

Report No. 6608-63-01
ASSESSMENT OF FOUNDATION WALLS
Québec City Armoury
East Building
Québec (Québec)
ARCOP/DFS/STGM
Consortium of Architects
File No. 6608-63
November 2014



**LABORATOIRES
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1.0 CONTEXT

A team of geotechnical, environmental, and soils and materials engineering consultants from Laboratoires d'Expertises de Québec ltée (hereinafter "L.E.Q. ltée") was contracted by the ARCOP/DFS/STMG consortium of architects to conduct an assessment of the foundations of the Québec City Armoury's east building, located at 805 Avenue Wilfrid-Laurier in Québec City. The building was built in 1885.

More specifically, the east building's front and right-side foundation walls show damage (efflorescence, crumbling and delamination) in the accessible concrete. The purpose of this assessment is to collect the information required to assess the quality of the concrete and identify the causes of deterioration. The field data collection campaign and the laboratory analysis program were carried out by L.E.Q. ltée.

As agreed, the following information was obtained from the collection of four (4) concrete core samples:

- Photographs and descriptions of the core samples;
- Core sample collection locations;
- General condition of the core sample concrete;
- Compressive strength of the concrete;
- Recommendations.



2.0 RECONNAISSANCE METHOD

The location of the core sample points was determined in collaboration with a representative from BPR Inc., Mr. Mathieu Bouchard, engineer, in order to obtain the desired information as well as the best representation of the general condition of the foundation wall concrete, in consideration of access limitations.

Sample collection was carried out by Groupe Diamantex using an electric corer fitted with a 100 millimetre-wide diamond-toothed core bit.

Sample collection was carried out using the following procedure:

- General inspection of the concrete;
- Core samples taken from the concrete;
- Holes filled with a “Sika Set Plug”-type quick-set mix.



3.0 FIELD ASSESSMENT

3.1 Site visit

During the visit on June 6, 2013, Mr. Pierre Beauséjour, engineer, conducted a detailed inspection, took photographs of the foundation walls and performed visual observations of the Québec City Armoury's east building located at 805 Avenue Wilfrid-Laurier Est in Québec City (photographs 1 to 4 in Appendix "A"). Sample locations were determined and information was collected from the BPR Inc. representative during this inspection.

According to information from the BPR Inc. representative, the concrete in the foundation walls has sustained gradual efflorescence, crumbling and delamination. In addition, surface run-off caused by humidity seeping through the foundation walls appears when the snow melts in the spring and during heavy rainfall.

3.2 Apparent damage

Damage was noted during the inspection visit on June 6, 2013. The most significant damage was mainly found on the interior surface of concrete of the front and right-side foundation walls, to which the study was limited.



The concrete showed surface crumbling, efflorescence and delamination. Despite the fact that the concrete was covered with mortar at several locations, the type of stone used in the concrete can be described on the basis of the various loose wall fragments and the core samples. The concrete is composed of crushed clayey limestone of variable size. The coarse aggregates in the mix appear to be of the same type as the rock found in the various excavations conducted as part of the operations that were underway during our visit on June 6, 2013. As a result, it appears that rock debris was used in the concrete used to build the foundation walls of the Québec City Armoury's east building.

Crumbling mostly appears on the surface. Resonance tests performed with a geologist's hammer indicated that the concrete is generally sounder at the core of the foundation walls.

Efflorescence is generally irregular on the concrete surface. Several factors can lead to efflorescence, which is the result of crystallization of certain salts on the concrete surface that creates a whitish powder. In order for this phenomenon to occur, water soluble salts must be present in the ground that rests against the concrete walls or in the concrete itself. The dissolved salts are carried by water or humidity and subsequently crystallize on the surface of the concrete as the water evaporates. Significant amounts of efflorescence may result in the degradation of a concrete structure given the pressure created by the changes in volume from the mineral salt crystallization process. These salts tend to accumulate in the spaces between different materials, as was noted in certain areas behind the mortar coating on the interior walls. Permeability differences between materials cause the salts to exert crystallization pressure on the side where permeability is weakest and the material is the least resistant, which in this case is concrete. Thus, salt crystallization has damaged the concrete and caused the efflorescence. The



whitish deposits normally seen appear to have been washed away by the surface runoff from the humidity that has seeped through the foundation walls.

In addition, a core sample collected at a shallow depth has revealed that the interior part of the right-side foundation wall that corresponds to the exterior stone block wall is composed of a stone and mortar assembly (photographs 5 to 7). The stone used appears to be of the same type as the rock found in the various excavations that were part of the operations underway during the visit on June 6, 2013. The stones thus appear to have been made from clayey limestone.

3.3 Sample collection

Core samples were collected during this inspection. As agreed, four samples were collected: two from the front wall at an accessible height and two from the right-side wall – one from an accessible height and the other from the bottom of the accessible wall. In total, four core samples 100 millimetres in diameter, identified as C-1 to C-4, were collected from the full thickness of the foundation walls.

Core sampling location points are shown on Drawing No. 6608-63-01 in Appendix “B”. In addition, a photograph of each core sample location is presented in Appendix “A” (photographs 8 to 11).

4.0 LABORATORY ASSESSMENT

All core samples were visually examined, measured and photographed. A description of each core sample is presented in Appendix “C”.

Table 1 below summarizes the characteristics of the materials found at soundings C1-C-4:

**TABLE I
OBSERVED MATERIAL CHARACTERISTICS**

Characteristic	Sounding			
	C-1	C-2	C-3	C-4
Average sample length (mm)	852	883	929	814
Interior mortar coating	Yes	Yes	Yes	Yes
Exterior coating	No	No	No	No
Type of stone	Clayey limestone debris	Clayey limestone debris	Clayey limestone debris	Clayey limestone debris
Maximum stone calibre (mm)	61	126	53	50
Sign of alkali-silica reaction	Slight	Slight	Slight	Slight
Type of sand (small quantity).	Natural	Natural	Natural	Natural
Reinforcement	No	No	No	No

Several consolidation defects or voids were also observed.

4.1 Compressive strength

Compressive strength tests were performed on core samples C-1 to C-4 in accordance with standard CAN/CSA-A23.2-14C. The details of these results are presented in Appendix “D”. Table II below provides the compressive strength test results for each core sample location:



TABLE II
COMPRESSIVE STRENGTH BASED ON STANDARD CSA A23.2-14C

Core Sample	Location	Compressive strength (MPa)¹	Average compressive strength (MPa)¹
C-1	West front wall	24.5	24.7
C-2	East front wall	29.2	
C-3	North right wall	18.7	
C-4	South right wall	26.4	

1- Core samples were saturated prior to testing.



5.0 INTERPRETATION

The low durability of concrete from that era is due to the methods and materials used in early 20th Century construction work. There were no building construction standards at the time.

Concrete used in those constructions often used a very high water/concrete ratio, granular component dosage was determined from an arbitrary recipe and lesser quality stones, such as clayey limestone, were used.

In this case, and as is the case with most concrete from that era, the concrete does not have the intrinsic characteristics required for proper resistance to frost/thaw and wet/dry cycles.

After so many years of service, this building's foundation walls reveal a certain level of degradation and must be protected to prevent or slow any further degradation in order to extend the structure's useful lifespan.



6.0 CONCLUSIONS AND RECOMMENDATIONS

To protect the concrete from any further degradation, we recommend that the structures be kept away from any humidity and to prevent exposure to frost/thaw cycles. For example, insulation and a waterproof membrane could be installed on the exterior of the foundation walls.



This report has been read and commented on by Mr. Charles Tremblay, Eng.
Ph.D.

We remain available to provide any additional information.

LABORATOIRES D'EXPERTISES DE QUÉBEC LTÉE

Pierre Beauséjour, Eng.
#OIQ: 145429
Project Manager

PB/mm

Encl.

Québec City, November 28, 2014

Distribution:

- . ARCOP/DFS/STGM consortium of architects 1 copy
- . Laboratoires d'Expertises de Québec ltée 1 copy

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APPENDIX “A”

Photographic Compendium
Pictures Nos. 1 to 11

Photographic Compendium



Picture 1 : View of the east building (right) of the Québec City Armoury. (2013-06-06)

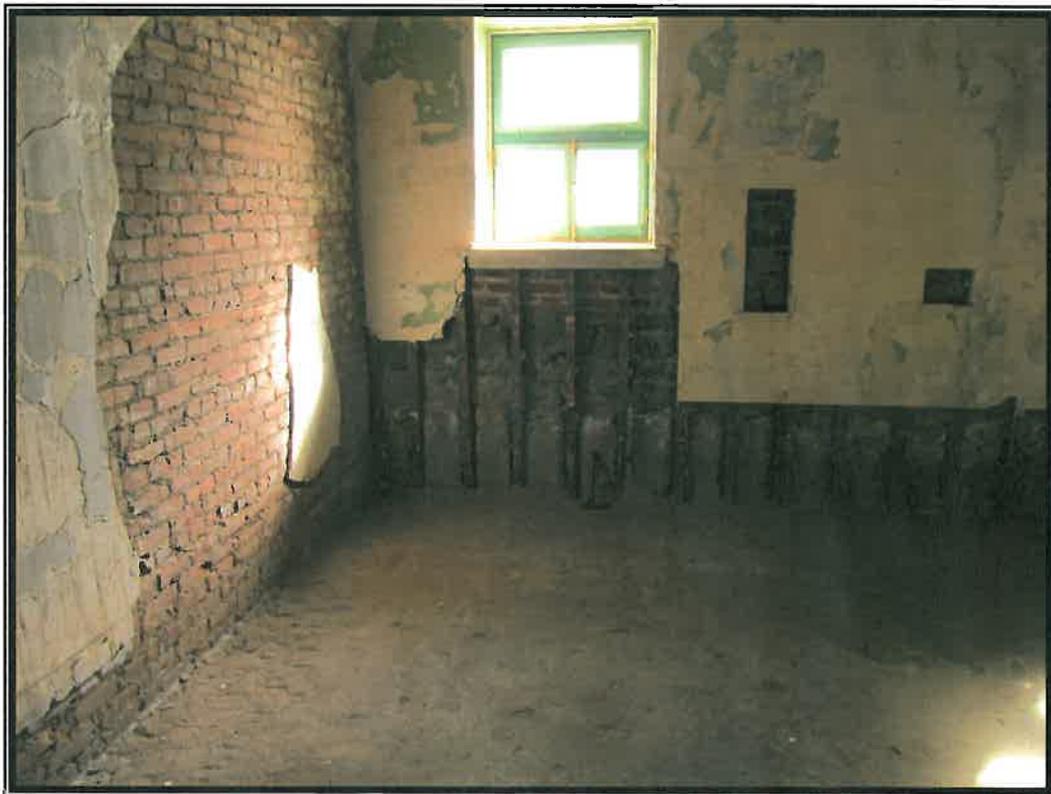


Picture 2 : View of the front wall of the east building. (2013-06-06)

Photographic Compendium



Picture 3 : View of the front and right walls of the east building. (2013-06-06)



Picture 4 : View of the right wall of the east building. (2013-06-06)

Photographic Compendium



Picture 5 : **Drilling of the exterior stone facing of the right wall of the east building
(2013-06-06)**



Picture 6 : **Inside view of the core through the right wall of the east building
(2013-06-06)**

Photographic Compendium



Picture 7 : Sample from the right wall from the exterior stone facing of the east building. (2013-06-06)

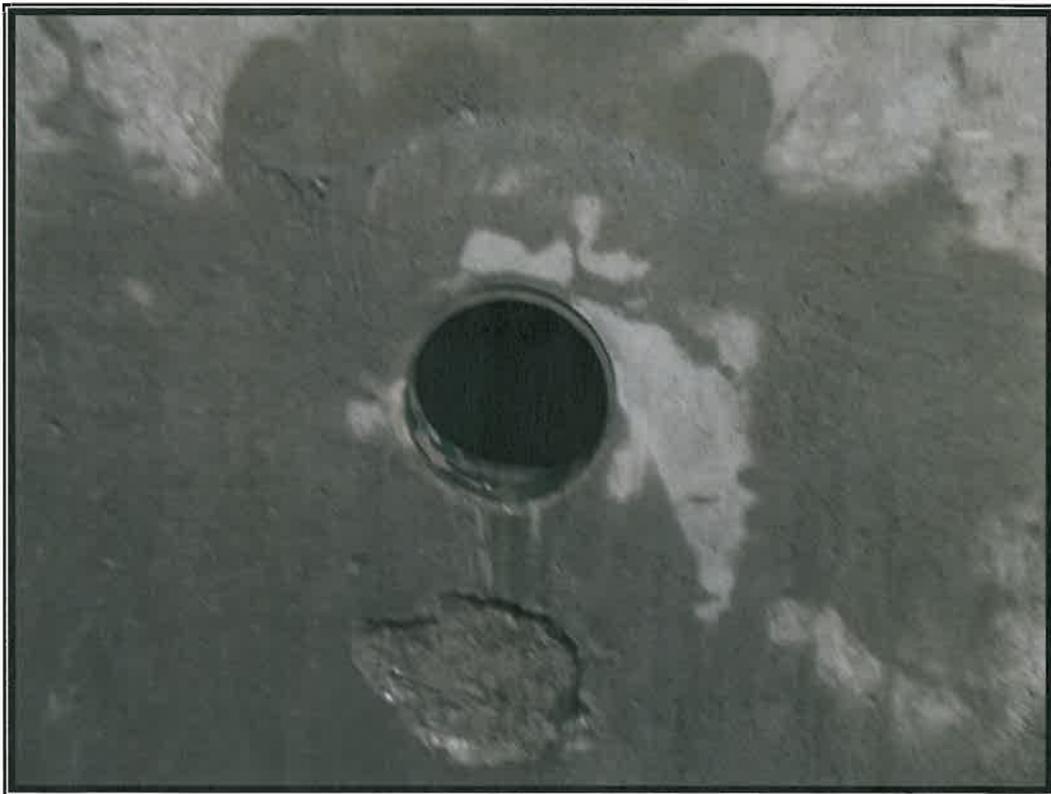


Picture 8 : Sample (C-1) from the front wall of the east building, below grade. (2013-06-06)

Recueil photographique



Picture 9 : Sample (C-2) of the front wall of the east building, below grade.
(2013-06-06)



Picture 10 : Sample (C-3) of the right wall of the east building, below grade.
(2013-06-06)

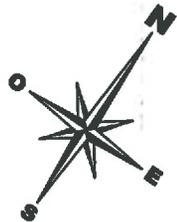
Photographic Compendium



Picture 11 : Sample (C-4) from the right wall of the east building, below grade.
(2013-06-06)

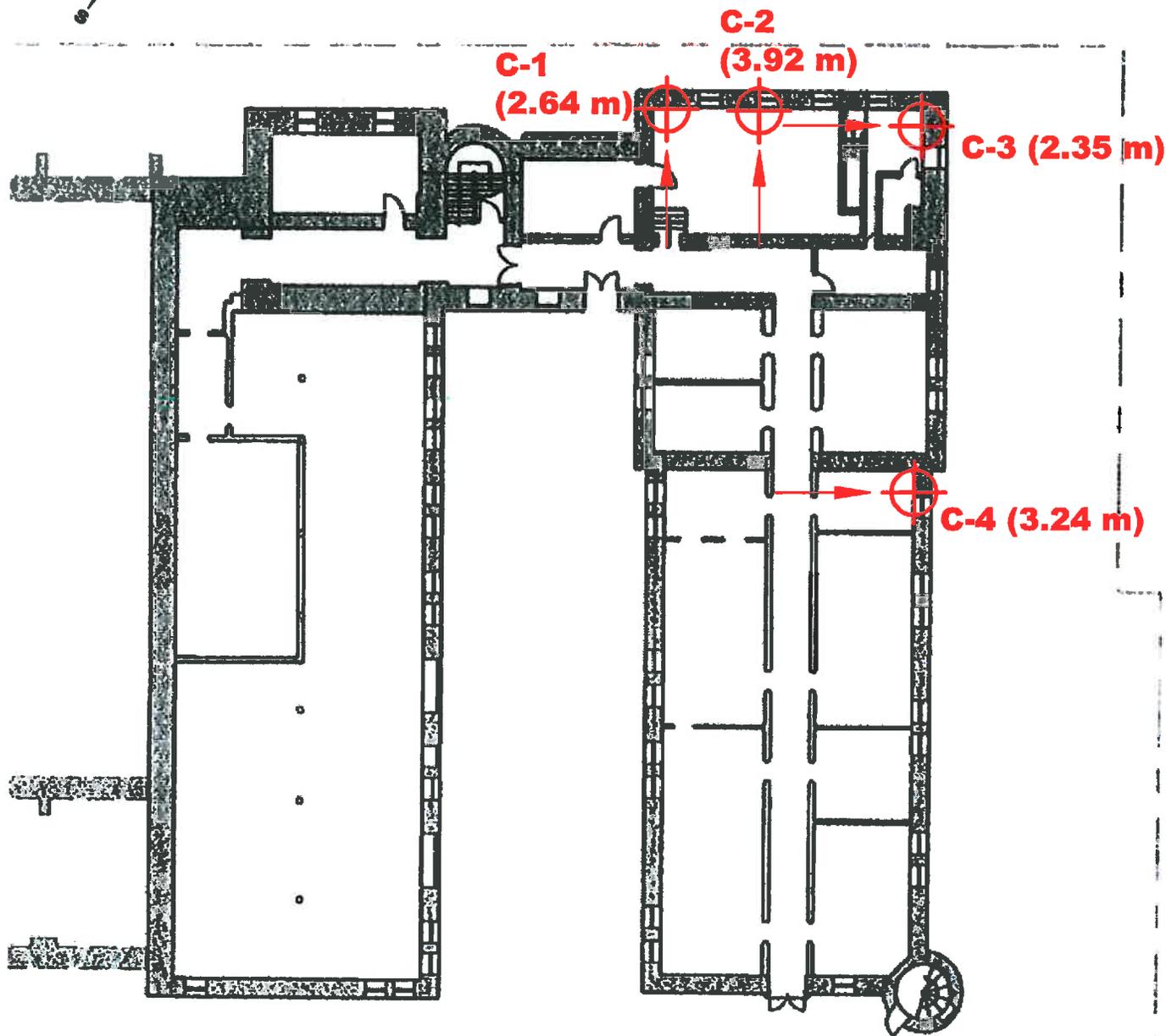
APPENDIX “B”

Sample Collection Locations
Drawing No. 6608-63-01



Échelle
1:750

1:750



Legend:

- Core
- Distance of the Core Sample from the 1st Floor
- Direction of Drilling

Prepared for:
ARCOP/DFS/STGM
Architect Consortium

Prepared by:

LABORATOIRES D'EXPERTISES DE QUÉBEC LTÉE
Géotechnique, environnement et ingénierie des sols et matériaux

Seal:

Project Title:
Foundation Wall Assessment
Québec City Armoury
East Building
Québec (Québec)

Drawing Title:
Sample locations

Author: D.S.	Scale: 1:750	Project No.: 6608-63
Verified: C.T.	Date: November 2014	Drawing No.: 6608-63-01

APPENDIX “C”

Core Sample Descriptions

Descriptive Sheet



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DE QUÉBEC

1100 Boulevard de la Concorde
Québec, Québec G1R 5K6

General Information

Project Title:	Assessment of the Foundation Concrete
Project No.:	6608-63
Client:	ARCOP/DFS/STGM Architect Consortium
Surveyed by:	Pierre Beauséjour, Eng.
Verified by:	Charles Tremblay, Eng. Ph.D

Technical Information

Location:	Québec City Armoury Québec (Québec)
Sample Location:	See drawing No. 6608-63-01
Drilling Angle:	Perpendicular to the surface
Core Diameter:	100 mm
Cored by:	Groupe Diamantex
Date Received:	2013-06-06
Core No.:	C-4
Sample No.:	6608-63-004

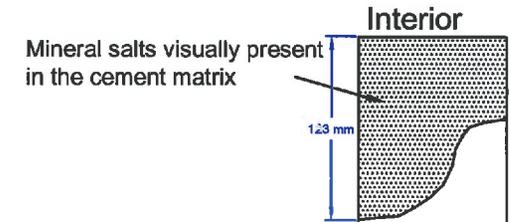
Notes and Observations

- Aggregate is partially and/or uncoated;
- Presence of wood fragments;
- Mixture is visibly heterogeneous;
- Crumbly surface;
- Granular discontinuity in the large aggregate;
- Consolidation defects are present.

Picture



Core Sample Description



Concrete	
Thickness:	812 à 816 mm
Cracking:	None
Compressive strength:	26.4 MPa
Notes:	

Aggregate	
Large:	Clayey limestone
Diameter:	± 50 mm max.
Small:	Natural sand
Signs of ASR:	Slight

Break

Exterior

Descriptive Sheet



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Compagnie des experts en services
et ingénierie des sols et structures

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Surveyed by:	Pierre Beauséjour, Eng.
Verified by:	Charles Tremblay, Eng. Ph.D

Technical Specifications

Location:	Québec City Armoury Québec (Québec)
Sample Location:	See drawing No. 6608-63-01
Drilling Angle:	Perpendicular to the surface
Core Diameter:	100 mm
Cored by:	Groupe Diamantex
Date Received:	2013-06-06
Core No.:	C-3
Sample No.:	6608-63-003

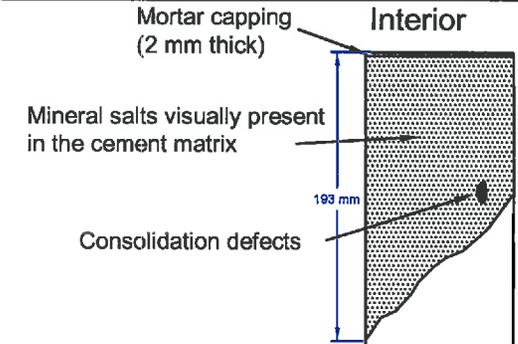
Notes and Observations

- Aggregate is partially and/or uncoated;
- Presence of wood fragments;
- Mixture is visibly heterogeneous;
- Crumbly surface;
- Granular discontinuity in the large aggregate.

Picture



Core Sample Description



Concrete	
Thickness:	927 à 931 mm
Cracking:	None
Compressive strength:	18.7 MPa
Notes:	

Aggregate	
Large:	Clayey limestone
Diameter:	± 53 mm max.
Small:	Natural sand
Signs of ASR:	Slight

Consolidation defects

Exterior

Descriptive Sheet



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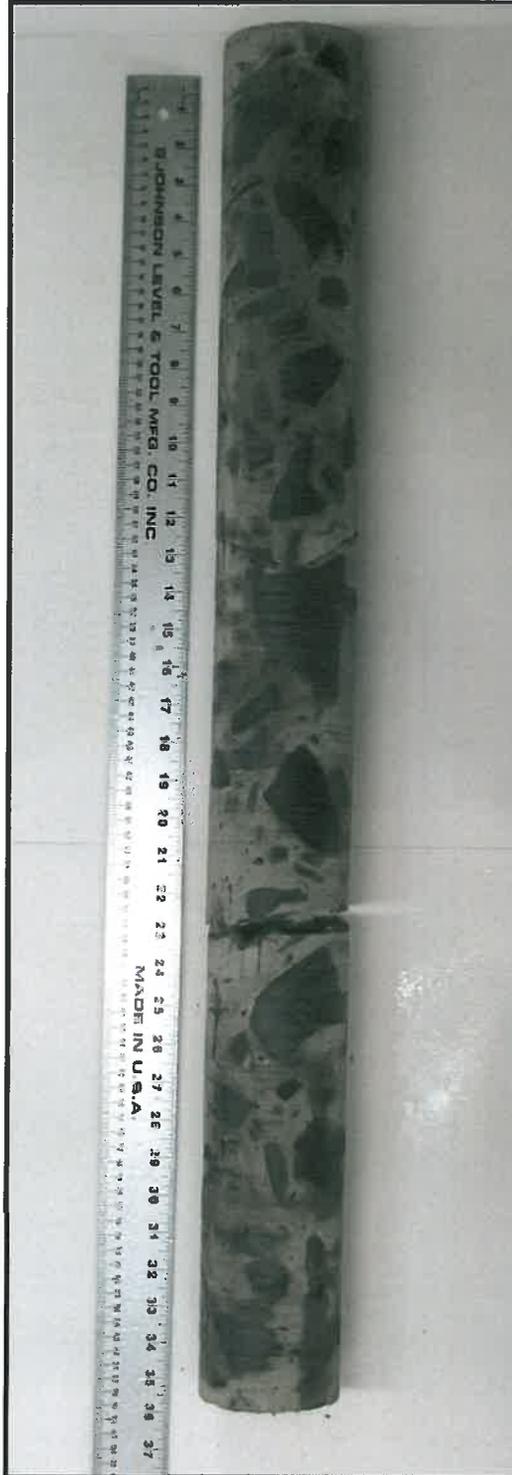
Technical Specifications

Location:	Québec City Armoury Québec (Québec)
Sample Location:	See drawing No. 6608-63-01
Drilling Angle:	Perpendicular to the surface
Core Diameter:	100 mm
Cored by:	Groupe Diamantex
Date Received:	2013-06-06
Core No.:	C-2
Sample No.:	6608-63-002

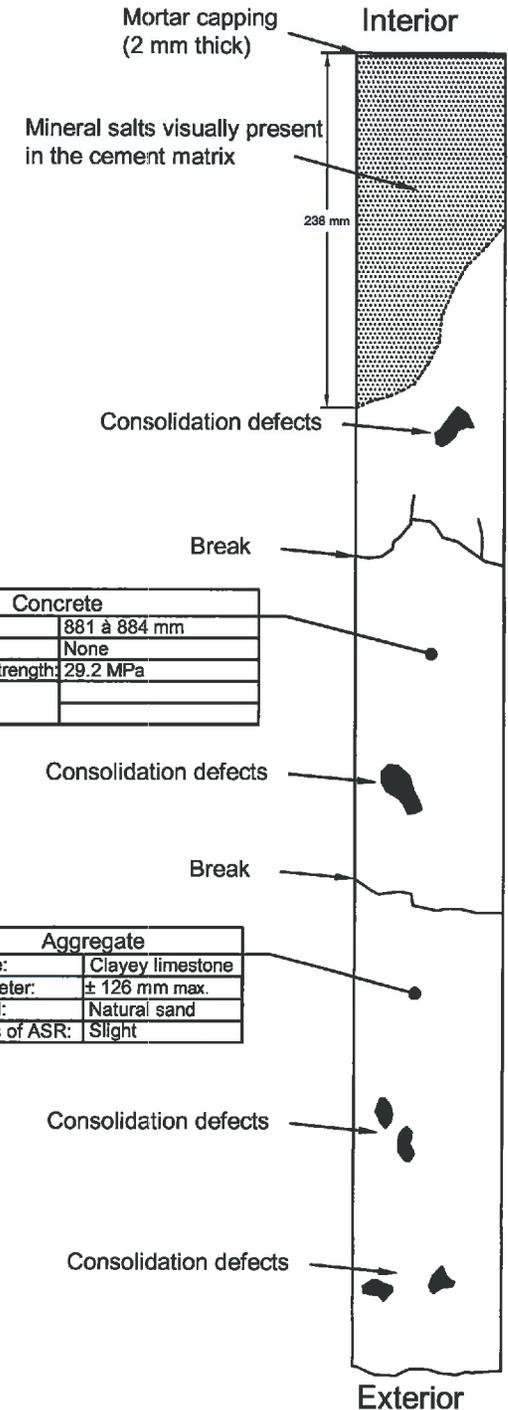
Notes and Observations

- Aggregate is partially and/or uncoated;
- Presence of wood fragments;
- Mixture is visibly heterogeneous;
- Crumbly surface;
- Granular discontinuity in the large aggregate.

Picture



Core Sample Description



Concrete	
Thickness:	881 à 884 mm
Cracking:	None
Compressive strength:	29.2 MPa
Notes:	

Aggregate	
Large:	Clayey limestone
Diameter:	± 126 mm max.
Small:	Natural sand
Signs of ASR:	Slight

Descriptive Sheet

General Information

Project Title:	Assessment of the Foundation Concrete
Project No.:	6608-63
Client:	ARCOP/DFS/STGM Architect Consortium
Surveyed by:	Pierre Beauséjour, Eng.
Verified by:	Charles Tremblay, Eng. Ph.D

Technical Information

Location:	Québec City Armoury Québec (Québec)
Sample Location:	See drawing No. 6608-63-01
Drilling Angle:	Perpendicular to the surface
Core Diameter:	100 mm
Cored by:	Groupe Diamantex
Date Received:	2013-06-06
Core No.:	C-1
Sample No.:	6608-63-001

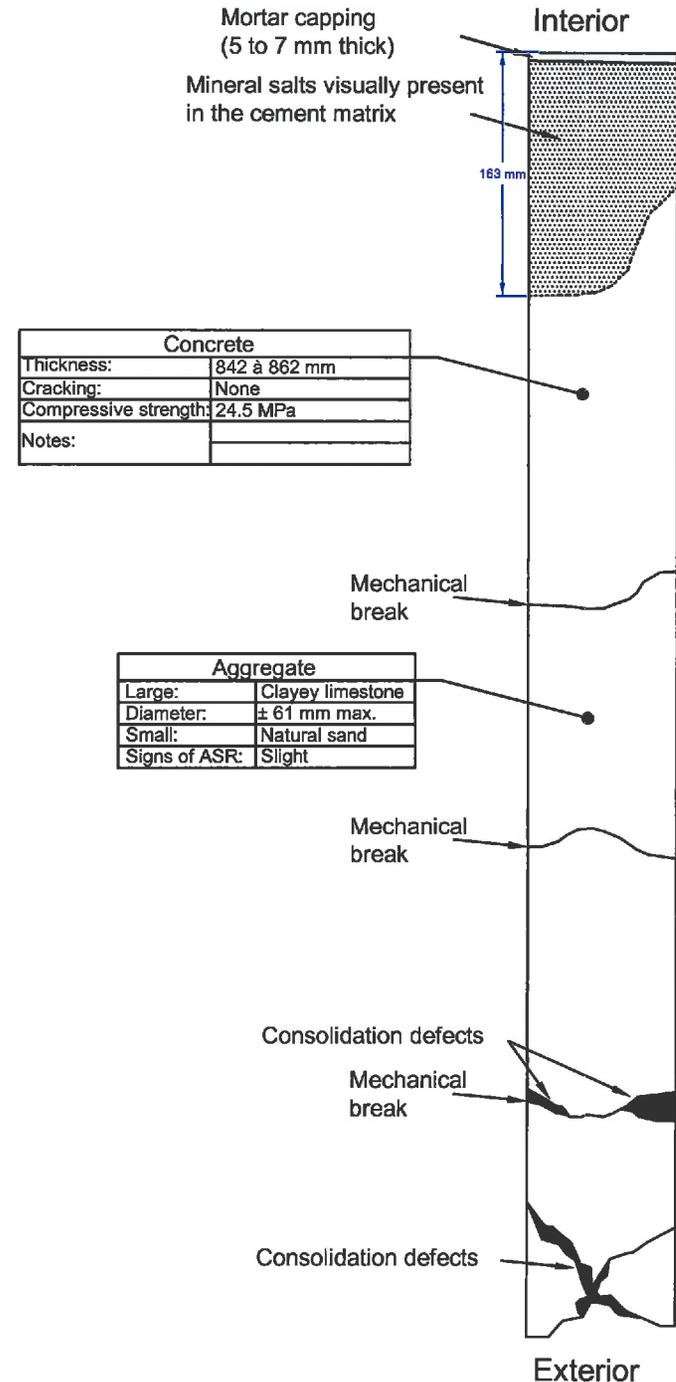
Notes and Observations

- Aggregate is partially and/or uncoated;
- Presence of wood fragments;
- Mixture is visibly heterogeneous;
- Crumbly surface;
- Granular discontinuity in the large aggregate.

Picture



Core Sample Description



APPENDIX “D”

Concrete: Determining the Compressive Strength of Concrete or Prefabricated Concrete
Paver Cores



CONCRETE

CAN/CSA A23.2-9C

DETERMINING THE COMPRESSIVE STRENGTH OF CONCRETE OR PREFABRICATED CONCRETE PAVERS

RL-6151 (2009-06)

Projet: Foundation Wall Assessment – Québec City Armoury	Project No.: 6608-63
Client: ARCOP/DFS/STGM Consortium	
Sampled by: L.E.Q.	Sampled on: 06-06-2013
Received on: 06-06-2013	

Sample #	Location	Length #1 (± 1 mm)	Length #2 (± 1 mm)	Length #3 (± 1 mm)	Average Length (L)	Diameter #1 (± 1 mm)	Diameter #2 (± 1 mm)	Average Diameter (D)
001	F1-2 (2/3)	137,12	137,42	137,24	137,26	94,20	94,47	94,34
002	F2-3 (3/3)	162,65	162,24	162,52	164,47	93,08	93,26	93,17
003	F3-2 (2/3)	149,13	149,47	149,28	149,29	92,94	92,98	92,86
004	F4-2 (2/3)	131,67	132,10	132,11	131,96	93,37	93,58	93,48

Sample #	Mean Ratio (L/D)	Correction Factor	Maximum Load (kN)	Type of Fracture	Resistance (MPa)	Notes (Curing, Rebar, Sample Age)
001	1,455	0,9552	176,1		24,5	Saturated conditioning
002	1,744	0,9798	204,6		29,2	Saturated conditioning
003	1,606	0,9688	132,3		18,7	Saturated conditioning
004	1,412	0,9492	191,2		26,4	Saturated conditioning

TYPE OF FRACTURE				
(a)	(b)	(c)	(d)	(e)

NOTES:
ANALYSED BY: S. Bergeron
DATE: 20-06-2013

Vérifié L.E.Q.	
Initials	Date
C.B.	26-06-2013