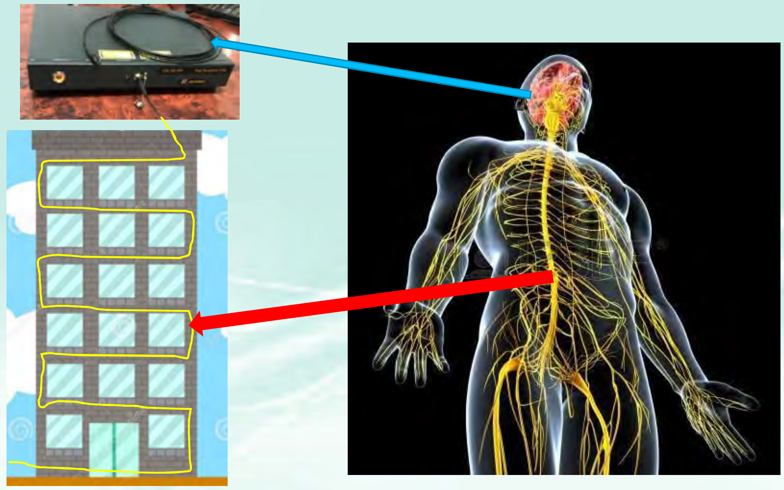
- 100% Earthquake Proof Buildings are Impossible and Impractical.
- Also, our structures are aging and deteriorating.
- The earthquake victims who lost their homes could be in serious distress and delayed rehabilitation can be a heavy burden to the governments.

02 Development of structural monitoring system like human nerve

The Working Principle

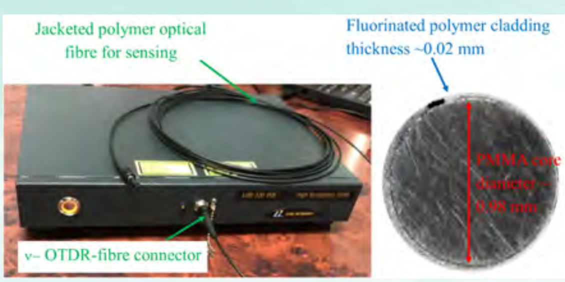
Photon-counting Optical Time Domain Reflectometer (ν–OTDR) as the BRAIN

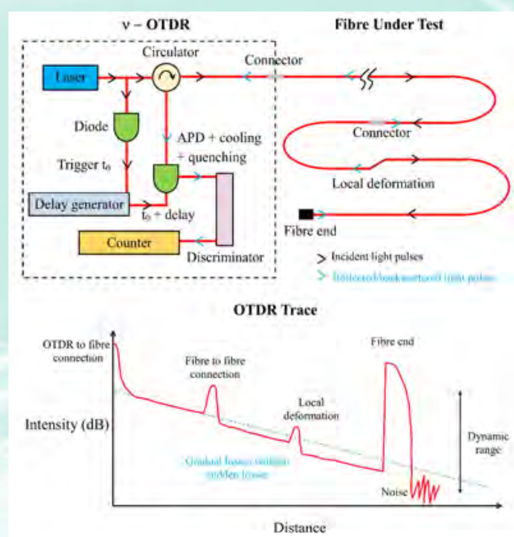
Polymer optical fibres (POFs) as the NERVE



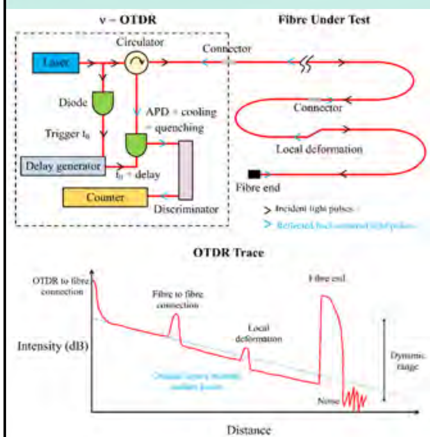
The Working Principle

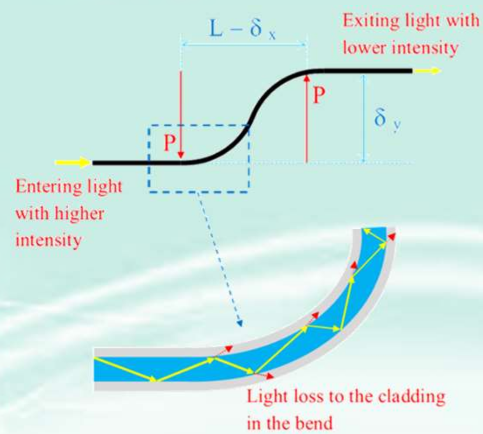
- The ν–OTDR sends out a train of light pulses (photons) with a certain pulse width into the optical fibre.
- When encountering "events" (e.g. variation in the medium properties, boundaries, interfaces), the light pulses will be backscattered to and measured by the ν–OTDR.
- The local optical fibre deformation (e.g. strain or bending) or connections can cause the sudden losses of the light pulse, which occur discontinuously at specific locations.





The Working Principle





The Working Principle

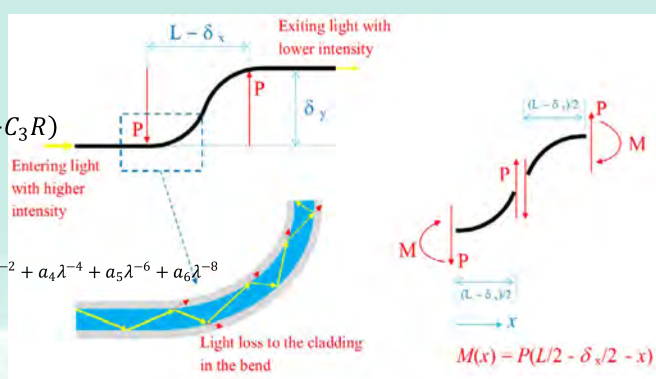
- Large beam deflection and optical bend loss theories were combined for detecting and measuring the magnitude of the deflections.

Optical bend loss-curvature equation

$$\alpha_{loss} = C_1 \cdot R^{C_2} \cdot \exp(-C_3 R)$$

$$\log_{10} \frac{P(0)}{P(x)} = \alpha_{loss}\, x$$

$$n^2(\lambda) = a_0 + a_1\lambda^2 + a_2\lambda^4 + a_3\lambda^{-2} + a_4\lambda^{-4} + a_5\lambda^{-6} + a_6\lambda^{-8}$$



(a) (b)

Large-beam deflection theory

$$\alpha = \frac{1}{\sqrt{2}} \int_0^{\phi_0} \frac{d\phi}{\sqrt{\sin\phi_0 - \sin\phi}}$$

$$\alpha = F\left(\frac{\pi}{2}, k\right) - F(\gamma, k)$$

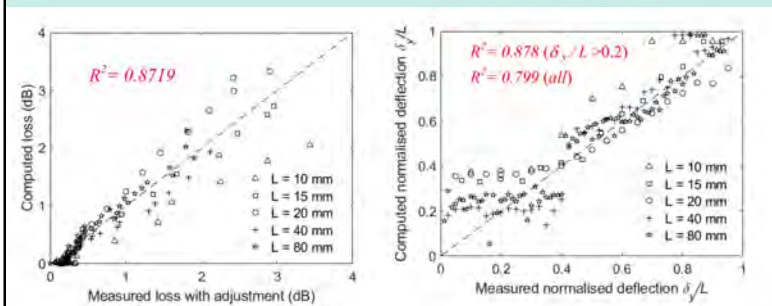
$$\frac{\delta_x}{L} = 1 - \frac{\sqrt{2}}{\alpha}\sqrt{2k^2 - 1}$$

$$\frac{\delta_y}{L} = 1 - \frac{2}{\alpha}\left[E\left(\frac{\pi}{2}, k\right) - E(\gamma, k)\right]$$

Loss-deflection equation: $Loss_a = 2\int_0^{\frac{L-\delta_x}{2}} C_1 \cdot \left(EI/M(x)\right)^{C_2} \cdot \exp\left(-C_3 \cdot EI/M(x)\right)/\cos\phi(x) \cdot dx$

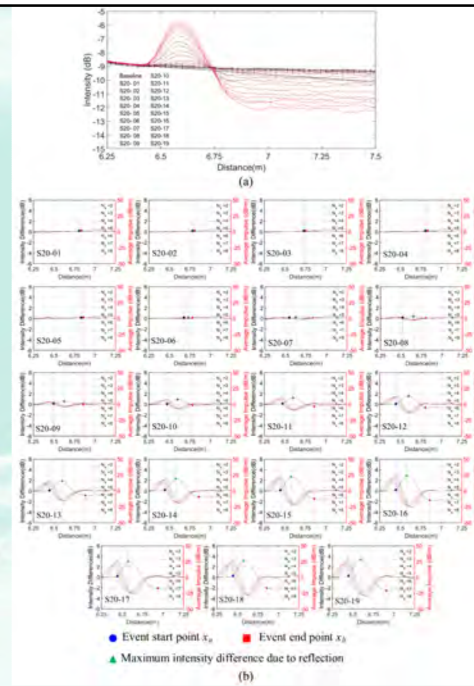
10

The Experiment - Single Shear Event



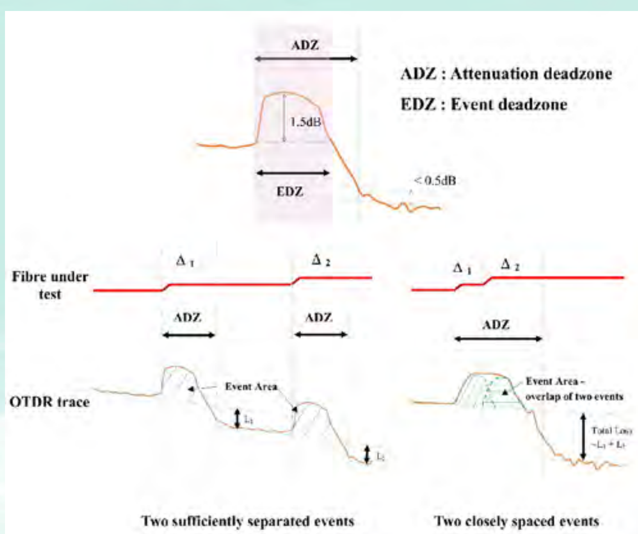
(a) (b)

Comparison between the computed and measured (a) loss and (b) normalised deflections.

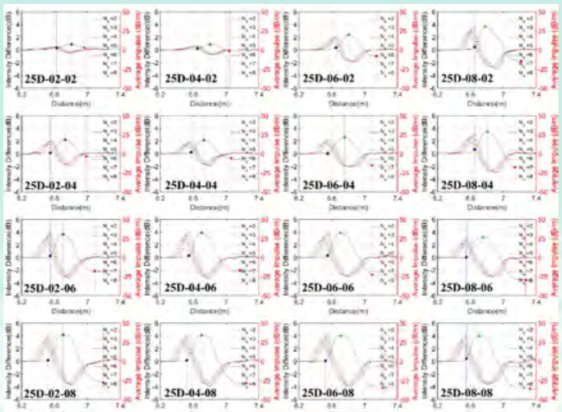


Single shear event with a deformed length of 20 mm

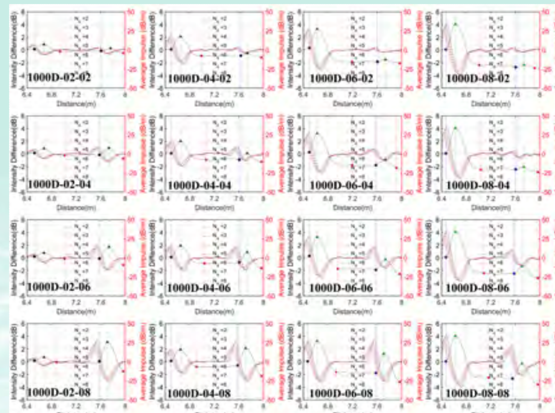
The Experiment – Multiple Shear Events



The Experiment – Multiple Shear Events

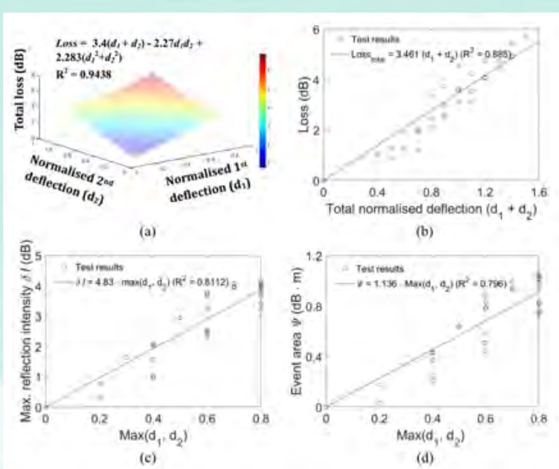


With separation length of 25 mm

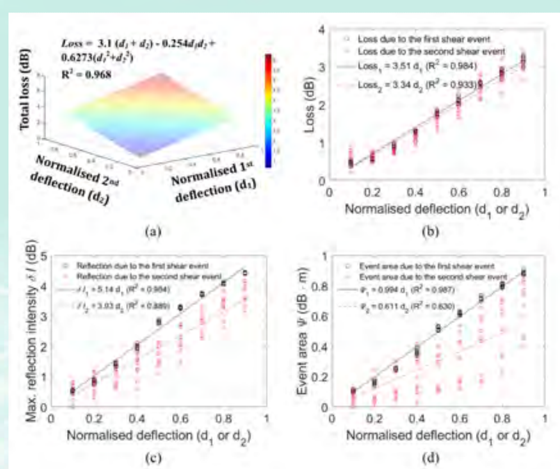


With separation length of 1000 mm

The Experiment – Multiple Shear Events

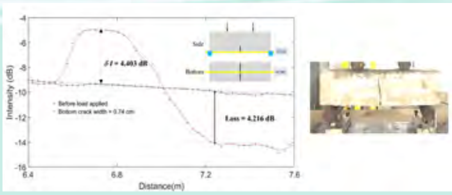


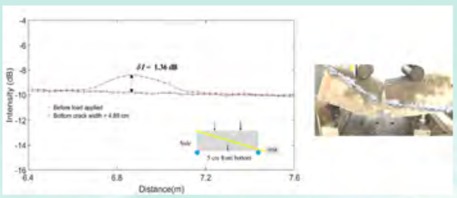
With separation length of 25mm

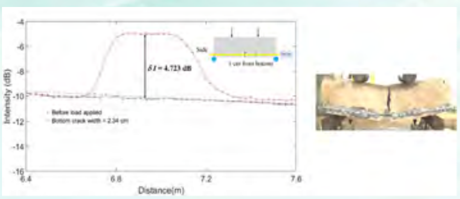


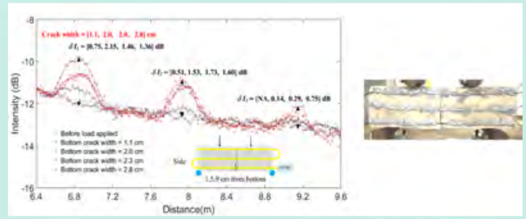
With separation length of 1000 mm

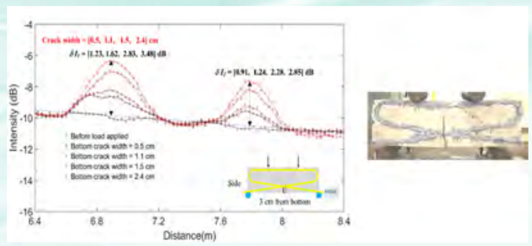
The Experiment – Failure Monitoring





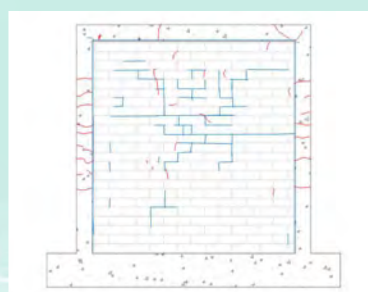


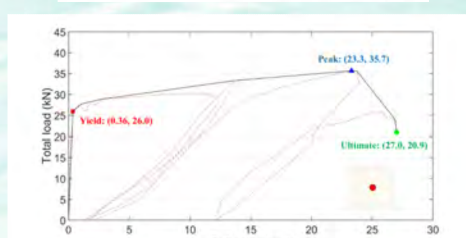




The Experiment – Failure Monitoring

Test results being analyzed… stay tuned!

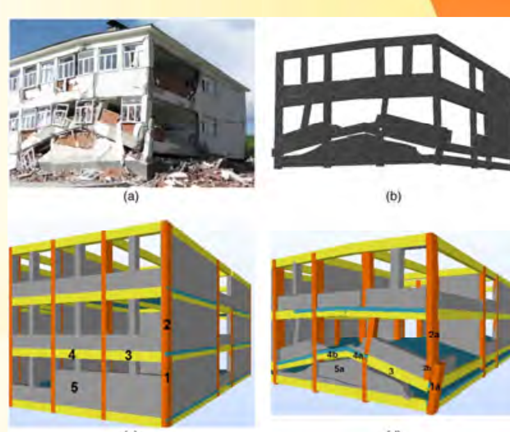




03 Possible Future Developments

Post-Earthquake Building Information Models

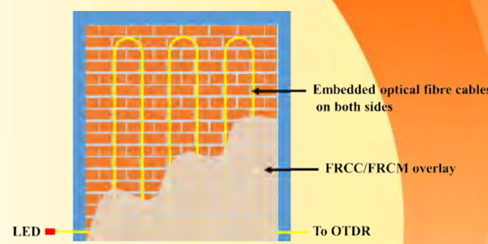
- The optical never system can provide detailed internal structural damage information.
- The information can be integrated with existing as-built BIM to develop the as-damaged BIM.
- It can facilitate the post-earthquake retrofitting and reconstruction planning.



Ma et al, 2016

Integrated Retrofitting and Sensing System

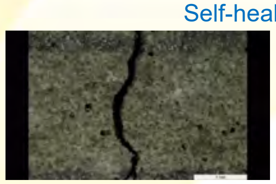
- Even if the building collapse is fortunately averted, structural damage may be inflicted which require retrofitting before safe reoccupation.
- Only strengthening cannot fully guarantee the future safety of the buildings, if the previous damage is not monitored.
- A retrofit-monitoring integrated system can developed for mitigating the collapse risk of seismically damaged structures.

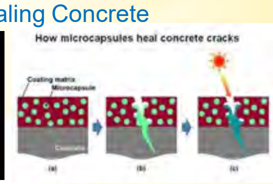


Integrated Self-Healing & Self-Sensing Structures

- The optical nerve fibres, which are embedded near the structure surface, can be coated with chemicals (e.g. super abosorbant polymer SAP)/bacteria (e.g. bacillus subtilis JC3).
- When those materials are released due to cracking, the concrete may be healed automatically.

Self-healing Concrete

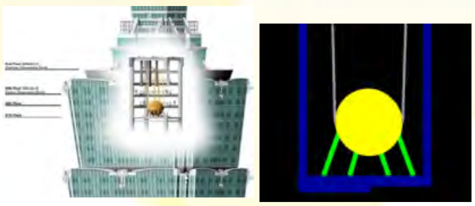




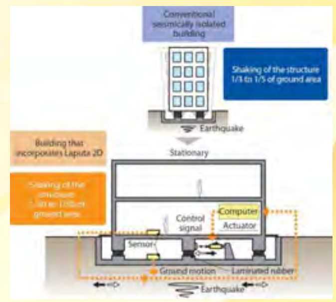
Young et al, 2013

Highly Integrated Active Control Devices

- Complete structural deformation information can be possibly acquired by the optical neve system.
- Based on such information, the active control devices can be manipulated to achieve the optimal global structural dynamic responses.
- But the current limitation is that the data acquisitions by conventional OTDRs are not real time (time lag can be > 10s seconds).



Passive control devices



Laputa 2D

Active control devices

Get ready…

We are heading for smart and intelligent engineered structures!

Thank You

EARTHQUAKE EARLY WARNING FOR CANADA

By Dr. H. Seywerd, Natural Resources Canada

Abstract

Earthquake Early Warning (EEW) systems are in development and operation in many parts of the world. Canada has several regions potentially subject to significant damaging earthquakes. In 2019, funding was announced for Natural Resources Canada to develop and operate such a system for Canada. The initial phase of the program will see the construction of an EEW system with operation anticipated to start in 2024. The system will consist of a core component consisting of risk areas, identified in collaboration with Public Safety Canada, as including locations containing critical infrastructure. A second component, covering other risk areas, installed, and operated by provincial and other partners will be partially funded by the program. The system will be closely integrated with the ShakeAlert system operating in the USA to ensure interoperability across the border – particular important in Southwest British Columbia.

Keywords: earthquake early warning, critical Infrastructure, ShakeAlert system.

Biography

Dr. Henry Seywerd is a Researcher at Natural Resources Canada. Henry has had a diverse career beginning in high-energy physics at DESY (Hamburg) and CERN (Geneva). After returning to Canada, he took up a position in a private company developing medical imaging equipment. In 2008, he joined Natural Resources Canada and led the nuclear emergency response group, before being appointed to run the Canadian seismic monitoring network. Since July 2019, he is Program Manager for the newly created Earthquake Early Warning Program.

Natural Resources Canada | Ressources naturelles Canada

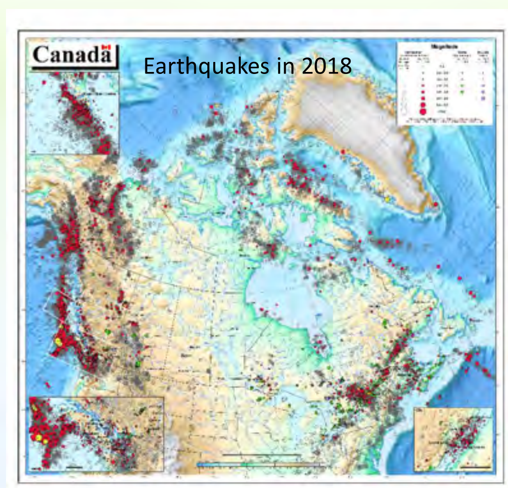
A National Earthquake Early Warning (EEW) System for Canada

H. Seyward
Natural Resources Canada
October 2019

Canada

Context: Why EEW?

- Parts of Canada with significant populations are exposed to substantial earthquake risk:
- Insurance Board of Canada study† shows large but plausible earthquakes could result in total direct losses of $75 billion in the West and $60 billion in the East
- EEW can provide seconds to minutes of warning before the arrival of strong shaking to allow protective measures and reduce the impact of an event
- Canada currently has earthquake monitoring, but not warning
- Building code provides limited level of protection
- EEW projects in other countries with high earthquake risk: Japan, Taiwan, China, USA…

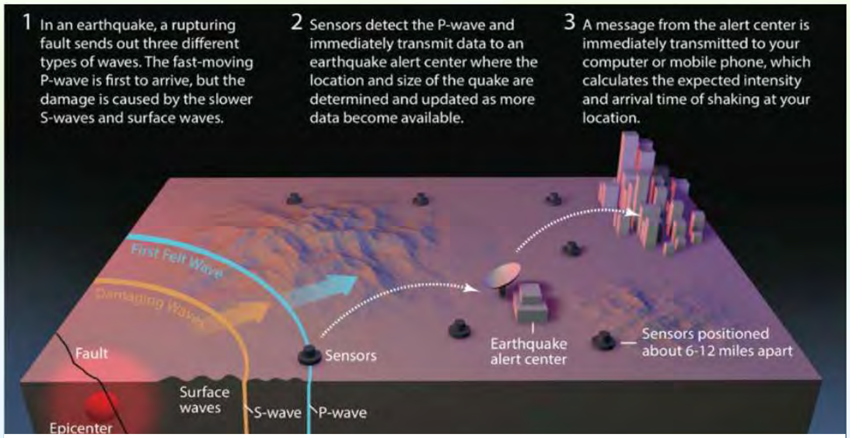


† Insurance Bureau of Canada, *Study of Impact and the Insurance and Economic Cost of a Major Earthquake in British Columbia and Ontario/Québec, 2013*

Natural Resources Canada | Ressources naturelles Canada

Canada

EEW Basics: General Principles



Credit: U.S. Geological Survey / Image created by Erin Burkett (USGS) and Jeff Goertzen (Orange County Register)

Natural Resources Canada Ressources naturelles Canada

Canada

EEW Basics: Limitations

- System cannot predict an earthquake
- Warning time is short
- Blind zone: very little/no warning time close to the epicentre
- Alerts to be provided only for strong damaging earthquakes
- Much of the at risk areas may be affected by an earthquake in USA
- System itself does not protect, requires that recipients of an EEW message must act

Natural Resources Canada Ressources naturelles Canada

Canada

Context: Canada's EEW Program

- Federal Budget 2019 included funding for 'Ensuring Better Disaster Management Preparation and Response', including Earthquake Early Warning
- Implementation phase of the EEW program runs from 2019-2024, with operation and sustainment thereafter
- Principal components:
  - Sensor Networks
  - Processing
  - Cross-border interoperability and data sharing with US – use of ShakeAlert system
- Authoritative source of alerts and information

Natural Resources Canada Ressources naturelles Canada

Canada

System Design: Sensor Networks

- Optimized specifically for EEW
- Strong motion accelerometers
- Tuned for fast response
- 1000+ stations in first phase
  - Core federal network (fully funded)
  - Partner PT-Other (partially funded)
- Dense networks
  - In areas at greatest risk: SW BC and areas within Ottawa to Quebec City corridor
  - Station density, a station every < 10-20km
  - Selected areas in other parts of the country
- Communications – high speed, redundancy

Natural Resources Canada Ressources naturelles Canada

Canada

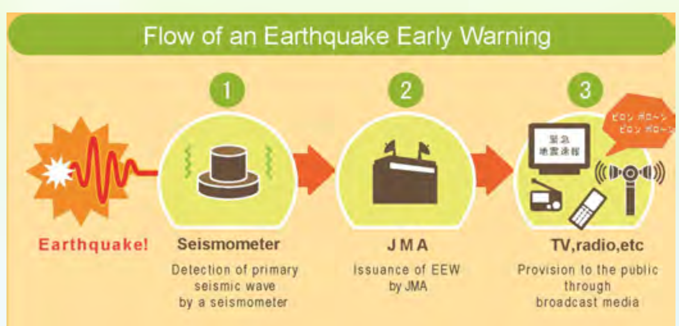
System Design: Processing

- Sensor networks provide waveform data to processing software in redundant data centres
- Consideration: Earthquakes don't respect borders
  - Much of at risk areas close to US border
  - US already operating EEW networks in Washington and other West Coast states
  - Cross border data exchange needed by Canada and US
  - Alerts need to be seamless and consistent across borders
- Canada to adopt US ShakeAlert system for data handling and alert generation
- Cybersecurity: misuse of system would have serious implications
- Dissemination of alerts in Canada will use Canadian systems

Natural Resources Canada   Ressources naturelles Canada   Canada

System Design: Alert Dissemination

- To critical infrastructure operators
  - Tailored alerts for specific users
  - Detailed mechanisms to be defined
  - Potential for third party value added services
- To FPT operations centres
- General public
  - Via NPAS
- ShakeAlert issues alerts as xml messages
- Further distribution is media specific

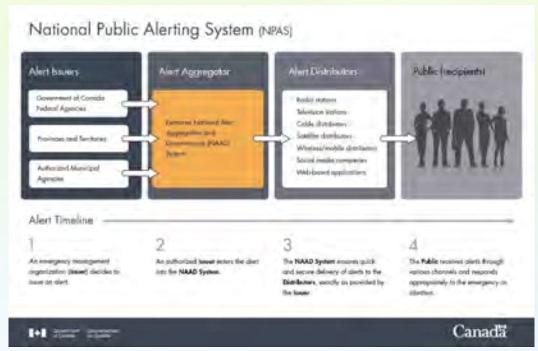


Japan Meteorological Agency http://www.jma.go.jp/jma/en/Activities/EEWLeaflet.pdf

Natural Resources Canada   Ressources naturelles Canada   Canada

System Design: Alert Dissemination - NPAS

- Currently operational for weather, flooding alerts etc.
- Distribution through radio/TV/web/social media/cell
- EEW places requires much lower latency, not within current capabilities for existing cell distribution
- US currently use Wireless Emergency Alert
  - 1/3 within 10s, 1/3 <30 s, 1/3 longer or not at all (experience from July 2019 Ridgecrest events)
- Development needed - 5G
- Need to decide thresholds – no chosen level will make everyone happy



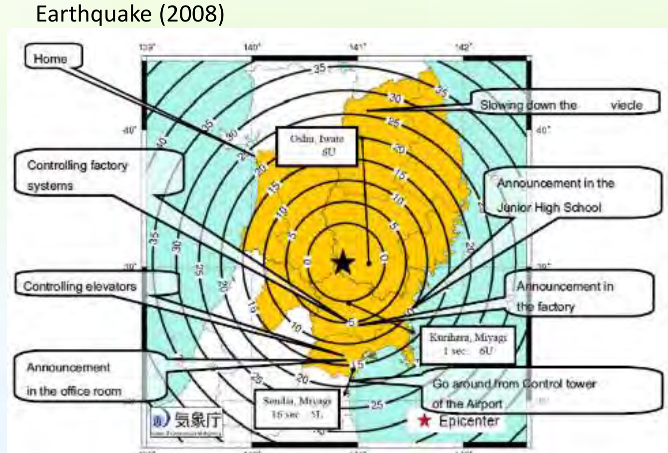
Natural Resources Canada | Ressources naturelles Canada

Canada

Mitigation: Automated Responses

- EEW connected systems can **automatically** take protective actions
  - Rail: Reduce risk of derailment
  - Elevators: Move to nearest floor
  - Stop Industrial Equipment
  - Data Centres: Park hard drives
  - Fire halls: Door openers to preclude doors jamming
  - Gas mains: Shutoff to prevent fire
- EEW connected systems - opportunity for value-added services
- Damage assessment, response, business resumption planning

Protective Actions After M 7.2 Iwate-Miyagi-Nairiku Earthquake (2008)



K. Cochran Soil Dynamics and Earthquake Engineering 31 (2011) 119–126

Natural Resources Canada | Ressources naturelles Canada

Canada

Mitigation: Personal Protection

- Personal safety via direct warning
  - Reduce injury caused by falling or falling objects significantly
- Personal safety of emergency personnel so they are able to help others
- Public education campaign needed
- Introduce via Shakeout exercises

Summary

- Earthquake Early Warning has the potential to mitigate the impact of major earthquake in Canada
- Natural Resources Canada is initiating a five year program to construct such as system with initial operation to begin in ~2024
- System will consist of a core Federal component with additional monitoring stations installed and managed by partners but supported by NRCan
- Close cross border integration with systems in the United States

MOST Research Funding Mechanisms

Ms. P. Lin

Science & Technology

Leading the Way to the Future

Ministry of Science and Technology

October 2019
http://most.gov.tw

Talents Cultivation Programs – International Collaboration Funding Mechanisms

Outbound

- Project-based Personnel Exchange Programs (PPP)
- Graduate Students Study Abroad Program / Postdoctoral Research Abroad Program
- Research Faculty to go abroad for short – term research
- Attending international conferences
- Group Participation in International Organization Conference
- *Dragon Gate Program*
- LEAP Program

Inbound

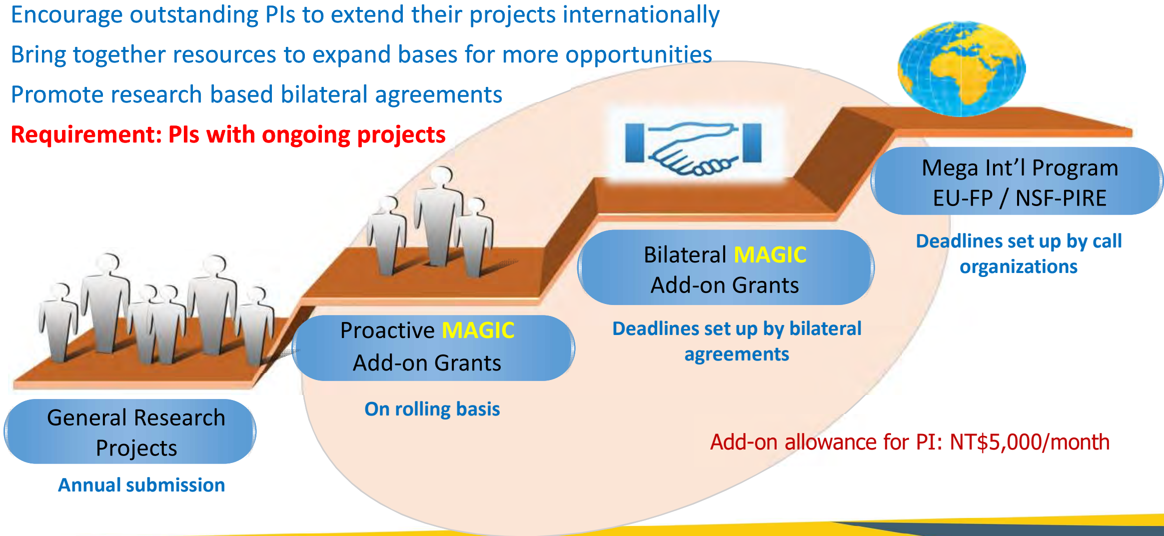
- Inviting overseas researchers for short-term visiting to Taiwan
- Recruitment of Visiting S&T Personnel
- Recruitment of Research Scholars and Implementation of Specific-topic Research Projects
- Hosting international conferences in Taiwan
- Leaders in Future Trends (LIFT)
- GASE Summer Program
- Einstein Program
- Columbus Program
- Shackleton Program

MAGIC Initiative

MOST Add-on Grant for International Cooperation

Aims and principles

- Encourage outstanding PIs to extend their projects internationally
- Bring together resources to expand bases for more opportunities
- Promote research based bilateral agreements
- **Requirement: PIs with ongoing projects**



Thank you!

What's next for future cooperation
Opportunities and funding mechanism from MOST

- Joint research projects – through MOST proactive MAGIC 1
  - Application at any time (with existing granted projects)
  - Supplementary funding for international cooperation
- MOST solicitation for research proposals (regular application)
  - Deadline: December 31, 2019
  - Proposals with international cooperation components are welcome
  - Group PIs with integrated efforts are welcome
- NCREE self-funded – mission oriented
- Opportunities for Bilateral MAGIC
  - Need to be discussed at next Steering Committee MOST-NRC

5

Appendix A

Workshop Agenda

NRC-MOST/NCREE Taiwan Workshop on Earthquake Engineering Technologies
100 Sussex Drive, Library Room
NRC Ottawa, Canada
7-8 October 2019

Day 1: October 7, 2019	
7:30 – 8:00 am	**Registration**
8:00 – 8:30 am	**Refreshments**
8:30 – 8:45 am	Introduction and Opening Remarks • **Dr. M. Dumoulin**, Vice-President, Engineering, NRC • **Mr. Winston Wen-Yi Chen**, Taiwan Representative
8:45 – 9:00 am	Objectives of Workshop • **Dr. R. Fathi-Fazl**, Team Lead of Seismic Resilience Group, Construction Research Centre, NRC • **Dr. Shyh-Jiann Hwang**, Director, National Center for Research on Earthquake Engineering, Taiwan
9:00 – 9:45 am	Keynote Speaker: **Dr. Abbie Liel** (University of Colorado Boulder USA) *Advancing Seismic Resilience: New Directions for Older Non-ductile Concrete Buildings*
9:45 – 10:00 am	Q/A
10:00-10:15 am	**Break**
10:15 - 12:30 pm	**Session 1: Seismic risk assessment and retrofitting of existing buildings (Part #1)** **Chair: Dr. Adebar**
10:15 – 10:35 am	Presentation #1: **Dr. Shyh-Jiann Hwang** (Taiwan – NCREE) *Current Seismic Retrofitting Projects of Reinforced Concrete Buildings in Taiwan*
10:35 – 10:55am	Presentation #2: **Dr. John Adams** (NRCAN– GSC) *Seismic Hazard Estimates for Canada, 1953-2020 – Some Implications for Future Risk Mitigation through Design and Retrofit*
10:55– 11:15 am	Presentation #3: **Dr. Aishwarya Puranam** (Taiwan – NTU) *Evaluation of Seismic Vulnerability Screening Indices using Earthquake Reconnaissance Data*
11:15 – 11:35 am	Presentation #4: **Dr. Carlos Ventura** (UBC) *Seismic Assessment and Retrofit of School Buildings in BC*
11:35 – 12:30 pm	Q/A and Discussion
12:30 – 1:30 pm	**Lunch**

1:30 - 3:30 pm	**Session 1: Seismic risk assessment and retrofitting of existing buildings (Part #2)** **Chair: Dr. Hwang**
1:30 - 1:50 pm	Presentation #5: **Dr. Fu-Pei Hsiao** (Taiwan – NCREE) *Seismic Assessment Methods and Experimental Verifications of Reinforced Concrete Buildings*
1:50 - 2:10 pm	Presentation #6: **Dr. Robert Tremblay (Polytechnique Montreal)** *Evaluation and Retrofit of Seismically Deficient Steel Braced Frames in Canada*
2:10 – 2:30 pm	Presentation #7: **Dr. Wen-I Liao** (Taiwan – NTUT) *Retrofitting Non-ductile RC Structures for Seismic Resistance Using Post-Installed Wing Wall, Shear Wall and RC Jacket*
2:30 – 2:50 pm	Presentation #8: **Dr. Murat Saatcioglu** (UOttawa) *An Overview of Seismic Retrofit Techniques Developed at the University of Ottawa*
2:50 – 3:10 pm	Presentation #9: **Dr. Dan Palermo** (York University) *Emerging Novel Materials for Seismic Retrofit*
3:10 – 3:30 pm	Presentation #10: **Dr. Oh-Sung Kwon** (UToronto) *Seismic Performance Assessment of Intact, Repaired and Retrofitted RC Moment Resisting Frames Through Hybrid Simulations*
3:30 – 3:45 pm	**Break**
3:45 – 4:40 pm	Q/A and Discussion
4:40 – 4:55 pm	**Closing Remarks** • **Dr. R. Fathi-Fazl**, Team Lead of Seismic Resilience Group, Construction Research Centre, NRC • **Dr. Shyh-Jiann Hwang**, Director, National Center for Research on Earthquake Engineering, Taiwan

NRC-MOST/NCREE Taiwan Workshop on
Earthquake Engineering Technologies
100 Sussex Drive, Library Room
NRC Ottawa, Canada
7-8 October 2019

Day 2: October 8, 2019	
8:00 – 8:30 am	**Refreshments**
8:30 – 9:15 am	Keynote Speaker: **Dr. Denis Mitchell** (McGill University) *A Framework for Performance-Based Seismic Design – The Canadian Highway Bridge Design Code*
9:15 – 9:30 am	Q/A
9:30 - 12:15 pm	**Session 2: Seismic Performance Based Design of Buildings** **Chair: Dr. Saatcioglu**
9:30 – 9:50 am	Presentation #1: **Dr. Perry Adebar** (UBC) *Towards the Performance Based Seismic Design of Unusual Irregular & Tall Buildings in British Columbia*
9:50 – 10:10 am	Presentation #12: **Dr. Chien-Kuo Chiu** (Taiwan - NTUST) *Design Base Shear Forces for RC Buildings Considering Seismic Reliability and Life-cycle Costs*
10:10 -10:25 am	**Break**
10:25 – 10:45 am	Presentation #13: **Dr. David Lau** (Carleton University) *Hybrid Simulation for Earthquake and Multi-Hazard Performance Based Design of Structures*
10:45 – 11:05 am	Presentation #14: **Dr. Chung-Che Chou** (Taiwan – NTU) *US-Taiwan Collaborative Research on Steel Columns: Cyclic Testing of Two-Story Subassemblages*
11:05 – 11:25 am	Presentation #15: **Dr. Stavroula Pantazopoulou** (York University) *Deformation Capacity of RC and Masonry Structural Members and Definition of Acceptance Criteria - A Review of the New Eurocode 8-I (2020)*
11:25 – 12:15 pm	Q/A and Discussion
12:15 – 1:00 pm	**Lunch**
1:00 - 3:50 pm	**Session 3: Advanced Research in Earthquake Engineering** **Chair: Dr. Chou**
1:00 – 1:20 pm	Presentation #16: **Dr. Juin-Fu Chai** (Taiwan – NCREE) *Development of Test Facility and Current Research on Non-structural Components and Systems at NCREE*

1:20 – 1:40 pm	Presentation #17: **Dr. George C. Yao** (Taiwan – NCKU) *Earthquake Performance Study of Suspended Ceiling and Smoke Barriers through Large Scale Shaking Table*
1:40 – 2:00 pm	Presentation #18: **Dr. Tzu-Kang Lin** (Taiwan – NCTU) *Structural Health Monitoring of Apartment Complex by Multi-Scale Cross-Sample Entropy: An Information Flow Perspective*
2:00 - 2:20 pm	Presentation #19: **Dr. Vahid Sadeghian** (Carleton University) *Analytical Modelling of Seismic-Deficient and Repaired Reinforced Concrete Structures: Challenges and Innovative Solution*
2:20 -2:35 pm	**Break**
2:35 – 2:55 pm	Presentation #20: **Dr. Yu Ping Yuen** (Taiwan – NCTU) *Optical Fibre Sensing with υ-OTDR for Large Structural Deflection and Failure Monitoring*
2:55 – 3:15 pm	Presentation #21: **Dr. Henry Seywerd** (NRCan-GSC) *A National Earthquake Early Warning System for Canada*
3:15 – 3:45 pm	Q/A and Discussion
3:45 – 3:50 pm	Research Funding Mechanisms (MOST)
3:50 – 4:00 pm	**Closing Remarks** • **Dr. R. Fathi-Fazl**, Team Lead of Seismic Resilience Group, Construction Research Centre, NRC • **Dr. Shyh-Jiann Hwang**, Director, National Center for Research on Earthquake Engineering, Taiwan