CSRN Canadian Seismic Research Network
RCRP Réseau canadien pour la recherche parasismique

Funded by NSERC / *Subventionné par le CRSNG*

# RESEARCH PROGRESS - CANADIAN SEISMIC RESEARCH NETWORK (CSRN)

**Denis Mitchell**
**Program Leader**

**Workshop on Seismic Hazard and Microzonation**
**Toronto**
**January 13, 2012**

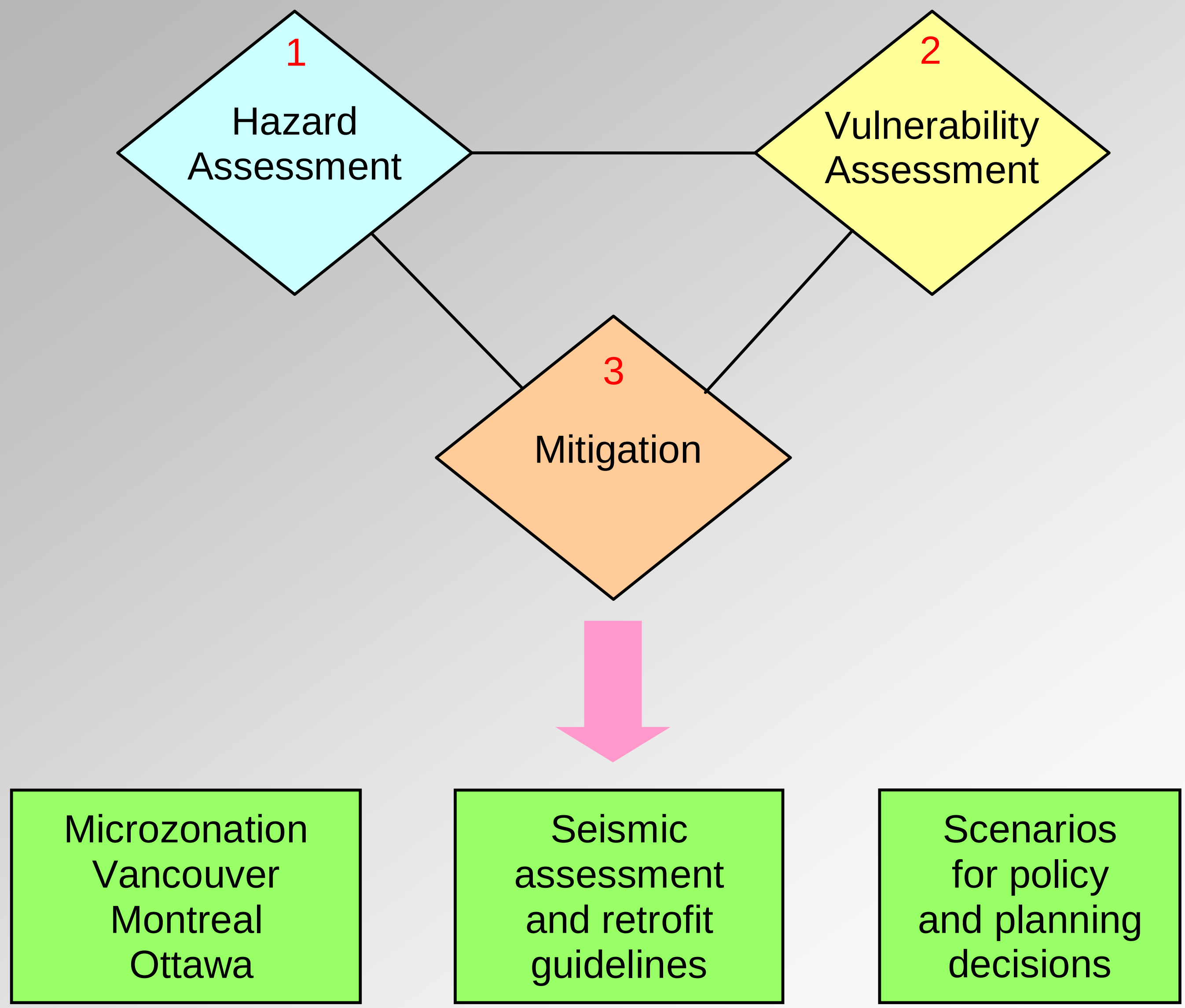
# CANADIAN SEISMIC RESEARCH NETWORK

## Network Goal:
## Reduce Urban Seismic Risk

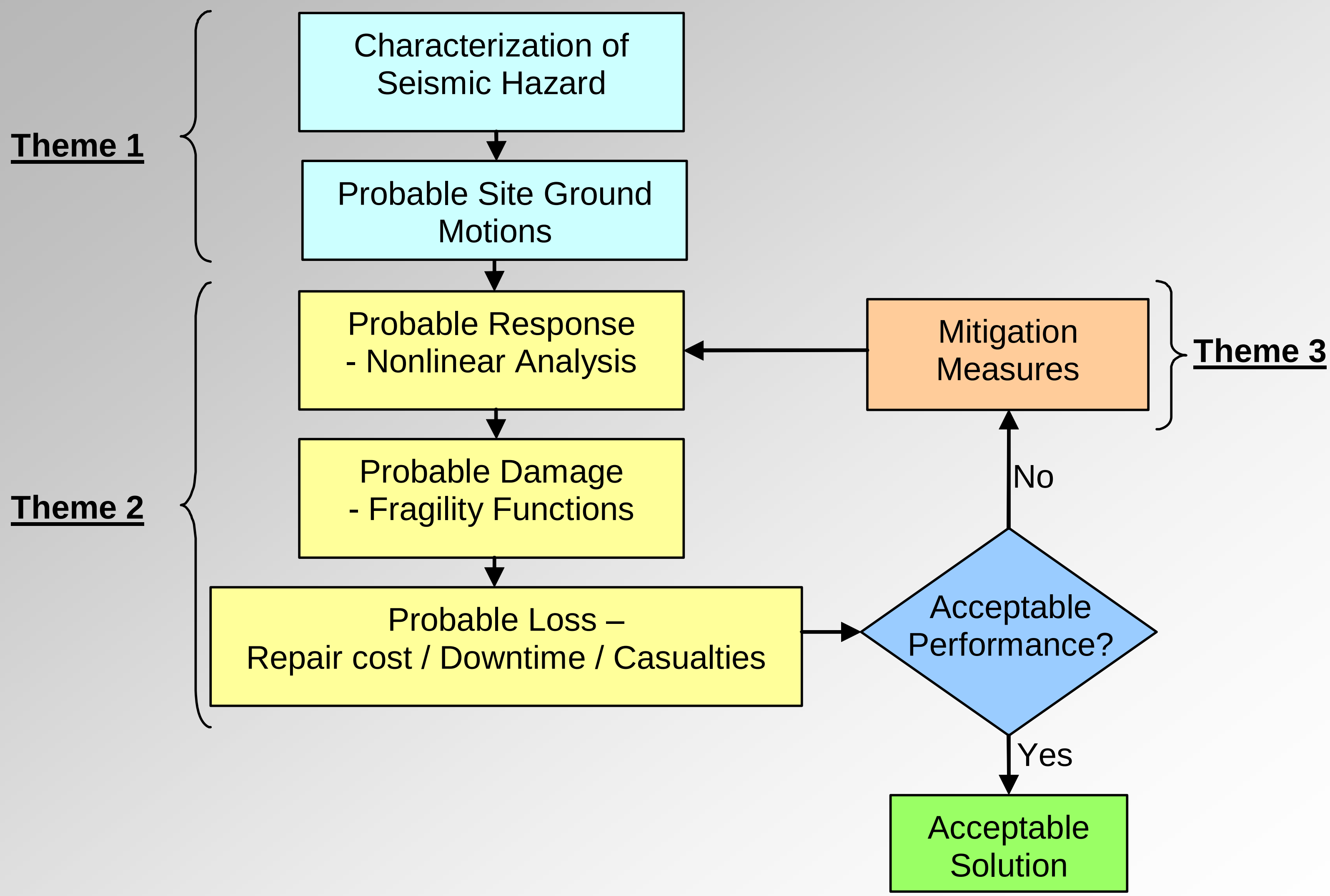
**Five-Year Program**

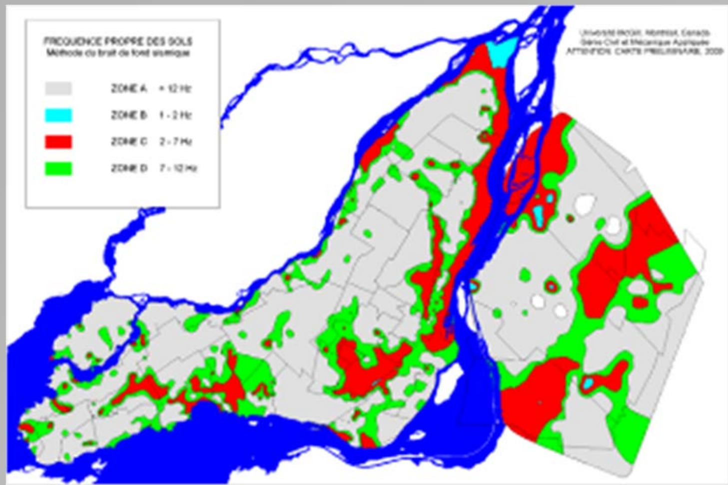
**Funded by the Natural Sciences and Engineering Research Council**

# Research Themes and Deliverables



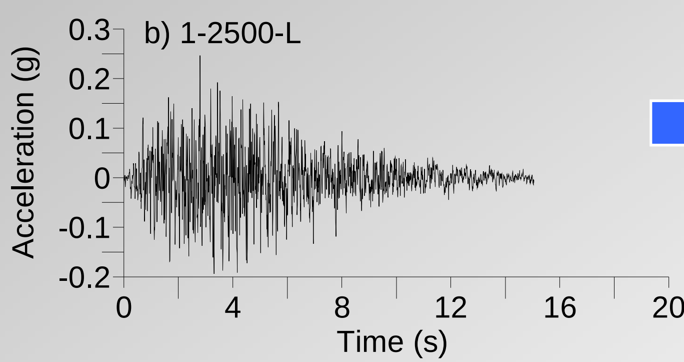
# *Performance-Based Approach - Collaboration with ATC and ASCE*



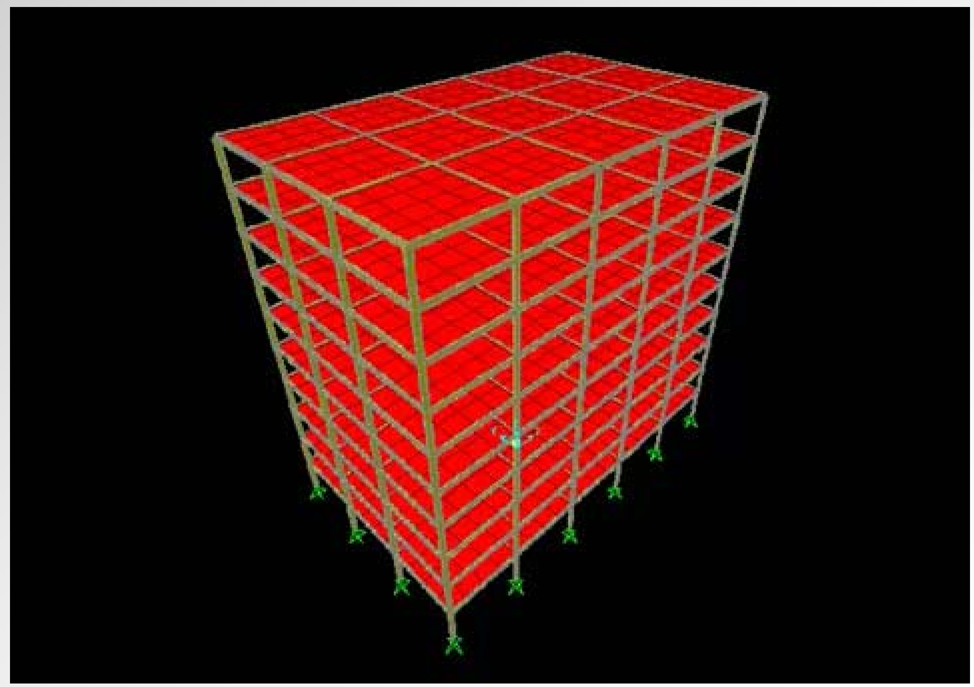



# Seismic Evaluation

**Microzonation**




**Probable ground motions**



**Non-linear dynamic analysis of structure**

D. Mitchell, McGill University

# The Researchers

***26 researchers from 8 Universities***

- McGill
- Ecole Polytechnique
- Sherbrooke
- Carleton
- Ottawa
- Toronto
- Western Ontario
- British Columbia

# *Theme 1*
# *Hazard Assessment*

- **Leader:** Prof. Gail Atkinson, University of Western Ontario
- 1.1 Probable Ground Motions
- 1.2 Seismic Microzonation
- 1.3 Liquefaction Assessment
- 1.4 Real Time ShakeMaps
- 1.5 From Hazard to Risk

# *Theme 2*
# *Vulnerability Assessment*

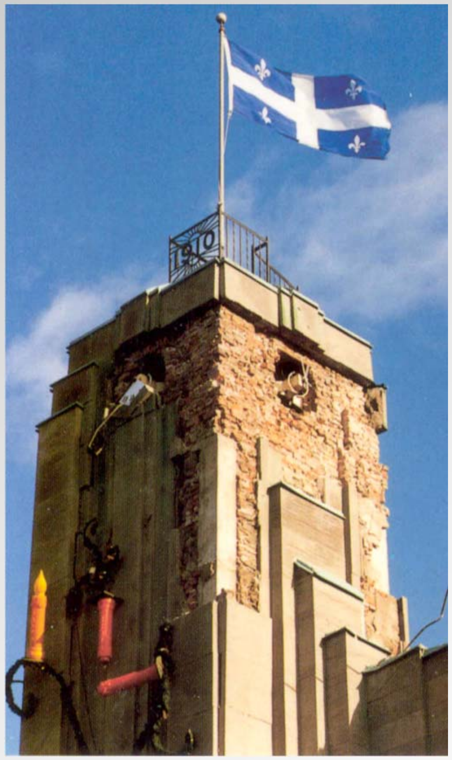
- **Theme Leader:** Prof. Patrick Paultre, Université de Sherbrooke
- 2.1 Inventory of Deficiencies – Rapid Screening
- 2.2 Masonry Buildings
- 2.3 Reinforced Concrete Buildings
- 2.4 Steel Structures
- 2.5 Operational and Functional Components
- 2.6 Bridges

# Project 2.1 Inventory of Deficiencies + Rapid Screening

Evaluation of critical infrastructure:

- Post-disaster structures (hospitals, schools)
- Other buildings
- Bridges

# *Project 2.2*
# *Masonry Buildings*



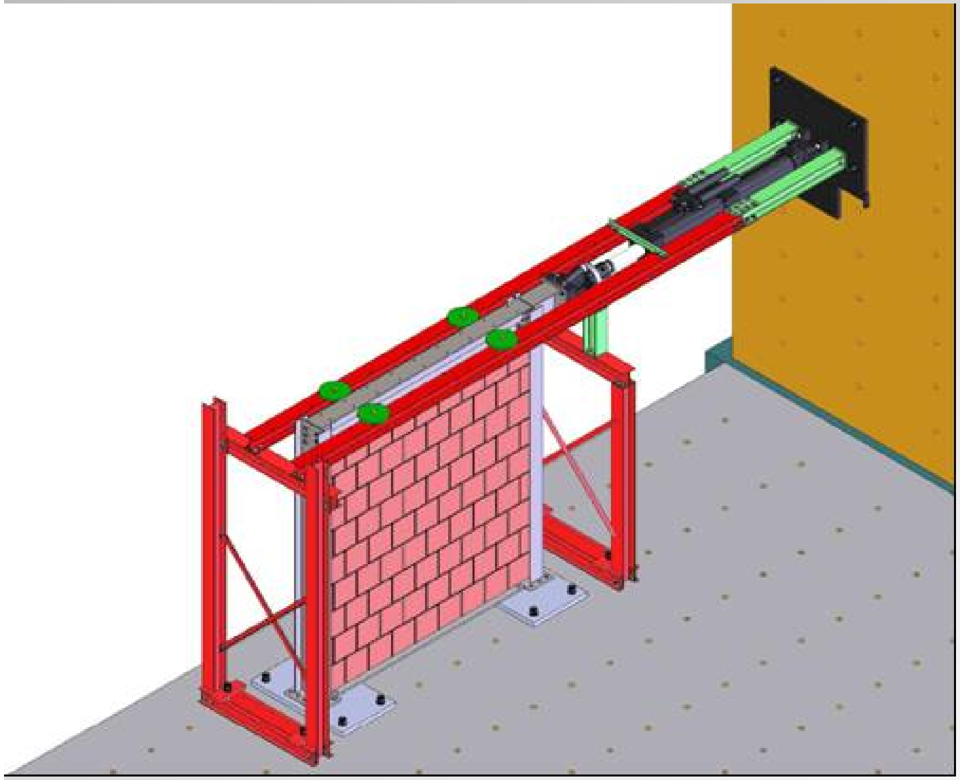
Testing and Analysis:

- Unreinforced masonry structures
- Infilled masonry frames

***Montréal East City Hall Saguenay 1988***

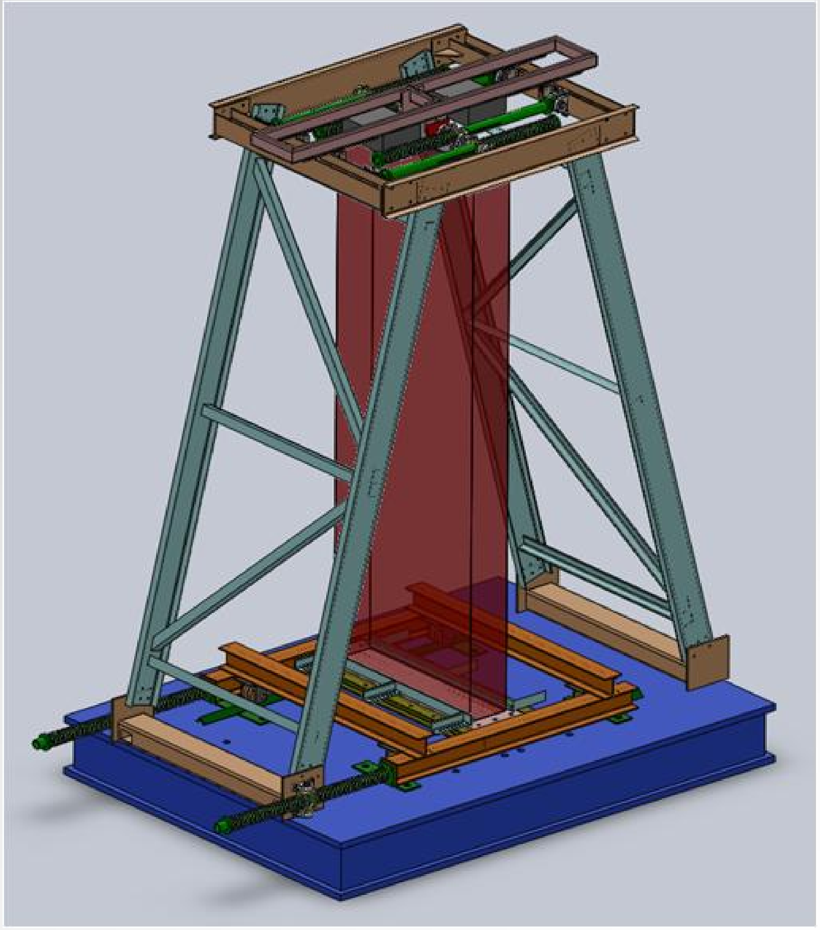
# *Masonry Infill Walls – In Plane*

- Sherbrooke tests
- In-plane reversed cyclic loading tests
- Terracotta infill walls



# *Unreinforced Masonry – Out of  Plane*

- UBC tests
- h/t limits
- Axial load
- Diaphragm stiffness



# Project 2.3 Reinforced Concrete Buildings

Large-Scale Testing and Analysis:

Concrete Frames:

- Determine drift limits

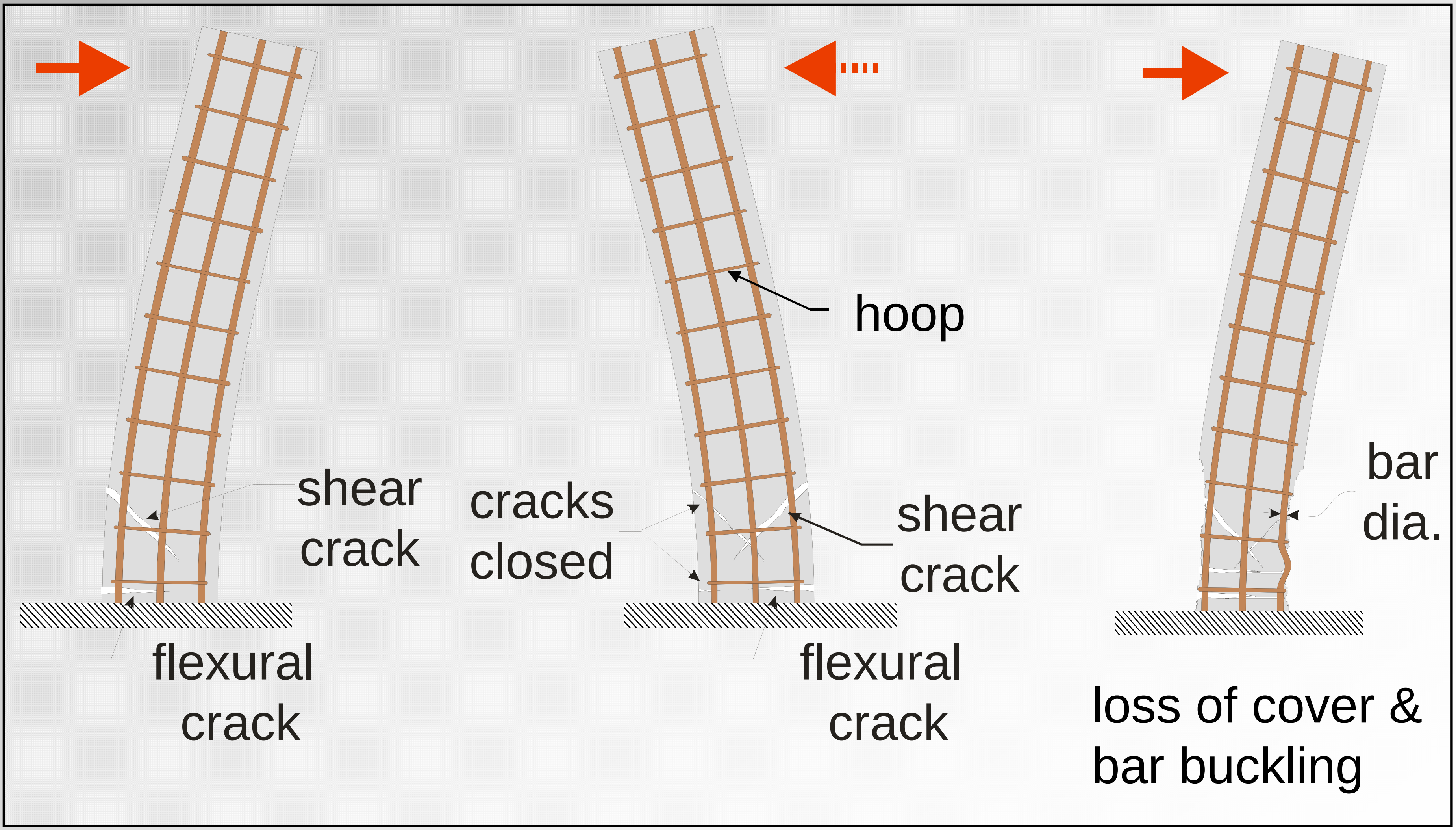
Concrete Shear Walls:

- Determine rotational capacities

*Hospital, Mexico City 1985*

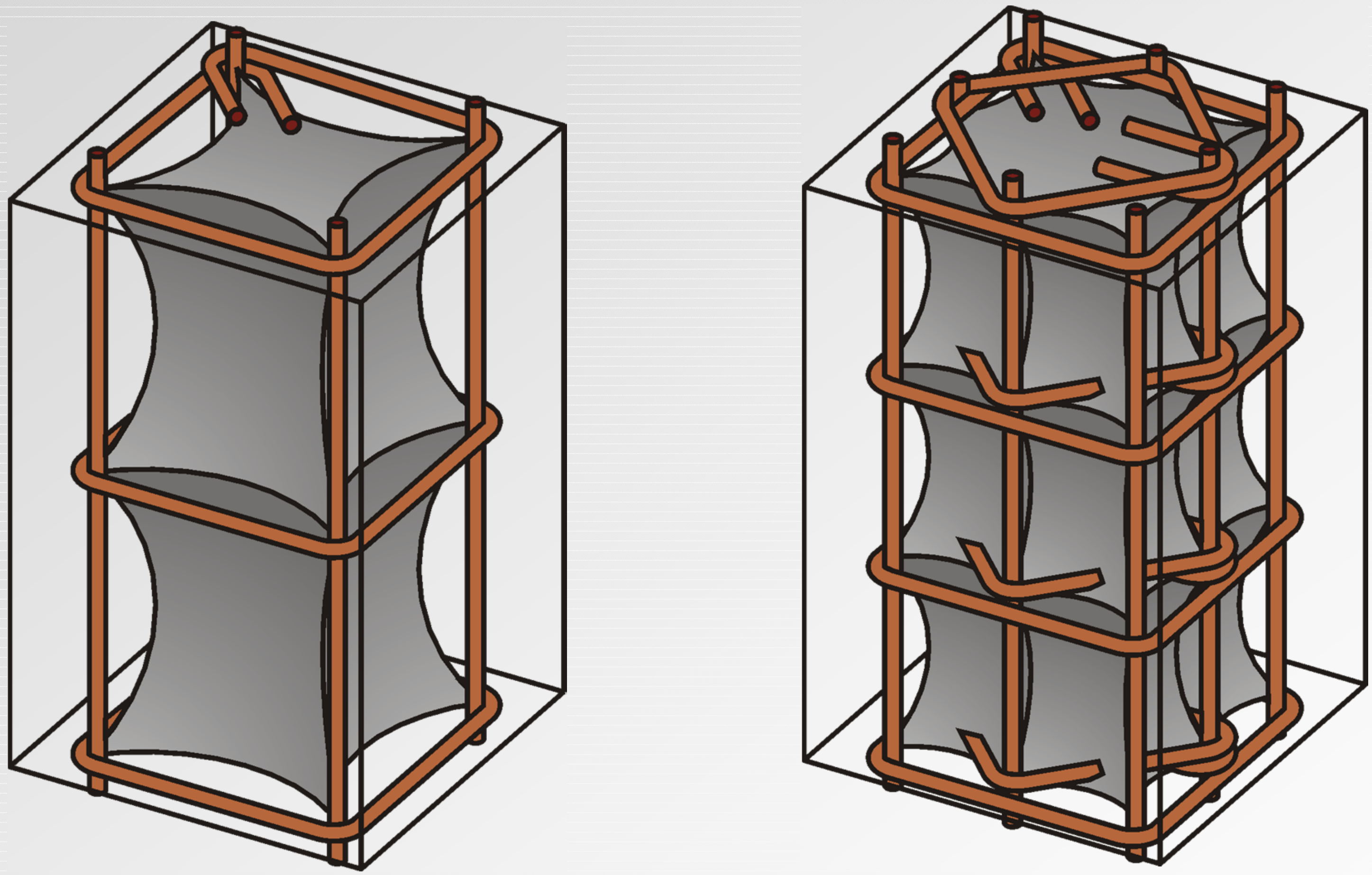
*School, Kobe1995*

# Reversed Cyclic Loading




D. Mitchell, McGill University

# *Hoops Confine the Concrete*

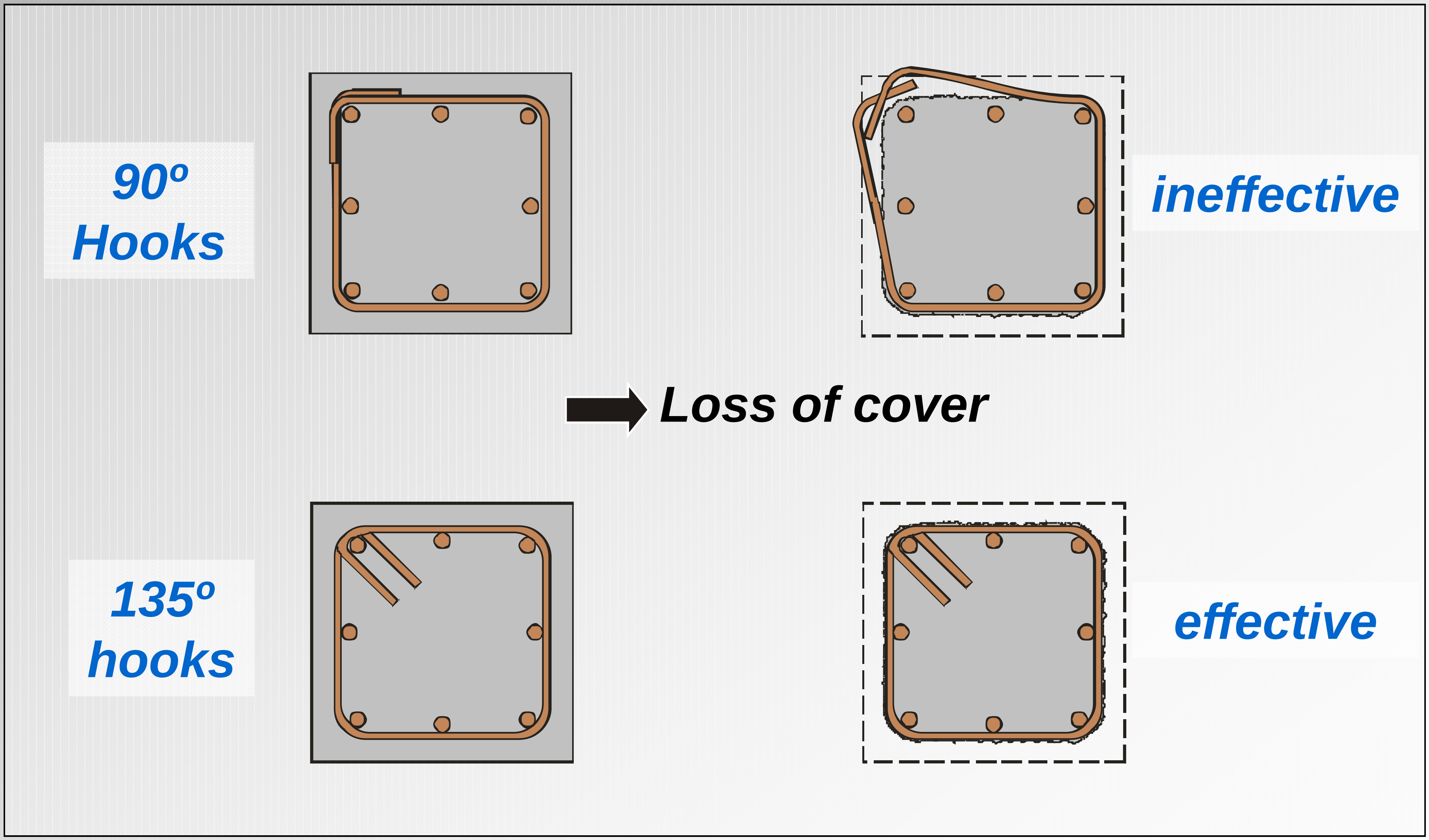


*Poor confinement*

*Good confinement*

*D. Mitchell, McGill University*

# Hoop Anchorage Details

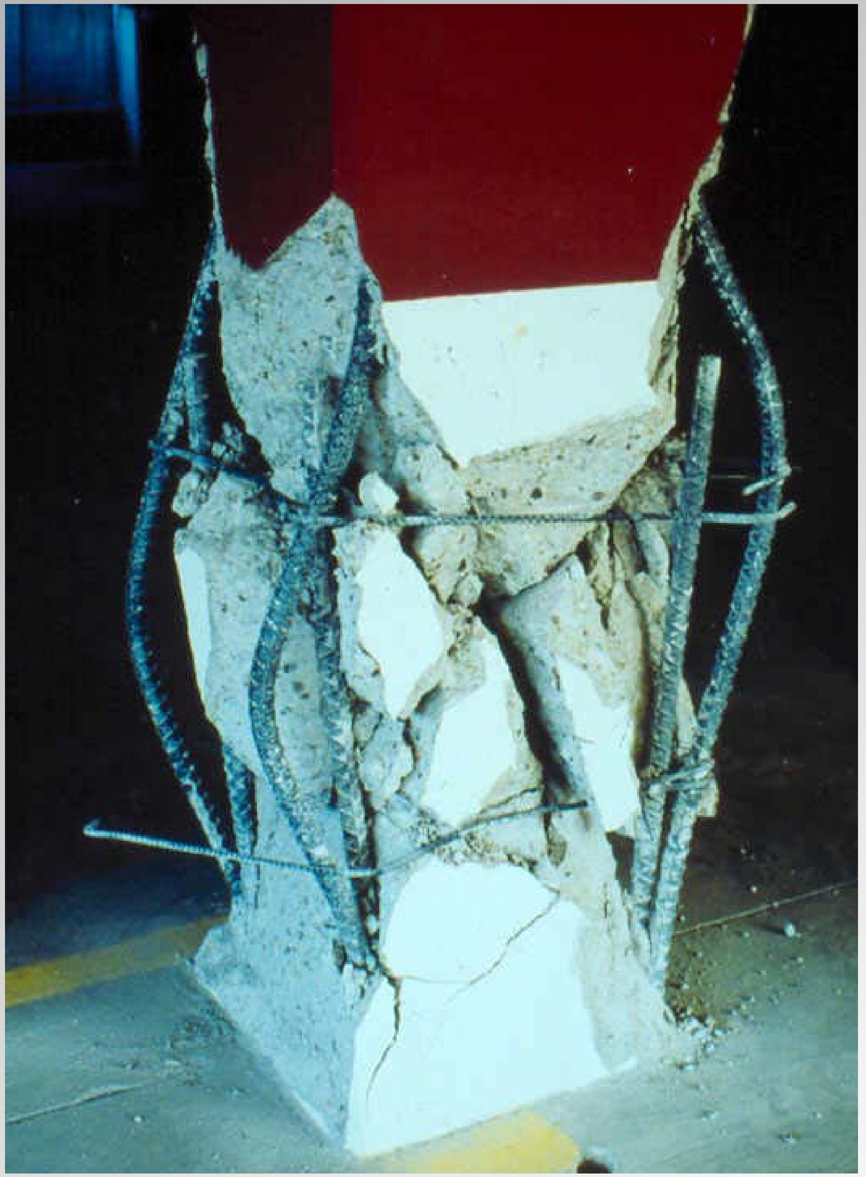


# *The Challenge of Earthquake Resistant Design*

"Earthquake effects on structures systematically bring out the mistakes made in design and construction, even the most minute mistakes."

Newmark and Rosenblueth

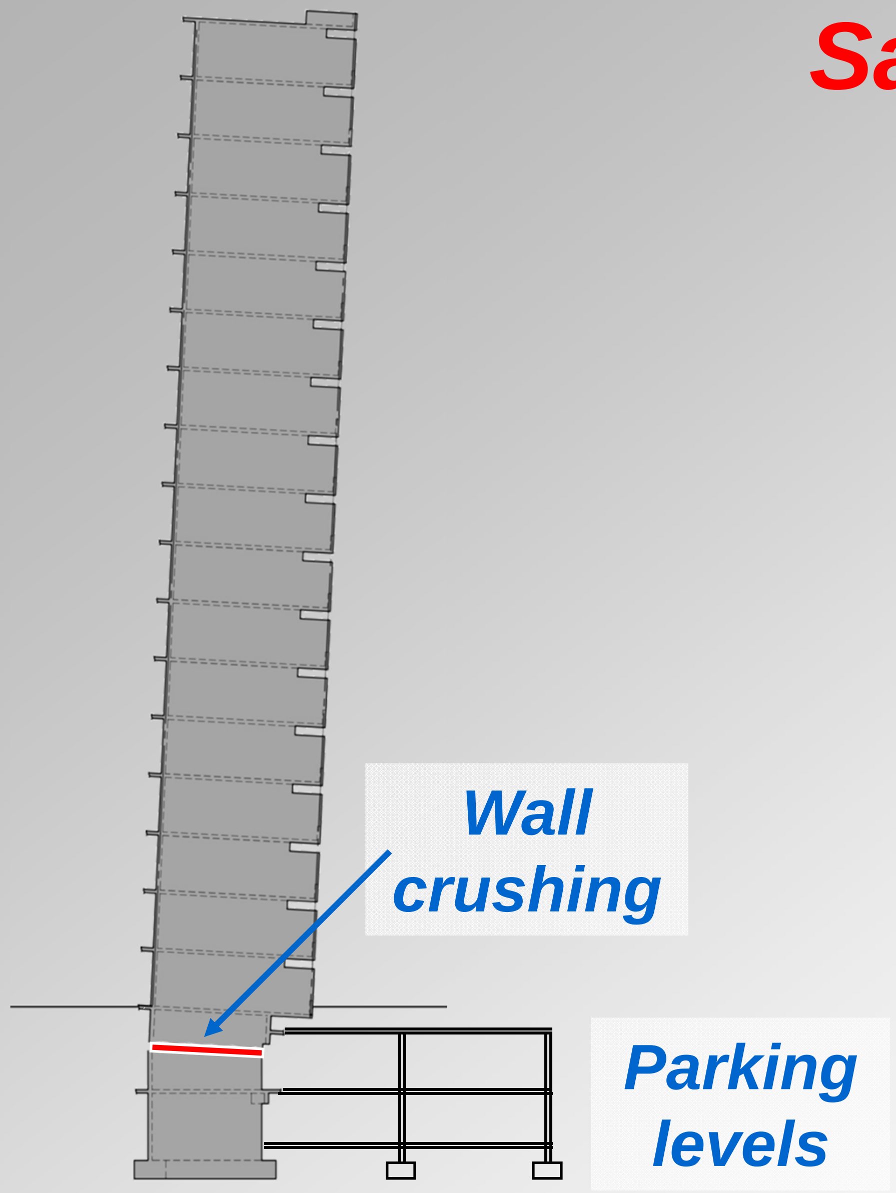
**Building Column**
**Northridge, 1994**



**Bridge Column**
**Chile, 2010**

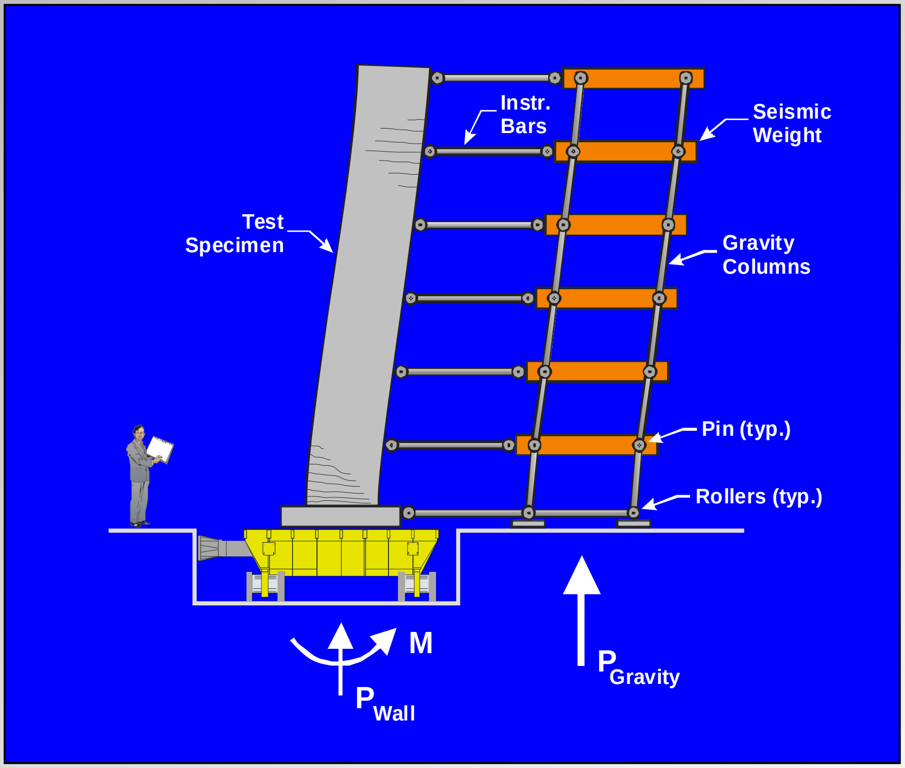
ity

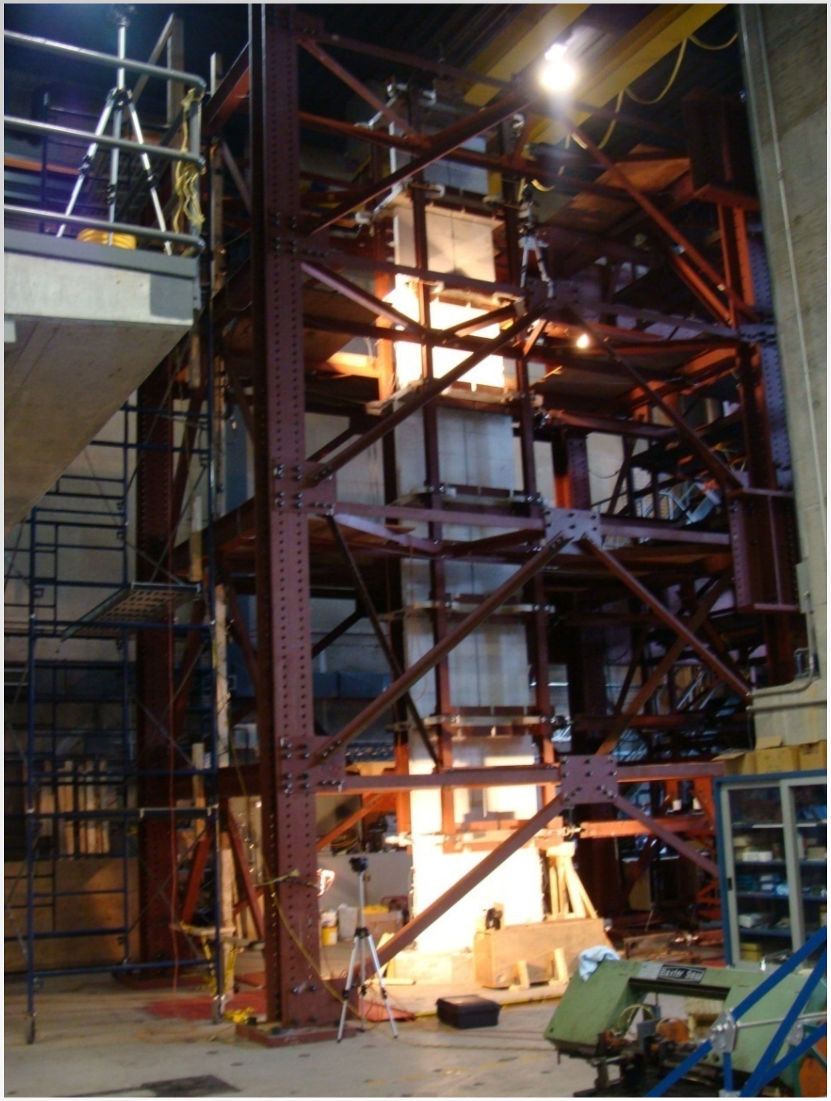
# 18-Storey Condominium Building, Santiago, Chile M8.8




# *Shake Table Tests on Concrete Walls*

- Ecole Polytechnique tests
- Higher mode effects on shear magnification



# *Project 2.4 Steel Structures*

Large-Scale Testing:

- Concentrically braced frames
- Connections

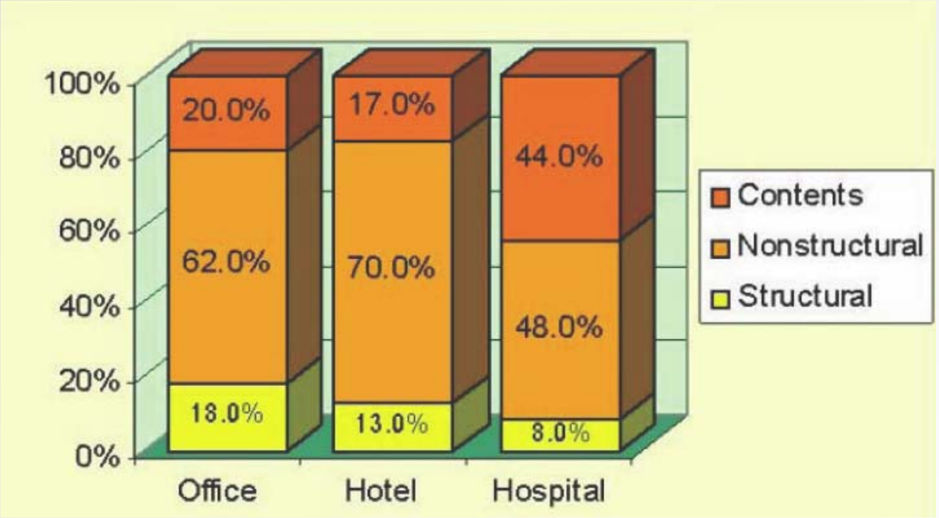
*Mexico City 1985*

# *Project 2.5 Operational and Functional Components*

Develop Performance-Based Approach:

- Safety hazards
- Failure

Develop Inventory of Deficiencies and Rapid Screening Method




*Importance of Component Damage*

# *Theme 3*
# *Mitigation*

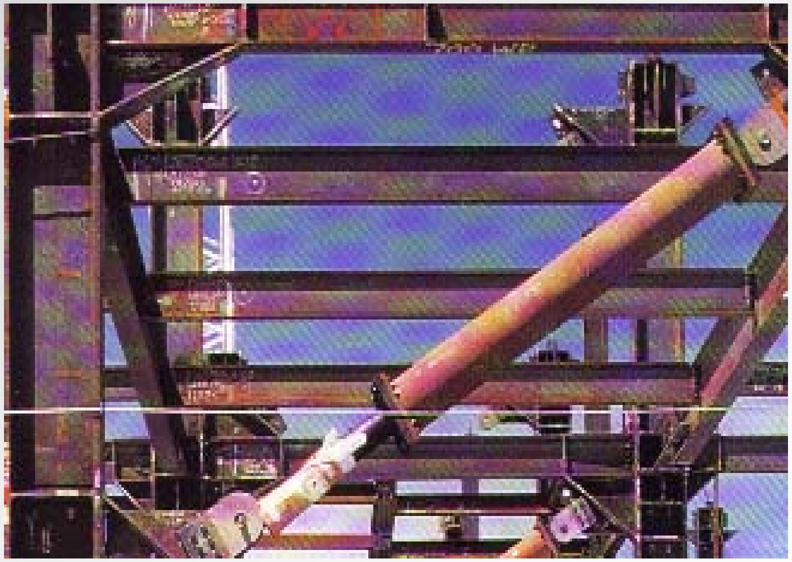
- **Theme Leader:** Prof. M. Saatcioglu, University of Ottawa
- 3.1 Supplementary Damping Devices
- 3.2 Added Stiffness
- 3.3 Innovative Materials
- 3.4 Base Isolators
- 3.5 Functional and Operational Components

# Project 3.1 Seismic Upgrade with Supplemental Damping Devices

Upgrading reinforced concrete and steel frame structures

Performance-Based Approach:

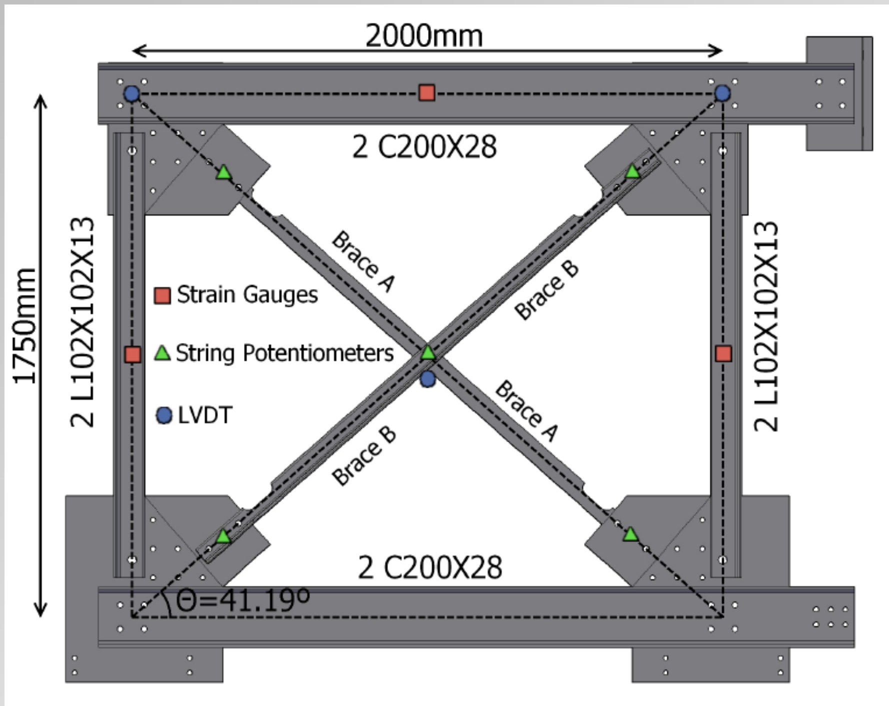
- buckling restrained systems
- steel yielding devices
- viscous devices
- self-centering braces

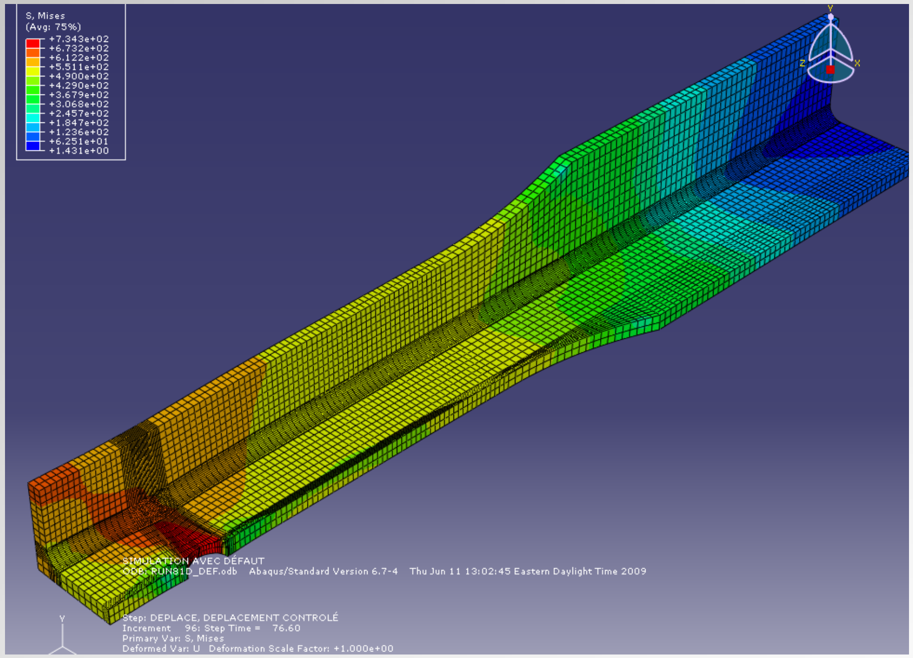


*Viscous Damping Device*

# Steel Structures

- Ecole Polytechnique & McGill U.
- Development of brace fuses
- Tests on brace connections



# Project 3.2 Seismic Upgrade with Added Stiffness

*Mexico City, 1986*

- Reduce storey drifts
- Protect brittle elements

Performance-Based Approach:

- Enlarging frame elements
- Adding shear walls
- Adding bracing

*Lion's Gate Hospital North Vancouver*

# *Project 3.3 Seismic Upgrade Using Innovative Materials*

Fibre-Reinforced Polymers:

- Masonry-Infilled Frames
- Unreinforced Masonry Wall
- Bridge Columns

***FRP wrap***

Diagonal Prestressing:

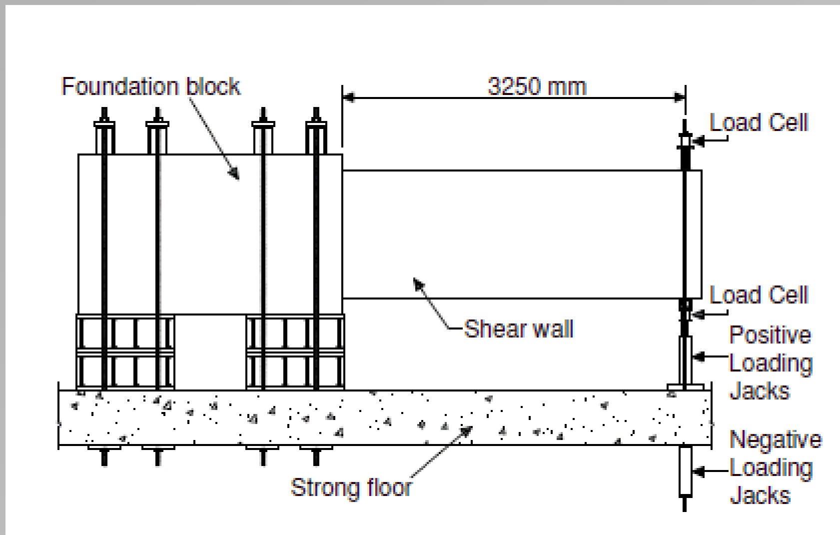
- Added restoring stiffness

Fibre-Reinforced Concrete:

- Bridges (degradation)

***Corrosion***

# *Poorly Detailed Walls*



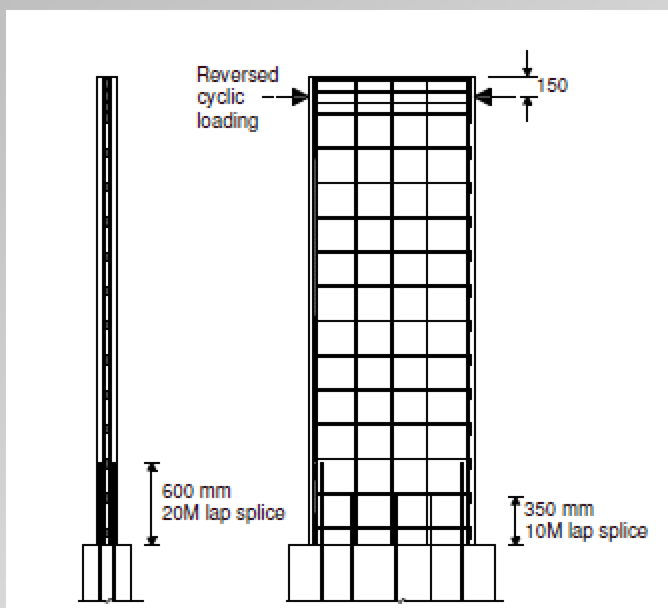
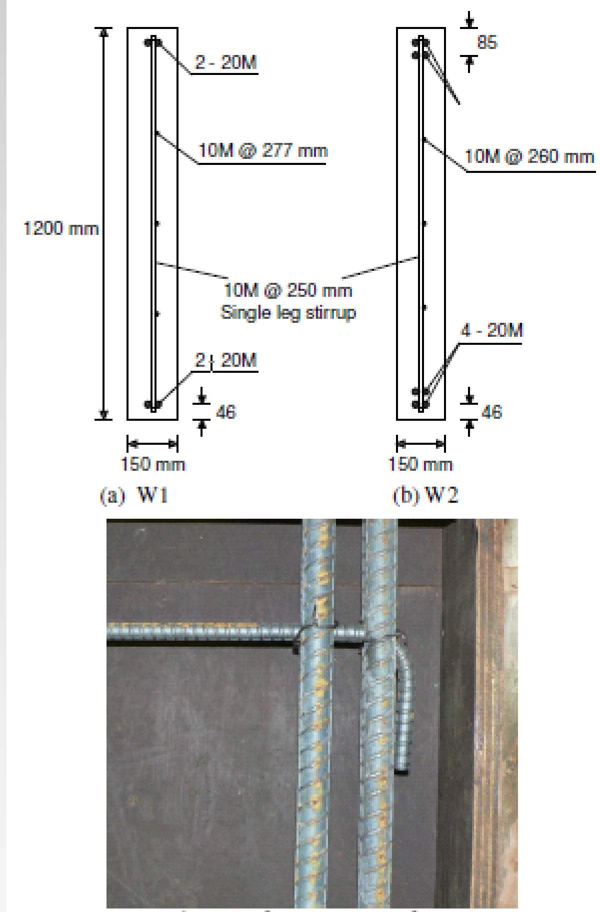
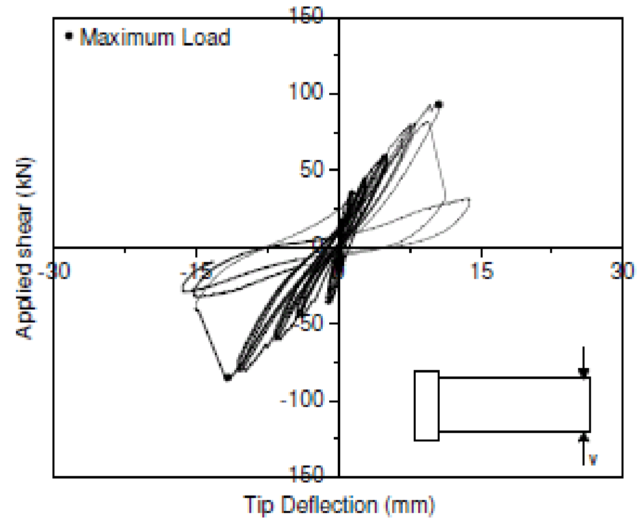



Fig. 4. Details of reinforcement and lap splices

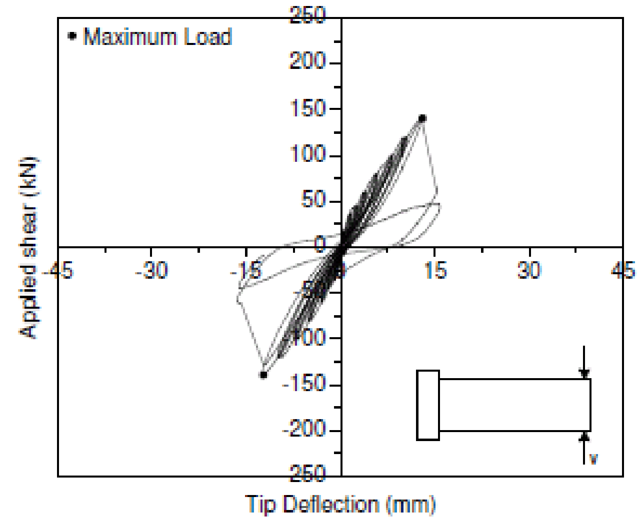


(c) anchorage of transverse reinforcement

*Layssi, H., Cook, W.D. and Mitchell, D., "Seismic Response and CFRP Retrofit of Poorly Detailed Shear Walls", accepted ASCE J. of Composites for Construction., Sept., 2011*




(a) shear versus tip deflection





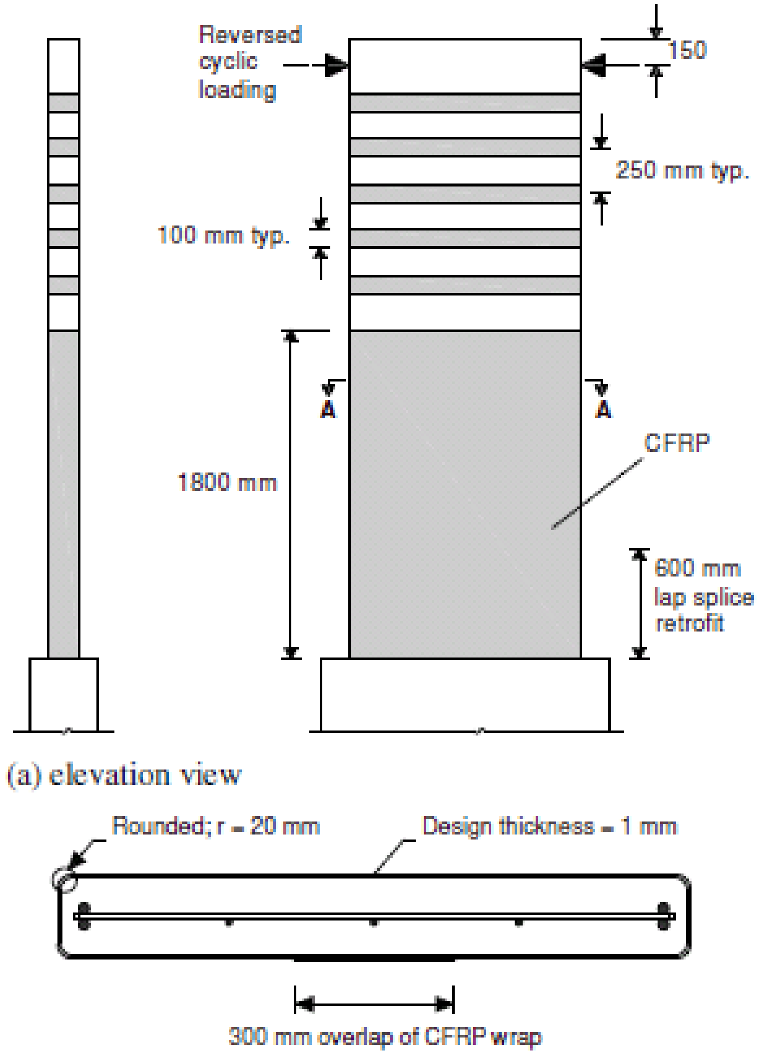
(c) photo at the end of testing

**Fig. 5.** Response of Wall W1


(c) photo at the end of testing

**Fig. 6.** Response of Wall W2

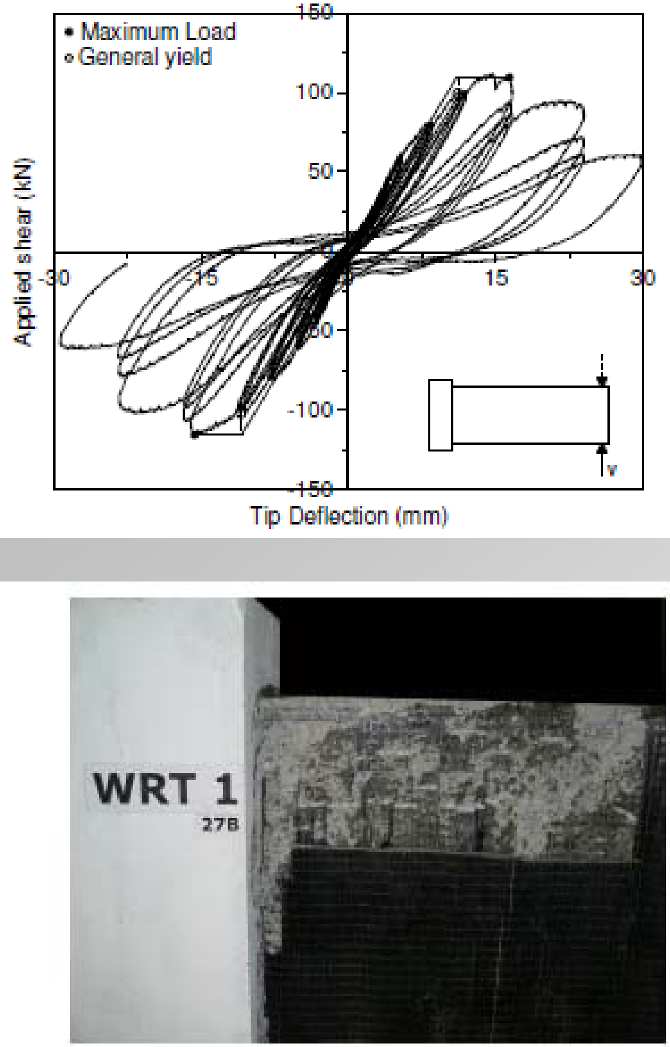
*Layssi, H., Cook, W.D. and Mitchell, D., "Seismic Response and CFRP Retrofit of Poorly Detailed Shear Walls", accepted ASCE J. of Composites for Construction., Sept., 2011*




(b) cross section

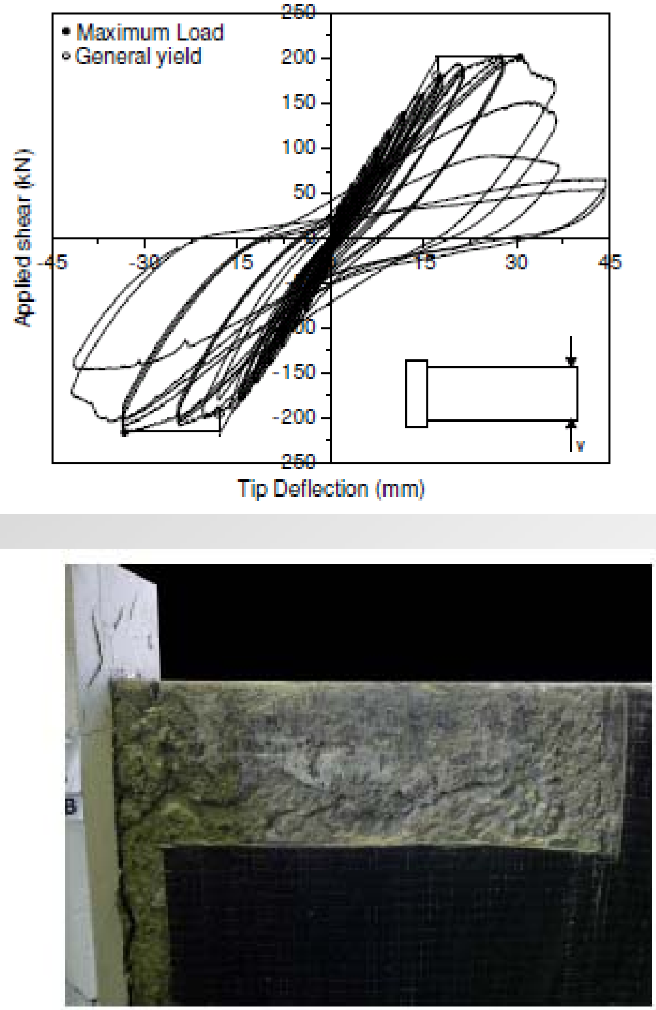
**Fig. 7.** Details of retrofit using CFRP wrap

*Layssi, H., Cook, W.D. and Mitchell, D., "Seismic Response and CFRP Retrofit of Poorly Detailed Shear Walls' accepted ASCE J. of Composites for Construction., Sept., 2011*




(c) lap splice at the end of testing after removal of CFRP

**Fig. 8.** Response of Wall WRT1



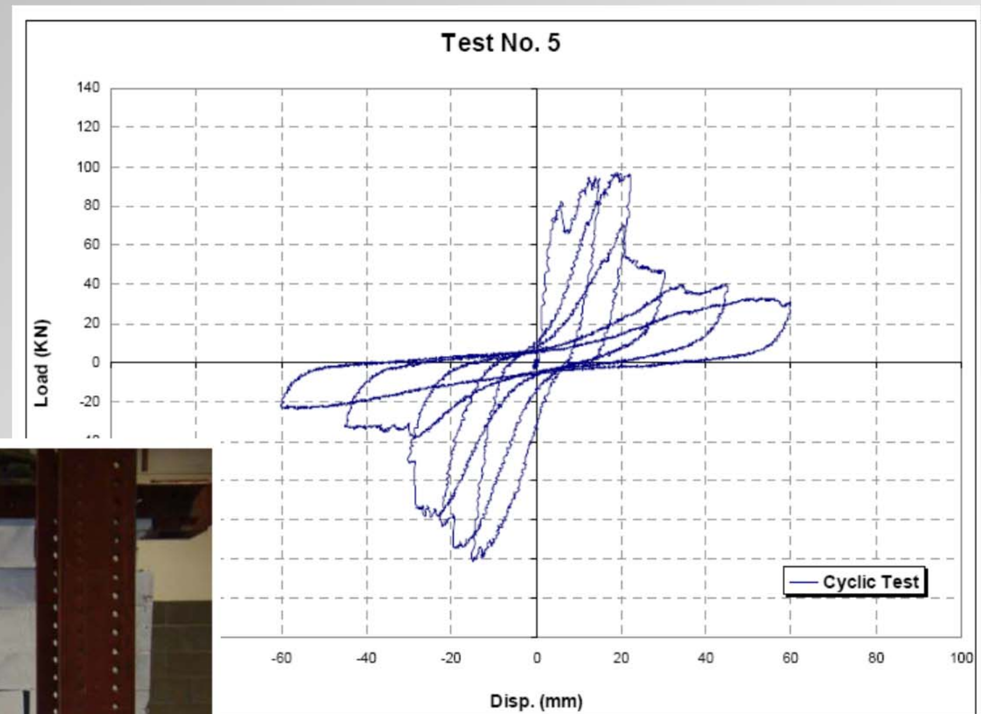

(c) lap splice at the end of testing after removal of CFRP

**Fig. 9.** Response of Wall WRT2

*Layssi, H., Cook, W.D. and Mitchell, D., "Seismic Response and CFRP Retrofit of Poorly Detailed Shear Walls", accepted ASCE J. of Composites for Construction., Sept., 2011*

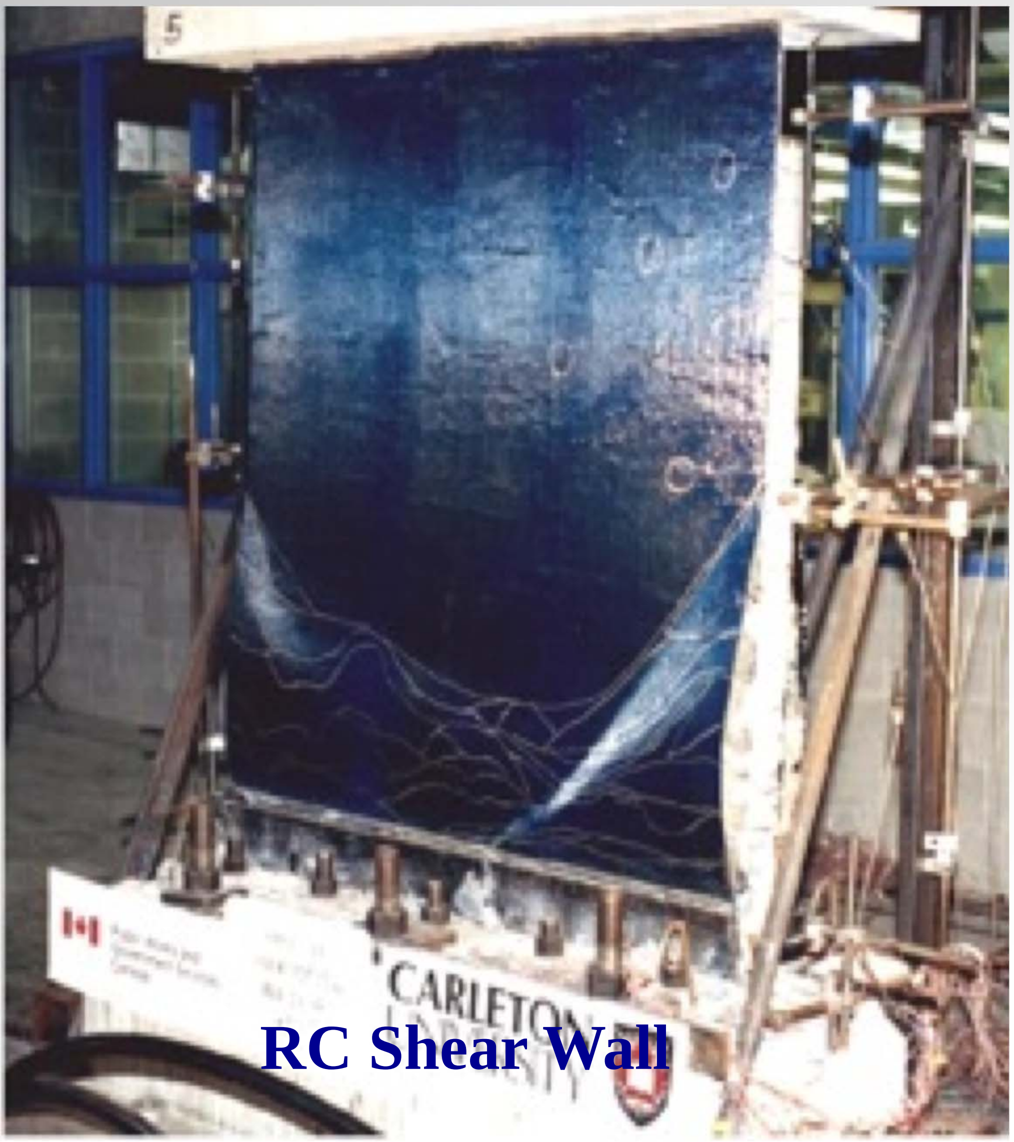
# Unreinforced Masonry Walls

- UBC tests
- In-plane loading




# *FRP Retrofit of Masonry and Shear wall U. Ottawa & Carleton U.*

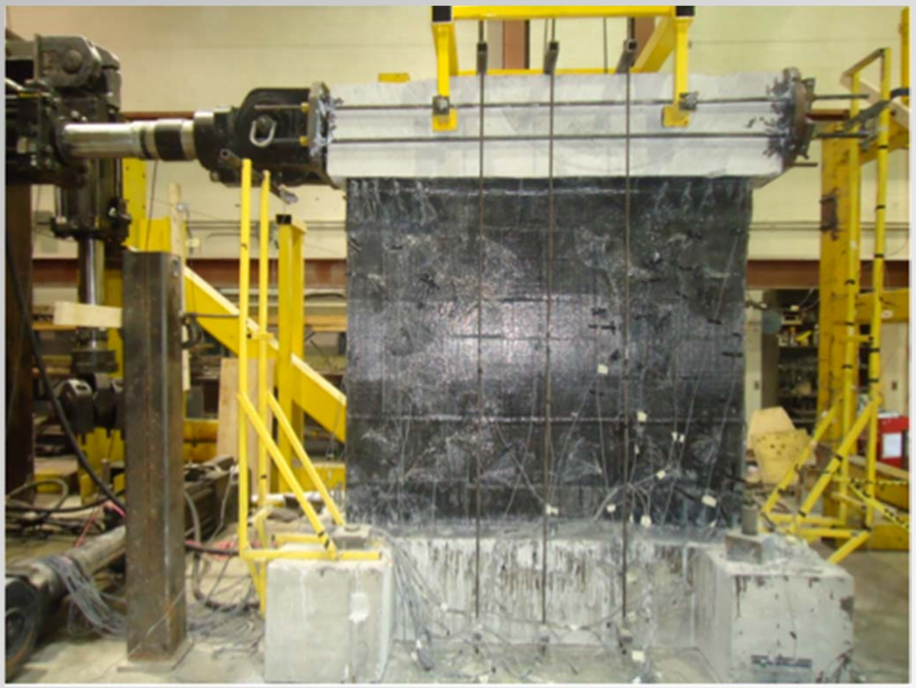

URM Infill Wall

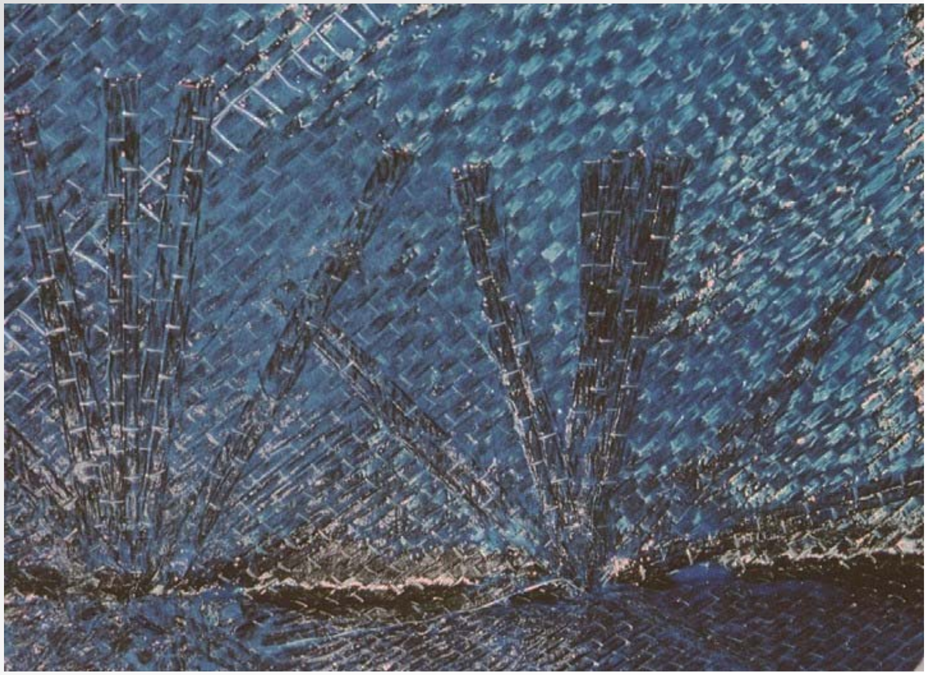


RC Shear Wall

# *Masonry Wall Retrofit*

- U. of Ottawa tests
- Surface bonded FRP
- FRP anchorage devices (U. of Ottawa and Carleton U.)





# Project 3.4 *Seismic Upgrade with Base Isolators*

Performance-Based Assessment for Buildings

Revise CHBDC Section 4.10 – Base Isolation for Bridges

Funded by NSERC / *Subventionné par le CRSNG*

# CSRN Evaluation and Retrofit Guidelines Based on ASCE - 41 (2013)

**CSRN Meeting – Task Coordinators**

**November 26-27, 2011**

**Vancouver**

# *Over 35 Partner Organizations*

- **Federal Government Agencies**
- **Provincial Government Agencies**
- **Municipalities**
- **Consulting Engineering Firms**
- **Utilities and Industry**
- **Emergency Preparedness Agencies**

# *Major Role Played by ICLR*

- Collaborative research with CSRN researchers
  - U. of Western Ontario (Gail Atkinson, Kristy Tiampo)
  - Risk Studies of Canadian Urban Centres
- Technology transfer
  - Briefings on research progress (meetings at ICLR)

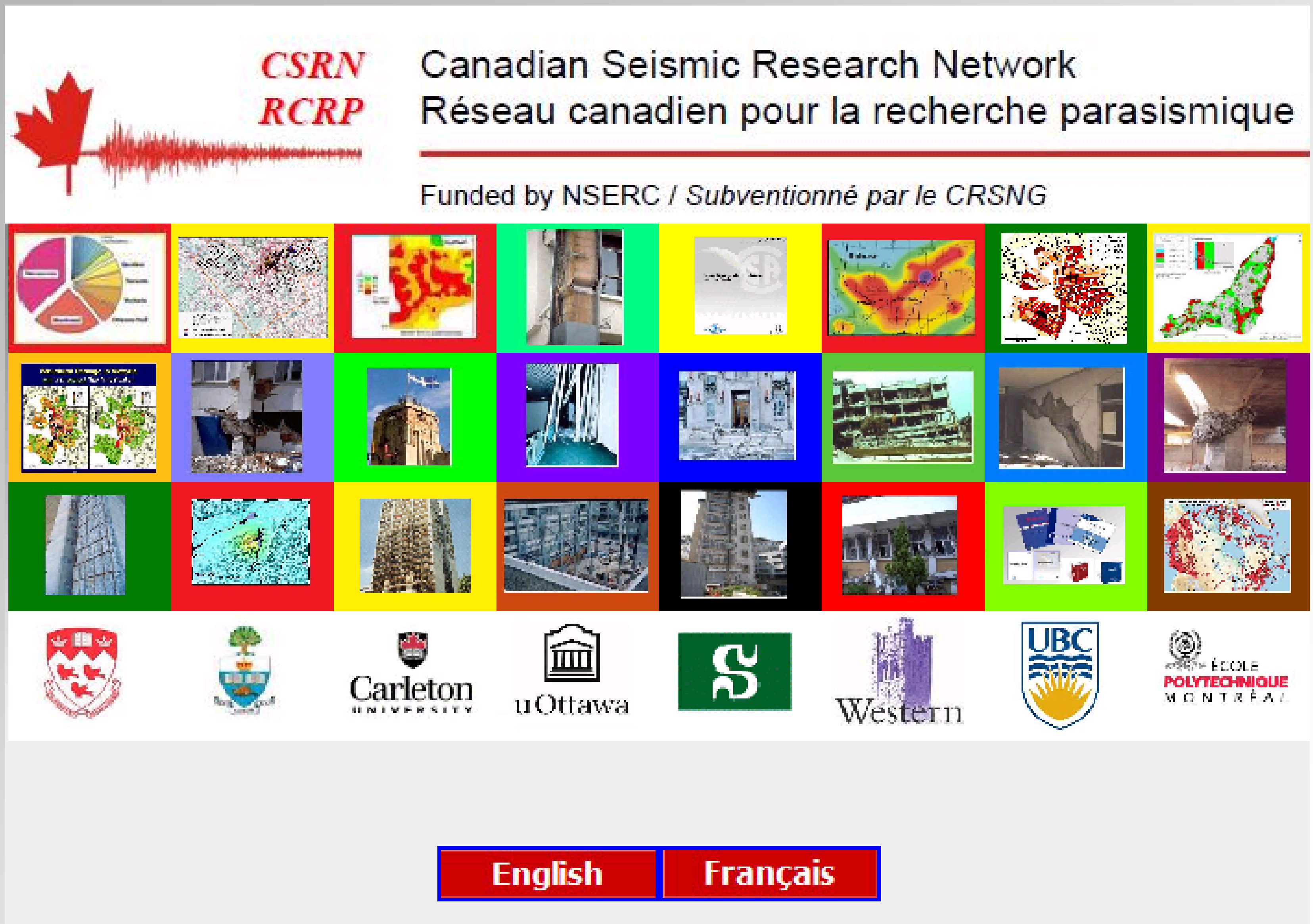
# *Major Role Played by ICLR*

- **Over 150 graduate students involved in Network research**
- **2 - $2500 ICLR Scholarships awarded each year to Graduate Students in the Network**

# *Major Role Played by ICLR*

- **Paul Kovacs is a member of the Board of Directors of the Canadian Seismic research Network**

# The Network Web Site: www.CSRN.mcgill.ca



# Historical Aspects - Canada

- 2010 NBC - Commentary L
  - Reduced “load factor” = 0.6 for triggering seismic upgrade
  - “for design of upgrading, the load factor should be increased, preferably to the NBC value….”
  - In Quebec – 60% for evaluation and rehabilitation

- “reducing the ground motion demands by a factor .. Does not result in a spatially uniform hazard”

- 1992 NRC Evaluation Report
  - Outdated

- Significant Code changes (NBCC and CSA)
  - CSRN paper on NBCC evolution
  - Emphasis on irregularities, capacity design, detailing for ductility, avoiding brittle failures

# *Examples of Input to Canadian Code Committees*

- Standing Committee on Earthquake Design (6)
- NBCC Standing Committee on Structural Design (1)
- CSA A23.3 Design of Concrete Structures (3)
- CSA S6 Seismic - Canadian Bridge Code (5)
- CSA S16 Limit States Design of Steel Structures (2)
- S136 Design of Cold Formed Steel Structures (1)
- CSA S832 Seismic Risk Reduction of OFC's (2)
- CSA S806 Design and Construction with FRP (2)