RESEARCH PROGRESS
- CANADIAN SEISMIC
RESEARCH NETWORK (CSRN)

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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

1. Hazard Assessment
2. Vulnerability Assessment
3. Mitigation

- Microzonation: Vancouver, Montreal, Ottawa
- Seismic assessment and retrofit guidelines
- Scenarios for policy and planning decisions
Performance-Based Approach
- Collaboration with ATC and ASCE

Theme 1
- Characterization of Seismic Hazard
- Probable Site Ground Motions

Theme 2
- Probable Response - Nonlinear Analysis
- Probable Damage - Fragility Functions
- Probable Loss – Repair cost / Downtime / Casualties

Theme 3
- Mitigation Measures

Acceptable Performance?
- Yes: Acceptable Solution
- No: Start over
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

Montréal Hospital
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, Kobe 1995
Reversed Cyclic Loading

- Flexural crack
- Shear crack
- Cracks closed
- Flexural crack
- Hoop
- Loss of cover & bar buckling

D. Mitchell, McGill University
Hoops Confine the Concrete

Poor confinement

Good confinement

D. Mitchell, McGill University
Hoop Anchorage Details

90° Hooks

135° hooks

Loss of cover

ineffective
effective

D. Mitchell, McGill University
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
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

- Reduce storey drifts
- Protect brittle elements

Performance-Based Approach:
- Enlarging frame elements
- Adding shear walls
- Adding bracing

Mexico City, 1986

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

Diagonal Prestressing:
- Added restoring stiffness

Fibre-Reinforced Concrete:
- Bridges (degradation)
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.
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
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)