the STEEL centre

2022
ANNUAL REPORT

Dr. Robert Driver
Director

UNIVERSITY OF ALBERTA

CISC Centre for Steel Structures Education and Research
University of Alberta
Faculty of Engineering
Department of Civil and Environmental Engineering

challenge traditional boundaries.

the STEEL centre

active

experiential

authentic

learning

mentorship+

contents

from the director

This year, we reflect on the powerful learning experiences that have come together at the Steel Centre thanks to our committed members and a tightly integrated education programme that positions student learning within the multidimensional context of professional engineering. Students enhance their core education with new learning from practicing professionals, self-teaching as they tackle real projects, and regular exposure to construction sites and all of the complex interactions that occur to get building designs from the drafting table to the roadside.

We recognize, celebrate, and appreciate the continued opportunities that our members offer Steel Centre students, where they express their learning in sometimes unexpected but always highly relevant modes. Doctoral and undergraduate students learn together—with and from each other. We are building a hub for the steel construction industry, from university students to professionals with decades-long careers. The interconnectedness across generations has built resilient, uniquely capable students.

I invite you to consider how far we've come in our mission to 'imagine and transform the future of steel construction', beginning with the reimagined training of future engineers and the skills and attitudes that they will bring to their careers.

Dr. Robert Driver
Director
The Steel Centre

CANADIAN INSTITUTE OF STEEL CONSTRUCTION

C.W. CARRY CHAIR in Steel Structures

SUPREME STEEL PROFESSORSHIP in Structural Engineering Education and Innovation

vision

The Steel Centre **imagines and transforms** the future of structural steel design, fabrication, and construction.

mission

We are an **industry-driven, student-centred** education and research network dedicated to **continually advancing the steel industry**, engaging in interdisciplinary collaborative research, providing **innovative education opportunities**, and developing leaders of the future.

values

We **challenge traditional boundaries.**

We are a **collaborative community** with uncompromised integrity.

Excellence is in our DNA.

We do **cool stuff for the real world!**

UNIVERSITY OF ALBERTA

learn by doing

The Steel Centre brings learning to life with hands-on experiences to frame and contextualize the design and construction process. Students see how engineers, trades workers, and general contractors work together to take buildings **from draft to delivered.**

Learning from the designer, standing alongside the finished structure gives students deep insight into the holistic nature and interconnectedness of components and how design decisions are made.

Industry partners **keep students up-to-date with cutting-edge tech** that will be commonplace in the workplace of tomorrow. Students arrive to their first day with background knowledge of the tools and systems that they will encounter in their professional practice.

COLLINS STEEL
WF STEEL & CRANE
CANAM Better Building Solutions
SUPREME STEEL
DIALOG
S-FRAME SOFTWARE
BuildingPoint
cwb welding foundation
TSE TSE STEEL LTD.
STEADFAST ENGINEERING LTD
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CANADIAN INSTITUTE OF STEEL CONSTRUCTION
C.W. CARRY CHAIR in Steel Structures
SUPREME STEEL PROFESSORSHIP in Structural Engineering Education and Innovation

experiential learning
at the Steel Centre

Steel Centre OutReach Engineering (SCORE) is a student-run consultancy that takes on real projects alongside industry partners, building authentic mentorship relationships and training students in **hands-on engineering.**

The Steel Squad offers unique opportunities for undergrads to **experience steel construction live and in person:** at active job sites, fabrication shops, in engineering offices, and beyond.

Steel Centre Industry Launchpad for Students (SCILS) is a unique and flexible way of matching students with industry partners for summer work experiences that give them professional skills that help them to stand out when launching their careers.

Steel for Lunch is a Friday lunchtime series that explores topics of interest to the steel construction community. Case studies, research presentations, and professional advice are all on the menu. **Students and practicing engineers come together** to learn and share their experiences first-hand.

Students are **recognized for these additional experiential learning opportunities** through the Steel Centre Industry-Ready endorsement. Motivated students complete a series of learning experiences across core areas to **develop their abilities outside the traditional curriculum**, making them more "Industry-Ready" on day one of their future careers.

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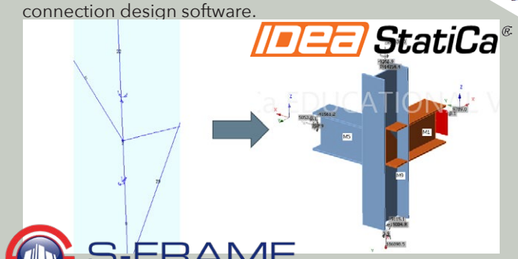
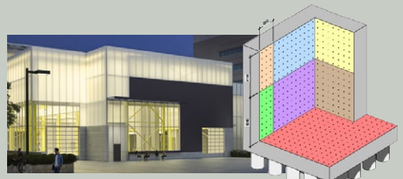
Client: S-FRAME
Automated tool to import data from S-FRAME models to IDEA StatiCa connection design software.



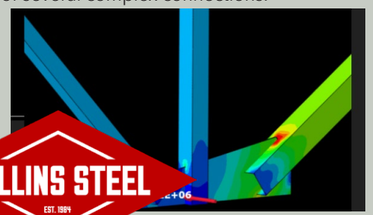
S-FRAME SOFTWARE

Client: DIALOG
Design of the new strong wall and floor of the Morrison Structures Lab.



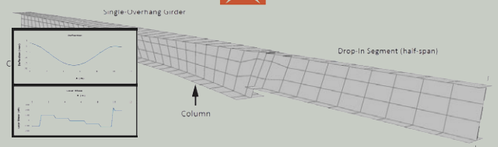
DIALOG

Client: Collins Steel
Finite element modelling and analysis to verify the design of several complex connections.



Client: Canadian Institute of Steel Construction
Modelling and behaviour studies for single-overhang cantilever girders.

cisc icca



S.C.O.R.E.
by the STEEL centre

Steel Centre OutReach Engineering (SCORE) is a student-run engineering consultancy by the Steel Centre. Students work with member organizations to take on real projects, developing authentic mentorship relationships and increasing their real-world experience while still in training.

SCORE has worked across a range of engineering specialties, from software design to improve the interoperabiilty of connection design software to numerical analysis to confirm design decisions for complex details. SCORE even received mention as part of the engineering team for the newly renovated Morrison Structural Laboratory at the U of A, where SCORE designed the strong wall and strong floor under the supervision of Steel Centre member DIALOG.

What's to come? We see continued and growing partnerships within our membership, along with new opportunities to collaborate with companies across Alberta. SCORE has proven to be a capable, highly competent team, and the working partnerships have been overwhelmingly positive for students and professionals alike.

Interested? Great! SCORE is open to new project proposals.
Get in touch at score@steelcentre.ca.

the STEEL squad

by the STEEL centre

2022 saw the return of full in-person events for the Steel Squad, greatly improving undergraduate student access to live construction sites and hands-on training opportunities such as the Welding Day workshop, hosted by Steel Centre Founding Member Collins Steel. The Steel Squad is a selective-entry undergraduate group for students with an expressed interest in steel construction. Squad members get special access to active jobsites, industry leaders, and training opportunities.

Exposure to elements of construction that are not part of the core curriculum helps to immerse future engineers in the full context of the construction process, providing a tangible reminder of how design decisions can have profound effects on constructability, efficiency, and cost. Engineers who better understand and appreciate the skills of their construction industry colleagues think more holistically about their role and ask more questions to help ensure their plans make sense to all involved.

Whether it's a uniquely complex connection design, a tight jobsite bordering a major transit corridor, or a future city landmark, there are opportunities to learn from and about the structures that surround us.

Above: The Steel Squad learns to weld and fabricates their very own girder!

Below: Students learn about the challenges of a multi-building site along busy Gateway Boulevard.

STEEL for lunch

by the STEEL centre

Steel for Lunch lunchtime webinars take students behind the decision-making process used for projects such as the Montréal Olympic Tower restoration and a tsunami evacuation tower on the BC coast. Direct access to the engineers who designed and oversaw construction enhances student awareness of the types of issues they are likely to encounter during their professional practice.

Students also gain from connections to practicing professionals and career- or business-focused advice to complement the technical training they receive during university studies.

SCILS

by the STEEL centre

Steel Centre Industry Launchpad for Students (SCILS) is a unique and flexible way of matching students with industry partners for summer work experiences that give them professional skills that help them to stand out when launching their careers. SCILS is more than just an internship placement; students are connected to the holistic mentorship and learning environment provided at the Steel Centre so that they are able to learn, grow, ask questions, and apply their knowledge as part of a functioning engineering team.

STEEL centre INDUSTRY-READY

industry-ready

Students are recognized for these additional experiential learning opportunities through the **Steel Centre Industry-Ready endorsement.** Motivated students complete a series of learning experiences across core areas to develop their abilities outside the traditional curriculum, making them more "Industry-Ready" on day one of their future careers.

STEEL centre INDUSTRY-READY

24 credits in total

at least **6 credits** per core area

maximum **3 credits** per event type

sample student portfolio

real-world engineering	industry collaboration	business sense
Steel for Lunch 1	CISC webinar	SCRG event coordinator
Jobsite visit 1	Office shadowing	Steel for Lunch 2
Engineers in Action*		Engineers in Action*
SCORE*	SCORE*	SCORE*
Summer internship*	Summer internship*	Steel for Lunch 3
Jobsite visit 2		

**Large or particularly complex projects may qualify for a maximum of 3 credits*

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people

support

Matt Jeppesen
Programs Administrator

Greg Miller
Structural Engineering Technician

Cam West
Structural Engineering Technician

current students

researchers

Dr. Robert Driver, P. Eng.
Supreme Steel Professor
Steel Centre Director
Steel Structures

Dr. Ali Imanpour, P. Eng.
Assistant Professor
Steel Structures

Dr. Doug Tomlinson, P. Eng.
Assistant Professor
Steel/Concrete Composite Systems

Dr. Leijun Li, P. Eng.
Professor
Welding Metallurgy

Dr. Yong Li
Assistant Professor
Reliability & Advanced Analysis

Dr. Ali Sadrara
Post-doctoral Fellow
Steel Structures

2022 highlights

New post-doctoral fellow

Dr. Ali Sadrara joins the Steel Centre as the latest member of the research team. Ali's work will support research across the range of Steel Centre programs, with special emphasis on the new Artificial Intelligence research stream. Welcome, Ali!

Welcome Canam Group!

CANAM
Better Building Solutions

The Steel Centre proudly welcomes Canam Group to its membership. Canam provides complete construction services across Canada and around the world, and we are glad to add their expertise to our education and research efforts.

Artificial Intelligence research stream launches

Dr. Ali Imanpour leads the research team on this new stream of research, a multi-year project to identify and potentially develop tools and approaches to leverage the power of artificial intelligence for the steel construction industry.

student awards 2022

Steel Centre students are top performers, receiving a number of honours and awards each year for academic and research accomplishments. In 2022, students were awarded scholarships totalling an impressive $112,300. The Steel Centre's excellent students have attracted direct support from outside organizations, most recently the CWB Foundation's Welding Advancement Award, given each year to a Steel Centre student or students whose research advances the welding field. We are honoured by this support, and proud of our students and their accomplishments.

cwbwelding foundation
building the future of welding in Canada

$112,300 total awards & scholarships in 2022

- CISC Alberta Region G.L. Kulak Scholarship ($15,000)
- Alberta Graduate Excellence Scholarship (2 recipients; $12,000 each)
- NSERC Undergraduate Student Research Award (3 recipients; $10,000 each)
- Walter H. Johns Graduate Fellowship ($5,800)
- Graduate Completion Scholarship ($5,000)
- J. Gordin Kaplan Award ($5,000)
- Norman and Tess Reid Graduate Scholarship ($4,000)
- CWB Foundation Welding Advancement Award ($2,500)
- Brian Gerbrandt Memorial Graduate Scholarship ($2,500)
- Dean's Research Award (3 recipients; $500 each)

Legend
National award
Alberta award
University of Alberta award
Steel Centre exclusive award

graduating students

Fardad Mokhtari, M.Sc.

Machine Learning-Based Substructuring Technique for Multi-Element Hybrid Simulation of Steel Braced Frames

Dr. Imanpour

Caine Smithaniuk, M.Sc.

Improving the Design and Constructibility of Steel/Reinforced Concrete Connections

Dr. Tomlinson

research

At the Steel Centre, every student, including undergraduates, is involved in a research project. This hands-on experience coupled with outstanding education quality produces students that have a deeper, more natural understanding of steel construction. Steel Centre students work closely with partners from leading companies to identify and solve real problems faced by the steel construction industry.

Steel structures research at the University of Alberta typically involves both large-scale testing in the I.F. Morrison Structural Engineering Laboratory, as well as computer modelling including high-fidelity applications. Steel structures research carried out at the University of Alberta has been influential in the development of design codes and standards world-wide.

A new Emerging Technologies stream is taking shape, using generative design and AR applications to understand new ways to design, build, and teach.

See the list at right for a snapshot of significant areas of research at the Steel Centre.

research topics

structural stability

Structural Stability and Design of Steel Cantilever Systems

Influence of Open-Web Steel Joists on Gerber Girder Stability

Reduced Web Doubler Design for Connections Used in Pipe Racks

Assessing the Inelastic Lateral–Torsional Buckling Provisions of Canadian Design Standards for Welded Girders

Design Method for Steel Gerber Systems

Quantify Contribution of Large P-Delta Effect to Design Forces of Columns in Steel MRFs

Stability of Extended Shear Tabs

Progressive Collapse Resistance of Composite Steel Frame Structures

emerging technologies

Optimization of Single-Storey Steel Buildings Using Generative Design Methodology

Applications of Artificial Intelligence Techniques on Optimization of Structural Steel Conenctions

Machine Learning for Optimization of Steel Shear Connections

Application of the Hybrid Simulation Technique to Evaluate the Seismic Response of EBF Links

seismic design

Enhanced Seismic Design Method for Steel Multi-Tiered Buckling-Restrained Braced Frames in Canada

Seismic Response Evaluation and Design of Steel Multi-tiered Eccentrically Braced Frames

Test-based Design Methods for Steel Multi-tiered Concentrically Braced Frames

Advanced Hybrid Steel–Timber System for Seismic Applications

Development of Enhanced Design Methods for Deep Wide-Flange Columns in Steel Moment Resisting Frames under Earthquake Loading

Development of Simplified Seismic Design Guidelines for Steel Concentrically Braced Frames in Regions of Low and Moderate Seismicity

Predictive Fracture Model for Hollow Structural Sections subjected to Earthquake Loading

construction & rehabilitation

Rehabilitation of Deficient Concrete Columns with Steel Confinement Collars

Standardization of Embedded Plates for Steel/ Reinforced Concrete Connections

Improving the Design and Constructibility of Steel/Reinforced Concrete Connections

prefabricated structures

Performance and Design of Prefabricated Steel Braced Frames for Industrial Buildings

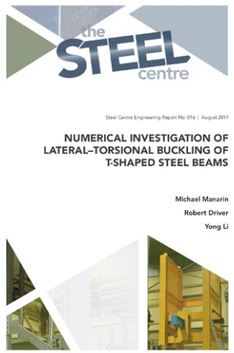
Development of a Modular Steel Structure for Multi-Storey Buildings

Development of a Resilient Steel Modular Moment-Resisting System for Seismic and Wind Applications

Steel Centre Engineering Reports (SCERs)

The Steel Centre keeps industry in the loop with new research

Research is an important part of what we do, but its value is only truly realized when that knowledge can make its way out into the world of practicing engineers. To aid this effort, we launched the Steel Centre Engineering Report (SCER) series. As students complete their investigations, their work is compiled and published as an SCER available to the public at steelcentre.ca/reports.



access the reports

Click here to download any published SCER. The full archive also includes Structural Engineering Reports published by the Steel Centre researchers prior to the Steel Centre's official formation.

Steel Centre publications 2022

Steel Centre students underlined.

Asgarpoor, M., Gharavi, A., Epackachi, S., Imanpour, A. (2022). "Macro Modelling of Steel-Plate Concrete Composite Shear Walls in the OpenSees Environment." *CSCE Annual Conference – Structures Specialty*, Whistler, BC, Canada, May 25 – 28.

Bani, M., Imanpour, A. (2022). "Dynamic Response of Multi-Tiered Buckling-Restrained Braced Frames in High Seismic Regions of Canada." *CSCE Annual Conference – Structures Specialty*, Whistler, BC, Canada, May 25 – 28.

Bani, M., Imanpour, A., (2022). "Seismic Performance of Steel Multi-Tiered Buckling-Restrained Braced Frames in Canada." *10th International Conference on Behavior of Steel Structures in Seismic Areas*, STESSA 2022, Timisoara, Romania, May 25 – 27.

Cano, P., Comeau, C., Imanpour, A., Tremblay, R. (2022). "Seismic Behaviour and Design of Chevron Multi-Tiered Concentrically Braced Frames." *10th International Conference on Behavior of Steel Structures in Seismic Areas*, STESSA 2022, Timisoara, Romania, May 25 – 27.

Chapman, J.R., Darras, A.J., Driver, R.G. (2022) "Tests of Collared Concrete Columns Under Eccentric Load." *Structural Journal*, American Concrete Institute, vol. 119, no. 3 (May), pp. 117127. DOI: 10.14359/51734488.

Chaya, H., Imanpour, A., Driver, R.G., Morgan, B. (2022). "Design and Assessment of Steel Pipe Rack Moment Connections with Emphasis on Web Doubler Plates." *CSCE Annual Conference – Structures Specialty*, Whistler, BC, Canada, May 25 – 28.

Comeau, C., Cano, P., Imanpour, A., Tremblay, R. (2022). "Seismic Response of Two-Bay Steel Multi-Tiered Concentrically Braced Frames." *10th International Conference on Behavior of Steel Structures in Seismic Areas*, STESSA 2022, Timisoara, Romania, May 25 – 27.

2022 publications, cont'd

Datoo, Z., Esmaeili, V., Driver, R.G., Imanpour, A. (2022). "Influence of Open-Web Steel Joists on Stability of Gerber Girders." *CSCE Annual Conference – Structures Specialty*, Whistler, BC, Canada, May 25 – 28.

Esmaeili, V., Imanpour, A., and Driver, R.G. (2022). "Numerical Assessment of Design Procedures for Overhanging Steel Girders." *CSCE Annual Conference – Structures Specialty*, Whistler, BC, Canada, May 25 – 28.

Essa, M., Driver, R.G., Imanpour, A. (2022). "Development of Unique Test Bed for Assessing Stability Response of Steel Cantilevered Girders." *CSCE Annual Conference – Structures Specialty*, Whistler, BC, Canada, May 25 – 28.

Gharavi, A., Asgarpoor, M., Epackachi, S., Mirghaderi, R., Imanpour, A. (2022). "Evaluation of the AISC Seismic Design Method for Steel-Plate Concrete Shear Walls." *CSCE Annual Conference – Structures Specialty*, Whistler, BC, Canada, May 25 – 28.

Ilozumba, E., Imanpour, A., Adeeb, S., Fathi, A. (2022). "Novel Remediation for Buried Pipelines under Ground Deformation: Cross-Sectional Testing and an Analytical Modeling Approach." *Journal of Pipeline Systems - Engineering and Practice, ASCE*. 13(3), 04022015.

Ilozumba, E., Imanpour, A., Adeeb, S., Fathi, A. (2022). "Novel Remediation for Buried Pipelines under Ground Deformation: Large-Scale Laboratory Testing and Numerical Modeling." *Journal of Pipeline Systems - Engineering and Practice, ASCE*. 13(2), 04022002.

Islam, A., Imanpour, A. (2022). "Stability of Wide-Flange Columns in Steel Moment-Resisting Frames: Evaluation of the Canadian Seismic Design Requirements." *Bulletin of Earthquake Engineering*. 20, 1591-1617.

Islam, A., Imanpour, A., (2022). "Evaluation of the Canadian Seismic Design Provisions for Wide-Flange Columns in Steel Moment-resisting Frames." *10th International Conference on Behavior of Steel Structures in Seismic Areas,* STESSA 2022, Timisoara, Romania, May 25 – 27.

Ji, X.L., Twizell, S., Driver, R.G., and Imanpour, A. (2022) "Lateral–Torsional Buckling Response of Compact Ishaped Welded Steel Girders." *Journal of Structural Engineering*, American Society of Civil Engineers, vol. 148, no. 10, 13 pp. DOI: 10.1061/(ASCE)ST.1943-541X.0003431, 04022149; online publication date: July 20, 2022.

Mahmoudi, B., Imanpour, A. (2022). "A Metaheuristic-based Methodology to Minimize the Concentration of Lateral Displacements in Low-Rise Steel Concentrically Braced Frames subjected to Seismic Loading." *CSCE Annual Conference – Structures Specialty*, Whistler, BC, Canada, May 25 – 28.

Moammer, O., Imanpour, A., Tremblay, R. (2022). "Seismic Behaviour of Steel Wide Flange Columns in Ductile Moment-Resisting Frames Considering Base Plate Flexibility." *CSCE Annual Conference – Structures Specialty*, Whistler, BC, Canada, May 25 – 28.

Mohamadien, A., Imanpour, A., Yoosef-Ghodsi, N., Kainat, M., Adeeb, S. (2022). "Experimental Evaluation of Strain-Based Damage of APL 5L X52 Pipeline Material under Various Constraints." *ASME International Pipeline Conference (IPC)*, Calgary, AB, Canada, September 26 – 30.

Mokhtari, F., Imanpour, A. (2022). "A Recursive Model Updating Algorithm for Multi-Element Hybrid Simulation of Structures." *14th International Conference on Computational Structures Technology*, Montpellier, France, August 23 – 25.

Mokhtari, F., Imanpour, A., (2022). "Data-Driven Substructuring Technique for Pseudo-Dynamic Hybrid Simulation of Steel Braced Frames." *10th International Conference on Behavior of Steel Structures in Seismic Areas,* STESSA 2022, Timisoara, Romania, May 25 – 27.

Mokhtari, M., Imanpour, A., (2022). "Evaluation of the Seismic Behaviour of Modular Steel Moment-Resisting Frame Structures with Knee Braces." *10th International Conference on Behavior of Steel Structures in Seismic Areas,* STESSA 2022, Timisoara, Romania, May 25 – 27.

Mokhtari, M., Islam, A., Imanpour, A. (2022). "Development, Seismic Performance and Collapse Evaluation of Steel Moment-Resisting Knee Braced Frame." *Journal of Constructional Steel Research*. 193, 107262.

Sadrara, A., Epackachi, S., Imanpour, A. (2022). "A New Methodology to Predict Cumulative Plastic Ductility Capacity of Steel Buckling-Restrained Braces." *CSCE Annual Conference – Structures Specialty*, Whistler, BC, Canada, May 25 – 28.

Smithaniuk, C., and Tomlinson, D. (2022). "Effect of Connection Type and Reinforcement Ratio on the Shear Capacity of Embedded Plates in Reinforced Concrete". *CSCE Annual Conference – Structures Specialty*, Whistler, BC, Canada, May 25 – 28.

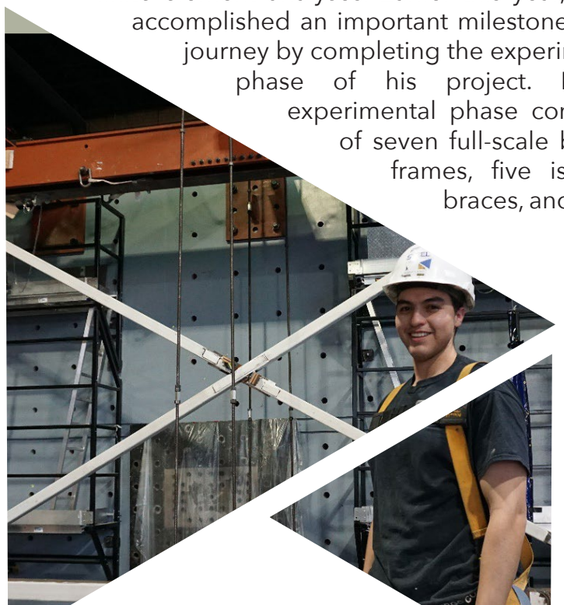
Zain, A., Imanpour, A., Driver, R.G. (2022). "Achieving Improved Construction Efficiency for Multi-Story Steel Concentrically Braced Frames." *International Journal of Steel Structures*. 22, 472–487.

seismic design for multi-tiered braced frames

Pablo A. Cano (Ph.D.)
Supervisor: Dr. Ali Imanpour

Pablo A. Cano has been part of the Steel Centre student body for over five years.During this time, he completed an NSERC Undergraduate Research Internship and an M.Sc. in Structural Engineering under the supervision of Dr. Ali Imanpour. Currently, he is a 4th-year Ph.D. student working on the behaviour and design of steel multi-tiered braced frames (MT-CBFs) for seismic applications.

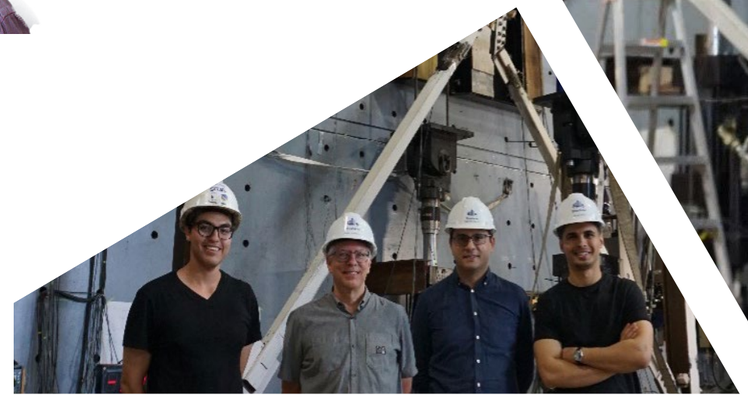
There is no existing experimental data to validate the current seismic provisions for the design of MT-CBFs. Pablo's research objective is not only to validate the current design methods for this type of system, but to also improve them using a combination of test-based methods and detailed finite element analyses. Earlier this year, Pablo accomplished an important milestone in his journey by completing the experimental phase of his project. Pablo's experimental phase consisted of seven full-scale braced frames, five isolated braces, and many tension coupons. The tests performed on the seven MT-CBFs are the first of their kind. These experiments were completed in collaboration with Polytechnique Montréal, where Pablo was located for three years.



The research programme was not easy; Pablo was faced with several challenges throughout the process—some expected and many more unexpected ranging from supply chain issues caused by steel tariffs to the COVID-19 global pandemic severely impacting the testing schedule. These challenges helped Pablo develop adaptability, resilience, and toughness—also some of the key characteristics of steel!

Pablo Cano

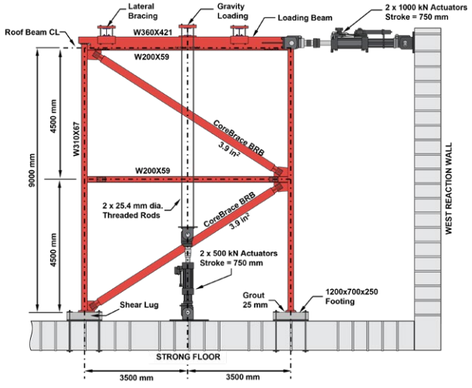
The research conducted by Pablo to date has validated concerns associated with MT-CBFs designed without special provisions, namely the concentration of inelastic drift in a single tier resulting in undesirable behaviour of brace fracture under severe ground motions. Moreover, these experiments have shown that the assumptions generally made about the boundary conditions at the base of the columns are not always correct. In practice, designers often assume connections at the base of the column to be pinned. This approach is conservative for the design of column members; however, it was observed in the physical testing that base connections can have significant rotational stiffness requiring footings to resist additional stresses other than those caused by axial and shear forces. Furthermore, the base condition can have a significant influence on the overall response and behaviour of MT-CBFs. Pablo is currently preparing several manuscripts where more details will be shared; be sure to keep an eye out for upcoming publications to find out more about his research.



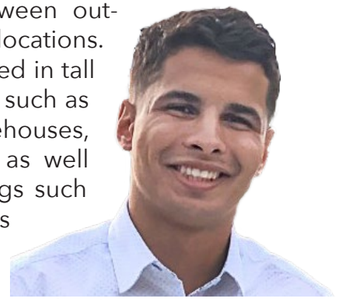
L to R: Pablo Cano, Professor Tremblay (Polytechnique), Professor Imanpour (U of A), Moad Bani

multi-tiered buckling-restrained braced frames

Moad Bani (M.Sc.)
Supervisor: Dr. Ali Imanpour



Steel Multi-Tiered Buckling-Restrained Braced Frames (MT-BRBFs) are among the most efficient seismic force-resisting systems used in buildings with tall storey heights located in regions of high seismicity. These systems consist of multiple bracing panels (or tiers) comprised of Buckling-Restrained Braces (BRBs) stacked vertically along the frame height between out-of-plane support locations. They are commonly used in tall single-storey buildings such as sports facilities, warehouses, and airplane hangars as well as multi-storey buildings such as convention centres and auditoriums. It has been shown that under earthquake loading, inelastic deformation does not distribute evenly along the frame height but rather concentrates in a single tier. This concentration of inelastic deformation induces in-plane bending moment demands on the columns which can cause column instability. Despite the extensive use of such systems in various regions of North America, the design of MT-BRBFs has not yet been addressed in the Canadian steel design standard. Design provisions were introduced in the U.S. in 2016 but lack supporting research and have been shown to be overly conservative. This lack of information has left designers without a unified and validated design strategy, which may lead to unsafe or inefficient structures being built in North America. Given the extensive application of MT-BRBFs in high seismic regions, an advanced design approach is currently being developed for design engineers that is based on a thorough performance evaluation of the braced frame system using numerical and experimental methods.

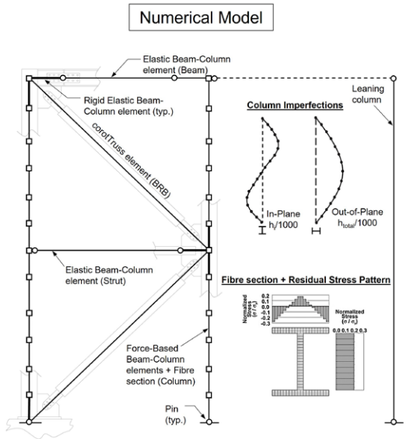


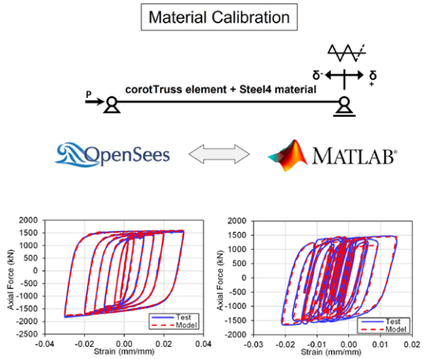
Moad Bani

Moad Bani prepared and conducted both numerical and physical tests to better understand the behaviour of MT-BRBFs during earthquake loading. Numerical simulations of various frame configurations subjected to hazard-specific sets of ground motions were conducted along with a statistical evaluation of demand parameters (See Numerical Model.jpg).

Subsequently, Moad tested a full-scale 9m-tall MT-BRBF in October 2022 at Polytechnique Montréal, as the University of Alberta's structural lab underwent major renovations. (See FrameTestSketch.png and FrameTestPhoto.jpg). Moad commented, "My experience in trying to assemble my frame in the lab was truly humbling. Sometimes things didn't fit the way they were intended, requiring various workarounds and trial and error. I gained a deep appreciation for steel fabricators and ironworkers, and the importance of considering fabrication and construction in the design stage."

The test results will shed light on the performance of the BRBs and columns in MT-BRBFs. The non-uniform distribution of inelastic deformation along the frame height has been confirmed in both the numerical simulations and experimental test. The induced in-plane bending moment demands on the columns were also found to be significant (as seen in the deformed shape of the frame) and should be considered in the design of MT-BRBFs. The research team expects to produce a robust design method that addresses the shortcomings of the system to ensure a stable seismic response under earthquake ground motions.





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