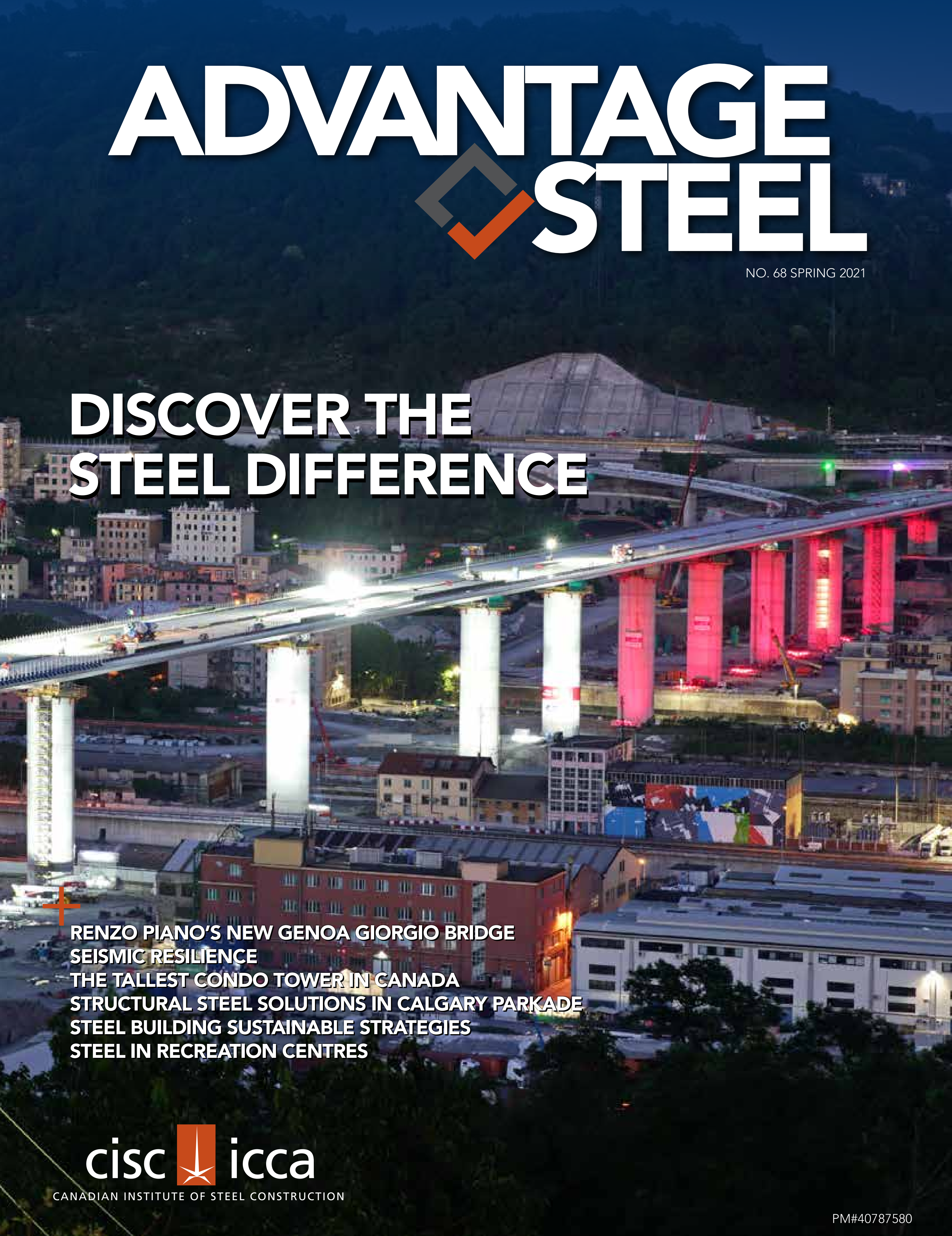
ADVANTAGE STEEL

NO. 68 SPRING 2021



DISCOVER THE STEEL DIFFERENCE

RENZO PIANO'S NEW GENOA GIORGIO BRIDGE
SEISMIC RESILIENCE
THE TALLEST CONDO TOWER IN CANADA
STRUCTURAL STEEL SOLUTIONS IN CALGARY PARKADE
STEEL BUILDING SUSTAINABLE STRATEGIES
STEEL IN RECREATION CENTRES

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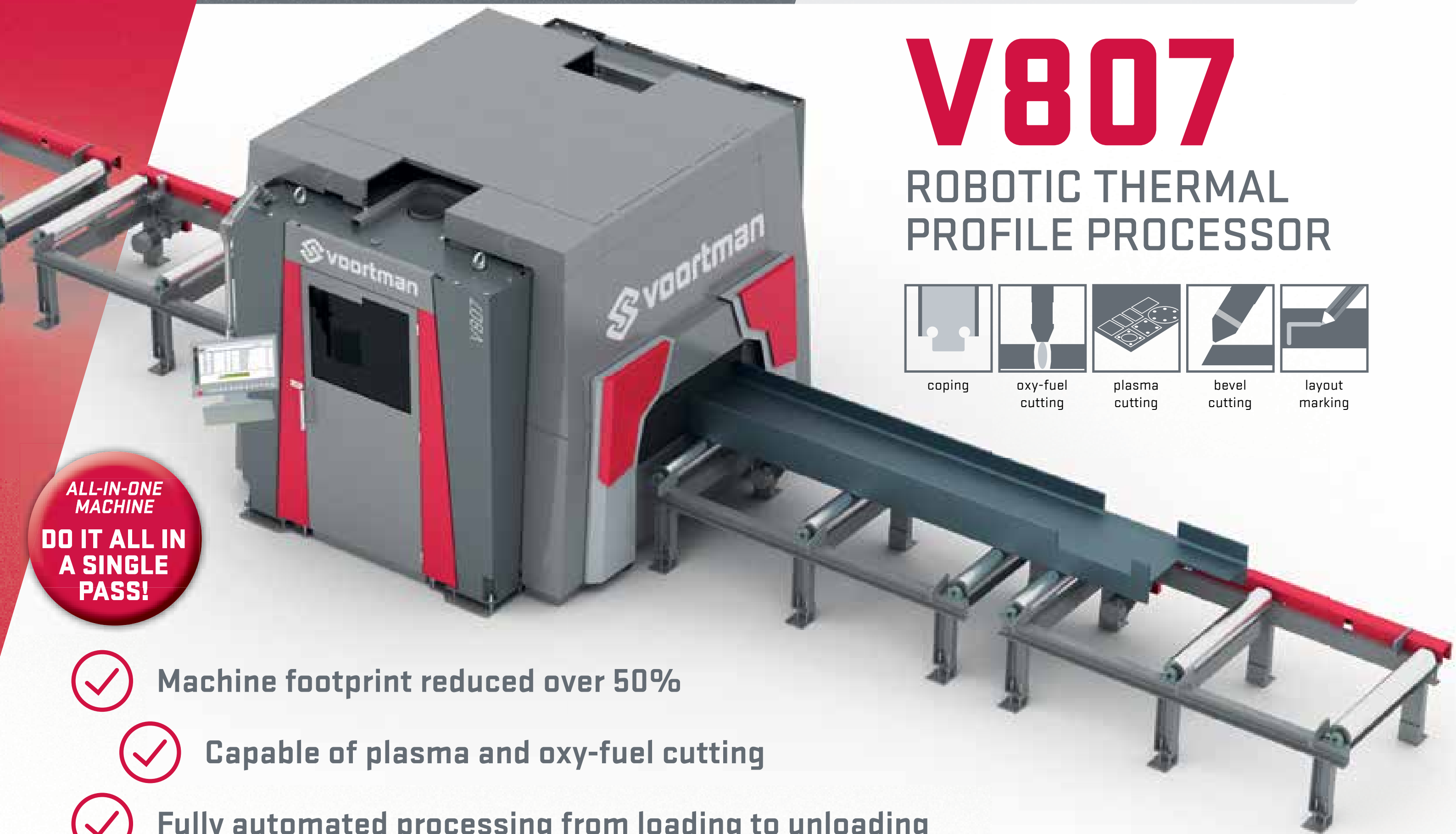
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ADVANTAGE STEEL

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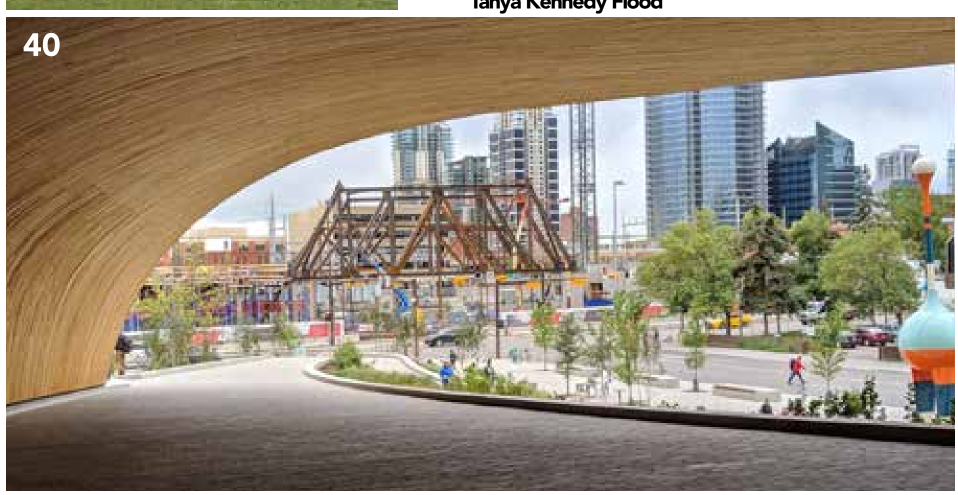
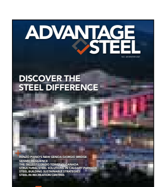
FEATURES

IN EVERY ISSUE



COLUMNS

The Canadian Institute of Steel Construction (CISC) is the Voice for the Canadian Steel Construction industry. The CISC represents a diverse community of structural steel industry stakeholders including manufacturers, fabricators, erectors, service centres, consultants, detailers, industry suppliers, owners and developers. Steel construction industry stakeholders are encouraged to apply to become a member or associate. Visit cisc-icca.ca for more information. If you are working on a project that you think should be featured, send us an email at ciscmarketing@cisc-icca.ca.



On the Cover:

Discover the Steel Difference

Ed Whalen, P.Eng.
President & CEO, CISC

Prompt Payment Legislation – Fact Check

AS PROMPT PAYMENT sweeps across the land, I am fascinated with the negative stories I hear about in Ontario. Ontario was the first to pass prompt payment legislation and the first to get it implemented. Coming into force October 2019, Ontario now has a full year under its belt with its prompt payment rules. Now may be a good time to review and see if the horror stories are true.

All of you know that getting paid, and getting paid on time as per your contract, has been the most difficult challenge. In addition, getting paid for all those extras, changes, directives, instructions or whatever the name convention is this month. After over a decade of lobbying for "what is right" with reams of legal and economic briefs, the federal and provincial governments seem to see the light. As of the time of writing, prompt payment legislation of some sort has passed in Ontario, Saskatchewan, Nova Scotia, Alberta, Quebec and federally within the government departments of public works and defence construction. We are also seeing movement in other provinces, which is reassuring. Resistance is still strong in the remaining provinces, and the arguments against are almost humorous now – most proven to be misguided, false or self-serving. That said, each program must be fair and not one-sided, otherwise the program will not survive.

The main purpose of prompt payment legislation was fourfold:

1. Fast and swift decisions to resolve payment issues, in favour of one side or the other;

2. Removing the practice of withholding money for an extended period of time, using it as a hammer, extortion or worse;

3. Resolve the current practice of incomplete drawings together with being paid promptly on legitimate extras;

4. Breed a new culture of collaboration up and down the construction supply chain; and

5. Reduce construction costs.

Interestingly, "fake news" was not only active globally in all things political this year, but it was also active in the prompt payment space, with fears of huge adjudication costs and lack of adjudicators. No doubt this is an effort to slow down other provinces with legislation pending. In most cases, the horrifying news references Ontario, so let's dig into the data (as publishing by ODACC, Ontario Dispute Adjudication for Construction Contracts) to see how Ontario, the only jurisdiction to have an active prompt payment process in place, fared over the past year.

In 2020, there were payment issues in Ontario which resulted in 32 requests for adjudication. What may really surprise you is of the 32 that started the process of adjudication, 21 were resolved prior to a decision and of those, 20 were resolved by the parties before an adjudicator was even appointed. Now that is fast and swift! At the end of the first 12 months, 3 adjudications were handed out, 21 resolved and 10 were in process.

Of the 3 adjudications that were handed out, one involved changes to the contract (extras). This is an important point or value of prompt payment legislation that many may fail to appreciate. Prompt payment adjudication can be used to gain fast and swift resolution to your extra claim that typically gets pushed by someone higher in the supply chain to the end of the project or

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Actually, for small claims the expenses are fixed and are extremely low, allowing any sized contractor to use the process without fees being a barrier.

later. Adjudication can now be used to get paid for all those extras in a timely fashion. It may soon be the case that we embrace incomplete drawings rather than dread them. The owners will now need to pay proper dollars for the practice and may or may not decide to have the design more refined before tender.

Prevalent claims of how expensive the Ontario adjudication system seem unfounded. In their annual report, Ontario Dispute Adjudication for Construction Contracts (ODACC), the body that regulates the adjudication process and the adjudicators, were paid less than $4,000 in adjudication fees by the parties for the entire year. That's not exactly a business model to get rich on – it's dirt cheap and downright a good bargain. Actually, for small claims the expenses are fixed and are extremely low, allowing any sized contractor to use the process without fees being a barrier. That said, the fees for large claims can be pricey (per hour rates) and that, too, is a good thing: being a deterrent for frivolous claims and bad acting. It keeps everyone honest.

ODACC also claims to have 65 accredited adjudicators with 28 of these being engineers, 26 project managers and 22 lawyers being the largest demographic. Not having it stacked with lawyers seems like they got it right. So, based on the number of arbitrations to date, there will be many more arbitrators than cases, driving hourly rates via supply and demand down. If you are thinking of retiring and getting rich in this field, think again – all good for the construction industry.

After a fact check, I would have to say that the Ontario system is doing a great job. It seems to be encouraging early resolution and better dialogue. That is a win in my mind. Can other provinces do it better? Absolutely, why not. As they say, lessons learned. AS

CISC provides this column as 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 licensed professional engineer or architect.

Charles Albert, P.Eng.
Manager of Technical Publications & Services, CISC

Question: When can structural steel be left unpainted?

Answer: This question is frequently asked by both engineers and architects. According to CSA S16-14 Clause 28.7.1, it is not necessary to paint the steelwork unless required by Clause 6.6 or when specified by the designer. In most buildings, the indoor environment is intended for human occupancy with low humidity and is therefore considered non-corrosive.

Some of the applications where steel is commonly left unpainted are mentioned in the CISC Commentary on CSA S16-14, Clause 28.7:

- **Steelwork** concealed by an interior building finish (i.e. sealed off from an external source of oxygen) or in a limited corrosive environment. Detrimental rusting of steel occurs when the relative humidity exceeds 70%.

  If the steel will be exposed for a short period during construction and then covered or enclosed, it generally does not need a protective coating. But if short-term protection is needed for periods up to 6 or 12 months, a primer complying with CISC/CPMA 1-73a or 2-75 would be specified as a minimum (Clause 28.7.3.3).
- **Steelwork** encased in concrete. Moreover, uncoated steel sections that are totally encased may not require shear connections to act compositely (some conditions apply; see Clause 17.6).
- **Faying** surfaces of slip-critical joints are unpainted, except as permitted by Clause 23. If painted, the slip resistance is based on the contact surface class (S16-14 Table 3).
- **Surfaces** finished to bear, unless otherwise specified (Clause 28.7.4.2).
- **Steelwork** where any coating could be detrimental to achieving a sound weldment. CSA W59-18 Clause 5.3 stipulates the conditions under which a light coat of shop-applied primer would not adversely affect welding.

Other situations where painting is avoided:

- **Spray-applied** and intumescent fire protection, since the paint may prevent proper adhesion. If corrosion protection is required, however, producers of fire-protection products may be able to recommend a compatible primer. Also see *Fire Facts*, Section 2.14.
- **Weathering steel applications**. CSA G40.21 types A – Atmospheric Corrosion-Resistant Weldable Steel and AT – Atmospheric Corrosion-Resistant Weldable Notch-Tough Steel are commonly used in highway bridges. Weathering steel can also be used on the exterior of buildings, although the detailing of joints needs special attention in order to avoid wet spots and pockets where water can collect.

References:

Turner, D.K. 1994. *Tips on Painting Structural Steel*. Advantage Steel No. 3, CISC.
Gewain, R.G., Iwankiw, N.R., Alfawakhiri, F. and Frater, G. 2006. *Fire Facts for Steel Buildings*. CISC.

Question: What are the differences between hollow structural sections (HSS) produced to ASTM A500 and those produced to CSA G40.20/G40.21?

Answer: Square, rectangular and round HSS are available in ASTM A500 Grade C and CSA G40.21-350W Class C or H (see Figure 1). Note that A500 Grade C is distinguished from grades A and B which have lower mechanical properties. And G40.21 Class C (cold-formed non-stress relieved) is distinguished from Class H (hot-formed or cold-formed stress-relieved) which has a greater axial resistance for columns of intermediate slenderness. The main difference between HSS produced to A500 and G40 lies in the wall thickness tolerance. For HSS produced to G40, the thickness tolerance is -5% or +10% from the nominal specified value,

FIGURE 1
Square, Rectangular and Round HSS

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.

Differences in wall thickness also affect width-to-thickness (b/t) ratios for establishing the class of section. Moreover, a decrease in plate thickness may substantially affect the applicable design strength when it depends on higher powers (e.g. square) of the thickness.

while the mass tolerance is -3.5% or +10%. For A500, the thickness tolerance is ± 10% and there is no restriction on mass variation.

Accordingly, CSA Standard S16 specifies that design properties for A500 products must be determined from a wall thickness equal to 90% of the nominal value. There is an exception to this rule in the new CSA S16:19, however, in the case of HSS used as yielding elements in seismic force-resisting systems. To account for the possibility of HSS bracing members specified as ASTM A500 being dual-certified, and thus having a wall thickness closer to the nominal value than the (90%) design value, the nominal section properties must be used to calculate the strength of the bracing members for the design of capacity-protected elements.

Differences in wall thickness also affect width-to-thickness (b/t) ratios for establishing the class of section. Moreover, a decrease in plate thickness may substantially affect the applicable design strength when it depends on higher powers (e.g. square) of the thickness.

The next differences to consider are the mechanical properties. The specified minimum yield stress (F_y) is slightly greater for square and rectangular G40.21-350W sections (350 MPa) than A500 (345 MPa), but the difference is more significant for round sections (350 vs. 317 MPa, respectively). As for the minimum specified tensile strength (F_u), the values for all shapes (square, rectangular and round) are 450 MPa for G40.21-350W and 427 MPa for A500.

For all the above reasons, there are separate tables of factored axial compressive resistances (C_r) in Part 4 of the Handbook of Steel Construction for G40 and A500 column sections.

For information on HSS produced to ASTM A1085, see the Technical Column in *Advantage Steel* No. 48, Winter 2014. AS

G.S. Frater

Structural Fire Protection Engineering

An Alternative Solution Approach to Fire Safety

Prescriptive building code criteria have been in place for decades in the U.S.A., Canada and in other countries to provide for building fire resistance and other fire prevention and protection measures. North American Building Codes, such as the National Building Code of Canada, reference a fire test standard for the fire resistance of structural building elements. The basis of a fire test standard is the "standard time-temperature curve," i.e., building materials within a floor, roof or wall assembly and individual columns are subjected to increasing temperatures in a test furnace. With real fire behaviour being understood through research and with a larger community of fire protection engineers, "performance-based" methods are being applied to "engineer" the amount of fire protection on steel structures. The engineered approach to fire safety has manifested itself in more and more building projects as fire researchers develop a wider understanding of how structures respond in fires. Design professionals now have access to a range of tools and guidance to help them take an engineered approach to the fire protection of steel structures. There are many examples where a performance-based design approach has led to steel components in the building structure being designed to be unprotected or with a significant reduction in fire protection materials. CISC's *Advantage Steel* magazine has recognized these developments in structural fire protection engineering and since 2005 has published 10 fire protection articles on the subject matter.

In *Advantage Steel's* no. 23 issue (summer 2005), CISC published its first article on fire protection engineering that was authored by fire protection engineer, Ralph Bartlett, who graduated with an undergraduate engineering degree in fire protection engineering from the University of Maryland, in College Park, MD between Baltimore and Washington, DC. That was one of the original schools with an engineering department granting an undergraduate Fire Protection Engineering degree (see https://fpe.umd.edu/). The article was entitled "Structural Fire Protection Determined Through Fire Protection Engineering Applications at Nova Scotia Community College." His firm, namely R.J. Bartlett Engineering Ltd., used fire protection engineering with the aid of advanced calculation techniques and computer fire modelling to produce a "Performance-based Design," or PBD, where "unprotected" structural steel was used in a two level 5,575 m^2 expansion project having college assembly occupancy. Another

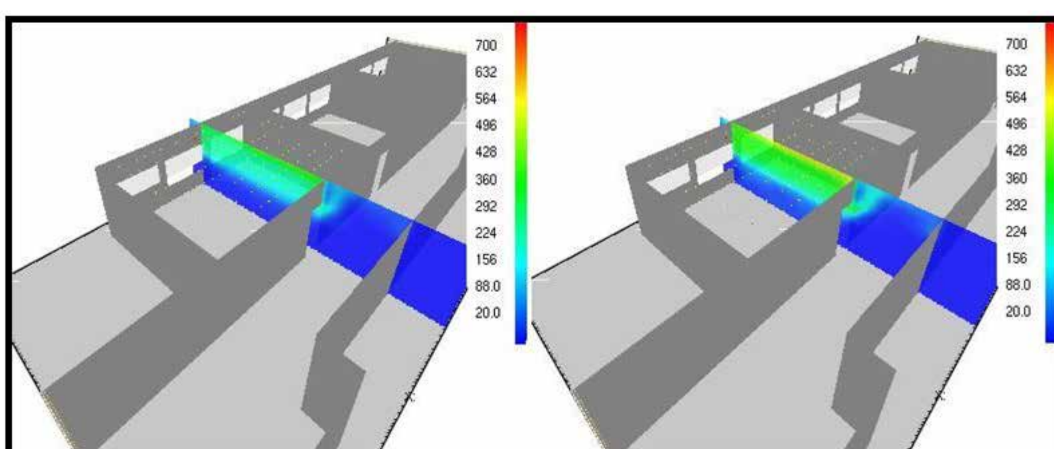

Photo: Courtesy of R.J. Bartlett Engineering Ltd.

Classroom fire simulations – taken at 300 seconds (left image) and 1,200 seconds (right image). Measured in degrees Celsius.

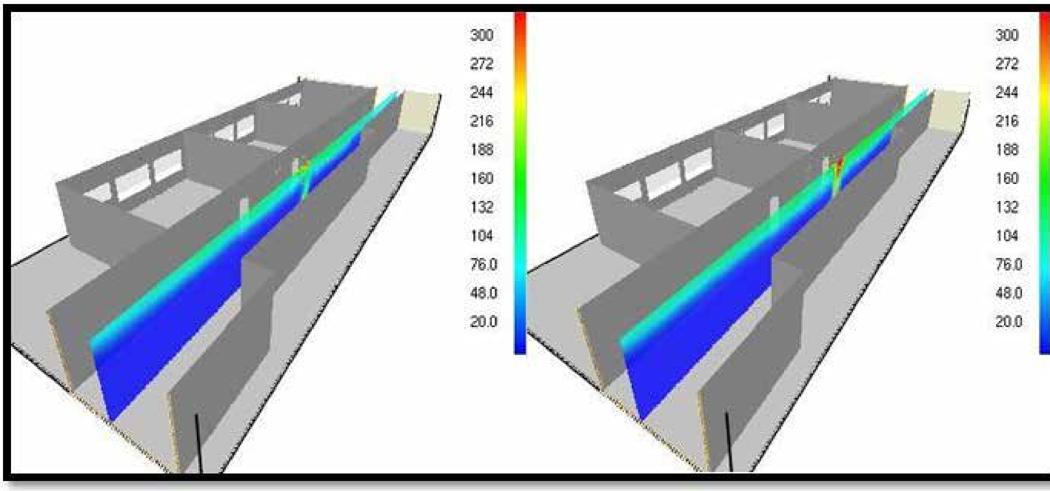

Photo: Courtesy of R.J. Bartlett Engineering Ltd.

School hallway fire simulations – taken at 300 seconds (left image) and 1,200 seconds (right image). Measured in degrees Celsius.

Advantage Steel (AS) article, found in issue no. 27 (fall 2007), reports on another R.J. Bartlett Engineering Ltd. project with the article entitled, "Citadel High School: A Performance-Based Solution for Unprotected Structural Steel."

The "design fire" for the Nova Scotia assembly occupancy buildings was modeled with a computer software package called Fire Dynamics Simulator (FDS) which was developed by the National Institute of Standards and Technology in the U.S.A. and is categorized as a computational fluid dynamics field model. The FDS model represents the building compartment's associated physical properties such as geometry, ventilation, finish, etc. Output from the model simulations provide relevant information such as ceiling jet temperatures, fuel burning rates, heat flux on enclosure boundaries and sprinkler activation times. The output data was used to assess the fire safety of the exposed steel beams in the floor and roof-ceiling assemblies in the Halifax high school building and other structural members, e.g., columns at the college building. In these early examples, structural stability was demonstrated by showing individual elements were below a critical temperature for all possible design fires.

Today, engineers and fire protection engineers who are involved in PBD for fire protection of buildings can use a range of computer models in addition to hand calculations and other simplified methods. A useful website with a survey conducted on a range of computer models in fire and smoke is http://www.firemodelsurvey.com/. The site lists 170-plus fire and smoke models in seven categories: fire endurance, egress, detector response, zone, field, miscellaneous and wildland fire (the latest model added to the type-of-model list). The website also provides background information on the development of fire and smoke modelling in the form of two downloadable *SFPE Fire Protection Engineering* journal papers (Friedman, R., 1992 & Olenick, S. M. and Carpenter, D. J., 2003) along with another hyperlink to a 43-page pdf file entitled "*Part 4: Software for Fire Design*" (Morente, F., de la Quintana, J. and Wald, F., xxx). (Note: SFPE = Society of Fire Protection Engineers. SFPE is a professional society for fire protection engineering that was established in 1950).

In AS 27, the freelance author of the article interviewed both the fire protection engineer Ralph Bartlett and the Nova Scotia Office of the Fire Marshal (OFM) fire protection engineer (namely Roy Strickland). OFM's fire protection engineer, in approving an "alternative solution" and as the "Authority Having Jurisdiction" for the performance-based analysis review, required the fire protection engineered analysis to follow all the steps, as outlined in "*SFPE Engineering Guide to Performance – Based Fire Protection, Analysis and Design of Buildings*" (SFPE, 2000 & 2006). At around the same time as these early examples of PBD in Canada, the 2005 edition of the National Building Code of Canada (NBC) was updated and written in objective-based format after 10 years of development (as opposed to the typical five-year cycle). This has created more

Photo: Courtesy of Fowler, Bauld & Mitchell Ltd.

Unprotected exposed steel in floor-ceiling assembly in a classroom at the Nova Scotia Community College and Citadel High School.

favourable conditions to pursue alternative solutions – for example, structural steel fire protection. Developing a PBD is one example of an alternative solution that can be used to demonstrate the functional and objective statements of the code have been met. The high majority of building designs follow the prescriptive-based design requirements in the NBC, i.e., the Code's Division B entitled "Acceptable Solutions," with Part 3 dealing with Fire Protection, Occupant Safety and Accessibility. Part 3 provisions require that building assemblies and structural members carrying the gravity loading (dead and live) have a "fire resistance rating" (FRR). Fire safety by way of the FRR requirement provides fire separations to compartmentalize the building and control the spread of fire. To determine the FRR of a building assembly or structural member, a fire test is required as per fire test standard *CAN/ULC-S101 Standard Methods of Fire Endurance Tests of Building Construction and Materials.* In the case of structural steel buildings, design professionals, when complying with the Building Code's Part 3, basically pick and choose a fire-rated assembly with a FRR from Appendix D in the NBC, "Fire-Performance Ratings," or from the ULC online directory (see https://canada.ul.com/). The ULC directory has a large inventory of roofs, walls, floors, beams and columns for Canada that have been tested to CAN/ULC-S101. The NBC defines a FRR as follows:

> *the time in minutes or hours that a material or assembly of materials will withstand the passage of flame and transmission of heat when exposed to fire under specified conditions of a test.*

(Note: ULC = Underwriters Laboratories of Canada. ULC is an independent product safety testing, certification and inspection organization accredited by the Standards Council of Canada. "CAN" indicates that a standard is published in both official languages.)

There is a strong demand from various design groups and developers to design sections of buildings, such as main entrances, atriums and other areas, using fire protection engineered analysis as an "alternative solution." In the Code's Division A, Compliance, Objectives and Functional Statements are given and in Article 1.2.1.1., entitled "Compliance with this Code," a design professional has the choice to provide a prescriptive "acceptable solution" or develop an "alternative solution." In the case of fire safety, a design professional can consider structural fire engineering as an alternative solution.

In AS 50 (summer 2014) the freelance author of the article interviewed Jensen & Hughes Senior Engineer, Nestor Iwankiw, who overviews the advantages of "engineering" the fire protection. The article is entitled, "Expanding the options, Structural fire engineering gives architects and owners a wider range of design and engineering choices." The article points out how a multi-storey building project with structural fire engineering can reduce fire protection material, hence fire protection costs that are multiplied over many floors. Another noteworthy point by Iwankiw is the application of structural fire engineering enables Architectural Exposed Structural Steel where the structural form is without fire protection material such as gypsum board or spray-on fire resistive materials.

The AS 50 article also notes the North American advance in fire design in AISC's Specification for Structural Steel Buildings (ANSI/AISC 360), which in its 2005 edition introduced a new Appendix 4 entitled, "Structural Design for Fire Conditions." Since 2005 the AISC Specification Task Committees (TC) who meet every six months have been operating with the relatively new TC8 (developing the updates to Appendix 4) that has been updated in 2010, 2016 and is now being readied for its 4th edition in 2022.

In line with this development in AISC 360, the technical committee responsible for the Canadian structural steel design standard, CSA-S16, Limit States Design of Steel Structures, adapted AISC 360's Appendix 4 with Canadian context into its new Annex K, also entitled "Structural Design for Fire Conditions" in 2009 and thereafter updated it in 2014 and 2019, following the changes made in AISC 360's Appendix 4. CSA S16's changing clause for Annex K, namely 6.7, Requirements under fire conditions, reads as follows:

> *The fire endurance of structural steelwork for buildings shall be determined using either*
>
> a) *CAN/ULC-S101; or*
>
> b) *When permitted by the regulatory authority, the methods specified in Annex K. Note: Annex K provides an "alternative solution" that can be evaluated to*

determine compliance with the NBC (Division A, Compliance, Objectives and Functional Statements).

A CSCE 2018 Smith, Gales & Frater conference paper entitled "Structural Fire Design in Canada using Annex K" discusses fire as a load case to be considered during structural design and by way of four design examples provides a stepping stone to a practitioner to consider using CSA S16's Annex K. Design examples include three simple analyses for tension hanger, column and truss and one advanced analysis for a composite floor.

The axial member examples use equations for simplified methods of analysis with equations provided in Annex K, while the composite floor is indicative of an advanced method where the effects of thermal expansion and large deformations must be considered, as well as the boundary conditions and connection fixity. The design of composite floors for fire has a method of analysis called the "Slab Panel Method" (SPM) and more information about SPM can be found in Clifton (2006) along with a more recent 2015 article in the South African Institute of Steel Construction's Steel Construction Journal, Vol. 39, No.2.

There has also been a development in a set of sophisticated codes of practice for the fire design of structures in Europe, namely Eurocodes. Eurocodes (EC) apply to the common building materials of concrete (EC2), steel (EC3), composite steel-concrete (EC4), timber (EC5), masonry (EC6) and aluminum (EC9). For steel structures, structural fire design, the code is *EN 1993-1-2, Eurocode 3: Design of Steel Structures - Part 1-2: General rules – Structural Fire Design,* introduced in 2005. The predecessor document giving foundation to Eurocode 3's new Part 1-2 was the May 2001 "*Model Code on Fire Engineering,*" published by the European Convention for Constructional Steelwork and developed by its Technical Committee 3.

The provisions in Eurocode 3 for steel structures and fire are more detailed than the aforementioned AISC 360 Appendix 4 and CSA S16 Annex K and deal with the complexity of internal forces induced by thermal expansion, strength reduction due to elevated temperatures, the associated amplified deflections and other design factors. A book, *Design of Steel Structures subjected to Fire* by Franssen and Zaharia (University of Liège, Belgium), published in 2005, offers background material and guidance for the designer when using Eurocode 3, Part 1-2.

In the U.S.A., a major development to aid the design professional and regulatory authorities in accepting an alternative solution was the inclusion of a new *"Appendix E: Performance-Based Design Procedures for Fire Effects on Structures"* in the U.S.A. structural building design standard *"ASCE/SEI 7-16: Minimum Design Loads and Associated Criteria for Buildings and Other Structures."* This Appendix E, introduced in 2016, acknowledges fire effects as a design load in a U.S.A. engineering standard and offers performance-based fire engineering as an alternative to the traditional prescriptive methods of design.

Noteworthy for the design professional when engaged in structural fire engineering is that, fire being an extreme event, a reduced live load factor is permitted. In Canada, *Structural Commentaries (User's Guide – NBC 2015: Part 4 of Division B)*, in Commentary A, Paragraph 25 has a Load Combination for

Determination of Fire Resistance, which is 0.5L as opposed to the higher 1.5L for ambient design. This is what a CSA S16 or AISC 360 design professional will find in Annex K or Appendix 4, respectively, and more background on this load combination can be found in AISC's Engineering Journal (Ellingwood & Corotis, 1991).

In summary, NBC's code compliance option for an alternative solution allows PBD with technical merit. It is providing opportunity for design professionals to apply engineered solutions to fire protection using structural fire engineering and advanced calculation techniques where some steel components in the building structure are designed to be unprotected or with a significant reduction in fire protection materials. The provisions in AISC 360 Appendix 4 and CSA-S16 Annex K are general introductory guidelines to orient a structural engineer in performance-based structural fire engineering, a skill that, for the most part, is unfamiliar territory for the profession. As noted in this article many organizations such as the SFPE, ASCE and ECCS have enhanced the dissemination of information related to structural fire engineering. Recently in October 2020, ASCE has issued guidance to its new ASCE7 Appendix E, a 268-page publication entitled "*Performance-Based Structural Fire Design, Exemplar Designs of Four Regionally Diverse Buildings using ASCE7-16, Appendix E.*" The guidance publications, along with building code and steel standard procedures, set the stage for more fire safety design of buildings by aiding both the authorities who approve building designs and the practitioners who are plying the relatively new approaches to structural fire engineering.

Finally, a list of 10 AS articles are cited, of which eight deal with alternative approaches to fire protection. Namely AS nos. 23, 27, 33, 39, 46, 50, 53 and 56, while AS nos. 43 and 45 have articles on the use of fire protection materials, namely intumescent coatings and spray-applied fire-resistive materials to achieve an acceptable solution utilizing fire-rated construction with a FRR determined by the ULC-S101 fire exposure. A list of references is also provided. AS

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Structural Fire Protection Determined Through Fire Protection Engineering Applications at Nova Scotia Community College
By Ralph Bartlett, P.Eng., PE
Advantage Steel No. 23, **Summer 2005**

Citadel High School: A Performance-Based Solution for Unprotected Structural Steel
By Michelle Ponto
Advantage Steel No. 27, **Fall 2006**

Fire Protection at the Vancouver Convention Centre
By Glenn A. Gibson, M.Eng., P.Eng., CP and Kin Man Wong, M.Sc., P.Eng., CP
Advantage Steel No. 33, **Winter 2008**

Fire Protection of Steel Structures – Acceptable and alternative solutions to protect steel structures against the threat of fire
By George Frater, Ph.D., P.Eng. and Carol Kleinfeldt, B. ARCH., M.O.A.A., M.A.A.A., F.R.A.I.C., LEED A.P.
Advantage Steel No. 39, **Spring 2011**

The Bow: Fire Protection of a Large Diagrid Structure
By Jon Winton, B.Tech. and John Roberts, P.Eng.
Advantage Steel No. 43, **Summer 2012**

Directly applied fire protection materials for steel structures
By Don Falconer, P.Eng.
Advantage Steel No. 45, **Spring 2013**

A U.K. perspective on how structural fire engineering can promote steel work
By Allan Jowsey, Ph.D., CEng
Advantage Steel No. 46, **Summer 2013**

Expanding the options: Structural fire engineering gives architects and owners a wider range of design and engineering choices
By Andrew Brooks
Advantage Steel No. 50, **Summer 2014**

Turning up the heat, Structural fire engineering case examples
By Kyle Langelier, Andrew Coles, M.Eng., PE and Jack Keays, M.Sc., P.Eng.
Advantage Steel No. 53, **Fall 2015**

Integrating fire as a load case with BIM, Highlights from a fire design framework project
By Matthew Smith, M.A.Sc., M.Eng., P.Eng. and John Gales, Ph.D., P.Eng., Assistant Professor
Advantage Steel No. 56, **Fall 2016**

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The Important Role of Architects

Future architects and the Architectural Student Design Competition

Craig Martin
Chairman of CISC's Education & Research Council

WE HAVE ALL SEEN AMAZING looking steel structures and wondered "who came up with that cool idea?" In many cases, the answer to that question is: *the architect*. Architects play an important role in envisioning the way the infrastructure that surrounds us both looks and functions – and the flexibility and creativity that steel provides should be their go-to material of choice. The use of Architecturally Exposed Structural Steel (AESS) continues to grow and evolve, and many architects have chosen to showcase structural steel and connections, exposing the art of steel fabrication to the public. The more we can encourage the architecture community to embrace the economy, flexibility and sustainability of steel, the better this will be for our industry.

CISC and the Education & Research Council (ERC) recognizes the important role that architects play in our industry and has several initiatives to support and encourage the next generation of architects.

One of our key programs in this regard is our annual "Architectural Student Design Competition." The 2021 competition marks the 20th anniversary of this important program, and over the years we have seen creative and visually striking submissions from several schools of architecture across Canada.

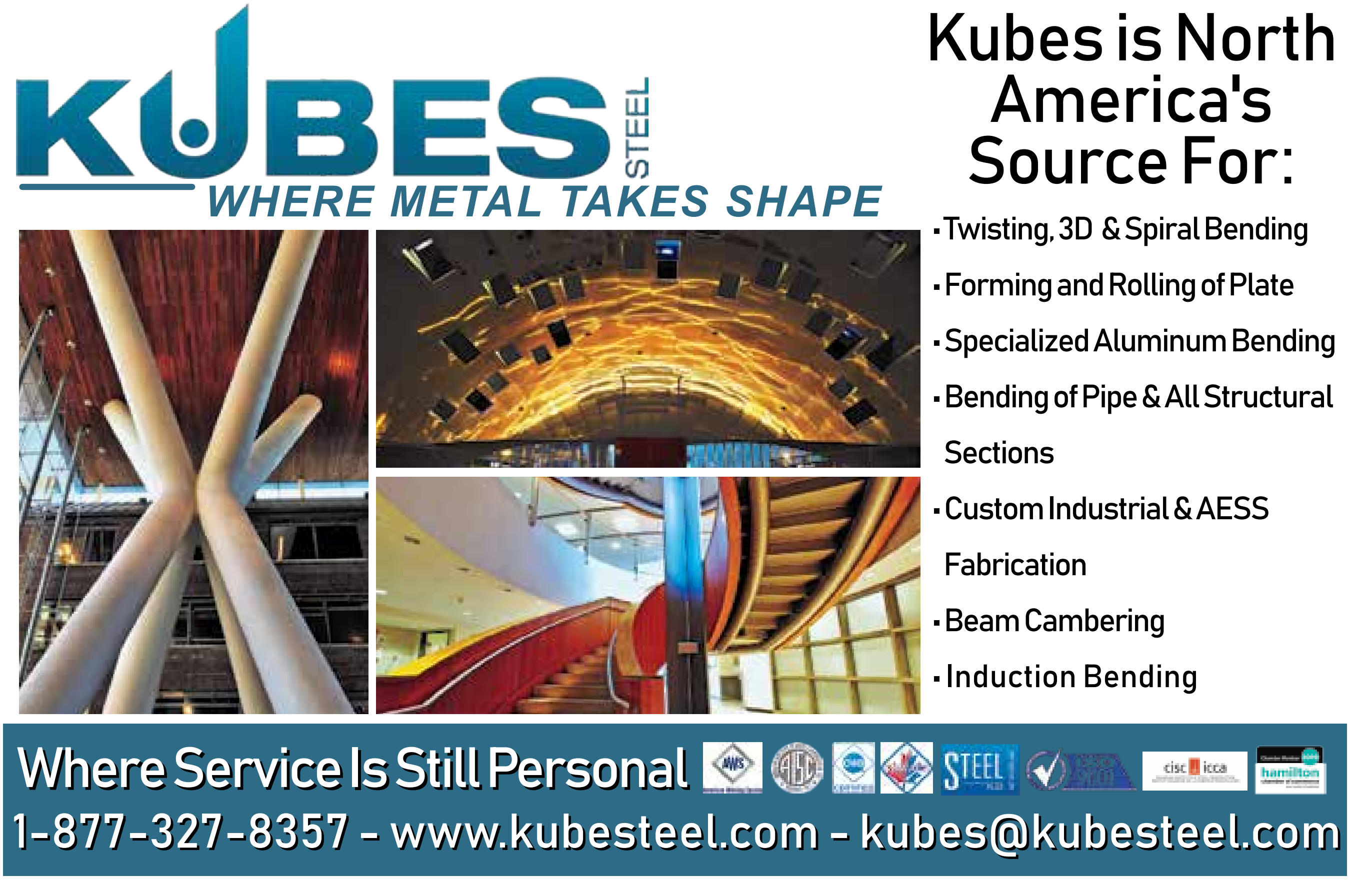
Each year, a specific theme is selected which forms the basis of the competition. Past themes have included "*Suspend*," "*Link*" and "*Surfaces*" and are chosen to define a specific emphasis/design challenge while ensuring students are not limited in their creativity on either structure type or approach. For 2021, the selected theme is "The Market." Students are free to explore ideas related to city, municipal, farmer or other types of markets. The design challenge is to create a steel canopy that acts as a giant roof for the market space. Students must select a site in a Canadian city where a market would reinvigorate an underused space/site and support the local community. And of course, structural steel must be the exclusive material used in the design!

The competition also requires a realistic and practical solution, with students needing to provide a structural grid with steel elements and design buildable connections. Furthermore, the competition helps encourage connections between architects and steel fabricators through a requirement for collaboration with a CISC fabricator to assist in choosing steel members and connections.

You can view information on this year's competition on the CISC website as well as view the winners and runners-up of our past competitions.

On behalf of the ERC, I would also like to express our gratitude for the continued support of the CISC and our funding partners. We have accomplished a great deal with your support and are focussed on expanding our support to address our industry's changing needs. If you have a passion for supporting the next generation of steel professionals and for the future of the Canadian steel construction industry, I encourage you to consider becoming an ERC financial supporter.

Working together, we can help steel be the material of choice for construction (and architects!) now and in the future. AS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Advancing Steel Education in Atlantic Canada

Dalhousie's new steel teaching aid

Dr. Kyle Tousignant, Dalhousie University

**with photos by Riley Nader and RKO Steel*

BACKGROUND

Readers of Advantage Steel Magazine are probably already familiar with CISC's Steel Teaching Aids. These structures help students visualize how steel shapes are joined to form the frameworks in buildings, towers, bridges and other structures, and encourage the growth of the steel industry through education.

The idea for the Steel Teaching Aid was dreamt up in 1986 by the late Duane S. Ellifritt, a then-new professor at the University of Florida in Gainesville. He wanted to provide students with hands-on exposure to structural steel components and connections, since it was difficult for them at the time to visit job sites to see examples of steelwork in full scale. Fast forward 30 years, and Steel Teaching Aids can be found dotting the landscape of North America on university and technical college campuses. Today, more than 170 of these structures exist, with more than 20 of them built in Canada.

DALHOUSIE'S NEW STEEL TEACHING AID

Over the last two years, members of CISC's Atlantic Region have been hard at work, collaborating to develop a new Steel Teaching Aid for students at Dalhousie University in Halifax (Figure 1). The Steel Teaching Aid is a first-of-its-kind effort to put the steel industry "front and centre" on Dalhousie's Sexton Campus, home of the Faculty of Engineering and the Department of Civil and Resource Engineering.

In the early months of 2019, CISC steel fabricator Marid Industries took leadership of the Teaching Aid project after it was met with support from the CISC Atlantic Region and other members, including RKO Steel, Cherubini Group and Russel Metals. In collaboration with Dalhousie University, Marid Industries re-imagined the original Steel Teaching Aid design, depicted in CISC's shop drawings, to fit the backdrop of Sexton Campus. The result was a complete revamp of the structure for functionality, safety and aesthetics – and so that it would

FIGURE 1. Dalhousie's new Steel Teaching Aid

> The Steel Teaching Aid is a first-of-its-kind effort to put the steel industry "front and centre" on Dalhousie's Sexton Campus, home of the Faculty of Engineering and the Department of Civil and Resource Engineering.

FIGURE 2. Details of the Teaching Aid

be truly useful to students learning about structural steel and connection design.

Marid's new design called for structural steel members and connections that are commonly used in the steel industry, such as:

- a column-to-base plate connection, with an example of re-work that is often required (Figure 2a);
- bolted column splices (Figure 2b);
- a welded column splice at different stages of the welding process (Figure 2c);
- shear connections, including a double end-plate connection with a safety clip, and skewed shear connections (Figure 2d);
- several moment connections;
- bracing members (and connections thereto), including HSS, back-to-back angle and tension-only round bar (Figure 2e); and

FIGURE 3. Fabrication of the Teaching Aid Components at RKO Steel

FIGURE 4. The A. Murray MacKay Bridge in Halifax

- other miscellaneous steelwork, including column cap plates, open-web steel joist shoes and kicker braces (Figure 2f).

The final structure consists of pieces ranging from 10" to 4' in length and has a total weight of 1,600 lbs. The structural steel members were both galvanized and painted – a "belt-and-suspenders approach" to improve their durability in Atlantic Canada's harsh maritime climate. For the same reason, galvanized A325 bolts and stainless-steel anchor rods also make an appearance. The fundamental incorporation of architecturally exposed structural steel (AESS) is also noteworthy. This giving evidence that, when properly specified, structural steel can have a striking visual impact.

A MAJOR MILESTONE

Dalhousie's new Steel Teaching Aid was lowered into place at its new home in front of the A.L. MacDonald Building on Sexton Campus on December 7, 2020. The milestone of completion was marked by modest fanfare amidst the COVID-19 pandemic, but it nonetheless represented a major achievement by the CISC Atlantic Region and all its members.

As described by Marid Industries, "The goal of the structure is to educate, promote and inform Dalhousie engineering students about steel construction." Moreover, it will become an integral part of Dalhousie's fourth-year steel design course, where it will be used to exemplify the benefits of steel in construction and assist students in making the connection between design drawings and as-built steelwork.

CISC MEMBER SUPPORT

This "monumental" project was accomplished by bringing together the resources and expertise of CISC members from across the Atlantic Region. In particular:

- Russell Metals donated dead stock material;
- RKO Steel provided cutting of the various plates and angles, fabricated the structure (Figure 3), and performed the trial fit-up;
- Marid Industries donated dead stock material, managed the project, designed and detailed the structure, and performed its final assembly and erection;
- Cherubini Group donated dead stock material via Cherubini Metal Works and provided painting through their member company, Quality Blasting & Coating; and
- CISC Atlantic Region members provided financial support for the construction of the foundation, paving and fencing.

This cooperation and partnership in support of the industry at large is a testament to CISC's impact.

A COMMITMENT TO EXCELLENCE

Dalhousie's new Steel Teaching Aid is a long-awaited and welcome addition to the Sexton Campus. It stands at over 9' tall next to a typically busy pedestrian walkway, where it is fenced in for safety. Its colours, green and orange, pay tribute to the Angus L. MacDonald and A. Murray MacKay steel suspension bridges that span the Halifax Harbour. The A. Murray MacKay Bridge is pictured in Figure 4.

With classes being virtual during the 2020-2021 academic year and students largely situated off campus, an appreciation and formal unveiling event for the Teaching Aid (to thank contributing members of the CISC Atlantic Region for their support) has been postponed until late 2021. Nonetheless, this project – for all those involved – has immediately become a symbol of Dalhousie's commitment to excellence in steel education. AS


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The Tower

Student design competition soars

James Peters

WITH VIRTUALLY EVERY human being on the planet affected by the pandemic in 2020, it was only fitting that CISC's Architectural Student Design Competition showcased such spectacular entries this year. The theme for the 2019-2020 competition was called "The Tower," which challenged students to "create an all-steel observation tower in a significant environment." Many of the entries were truly inspiring and, consciously or not, a testament to the creativity and dignity of the human spirit in what proved to be a very difficult year.

It's fair to say that towers in general hold a special fascination for even the most casual observer, long before Gustave Eiffel's famous one became the gold standard. As the competition's entry description suggests, "Towers have always fascinated for their iconic quality as well as their attraction to reach their top. The objective is to present an elegant structure made of exposed structural steel members and plate, used in any combination."

The three top awards for the 2019-2020 competition were:

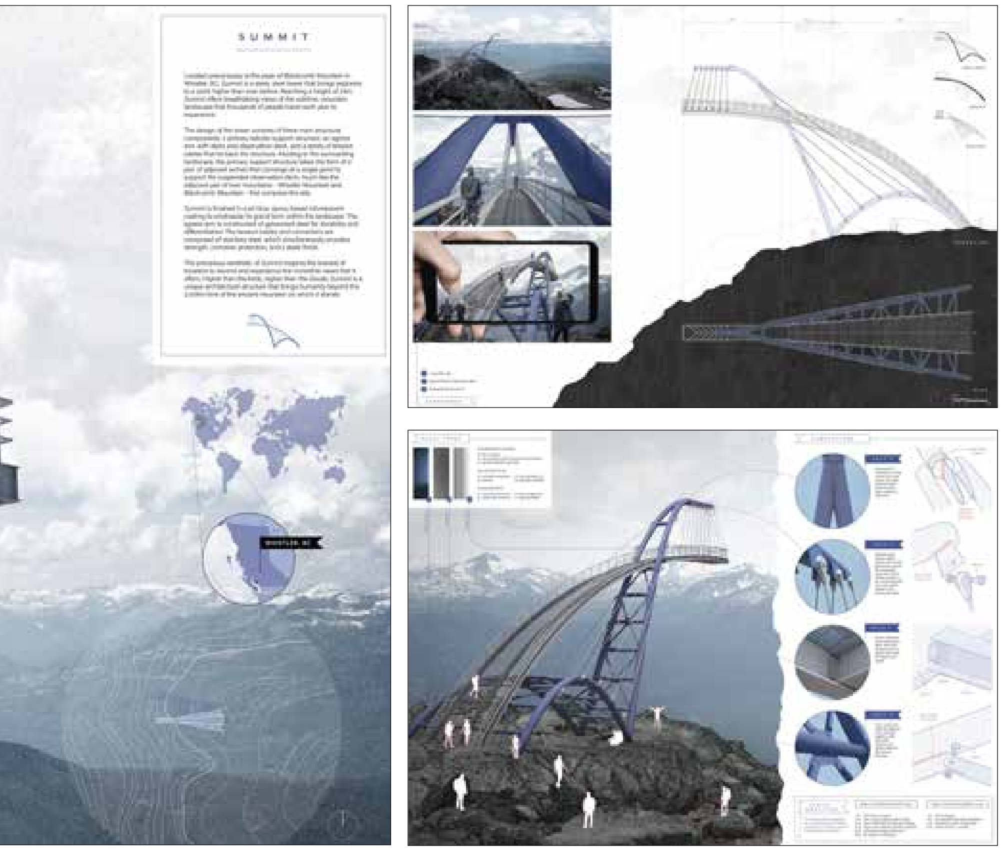
- Award of Excellence to Christina Vogiatzis from the University of Waterloo for "Summit." As the project is described, "Summit is located precariously at the peak of Blackcomb Mountain in Whistler, BC. The sleek steel tower brings explorers to a point higher than ever before."
- Award of Merit to James Kwon and Phil Carr-Harris from the University of Waterloo for "Grand Canyon Lookout." As presented, "The lookout uses as its conceptual and physical base the lasting vigour of the Grand Canyon's geology." Located at the further edges of the park, the structure enhances a less obvious, but popular, viewpoint in the park.
- Award of Merit to Christopher Cleland and Armando Macias from Ryerson for "Windswept." Located in Killarney Provincial Park along the Chikanishing Trail, this structure is meant to provide a spectacular overlook to the scenic and well-forested park.

The rules specify that the height, site and artistic expression are left to the student's discretion. In other words, knowing what to leave out is almost as important as knowing what to include. Student competitors spend a lot of time and energy designing, and ultimately, presenting their projects. And with their visions limited to three A1 size panels, the competitors need to include a lot of material, while at the same time calling up any graphic design and marketing skills they possess. Aesthetics are important – the contest rules even specify that the type of steel, the surface finish and the finish quality (AESS categories) must be specified.

Terri Meyer Boake, a professor at University of Waterloo's School of Architecture, says, "The students have to know what makes for compelling information. When a jury is looking at 60 entries or more, you need to think about what's going to grab their attention, what's going to draw the judges in further, and finally, what's going to get them to vote for your entry. So your renderings can be beautiful, but you have to be able to back up innovative designs with specific details and reasonableness. You have to ask yourself, 'could this structure actually be built?'"

Award of Excellence winner Christina Vogiatzis, who is now working towards her Masters at Waterloo, adds, "Winning the award this year was exhilarating. You never know if you've captured something the judges will like, so you have to trust your own instincts and just run with it. A year before I started the project, I had the opportunity to take a daytrip to visit Whistler – I'd never actually seen a winter landscape quite that breathtaking. So when the tower competition came out I thought of great heights and I thought of Whistler and Blackcomb immediately."

"And yes, you have to really think about how to present your vision graphically. We had an entire course at the university on best



AWARD OF EXCELLENCE:
Summit
Christina Vogiatzis

Faculty Advisor:
Terri Meyer Boake

Located precariously at the peak of Blackcomb Mountain in Whistler, BC, Summit is a sleek, steel tower that brings explorers to a point higher than ever before.

The judges for this year's CISC's Architectural Student Design Competition were:

Paul Laurendeau, ASDC Chair, Architect, Atelier Paul Laurendeau

Michel Comeau, M.Sc., P.Eng., Campbell Comeau Engineering Limited

Bechara Helal, PhD, Assistant Professor, School of Architecture, Université de Montréal

Todd Collister, P.Eng, Director Engineering & Business Development, Supreme Group

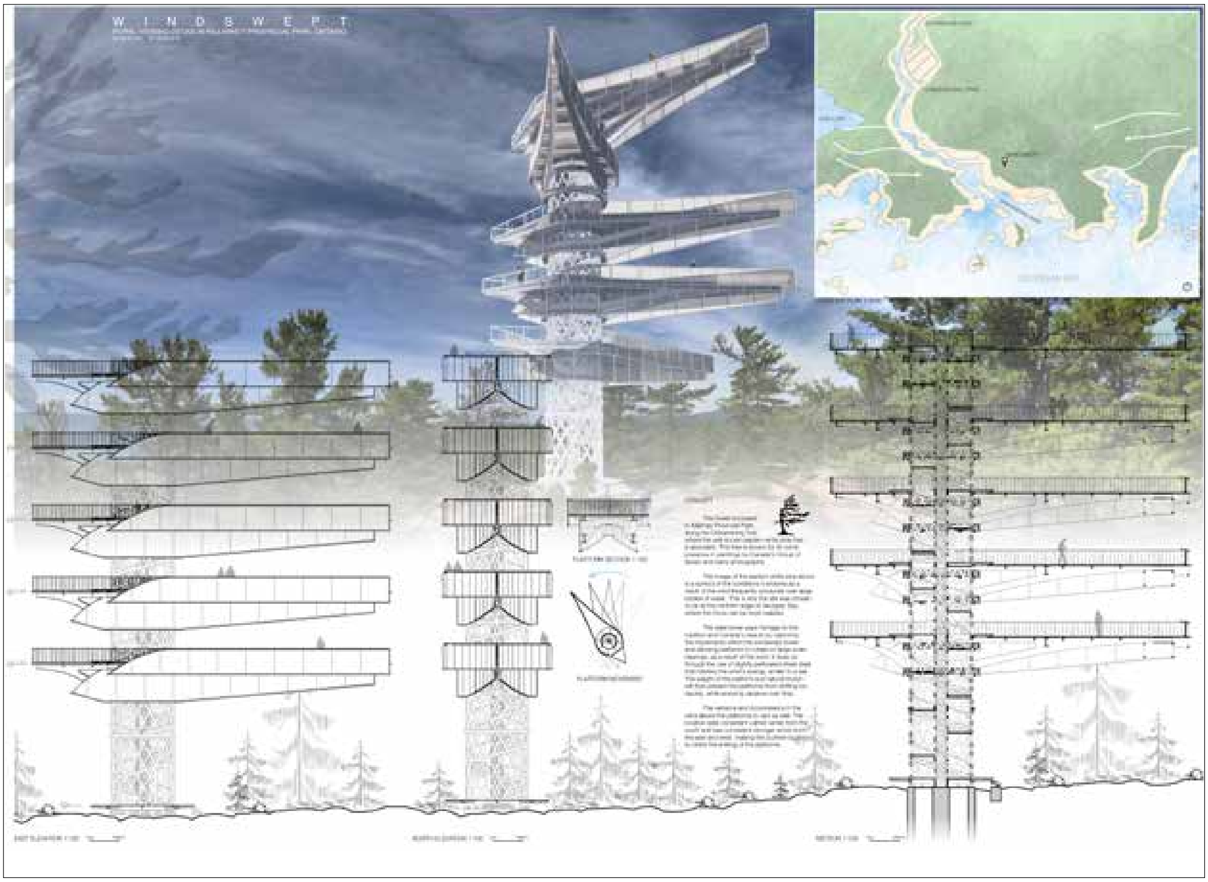
practices for graphic design, colour schemes and layout, which was extremely beneficial. So I started by sketching and I had this image right away of sweeping arches. After more sketching and perspective drawings I moved to computer modelling, eventually arriving at the final form. I just started with the grandest vision I could think of suitable to the site and refined it from there."

Meyer Boake, not by coincidence the sponsor for many U of W entries over the years – including Christina's – echoes the sentiment. "I think these kinds of competitions really allow students to focus on solving a specific problem and not spending months on things they don't want to think about. The CISC competition allows students to explore detailing – and our younger students love the idea of creating something that they think will be structurally sound."

"Ultimately, the competition is won in the detailing," says Meyer Boake. "So the task is to design a credible structure and provide the supporting details that explain how it will actually stand up. Through their detailed presentations, the students allow the judges to see how everything fits together, right down to the nuts and bolts. Again, there's so many learning lessons in this competition – you'll find that students in their fourth year will still have this first-year project in their portfolios, which speaks volumes to its credibility."

Although many Canadian architectural schools encourage their students to participate in the annual contest, not every college does, and many don't advertise the event at all. "And that's truly unfortunate," says Meyer Boake. "At the University of Waterloo, the competition's timeframe is aggressive but always promoted as being worthwhile, given that the student competitors are also, well, students. Across the architectural community, we'd really like to see more students submit to the competition and we're trying to understand why they're not. The number of entries could be much higher."

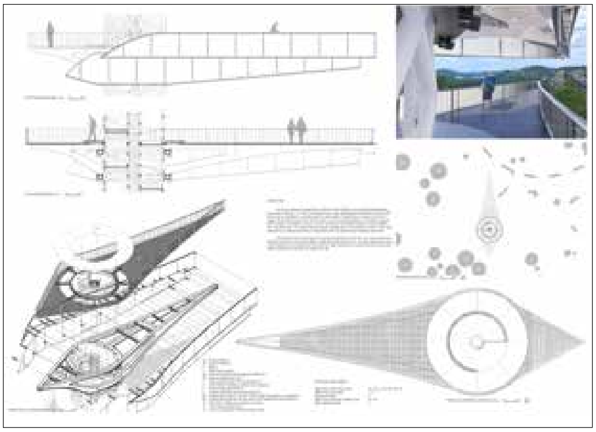
In the real world, of course, architects are almost always working on deadline, which is another reason the competition has long been recognized at the university level as a valuable exercise for helping young architects with planning and design, even if their actual projects are never built.

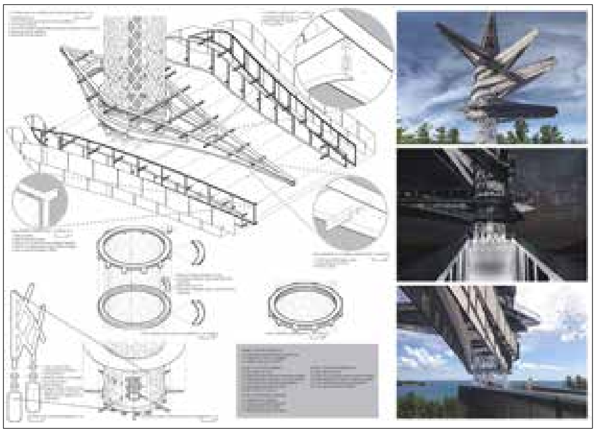


AWARD OF MERIT:
Windswept
Christopher Cleland & Armando Macias

Faculty Advisor
Vincent Hui

This tower is located in Killarney Provincial Park, along the Chikanishing Trail, where the well-known eastern white pine tress is abundant.





The Tower competition was issued in September of 2019. The timeframe allows interested students to work on the projects during the academic year, which is why the judging takes place in May of the following year after the school year concludes. Surprisingly, COVID-19 had little impact on the competition, since in Ontario at least, the schools weren't closed until mid-March.

Deservedly proud, Meyer Boake adds, "The U of W has won a place in the competition every year, since the beginning of the competition in 2001." In addition to two of the top awards, the U of W took five of the honourable mentions; Ryerson took four and one was claimed by students at the Université de Montréal.

Throughout the year, Meyer Boake strongly encourages her students to enter. "And the majority do," she says. "I've had first-year students become masters students as a result of this competition, and it really empowers them. It's such a high for the kids when they're only wrapping up their first year and then win a major contest like this."

And what were the professor's architectural and aesthetic influences? "In 2008 I accompanied on a high school field trip to Egypt, which made me think back to when I was an early teen and how I discovered this interest in ancient things. Over the years, of course, there were countless influences for me but eventually structural steel became my specialty."

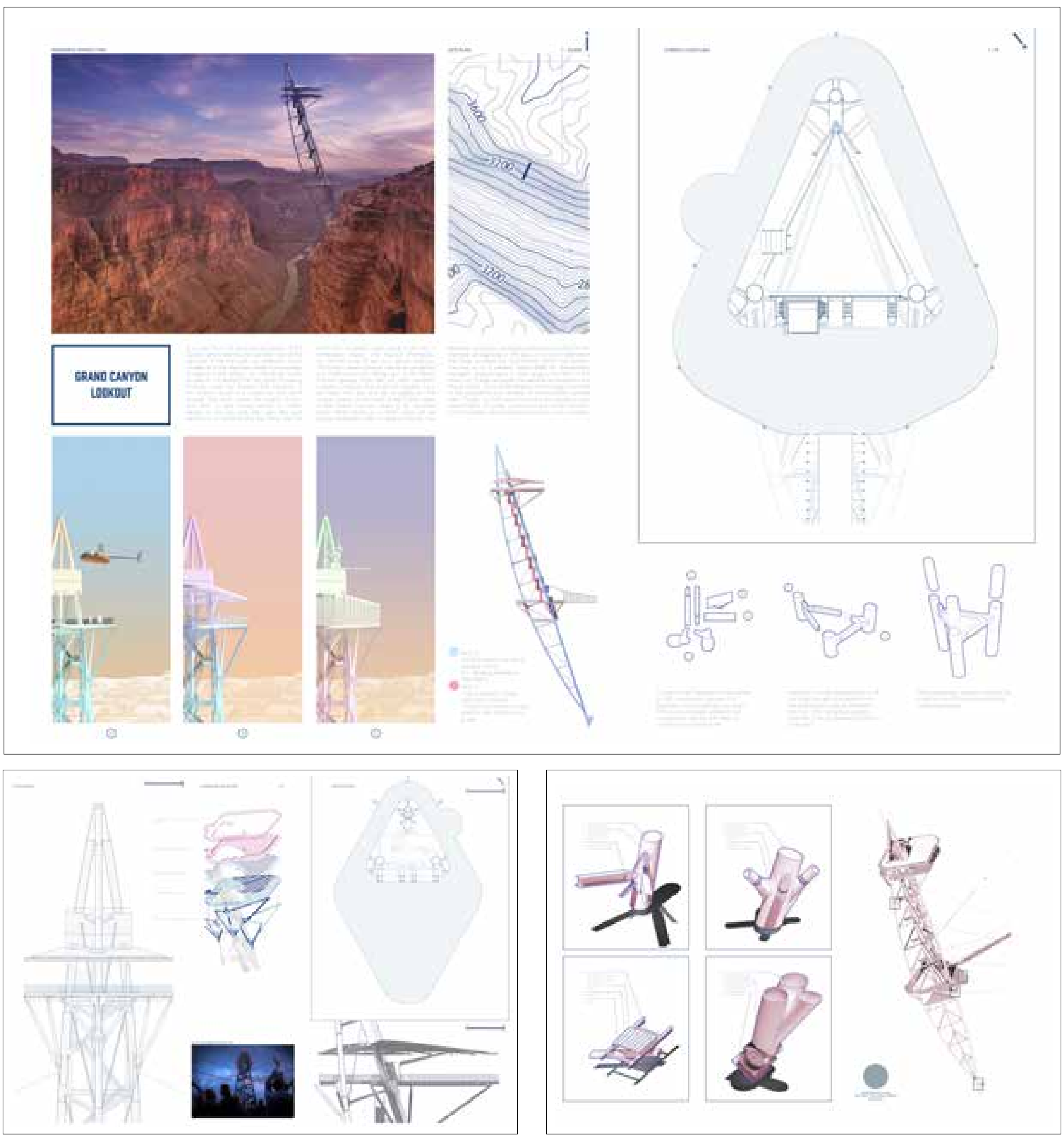
An understatement given the fact that Terri Meyer Boake has authored four books on the subject. She also cites the ability to travel to other countries and attend professional conferences as invaluable. "What you can't take for granted is the simple ability to share ideas, meet with other engineers and architects, understand the role of steel fabricators, and of course, tour buildings and other structures under construction."

As far as encouraging student uptake in the competition, Meyer Boake says, "Some of us have been talking about doing in-person presentations to promote it, and next year hopefully, after the vaccines roll out and the pandemic is under control, we'd like to see regional reps give presentations at schools across the country." In addition, one of the judges this year and Meyer Boake have discussed the idea of producing a professional video that can be played at the presentations. "Paul Laurendeau and I think we might be able to reach more students that way – pictures are so much more vivid and emotional."

Loraine Fowlow, Associate Professor at the University of Calgary's School of Architecture, was one of the people involved with creating the CISC student competition originally. She says, "At the time, we knew there were these kinds of competitions in the U.S.A. but there wasn't anything that was Canadian exclusive. The idea was embraced from the very beginning."

"I think one of the lesser-known aspects of the entire competition is just how much the steel industry gets involved. There are almost always representatives that attend the finals to see what the students come up with – they really warmly embrace their work. Actually, I think there could be more collaboration with the industry and the universities in that regard."

She adds, "The students are so enthusiastic and really embrace working with steel fabricators, and others, to fill out some of their project details. For a student to receive an award like this is huge – it provides recognition and a certain validation. There's a lot of insecurity about creative work, especially as a new graduate. No question, winning an award in this competition is a credential." AS



AWARD OF MERIT:
Grand Canyon Lookout
James Kwon & Phil Carr-Harris
University of Waterloo

Faculty Advisor
Terri Meyer Boake

The Grand Canyon Lookout uses as its conceptual and physical base the lasting vigor of the Grand Canyon's geology. The unique location of this tower, at the further edges of the Grand Canyon, allows it to introduce public infrastructures to a rather closed off yet popular destination.

RENZO PIANO'S NEW GENOA

Setting new standards in efficiency in the aftermath of a tragedy

By Hellen Christodoulou, PH.D. Ing., B.C.L., LL.B, M.B.A. Director, Steel Market and Industry

SAN GIORGIO BRIDGE

Development, Canadian Institute of Steel Construction (CISC-ICCA)

Photo Credit: Pergenova

Photo Credit: Pergenova

Photo Credit: Pergenova

THE TRAGIC COLLAPSE OF THE MORANDI BRIDGE

The Morandi Bridge in Italy was known as the Polcevera Viaduct, and was one of the longest concrete bridges in the world when it opened in September 1967; it spanned 1,102 metres and was both a significant and integral part of Genoa's infrastructure. Tragically, on August 14, 2018, the bridge partially collapsed onto a railway line and a warehouse 45 metres below, tragically killing 43 people and injuring close to 600 others; the city and the country were left devastated. Although the cause of the collapse has yet to be determined, the consensus by experts around the world is that over two decades of neglect was the contributing cause.

A few months later, on December 19, 2018, the announcement was made that a new bridge was to be immediately constructed as a replacement, with a then-estimated price tag of €202 million ($229 million USD), plus an additional €90 million for the demolition of the Morandi bridge. The new bridge was to be christened the "Genoa-Saint George Bridge," and the vision for the construction of a new steel bridge was that it would set new standards in efficiency for a project of its size and complexity.

THE OFFICIAL OPENING OF THE NEW GENOA SAN GIORGIO BRIDGE – ON TIME AND ON BUDGET

Amazingly enough, on August 4, 2020, just 15 months after the reconstruction project began, the Italian prime minister Giuseppe Conte inaugurated the new Genoa San Giorgio Bridge. The management of such a challenging and fast-tracked project of this size and complexity was a mammoth achievement by RINA, the management project consultants. They implemented a team of 80 technical specialists, focused on supervising and navigating all stages of construction, critical timelines, financial budgets and controlling the work progress.

The commitment was phenomenal: 20 sites were operating simultaneously and uninterrupted for 7 days a week, 24 hours a day for almost two years. The expert management during deconstruction and construction was unparalleled. The design of the bridge has been termed by RINA as a "statement in its understatement."

A NEW CONSTRUCTION WITH STRATEGIC SIGNIFICANCE

The structure, or the new Genoa San Giorgio Bridge, was designed free of charge by famous architect Renzo Piano. The construction of the replacement bridge was completed by Pergenova in a joint venture with


Photo Credit: Pergenova


Photo Credit: Pergenova


Photo Credit: Pergenova

infrastructure group Salini Impregilo and shipbuilder Fincantieri Infrastructure. Itzler was the consulting firm that handled the engineering. It was designed for a 100-year lifespan.

This new steel bridge is composed of six lanes: two traffic lanes in each direction and an additional lane on either side for emergency traffic and for carrying out maintenance work and avoiding the main lane closures. It is comprised of 19 spans, varying from 26 to 100m in length, and it is 1,100 metres long, having a continuous steel deck over a 30-metre width. It is supported by 18 elliptical-shaped reinforced concrete piers, spaced at 50 metres apart. The three central spans which cross the Polcevera stream and the railway sections are 100 metres each having two steel wings on the sides with an internal passage for maintenance activities.

Solar panels mounted along each side of the wings were intended to power its lights and sensors. To enhance safety and durability, robots run along the hull of the spans for constant monitoring of maintenance requirements, and a dehumidification system was installed to help prevent corrosion.

The new bridge configuration is as follows:

- 14 spans of 50 metres;
- 3 spans of 100 metres;
- 1 span of 40.9 metres;
- 1 span of 26.27 metres.

THE STRUCTURE

Piano has emphasized that using a steel design enhanced the durability of this bridge. He believed that longevity in such a construction was an achievable goal: "If you use steel, you add the right protection and you make every piece accessible, so that you can repair or repaint every five to 10 years."

The design followed the direct alignment of the existing bridge to connect with the existing Coronata tunnels on the west side and the A7 motorway junctions on the east side. The only exception was at the west side, where the bridge was moved an additional 20 metres away from an industrial building that had been an obstruction to the existing bridge.

Photo Credit: Renzo Piano Building Workshop

Photo Credit Renzo Piano Building Workshop

THE TEAM:

CLIENT: COMMISSARIO RICOSTRUZIONE GENOVA **CONCEPT AND SUPERVISION:** RENZO PIANO, ARCHITECT **DESIGN TEAM:** S.RUSSO (ASSOCIATE IN CHARGE), A.MONTANARI, A.ZANGUIO WITH M.CARROLL (PARTNER), G.SPADOLINI; B.PIGNATTI, A.PIZZOLATO, G.SEMPRINI, C.ZACCARIA (CGI); M.ABIDOS, D.LANGE, F.TERRANOVA (MODELS) **TECHNICAL:** PROJECT ITALFERR **GENERAL CONTRACTOR:** PERGENOVA SCPA - WEBUILD SPA (SALINI IMPREGILO) / FINCANTIERI INFRASTRUCTURE SPA (GENERAL CONTRACTOR) **PROJECT & CONSTRUCTION MANAGEMENT AND QUALITY ASSURANCE:** RINA CONSULTING SPA **LIGHTING CONSULTANTS:** IGUIZZINI


Photo Credit: Pergenova


Photo Credit: Pergenova

The five-metre-deep composite deck was an aerodynamic concept design, isolating it from the piers to protect the structure from seismic activity. This method of separation using support devices allows the bridge to "breathe," optimizing the structure, substructures and foundations, permitting the bridge to naturally expand and contract without compromising stability or strength.

From an architectural perspective, the hull of a ship-shaped deck permitted a gradual reduction of the section towards the ends of the bridge, mitigating the visual impact of the new infrastructure. Light-colour painting of the steel elements makes the bridge bright, harmonising its presence in the landscape.

For the design and construction processes, technology, innovation and experience were key. At every step, Bentley BIM was utilized to provide a digital twin for each segment of steel and concrete component, the mechanical and electrical systems and even the road and surrounding terrain. Focusing on the use of technology was the effective means to reduce costs, promote collaboration and attain accuracy.

Laser scanners flown over the area provided scans with details that could be digitally reconstructed into a 3D surface of the bedrock, enabling precise depth measurements needed for the foundation piles. These templates for both small and large components used the dataset with information on physical elements, construction schedule, dimensions, volume and other vital factors.

FABRICATION

The prefabrication of some major components supported the targeted timeline. The 5m-deep, 30m-wide hollow hybrid steel shell concrete slab structure was fabricated in shops across Italy and shipped to Genoa.

Piling commenced in mid-April, and as pier work expanded along the viaduct, the steelwork was arriving by boat from Sestri Ponente or on trucks from Valeggio sul Mincio, Verona.

Noise and dust levels were monitored throughout the construction process and mitigation steps were instigated to minimize any environmental or social impacts. Roads were wetted to reduce dust, and noise levels were controlled during operations.

Load tests were conducted, during several weeks prior to inauguration, to ensure the loading capacity of the new bridge, using 16 trucks driven along the bridge before static load tests began using 56 trucks, weighing 44 tonnes (48.5 US tons) each. Further tests were done, using a total combined weight of 2,500 tonnes (2,756 US tons).

COVID-19

The effect of COVID-19 cannot be discounted. Teams had to be organized in smaller groups to maximize social distancing. RINA's challenge was the procurement of sufficient personal protective equipment for the approximately 450 people at the site daily. The RINA team held a high level of safety standards and received constant praise from authorities. AS

Credit for info and photos: Pergenova ScpA - Webuild SpA (Salini Impregilo , Renzo Piano Society, Fincantieri Infrastructure SpA

Enzo Siviero, 2019 « Convego del 22 Gennaio a Palermo Storai du in Ponte Il Viadotto Polcevera du Genova », Galileo

Enrico Pietra, 2019 « Ponte Morandi : mainstream ingegneria social e fabbrica de consenso », Galileo

Di Marco Imarisio, 2020 « Su 7 Nel cantiere del Ponte di Genova si ricostruisce mentre l'Italia è ferma Tra fatica, coraggio e speranza », Roconstruire

WA, 2020 « Renzo Piano's new Genoa Bridge opens to traffic in Italy », Italy Architectural News

Olga Mascolo, 2018 «The new bridge on the Polcevera designed by Renzo Piano», Domus for Design

Roberto Carpaneto, 2020 « Efficiency, speed the hallmarks of Genoa bridge replacement », The source

K. Slowly, 2020 « Salini Impregilo, Ficantieri complete Morandi bridge replacement in Italy », Construction Dive

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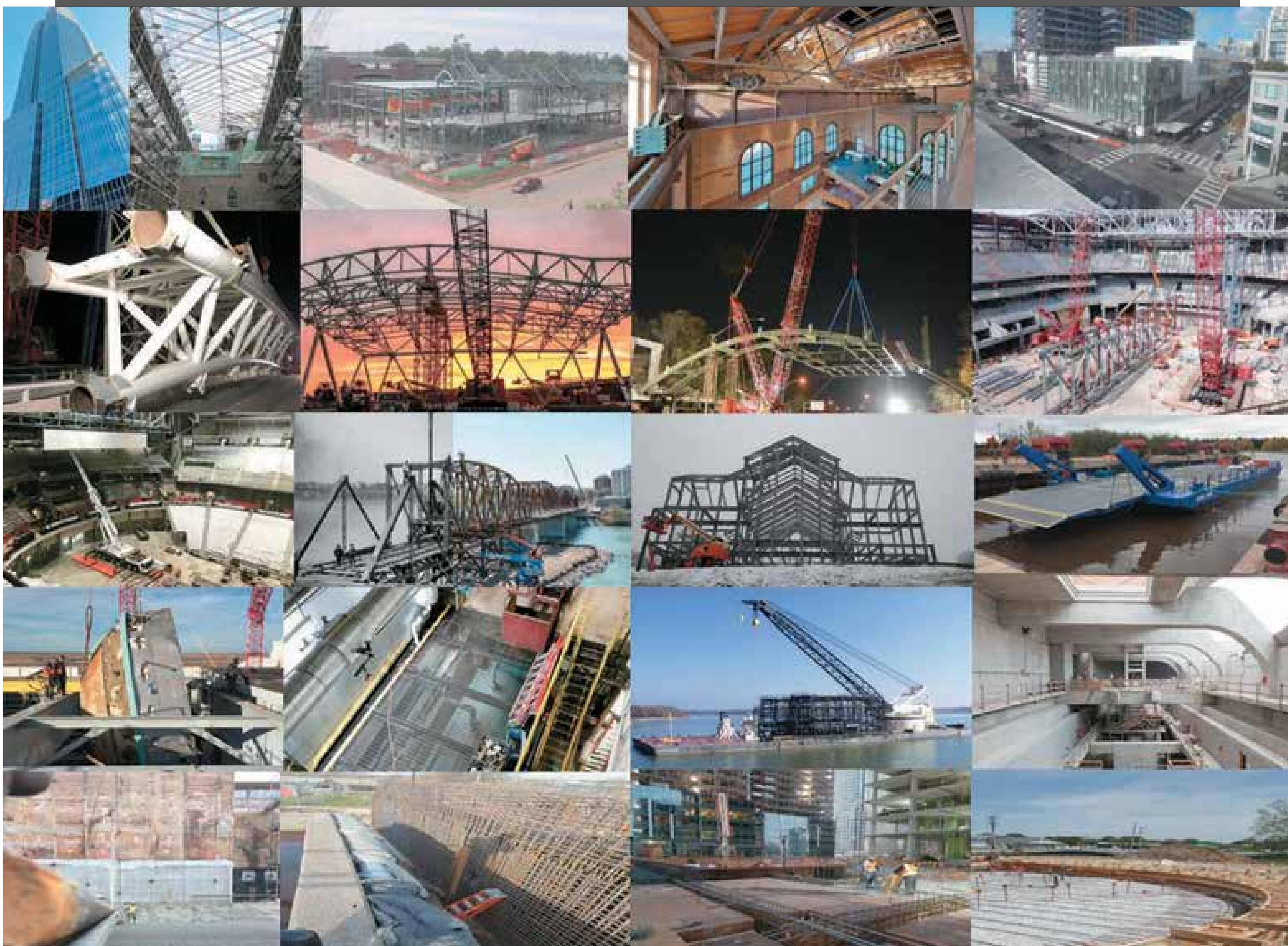

DESIGNING FOR SEISMIC RESILIEN

Faster construction both before and after an earthquake

By Lydell Wiebe, Endowed Chair in Effective Design of Structures and Associate Professor, McMaster

MODERN SEISMIC DESIGN is something like the crumple zone of your car. Just like your car is designed to absorb the energy of a collision while keeping you safe inside, steel buildings are designed to absorb the energy of an earthquake while protecting building users. Unfortunately, though, a building is much more difficult to fix or replace than a car.

Forward-thinking earthquake engineers are working to change that. Where previous generations of building codes and standards have focused on life safety, emerging research and practice looks at promoting seismic resilience, allowing structures to be rapidly returned to service after a large earthquake.

Steel braced frames are a popular lateral force resisting system across Canada because they can readily be designed to provide the necessary stiffness and strength. While the diagonal braces should not visibly deform under day-to-day loading, under earthquake loading they are designed to buckle in compression and yield in tension. In this way, they can withstand the repeated cycles of earthquake energy with damage but not failure, protecting the overall integrity of the structure.

Braces are commonly made using hollow structural sections, which are connected to the beams and columns using gusset plates that are intended to bend when a brace buckles in compression. To promote desirable forms of deformation and energy dissipation during an earthquake, the braces are often connected using site-welded details, even though this adds a layer of complication to the erection process and makes post-earthquake repairs challenging. In addition, typical detailing promotes buckling out of the plane of the frame, which can cause damage to adjacent partitions or cladding.

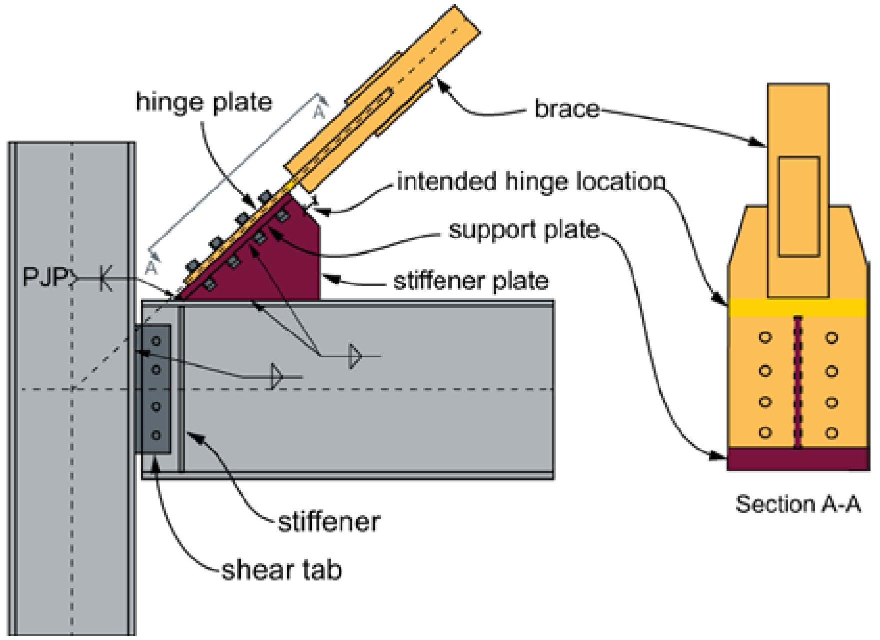

FIGURE 1: Replaceable Brace Module connection

Steel braced frames are a popular lateral force resisting system across Canada because they can readily be designed to provide the necessary stiffness and strength.

A NEW PARADIGM: REPLACEABLE BRACE MODULES

Since 2014 and with the support of the CISC, researchers at McMaster University have been developing an alternative approach to connecting the braces in a concentrically braced frame. This concept is based on a *Replaceable Brace Module*, a unit that is fabricated in the shop and bolted into position on site.

As shown in Figure 1, with a Replaceable Brace Module, the traditional gusset plate is replaced with a designated

CE WITH STEEL BRACED FRAMES

University; Vahid Mohsenzadeh, PhD Graduate

hinge plate that is designed to bend when the brace buckles, together with a stiffener plate to ensure stability of the assembly. In this way, the goal is to avoid site welding and out-of-plane buckling and to facilitate post-earthquake repairs.

An earlier phase of proof-of-concept testing focused on the module itself, demonstrating that the module could confine damage to within the replaceable unit while still providing the same level of seismic performance as more conventional details.

LARGE-SCALE TESTING AT MCMASTER UNIVERSITY

In this latest phase of the research, large-scale system-level testing was conducted on frames using Replaceable Brace Modules, as shown in Figure 2. This testing was possible through the support of the CISC and its members Walters Group, Salit Steel and Atlas Tube, together with the Natural Sciences and Engineering Research Council of Canada (NSERC). The purpose of these tests was to assess whether the Replaceable Brace Module was compatible with typical beam connection details, and whether the replaceable brace modules could indeed be replaced to restore the original performance of the frame even after severe seismic loading.

This 70%-scale testing represented the second floor of a multi-storey building in Vancouver. Three different beam-column connection types were included in the test program: (1) a shear tab connection (i.e. acting as "pinned"); (2) an end-plate connection (pinned); and (3) a bolted unstiffened end-plate connection (fixed). For each of these three connection types, two

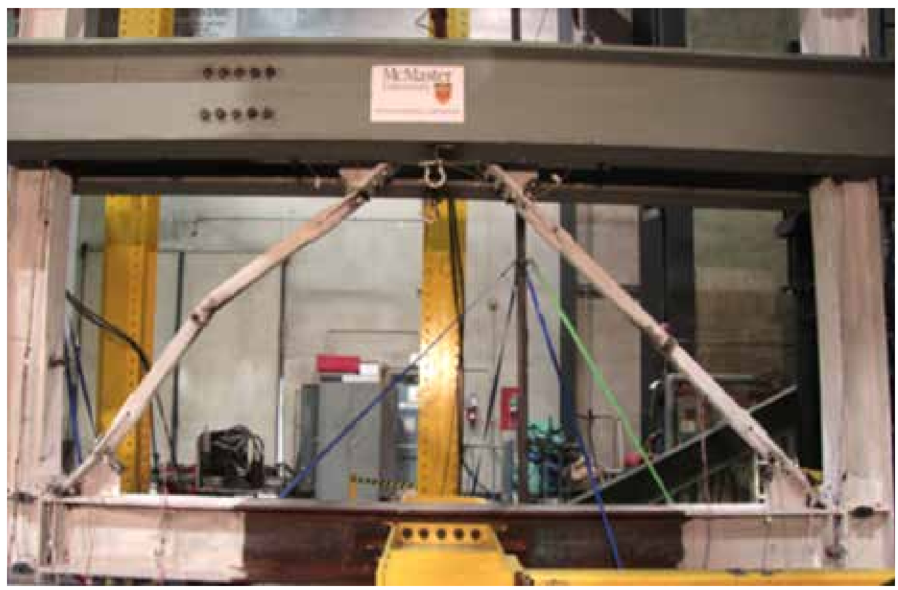

FIGURE 2: Large-scale frame testing with Replaceable Brace Modules at McMaster University

tests were conducted, one with an original Replaceable Brace Module and one with a replacement module.

Figure 3 shows typical deformations that were observed during the test program. In keeping with the design intent, damage was essentially confined to within the Replaceable Brace Modules. As intended for any brace in a seismically designed concentrically braced frame, compression buckling (Figure 3a) led to a plastic hinge and local cupping at the middle of the brace (Figure 3b), with eventual fracture in tension at that location after many large cycles of loading (Figure 3c). This eventual fracture occurred at the same point during the tests that would be expected with any well-designed brace connection detail.

As intended, the hinge plates yielded in bending (shown by the white paint flaking off in Figure 3d) to allow the brace to buckle. After a test was complete, the damaged brace module was removed and replaced relatively easily, and the frame had essentially identical performance with the replacement set of Replaceable Brace Modules.

Of the two pinned beam-column connections, the shear tab connection was preferred not only because of its ease of construction, but also because it was more effective in limiting the demands on the columns. The fixed beam-column connection saw some damage at very large drifts, but also provided the benefit of increased redundancy and reserve capacity.

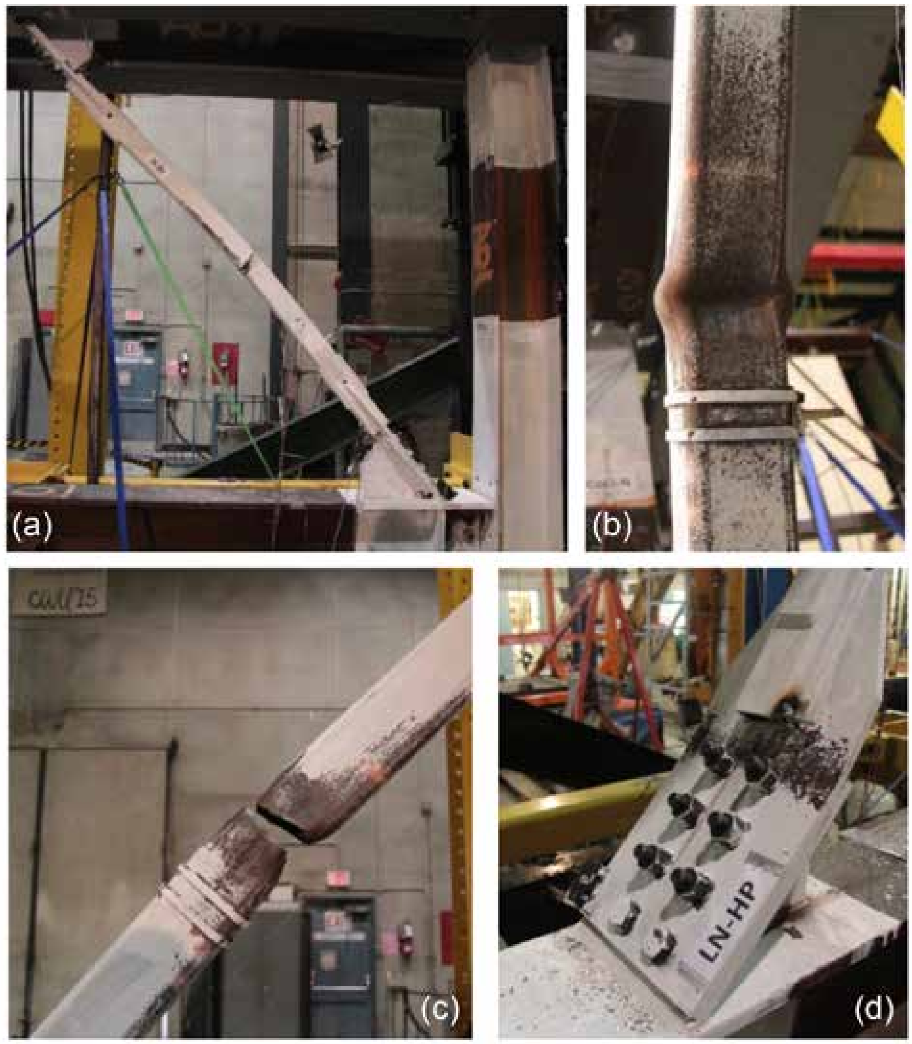

FIGURE 3: Typical Damage Progression

Overall, this test program exceeded expectations in confirming that Replaceable Brace Modules are viable within a complete seismically designed steel braced frame.

DOCUMENTATION AND DESIGN

The results of both phases of this test program have been published in two papers in the *Journal of Structural Engineering*, and the final drafts of these papers are available by contacting the author or the CISC. The design calculations for the experimental test program are also available on request, for those interested in detailed information about how a Replaceable Brace Module can be designed to achieve the benefits in construction and seismic resilience that this test program has demonstrated. AS

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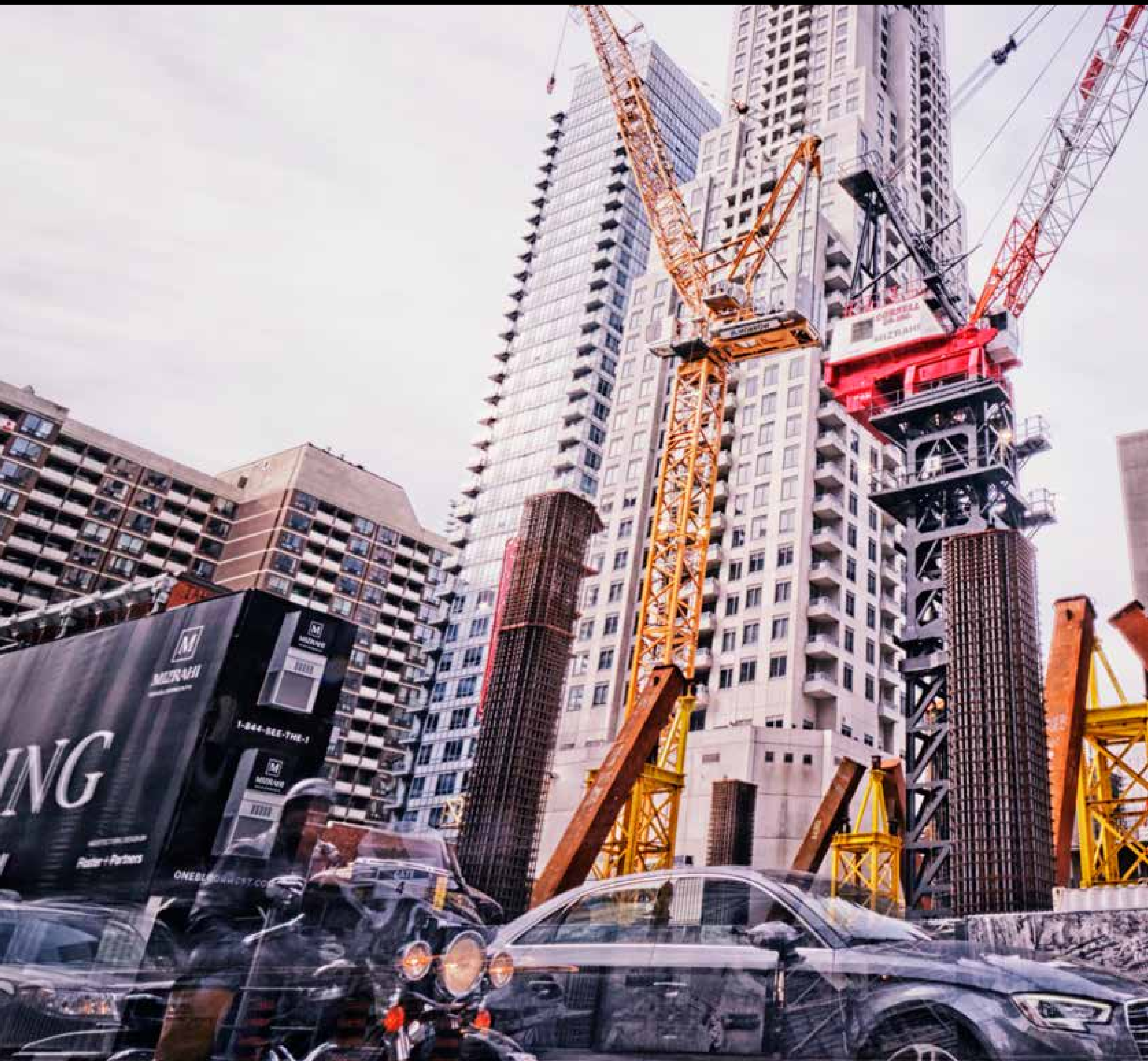
THE ONE WAY TO BUILD THE TALLEST

Steel proves to be essential for constructing the 85-storey building

By Tim Verhey, Executive Vice-President, Engineering & Operations, Walters Group



CONDOMINIUM TOWER IN CANADA

at Toronto's most prestigious address

STEPS FROM CANADA'S most stylish neighbourhood and at the crossroads of two of Toronto's busiest subway lines is a bustling construction site soon to be home to the first super-tall skyscraper in Canada.

It will be called The One, a towering 85-storey building at the intersection of Yonge and Bloor that will rise 308 metres to house 416 condominium units, a hotel, restaurants and 200,000 square feet of column-free retail space.

The design ingenuity behind The One came from the British firm Foster and Partners as well as Core Architects in Toronto. Bringing it to life involves many businesses, including the engineering work of RJC and the design/supply/installation expertise of Canada's own steel fabricator and constructor, Walters Group.

COME TOGETHER

In 2018 Walters Group joined with other trades to work on the design-assist component of the project.

Although a design was already well on its way when Walters was brought onboard, RJC and Walters worked on many challenges, starting with the foundation, all the way to the 85th floor.

"You don't often get to see a large, capable fabricator like Walters get involved in a residential job," says Kevin MacLean, Principal, BSc, MSc, P.Eng., at RJC. "Combined with all of our other

FACTS:

ADDRESS: 1 BLOOR WEST, TORONTO, ONTARIO
HEIGHT: 1,013 FEET / 308.60 METRES **STOREYS:** 85 **NUMBER OF UNITS IN CONDOMINIUM:** 416 **OWNER:** MIZRAHI DEVELOPMENTS **ARCHITECT:** FOSTER + PARTNERS, CORE ARCHITECTS **STRUCTURAL ENGINEER:** RJC ENGINEERS **CONSTRUCTION MANAGER:** MIZRAHI DEVELOPMENTS

On each side of the tower's four sides are groups of very large diameter caissons stretching 37 metres (120 feet) into the bedrock below.

trades partaking in the process, we were able to use high-performance concrete and steel materials in the right way. We leveraged the strength and stiffness of structural steel on the lower levels, allowing us to transfer the loads to the perimeter of the ground floor commercial space, and together came up with innovative solutions for the project's challenges."

FABRICATING TALLER, FASTER, BETTER

Creating the massive steel components of The One is a task that Walters Group takes on with pride.

"All of the 4,500 metric tons of heavy structural steel on site are the responsibility of Walters Group, and we take that responsibility very seriously," says Tim Verhey, M.Eng., P.Eng. Executive Vice-President, Engineering & Operations of Walters Group. "Most components on this project are very heavy but need to be fabricated to incredibly tight tolerances. Some are 50-60 metric tons in weight, yet dimensionally they need fabrication within a couple of millimetres of accuracy."

With the design work and fabrication work well on its way, Walters Group delivered its first truckload of steel in August 2019.

STEEL INNOVATION FROM THE GROUND UP

On each side of the tower's four sides are groups of very large diameter caissons stretching 37 metres (120 feet) into the bedrock below. These caissons support heavy reinforced concrete basement mega-columns which transition to composite mega-columns at the P2 level which are approximately 3 metres by 3 metres in plan dimension. Walters provided an innovative solution which was to pre-install the reinforcing steel onto the composite columns prior to being shipped to site and installed. This was a huge undertaking for Walters Group and required tremendous coordination to ensure the rebar and structural steel were precisely located once placed in the field. This innovation provided significant value to the project.

"There was no readily available solution to quickly install the large rebar on site as needed, so we modularized the structural rebar and installed it in a fabrication shop," says Verhey. The rebar needed was 55 millimetres (2 inches) in diameter and it was simply not an option to install each piece individually on site using a tower crane. Walters worked alongside Rebar Enterprises Inc. to coordinate the rebar detailing, making extensive use of 3D models to arrive at practical solutions.

The team created massive composite structural steel and rebar assemblies in the Walters fabrication shops using unique processes that have never been done before, cutting many months off the construction schedule. Upon installation, each mega-column was formed, then filled with concrete. At the ground floor, the composite columns were capped with specialized structural steel nodes to support the heavy structural steel diagonal framing, which will eventually reach the tower's ninth floor.

THE ONE'S NEED FOR SPEED

One of the highest-capacity tower cranes in North America was brought in from New York to hoist the giant rebar cages, structural steel and other construction materials to be erected with ease and speed.

"This rebar prefabrication and installation process has allowed steel installation to go very quickly," says MacLean. "And the quality of the work and the precision done in the Walters plant is remarkable, and inspected off site, which saves significant time."

"Our fabrication facilities are just outside the GTA, but we still often stage large assemblies just off site down at the docks, or at partners' locations," Verhey continues. "This has helped us to cut down on the waiting time, even though we're only an hour away from the site on days with good traffic."

TOPPING IT ALL OFF

Connected to the caissons and basement columns are mega-columns that could only be possible with steel, spreading the tower's load to the perimeter. The heavy structural steel will continue until the ninth floor, which is where the primary building structure will transition from composite steel and reinforced concrete to just concrete, stretching to the 85th storey. Steel hangers on a six-floor module will be installed by Walters to support the corners of the building from Level 3 to the top of the tower, structural features which are accentuated in the facade detailing of the tower.

Also on the plate of Walters Group is the supply and installation of The One's tuned mass damper. The shaping of the tower's massing on the mechanical levels will improve wind performance, but it will be the damper that ultimately plays the biggest role in controlling vibrations and movements.

"Walters has probably erected more tons of tuned mass dampers than any steel fabricators out there," says MacLean. "They have a lot of experience in this area, so we were very lucky to have their expertise from the start."

By spring 2023, when Walters scope of work is scheduled to be completed, more than 250 truckloads of steel will have been delivered to the downtown Toronto site, including tens of thousands of bolts, the heaviest being over 3.6 kg (8 lbs).

ABOVE THE CLOUDS AND BEYOND

Walters Group has recently completed and is actively working on no less than half a dozen sites in the City of Toronto – yet working on The One is a badge of honour for the whole team.

"Every project we work on is special, but we're especially proud to be involved with this record-breaking tower," Verhey continues. "Through innovation and hard work, we're fortunate to work on some of Canada's most challenging steel projects, especially in the high-rise market."

MacLean agrees with his sentiments, adding, "It is an absolute pleasure to work with Walters on building the tallest building in Canada. They bring a big picture strategic look to the project. They go in with an open mind and make decisions to benefit everyone."

Cooperatively working with design and construction teams to come up with better, faster and more cost-effective ways to build has certainly paid off for the family-owned Walters Group, which has built decades of expertise and an innate ability to make the impossible, possible. AS

BRINGING STRUCTURAL STEEL SOLU

Mixed-use development

By Ian Washbrook P.Eng, Principal and Kirk Haugrud P.Eng, Engineer, Entuitive

TIONS TO A CALGARY PARKADE

THE 9TH AVENUE PARKADE in Calgary's East Village neighbourhood is by no means your average parkade.

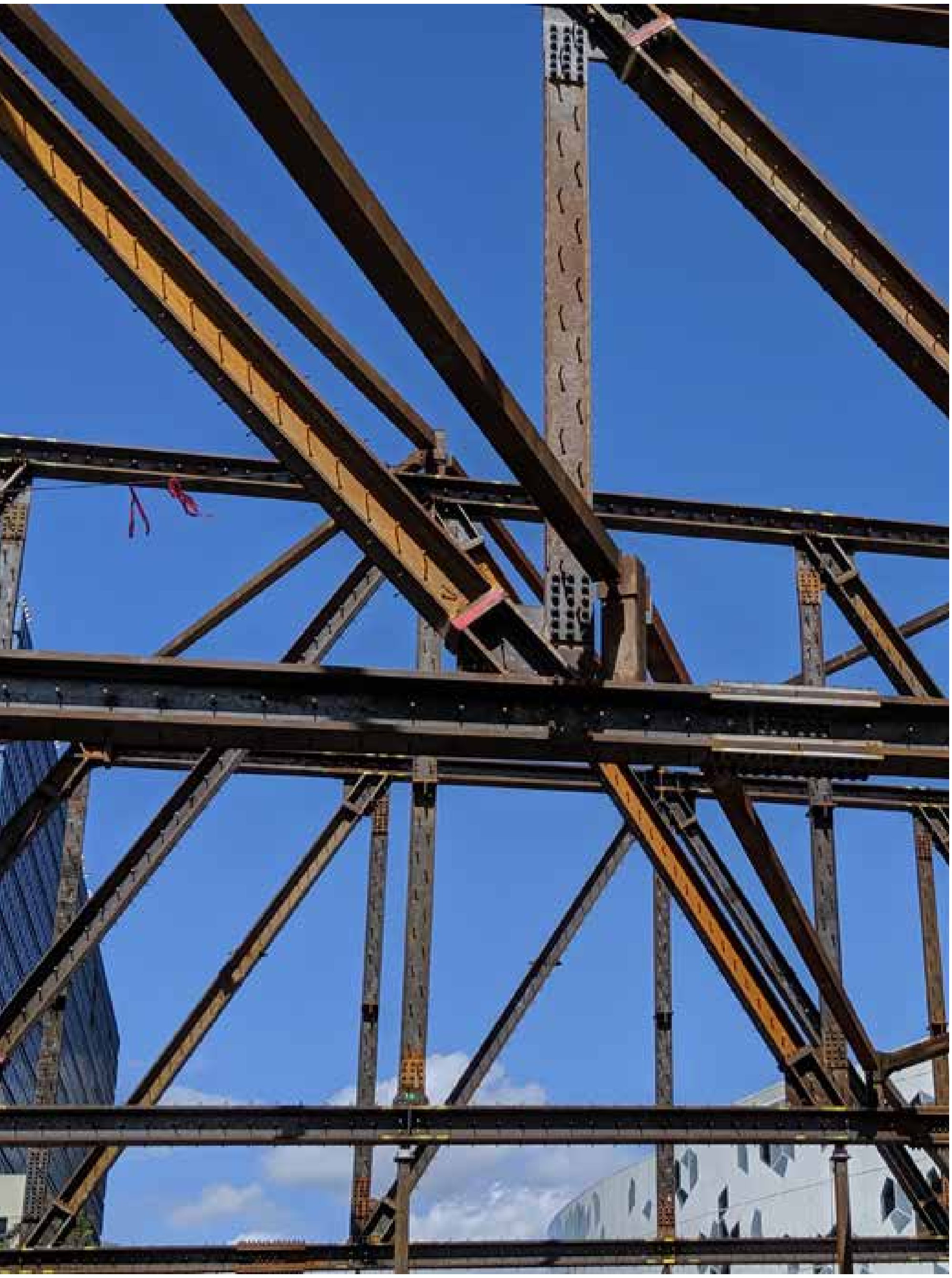
In fact, this 510-stall parkade structure, in addition to serving the cultural landscape that surrounds it, also serves as an innovation incubator space and is truly an interesting mixed-use development.

There were also specific requirements toward ensuring flexibility so that amenity spaces and future occupancy changes could be facilitated. If parking garages slowly phase out, this resilient structure can easily adapt to other types of occupancy with additional superimposed dead loads.

The site presents a number of challenges, including the fact that it's relatively narrow and bounded by Calgary's CP Rail corridor to the south, 9th Avenue SW to the North, utility buildings on both the west and east sides, and Calgary Transit's Red Line tunnel and major utility corridor bisecting the site.

PROJECT SUMMARY

This project, in part due to its unconventional nature and requirements, has brought our team a myriad of technical challenges, many of which could only be solved by implementing structural steel as a framing material.



PROJECT:

STRUCTURAL ENGINEER: ENTUITIVE **DEVELOPMENT MANAGER:** CMLC

OPERATOR: CALGARY PARKING AUTHORITY **TENANT:** PLATFORM CALGARY

EXECUTIVE ARCHITECT: KASIAN ARCHITECTURE **DESIGN ARCHITECT:** 5468796

CONSTRUCTION MANAGER: ELLISDON **STEEL FABRICATOR & ERECTOR:** SUPERMÉTAL

PROJECT MANAGERS: COLLIERS PROJECT LEADERS

Technical Challenge #1

MEGA TRUSSES.

Much like the adjacent New Central Library, the site is bisected by the LRT tunnel roughly 2m below grade. Spanning the building 33m over the tunnel was a considerable constraint of the site which was really only feasible with the use of mega steel trusses. A total of five trusses were needed to span over the LRT tunnel and utility right-of-way, which are skewed in plan, and vehicle drive aisles. Two of these trusses are two storeys tall and the four main trusses weigh roughly 59,000 kg each.

An unconditioned open parking structure exposed to extreme temperature changes, de-icing salts and potential vehicle impacts is not the most forgiving environment for a steel structure. Considering also that the steel would need to be fire protected and support and connect with a primarily concrete building, meant that concrete encasement was essential. To retain a consistent look for the building, the truss members were kept compact so that even the 6.7m-tall column supporting an 18,400 kN (1,900 metric tonnes) design load was no wider than the typical parking column.

While much of the truss framing will be exposed to temperatures below -30°C and necessitated the appropriate Charpy V-notch requirements; large portions of the trusses are also within the conditioned level 2 office space. This temperature gradient added additional complexity to the design and significant additional forces to be resisted, including bending of the web members.

Technical Challenge #2

CONSTRUCTION CONSTRAINTS.

One of the site constraints was that construction loading over the LRT tunnel was not to exceed a uniform factored pressure of 14 kPa. This meant that just the self weight of the trusses alone along with temporary construction loading was close to this maximum threshold. Therefore, the trusses had to be erected and be temporarily stabilized on their own without the concrete slabs in place. Additionally, since the weight of no more than one floor of concrete could be shored at grade over the tunnel, the trusses needed to be sequentially loaded and concrete construction progressed while maintaining the required temporary bracing of the trusses. A carefully planned out schedule was devised that included erecting and removing bracing between the four main trusses with minimal impacts to the concrete formwork, reinforcement and finishing. This required bracing the truss nodes up to a vertical offset of 1m above their work points and a total of 35,040 kg of temporary erection steel.

Technical Challenge #3

FLYING RAMP.

Another challenge involved the fact that level 2 of the parkade is a conditioned innovation space with nearly all parking stalls situated on the floors above. More challenging still was that the innovation space tenant became part of this unique building halfway through the detailed design phase. We had to find a way for vehicles to reach the third level.

The solution was to design a long "flying" vehicle ramp through the atrium of the parkade to allow cars to bypass level 2 from the ground floor. The ramp is supported on 14 girders that crank up and down at different angles and provide a uniquely articulated look. The girders are supported on what was essentially designed as four separate structures with differential relative movements that had to be considered. To allow for this movement, unique large sliding pin details were used at one end of the girders along with a movement joint halfway up the ramp. This one vehicle ramp is made up of 67,443 kg of steel.

Since the site is bisected by a significant water main, the ramp also needed to be framed relatively thin and with a slope profile to allow emergency crews and equipment enough vertical clearance to maintain or repair the pipe. The flying steel ramp also has steel vehicle barriers encased in concrete for durability and enhanced resiliency designed significantly beyond code minimum vehicle code impact loads.

FINAL THOUGHTS

Overall, it's extremely exciting to see the transformation and to help shape Calgary's East Village neighbourhood. Entuitive has had the opportunity to work on the New Central Library and the St. Louis Hotel Restoration, both requiring significant amounts of steel, and now we're part of the team that's helping to design the new Calgary Event Centre. AS

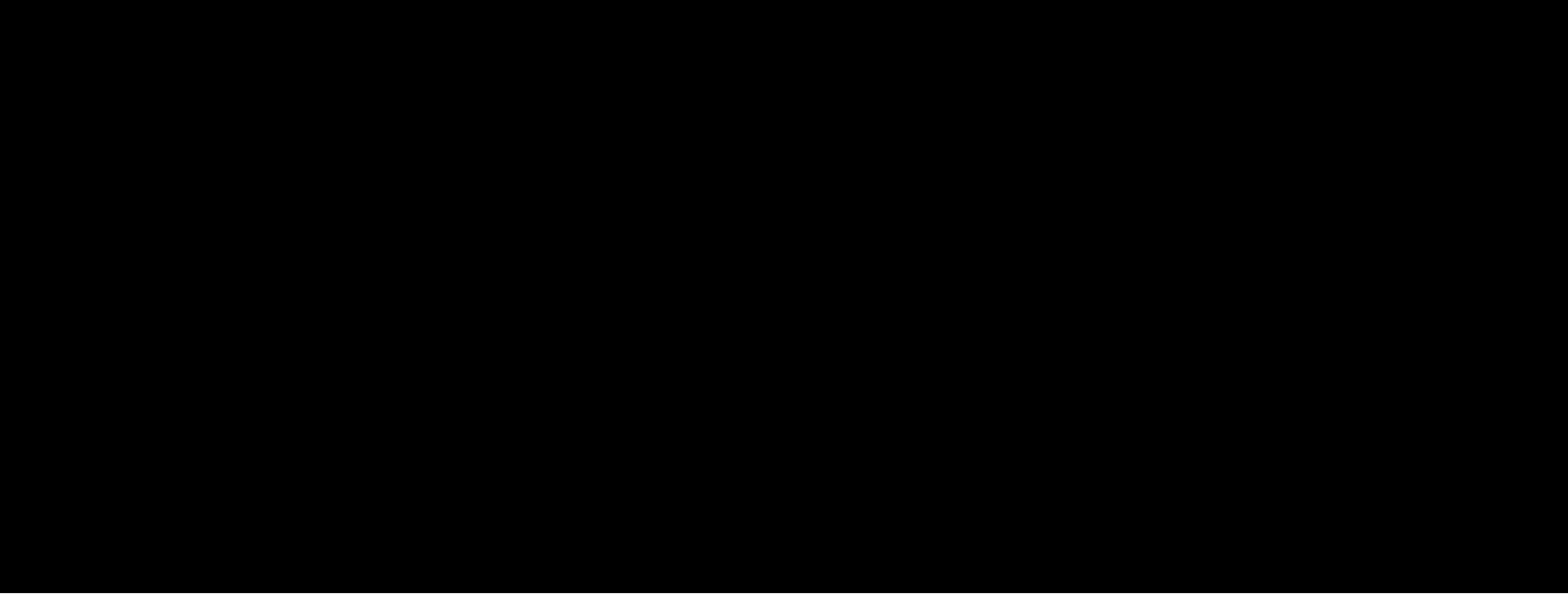
https://www.youtube.com/watch?v=btA4arMiJUQ

"Another challenge involved the fact that level 2 of the parkade is a conditioned innovation space with nearly all parking stalls situated on the floors above."

JOURNEY TO NET ZERO

How steel buildings support sustainability strategies

By Karen Bell and Jacob Rouw, Global Research and Development, ArcelorMittal Dofasco



ONE OF THE BIGGEST CHALLENGES the world faces today is how to address and minimize climate change resulting from carbon and greenhouse gas emissions. Buildings constructed using conventional methods have and continue to consume significant quantities of energy for heating and cooling, producing greenhouse gases in the process. The building industry and government bodies have recognized this problem and are in the process of updating the national building energy codes to achieve net zero ready buildings for 2030[1]. To achieve this goal, energy consumption for a given building must be drastically lowered, allowing it to be powered through renewable sources only once the relevant infrastructure is available. In addition, climate-resilient and energy-efficient buildings are figured prominently in a recent report from the *Task Force for A Resilient Recovery*[2], specifically recommending a coordinated approach with the provincial governments to ensure future buildings will be capable of meeting the upcoming net zero and building resiliency codes.

To support the industry goal of net zero energy ready buildings, the research and development team at ArcelorMittal Dofasco using independent consultants applied Steligence® principles and methodology to a hypothetical mid-rise residential building. Steligence® is an initiative that was launched by ArcelorMittal in 2018 which uses scientific evidence to showcase the environmental and financial benefits of steel in building construction through case studies and building design[3]. In order to develop a building capable of net zero energy performance, the study team turned to a Passive House design concept. The Passive House Institute[4] has developed a set of standards for buildings specific to energy consumption, airtightness and interior temperature variation. As the Net Zero Energy Ready standard is phased in over the next ten years, the demand for passively designed structures is expected to increase. These standards, while not mandatory for net zero, provide guidance for buildings to achieve a net zero energy ready state, primarily through aggressively reducing heating and cooling energy demands.

Passive House Design Criteria used in this study were:

- Space heating demand ≤ 15 kWh/m²yr
- Space cooling demand ≤ 15 kWh/m²yr
- Temperature frequency (T>25°C/77°F) ≤ 10%[5]
- Primary energy demand ≤120 kWh/m²yr
- Airtightness ≤ 0.6 ACH@50Pa (ACH: Air Changes per Hour)[6]

In the study, three building design scenarios were developed covering steel, concrete and timber construction for comparative analysis. Each scenario incorporated a unique structure and exterior wall system designed to achieve the Passive House energy standard. Energy modeling was conducted to validate each scenario could achieve the energy consumption metrics, and therefore be considered net zero energy ready. In addition to the energy model, the study team conducted a Life Cycle Analysis and Cost Estimation to determine how steel, concrete and timber solutions compare from an environmental and financial perspective.

BUILDING OVERVIEW & FUNCTIONALITY

The case study was designed as a six-storey mixed-use commercial and residential building located in the Greater Toronto and Hamilton

Notes:

1. *National Energy Code for Building (NECB) 2017 https://nrc.canada.ca/en/stories/construction-innovation/laying-foundation-net-zero-energy-ready-building-codes-2030*
2. *Bridge To The Future: Final Report From The Task Force For A Resilient Recovery September 2020 https://www.recoverytaskforce.ca/*
3. *Steligence® https://dofasco.arcelormittal.com/what-we-do/architects-corner/steligence-case-studies.aspx*
4. *A Developer's Guide to Passive House Buildings https://www.passivehousecanada.com/downloads/PHC-developers-guide.pdf*
5. *Internal temperature variation was considered during building mechanical design and in energy modeling but is assessed during on-site performance measurements and testing on a completed building.*
6. *Building airtightness was considered during building design and in energy modeling but is assessed during on-site performance measurements and testing on a completed building.*

area, as shown in the architectural rendering[7] in Figure 1. The design used the ground level for commercial space, with residential units occupying the upper levels.

- Size: 6,916m² Gross Construction Area
- Functionality: Mixed-use, commercial and residential
- Stacking: 6-storey
- Level 1: Retail, building amenities
- Levels 2-6: Mix 1-2 Bedroom Units (75)
- Rooftop mechanical penthouse

A unique architectural feature of the building was the split ground-level podium with a pedestrian walkway. The design was intended to reflect the current multi-family residential market and to resonate with a modern developer/construction team's approach to materiality and construction. In considering the three unique design scenarios for steel, concrete and timber, the study maintained functionally equivalent buildings, with all designs intended to be financially viable in today's residential market and reflective of the current residential building code in Ontario.

FIGURE 1:

TABLE 1:

	Steel	Concrete	Timber
Foundation	Insulated slab-on-grade		
Level 1 Podium	Cast-in-place (CIP) concrete transfer slabs, beams, walls, columns		
Mechanical, Electrical, Plumbing	Central energy recovery system, high efficiency mechanical systems		
Glazing	Triple-glazed curtainwall & windows		
Exterior Walls	Insulated steel stud, masonry, Indaten™ cladding	Insulated CMU, masonry, Indaten™ cladding	Insulated double wood stud, masonry, Indaten™ cladding
Core, Shear Wall	CIP concrete	CIP concrete	Cross laminated timber (CLT)
Levels 2-6	Composite deck, steel load bearing walls, light HSS columns and W beams across hallways	CIP concrete walls, columns, floor slabs	Glue laminated timber (GLT) floor slabs, beams, columns, CLT load bearing
Roof	Steel deck	Precast concrete	GLT slabs

PASSIVE DESIGN SCENARIOS

Table 1 provides an overview of the building components used for the structure and exterior wall systems for each scenario[8]. All designs featured the same structural design for the first level, and for the exterior wall assemblies, the steel design using steel stud walls, replaced with CMU for concrete and double wood stud for timber. Additionally, designs were enhanced to meet the Passive House standard with these upgrades:

- Insulated slab and footings
- Increased exterior wall insulation
- Triple-glazed curtainwall, windows
- Thermally broken floor assemblies and balcony connections
- Centralized energy recovery system
- Increased roof insulation

ENERGY MODELING

Energy modeling was conducted using eQuest V3.65[9] to understand the impact that concrete, steel and timber structural systems have on energy consumption, and also confirm that each was capable of Passive House energy performance. Occupancy schedule used for the model was in accordance with NECB Schedule G/C (MURB/Retail)[10]. Limited thermal bridging is permitted in Passive design and requires that the affected areas be calculated and accounted for. To compensate for the energy loss, the envelope needed to incorporate additional insulation

7 Architectural Design Source: mcCallumSather Architects
8 Structural Engineering Source: WSP
9 Energy Model Source: mcCallumSather Architects
10 Energy Modeling Documents:
MMAH Supplementary Standard SB-10: Energy Efficiency Requirements (December 22, 2016)
ANSI/ASHRAE Standard 62.1-2013
National Energy Code for Building (NECB) 2015
BC-Hydro Building Envelope Thermal Bridging Guide
OAA 2030 Targets Ontario Data "Building Type's Energy Use Intensity (EUI) Goals for 2030 Challenge
The City of Toronto Zero Emissions buildings Framework

FIGURE 2:

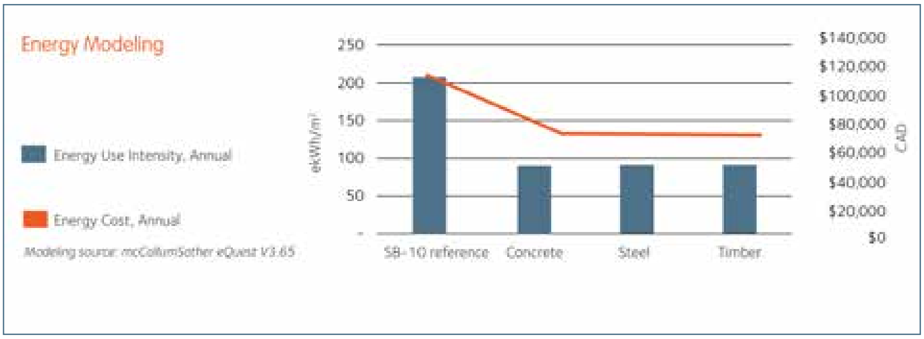
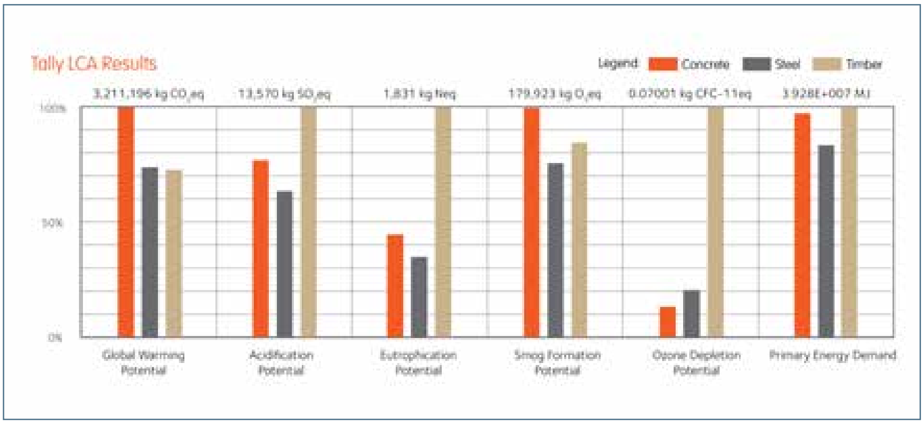


FIGURE 3:



with high R-values to meet the required thermal performance[11]. In the study, the thermal bridging loss was accounted for with the affected surface areas representing 5-6% of the total wall area. Therefore, the overall heat flows for the building as a whole did not significantly change across the designs. When considering air leakage, the model assumed 0.05cfm/ft² of the exterior surface area.

Figure 2 shows the results of the three models for concrete, steel and timber, as well as a reference energy model. The reference was developed using the Ontario Building Code Supplementary Standard SB-10 guidelines. The purpose of the SB-10 model was to provide a non-passive energy benchmark as a basis for comparison to the three Passive House design models. By incorporating passive design elements of a high-performance envelope and high-efficiency mechanical systems with central energy recovery, the annual energy consumption was reduced by 55% relative to SB-10 reference model, with natural gas heating eliminated (SB-10 model used both gas and electric for space heating). The reduction in energy use in turn lowered the building utility cost estimate by one third or $40,000 CAD annually[12]. Comparing the energy performance of steel, concrete and timber buildings, there was minimal difference (all within 5%) with each able to achieve a Passive House energy rating despite differing wall assemblies. Having near equivalent energy performance was considered important to this study, as it validates that each design scenario was neither over nor under designed and could be compared equally.

With all design scenarios functionally equivalent with virtually identical energy ratings, the question now becomes, which structural design scenario should an architect or structural engineer choose? To answer this, the study team completed an entire building Life Cycle Analysis and Cost Estimation.

ENVIRONMENTAL RESULTS

To assess the environmental impact of the design scenarios, a cradle-to-grave Life Cycle Analysis (LCA) was conducted using the Tally® plug-in for Autodesk Revit[13], based on GaBi Life Cycle Inventory (LCI)[14]. The LCA includes modules[15] A, C, D and excludes the B module (Use). Combining the bill of materials, North American environmental product declarations (EPDs) and LCA data, Figure 3 shows the results for the following impacts assessed over a 60-year building lifespan:

- Global warming (Embodied carbon, kg CO_2)
- Acidification (Acid rain, kg SO_2)
- Eutrophication (Nitrate equivalent, kg N)
- Ozone depletion (CFC equivalent)
- Smog formation (NO_x, VOCs, O_3)
- Primary energy (fossil and renewable, MJ)

Results from the Tally LCA determined the steel-based design outperformed concrete and timber in a majority of the categories. Steel had the lowest potential for acidification, eutrophication, smog formation and energy demand. For global warming, steel and timber were similar, and both were significantly lower than concrete in CO_2 equivalent emissions. For ozone depletion potential, it should be noted that quantities of this scale were considered insignificant for all three designs, attributed to CFC emission restrictions.

When considering and comparing all environmental impacts together, it was found that the steel-based design had the smallest environmental footprint overall. In all cases, it either showed the lowest or intermediate potential, but never the highest for any given impact.

FINANCIAL RESULTS

Construction cost estimates were obtained for the three design scenarios, intended to represent realistic budget and market value conditions in 2020[16]. The estimate was based on the following assumptions:

- Location cost base was Southern Ontario
- Rates include labour and materials, including equipment and subcontractor overhead and profit
- Competitive bidding with union contractors
- PST included in unit rates (HST and/or GST have not been included)
- Totals are the Net Construction Estimates (excludes Z1 General Requirements and Fees and Z2 Contingencies[17])

11 Concrete, Steel, Timber wall assemblies were calculated at R-42, R-40, R-43, respectively
12 Assumed electricity and natural gas rates were $0.125/kWh and $0.09/m3
13 Tally methodology is consistent with LCA standards ISO 14040-14044, ISO 21930:2017, ISO 21931:2010, EN 15804:2012, and EN 15978:2011. For more information about LCA, please refer to these standards or visit www.choosetally.com.
14 LCA modeling was conducted in GaBi 8.5 using GaBi 2018 databases and in accordance with GaBi databases and modeling principles.
15 Life-Cycle Stages as defined by EN 15978.
16 Construction Cost Source: Altus Group
17 Z1 General Requirements & Fee assumed at 15% on Net Construction Estimate, Z2 Contingencies assumed at 8% on Total Construction Estimate

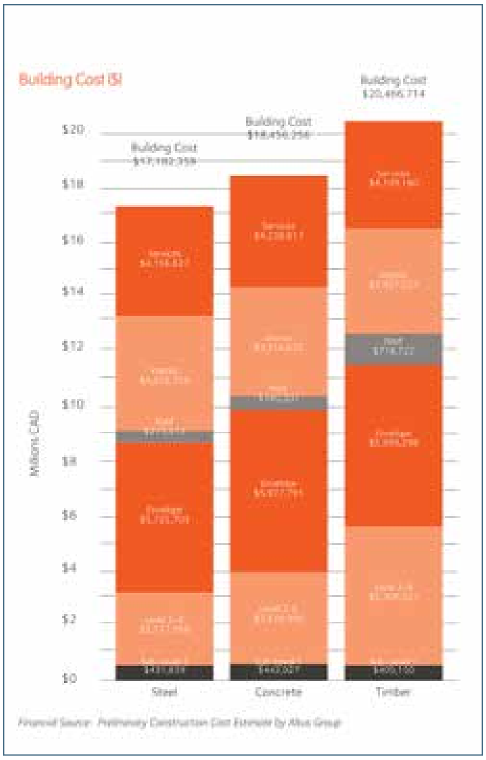


FIGURE 4:

	Steel	Concrete	Timber
Structure	98	135	106
Exterior Walls	177	177	177
Overlap	-65	-95	-65
Total	210	217	218

TABLE 2:

"A shortened schedule can contribute to lower financial costs through benefits such as: reduced crane and trade costs, lower financing and construction insurance, and earlier occupancy date for rental revenue."

Figure 4 shows the Building Cost by Net Construction Estimate for each design scenario and includes a breakdown of the Elemental Summaries. In terms of total cost, the steel design was the most economical at $17.2M CAD. The concrete estimate was 7% higher than steel, while mass timber was significantly higher at 19%. The difference in cost was attributed to the increased material and installation costs of the concrete and mass timber in the upper floors (levels 2-6) and the roof.

The study team also conducted an analysis of the construction schedule[18]. A shortened schedule can contribute to lower financial costs through benefits such as: reduced crane and trade costs, lower financing and construction insurance, and earlier occupancy date for rental revenue. The construction schedule was determined by calculating the working days per floor for the structure and exterior walls, while accounting for overlap. The following assumptions were used to calculate the working days for floors 3 to 6:

- Steel (13 Working Days/floor)
- Prefabricated steel stud wall lifts (150): 5 days
- Concrete shaft, shear wall work: 4 days
- Composite Decking: lifts (60) 2 days, 2 days installation
- Concrete (20 Working Days/floor)
- Forming, pouring elevator and mechanical shafts, stairwell, floor slabs, load bearing and exterior walls, form work removal: 20 days
- Timber (15-16 Working Days/floor)
- GLT floor slab lifts (150, 2 slab gang): 6 days
- Columns, beams, CLT shaft wall: lifts (160) 8 days, 1-2 days installation

The exterior wall construction scheduling included the Passive House requirements for air tightness and inspection/testing of the envelope, which were the same for each design. The overlap indicates when enough of the structure is completed to allow work to proceed on the exterior walls. The overlap for concrete was found to be greater than the other designs due the additional days required to finish the structure as opposed to the exterior wall work starting earlier. Using these assumptions, the total number of construction days required for each design scenario was determined and summarized in Table 2. The estimates determined the steel design would have the shortest construction schedule with a 3% total reduction compared to concrete and timber. The building could be erected in 210 days total, which was seven days fewer than concrete and eight days less than timber.

CONCLUSION

In this Passive House/Net Zero Energy Ready case study, the steel-based design was found to be the most environmentally sustainable and economical compared with concrete and timber alternatives.

As the construction industry continues to move towards net zero energy ready buildings, steel provides both a viable and favourable solution. It can achieve the energy requirements as defined in the Passive House standard, while maintaining the lowest environmental impact, cost and speed of construction. AS

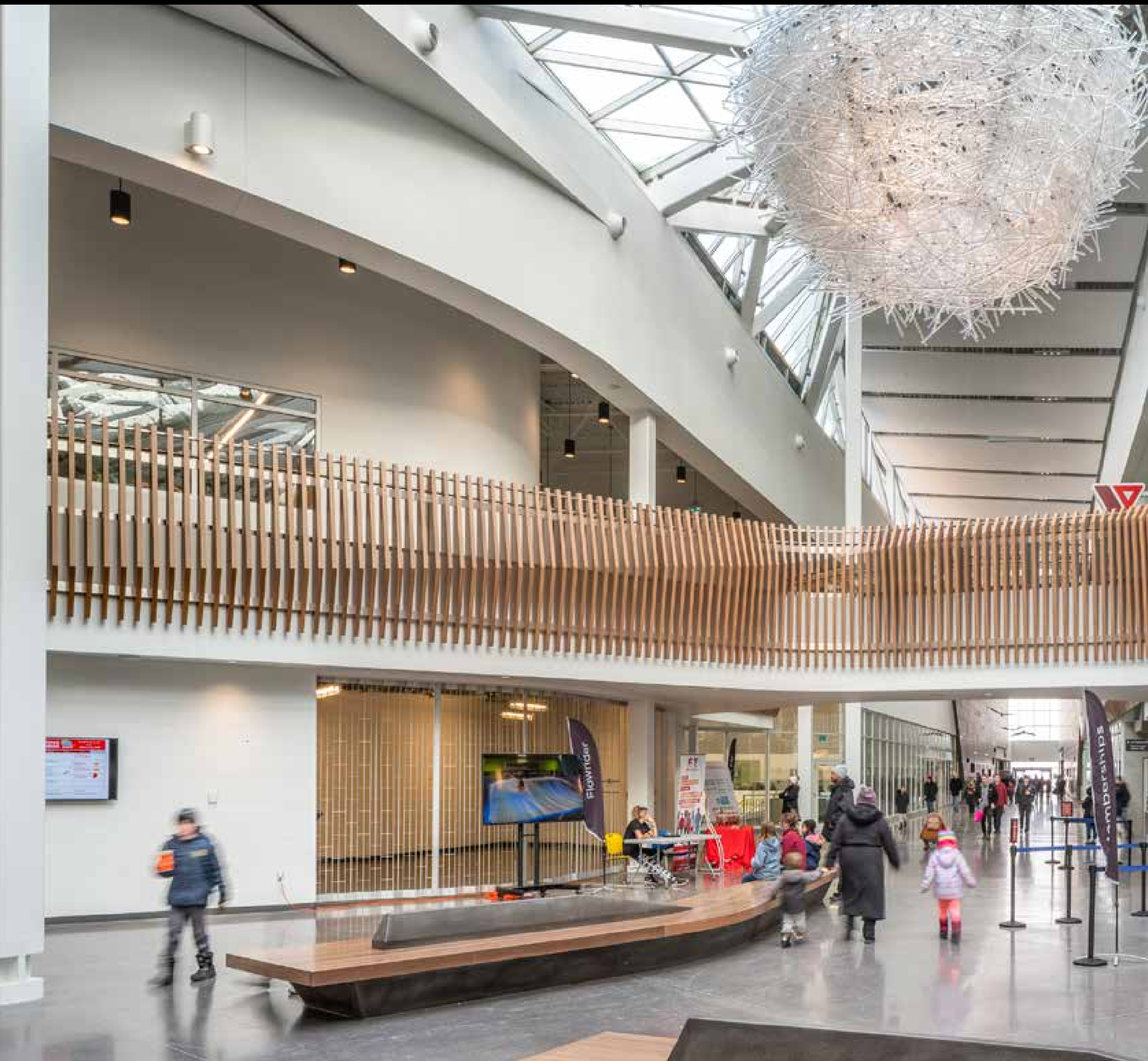
18 *Construction Scheduling Source: MPa Project Consulting*

FEATURE

THE EVOLUTION OF STEEL

An Interview with Frank Cavaliere, P.Eng., Managing Principal, RJC

By Tanya Kennedy Flood



IN RECREATION CENTRES

Engineers

THE STEEL INDUSTRY has adapted and responded to the evolution of recreation centres. These long span buildings have changed dramatically in the last 20 years, from simple, pre-engineered structures to dramatic custom landmark buildings, with steel being a popular material for both.

Frank Cavaliere, Managing Principal with RJC Engineers, has witnessed first-hand as a structural engineer how recreation centres have advanced from traditional pre-engineered structures to complex, highly aesthetic buildings. "Municipalities are investing in recreation centres, developing them as community buildings that house more than sport; they may include libraries or schools, for example. Larger municipalities now want award-winning design, highly aesthetic, architectural buildings."

Based in Edmonton, Cavaliere shares that, historically, many recreation centres in Alberta used wood or pre-cast concrete for the structural system. At the time of his first recreation centre in the early 2000s, municipalities were constructing pre-engineered steel buildings to develop recreation centres. Using pre-engineered structures allowed owners to get major square footage for a relatively low cost. Design teams would incorporate one or two pre-engineered shells to house an arena or two, and potentially a gymnasium. The facility would be built out within the defined shell, possibly adding custom steel fabricated office areas, libraries, schools etc. Since the pre-engineered look was not desirable, the large space elements such as an arena or natatorium would be put at the back of the building. This approach created a highly efficient structure that provided major square footage at a relatively low cost.

Servus Place in St. Albert, the Bold Centre in Lac La Biche, the Leduc Recreation Centre and the Camrose Recreation Centre are all examples that used this pre-engineered steel structure approach. Delivering these structures was a team effort. The supplier of the pre-engineered structure was very involved throughout the design, because often-additional elements, such as mezzanines or running tracks, had to be supported off the pre-engineered structure. The process was very collaborative and non- traditional, with the suppliers of the pre-engineered structures and the structural engineer of record working closely to deliver these facilities. Typically, the pre-engineered suppliers would work on their own to design big open spaces like shops or industrial buildings, but these recreation centres required a more custom approach to deliver a more customized building from their kit of parts.

"We learned a lot about how pre-engineered suppliers do things and how they are efficient. In turn, they learned from us too. It wasn't just a matter of putting a snow load on the roof and a wind load on

Commonwealth Community Recreation Centre and Field House

Lewis Farms Recreation Facility

the wall and away you go; there was a lot of coordination between what they were supplying and what we were supplying. On the Camrose Recreation Centre for example, one arena is a performance arena with 2,000 seats, so the bowl structure for the arena seating was cast-in-place concrete, but the perimeter of the building was pre-engineered steel. We had to develop an interface between the cast-in-place concrete and the engineered steel." The two groups worked together closely to communicate loads and details, pushing the boundaries of the pre-engineered structures and allowing for the necessary customization. It was a new concept at the time and had challenges, who is responsible for what structurally? How do both groups detail and coordinate the design properly with respect to scopes of work – what is each discipline, supplier and trade responsible for? For example, it was a change for everyone to take a pre-engineered steel building that then had elements welded onto it in the field in order to integrate it with concrete. All team members had to literally think outside the box!

Over time, municipalities began to desire more architectural pieces for their recreation facilities, making pre-engineered structures less desirable. Changes to the energy code also spurred this change; owners were no longer saving as much money using a pre-engineered shell because of the modifications to the building envelope that had to be made to achieve the required energy efficiency.

The next generation of steel recreation centres are highly architectural and custom. Often there aren't equal modules as far as grid line spacing or the building has odd shapes. Recreation centres are no longer just rectangular; they are parallelograms or rhombi for example. "For Clareview Community Recreation Centre," says Cavaliere, "we have one big irregularly shaped box that houses both a natatorium and a library, and below the library is all the pool mechanical for that adjacent space. That entire box only has three interior columns carrying nearly 50,000 square feet of roof area. There are massive trusses spanning diagonally because the roof is ridged along the diagonal. There is just no way to do that kind of design effectively in any material but steel."

Custom recreation centres is where steel really began to shine for this building type. The flexibility

Clareview Community Recreation Centre

allows for trusses that span massive spaces and for things to hang wherever you want. In steel recreation centres, mezzanines, running tracks and viewing areas can hang in midair. Architects can design very impressive buildings with features such as a library with a glass wall separating it from a pool, while still maintaining the integrity of the envelope. Many recreation centres today feature custom fabricated steel structures that span anywhere from 60-70m with no internal columns allowing for large arenas or natatoriums. Architects are able to put these big areas wherever they need to be in the building. Pre-engineered structures did allow for this in plain rectangular geometries, but the pre-engineered components were always at the back because it wasn't desirable to have them facing the street.

Today, Cavaliere's work includes Lewis Farms Facility and Park, a highly architectural modern recreation centre designed by architects Stantec and Saucier + Perrotte. One of the most dynamic features is also one of the most structurally complicated. Covered by a very large round roof are three levels of community space that include gymnasia, office space and wide-open circulation space, all under the rotunda roof that is 21m in the air. Steel allowed the design team to span 42m over a second-floor gymnasium and 18m over the main lobby/entrance area. The tallest part of the pool, where the dive towers are, is also underneath that high roof and then it steps down to enclose the shallower end of the competitive pool and recreational pools. The flexibility and customization of steel has made this design achievable.

"One of the advantages of steel, aside from its efficiency, is the variety of shapes you can get in steel members, and the finishes you can achieve. It gives architects the opportunity to decide if they want to hide the structure or leave it exposed. You can use very architecturally pleasing sections to make the trusses a feature versus hiding it behind a ceiling," states Cavaliere.

Leaving the structure exposed can not only save money, but there are issues that can come with having a ceiling in high humidity space such as a pool or arena. A ceiling can hide potential issues that may be developing, such as corrosion, and depending on the ceiling material it may not perform well in a humid

Leduc Recreation Centre

environment. Damage can also happen to ceilings in recreation facilities. "The Field House we designed for Commonwealth Stadium Community Recreation Centre is where the Edmonton Football team practices, so there were strict height requirements, we had to have a clear height of 14m," says Cavaliere. "Even with these heights, there's always a risk of damage. You don't want the ceiling to be damaged from footballs hitting it, so you don't want a ceiling in that space."

Leaving the steel structure exposed can be very attractive given the ability to develop customized trusses. Architects and engineers can use anything from the most highly efficient trusses, which tend to be less attractive, to very architecturally ornate trusses. Mechanical can also be run through the trusses, which is desirable for recreation facilities that have big spaces and need a lot of air movement. Trusses can allow for massive 1,200 diameter ducts to pass through, efficiently creating a very neat and tidy ceiling space and enhancing the look of the building.

Cavaliere only sees the use of steel in recreation facilities and other custom buildings increasing. "The steel industry itself provides many advantages over other materials. Fabrication shops are getting much more high-tech, a lot of them use computer aided fabrication methods and welding methods. The industry has really embraced the architectural side. Steel is not just some ugly thing that you need to hide anymore, the steel industry has really stepped up their game architecturally to make it more attractive for architects and owners who want to use it and to leave it exposed." Cavaliere also points to the welding methods and guidelines that the CISC created around architecturally exposed steel and the different levels of architecturally exposed steel. "The methods and guidelines have made it much easier for architects and engineers to speak the same language by creating a standard of finish that can easily be quantified and selected. It gives the architect a cheat sheet of sorts to say 'this is the level of finish that I want for this element', and it is just a matter of writing that into the specifications."

Steel is and will continue to be an excellent choice for recreation centres. While many municipalities desire iconic buildings, others continue to have limited budgets that benefit from the cost savings of pre-engineered steel structures. The ability for steel to benefit recreation centres at all ends of the design spectrum highlights the flexibility and advantages of this material. It will be interesting to see what the next 10 years brings in steel and recreation centre design! AS

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ST. AUGUSTIN DE DESMAURES, QC

ACIER PACIFIQUE INC.
LAVAL, QC

ALBERTA INDUSTRIAL METALS
A DIVISION OF RUSSEL METALS INC.
RED DEER, AB

B & T STEEL
A DIVISION OF RUSSEL METALS INC.
STONEY CREEK, ON

CUSTOM PLATE & PROFILES LTD.
A DIV. OF SAMUEL, SON & CO. LTD.
DELTA, BC

MCCABE STEEL
A DIVISION OF RUSSEL METALS INC.
STONEY CREEK, ON

MEGANTIC METAL
DIVISION DE METAUX RUSSEL INC.
THETFORD MINES, QC

METAUX RUSSEL INC.
DIVISION DE METAUX RUSSEL INC.
BOUCHERVILLE, QC

METAUX RUSSEL INC.
DIVISION DE METAUX RUSSEL INC.
EDMUNDSTON, NB

PEMCO STEEL
A DIVISION OF RUSSEL METALS INC.
PEMBROKE, ON

RUSSEL METALS INC.
ABERFOYLE, ON

RUSSEL METALS INC.
CALGARY, AB

RUSSEL METALS INC.
CAMBRIDGE, ON

RUSSEL METALS INC.
EDMONTON, AB

RUSSEL METALS INC.
GRANDE PRAIRIE, AB

RUSSEL METALS INC.
KINGSTON, ON

RUSSEL METALS INC.
LAKESIDE, NS

RUSSEL METALS INC.
LONDON, ON

RUSSEL METALS INC.
MISSISSAUGA, ON

RUSSEL METALS INC.
MOUNT PEARL, NL

RUSSEL METALS INC.
OTTAWA, ON

RUSSEL METALS INC.
REGINA, SK

RUSSEL METALS INC.
SACKVILLE, NB

RUSSEL METALS INC.
SAINT JOHN, NB

RUSSEL METALS INC.
SASKATOON, SK

RUSSEL METALS INC.
WINNIPEG, MB

RUSSEL METALS PROCESSING
SASKATOON, SK

RUSSEL METALS SPECIALTY PRODUCTS
BURLINGTON, ON

RUSSEL METALS SPECIALTY PRODUCTS
SASKATOON, SK

RUSSEL METALS SPECIALTY PRODUCTS
WINNIPEG, MB

SAMUEL, SON & CO. LIMITED
NISKU, AB

TRIAD METALS INC.
OSHAWA, ON

VARSTEEL LTD.
DELTA, BC

VARSTEEL LTD.
NISKU, AB

VARSTEEL LTD.
SASKATOON, SK

STEEL DETAILER / DESSINATEUR

A.D. DRAFTING
BRAMPTON, ON

A-1 DETAILING AND ENGINEERING LTD.
NACKAWIC, NB

APEX STRUCTURAL DESIGN LTD.
RED DEER, AB

ASTRUCTURES INC.
CHAMBLY, QC

CADD ALTA DRAFTING & DESIGN INC.
EDMONTON, AB

DESSINS DE STRUCTURES DCA INC.
LEVIS, QC

DTECH ENTERPRISES INC.
WHITE ROCK, BC

EXACT DETAILING LTD.
VICTORIA, BC

HACHE TECHNICAL SERVICES LTD./HACHE SERVICES TECHNIQUES LTEE
CARAQUET, NB

HUSKY DETAILING INC.
ZURICH, ON

IKONA DRAFTING SERVICES INC.
REGINA, SK

INFOCUS DETAILING INC.
KEMBLE, ON

IRESCO LTD.
EDMONTON, AB

JCM & ASSOCIATES LIMITED
FRANKFORD, ON

JITECH ASSOCIATES INC.
MONTREAL, QC

JMT CONSULTANTS INC.
WINNIPEG, MB

KGS GROUP STEEL DETAILING DIVISION
WINNIPEG, MB

LES DESSINS TRUSQUIN INC.
BOISBRIAND, QC

RANMAR TECHNICAL SERVICES
MT. PEARL, NL

REDFOX STRUCTURAL DESIGN LTD.
ROGERSVILLE, NB

RIVER CITY DETAILERS LIMITED
WINNIPEG, MB

SERVICE TECHNIQUE ASIMUT INC.
CHARNY, QC

SUMMYX INC.
SAINTE-MARIE DE BEAUCE, QC

TDS INDUSTRIAL SERVICES LTD.
SURREY, BC

TECHFLOW INC.
MAPLE RIDGE, BC

TENCA STEEL DETAILING INC.
QUEBEC, QC

VET DESSIN
TERREBONNE, QC

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CWB GROUP/LE GROUPE CWB
MILTON, ON

ASSOCIATES / ASSOCIÉS

SMALL & MISC. STEEL FABRICATOR / PETIT & DIVERS FABRICANT D'ACIER

ACIER CHARRON LTEE
BOISBRIAND, QC

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SAINT JOHN, NB

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CAMPBELL RIVER, BC

EZ-STEEL (A DIVISION OF QUIRION METAL)
LEDUC, AB

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MAGNUM FABRICATORS LTD.
KAMLOOPS, BC

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CHATHAM, ON

OLD TYMER WELDING
ORILLIA, ON

OUTRIDER STEELWORKS LTD.
STONY PLAIN, AB

PAYFORD STEEL INC.
THUNDER BAY, ON

TIMES IRON WORKS INC.
STOUFFVILLE, ON

STEEL ERECTOR / MONTEUR

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NIAGARA FALLS, ON

KWH CONSTRUCTORS LTD.
BURNABY, BC

NIAGARA RIGGING & ERECTING COMPANY LTD.
THOROLD, ON

STAMPA STEEL ERECTORS LTD.
VAUGHAN, ON

STRUCTURES DE BEAUCE
SAINTE-MARIE-DE-BEAUCE, QC

VALLEY STRUCTURES LTD.
PERTH-ANDOVER, NB

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CHOMEDEY, LAVAL, QC

ACIER PICARD INC.
ST-ROMUALD, QC

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LANGLEY, BC

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SURREY, BC

AGT ROBOTICS
TROIS-RIVIERES, QC

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BRAMPTON, ON

AKHURST MACHINERY LTD.
EDMONTON, AB

ALL FABRICATION MACHINERY INC.
LEDUC, AB

AMCAN JUMAX INC.
ST-HUBERT, QC

AMICO CANADA INC.
LANGLEY, BC

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WINNIPEG, MB

BELLEMARE MANUTENTION INC.
STE-CATHERINE, QC

BORDEN METAL PRODUCTS (CANADA) LIMITED
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BRUNSWICK STEEL
SPRINGFIELD, MB

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BOISBRIAND, QC

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SUNNYSIDE, MB

CANSTUD WELDING AND SUPPLY INC.
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CAST CONNEX CORPORATION
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LACHINE, QC

CORRCOAT SERVICES INC. SANDBLASTERS AND COATERS
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CAMBRIDGE, ON

COWAN INSURANCE GROUP
CAMBRIDGE, ON

DAAM GALVANIZING
EDMONTON, AB

DAAM GALVANIZING
SASKATOON, SK

DASS METAL PRODUCTS
MISSISSAUGA, ON

DRYTEC TRANS-CANADA
TERREBONNE, QC

EBCO METAL FINISHING L.P.
RICHMOND, BC

FICEP CORPORATION
FOREST HILL, MD

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NISKU, AB

GRAITEC INC.
MONTREAL, QC

HDIM PROTECTIVE COATINGS INC.
EDMONTON, AB

INDUSTRIES DESORMEAU INC.
ST-LEONARD, QC

INFASCO
MARIEVILLE, QC

INLAND STEEL PRODUCTS INC.
SASKATOON, SK

KUBES STEEL INC.
STONEY CREEK, ON

LELAND INDUSTRIES INC.
TORONTO, ON

LINCOLN ELECTRIC COMPANY OF CANADA LP
TORONTO, ON

MAGNUS INC.
STE-THERESE, QC

MCCANN EQUIPMENT LTD. / EQUIPEMENT MCCANN LTEE.
OAKVILLE, ON

MIDWAY WHEELABRATING LTD.
ABBOTSFORD, BC

MOORE BROTHERS TRANSPORT LTD.
MISSISSAUGA, ON

NUCOR GRATING
EDMONTON, AB

NUCOR GRATING
POINTE AUX TREMBLES, QC

NUCOR GRATING
SURREY, BC

PACIFIC BOLT MANUFACTURING LTD.
LANGLEY, BC

PEDDINGHAUS CORPORATION
BRADLEY, IL

PURE METAL GALVANIZING, A VALMONT COMPANY
MISSISSAUGA, ON

RELIABLE TUBE INC.
LANGLEY, BC

SELECTONE PAINTS INC.
WESTON, ON

SILVER CITY GALVANIZING INC.
DELTA, BC

SIVACO QUEBEC
MARIEVILLE, QC

SKYWAY CANADA INC.
EDMONTON, AB

STRUMIS LLC
COLLEGEVILLE, PA

SUPERIOR FINISHES INC.
WINNIPEG, MB

SUPREME GALVANIZING LTD.
BRAMPTON, ON

TERRAPROBE INC.
BRAMPTON, ON

THE BLASTMAN COATINGS LTD.
BRAMPTON, ON

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ST. HUBERT, QC

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IMPACT CANADA
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IRONWORKERS LOCAL 97
BURNABY, BC

IRONWORKERS LOCAL UNION 728
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MANITOBA INFRASTRUCTURE (WATER MANAGEMENT AND STRUCTURES)
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NEEGINAN COLLEGE OF APPLIED TECHNOLOGY
WINNIPEG, MB

ONTARIO ERECTORS ASSOCIATION
THORNBURY, ON

UPBRELLA CONSTRUCTION
BROSSARD, QC

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RJC ENGINEERS
EDMONTON, AB

RJC ENGINEERS
KELOWNA, BC

RJC ENGINEERS
KITCHENER, ON

RJC ENGINEERS
LETHBRIDGE, AB

RJC ENGINEERS
MONTREAL, QC

RJC ENGINEERS
TORONTO, ON

RJC ENGINEERS
VANCOUVER, BC

RJC ENGINEERS
VICTORIA, BC

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STANTEC CONSULTING LTD.
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STANTEC CONSULTING LTD.
EDMONTON, AB

STANTEC CONSULTING LTD.
LONGUEUIL, QC

STANTEC CONSULTING LTD.
MARKHAM, ON

STANTEC CONSULTING LTD.
MISSISSAUGA, ON

STANTEC CONSULTING LTD.
OTTAWA, ON

STANTEC CONSULTING LTD.
RED DEER, AB

STANTEC CONSULTING LTD.
REGINA, SK

STANTEC CONSULTING LTD.
SASKATOON, SK

STANTEC CONSULTING LTD.
ST. JOHN'S, NL

STANTEC CONSULTING LTD.
STONEY CREEK, ON

STANTEC CONSULTING LTD.
TORONTO, ON

STANTEC CONSULTING LTD.
VANCOUVER, BC

STANTEC CONSULTING LTD.
VICTORIA, BC

STANTEC CONSULTING LTD.
WATERLOO, ON

STANTEC CONSULTING LTD.
WHITEHORSE, YT

STANTEC CONSULTING LTD.
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STANTEC CONSULTING LTD.
YELLOWKNIFE, NT

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AECOM
MISSISSAUGA, ON

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WILLOWDALE, ON

ARUP
TORONTO, ON

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TORONTO, ON

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CALGARY, AB

BAR ENGINEERING CO. LTD.
LLOYDMINSTER, AB

BBA INC.
MONT-SAINT-HILAIRE, QC

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BPTEC ENGINEERING LTD.
EDMONTON, AB

BRENIK ENGINEERING INC.
CONCORD, ON

BUREAU D'ETUDES SPECIALISEES INC.
MONTREAL, QC

CBCL LIMITED
HALIFAX, NS

CIMA+ PARTENAIRE DE GENIE
LAVAL, QC

COSEB INC.
CHAMBLY, QC

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CROSIER KILGOUR & PARTNERS LTD.
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LAVAL, QC

DAVINCI STRUCTURES INC.
QUEBEC, QC

DIALOG
CALGARY, AB

DIALOG
EDMONTON, AB

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MISSISSAUGA, ON

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BRAMPTON, ON

DTI STRUCTURAL ENGINEERS INC.
TECUMSEH, ON

ELEMA EXPERTS-CONSEILS
MONTREAL, QC

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CALGARY, AB

ENTUITIVE CORPORATION
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MEDICINE HAT, AB

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SASKATOON, SK

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GORMLEY, ON

SCHORN CONSULTANTS LTD.
WATERLOO, ON

SDK ET ASSOCIES, INC.
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SIEFKEN ENGINEERING LTD.
NEW WESTMINSTER, BC

SKC ENGINEERING LTD.
SURREY, BC

SNC LAVALIN INC.
MONTREAL, QC

STEPHENSON ENGINEERING LTD.
TORONTO, ON

TACOMA ENGINEERS
GUELPH, ON

TETRA TECH QI INC.
QUEBEC, QC

TOWER ENGINEERING GROUP LIMITED PARTNERSHIP
WINNIPEG, MB

VALRON STRUCTURAL ENGINEERS - STEEL DETAILERS
MONCTON, NB

WALTERFEDY
KITCHENER, ON

WEILER SMITH BOWERS
BURNABY, BC

WHM STRUCTURAL ENGINEERING
BURNABY, BC

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DARTMOUTH, NS

WOOD CANADA LIMITED
SASKATOON, SK

WOOD CANADA LIMITED
TRAIL, BC

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MARKHAM, ON

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RED DEER, AB

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CALGARY, AB

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VAUGHAN, ON

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VANCOUVER, BC

ANDREW W. METTEN
VANCOUVER, BC

ANDREW WATSON
KAMLOOPS, BC

ANTONI KOWALCZEWSKI
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OUTREMONT, QC

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DAWSON CREEK, BC

BRAM TOOMATH
VAUGHAN, ON

BRIAN JOHNSON
OTTAWA, ON

BRIAN MCCLURE
NANAIMO, BC

BRIAN WADDELL
CAMBRIDGE, ON

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EDMONTON, AB

CHET LIU
CHATHAM, ON

CHRIS EVANS
UDORA, ON

CHRISTIAN AUDET
SHERBROOKE, QC

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SHEFFORD, QC

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VANCOUVER, BC

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SAINT JOHN, NB

DANIEL DUMONT
GATINEAU, QC

DANIEL E. TURNER
MONTREAL, QC

DANIELA XAVIER
TORONTO, ON

DAVE R.M. VRKLJAN
CALGARY, AB

DAVID T MOLLOY
BURLINGTON, ON

DEAN ANDERSON
ST. ALBERT, AB

DONALD GREGORY WEEKES
HAMILTON, ON

DWAIN A. BABIAK
CALGARY, AB

ELIE EL-CHAKIEH
LAVAL, QC

ERICK PEPIN
ST-GEORGES, QC

FRANCIS PARE
TROIS-RIVIERES, QC

FRANCOIS CHAREST
REPENTIGNY, QC

FRANZ KNOLL
MONTREAL, QC

GEORGE CASOLI
RICHMOND, BC

GERARD PILON
SALABERRY-DE-VALLEYFIELD, QC

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LONDON, ON

GORDON D. BOWMAN
GLOUCESTER, ON

GRAHAM LAWRENCE
SAINT JOHN, NB

HAIJUN LI
MARKHAM, ON

HAROLD DIBBEN
TRENTON, ON

HAVEN ENGINEERING
SURREY, BC

HELENE THERIAULT
MONCTON, NB

IBE MARCUS
REGINA, SK

DAVID PARENT LABBE, ICONEX
QUEBEC, QC

IRAJ HOSHYARI
LANGLEY, BC

JACOB KACHUBA
MISSISSAUGA, ON

JAMES CHAPMAN
EDMONTON, AB

JASON MEWIS
SASKATOON, SK

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NOTRE-DAME, NB

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ST-LAURENT, QC

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LONDON, ON

JINSHENG ZHAO
CALGARY, AB

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ST. CATHARINES, ON

KYLE GIROUARD
BATHURST, NB

LAUCHLIN SMITH
EDMONTON, AB

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HALIFAX, NS

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LEPREAU, NB

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BURLINGTON, ON

MICHEL WALSH
LASALLE, QC

NAZMI LAWEN
CHARLOTTETOWN, PE

NEIL MCMILLAN
NEPEAN, ON

PAUL SLATER
KITCHENER, ON

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POINTE-CLAIRE, QC

R. PAUL RANSOM
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MOFFET, ON

RAY T. BAILEY
ST. JOHN'S, NL

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NORTH VANCOUVER, BC

ROGER VINO
SURREY, BC

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WINNIPEG, MB

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SASKATOON, SK

RYAN DEMERCHANT
FREDERICTON, NB

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NORTH YORK, ON

SERGE PARENT
SHERBROOKE, QC

STEPHEN BARBOUR
ST. JOHN'S, NL

TERRENCE D. SMITH
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THOMAS EGLI
MONTREAL, QC

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WINNIPEG, MB

VASSILY VERGANELAKIS
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CALGARY, AB

WILLIAM J. ALCOCK
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YANNICK MICHAUD
POHENEGAMOOK, QC

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BURLINGTON, ON

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AJAX, ON

US STEEL MILL PRODUCER / ACIÉRIE AMÉRICAINE

ARCELORMITTAL INTERNATIONAL
CHICAGO, IL

STEEL DYNAMICS, INC. STRUCTURAL AND RAIL DIVISION
COLUMBIA CITY, IN

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ASSINIBOINE COMMUNITY COLLEGE

HENRY OSTERMANN
BCIT (BRITISH COLUMBIA INSTITUTE OF TECHNOLOGY)

SEAN OWEN
BCIT (BRITISH COLUMBIA INSTITUTE OF TECHNOLOGY)

SAMANEH HASHEMI
BCIT (BRITISH COLUMBIA INSTITUTE OF TECHNOLOGY)

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CAMBRIAN COLLEGE OF APPLIED ARTS AND TECHNOLOGY

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SERGE DESBIENS
CEGEP DE JONQUIERE

FRANCOIS LANDREVILLE
COLLEGE AHUNTSIC

CLAUDE GHAZAL
COLLEGE MONTMORENCY

PATRICE CARON
COLLEGE MONTMORENCY

GENEVIEVE BERUBE
COMMISSION SCOLAIRE DE LA CAPITALE/ CFP NEUFCHATEL

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COMMISSION SCOLAIRE DE LA POINTE-DE-L'ELE

RICCARDO GIOIA
CONCORDIA UNIVERSITY

JASSIM HASSAN
CONCORDIA UNIVERSITY DEPARTMENT OF BUILDING, CIVIL & ENVIRONMENTAL ENGINEERING

LUCIA TIRCA
CONCORDIA UNIVERSITY DEPARTMENT OF BUILDING, CIVIL & ENVIRONMENTAL ENGINEERING

ANJAN BHOWMICK
CONCORDIA UNIVERSITY DEPARTMENT OF BUILDING, CIVIL & ENVIRONMENTAL ENGINEERING

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CONESTOGA COLLEGE

MITKO MANCEVSKI
CONESTOGA COLLEGE

AHMED ALYOUSIF
CONESTOGA COLLEGE

CHARLES JENKS
CONESTOGA COLLEGE

YI LIU
DALHOUSIE UNIVERSITY

KYLE TOUSIGNANT
DALHOUSIE UNIVERSITY

EMANUEL JANNASCH
DALHOUSIE UNIVERSITY (ARCHITECTURE)

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DAWSON COLLEGE

MICHAEL DELLAR
DAWSON COLLEGE

ROBERT TREMBLAY
ECOLE POLYTECHNIQUE, CGM DEPT.

DOMINIQUE BAUER
ECOLE POLYTECHNIQUE, CGM DEPT.

RAKESH RANJAN
ECOLE POLYTECHNIQUE, CGM DEPT.

BAHMAN (BEN) MARVI
EPIC COLLEGE OF TECHNOLOGY

RYAN HABKIRK
GEORGIAN COLLEGE

TERRY MCKENNA
HOLLAND COLLEGE

MARTIN TURGEON
LA CITE COLLEGIALE

JONATHAN LANDRY
LA CITE COLLEGIALE

ANTONY GILLIES
LAKEHEAD UNIVERSITY

YANGLIN GONG
LAKEHEAD UNIVERSITY

SAM SALEM
LAKEHEAD UNIVERSITY - CIVIL ENGINEERING

CORY HUBBARD
LAKEHEAD UNIVERSITY - CIVIL ENGINEERING

AHMED ELSHAER
LAKEHEAD UNIVERSITY, ENGINEERING

BOB FENCOTT
LOYALIST COLLEGE

ABDUL NABI LASHARI
LOYALIST COLLEGE

LYDELL WIEBE
MCMASTER UNIVERSITY

REZA USHAKSARAEI
MCMASTER UNIVERSITY

TRACY BECKER
MCMASTER UNIVERSITY

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KEN S. (SIVA) SIVAKUMARAN
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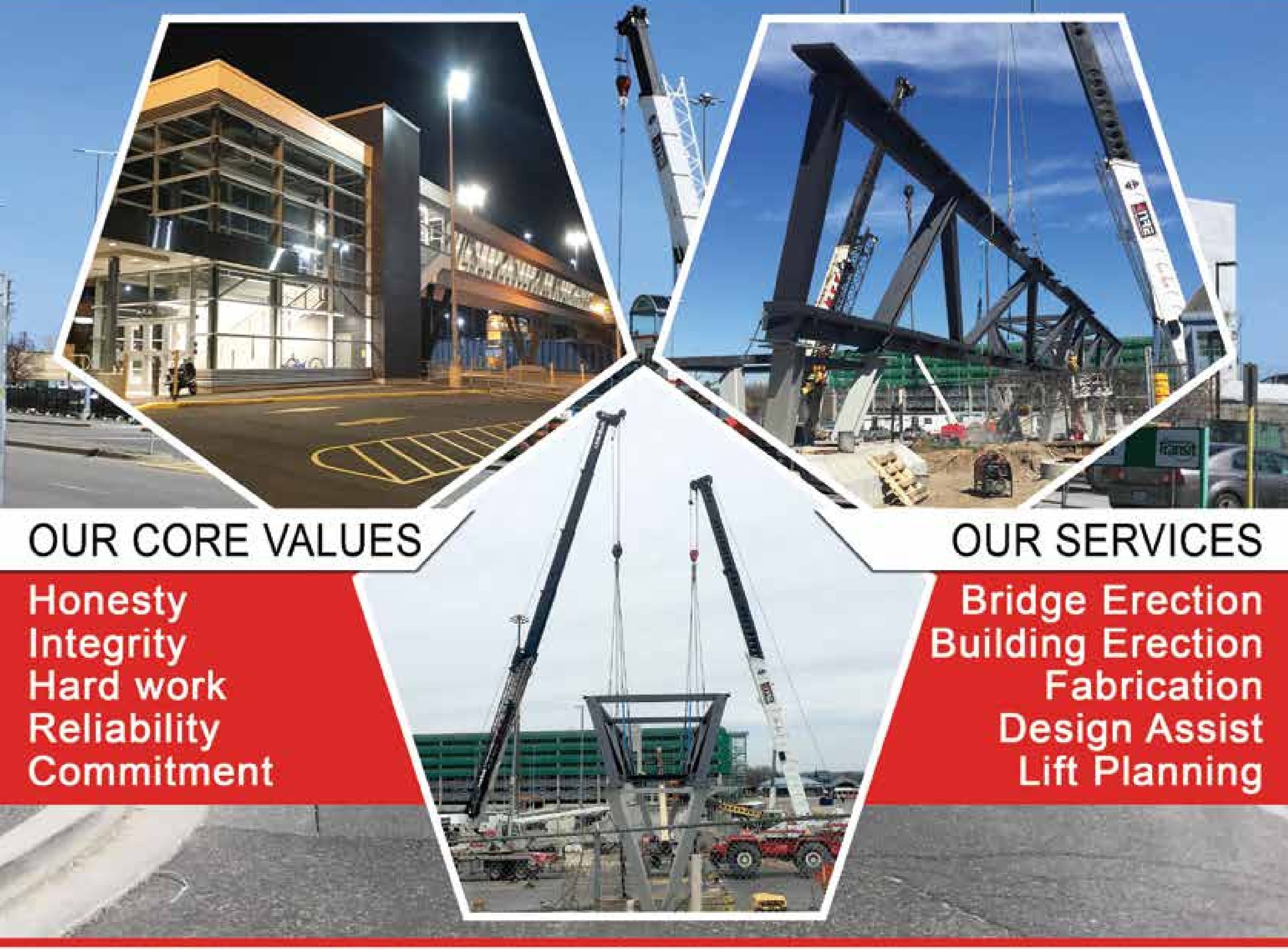

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