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

NEWSLETTER

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From the Editor's Desk

by Tuna Onur

INSIDE THIS ISSUE

Two Canadian cities are hosting earthquake engineering conferences this year. The 71st Annual Meeting of Earthquake Engineering Research Institute (EERI) will be held in Vancouver in March, and Quebec City will host the 12th Canadian Conference on Earthquake Engineering (CCEE) in June. Registration is open to both conferences.

This is a great opportunity to meet earthquake scientists, academics, practicing engineers and engineering students to keep up to date on latest research and state-of-the-art practice, as well as to broaden your professional network in all fields related to earthquake engineering.

Check our Upcoming Events section for details, and as usual we welcome short articles to be published in the CAEE Newsletter (secretary@caee-acgp.ca).

Public Perceptions of Earthquake Hazard and Expectations from Building Codes

by Mark Seemann

Perceptions of hazard and risk vary widely among both the public and public safety professionals, and preliminary assessments suggest that regional earthquake hazard perceptions consistently over-estimate the calculated seismic hazard in southwestern BC.

Graduate research conducted in 2016/17 at the University of Victoria by Brittany Schina explored a range of disaster and earthquake perceptions among two populations: the general public and emergency managers (N=120). Surveying disaster perceptions of both urban and rural populations across the Cowichan Valley, Nanaimo and Capital Regional Districts on southern Vancouver Island, she first asked respondents to identify what they perceived to be the five greatest disaster risks. Then, following questions focusing on the "likelihood of occurrence" and the "magnitude of impact" of regional disasters, she again asked them to re-assess their assessment of disaster risk. In each case, while assessments varied within and between groups, the greatest risk identified on southern Vancouver Island was 'earthquakes', followed variously by 'hazardous material releases' and 'wildfire' for emergency managers; and 'crime/violence' and 'environmental disasters' for the general public.

Given the perceived risk posed by earthquakes, Islanders' perception of the likelihood of a structurally damaging earthquake shaking was explored further. Defined descriptively as MMI VII-intensity shaking, respondent's perceptions indicated that there was a 37% chance of occurrence in 10 years, and a 51% chance in 25 years.

Public Perceptions on Earthquake Hazard… *Continued from Page 1*

This compares to a calculated seismic hazard (including crustal, subcrustal and subduction sources) averaging 19% in 10 years and 35% in 25 years on southern Vancouver Island (Seemann et al., 2011). Emergency managers tended to estimate the seismic hazard slightly higher than the general public, but both populations tended to substantially overestimate the calculated hazard by 15-20%. Interestingly, emergency managers' perception of the public's estimate of the hazard was closer to the scientifically calculated estimate (within 6-7%).

Follow-up questions of both groups about the perceived need for seismic design standards for various structures were assessed on a 1-5 Likert Scale. The public agreed (4) or strongly agreed (5) that the following structures should be built to seismic design standards:

- Single and Multi-Family Residential Homes (4.1)
- Walk-Up Residential Apartments (4.4)
- Commercial and Retail Structures (Shopping Malls, Sport Facilities) (4.5)
- Rail, Sea and Air Terminals (4.7)
- High Rise Residential Apartments (4.8)
- Bridges, Tunnels and Overpasses (4.8)
- On-shore Oil and Gas Pipelines (4.9)
- Off-shore Oil and Gas Pipelines (4.9)

While the public clearly expects seismic design provisions be incorporated into the design of each of these structures, both on-shore and off-shore pipelines were perceived to be of the highest importance. While most Canadian design codes do address seismic loads, the Oil and Gas Pipelines Systems Standard (CSA Z662) does not require consideration of seismic loads in the design of on-shore pipelines (Onur et al., 2012).

With respect to retrofitting, a consensus (~59%) across both groups felt that 1) critical infrastructure and 2) buildings open to the public, should be retrofitted as soon as possible, and/or within 10 years following a change in seismic design codes. When asked about retrofit level expectations, ~45% of respondents felt retrofits should be conducted to 100% of the current seismic design code, while the remainder felt that on, an average, retrofitting to ~75% of the current standard was acceptable.

> *"Code development must accommodate public risk tolerance and be mindful of the residual risk."*

While this survey is a preliminary study, expanded investigations into public perceptions of disaster risk would lend themselves to a refined understanding of disaster risk tolerance in Canada and public expectations of structural mitigation efforts. In turn, code development must accommodate the public risk tolerance and be mindful of the residual risk.

Seemann, M., Onur, T., and Cloutier-Fisher, D.M. 2011. *Earthquake shaking probabilities for communities on Vancouver Island, British Columbia, Canada. Natural Hazards, DOI 1 0.1007/s11069-011-9727-6.*

Onur, T., Seemann, M.R., and Gerin, M. 2012. *A preliminary survey of seismic provisions in Canadian construction codes and standards. Proceedings of the 15th World Conference on Earthquake Engineering. Lisboa, Portugal.*

Code Corner

By Jag Humar

In previous issues of the Newsletter, we highlighted some of the significant changes between 2010 and 2015 Editions of the National Building Code (NBC) of Canada. In this issue, we focus on provisions related to buildings with flexible diaphragms.

Single-storey buildings with large footprints, such as those used for commercial, educational, or institutional purposes, often have a flexible steel deck or wood panel diaphragm. The response of such buildings to seismic loads is strongly affected by the flexibility of the roof diaphragm. Diaphragm flexibility alters the manner in which the inertia forces, shears, and bending moments are distributed along the length of the diaphragm. In addition, diaphragm flexibility causes a significant increase in the ductility demand on the lateral load resisting system that is expected to be strained into the inelastic range under the design level earthquake shaking. NBC 2015 includes design specifications that account for the effect of diaphragm flexibility on the period of the building and the increased ductility demand on the seismic force resisting system (SFRS). These specifications are based on several research studies related to the seismic response of buildings with flexible diaphragms (Humar and Popovski, 2013; Tremblay et al., 2000; Tremblay and Stiemer, 1996; Trudel-Languedoc et al., 2012).

Flexibility of the diaphragms elongates the period of a building, so the empirical formulas for determining the period should account for it. Based on modal analysis of a large number of prototype buildings with flexible diaphragm the following empirical formulas for the fundamental period have been developed for NBC 2015 as follows:

$T_a = 0.05\ h_n^{3/4} + 0.004L$ for shear walls, and

$T_a = 0.035\ h_n + 0.004L$ for steel moment and braced frames.

In these equations L is the span of the diaphragm, in metres, between adjacent vertical elements of the SFRS. In case of multiple spans, the shortest span is to be used. The term containing L accounts for the flexibility of the diaphragm. As an alternative to the empirical formulas, the period may be determined by the method of mechanics, but the T_a so determined should not exceed 1.5 times the empirical period. As in the case of other structures, the upper limit on the analytical period for buildings with flexible diaphragm is meant to account for the possibility that the model used to calculate the period does not consider all of the structural and non-structural elements that could contribute to the stiffness.

Studies have shown that in single storey buildings with flexible diaphragm, the flexibility of the diaphragm generally causes an increase in the ductility demand on the SFRS. Consequently, to keep the ductility demand unchanged, the ductility related force modification factor must be assigned a value that is smaller than the ductility capacity R_d. The revised force modification factor is denoted here by R_{dr}.

To estimate the increase in ductility demand Humar and Popovski (2013) carried out time history analyses on 65 single-storey buildings with flexible steel deck diaphragm designed by Tremblay and Stiemer (1996) for their response to El Centro 1941 ground motion as well as to five other spectrum compatible ground motions.

Based on the results of their study, Humar and Popovski (2013) suggested an equation relating the force reduction factor to the ductility capacity of the SFRS and the drift ratio r.

> *"NBC 2015 includes design specifications that account for the effect of diaphragm flexibility on the period of the building and the increased ductility demand on the lateral force resisting system."*

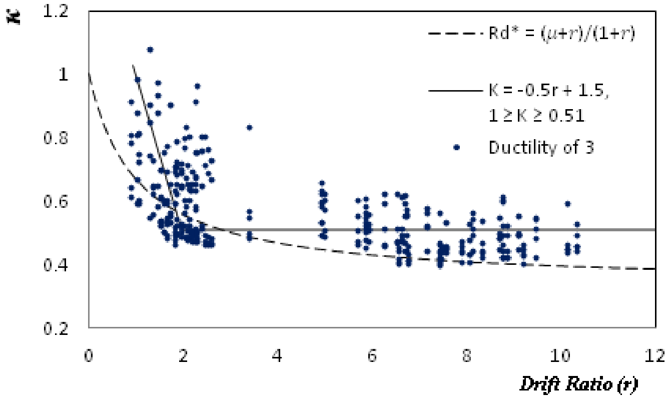
Code Corner

Continued from Page 3

The drift ratio, r is defined as the ratio of the maximum horizontal deformation of the diaphragm along its length (Δ_D) to the average inter-storey drift of the lateral load resisting elements supporting the diaphragm (Δ_B) produced by the action of uniform static lateral load acting along the length of the diaphragm.

The proposed relationship between R_{dr} and R_d is:

$$R_{dr} = \kappa R_d, \text{ where } \kappa = -0.5r + 1.5$$



Relationship between κ and r obtained from response history analyses of selected buildings to ground motions compatible to the UHS for Vancouver along with idealized relationships; ductility capacity of brace, μ = 3.

$$1 > \kappa > 0.64 \text{ for } \mu = 2$$

$$1 > \kappa > 0.5 \text{ for } \mu = 3$$

$$1 > \kappa > 0.4 \text{ for } \mu = 4$$

The Figure above shows the response data obtained from the time history analyses of the 65 buildings for ground motions compatible with the UHS for Vancouver. Also shown are the straight line relationships given by the Equations above.

For NBC 2015, a simple relationship between R_{dr} and the drift ratio, r was developed. Consider a system that consists of two springs in series with a mass attached to the end of the second spring. The first spring represents the lateral force resisting system while the second represents the diaphragm. When the system remains elastic, the dynamic force imposed on the mass by earthquake motion is V_e. Assuming a revised ductility related force modification factor R_{dr} and overstrength related modification factor R_o, the design force is:

$$V = V_e / (R_{dr}R_o)$$

And the elastic displacement is given by:

$$\Delta_e = V_e/K_B + V_e/K_D = R_{dr}R_o (\Delta_B + \Delta_D)$$

When the diaphragm remains elastic while the SFRS is strained into the inelastic range, the acceptable elasto-plastic displacement is determined from:

$$\Delta_i = R_o \Delta_D + R_o R_d \Delta_B$$

Assuming that the equal displacement concept holds, that is $\Delta_i = \Delta_e$, a relationship between R_{dr} and the ductility capacity R_d is obtained from the Equations above as follows:

$$R_{dr} = (R_d \Delta_B + \Delta_D)/(\Delta_B + \Delta_D) = (R_d + r)/(1 + r)$$

$$\kappa = (R_d + r)/R_d (1 + r)$$

This Equation roughly provides a lower bound to the data from dynamic analyses and forms the basis for design of buildings with flexible diaphragms in NBC 2015. κ is less than 1, which implies that R_{dr} should be less than R_d. If $R_{dr} > R_d$, the displacement of the SFRS, $R_{dr}R_o (\Delta_B+\Delta_D) - R_o\Delta_D$, will be greater than $R_oR_d\Delta_B$, and the ductility capacity of the SFRS will be exceeded.

NBC 2015 provides that, as an alternative to increasing the design force by using R_{dr} instead of R_d, the SFRS may be designed to accommodate the increased displacement.

Humar, J. and Popovski, M. 2013. *Seismic response of single-storey buildings with flexible diaphragms. Canadian Journal of Civil Engineering, 40, 875-886.*

Tremblay, R., Berair, T., and Filiatrault. 2000. *Experimental behaviour of low-rise steel buildings with flexible roof diaphragms. Proceedings of the 12th World Conference on Earthquake Engineering. Auckland, NZ. Paper No. 2567.*

Tremblay, R. and Stiemer, S.F. 1996. *Seismic Behavior of Single-storey Steel Structures with a Flexible Roof Diaphragm. Canadian Journal of Civil Engineering, 23(1): 49-62.*

Trudel-Languedoc, S., Tremblay, R., Shrestha, K. and Rogers, C.A. 2012. *Seismic force and ductility demand on the braced bents of single-storey buildings with flexible roof deck diaphragms. Proceedings of the 15th World Conference on Earthquake Engineering, Lisbon, Portugal.*

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News

The New Champlain Bridge Technical Tour at the 12th CCEE

The CCEE 2019 Organizing and Site Visit Committees are pleased to invite you to be among the first visitors of the New Champlain Bridge in Montreal. This strategic bridge crossing the St Lawrence River is intended to replace the existing Champlain Bridge, one of North America's busiest spans, with 50 million vehicles crossing it each year.

The new structure mainly consists of multiple simply-supported spans with a cable-stayed central span. The New Champlain Bridge is planned to be opened to public a few days after the 12th CCEE and the Technical Tour in June.

To check the fees and register for the technical tour, visit the conference web site:

www.ccee2019.org/technical-tour

News and Upcoming Events

We are soliciting earthquake engineering related news and events that you would like to bring to the attention of your colleagues. Please send your contributions by March 15 to secretary@caee-acgp.ca to get them included in the April Newsletter.

Upcoming events

2019 Pacific Conference on Earthquake Engineering
4-6 April 2019
Auckland, New Zealand
www.confer.nz/pcee2019/

SSA 2019 Annual Meeting
23-26 April 2019
Seattle, Washington
www.seismosoc.org/annual-meeting/

ICEES 2019: International Conference on Earthquake Engineering and Seismology
6-7 June 2019
San Francisco, CA
waset.org/conference/2019/06/san-francisco/ICEES

CSCE Annual Conference
12-15 June 2019
Laval, Quebec
csce2019.ca/

7 ICEGE 2019 - International Conference on Earthquake Geotechnical Engineering
16-20 June 2019
Rome, Italy
www.7icege.com/

12th CCEE - Canadian Conference on Earthquake Engineering
17-20 June 2019
Quebec City, Quebec
www.ccee2019.org/