Canadian Association for Earthquake Engineering (CAEE)
L'Association Canadienne du Génie Parasismique (ACGP)

NEWSLETTER

July 2018
Volume 3, Issue 3

http://caee.ca/

From the Editor's Desk

by Tuna Onur

You are probably aware of large water reservoirs' ability to trigger earthquakes. Did you know that Canada hosts four of the 20 largest water reservoirs in the world? In fact, Canada has 16 reservoirs that are deeper than 75m and have a volume bigger than 1 km^3. Earthquake activity associated with large water reservoirs are often termed "reservoir-triggered seismicity (RTS)". Six of Canada's 16 large reservoirs have RTS associated with them. In this issue of the CAEE Newsletter, we cover this significant topic. We also cover performance based seismic design issues and challenges in Code Corner, and offer other interesting highlights for your summer reading!

Inside This Issue

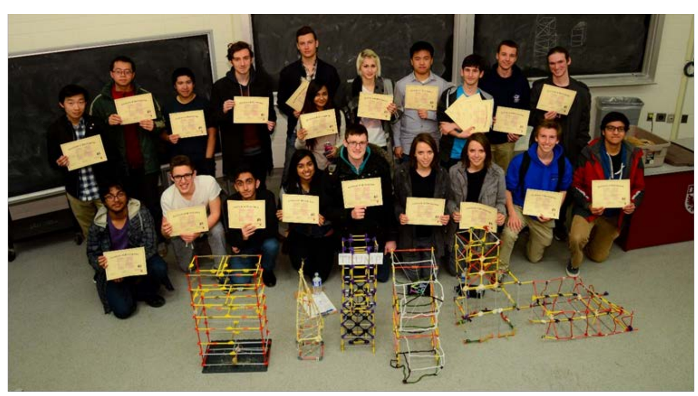
University Spotlight: McMaster University

by Lydell Wiebe

McMaster University in Hamilton, Ontario, is a hub for earthquake engineering training and research. Earthquake engineering courses are popular at both the undergraduate and graduate levels, and more than 20 graduate students are currently active in earthquake engineering research with five different professors. The Applied Dynamics Laboratory boasts three shake tables, along with numerous high-capacity and dynamically rated actuators.

At the centre of all this activity, EERI McMaster is one of only three Canadian student chapters of the Earthquake Engineering Research Institute (EERI). EERI McMaster's goal is to promote earthquake engineering and research among students, communities and industries. EERI McMaster has an active guest lecture series, with an average of six to eight academic and industry mentors every year. Speakers include practitioners from Southern Ontario, visiting researchers, and California-area engineers supported by the EERI's Friedman Family Visiting Professionals Program. Recent lectures included topics of energy dissipation devices, seismic performance and retrofitting, and real-time hybrid simulation testing.

EERI McMaster is also active in outreach to younger students, hosting an Annual Earthquake Engineering Competition for local high school students. Schools enroll a group of six students who are challenged to plan and construct a building out various materials including K'Nex, twist ties, twine, various adhesives and elastic bands.



University Spotlight… *Continued from Page 1*

These structures must be able to withstand two earthquakes at different intensities. The buildings are tested on a shake table, and their performance is monitored using smartphone technology with in-house acceleration recording software.

The future of the earthquake engineering at McMaster is bright, with new laboratory equipment being installed this year, and with continued growth in the community of students at all levels who are knowledgeable about earthquake engineering.

Monitoring of Reservoir-Triggered Earthquakes in Canada

by Maurice Lamontagne[1], Martin Lawrence[2], John F. Cassidy[3], Garry Rogers[3] and Jean-Pierre Tournier[4]

From the 1920s on, it has become more and more apparent that large water reservoirs could trigger earthquakes. Reservoirs do not create the stresses that lead to an earthquake (these stresses are already present in the Earth's crust); they only favour its occurrence by lowering the normal stress acting on a pre-existing fault. For this reason, the expression "Reservoir-triggered Seismicity (RTS)" is used to define these earthquake sequences. Historically, less than 25% of global reservoirs deeper than 90 m have caused earthquakes, and only 1% have triggered earthquakes larger than magnitude 5.7 on the Richter scale. Canada has four of the 20 largest water reservoirs in the World with 16 that are at least 75 m deep and with a volume larger than one cubic kilometer. The proportion of Canadian reservoirs with RTS (37%) is larger than for worldwide dams (10%) higher than 90 m. Five reservoirs are located in the Cordillera of British Columbia and Alberta (see Figure 1), but regional and local seismographs have not detected any RTS in any of them. Eleven reservoirs are located in the Canadian Shield of Quebec (see Figure 2). RTS was detected in six of these large reservoirs, in addition to two smaller ones. Four reservoirs had earthquakes larger than magnitude 3, and the 1975 magnitude 4.1 Manic-3 event was the largest RTS ever recorded in Canada.

Currently, all these reservoirs are seismically quiet, except along the La Romaine River where Hydro-Québec has created three new reservoirs since, with a fourth one to be impounded in the coming few years. Seismographs monitor these new reservoirs and some earthquakes were triggered with two events of magnitude 3.2.

Such small triggered earthquakes generally do not represent any significant risk to dams and related hydroelectric infrastructure. Seismograph monitoring allows the detection of anomalous seismic activity during reservoir impoundment. It has also provided useful information for seismologists and dam owners to draw some conclusions about their potential for RTS prior to impoundment, an aspect that is often raised during environmental assessments.

Unlike the offshore region of BC that is subject to plate tectonics, the Canadian Shield of Quebec is an area within a very large tectonic plate; i.e., an "intraplate" area that is weakly seismic. Most natural (tectonic) earthquakes occur in well-defined areas, mostly north of the Ottawa River and in two areas along the St. Lawrence River. Historically, these areas have had tectonic earthquakes up to magnitude 7 on the Richter scale. Unlike tectonic earthquakes that can occur as deep as 30 km below the surface, triggered earthquakes are relatively shallow focus (3 km or less) and occur shortly after impoundment (i.e., days to a few years). The weight of the reservoir does not appear to be a main factor for triggering RTS; two of the largest reservoirs by volume, Manic-5 (the site of a meteor impact) and Caniapiscau as examples, do not have any associated RTS. It is almost impossible to relate RTS to some specific fault characteristics, such as permeability, orientation, or last episode of activation, as most of these factors are poorly known. On the other hand, it is the diffusion of pore-water pressure along pre-existing faults at depth that appears to have caused these earthquakes.

Based on the current knowledge, most RTS cases were of the delayed-response type; i.e., the earthquake activity started shortly after the initial impoundment, continued for many months, sometimes concentrated spatially and temporally (as swarms), and finally ceasing after a few years. Most reservoirs that have had RTS decades ago are now seismically inactive, similar to their state prior to impoundment.

In conclusion, RTS remains a very enigmatic process of scientific (seismological and earthquake hazard) interest but without any precedent for engineering consequences in Canada.

For more information, see: Lamontagne, M., Rogers, G., Cassidy, J., Tournier, J-P. and Lawrence, M. (2018) "Review of Reservoir Monitoring and Reservoir-Triggered Seismicity in Canada", Bulletin of the Seismological Society of America, in press.

[1] *Geological Survey of Canada, Ottawa, ON.*

[2] *BC Hydro, Burnaby, BC.*

[3] *Geological Survey of Canada, Sidney, BC.*

[4] *Hydro-Québec, Montréal, QC.*

Figure 1 Locations of the large reservoirs in British Columbia and Alberta. None of them had detected RTS

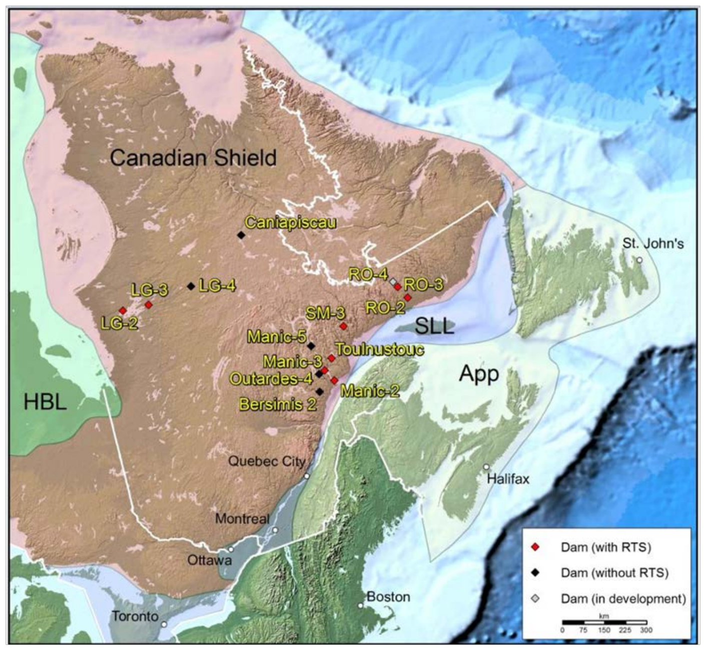


Figure 2 Locations of the large reservoirs in eastern Canada, emphasizing those with associated RTS. The physiographic provinces shown are the Canadian Shield, the Hudson's Bay Lowlands (HBL); the St. Lawrence Lowlands (SLL) and the Appalachians (App).

Announcement: Short Courses

Contributed by Don Kennedy

CSCE is pleased to offer several half-day short courses on **Tuesday, July 31, 2018**, as part of the 10th International Conference on Short and Medium Span Bridges. All courses will take place at **Hilton Quebec City** hotel. The courses are:

1: Applications of Fibre Reinforced Polymer (FRP) Technology in Bridges: Part I

2: Seismic Design of Bridges

3: Recent Advances in Accelerated Bridge Construction

4: Applications of Fibre Reinforced Polymer (FRP) Technology in Bridges: Part II

5: Design, Assessment & Interventions in new and existing bridges: *fib* Model Codes 2010 and 2020

For more information, please refer to: www.smsb-2018.ca/short-courses/

Code Corner

by Don Kennedy

This quarter, we highlight some of the issues and challenges in the introduction of Performance Based Design (PBD) in the Canadian Highway Bridge Design Code (CHBDC), CSA S6-14.

Performance Based Design – Issues and Challenges

Issues and challenges in the introduction of PBD into bridge design in British Columbia (BC) and nationally included:

- **Introducing change into an established design process**: The use of deformation measures for seismic design is a fundamental change for bridge engineers.
- **Introduction of PBD with limited calibration of the damage measures, and simultaneous revisions to seismic hazard**: Seismic design of bridges may be either significantly less or significantly more conservative than past practice, depending on soil conditions, strain measures adopted, or other factors.
- **Design targets traffic function, service and repair rather than readily-calculated forces**: While bridge function is more important, it is more difficult to measure and calibrate, especially for a 'partial' return to emergency traffic and for repair duration estimates in the context of a recovery from a major earthquake.
- **Damage measures and design currently focus on component-level behaviour**, e.g. of the most highly strained plastic hinge occurring anywhere within the bridge: This is not an ideal measure of system performance, and some improvement in this area is needed. This has been an issue of the force-based design approach in bridges since design for ductility using R factors was introduced in the early 1980s.
- **The prescription of strain measures within the code, rather than in the Commentary**: This was debated extensively, with a consensus decision to introduce PBD along with required strain limits in the code body to help designers in the transition from FBD. This may or may not remain the case in the next edition of the CHBDC, S6-2019.
- **The design approach as implemented is deterministic rather than probabilistic**: This is not believed to be a significant drawback, but an evolution towards probabilistic aspects may occur. 'Expected' material properties are currently used, and capacity design as a deterministic requirement is also mandated.
- **PBD facilitates the use of novel systems**: Experience in the design of resilient structures remains essential.
- **An appreciation of the immediate and long term seismic resilience remains low for many owners or developers** who often value first and low cost in both engineering and construction. Knowledge, discussion, effective communication and engineering expertise are critical to achieve the objectives of PBD.
- **High construction quality is essential**: Small oversights, such as a single poorly detailed or constructed plastic hinge zone can lead to partial or global collapse of a bridge. The importance of diligence became further apparent in recent earthquakes.

"The use of deformation measures for seismic design is a fundamental change for bridge engineers"

CAEE
Dept. of Civil Engineering
Univ. of British Columbia
6250 Applied Science Lane
Vancouver, BC,
Canada V6T 1Z4
Fax:
604-822-6901
E-mail:
secretary@caee-acgp.ca

We're on the Web!

Visit us at:

http://caee.ca

News

CAEE Announces the 12th Canadian Conference on Earthquake Engineering (CCEE) !

The 12th CCEE will be held at the Château Frontenac Fairmont Hotel in Quebec City, on June 17-20, 2019.

The theme of the conference is "Improving Seismic Infrastructure Performance and Community Resilience". The conference includes a variety of topics including seismic hazard, codes and standards, geotechnical issues, structural behaviour and design, seismic rehabilitation and mitigation, societal impacts, seismic risk, dam safety, seismic reliability of structures and structural health monitoring.

Abstract submission is open from now until September 15, 2018 at the conference web site: http://www.ccee2019.org/

News and Upcoming Events

We welcome news items, announcements, and events to publish in this column. Please let us know if you hear of earthquake engineering related news or events that you would like to bring to the attention of your colleagues.

Upcoming events

CDA Conference & Exhibition
13-18 October 2018
Quebec City, Quebec
cda.ca/EN/Professional_Development/Conference_Home_2018.aspx

17th U.S.-Japan-New Zealand Workshop on the Improvement of Structural Engineering and Resilience (ATC-15-16)
12-14 November 2018
Queenstown, New Zealand
www.atcouncil.org/atc-15-16

AEES (Australian Earthquake Engineering Society) 2018 Annual Conference
16-18 November 2018
Perth, Australia
www.aees.org.au/aees-2018-conference-perth/

EERI 71st Annual Meeting
5-8 March 2019
Vancouver, British Columbia
2019am.eeri-events.org

SSA 2019 Annual Meeting
23 - 26 April, 2019
Seattle, Washington

7 ICEGE 2019 - International Conference on Earthquake Geotechnical Engineering
16-20 June 2019
Rome, Italy