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From the Editor's Desk

by Tuna Onur

Canadian engineering students fared well in the annual EERI seismic design competition, with four Canadian universities placing in the top 10. See the News section for more information. Big congratulations to all the teams!

This quarter, our Earthquake Waves column covers a past "surprise" earthquake in the Prairies, seismically the quietest region of Canada. And the Code Corner column discusses some aspects of design for bridges classified as Seismic Performance Category 1.

Inside This Issue

We hope you are enjoying what is left of the summer and 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

Earthquake Waves: A Most Unusual Earthquake

by John Cassidy

In terms of significant earthquakes, all has been quiet across Canada during the past few months. In this column, I highlight another one of Canada's interesting historical earthquakes. This one occurred in a part of Canada where we generally don't see earthquakes – especially earthquakes large enough to cause damage.

A magnitude ~5.3 earthquake struck the Saskatchewan-Montana border region on May 15th, a Saturday night, at 10:15 p.m. local time. This rare, Prairie earthquake was felt across Saskatchewan, Alberta, Manitoba, parts of Ontario, Minnesota, Montana, North Dakota, South Dakota, and Wyoming – an area of more than 1.5 million km^3.The closest Canadian communities include Estevan and Regina, SK (180-190 km) and shaking was felt at Lethbridge, AB (550 km), Prince Albert, SK (490 km), Winnipeg, MB (610 km) and even as far as St. Paul, Minnesota (1,000 km). There were no reports of structural damage, but some windows were broken, items were knocked from shelves, and many people were extremely frightened and ran from buildings (even as far away as Winnipeg).

For many decades, both the magnitude of this earthquake and its location were not well known. A detailed study published in 2011 used two instrumental recordings from Europe, as well as a re-evaluation of felt intensities and modern seismicity to determine a preferred magnitude of M5.3 (M5-5.7 at a 95% confidence level) and a location of 48.81° N, 105.38° W (just south of the Saskatchewan-Montana border). This location places the earthquake within a 300-km-long northeast-southwest trending band of low-level seismicity, suggesting a region of higher seismic hazard. You can find additional information on this earthquake here: *www.pressreader.com/canada/regina-leader-post/20080526/281500746994174*

Earthquake Waves… *Continued from Page 1*

This earthquake serves as a reminder that rare, potentially damaging (and certainly frightening) earthquakes can, and do, strike even in those parts of Canada that we don't generally associate with earthquakes.

Lessons learned from rare earthquakes such as this one, have been incorporated into our seismic hazard models and National Building codes – but we still have much to learn.

Code Corner: Design Approaches to Lateral Demands in SPC 1 Bridges

by Don Kennedy

It is self-evident to engineers that bridges need to be designed for lateral demands (loads and deformations) between the superstructure and substructure elements, in combination with gravity and other vertical demands. Lateral demands arise from wind pressures, vehicle braking or centrifugal forces, thermal effects, vehicle impacts on superstructures or substructures, hydraulic or ice forces, soil pressures or settlements, or earthquake effects. Some lateral effects are more predictable during design, some are less certain given interactions between environmental demands and restraints introduced through the bridge's articulation details (joints, bearings and other restraints to accommodate movements while resisting forces).

In regions of higher seismicity, the lateral demands can be large and typically would be considered early and as fundamentally as for gravity loads. In regions of lower seismic hazard, lateral forces are smaller and often considered separately in the design decisions regarding bridge arrangement and articulation.

For bridges in low seismic hazard regions, the seismic design process commences with reference to S6:19 hazard levels and Table 4.10 to determine a Seismic Performance Category (SPC). The SPC may be 1, 2 or 3 and this affects the requirements for design approach, seismic analysis and detailing. If the SPC is 1, then the seismic hazard is low and no seismic analysis is specified. Right? Not necessarily.

What seismic design, or analysis, is required for SPC 1 bridges? And what design features used in bridges in higher seismic regions might be useful in bridges even in low hazard regions?

First – to determine the SPC, one may need to determine whether the bridge is laterally stiff or flexible to use Table 4.10 of S6:19. If the design response spectrum is low at both high and low frequency regions then SPC = 1 can be determined without analysis. At some sites the engineer will need to estimate the bridge's fundamental period in order to confirm whether SPC 1 applies. That would require an initial analysis, whether by hand calculation or with software. Thus, some level of dynamic analysis is implied just to start the lateral design even in low-hazard regions.

Second – the Note to Table 4.10 states that for "Lifeline" bridges in SPC 1 then "…. detailing of structural elements shall adopt requirements for SPC 2 as a minimum" (CSA S6:25). In this article we focus on a sub-set of detailing requirements for SPC 1 bridges – superstructure-to-substructure restraint forces or minimum support lengths. "Detailing" goes further, for example would affect column or other reinforcing details among other design aspects. These detailing considerations are left for a future Code Corner column.

Third, for SPC 1 bridges – albeit having set aside "detailing" – the designer must turn to Clause 4.4.5.1 – Analysis and design approach. The "design approach" aspects specify that the design

Code Corner… *Continued from Page 2*

needs to provide either minimum support lengths for the superstructure support, or alternatively a minimum set of lateral forces between the superstructure and substructure. One or the other is sufficient for this clause. Philosophically this makes sense for bridges in higher seismic regions, and also does even for SPC 1 bridges. Designing for non-seismic lateral demands may provide for a sufficiently robust lateral load path for modest seismic demands. Also, low seismic hazard does not imply zero seismic hazard, and earthquake hazard changes over time. In some locations, an SPC 1 bridge may evolve into an SPC 2 bridge as earthquakes occur or as new ground motion models and methods evolve in code updates. The latter will occur as hazard for the National Building Code (NBC) of Canada is updated prior to the publication of S6:25, but adoption into S6:19 in the interim is not certain and will require some case study and consideration by CSA and Owners prior to adoption into their projects. For an update on evolving seismic hazard, see *doi.org/10.4095/321473* and *www.caee.ca/seismic-hazard-assessment-in-canada-for-engineering-applications/*

Note that there appears to be is a discrepancy within S6:19 regarding SPC 1 bridge requirements. Clause 4.4.5.1 (Analysis and design approach) requires either minimum forces (4.4.10.2) or minimum support lengths (4.4.10.5). However, Clause 4.5.1 (Analysis; General) states that Clause 4.4.10.2 and Clause 4.4.10.5 apply. But Clause 4.5.1 would not need to be referenced as part of the design process for SPC 1 bridges, and hence this discrepancy may not be noticed. Ideally this discrepancy will be resolved through CSA. In the writer's opinion, this paragraph within Clause 4.5.1 is redundant and not needed given the clear coverage in Clause 4.4.5.1. Further, it is philosophically inconsistent with a seismic design intent to prevent superstructure loss-of-span collapses.

Regarding design features of bridges in higher seismic regions that might be useful in bridges even in low hazard regions – seismic design does offer opportunities to increase bridge resilience at little or no cost. For example:

- Many bridges are designed with traditional 'fix – expansion' bearings both among and across each support. Fixed bearings may be rigid but may be brittle at larger loads, and expansion bearings often use stainless steel / Teflon sliding interfaces. These arrangements are intended to reduce restraint forces, but can also reduce the lateral resilience of a bridge for lateral loads in general.
- The use of elastomeric bearings having some lateral flexibility can be considered to simplify and arguably improve load distribution and bridge articulation. In higher seismic regions this is practical way to design a seismically isolated bridge. In lower regions this can be a simple and robust way to provide for bridge articulation needs.
- Also, from the design tool-kit of bridge isolation, high quality and explicitly tested elastomeric bearings (with or without lead cores) can resist higher gravity loads, i.e. can use smaller bearings, than traditional elastomeric bearings prior to S6:19. Such bearings can provide sufficient lateral capacity to distribute very large non-seismic or seismic demands (the latter would be reduced in an isolated bridge). They can be designed with sufficient lateral capacity to yield bridge piers (a good thing), or share large lateral loads thus reducing non-seismic demands, or improve the stiffness balance between piers and laterally stiff abutments.

Conversely, the adoption of integral abutment bridges for low-maintenance reasons in non-seismic regions has been widely adopted as seismically resilient, low-damage systems in higher seismic regions. Experience shows that bridge designers in any province or territory can draw on the lessons of others to help optimize the cost, constructibility and durability of bridges across Canada.

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News

Congratulations to Canadian Universities for their Placements in the EERI Annual Undergraduate Seismic Design Competition!

EERI's Annual Undergraduate Seismic Design Competition was held virtually in the 2020-2021 academic year. Teams from four Canadian universities placed in top 10:

1st Place: University of British Columbia

3rd Place: University of Toronto

6th Place: McMaster University

9th Place: University of Victoria

Congratulations!

You can find more information in the following link:

slc.eeri.org/2021-sdc/

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

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

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

SMIP 21 Seminar on Utilization of Strong Motion Data
21 October 2021
Online
www.conservation.ca.gov/cgs/smip/seminar

USGS Workshop on Seismic Directivity
28-29 October 2021
Online
To sign up: forms.office.com/g/SXTpRjuDtz

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

12th US National Conference on Earthquake Engineering and 2022 EERI Annual Meeting
Paper submission open; papers are due 15 October 2021
27 June - 1 July 2022
Salt Lake City, UT
12ncee.org/call-for-papers