



A Post-buckling Journey: 25 years with the Thin-walled Structures Group

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Abstract

For twenty-five years, the Thin-Walled Structures Group at Johns Hopkins University has provided a home for exploring structural stability. This paper reflects on that journey through the work of my PhD students and close collaborators, whose creativity and persistence have defined the group's approach to stability problems in structural engineering. Each researcher brought new insight to the mechanics of thin-walled members and systems, and the methods we now take for granted in analysis and design. The lessons; however, extend well beyond code provisions and finite strip models. They taught me that progress in stability research depends as much on collaboration, curiosity, diversity, and trust as on computational modeling and testing. The evolution of CUFSM, the Direct Strength Method, and subsequent advances in reliability, system behavior, and imperfection modeling all trace back to the energy and imagination of a community willing to share ideas freely and explore together. This paper briefly highlights key contributions from each of my doctoral students, with emphasis on what their work revealed about the nature of stability and the broader process of a life in research. From the earliest studies of cold-formed steel columns to current investigations of wind-turbine support towers and modular steel systems, these projects form a continuum of learning that has shaped not only my research, but also my understanding of mentorship and friendship. The post-buckling path, it turns out, is where most of the interesting behavior occurs—both in structures and in careers.

1. Introduction

Thank you for reading this paper. I can't say it is quite like anything I have tried to write before. I am greatly honored to have received the Beedle Award from the Structural Stability Research Council, and this paper is part of my response and reaction to receiving this award. Half technical retrospective, half personal retrospective – the paper is my attempt to explain some aspects of the joys of being a professor of structural stability. It bothers me that I will invariably leave out some people, and some critical moments – of that I am sorry. Also, I have not attempted to provide a proper review article with real technical detail – you will have to find that elsewhere. That said, as I surveyed the last twenty-five years, and the many wonderful students that participated in my journey I could see critical technical and personal themes emerge. So, I have done my best to provide those in the paper. Any mistakes in recollection of people and places are my own. I hope you enjoy learning more about the journey in structural stability my students and I have been on for these last years. I know that I have enjoyed it all immensely.

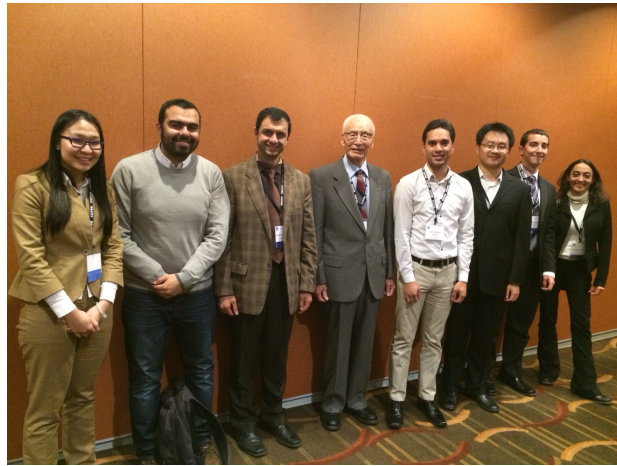
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2. Thin-walled Structures Group

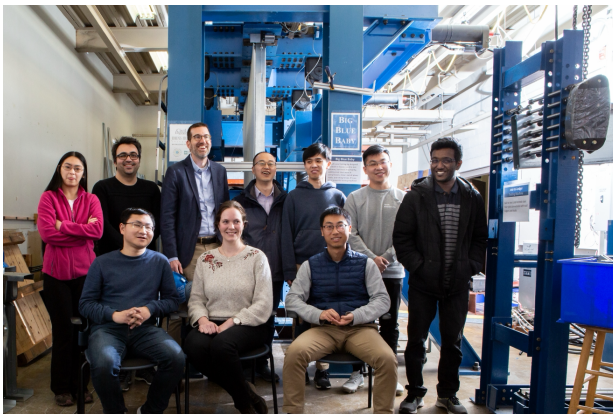
The Thin-walled Structures Group was formed when I joined the Department of Civil Engineering at Johns Hopkins University (JHU) in the Summer of 2000. Prior to joining JHU I worked at Simpson, Gumpertz & Heger, (SGH) Inc. – and was exposed to a wide array of interesting problems in structural engineering and engineering mechanics. This experience at SGH broadened my thinking from my dissertation at Cornell University, which focused exclusively on cold-formed steel members, to cover all situations where structural stability, especially plate stability, played an influential role in the response, prediction, and design of structures. With that vision, the group was formed. Photos of the Thin-walled Structures Group through time are provided in Figure 1.



(a) March 2006, 3rd Floor Latrobe Hall (first office), L to R: Rachel Sangree, Gustavo Choudrai, Yared Shifferaw, Ben Schafer, Cris Moen, Puneet Bajpai



(b) November 2014, CFS Spec. Conference, L to R: Xi Zhao, Abdullah Mahmoud, Shahab Torabian, Wei-Wen Yu, Jean Batista Abreu, Jiazhen Leng, David Fratamico, Ornella Iourio



(c) March 2020, Structures Laboratory, Back row L to R: Victoria Ding, Hamid Foughi, Ben Schafer, Ziqi He, MS students (2), Joel Ben John; Front row L to R: Zhidong Zhang, Astrid Winther Fischer, Chu Ding



(d) December 2024, Hallway outside Structures Laboratory atop tested cylinders L to R: Damir Akchurin, Rajshri Kumar, Fidence Rukundo, Victoria Ding

Figure 1. Thin-walled Structures Group – Sample photos over time

Figure 1a, taken in March 2006 is the Spring after our first graduate Dr. Cheng Yu completed his work. Notably in this photo Dr. Rachel Sangree and Dr. Cris Moen are pictured and today they lead the undergraduate and master's programs in the Department of Civil and Systems Engineering

(CaSE) at JHU. Figure 1b, taken in November 2014 celebrates the group meeting one of the most important academics in the history of cold-formed steel structures: Dr. Wei-Wen Yu. Also in this picture, Dr. Shahab Torabian has joined the group – a collaboration that is at 55 papers and counting today. In addition, this conference was a reunion with one of our wonderful international visitors: Dr. Ornella Iuorio (far right in the 1b picture) who spent part of her dissertation with the group and today is a Professor at Politecnico di Milano doing groundbreaking work in circular design and sustainability for construction.

Figure 1c provides an image of the group in March 2020 mere days before the COVID shutdowns. This image is taken in the structures laboratory at JHU. The image was taken prior to another one of our international visitors Prof. Ziqi He leaving to return to China, on what would turn out to be one of the last international flights for some time. Finally, Figure 1d, taken near the conclusion of Dr. Victoria Ding’s work – and showing several current JHU Thin-walled Structures Group PhD students celebrating the tidy end of Victoria’s test series.

If one takes the Elsevier database Scopus at face value, I have co-authored 390 papers with 276 unique co-authors to date. So, summarizing the work with any level of completeness is not a practical reality for one paper; however, the group has graduated 21 PhD students over its 25 years, as summarized in Table 1. These 21 people and the work they led represent the essential core of the group, and can provide an organizing means for summarizing the work of the group.

Table 1. PhD Dissertations from the Thin-walled Structures Group

Doctoral Student	Year	Dissertation Title
Cheng Yu	2005	Distortional buckling of cold-formed steel members in bending
Rachel Sangree	2006	Covered wooden bridges an experimental and numerical investigation of system and component behavior
Cris Moen	2008	Direct strength design of cold-formed steel members with perforations
Mina Seif	2010	Cross-section stability of structural steel
Yared Shifferaw	2010	Section capacity of cold-formed steel members by the Direct Strength Method
Zhanjie Li	2011	Finite strip modeling of thin-walled members
Luiz Vieira	2011	Behavior and design of sheathed cold-formed steel stud walls under compression
Vahid Zeinoddini	2011	Geometric imperfections in cold-formed steel members
Kara Peterman	2014	Behavior of Full-Scale Cold-Formed Steel Building under Seismic Excitations
Jean Batista	2015	Fire Performance of Cold-Formed Steel Walls
Jiazhen Leng	2015	Simulation of cold-formed steel structures
Xi Zhao	2016	Measurement and application of geometric imperfections in cold-formed steel members
Guanbo Bian	2017	Modeling cold-formed steel members and systems
David Fratamico	2017	Experiments, Analysis, and Design of Built-Up Cold-Formed Steel Columns
Abdullah Mahmoud	2017	Analysis and Design of Spirally Welded Thin-Walled Steel Tapered Cylindrical Shells Under Bending with Application to Wind Turbine Towers
Fardad Haghpanah	2020	Multi-Scale Evacuation Models to Support Emergency and Disaster Response
Hamid Foughi	2021	Enhancing Seismic Resiliency of Steel Buildings through Three-Dimensional Modeling of Diaphragm System Interaction with Braced Frame
Astrid Winther Fischer	2022	Seismic Performance and Topology Optimization of Building Diaphragms
Chu Ding	2022	Strength and Behavior of Advanced High Strength Steel Structural Components
Zhidong Zhang	2023	Simulation and performance of steel sheet sheathed shear walls in CFS-framed building systems
Victoria Ding	2024	Strength of steel cylindrical shells under combined actions with application to wind turbine towers

In addition to the PhD graduates, the current PhD students: Damir Akchurin, Mohammed Eladly, Rajshri Kumar, Chi Luc, Xi Peng, and Fidence Rukundo also provide a means to help organize a summary of the group's efforts. Three postdoctoral research associates also contributed meaningfully to the group and need to be included when summarizing the research: Dr. Deniz Ayhan, Dr. Stefan Szyniszewski, and Dr. Amanpreet Singh. Additional students and visitors associated with the group are listed online².

Two additional people deserve special mention for their long-term commitment and exceptional contributions to the Thin-walled Structures Group: Dr. Shahab Torabian and Dr. Sándor Ádány. Dr. Torabian came to the group as a visitor in 2013, became a postdoctoral research associate then a research engineer and today continues as an adjunct research engineer at JHU with the group while working full-time at SGH. His contributions can be felt in almost every project from the group from 2013 forward, and he has been an incredible partner in the laboratory, code committees, and engineering consulting. Shahab has an incredibly keen mind for structural engineering, and is a kind mentor of people, not to mention a doting father and able husband. He approaches every issue with systematic rigor, with multiple options for solution, and with detailed thinking of how to assess and decide how to move forward – regardless of the type of problem. He is a master collaborator, and his friendship and partnership has benefitted myself and every one of my students since he arrived.

During my PhD I was fortunate to have interactions with other cold-formed steel academics through the American Iron and Steel Institute code committees I was presenting to, and later participating on. One such interaction, with Waterloo's Prof. Reinhold (Reini) Schuster would lead me eventually to Hungary and my longest-term collaborator. Reini was working with Butler buildings and initiated a collaboration with Laszlo Dunai in Hungary which led to Dr. Sándor Ádány becoming interested in cold-formed steel (CFS). On Reini's further suggestion and with the support of the Chohnoky Foundation Sandor brought his wife and family to Baltimore in the 2003-4 academic year. This was followed by my visit to Hungary in 2005 – where the terms modal identification and modal decomposition as the two hallmarks of the constrained finite strip method's abilities were cemented. These collaborations led to further stays of Sandor and his family in 2012-2013, and starting in 2021 Dr. Ádány has been essentially full-time with the group. Our work together spans 27 papers to date, and provides foundational contributions to how we understand buckling of thin-walled plated structures. Lately we have been expanding our collaborations to tubular members, and reliability concepts. We have shared offices multiple times and in doing so shared perspectives on all matters technical and otherwise. I consider my collaboration with Sandor to be one of the true joys of my academic and personal life – he has a wit, wisdom, and outlook forged through a different set of life experiences that I constantly benefit from. His wife Orsi is a true treasure, passionate about the world, their three children (now mostly grown!), and an excellent structural engineer in her own right. Through the encouragement and support of others Sandor and I have been able to enjoy a more than two decades long collaboration – I certainly hope we get more than two decades more.

² Online list of Thin-walled Structures Group: <https://www.ce.jhu.edu/bschafer/people/>

3. Research Vignettes

Utilizing the central contributions from the PhD students and close collaborators this paper is organized in a series of vignettes that cover each of their work, and spans the following areas:

- Structural engineering history,
- Cold-formed steel members,
- Cold-formed steel members - modeling,
- Structural steel members and reliability,
- Cold-formed steel framing – system behavior,
- Cold-formed steel framing – seismic behavior,
- Cold-formed steel framing – fire performance,
- Disaster resilience,
- Cold-formed steel diaphragms and floor systems,
- Metal building systems,
- Wind turbine support towers, and
- Steel foams.

This organization does miss a few smaller efforts, but in the main captures our contributions to structural engineering and structural stability together.

3.1 Structural Engineering History

In 1993 I was assigned to read the book The Tower and the Bridge: The New Art of Structural Engineering a 1985 book by David P. Billington as part of an elective undergraduate course in pre-stressed concrete at the University of Iowa. Professor Dan Branson (of the Branson effective moment of inertia formula in ACI 318) taught essentially all my structural analysis and most of my structural design undergraduate courses. He had a crew-cut, held strict deadlines, locked his classroom at 730am sharp (classes he taught were always at 730am), and was clear that structural engineering was a serious matter. To check up on one's reading of the Tower and the Bridge, Prof. Branson conducted an oral examination – during this one conversation (that I was completely afraid of!) my passion for structural engineering history and ideals was cemented. The book, and Professor Branson's passion for it, showed why one might want to be a structural engineer, what our great achievements actually were, and where we should try to be going. Later, I would also come to know Professor Billington and even get to host him for multiple visits. My passion for structural engineering history and our ideals as structural engineers ignited by Professor Branson has never wavered and has driven much of my research since those early days.

So, when my Cornell colleague Prof. Ron Ziemian mentioned that there might be a young bridge engineer, Rachel Sangree (PhD 2006), interested in coming to JHU for her PhD I was intrigued – and even more thrilled when she agreed to be my 2nd PhD student. When it became clear that the Historic American Engineering Record (part of the National Park Service) was interested in having real engineering insights on their field work – I knew we had a great project match. So, for several years Rachel Sangree led our effort to uncover the engineering secrets to historic covered wooden bridges, and we learned together how to take modern structural engineering ideas and methods, and apply them to these historical structures. Her experimental work on scarf joints was grounded in the goal of better understanding structural behavior so that historic “preservation” did not turn these bridges into glorified barns and their function could still be preserved.

Rachel's PhD was just the beginning of our journey together. After her PhD and through her time as a young mother I was able to coax her into helping me design a new testing rig in the lab (what would become the Big Blue Baby in the background of Figure 1c) and in teaching in the department at JHU. We would go on to co-teach, for nearly a decade, a course based on Billington's principles from the Tower and the Bridge. Dr. Sangree led the re-design of our JHU undergraduate curriculum under the banner: civilization engineered – and has become the leader of our undergraduate program. It continues to be an honor to work with her everyday – and her impact on my personal, teaching, and research life cannot be overstated.

3.2 CFS Members

Given that my PhD was completed on cold-formed steel member behavior and design it is probably no surprise that my first PhD student: Cheng Yu (PhD 2005), and one of my most recent PhD graduates: Chu Ding (PhD 2022) have all continued to make enormous contributions to this space. It is now common to summarize cold-formed steel member design as considering the interaction of yielding with local, distortional, and global buckling – and the latest CFS standard: AISI S100-24 now provides an integrated method for covering all these issues including for members with holes, but it was not always the case.

In 2000 when Cheng Yu agreed to join the group as my first PhD student there was great hesitation in the standards committee in the US to address distortional buckling of CFS members explicitly. Cheng would develop and execute a series of experiments that would put these issues to rest in US CFS design – and further explain why and when distortional buckling was a concern for typical cold-formed steel member applications. He performed a series of flexural tests where the compression flange was effectively restrained from rotation – and successfully forced local buckling and demonstrated excellent agreement with the then governing design specification. He then relaxed the restraint and performed a second set of tests with unbraced lengths long enough to allow distortional buckling but precluding lateral-torsional buckling. These tests exhibited far lower strengths, and did not agree with the current specification, but did agree well with proposals largely emanating from the work of Prof. Greg Hancock at the University of Sydney and would ultimately be adopted. My own PhD was computational, and included no testing, so imagine my surprise when my first funded project was largely experimental. Cheng never suggested that we did not know what we were doing – and we had great help from friends in industry including Maury Golovin from CECO metal buildings who hosted me for a trip to their testing lab and patiently answered a day's worth of detailed questions. As my first PhD student, Cheng and I got to grow up together, he has had a wildly successful career as a Professor at the University of North Texas with significant industry collaborations and academic contributions. In 2019 I had the honor of spending time in China with him where we gave a joint lecture and he was the superstar guest.

In 2004 when Cris Moen (PhD 2008) joined the group, the Direct Strength Method (DSM) of CFS design had just been adopted by the US standard. A key barrier to wider adoption was the fact that the method had not been developed to consider members with holes – a condition that is exceptionally common in cold-formed steel members. Cris, who came to the group with a unique amount of engineering design practice, was ready for high level work from day one – and drove the project and his PhD to completion in record time. Since I commute on train from Washington DC to Baltimore where JHU has its home campus I have a couple of hours a day open for meetings that most people don't take advantage of, but we finished Cris's thesis on the train over a series of

trips – which were one-way for me, but two-way for Cris. Cris made foundational contributions to our understanding of the impact of holes on local, distortional, and global buckling – his work was adopted by the US standard, and he left for a career as an academic in his own right. We did not know then, we were just starting our collaborations. Cris and I would collaborate on several projects while he worked his way through the tenure ranks as a professor at Virginia Tech (on system reliability, cyclic behavior of cold-formed steel members and connections, photogrammetry for buckling tests, and more), and would then collaborate in an engineering consulting venture where I would serve as his number two. Cris even found a life partner in the group, marrying Dr. Deniz Ayhan who was an international visiting PhD student and later postdoctoral researcher working on seismic CFS issues (detailed more below). Cris would be convinced to return to JHU to run our master's program and splits his time with his current consulting firm RunToSolve. I learn from every one of my students, but Cris is my best teacher for making out of the box choices that make you happy and making sure that you are fulfilling your own vision, not that of others for you. His companionship in work, life, and indeed many runs, means a great deal to me.

Yared Shifferaw (PhD 2010) joined the thin-walled structures group a year after Cris Moen, and after completing a BS and MS in Ethiopia. His primary dissertation work was focused on a longstanding limitation in CFS member design – utilization of inelastic reserve in flexure. The classic effective width expressions of von Karman or Winter assumed a maximum capacity equal to first yield – and the exact manner in which inelastic reserve should be considered was unsettled in the US standard. A wide survey of available tests showed that inelastic reserve was common in CFS flexural members. Foundational work by Leroy Gardner for the Continuous Strength Method (CSM) was showing that strain capacity, the key ingredient for understanding inelastic reserve, was indeed a function of local (and presumably distortional) cross-sectional slenderness. Through a series of well executed numerical studies Yared showed that simple expressions, akin to CSM in their own way, could be added to current approaches and provide accurate predictions. Yared went on to work as an assistant professor at Drexel before returning to academia in Ethiopia. Yared was the first of several students from Africa and the middle east that would convince me that regional diversity could be a key and unique strength in a research group – as each nation and region has its own proclivities in training its students – and a creative team can benefit from all of them.

The group's fundamental work on CFS member behavior would continue with Dr. Shahab Torabian in the lead working on DSM for beam-columns and then begin to branch out towards CFS modeling and CFS subsystems (e.g. sheathed walls) and CFS framed buildings. In addition, in 2016 then PhD student Guanbo Bian (PhD 2017) completed a series of work on member torsion – that followed from pilot testing by a previous PhD Student Kara Peterman (PhD 2014), that would help lead towards new CFS torsion provisions.

The most recent PhD student to work directly on CFS member research is Chu Ding who completed his PhD in 2022. Chu completed his MS under Cris Moen at Virginia Tech, then worked in engineering practice before joining the group – and he came with amazing organization, presentation, and self-motivation. Chu was challenged to tackle a project on CFS behavior for Advanced High Strength Steels (AHSS) which included collaborations with Dr. Zhanjie Li (PhD 2011) and professor at SUNY Poly and Dr. Hannah Blum – who completed a BS and MS at JHU before completing her PhD at University of Sydney with Kim Rasmussen – another close

colleague. Chu tackled both experiments and simulations for bolted connections, as well as compression and flexure of AHSS members – and his work included 690, 960, and even 1200MPa sheet steels. Chu’s PhD was a tour de force of work, and papers are still generating from his efforts. High strength sheet steels result in member behavior that remains in the elastic range in far more cases than typical low yield sheet steels. This large amount of deformation in the elastic range creates and increases the chance for unique interactions amongst local, distortional, and global buckling – interactions that require novel extensions to some of the current design methods, including DSM. Today Dr. Ding has been working independently in engineering software development, including collaborating with Cris Moen’s company.

3.3 CFS Members – Modeling

All our group’s work on CFS members includes modeling and experimentation. Several of the PhD students in the group have focused on aspects directly related to modeling. Modeling includes high-throughput elastic stability analysis as well as more research-oriented geometric and material nonlinear shell finite element (FE) models for exploring collapse behavior. During my PhD I realized the power of the finite strip method (FSM) for cold-formed steel members as demonstrated by the work of Professor Greg Hancock and the software BFINST (Buckling Finite Strip). Working from the seminal textbook of Tham and Cheng I created the first version of our group’s elastic buckling software: CUFSM so that I could perform my own parametric work and developments. CUFSM would become the foundation for Dr. Zhanjie Li’s PhD completed in 2011 and for the long-term collaboration on the constrained Finite Strip Method developed by Dr. Sándor Ádány and myself.

Zhanjie’s 2011 PhD greatly extended CUFSM – instead of providing only the single longitudinal term signature curve analysis he expanded the method to general end boundary conditions and therefore series solutions in the longitudinal direction. This led to deeper understanding of the FSM in comparison with FE methods – and the role of end boundary conditions in local, distortional, and global buckling. In addition, based on our work with Dr. Ádány, Zhanjie also extended the constrained finite strip method to cover general end boundary conditions as well. This led to a marked increase in the applicability of our FSM solutions – covering most practical problems. Further, it demonstrated the importance of open-source platforms for researchers and engineering practice as CUFSM was becoming more widely used in both domains. Zhanjie stayed on at JHU for a postdoc and helped me begin to explore my ideas and interests in energy analysis for buildings before taking a position at SUNY Poly. Today we have collaborated on multiple projects since his PhD, most recently on wind energy structures. I am also happy to say that at least once a year I meet Zhanjie at a conference and we go for a run together. While Zhanjie did not run with me too much during his time at JHU, he has become a skilled runner – and now posts marathon times that I can only dream of! He is also a wonderful Dad to his two girls, a new chair of his academic department, and a great colleague and friend.

During my own dissertation (late 1990’s) the power of shell finite element models to predict the strength of cold-formed steel structural members was moving from supercomputers to desktops. In the long term it seemed physics-based models would eventually supplant approximate analytical design formulas. However, before this could happen there was a matter of the sensitivity of these models – they were sensitive to modeling choices, but also to physical reality such as the geometric

imperfections that were inherent in fabricating cold-formed steel shapes. Vahid Zeinoddini's PhD in 2011 and Xi Zhao's subsequent PhD in 2016 were aimed squarely at addressing this issue.

Vahid's PhD began with him traveling about the country measuring CFS imperfections at roll-formers in the US. Even then, it was a brave move to send an Iranian student from airport to airport with a large cardboard tube full of aluminum 80/20 and a Pelican case full of wires and dials to measure imperfections. Somehow, this tour of industrial centers in the US worked out and the result was the first comprehensive statistical record for bow, camber, and twist of CFS members. This provided the first real examination in the open literature of what an engineer could expect for these key imperfections. Vahid then developed a means to incorporate these imperfections into shell finite element models along with imperfections compatible with local and distortional buckling modes. This led to additional reliability studies on imperfections and foundational work to examine modeling sensitivity due to material yielding and geometric initial imperfections. Vahid worked with Cris Moen and I in engineering consulting after his PhD and married a brilliant environmental engineer (and runner) also from JHU: Roshanak Nateghi. Currently he works at Google and Roshanak is an Associate Professor at Georgetown University.

Xi Zhao came to the group with an interest in control and dynamical systems. This was ultimately directed into building and utilizing a unique, automated, experimental platform for measuring initial imperfections of cold-formed steel members for her PhD in 2016. At the heart of the system is a 2D line laser with 200 laser points and a $5\ \mu\text{m}$ (0.0002 in.) accuracy. A cold-formed steel part is placed on a fixed stage and the profiler is swept over the part longitudinally at different scan angles to develop a highly accurate 3D point cloud of a CFS part. This cloud is processed for geometric dimensions, spatial series of imperfections along the length, or for direct interpolation into a finite element mesh. The scanner was used to develop statistics on the full spatial variation of geometric imperfections, to compare against QA/QC limits from product standards, and to complete model-based design loops. Building on this work Xi worked at West Virginia University before moving to Beijing University of Civil Engineering and Architecture where she is now an Associate Professor. She currently lives in Beijing with her husband (a mechanical engineer), and her two children, and leads the international collaboration office at her university.

3.4 Structural Steel Members and Reliability

While the first stage of my career was largely supported by and in collaboration with the American Iron and Steel Institute (AISI) and their interests in cold-formed steel most of my service today, and indeed much of my research, is tied to the American Institute of Steel Construction (AISC) and their work in steel more broadly. This relationship began when I was awarded the Milek Fellowship from AISC which provided the groundwork for Mina Seif's 2010 PhD on cross-section stability of structural steel.

With the growth of higher strength steels and the continued interest in structural steel members under extreme loading (seismic, fire, blast) understanding and predicting local buckling in structural steel remained of interest for AISC and the US structural steel standards. Given that DSM had shown it could provide accurate local buckling predictions for CFS, interest in alternatives and improvements for structural steel were sought. Mina Seif worked on this problem completing his PhD in 2010. He provided the first closed-form (empirical) expressions for local buckling in structural steel shapes that properly included web-flange interaction. He performed

extensive computational studies and identified strengths and weaknesses for current methods in the AISC Specification as well as proposed effective width and DSM solutions. This work led to updates in the AISC Specification for locally slender columns and set the stage for ongoing work to bring together the design methods for cold-formed steel and structural steel. But, Dr. Seif's lessons for me were not just about structural stability and steel design – after working at NIST for several years Mina took an offer to become trained and ordained as a Coptic Orthodox minister and was ordained as the priest of St. George Coptic Orthodox Church of Toledo, OH on June 1st, 2019. He showed how great intellect can be harnessed to provide great public good – and now I enjoy hearing about all the good works he does for his members and the local community. In addition, he maintains his “engineering hobby” and as chair of the SSRC awards committee was the person who informed me of being honored with the Beedle award!

One of my current PhD students, Damir Akchurin, continues the tradition of creating work relevant to AISC. Damir has worked on the reliability implications of ASD vs. LRFD for structural steel which supported ongoing changes in ASCE 7 and is currently working on assessments of the system reliability of structural steel frames for AISC. This work provides a much-needed improvement beyond component-based reliability that is still the center of steel design – and opens new pathways for engineers. Damir came to JHU after studying under Dr. Li at SUNY Poly and has also contributed substantially to CFS work with his master's experiments on CFS solar pile sections in compression – and more recent work on the same section in torsion and flexure. Damir is a remarkably proficient researcher and communicator and a joy to work with, he is on track to become an alumnus of the group soon.

3.5 CFS Framing – Systems

CFS has a rich tradition in metal building systems and rack structures – but the big new growth in CFS initiated in the 2000's and occurred in buildings framed from cold-formed steel members. Initially mimicking timber construction, lipped channel studs and joists with common dimensions were placed into track to frame out walls and floors, and produce complete buildings. After CFS member design began to come into focus in the first 5-10 years of the group's work, attention shifted to the behavior and design of CFS systems, with a decided emphasis on these new CFS framing systems.

In 2006 I hosted a student visitor from Prof. Malite in Brazil – Gustavo Choudrai (Figure 1a). Gustavo was working on CFS battened columns and I traveled to Brazil for his PhD defense. There I met my 7th PhD student: Luiz Vieira (PhD 2011). Luiz was working as an MS student in Brazil studying the behavior of CFS purlins for Professor Malite. After Luiz shared with me his MS research, I offered him a position to study at JHU on the spot – thankfully he took me up on the offer and the next Fall joined the group. Luiz was an incredible student, not only did he implement completely unique tests in a one-of-a-kind homemade testing rig (the BBB), perform novel analysis on CFS framing systems, and develop a completely new paradigm for predicting strength of sheathed members – he elevated the mood, spirit, and engagement of everyone in the group and everyone he interacted with at JHU. Few people have the power to do introverted engineering efforts and play the extroverts role of injecting energy into those around them, but Luiz has this capacity at maximum. Luiz took on anything and everything, including running with me and my ultra-running colleagues. A hobby for him that would grow from 10K to ½ marathon to 50K and beyond. After returning to Brazil he led multi-day quests across portions of the Amazon. I am

happy to say I still run regularly with Luiz. He and his amazing wife Stefanie (also a JHU PhD in environmental engineering!) and children all currently live in Washington DC and now I can see him regularly.

Our work on framing systems continued to grow and was greatly impacted by a visiting doctoral student: Deniz Ayhan. Deniz's doctoral work focused more on CFS members – developing the backbone nonlinear response of CFS members through collapse – provisions that would find their way into ASCE 41. However, she returned for a post-doctoral appointment and completed two amazing projects: (1) on the experimental response of joist-to-ledger-to-wall stud assemblages and (2) initiating the database of CFS shear walls so that we could develop nonlinear modeling parameters for CFS lateral systems in ASCE 41. After that Dr. Ayhan was the technical manager for the Cold-Formed Steel Research Consortium, that I ran with her, for a decade. Somewhere in all that hard work, Dr. Ayhan and Dr. Moen found each other and are currently raising two wonderful children in Baltimore. After working with Deniz for several years on computational projects, one of my fondest memories is working with her in the lab for the ledger framing based joist tests – Deniz taught me that all of us contain multitudes of aptitude and it is a joy to get to work on different types of efforts. I am still proud that I get to see her on a semi-regular basis, and excited to see her brilliant children growing up.

Some people are just smooth and cool – you can't help but think they are going to succeed when you meet them! That was my first impression of David Fratamico – who would finish his PhD in 2017. In CFS framing it is common to need more than one member to carry the load in compression or flexure – so built-up members – where the CFS members are screwed to one another are common, but practicing engineers generally still make very simplified assumptions about the behavior. Given how hard we work to accurately calculate the member strength of our oh so thin CFS members, it seems wasteful to not do the same for CFS built-up members. David's experimental work addressed this issue head on. He provided benchmark tests for the most common CFS built-up members and explicitly showed the limitations of current design rules. David came to the group with real experience in architecture and structural engineering – and he took these talents back to his home in Philadelphia where he leads a research and development team on building facades and enjoys a full life with his family.

It is worth mentioning that I was also involved in an exciting project on CFS framing system reliability around this same time (2013-2016). This project which was led by professors Cris Moen and Sanjay Arwade led to an enormous number of insights on how CFS framing systems behave and their true system level reliability. The US standard AISI S240 even picked up new system factors for floor joists as a result of this work. The project also gave me a chance to work with great students at Virginia Tech and University of Massachusetts-Amherst. Two places where I continue to have significant collaborations, across a variety of technical areas.

3.6 CFS Framing – Seismic

In 1993 when I joined Cornell University as a master's student I was focused on finding a way to do research in earthquake engineering. However, it certainly did not happen during my MS or PhD dissertation work. While at SGH, in 1998, I was involved in the post-Northridge earthquake analysis around structural steel moment connections – but for the most part my ability to win research in earthquake engineering was minimal until 2010 (17 years after I intended graduate

studies in earthquake engineering) when we won the CFS-NEES project from NSF – an effort and direction that would profoundly change my view of CFS framing systems and lead to a whole new branch of learning and ideas on CFS system behavior.

CFS-NEES – which culminated in the first full-scale shake table tests on a CFS-framed building was only possible because of an enormous number of people – the other investigators: Naru Nakata, Steve Buonopane, and Rob Madsen, industry and the U. of Buffalo site - but mostly because of the two amazing PhD students that worked on the project: Kara Peterman (PhD in 2014) and Jiazhen Leng (PhD in 2015). Kara came to Hopkins after her time at Swarthmore and an undergraduate research experience with friends at University of Massachusetts – Amherst. She completed a fascinating M.S. thesis on the combined bending and compression performance of sheathed CFS walls and then agreed to stay for a PhD. Kara led the experimental shake table program including the on-site construction, testing, and deconstruction. Only a handful of people could pull off such a complicated testing program with minimal oversight and support – and most of them are full professors when they do it – not PhD students – Kara is unique. The CFS-NEES effort demonstrated that the seismic performance of CFS-framed buildings is far different than the engineering models used in practice – and the performance is far better than assumed at the time. After a postdoc at Northeastern with Jerry Hajjar, Kara would join UMass-Amherst as a faculty member, find a life partner, bring a brilliant young girl into the world and later receive tenure in her own right. Kara and I share tastes in bad science fiction, mid-century modern furniture and lighting, and the importance of a fantastic bag. She has taught me enormously about how to view engineering from unique perspectives – and watching her continue to grow and lead in the field is an absolute joy.

Jiazhen Leng (2015 PhD) initiated an impossible task at the time for the CFS-NEES effort – make a useful building model with enough fidelity to capture CFS nonlinearities as the building responds during an earthquake. Jiazhen was the first of my students to take on highly detailed modeling in OpenSees – an open-source engine with great capability and great complexity and difficulty. Jiazhen’s work demonstrated specifically that the performance of CFS buildings, and the seismic response modification coefficient, R , that is assigned to CFS framing relies on more than the designated shear walls to justify its response. In addition, the final system response is significantly better than the code assumptions. Jiazhen is a deep and highly analytical thinker – his models broke new ground for CFS, after some stark health challenges during COVID he has decided to dedicate himself to mathematics and is today pursuing additional degrees in pure math.

After CFS-NEES most of my seismic work was focused on steel diaphragms (see Section 3.9); however, Deniz Ayhan completed her cyclic testing on joist-to-ledger connections (see Section 3.5); and Guanbo Bian (PhD 2017) completed a series of simulations on OSB shear walls to assess their reliability. Guanbo’s simulations demonstrated how system variability can be much lower than component variability – and created a vein of thinking that has led to much of the system reliability research of Section 3.4. Guanbo was always multi-faceted in his talents, with a real proclivity for applied math and programming in addition to mechanics, and he would apply those skills into a career at Fannie Mae and now M&T Bank. Guanbo’s wife is a medical doctor at Johns Hopkins, and his lovely family visits us almost annually for a local spring 10K run – a visit I look forward to every year.

Following CFS-NEES was CFS-NEHRI which initiated in 2017. CFS-NHERI has been a massive effort to focus on seismic performance of mid-rise CFS framing and culminated in the summer of 2025 with a full-scale test of a 10-story CFS-framed building. The list of people to thank on this project is too long and is a subject of another talk at this very conference; however, it's critical to mention my partner in the entire effort Professor Tara Hutchinson at UCSD – who's expertise and commitment to large-scale testing made the effort possible. Kara Peterman also joined in on this work – now as a PI in her own right, as well as my colleague at JHU Thomas Gernay – and so many others. Returning to the PhD students: Zhidong Zhang (2023 PhD) partnered with then UCSD student Amanpreet Singh (later Amanpreet would be a postdoc in the group from 2023-2025) on the first phase of CFS-NHERI which included shear wall testing, fastener testing, high fidelity wall line modeling, novel practice-oriented building modeling, and more.

Zhidong's modeling work, based on his own cyclic fastener testing, led to the CFS shear wall detail utilizing HSS chord studs employed in one-direction for the 10-story CFS10 building tested on the shake table. Zhidong's work really teased out further how steel sheet shear walls behave and the interplay between the boundary members and the local stiffness at the sheet-to-stud connectors and then extended this to how wall lines can be modeled in parallel with Amanpreet's wall-line testing. Early in his PhD, right before COVID, Zhidong also was my primary guide for a two-week trip to China that mixed a great deal of CFS collaboration with some family time – as my wife and son came as well. This trip across China created an unusual bond between Zhidong, myself, and my family – as he was the one with all the answers and capabilities, and language, and cultural understanding for several weeks – and it was an experience that helped me better understand the way so many of my and other international students feel when they come to America to study with the group. Zhidong is currently a postdoc in the US, is lucky to have found a brilliant, joyful wife, and is making every effort to stay and work in the states.

Current PhD student Mohammed Eladly started his PhD in the pandemic, taking classes from Johns Hopkins in the middle of the night from Egypt. Once travel was allowed and he was able to join the group in Baltimore his research ramped up. First, working on nonlinear deflection predictions for CFS shear walls, and later becoming the primary modeler in the CFS-NHERI effort. He built a high-fidelity 3D OpenSees model of the CFS10 building – leveraging all that the previous PhD students Jiazhen and Zhidong had learned – to provide critical insights on our full-scale building and test response for both structural and nonstructural systems. Mohammed also found his life partner in Baltimore, and I was honored to represent his family who could not make it from Egypt on the “groom's side” at his wedding. Mohammed is working on completing his dissertation and we chat regularly, including times when he (like Cris Moen before him) ride the train from Baltimore to DC (where I live) with me so that I can provide a dedicated hour to their research. A compromise I greatly appreciate – as he had to get off the train and right back on the same train to return home! I have had the honor of working with many wonderful students, Mohammed's earnest desire to learn more in every situation he is in, is unparalleled and inspiring.

PhD candidate Fidence Rukundo's journey is largely summarized in Section 3.9; however, it is important that he get a mention for CFS-NHERI/CFS10 – as he spent a year at the UCSD shake table supporting the testing – and focusing on the floor diaphragms. That testing was made possible by a wonderful group of UCSD students managed by Tara Hutchinson, including Jiachen (Charlie)

Zhang, Shokrullah Sorosh, Ruipu Ji, Daniel Rivera, Xianzhao Zhang and many other undergraduates and visiting students.

Amanpreet Singh received his PhD from UCSD on CFS-NHERI, then joined my group as a postdoc, with the support of NIST, to focus on the non-structural systems tested within the CFS10 building. This was part of a larger functional recovery effort from NIST colleagues – especially Matthew Speicher, Dustin Cook, and Siamak Sattar. Amanpreet’s wall line tests established the experimental baselines that we would leverage in the CFS10 building, his modeling work provided the first practice-oriented model with enough accuracy to be used in collapse simulations, and his nonstructural components work created new benchmark datasets and demonstrated the excellent performance of CFS framing systems. CFS-NHERI was a 3-year project that took 8 years to complete – after the two PIs no one experienced that journey more intimately than Amanpreet. He has been involved in essentially every meeting and every test - first as a student, later as a postdoc, through the life of the project. Throughout all he has remained preternaturally calm and simply focused on advancing our work, day by day, week by week. He always had new results to share and is an excellent communicator and collaborator. Essentially, within the life of this one project evolving from student to colleague. I have witnessed him calmly work through complex issues in testing, in modeling, even in people – in every case finding solutions that seemed unobtainable at the start and making them natural by the end. I am honored to know Amanpreet and his wife and excited about their next steps as he considers future career options.

Today, the newest PhD student to join the group Chi Luc, is also highly interested in seismic structural engineering and is supporting efforts to revise ASCE41 and help create educational outreach tools to better explain CFS seismic response. Everyone is looking forward to Chi’s journey and his contributions in the coming years.

3.7 CFS Framing – Fire

Fire performance of CFS framing systems has largely been a prescriptive, experimental affair. However, thanks to great research from Mahen Mahendran in Brisbane, and today my colleague professor Thomas Gernay, and others, that is changing a great deal – and engineering and prediction in fire performance-based design is becoming a reality. I am pleased that my PhD student Jean Batista Abreu (PhD 2015) has been able to contribute to that effort. For our team an industry collaboration with USG created the opportunity to study fire behavior – and the work built directly upon our extensive research in the performance of CFS wall systems at ambient temperature. Jean showed how DSM could be extended to uniform and non-uniform elevated temperatures, why CFS walls behaved differently in furnace tests than similar timber walls, and demonstrated how we could predict degradation in the bracing performance of sheathing and sheathing connectors at temperature. These pieces were fundamental building blocks for the new CFS fire standards adopted in the US. Today, I am pleased to continue my work in this area in collaboration with Thomas Gernay and his students. Meanwhile Jean, who was already a great teacher during his PhD, including teaching a summer stint for the Hopkins Center for Talented Youth, is now a successful professor at Elizabethtown College in Pennsylvania.

3.8 Disaster Resilience

In addition to research on seismic and fire – I have had the privilege of collaborating in research more broadly on disaster (and community) resilience. Dr. Judy Mitrani-Reiser, now at NIST,

created an opportunity for me to collaborate with colleagues during her time at Johns Hopkins, one of which resulted in Fardad Haghpanah's PhD in 2020. Working with Fardad always interjected new thoughts into my research – he has a very high aptitude in mathematics and programming and we were able to develop a hierarchy of human building evacuation models that followed everything from fluid mechanics down to state-of-the-art robot navigation algorithms. We even managed to interject a little CFS into Fardad's life – as he led the use of our shear wall database to update consequence-based fragility functions for CFS shear walls. Current PhD students Mohammed Eladly, and Chi Luc, as well as recent postdoctoral student Dr. Amanpreet Singh have all benefitted from and built upon Fardad's work.

3.9 CFS Diaphragms and Floor Systems

In the summer of 2014, I received a call from Bonnie Manley, one of the guiding lights in the steel association world for seismic design. Bonnie challenged me to assemble a group to improve our understanding of building diaphragms used in steel systems – and convert that understanding in near real time into improved design standards for engineers – with that the Steel Diaphragm Innovation Initiative (SDII) was born – an effort that has consumed every Wednesday morning in my life for more than 10 years now. Working with Sam Easterling, Matt Eatherton, Jerry Hajjar and in the early days Cris Moen, and in the later days Onur Avci and Amit Varma and a host of wonderful students – we have been consistently performing research and enabling design engineers in a virtuous cycle across all diaphragm systems utilized in steel structures.

Hamid Foroughi (PhD in 2021) and Astrid Winther Fischer (PhD in 2022) were the two primary students from my group who contributed to the SDII effort (noting that Guanbo Bian (PhD in 2017) also helped at the end of his PhD as the project initiated). Hamid's primary work was on the interaction of the building diaphragm and the seismic force resisting systems (BRBs in his case) in the 3D seismic response of buildings. These incredibly challenging models provided the key validation for new design procedures for concrete-filled steel deck and bare (un-topped) steel roof deck diaphragms that have already been adopted in US standards: ASCE 7, AISC 360 and AISI S400. Hamid's journey was not an easy one – he was unable to go home during the entirety of his PhD due to a travel ban then the COVID pandemic. So, he had to make a new home and extend his family to new friends in Baltimore – we are all so glad he did. Today he works as a research engineer with Nucor, one of our former research partners during his PhD.

Astrid Winther Fischer's research spanned two important topics in seismic response of floor diaphragms. The first was the use of relatively simple models to understand how ductility and overstrength in the walls and floors (vertical and horizontal lateral force resisting systems) interact across a wide variety of parameters. This work provided real systematic insights into the use of separate seismic response coefficients R and R_s for walls and floors respectively. The second work took a fresh look at the way we construct floor diaphragms utilizing topology optimization – and showing novel structural layouts that could lead to improved diaphragm performance even with less material. Astrid is a natural leader and an incredibly caring individual, by the time she was in the last years of her PhD she was facilitating all the student activities in the group. As one of the students that bridged us through COVID, her ability to connect to everyone, including my dog BG (!), was invaluable. Astrid continued with the group as a postdoc helping with our wind turbine support tower efforts and currently works at Exponent in California and is raising twins!

Today our work on diaphragms continues with current PhD students – and has expanded to include innovations in floor systems more generally. PhD candidate Rajshri Chidambaram Muthu Kumar is working on the all-steel long span modular floor system: FastFloor C. This effort is the most direct follow-on from SDII and involves all the same investigators and now partners with AISC, Pankow, and MKA. This structural steel floor system has provided opportunities for Rajshri to explore some unique aspects of local buckling in an intermittently fastened slender plate, and to extend our traditional stability analysis methods into floor vibration analysis. Rajshri has an irrepressible spirit that has carried her through the rough middle trough of any doctoral journey and is now in the home stretch towards producing her dissertation. There is a lot more to say about her work and opportunities in the near future.

PhD candidate Fidence Rukundo already has important contributions on CFS members and in our seismic work with CFS-NHERI and the CFS10 testing. The through line in his work is steel floor systems and diaphragm behavior. He has been instrumental to the development of the FastFloor R system – a novel CFS-based floor system that uses steel deck composite with screw fastened cementitious panels. Like so many of my students, Fidence brings remarkable life experience, and a heart-warming smile and laugh, to the group having already studied in Africa and Turkey – and speaking 6 languages. This experience serves him well, whether he is installing sensors on a 10-story building, or developing a novel analysis model for floor diaphragm response in OpenSees. By the completion of his PhD, Fidence will have the broadest experimental experience of any of my students, and I am excited to see all that he discovers as we continue to develop his work, and this new floor system.

3.10 Metal Buildings

Metal building systems have always been one of the most important application areas for cold-formed steel structures. The first truly involved and critical audience for the Direct Strength Method (DSM) was during a short course I led with metal building engineers to investigate the impact of DSM on roof purlins and wall girts. I have continued to work with the Metal Building Manufacturers Association and particularly their technical director Lee Shoemaker (who retired in 2025 and has now been replaced by JP Cardin) since those days 25 years ago. Cheng Yu's 2005 dissertation was driven by distortional buckling issues in roof purlins. During our work on diaphragms, I was also happy to get to contribute with a small effort on rod-braced diaphragms where Cris Moen, myself, and PhD student Hamid Foroughi performed a series of experiments and developed design criteria for rod-braced diaphragms. My biggest effort with metal building systems has been our work on the seismic performance of metal building moment frames. This work was not the topic of any one student's PhD – but former PhD students and collaborators: Cris Moen, Vahid Meimand Zeinoddini, Brooks Smith, Shahab Torabian and SGH engineers all contributed to this multi-year effort. Earlier this Spring I gave a talk summarizing this seismic effort at the MBMA Researcher Symposium and was honored and touched to receive the Duane Ellifritt award for my long-time work with MBMA.

3.11 Wind Turbine Support Towers

When I joined Johns Hopkins in the summer of 2000 the first class that was assigned for me to teach was undergraduate design of steel structures, I was also assigned as the advisor for that year's freshmen class in civil engineering. That group of undergraduates was amazing and had a huge impact on my teaching and career – none more so than Andy Myers. Professor Andy Myers at

Northeastern University is now a world authority in wind energy and the structural engineering of wind turbine support towers and monopiles. When Andy first joined Northeastern university, he suggested we collaborate on the stability aspects of wind turbine support towers – specifically for a new technology being developed by Eric Smith at Keystone Tower Systems – which used spiral welding to create continuous large diameter tapered tubes. Today, I continue to collaborate with Andy and others in wind energy structures, and this has turned into two PhDs with a third one underway - and it all began in an undergraduate steel design course.

Abdullah Mahmoud was my first PhD in wind energy (completing in 2017) – and we had to learn a lot together. We were the analytical and computational stability side of a large experimental effort to investigate spirally welded tapered tubes. The modeling was new, the geometry and meshing was complicated, the behavior was sensitive to details (as a curved shell that I had not dealt with in my previous cold-formed steel modeling), and no step in our work was straightforward to complete. Abdullah was always calm, never getting too high or too low as we progressed through the work, and before long had developed a comprehensive set of modeling protocols that we continue to use today. Abdullah was lured back to bridge engineering and is having a successful career at Moffatt & Nichol.

Victoria Ding was my second PhD student in wind energy and my most recent PhD graduate (completing in 2024). Again, working with Andy, but this time in a collaboration with Vestas, we sought to improve the ultimate strength methods used by Vestas in certifying towers. This was a deep and fruitful collaboration with engineers inside Vestas – and the platform for learning about real world issues was unique. Previously we had focused most of our structural attention on the base of towers which see large bending moment, and this is indeed important. However, we learned that near the top of the tower, misalignment between the yaw of the nacelle and the thrust from the wind can create significant torsion. So, torsion, bending (and shear), acting at the same time, were a critically important load to be considered. For a thin shell, this is not a well-studied case computationally or experimentally – and the unique combination of torsional shell buckling and shell buckling from flexure creates a highly unusual and sensitive response. This led to new work and insight from the team and a series of unique experiments from Victoria. Victoria understands that in engineering the details matter, and this strength of her personality came into full relief when she tackled her experimental work. Once she donned her pink work gloves, she was meticulous in specimen preparation and execution, and we built an entirely new test rig – including actuator control for her testing. Victoria is also an incredible communicator, and she won awards for her talks and taught her own section of the summer Sustainable Energy Innovation course for high school students.

Today PhD candidate Xi Peng continues our work in wind energy structures. Xi is a dedicated computational developer and analyst. He completed his MS degree with the team on the same Vestas project with Victoria. He has already advised a high school research student in wind energy structures and has had the chance to collaborate with wind researchers at Hopkins, CU-Boulder, PNL, UMass, Northeastern and the offshore wind center ARROW. We continue to be focused on improved methods for ultimate strength prediction and now are putting a great deal of work into the fatigue performance of wind turbine support towers. We both expect great things from his PhD.

3.12 Materials and Steel Foam

In 2010 Professor Sanjay Arwade and I took on a project to look at the use of foamed steel. Steel with intentional porosity has some interesting energy dissipation abilities and potential for EM shielding and other applications – we were actually seeking a light but stiff steel plate for broad applications in buildings. We were lucky to have Dr. Stefan Szyniszewski and then master’s student Brooks Smith work with us on this novel effort. Stefan was incredibly creative and fun to work with and is now a professor in his own right in the UK. Brooks was a brilliant young graduate student, and after stints on the Appalachian trail, working in structural engineering consulting, and software development, is about to start a PhD in Australia. In the end, steel foam basically makes properties that equate to expensive aluminum – but we had a great time figuring that out!

4. Looking Ahead

After 26 years in academia, and 21 PhDs in the group it may seem that there is not much left to be done. Of course, I don’t find this to be the case at all. I am an optimistic optimizer at heart, and I can see a myriad of research pathways that still need our attention in every one of the areas that we have had the pleasure of adding some knowledge towards. Curiosity, a willingness to learn, and a core mission to enable structural engineers will continue to drive our work. At the same time, it is a joy to see the work that the graduates of the group have taken on, and are advancing. Collectively, it is easier for me to see that today there are many of us in structural engineering, who are aligned to perform research to better enable the structural engineers of tomorrow. There is so much more to do, and still a little time left for me to help do it, so - not quite the end.

5. Conclusions

This paper has provided a brief retrospective on the work of the Thin-Walled Structures Group over the past 25 years, organized through the contributions of its PhD students and close collaborators. The technical developments span a wide range of topics in structural stability, including member behavior, system response, modeling, and applications to emerging structural systems. While individual results have contributed to advances in analysis and design, the broader lesson is that progress in this area has been driven by people—by diverse students willing to take on difficult problems with a positive attitude, and collaborators who shared ideas openly, and a community that values both rigor and practicality. The work summarized here is necessarily incomplete, but it reflects a consistent effort to better understand structural behavior and to translate that understanding into tools and approaches useful for engineering practice. Looking ahead, there remain many open questions and opportunities, and the next generation of stability researchers and structural engineers have a wide opportunity to continue to advance the field.

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I have also had the joy of collaborating with several postdoctoral scholars in my group, including Amanpreet Singh, Deniz Ayhan, Shahab Torabian, and Stefan Szyniszewski. Of course, many other wonderful students have made an enormous impact through various collaborations (e.g., Brooks Smith, Yu Xia, and the many outstanding SDII and CFS-NEES students), as well as those working with the team for an MS or BS degree.

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