Preventing a shock to the system

Expert engineer and structural dynamics specialist **Professor Ghyslaine McClure** sheds light on work towards reducing the risk posed by earthquakes in Eastern Canada by developing a methodology with which priority buildings can be better protected

What are the goals, background and rationale behind this project on 'Post-earthquake functionality of schools and hospitals in Eastern Canada'?

Eastern Canada is a seismic zone of moderate activity. Risk in the Montreal area is the second highest in Canada, after Vancouver, but to date there has been no systematic seismic assessment of essential 'post-critical buildings'– such as hospitals and schools – in this region. Several methods exist to assess the structural performance of buildings, but their post-earthquake functionality is not sufficiently addressed. This project aims to fulfil that need.

How has progression of this work been supported?

The Natural Research and Engineering Research Council of Canada (NSERC) has supported our efforts in two ways: through a major strategic network project called the Canadian Seismic Research Network (CSRN), which ran from October 2007-September 2013 and, more recently, through a strategic research project, which ran from April 2008-February 2014.

I am Principal Investigator (PI) of the latter project, working closely alongside my co-PIs Professor Carlos Ventura from the University of British Columbia, Professor Jean Proulx from Université de Sherbrooke and Professor Marie-José Nollet from École de technologie supérieure in Montreal. Our partners for this project are the Quebec Ministry of Education, Montreal Health and Social Services Agency, a large number of hospitals based in Montreal and RAMPART Partitions, Inc who produce office partition systems. The City of Montreal's Centre de sécurité civile (CSC) was another very important partner for CSRN.

Are you implementing any existing methodologies from seismically active regions around the world?

We share our research through publications and both national and international conference presentations; we also influence Canadian code developments. Although we have not yet established formal collaborations on this topic at the international level, there are a few groups of researchers taking a similar functionality-focused approach in the US, Italy and New Zealand. Currently, we are working on gaining more exposure for our work, which will lead to increased collaboration.

In what way has your research contributed to improving structural engineering of schools and hospitals so far?

We have prepared practical assessment reports for Montreal's CSC and several hospital managers who use this information for risk management. Some hospitals have implemented risk mitigation measures following our reports. It is also important to note that our research directly feeds into the National Standards CSA-S832, which influences the National Building Code of Canada for seismic design of non-structural components in new buildings.

Could your findings be applied to other buildings or utilities, and to other high seismic risk countries?

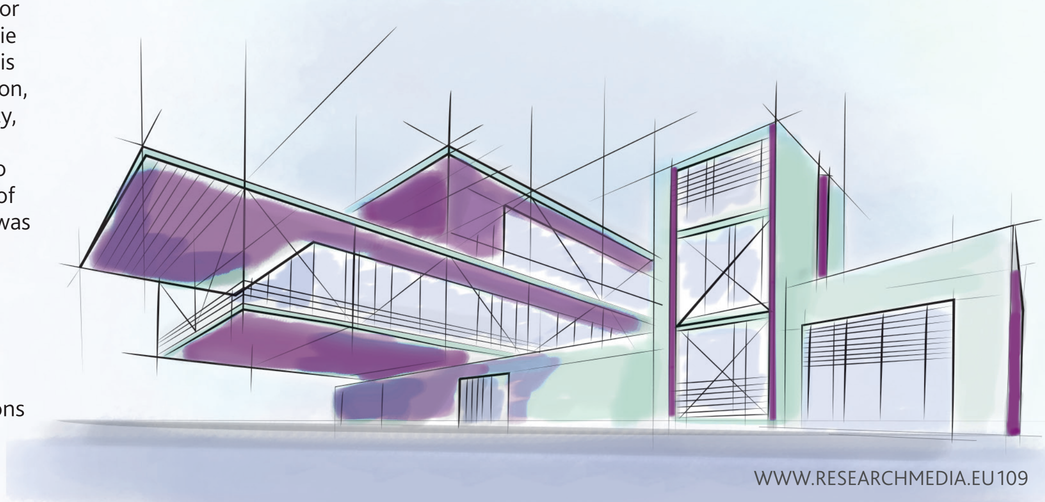
Some findings are specific to Canadian seismic zonation, but the general approach can be implemented anywhere and for any building type. Our assessment method for low-rise irregular buildings is original and quite useful: it's called the 3D-SAM method, and the limitation is to moderate damage. Of course, for very high design level earthquakes (those with the strongest level of shaking), if the structure of the building is heavily damaged, there will be no functionality at all.

Why are you investigating demountable architectural partitions (DAPs) and suspended ceilings, specifically? During your studies, what did you discover about the benefits, challenges and overall performance of these systems?

We looked at DAPs and suspended ceilings in particular because they are commonly used in office buildings, at least in North America, and their interaction was poorly understood. Suspended ceiling systems are typically highly vulnerable – a fact which several earthquake reconnaissance reports have highlighted – and the consequences of their failure can be dramatic. At worst, they can fall on building occupants causing significant injury, but even in less severe cases they're more than capable of blocking egress routes and causing other problems. DAP-ceiling interaction effects cannot be ignored – they respond together, so seismic regulations have to account for that. Ceilings must be restrained for good overall performance.

Looking ahead, what are the project's next stages?

We have two main axes of research in our future plans: seismic assessment of building facades, and rational integration of soil/structure interaction effects in simplified building assessment methods.



Public service protection

A research group based at **McGill University** in Montreal, Canada, is trying new methods to assess the post-earthquake functionality of buildings including schools and hospitals and seeking to further improve earthquake preparedness in the region

WHEN PREPARING FOR natural disasters, the most commonly considered factor is hazard probability. Some areas, for example, are more prone to extreme weather, which presents a greater hazard to their built infrastructure and population than many other phenomena. Preparations against such an eventuality therefore make sense. However, this rationale is incomplete and may in fact be misleading as it does not account for vulnerability and consequences. Protecting a sparsely inhabited but hazardous area is probably less important than defending a densely populated and moderately hazardous one: more is at risk in the latter instance than in the former.

The subtleties of such risk assessments, which are measured through the combined effects of hazard, vulnerability and consequences, are well exhibited by earthquake incidence in Canada. The west coast – which is home to Vancouver – poses a far greater seismic hazard than the area surrounding Montreal on the east coast, because Montreal is positioned almost directly in the middle of the North American plate, whereas Vancouver sits atop the Pacific Rim. In terms of risk, however, the Montreal area demands more attention: its population is more than 50 per cent higher than Vancouver's, and its civil infrastructure is older and subjected to harsher climate (hence more vulnerable). Montreal closely neighbours Ottawa and Quebec City, all of them similarly earthquake-prone; these three cities account for a population of 4.8 million and the characteristics of earthquakes in the region could be particularly damaging to the built environment and its inhabitants.

'MODERATE' MONTREAL

Despite the Montreal area's importance to Canada's economic and political stability, its 'moderate' seismic hazard has meant that historically little provision has been made against earthquakes. In terms of improving existing (and developing new) infrastructure, earthquake-proofing measures have fallen short. Therefore, within the context of serious budgetary constraints, provincial and local governments must rely on robust seismic risk assessment methods that are adapted to their existing facilities and local seismicity in order to effectively prioritise their actions and put in place efficient mitigation programmes. However, until recently, such methods had not yet been implemented in practice.

This state of affairs is now set to change. A group of researchers based in Montreal has been busy developing the reliable assessment methods required by government as a first step towards safeguarding the seismic safety of Eastern Canada. Led by Principal Investigator Professor Ghyslaine McClure of McGill University in Montreal, the team includes a number of researchers from neighbouring Quebec institutions, as well as Professor Carlos Ventura from the west coast's University of British Columbia – whose expertise in vulnerability assessment within a highly seismic area is proving invaluable. Their 'Post-earthquake functionality of schools and hospitals in Eastern Canada' project focuses uniquely on the operational and functional objectives of the buildings most at risk from earthquake damage.

A STATE OF EMERGENCY

Hospitals and schools are of vital importance following a major earthquake, providing medical care and shelter to those in need. Whereas traditional seismic vulnerability assessment methods rely on testing a building's framework resistance, the Canadian engineers are developing methods that centre on the practical objectives of the buildings in question, taking their functional and operational components into account when assessing how they may fare under earthquake duress. Having developed these methodologies, the research plan calls for testing them in partnership with a number of public schools and hospitals in Quebec to validate their efficacy.

The proposed assessment methods combine technical data gathering from drawings, onsite visits and inspections, as well as seismic microzonation maps of the Montreal and Ottawa regions developed by McClure's colleagues in the Canadian Seismic Research Network (CSRN). An important new feature of the proposed simplified methods for predicting the response of both structure and individual functional components to seismic activity is to make use of the measured building characteristics extracted from ambient vibration testing (AVT). In terms of practice, the methods adhere to the principles of the National Building Code of Canada applicable to new buildings, and Canadian Standards CSA S832, a government guide to seismic risk reduction that McClure herself helped to create with the technical committee who worked on a recent comprehensive revision to be published later in 2014.

BUILDING POST-EARTHQUAKE FUNCTIONALITY

The project has been underway for several years, producing a number of telling results on post-earthquake building functionality. In a pilot study of six Montreal hospitals in 2010, the group found that 27 per cent of the operational and functional components evaluated posed a higher risk level. Among this high risk category, 58 per cent were accounted for by building services – with the main deficiencies relating to a lack of restraints on mechanical components such as emergency generators, elevator engines and boilers.

Based on this – as well as a CSRN study of 17 schools designated as emergency shelters – the team decided that a 'bottom-up' concept would be most appropriate for determining the building functionality index (BFI); this estimate should be based on the vulnerability of a building's operational components, the vulnerability of its structure and lifeline interfaces, such as water and electricity, and the original seismic hazard as well as its localised soil effects. The researchers have completed seismic functionality assessments of operational components for several Montreal hospitals, and almost all buildings designated by the Centre de sécurité civile of Montreal as emergency shelters – assessing well over 100 buildings in total.

SHAKE TABLE TESTS

Many functional building components have been tested as part of this process; in particular, the Canadian team has been responsible for a number of studies into the seismic properties of suspended ceilings and partition walls, as well as the interaction between the two. These components are a common architectural feature in schools as well as hospitals and most large office buildings, and can be particularly vulnerable to earthquakes. The studies conducted by the team mostly rely on testing these systems using a 'shake table' set up, and their research has shown, among other things, that a partition wall system of limited unsupported span length without top restraints may be suitable for resisting earthquakes in the region, and that wall bracing alone is not the most effective solution. Indeed, recent tests of coupled wall/ceiling specimens have indicated that ceiling bracing is paramount to increase the endurance of both suspended ceilings and partition walls.

A number of other studies are underway that have not yet been fully reported on, including the assessment of many smaller school buildings of various architectural types, the development of a functionality assessment method for hospitals with fault-tree analysis and the shake table testing of masonry wall systems and coupled wall and ceiling systems. Ventura has also been using AVT to study the seismic responses of piping and ductwork systems in hospitals and other buildings in Vancouver. The number of studies conducted by this group is staggering, and the volume of work they have already carried out is huge; their new assessment methods, however, may soon be forthcoming – and this could well lead to significant improvements in Montreal's earthquake preparation efforts.

Damaged c-shape dismountable wall partition system without top restraint.

Construction of ceiling system for shake table set-up.

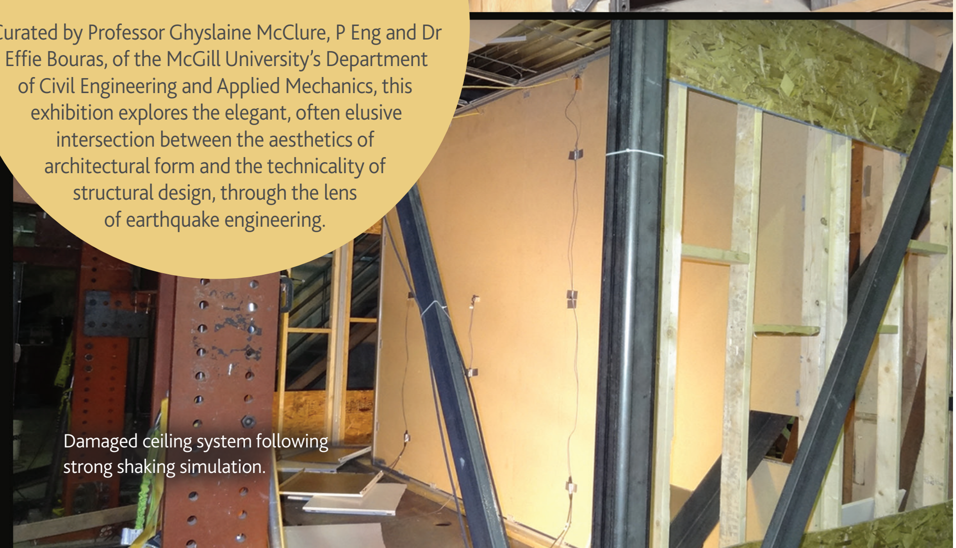
DATE FOR THE DIARY

Considering the Quake: Seismic Design on the Edge

February 13 – May 26, 2014

AIA New York Center for Architecture

Curated by Professor Ghyslaine McClure, P Eng and Dr Effie Bouras, of the McGill University's Department of Civil Engineering and Applied Mechanics, this exhibition explores the elegant, often elusive intersection between the aesthetics of architectural form and the technicality of structural design, through the lens of earthquake engineering.



Damaged ceiling system following strong shaking simulation.

INTELLIGENCE

POST-EARTHQUAKE FUNCTIONALITY OF SCHOOLS AND HOSPITALS IN EASTERN CANADA

OBJECTIVES

- To develop simplified seismic vulnerability assessment methods for buildings and their functional and architectural components
- To apply these methods to post-critical buildings in the Montreal region

PARTNERS

Canada: **City of Montreal's Centre for Civil Safety • Montreal Agency for Health and Social Services • Quebec Ministry of Education • RAMPART Partitions, Inc • McGill University • University of British Columbia • Université de Sherbrooke • École de technologie supérieure**

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PROFESSOR GHYSLAINE MCCLURE joined McGill University in 1991, after five years of professional practice in transmission line engineering. She has more than 25 years of experience in structural dynamics and advanced computational solid mechanics research. One of her main research axes of the last 15 years relates to realistic assessment and improvement of post-earthquake functionality of buildings. She is among the founding members, and current Chair of the technical committee of the Canadian Standard CSA S832 on Seismic risk reduction of operational and functional components of buildings.