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NO. 63 WINTER 2019

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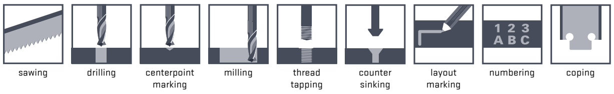

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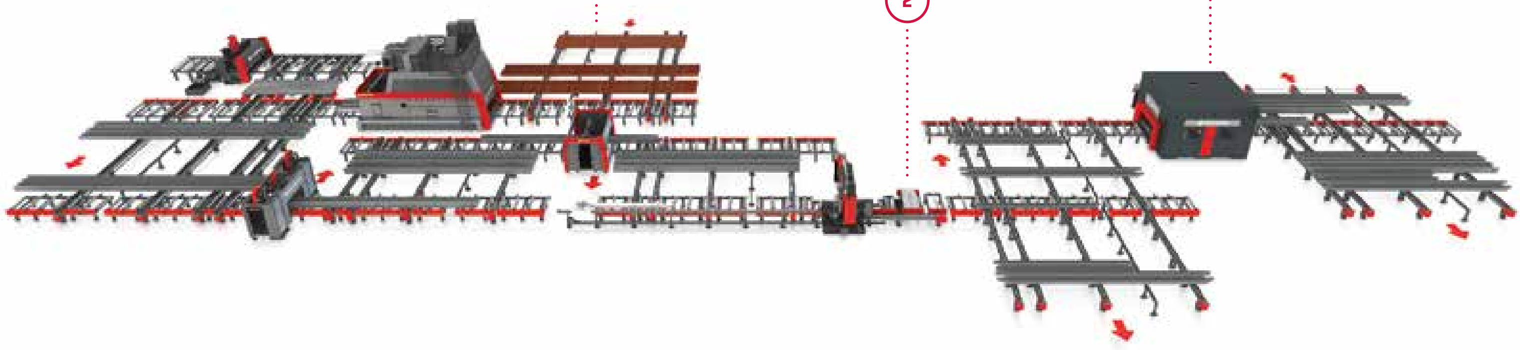

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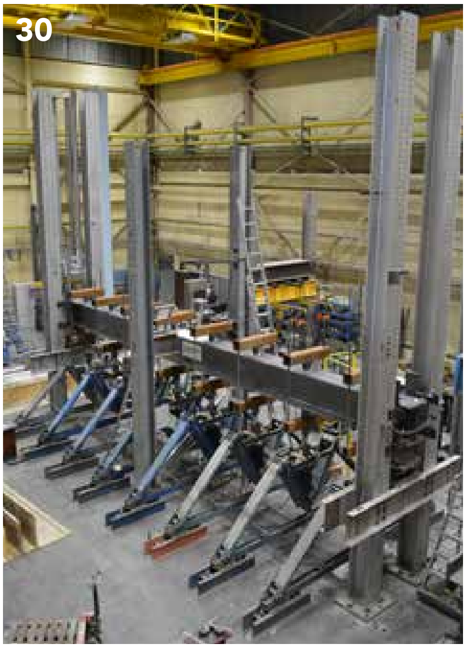
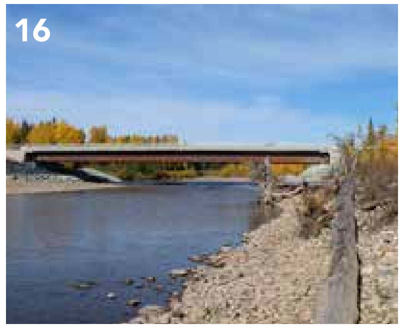


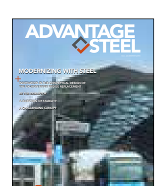


FEATURES

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:
Vaughan Metropolitan Centre (VMC) Station Canopy

Photo courtesy of Justin Wuohela, P.Eng.

One Big Happy Steel Mill Smile

Ed Whalen, P.Eng.
ewhalen@cisc-icca.ca

AT THE MOMENT, I am attending the World Steel Conference, alongside the steel mills and steel associations from around the world. The major items of conversation are: overcapacity in steel making globally, market distorting subsidies and support practices, global warming, the circular economy and of course, protectionist tariffs.

Back in 2016, the G20 set up a Global Forum on Excess Capacity facilitated by the Organization for Economic Cooperation and Development (OECD). The mandate was to try to resolve excess capacity and country sponsored market distorting practices. With its three-year term coming to an end and its job incomplete, there is a push to have its mandate extended to finish what it started. Although it is being touted as having led to many positive changes (such as transparency in production and capacity), steel production grew by 8% this year with only a 1% increase in consumption over last year. World Steel estimates that the demand for steel will only grow at 1% annually into the future due to factors such as the circular economy (reuse rather than recycle), the use of alternate materials and the loss of traditional markets (especially in the automotive sector). Interestingly, World Steel estimates the construction sector being possibly the most affected by the circular economy in the years to come. It suggests that future codes and legislation mandating reuse in construction could lead to high tech companies cataloging existing building inventories, stocking and selling used steel for new developments.

So, as existing steel mills continue to ramp up production and expand, countries with little or no previous steel production enter the game and the global demand flattens. The Global Forum seems to be a political place of happiness with no real power or ability to stop the train.

Enter Trump. Now, whether you agree with his policies or not, the Section 232 steel tariffs on the world has done what no forum, WTO appeal or anti-dumping case has been able to do in the past. It has increased prices in an environment where prices should be continually falling. If China and other dumping countries intended on winning by over supply and low prices, the U.S. steel tariffs stopped that strategy in its tracks. Steel prices and domestic consumption within the U.S. has rapidly increased. Almost all countries around the world have imposed safeguards in light of the U.S. action, resulting in what? The best of times in a very long time for every steel mill in the world. Well, almost all. Believe it or not, there wasn't a long face at the World Steel Conference, with the exception of maybe one country. All mills I spoke to had volumes up, prices at where they were extremely pleased, and many had expansion plans in the works.

Section 232 steel tariffs has led to force local steel procurement. Increased local procurement leads to increased local steel production, increased employment, increased utilization and thus increased profits. Successful steel mills provide the spinoff benefits for the countries they are operating in and any safeguard tariffs received from steel imports are stashed into the government coffers.

It seems the last thing most steel mills around the world really want to see is the removal of Section 232 steel tariffs, with the exception of a few. They are enjoying the ability to safeguard against surges and thus directly stopping the dumping steel countries they have been long complaining about. The unorthodox and unpredictable trade action of Trump has given steel mills around the world a breather, at least for the time being. Smiles all around.

As the steel mills muse about loss of market share and slow growth due to mega-trends, it seems almost comical they aren't looking at the impact high steel prices and steel tariffs will have downstream. Steel mills are more than ever dependent on their local customer base, but there are no strategic plans to assist in their customers' long-term survival as a way to ensure their own.

Similarly, while governments seem ever-enthusiastic to protect the short-term survival of steel mills in times of tariff crisis, they have no long-term strategy for the true steel economic engines which are the downstream industries of construction and manufacturing within their country. In this global economy, where more steel is produced than we know what to do with (to the tune of the entire consumption of the EU), governments will need to nurture downstream steel industries and strengthen free and fair trade rules for these industry sectors if we are to see the long-term survival of our local steel mills. AS

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

This is the last time I write as the regular columnist. I take the opportunity to thank all readers, especially those who have been supportive since the column's inception.

Question 1: The current Canadian Highway Bridge Design Code, CSA S6-14, requires that Charpy V-notch tests for primary tension members be specified on a per plate frequency. What is the rationale for this more stringent requirement as compared to earlier editions of the Code?

Answer: The "per plate" Charpy V-notch test frequency requirement for "primary tension members" in the initial printing of S6-14 was the result of an error. It was corrected in Update #1 to S6-14, which was officially issued by CSA on July 17, 2017, to reinstate the "per heat" test frequency requirement as specified in S6-06.

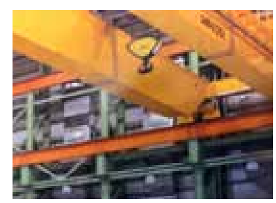
Question 2: Is there a standard on coatings for high-strength bolts and nuts?

Answer: ASTM F1163 "Standard Specification for Zinc/Aluminum Corrosion Protective Coatings for Fasteners" is referenced in the Research Council on Structural Connections' Specification for Structural Joints Using High-Strength Bolts, 2014 Edition. It generally covers basic requirements and associated test methods for water-based corrosion protective zinc/aluminum dispersion inorganic basecoats, and optional sealers and topcoats for fasteners. ASTM F3125 also sets restrictions on galvanizing as applicable. The Table entitled "High-Strength Bolts, Nuts and Assemblies," included in Part 6 of *CISC Handbook of Steel Construction - 11th Edition*, provides information on bolts, nuts and washers that may be galvanized and those that are suitable for the application of zinc/aluminum corrosion protective coatings in accordance with ASTM F1136. This Table is also consistent with the above-mentioned Research Council on Structural Connections Specification. Other applicable coatings standards will be referenced in due time.

Question 3: When bolted end-plate connections are used in a Conventional Construction moment resisting frame for a low seismicity application, should the bolted joints be: a) slip-critical, b) bearing-type with pretensioned bolts, or c) bearing-type with snug-tight bolts?

Answer: CSA S16-14 and S16-09 do not require slip-critical joints for such application, provided the bolt holes are standard size holes. The bolts, however, should be pretensioned because they are subjected to tension.

Question 4: CSA S16-14 requires structures subjected to variable amplitude fatigue loading to be evaluated for cumulative damage, whereas S6-14 permits a simpler calculation based on constant amplitude loading. Can fatigue loading on crane-supported structures be evaluated using S6 rules for bridge structures?



Crane-supported structure

Answer: North American highway bridge design codes permit the evaluation using the stress range and stress cycles derived from the fatigue truck, but restrict the allowable constant amplitude stress range to one-half its value. This, in effect, amplifies the stress range generated by the fatigue truck by a factor of 2, to accommodate heavier but less frequent trucks. Decades of satisfactory experience support this design practice. However, the above-mentioned factor of 2 may be inadequate when applied to crane-supported structures due to many possible combinations of stress ranges and frequencies. S16 adopted the Palmgren-Miner rule to account for these possible combinations.

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.

Michael Holleran, P.Eng.
Canam Buildings and Structures

Building Bridges for the Future

AS THE STEEL industry navigates through challenges from steel tariffs and safeguards, it reinforces our need to invest in the future through Education and Research. With great knowledge and comprehension, we can position steel as the material of choice. The Education and Research Council (ERC) remains committed to enhancing the steel industry by supporting education and research through numerous ongoing initiatives and activities.

To encourage the development of structural steel knowledge, as well as the development of steel expertise, knowledge and innovation in steel design and construction, the ERC has engaged the steel community to assist in research topics. As part of the ERC's mandate to foster steel research and guide the academic community to relevant research topics, the ERC is asking for the membership to submit needed topics. The Research Grant Committee will review the submitted topics that are considered to be of interest and of importance to the steel industry. These topics are given to researchers within Canadian universities and colleges to offer insight to current challenges facing the industry. I welcome all stakeholders to submit topics to the CISC for consideration.

Another important initiative for the ERC is the Canadian National Steel Bridge Competition (CNSBC). This annual competition was created in partnership between CISC and the Canadian Society for Civil Engineering (CSCE) in response to a need within the industry to give students an opportunity to enhance steel knowledge within Canada. This event empowers students to learn structural steel design, demonstrate construction competencies, and value the knowledge and team building skills that they will use as the future generation of design professionals. During this event, Canadian universities conceive, build and assemble steel bridges respecting a realistic scenario. To distinguish themselves from other teams, a compromise must be made between the architectural, technical and economic aspects. The CNSBC fosters impactful relationships between students and industry professionals by connecting steel design, fabrication and erection with a practical project, while at the same time developing their interpersonal and professional skills. The inaugural CNSBC was hosted by McGill University in 2016 and has grown each subsequent year. The 4th edition of the Canadian National Steel Bridge Competition will be hosted by École Polytechnique de Montréal in Montreal, Quebec, from May 15 – 18, 2019. I would strongly encourage all stakeholders to reach out to your local universities, engage with the future leaders and build a relationship with these students. Your support will build bridges for the future.

Once again, please consider supporting the ERC to ensure these initiatives can continue to thrive and to encourage the growth of the structural steel industry. Please contact the CISC for more information on how your funding can directly support education and research in the steel industry. AS

"With great knowledge and comprehension, we can position steel as the material of choice. The ERC remains committed to enhancing the steel industry by supporting education and research through numerous ongoing initiatives and activities."

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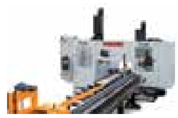
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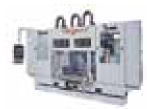
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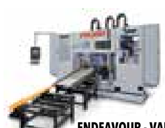
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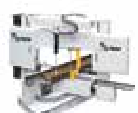
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HSS Joint Welding

By Jeff Packer

This project will clarify some options available for the fabrication of welded rectangular Hollow Structural Section (HSS) K-connections, and their implications for design. The study will focus on truss-type K- and N-connections with a wide range of centre-line eccentricities, branch gaps and overlaps, and with branch members under different loading arrangements, as illustrated in Figure 1. In particular, any requirements for welding (or not welding) the so-called "hidden toe" in overlapped K-connections will be resolved.

At present there is a tendency for HSS connection fabrication to be based on joining members for their cross-section (yield) capacity, with full-strength fillet, PJP, or even CJP, welds being specified along every side of each branch. Justification, however, for welded joints that are instead "fit-for-purpose," based on weld effective length knowledge, has been progressively developed at the University of Toronto since the 1980s. For rectangular HSS, this began with effective length rules for gapped K-connections, then axially loaded T-, Y- and X-connections, then T-connections under in-plane bending, and then overlapping branches in symmetrically loaded overlapped K-connections. These weld effective length rules for HSS have been adopted by AISC and are best summarized, at present, in section K5 of the Specification AISC 360-16. The effective length method is now being introduced more clearly as a design option for proportioning welds in Clause 13.13 of the forthcoming CSA S16-19.

Recent University of Toronto research on weld-critical HSS connections has revealed that fillet welds around the ends of rectangular HSS tension members are not capable of developing the "fillet weld directional strength increase" given by the factor $(1.00 + 0.50\sin^{1.5}\theta)M_w$ in CSA S16 Clause 13.13.2.2. This is attributed to single-sided fillet welds, under such loading, being subjected to tension at the root of the weld, which is detrimental. This behaviour has been confirmed through both experimental and numerical (finite element) studies, as shown in Figure 2. As a result, the so-called "fillet weld directional strength increase factor" will not be permitted for single-sided fillet welds connected to an element in tension, in CSA S16-19. A similar exclusion of this "sinθ factor" is also being adopted for fillet welds to tension-loaded rectangular HSS walls in AISC 360-22.

This current project supported by the CISC Research Committee thus continues a long tradition of practical research on HSS connection design and welding at the University of Toronto. AS

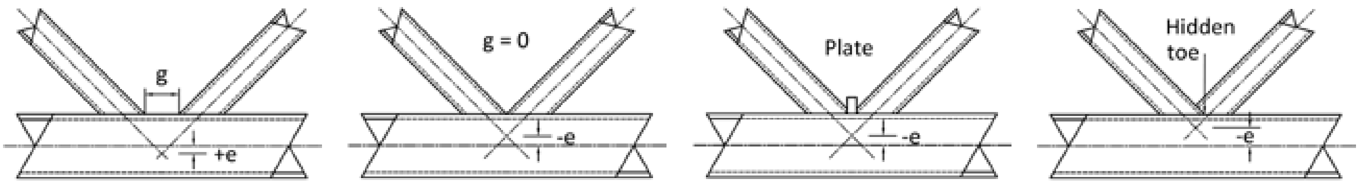
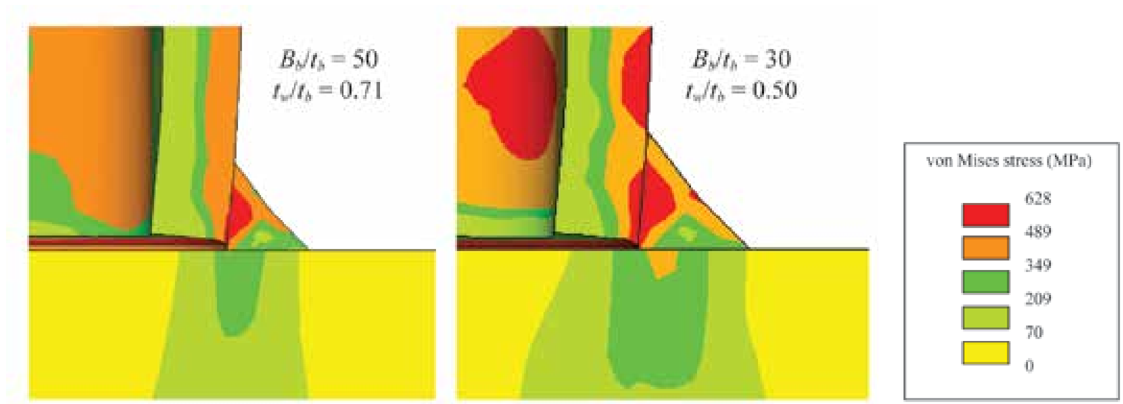


FIGURE 1: Types of HSS K-connections, with variable gap and overlap fabrication conditions

"Recent University of Toronto research on weld-critical HSS connections has revealed that fillet welds around the ends of rectangular HSS tension members are not capable of developing the "fillet weld directional strength increase" given by the factor $(1.00 + 0.50\sin^{1.5}\theta)M_w$ in CSA S16 Clause 13.13.2.2."

FIGURE 2: Fracture research on fillet welds to HSS loaded in tension, revealing bending about the weld axis



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

Diaphragm-Collector Shear Transfer

This is the last time I write as the regular writer for Seismic Corner. I take this opportunity to thank all readers for your support over the years.

SEISMIC FORCES IN a building structure must be transmitted from the roof and floor diaphragms to the vertical *seismic force-resting system* (and the foundations). In a steel-framed structure, they are typically transmitted via horizontal members, such as beams, joists and trusses, serving as collectors. Thus, the forces are typically transferred in shear between the sheet steel roof deck and the roof diaphragm collectors, or the floor deck-slab and the floor diaphragm collectors. While CSA Standard S16 does not dictate specific means for diaphragm-collector shear transfer, this article briefly summarizes the most common methods used in construction.

ROOF DIAPHRAGMS

The most common roof structures feature a sheet steel roof deck on open-web steel joists, wide-flange girders and spandrel beams. Figure 1 shows the plan view of a roof example of a single-storey building. The vertical braced bents are shown in red, whereas the main collectors are in blue. Typically, the roof deck is connected to the OWSJs and spandrel beams by means of arc spot welds or screws. The girders, however, must be lowered to accommodate the joist shoes. Collector shear transfer connectors matching the joist shoe depth are therefore required to bridge the gap. See Figure 2.

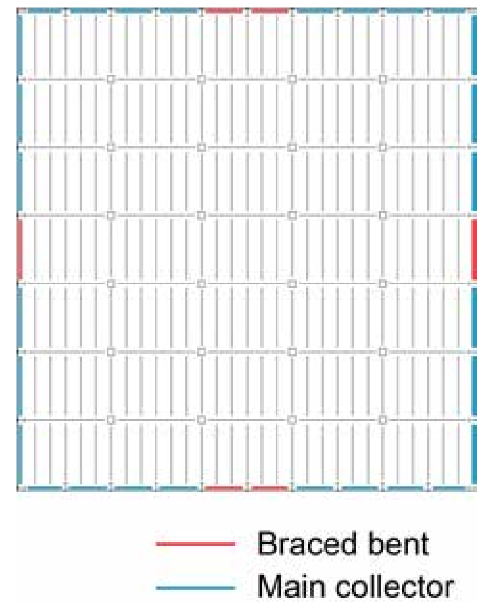


FIGURE 1: Roof Diaphragm

FLOOR DIAPHRAGMS

When floor diaphragm forces are relatively low and do not exceed the factored shear resistance of sheet steel floor deck alone, the above-mentioned roof diaphragm shear transfer method may be adequate. For larger shear forces, particularly when the design includes the contribution of the concrete cover slab

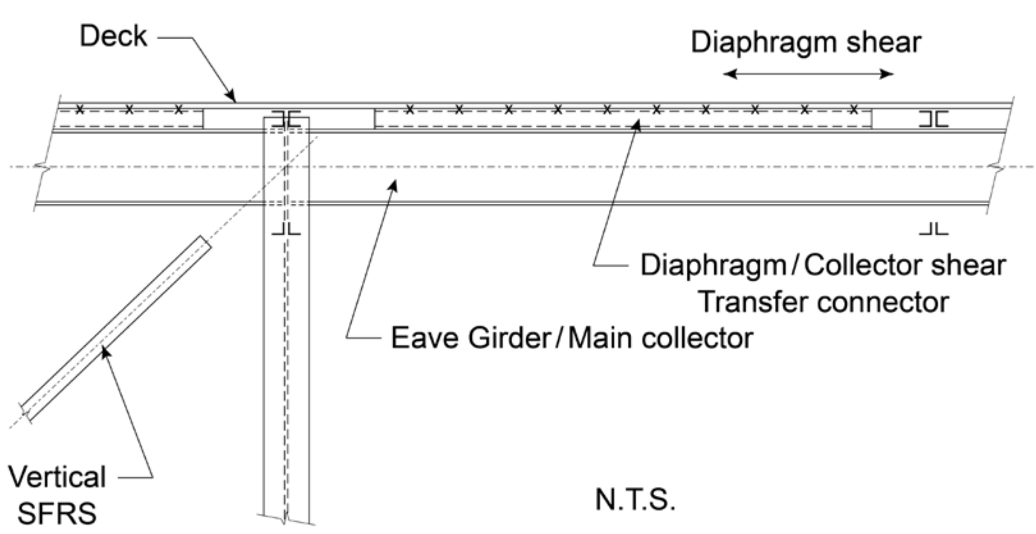


FIGURE 2: Girder-Collector Shear Transfer

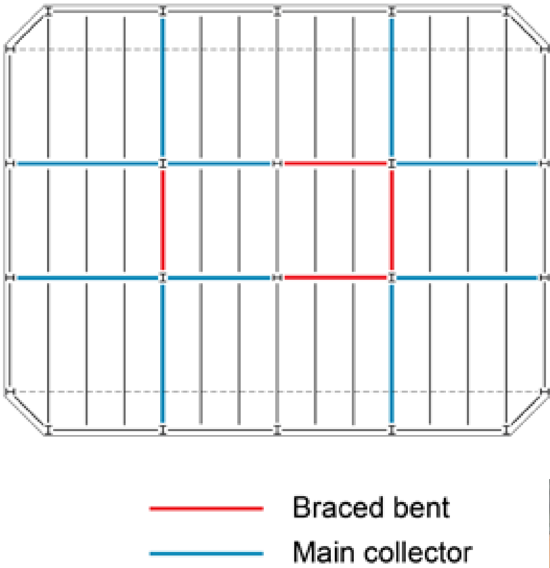


FIGURE 3: Floor Diaphragm

> "When floor diaphragm forces are relatively low and do not exceed the factored shear resistance of sheet steel floor deck alone ... the roof diaphragm shear transfer method may be adequate."

for diaphragm shear resistance, welded-stud shear connectors are commonly used to transfer the diaphragm shear between the deck-slab diaphragm and the main collectors. For example, in the floor as shown in Figure 3, welded studs can be placed on the main collector beams and girders as shown in blue.

Welded stud shear connectors may also be placed on the beams within the vertical seismic force-resting system (identified as red lines in Figure 3) with several exceptions. They are not permitted on beams in *chevron moderately ductile and chevron limited-ductility concentrically* braced frames that are not designed to be capacity-protected members. Where these beams in low-rise frames are permitted to be designed to serve as yielding elements, the presence of shear studs inflates the flexural capacity of these beams. Similarly, they are not permitted within the protected zones in *ductile eccentrically braced frames* in order to avoid inflating the capacity of the ductile links. Also, welded studs should not be placed in the protected zones in *ductile, moderately ductile* and *limited-ductility moment-resisting frames,* unless the studs formed a part of the tested assembly that serves to qualify the use of the beam-to-column connections in the construction. AS

FEATURE

INNOVATION IN THE CONC
THE SALMON RIVER BRID

By C.P. (Ken) Rebel and Raj Singh, McElhanney Consulting Services Ltd.

EPTUAL DESIGN OF GE REPLACEMENT

ON A STRETCH of highway in northern British Columbia, 27 km north of Prince George, a narrow two-lane truss bridge crossing the Salmon River had to be replaced due to its aging structural condition and restricted functionality. The 55-metre-long single span structure had a small roadway width and a 5.4 m roadway vertical clearance which was insufficient for the area's truck traffic. The structure's owner, the British Columbia Ministry of Transportation and Infrastructure (MoTI), engaged McElhanney to engineer the bridge replacement, including highway engineering, traffic and environmental management, and electrical engineering services. McElhanney worked collaboratively with MoTI to prioritize project issues and stakeholder concerns to develop pertinent solutions. The options were evaluated using a Multi Account Evaluation (MAE) approach and a preferred design was recommended to the owner. We developed a new 67-m-long composite steel single span bridge, centred on the existing highway alignment, as the optimal solution which best addressed the project goals and design constraints. In addition to the two traffic lanes of the old bridge, the new bridge deck accommodates two 2 m shoulders with a 1.8 m-wide pedestrian sidewalk on one side, for a total deck width of 14 m.

The Salmon River, a tributary of the Fraser River, is classified as a sensitive stream under the *Fish Protection Act* and is recognized as a vital habitat for fish and amphibian species. The optimal bridge solutions minimized impacts and disturbance to the habitat. Our first consideration during the conceptual design was selection of the highway alignment for the new bridge. We considered geometric improvements, influence on adjacent intersections, property acquisition, and environmental impacts. We identified three highway alignment options: upstream, downstream, or existing. The upstream alignment offered the advantage of improved sight lines for the Salmon Valley Road intersection. However, disadvantages included property acquisition and encroachment into the riparian area and floodplain of the Salmon River. Locating the highway alignment downstream required the introduction of "s-curves" to the highway alignment and resulted in reduced sign distances for the existing accesses and intersections. We ultimately recommended the existing alignment, as it met the highway design criteria requirements, eliminated environmental disturbance, and did not require reconstruction and realignment of the adjacent intersections.

A hydrotechnical assessment of the site, completed by Northwest Hydraulics Consultants Ltd. of North Vancouver, analyzed the 100-year and 200-year open water peak flood levels and high ice elevations at the bridge, to define the waterway opening and to establish wildlife underpass evaluations. The

recommended waterway for the new bridge featured a clear, trapezoidal channel with a bottom width of 48 m, measured at low water level and end slopes at 2H: 1V resulting in a top width of 65.2 m at the ice freeboard elevation. Except for in-stream piers, all other bridge components, including the girders and abutments, had to remain clear of this waterway opening. An initial high-level comparison indicated precast concrete girders were not economical for 50 m plus span ranges (and are challenging to transport and erect, compared to steel girders). Furthermore, steel plate girders are common throughout British Columbia, and local fabricators and contractors are familiar with them, making the girders a cost-effective solution. Therefore, only steel girder options were considered in conceptual design.

We developed four bridge concepts:

1) a 67 m single span with steel I girders;
2) a 67 m single span with steel box girders;
3) a multi-span 15-50-15 m with steel I-girders;
4) and a multi-span 15-50-15 m with steel box girders.

The options were compared using an MAE approach by scoring between one and five for each of the criteria, which included bridge, hydrotechnical, environmental, and geotechnical considerations. The 67 m single span arrangement avoided significant

"An initial high-level comparison indicated precast concrete girders were not economical for 50 m plus span ranges (and are challenging to transport and erect, compared to steel girders). Furthermore, steel plate girders are common throughout British Columbia, and local fabricators and contractors are familiar with them, making the girders a cost-effective solution."

encroachment into the waterway with only riprap protection required along the river banks to protect the abutments. The single span option also has less substructure costs due to the elimination of the river piers, and by minimizing the instream work the bridge could be constructed in less than a year. The plate girder option consistently scored highest on all accounts, except for aesthetic appeal, where it scored less than the box girder option. The final bridge has a cast-in-place, reinforced concrete deck and four steel plate girder lines. We put significant effort into reducing the depth of the steel plate girders, through a detailed analysis of flexural frequency of the structure, dead and live loads, and deflections. Shallowing up the girders enabled a reduction in the height and length of the roadway approach fills on the project. The final design resulted in shallow 2.1 m deep girders with a slenderness ratio of about 32.

The client completed a bore hole investigation in the winter of 2015, 30 m south of the south abutment, and 30 m north of the north abutment. Underlying sand, gravel, and an extensive thick layer of stiff-to-hard, low-to-intermediate plastic silty clay with sporadic boulders was observed, and steel pipe piles were chosen for the piled foundations. The bridge abutments were designed to resist horizontal forces from retaining soil pressures on the backwalls, in addition to vertical loads from the design dead and live loads. To efficiently carry the abutment demands, we designed the abutment with two rows of piles that transfer a substantial portion of the moment induced into axial compression in the front row (river side) of piles and axial tension into the rear row (abutment soils side) of piles. Two rows of 762 mm diameter steel piles with four piles per row spaced at three pile diameters, with the front row pile length at 28 m and the rear pile length at 18 m, was the optimum arrangement of piles to satisfy all loading requirements.

Two-way traffic flow needed to be maintained for the duration of the bridge's construction. Therefore, a two-lane detour was needed until such a

time that traffic flow could be moved to the new highway. Constructing the detour on the downstream side of the bridge was the recommended option, as it required a shorter bridge span, with available right-of-way on the north side, and an existing pullout area on the southeast side of the bridge. We evaluated three options for the temporary detour bridge: sliding the existing truss bridge transversely to the downstream detour alignment, constructing the new superstructure offline on temporary foundations supports and sliding it into final position alignment, or utilizing a temporary Acrow bridge on the downstream detour alignment. Using the existing truss bridge as the detour bridge was the most cost-effective solution, with minimal throwaway costs. The existing steel truss bridge was transversely relocated 15 m downstream along the detour alignment during a four-hour night closure of the highway, clearing the space to allow the construction of the new bridge along the existing alignment.

Structural steel offered the most effective, constructible and sustainable solution for the key superstructure and foundation components for this bridge, resulting in a project successfully completed on schedule and within the owner's approved budget. AS

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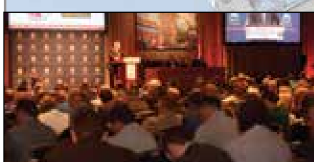
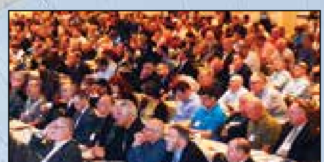

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BE THE DISRUPTOR

Thoughts from a structural engineer on embracing the dizzying

By Jeff DiBattista, DIALOG

IT'S NO SECRET that the world around us, because of the technology we create, is changing at a breathtaking pace. In fact, this change is so far from being a secret—so present in our personal and professional lives—that many of us wish we didn't have to confront it so often. From smartphones to smart houses, from Uber to autonomous vehicles, from Siri to Alexa, we are immersed in new technologies constantly. And while experiencing new technologies can be exciting (especially for people younger than I am!), for others of us it can be unnerving, overwhelming, or confusing. But it need not be, if we understand the trends behind the changes. I believe it's important to seek out the patterns behind the technological changes surrounding us, and to engage with those developments, rather than allowing our fears to paralyze us into inaction.

So, I'm writing to share some of my observations and thoughts on these technological trends, in the hope they will help you and your organization take full advantage of them. But first, full disclosure: I'm not a computer scientist. I haven't even done any programming since I left university 20 years ago. I'm a structural engineer (who loves to design in steel) and a business owner who has simply been working to develop my understanding of technological change. The goal I keep in mind is to help my company, DIALOG, be a leader in a changing world. I fundamentally believe that we should see the rapid progression of technology as an opportunity, not a threat. Instead of standing still and allowing the technological change in the world to disrupt us, let us embrace new technologies and use them to strengthen our businesses, to enable our employees, and to meaningfully improve the well-being of our communities. Let us not be among those disrupted by technological change—let us be the disruptor!

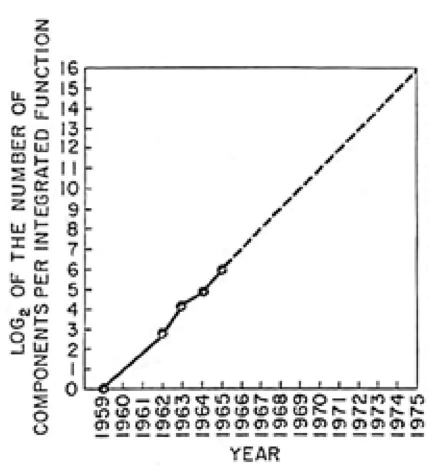

FIGURE 1: Gordon E. Moore, "Cramming More Components onto Integrated Circuits," Electronics, pp. 114–117, April 19, 1965.

From chips to Crays to crazy fast

Before we can look forward to the emerging trends in technology, we must look back to gain context. Many of you have probably heard of "Moore's Law" in computing, but few people know its actual origins. Way back in 1965, Gordon Moore—co-founder of Intel—observed a trend with integrated circuits, which are otherwise known as computer chips. Year over year, starting in 1959, Moore mapped out the number of transistors that could fit onto a single computer chip. He observed that technological progress was enabling the number of transistors on a single chip to double every year or two: one transistor in 1959; eight transistors (2x2x2) by 1962; 32 transistors (2x2x2x2x2) by 1964; and so on. This rate of change, plotted by year, appears as a straight line on a logarithmic graph—the essence of Moore's Law (Figure 1). And, with great foresight, Moore extended a dashed line from his data and predicted that the doubling trend would continue for years into the future. Ever since, the persistent developments of technology have consistently met the expectations of this trend—from a single transistor on a chip back in 1959 to chips today that contain tens of billions of transistors. If I were a betting man (and I am), I'd wager that the exponential increase we've seen in computing power will continue well into the future. The real question for us is: what will that computing power be able to do?

So that we can wrap our heads around what Moore's Law actually means in our lives, let's look at a few examples. Way back in 1985, when I was just a gangly teenager, the Cray 2 was the leading supercomputer in the world. It had a computing power of about 1.9 gigaFLOPS (1.9 billion floating point operations per second). In other words, it could do billions of tiny math calculations every second. The Cray 2 cost

pace of technological change

millions of dollars, weighed about four tons, and needed a 200-gallon tank for cooling fluid. But by 2010—only 25 years later—the Apple iPhone 4 had a roughly equivalent computational capability, cost less than $1,000, and could fit in your shirt pocket. That's the surprising power of Moore's Law.

Let's consider an example even closer to our everyday lives. Think about the smartphone in your pocket right now and compare it to the phone you had 10 years ago. In 2008 I had a BlackBerry 8800 with a weird little trackball instead of a touch screen. Some of my colleagues had the first model of the iPhone, which had just been released the previous year. Today, my Samsung Galaxy S8—which is a bit out of date, since it was released over a year ago—has about 1,000 times more computing power and 1,000 times more memory than that old BlackBerry 8800. If this rate of technological progress continues for the next 10 years—and 25 years—what power will we carry with us in our pockets then?

FIGURE 2: The Cray 2 supercomputer in 1985…roughly the same capability as an already outdated Apple iPhone 4.

"Instead of standing still and allowing the technological change in the world to disrupt us, let us embrace new technologies and use them to strengthen our businesses, to enable our employees, and to meaningfully improve the wellbeing of our communities."

FIGURE 3: Autonomous cars are a common sight these days in cities like San Francisco.

Tech today

Today we are all carrying around little supercomputers in our pockets, supercomputers that are wirelessly connected to endless numbers of other supercomputers. Together, those supercomputers are changing our lives, and the lives of our children and the lives of our colleagues. Think about how much your smartphone has changed your life already. For example, smartphones have enabled new business models like Uber and Lyft to radically disrupt personal transportation. Push a button on your smartphone and a driver will pick you up, usually within five minutes, more reliably, more cost effectively, and with less payment hassle than a taxi. Uber is so convenient and affordable that I've concluded that I don't need to own a car anymore, and I can eliminate all the extra costs that come with owning a vehicle. (For the record, I don't own any Uber shares, and am not on their payroll.) Right now, as I write, my car is listed for sale on AutoTrader and Kijiji. I just don't need it anymore, thanks to Uber. (It's a 2015 Toyota Camry Hybrid XLE with low miles. Make me an offer!)

But ride-sharing apps are just the starting point. Uber and many other players are investing billions to develop autonomous vehicles—putting at risk the jobs of millions of drivers. While here in Canada the thought of driverless cars on our streets may seem like a far-off dream, autonomous vehicles are already driving the streets in cities like Phoenix and San Francisco (Figure 3). These technologies are being enabled by the continuing development of smaller, faster, cheaper computing power coupled with more advanced sensors. And these smaller, faster, cheaper computers are also enabling another trend: the exponential improvement of machine learning and artificial intelligence, or "AI." These are, in other words, computers that teach themselves by recognizing patterns in data.

Applying machine learning and artificial intelligence to work that has traditionally been done solely by humans is the next industrial revolution. As an example of the speed of progress, in November 2016, Google replaced the engine of their traditional online translation service with an AI "brain"; at first, the AI translator made a lot of mistakes, but it learned remarkably quickly. Within weeks the AI translator was working at a level nearly on par with human translators.[1] Building on that success, by October 2017, the AI engine allowed Google to translate in real time through its Pixel earbuds.[2] Two people can have a conversation using different languages, and Google's AI engine translates in real time. More recently, Google demonstrated its new AI Assistant, which learns and responds so effectively that it sounds like an entirely human conversation: while making a live phone call, the Assistant talked to a person who couldn't tell that they were speaking with a computer.[3] The ability of the Assistant to have a human conversation was amazing, to the point of being a bit disturbing: how long will it be before having natural conversations with computers becomes normal?

Other examples of AI-driven technological progress are emerging daily. Researchers in Singapore recently created a robot that can devise and execute a plan to put together an Ikea chair in just over 20 minutes, starting from a loose pile of parts.[4] (Still not as fast as me, if I force myself to read the instructions first!) In 2017, an AI-driven computer from Carnegie Mellon won a 20-day poker tournament, learning how to bluff and outsmarting some of the world's top poker players.[5] And, as of June 2018, the most powerful supercomputer in the world is at Oak Ridge National Laboratory in Tennessee, reclaiming the title from China. It's capable of performing at 200 petaFLOPS: 200 million billion calculations per second.[6] While this is only two-tenths as fast as the estimated capacity of the human brain, if current technological trends continue then we might expect that

1. https://www.nytimes.com/2016/12/14/magazine/the-great-ai-awakening.html
2. https://www.engadget.com/2017/10/04/google-pixel-buds-translation-change-the-world/
3. https://www.youtube.com/watch?v=D5VN56jQMWM
4. https://www.nytimes.com/2018/04/18/science/robots-ikea-furniture.html
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6. https://www.technologyreview.com/s/611077/the-worlds-most-powerful-supercomputer-is-tailor-made-for-the-ai-era/


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in the next 25 years you will be able to buy a computer that fits in your pocket, costs less than $1,000, and has the computing power of the human brain. What will that technology be able to do for us? And are we prepared for this emerging reality?

"The big risk is that a fundamental assumption of macroeconomics—that as technology eliminates jobs, people can retrain for new jobs—isn't necessarily valid anymore, because the technological changes are coming at us too quickly."

The Steel Industry: AI warriors, or worriers?

Similar to autonomous cars, heavy investments are being made into developing long-haul autonomous trucks that will someday threaten the jobs of millions of truck drivers.[7] This investment is happening close to home here in Canada, too: This summer, Imperial Oil started testing driverless oilsands haulers at their Kearl site in Alberta.[8] With these developments happening in our own backyard, the relevance to the steel industry of technological shifts will assuredly continue to grow. What happens to those people and their livelihoods? The big risk is that a fundamental assumption of macroeconomics—that as technology eliminates jobs, people can retrain for new jobs—isn't necessarily valid anymore, because the technological changes are coming at us too quickly.

As many other sectors accelerate, construction has had the lowest productivity gains of any industry: incredibly, in America construction productivity has actually fallen by half since the late 1960s.[9] This is partly because workers are used more than machinery. The *Economist* notes that the construction industry "mostly ignores tools that might improve productivity."[10] The McKinsey Global Institute looked at the state of digitization in sectors across the U.S. economy, analyzing digital assets, usage, and labour. In their results, construction is ranked second-lowest only to agriculture and hunting.[11]

We should not take comfort from the fact that it seems that employees of the construction industry aren't being ousted by AI as rapidly as workers in other sectors. Rather, we must recognize the risk that the construction industry is falling dangerously behind in a fast-paced world—and any industry that falls behind becomes a primary target for disruption. Why? Because industries that do not optimize themselves are a juicy, profitable target for the implementation of game-changing technologies. Netflix destroyed Blockbuster. iTunes and Spotify bankrupted HMV. Uber is overwhelming the taxi business. Who is going to disrupt the construction industry?

FIGURE 4: Hackathons have become regular events in the DIALOG studios, where people learn the power of programming to develop tools to optimize their own work.

7. https://www.nytimes.com/2017/01/25/business/dealbook/how-efficiency-is-wiping-out-the-middle-class.html
8. http://www.mining.com/web/imperial-testing-driverless-oilsands-haulers-kearl/
9. https://www.economist.com/business/2017/08/17/efficiency-eludes-the-construction-industry
10. https://www.economist.com/business/2017/08/17/efficiency-eludes-the-construction-industry
11. https://hbr.org/2016/04/a-chart-that-shows-which-industries-are-the-most-digital-and-why

Self-disruption, not self-destruction

Who can disrupt the structural steel industry? We can.

There is no one better equipped to disrupt our industry than ourselves. We already have the supply chains, the shop space, the CNC equipment, and the people with decades of steel know-how. We just need to inject some new thinking. We just need to open our minds to change. We just need to systematically challenge and digitize the way we get things done in every corner of our industry, from designers to steel mills to service centres to fabricators to erectors.

Where are we going to get the injection of new thinking that will help us disrupt ourselves? There are opportunities everywhere. Share learnings from each other through the CISC. Build relationships with universities, like the CISC Steel Centre at the University of Alberta (check out www.steelcentre.ca). Hire co-op students, not just from engineering, but from computer science. Poll your own staff to see who has a background in technology—you'll probably be surprised to see the tech talent you already have on your team. And it's not just about

technology: it's about lean process; it's about prefabrication; it's about measuring and tracking data. Taken in combination, these are powerful tools that will allow the steel industry to disrupt itself.

In particular, challenge yourselves to capture data from every part of your process and your supply chain. With rich data, you have the feedstock to carry out analyses of your performance, to find trends, and to discover opportunities for disruption and efficiency. Without data, you have nothing. Some steel industry players are well on their way down the path of data analysis, supplemented by the predictive power of AI. Big River Steel in Arkansas, for example, "makes extensive use of sensors, control systems, and machine learning-based optimization" in six key areas: demand prediction, sourcing and inventory management, scheduling optimization, production optimization, predictive maintenance, and outbound transportation optimization.[12] No matter where you stand in the steel supply chain, you first need to get serious about measuring and tracking data like Big River Steel to enable the use of intelligent technological tools in your production process.

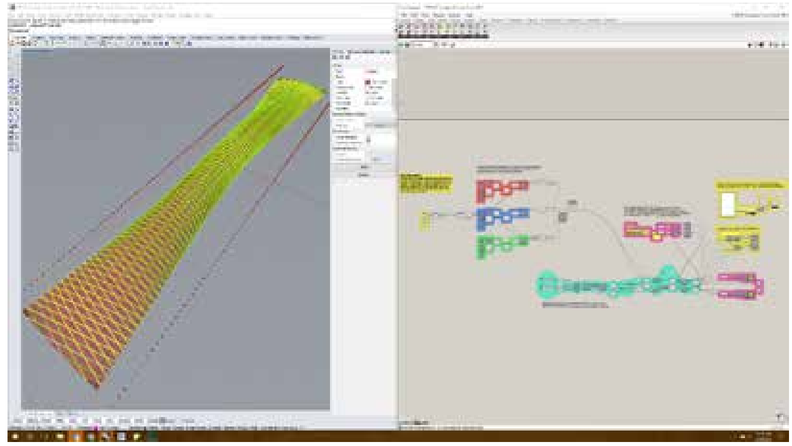

FIGURE 5: Computational design in action, disrupting traditional approaches to design and drafting. This tool parametrically generates structural framing on complex surfaces.

Steel yourself!

I fundamentally believe that we should see the rapid progression of technology as an opportunity, not a threat. Technology will allow us to automate many menial tasks, allowing our talented people to focus more of their energies on creative, high-value work for our clients and customers. I've been challenging the people I work with to see the tremendous opportunity that lies before us, and to open our minds to embrace technological change. Now, I'm challenging you. Though it won't be easy at first, let us embrace new technologies and use them to strengthen our businesses, to enable our employees, and to meaningfully improve the well-being of our communities. There is a lot to be excited about—we can learn from the world around us and we can find support in our environments of teamwork. Together, let's disrupt the steel industry for the better! AS

12. https://www.forbes.com/sites/tomdavenport/2018/02/08/shining-up-a-rusty-industry-with-artificial-intelligence/#e2ff77c61c43

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A QUESTION OF STA

Reassessing lateral-torsional buckling capacity of modern welded

By Dimple Ji, Robert G. Driver, Ali Imanpour, University of Alberta

LATERAL-TORSIONAL BUCKLING is a potential failure mode of steel girders. Under flexural bending, it involves the vertical movement, then simultaneous horizontal sway and rotation of a girder within an unbraced span. Visually, this results in a girder with a twisted appearance.

The Canadian steel design standard, CSA S16, prescribes provisions to determine lateral-torsional buckling capacity by means of a unified curve that identifies three major regions of behaviour: elastic lateral-torsional buckling, inelastic lateral-torsional buckling, and full cross-sectional capacity. The current design equations were introduced in 1974 and apply to both rolled and welded sections. Though there have been slight modifications, the root equation has remained the same since then. The basic premise is relatively simple; for a given girder cross-section and unbraced length, the flexural capacity must exceed the bending moments induced by the design loads. However, this is with the assumption that we understand the lateral-torsional buckling behaviour of steel girders and the current design equations can properly predict the flexural capacity of the member. In fact, concerns have been raised that the existing provisions may be unconservative for welded sections.

The cause of concern lies in the nature of welded sections and their residual stresses, which are inherent stresses created in girders during the production process. Though residual stresses exist in both rolled and welded sections (Figure 1), the welds in the latter produce residual stress distributions that may cause them to be more susceptible to lateral-torsional buckling. Specifically, this refers to the compressive stresses in the compression flange tips. Because the compression flange contains pre-existing compressive residual stresses, yielding can occur well before the full yield stress is applied to the section. As welded sections possess larger regions of compressive stress, there may be significant losses of the compression flange stiffness and rapid decreases in the flexural bending capacity.

Recent numerical studies by Kabir and Bhowmick [1] echo these sentiments and have implied that the existing design curve is unconservative for welded sections, particularly in the inelastic lateral-torsional buckling region where residual stresses may significantly affect the capacity of such girders. A 2011 study by well-known researchers MacPhedran and Grondin [2] recommended that the existing provisions be revised to consist of two separate girder design curves – one for rolled sections and the other for welded sections, similar to the approach adopted in Eurocode 3.

As reducing predicted design strengths for welded girders could increase their cost significantly, it is prudent to further assess the situation. While recent research may suggest concerns with the existing design curve, it is important to note that these studies have been performed using numerical methods or have utilized data from physical testing conducted mainly in Japan in the 1960s to 1980s. Since then, manufacturing and fabrication processes have changed significantly, which is likely to have a considerable effect on residual stress amplitude and distribution, and therefore flexural bending capacity. Moreover, these processes vary from country to country; girders tested in Japan may not necessarily be representative of those fabricated in Canada. Therefore, it

[1] M. I. Kabir and A. K. Bhowmick, "Lateral torsional buckling of welded wide flange beams," Concordia University, 2016.
[2] I. MacPhedran and G. Y. Grondin, "A simple steel beam design curve," Can. J. Civ. Eng., vol. 38, no. 2, pp. 141–153, 2011.

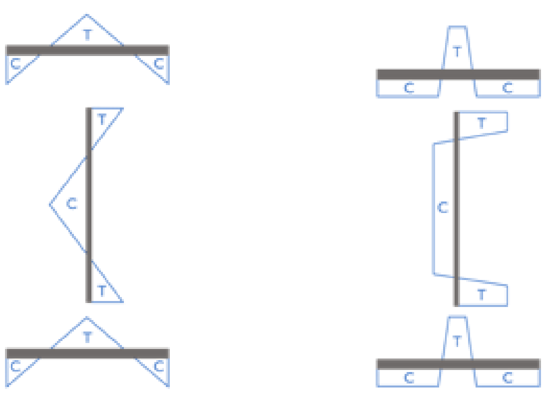

FIGURE 1: Residual stress distribution in rolled (left) and welded (right) girders; T = tension, C = compression (image courtesy of Steel Centre MSc student, Daniel Unsworth, 2018)

BILITY

steel girders

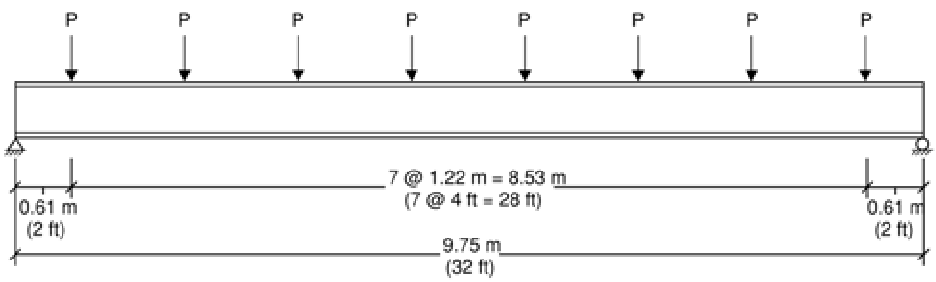

FIGURE 2: Girder dimensions and loading scheme

seems to be in the steel industry's best interest to conduct further studies before we adopt or reject modifications to the existing design provisions.

The CISC Centre for Steel Structures Education and Research (Steel Centre) is an education and research network at the University of Alberta that aims to conduct research closely aligned with industry needs. The Steel Centre has launched a research program to investigate lateral-torsional buckling in welded girders and address the gaps in literature. In response to the lack of recent physical testing, one of the research projects is focused on investigating the stability response of modern welded girders using large-scale testing. The girders will span approximately 10 m in length, with flange widths ranging from 300 to 470 mm and section depths of 600 to 900 mm – representing girders commonly used in building applications and comparable to small or half-size bridge girders. Girders are simply supported in-plane and torsionally pinned, with eight concentrated loads applied at the top flange (Figure 2). The only lateral support provided is at the ends of the girder, meaning it is free to buckle along its 10 m unbraced length. Nine unique cross-sections and a total of 11 tests are planned; all girders are produced with modern manufacturing and welding processes.

The design of a testing bed capable of accommodating the large girders, as well as the displacements and rotations expected during lateral-torsional buckling, posed a substantial challenge. An early obstacle was determining a way to allow lateral sway of the test girder while maintaining vertical load, which is difficult to achieve and a major reason for the paucity of lateral-torsional buckling testing completed. The solution involves gravity load simulators, a unique pin-jointed loading apparatus originally developed at Lehigh University for testing specimens permitted to sway. The pinned connections allow the girder to sway freely in the lateral direction, while keeping load application close to vertical (Figure 3). No manual adjustments are necessary and the apparatus can sway from the equilibrium position in either direction. By using a gravity load simulator to apply each of the eight loads, any lateral girder movement can be accommodated with close to zero restraint.

The load application challenge, among many others, has been overcome

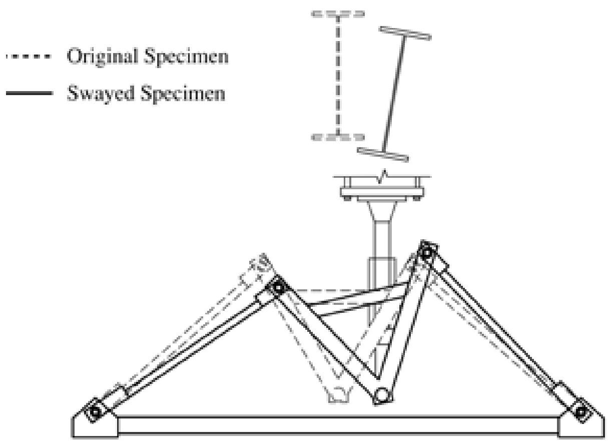

FIGURE 3: Gravity Load Simulator

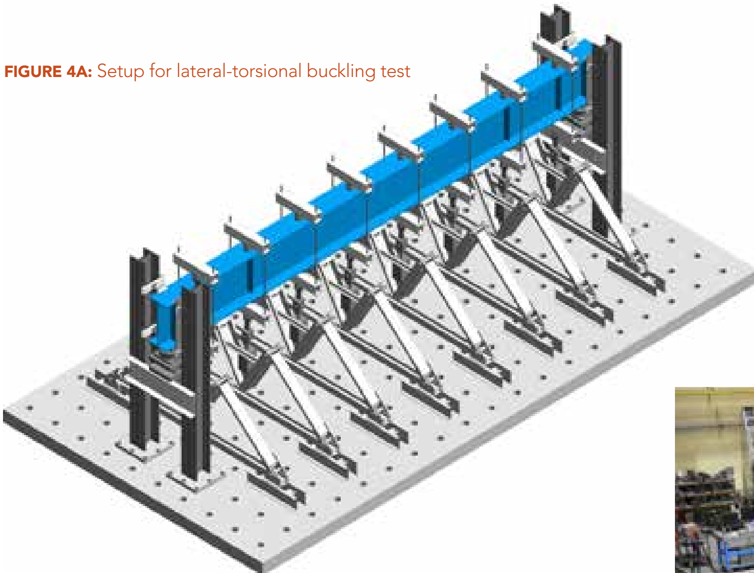

FIGURE 4A: Setup for lateral-torsional buckling test

and the testing bed design is complete (Figure 4A and Figure 4B). A look inside the I.F. Morrison Structural Engineering Laboratory at the University of Alberta reveals a sizable footprint as preparations for testing are underway. The set-up occupies an area of 11 m x 5 m and extends over 3.5 m in height. Excitingly, it will be the first lateral-torsional buckling test of this magnitude! Upon its successful completion, the research will contribute important new experimental results to an otherwise aging database of tests and comment on the adequacy of the S16 provisions. Through an improved understanding of lateral-torsional buckling, the research results will give engineers increased confidence in the design of safe and efficient modern welded girders.

This research project is another example of the benefits of the close partnership the Steel Centre has forged with the Canadian steel industry. Steel Centre and CISC member Supreme Group is providing all fabrication for the girders and the ancillary testing fixtures, along with extensive expertise in bridge girder fabrication, and SSAB has generously provided all the plate material required for the girders. This support for applied research that benefits the steel industry is greatly appreciated. AS

FIGURE 4B: Setup for lateral-torsional buckling test

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A CHALLENGING CA

Becomes a mainstay project

By Justin Wuohela, P.Eng., IBI Group

FIGURE 1

NOPY

THE VMC STATION, which is located at the intersection of Millway Avenue and Highway 7, is the interchange between the Toronto-York Spadina Subway Extension (TYSSE) and the VIVA HWY. 7 BRT (bus rapid transit) transitway.

The canopy (see Figure 1), which is provided to shelter transit users on the VIVA bus platforms, while accommodating bus through-traffic, consists of a rigid structural steel frame comprised of round HSS sections (HSS356x13.0 primary framing members and HSS178x9.5 secondary framing members). These HSS members support the glass and aluminum panel cladding, and other required design loads (e.g. live, climatic and seismic loads). They also partially support glass enclosures below the canopy, which provide an additional degree of shelter to the transit users. The primary member module is 5 m (see Figure 2), with the secondary members being more closely spaced to support the glazing system.

The canopy design takes an elliptical dome form that blends elements of the vivaNext station shelter program and the adjacent VMC subway station entrance geometry. The geometric logic is extracted from the top surface of a 250 m radius torus (see Figure 2).

The canopy is approximately 50 m long, 22.4 m wide and 9.1 m high, and is open to the outdoors on its east and west ends. The composition of opaque and transparent cladding materials balances shading of the main structure with daylighting and transparency within the public realm – supporting CPTED (crime prevention through environmental design) planning principles.

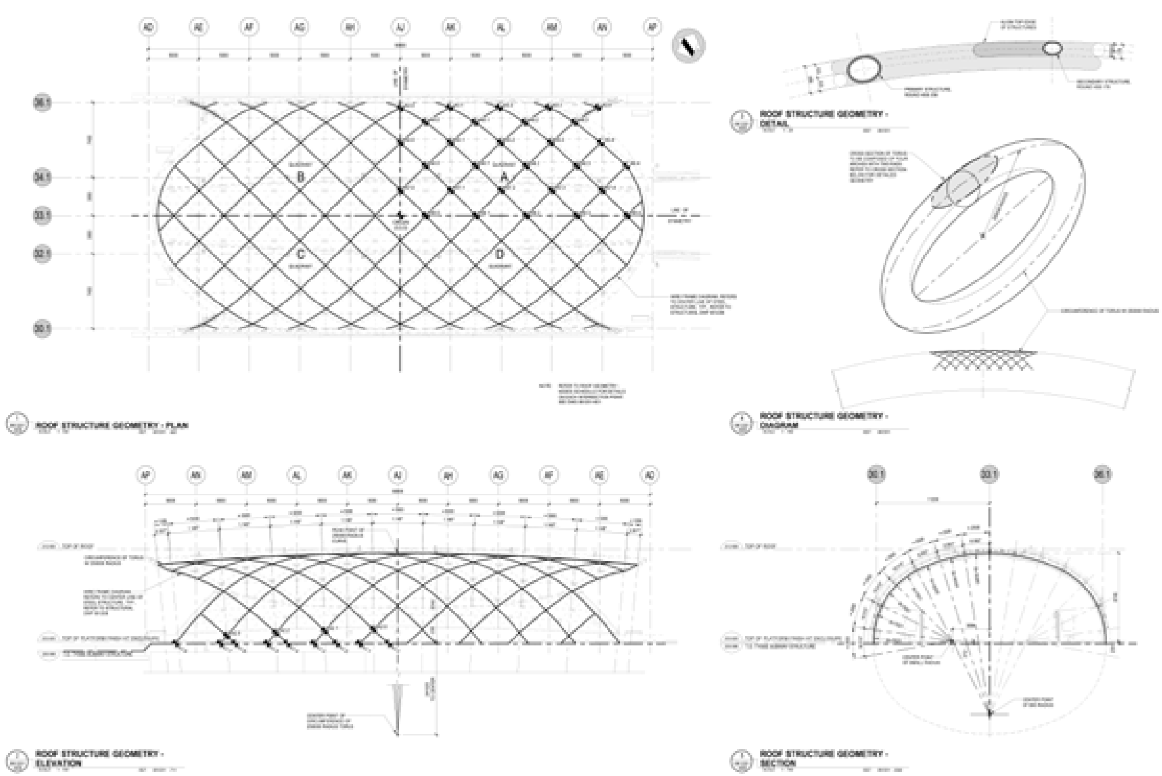

FIGURE 2

PROJECT TEAM

STRUCTURE: VAUGHAN METROPOLITAN CENTRE (VMC) STATION CANOPY **OWNER:** YORK REGION RAPID TRANSIT CORPORATION (YRRTC)

CONSTRUCTOR: KIEWIT-ELLISDON, A PARTNERSHIP (KED) **STRUCTURAL STEEL FABRICATOR AND ERECTOR:** MARIANI METAL FABRICATORS LIMITED

ARCHITECTURAL AND ENGINEERING: QUICK-START DESIGN CONSORTIUM (QSD), CONSISTING OF AECOM, IBI GROUP AND PARSONS CORPORATION

FIGURE 3

The canopy is clad in aluminum panels to create a faceted appearance. It is topped with a continuous skylight running the full length of the building, to provide natural light onto the transitway platforms. The glass is tinted blue to match the colour of the VIVA line stations' shelter glass. Clear glass is used to enclose the north and south sides, allowing openness and visibility.

The canopy frame incorporates complex geometry, including dramatic sweeping curves. This, and the open nature of the canopy, led to complex snow and wind design loads. Sophisticated, three-dimensional frame analysis was therefore undertaken.

Structural steel was selected for the canopy frame based on the aesthetic appearance of round HSS members and associated member-connections, and for its ability to accommodate the complex geometric forms involved. Architecturally Exposed Structural Steel (AESS) was employed.

The round HSS sections employed provide uniform strength, stability and stiffness in all directions, and have excellent torsion resistance properties, which greatly assisted the structural design process. They also facilitated the connections of the cladding supports and fall-arrest roof anchors at the various orientations of the canopy framing members.

The canopy is supported by a reinforced concrete substructure. Large steel base plates and large-diameter, high-strength steel anchor bolts transfer canopy loads to the supporting structure.

The canopy, which incorporates approximately 127 tonnes of structural steel, was constructed in modules in the fabrication shop. The modules were then transported to the site for final erection (see Figure 3). Forming the sweeping curves of the frame members presented particular challenges, as did the many highly-complex, compound connections of the framing members. Both shop and field connections are welded. During erection, the canopy was partially supported by a steel, temporary support frame (see Figure 3).

The VMC station is now in use, with the canopy serving its intended function. The iconic nature of the canopy will be a mainstay of the Vaughan Metropolitan Centre in the years to come. AS

COMMON CODES AND STANDARDS FOR DESIGN AND CONSTRUCTION OF STEEL STRUCTURES

Current Status and Future Publication Targets

Code/Standard/Supplement/ Commentary/Referenced Document	Current Edition	Next Edition/Revision	Publication Target
National Building Code of Canada (NBC)	NBC 2015	NBC 2020	Dec. 2020
NBC Structural Commentaries (Part 4 of Div. B)	NBC 2015 Str. Comm.	NBC 2020 Str. Comm.	2021
CSA S16 Design of Steel Structures	CSA S16-14	CSA S16-19	Sep. 2019
CISC Commentary on CSA S16 (Part 2 of CISC Handbook of Steel Construction)	CISC Handbook 11th Edition[1] 3rd Printing[2]	CISC Handbook 12th Edition	late 2020
CISC Moment Connections for Seismic Applications	2nd Edition[3]	3rd Edition	Sep. 2019
CSA S6 Canadian Highway Bridge Design Code	CSA S6-14	CSA S6-19	Sep. 2019
CSA S6.1 Commentary on Canadian Highway Bridge Design Code	CSA S6.1-14	CSA S6.1-19	Sep. 2019
CSA G40.20/G40.21 General Requirements for Rolled or Welded Structural Quality Steel/Structural Quality Steel	G40.20-13 G40.21-13	TBA	
CSA W59 Welded Steel Construction (Metal Arc Welding)	CSA W59-18	TBA	
CSA W47.1 Certification of Companies for Fusion Welding of Steel	CSA W47.1-09 (R2014)	CSA W47.1-19	Summer 2019
CSA S136 North American Specification for the Design of Cold-Formed Steel Structural Members	CSA S136-16	TBA	
CSA S136.1 Commentary on CSA S136	CSA S136.1-16	TBA	

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

[2]3rd Printing of Handbook has been updated to reflect changes introduced in CSA S16-14 Update No. 1 released in Dec. 2016

[3]Adopted in S16-14 by reference

FAREWELL ALFRED WONG, P.ENG., FCSCE

It is with regret but warm wishes that we announce the retirement of CISC's Director of Engineering, Alfred Wong, P.Eng., FCSCE, as of January 15, 2019.

Alfred has been with the CISC for almost 40 years. He has provided leadership on innumerable projects and has contributed immensely to the steel design and construction industry, as well as to the CISC's success.

We congratulate Alfred on a legendary career with the CISC! We wish him all the best as he embarks in this new phase of his life! AS

EVENTS

STEELDAY
September 28, 2018

STEELDAY 2018 SHOWCASES THE BEST OF OUR VIBRANT STRUCTURAL STEEL INDUSTRY YET AGAIN!

This year's SteelDay was held on September 28, 2018 at several locations all across Canada. With over 1000 attendees and 14 hosts, we were able to showcase how Canadian producers, service centres, fabricators and erectors contribute to our vibrant steel industry. Through various activities, such as tours, demonstrations, presentations and BBQs, attendees got to experience the exciting steel process for various types of projects from beginning to end.

A very special thank you to this year's SteelDay hosts, Rapid-Span Structures Ltd., Gerdau, ACL Steel, Brunswick Steel, Coastal Steel Construction, Corrcoat Services Inc., Daam Galvanizing, Lakehead Ironworks Inc., Pacific Bolt Manufacturing, Supreme Group and Conestoga College. Walters Group Inc. also hosted a virtual SteelDay on Instagram! We encourage all steel companies and academic institutions from coast to coast, as well as individuals with a steel passion, to find their unique way to celebrate our growing steel industry every SteelDay! AS

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