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

NEWSLETTER

January 2021
Volume 6, Issue 1

http://caee.ca/

From the Editor's Desk

by Tuna Onur

Happy 2021! Let's hope this is the year we are able to resume attending conferences, teaching lectures in person, working with our colleagues at the office, mingling and enjoying each other's company, ideas and intellect in person.

In this issue we bring to your attention a mostly forgotten Canadian earthquake that happened during a pandemic of the past…

We also conclude a Code Corner series in this issue related to the 2019 edition of the Canadian Highway Bridge Design Code.

INSIDE THIS ISSUE

We hope everyone is staying healthy, and as always, we encourage you to share short articles, news or other items related to earthquake engineering to be published in our Newsletter. Please send your contributions to secretary@caee-acgp.ca

Seismic Hazard Updates in Canada and the US

by Tuna Onur

Geological Survey of Canada (GSC) released its 6th generation hazard model for Canada. The model is intended for the 2020 Edition of the National Building Code (NBC) of Canada.

Various aspects of the model were presented in the 12th Canadian Conference on Earthquake Engineering. These and other papers on the topic can be found at the following link: *Recent publications on seismic hazard (rncan.gc.ca)*

The model input files and sample results for select cities can be found in: *doi.org/10.4095/327322*

The main changes with respect to the 5th generation model are:

1. Cascadia Subduction Interface earthquakes are now thought to happen more frequently (every ~430 years rather than ~530 years) and the model reflects this in the recurrence relations
2. Spatial distribution of inslab earthquakes that occur within the subducting Juan de Fuca plate are represented with a new source delineation that gradually deepens towards the east and extends further to the east.
3. Leech River Valley Fault and Devil Mountain's Fault near Victoria, BC are explicitly modeled as fault sources.
4. Major changes are implemented in ground motion models including the representation of uncertainty.

Seismic Hazard Updates… *Continued from Page 1*

The 2020 Edition of the NBC is retiring site amplification factors. Consequently, GSC produced hazard for multiple Vs30 values in this update.

For most localities in Canada, the 2% in 50-year hazard increased for all intensity measures compared to the 5th generation hazard model. While changes to the source models account for some of the regional and localized changes (such as additional Cascadia interface events and the addition of the Leech River and Devil's Mountain fault systems into the model), for many regions the changes in the ground motion characterization are the major driver for the increase.

In western Canada, an overall increase in the aleatory uncertainty as well as the change in geometry of inslab sources increases the hazard.

In the east, hazard increases result from the inclusion of the NGA-East-13 relations and an updated site amplification model which increased median ground motions and their epistemic range. There was no update to the source models in eastern Canada.

In 2023, the US National Seismic Hazard Mapping Project (NSHMP) plans to release a 50-state update of the National Seismic Hazard Maps for the US.

On the other side of the border, this month, the USGS has kicked off a series of virtual NSHMP workshops for the 2023 update of their seismic hazard maps. The next workshop in the series is going to be held on Feb 23rd (9:00am to 1:00pm) and is titled "Recurrence Models for Earthquakes on the Cascadia Subduction Zone". Follow the link below for a description of the workshop and to RSVP if you are interested in attending:

NSHMP Workshops (usgs.gov)

The current US national seismic hazard maps were released in 2018 for the lower 48 states, and can be found at:

2018 United States (Lower 48) Seismic Hazard Long-term Model (usgs.gov)

Earthquake Waves: Canada's "Pandemic Earthquake" of 1918

by John Cassidy

Given the relative lack of significant earthquakes across Canada during the past few months (and that is very good, given all of the other things that we are dealing with at this time), in this column I will highlight another of Canada's significant historical earthquakes - Canada's "Pandemic Earthquake".

In the early-morning hours of December 6, 1918 – in the midst of the Spanish Flu pandemic, and only weeks after the end of World War I, one of Canada's largest earthquakes struck the west coast of Vancouver Island.

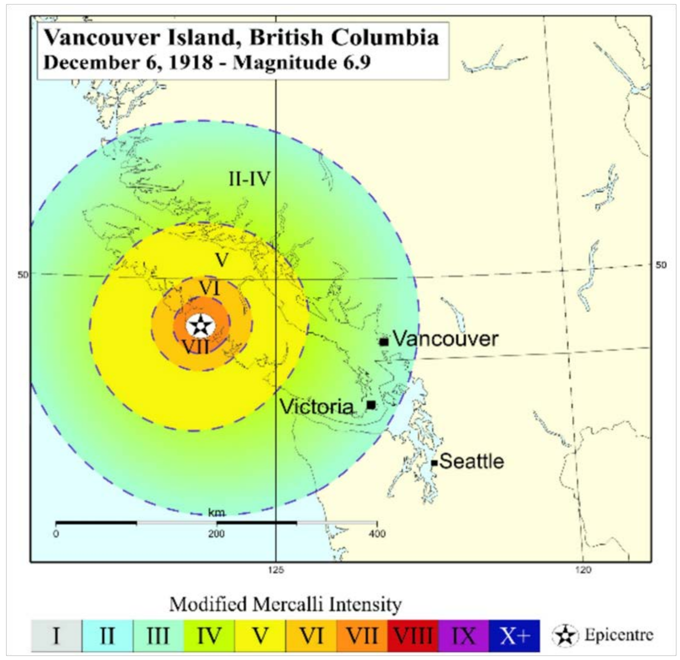
This magnitude ~7 earthquake occurred at 00:41 about 40 km to the NNW of Tofino, and about 40 km SSW of Gold River. It caused damage to the 110-foot-high concrete Estevan Point lighthouse (cracked the full length and broke the mirror) as well as minor damage in Ucluelet (broken wharf pilings). The earthquake caused people in Vancouver to run out into the streets, knocked items from shelves, and it was felt to about 500 km distance, including the Okanagan Valley and Washington State. It is likely that it was a shallow

Earthquake Waves... *Continued from Page 2*

earthquake, as it was followed by numerous (and some large) aftershocks. There were so many aftershocks that the lighthouse keeper wrote to headquarters: "Upon present conditions with unusual weather and earthquakes find that I will have to be releaved [sic] either for a trip or for good, do not care which."

At magnitude 7, this is one of the largest known crustal earthquakes in the entire Cascadia subduction zone. No fault has been identified as the source of this earthquake (not a surprise given the challenging environment), and little is known about ground shaking from this earthquake due to the lack of seismographs at this time – the closest instruments were in Victoria, BC, Sitka, Alaska and Berkeley, California. There is no known information describing the impact or complications of a large earthquake occurring during a pandemic for this event – as the region it struck was lightly populated at the time.

This earthquake serves as a reminder of the rare but large earthquakes that strike without warning along the active plate boundary of Canada's west coast.



Code Corner

by Don Kennedy

In the April 2020 Newsletter (Volume 5 Issue 2), this column summarized the process of performance-based design seismic design of road and pedestrian bridges in Canada. It described a typical work flow and tasks and provided some guidance for each step. It also discussed the use of material properties in the Code in a PBD context and readers are encouraged to review that. The 2014 and 2019 editions of CSA Group's Canadian Highway Bridge Design Codes (CHBDC, CSA S6:14 and CSA S6:19) emphasize a displacement-based method that targets damage, repair and return to service requirements at multiple levels of seismic hazard.

In this column, the margin of seismic demands to resistances of capacity-protected elements (or the inverse) is explored, and the adequacy of this margin is considered. The implications and use of material properties within damage assessment for the selected structural elements is also discussed.

The intent of 1970's principle of capacity design, which remains valid today, was to provide a predictable, ductile plastic mechanism for structures subjected to large seismic demands. This goal must account for uncertainties in specified material properties and code equations, variations in site conditions, and variations from nominal strengths in actual section capacities. It remains important to design in a suitable margin between the ductile mechanism and unintended (and especially brittle) failure modes.

In the CHBDC, both capacity design and damage checks are based on expected material properties. This means the use of stresses in cross-sectional

Code Corner... *Continued from Page 3*

strength or damage assessments that better reflect the materials that would be measured from field samples. Since structural design (other than for seismic design) is based on historic target reliabilities calibrated to material strengths towards the lower end of the tail of a normal distribution, e.g. the lower fifth-percentile material stresses, we should expect that reinforcing steel, structural steel and unconfined concrete compression strengths would be greater than these the minimum specified design strengths.

For capacity-protected elements in CSA S6:19, the margin against unintended failure modes is the ratio between "probable" (often called "overstrength") demands (D) and factored resistances or capacities (C), each quantity using expected material properties. For reinforced concrete elements this becomes:

$\phi\, C_{expected} > \phi_{probable} \times \{D_{expected}\}$ **Clause 4.4.10.4.2.2**

ϕ : Material resistance factors (0.75 for concrete and 0.90 for rebar) **Clause 8.9.3.4**

$C_{expected}$: capacity (shear, flexure, other) using $R_y f_y$ and $R_c f'_c$ where $R_y = 1.1$ for resistances of capacity-protected elements, and $R_c = 1.25$ **Clause 4.7.2**

$\phi_{probable}$: Probable resistance for section strength greater than nominal **Clause 4.4.10.4.2.2**

$D_{expected}$: flexural demand in plastic hinge, using $R_y f_y$ and $R_c f'_c$ where $R_y = 1.1$ for sections with modest ductility demands, $R_y = 1.2$ for sections with higher ductility demands and $R_c = 1.25$ **Clause 4.7.2**

For convenience below, for factored resistances we will use the average of concrete and rebar material factors, or (0.75 + 0.90) / 2 = 0.82, which implies that rebar and concrete contributions are equal. The ratio of demand over capacity then becomes:

1.3 * {1.1 or 1.2} / (0.82 * 1.1) = {1.58 or 1.73}, the 1.73 value for hinges with greater ductility demands.

Some observations on this ratio between capacity to demand in capacity-protected elements:

- The use of either 1.1 or 1.2 for the rebar *expected* yield stress, the latter at higher ductility values, suggests that strain hardening is accounted for, in part, on the resistance side of the equation.
- The 1.3 "probable" factor for reinforced concrete also accounts for some strain hardening and does account for confinement effects. This lack of transparency is a source of confusion.
- Engineers have questioned whether this margin is sufficient. What can erode this calculated reserve margin? Potentially:
  - o If axial loads in the demand or capacity equation are inconsistent with the force distribution throughout the plastic mechanism being designed. Axial forces from linear elastic analyses should not be used.
  - o Confinement enhancements on flexural strength can be larger than implied by the 1.3 *probable* factor in CSA S6, particularly at higher axial loads. One design curve for New Zealand materials (circa 1990's) is shown below. Note the data points for this curve start at about 1.1* M_{code}, i.e. using nominal and specified material strengths. This y-axis intercept is captured through the *expected* properties in CSA S6:25. Note that axial loads in most bridge columns in British Columbia are well below the 0.4 value of $P/(A_g f'_c)$, such that confinement effects are less important than for many columns in California, where heavy superstructures are common and fewer columns support gravity loads.

Code Corner… *Continued from Page 4*

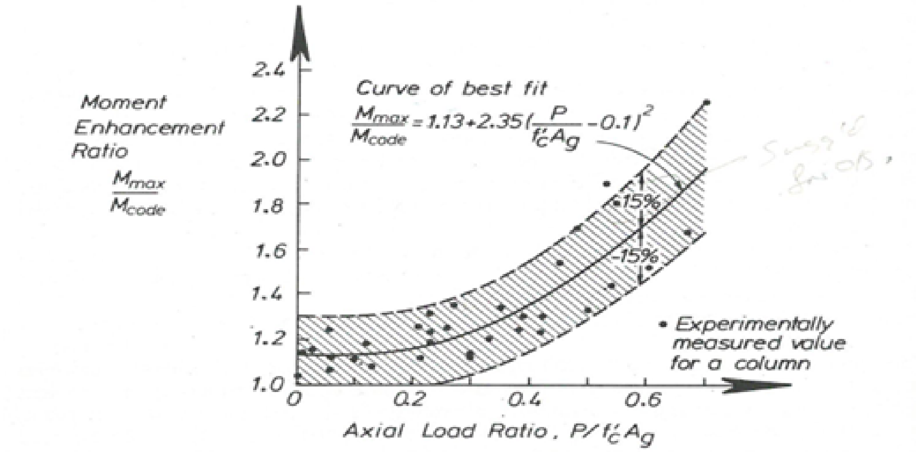


Fig.A.2.3 Maximum Measured Moments for Confined Reinforced Concrete Columns Related to Flexural Strength Predicted by Code Approach [2.11]

- CSA S6.1:19 commentary in Clause C4.4.10.4.3 discusses this further. Note that for *damage* assessments in PBD one would normally use $M-\phi$ relationships that account for confinement benefits. If this approach is also used for capacity design, while retaining the factors discussed above, then a somewhat higher reserve strength in the capacity-protected element would result. This may be beneficial, however, should shear capacity appear problematic, and an iteration in member proportioning is considered, then one should review what C/D ratio is strictly needed to balance cost and member proportions.
- If some of the rebar is neglected in either the plastic hinge or in the capacity-protected element. For example, distributed side steel in a deep beam, or the full arrangement of column flexural rebar should be accounted for. An M_p of $A_s f_y$ {d-a/2} as in singly-reinforced beams would underestimate flexural capacity in a typical bridge element.
- The inherent strengths of the concrete or reinforcing steel within or between elements. CSA G30.18 *Carbon steel bars for concrete reinforcement* for Grade 400W rebar specifies an F_y between 400 and 525 MPa. This worst-case ratio is 1.3, and potentially therefore one may find a larger M_p demand than expected, and a reduction in the C/D ratio. While this worst case would be significant, it is also unlikely but worth exploring as the provisions for CSA S6:25 are now being developed. A similar effect may occur in f'_c in capacity-protected elements, but the effect on C/D margin for shear would be minor.

The margin of strength reserve for capacity-protected elements in Canadian bridges in CSA S6 has been set with care and supported by the above. The seismic shear capacity equations in CSA S6:19 for reinforced concrete columns use the MCFT approach with conservative, simplified design values and this further increases the margin of capacity to demand for this critical failure mode in columns. For the design of columns of unusual demand, proportion or other concern the design engineer is encouraged to delve more deeply into the particulars to demonstrate appropriate margins for capacity-protected elements.

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News

GEER Releases Reconnaissance Report on the 2020 Mw7.0 Samos Island (Aegean Sea) Earthquake

The Geotechnical Extreme Events Reconnaissance (GEER) Association released its reconnaissance report on the Mw7.0 earthquake that hit Samos Island (Aegean Sea) on October 30th, 2020.

The earthquake was a result of normal faulting under the Aegean Sea, causing a tsunami with a maximum run-up of more than 3.5m. The earthquake resulted in significant damage and more than 100 casualties.

The full report can be accessed at:

http://www.geerassociation.org/administrator/components/com_geer_reports/geerfiles/Samos%20Island%20Earthquake%20Final%20Report.pdf

News and Upcoming Events

Due to COVID-19 pandemic, many conferences and workshops have been cancelled, postponed or converted to online events globally. We provide information on events available this quarter.

Upcoming events

IABSE Conference Christchurch 2020: Resilient Technologies for Sustainable Infrastructures
3-5 February 2021
Christchurch, New Zealand
iabse.org/Christchurch2020

2021 EERI Virtual Annual Meeting
23-25 March 2021
Online
www.eeri.org/2020/12/call-for-abstracts-2021-eeri-annual-meeting/

2021 SSA Annual Meeting
19-23 April 2021
Online
www.seismosoc.org/annual-meeting/

37th General Assembly of the European Seismological Commission
19-24 September 2021
Corfu, Greece
www.escgreece2020.eu/

17th World Conference on Earthquake Engineering
27 September - 2 October 2021
Sendai, Japan
www.17wcee.jp/

3rd European Conference on Earthquake Engineering and Seismology
19 - 24 June 2022
Bucharest, Romania
3ecees.ro/