ADVANTAGE STEEL

NO. 56 FALL 2016

HEADS IN THE "CLOUD" AT YORK UNIVERSITY'S BERGERON CENTRE

+ PORT MANN BRIDGE DECONSTRUCTION

FIRE AS A LOAD CASE IN BIM

CISC DONOR DIRECTED SCHOLARSHIPS

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CANADIAN INSTITUTE OF STEEL CONSTRUCTION

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ADVANTAGE STEEL

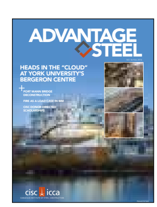
NO 56 FALL 2016

FEATURES

IN EVERY ISSUE

COLUMNS

Professional engineers, architects, structural steel fabricators and others interested in steel construction are invited to inquire about CISC membership. Readers are encouraged to submit their interesting steel construction projects for consideration for inclusion in this publication by contacting CISC.



On the Cover: York University's Bergeron Centre for Excellence

Engineering Consultants – Are you ready for the squeeze play?

Ed Whalen, P.Eng.
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/cisc_icca

I SPOKE SOME TIME ago on the state of the union as it relates to the quality, or lack thereof, of consultant drawings and documents. What may surprise you is this issue (it is bad and getting worse) is global and seems to be an issue for all trades. The Canadian Construction Association (CCA), over the past year or so, held a number of workshops across the country to assess why this is happening in Canada. CCA seems happy to stop at identifying the problem and failed to propose solutions. So the world will go on with excuses such as those below. Their findings were as follows:

- Lack of final coordination, checking and proofreading
- Insufficient time for design
- Lack of coordination between architects and engineers
- Owners' (unnecessary) pressure
- Insufficient fee/design contingency

I believe there are number of other factors not identified such as:

- Overuse of standard sections that are not applicable in all cases
- Lack/void of experienced middle managers in consultant companies
- Consultant industry consolidation and effect on management
- Use of computer programs resulting in operators rather than draftspeople
- Serious cost penalties (or the lack of to date) to consultants for non-conforming drawings

I can't speak for other trades and their related construction standards but incomplete structural design drawings and documents can be considered non-compliant documents as per CSA S16. CSA S16-14 Design of Steel Structures (as well as previous versions) clause 4.2 mandates the minimum requirements in the structural design documents using "shall" language. Clause 4.2.1 states that "design documents show a complete design with members suitably designed and located, including such dimensions and details necessary to permit the preparation of the fabrication and erection documents." Clause 4.2.2 requires with a "shall" a whole list of items to be included in the structural design documents such as: snow, wind, seismic, deal, live, superimposed and special loads. It also mandates that connection shears, moments, axial forces, and torsions be included among others.

CSA S16 Section 4.2 Structural design documents is not just a nice to do but a must. This section should be a mandatory read for all beginner engineers and a reread for all experienced ones. If engineers followed this section more religiously the complaints about drawings would go away. Failure to comply with this section may put yourself, your company and the owner in the role of the defendant in a serious claim. If owners are truly the problem, it is your responsibility to explain the bigger risk and cost of speedy incomplete drawings.

Another important document that has also been recently updated, that all structural consultants, architects, owners and contractors should be aware of, is the CISC Code of Standard Practice. Originally published in 1958, and updated in 2015, it defines standard industry practices relating to design, fabrication and erection of structural steel.

To date the lack of financial penalties/ramifications directly to consultants for incomplete drawings has allowed the quality to drop to a state where now the entire construction industry seems to be gearing up for legal retaliation. This has to be stopped for the benefit of everyone including you and the owner. There is one group that is rubbing its hands and anticipating this

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possible litigious future, and surprise surprise, they are the same group that benefit from payment conflict and are dead against Prompt Payment legislation. I will leave it to you to guess who they may be. So let's all work together to understand what's needed and educate the people that need to be educated to change the future. Don't assume that because you got away with it in the past you will be able to do so in the future.

So you ignore my warning and you find yourself in court. You can try using the excuses listed above but now knowing that you have prescriptive mandatory requirements in CSA S16 you can easily determine the percentage of success. But if you do indeed fair badly in the claim, I'm sure the owner will be there right beside you to support your loss? Right? AS

CISC provides this column as a part of its commitment to the education of those interested in the use of steel in construction. Neither CISC nor the author assumes responsibility for errors or oversights resulting from the use of the information contained herein. Suggested solutions may not necessarily apply to a particular structure or application, and are not intended to replace the expertise of a professional engineer, architect or other licensed professional.

Alfred F. Wong, P.Eng., FCSCE
Director of Engineering

Question 1: As I understand, sheet steel floor deck running perpendicular to a beam and welded to its top flange provides full lateral support to the beam. What if the deck runs parallel to the beam?

Answer: Clause 9 of CSA S16-14 covers lateral support requirements to prevent lateral-torsional buckling of beams. When the top flange is braced uniformly along its length the required lateral brace force, in accordance with Clause 9.2.7, shall be at least 0.05 times the maximum force in the flange unless a lesser amount can be justified by analysis.

Sheet steel deck running with the deck ribs parallel with the beam lacks the strength and stiffness required for effective lateral support. Once the concrete attains its strength, the deck-slab is considerably stronger and stiffer than the bare deck. The beam, however, usually serves as a girder supporting secondary beams that typically frame into this girder and brace it at these discrete points (see Clauses 9.2.5 and 9.2.6 of S16-14).

Question 2: Must the compression flange of beams be braced directly to prevent lateral-torsional buckling?

Answer: For unbraced I-shaped beams, the centre of twist of the buckled shape lies on the tension side of the neutral axis, as shown in Figure 1. Bracing the centre is ineffective. Conversely, direct bracing of the compression flange, which is farthest from the centre of twist, is most effective. In practice, the lateral supports are typically provided to either the compression flange or the web near it. Figure 2 shows a common example where the braces (beams) are connected to the web.

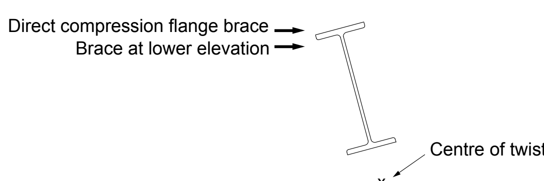


FIGURE 1: Flexural-torsional buckling

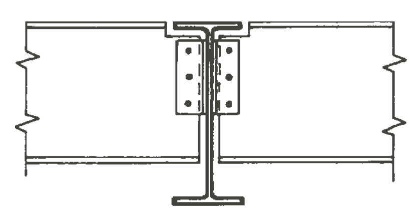


FIGURE 2: Braces connected to girder web near compression flange

Question 3: When I use *conventional construction*, must the high-strength bolts in the *seismic force-resisting system* be pretensioned?

Answer: Bolts used in *conventional construction* (R_d = 1.5) generally need not be *pretensioned* (i.e. *snug tight*). There is an exception where $I_E F_a S_a(0.2) \geq 0.35$ and the height of *conventional construction* exceeds 15 metres. In this case, Clause 27.11.3.e) of CSA Standard S16-14 invokes Clause 27.1.6, which calls for *pretensioned* bolts.

Question 3: When *long slotted holes* are used in *bearing-type* connections in double shear in accordance with Sub-Clause 22.3.5.2 c) ii) of S16-14, should the long slots in the outer plies of the joints be covered with plate washers?

Answer: Yes, a continuous bar not less than 8 mm in thickness or structural plate washers should be used to completely cover long slots that are in the outer plies of joints after installation. Requirements for plate washers and bars are waived for joints having long slotted holes in the inner ply only. AS

Questions on various aspects of design and construction of steel buildings and bridges are welcome. They may be submitted via email to info@cisc-icca.ca. CISC receives and attends to a large volume of inquiries; only a selected few are published in this column.

Demand Critical Welds

Alfred F. Wong, P.Eng., FCSCE
Director of Engineering

IN COMPLIANCE WITH capacity-based design, certain elements in steel structures are proportioned and detailed to endure stable inelastic cyclic deformation when subjected to the design ground motions. When these elements include welded joints, the performance of these welded joints is critical. In CSA S16-14, *demand-critical welds* are designated for specific welded joints in varies types of *seismic force-resisting system*. As a measure against brittle fracture, the weld filler metals are required to comply with a more stringent minimum notch-toughness requirement. This requirement applies where the specified short period *spectral acceleration ratios*, $I_E F_s S_a(0.2)$, is greater than 0.35.

Annex L of S16-14 provides general guidance for design to prevent brittle fracture. This article focuses on the designation of *demand-critical welds* and notch-toughness requirements for weld metals used in these welds. It should be noted that other factors contribute to brittle fracture. Moreover, brittle fracture resistance of welded joints also depends on proper welding and adequate design of the welded joints, etc.

NOTCH TOUGHNESS OF WELD FILLER METALS

Loading rate, service temperature and material notch-toughness are some of the factors contributing to the potential of brittle fracture. Notch-toughness of weld metals is a measure of their ability to absorb energy in the presence of a flaw. Typically, the absorb energy level increases with increase in temperature but decreases with increase in loading rate. The standard specimens used in the Charpy V-notch impact tests are small bars that measure 55 mm by 10 mm by 10 mm and feature a v-shaped notch (see Figure 1). These specimens are machined from the 'test assembly' representing a standard welded joint (see Figure 2). In the test, each notched specimen is broken by a single blow of a freely swinging pendulum released from a fixed height (Figure 3). The Charpy impact machine registers the energy absorbed in breaking the specimen.

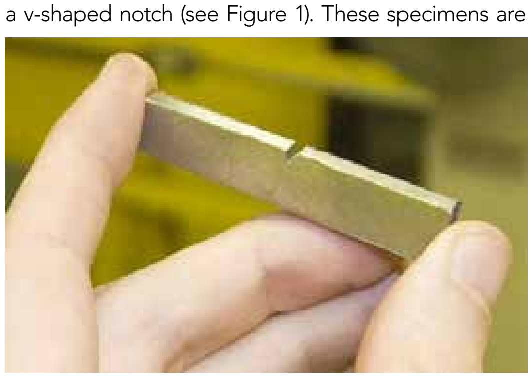


FIGURE 1: Charpy test specimen (subsize steel specimen shown)

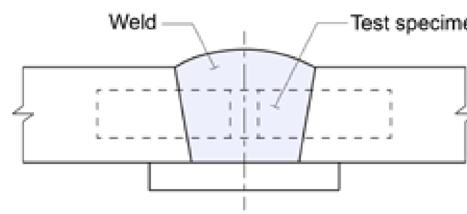


FIGURE 2: Charpy V-Notch Impact Test Speciment for Weld Metal (For detail information, see CSA W48-14)

FIGURE 3: Charpy impact machine

> "More stringent test conditions should be considered when more critical service temperatures are expected."

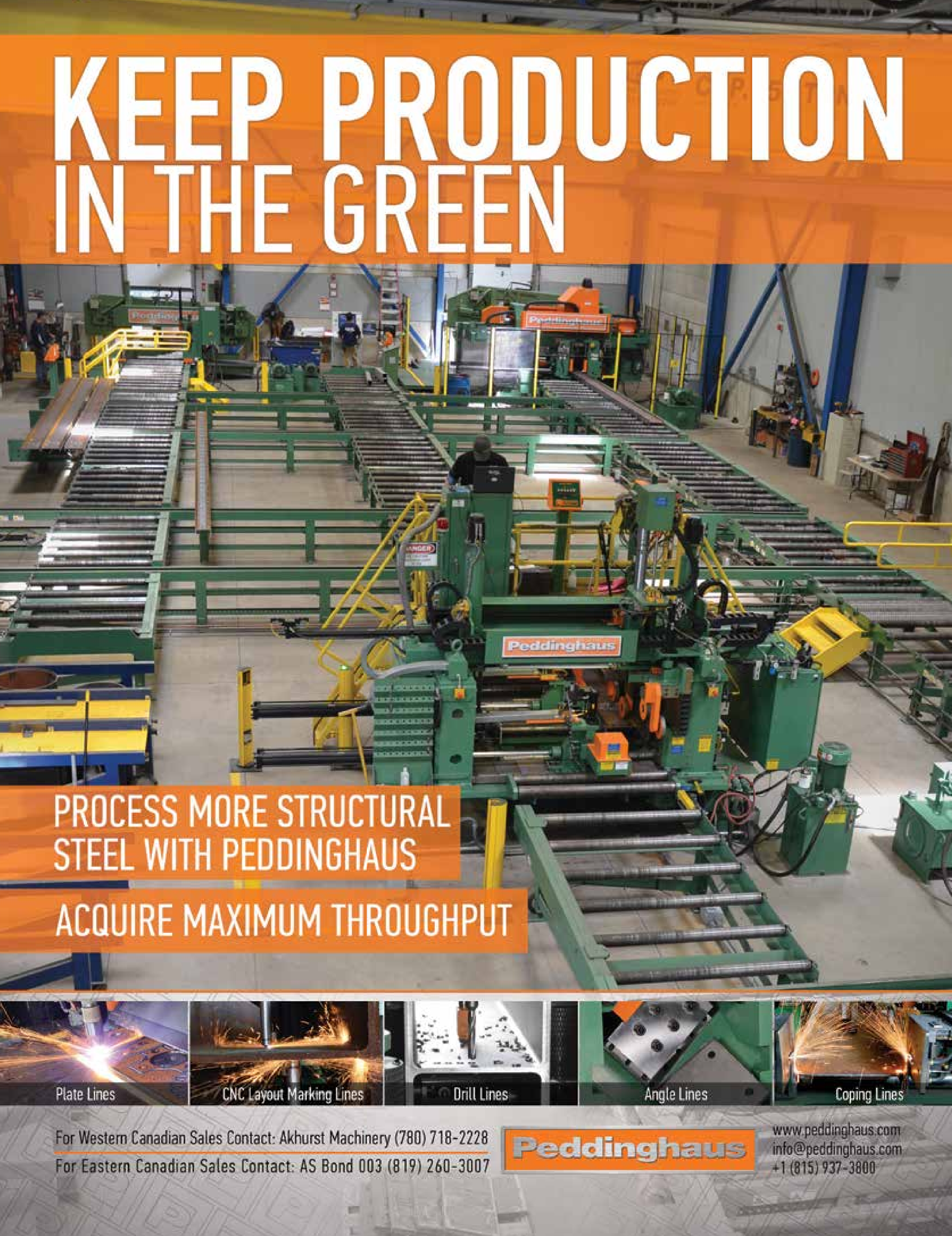
TEST TEMPERATURE VS. SERVICE TEMPERATURE

Ideally, the test temperature and loading rate reflect the conditions that the structure is designed to withstand. But this is not the case as the specimens are subjected to a more severe loading rate in the Charpy impact tests. S16-14 has adopted a 10 °C 'temperature shift' adjustment to account for the difference in loading rates. Accordingly, weld metals used for *demand-critical welds* in clad and heated structures, where the service temperatures seldom drop below +10°C, are required to meet a minimum average Charpy V-notch impact test value of 54 J at +20°C. For structures that are exposed to temperatures lower than +10 °C in service, the maximum testing temperature is 20 °C above the 2.5% January design temperature as defined in the *NBCC*. In these cases, the point-in-time service temperature is taken to be 10°C above the said 2.5% January design temperature. More stringent test conditions should be considered when more critical service temperatures are expected. For example, for a cold storage structure whose service temperatures are lower than the above-mentioned point-in-time temperature, the minimum test temperature should be lower, i.e. 10 °C above its service temperature.

Demand critical welds include:

a) groove welds in column splices;
b) welds at column-to-base plate connections when plastic hinging or net section fracture in tension is expected at the column bases;
c) except when Item e) applies, complete joint penetration groove welds joining beam flanges and beam webs to columns in moment connections for *Type D and MD moment-resisting frames;*
d) except when Item e) applies, complete joint penetration groove welds joining beam flanges to columns in moment connections for *Type LD moment-resisting frames and Type D plate walls*;
e) when moment connections are designed in accordance with the CISC *Moment Connections for Seismic Applications*, all demand critical welds designated therein;
f) welds joining link beam flanges and webs to columns in *Type D eccentrically braced frames*;
g) welds joining webs and flanges in built-up tubular link beams in *Type D eccentrically braced frames*; and
h) welds joining infill plates to perimeter frame members in *Type D plate walls*.

The requirements of this Clause may be waived when *IEFaSa(0.2)* is less than or equal to 0.55 and the welds are loaded primarily in shear.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Director of Marketing, Communications, and Membership Services

Health Product Declarations

Architects, specifiers, and designers continue to demand greater information and transparency about the environmental and health effects of building materials used in construction projects in an effort to truly capture life cycle impacts on the surrounding environment and on the wellbeing of the building's occupants.

This has led to accelerating effort by the industry – from rating system providers to environmental consultants and, of course, product manufacturers – to develop standardized reporting frameworks to address these market needs.

Examples of these standardized reporting documents include Environmental Product Declarations (EPD)s and the WELL Building standard that we covered in past issues. In this issue, I would like to introduce Health Product Declarations (HPD)s.

The Health Product Declaration (HPD) Open standard is a standardized product transparency reporting tool that identifies the materials or ingredients in a building product and the associated health effects. The HPD framework was developed by the HPD Collaborative, a partnership of various organizations that are committed to promoting transparency, openness and innovation in the practices of reporting, disclosure, specification and selection of building products.

HEALTH PRODUCT DECLARATION (HPD)

The Health Product Declaration (HPD) Open Standard discloses product contents and potential associated human and environmental health hazards. Hazard associations are derived from the HPD Priority Hazard Lists, the GreenScreen List Translator, and full GreenScreen assessments. In order to develop an HPD, disclosure must be made of both the product's material contents as well as the itemized chemical substances contained within each material.

The unified and standardized format of the HPD Open Standard allows for clear communication between all stakeholders and supports a variety other industry standards and rating systems such as LEED. It also provides flexibility to address any disclosure limitations such as intellectual property and trademark concerns, technical capacity, and supply chain communication gaps. As a result, HPDs can be applied for many different purposes such as rating system reporting, red-list compliance, product certification, manufacturing standards, supply chain management, and purchasing protocols.

HPD DEVELOPMENT PROCESS

The HPD Collaborative™ has outlined several steps to create a Health Product Declaration.

INVENTORY - Collect the documentation and list product contents.

ASSESS - Review contents against authoritative chemical Hazard Lists.

COMPLIANCE - Provide the details of product testing and compliance.

ACCESSORIES - Note installation/ maintenance/cleaning/operations materials.

SUMMARIZE - Confirm the summary page, fill in explanatory notes and release date.

The HPD development process helps building product manufacturers identify all of the players in their manufacturing process, often times vendors and suppliers up the supply chain so far that they are unaware of them.

LEED CREDITS

The HPD plays a significant role in the new LEED v4 green building rating system. Building product manufacturers have several new opportunities to get specified by contributing more points on projects under LEED v4. The life-cycle approach to Materials and Resources credits in LEED offer incentives for project teams to specify products from manufacturers that provide full transparency of their product's environmental performance.

Building product manufacturers can contribute up to 2 points under the LEED credit Building Product Disclosure and Optimization - material ingredients. The LEED credit states that projects must use at least 20 different permanently installed products from at least five different manufacturers that use the HPD. Both versions of HPD 1.0 and 2.0 can be used to achieve this credit.

The Health Product Declaration (HPD) is an example of the evolution of the green building industry to a true holistic life cycle based reporting framework starting with capturing the impact of building materials in their manufacturing stage (EPDs), insights into potential health hazards in material and chemical composition, and finally any potential impacts from the building material during the operational use phase of the building's life cycle. AS

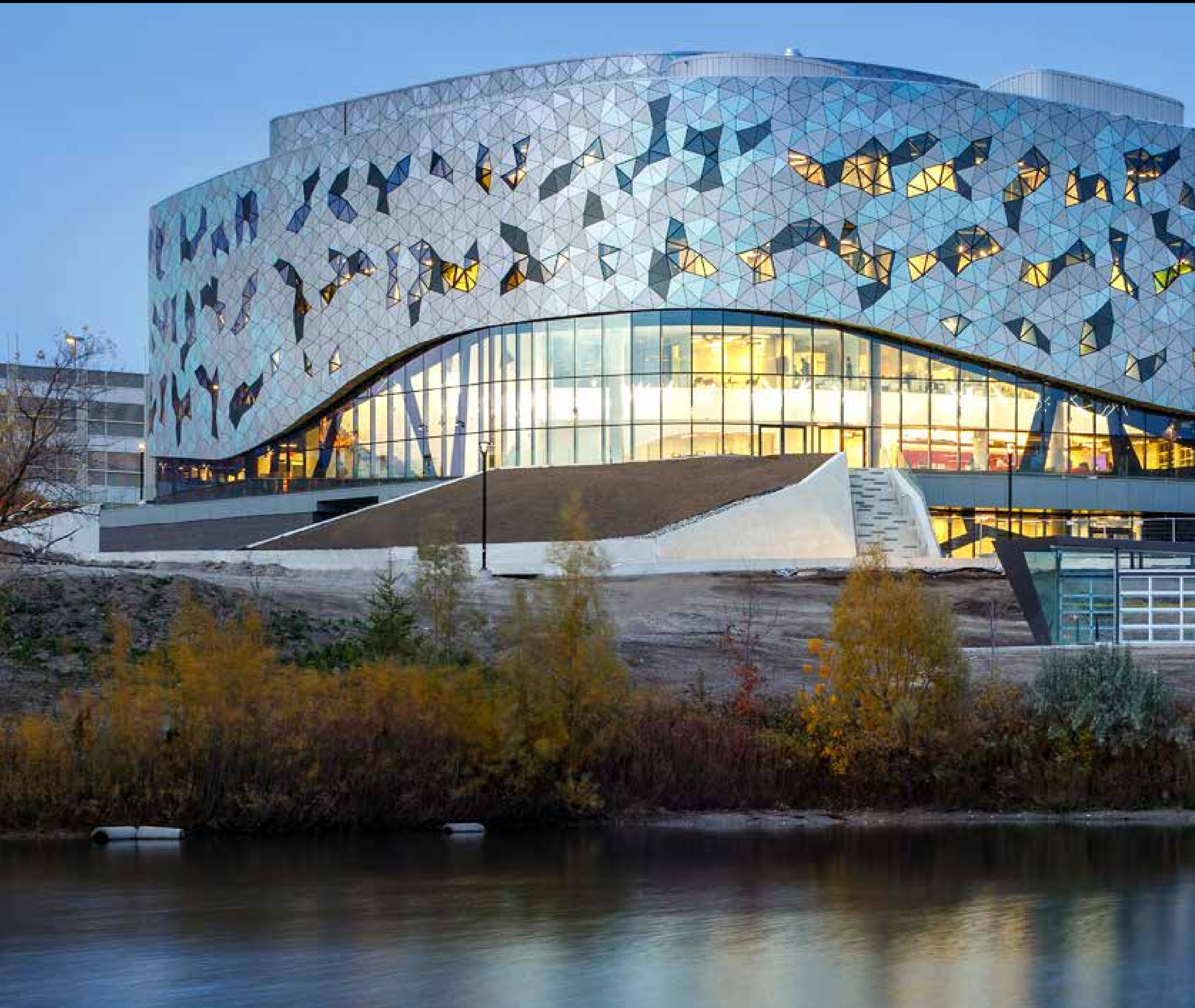
Source: Health Product Declaration Collaborative (www.hpd-collaborative.org)

FEATURE

YORK UNIVERSITY'S BER FOR ENGINEERING EXCEL

Steel façade and elements brings innovation to Toronto campus

Matthew Bradford



GERON CENTRE
LENCE

YORK UNIVERSITY HAS steel innovation to thank for adding the Bergeron Centre for Engineering Excellence (BCEE) to its Lassonde School of Engineering.

Opened in September 2015, the 170,000 sq. ft., five-storey facility features active learning classrooms, various labs, study spaces, and offices designed by ZAS Architects + Interiors (in collaboration with Arup Engineering and Scott Torrance Landscape Architect Inc.) to house four undergraduate engineering programs and inspire tomorrow's engineering leaders.

While there are several innovative engineering feats incorporated into the building's design, its standout feature is the stunning steel facade and structural highlights that make it a one-of-a-kind facility at the Toronto-based campus.

"This unique building voices an ambitious mandate: to create the home of the Renaissance engineer where students are free to explore their passions and gain different perspectives from the world around them," says Paul Stevens, Senior Principal with ZAS Architects + Interiors. "The shimmering 'cloud' facade is an architectural metaphor for this mandate - supporting and inspiring limitless blue sky thinking, reflective of Renaissance principles of innovation and breaking from convention."

Norak detailed, fabricated, and installed 165 unique steel frames to create the facade's secondary framing system assembly that frames the envelope of the building, forms the contours of the parapet and soffit, and houses the "cloud"-like facade's exposed windows. Originally, the system was to be constructed with metal stud, but the weight of the windows, and logistical requirements led the construction team (helmed by Laing O'Rourke in association with Gillam Group) to work with structural steel instead.

Steel also made it easier to craft the facade's complex "cloud" geometry (rationalized by MESH Consulting). And since the steel components could be fabricated offsite, crews were able to move forward with their work on York University's campus while they were being prepared.

"The facade's geometric complexity created a lot of anxiousness and uncertainty in the early design stages, and it was also paramount that the envelope installation schedule be met without delay," says Stevens. "To achieve this, we created a separate BIM model with a high degree of detail and technical resolution. This allowed the façade steel fabricator and various envelope trades to successfully advance their own fabrication models and share important information such as tolerances and set-out points with each other. The result was a very rapid and accurate install process that could only be achieved using steel."

Moreover, adds Gillam Group Project Coordinator Rylee Mitchell, steel was key in constructing a rainscreen system of 8000

"The structure is unique in every way; not just in how it was constructed, but in how it intends to nurture and shift the approach to engineering education."

Anthony Ober, Vice President of Norak Steel Construction

"The Bergeron Centre for Engineering Excellence is a truly forward - looking, uniquely designed facility that will offer our engineering students unsurpassed experiential learning opportunities. The centre is an exciting addition to campus life at York—one that will give our students a distinct advantage through access to flexible, collaborative learning spaces and research labs."

Mamdouh Shoukri, President and Vice-Chancellor, York University

aluminum panels around the round base structure within schedule and budget. "A network of 80 SFS steel frames was installed around the entire building, from slab to slab. This enabled the waterproofing to continue and the irregular windows to be framed out integrally as well, pushing both the schedule and the constructability."

Among the centre's development team was Base Line Drafting (BLD) Services Inc., who worked with Norak Steel in detailing the steel supporting the cladding and glazing, which enabled the building to be closed before the onset of winter conditions.

According to Boris Shtulberg, Senior Project Manager of BLD Services Inc., the unique geometry of the facade and the triangle-shaped window patterns required a calculated approach. "The walls were on radius, the cladding and glazing were facetted, and all windows were a different size and shape. In order to be successful with this project, we created a model using SDS/2 to ensure our geometry closed and CNC files for fabrication could be provided."

Beyond bringing ZAS Architects vision to life, steel played a major role in reinforcing BCEE's structure. Its High Bay Structural Lab includes several steel components, such as composite columns embedded along two elevations to facilitate a double-height space; two 32,000 lbs transfer trusses spanning the ceiling to support the installation and usage of a 13.5 tonne gantry crane; and the 537-metre tie-down assemblies that penetrate the full depth of the High Bay slab for the hydraulic testing of equipment and concrete components.

"Unlike other engineering schools, the Bergeron Centre's High Bay is located centrally within the building's footprint. Designed as a 'building within a building', the rest of Bergeron is protected from the vibration, noise and dust inherent to this unique raw space," notes Stevens.

Elsewhere, the Bergeron Centre's main stair – an interior focal point – was fabricated almost exclusively of triangular tack-welded steel plates and posts, and engineered stone treads.

"Both the feature stair and the façade standout quite prominently," notes Mitchell, adding, "The 'cloud' can be seen from the long drive around The Pond Road and truly embodies the spirit of both the design and construction of the BCEE."

Benson Steel Limited was also critical to the team, contributing major structural steel components for the project's lab assemblies, framing of the penthouse systems, and cast-in-place services for multiple trades across the project. Reflecting on the project's importance, Benson's President & CEO Stephen Benson notes, "York University is going to represent an iconic shift in how engineering is viewed in both Canada and the world over the next

few years. The Renaissance engineer is exactly what we need to be supporting, and giving equal access and opportunities for male and female engineers is absolutely what we need to be doing to empower both to succeed in any environment."

INSPIRED SOLUTIONS

The Bergeron Centre's lofty design presented crews with unique – yet welcome – challenges. First and foremost, the team faced a tight development schedule that required the facade to be installed quickly for weatherproofing and to support work on its interior. To accomplish this, a full-time OLS was installed onsite to plot the locations of approximately 850 perimeter embeds to which the SFS steel façade frames would be connected.

"Once the framing was complete and DensGlass installed, it then became just as important to ensure the triangular panel system would fit as designed," explains Mitchell. "LiDAR technology was utilized to shoot over one billion points around the building so that the sub-girt system would receive each aluminum triangle without error."

Fabricating the steel frames to fit the centre's shape also put crews through their paces. Notes Anthony Ober, Vice President of Norak Steel Construction Ltd., "This was unlike anything we had come across in the past, and required a great deal of creative thinking, whilst trying to quantify the unknown. For starters, the main structure has a footprint that is neither round or square. Instead, there are curvatures of multiple radii, paired with relatively straight sections. The primary challenge was to follow the curvature of the edge of slab with straight sections of steel. In other words, make straight steel follow a rounded profile, and keep the geometry of both the existing slab and the frames Norak fabricated copacetic."

Rolling the HSS was not a viable option given the wall thickness and scheduling factors. Therefore, the solution was to introduce short sections of straight HSS, known as "cranks", which were mitred and butt-welded to create an assembly that would fit with the perimeter's flow. This assembly was then segmented into individual frames, which were further grouped into sequences of six per floor, over 5 levels, with 3-8 frames comprising a single sequence.

No two windows in the triangular-shaped design were alike, increasing the level of workmanship for the steel components that framed them. The project required significantly low tolerances with a point-to-point tolerance of only +/-5mm, over spans of many metres.

For example, notes Ober, "If there was a given measurement of 4683mm between a certain node on one window and a separate node on another window, we could only afford a variance of +/-5mm. Over numerous visits to Norak by Blackwell Engineering, specifically by Shannon Hilchie, the Engineer of Record, countless windows were measured, and only three windows were found to be slightly off. The frames associated were brought back into our shop, reworked, verified as correct, and released to site."

Complex as it may have been, the team's hard work has not gone unnoticed. In addition to receiving accolades from York University staff and students, the Bergeron Centre received an award in the 2015 CISC Ontario Steel Design Awards' "Projects Converted to Steel" category,

"Within this cutting-edge new learning space, York is advancing an innovative curriculum that is giving students access not only to training across a variety of engineering disciplines, but also to a number of critical skills employers are looking for like entrepreneurship, collaboration, and creativity."

Reza Moridi, Minister of Training, Colleges and Universities

turning a well-deserved spotlight on Norak Steel Construction and its sub-contractors, Stampa Steel and BaseLine Drafting.

"The unique nature of design meant this was not a typical structural steel project. It required a solid team effort from all parties concerned," says Shtulberg, adding, "This centre deserves recognition as an innovative and forward-looking institution."

For its part, Ober says Norak Steel is also very grateful to the Bergeron Centre team for the experience and for their collaborative efforts: "We are very proud to have been a part of the process, and thankful for the opportunity. We believe the Bergeron Centre will foster a new generation of engineers – ones that understand that anything is possible if you dare to dream it." AS

PROJECT TEAM

OWNER: YORK UNIVERSITY **ARCHITECT:** ZAS ARCHITECTS + INTERIORS **STRUCTURAL ENGINEER:** BLACKWELL (SECONDARY STEEL FAÇADE) **PROJECT MANAGER / GENERAL CONTRACTOR:** LAING O'ROURKE CANADA INC. **FABRICATORS:** NORAK STEEL CONSTRUCTION LTD. (FAÇADE AND PERIMETER STEEL), BENSON STEEL LIMITED (INTERIOR AND PENTHOUSE STEEL) **DETAILER:** BASE LINE DRAFTING INC. (FAÇADE) **ERECTOR:** STAMPA STEEL ERECTORS LTD. (FAÇADE)

FEATURE

THE PORT MANN BRIDGE

A demonstration of excellence in reverse erection engineering

Raj Singh, P.Eng, PE, Bridge Market Sector Lead

DECONSTRUCTION

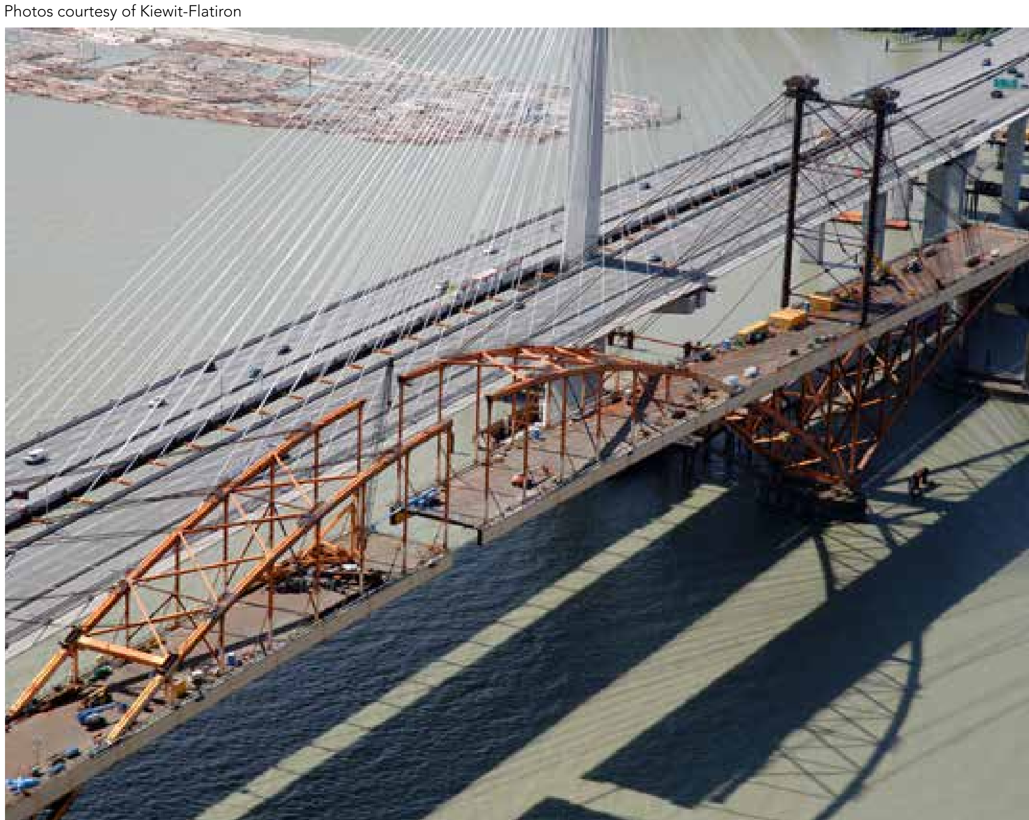
IN 2012, THE GOVERNMENT of British Columbia completed the massive upgrade of Highway 1 east of Vancouver, including the construction of the new, 10-lane Port Mann Bridge over the Fraser River. As part of this landmark project, the old Port Mann Bridge—which formerly carried the highway for 50 years— needed to be removed primarily due to maintenance costs and seismic deficiencies.

Most river bridges are simply demolished with explosives when it comes time for decommissioning. However, the presence of lead-based paint and asbestos in the bridge presented a risk to the fish habitats in the Fraser River. Additionally, close proximity to the new bridge (a mere 25 metres away) required that the old bridge be removed in a highly controlled manner.

The BC Ministry of Transportation and Infrastructure contracted with the Connect BC Development Group (CBCDG) for the project. CBCDG's contractor, the Kiewit-Flatiron Joint Venture, needed to execute the deconstruction to a tightly planned schedule to control costs. The McElhanney team was retained as the lead construction engineer in late 2012 for the controlled removal of the old bridge.

Because of the precise control required, the team determined that the best way to remove the bridge was to reverse the erection process followed in 1954, by removing the bridge piece by piece. This involved the use of a cable-stayed system that essentially converted the tied-arch into a cantilever system and allowed for progressive removal. However, several changes, including an expanded railway yard underneath

Photos courtesy of Kiewit-Flatiron



"The steel design was easier to remove compared to a concrete structure that would have significantly increased the project cost and duration."

the south side span, introduced new and significant challenges.

After five decades of fatigue stressing, corrosion, and various modifications on the old bridge, it was difficult to accurately predict what stresses might be released by cutting into the structure. The removal procedures also needed to ensure continued access through the river's shipping channel and the railway tracks below the south side during the entire deconstruction process.

In relative terms, the steel design was easier to remove compared to a concrete structure that would have significantly increased the project cost and duration. The steel pieces that were removed in chunks were also lighter and much easier to cut in mid-air, which meant the components could be removed in longer lengths than concrete pieces, minimizing interference with the environment.

THE BRIDGE AS A HOUSE OF CARDS

During the process to develop the detailed plan for deconstruction, the team held discussions with the designer of the original bridge and studied archived erection plans such as temporary works, construction photos, design plans, and shop drawings. This allowed them to establish that the bridge and its components were configured for high-efficiency and minimal steel usage in the final constructed state of a continuously tied arch. However, the original design considered that prior to attaining full tied-arch action, the partially erected structure and its components would be extremely sensitive to construction stage demands for strength and stability. For example, the deck longitudinal tie-girders were proportioned as a tension tie with only local secondary flexural moments in the final state. This original design aspect presented the biggest engineering challenge in the deconstruction because the girders were subjected to compression forces from the temporary stay cables and to significant global flexural demands. In other words, the bridge in a cantilevered state was to behave akin to a "house of cards" that required precise control to maintain stability.

"This project presented a greater technical challenge than engineering a new cable-stayed bridge," says David Jeakle, PEng, PE, McElhanney's principal engineer on this project who has worked on the design of several cable-supported bridges throughout his career.

CONTROLLING THE HOUSE OF CARDS

McElhanney's plan required the stressing of temporary cables to transfer load from the arch

"McElhanney's plan required the stressing of temporary cables to transfer load from the arch system to the cable-stayed system."

system to the cable-stayed system. Given the sensitive nature of the structure and the number of re-stressing operations that would be required, a relatively extensive stressing system was used to allow for quick and efficient re-tuning of the cables.

One of the most unique innovations on the project was the use of the "crow's nest" control centres on top of the temporary towers. From here the ironworkers could precisely orchestrate the cantilever by stressing or de-stressing the cables in quick order to ensure component stresses remained within allowable limits. The cable jacking forces were determined from a detailed step-by-step construction staging analysis. This analysis, conducted on specialized software, was used to tune the stay cable system. Its results, including cable jacking sequences and pertinent geometric data, were documented in a deconstruction manual.

Falsework bents were erected close to the main piers on each side of the bridge, in order to resist out-of-balance loads and wind forces for the stage when the main span was reduced until the cantilever was at a length approximately equal to the side span. On the north side, where there were no obstacles, the falsework bent consisted of 1.5-metre diameter driven pipe piles supporting a frame system located about

30 metres away from the main pier, similar to the bent used during the construction of the bridge. However, on the south side, the railway yard had expanded since the bridge was built and the proximity of the tracks precluded the use of a similar system. Instead, a frame was put in place straddling the south main pier, using inclined pipes in two directions and supported on the existing footing cap.

In order for the falsework bents to provide the necessary longitudinal overturning stability to the partially deconstructed bridge, diagonal bracing pipes were installed between the falsework bents and the main pier, enabling it to behave locally as a truss system. While similar diagonal braces had been used during the original construction, the connection gusset plates had been severed and removed on completion. A significant effort was needed to re-establish the connection points on the existing members to allow installation of the new braces.

> "Despite completing the arch relief cut and reducing the arch rib force to zero at midspan, the tie-girder at mid-span was still resisting large axial tension forces, local flexural moments."

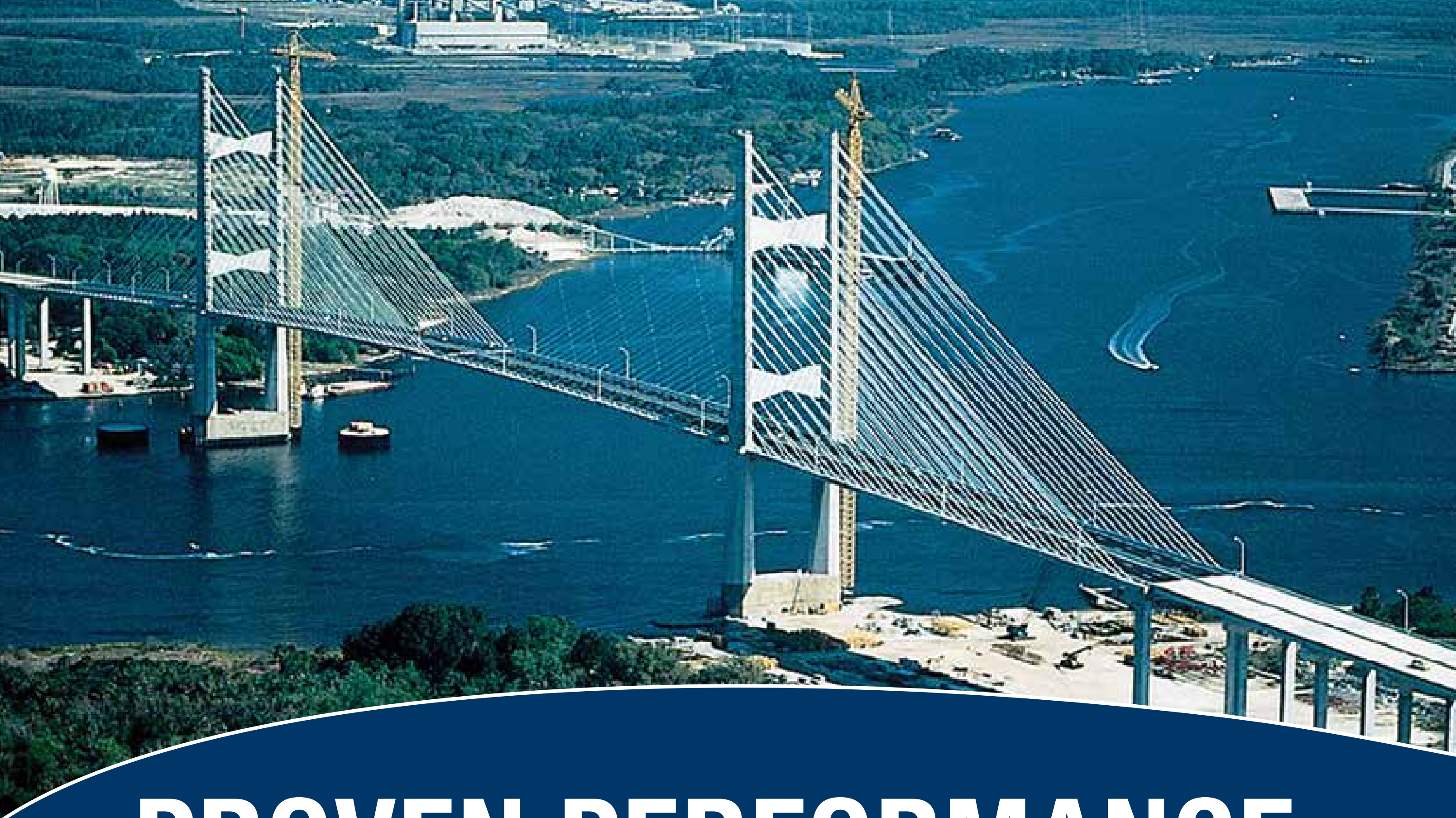
STRESSFUL CUTS

The first major step in the deconstruction process was to remove the axial compression in the arch rib at mid-span, prior to making the first relief cut in the arch. After stressing the initial configuration of stay cables, one-metre square "windows" were cut from the arch rib web plates so steel brackets and hydraulic jacks could be installed and pressurized to virtually eliminate the remaining arch rib compression. With the cutting of the rib, any residual forces were transferred to the jacks, which, when de-stressed, allowed for a gradual release of the residual forces and caused the arch rib tips to move inward by approximately 250 millimetres.

Despite completing the arch relief cut and reducing the arch rib force to zero at midspan, the tie-girder at mid-span was still resisting large axial tension forces, local flexural moments, and potentially shear forces. To address this, strongback beams that straddled the mid-span cut location were welded directly to the tie-girder and had stressed post-tensioning bars to partially offset the anticipated internal forces. As the tie-girder was sequentially cut, residual forces were transferred to the post-tensioning bars which, upon completion of the cut, were de-stressed to allow the cut gap to grow by approximately 225 millimetres. After the release of the bars, the bridge was transformed from a continuous tied-arch to a cable-stayed cantilever system.

REMOVAL WORKS

With the main span arch rib and tie-girder relief cuts made, the main span could be deconstructed in segments using a barge-mounted crane on the north side and a deck-mounted stiff-leg derrick on the south side. The ribs and edge girders were removed in 15-metre-long sections, while the orthotropic deck panels were removed in sections 20 metres



"As the most recycled material on the planet with an overall recycle rate of 88 per cent, the steel from the old bridge can be used in cars, buildings, or other infrastructure projects."

wide by 8 metres long. The majority of sections weighed less than 35t; however, some pieces from the knuckle and main pier regions were as heavy as 100t, or about the weight of a Boeing 757-200 aircraft. The main span and some of the side span segments were lowered onto a barge, while the remainder of the south side span segments were lowered onto a truck in the rail yard and transferred to barges for recycling.

In several stages, the suspended cantilevered structure was very flexible with natural periods of vibration up to three seconds and prone to oscillations in severe winds. In collaboration with an expert wind laboratory, McElhanney assessed the potential for dangerous oscillations in severe wind and designed systems of temporary support to limit wind effects to acceptable levels in all stages of the deconstruction.

STEEL SENT FOR RECYCLING

As the team managed to successfully remove the old bridge, they cleared the view of the new Port Mann Bridge traversing the Fraser River. In total, 9,000t of steel were sent for recycling rather than to a landfill. Fifty years ago, or in other parts of the world, this bridge might have been demolished instantly with explosives. With British Columbians demanding higher and higher environmental standards, the project team devised a way to safely remove the bridge, without harming the fish-bearing river.

As the most recycled material on the planet with an overall recycle rate of 88 per cent, the steel from the old bridge can be used in cars, buildings, or other infrastructure projects. And because of steel's metallurgical properties, it can be recycled endlessly without any performance degradation. This demonstrates the advantage of steel in meeting the project's environmental, economic, and sustainability goals. AS

INTEGRATING FIRE AS A L

Highlights from a fire design framework project

Matthew Smith and John Gales

OVER THE PAST several years, the consideration of fire to the structural performance of buildings has seen more inclusion in the design process. To this extent, a CISC-ICCA supported research project entitled *Towards a Performance Based Fire Design Framework for Composite Steel Deck Construction in Canada* was undertaken by the authors with the goal of developing a framework for performance-based fire design for composite steel deck structures within Canada.

This applicable research is a collaboration of academic, consultancy, and industry interest. The work is drawing on the lessons learned internationally and the various precedents that have already been established in areas of Canada by others.

This project will assess the required level of competency across all stakeholders; critique the education system that supports performance-based design within Canada (and abroad); perform novel testing of steel sections to begin to quantify the post-fire state that informs business continuity and resiliency of the building; and develop case studies to demonstrate and highlight the range of design options available.

To highlight recent progresses towards these goals, the authors present a short example of novel tools and technologies being employed in this project. These tools specifically deal with the conceptualization of treating fire as a load within the design process.

FIRE AS A LOAD

There has been a recent shift towards including fire as a load case on structures, specifically internationally where many structures see their fire performance quantified and considered in design – the overarching goal of this CISC-ICCA research.

Examples of fire as a load can be seen in Annex K of the steel design standard CSA S16-14, as well as Appendix 4 of ANSI/AISC 360-10 that are both

OAD CASE WITH BIM

entitled *Structural Design for Fire Conditions*. Both of these material design standards now include provisions for the structural engineer to consider the effects of fire, albeit in an introductory manner. This can orient the engineer with performance-based fire engineering (as discussed in Advantage Steel issue 39, Fire Protection of Steel Structures).

The *SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings* has also been previously referenced in Canadian case studies to help guide the process. Within CSA S16-14, a load case for fire is provided and contains the effects caused by the design basis fire as T_s. The design basis fire is discussed in the annex as being due to either a localized fire (non-flashover), or a post-flashover compartment fire. Most of the previously published Canadian case studies have focused on using Computational Fluid Dynamics (CFD) models, such as Fire Dynamics Simulator, to calculate temperatures in the structure for a given fire scenario.

While the results and the trends displayed can be insightful, this is not the only tool available and can be quite resource intensive if fire is to be considered as a load case in structural design. Indeed, there needs to be a range of tools available to the design depending on the complexity and boundaries of the problem. This is similar to what we see in the rest of structural engineering.

In many structural engineering practices, Building Information Modelling (BIM) is used by default on projects because of the benefits it brings. This technology is often leveraged to streamline the creation of structural analysis models. Fire Engineering, when fire is considered as a load case, can benefit from this same workflow integration and utilize the information already being captured in the BIM. As the case studies were developed as part of this CISC-ICCA research project, it is natural to develop links with BIM software to demonstrate synergy with the standard design processes being seen in practice.

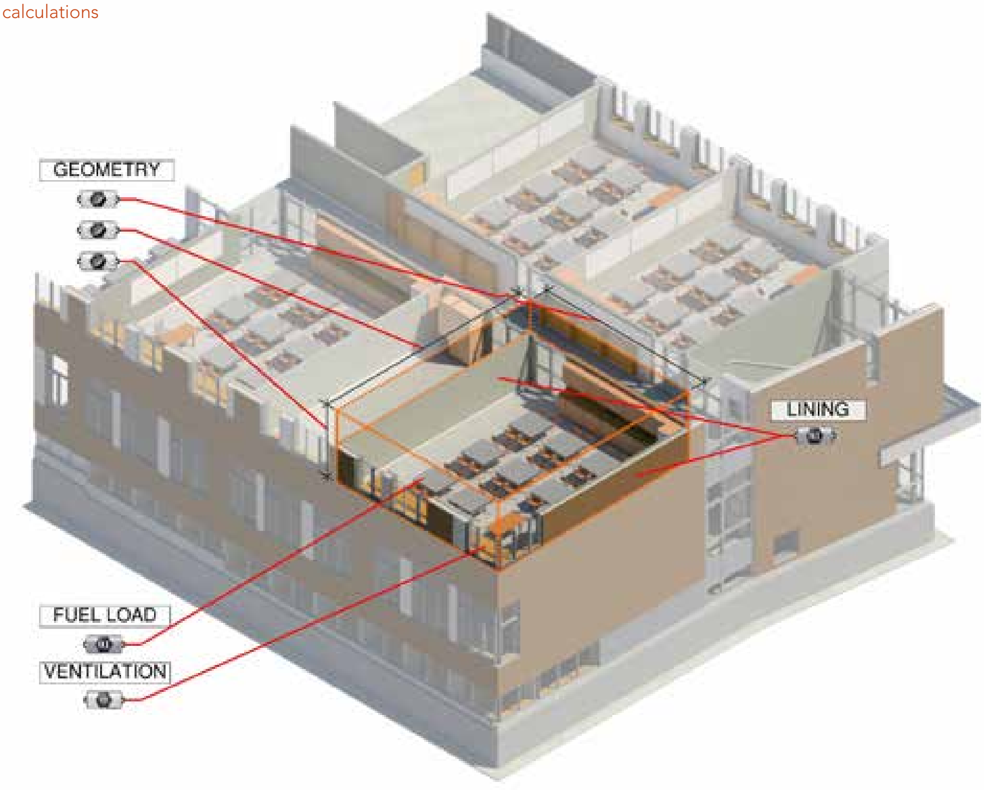
INTEGRATION WITH BIM

Industry best-practice uses BIM to increase coordination, efficiency, and document clarity. When used, these models are typically started at the very beginning of a project. These models contain both the structural and architectural information, among other disciplines, which means many of the parameters that can be used to define design basis fires are already being modelled (see Figure 1).

EUROCODE PARAMETRIC CURVES

A time-temperature curve that describes compartment fires and has often been used for design is the Eurocode Parametric Curve (CEN 1991-2002). That design fire is based off heat-balance calculations of average-sized compartments. The input to this equation includes the compartment geometry, interior finishes, ventilation conditions, and fuel load. A workflow can be developed that efficiently

FIGURE 1: Sample BIM showing parameters that can be used for input to design basis fire calculations



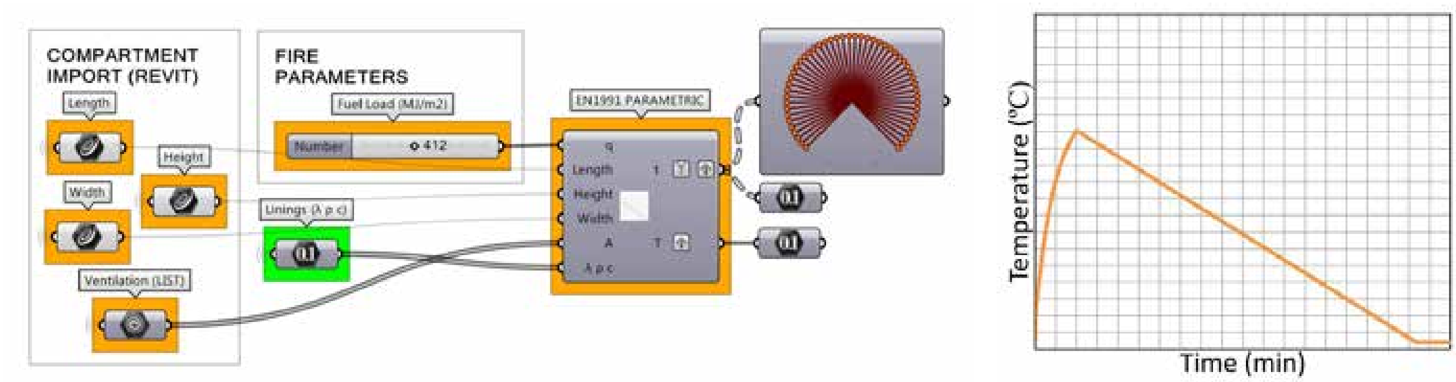


FIGURE 2: Simplified implementation of EN1991 Parametric Curve, using compartment geometry read from BIM and calculations subsequently performed in Grasshopper. Calculations are directly driven from BIM.

extracts this information directly from the BIM and calculates the temperatures resulting from a design basis fire for each compartment within a structure (Figure 2). The calculations can be performed by and optimized within Grasshopper by powerful optimization plug-ins such as Galapagos or Octupus. Grasshopper is a graphical programming interface seeing increased usage in structural design that allows for generative algorithms to drive the 3-D modelling capabilities of Rhinoceros. It allows for complex geometry to be parametrically modelled, optimization and form-finding exercises to be run, and direct two-way linkage with structural analysis software. It is an ideal tool to make complex steel structures a reality, from both an architectural and structural perspective.

Performing compartment fire calculations with direct input from the BIM allows for efficient analysis of the effects of temperature and can highlight areas that require special attention from the structural engineer – all without the complexities and resources that a CFD model could require. However, it has to be recognized that there will still be complex cases that exceed the limitations of the analytical correlations and could require a more robust CFD model.

TRAVELLING FIRES

In recent years, consideration has been given to fires which do not engulf the compartment homogeneously, and instead travel from one end to another. This behaviour is supported by observations of how accidental fires behave, as well as experimental observations.

It is a necessary consideration in design since contemporary buildings typically have large open spaces and other attributes that can fall outside the validity of the Eurocode Parametric Curve. An analytical method for determining the effects of a travelling fire have been well developed and documented by Rein et al (2007), Gales (2014), and Rackauskaite et al (2015). The method itself has been used for steel design in Europe, although it is often not the only design basis fire considered.

The travelling fire methodology is well suited to being integrated with BIM software since it is heavily dependent on the building geometry and properties. An example of a travelling fire moving through an open compartment is shown in Figure 3.

The benefit of powering the travelling fire calculations directly from BIM is that new geometry is automatically captured and actual

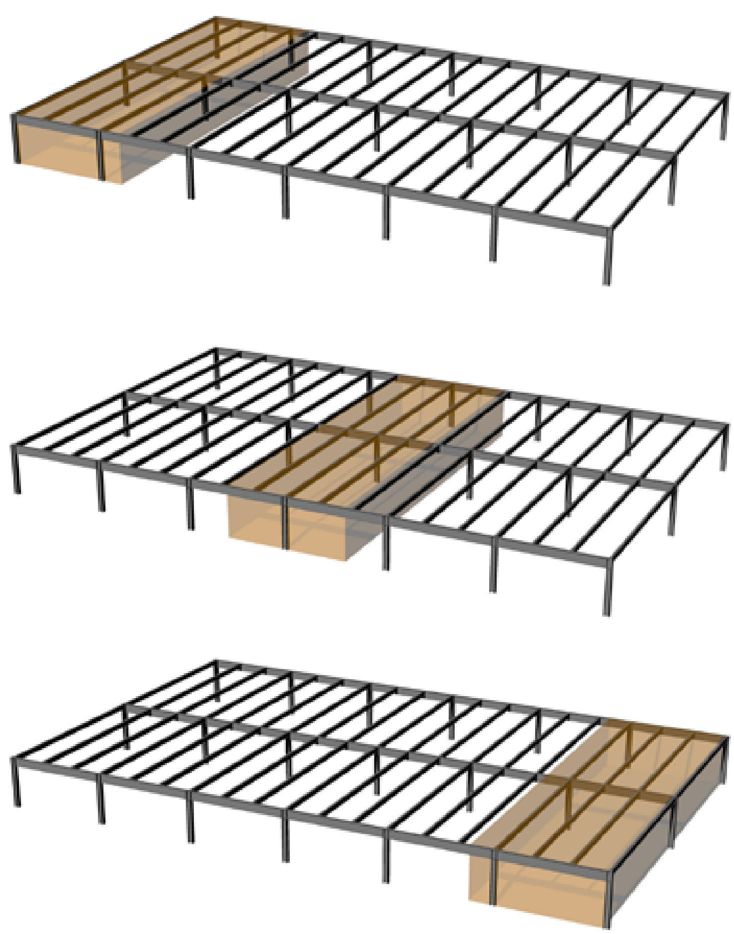
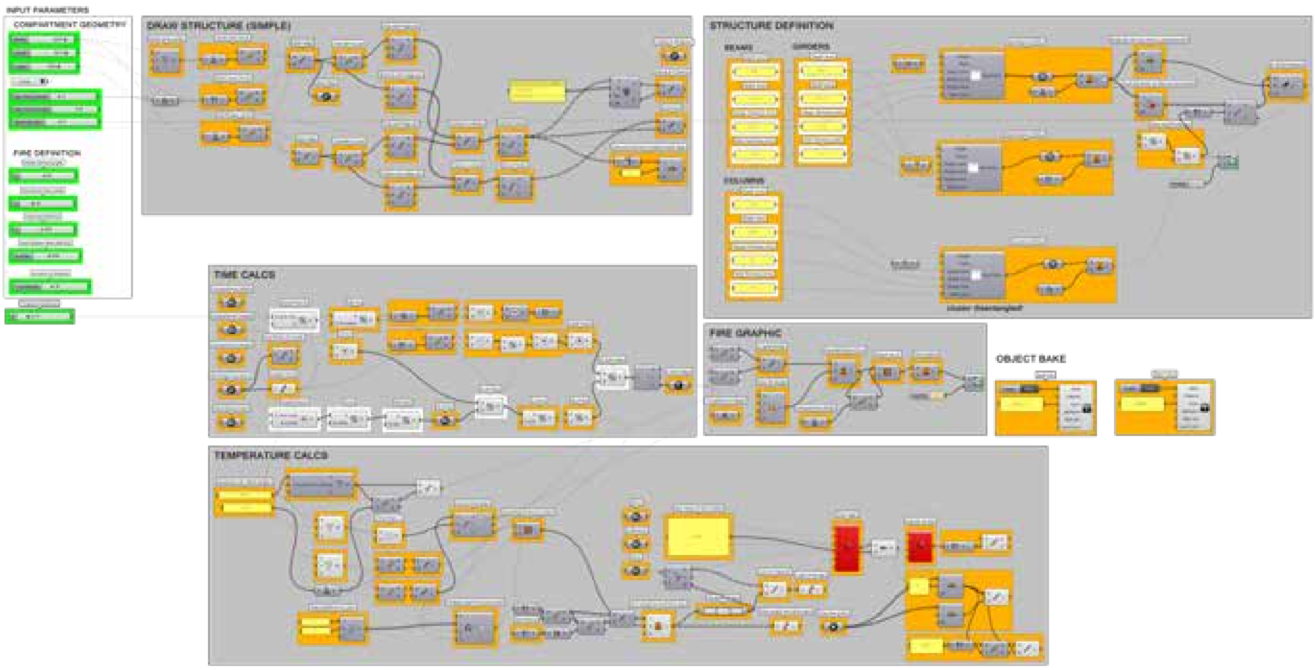


FIGURE 3: Visual representation of a travelling fire (equal to 20% of the floor area) within a sample structure



structural steel member sizes can be included in the heat transfer calculations. By utilizing Grasshopper to perform the calculations, there is also an opportunity to quickly assess ranges of parameters such as fire size, travel speed, flapping angle, etc. This proposed workflow is presented in Figure 4.

PRELIMINARY CONCLUSIONS

As fire begins to see consideration as a load case in structural design in Canada, there will have to be a range of tools considered that vary in complexity, scope, and limits of validity. Analytical correlations such as the Eurocode parametric curves and Travelling Fire Methodology represent opportunities to calculate expected structural temperatures for a range of fire scenarios which can inform a performance-based approach.

By using the BIM of a project to provide direct and real-time input with the fire calculations, similar to what we already see in structural design, efficiencies can be found and fire itself will see better inclusion as a load case in structural engineering in Canada and abroad. As fire engineering matures as a profession within Canada, it is expected that more links will be created with the structural engineering workflow so that the actual performance of our structures can be better quantified and accounted for in design.

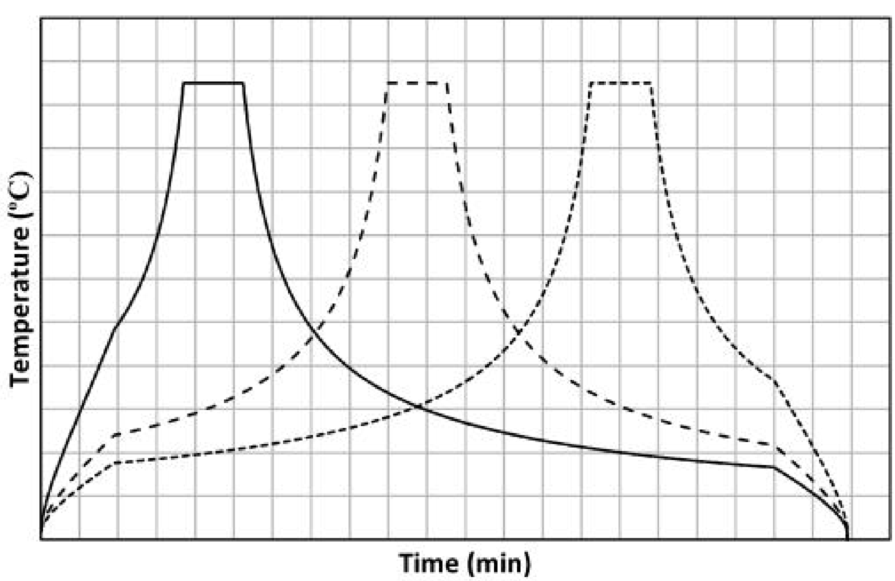


FIGURE 4: Sample workflow of BIM parameters imported to Grasshopper, with temperatures output for a range of design basis fires and locations of interest.

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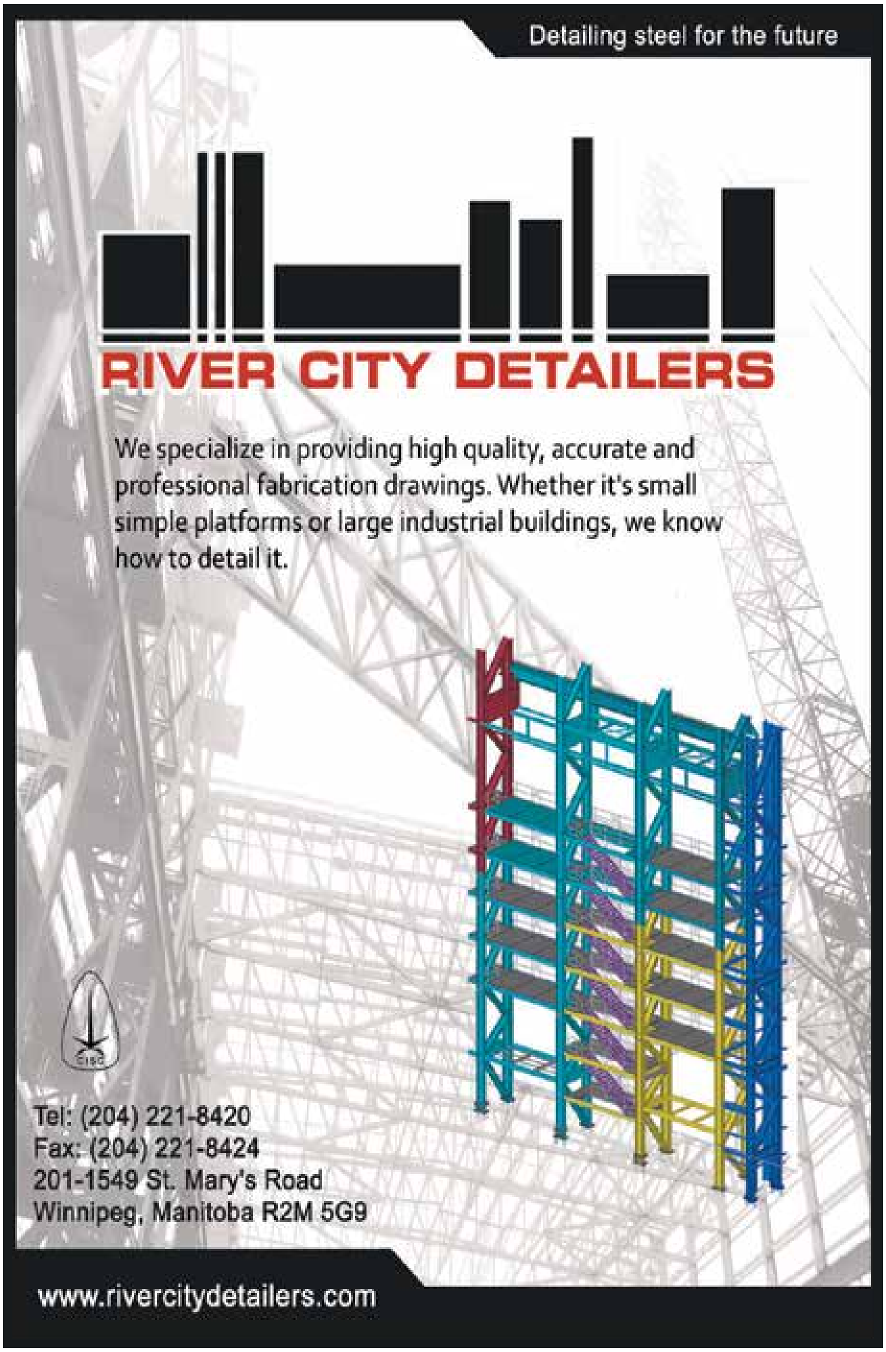
"Better defining how the performance-based fire protection opportunities can be integrated with the structural design is an essential part of this CISC-ICCA research project."



Better defining how the performance-based fire protection opportunities can be integrated with the structural design is an essential part of this CISC-ICCA research project, and developing tools to define the design basis fires of real buildings will allow for demonstration case studies to show what benefits can be realized for Canadian practice. Ensuring these tools are validated, practical, and well integrated will make the performance-based process more appealing and transparent to all stakeholders. AS

Matthew Smith, P.Eng., is a structural engineer at Entuitive, a consulting firm based out of Toronto, Ontario, and also a graduate student at Carleton University studying and researching Fire Safety Engineering. He is a member of the ASCE fire protection committee.

John Gales PhD., is Graduate of the University of Edinburgh's BRE Centre for Fire Safety Engineering and currently Assistant Professor of Civil and Environmental Engineering at Carleton University. He is a member of the ASCE fire protection committee and task group chair for acceptance criterion, voting member of ASTM E05 fire standards, and member of the Fire Technology Editorial Board.

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Rein G, Zhang X, Williams P, Hume B, Heise A, Jowsey A, Lane B, and Torero J (2007) Multi-storey fire analysis for high-rise buildings. Proceedings of 11th Interflam.

Continuing Education Courses

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Annex M of CSA S16-14 will be introduced. The provisions of Annex M extend and modify the requirements of Clause 27 of CSA S16-14 as these requirements apply to industrial structures which do not resemble buildings. Seismic Force Resisting Systems, redundancy, damping, effective mass, methods of analysis and vertical earthquake effects will be reviewed.

Course Leader:

R. Mark Lasby, B.Sc., P.Eng., Principal Structural Engineer - Fluor Canada Ltd.

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Live Online	12:00 pm and 3:00 pm ET, Thursday, October 20, 2016

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The Handbook of Steel Construction contains detailed information on the design and detailing of structural steel in metric units. The new 11th Edition is intended to be used together with the National Building Code of Canada 2015. Member design tables are based on steel grades ASTM A992, A572 Grade 50, A913 Grade 65, A500 Grade C and CSA G40.21-350W.

The four sessions will cover:

1. Handbook overview, Part 1 - Changes to CSA S16-14, Part 2 - CISC Commentary on S16-14
2. Part 3 - General design data for bolted and welded connections, Part 7 - CISC Code of Standard Practice
3. Part 3 - Framed beam shear connections, Part 4 - Compression members
4. Part 5 - Flexural members, Part 6 - Properties and dimensions

Course Leaders:

Stephanie D'Addese, M.Eng., P.Eng., Engineer, Solutions Centre, CISC

Charles Albert, M.Sc.E., P.Eng., Manager of Technical Publications and Services, CISC

Live Online	12:00 pm and 3:00 pm ET, Tuesday,November 8, 2016
	12:00 pm and 3:00 pm ET, Wednesday, November 9, 2016

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The presentations and the Course Notes include four updated design examples illustrating extensive design calculations for I-girders and box girders of straight and curved configurations. Topics include fatigue and brittle fracture, integral abutments, aesthetics, design process and economics, highway bridge loads and methods of analysis, I-girder design, straight and curved box girder design, wind and seismic effects, fabrication and economical details, construction and erection methods, and an architectural perspective on pedestrian bridges.

Major changes and new provisions that were introduced in the 11th edition of CAN/CSA-S6 and their effect on the design of steel girders are highlighted.

Course Leaders:

Gilbert Grondin, Ph.D., P.Eng., Senior Bridge Engineer, AECOM

Paul J. King, M.S., P.Eng., VP Engineering, Rapid-Span Structures Ltd.

James Montgomery, Ph.D., P.Eng., Principal, DIALOG

Terri Meyer Boake, M.Arch., LEED AP, Professor of Architecture, University of Waterloo

COMMON CODES AND STANDARDS FOR DESIGN AND CONSTRUCTION OF STEEL STRUCTURES

Current Status and Future Publication Targets

Code/Standard/Supplement/ Commentary/Referenced Document	Current Edition	Next Edition/Revision	Publication Target
National Building Code of Canada (NBC)	NBC 2015	NBC 2020	Dec. 2020
NBC Structural Commentaries (Part 4 of Div. B)	NBC 2010 Str. Comm.	NBC 2015 Str. Comm.	late 2016
CSA S16 Design of Steel Structures	CSA S16-14	CSA S16-19	2019
CISC Commentary on CSA S16 (Part 2 of CISC Handbook of Steel Construction)	CISC Handbook 11th Edition[1]	TBA	
CISC Moment Connections for Seismic Applications	2nd Edition[2]	TBA	
CSA S6 Canadian Highway Bridge Design Code	CSA S6-14	CSA S6-19	
CSA S6.1 Commentary on Canadian Highway Bridge Design Code	CSA S6.1-14	CSA S6.1-19	
CSA G40.20/G40.21 General Requirements for Rolled or Welded Structural Quality Steel/Structural Quality Steel	G40.20-13 G40.21-13	TBA	
CSA W59 Welded Steel Construction (Metal Arc Welding)	CSA W59-13	TBA	
CSA W47.1 Certification of Companies for Fusion Welding of Steel	CSA W47.1-09 (R2014)	TBA	
CSA S136 North American Specification for the Design of Cold-Formed Steel Structural Members	CSA S136-12	CSA S136-16	Sep. 2016
CSA S136.1 Commentary on CSA S136	CSA S136.1-12	TBA	

[1]*CISC Handbook of Steel Construction - 11th Edition includes CSA S16-14, its Commentary, CISC Code of Standard Practice - 8th Edition (new), and design and detailing aids in accordance with CSA S16-14*

[2]*Adopted in S16-14 by reference*

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CISC had a high-profile presence at the Canadian Society for Civil Engineering (CSCE) Conference in June 2016 with our booth, a presentation to over 400 engineers, promoting our upcoming National Steel Symposium, new courses, new Handbook of Steel Construction, steelknowledge.ca blog, and Solutions Centre and Education & Research activities. We were also in the spotlight with our involvement as co-hosts of the first Canadian National Steel Bridge Competition (CNSBC).

As well, CISC exhibited and presented at the Royal Architectural Institute of Canada (RAIC) Annual Conference; as well as at the Canada Green Building Council's (CaGBC) "Building Lasting Change" conference on the design versatility, performance, and sustainability of steel.

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The Symposium will have an innovative format with a series of "mini conference sessions" designed as "speed meetings". Each group of participants will attend a session at each booth for a period of 15 minutes and subsequently move on to the next booth and so on for periods of two hours at a time. Plenary sessions will be held between each two-hour period of mini-conferences.

CISC QUEBEC STEEL DESIGN AWARDS OF EXCELLENCE: NOVEMBER 4, 2016

The signature awards event of the Quebec steel industry will feature 300+ participants, representing more than fifty companies from across Quebec; 82 project submissions; 45+ finalists; and 1 winner in each of the 10 categories.

For more information, please contact Hellen Christodoulou (514) 909-6186 or visit www. rendezvousacier.com/prix-excellence/.

The CISC Donor Directed Scholarship Program

One need only review the list of scholarships on the CISC website to realize the Canadian steel construction industry digs deep when it comes to recognizing and rewarding students with good academic standing and leadership qualities. Our goal is to find and attract the best to our industry, and a quick scan of recipient lists for the Jackson Fellowship or Kulak Scholarship proves that point.

Always on the lookout for new ways to expand this very successful method of supporting promising talent, the CISC Board approved the creation of the CISC Donor Directed Scholarship Program. In this program, any individual, company, or estate with current or past ties to the steel construction industry can underwrite a scholarship of at least $5,000 per year at a specific educational institution – or all educational institutions within a geographical range – as long as the institution educates and trains designers, fabricators, and constructors that are potential candidates for employment in the steel construction sector.

The advantage of this program over going it alone is the recognition of the CISC brand and CISC's administration expertise in this area. CISC will enter into an agreement with the donor that sets out the details of the award, amount, length of commitment, contribution, adjudication process, recipient characteristics, and selection criteria. Depending on the geographical range, CISC either works with an individual institution or establishes a committee to market and administer the scholarship internally.

Recognition of the donor and the scholarship includes an entry in the scholarship listings on the CISC website, in an awards recognition event at the Annual Convention, and in any other communications relating to the advancement of CISC's education and research efforts.

An option that may be of great interest to corporate donors is the personal presentation of the scholarship at the CISC Annual Conference. Although recipient travel expenses fall to the donor, the elite of the steel construction industry are present when the donor introduces the scholarship, announces the winner, presents the award, and receives thanks from the recipient.

CISC'S KENNETH B. BENSON SCHOLARSHIP

The first patron of the CISC Donor Directed Scholarship Program is Benson Steel. Steve Benson wanted to honour his father with a $7,500 scholarship at the new Lassonde School of Engineering at York University in North York, Ontario, Steve's alma mater. He also wanted to acknowledge Ken's decades of involvement with CISC, so he turned to the CISC Donor Directed Scholarship Program for branding and assistance with York University's Division of Advancement. It was a carefully guarded secret until Steve Benson surprised his father with the announcement at the CISC Gala in St. John's, Newfoundland in 2014.

Although the scholarship will eventually be awarded to a third year student in the structural design course, the first intake of students into the brand new Department of Civil Engineering was in September 2014. As such, the first recipient of the CISC Kenneth B. Benson Scholarship in the 2014-2015 academic year was Ashley Hannah, a first year student in Civil Engineering.

This year's recipient is Adol Arop Mawien, a second year student in Civil Engineering. Steve Benson will announce the winner and present the scholarship at the CISC Annual Conference Gala in Toronto, Ontario this September.

One unique attribute of the Benson Scholarship is the opportunity for the recipient to gain summer employment at Benson Steel. This alone is guaranteed to bring more talent into the steel construction industry.

For more information about the CISC Donor Directed Scholarship Program, please contact David MacKinnon, Director, Education and Research (dmackinnon@cisc-icca.ca).

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