.68	Silty sand, trace of gravel and cobbles

* Very loose to loose layer of sand and silt embedded in the till deposit

4.4 BEDROCK

Rock core samples were recovered in boreholes B-05 to B-11. Table 5 shows the depth at which bedrock was encountered and the length of the recovered core. Total core recovery as well as RQD values are also shown.

Table 5: Thickness of Bedrock encountered at boreholes						
Borehole	Sample	Depth (m)		Length of core (m)	Recovery (%)	RQD (%)
		From	To			
B-05	CR-9	5.79	6.45	3.50	100	86
	CR-10	6.45	7.25		100	?
	CR-11	7.25	8.04		100	51
	CR-12	8.04	9.29		100	96
B-06	CR-6	3.18	4.46	2.89	100	100
	CR-7	4.46	6.07		100	100
B-07	CR-9	5.26	5.92	2.89	100	90
	CR-10	5.92	7.45		100	85
	CR-11	7.45	8.15		100	86
B-08	CR-10	5.28	6.58	2.88	100	92
	CR-11	6.58	8.16		100	100
B-09	CR-8	5.05	5.54	3.35	100	?
	CR-9	5.54	6.84		100	85
	CR-10	6.84	8.40		100	100
B-10	CR-3	1.35	1.87	3.50	100	65
	CR-4	1.87	2.87		100	78
	CR-5	2.87	3.98		100	90
	CR-6	3.98	4.85		100	80
B-11	CR-4	1.68	2.79	4.52	100	59
	CR-5	2.79	4.40		100	82
	CR-6	4.40	5.30		100	56
	CR-7	5.30	6.20		100	89

The bedrock consists of a light to dark green, aphanitic to fine grained, massive to volcaniclastic, mafic volcanic rock. The rock is affected by a strong carbonate alteration and a weak to moderate sericitic alteration. A strong penetrative schistosity is present throughout and is generally oriented at 60° to the core axis (every boreholes were drilled vertical). Calcite veinlets are locally found; the veinlets crosscut the schistosity and are moderately dipping.

The uniaxial compressive strength of the rock as well as density was measured on two samples. The results of those measurements are presented in table 6 bellow.

Table 6: Uniaxial Compressive Strength and Density of Selected Samples		
Sample (Borehole, Sample, Depth)	**Uniaxial Compressive Strength, (MPa)**	**Density, γ kg/m^3**
B-08, CR9, 5.39 m	85.7	2748
B-11, CR-5, 4.03 m	65.2	2789

Upon examination of the core, three families of structures were discriminated. The first and most prominent family of structures is represented by a weakness plane coplanar with the schistosity. The surface planes of the second family are generally sub-vertical to steeply dipping. The structures representing the third family are sub-horizontal. For each joint set, the spacing and joint condition are presented in table 7. This table also shows the rating for each parameter needed to calculate the RMR Rating (after Bieniawski, 1989).

Table 7: Value for each parameter used to calculate the RMR Rating (after Bieniawski, 1989)			
Parameter			RMR Rating
Intact rock Strength		65 – 85 MPa	13
RQD		50 - 100	13-20
Spacing	Family 1	0.2 m	10
	Family 2	0.45 m	20
	Family 3	1.0 m	20
Joint condition	Family 1	Slickensided	6
	Family 2	Smooth to Slightly rough	12
	Family 3	Rough	22
Water Condition			10
Orientation of joints			0

The RMR value was evaluated using Bieniawski (1989) and varies from 50 to 70 with a mean value of 57 indicating a rock of fair quality (Class III).

The bedrock elevations on site range from 384.51 to 377.38 m. The higher and lower elevations were encountered respectively at borehole B-10 and B-04.

4.5 GROUND WATER

Groundwater levels were measured in Casagrande piezometers installed in boreholes B-05 to B-11. The depth and elevation of the groundwater table at different test locations are shown in Table 8.

Table 8:
Groundwater Level

Test Location	Groundwater Level		Date of measurement
	Depth (m)	Elevation (m)	
B-02*	0.60	382.34	2014-05-07
B-03*	0.00	382.76	2014-05-07
B-04*	0.00	382.21	2014-05-07
B-05	1.82	382.79	2014-05-07
B-06	3.34	383.06	2014-05-07
B-07	1.60	382.66	2014-05-07
B-08	0.87	383.24	2014-05-07
B-09	2.45	383.08	2014-05-07
B-10	1.60	384.26	2014-05-07
B-11	0.38	384.76	2014-05-07

* Presumably stabilized water level observed during a drilling stop, no piezometer installed

It should be noted that groundwater levels can change with climatic conditions and that they are subjected to seasonal variations.

5.0 GEOTECHNICAL RECOMMENDATIONS

5.1 SUBSURFACE CONDITIONS SUMMARY

The overburden is mostly composed of compact till underlying a layer of surficial soils such as top soil, fill or organic soil, which is usually less than 1 meter thick except at boreholes B-06 and B-09, where the thickness is 2.5 m. The occurrence of cobbles and boulders in the till may vary at the site since it was only reported in boreholes B-07, B-08 and B-11.

Shallow bedrock was encountered in every borehole, usually at less than 5 meters of depth

A 1.4 m-thick, very loose to loose sand and silt layer was detected in the till deposit at 2.2 m and 4.4 m of depth in boreholes B-04 and B-05, respectively. The loose state of the layer and its presence needs to be considered in the design.

The bedrock is composed of a mafic volcanic rock with three major families of structures. Based on the RMR values, the rock quality is considered fair.

High groundwater table conditions were encountered at the site, usually at a depth less than 1.5 m.

5.2 PROJECT SUMMARY

The current geotechnical investigation covered most of the site for the construction of new industrial facilities at the Barette-Chapais Lumber Mill. Based on a sketch given by the consultant, the plant's floor will be at level 384.0 m (geodetic elevation) while the storage building's floor will be at level 387.0 m. The floor in both cases will be a slab-on-grade. The embedded depth of foundation will be controlled by the frost penetration depth in this area.

General geotechnical recommendations are given in the following sections, as well as comments pertaining to construction issues.

5.3 FROST PROTECTION

5.3.1 Freezing Index and Frost Penetration

Based on Canada's normal freezing index map [CFEM 2006, Figure 13.6], the mean freezing index in the Barette-Chapais area is approximately 2250 °C-days. The corresponding design (maximum) freezing index reaches 3005 °C-days (approximately 5450 °F-days). The frost penetration is dependent on the freezing index, the type of soil and the water content. For this study, a maximum frost penetration of 2.5 m was estimated.

5.3.2 Frost Protection for Shallow Foundations on Soil

In order to provide sufficient frost protection, all exterior footings (and interior footings in unheated buildings) should be embedded 2.5 m bellow the finished ground level.

Alternatively, rigid board insulation could be used to protect the footings. We recommend using STYROFOAM High Load HI40 or equivalent for this purpose. The thermal insulation should be designed in accordance to the Canadian Foundation Engineering Manual (CFEM 2006), Article 13.5.2 or by the manufacturer’s specifications.

5.4 STABILITY OF EXCAVATIONS AND DEWATERING

5.4.1 Sloping of trench walls

During construction, the walls of trenches in the overburden or the rock should be sloped in accordance with the *Code de sécurité pour les travaux de construction* [2001, S-21, r.6) of the Commission sur la Santé et la Sécurité au Travail (CSST). At any time, the contractor will be responsible for the stability of the excavations. However, the following guidelines can be used by the designer to estimate excavation volume and cost.

With adequate groundwater control (see article 5.4.2 below), excavations less than 8 meters deep in the till should have walls sloped at 1.0H:1.0V or flatter.

The walls of excavations in soil should be inspected regularly for any signs of instability.

Excavated materials and heavy vehicles should not be allowed at distance less than one time the excavation depth from the edge of the excavation.

5.4.2 Water Control

Surface runoffs should be controlled by sloping the ground away from the excavation, constructing dikes around the top of the trench or with permanent or temporary collection ditches. Excavation under the groundwater table shall be required. The contractor will have to provide an adequate dewatering system in order to conveniently compact the fill material that will be required for this project. Groundwater pumped out from the excavation will likely have to be desilted before it is rejected to nearby lakes or creeks.

5.5 BACKFILLING OF FOUNDATIONS

The exterior of the foundation walls should be backfilled with a free draining, non-frost susceptible granular fill meeting the specifications of a MG-112 sand, as described in BNQ standard NQ 2560-114. The backfill material shall be placed in lifts not exceeding 300 mm, compacted at 92% of the Modified Proctor maximum dry density. The backfill should extend up the floor elevation and the top layer should be 2.0 m wide with 1H: 1V slope to protect foundation from frost penetration.

The top layer should be constructed with a less permeable material (such as compacted till) and sloped away from the foundations, to minimize runoff infiltration along the wall.

The backfill specifications for the interior side of the wall (under the floor slab) are given in the next article.

To prevent structural damages to the foundation wall, backfilling should be done simultaneously on both sides of the wall. The backfill level difference between the inside and the outside should not exceed 600 mm.

5.6 SLAB-ON-GRADE AND MODULUS OF SUBGRADE REACTION (K_S)

The following recommendations are common practice for the design of slab-on-grade.

- Remove the topsoil or any existing fill to expose the undisturbed till deposit or the bedrock;
- At shallow rock locations, a tapered transition (see article 6.3) should be provided between the sloping rock and the adjacent till deposit;
- Replace excavated soils to base level with a granular fill constructed with MG-112 sand. Lifts shall not be thicker than 300 mm and compacted to 95% of the material's maximum dry density, as defined by the Modified Proctor method of compaction;
- The base course thickness will be designed to meet the required bearing capacity for the slab. The base will be constructed with MG-20 crushed gravel (as described in NQ 2560-114), in lifts less than 300 mm thick, compacted to 95% of the Modified Proctor maximum dry density (hereafter referred to as MPMDD);
- The modulus of subgrade reaction for the sub-base, MG-112 compacted to 95% MPMDD shall be taken equal to 50 MN/m3.

5.7 ROCK ANCHORS

If required to provide uplift resistance we recommend using mechanical rock anchors equipped with an expansion shell (NCA AR series or equivalent). The size of the steel rod and diameter of the mechanical shell anchor should be designed according to the manufacturer specification.

To protect the steel from rust every anchor should be completely injected using a shrinkage compensated grout. Every anchor should be proof tested with a calibrated torque-wrench.

The Qualitas anchor design procedure is provided in Appendix 5. The design parameters are provided in Table 7.

Table 7 :
Rock Anchors Design Parameters

Failure mode	Parameters		
	Symbol	**Description**	**Design Value**
Failure of the steel tendon/top anchorage, expansion shell	σ_y	Tensile strength of anchorage	See manufacturer specs
Rock mass failure	β	Failure cone apex half angle	45^o
	γ	Unit weight of rock	26 kN/m^3

5.8 ROCK BLASTING

The following recommendations shall be followed during rock blasting operations:

- Close-control of throw and flyrocks;
- Limitation of peak particle velocity (PPV) to 25 mm/s;
- No blasting in proximity of freshly poured concrete.

Usual safety measures for rock blasting works should also be applied. Loose rock debris shall be completely removed from the blasted trenches. Under adequate PPV control, the bedrock bearing capacity will remain unchanged after blasting, although some settlements could occur (less than 25 mm). Also, rock anchors design shall take into account the fractured layer of rock from the blast. As a conservative design approach, the rock/grout bond contribution over the first meter below the bottom of the blasted trench should be neglected.

5.9 INTERACTION OF ADJACENT FOOTINGS

When footings are installed too close to one another, their pressure bulbs overlap, causing a stress buildup and increased settlements in the soils (footings on rock are not subjected to such constraints). Precise calculation of this effect is difficult to achieve. Instead, it is preferable to keep a minimum distance between the foundations to keep the stress bulbs from overlapping. As shown in Figure 2 below (from Bowles, 1997, Fifth Edition), this minimum distance is equal to 3B for strip (continuous) footings, and 1.5B for square footings (where B is the width of the foundation).

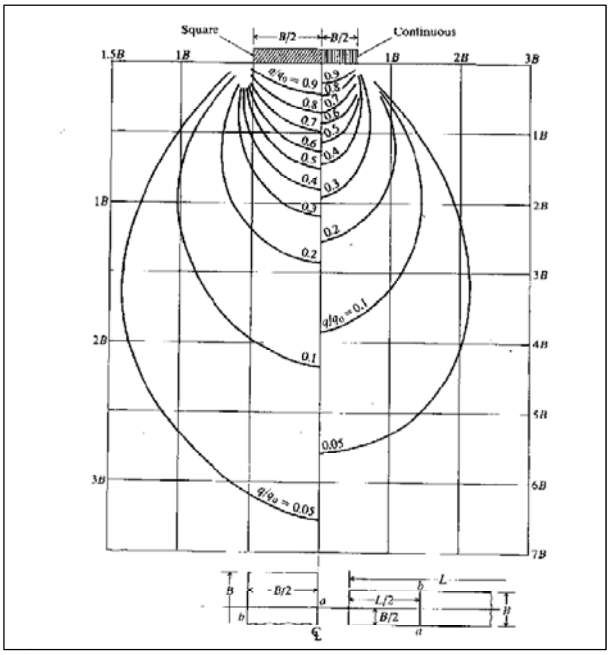
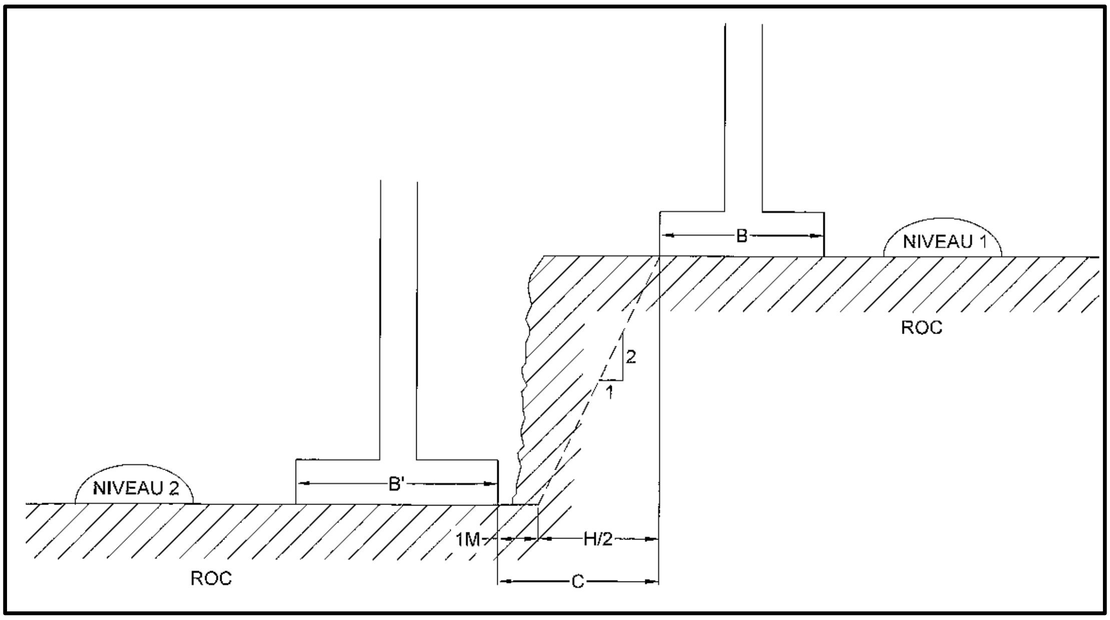


Figure 2 - Stress bulb under square and strip footing (from Boussinesq equation).

Moreover, footings installed on the rock at different levels should be positioned as recommended on Figure 3.



B : Width of footing on level 1 (Niveau 1);
B' : Width of footing on level 2 (Niveau 2);
C : Recommended distance between foundations.

Figure 3 – Horizontal distance between foundations at different levels (footings on rock only)

5.10 SEISMIC SITE CLASSIFICATION

Spectral acceleration values for short (0.2 s) and long (1.0 s) periods are provided in Table 8 based on the National Building Code of Canada 2010 (NBCC2010) Seismic Hazard Calculation. These spectral acceleration values have a 2% probability of exceedance in 50 years. Since bedrock is near the surface (less than 5 m in most boreholes), site class is C.

Table 8 : Spectral accelerations				
Foundations supporting soil/rock	**Seismic Class**	**PGA (g)**	**Sa (0.2) (g)**	**Sa (1.0) (g)**
Till on fractured rock	C	0.036	0.098	0.065

6.0 BEARING CAPACITIES AND SETTLEMENTS

6.1 GENERAL

A plant and a storage building will be constructed at the Barette-Chapais Lumber Mill. The plant's floor will be set at elevation 384 m while the storage's floor will be at elevation 387 m. In both cases, a frost protection of 2.5 m has been considered for calculations.

6.2 SUBSURFACE CONDITIONS

Detailed subsurface conditions have been given in Section 4.0. The borehole logsd can also be consulted in Appendix 2. The test locations are shown on Drawing No. 7001420-0, in Appendix 4.

The investigation work has shown that the bedrock elevation is variable throughout the site and it can be encountered anywhere between the surface and 6 meters of depth. We must therefore assume that the buildings foundations will be constructed on different supporting materials such as: rock, till, or an engineered fill. Recommendations for these three cases are provided in sections below.

6.3 GENERAL RECOMMENDATIONS FOR SHALLOW FOUNDATIONS

The following general recommendations apply for the installation of shallow foundations (in supplement of the recommendations given in Chapter 5.0):

i- Prior to excavation, water control systems (as described in Section 5.4.2) should be installed to manage the water coming from nearby lakes, rivers, surface runoffs, and underground water;

ii- Under the buildings foundation, we recommend excavating 500 mm bellow the footing level in the undisturbed till. The bottom of excavation should be statically compacted (to avoid any soil liquefaction under the vibration, bull liver effect);

iii- A 500-mm-thick pad should be placed on the compacted till in lifts of 300 mm before compaction. The pad should be constructed using MG56 or MG20 crushed aggregates. The first lift should be statically compacted to avoid liquefaction of the underlying soil. The second lift should be compacted using a vibration roller to 95 % of MPMDD (see article 6.6).

The purpose of this pad is to install a supporting material with similar strength properties under the foundation since it will most probably overlie different materials.

A very loose to loose sand and silt layer was observed inside B-04 and B-05 and could be present elsewhere. If encountered, precaution will have to be taken to insure it is not disturbed. First, this material will have to be over-excavated an extra 500 mm, and covered by a geotextile (TEXEL 9619 or equivalent). Then the 500- mm-deep over-excavation should be backfilled using a MG-112 sand placed in layers 300 mm thick and statically compacted. Then the excavation will be fully backfilled using the crushed aggregates specified above;

iv- Most of the excavated material will be glacial till, composed of silty sand, with some gravel. Material may contain significant percentages of cobbles and boulders;

This material is not likely to be reused to build dikes, road embankments, or in subgrade fill sections because of its high moisture content. For such usage, the material moisture content will have to be kept close to the optimum water content determined by the Proctor tests. Therefore, we recommend stockpiling only dry or slightly moist till. The stockpiles will have to be protected from the rain. Also, boulders bigger than 300 mm will have to be removed from the till before it is used as construction material;

v- As previously mentioned, the trenches shall be adequately dewatered. The bottom of the trenches shall be sloped to avoid ponding. Water will have to be redirected toward a sum and pumped out of the excavation;

vi- Where structural fills are to be built on very uneven bedrock, 5,0H:1,0V benches transitions shall be excavated in the rock or constructed with lean concrete;

vii- Where footings are installed directly on the rock, the latter shall be pressure-washed before concrete is poured. Rock dowels shall be installed where the bedrock surface is dipping more than 10 degrees to prevent sliding of the footing.

6.4 ROCK FOUNDATIONS

Based on rock core samples examination, we have considered that the foundations would rest on fractured but un-weathered rock.

Bearing capacity on rock is governed exclusively by the settlements associated with the defects in the rock (therefore by the Serviceability Limit State). In the present case, the SLS value for settlements lower than 25 mm is equivalent to an allowable bearing capacity of **1,5 MPa** (including a Factor of Safety of 3.0).

The bearing capacity and the following design values shall be used for mafic volcanic rock found at the site.

Table 9:
Rock properties

Property	Value
Unit Weight	26 kN/m^3
Unconfined compressive strength (UCS)	65 MPa

Weathered rock and loose fragments should be excavated under the supervision of skilled technician and the surface should be approved by a geologist. In any case, rock foundations should be constructed on a clean, flat surface.

6.5 FOUNDATIONS ON UNDISTURBED TILL

The ultimate bearing capacity of shallow foundations over soil may be calculated from Terzaghi's general equation as shown in the Canadian Foundation Engineering Manual (CFEM 2006), Section 10.2.1. :

$$q_u = cN_cS_c + \ q_sN_qS_q + \frac{1}{2}\gamma BN_\gamma S_\gamma$$

Taking out the first term of the equation for cohesionless soil (c = 0), the ULS shall be calculated with the following values for foundations bearing on a structural fill or on natural undisturbed till:

Table 10:
Design values for bearing capacity of shallow foundation on soil

Bearing material	**Parameters**				
	γ	γ_{sub}	ϕ'	N_q ,N_γ	S_q, S_g
Undisturbed till	20 kN/m³	10.2 kN/m³	30	CFEM (2006) Table 10.1	CFEM (2006) Table 10.2
Structural fill	22 kN/m^3	12.2 kN/m³	40	CFEM (2006) Table 10.1	CFEM (2006) Table 10.2

The geotechnical resistance at the ultimate limit state (ULS) must be reduced by the appropriate geotechnical resistance factor (Φ) to provide the factored geotechnical bearing resistance for foundation design. For the bearing capacity of shallow foundations, Φ = 0.5. However, in the present case, the foundations should be designed in order to limit settlements to allowable values. <u>Therefore SLS values shall be used for most applications.</u>

Serviceability Limit Strength is given in Table 11 below for foundations with the following specifications:

Table 11: Bearing Capacity of Shallow Foundation on soil			
Bearing material	SLS (kPa)		Total settlement (mm)
	B ≤ 2 m (for the plant)	**B ≤ 2 m** for the storage building	
Footing on till with 500-mm crush gravel pad	200	200	< 25

6.6 FILL MATERIAL

Crushed waste rock can be use as engineered fill material. The rock should be massive, non-altered and not subjected to swelling (caused by the presence of potentially swelling ferrous sulphides). The swelling potential of the rock has not been evaluated for the investigated site.

The crushed rock shall be well graded with grain size ranging from 0 to 150 mm, with at least 50% retained on the 25 mm sieve and less than 10% of fines (passing the 80 μm sieve). The crushed rock shall be placed in 300-mm-thick layers, compacted to 95% of the MPMDD. A transition layer at least 300-mm thick will be inserted between the crushed rock fill and the crushed gravel pad of the foundations. This transition layer will be composed of MG-56 crushed gravel. It will be placed in one 300-mm-thick lift, compacted at 95% of MPMDD. If required, the materials should be wetted to achieve the required compaction levels.

APPENDIX 1

GEOTECHNICAL LOGS EXPLANATION SHEET

Qualitas

EXPLANATIONS OF THE "BOREHOLE LOG" FORM

A- DEPTH:

This column gives the scale of depth used (in meters or in feet), related to the ground level, or as indicated otherwise in the column "stratigraphy"(boring platform, barge floor, ice cover,…).

B- SAMPLE:

State: this column shows the position, length and state of each sample in the borehole. The sampling symbol illustrates the state of the sample, following the legend given in the borehole log heading.

Type and Number: each sample is numbered following the recovery order and the given notation refers to the type of sampling as described below:

CF:	standard split spoon (51 mm φ)	LA:	recovered by washing
CF_n:	split spoon, N size (76 mm φ)	MA:	manual sampling
TM:	thin wall tube	TU:	recovered with casing
PS:	Osterberg sampler thin wall tube	TA:	auger sampling
CR:	core barrel sampling		

Recovery: sample recovery is given in percentage of the penetration length of the sampler into the soil. The length of the sample is measured from the top of the sampler to the cutting edge of the sampler, even if the lower part of the sample in lost.

C- FIELD AND LABORATORY TESTS:

This column gives the results of field and laboratory tests performed at the corresponding depth:

- **Field Tests:**

N	:	Standard Penetration Test (blows per 300 mm of penetration);
N_{dc}	:	Dynamic Cone Penetrometer Test (blows per 300 mm of penetration);
c_u	:	Undrained Shear Strength (undisturbed state) (kPa);
c_{ur}	:	Undrained Shear Strength (remoulded state) (kPa);
S_t	:	Sensitivity ($S_t = c_u/c_{ur}$);
P_L	:	Pressuremeter Limit Pressure (kPa);
E_m	:	Pressuremeter Modulus (MPa);
k	:	Field Permeability Test (cm/s); k_{bt} = Casing End Test; k_L: Lefranc Test
Abs	:	Rock Absorption (1/min/m).

The Standard Penetration Resistance given in this column refers to the N Index value. This index is obtained from the SPT and corresponds to the number of blows required to drive the split-spoon sampler into the soil on a 300-mm depth with a 63-kg hammer dropped 76 cm.

- **Laboratory Tests:**

AG::	Grain Size Analysis;	k_o:	Coefficient of permeability (labo.) (cm/s);
W_o:	Water Content (%);	CIU:	Consolidated Isotropically Undrained Triaxial Test;
w_P:	Plastic Limit (%);	P_{mod}:	Optimum-moisture Density Test (Modified Proctor Method);
w_L:	Liquid Limit (%);	P_{nor}:	Optimum-moisture Density Test (Standard Proctor Method);
D_r:	Specific Gravity;	σ_c:	Compressive Strength (MPa);
γ_h:	Moist Unit Weight (kg/m^3);	γ_b:	Concrete Unit Weight (kg/m^3);
c_{ul}:	Laboratory Vane (undisturbed shear);	γ_r:	Rock Unit Weight (kg/m^3);
c_{url}:	Laboratory Vane (remoulded shear);	C97:	Absorption (%);
S_t:	Sensitivity;	UU:	Unconsolidated Undrained Triaxial Test;
σ_p:	Uni-axial Consolidation Test;		

Not all the above-mentioned laboratory or field tests will be identified in the general heading of the borehole log. Results of some tests will be presented on figures in appendix, these figures being identified between parentheses, beside the related test.

R.Q.D.: The Rock Quality Designation index is obtained from the rock cores by summing up the length of core recovered L_i, counting only those pieces of sound core that are 100 mm or more in length. It is expressed as a percentage of the ration of the summed core lengths to the total cored length (L_c):

$$\text{R.Q.D. (\%)} = \left(\frac{\Sigma L_i \geq 10\text{ cm}}{L_c} \right) \times 100$$

D- STRATIGRAPHY:

1- **Column "Elev/Depth"** this column gives the elevation and depth of boundaries between the various strata. The elevation is referred to the datum indicated in the general heading. The depths are related to the ground surface, unless indicated otherwise in the "soil or rock description".

D- STRATIGRAPHY: (continued)

2- **Description** : each strata is described using the standard geotechnical terminology:

Classification	Particule Size	Terminology	Content
CLAY	smaller than 0,002 mm	"trace"	1 - 10 %
SILT	from 0,002 to 0,080 mm	"some"	10 - 20 %
SAND	from 0,080 to 5 mm	adjective (sandy, silty, etc.)	20 - 35 %
GRAVEL	from 5 to 80 mm	"and" (sand and gravel, etc.)	35 - 50 %
COBBLES	from 80 to 300 mm		
BOULDERS	bigger than 300 mm		

Compactness condition (cohesionless soils)	Standard Penetration Test Index N (blows per 300 mm of penetration)
Very loose	0 - 4
Loose	4 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	50 - 100
Extremely dense	more than 100

Consistency (cohesive soils)	Undrained Shear Strength, c_u (kPa)
Very soft	less than 12
Soft	12 - 25
Firm	25 - 50
Stiff	50 - 100
Very stiff	100 - 200
Hard	more than 200

Plasticity of cohesive soils	Liquid Limit, w_L
Low	lower than 30 %
Medium	between 30 % and 50 %
High	higher than 50 %

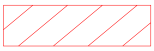
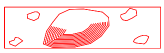
Sensitivity of cohesive soils	Sensitivity S_t (c_u/c_{ur})
Low sensitivity	< 10
Medium sensitivity	10-30
High Sensitivity	30-50
Extra-high sensitivity	50-100
Ultra-high sensitivity	> 100

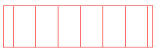
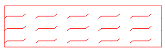
Rock Quality Classification	Quality Index* (RQD %)
Very poor	< 25
Poor	25 - 50
Fair	50 - 75
Good	75 - 90
Excellent	90 -100

*After Table 3.6, Canadian Foundation Engineering Manual, C.G.S. [1985]

3- **Stratigraphy**:

Symbols in this column come from the Unified Soil Classification System. The most common soil types are designated by the following stratigraphic symbols:

Clay:  Sand:  Boulders: 

Silt:  Gravel:  Organic matter: 

Water level: The groundwater level measured during the boring campaign is indicated graphically in this column by a horizontal line and a black triangle. Elevation ans date of the last measure are indicated in the general heading of the borehole log.

E- NOTES :

This column contains observations noticed during boring or after samples examination. Water contents and Atterberg limits can be plotted on graph, as well as dynamic cone penetrometer test profile (DCPT, when performed). The DCPT differs from the SPT method by penetration of a steel cone of 60° apex angle and 51 mm of diameter, driven into the strata under constant energy, mostly at 475 N-m.

Furthermore, undrained shear strength profile of cohesive soil layers, obtained by field vane, can be presented in this column.

APPENDIX 2

GEOTECHNICAL LOGS

Qualitas

FORAGE GÉOTECHNIQUE

Date(s):	Dossier no:	Sondage no:
2014-05-07	7001420	B-01

Projet : **Geotechnical Study, Construction of new industrial facilities, Barette-Chapais Lumber Mill, Chapais, Québec**

Emplacement:

Type de forage:

Élévation du terrain : **384.70 m** (Geodesic) Foreuse: **Pionjär** Coord. nord: 5517215.035m Coord. est: 217343.846m

Effectué par: **R. Tremblay, tech.** Vérifié par: **P-A. Konrad, Jr. Eng.** Approuvé par: **A. Duchesne, Eng.** Date: 2014-05-23

ÉTAT

- INTACT
- REMANIÉ
- PERDU
- CAROTTÉ

TYPE D'ÉCHANTILLON

CF : Carottier fendu (standard).
TM : Tube à paroi mince.
CR : Tube carottier.
PMT : Essai pressiométrique.

ESSAIS IN SITU

N : Essai de pénétration standard (coups / 300mm).

Commentaire:
Pour l'identification des symboles inhérents aux essais in situ et en laboratoire, voir les notes explicatives sur les rapports de forage, en début de cette annexe.

ESSAIS EN LABORATOIRE

AG : Analyse granulométrique.
W : Teneur en eau naturelle.
W_P : Limite de plasticité.
W_L : Limite de liquidité.
Dr : Densité relative des grains.

Calibre des tubages:

Profondeur (mètres)	ÉCHANTILLONS: ETAT	TYPE ET NUMERO	Échanti env.	CALIBRE	REC %	Nb. coups /300 mm	ESSAIS EN LABORATOIRE	ÉLÉV. PROF (m)	STRATIGRAPHIE: DESCRIPTION	SYMBOLE	NIVEAU D'EAU	NOTES
								384.70	Surface du terrain			
								0.00	Undifferentiated fill material.			
								383.04 1.66	End of borehole on bedrock (probable).			

Profondeur scale: 1, 2, 3, 4, 5, 6, 7, 8, 9

REMARQUES:

Qualitas

FORAGE GÉOTECHNIQUE

Date(s):	Dossier no:	Sondage no:
2014-05-07	7001420	B-02

Projet : **Geotechnical Study, Construction of new industrial facilities, Barette-Chapais Lumber Mill, Chapais, Québec**

Emplacement:

Type de forage:

Élévation du terrain : **382.94 m** (Geodesic) Foreuse: **Acker tripod** Coord. nord: 5517188.769m Coord. est: 217359.849m

Effectué par: **R. Tremblay, tech.** Vérifié par: **P-A. Konrad, Jr. Eng.** Approuvé par: **A. Duchesne, Eng.** Date: 2014-05-23

ÉTAT

- INTACT
- REMANIÉ
- PERDU
- CAROTTÉ

TYPE D'ÉCHANTILLON

- CF : Carottier fendu (standard).
- TM : Tube à paroi mince.
- CR : Tube carottier.
- PMT : Essai pressiométrique.

ESSAIS IN SITU

N : Essai de pénétration standard (coups / 300mm).

Commentaire:
Pour l'identification des symboles inhérents aux essais in situ et en laboratoire, voir les notes explicatives sur les rapports de forage, en début de cette annexe.

ESSAIS EN LABORATOIRE

- AG : Analyse granulométrique.
- W : Teneur en eau naturelle.
- W_P : Limite de plasticité.
- W_L : Limite de liquidité.
- Dr : Densité relative des grains.

Calibre des tubages:

Profondeur (mètres)	ÉCHANTILLONS: ETAT	TYPE ET NUMERO	Échanti env.	CALIBRE	REC %	Nb. coups /300 mm	ESSAIS EN LABORATOIRE	ÉLÉV. PROF (m)	STRATIGRAPHIE: DESCRIPTION	SYMBOLE	NIVEAU D'EAU	NOTES
								382.94	Surface du terrain			
								0.00	Topsoil.			
	Remanié / Perdu	SS-1	-	-	83	7 -		382.69 0.25	Brown sand and silt. Loose.		0.60m 2014-05-07	
1	Remanié / Perdu	SS-2	-	-	58	41 -		381.99 0.95	Greenish gray gravely sand with some silt. Dense to very dense.			
2	Remanié / Perdu	SS-3	-	-	42	61 -						
	Remanié / Perdu	SS-4	-	-	67	30 -						
3								379.83 3.10	End of borehole on bedrock.			
4												
5												
6												
7												
8												
9												

REMARQUES:

Qualitas

FORAGE GÉOTECHNIQUE

Date(s):	Dossier no:	Sondage no:
2014-05-07	7001420	B-03

Projet : **Geotechnical Study, Construction of new industrial facilities, Barette-Chapais Lumber Mill, Chapais, Québec**

Emplacement:
Type de forage:

Élévation du terrain : **382.76 m** (Geodesic) Foreuse: **Acker tripod** Coord. nord: 5517198.734m Coord. est: 217307.58m

Effectué par: **R. Tremblay, tech.** Vérifié par: **P-A. Konrad, Jr. Eng.** Approuvé par: **A. Duchesne, Eng.** Date: 2014-05-23

ÉTAT

- INTACT
- REMANIÉ
- PERDU
- CAROTTÉ

TYPE D'ÉCHANTILLON

CF : Carottier fendu (standard).
TM : Tube à paroi mince.
CR : Tube carottier.
PMT : Essai pressiométrique.

ESSAIS IN SITU

N : Essai de pénétration standard (coups / 300mm).

Commentaire:
Pour l'identification des symboles inhérents aux essais in situ et en laboratoire, voir les notes explicatives sur les rapports de forage, en début de cette annexe.

ESSAIS EN LABORATOIRE

AG : Analyse granulométrique.
W : Teneur en eau naturelle.
W_P : Limite de plasticité.
W_L : Limite de liquidité.
Dr : Densité relative des grains.

Calibre des tubages:

Profondeur (mètres)	ÉCHANTILLONS: ETAT	TYPE ET NUMERO	Échanti env.	CALIBRE	REC %	Nb. coups /300 mm	ESSAIS EN LABORATOIRE	STRATIGRAPHIE: ÉLÉV. PROF (m)	DESCRIPTION	SYMBOLE	NIVEAU D'EAU	NOTES
								382.76	Surface du terrain			
	Remanié / Perdu	SS-1	-	-	83	4 -		0.00	Topsoil.		0.00m 2014-05-07	
								382.46 0.30	Greenish gray silty sand. Compact.			
1	Remanié / Perdu	SS-2	-	-	67	14 -		381.56 1.20	Greenish gray silty sand with some gravel. Very dense.			
2	Remanié / Perdu	SS-3	-	-	63	65 -		380.79 1.97	End of borehole on bedrock.			
3												
4												
5												
6												
7												
8												
9												

REMARQUES:

Qualitas

FORAGE GÉOTECHNIQUE

	Date(s):	Dossier no:	Sondage no:
	2014-05-07	7001420	B-04

Projet : **Geotechnical Study, Construction of new industrial facilities, Barette-Chapais Lumber Mill, Chapais, Québec**

Emplacement:

Type de forage:

Élévation du terrain : **382.21 m** (Geodesic) Foreuse: **Acker tripod** Coord. nord: 5517208.699m Coord. est: 217255.311m

Effectué par: **R. Tremblay, tech.** Vérifié par: **P-A. Konrad, Jr. Eng.** Approuvé par: **A. Duchesne, Eng.** Date: 2014-05-23

ÉTAT

- INTACT
- REMANIÉ
- PERDU
- CAROTTÉ

TYPE D'ÉCHANTILLON

CF : Carottier fendu (standard).
TM : Tube à paroi mince.
CR : Tube carottier.
PMT : Essai pressiométrique.

ESSAIS IN SITU

N : Essai de pénétration standard (coups / 300mm).

Commentaire:
Pour l'identification des symboles inhérents aux essais in situ et en laboratoire, voir les notes explicatives sur les rapports de forage, en début de cette annexe.

ESSAIS EN LABORATOIRE

AG : Analyse granulométrique.
W : Teneur en eau naturelle.
W_P : Limite de plasticité.
W_L : Limite de liquidité.
Dr : Densité relative des grains.

Calibre des tubages:

Profondeur (mètres)	ÉCHANTILLONS: ETAT	TYPE ET NUMERO	Échanti env.	CALIBRE	REC %	Nb. coups /300 mm	ESSAIS EN LABORATOIRE	ÉLÉV. PROF (m)	STRATIGRAPHIE: DESCRIPTION	SYMBOLE	NIVEAU D'EAU	NOTES
								382.21	Surface du terrain			
	REMANIÉ	SS-1	-	-	100	7 -		0.00 / 381.36	Topsoil.		0.00m 2014-05-07	
1	REMANIÉ / PERDU	SS-2	-	-	83	15 -		0.85 / 380.86	Gray silty sand. Compact.			
2	REMANIÉ / PERDU	SS-3	-	-	42	17 -		1.35	Greenish gray sand and silt. Very loose to compact.			
	REMANIÉ / PERDU	SS-4	-	-	75	8 -						
3	REMANIÉ / PERDU	SS-5	-	-	75	3 -		378.61				
4	REMANIÉ / PERDU	SS-6	-	-	75	24 -		3.60 / 377.86	Greenish gray, sand with some silt. Compact.			
5	REMANIÉ / PERDU	SS-7	-	-	61	25 -		4.35 / 377.11	Greenish gray silty sand with some gravel. Compact.			
								5.10	End of borehole on bedrock.			
6												
7												
8												
9												

REMARQUES:

Qualitas

FORAGE GÉOTECHNIQUE

Date(s):	Dossier no:	Sondage no:
2014-05-03	7001420	B-05

Projet : **Geotechnical Study, Construction of new industrial facilities, Barette-Chapais Lumber Mill, Chapais, Québec**

Emplacement:

Type de forage:

Élévation du terrain : **384.61 m** (Geodesic) Foreuse: **L-34**

Coord. nord: 5517214.769m Coord. est: 217199.545m

Effectué par: **R. Tremblay, tech.** Vérifié par: **P-A. Konrad, Jr. Eng.** Approuvé par: **A. Duchesne, Eng.** Date: 2014-05-23

ÉTAT

- INTACT
- REMANIÉ
- PERDU
- CAROTTÉ

TYPE D'ÉCHANTILLON

- CF : Carottier fendu (standard).
- TM : Tube à paroi mince.
- CR : Tube carottier.
- PMT : Essai pressiométrique.

ESSAIS IN SITU

N : Essai de pénétration standard (coups / 300mm).

Commentaire:

Pour l'identification des symboles inhérents aux essais in situ et en laboratoire, voir les notes explicatives sur les rapports de forage, en début de cette annexe.

ESSAIS EN LABORATOIRE

- AG : Analyse granulométrique.
- W : Teneur en eau naturelle.
- W_P : Limite de plasticité.
- W_L : Limite de liquidité.
- Dr : Densité relative des grains.

Calibre des tubages:

Type et numéro	Échanti env.	Calibre	REC %	Nb. coups /300 mm	Essais en laboratoire
SS-1	-	-	92	10 -	
SS-2	-	-	75	48 -	Frozen
SS-3	-	-	75	67 -	Frozen
SS-4	-	-	0	- -	N: 2/600mm
SS-5	-	-	0	14 -	
SS-6	-	-	-	32 -	
SS-7	-	-	100	4 -	
SS-8	-	-	100	9 -	
CR-9	-	-	100	- 86	
CR-10	-	-	100	- -	
CR-11	-	-	100	- 51	
CR-12	-	-	100	- 96	

Élév. / Prof (m)	Description
384.61	Surface du terrain
0.00	Greenish gray silty sand with traces of gravel. Compact to very dense.
382.66 / 1.95	Greenish gray silty sand. Compact.
380.21 / 4.40	Greenish gray sand and silt, trace of gravel. Very loose to loose
378.82 / 5.79	Bedrock: green, epiclastic to massive mafic volcanic rock
375.32 / 9.29	End of borehole

Niveau d'eau: 382.79m 2014-05-07

NOTES

REMARQUES:

Qualitas

FORAGE GÉOTECHNIQUE

Date(s):	Dossier no:	Sondage no:
2014-05-02	7001420	B-06

Projet : **Geotechnical Study, Construction of new industrial facilities, Barette-Chapais Lumber Mill, Chapais, Québec**

Emplacement:
Type de forage:

Élévation du terrain : **386.40 m** (Geodesic) Foreuse: **L-34** Coord. nord: 5517219.435m Coord. est: 217150.463m

Effectué par: **R. Tremblay, tech.** Vérifié par: **P-A. Konrad, Jr. Eng.** Approuvé par: **A. Duchesne, Eng.** Date: 2014-05-23

ÉTAT

- INTACT
- REMANIÉ
- PERDU
- CAROTTÉ

TYPE D'ÉCHANTILLON

- CF : Carottier fendu (standard).
- TM : Tube à paroi mince.
- CR : Tube carottier.
- PMT : Essai pressiométrique.

ESSAIS IN SITU

N : Essai de pénétration standard (coups / 300mm).

Commentaire:
Pour l'identification des symboles inhérents aux essais in situ et en laboratoire, voir les notes explicatives sur les rapports de forage, en début de cette annexe.

ESSAIS EN LABORATOIRE

- AG : Analyse granulométrique.
- W : Teneur en eau naturelle.
- W_P : Limite de plasticité.
- W_L : Limite de liquidité.
- Dr : Densité relative des grains.

Calibre des tubages:

TYPE ET NUMERO	Échanti env.	CALIBRE	REC %	Nb. coups /300 mm	ESSAIS EN LABORATOIRE
SS-1	-	-	83	45 -	Frozen
SS-2	-	-	100	100 -	N: Refusal Frozen
SS-3	-	-	44	120 -	Frozen
SS-4	-	-	58	25 -	
SS-5	-	-	83	4 -	N: Refusal
CR-6	-	-	100	- 100	
CR-7	-	-	100	- 100	

ÉLÉV. PROF (m)	DESCRIPTION
386.40	Surface du terrain
0.00	Fill : Gray sand with some silt. Frozen at the moment of the field work.
383.85 / 2.55	Topsoil.
383.30 / 3.10	Gray sand. Loose.
383.22 / 3.18	Bedrock:
380.33 / 6.07	End of borehole

NIVEAU D'EAU: 383.06m 2014-05-07

NOTES

Profondeur (mètres): 1 2 3 4 5 6 7 8 9

REMARQUES:

Qualitas

FORAGE GÉOTECHNIQUE

Date(s):	Dossier no:	Sondage no:
2014-05-05	7001420	B-07

Projet : **Geotechnical Study, Construction of new industrial facilities, Barette-Chapais Lumber Mill, Chapais, Québec**

Emplacement:

Type de forage:

Élévation du terrain : **384.22 m** (Geodesic) Foreuse: **L-34** Coord. nord: 5517163.884m Coord. est: 217328.02m

Effectué par: **R. Tremblay, tech.** Vérifié par: **P-A. Konrad, Jr. Eng.** Approuvé par: **A. Duchesne, Eng.** Date: 2014-05-23

ÉTAT

- INTACT
- REMANIÉ
- PERDU
- CAROTTÉ

TYPE D'ÉCHANTILLON

- CF : Carottier fendu (standard).
- TM : Tube à paroi mince.
- CR : Tube carottier.
- PMT : Essai pressiométrique.

ESSAIS IN SITU

N : Essai de pénétration standard (coups / 300mm).

Commentaire: Pour l'identification des symboles inhérents aux essais in situ et en laboratoire, voir les notes explicatives sur les rapports de forage, en début de cette annexe.

ESSAIS EN LABORATOIRE

- AG : Analyse granulométrique.
- W : Teneur en eau naturelle.
- W_P : Limite de plasticité.
- W_L : Limite de liquidité.
- Dr : Densité relative des grains.

Calibre des tubages:

Profondeur (mètres)	ÉCHANTILLONS: ETAT	TYPE ET NUMERO	Échanti env.	CALIBRE	REC %	Nb. coups /300 mm	ESSAIS EN LABORATOIRE	ÉLÉV. PROF (m)	STRATIGRAPHIE: DESCRIPTION	SYMBOLE	NIVEAU D'EAU	NOTES
								384.22	Surface du terrain			
		SS-1	-	-	42	43 -		0.00	Greenish gray silty sand with some gravel. Presence of cobbles. Dense to very dense.			
1		SS-2	-	-	48	50 -						
2		SS-3	-	-	67	35 -					382.66m 2014-05-07	
		SS-4	-	-	50	60 -						
3		SS-5	-	-	33	49 -						
4		SS-6	-	-	42	80 -						
		SS-7	-	-	0	50 -						
5		SS-8	-	-	0	-		378.96 5.26	Bedrock:			
		CR-9	-	-	96	- - 91						
6												
7		CR-10	-	-	10	- 85						
8		CR-11	-	-	100	- 86		376.07 8.15	End of borehole			
9												

REMARQUES:

Qualitas

FORAGE GÉOTECHNIQUE

Date(s):	Dossier no:	Sondage no:
2014-05-05	7001420	B-08

Projet : **Geotechnical Study, Construction of new industrial facilities, Barette-Chapais Lumber Mill, Chapais, Québec**

Emplacement:
Type de forage:

Élévation du terrain : **384.11 m** (Geodesic) Foreuse: **L-34** Coord. nord: 5517173.849m Coord. est: 217275.751m

Effectué par: **R. Tremblay, tech.** Vérifié par: **P-A. Konrad, Jr. Eng.** Approuvé par: **A. Duchesne, Eng.** Date: 2014-05-23

ÉTAT

- INTACT
- REMANIÉ
- PERDU
- CAROTTÉ

TYPE D'ÉCHANTILLON

- CF : Carottier fendu (standard).
- TM : Tube à paroi mince.
- CR : Tube carottier.
- PMT : Essai pressiométrique.

ESSAIS IN SITU

N : Essai de pénétration standard (coups / 300mm).

Commentaire:
Pour l'identification des symboles inhérents aux essais in situ et en laboratoire, voir les notes explicatives sur les rapports de forage, en début de cette annexe.

ESSAIS EN LABORATOIRE

- AG : Analyse granulométrique.
- W : Teneur en eau naturelle.
- W_P : Limite de plasticité.
- W_L : Limite de liquidité.
- Dr : Densité relative des grains.

Calibre des tubages:

ÉCHANTILLONS

TYPE ET NUMERO	Échanti env.	CALIBRE	REC %	Nb. coups /300 mm	ESSAIS EN LABORATOIRE
SS-1	-	-	75	17 -	
SS-2	-	-	83	26 -	
CR-3	-	-	100	- -	
SS-4	-	-	42	42 -	
SS-5	-	-	50	24 -	
SS-6	-	-	42	22 -	
CR-7	-	-	83	- -	
SS-8	-	-	33	54 -	
SS-9	-	-	83	18 -	
CR-10	-	-	100	- 92	σ_c = 86 MPa
CR-11	-	-	100	- 100	

STRATIGRAPHIE

ÉLÉV. PROF (m)	DESCRIPTION
384.11	Surface du terrain
0.00	Fill: Silty sand.
384.02 / 0.09	Topsoil.
383.81 / 0.30	Greenish gray silty sand, some gravel. Compact to dense. From 1.27 m to 1.70 m of depth : boulder 430 mm.
381.11 / 3.00	Greenish gray silty sand with some gravel. Presence of cobbles. Compact to very dense. From 3.78 m to 4.43 m of depth : boulder 650 mm.
378.83 / 5.28	Bedrock:
375.95 / 8.16	End of borehole

NIVEAU D'EAU: 383.24m 2014-05-07

NOTES

REMARQUES:

Qualitas

FORAGE GÉOTECHNIQUE

Date(s):	Dossier no:	Sondage no:
2014-05-06	7001420	B-09

Projet : **Geotechnical Study, Construction of new industrial facilities, Barette-Chapais Lumber Mill, Chapais, Québec**

Emplacement:

Type de forage:

Élévation du terrain : **385.53 m** (Geodesic) Foreuse: **L-34** Coord. nord: 5517185.769m Coord. est: 217206.98m

Effectué par: **R. Tremblay, tech.** Vérifié par: **P-A. Konrad, Jr. Eng.** Approuvé par: **A. Duchesne, Eng.** Date: 2014-05-23

ÉTAT

- INTACT
- REMANIÉ
- PERDU
- CAROTTÉ

TYPE D'ÉCHANTILLON

- CF : Carottier fendu (standard).
- TM : Tube à paroi mince.
- CR : Tube carottier.
- PMT : Essai pressiométrique.

ESSAIS IN SITU

N : Essai de pénétration standard (coups / 300mm).

Commentaire:
Pour l'identification des symboles inhérents aux essais in situ et en laboratoire, voir les notes explicatives sur les rapports de forage, en début de cette annexe.

ESSAIS EN LABORATOIRE

- AG : Analyse granulométrique.
- W : Teneur en eau naturelle.
- W_P : Limite de plasticité.
- W_L : Limite de liquidité.
- Dr : Densité relative des grains.

Calibre des tubages:

ÉCHANTILLONS

ETAT	TYPE ET NUMERO	Échanti env.	CALIBRE	REC %	Nb. coups /300 mm	ESSAIS EN LABORATOIRE
REMANIÉ / PERDU	SS-1	-	-	75	7 -	
PERDU	SS-2	-	-	0	1 -	
REMANIÉ / PERDU	SS-3	-	-	42	34 -	
REMANIÉ / PERDU	SS-4	-	-	42	17 -	
REMANIÉ / PERDU	SS-5	-	-	83	33 -	
REMANIÉ / PERDU	SS-6	-	-	75	19 -	
REMANIÉ / PERDU	SS-7	-	-	43	140 -	
CAROTTÉ	CR-8	-	-	86	- -	
CAROTTÉ	CR-9	-	-	100	- 85	
CAROTTÉ	CR-10	-	-	100	- 100	

STRATIGRAPHIE

ÉLÉV. PROF (m)	DESCRIPTION
385.53	Surface du terrain
0.00	Fill: Sand with some silt and traces of gravel.
383.28 / 2.25	Fill: Sand with some gravel. Presence of wood chips.
383.03 / 2.50	Topsoil.
382.43 / 3.10	Greenish gray silty sand. Compact.
381.33 / 4.20	Greenish gray silty sand with some gravel. Very dense.
380.48 / 5.05	Bedrock:
377.13 / 8.40	End of borehole

NIVEAU D'EAU: 383.08m 2014-05-07

NOTES

REMARQUES:

Qualitas

FORAGE GÉOTECHNIQUE

	Date(s):	Dossier no:	Sondage no:
	2014-05-02	7001420	B-10

Projet : **Geotechnical Study, Construction of new industrial facilities, Barette-Chapais Lumber Mill, Chapais, Québec**

Emplacement:

Type de forage:

Élévation du terrain : **385.86 m** (Geodesic) Foreuse: **L-34** Coord. nord: 5517180.29m Coord. est: 217154.791m

Effectué par: **R. Tremblay, tech.** Vérifié par: **P-A. Konrad, Jr. Eng.** Approuvé par: **A. Duchesne, Eng.** Date: 2014-05-23

ÉTAT

- INTACT
- REMANIÉ
- PERDU
- CAROTTÉ

TYPE D'ÉCHANTILLON

CF : Carottier fendu (standard).
TM : Tube à paroi mince.
CR : Tube carottier.
PMT : Essai pressiométrique.

ESSAIS IN SITU

N : Essai de pénétration standard (coups / 300mm).

Commentaire:
Pour l'identification des symboles inhérents aux essais in situ et en laboratoire, voir les notes explicatives sur les rapports de forage, en début de cette annexe.

ESSAIS EN LABORATOIRE

AG : Analyse granulométrique.
W : Teneur en eau naturelle.
W_P : Limite de plasticité.
W_L : Limite de liquidité.
Dr : Densité relative des grains.

Calibre des tubages:

Profondeur (mètres)	ETAT	TYPE ET NUMERO	Échanti env.	CALIBRE	REC %	Nb. coups /300 mm	ESSAIS EN LABORATOIRE	ÉLÉV. PROF (m)	DESCRIPTION	SYMBOLE	NIVEAU D'EAU	NOTES
								385.86	Surface du terrain			
	REMANIÉ	SS-1	-	-	100	35 -	Frozen	0.00	Greenish gray silty sand with traces of gravel. Frozen at the moment of the field work.			
1	REMANIÉ	SS-2	-	-	100	104 -	Frozen	384.51				
	CAROTTÉ	CR-3	-	-	100	- 65		1.35	Bedrock:		384.26m 2014-05-07	
2	CAROTTÉ	CR-4	-	-	100	- 78						
3	CAROTTÉ	CR-5	-	-	100	- 90						
4	CAROTTÉ	CR-6	-	-	100	- 80		381.01				
5								4.85	End of borehole			
6												
7												
8												
9												

REMARQUES:

Qualitas

FORAGE GÉOTECHNIQUE

Date(s):	Dossier no:	Sondage no:
2014-05-05	7001420	B-11

Projet : **Geotechnical Study, Construction of new industrial facilities, Barette-Chapais Lumber Mill, Chapais, Québec**

Emplacement:

Type de forage:

Élévation du terrain : **385.14 m** (Geodesic) Foreuse: **L-34** Coord. nord: 5517128.978m Coord. est: 217206.886m

Effectué par: **R. Tremblay, tech.** Vérifié par: **P-A. Konrad, Jr. Eng.** Approuvé par: **A. Duchesne, Eng.** Date: 2014-05-23

ÉTAT

- INTACT
- REMANIÉ
- PERDU
- CAROTTÉ

TYPE D'ÉCHANTILLON

- CF : Carottier fendu (standard).
- TM : Tube à paroi mince.
- CR : Tube carottier.
- PMT : Essai pressiométrique.

ESSAIS IN SITU

N : Essai de pénétration standard (coups / 300mm).

Commentaire:
Pour l'identification des symboles inhérents aux essais in situ et en laboratoire, voir les notes explicatives sur les rapports de forage, en début de cette annexe.

ESSAIS EN LABORATOIRE

- AG : Analyse granulométrique.
- W : Teneur en eau naturelle.
- W_P : Limite de plasticité.
- W_L : Limite de liquidité.
- Dr : Densité relative des grains.

Calibre des tubages:

Profondeur (mètres)	ETAT	TYPE ET NUMERO	Échanti env.	CALIBRE	REC %	Nb. coups /300 mm	ESSAIS EN LABORATOIRE	ÉLÉV. PROF (m)	DESCRIPTION	SYMBOLE	NIVEAU D'EAU	NOTES
								385.14	Surface du terrain			
0	Remanié	SS-1	-	-	83	30 -		0.00	Greenish gray silty sand with traces of gravel. Presence of cobbles. Compact.		384.76m 2014-05-07	
1	Remanié	SS-2	-	-	100	30 -	N: Refusal on a cobble					
	Remanié	SS-3	-	-	56	35 -	N: Refusal on bedrock	383.46				
2	Carotté	CR-4	-	-	100	- 58		1.68	Bedrock:			
3–4	Remanié	CR-5	-	-	100	- 82	σ_c = 65 MPa					
5	Carotté	CR-6	-	-	100	- 56						
6	Carotté	CR-7	-	-	100	- 89		378.94				
								6.20	End of borehole			
7												
8												
9												

REMARQUES:

APPENDIX 3

LABORATORY TEST RESULTS

Qualitas

3306, boul. Saint-François
Jonquière, (Québec), G7X 2W9
Téléphone : (418) 547-5716
Télécopieur : (418) 547-0374

SOLS ET GRANULATS
SOMMAIRE DES ESSAIS

Soumis à : Christopher Amey
Rentech
10887 Wilshire Blvd
Los Angeles, California

Dossier N° : 7001420
Date : 2014-05-14

Entrepreneur :

Projet : Geotechnical Study, Construction of new industrial Facilities, Barette-Chapais Lumber Mills, Chapais Quebec

Localisation :

RENSEIGNEMENTS GÉNÉRAUX

No échantillon : 14-SG-08687
Type de matériau : Sable et gravier
Calibre du matériau : Forage
Usage proposé : Analyse
Lieu de prélèvement : B-02, SS-4 (2,25 à 2,85 m.)
Date de prélèvement : 2014-05-07

Prélevé par : Réal Tremblay
Source : En place
Date de l'essai : 2014-05-14
Date de réception : 2014-05-09

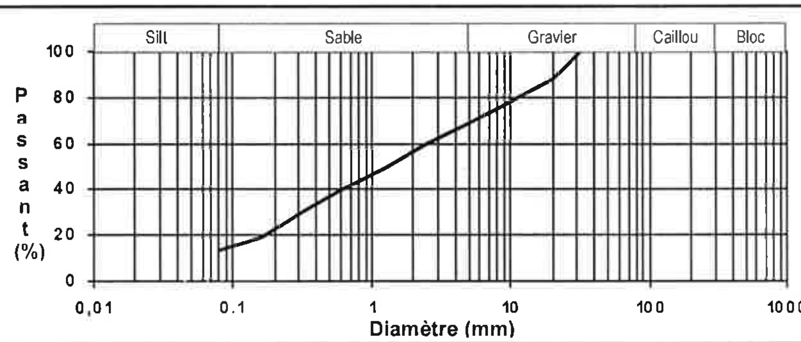
GRANULOMÉTRIE
(LC 21-040)

Tamis	% passant	Exigences min.	Exigences max.
40 mm	100		
31,5 mm	100		
20 mm	88		
14 mm	83		
10 mm	78		
5 mm	69		
2,5 mm	60		
1,25 mm	50		
0,630 mm	40		
0,315 mm	30		
0,160 mm	19		
0,080 mm	13,6		

MODULE DE FINESSE : 3,66

Cu

Cc



ESSAIS DIVERS	Résultats	Exigences min.	Exigences max.

PROCTOR MODIFIÉ (NQ 2501-255) **Méthode** :
Masse volumique sèche maximale : kg/m³
Humidité optimale : %

REMARQUE : * Un astérisque accompagne tout résultat individuel non conforme lorsque les exigences sont spécifiées.
Sable fin à grossier graveleux avec un peu de silt.

Vérifié par : Denis Potvin Chef laboratoire

Chargé de projet :

- Le rapport d'essai ne doit pas être reproduit, sinon en entier, sans l'autorisation écrite de Groupe Qualitas inc.
Ces résultats ne se rapportent qu'aux échantillons soumis pour analyse

Qualitas

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Jonquière, (Québec), G7X 2W9
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10887 Wilshire Blvd
Los Angeles, California

Dossier N° : 7001420
Date : 2014-05-14

Entrepreneur :
Projet : Geotechnical Study, Construction of new industrial Facilities, Barette-Chapais Lumber Mills, Chapais Quebec

Localisation :

RENSEIGNEMENTS GÉNÉRAUX

No échantillon : 14-SG-08688
Type de matériau : Sable
Calibre du matériau : Forage
Usage proposé : Analyse
Lieu de prélèvement : B-03 SS-2 (0,75 à 1,35 m.)
Date de prélèvement : 2014-05-07

Prélevé par : Réal Tremblay
Source : En place
Date de l'essai : 2014-05-13
Date de réception : 2014-05-09

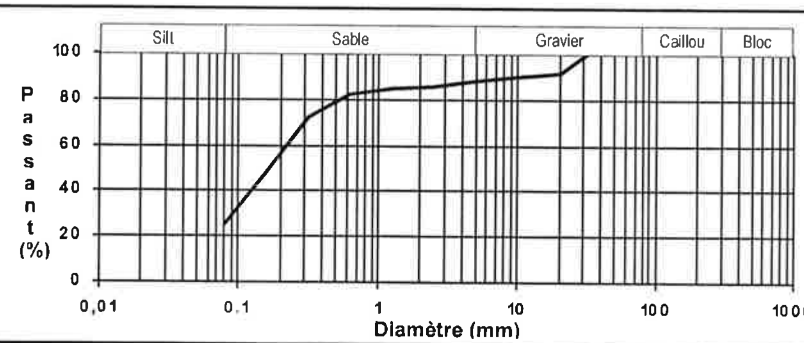
GRANULOMÉTRIE
(LC 21-040)

Tamis	% passant	Exigences min.	Exigences max.
31,5 mm	100		
20 mm	92		
14 mm	91		
10 mm	90		
5 mm	88		
2,5 mm	86		
1,25 mm	85		
0,630 mm	82		
0,315 mm	72		
0,160 mm	49		
0,080 mm	25,2		

MODULE DE FINESSE : 1,56

Cu

Cc



ESSAIS DIVERS	Résultats	Exigences min.	Exigences max.

PROCTOR MODIFIÉ (NQ 2501-255) **Méthode** :
Masse volumique sèche maximale : kg/m³
Humidité optimale : %

REMARQUE : * Un astérisque accompagne tout résultat individuel non conforme lorsque les exigences sont spécifiées.
Sable fin à grossier silteux avec un peu de gravier.

Vérifié par : Denis Potvin
Denis Potvin Chef laboratoire

Chargé de projet :

- Le rapport d'essai ne doit pas être reproduit, sinon en entier, sans l'autorisation écrite de Groupe Qualitas inc.
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Qualitas

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Dossier N° : 7001420
Date : 2014-05-14

Entrepreneur :

Projet : Geotechnical Study, Construction of new industrial Facilities, Barette-Chapais Lumber Mills, Chapais Quebec

Localisation :

RENSEIGNEMENTS GÉNÉRAUX

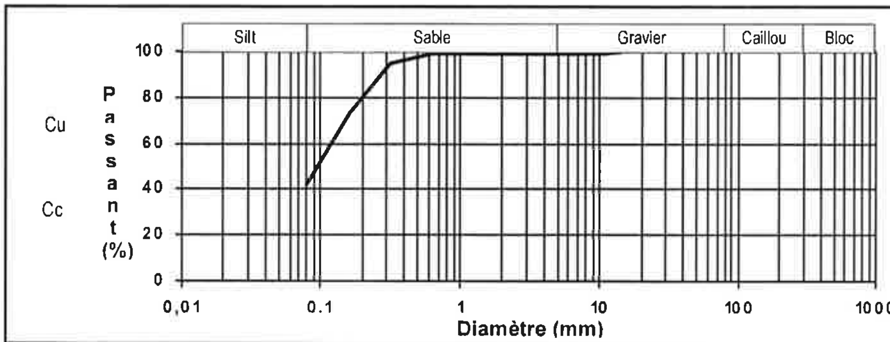
No échantillon : 14-SG-08690
Type de matériau : Sable
Calibre du matériau : Forage
Usage proposé : Analyse
Lieu de prélèvement : B-05 SS-7 (4,50 à 5,10 m.)
Date de prélèvement : 2014-05-03

Prélevé par : Réal Tremblay
Source : En place
Date de l'essai : 2014-05-14
Date de réception : 2014-05-09

GRANULOMÉTRIE
(LC 21-040)

Tamis	% passant	Exigences min.	Exigences max.
40 mm	100		
31,5 mm	100		
20 mm	100		
14 mm	100		
10 mm	99		
5 mm	99		
2,5 mm	99		
1,25 mm	99		
0,630 mm	99		
0,315 mm	95		
0,160 mm	73		
0,080 mm	41,8		

MODULE DE FINESSE : 0,37



ESSAIS DIVERS	Résultats	Exigences min.	Exigences max.

PROCTOR MODIFIÉ (NQ 2501-255) **Méthode :**
Masse volumique sèche maximale : kg/m³
Humidité optimale : %

REMARQUE : * Un astérisque accompagne tout résultat individuel non conforme lorsque les exigences sont spécifiées.
Sable fin et silt.

Vérifié par : Denis Potvin
Denis Potvin Chef laboratoire

Chargé de projet :

- Le rapport d'essai ne doit pas être reproduit, sinon en entier, sans l'autorisation écrite de Groupe Qualitas inc.
Ces résultats ne se rapportent qu'aux échantillons soumis pour analyse

Qualitas

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SOMMAIRE DES ESSAIS

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10887 Wilshire Blvd
Los Angeles, California

Dossier N° : 7001420
Date : 2014-05-14

Entrepreneur :
Projet : Geotechnical Study, Construction of new industrial Facilities, Barette-Chapais Lumber Mills, Chapais Quebec

Localisation :

RENSEIGNEMENTS GÉNÉRAUX

No échantillon : 14-SG-08691
Type de matériau : Sable et gravier
Calibre du matériau : Forage
Usage proposé : Analyse
Lieu de prélèvement : B-08 SS-2 (0,75 à 1,35 m.)
Date de prélèvement : 2014-05-05

Prélevé par : Réal Tremblay
Source : En place
Date de l'essai : 2014-05-13
Date de réception : 2014-05-09

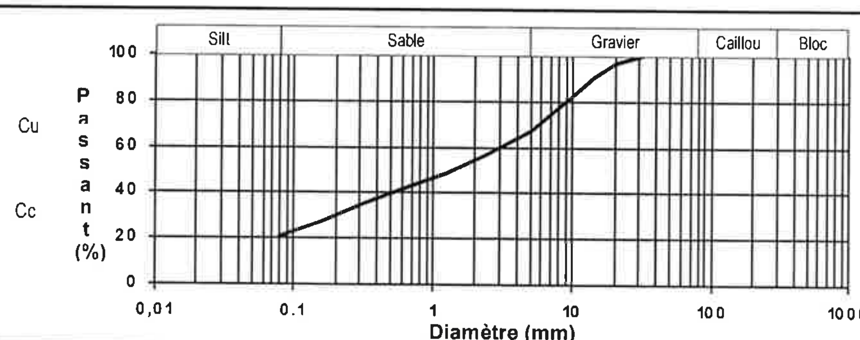
GRANULOMÉTRIE
(LC 21-040)

Tamis	% passant	Exigences min.	Exigences max.
40 mm	100		
31,5 mm	100		
20 mm	97		
14 mm	91		
10 mm	82		
5 mm	67		
2,5 mm	57		
1,25 mm	49		
0,630 mm	42		
0,315 mm	35		
0,160 mm	28		
0,080 mm	21,4		

MODULE DE FINESSE : 3,43

Cu

Cc



ESSAIS DIVERS	Résultats	Exigences min.	Exigences max.

PROCTOR MODIFIÉ (NQ 2501-255) **Méthode** :
Masse volumique sèche maximale : kg/m³
Humidité optimale : %

REMARQUE : * Un astérisque accompagne tout résultat individuel non conforme lorsque les exigences sont spécifiées.
Sable fin à grossier gravelo-silteux.

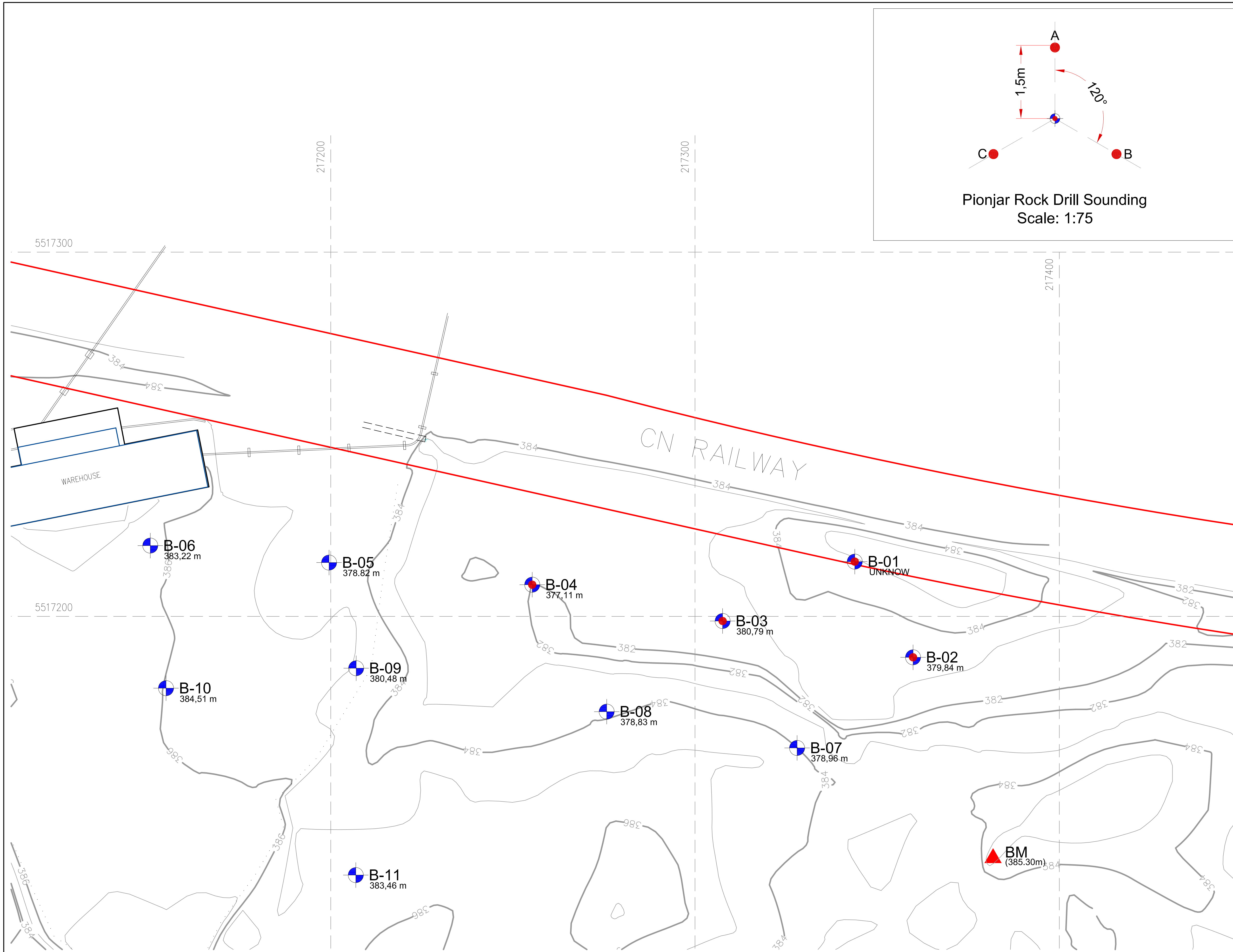
Vérifié par : Denis Potvin
Denis Potvin Chef laboratoire

Chargé de projet :

- Le rapport d'essai ne doit pas être reproduit, sinon en entier, sans l'autorisation écrite de Groupe Qualitas inc.
Ces résultats ne se rapportent qu'aux échantillons soumis pour analyse

APPENDIX 4

DRAWINGS



Pionjar Rock Drill Sounding

Borehole	Pionjar Rock Drill Sounding	Depth (m)	Note
B-01		1,66	unknow
	A	0,82	bedrock
	B	1,38	unknow
	C	1,55	bedrock
B-02		3,10	bedrock
	A	3,21	bedrock
	B	1,24	boulder
	C	2,77	bedrock
B-03		1,97	bedrock
	A	2,26	bedrock
	B	2,00	bedrock
	C	1,76	bedrock
B-04		5,10	bedrock
	A	4,63	bedrock
	B	5,20	bedrock
	C	5,08	bedrock

* ALL UNITS IN METRIC

Project:

GEOTECHNICAL STUDY
CONSTRUCTION OF NEW INDUSTRIAL FACILITIES

BARRETTE-CHAPAIS LUMBER MILL
CHAPAIS, QUÉBEC

Client:

RENTECH WP DEV CANADA

Title:

BOREHOLE LOCATION MAP

LEGEND

383,22 m BOREHOLE ROC ELEVATION
BENCHMARK (BM)
PIONJAR ROCK DRILL SOUNDING

Qualitas
3306, boul. Saint-François, Jonquière, Québec, G7X 2W9
Tél.: (418)547-5716 Télécopieur: (418) 547-0374

10 5 0 10 20 30 40m

SCALE: 1:1000

REFERENCE:
Paul Roy Arpenteur-Géomètre, dossier 4580

DRAW BY : A. Boucher
APPROUVED BY : A. Duchesne, ing.
FILE NO : 7001420
DATE : 2014-05-21
DRAWING NO : 7001420-01

1/1

APPENDIX 5

ROCK ANCHORS DESIGN METHOD

1. ROCK ANCHOR DIAGRAM

- L : Total anchor length (m)
- L_s : Bonded length (m)
- L_w : Cone depth (m)
- D : Diameter of the drilled hole (m)
- β : Half angle of the cone apex (°)
- P : Total pullout load (kN)

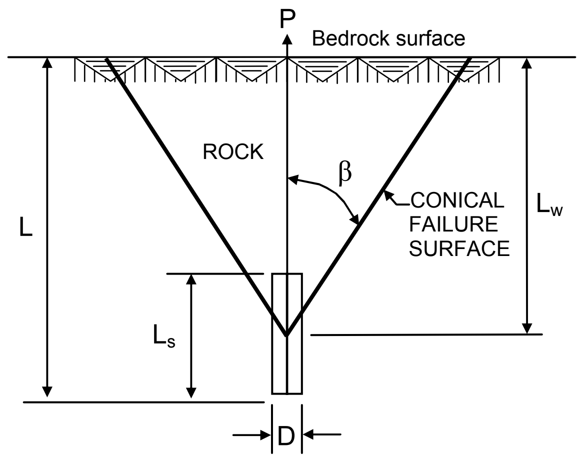


FIGURE 1

2. OBJECTIVES OF THE METHOD

The purpose of an anchorage system is to develop a resistance load higher than the pullout load.

$$R_g \geq P \qquad R_g = R \times \Phi$$

where
- R_g : Factored geotechnical resistance (kN)
- R : Ultimate resistance load (kN)
- P : Total pullout load (kN)
- Φ : Resistance factor

Section 3 calculation below, consider 4 types of failure :

- Tensile stress in the steel rod
- Bond between steel rod and grout
- Bond between rock and grout
- Rock pull-up

The resistance must be calculated for each of these types of failure. The lowest resistance value obtained from those 4 criteria shall be used in the final design.

3. CALCULATION METHOD

TENSILE STRESS IN THE STEEL ROD

The allowable resistance developed by the steel rod in function of the rod characteristics (section, tensile, yield strength …). The steel rod manufacturer will specify the characteristics. The safety factor must be sufficient.

BOND BETWEEN THE STEEL ROD AND THE GROUT

The purpose of this calculation is to obtain a bonded rod length between the steel rod and the grout, which is long enough to develop the allowable resistance. This resistance is determined according to the following formula :

$$R_g = \pi \; d \; L_{s1} \; S_b$$

where d : Rod diameter (m)

L_{s1} : Bonded length between rod and grout (m)

S_b : Bonded strength between rod and grout (kPa)

where $S_b = 0.95 \sqrt{f'_c} \times \Phi \times 1000$ (kPa)

f'_c : Unconfined compression strength of the grout, generally specified as 30 MPa at 28 days (MPa)

Φ : Resistance factor of 0.4

Thus $$L_{s1} = \frac{R_g}{\pi \; d \; S_b}$$

3.3 BOND BETWEEN THE ROCK AND THE GROUT

The purpose of this calculation is to obtain a bonded rod length between the rock and the grout, which is long enough to develop the allowable resistance. This resistance is determined according to the following formula :

$$R_g = \pi \; D \; L_{s2} \; S_r$$

where D : Drilled hole diameter (m)

L_{s2} : Bonded length between rock and grout (m)

S_r : Bonded strength between rock and grout (kPa)

S_r equals the lowest value obtained from the 3 following criteria :

$S_r \leq 0.1 \; q_u \times \Phi$ $\qquad S_r \leq 0.1 \; f'_c \times \Phi$ $\qquad S_r = 1\,300$ kPa

where q_u : Unconfined compressive strength of the rock (kPa)

f'_c : Unconfined compressive strength of the grout, generally specified as 30 MPa at 28 days (kPa)

Φ : Resistance factor equal to 0.4

Thus $$L_{s2} = \frac{R_g}{\pi \; D \; S_r}$$

Furthermore, the following criteria must also be considered :

a) For fair to excellent rock quality (RQD > 50 %), the bonded length L_{s2} must equal at least 30 times the drilled hole diameter of the anchor.

b) For poor to very poor rock quality (RQD ≤ 50 %), the bonded length L_{s2} must equal at least 40 times the drilled hole diameter of the anchor.

c) For shale or rock with shaly beds, the bonded length L_{s2} must equal at least 80 times the drilled hole diameter of the anchor.

d) For all other cases, the bonded strength L_{s2} must equal at least 3 m.

3.4 ROCK PULL-UP

This calculation is used to evaluate the total anchor length required to ensure that the working load will be resisted safely without failure occurring in the rock mass. For this analysis, it is assumed that for a single rock anchor at failure, an inverted cone of rock is pulled out of the rock mass. The conical failure surface has its apex at the middle of the anchor assuming a contained angle of 2 times β.

$$R_g = L_w^3 \, \gamma \, \Phi \, \tan^2 \beta \qquad L_w = L - \frac{L_s}{2} \quad \text{(see Figure 1)}$$

where

- L_w : Length of the inverted cone, from the middle of the anchor to the bedrock (m)
- L : Total anchor length (m)
- L_s : Bonded length, higher value of L_{s1} and L_{s2} obtained from steps 3.2 and 3.3 (m)
- γ : Unit weight of the rock (kN/m^3)
- β : Half angle of the cone apex (°)
  - β = 30 ° for very poor to poor rock quality (RQD ≤ 50 %)
  - β = 45 ° for fair to excellent rock quality (RQD > 50 %)
- Φ : Resistance factor equal to 0.4

Therefore, the total anchor length is :

$$L = L_w + \frac{L_s}{2}$$

or

$$L = \left(\frac{R_g}{\gamma \, \Phi \, \tan^2 \beta} \right)^{1/3} + \frac{L_s}{2}$$

4. INTERACTION OF ANCHORS

4.1 RECOMMENDED EXACT METHOD

For a group of anchors, the interaction of the conical failure surface with that of each adjacent anchor should be taken into account by reducing the load per anchor as followed :

$P' = \psi' P$

where P' : Reduced pullout load due to the interaction of one adjacent anchor (kPa)

P : Pullout load of one single anchor (kPa)

ψ' : Reduction factor to take into account adjacent anchors function of a/r

For 1 adjacent anchor : $\psi' = 0.5 + 0.4\ a/r$ if $0 < a < 1.25\ r$

For 2 adjacent anchors : $\psi' = (0.5 + 0.4\ a/r)^2$ if $0 < a < 1.25\ r$

$\psi' = 1$ if $a \geq 1.25\ r$

where a : Distance between 2 anchors (m)

r : Distance between the center of the anchor and the conical failure surface at the bedrock (m)

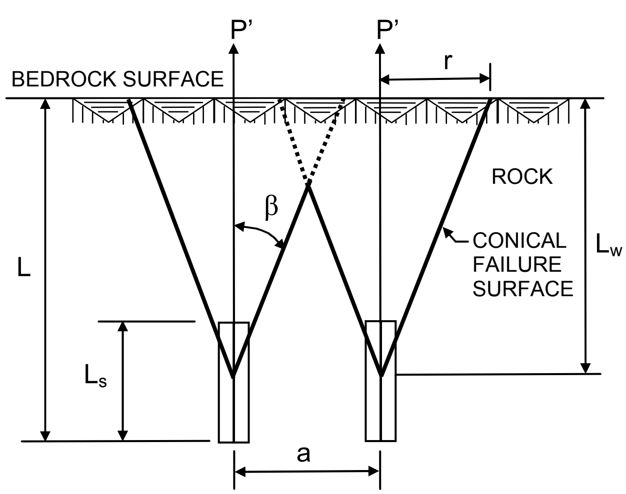


FIGURE 2

4.2 CONCENTRATED ANCHORS, GLOBAL METHOD

A group of closely spaced anchors (between 5 and 10 times the drilled hole diameter) can be considered as one unit in rock pull-up. The rock failure surface forms an inverted truncated pyramid as shown in Figure 3.

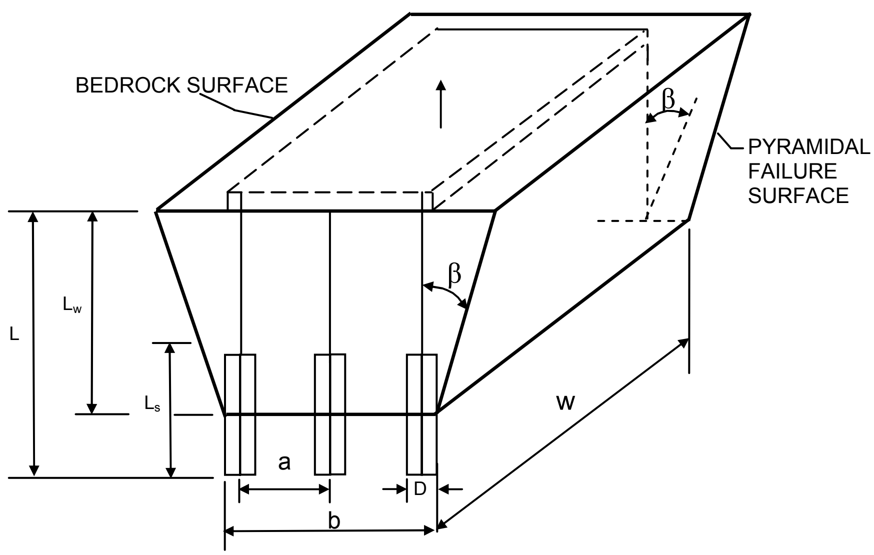


FIGURE 3

For $a < 10\ D$, the resistance load is :

$$R_{gg} = \frac{1}{3}\ \gamma\ \Phi\ L_w\ (A_1 + A_2 + \sqrt{A_1\ A_2})$$

where
- R_{gg} : Global factored geotechnical resistance load (kPa)
- Φ : Resistance factor equal to 0.4
- γ : Unit weight of the rock (kN/m^3)
- L_w : Length of the inverted truncated pyramid from the middle of anchors to the bedrock surface (m)
- A_1 : Area of the group anchors (m^2) ($A_1 = b \times w$)
- A_2 : Area of the upper base of the inverted pyramid (bedrock) (m^2)
  $A_2 = 4\ L_w^2\ \tan^2\beta + 2\ L_w \tan\beta\ (b + w) + b\ w$
- b : Width of the group anchors (m)
- w : Length of the group anchors (m)
- β : Half angle of the cone apex (°)
  - β = 30 ° for very poor to poor rock quality (RQD ≤ 50 %)
  - β = 45 ° for fair to excellent rock quality (RQD > 50 %)
- a : Distance between 2 anchors (m)
- D : Diameter of the drilled hole (m)

5. FURTHER RECOMMENDATIONS

The minimal distance between 2 adjacent anchors must be greater than 5 times the diameter of the drilled hole in the rock.

The holes have to be filled up with a lean grout above the bonded length in order to protect the anchors.

Two anchors will have to be tested on the site. The maximum load must reach at least 1.33 times the calculated resistance load R_g.

6. REFERENCES

1) BUREAU SECURITAS. *Recommandations concernant la conception, le calcul, l'exécution et le contrôle des tirants d'ancrage,* Eyrolles Editions, Paris, 1972.

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3) RADHAKRISHNA, H.S., J.J. Deans and F. Devisser. *Shallow Rock Anchors,* The Canadian Geotechnical Society, Papers for a Symposium on Anchor Systems in Geotechnical Engineering, 1986.

4) NAVAL FACILITIES ENGINEERING COMMAND. *Design Manual – Soil Mechanics, Foundations and Earth Structures,* Virginia, 1971.

APPENDIX 6

REPORT SCOPE

REPORT SCOPE

1. USE OF REPORT

A. Project modifications: The factual data, interpretations and recommendations contained in this report refer to the specific project described in the report, and do not apply to any other project or site. Should the project be modified from a design, dimension, location or level point of view, Qualitas Inc. will have to be consulted so that we can confirm that the recommendations previously made remain valid and applicable.
B. Number of boreholes: The recommendations made in this report are only intended to serve as a guide to the design engineer. The number of boreholes needed to determine all underground conditions that can affect construction (costs, techniques, equipment, schedule, etc.) should normally be higher than the number needed for dimensioning. Contractors who bid or subcontract the work should rely on their own studies and their own interpretations of borehole factual results to form an appreciation of how the underground conditions could affect their work.

2. DRILLING REPORTS AND INTERPRETATION OF UNDERGROUND CONDITIONS

A. Soil and rock descriptions: The soil and rock descriptions in this report are based on commonly accepted classification and identification methods used in geotechnical practice. Soil and rock classification and identification call for judgment. Such descriptions can differ from those that another geotechnician with similar knowledge of good geotechnical practices might give.
B. Soil and rock conditions at borehole locations: Drilling reports only provide subsurface conditions at the borehole locations. The boundaries between the various strata on the drilling reports are often approximate, corresponding instead to transition zones, and were thus subject to interpretation. The accuracy with which underground conditions are indicated depends on the drilling method, sampling method and frequency, and uniformity of the terrain encountered. Borehole spacing, sampling frequency and type of drilling are also dictated by budget and schedule considerations beyond the control of Qualitas Inc.
C. Soil and rock conditions between boreholes: Soil and rock formations vary over a more or less greater extent. Underground conditions between boreholes may vary with respect to the conditions encountered in the boreholes. Any interpretation of conditions between boreholes involves some risk. Such interpretations may lead to the discovery of conditions that differ from those anticipated. Qualitas Inc. cannot be held liable for the discovery of soil and rock conditions different from those described elsewhere than in the places where the boreholes were drilled.
D. Groundwater levels: The groundwater levels given in this report correspond solely to those observed in the place and date indicated in the report. These conditions may vary seasonally or as the result of construction on the site or on adjacent sites. Such variations are beyond the control of Qualitas Inc.

3. STUDY AND CONSTRUCTION FOLLOW UP

A. Final phase verification: Not all design and construction details are known at the time this report is issued. We therefore recommend that the services of Qualitas Inc. be retained to shed light on the consequences construction may have on the finished structure.
B. Inspection during execution: We recommend that the services of Qualitas Inc. be retained during construction to verify and confirm that subsurface conditions over the entire extent of the site do not differ from those given in the report, and that construction work will not have any negative impact on site conditions.

4. CHANGED CONDITIONS: The soil conditions described in this report are those observed at the time of the study. Unless otherwise indicated, these conditions form the basis of the report recommendations. Soil conditions can be altered significantly by construction work (traffic, excavation, etc.) on the site or on adjacent sites. An excavation can expose soil to changes due to humidity, drying or frost. Unless otherwise indicated, the soil should be protected against such changes or reworking during construction.

When the conditions encountered on the site differ significantly from those provided in this report due to the heterogeneous nature of the subsoil or construction work, it is up to the client and user of this report to notify Qualitas Inc. of any changes and to provide Qualitas Inc. with an opportunity to review the recommendations in this report. Recognizing changes in soil conditions requires a certain amount of experience. We therefore recommend that an experienced geotechnical engineer be seconded to the site to verify whether conditions have undergone any significant changes.

5. DRAINAGE: Groundwater drainage is often required for temporary as well as permanent project installations. Improper drainage design or execution can have serious consequences. Qualitas Inc. can in no case assume responsibility for the effects of drainage unless Qualitas Inc. is specifically involved in the detailed design and construction supervision of the drainage system.

6. ENVIRONMENTAL CONDITIONS: In some cases, land on which Qualitas Inc. carries out its investigations may have been subject to contaminant spills, or the water table may contain pollutants originating from a site outside the land under study. Such conditions require an environmental characterisation study. The present geotechnical study was not carried out based on such a study. It should be noted that environmental laws and regulations can have significant impacts on project viability, orientation and costs. Such laws and regulations are subject to amendment and will have to be verified and taken into account during the project design and preparation phase.