Industry–Academia Research Collaboration Event

"New Generation of Sustainable and Resilient Reinforced Masonry Buildings"

A show case of collaborative research and development projects between
the Québec masonry industry and Concordia university

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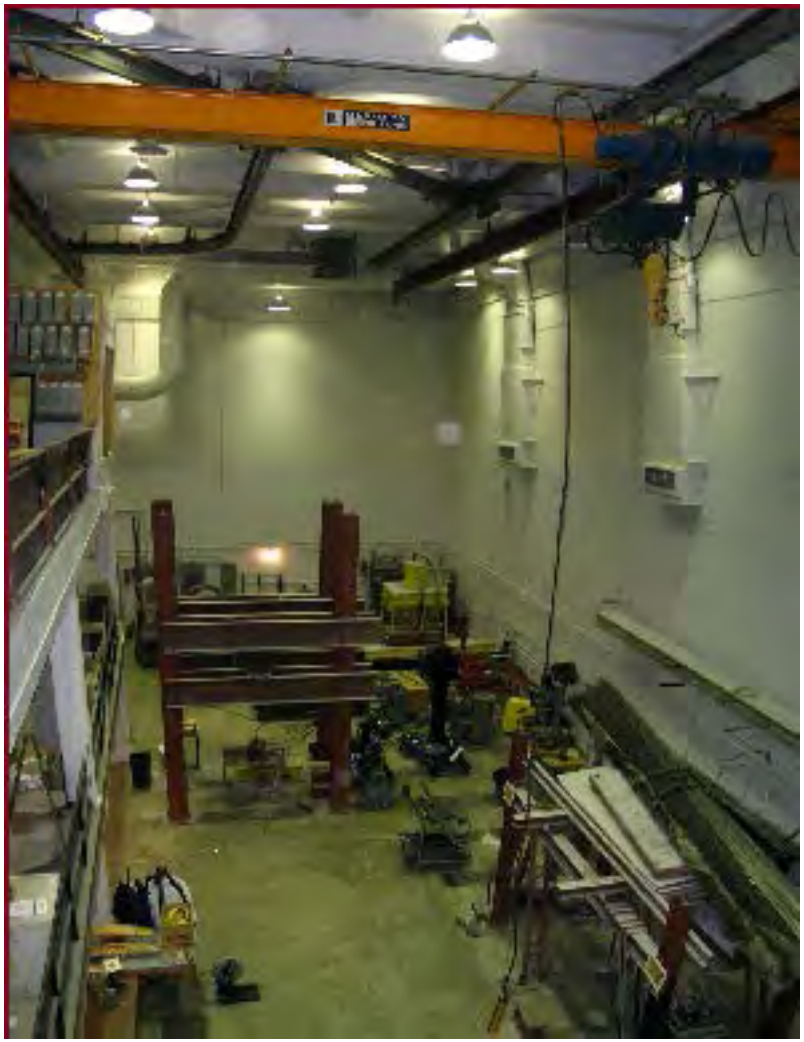
PRESENTATION CONTENTS

- Structures Laboratory at Concordia University
- Snapshots of previous research projects
- Current research project supported by AEMQ

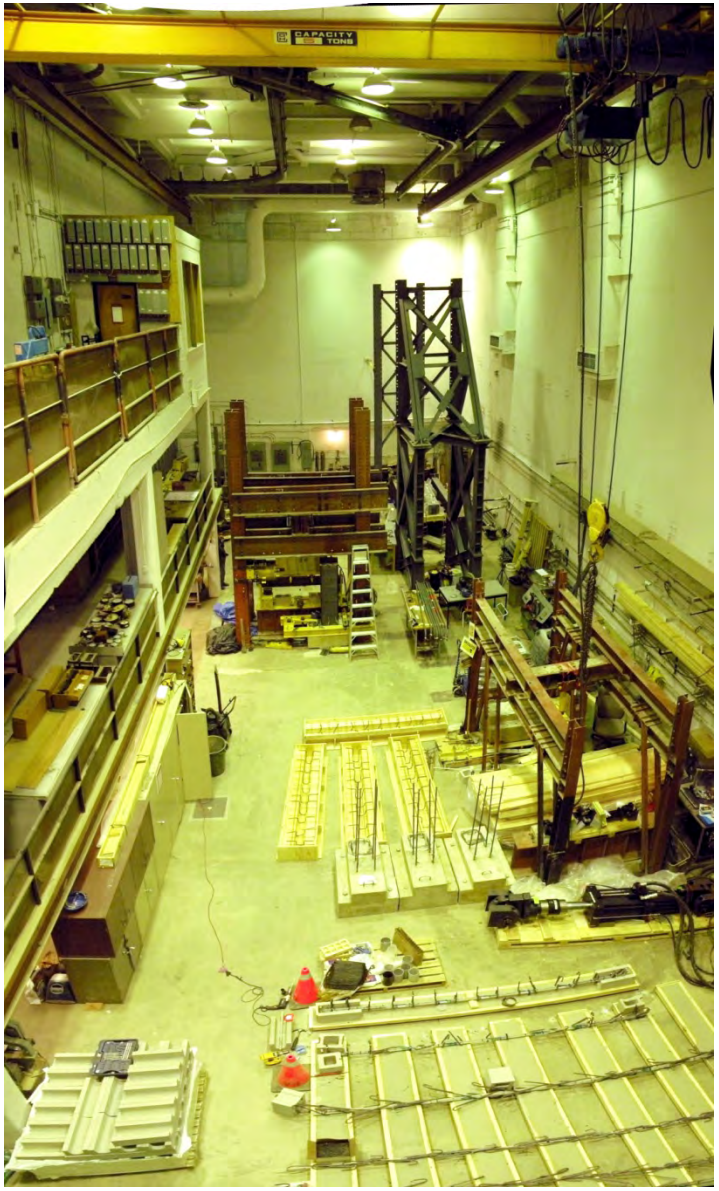
PART 1

STRUCTURES LABORATORY AT CONCORDIA UNIVERSITY

Upgrading the Structures Laboratory



Before



After

STRUCTURES LABORATORY AT CONCORDIA

3 Actuators for dynamic loads

1 Actuator for Shake Table

+

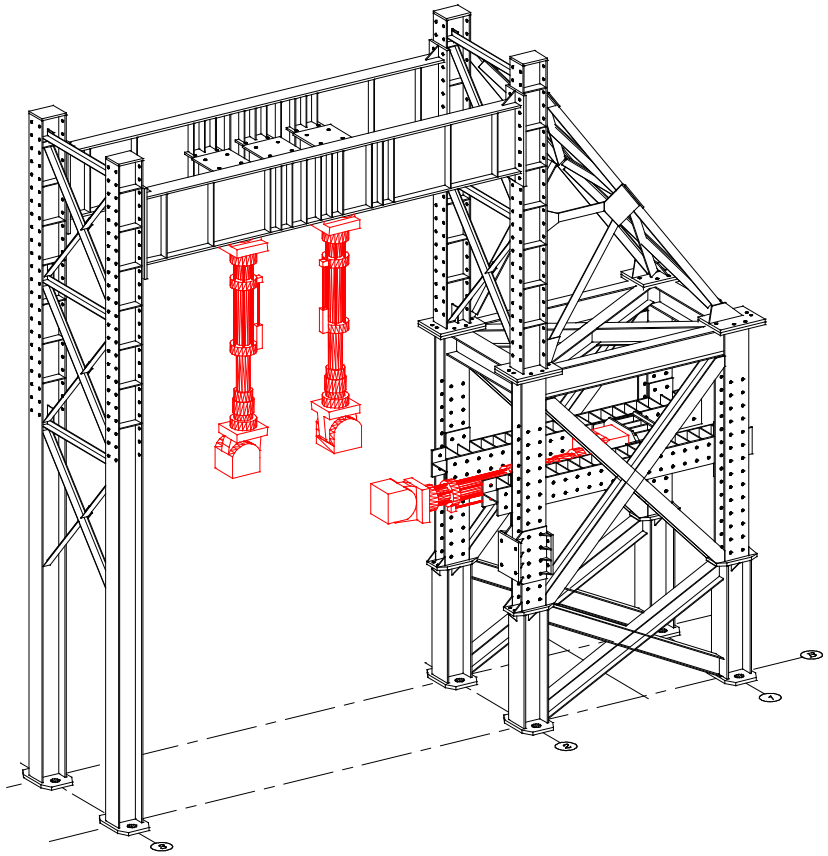
Hydraulic pump

+

Digital controller

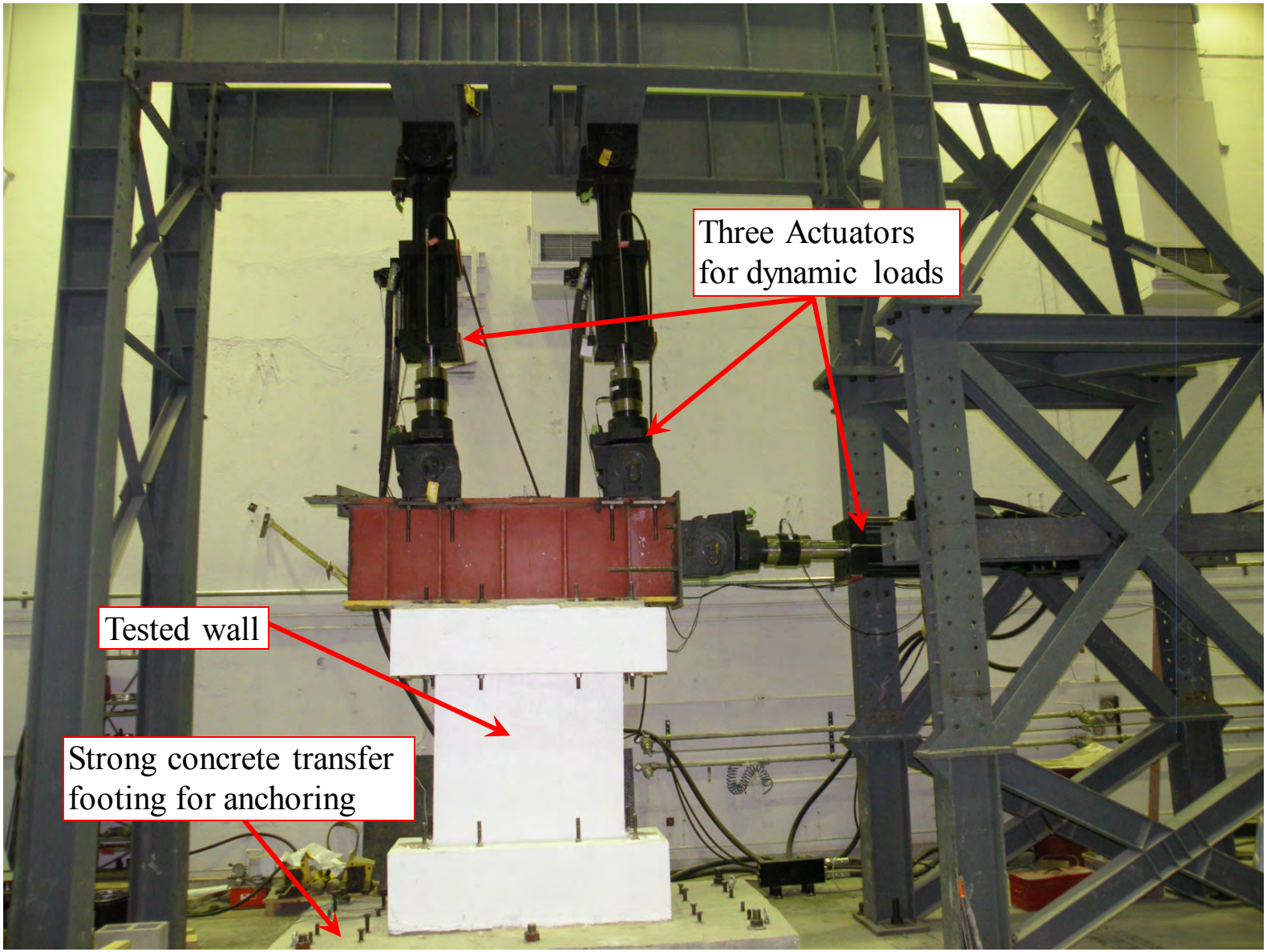
+ Data acquisition systems for fibre optic and wireless sensors

Structural Testing Facility



Strong Steel Reaction Frame to support the actuators

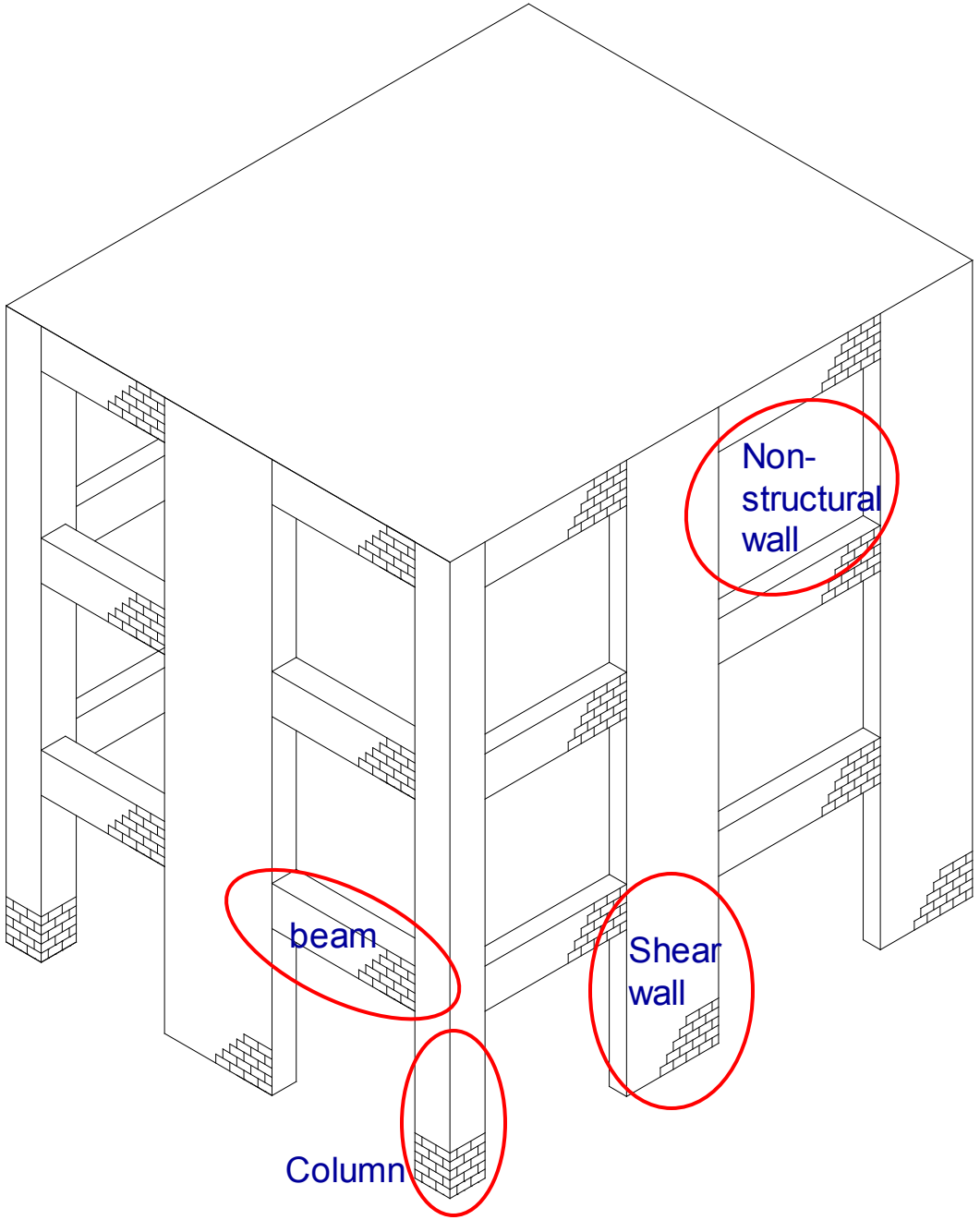
STRUCTURES LABORATORY AT CONCORDIA



PART 2

SNAPSHOTS OF PREVIOUS RESEARCH PROJECTS

Structural Elements in a Typical Reinforced Masonry Building



Snapshots of Previous Research Projects

1. Seismic rehabilitation of RM Columns
2. GFRP-reinforced masonry beams
3. GFRP-reinforced masonry walls
4. Strengthening URM walls for high wind loads
5. Seismic performance of RM Walls
6. Sustainable Low-Energy Consumption Buildings

1- SEISMIC REHABILITATION OF RM COLUMNS

Construction of full-scale RM columns:

Shear reinforcement

Grouting the cells

1- SEISMIC REHABILITATION OF RM COLUMNS

Glass FRP (GFRP) bar

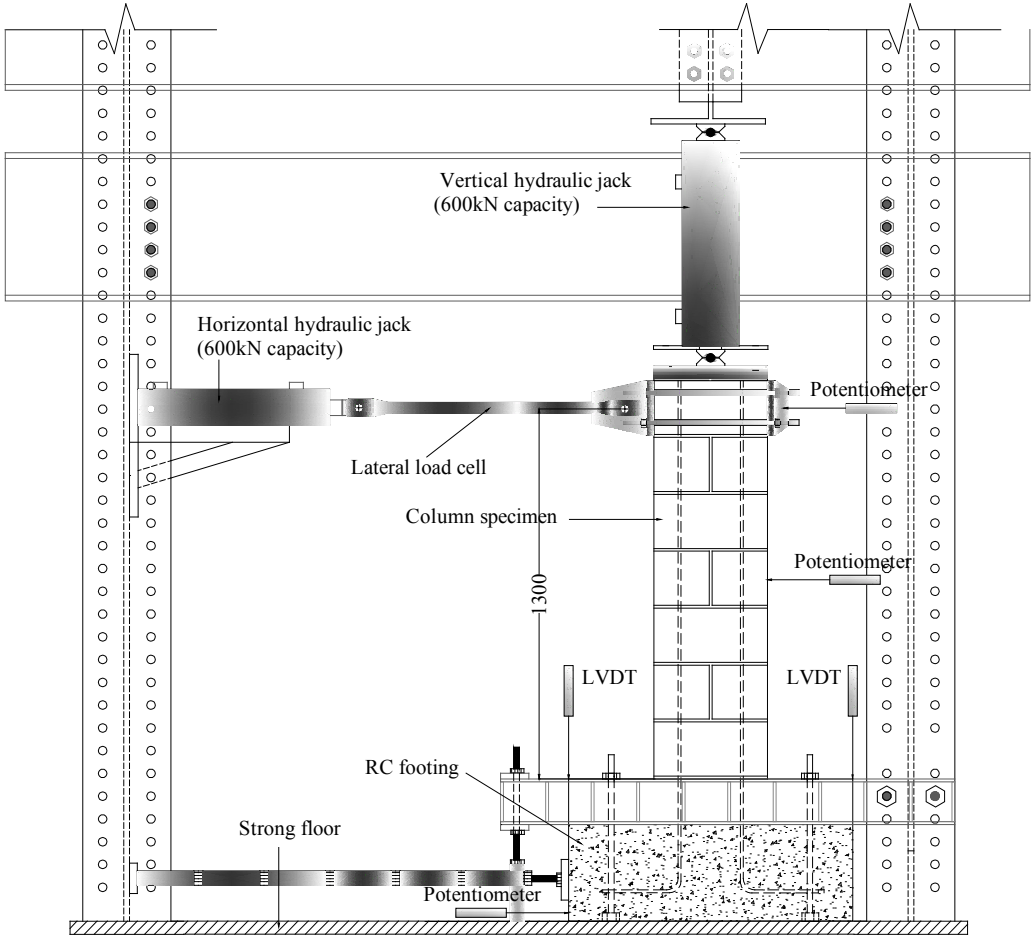
Carbon FRP (CFRP) sheets

Examples of Fibre-reinforced Polymer (FRP) composites

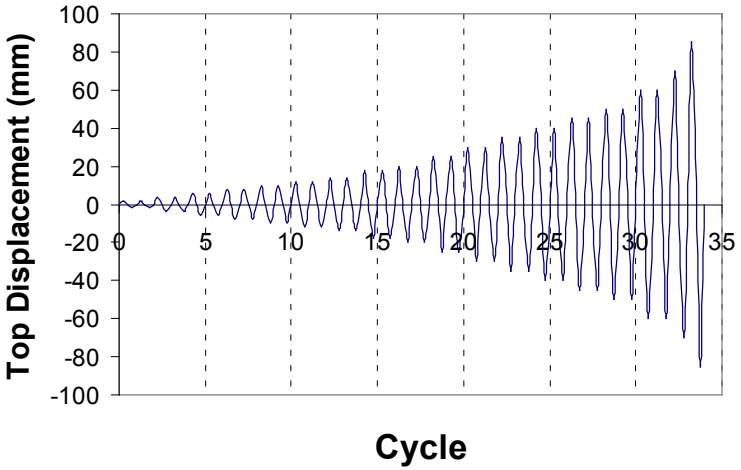
1- SEISMIC REHABILITATION OF RM COLUMNS

Wrapping with FRP sheets

1- SEISMIC REHABILITATION OF RM COLUMNS

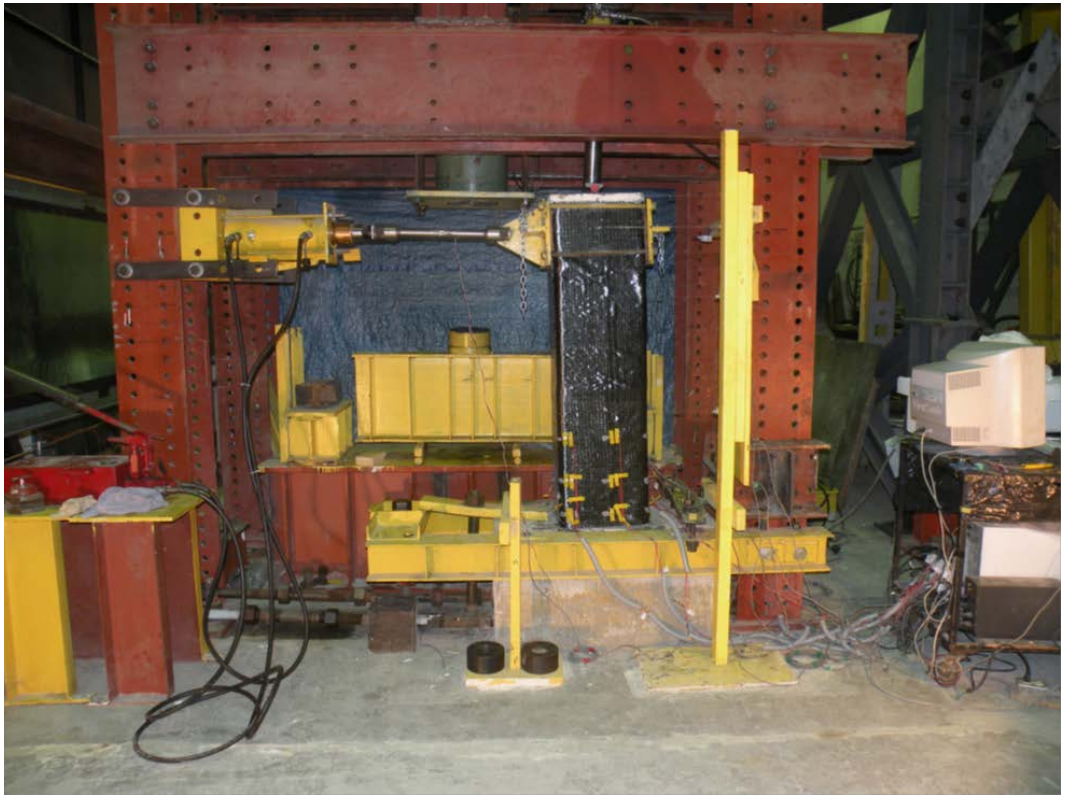


Test setup and Instrumentation



Lateral displacement protocol

1- SEISMIC REHABILITATION OF RM COLUMNS

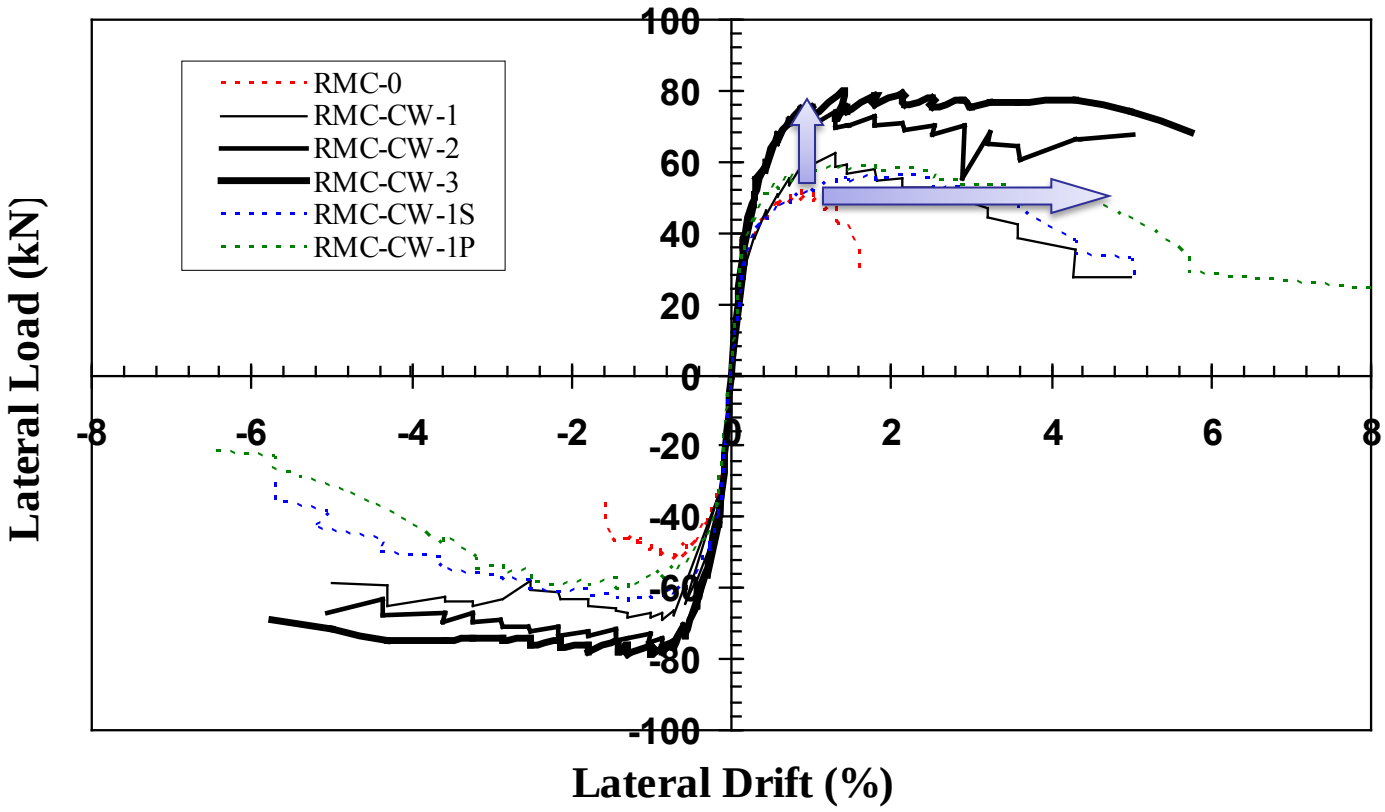


Test setup and Instrumentation

1- SEISMIC REHABILITATION OF RM COLUMNS

Rehabilitated RM column under axial and lateral loads

1- SEISMIC REHABILITATION OF RM COLUMNS



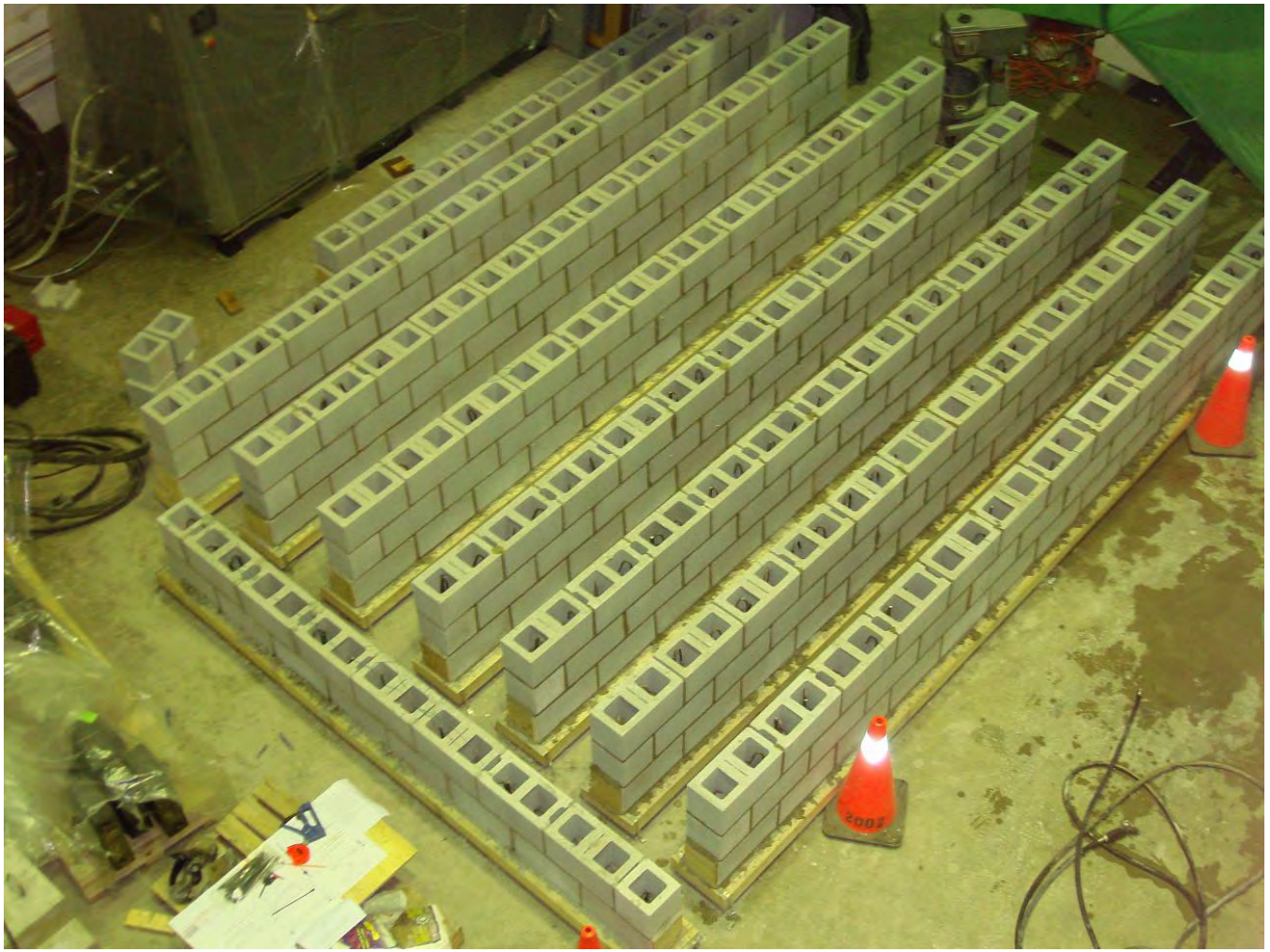
Lateral load-drift relationship

2- GFRP-Reinforced Masonry Beams

Construction of full-scale RM beams:

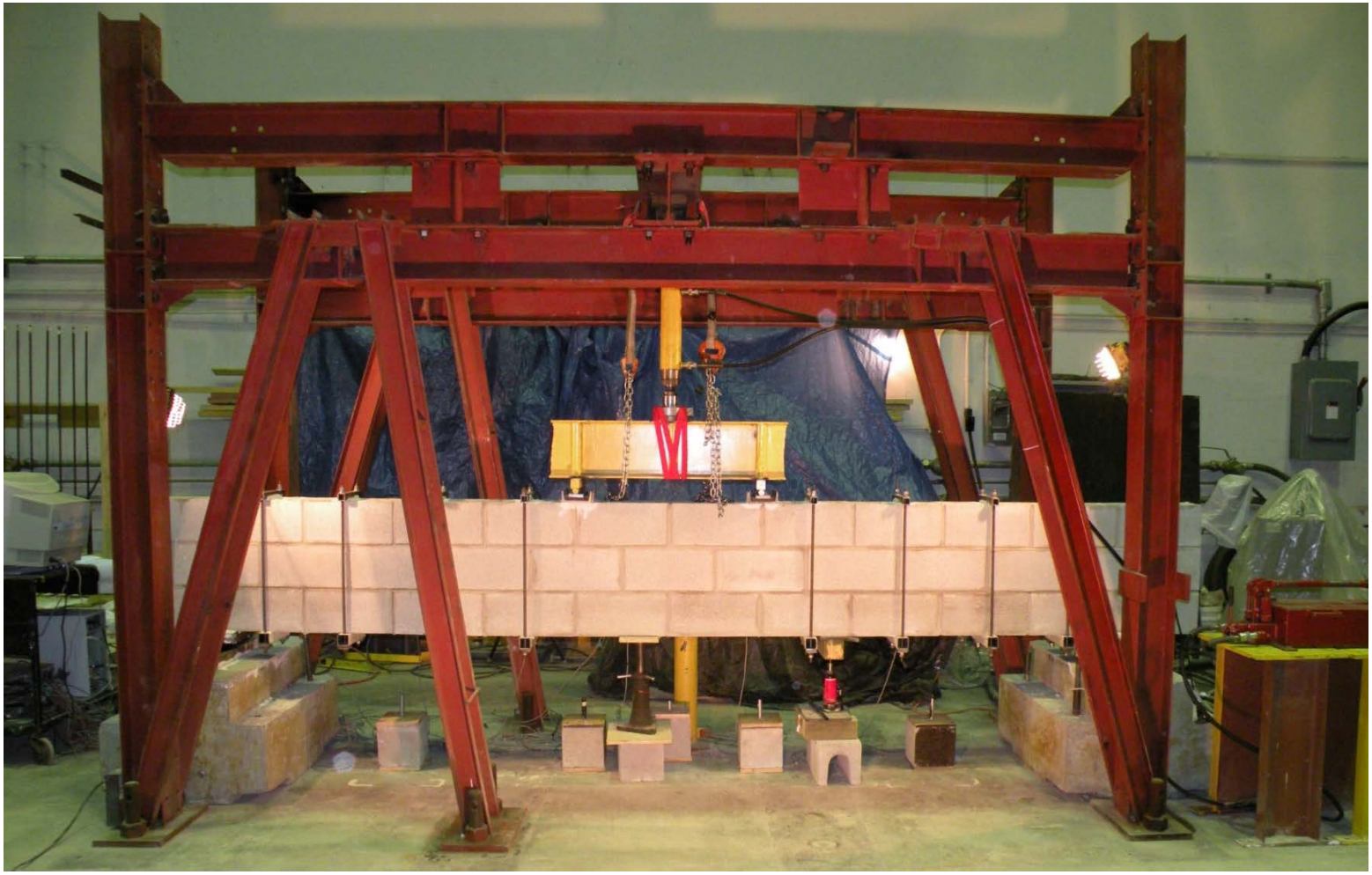
2- GFRP-Reinforced Masonry Beams

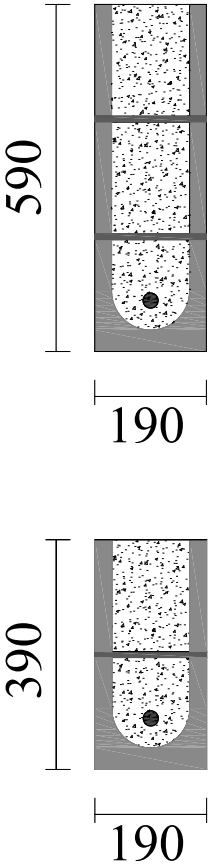
Construction of full-scale RM beams:



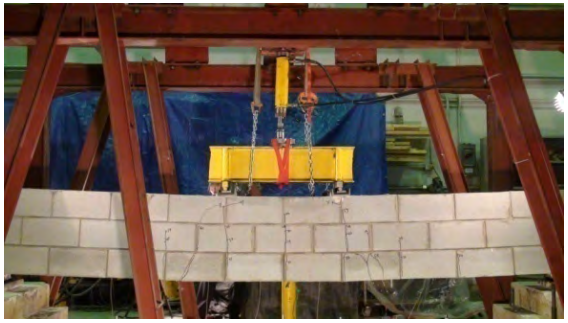
2- GFRP-Reinforced Masonry Beams

Test setup





2- GFRP-Reinforced Masonry Beams



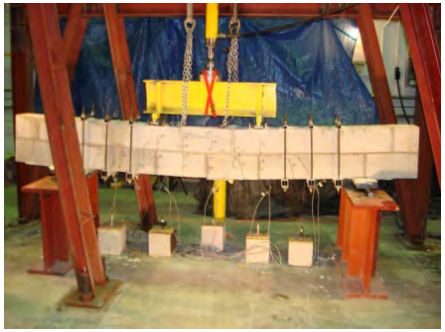
S-3-1-15M

F-3-1#13

F-3-1#19

F-3-2#16

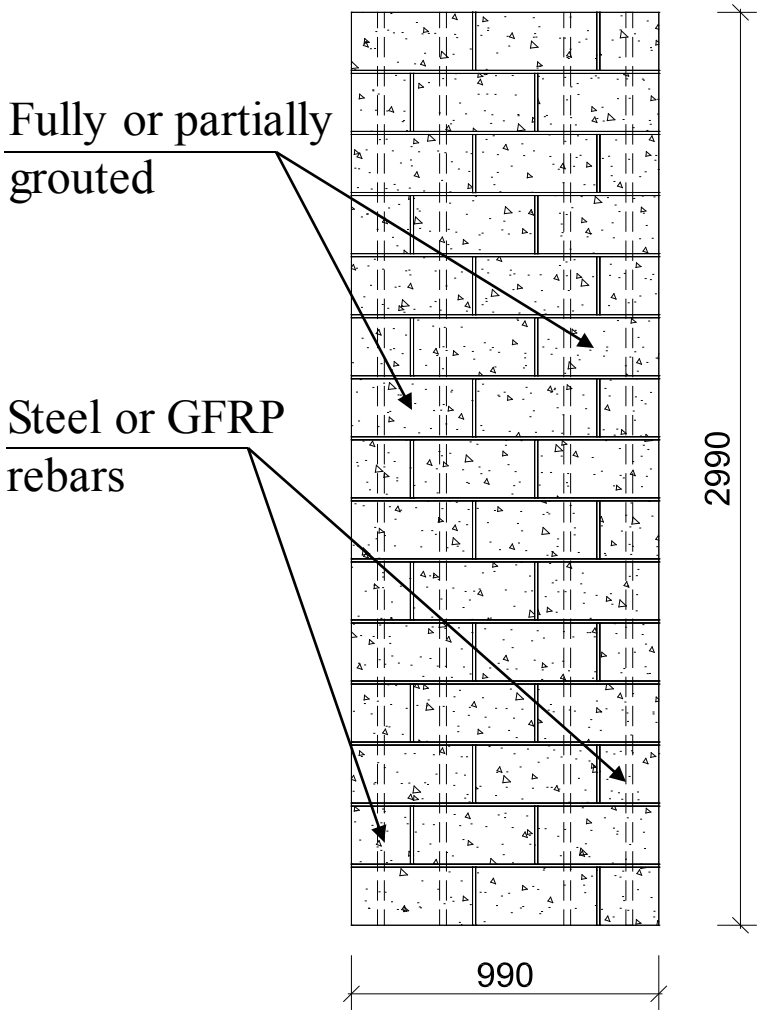
F-3-2#19&1#16



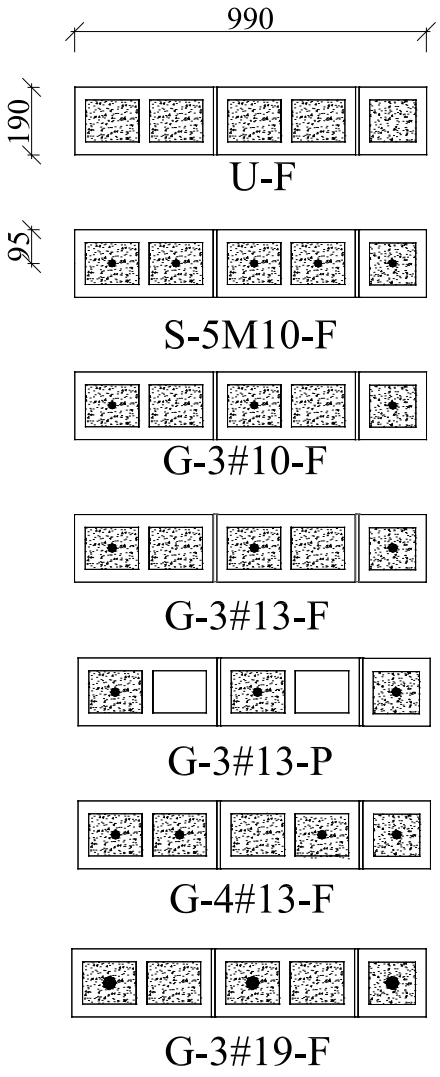
F-2-2#16

Beams during testing

3- GFRP-Reinforced Masonry Walls



Elevation



Cross-section

Description of the test specimens

3- GFRP-Reinforced Masonry Walls

Construction of the walls:

3- GFRP-Reinforced Masonry Walls

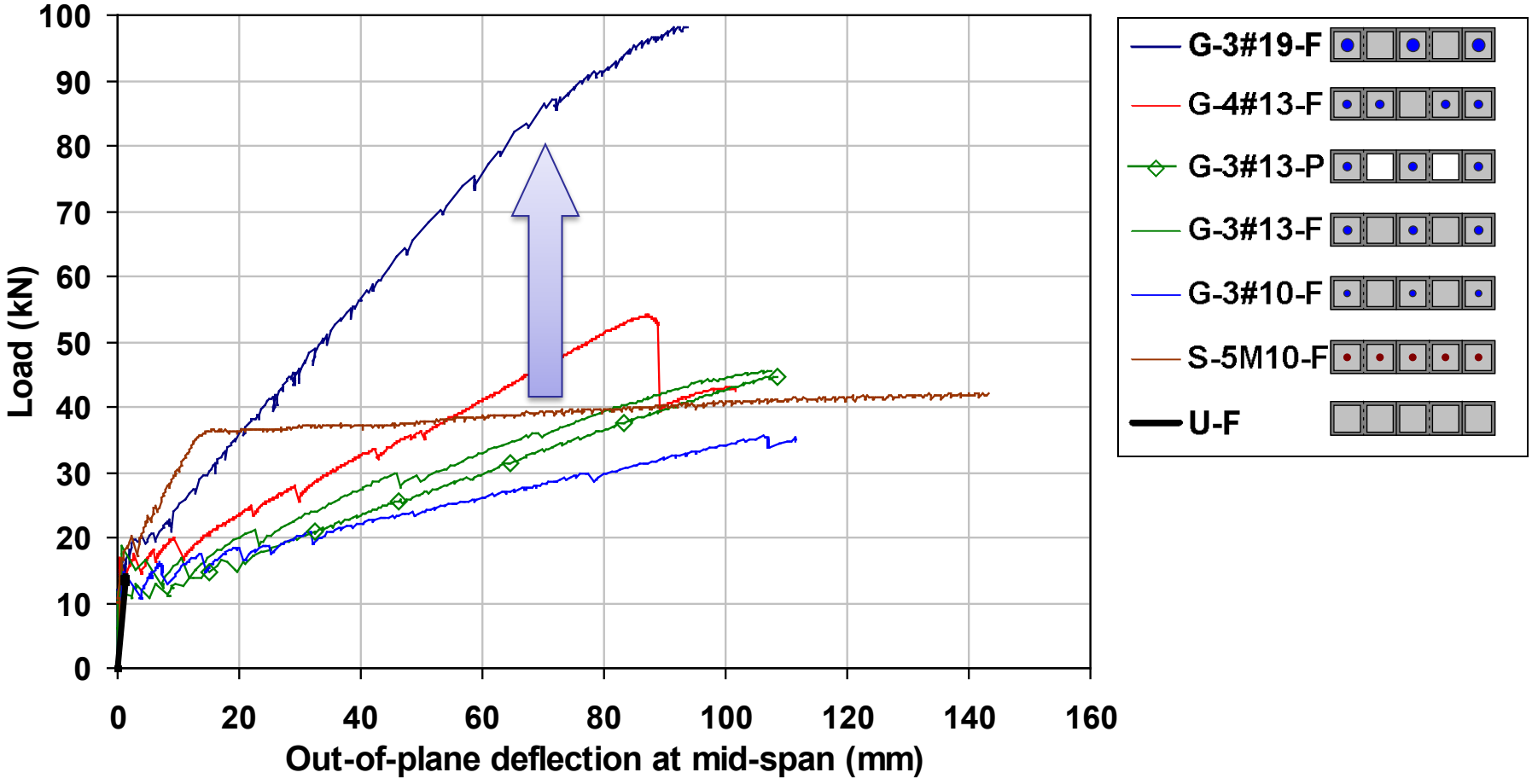
Construction of the walls:

3- GFRP-Reinforced Masonry Walls

Test setup and instrumentation:

3- GFRP-Reinforced Masonry Walls

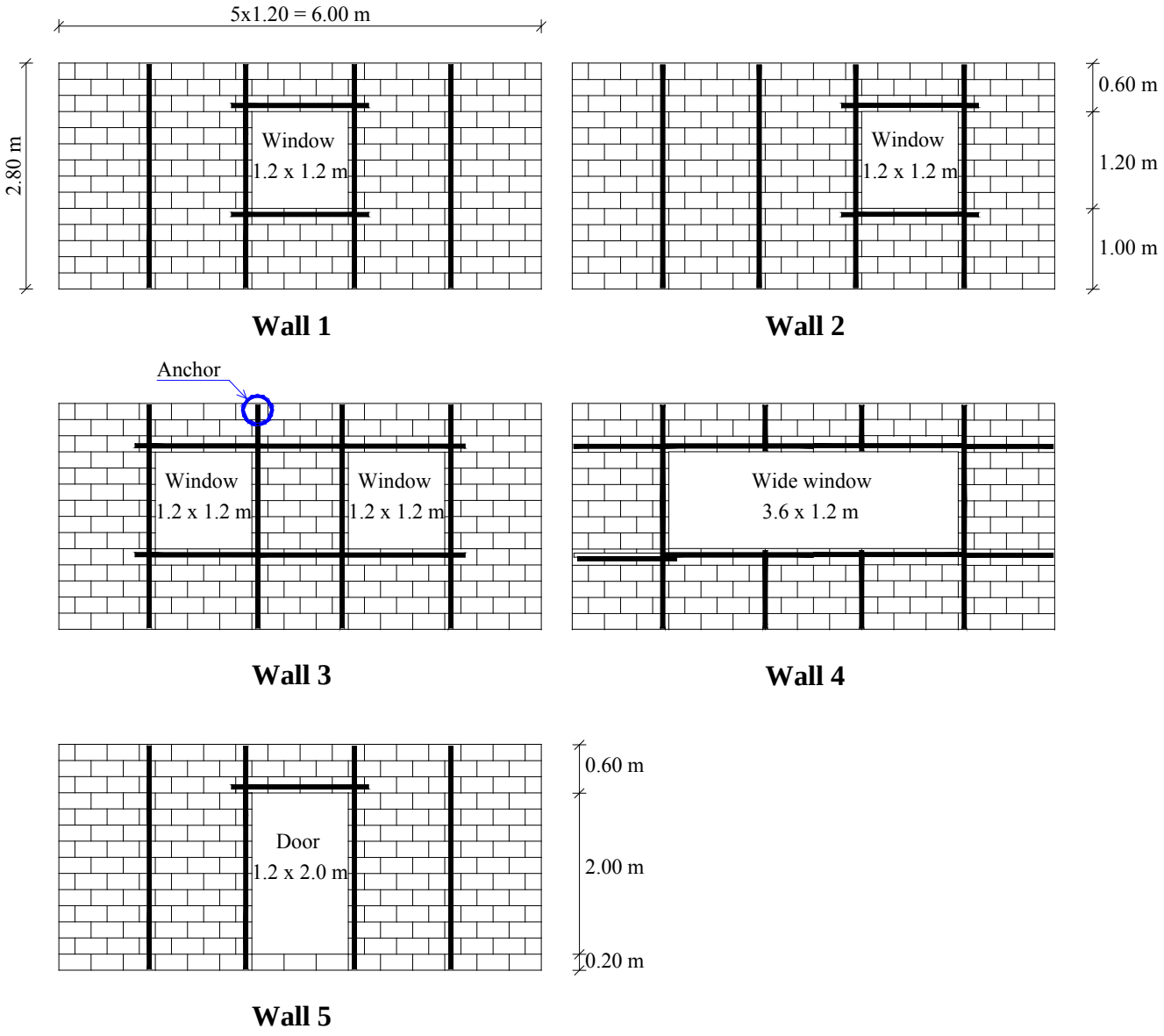
Load-deflection relationships of the tested masonry walls:



4- STRENGTHENING URM WALLS

Examples of out-of-plane failure of URM walls

4- STRENGTHENING URM WALLS



Elevation of tested full-scale URM walls strengthened with FRP

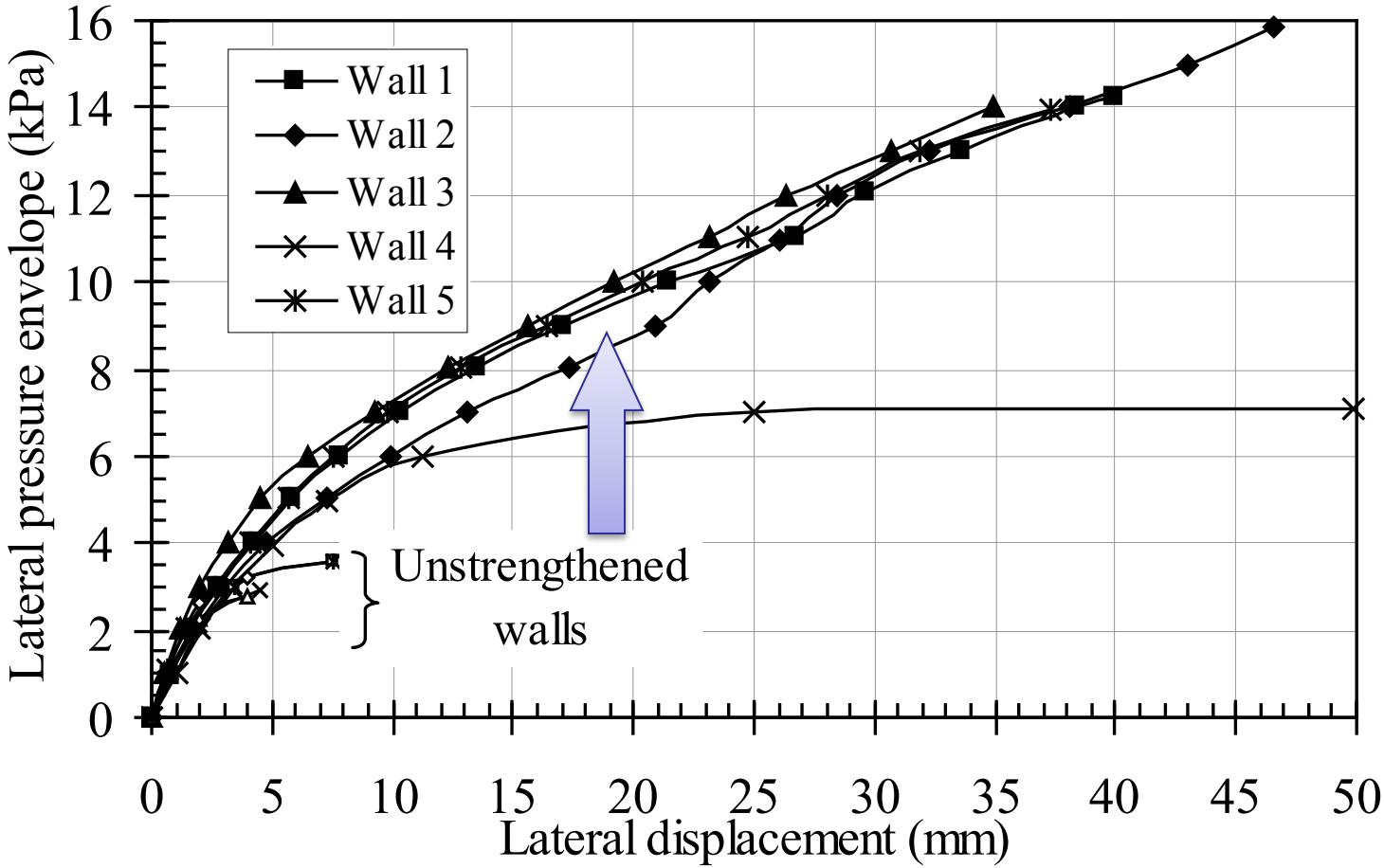
4- STRENGTHENING URM WALLS

Strengthened Wall 4 before testing

4- STRENGTHENING URM WALLS

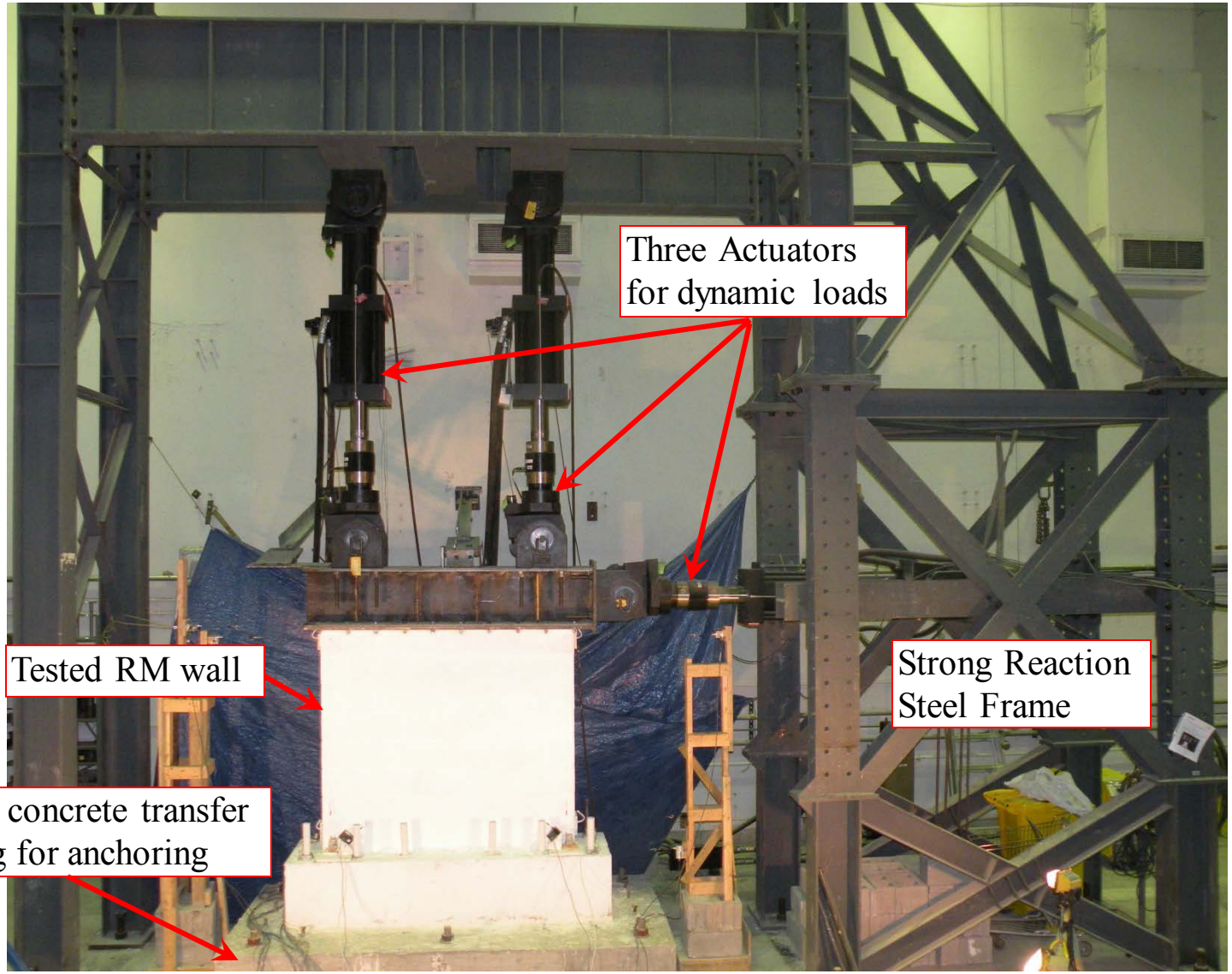
Strengthened Wall in the test setup

1- STRENGTHENING URM WALLS



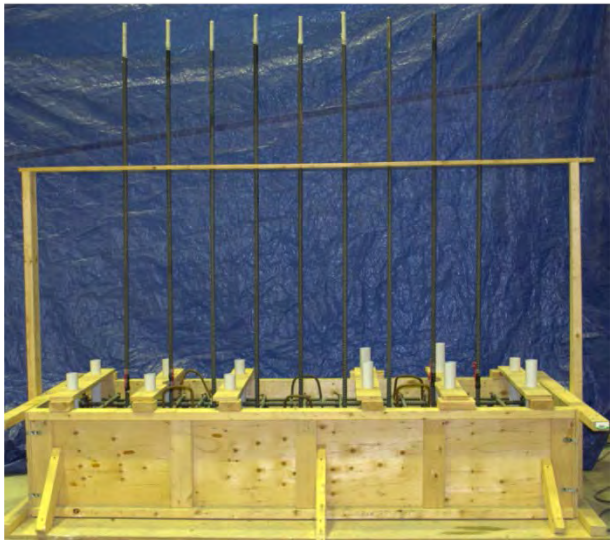
Comparison between the lateral capacity of strengthened and unstrengthened walls

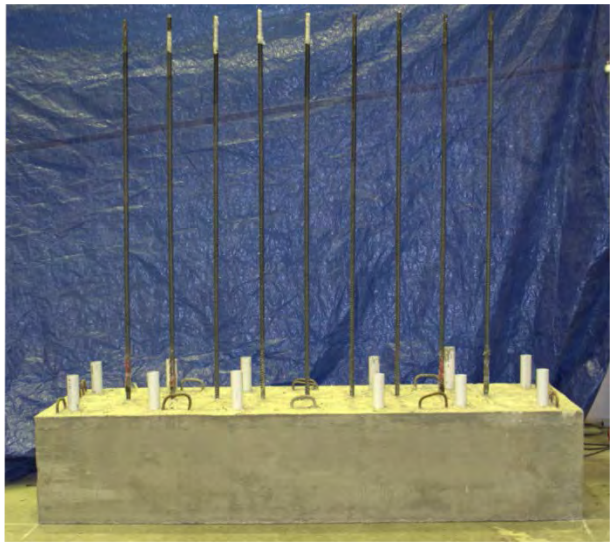
5. Seismic performance of RM shear walls



Test setup at Concordia's Structures Laboratory

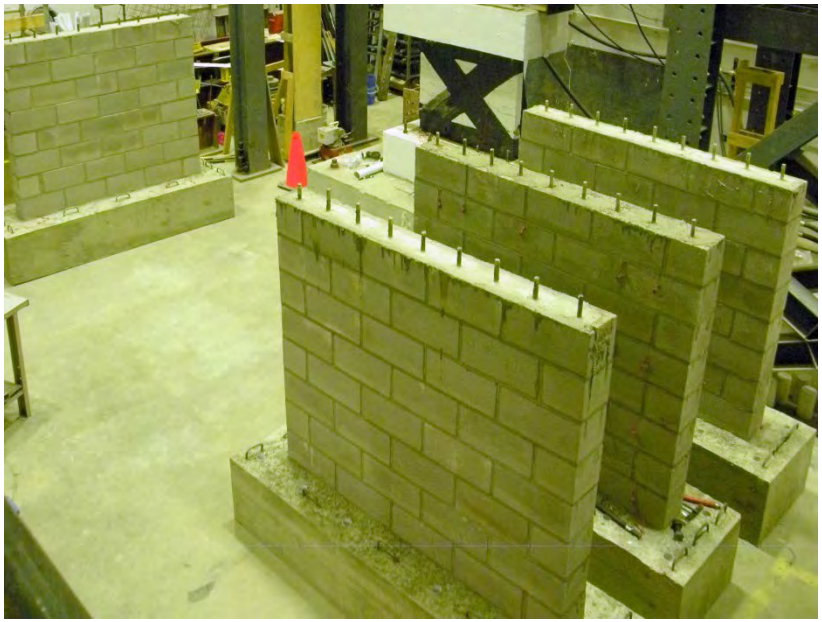
5. Seismic performance of RM shear walls





Construction procedure

5. Seismic performance of RM shear walls



Constructed Walls

5. Seismic performance of RM shear walls

W-Ref

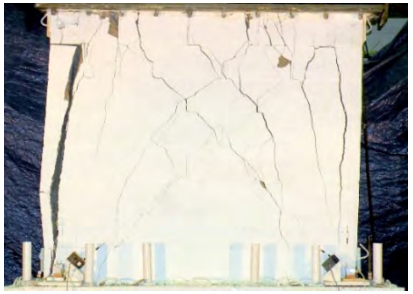
W-ρ_h0

W-90°

W-str

W-σ_n0

W-σ_n1.5



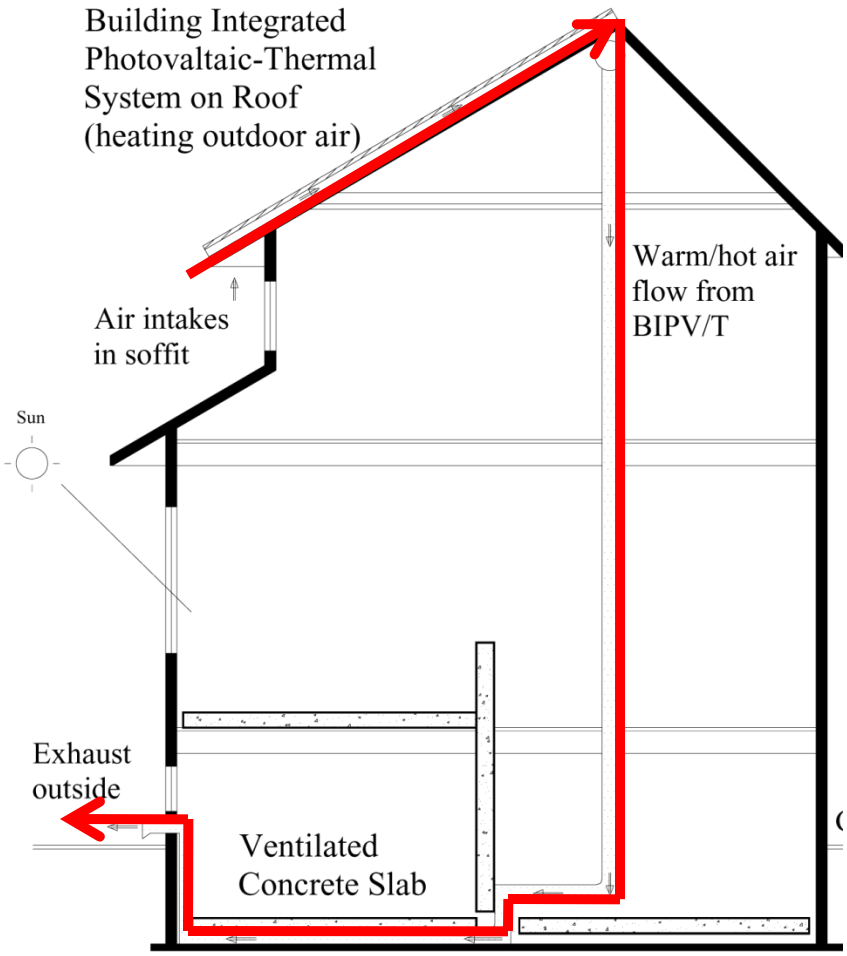
W-M/Vd_v2

W-S_v800

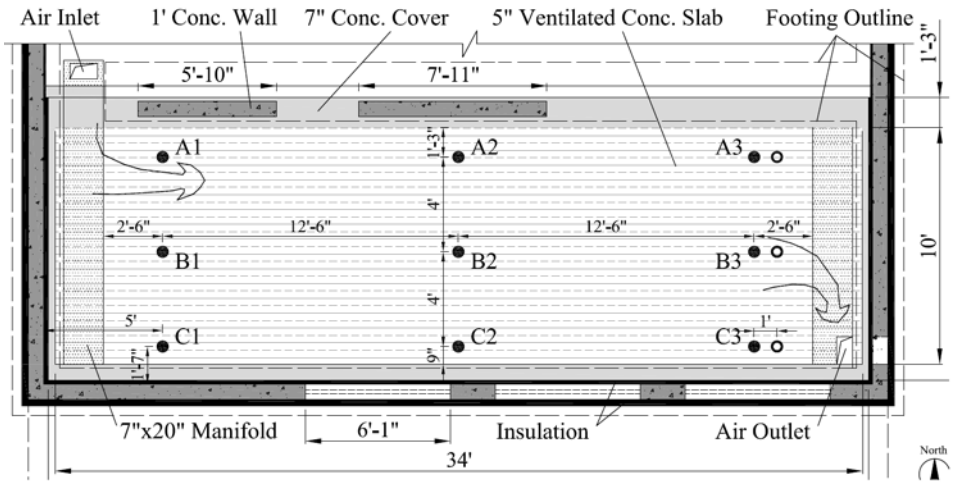
W-S_h800

Crack pattern of the tested walls at failure

Modeling and Design of a Solar House with Focus on a Ventilated Concrete Slab (VCS) Coupled with a Building-Integrated Photovoltaic/Thermal (BIPV/T) System



Concept



Modeling and Design of a Solar House with Focus on a Ventilated Concrete Slab (VCS) Coupled with a Building-Integrated Photovoltaic/Thermal (BIPV/T) System

CMHC initiative: EQuilibrium™

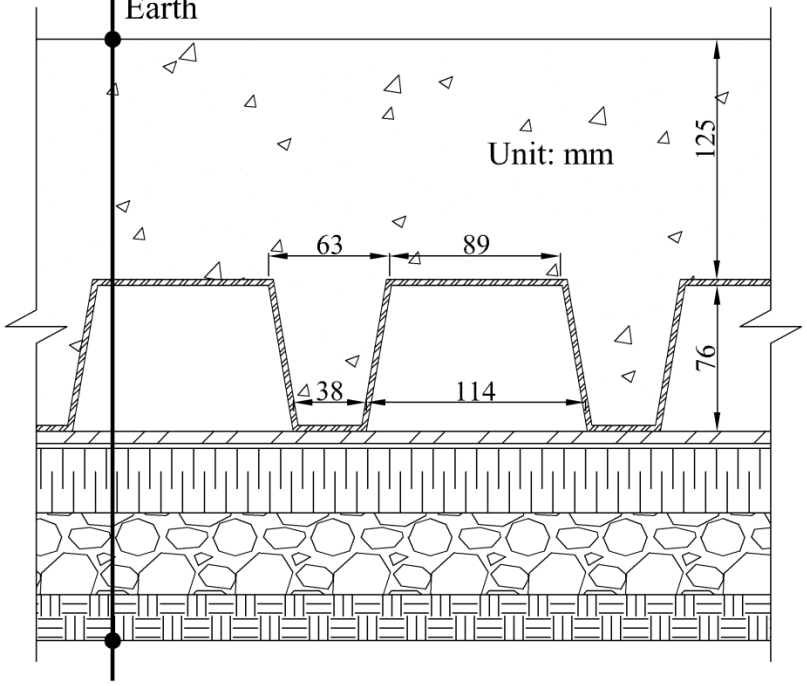
► **Promote sustainable housing and Approach net-zero annual energy consumption**

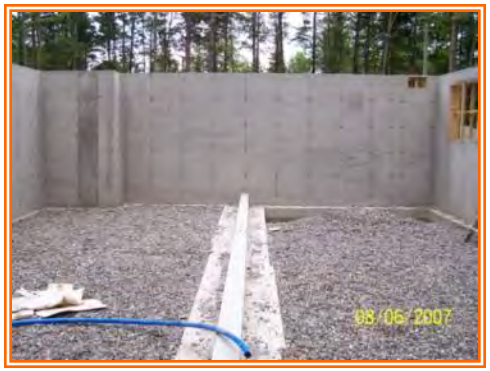
ÉcoTerra House built in Eastman city (Québec) in 2007

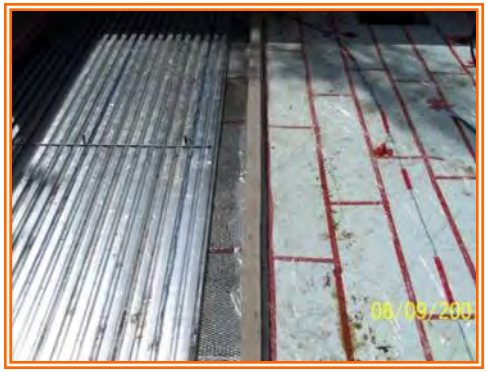
Modeling and Design of a Solar House with Focus on a Ventilated Concrete Slab (VCS) Coupled with a Building-Integrated Photovoltaic/Thermal (BIPV/T) System

VCS construction:

Normal Density Plain Concrete (125mm (5"))
Steel Deck (0.7mm (1/32") galvanized steel)
Ventilation Channel (air cavity)
Metal Mesh (8mm (1/4"))
Water/Vapor Barrier
Insulation (50mm(2") EXPS, RSI-1.7(R10))
Gravel Backfill
Earth



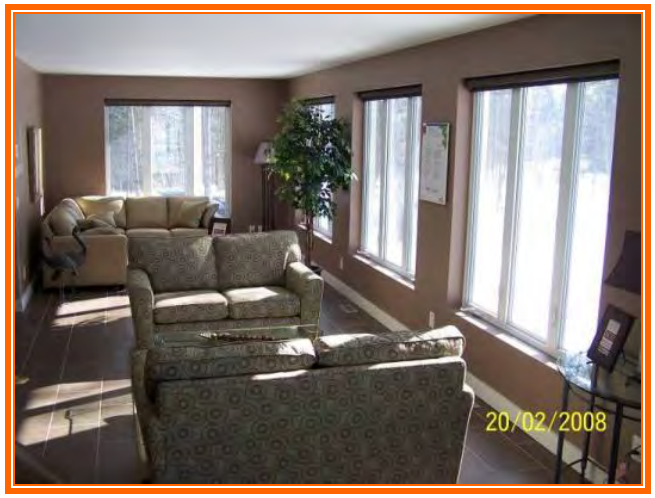




Modeling and Design of a Solar House with Focus on a Ventilated Concrete Slab (VCS) Coupled with a Building-Integrated Photovoltaic/Thermal (BIPV/T) System

ÉcoTerra - built environment

Family Room



Basement

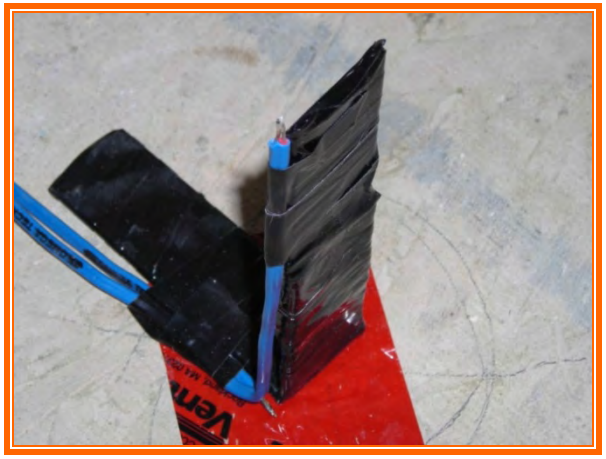
Concordia Data Acquisition System

PV Monitoring

Modeling and Design of a Solar House with Focus on a Ventilated Concrete Slab (VCS) Coupled with a Building-Integrated Photovoltaic/Thermal (BIPV/T) System

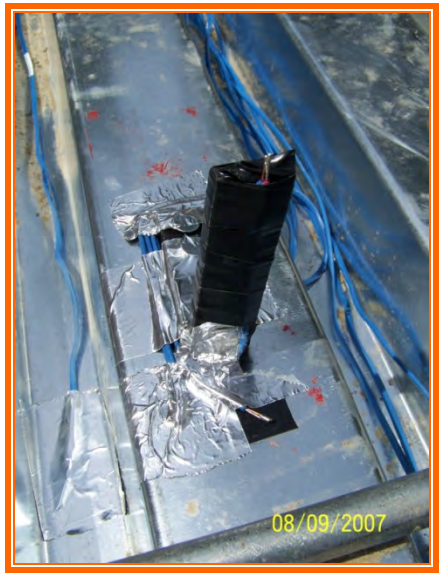
ÉcoTerra - monitoring

House automation and monitoring system



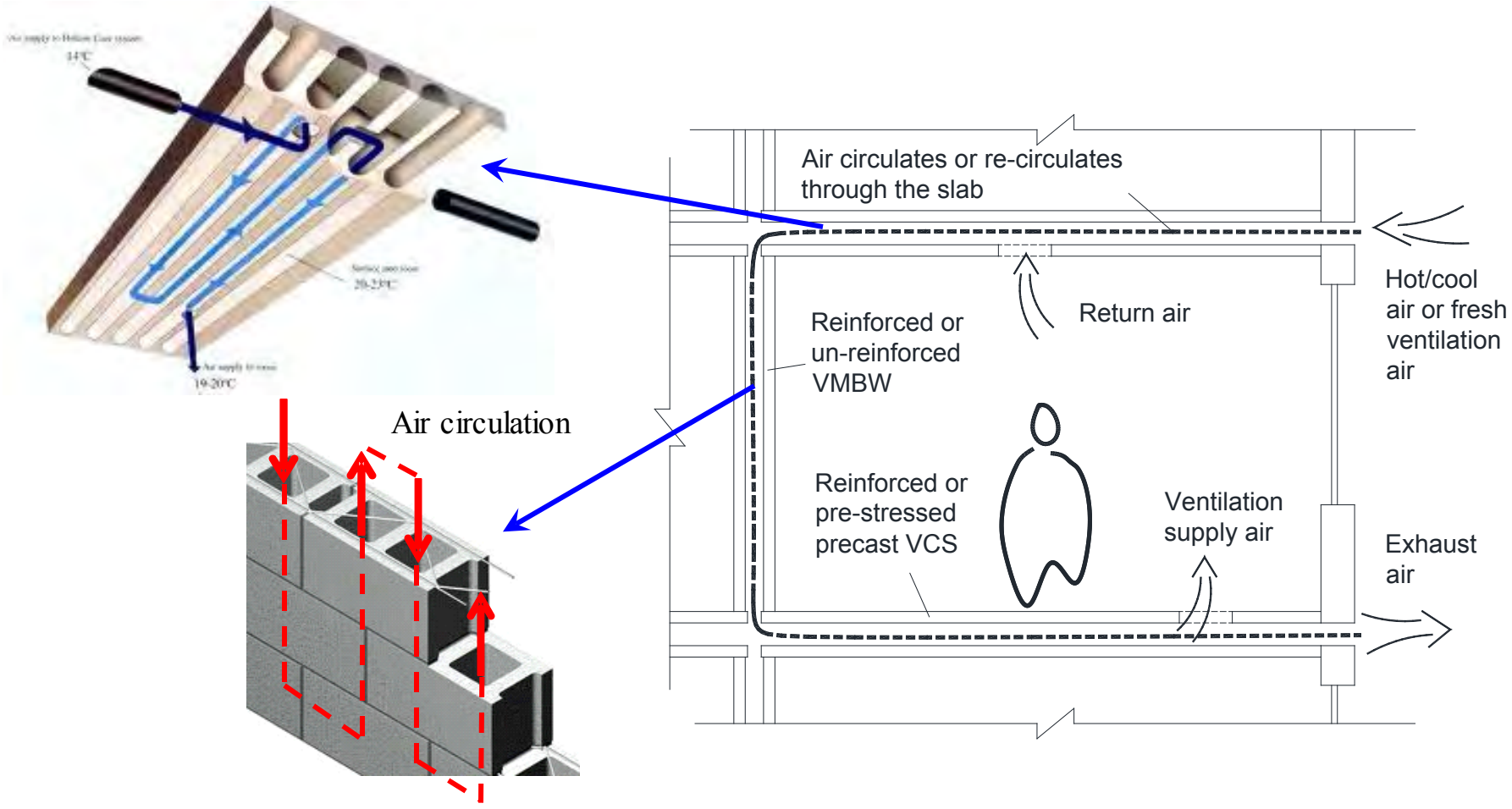
TC in the ground floor slab

HQ monitoring system



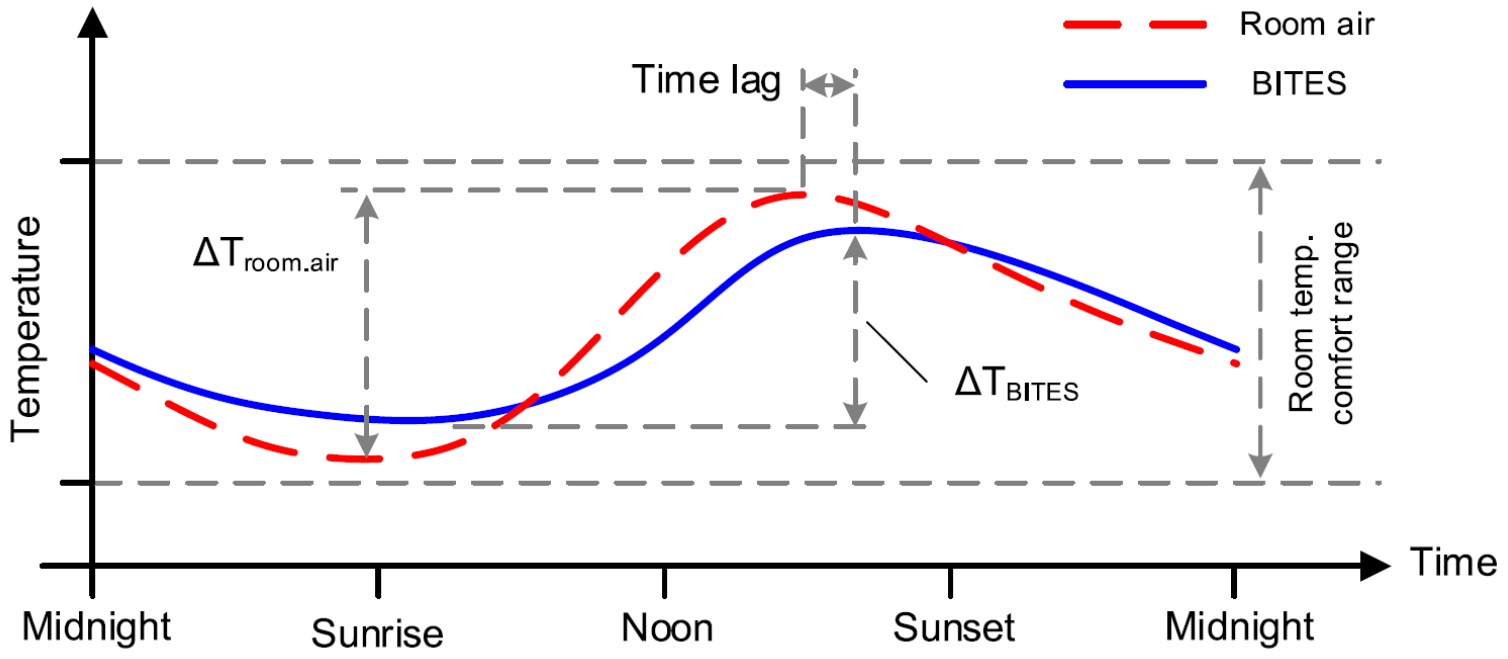
TC in the VCS

Towards the Development of Sustainable Low-Energy Consumption Buildings



Schematic of the active charge and discharge processes with ventilated systems

Towards the Development of Sustainable Low-Energy Consumption Buildings

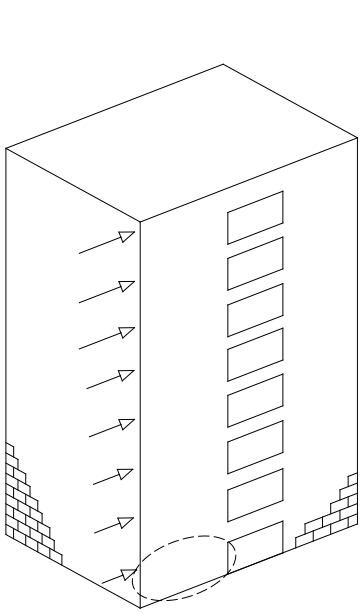


Conceptual thermal response of a zone with strong thermal coupling between passive Building-Integrated Thermal Energy Storage and the thermal zone

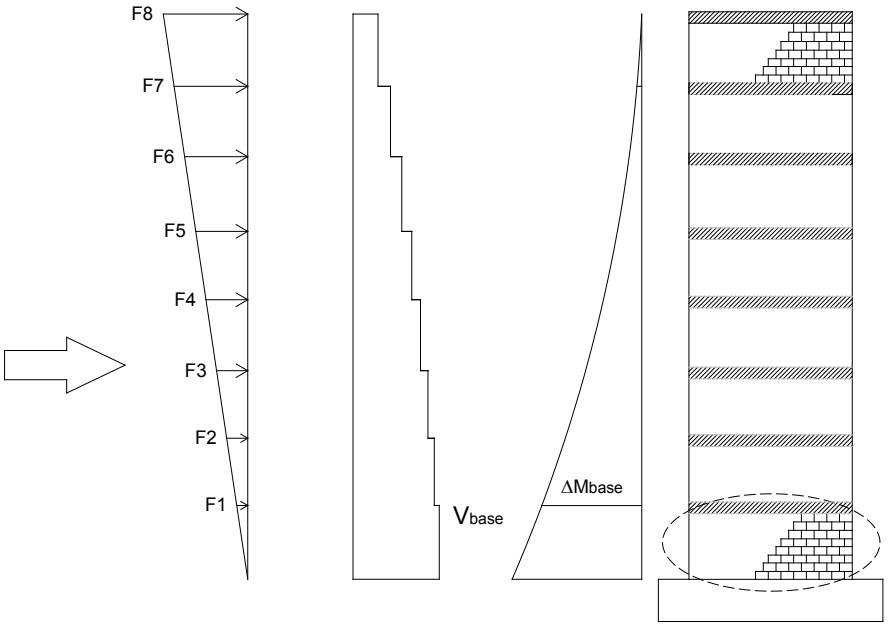
PART 3

CURRENT RESEARCH PROJECT SUPPORTED BY AEMQ

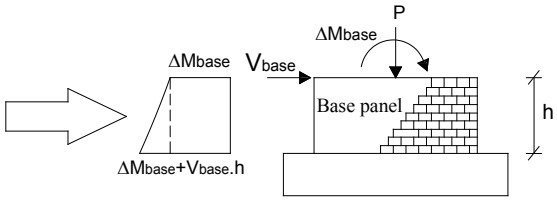
Current research project supported by AEMQ



Full reinforced masonry building



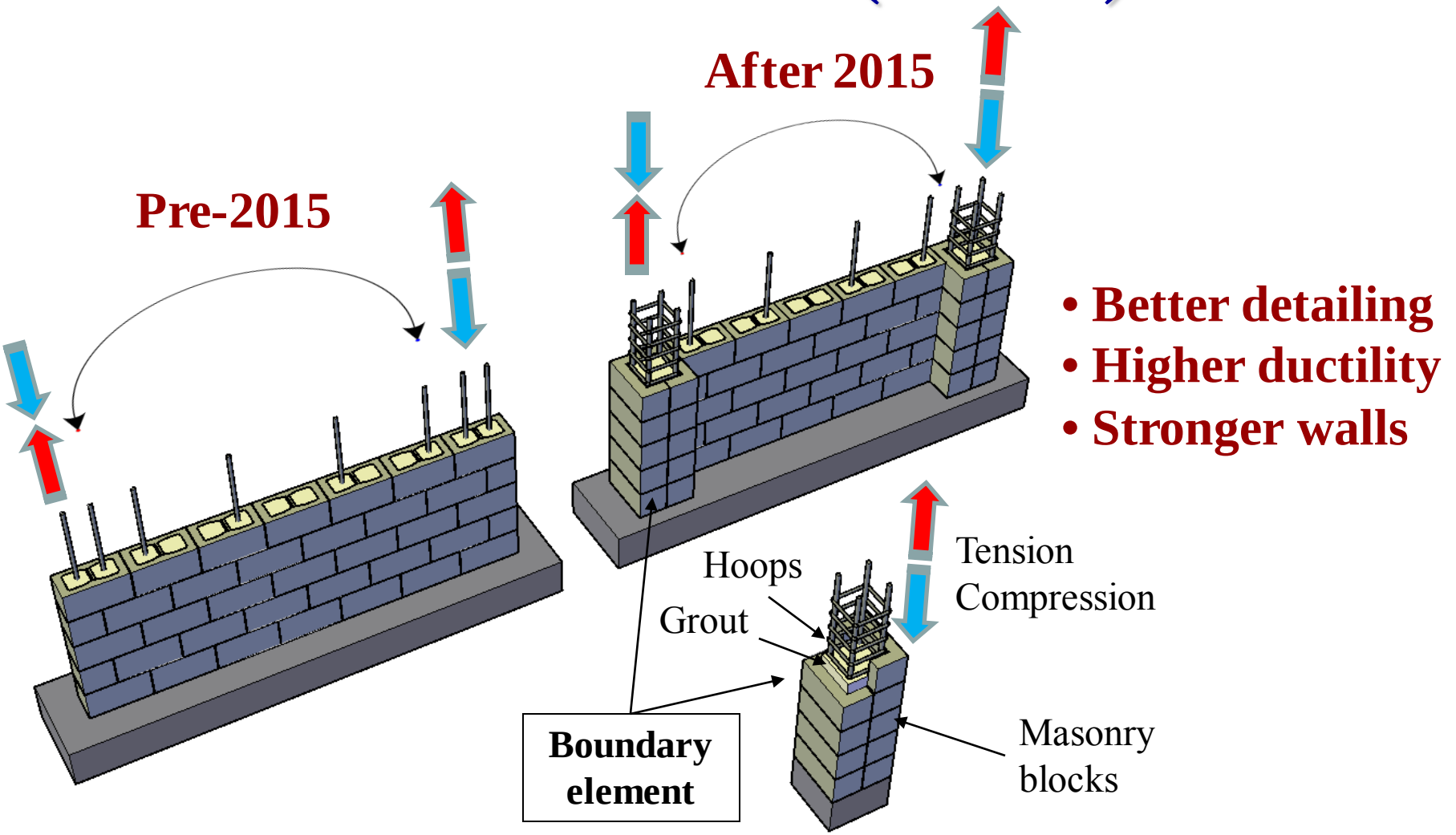
Reinforced masonry shear wall
Full height



Tested wall panel

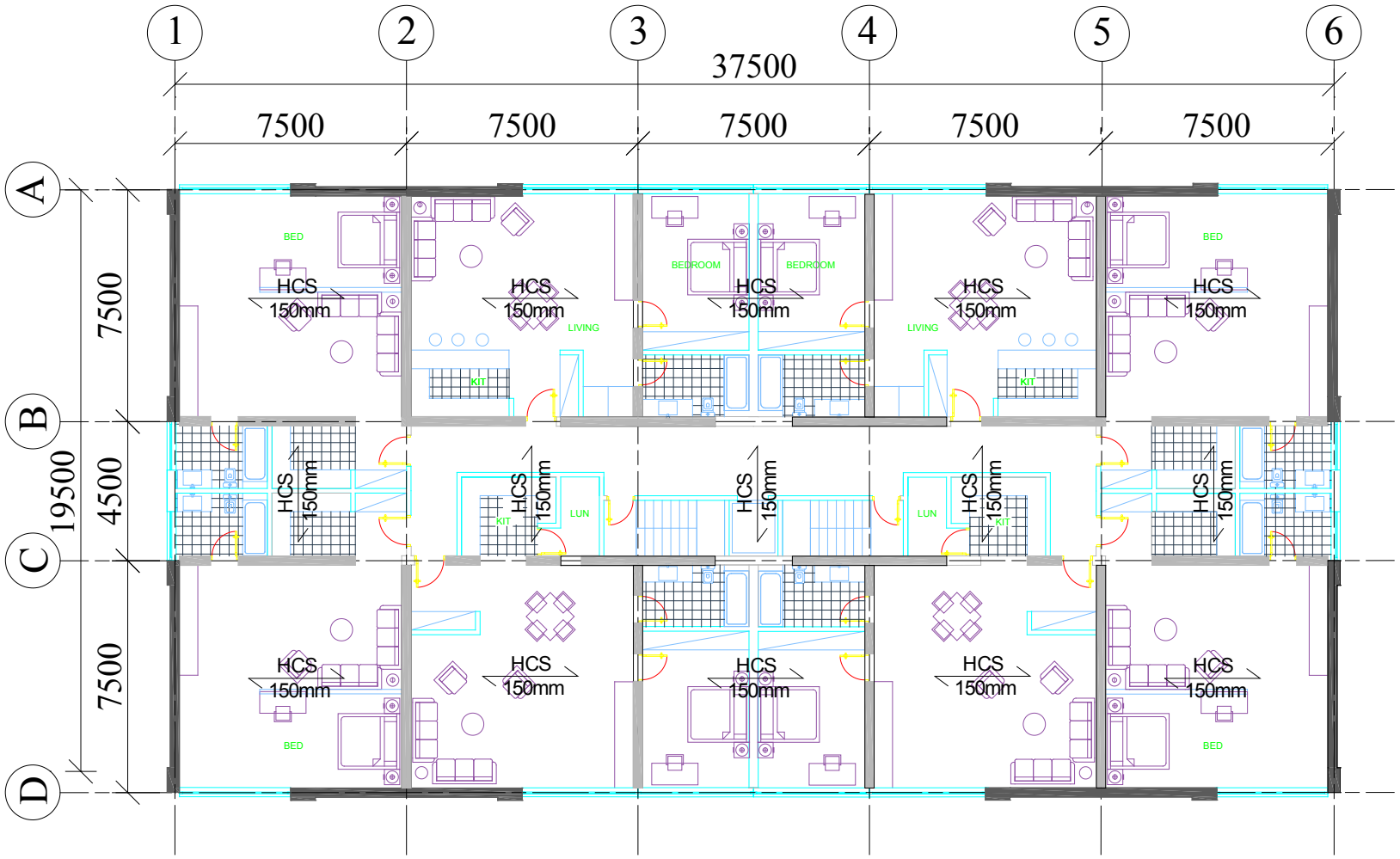
Simulation of critical panels of a reinforced masonry shear wall

Reinforced Masonry in the National Building Code of Canada (NBCC)



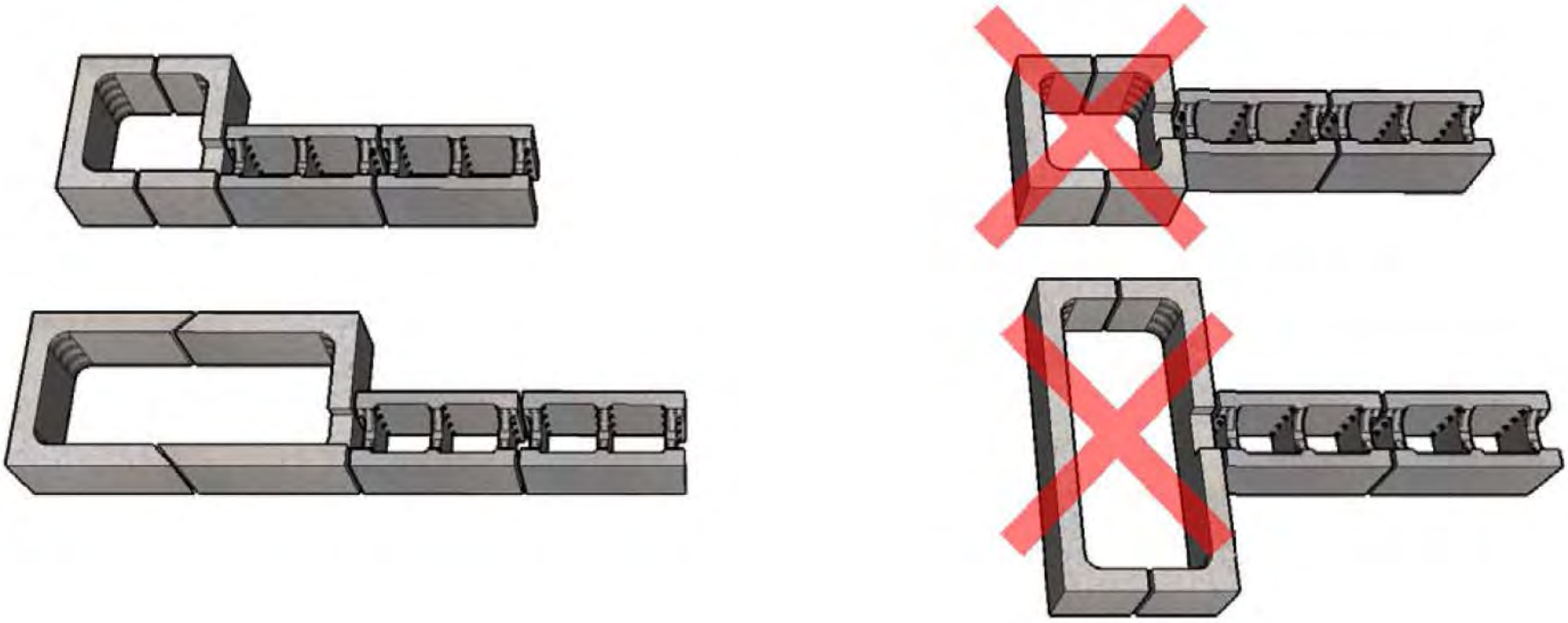
- **Better detailing**
- **Higher ductility**
- **Stronger walls**

Current research project supported by AEMQ



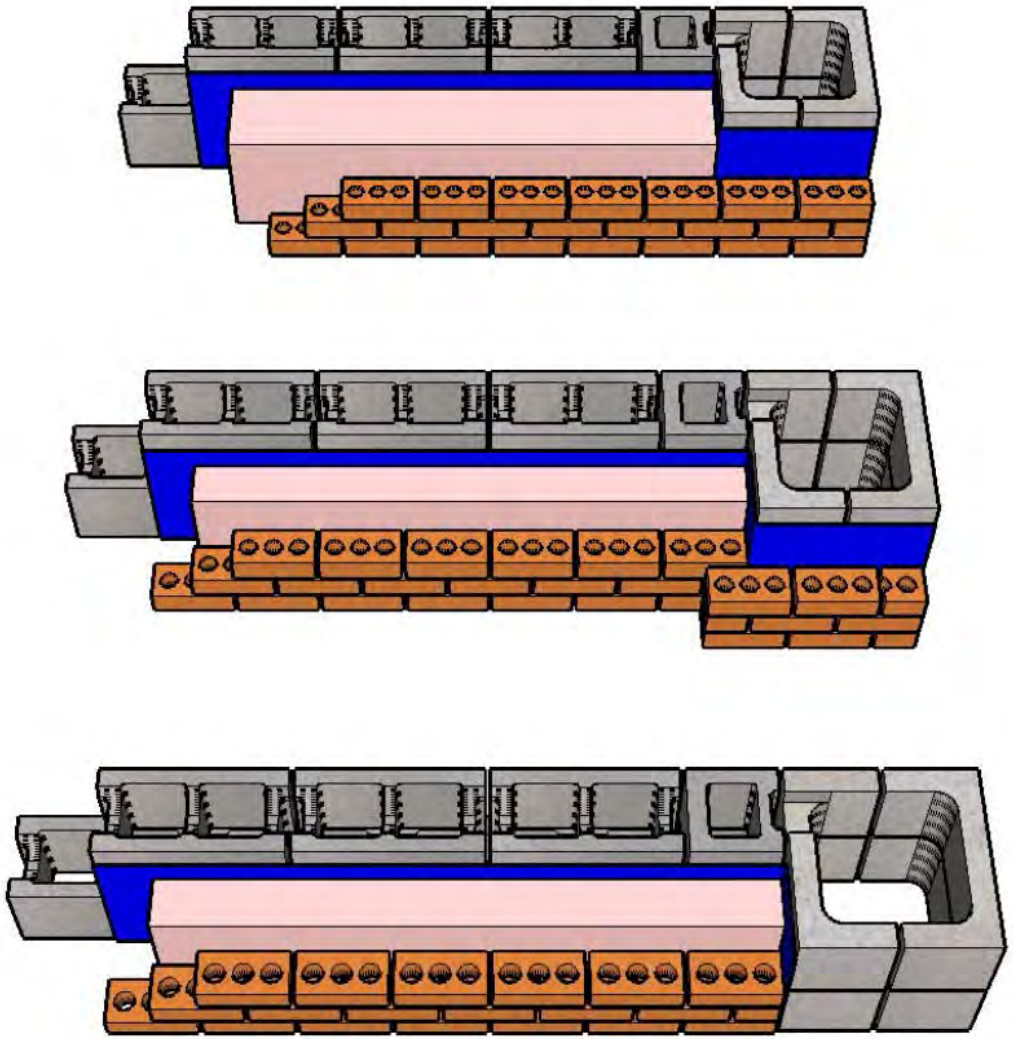
Example of a 12-story reinforced masonry building in Montréal

Current research project supported by AEMQ



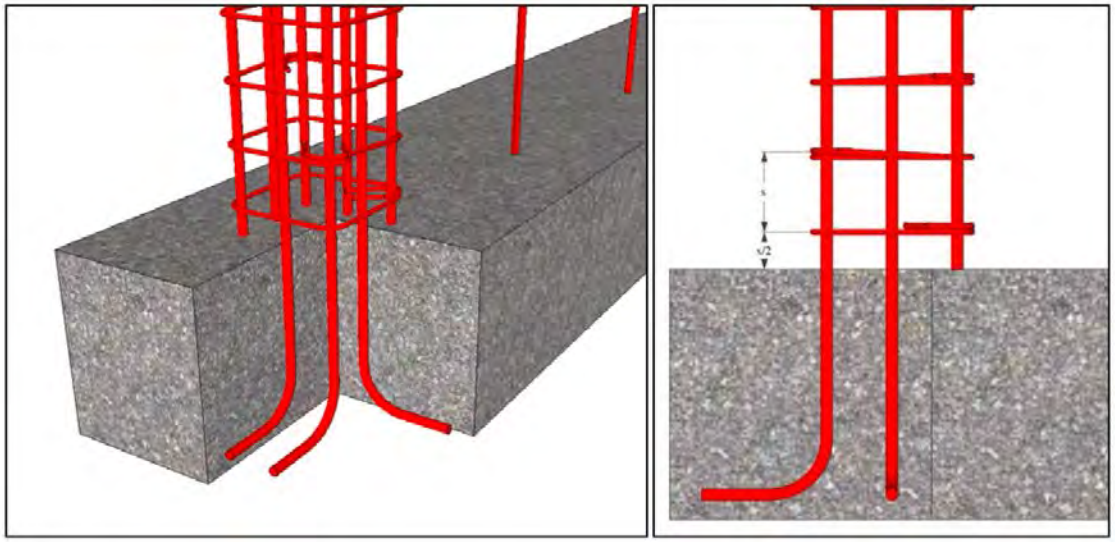
Preferred boundary element orientation

Current research project supported by AEMQ

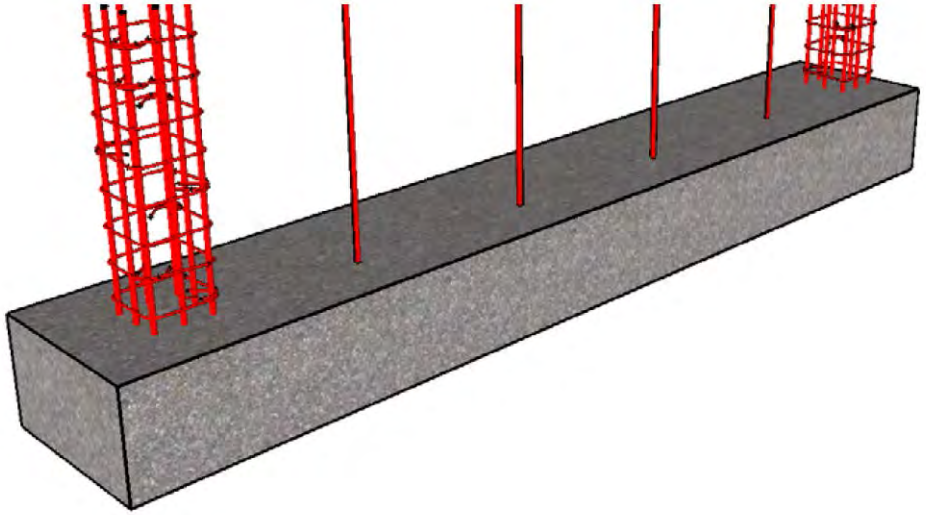


Veneer options with boundary element

Current research project supported by AEMQ

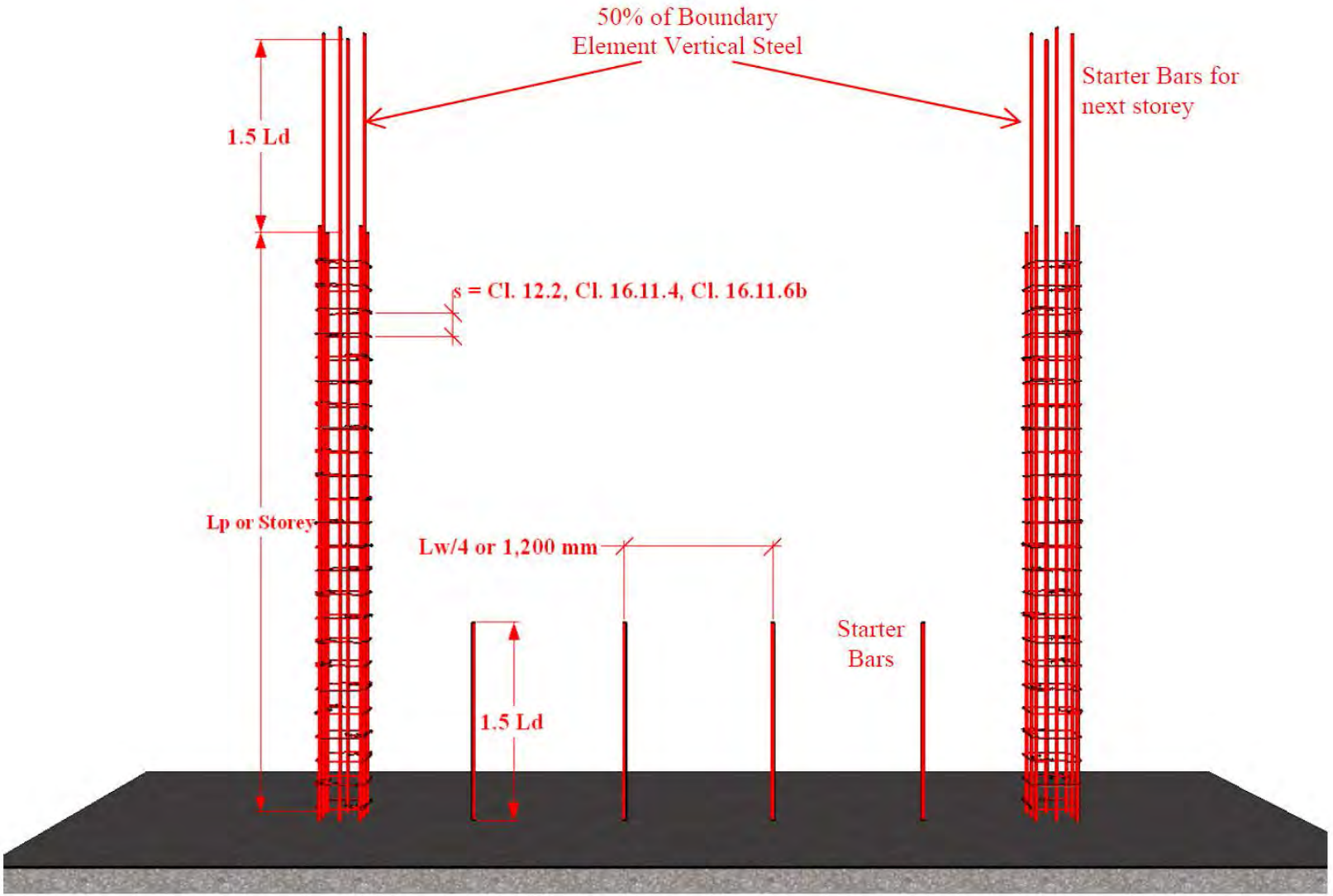


Embedment of boundary element reinforcement



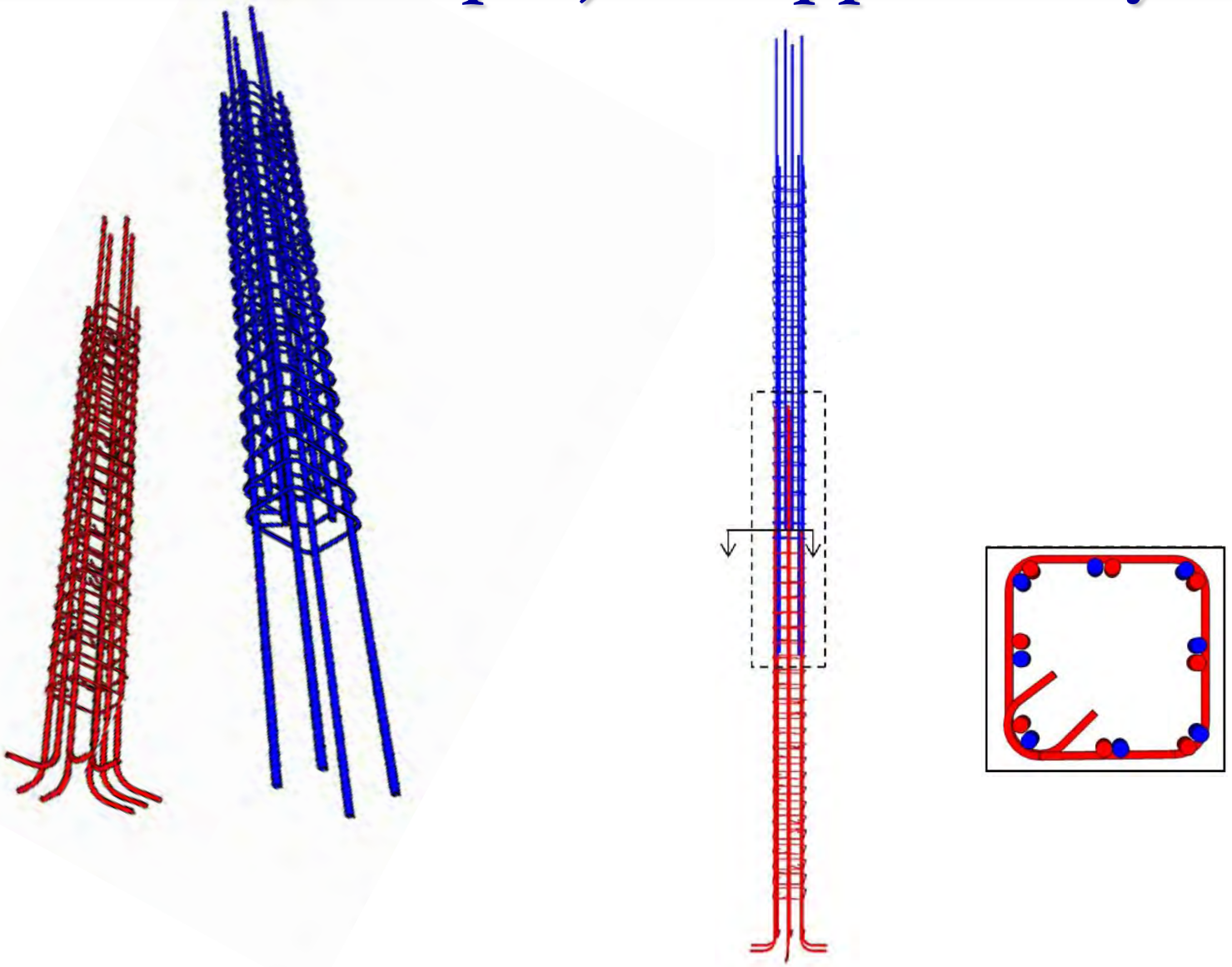
Foundation with vertical wall reinforcement embedded

Current research project supported by AEMQ



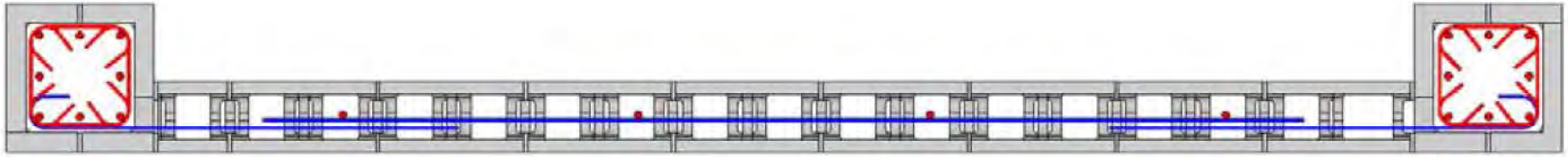
Reinforcement requirements

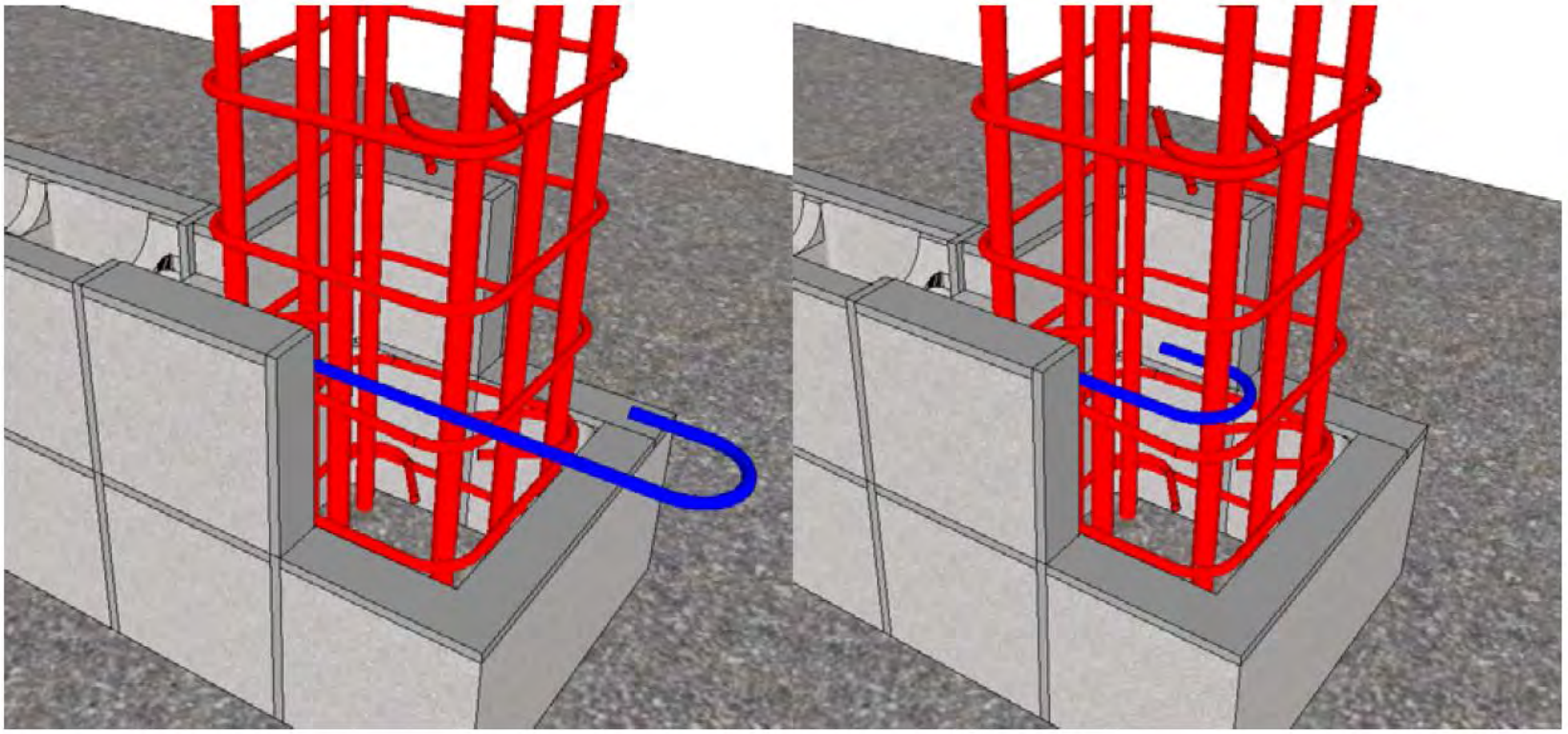
Current research project supported by AEMQ



Close-up of Boundary Element reinforcement cage lap splice detail

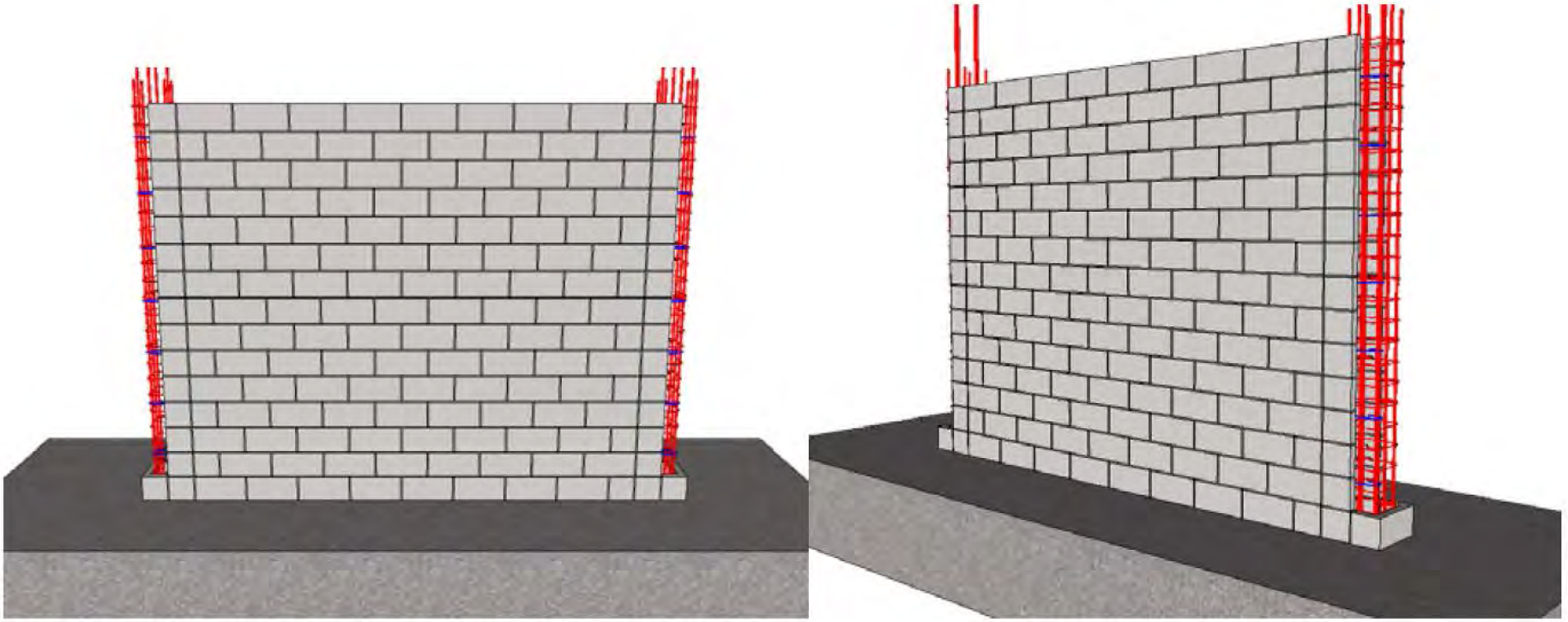
Current research project supported by AEMQ





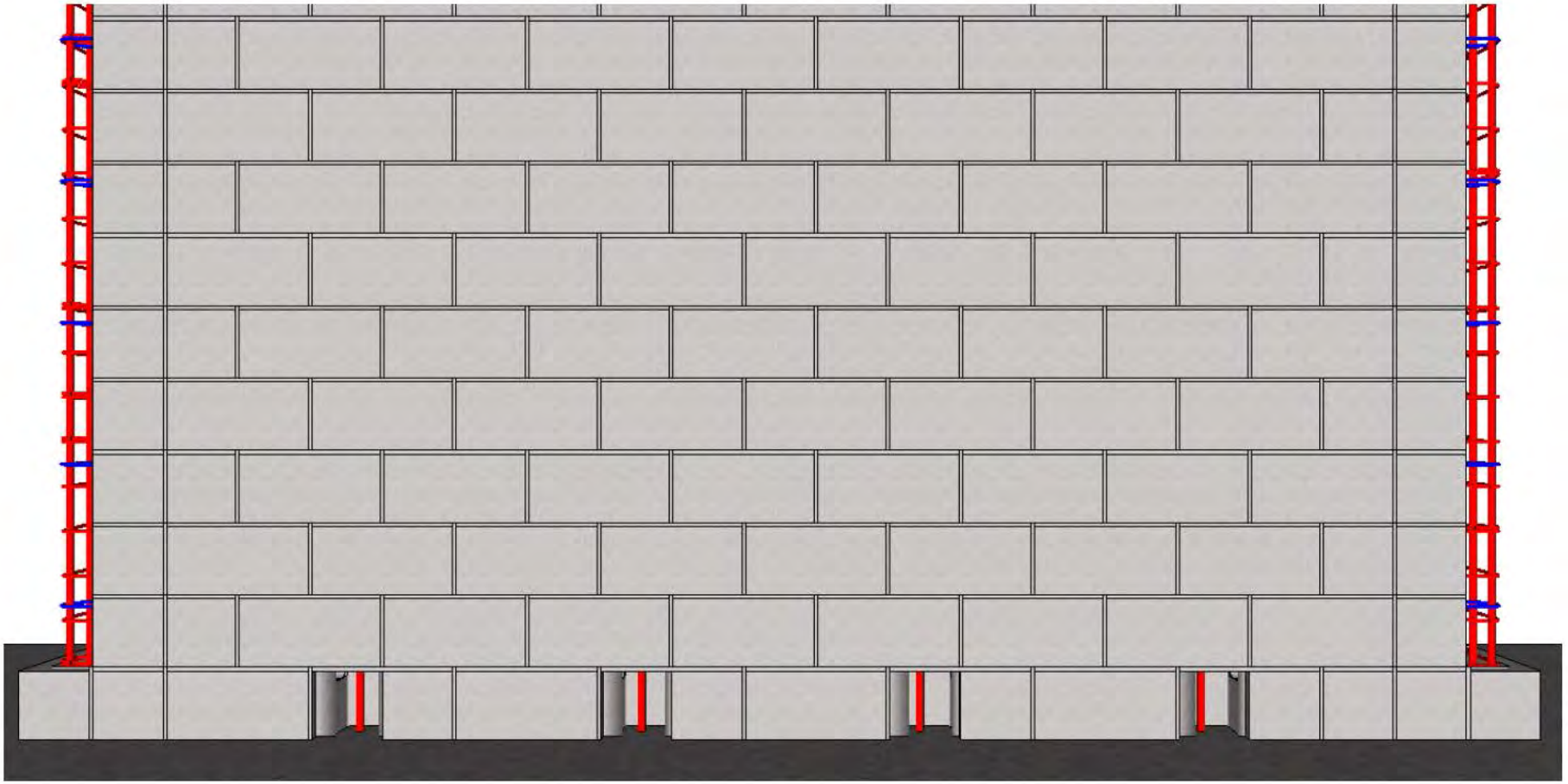
Placement of Horizontal reinforcement

Current research project supported by AEMQ



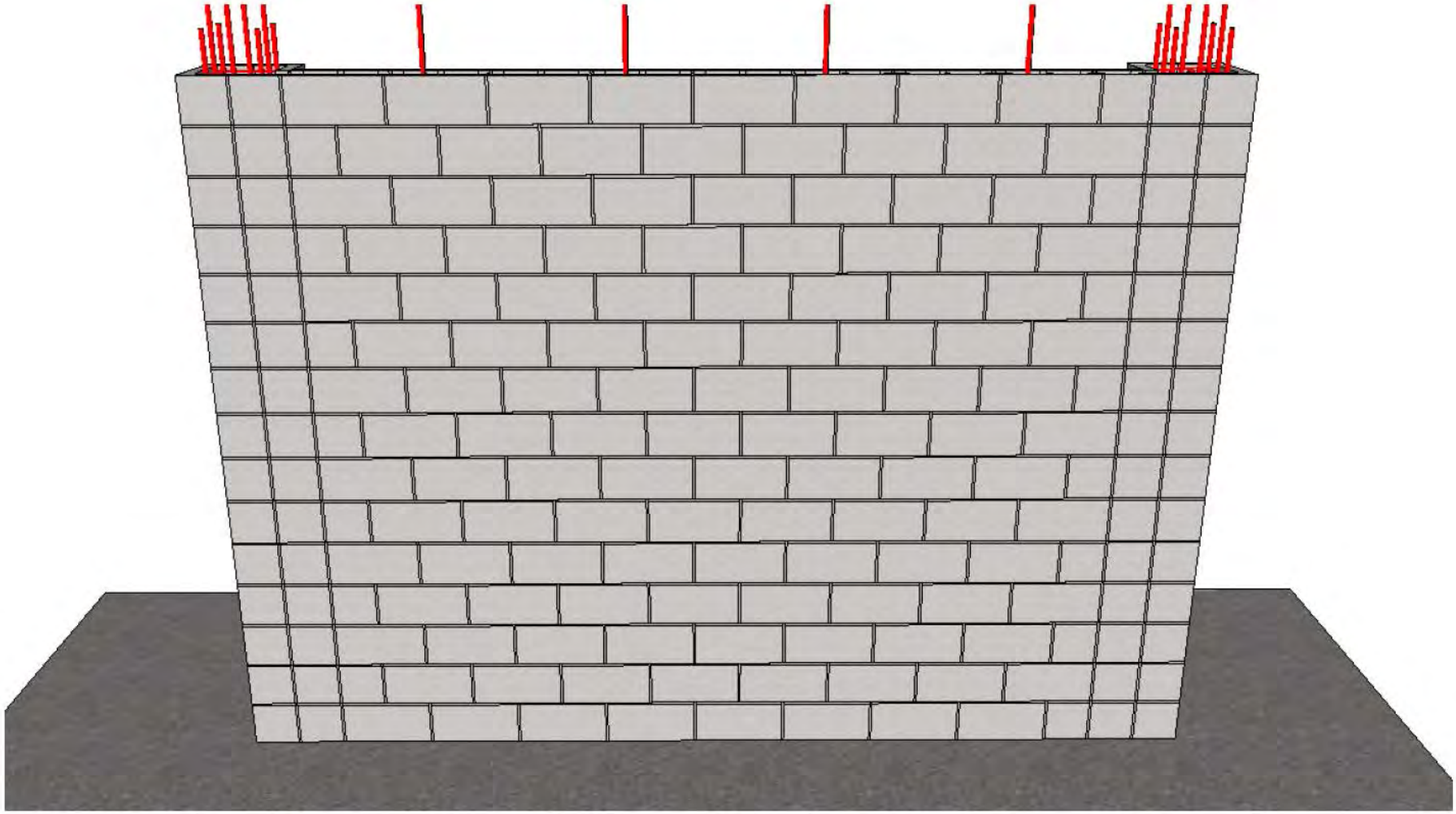
Complete the construction of the wall

Current research project supported by AEMQ



Cleanouts and lapped vertical reinforcement

Current research project supported by AEMQ



Laying of boundary element units and cleanouts, then grout

Example of Reinforced Masonry Building

Example of Reinforced Masonry Building

Example of Reinforced Masonry Building

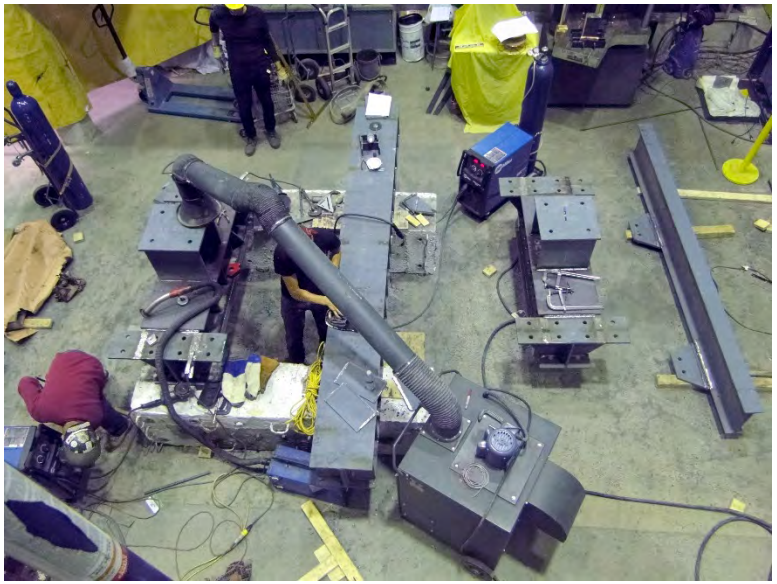
video

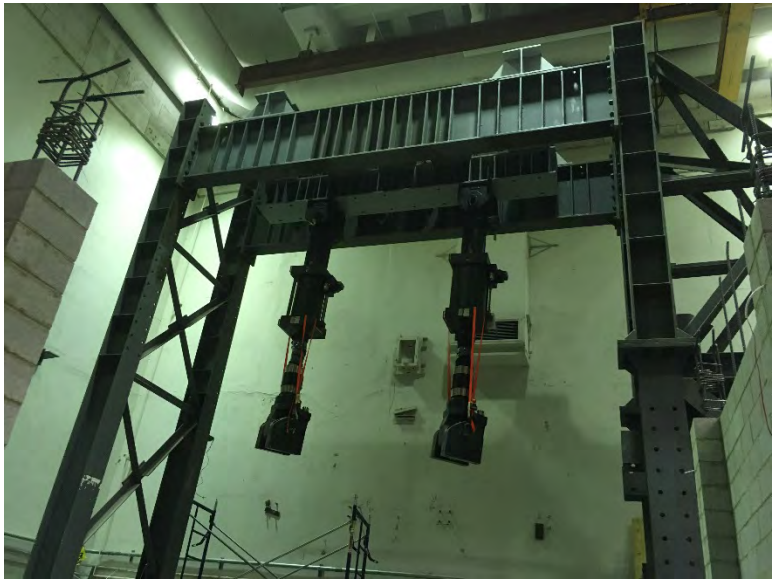
ONGOING ACTIVITIES IN THE STRUCTURES LAB AT CONCORDIA

Strengthening of the MTS testing frame

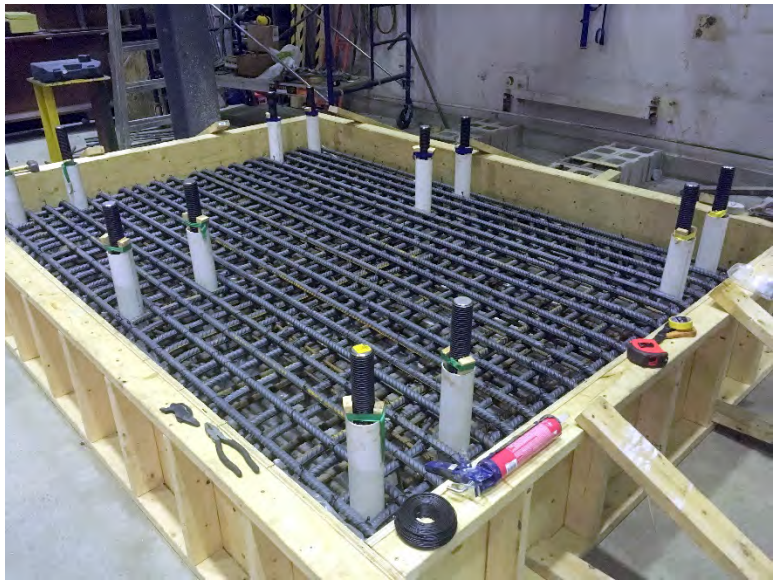
Strengthening of the MTS testing frame

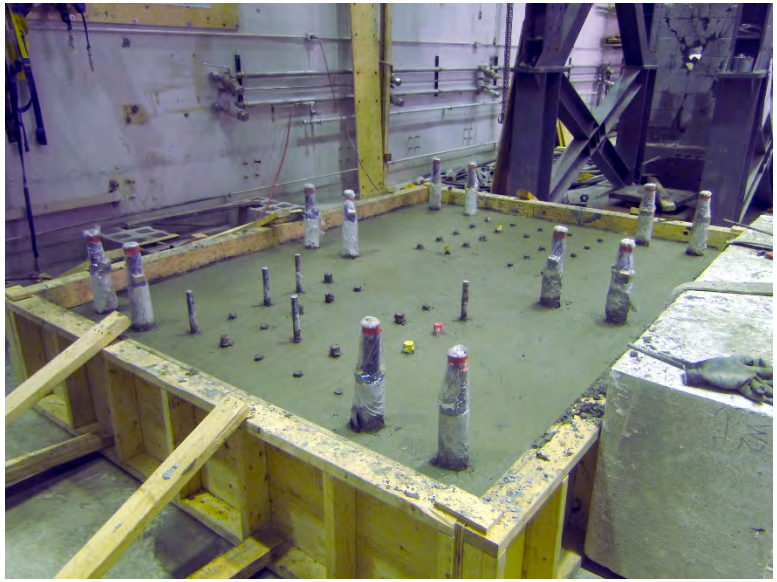
Strengthening of the MTS testing frame



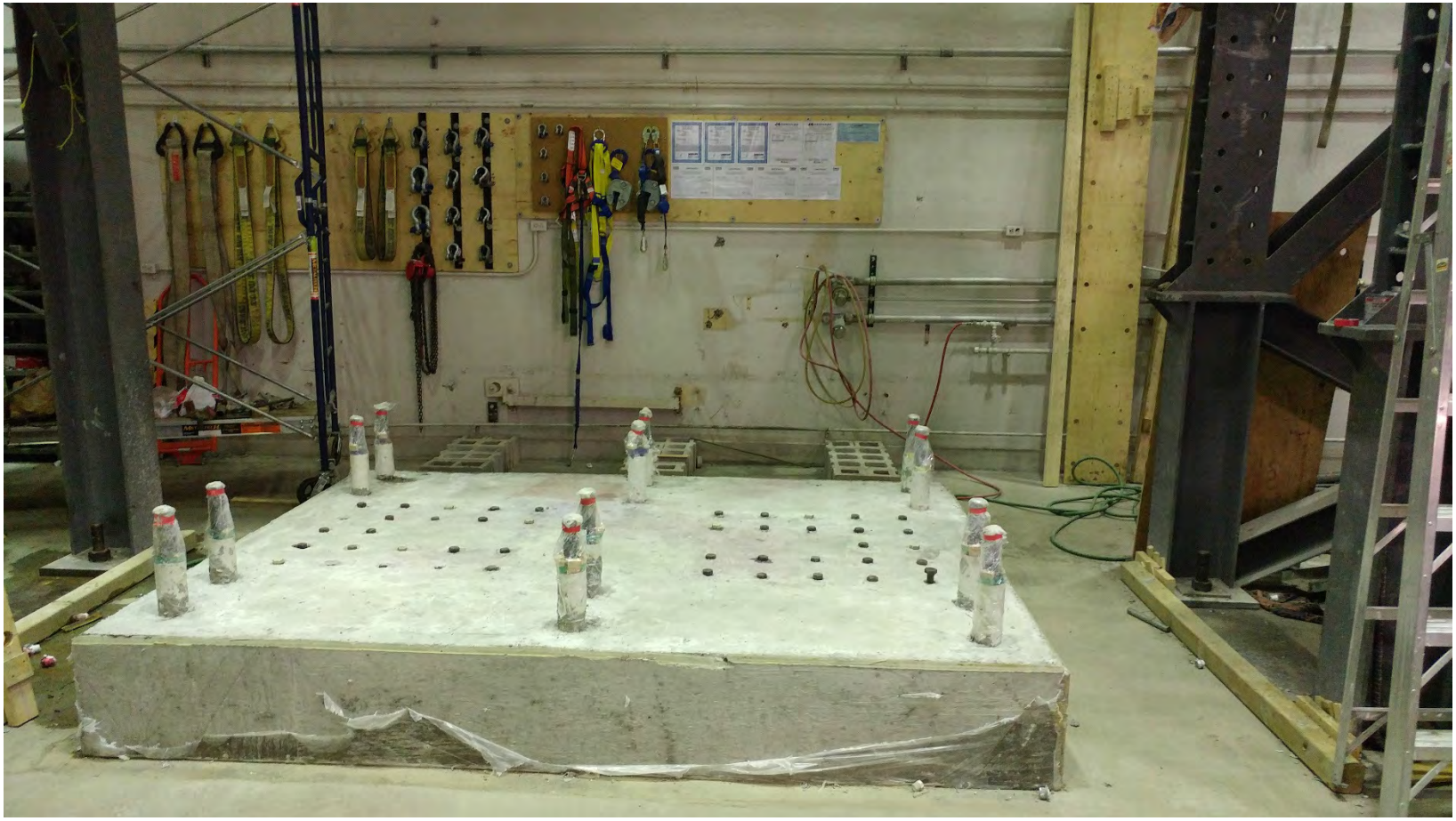


Construction of new strong foundation

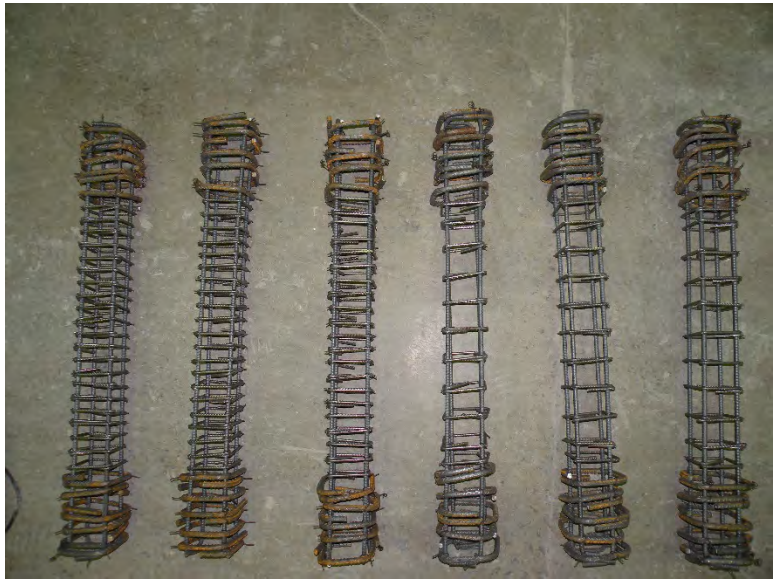


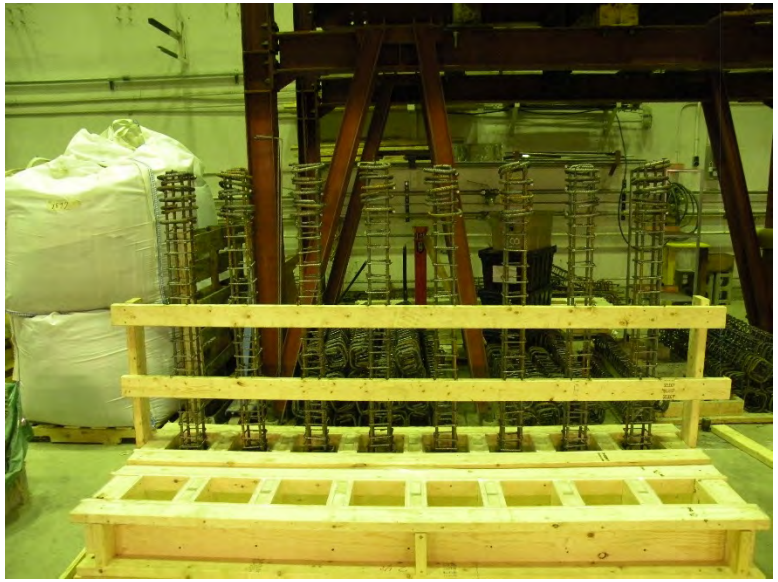


Construction of new strong foundation

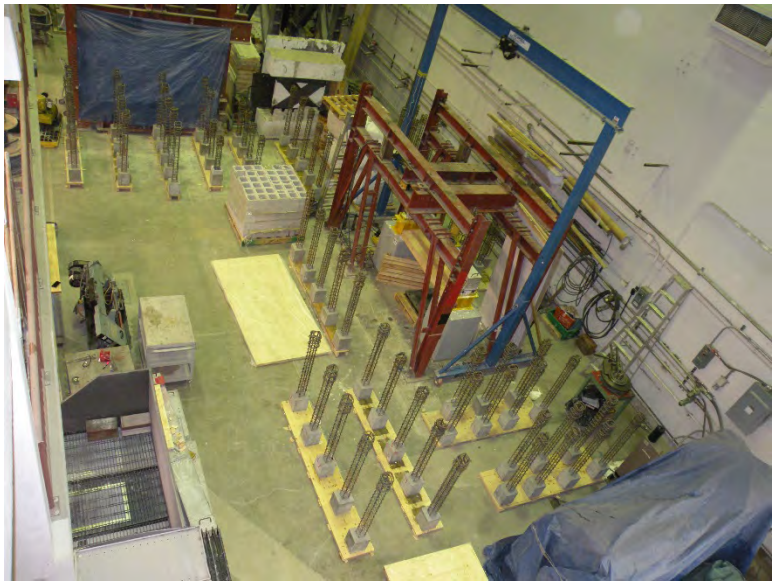


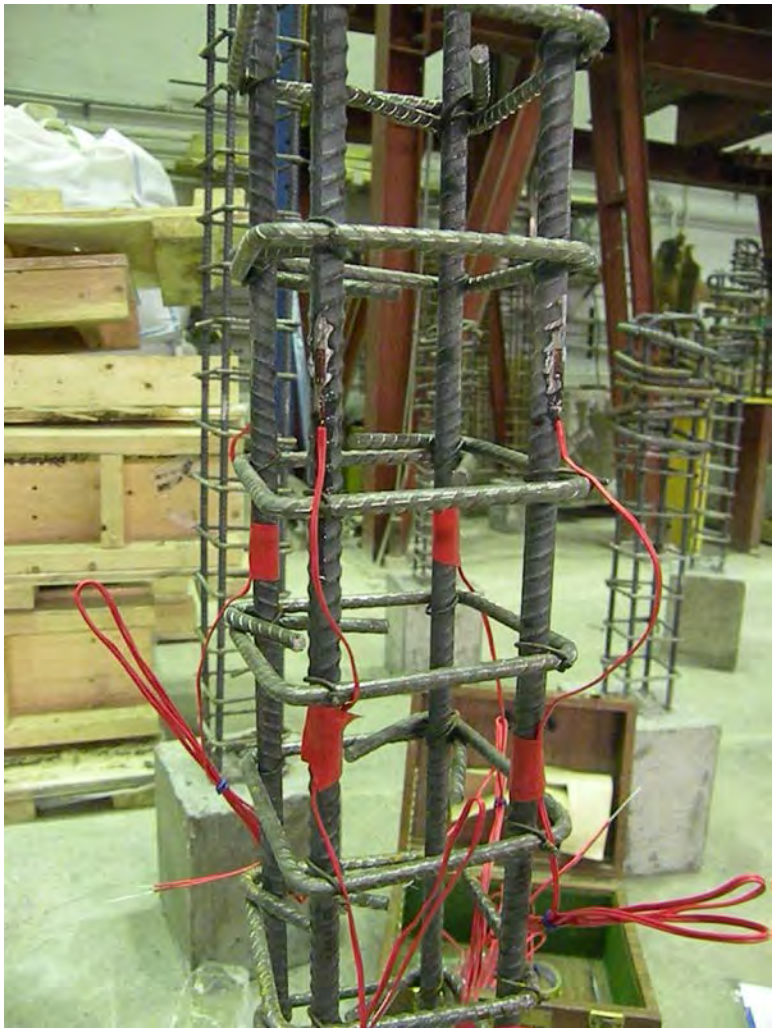
Construction of 120 boundary elements



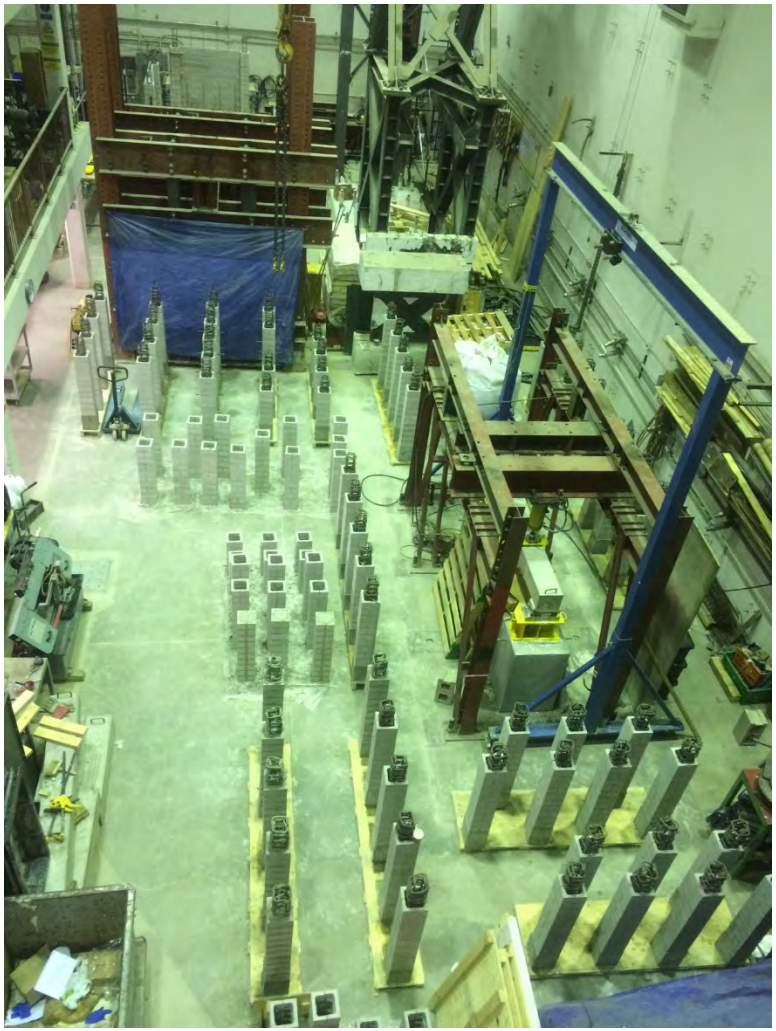


Construction of 120 boundary elements

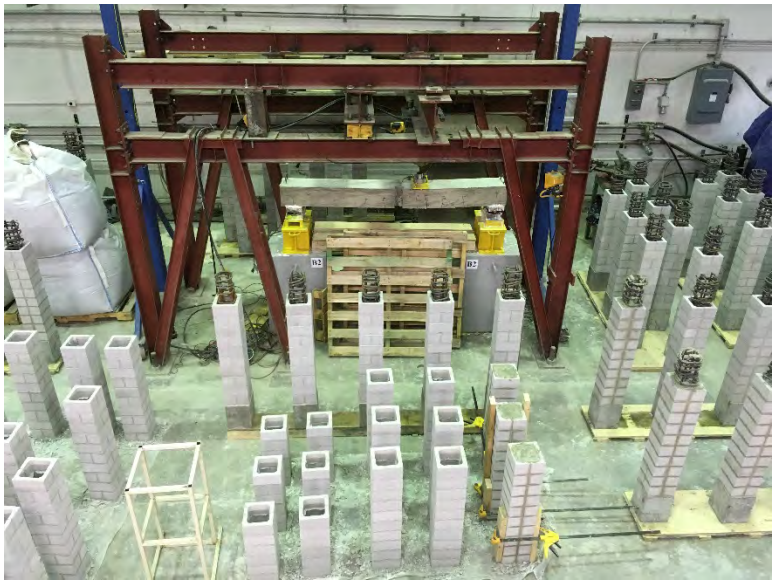


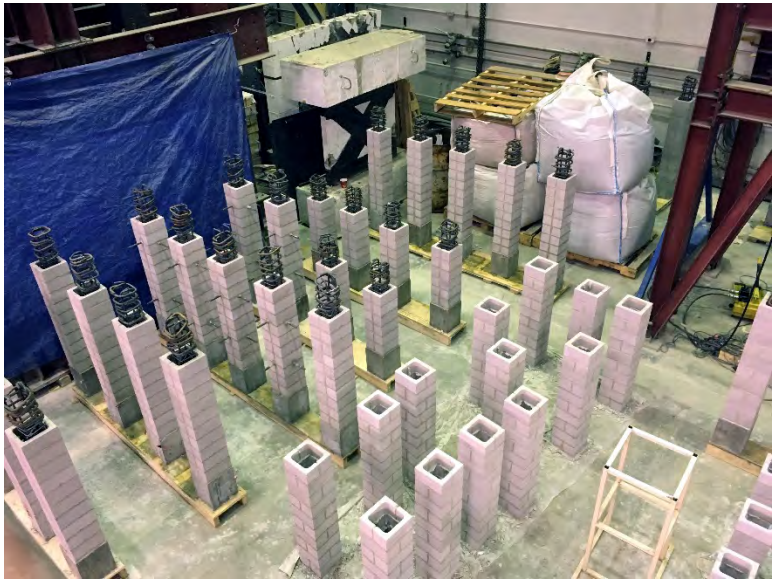


Construction of 120 boundary elements



Construction of 120 boundary elements



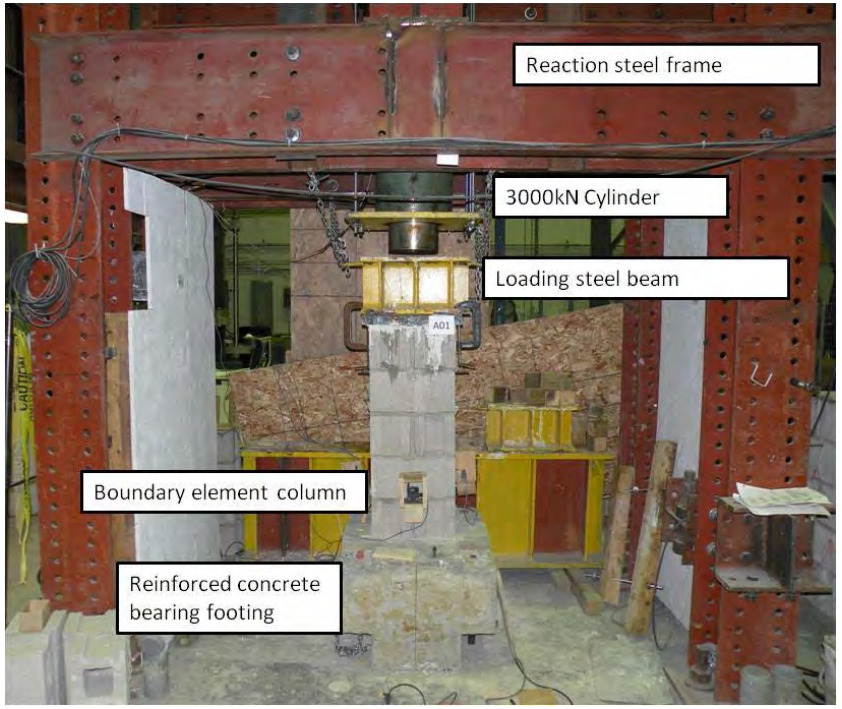


Construction of 120 boundary elements

Construction of 120 boundary elements

6. Confinement of RM Boundary Elements

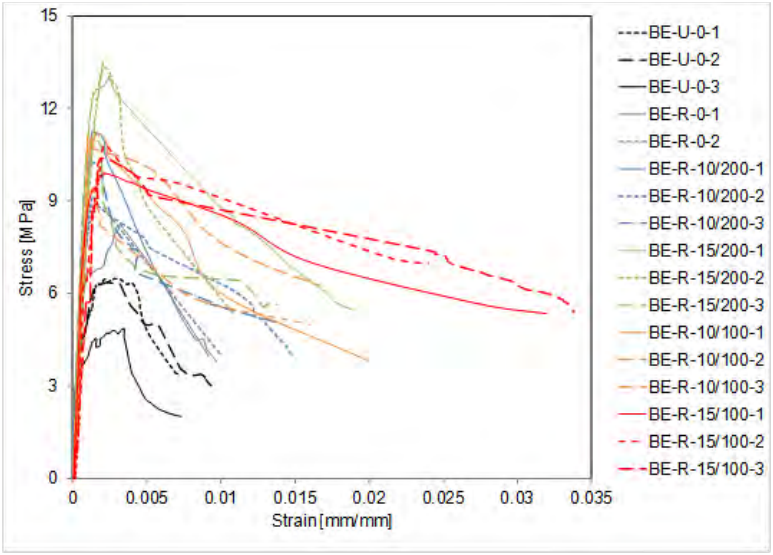
Construction of full-scale reinforced concrete block boundary elements



Compression test setup

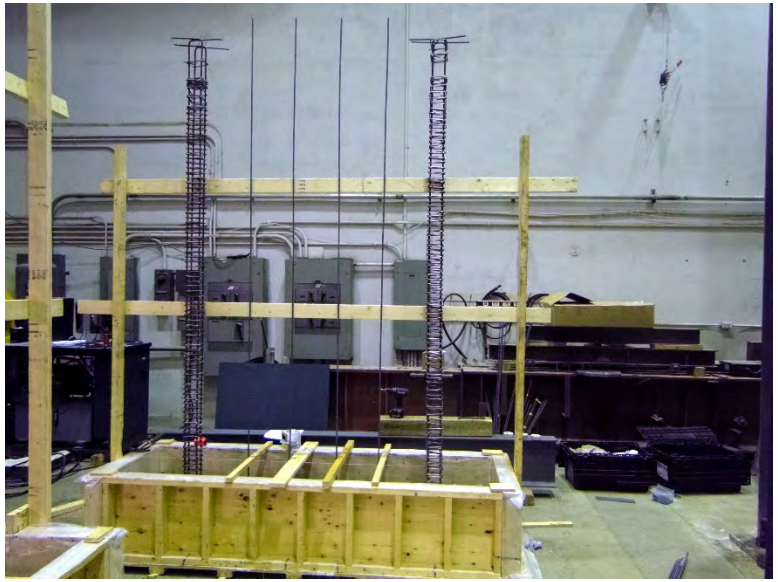
6. Confinement of RM Boundary Elements

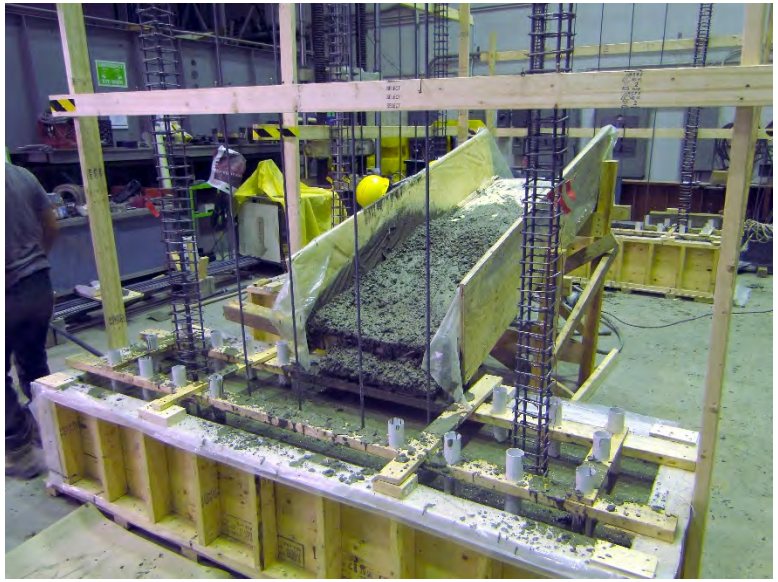
Failure mechanisms

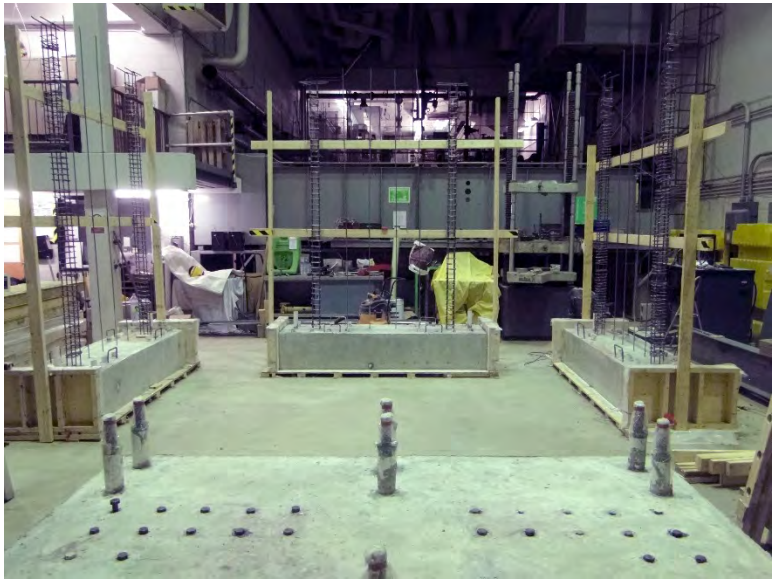


stress-strain curves

Construction of Phase 1 of RM walls



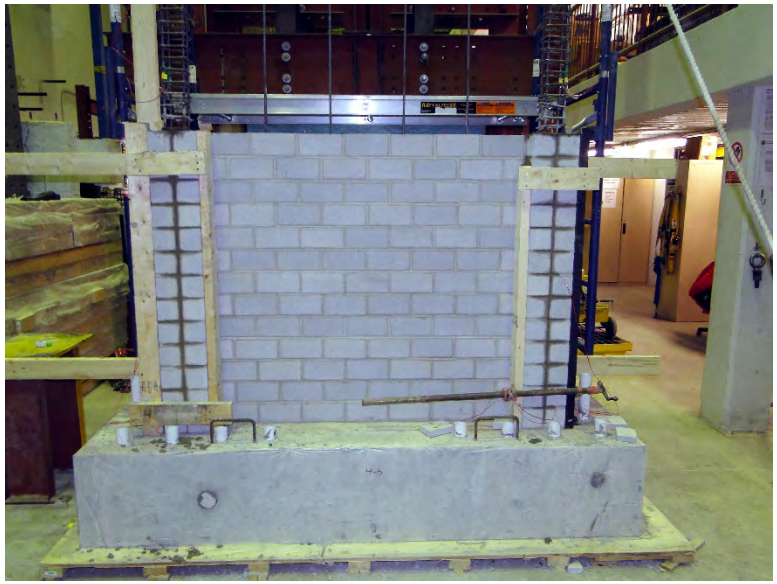


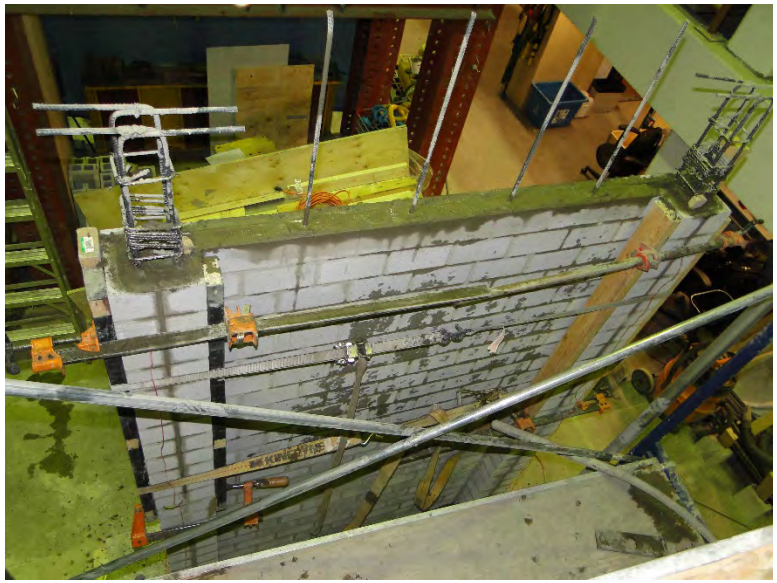


Construction of Phase 1 of RM walls

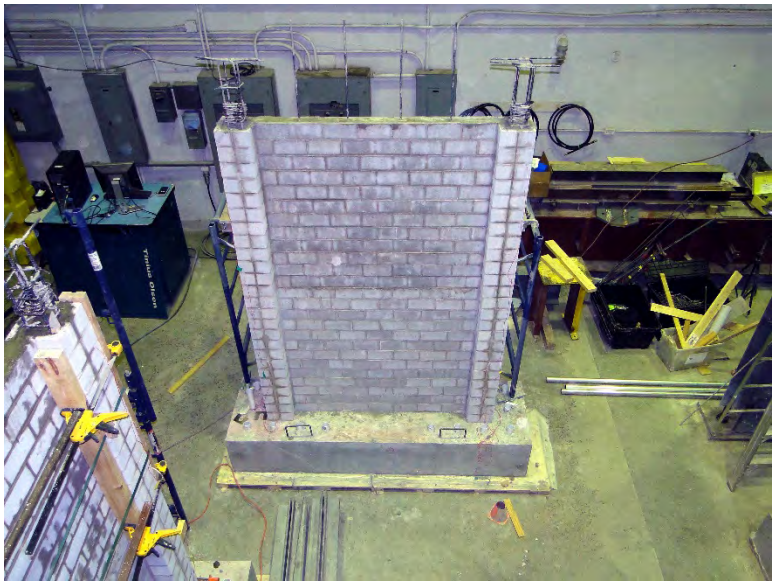
Construction of Phase 1 of RM walls

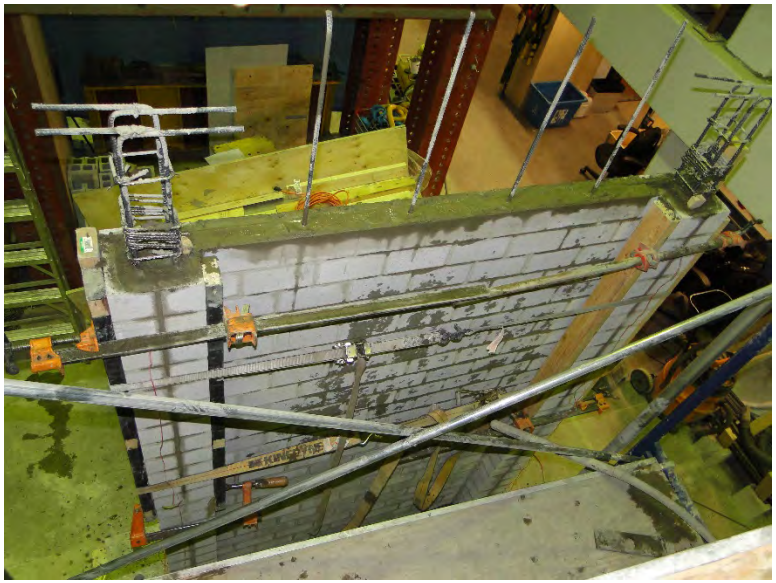
Construction of Phase 1 of RM walls

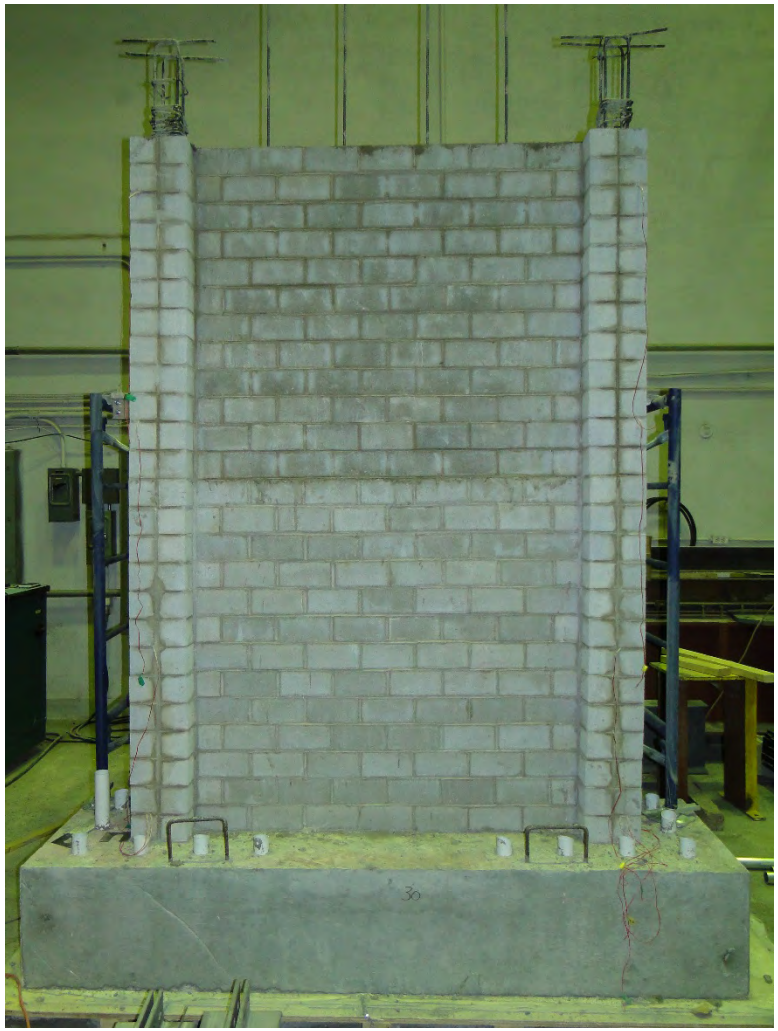




Construction of Phase 1 of RM walls





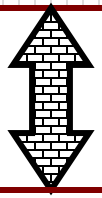



RCO

INDUSTRY-ACADEMIA RESEARCH COLLABORATION

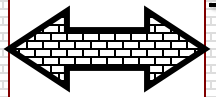
Design | Rehabilitation | Sustainability

Energy Efficient Systems



Concordia

- Full-scale testing
- Advanced systems
- Durability
- Safety
- Life Cycle Analysis



AEMQ Architects & Engineers

- Practical Expertise
- Design and Construction of Demonstration Innovative RM Buildings

Acknowledgements

- Research Students
- NSERC (Natural Sciences and Engineering Research Council of Canada)
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- Moçonnerie S.D.L. inc.
- CCMPA (Canadian Concrete Masonry Producers Association)
- CMDC (Canada Masonry Design Centre)
- Lafarge Canada

Merci

Thank you