SEABC NEWSLETTER

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- SEABC's Newsletter is both edited and managed by The Communications Committee. newsletter@seabc.ca
- Submissions to the newsletter are encouraged and all members of the SEABC are asked to actively participate in contributing to our newsletter. Submissions letters to the Editor, questions and comments can be sent to: newsletter@seabc.ca
- SEABC editing staff reserve the right to include or exclude submitted material and in some cases edit submitted material to suit overall space requirements. If submittals are not to be edited, please advise editor at submission time.

Message from the President

November 2013

By Cameron Kemp, P.Eng.,
SEABC President

Be Part of the Solution

Recently two new earthquake related studies have been reported in the press, one a Canadian and the other an American:

- "Study of Impact in the Insurance and Economic Cost of a Major Earthquake in British Columbia and Ontario/Québec" commissioned by the Insurance Bureau of Canada and prepared by AIR Worldwide.
- "Cascadia Subduction Zone Earthquakes: a Magnitude 9.0 Earthquake Scenario" prepared by CREW (Cascadia Region Earthquake Workgroup) with support from FEMA (Federal Emergency Management Agency) and NEHRP (National Earthquake Hazard Reduction Program)

Both reports envision a 9.0 magnitude earthquake in the Cascadia Subduction Zone located west of Vancouver Island and northwest Washington. The Insurance Bureau of Canada study predicts a total economic loss (direct and indirect) of approximately $75 billion (of which approximately $20 billion will be insured) with no estimate for the anticipated loss of life.

The CREW report estimates an economic loss for the states of Washington, Oregon and California to be in the order of $70 billion, again, with no estimate for the anticipated loss of life.

www.crew/earthquake

The combined economic loss for both Canada and the United States from such an event would be in the order of $150 billion with a likely loss of life between both countries measured in the thousands.

Most of the economic loss would result from the direct physical damage of our built environment; buildings, roads, bridges, utilities, ports, airports, etc. as well as the indirect economic loss resulting from the loss of this built environment to shelter and support people and businesses.

Similarly the large loss of life anticipated will largely result from partial or full collapse of these engineered structures or from resulting tsunami, slide or fire after-effects.

These two reports make for very sober reading and both beg the question, "What can we, as structural engineers, do to minimize this potential loss of life and economic loss?"

As designers and builders of most of these engineered structures we are in a unique position to participate in the discussion about what can be done to mitigate these losses.

How can you assist in this discussion?
By getting involved!

Involvement can take many forms. A few that come to mind include;

- Our Day Jobs

  By continuing to stay current with respect to the latest design codes and design philosophies and incorporating this work into your designs you will contribute to increasing the overall safety of our engineered structure stock. Attend all available courses and seminars to maintain your currency on these topics.

- Getting Involved in 'Setting Policy.'

Sitting on technical or advisory committees which determine future building code content or provide technical input to law and policy makers with respect to risk assessment and mitigation strategies will provide valuable input to determine practical strategies and solutions.

- Post-Disaster Support

  Following a major seismic event many engineers will be needed to assess post-disaster damage and determine which structures are safe to occupy. Taking a course like ATC 20 (Procedures for Post-Earthquake Safety Evaluation of Buildings) and signing up for the provincial post-disaster callout list would be a critical way to assist in the early days following such a disaster.

There are, undoubtedly, many more avenues to contribute to minimizing the human and economic loss resulting from such a natural disaster and I urge you to get involved and "Be Part of the Solution".

Please contact any of the Board members of the SEABC through our website for advice and guidance in how you can get involved.

Sustainability Design Education

By Mark Porter, P.Eng., Struct.Eng., FIStructE.

In January 2014 the updated APEGBC 'Sustainability Guidelines' will be adopted into Professional Practice. The guidelines have been updated to be relevant and helpful, encourage member engagement and reflect the changing practice with respect to sustainability.

The five guidelines are:

1. Maintain a current knowledge of sustainability.

2. Integrate sustainability into Professional Practice.

3. Collaborate with peers and experts from concept to completion.

4. Develop and prepare clear justifications to implement sustainable solutions.

5. Assess performance and identify opportunities for improvement.

In support of these guidelines and to help to define, encourage and inspire our contribution to sustainable design; the SEABC sustainability task group has been working hard to develop a workshop for Structural Engineers in applied Sustainability. This workshop is planned for early 2014 and will cover a range of topics over two days. The anticipated topics include:

- An Introduction to Sustainability
- Models for Process Change, Sustainability Frameworks and our Role
- Energy, Envelope and Structure
- Designing for Adaptability and De-Construction
- Designing for Longevity
- Water and Structure
- Green Roofs
- Materials
- Specifications and Contractual Issues
- Case Studies

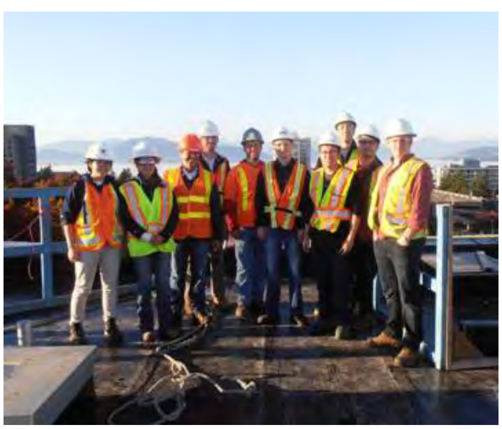
We believe this workshop will provide in-depth learning with best practices from around the world as well as practical case studies. We look forward to welcoming you to the event.

Young Members Group

By James Macauley, BASc, EIT

On October 23, fourteen members of the SEABC Young Members Group toured the new UBC Student Union Building at UBC Vancouver. Led by Bird Construction and with insight from Damien Stoneham from RJC, the tour explored the five storey LEED Platinum structure. The new structure uses an elegant mix of concrete, steel and timber that in places seems to defy gravity. The structure will eventually house facilities for a multitude of activities, including a climbing wall, art gallery and a full-storey slide. The main atrium runs the full height of the building, and features a steel 'birds nest' elevated platform in the middle. Also featured in the atrium are CLT cantilevered walkways along the exterior window line.

The SEABC YMG would like to thank Craig Shirra from Bird Construction and Damien Stoneham from RJC for leading the tour.



SEABC YMG members posing on the roof of the new UBC SUB

Conceptual rendering of the atrium

Communications Committee

By David Harvey, P.Eng, Struct.Eng., Director SEABC

I hope you enjoy reading SEABC's exciting and highly-regarded newsletter – many thanks to those who forwarded articles describing their recent work. This edition features a report written by two young structural engineers about the interesting project to replace the bearings supporting a local landmark – the Granville Street Bridge. If you enjoyed reading this article, please take the time to tell us about your current project and how you overcame the challenges you encountered.

By informing our members of the engineering we carry out, we maintain interest in our well-read magazine and help raise the profile of the profession. There is always much to learn from the information that the structural engineer responsible for the work can provide. It is also a great way to raise your profile in the structural community, so why not give it a go? We look forward to hearing from you.

Please forward information for publication to:-
newsletter@seabc.ca

Fire Resistance of High Performance Concrete

By Mark Robertson, P.Eng., Struct.Eng.

On October 30, 2013 Dr. Sidney Mindess presented to SEABC members with an evening seminar discussion on Fire Resistance of High Performance Concrete (HPC). As a Professor Emeritus at the University of British Columbia - Department of Civil Engineering, Dr. Mindess has taught and researched on Portland cement and concrete, its materials testing, and fracture mechanics since 1969.

In his presentation, he first defined HPC as concrete with its water to cement ratio of 0.36 and less. With all available water having been consumed by the hydration process, concrete becomes a theoretical perfect solid. This compact structure can make HPC an excellent material with enhanced high strength and durability. However, due to this same compact property, particular care must be taken with HPC when there is potential fire exposure because:

- Aggregate and cement paste are thermally incompatible materials
- It tends to lose strength and stiffness more rapidly than regular concrete
- It tends to display explosive spalling behaviour of its outer 2 to 3 inches of concrete and ties at high temperatures compared to regular concrete

Dr. Mindess provided engineers with following mitigative measures to improve the fire resistance of HPC:

- Provide thorough external and internal water curing
- Reduce tie spacing to ¾ of conventional spacing
- Provide 135 degree hooks on column ties
- Consider specifying carbonate aggregates such as limestone with better fire resistance properties
- Avoid light-weight aggregates because they have poor fire-resistance properties
- Employ ploy-propylene fibres (0.2% by volume) in the mix. The fibres provide pathways for more uniform water curing and for surface steam pressure relief
- Using steel fibres for additional concrete tensile strength to outmatch water-vapour pressures

When one or more of the above measures are implemented, testing of HPC concrete has shown improved performance and resistance to fire temperatures.

In closing, Dr. Mindess emphasized that HPC is a more temperamental material compared to conventional concrete. With or without above measures, special attention and qualified professionals should be involved in a project when HPC is considered.

Dr Mindess

Post-Earthquake Structural Assessments

By Andrew Seeton, P.Eng.

A SEABC-led Task Group was formed in early 2012, with the following terms of reference and goals:

1. **Purpose**. SEABC is interested to assist in developing and implementing a plan for post-earthquake assessment of structures following a major earthquake affecting the Lower Mainland and/or Victoria area. SEABC members (structural engineers) can contribute as a key resource if prepared. How best to integrate a coordinated structural assessment plan with the various emergency response plans already in place?

2. **Deliverables**. Following a review of the applicable emergency response plans, formulate a simple, effective plan for post-earthquake assessment of structures, the key aspects of which can be summarized in a 2 page document to share with SEABC members and appropriate emergency response agencies. SEABC to update this document periodically and maintain roster of structural engineers recently trained/re-trained in assessment procedures.

The Task Group includes members from the following groups: SEABC, APEGBC, Emergency Management BC, BC Housing, UBC, City of Vancouver, City of Victoria, and the Earthquake Engineering Research Institute (BC Chapter).

In March of 2012, SEABC held an ATC-20 training sessions for our members in Vancouver and Victoria. At these sessions we obtained a list of 83 members agreeing to have their names added to a roster of volunteers willing to participate in post-earthquake structural assessments in the Lower Mainland and Victoria. By holding future re-training sessions, this list can be updated with time.

Recently, APEGBC has indicated interest to manage the roster and coordinate with municipalities and the Province as needed. The SEABC-led Task Group will be meeting again soon to sort out some details for how best to implement this initiative. The Task Group will also aim to formulate concise answers the following questions related to post-earthquake structural assessments:

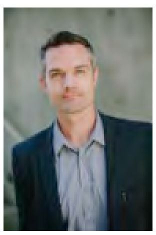
1. When to go? What triggers mobilization?
2. Where to go?
3. Who to report to? Who will manage volunteer engineers?
4. What damage assessment procedures to follow?
5. What buildings/structures to assess?
6. How to reconcile volunteerism vs. servicing client needs?
7. What are the legal issues?

As structural engineers, we have an opportunity to make a significant contribution to the disaster resilience of the province of BC. By drawing on lessons from earthquakes in other areas and proactively formulating a simple plan that is integrated with existing emergency plans at municipal, provincial, and federal levels, we can enhance the post-earthquake response and recovery phases of our region when the earthquake happens. Watch this space for updates on this initiative!

Idea Calculator

By Ian Boyle, P.Eng., Struct.Eng.

Vancouver firm pioneers first 'idea calculator' for architects and engineers



Stemming from clients' desire to assess project feasibility before putting pencil to paper, structural engineers at Fast + Epp have developed CONCEPT – a free iPhone app that allows architects and engineers to calculate member depths and browse project photos for inspiration.

Created in collaboration with app developers at Burnkit, the project was conceived by the firm's internal ideas division, a group tasked with applying structural engineering concepts in other fields of endeavor.

CONCEPT's depth calculator uses typical span-to-depth ratios for common steel, concrete, and wood members. The user simply indicates if the information they are inputting is a roof or floor, with the internal calculator determining an approximate depth. Additional information is provided to qualify the load assumptions and tributary areas. Users are able to share search and calculation results by emailing them to co-workers and clients for discussion prior to the first design charrette.

Download the app: www.hitunes.apple.com/ca/app/concept-by-fast-and-epp

Media Release

By Heidi Kandathil

CREW Releases New Cascadia Earthquake and Tsunami Scenario

SEATTLE — On January 26, 1700 an estimated M9 earthquake unzipped the 700+ mile Cascadia Subduction Zone fault from northern California, USA to southern British Columbia, Canada, much like recent events in 2011 in Japan and 2010 in Chile. The newly released "*Cascadia Subduction Zone Earthquakes: A Magnitude 9.0 Earthquake Scenario*" examines how the Pacific Northwest may fare after the next great 'megathrust' earthquake and tsunami.

"The new report conveys the most current scientific and emergency planning information accessible to a wide variety of audiences," said Tamra Biasco of the Federal Emergency Management Agency, one of the lead authors.

The new report by the Cascadia Region Earthquake Workgroup (CREW) summarizes not only why these earthquakes occur repeatedly, but also the likely consequences of the next Cascadia fault rupture. Future Cascadia earthquakes and tsunamis will have lasting impacts to coastal communities and the potential to inflict tens of billions of dollars in physical damage, dramatically impacting the region's economy.

www.crew/earthquake

Written by a team of social scientists, emergency managers, earth scientists, engineers, public administrators, and businessmen under the umbrella of CREW, the new scenario provides a guide to citizens curious about the geologic processes that make the Pacific Northwest so rich in natural beauty and resources, to planners wanting to know what hazards they face, and to policy makers striving to make the Pacific Northwest more resilient.

Pushover Analysis

By Farshid Borjian P.Eng., Struct.Eng.

Event Summary

On September 11th, 2013, an estimated audience of 65 people attended the SEABC evening seminar *Pushover Analysis* held at UBC Robson Square. The speaker Saqib Khan, M.A.Sc., S.E., P.E., P.Eng., is a structural engineer with extensive experience in seismic analysis and design, currently working as a technical specialist in seismic analysis and a design lead with MMM Group Ltd.

Pushover analysis is a tool for designing new bridges as well as assessing and retrofitting seismically deficient structures. With more and more emphasis being placed on displacements, as opposed to forces, this analysis provides a convenient and straightforward approach to seismic analysis and design. Pushover analysis can be used in a displacement-based design context to determine plastic hinge locations, and to design capacity-protected elements for over-strength demands. Pushover analysis is also routinely used in the assessment of seismically deficient bridges and to ascertain the suitability of retrofit designs.

The speaker started the seminar by explaining the general concept of capacity design using the “chain link” analogy. In the seismic design of structures, some elements are purposefully weakened so that plastic hinges will form at predetermined locations. In bridges, these locations are usually at the top and bottom of columns, whereas for the seismic design of buildings, the beam ends are the desired location for plastic hinges.

The seminar focused on familiarizing the participants with the pushover analysis concept and describing different application methods, including stepwise linear analysis and the fully automated non-linear approach.

The seismic analysis of a bent was used as an illustration. The speaker noted that it is always important to consider the dead load effects at the start of a pushover. In stepwise linear analysis, the gravity and lateral load demands have to be superimposed until a given location hinges. Each time a plastic hinge forms, a new equivalent system is analyzed starting from the previous state, until in a two-column bent a four-hinge mechanism is obtained. The speaker then interpreted the pushover analysis results and discussed potential pitfalls.

At the end of the seminar there was further discussion and the presenter answered questions from the audience. The seminar was webcast and recorded – the seminar and the course notes will be accessible to SEABC members via the website in due course.

Saqib Khan describes the Pushover Analysis Method to an Attentive Audience

Steel Day

By Matthew Wong, USB Student Representative for SEABC YMG

Steel Day is a national event organized annually by the Canadian Institute of Steel Construction (CISC) to promote the importance of steel across Canada and its viability in intricate design and fabrication projects.

This year, on October 4th, steel fabricators, mills, service centres and other specialized steel facilities across Canada opened their doors to architects, engineers, contractors, developers, students, educators and the general public. UBC civil engineering students were able to participate by having an organized tour of the steel fabrication plant of George Third & Sons Ltd (GTS) in Burnaby.

Transportation for the trip was sponsored by Structural Engineers Association of British Columbia (SEABC) in collaboration with the UBC Steel Bridge, the UBC CSCE Student Chapter and the UBC Civil Engineering Department.

GTS is primarily involved with the fabrication of steel components for a variety of structural steel projects. In the past they have been involved in a variety of industrial and commercial projects, such as the W Hotel, Safeco and QWest Field in Seattle, as well as the Richmond Olympic Oval and local stations. Along with SEABC, GTS remains a valued sponsor of the UBC Steel Bridge team. GTS generously provides design and fabrication guidance to the team and their constant support has greatly helped the team perform at a high level in competitions.

GTS is currently working on the steel fabrication for the TELUS garden development located in downtown Vancouver at 520 West Georgia. Glotman Simpson Consulting Engineers and Henriquez Partners Architects are also collaborating on TELUS garden and were kind enough to accept the invitation to come and visit GTS and give a presentation. Fortunately, Steel Day coincided with GTS fabricating the large steel girders for the landmark plaza of the TELUS garden.

The presentation consisted of the architect from Henriquez detailing the conceptual iterations the plaza went through before a final design was reached. Also, the engineers commented on how structural members were optimized to meet demands and deliver an aesthetic design.

After the presentation, the group consisting of UBC students, Glotman Simpson, and Henriquez, had a personally guided tour around the facility from Rob Third. Included in the tour was the large scale model of the TELUS garden plaza, which gave the visitors an opportunity to experience what the open plaza will feel like upon completion. The tour offered up a close up look at different pieces of fabrication equipment, including one that bends steel plates into specified curved and circular shapes. Of interest also was the opportunity afforded to students to try out a virtual welding simulator machine.

In conclusion, it was a wonderful opportunity for students to see a structural engineering and steel facility. No doubt this experience will benefit all students in their education of this industry and enhance their professional development. We want to give a hearty thanks to all those involved in this successful event.

Granville Bridge

By Grant Fraser, EIT; and Sean Donelan, EIT

Grant Fraser *Sean Donelan*

The Granville Bridge is an eight lane vehicular bridge that spans over Granville Island and False Creek, South of the downtown core. The bridge was constructed in the 1950's to replace the then-existing timber trestle. Providing four lanes of traffic in both the northbound and southbound directions, the bridge serves as a vital link for vehicular traffic, including public transit services.

The main bridge across False Creek comprises seven steel deck truss spans, with a total length of 538 m, and a concrete deck. The approach spans comprise cast-in-place concrete girders. All bridge spans are supported on concrete piers. The entire bridge was previously retrofitted in the early 1990's.

Original truss span steel roller bearing in PCB bath

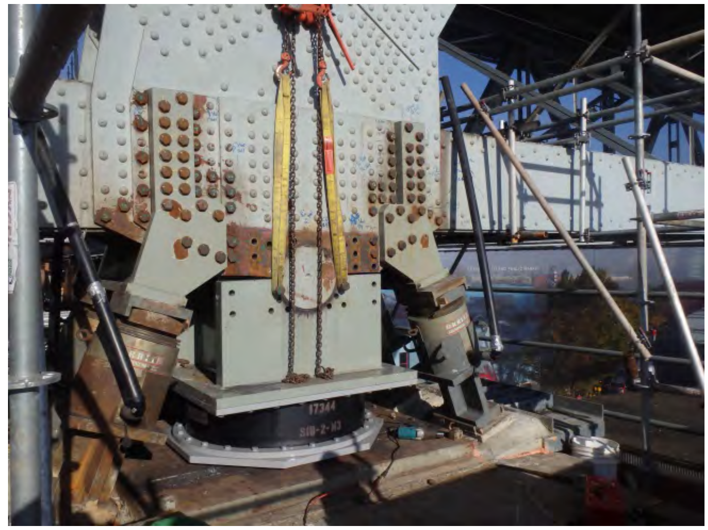
The original expansion bearings supporting the main spans were steel rollers in a bath of PCB oil for bearing lubrication. PCB is classified as a hazardous material, and required removal to comply with Federal and Provincial legislation. The City of Vancouver retained Associated Engineering to remediate the original bearings without considering seismic upgrades, a decision predicated on the bridge having been previously retrofitted.

It became apparent through the design phase that bearing remediation provided an opportunity to greatly improve the seismic performance of the Granville Bridge, through the implementation of a seismic isolation retrofit.

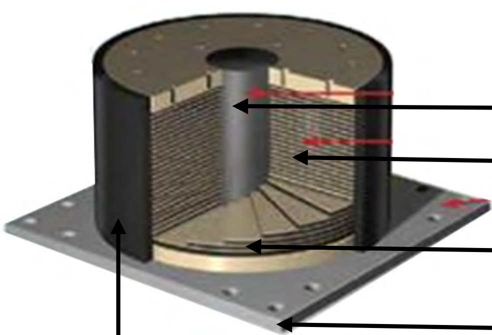
The previous retrofit of the steel truss spans target a 'loss of span prevention' criterion for a 475-year event. In the proposed seismic isolation scheme, we targeted an immediate or near-immediate return to service for the main spans following a design earthquake. We also examined the expected structure response in larger earthquakes, up to a 2475-year return period event. Our other objectives included:

- Solution needed to be constructible; structure behavior during jacking operations should not cause damage to bridge elements.
- Major elements that are part of seismic load path (such as portal braces and piers) to remain essentially elastic, or suffer only minor damage, during the design event.
- A reserve 50% displacement capacity at isolation bearings under the design earthquake.
- Design for acceptable changes in service conditions, (live load thermal loads and wind, deck joint movements), following bearing replacement and articulation changes.
- Provide comparable or better seismic performance for the steel spans, compared to the approach spans.
- Eliminate all PCB's in the bridge bearings.

The first design detail to be determined was the type of isolation bearing to install. In preparing our design we considered multiple bearing types including laminated rubber bearings, lead core rubber bearings (LCRB), friction pendulum bearings, and seismic isolation disk bearings. Factors considered in selected an isolation system included performance, geometry, cost, structural modifications required, and compatibility with existing articulation. Based on these considerations, LCRBs were selected and implemented. The installed bearings range in diameter from 570 mm to 1150 mm. Following discussion with the client, it was decided to divide the isolation retrofit into two phases, with all on-land bearings replaced as part of Phase 1, and the in-river pier bearings to be replaced in Phase 2.



Truss node supported by jacks while the isolation bearing is installed



Components of a lead-rubber isolation bearing

One of the biggest challenges faced during design was to determine how the temporary works and jacking could be implemented to allow safe bearing replacement. The bridge was to remain open to traffic throughout the bearing replacement process, with the exception of a brief closure during initial lifting and lowering of the bridge. This meant that temporary works needed to account for full live load and thermal considerations. The retrofit details include both temporary and permanent jacking diaphragms within the truss chords, pre-stressing the concrete substructure at each jacking location, and hinged jacking supports.

The contract required the contractor to successfully complete 16 jacking operations on the Granville Bridge. 14 of the 16 lifts were completed on Granville Island, Vancouver's largest tourist attraction, while the remaining two were completed on the north side of False Creek just south of the downtown core.

The contractor, Graham Construction, mobilised in early March, 2013. The first jacking was successfully completed at 4:15 am on July 22, 2013 under a closed Granville Bridge. Over the preceding 4 months leading up to the lift, crew worked on providing access to each pier, completing detailed surveys for steel fabrication, and strengthening each existing bearing location by installing supplementary strengthening bolts.

To facilitate this installation, the crew initially had the labour intensive task of removing over 2000 original rivets, one-by-one from the bridge. In many cases, these rivets were over 150 mm long, and over time, had become fused with the connecting gusset plate assemblies, often forcing crew to manually core through over 150 mm of steel. Noise control measures were enforced during peak times on Granville Island to ensure pedestrians and businesses were protected from unsafe noise levels, often reaching over 110 dB at source.

Although many of the existing roller and fixed bearings differed in size; the same basic pre-jacking procedure was carried through on all lifts. This consisted of the installation of permanent and temporary jacking brackets and diaphragms, possible pier modifications, and the installation of jacks, grout pads and final seating of the jacks. With the equipment installed and seated, and the jacking scheme approved, the bridge was raised by 13 mm. This facilitated removal and replacement of the original bearing assemblies with the new isolation bearing.

Once the new isolation bearing had been installed, the bridge could be lowered onto the new bearing and fixed into position. This process was then completed for the bearing on the opposite side of the same pier prior to repeating on other piers in a sequence followed by the other piers in a sequence complaint with the engineer's specification. As a precautionary measure, the first jacking was completed under dead load conditions only. All subsequent lifts were completed while the bridge was open to traffic.

Installation of isolation bearings underway at an expansion pier.

On average, it took the crew approximately six days to complete each bearing replacement from jacking, through to final installation of the new bearing. Throughout this time, the bridge was supported on two to four 450 tonne custom-made hydraulic jacks. This six day period allowed for the removal of the existing bearing, PCB abatement, and installation of the new isolation bearing. The final jacking was completed at 8:30 am on October 31, 2013, 102 days after the first lift.

Phase 1 of the project is now complete. Replacement of the in-river pier bearings, as part of Phase 2 is expected to be undertaken in the coming months. The completed isolation scheme will provide significantly improved seismic performance to one of Vancouver's most recognizable and vital bridges.

IStructE News

By Bill Alcock, Director SEABC; and Victoria Janssens, SEABC Young Member Delegate

As your SEABC representatives on IStructE Council, Victoria Janssens and I attended meetings in London on November 15, including the International Interest Group, Young Members Panel, Council and 2013 Structural Awards Night. Highlights of our meetings and the awards night follow below.

International Interest Group

Presentations on Professional Registration requirements in the Caribbean and UAE were made by Clifford Murray and Dr. Shapour Mehrkar-Asl respectively. Information on these presentations will be added on the IStructE website.

There was considerable discussion about the Associate grade of membership of the Institution, AIStructE. The Associate grade may only be achieved by a mutual recognition agreement route. This option is currently available to individuals in a five regions (Ireland, South Africa, Australia, New Zealand, and Singapore) who are registered as Chartered Engineers with their local governing bodies. Concern was expressed that the designation "waters down" the status of MIStructE. There was also concern that other regions do not have access to the AIStructE designation. Currently there are approximately 130 AIStructE members worldwide. Further discussions are expected to follow at subsequent IIG and Council meetings.

Young Members Panel

Over recent months, the Institution's Young Members Panel (YMP) has struggled with participation and attendance at meetings. In order to try to improve this situation, it has been decided that YMP meetings will be held at the same time as Council meetings for the foreseeable future. This gives the eight Graduate Members on Council the opportunity to attend YMP meetings. Together with an influx of new members for the 2014 session, the momentum of the group should start to build again. Much of this meeting was concerned with reviewing the objectives of the group and trying to restructure the panel's activities to better meet the needs of young members (both in the UK and internationally).

Additionally, there was some discussion about the possibility of introducing a GradIStructE designation for Graduate Members of the Institution. Similar to APEGBC's EIT designation, this would demonstrate the attainment of the required academic base for Chartered Membership of the Institution and the commitment of the individual to their personal professional development. If you have any views (positive, negative or neutral) on this proposal, please pass them on to Victoria (email: vjanssens@whmengineers.com) who will be presenting the views of international members to the panel in January.

Council Meeting

New Home for the Institution

CEO Martin Powell announced that the Institution has purchased a new home at 43-57 Bastwick Street in the Barbican area of London. The $5 million purchase was made possible by negotiating a $6 million payout to the Institution by the owners of the current site of the Institution, in the upscale Belgravia area of London. The institution had a 99 year lease on that building, with 20 years remaining at $200 per year. The Barbican area is undergoing major renewals and the Board felt that the new site has great future potential. Major renovations are planned for the new building which is expected to be ready for occupancy in the summer of 2014.

New IStructE Headquarters Building

Exam Preparation Course

Dr. Peter Gardner gave an impassioned and detailed summary of the history of the exam and the various attempts to organize a formal training course. Dr. Gardner noted that the exam is not easy and that there are often many acceptable solutions to a given problem.

It was acknowledged that many of the branches and regions put on their own course. These can vary from one to several evening sessions or a full day (or more). Under Dr. Gardner's direction, the Institution has now prepared a full training course complete with information for instructors. The course is expected to be distributed to the regional groups before the end of this year. Dr. Gardner organized IStructE exam preparation seminars in BC in 2001 and 2002.

2013 Structural Awards

The annual Structural Awards ceremony was held at "The Brewery", a beautifully restored convention facility in what used to be a Whitbread brewery. BC and Ontario were well represented with four entries from Fast & Epp, and one from Halsall and Associates. The competition was fierce with many excellent entries.

Congratulations to Gerry Epp and Derek Ratzlaff of Fast + Epp, who were on hand to receive a Commendation for the Community or Residential Structures category for Tsingtao Pearl Visitor Centre, Qingdao, China.

Full details of the Awards can be obtained by contacting the authors or going to the website: www.structuralawards.org

Gerry Epp receives Commendation for Tsingtao Pearl Visitor Centre from IStructE President YK Cheng. The Structural Engineer Managing Editor, Lee Baldwin, and media personality Mary Nightingale, look on.

Victoria Alcock (second from left), Victoria Janssens (third from left), and Bill Alcock (fifth from left) at the Structural Awards Reception in London, UK

Award for Community or Residential Structures – Commendation: Tsingtao Pearl Visitor Centre

Structural Designer: Fast + Epp

LOCATION
Qingdao, China

CLIENT NAME
China Vanke Co. Ltd

ARCHITECT
Bohlin Cywinski Jackson Architects

PRINCIPAL CONTRACTORS
Images: © Benjamin Zhuang; StructureCraft Builders

Timber was an inspired choice for the main structural material in this visitor centre. The client's vision of a spectacular undulating roof structure has been achieved through structural design which uses innovative manufacturing processes in Canada, a bespokely-trained workforce in China, and parametric analysis of considerable detail to allow for construction tolerances. The undulating form is achieved through the use of straight timber members, helped in their performance through king posts. This stunning structure was designed, fabricated and constructed over a total of just eight months, pointing to Chinese-Canadian collaboration of great effectiveness.

Judges' Comment:

The designers have achieved an exceptional building against a backdrop of unease over possible construction practice and a very challenging timeline. They overcame both obstacles through outstanding structural design, perfectly suited to the project conditions.

R.A. McLachlan Memorial Award

By David Harvey, P.Eng, Struct.Eng.

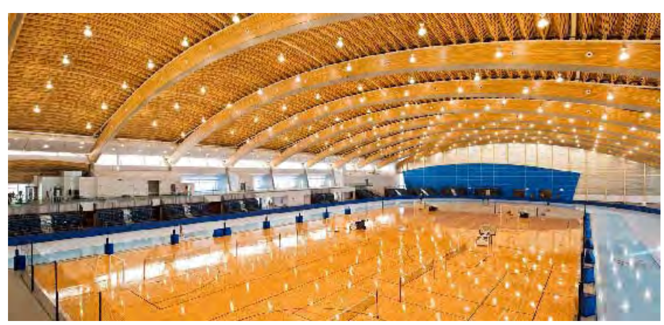
SEABC Director Paul Fast is the recipient of the 2013 R.A. McLachlan Memorial Award, APEGBC's premier award for professional engineering. The R.A. McLachlan Memorial Award was established in 1965 in honour of R. A. McLachlan, P.Eng., President of the Association in 1951 who was highly respected for his ability as an engineer and for his personal integrity and fairness. Paul was nominated by SEABC President, Cameron Kemp, on behalf of SEABC members; Duane Palibroda. Paul's colleague at Fast & Epp, supported the nomination.

Paul is a worthy recipient of this distinguished award, rarely accorded to structural engineers. Paul's commitment to excellence; along with his acclaimed work on the VanDusen Botanical Garden Visitor Centre, the Richmond Olympic Oval Roof, and his charitable work with orphaned children in Russia, were key deciding factors. Paul received his award at the President's Awards Gala, which took place during the APEGBC Annual Conference in Whistler. Paul was joined by fellow structural engineers, Cameron Kemp, Andy Mill and me, his Fast & Epp colleagues, and many members of his extensive family, who were delighted to share in the celebration of Paul's impressive career.

The stunning VanDusen Botanical Garden Visitor Centre

Paul Fast receives the R. A. McLachlan Memorial Awards from APEGBC President Dr. Michael Isaacson, P.Eng. – Photo: Andrea Sunderland

Paul Fast addresses the audience at the President's Awards Gala in Whistler – Photo: Andrea Sunderland



The innovative Richmond Oval Roof – Photo: Hubert Kang

APEGBC Council Elections

By David Harvey, P.Eng, Struct.Eng.

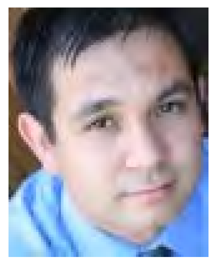
APEGBC's Nominations Committee asked me to run in this year's Council elections; much to my surprise and delight, I was elected as Councillor for a two-year term commencing in 2013. I would certainly like to thank SEABC members that voted for me – several of you have told me that you did – for placing their trust in me. More importantly, I would like to thank everyone who participated in the ballot and supported the candidates of their choice. It is vital for a self-regulating body like APEGBC that the members exercise their democratic rights and that the elected representatives represent a broad spectrum of the membership. Widespread participation in the ballot helps to guard against over-representation by minority groups, which may not be in everyone's best interest.

Councillors are duty-bound to act in the public interest and to represent the membership as a whole. This is important because Council was elected by the entire membership. Nonetheless, serving Councillors, Andy Mill and I are structural engineers, so we are in an excellent position to ensure that regulatory matters affecting structural engineering are given proper consideration. While structural engineering makes up only a small part of engineering, our work is very prominent and is often seen by the public to represent the profession as a whole. Furthermore, structural engineering has a unique influence on the quality of life of our community. These points of differentiation are important and reflect the contribution structural engineers need to make to APEGBC activities.

Good examples of how we can contribute to APEGBC initiatives are the six storey wood frame guidelines, and the Seismic Retrofit Guidelines for BC Schools, which won the special 'Engineering a Better Canada Award' at the 2013 Canadian Consulting Engineer Awards. Thank you again for participating in the APEGBC elections – I'll keep you posted with developments!

The Professional Practice Committee

By Leonard Pianalto, M.Sc P.Eng., LEED AP, FEC



The professional practice committee continues to be active in our liaison with APEGBC. Recently we headed a small task group to revise the Guidelines for Structural Engineering Services for Part 9 Buildings as well as the Structural Design Issues for Housing and Small Buildings. These documents are widely used by the Authorities Having Jurisdiction as well as professional practitioners in navigating the most recent changes to the BCBC requirements for the structural design of houses and small buildings. These documents are available for download from the APEGBC website.

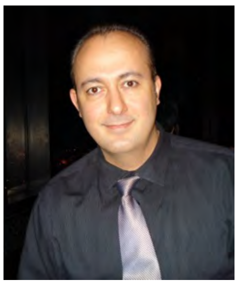
There are a number of important issues that the professional practice committee continues to pursue. We are working to maintain a roster of ATC trained professional engineers that can be called upon to conduct post-earthquake structural damage assessments as the need arises.

We are also working towards developing a comprehensive method for determining seismic upgrade triggers on existing buildings undergoing renovations. Currently, the City of Vancouver is the only jurisdiction that has a by law in place that regulates such upgrades. Our goal is to develop a standard of practice that can be applied throughout the province.

APEGBC Annual General Meeting

By Farshid Borjian, P.Eng; Struct.Eng.

Structural Stream



On October 25th, 2013 the APEGBC annual general meeting was held in Whistler. The structural stream had five presenters who covered structural topics in Masonry, Wood and Concrete materials. Farshid Borjian volunteered to help APEGBC as the structural stream coordinator.

Dr. Svetlana Brzev's topic was "**Lateral Instability of Reinforced Masonry Shear Walls Subjected to In-Plane Seismic Loading".** In her presentation she explained that:

Reinforced concrete and reinforced masonry (RM) shear walls subjected to combined gravity axial stresses and overturning moments due to lateral seismic loads can experience lateral instability when the longitudinal reinforcement in the wall end zones is subjected to compression loads subsequent to cycles of high tensile strain. Lateral instability is characterized by out-of-plane buckling of the wall end zone along the plastic hinge height. Significant damage due to lateral instability was observed in a few reinforced concrete wall buildings affected by the February 2010 Maule, Chile earthquake (M 8.8) and the February 2011 Christchurch, New Zealand earthquake (M 6.3); however, there is a lack of evidence of similar damage to RM shear walls in past earthquakes. The Canadian masonry design standard CSA S304.1-04 placed stringent limits on the height-to-thickness (h/t) ratio (from 14 to 20) of ductile masonry walls (R_d=2) to prevent potential lateral instability in these walls. However, in some cases, these restrictions may unnecessarily inhibit the use of masonry in some common design applications, such as fire halls or warehouse buildings. The presentation summarized key findings of an ongoing research program, which aims to characterize out-of-plane instability in RM shear walls and develop rational criteria for lateral instability in these walls. The research has been undertaken by UBC and BCIT civil engineering faculty as well as students and it is sponsored by the Masonry Institute of BC and the Canadian Concrete Masonry Producers Association.

Dr Svetlana Brzev

The other topic on masonry was "**Effect of Diaphragm Flexibility on Out-of-Plane Dynamic Stability of Unreinforced Masonry Walls"** by Mr. Osmar Penner.

Osmar explained that, the vulnerability of unreinforced masonry (URM) buildings to out-of-plane damage and collapse has been clearly demonstrated in past earthquakes, most recently in the 2010 and 2011 earthquakes near Christchurch, New Zealand. A cost-effective, widely-used approach for reducing the out-of-plane vulnerability of URM walls is to connect the walls to the diaphragms. Given sufficient anchorage to the diaphragms, a URM wall subjected to out-of-plane inertial forces will likely develop a horizontal crack above mid-height. This crack will cause the wall to behave as two semi-rigid bodies, which rock in the out-of-plane direction. Treatment of the effect of diaphragm flexibility on out-of-plane wall stability in studies to date has been limited, and wall slenderness limits in the ASCE 41 assessment standard do not account for this effect.

The presentation summarized key findings of an ongoing study examining the out-of-plane stability under seismic loading of URM walls connected to flexible diaphragms. The study is comprised of full-scale shake table testing of wall specimens at the UBC Earthquake Engineering Research Facility as well as a parametric study using an analytical model. The research is sponsored by the Masonry Institute of BC, the National Sciences and Engineering Research Council of Canada, and the Canadian Seismic Research Network.

Osmar Penner

The next structural material was wood: **"A Discussion on a Natural Structural Material"** and was presented by Mr. Mack Magee.

Mack mentioned that: 'We', architects, engineers, builders, and the inhabitants of the structures we build, appreciate wood's characteristics; its warmth, beauty, flexibility, strength, seemingly endless variability in color and figure, and its organic nature. With all of the focus on sustainability and green building, wood's importance as the only truly renewable, structural material will only increase.

Yet, it is precisely its nature—the fact that it is grown, that it is organic—that creates variability in behaviour and performance we don't generally encounter when we use other, manufactured, structural materials. With dozens (or more) of commercial species available from around the world, and many species available from different regions of the continent or even the world, we, in the building community are challenged to know much more about wonderful and wonderfully variable, material.

His presentation surveyed many of the factors and characteristics with which the building community should be aware when wood is used in our structures. It reviewed the implications of these characteristics and, hopefully, insight into how these factors and characteristics can be employed, and maybe even celebrated in our structures.

Mack Magee

In the afternoon Mr. Paul Jaehrlich presented a topic about "**Plywood 101".** He covered the following issues in his presentation:

AIA accredited, Plywood 101 is a hands-on and practical look at the Canadian plywood industry. Learn how to specify the right panel grades for the job. Important facts about imported plywood and OSB. Eligible LEED points, indoor air quality and which plywood glues to avoid. Plywood's manufacturing process and its QC. An in-depth look at plywood's unique engineering properties.

Paul Jaehrlich

Kyle Gilmour

The final structural material which was discussed was concrete. Mr. Kyle Gilmour's presentation was "**Lessons Learned in Concrete".**

His presentation highlighted examples of interesting applications, problems and resolutions pertaining to concrete. All of the topics shown were from various projects within British Columbia. The presentation also included some of the current limitations of ready-mixed concrete in the BC marketplace and discussion regarding specialty concrete such as self-consolidating concrete, high density, semi-lightweight and many more.

The structural stream was well attended and the audience enjoyed the sunny weather in Whistler as they heard the structural presentations.

Upcoming Changes to CSA Standard for Concrete Structures – CSA A23.3

By Perry Adebar, Ph.D, PEng., Director SEABC; and James G. Mutrie, P.Eng.

The 2014 edition of CSA A23.3 – Concrete Structures will soon be going to the printers. The Public Review of the draft document was completed in May 2013, and the technical committee met shortly thereafter to consider the input received. An updated draft was produced in August, and the committee recently completed the official balloting of the document. The committee will meet one last time later this month to consider any final changes.

It has been ten years since CSA A23.3-2004 was issued – so what has changed?

The majority of the changes are in Clause 21 – *Seismic Design*. As there are too many changes to describe in one article, the plan is to have more than one article describing the changes. This first article will give a brief overview of all the changes, with a focus on the changes other than in Clause 21. Subsequent articles will provide additional information on some of the major changes in

Clause 21 including a brief description of the background to the changes.

There have been some recent discussions with the Educational Committee of SEABC about organizing a seminar on the upcoming changes to Clause 21 of CSA A23.3. There have also been discussions with the SEABC Certificate in Structural Engineering (CSE) Board of Directors about offering new courses on the seismic design of concrete structures. One possibility being considered is to offer an introductory course on seismic design of concrete structures in September 2014, followed by an advanced course dealing with some of the newest CSA A23.3 seismic design requirements in January 2015. "Stay tuned" for more to come on this.

The following is a "chronological" list of the changes as they appear in the document.

Clause 7 – *Details of reinforcement* has a couple of small changes related to spacing of prestressing strands and column ties in column-slab connections where the slab is discontinuous.

Clause 9 – *Structural analysis and computation of deflections* has more significant changes. The first relates to the effective stiffness of the lateral-load-resisting system when subjected to the design wind load. While the clause already states that:- "member stiffnesses… shall be representative of the degree of member cracking," it is felt that more specific requirements are needed to ensure that designers are adequately accounting for cracking in their prediction of the lateral deflections and the period of vibration. In the end it was decided to put the detailed recommendations for effective stiffness and damping in the commentary, similar to where they were located for seismic design prior to the 2004 edition.

Other changes relate to the calculation of deflection due to gravity loads. The committee discussed for many years the concept of replacing the classic “Branson equation” (Equation 9-1) for the effective stiffness of a member, depending on the ratio of cracking moment to applied bending moment, with the more rationale and more complex “Bischoff equation.” The committee had pretty well decided to make the change, when it was realized that the existing simpler equation gives the same result as the more complex equation if the concrete tension strength is reduced appropriately. Thus the “temporary fix” instituted in the 2009 update of CSA A23.3 – reducing the concrete tension strength by 50% for one-way members, similar to what was done earlier for two-way slabs – was made into a “permanent fix” of the Branson equation. This will be a change for the many designers that are still not using the 2009 update of CSA A23.3.

The multiplier on immediate deflection used to obtain the total immediate plus long-term deflection (Equation 9-5) reflects the creep that occurs when the sustained load is applied weeks after casting, e.g., four weeks (28 days) after casting. Concrete structures are often (usually) loaded only days after casting and, as some recent slab tests conducted at UBC has shown, this results in much larger long-term deflections due to creep. Additional guidance on how to calculate the increased creep deflections is given.

Clause 10 – *Flexure and axial load* has a number of changes. The first is that Clause 10.9 on reinforcement limits and Clause 10.10 on resistance have been revised to make it clear that the requirements must be applied to all *compression members* and not just *columns*. The minimum required ratio of spiral reinforcement has been increased, and the maximum factored axial load resistance $P_{r,max}$ of spirally reinforced columns has been increased to 0.90 P_{ro} to reflect the enhanced toughness of these members as observed in some of the recent terrorist-damaged concrete structures in the United States. The minimum bending moment to be used in assessing the slenderness effects in non-sway columns (Clause 10.15.3), which reflects construction tolerances, must be applied with the member bent in single curvature. Perhaps the largest change in Clause 10 is a reduction in the maximum factored axial load resistance $P_{r,max}$ for columns and walls that are less than 300 mm thick. The influence of the change will depend on how the designer is currently accounting for the slenderness of these members. A recent informal survey suggests the differences are large. For some designers, the reduction in axial load that can be supported on thin columns and walls will be very significant. For example, 150 mm walls will have $P_{r,max}$ reduced to 0.45P_{ro}. This change was made to reflect the lack of toughness in such

thin compression members as shown in Fig. 1 (Adebar, 2013).

Figure 1. Photograph of 140 mm thin concrete “wal-lumn” specimen subjected to 35% of $f_c'A_g$

shown after sudden complete collapse. Tested by Helen Chin as part of her M.A.Sc. thesis.

Clause 11 – *Shear and Torsion* has seen many refinements; but no major changes (*sigh*). The refinements include: the need to account for cover spalling in members with a large amount of stirrups; new requirements for design of sections near supports; revised definitions of special member types that can be designed using the (similar to) traditional values of V_c and V_s; accounting for the increased longitudinal strains due to longitudinal bars being terminated in the flexural tension zone, and; a relaxation of the maximum spacing limit for transverse reinforcement in large members. Changes to the strut-and-tie design provisions of Clause 11.4 include: the introduction of refined strut-and-tie models accounting for the influence of minimum transverse reinforcement on reducing the anchorage requirement for longitudinal reinforcement; guidance on strut-and-tie models for members subjected to uniform loads; revised dimensions of compression struts anchored by reinforcement and for struts in the narrow part of fanning compression regions; new detailing requirements for anchorage of ties, and; provisions that allow for increased bearing stress limits when nodal regions are confined by concrete with minimum crack-control reinforcement in all directions.

Clause 13 – *Two-way slab systems* has only a few small changes: the shear depth d_v is now to be used instead of the effective depth d when determining the one-way shear resistance; there are new details for bottom bars in column strips of slabs with drop panels, and; V_{se} used for the design of structural integrity reinforcement no longer has a lower-bound value equal to twice the weight of the slab self-weight.

Clause 14 – *Walls* underwent a major “upgrade” in 2004 with many of the requirements for wall design from Clause 21 being adopted into Clause 14. The redundant requirements in Clause 21 have been removed for 2015 and thus Clause 14 becomes an important starting point for the seismic design of walls. The changes to Clause 14 are in response to recent concerns about thin walls (see Adebar, 2013). The calculation of the factored resistance of bearing walls must account for significant strong axis bending moments if present. Strong-axis bending moments may be applied to bearing walls when the resultant of the axial load is not at the centroid of the wall section; or due to deformation of the lateral-force-resisting system from wind or seismic loads. There are also new requirements to consider the slenderness of the compression region of thin walls. When the wall is subjected to low axial compression, the new requirement is a simple limit on the height-to-thickness ratio, while when the wall is subject to a higher level of axial compression, a full slenderness analysis must be done for the compression region of the wall.
Clause 18 – *Prestressed concrete* has one small change – a higher compressive stress limit for concrete at transfer at the ends of simply supported members.

As mentioned, Clause 21 – *Special provisions for seismic design* has a large number of substantive changes, and only a very brief overview is given here. The clause has been completely reorganized so that all the requirements for ductile frames are in Clause 21.3, while all the requirements for moderately ductile frames are in Clause 21.4. This consolidation of the “frame” requirements is appropriate given the limited use they see in practice. One small change in this section is new dimensional limitations for moderately ductile moment-resisting frames.

On the other hand, the requirements for moderately ductile shear walls have been greatly expanded to reflect the popularity of this system, particularly in Montréal and Ottawa. Because of the significant overlap with the requirements for ductile shear walls, the requirements for moderately ductile and ductile shear walls are presented together in Clause 21.5.

The changes to the design provisions for shear walls include: new requirements for the increased shear force in walls due to the inelastic effects of higher modes; new requirements for the anchorage of horizontal reinforcement at the ends of walls depending on the level of ductility, and; new requirements to ensure that walls have adequate ductility to tolerate some yielding near mid-height due to higher mode bending moments.

Design requirements for two new reinforced concrete SFRS – moderately ductile coupled walls and moderately ductile partially coupled walls – have been added. These are essentially “de-tuned” versions of the popular ductile systems. The requirements for squat shear walls have been expanded and a complete design procedure, which can be applied to moderately ductile or conventional squat shear walls, is presented. The requirements for conventional construction flexural shear walls have been significantly expanded.
Complete design requirements have been added for the seismic design and detailing of tilt-up construction, including moderately ductile and limited ductility tilt-up walls and frames. This was accomplished by “marrying together” (i.e., reaching a compromise between) the current best-practice from tilt-up construction in BC with well-established seismic design principles for cast-in-place construction.

Major changes have been made to the provisions on the seismic design of foundations in both the draft 2015 NBCC and 2014 CSA A23.3. The movement of all foundations must now be considered, and the large increase in displacements due to “rocking foundations” must now be explicitly accounted for. As foundations do not actually behave anything like the classical *rocking* phenomenon, the term is no longer being used. Not capacity protected (NCP) is the somewhat clumsy, but more accurate, new term for such foundations.

Perhaps the single largest change in CSA A23.3 for 2014 is the many additional and revised design requirements for members not considered part of the seismic-force-resisting system. A complete article is needed to briefly describe these new requirements. Separate articles could also be written on the new foundation requirements, the new tilt-up requirements and the new requirements for shear walls.

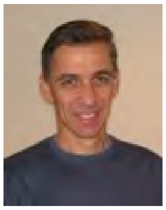
Clause 23 – *Tilt-up wall panels* (non-seismic) has new requirements for structural integrity.
Annex D – *Anchorage* has been modified to be consistent with ACI 318M-11. There are new provisions for horizontal and upwardly inclined anchors; the bond strength of adhesive anchors in tension; the resistance of anchors for load cases involving earthquake effects; revised breakout resistance in shear for an anchor in cracked concrete, and; new requirements for the installation of anchors.

Reference:

Adebar, P., “Compression failure of thin concrete walls during 2010 Chile earthquake: lessons for Canadian design practice,” *Canadian Journal of Civil Engineering*, Vol. 40, No. 8, Aug. 2013, pp. 711-721.

On the Web

By Stephen Pienaar, P.Eng.



The past summer was a memorable sunny and warm one. Providing some warmth for winter, the SEABC website offers access to good content…

Upcoming event registrations

- Registrations for the two-day course:
  Engineering for Cold Regions
  To be presented on Friday and Saturday November 29 and 30 by
  William G. Nelson, Ph.D., P.E. (University of Alaska Anchorage), John P. Zarling, Ph.D., P.E. (University of Alaska Fairbanks) and Adrian Gygax, P.Eng., Struct.Eng. (Gygax Engineering Associates Ltd.)
  The course will also be available via live webcast.
  www.seabc.ca/events
- Seminar recordings:
  Did you miss an evening seminar or AGM the keynote presentation?
  Video recordings are be available to members.
  www.seabc.ca/seminar-recordings
- Certificate in Structural Engineering Program:
  Registration for the **January 2014 Term** is now open.
  www.seabc.ca/cse-current
- Administrative:
  Annual membership renewal
  www.seabc.ca/renewal
- Be in the know:
  Join our **Twitter feed**: announcements for SEABC events and other interesting structural engineering snippets.
  www.twitter.com/seabc

Suggestions

We welcome your comments for improving and expanding on the SEABC's website and other online services. Please send your suggestions to: webmaster@seabc.ca.

Membership Renewal

By Stephen Pienaar, P.Eng.

It is the time again for all SEABC members to renew their membership. Please renew your membership before December 31 to continue enjoying the benefits of membership: free monthly seminars, discounts on full-day seminars and courses, access to the SEABC's web archive of seminars, and more. SEABC seminars and courses are a valuable source for compliance with the APEGBC professional development guidelines.

Membership Fees

Annual membership fees remain unchanged from 2013. The Associations' finances are very healthy, thanks largely due to successful events hosted by the Education Committee.

The membership fees for 2014 are as follows:

- Individual Members: $75 plus GST
  Structural and civil engineers who hold P.Eng. or E.I.T. status.
- Associate Members: $75 plus GST
  Technologists and non-structural engineers.
- Affiliate Members: $75 plus GST
  Individual members of organisations that share the interest of the SEABC.

- Student Members: Free
  Engineering students enrolled full-time on January 1, 2014.

Renewal

You can renew your membership online (credit card payment) or offline (mail in a cheque).

Corporations can also do a bulk renewal for their employees. For more information, please go to:

www.seabc.ca/renewal.

Invitation to new members: Please invite your colleagues that are not yet members of SEABC to join at this time. Joining now will grant them membership until the end of 2014.

Recent Research at UBC

By Manuel Archilla & Carlos E. Ventura, Ph.D., P.Eng., UBC Department of Civil Engineering

SEISMIC RESPONSE OF TALL BUILDINGS TO NEAR-FAULT EARTHQUAKES

INTRODUCTION

Shallow earthquakes caused by faults in the proximity of populous urban areas generate strong shaking that can damage buildings and infrastructure, and cause numerous casualties and large economic loses. A list of notable events of this type in the last 25 years is given in Table 1. British Columbia is a region that is not exempt from this type of seismic hazard. Historical records indicate that shallow earthquakes have occurred on Vancouver Island in 1918 and 1946 with magnitudes of M7.0 and M7.3 respectively (CREW, 2009).

The importance of near fault ground motions having energetic long period pulses on seismic response of buildings was recognized long time ago (Bertero et. al., 1978). Despite major advances on this field of research, a complete understanding of the problem is not yet readily available. One of the most challenging problems is the understanding of the directionality effects of near fault ground motions on the seismic response of tall buildings. And this is one topic of ongoing research at the Earthquake Engineering Research Facility (EERF) at UBC Civil Engineering Department. The goal of this study is to gain a better understanding of these effects and develop recommendations for an adequate seismic design of buildings when near-fault ground motions are likely to shake a building. This article provides a brief summary of the research that we have conducted so far.

SEISMIC RESPONSE OF BUILDINGS TO NEAR FIELD AND FAR FIELD ground shaking

Near-fault (or near-field) ground motions (typically within 10 km of the causative fault) have very distinct characteristics when compared to ground motions observed far away from the fault (far-field motions). They have a shorter duration and can exhibit few cycles of large motions either in the form of acceleration, velocity or displacement strong pulses. Often these pulses are polarized along a narrow range of orientations. It has been observed that near-field impulsive ground motions affect the seismic response of structures in a different manner than far-field ground motions (Bertero et. al., 1978; Kalkan and Kunnath, 2006).

The complex nature of near-field ground motions is one of the reasons why the effects of earthquake ground shaking on buildings located at close distance of the causative fault are not fully understood.
Studies have shown that the ratio of the period of the pulse to the fundamental period of the building is one parameter that determines the demands caused by a strong near-fault motion on the seismic response of buildings. When the pulse period approaches the fundamental period of the building, the pulse excitation drives the seismic response of the building into few large motion reversals, which could result in few inelastic excursions. In contrasts, far-field ground motions impose numerous cyclic loading reversals that progressively build up the response under seismic waves of longer duration (Kalkan and Kunnath, 2006). The consequence of this difference on how a building is excited during an earthquake is that different considerations are required to determine the response of a building to near-field ground shaking.

Despite of these important findings, several issues related to impulsive ground motions and seismic response of structures have not been widely investigated yet, including the effect of ground motion directionality. To this date there is not a reliable design guideline on how to estimate the critical direction of response of a building. Furthermore, this issue is not addressed in the current version of the National Building Code of Canada (NBCC).

Understanding the potential demands that near fault ground shaking can impose on buildings is a crucial task in order to make informed decisions regarding the seismic design of tall buildings. Under certain conditions, the directionality effect of near-fault motions results in significant amplification of the expected seismic demands on structures. The present research study at the EERF is addressing these effects through simulations on parametric and case studies.

STUDY OVERVIEW

The nonlinear response history analysis (NRHA) method is now used by earthquake engineers as a tool to assess the seismic performance of tall buildings subjected to severe ground shaking. This method is the most advanced tool available today that provides the best estimates of structural inelastic response to ground shaking. This procedure follows a direct time step-by-step integration scheme of the coupled equations of motions of the multi-degree of freedom model of the building's structure.

The earthquake input for NRHA required for the analysis of modern tall buildings includes site seismic hazard estimates, selection and scaling of ground motion records representative of the seismic hazard at the site, site response analysis and soil structure interaction effects (PEER, 2010). The influence that the horizontal ground motion directionality has over the building seismic response is not routinely considered in conventional NRHA.

The input ground motions are typically applied along the main structural axes of the building model. These axes are usually perpendicular to each other, and many structural systems have different lateral strength and stiffness along these two orthogonal structural axes. Structures exhibiting dynamic characteristics that are dependent on the orientation along which they are evaluated usually will have preferred directions of response. Stewart et. al. (2011) recently coined the term *azimuth-dependent* structures to identify these types of structures. These structures are deemed to be sensitive to the ground motion directionality. Other structures that have same lateral strength and stiffness along all directions and do not have preferred directions of response, e.g. flagpoles and circular tanks, have been classified as *azimuth-independent* structures.

In the present study, we have evaluated the influence of ground motion directionality on the nonlinear dynamic response of tall buildings. This article presents the influence of ground motion directionality for a case study building. The building has 44 storeys, and resembles the general features of the structural configuration commonly found in modern reinforced concrete tall buildings in Vancouver. The NRHA method was used to estimate seismic response of the building model to bi-directional ground shaking. The NRHA case study results were calculated using the program CANNY (Li, 2010).
In a parametric study that we conducted, horizontal ground motion pairs were systematically applied at different angles of incidence to the building model. The results for one pair of ground motions are presented in this article. For each pair, the numerous calculations were conducted and then compared to a reference response. The scenario for the reference response had the ground motion applied to the model with the as recorded-orientation matching the principal axes of the building, an approach that is typically preferred by practicing engineers.

CASE STUDY

The 44 storey building used in the case study was designed in accordance to the 1995 NBCC. The design of the reinforced concrete elements and components was carried out according to the CSA A23.3 (1994). The building tower is for residential occupancy, which is part of a complex that comprises a residential tower and a hotel tower. The residential tower plan layout is non-symmetrical and the columns are arranged in a non-rectangular grid. The plan average dimensions are 25m and 31m along east-west and north-south. Elevation layouts along two perpendicular orientations and a 3D view of the typical plan layout are shown in Figure 1.

A thorough description of the mathematical building model, the ground motion selection and scaling can be found in the thesis of Archila (2011). The mathematical model was calibrated to a modal model developed through system identification using ambient vibration measurements of the actual building (Turek et. al., 2007). The gravity loading criteria was taken from the NBCC 2010 (NRC, 2010) and ATC 72-1 (PEER, 2010) for the NRHA. The natural periods of the building along east-west direction were computed as 4.27s, 0.96s, 0.44s for the first three modes, and 3.75s, 0.85s and 0.35s along the north-south direction.

The seed pair of ground motion records that we are presenting here was selected from the suite of records obtained during the magnitude Mw 7.1, 1989 Loma Prieta earthquake in California. This event was due to a reverse faulting mechanism at a shallow depth of 18 km. The records were retrieved from the PEER Strong Motion Database (PEER, 2010) and correspond to the CDMG 58065 Saratoga Aloha Ave Station (NGA 0802) station located close to the rupture of the fault, at a distance R_{rup} of 8.5km. The site shear wave velocity, V_{s30}, was determined to be of 370 m/s.

In the present case study the two orthogonal horizontal components of the recorded ground motions were applied along the structural axes of the building first. This corresponded to an angle of incidence of the ground motions of zero degrees. Then, the records were rotated a prescribed angle of incidence, and the resulting rotated records were again applied along the structural axes of the building. The operation was repeated several times, and for each rotated set of motions, the response of the building (displacements, interstorey drift, shears and moments, etc.) was saved in a database for further analysis. The angle of incidence of the ground motions was varied from 0 to 360 degrees. Figure 2 illustrates how the response spectrum for one of the components of the input motions varies as a function of the angle of incidence. In this figure, the spectra for the EW component for incident angles of 0° and 90° are presented. For reference, the first three natural mode periods of the building model along east-west are shown by the dashed vertical lines in this figure.

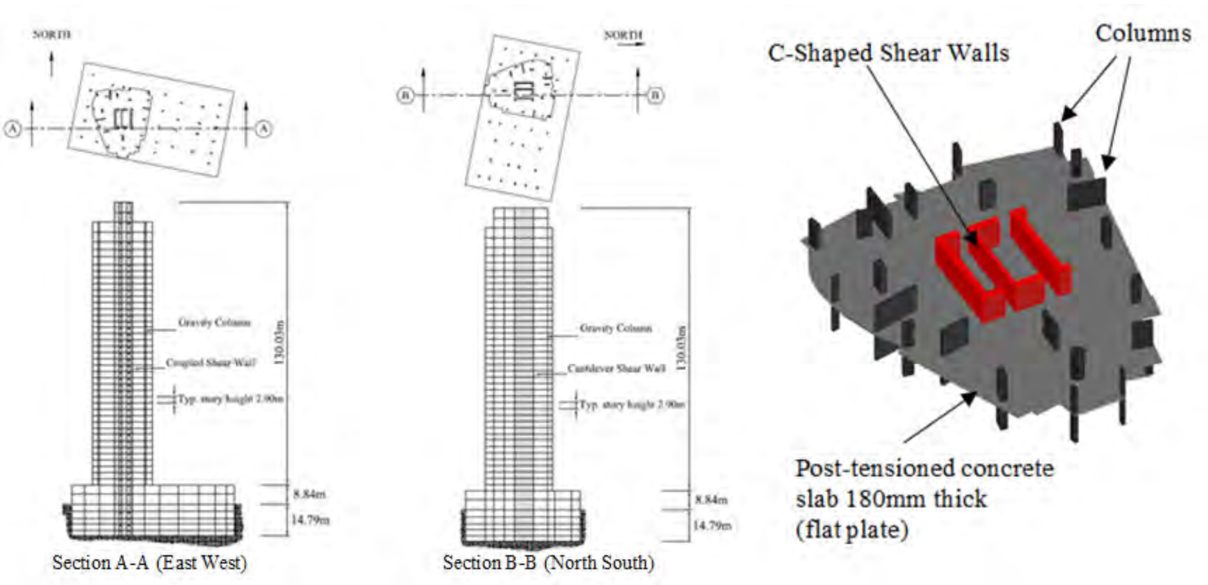


Figure 1. Building plan layouts/sections and 3D view of typical floor layout.

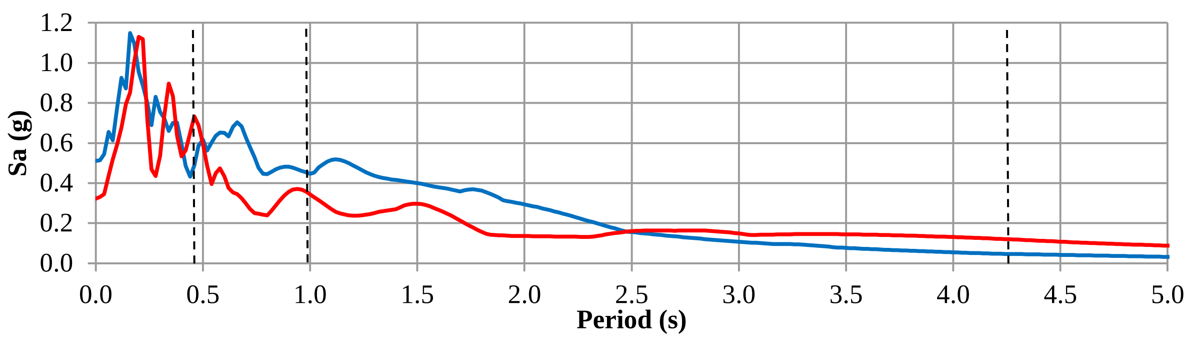


Figure 2. Acceleration Response Spectra for the EW component of the Loma Prieta ***(NGA 0802) record (5% damping). Blue line – 0° angle of incidence; Red line – 90° angle of incidence***

An interesting aspect of this set of records is that the directionality of the ground shaking is well defined and does not change much during the duration of the shaking. Figure 3 shows the planar motion at the site (called particle motion). From this it can be observed that the directionality of the displacement of the ground is mainly along the direction of component 2 of the motion, so one could say that only one component dominates the ground motion, but it is not possible to confirm that that this component will result in the largest response of the building. The question to be answered is: which direction of shaking produces the largest structural response?

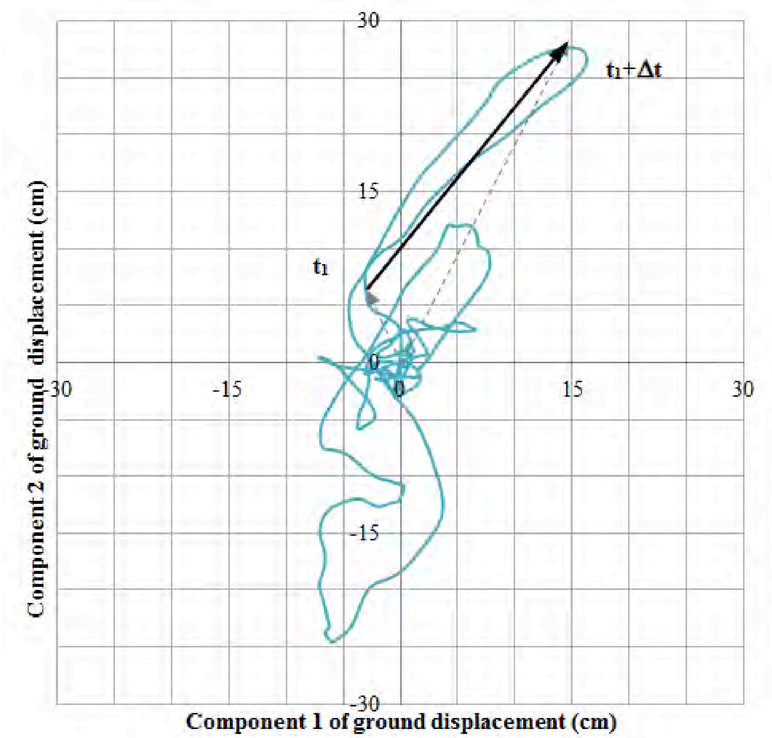


Figure 3. Loma Prieta (NGA 0802) record, horizontal particle motion.

RESULTS

The east-west floor displacement envelopes to the Loma Prieta input motions are presented in Figure 4. The envelopes correspond to scenarios of ground motion at various angles of incidence with respect to the main axes of the building, ranging from 0 to 360 degrees. The displacement envelope obtained when the input motion is applied at an angle of incidence of zero degrees is shown in blue colour. The displacement envelope with the ground motion rotated at a 90 degrees angle of incidence is shown in red colour. The remaining envelopes in grey colour correspond to other different angles of incidence.

For this case it is evident that using the as-recorded orientations of the ground motion, either at 0° or 90° does not suffice to estimate the response at the critical angle of incidence, that is, the angle of incidence at which the largest response of the building is obtained. The results clearly show that the common practice of conducting two different analyses, one with the input motions at an angle of incidence equal to 0° and the other with the input motions at an angle of incidence of 90° may result in unconservative estimates of displacement response of certain types of tall buildings.

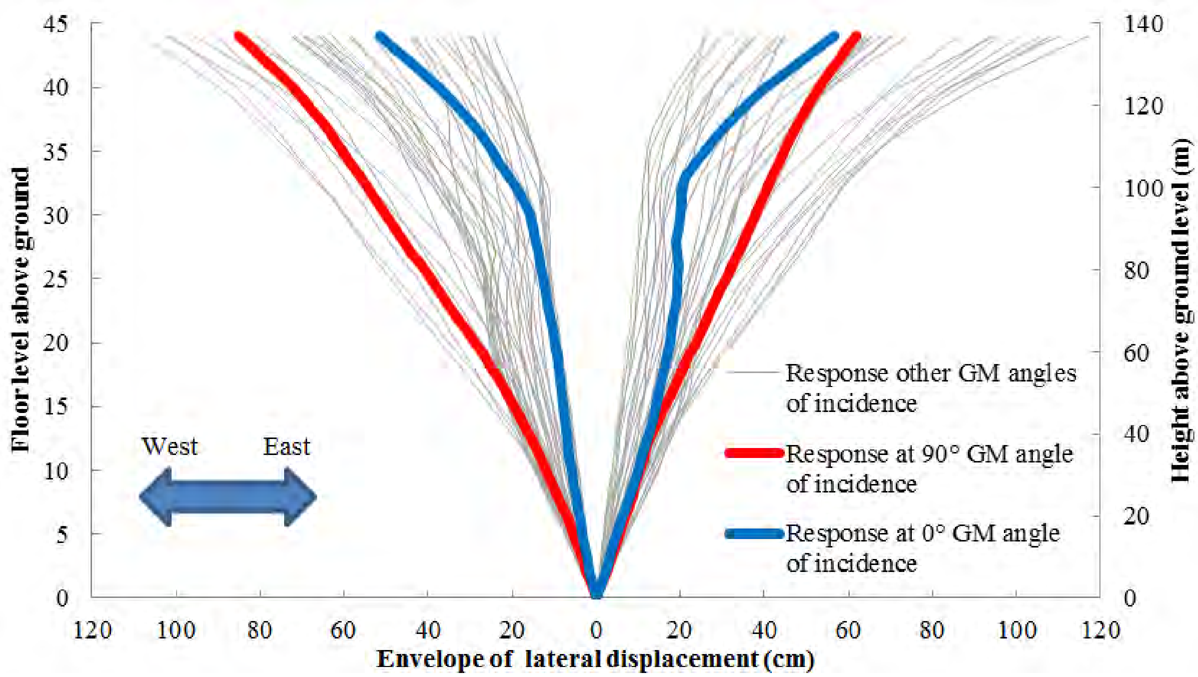


Figure 4. Envelopes of displacement response along east-west direction.

DISCUSSION

The response spectra for 0° and 90° components of input ground motion show clear differences in their frequency content, which are reflected in different dynamic responses of the building model along the East-West direction in Figure 4. The 90 degrees angle of incidence ground motion (east component) has more energy in the long period range (2.5s – 10s) than its counterpart; conversely the 0 degrees angle of incidence ground motion (east component) has more energy in the intermediate period range (0.7s – 2.5s). The 90 degrees angle of incidence ground motion would mainly excite the first mode at 4.27s whereas the 0 degree angle of incidence ground motion would mobilize higher modes.

This is confirmed in Figure 4 by the almost linear profile of the displacement envelope, the building model response under the 0 degrees angle of incidence ground motion exhibits a significant participation of higher modes. Therefore the widespread responses in the displacement can somehow justified by the differences in the frequency content of the input motions. An additional source of the variability of the estimates is the model inelastic response.

The widespread responses shown in Figure 4 indicate there is a critical angle of incidence where the displacement response can be significantly amplified. This amplification is better explained due to the presence of a strong velocity pulse along a range of orientations. The properties of such pulses are being studied to better assess the potential expected demands from near fault earthquakes on buildings.

ACKNOWLEDGEMENT

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Table 1 – List of notable shallow damaging earthquakes

Earthquake	Magnitude	Year
San Salvador	5.8	1986
Northridge	6.7	1994
Kobe	6.9	1995
Kocaeli	7.5	1999
Chi Chi	7.6	1999
Sichuan	7.4	2008
Darfield	7.1	2010
Christchurch	6.3	2011

Ask Dr. Sylvie

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Seminars

Engineering for Cold Regions (see end of newsletter for more information)
Date: November 29 & 30, 2013
Venue: Executive Hotel and Conference Centre, 4201 Lougheed Highway, Burnaby
Time: Friday: 8am – 5pm, Saturday 8am – 3pm
Presenters: John Zarling, William Nelson and Adrian Gygax.
Sponsor: Dow Building Solutions

Base Isolation
Date: January 22, 2014
Venue: UBC Robson Square, Room C300
Time: 6pm – 8pm
Presenter: Tony Yang, UBC

Lessons Learnt from the Christchurch Earthquake – a Personal Perspective
Date: February 24, 2014

Venue: TBD
Time: 6pm-9pm
Presenter: Dale Turkington

Events

SEABC Young Members Group Presentation Competition
So You Think You Can Give a Seminar?

Date : February 14, 2014
Time : 6pm – 9pm
Venue : TBD

SEABC Annual General Meeting and Dinner

Date: March 5, 2014
Presenter: Glen Bell
Venue: Versailles A, Sutton Place Hotel, Vancouver
Time: 5:30pm – 9pm

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Two-Day Short Course

ENGINEERING FOR COLD REGIONS

Date:	Friday November 29 and Saturday November 30, 2013
Venue:	Executive Suites Hotel & Conference Centre, 4201 Lougheed Hwy, Burnaby
Time:	Friday 8:00 a.m. - 5:00 p.m., Saturday 8:00 a.m. - 3:30 p.m. (Pacific Standard Time)
Presenters:	William G. Nelson, Ph.D., P.E., Professor Emeritus, University of Alaska Anchorage John P. Zarling, Ph.D., P.E., Professor Emeritus, University of Alaska Fairbanks Adrian Gygax, P.Eng., Struct.Eng., Principal, Gygax Engineering Associates Ltd.
Cost:	SEABC Members: $425 + GST SEABC Student Members: $250 + GST Non-Members: $500 + GST Live Webcast: Same rates as above
Registration:	www.seabc.ca/coldregions Registration deadline: Monday Nov 25

Also available by ***live webcast!***
Check SEABC website for details:
www.seabc.ca/coldregions

During this two-day short course, participants will explore the challenges of cold regions engineering and solutions for technical problems related to cold weather, snow and ice. Consider foundation and building designs for arctic regions. Learn about snow control, ice growth on water surfaces, ice mechanics and the physical and thermal properties of frozen ground. Study the effects low temperatures have on construction materials and personnel.

This course contains material from the University of Washington's 5-day course, condensing the geotechnical and structural aspects into a 2-day program.

Dr. Nelson earned his B.S. and Ph.D. in Mechanical Engineering at Oregon State University. He was employed by EXXON as a production engineer and taught and conducted research at the University of Alaska Anchorage from 1972 until 1998. He presently consults and conducts research in areas related to arctic engineering. He has conducted extensive research in the areas of ice and snow engineering and recovery of spilled oil from ice infested waters.

Dr. Zarling earned his B.S., M.S. and Ph.D. in Mechanical Engineering from Michigan Technological University. He was a professor at the University of Wisconsin for six years prior to joining the faculty of the University of Alaska Fairbanks in 1976. During his 23 years at UAF he taught, served as an administrator and conducted research in areas of arctic engineering and heat transfer. After his retirement from UAF he developed an active engineering consulting practice, Zarling Aero and Engineering, with numerous clients such as Alyeska Pipeline Service Co., Michael Baker, CH2M-Hill, ConocoPhillips, and CRREL. Dr. Zarling has taught the Cold Regions Engineering short course since 1978 at the University of Washington and continues to teach UAF's semester arctic engineering course.

Adrian Gygax has over 30 years of structural and foundation engineering experience, including 15 years with a large Swiss-based international engineering firm. Since 1997, Adrian has been the principal of GEA. Adrian's professional experience has included major urban infrastructure facilities, municipal water supply projects, hydro-electric and thermal power projects, large urban rail projects as well as industrial plants such as cement terminals, clinker plants and weaving mills. Since forming GEA, Adrian has provided high-grade senior engineering services for public and private-sector clients in Canada's arctic.