Structural Stability Research Council

NEWSLETTER

Volume 3, Issue 1 **December 18, 2013**

Welcome from the new SSRC Chair, Ben Schafer

As the new Chair of the Structural Stability Research Council it is my pleasure to welcome you to our Winter newsletter. The extensive activities of all of the SSRC members are a reminder of the continued vibrancy of our little field of study. The research updates in this issue demonstrate the wide variety of efforts underway, and highlight the contributions of our newest student researchers. Every year we come together at the Annual Stability Conference held in conjunction with AISC's North American Steel Construction Conference to learn from one another, meet old friends and the newest student researchers, and celebrate our progress in research to reveal more about the stability of structures and improve their design. This year we will celebrate the work of Professor Sriramulu Vinnakota as the Beedle Award Winner. I invite you to learn more about his accomplishments and his incredible contributions to SSRC on the last page of this newsletter. In addition, I invite you to preview our upcoming conference as detailed herein, and better yet to join us in Toronto on Tuesday March 25th and get involved in the activities of SSRC.

Few people were ever more involved in stability research and SSRC than past Beedle Award winner Professor William McGuire (Bill). As a Cornellian myself there is no way for me to overstate Bill's impact; it had enormous depth and was driven by a vision far ahead of its time. Thanks to former SSRC Chair, Professor Ron Ziemian, for providing his personal and inspiring summary of Bill's life and contributions. I am positive you will enjoy reading it. Ron also deserves thanks for his excellent service as Chair over the last 4 years and for his willingness now to take on the role as Treasurer and formal Liaison to AISC. As most of you now know SSRC headquarters, after over a decade of excellent service at the University of Missouri Science and Technology aided by Professor Roger LaBoube and Ms. Christina Stratman, moved its headquarters to AISC. Hearty thanks are due to Roger and Chris and an equally friendly hello to Dr. Charlie Carter and Ms. Janet Cummins who now assist SSRC at AISC headquarters.

SSRC's activities in research, task groups, the annual conference, and continuing education require volunteer efforts from a large group of people. In particular, I would like to highlight the contributions of Professor Todd Helwig the newly elected Vice Chair of SSRC. Todd's allegiance to SSRC is inspiring and his volunteer efforts touch every part of SSRC's activities - thanks Todd. Your SSRC Executive Committee, along with the Task Group Chairs, is working hard to expand SSRC's efforts and increase our impact - a number of exciting developments are in the works harnessing new collaborations with AISC, and we are striving to increase SSRC's ability to promote stability research more widely. Thank you for the opportunity to serve as your Chair, I hope you enjoy getting caught up on SSRC activities in this newsletter.

-Ben Schafer

Inside this issue:

Professor William "Bill" McGuire Honored

On September 7th at Cornell University, a memorial gathering was held to honor the late Professor Emeritus William "Bill" McGuire, who died earlier this year at age 92. Friends, family, and colleagues, including several members of the SSRC, remembered Bill as a gentleman, an avid reader of nonfiction, and a wonderful conversationalist who invoked history, travel, politics and current news in addition to what he termed his "sea stories," many of which had nothing to do with his distinguished years in the Navy. As a member of the National Academy of Engineering and an Honorary Member of ASCE, Bill's scholarship focused primarily on the design and analysis of steel structures, and included numerous papers, the influential textbooks *Steel Structures* (Prentice-Hall, 1968) and *Matrix Structural Analysis* (Wiley, 2000), and co-authorship of the nonlinear analysis software MASTAN2 (www.mastan2.com). As an active member of SSRC and AISC committees, he always emphasized the need to deliver rather sophisticated topics of structural stability in a form useful to the practicing engineer. At the memorial gathering, several of his colleagues, former students, and family members, including John Abel, Philip Liu, Greg Deierlein, Yeong-Bin Yang, Carlos Pesquera, Ron Ziemian, Bob McGuire (son), and Marketa Elsner (granddaughter), offered recollections and remarks.

Below and on the following pages is the "tribute" that SSRC past-chair Ron Ziemian presented at this event. Before starting, Ron admitted that he could not sing, does not play an instrument, and his poetry skills are rubbish, and thus his "tribute" could only be his wonderful memories of Bill embraced with a title.

My Four Seasons with Professor Bill McGuire

Let's start with **autumn**, specifically the fall of 1984 when as a recent Cornell graduate and a new MENG student, I would have Professor McGuire for the first time in his legendary steel structures course. I recall three distinctive features from his courses, including no hats in class, no sleeping in class, and an education based on developing a true understanding of structural behavior. With respect to the latter, this understanding came through the basics of mechanics, and through the clever use of state-of-the-art structural analysis and design software that several of you in the audience contributed to significantly. It was hard work, but the reward of such an educational process was that we were becoming rather unique structural engineers, who instead of being given fish, we learned how to fish. After five years of hectic undergraduate and graduate level courses, I recall leaving his classes thinking "Wow. I'm starting to learn. I think I might get this". When I reflect on my "relationship" with Professor McGuire at this time, the most obvious words that come to mind are respect, admiration, and fear (of mostly that I'd fail to meet his high expectations).

But speaking of fear… I do remember a specific incident in one of Professor McGuire's lectures when a classmate, who never quite got the message, arrived to lecture late and never removed his plastic baseball hat. You may recall these hats were batting helmets that were a bit of rage to wear on a casual basis in the early 80's (professional baseball player George "Boomer" Scott started the fashion when he wore a batting helmet while fielding at first base). To make matters worse, the student had on a Red Sox helmet and Professor McGuire was a bit of a Yankees fan. And to make matters even worse, the student started to fall asleep. Now, we could see that Professor

"It was hard work, but the reward of such an educational process was that we were becoming rather unique structural engineers, who instead of being given fish, we learned how to fish."

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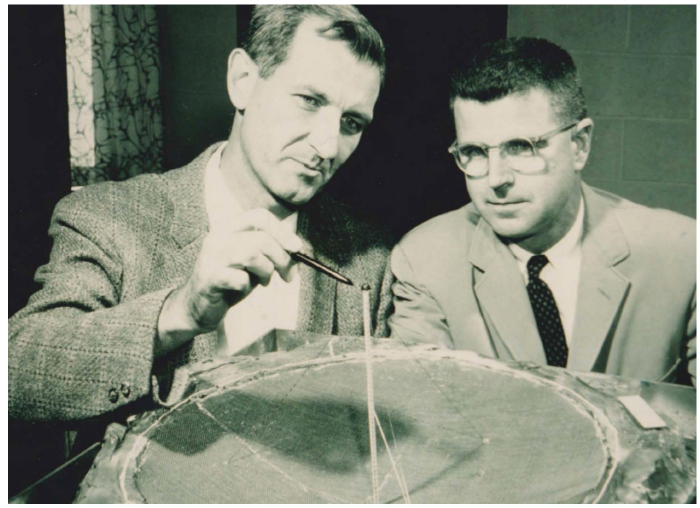
My Four Seasons with Professor Bill McGuire *(continued from page 2)*

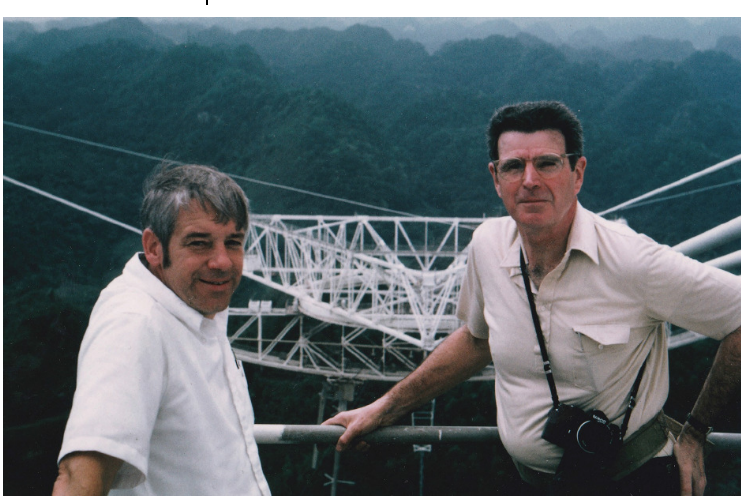
McGuire was distracted by all of this, but he continued to lecture on, until the student's head dropped backwards. I can still hear that helmet ricocheting around the wooden desks and tile floors of our quiet Hollister Hall classroom. But most of all, I can remember being frozen in fear. So frozen in fear, that I don't honestly recall exactly how Professor McGuire quietly, and thoroughly, dealt with the situation. But somehow, we all survived each other in our courses, and I later recognized that this course as one of several taught by Professor McGuire that had a huge impact on steering my interests towards the analysis and design of steel structures.

Moving on to my Ph.D. program brings us to **winter**, specifically the winter of 1987 when my wife Constance and I returned to Cornell after a few years in industry. I recall that particular January as being

"...as with so many things he was simply too many years ahead of his time"

colder and having more snow than any other I had seen before, and I grew up in New Hampshire. But, Professor McGuire was eager to get started and he braved the snow everyday walking from his home on Kelvin Place a few miles away, and he certainly expected me to do the same. I finally got started, sometime in early February, and I can remember often feeling that it was an awesome experience. I was not part of the Rand Hall elite; in fact, I was only one of two or three of Professor McGuire and Abel's computational students who actually worked from Hollister. We embarked on a research project that only recently in 2010 finally became a formal part of the AISC Specification, titled Appendix 1 - *Design by Inelastic Analysis*. I should note that Professor McGuire chaired an AISC committee in the late 80's aimed specifically at this topic, but as with so many things he was simply too many years ahead of his time. Although I knew how accomplished Professor McGuire was, and what an amazing opportunity it was to work with him, I did not yet fully appreciate how respected and well known he was outside of Cornell's campus. And, I certainly wasn't going to get this information from Professor McGuire himself. But, one of the first indicators came after working for a year or so on this topic, when he invited a few of his "AISC friends" to Cornell for me to present my preliminary results to. By then, I had completed my literature survey and to my delight and amazement in walked many of the authors of the books and papers I had been assimilating, including W.F. Chen (Mr. Analysis), Joe Yura (Mr. K-factor), Gerry Haijer (VP-Research-AISC), Reidar Bjorhovde (Mr. Column Curve), Ted Galambos (Mr. Stability), Jerry Iffland (practicing engineering extraordinaire), and the list went on.





My experiences with Professor McGuire over the next four years were life changing. At times, however, it reminded me of those beautiful sparkling winter nights in NH, when as kid I would have to shovel the driveway. Everything going perfectly, making great progress, and just as the

"I learned much from Professor McGuire during those years, especially the importance of being not only technically sound but also the absolute requirements when communicating your results"

driveway was completely shoveled, a giant snow plow would go rumbling past and deposit a road's worth of snow back on my driveway. I learned much from Professor McGuire during those years, especially the importance of being not only technically sound but also the absolute requirements when communicating your results, either through papers or conference presentations, which included the three C's, including correctness, clarity, and most importantly conciseness. When I reflect on my "relationship" with Professor McGuire at this time, I think most of respect, teacher/mentor, and again, fear (now the fear of having to

(continued on page 4)

My Four Seasons with Professor Bill McGuire *(continued from page 3)*

write a thesis that would be acceptable to him, especially given his 1100-page tome *Steel Structures*).

Next up is **spring**, specifically the spring of 1996 when I received one the greatest professional opportunities of my life, an invitation from Professors McGuire and Gallagher to join them in preparing a new edition to their *Matrix Structural Analysis* textbook. What made this most interesting was that Professor McGuire was not interested in simply fixing typos and creating new end-of-chapter problems. No, he wanted to provide a unique book that had several chapters on nonlinear analysis, all to be presented in a form that an MENG student or a practicing engineer could actually comprehend. As we pursued this endeavor, two things happened, first Professor McGuire insisted that I now call him Bill. And secondly, I was to seriously review and constructively criticize his chapters, just as he would do to my chapters. Yikes! I found it fascinating how hard Bill worked to make his chapters concise. By the time we submitted the final draft to our publisher, Bill's chapters were often only ½ to 2/3 of their original length, and he did this without ever reducing technical content. I should also note this draft was submitted on the exact day it was contracted for (Bill's Navy days would not permit otherwise), which was also the same day that I traveled with Bill as he set a land-speed record on the way to the nearby Fed Ex office.

"I found it fascinating how hard Bill worked to make his chapters concise … and he did this without ever reducing technical content"

Another opportunity that came with preparing the textbook was the need for complementary software, an effort that Bill and I partnered in, he finding all the bugs and me programming away to fix them. Bill also showed me the importance of meeting face-to-face with those involved in a project, including meetings in Hoboken, NJ with our publisher and in Natick, MA with the MathWorks staff. In fact, when all of this was completed, Bill's good friend Enrique Martinez Romero (chief structural engineer of one of the tallest buildings in Mexico City) invited Bill and me to a conference in Pueblo, Mexico to overview the book and software. I remember at the end of our presentation, Enrique asked Bill before the audience, how do you do it? How are you always so successful? Who has had the biggest impact on your professional success? Bill, thought for moment and I was waiting to hear about his former professors, colleagues, academic mentors, and/or his parents, but to my absolute surprise Bill honored all of his previous graduate students; it was most inspiring to hear, and impressive because Bill recited at least a dozen names all from memory and without batting an eye. When I reflect on my relationship with Bill during this time, the "fear" is no longer there. I think of how much I enjoyed working with him as a colleague, struggling together to keep the software running on ever-changing operating systems, yet still constantly learning from him.

"I think of how much I enjoyed working with him as a colleague, struggling together … yet still constantly learning from him"

Bill and I would continue to work on some small research projects and prepare papers related to the task of advocating the use of more sophisticated methods of analysis in the design of steel structures. Finally, however, **summer** would come. Bill's technical developments and writing were slowed by health problems; all structural - for his mind remained sharp to the end. It was during these years, that I continued to visit with Bill in Ithaca, and it was at this time that we moved from professional colleagues to good friends. And with this the "sea stories"

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My Four Seasons with Professor Bill McGuire *(continued from page 4)*

came, on every topic and always over some delicious lunch that included Pinot Grigio at his house or the Ithaca Country Club. My best recollections of Bill are hearing all of his memories about his previous students, and his recognition of the wonderful people they had become and his knowledge of their wives and families. Bill also started to loosen up a bit and let me know how very proud he was of his sons, Bob and Tom. I also got to appreciate Bill's subtle sense of humor. In fact, at one point I was telling Bill about a new job opportunity that I might pursue, but

"My best recollections of Bill are hearing all of his memories about his previous students, and his recognition of the wonderful people they had become"

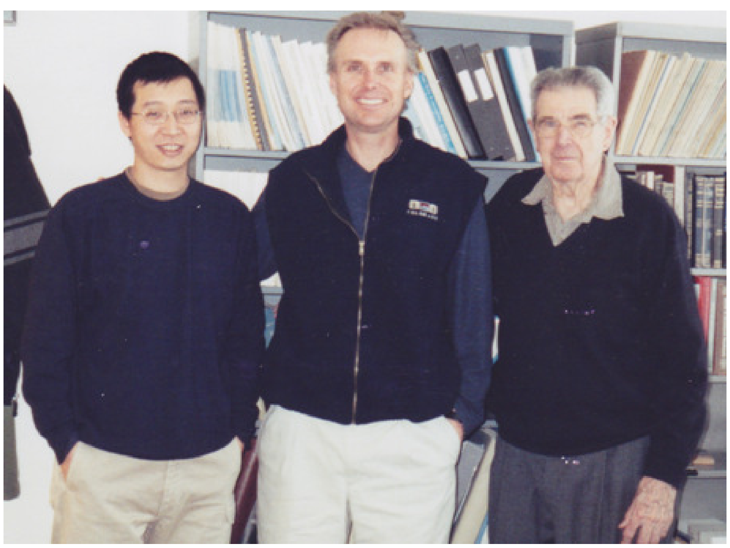
how I was concerned that my resume was no where near long enough, to which Bill smiled and replied, "Just have Don White re-write your CV". For those of you who don't know, Don is a prolific author on steel structures and I think he still holds a Cornell record for the longest PhD dissertation (of which Bill had to review!).

Seriously, in his most recent years, I was also able to share in Bill's passion for reading, especially non-fiction. But, over the summer of 2012, I noticed that he was rereading some fiction, especially several of the classics. In fact, Bill insisted that I join him by reading Hemingway's *A Farewell to Arms*. Having attended a small NH public school, I am embarrassed to admit that I had not read one of these classics, so I decided to give it a read. It was a wonderful book, that is right up to the tragic ending; and boy, did I give Bill hard time for that. His sly response was simply that this is why we stick with non-fiction. I also grew very close to Bill, because I started to realize the many similarities we had; as I child I lived for a few years on Staten Island, only a stones throw from the house where Bill grew up; Bill went to Bucknell where my wife and I have spent our academic careers; during Bill's undergraduate summers, he remained in Lewisburg and worked on the tracks of the local railroad, which has now been converted to the rails-to-trails that my wife and I run on almost every morning; and after graduating with our masters degrees, Bill and I both worked in Boston for power companies, Bill with Jackson & Moreland Engineers designing rigid steel frames and I was at Stone & Webster always designing more simplistic braced frames.

It has been a neat summer and I could go on and tell you stories about when Bill was blindfolded as part of his role as a professional witness, or when he enrolled at age 87 in a driver's education course (to prevent a speeding ticket from causing havoc to his insurance rate) that required spending the day with some of society's most interesting 18 to 20 year olds. Or, the story of how Bill prepared the entire *Steel Structures* textbook over several years, all handwritten

"Bill had a very significant influence on many aspects of my life and for that I am forever grateful."

and with the same pen; only to lose that treasure of a pen a few weeks after the book was complete. But, I think I have already grossly violated Bill's strict requirement for conciseness, so I will end here.



Bill, Ron, and Bai Dong, three generations of graduate students

Bill had a very significant influence on many aspects of my life and for that I am forever grateful. To wrap this up with regard to my theme of four seasons, I would like to return to Hemingway and end with the following quote taken from *A Farwell to Arms*

> *"In September the first cool nights came, then the days were cool and the leaves on the trees in the park began to turn color and we knew the summer was gone."*

-Ron Ziemian

SSRC Continuing Education Endeavors

SSRC has been active over the past year in providing continuing education opportunities. Earlier this past summer, several council members participated in the AISC Night School Program, which consists of 90-minute webinars presented in the evening for eight consecutive weeks. In this event, SSRC teamed up with AISC in offering the program titled "Fundamentals of Stability for Design", which was presented by council members Perry Green, Todd Helwig, Don White, Joe Yura, and Ron Ziemian. The webinars consisted of online presentations that were moderated by AISC's Patrick Newman. Attendees were able to submit immediate questions on the presentations to Patrick, who would then pose the questions to the speaker at opportune points during the lecture. Although time constraints did not allow all of the questions to be answered "live", the speakers did provide answers following the presentations that were then forwarded to the individuals who posed the questions. The effort also included post-webinar quizzes and even a final exam. Based on feedback from AISC and the webinar participants, it appears that this event was win-win-win for SSRC, AISC, and the structural engineering community.

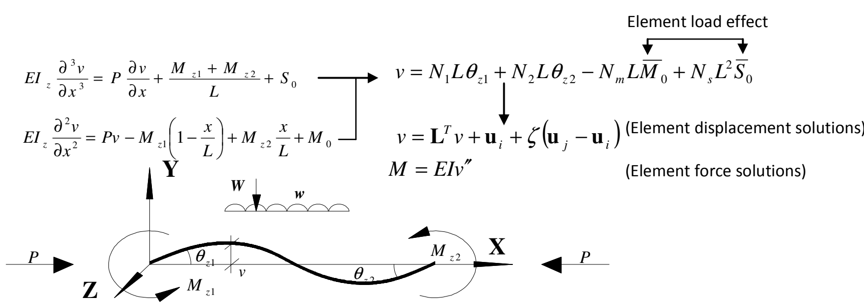
SSRC also regularly participates in continuing education by offering a short course each year at the North American Steel Construction Conference (NASCC). The course "Beam Buckling and Bracing" was presented by Todd Helwig and Joe Yura at the 2013 NASCC in St. Louis. Todd and Joe will present the complement to this lecture, titled "Stability Bracing of Columns and Frames", at the 2014 NASCC in Toronto.

The AISC Night School program and NASCC short courses provide SSRC good exposure to the engineering profession and also generate important revenue for the council. SSRC looks forward to participating in continuing education endeavors in the future, so please be sure to contact SSRC headquarters with any suggestions you might have for future topics related to structural stability.

Ongoing Stability Research

Generalized Element Load Method - First- and Second-Order Elastic Element Displacement and Force Solutions

Jerry Iu, Queensland University of Technology, Australia



Equilibrium of a beam-column element about z-axis

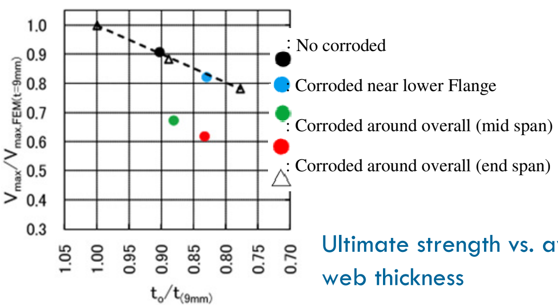
Higher-order element formulation for accurate element solutions under element loads

In numerical modelling, the element loads can be merely converted into the end nodes of an element by either the lumping load or consistent load method commonly, and the equilibrium and compatibility conditions are merely enforced at the nodes of the modelling through the system analysis. As a result, accurate solutions along an element in terms of neither deflection nor internal force distribution are neglected. It means that the reliable structural safety within an element when subjected to external element loads is questionable when using the conventional finite element method; especially for the structural concern using single element per member approach. To facilitate the advanced analysis for reliable and effective structural design, the element load effect should be taken into account at the element level as sophisticated higher-order element formulation as shown in the figure, in which both compatibility and equilibrium are satisfied, instead of at global system alone. Therefore, this research can yield the accurate first- and second-order elastic displacement and force solutions along an element when under element loads. The significant impact of this research is to generalize a great diversity of transverse element loads into a standardized element stiffness formulation by virtue of equivalent element load M_o & S_o as summarized in the figure. The significance of this research is put on shifting the nodal responses (global system analysis) into both nodal and element response (sophisticated element formulation) when using least element(s) for a more reliable design of a whole structure.

Remaining Capacity of Corroded Shear Panel Element

Tetsuya Yabuki, University of Ryukyu, Okinawa, Japan

In order to estimate an appropriate approach for repair work of steel bridges, it is practically necessary to grasp effects of corrosion on remaining capacities of the structural elements. Especially, the capacity of the bridge end panel, which is under most severe corrosion state in steel bridge structure, should be clarified. The capacity of the bridge end panel was examined by loading test. FEM analysis with uniform web thickness was also performed for comparison purpose. The shear panels used for the shear strength tests were sampled from the bridge girder collapsed by corroding in Okinawa, Japan. The sampled shear panel was incorporated to the test specimen beam model as shown in the picture. The interaction between the ultimate shear strength obtained by the loading test and the average value of part-thicknesses of the web panel reducing by corrosion is shown in the lower left figure. The target panels for the tests are no corroded, corroded near lower flange, corroded around overall with most severely around upper horizontal stiffener sampled from mid span and end span of the girder. The examination shows that the ultimate strengths of the web panels corroded specially around upper stiffener, as shown in the lower right figure, are smaller than the others. The effect of severe corrosions occurring around the upper horizontal stiffeners on the ultimate strength might be cleared in the future.



Ultimate strength vs. average web thickness

Test setup

Failure mode of shear panel corroded around upper stiffener

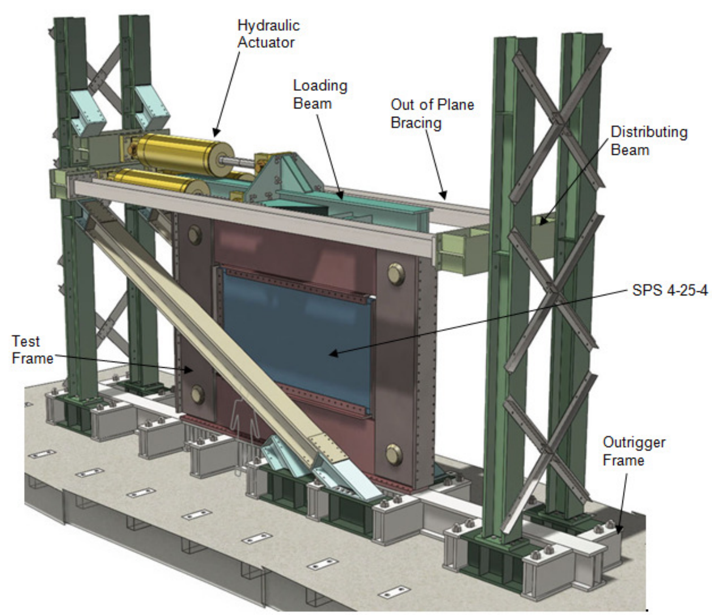
Full Scale In-Plane Shear Testing of SPS

Stephen Kennedy, Intelligent Engineering, Ottawa, Ontario, Canada

Intelligent Engineering (IE) has developed and patented the Sandwich Plate System (SPS), in which two steel plates are bonded to form a sandwich with a compact polyurethane elastomer core. The elastomer provides continuous support to the steel plates and precludes local plate buckling and the need for stiffeners. The flexural stiffness and strength of the sandwich plate is tailored to meet particular static and dynamic structural requirements by selecting appropriate thicknesses for the sandwich elements. SPS plates can be used for modular built up construction of elevator shafts or thin walled shear cores in buildings.

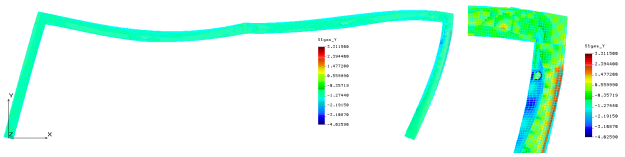
To characterize the shear stiffness and the hysteresis behaviour of SPS, full scale testing of a 2 m x 4 m SPS 4-25-4 panel will be performed at the ATLSS lab at Lehigh University under the direction of Dr. Jim Ricles. A total of four static tests will be conducted where either monotonic or cyclic in-plane shear loading is applied to the long or short edge of the panel. A custom designed steel reaction frame weighing approximately 80 T was required to supplement the strong floor capacity for loads as high as 8800 kN. The plates can reach their full shear yield capacity without developing local buckling. The capacity of an SPS diaphragm system will likely be governed by the bolted fasteners or the drift limits of the structure and not the capacity of the plate.

Test setup



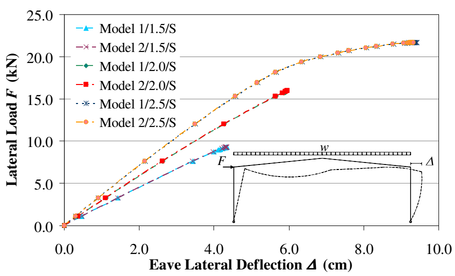
No-Sway and Sway Performance of Portal Frames Composed of Cold-Formed Lipped Channel Sections

Ghada El-Mahdy & Maged Hanna, Structures and Metallic Construction Research Institute, Housing and Building National Research Center (HBRC), Giza, Egypt



Stress distribution and response at failure of Model 1/1.5/S: Overall response of frame (left) and local buckling in column (right)

Load-deflection curves for eave lateral deflection of the sway frames (below)



Cold-formed sections buckle locally and distortionally in combination with overall buckling of the member. When these sections are incorporated into a portal frame structure, this combination of buckling modes affects the overall buckling behaviour of the portal frame. The objective of this research is to study the effect of local and distortional buckling on the overall behaviour of portal frames. The portal frames studied have a span of 10 m and an eave height of 3 m with a roof pitch of 1:10. The frames sections are two lipped channels connected back to back with intermediate connectors. Two frames are studied, the first with one intermediate interconnector at the midpoints of the column and rafter members and the second with two intermediate interconnectors at the third points of the column and rafter members. Three section thicknesses, 1.5 mm, 2.0 mm, and 2.5 mm are studied for each frame to vary the mode of failure of the frame. Both no-sway behaviour due to gravity loads and sway behaviour due to wind and gravity loads are studied. A nonlinear finite element analysis is performed for each frame. The figure at the bottom left represents load-deflection curves, while the top figures show the characteristic failure mode obtained (local buckling). The critical frame section is designed according to the AISI S100. Generally, the interconnector spacing has no significant effect on the ultimate capacity of the frames. In addition, the factor of safety calculated of AISI-100 ranges from 2 to 2.5.

Advancing System Reliability with Application to Light Framed Structures

Aritra Chatterjee & Cris Moen, Virginia Tech; Sanjay Arwade, University of Massachusetts; Ben Schafer, Johns Hopkins University

This project is being coordinated through the Cold-Formed Steel Research Consortium: www.cfsrc.org

Please visit our research blog for information and updates: http://cfs-sysrel.blogspot.com

This National Science Foundation sponsored Grant Opportunities for Academic Liaison with Industry (GOALI) project seeks to accelerate transformation of structural design practice for buildings from one based on the safety and reliability of the individual pieces (components) of a building to one based on the safety and reliability of building's structural systems: roof, walls, and floors. This change in design practice has the potential to lead to both safer and more economically efficient buildings. Buildings framed from cold-formed steel are targeted for initial application. The industry partner, the American Iron and Steel Institute (AISI), is a consortium of the nation's steel producers and spearheads the development of codes and standards for buildings designed from cold-formed steel. AISI will work directly with the academic research team from Virginia Polytechnic and State University, Johns Hopkins University, and the University of Massachusetts – Amherst, to insure that industry is utilizing the latest research findings in system reliability, and to insure the research has maximum impact on the practical design of cold-formed steel buildings. The research combines new analytical models for system reliability, with new frameworks for implementing reliability in building design, along with a series of physical tests on cold-formed steel framed walls, floors, and roof trusses - all specifically design to demonstrate how component and system reliability of buildings interact.

We are currently focusing on cold-formed steel floor systems composed of OSB sheathing, floor joists and screw fasteners. On-going work includes development of finite element models in ABAQUS and tracking failure propagation under lateral seismic loads.

Improved Cross Frame Details

Anthony Battistini, Weihua Wang, Sean Donahue, Todd Helwig, Mike Engelhardt & Karl Frank, The University of Texas at Austin

Testing of a Z-type double angle cross frame

Cross frames are critical to the stability of straight and curved steel bridges. In order to be considered an effective brace, the cross frame must meet both strength and stiffness requirements. Often, the cross frames are fabricated using single angle members to create an X-type or K-type configuration. The research team at Ferguson Structural Engineering Laboratory has been investigating the strength and stiffness of these systems, as well as the performance of Z-type cross frames using double angles or tubular members.

Due to the eccentric connection between the single angle members and the gusset plates, the stiffness of the member is lower than an equivalent concentric connection. The reduction in individual member stiffness can significantly lower the overall torsional stiffness of the brace, in some cases up to 50%. As part of the research, reduction factors were developed for both the X-type and K-type frames. The reduction factors can be easily applied to the available analytical solutions for brace stiffness.

Computational studies indicated that as the value of the eccentricity of the member increases, the reduction in stiffness increases. Full-scale cross frame stiffness tests confirmed this behavior, showing that an X-type brace using unequal leg angles (long legs attached to the gusset plate) can provide higher stiffness than when equal leg angles are used with the same member area.

Finally, finite element analyses are being used to investigate the effect of cross frame stiffness on the member forces induced during construction and from fatigue loading. Results indicate that cross frames with higher stiffness tend to attract more force; therefore, to accurately predict the cross frame forces, it is imperative to properly model the stiffness of the brace during design.

X-type unequal leg angle cross frame specimen after buckling

Seismic Behavior of Plastic Hinges in Deep, Slender Wide-Flange Structural Steel Beam-Column Members

Chia-Ming Uang, University of California at San Diego; John Harris, NIST

Components of the test setup

Research on cyclic behavior of W14 columns under high axial load and seismic drift has been conducted by Newell and Uang (2008)[1]. For Special Moment Frame design, however, designers prefer to use deeper columns to satisfy the story drift requirement. Work is ongoing to investigate the behavior of plastic hinges in deep, slender wide-flange structural steel beam-columns undergoing significant cyclic loading. The University of California, San Diego (UCSD), under contract to Applied Technology Council (ATC), is performing twenty-five full-scale W24 wide-flange section columns subjected to reversed, increasing amplitude axial load and rotational demand for the National Institute of Standards and Technology (NIST).

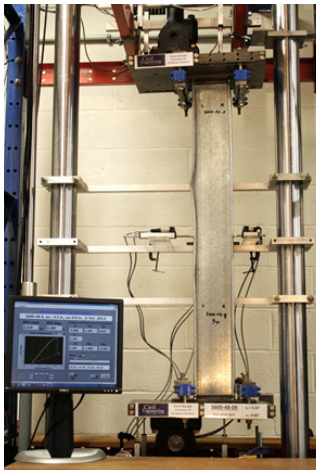
This project is the first work towards accomplishing the goals established in NIST GCR 11-917-13, *Research Plan for the Study of Seismic Behavior and Design of Deep, Slender Wide Flange Structural Steel Beam-Column Members* (NIST 2011)[2]. The experimental tests will address both the inelastic cross section response of deep beam-columns as well as the inelastic response in the presence of both local and overall member buckling. Experimental results will be used by NIST to validate computational models that in turn will be used to broaden the applicability of the experimental findings. Testing initiated this fall and is scheduled to complete next summer.

[1] Newell, J. D. and Uang, C. M. (2008), "Cyclic Behavior of Steel Wide-Flange Columns Subjected to Large Drift," *Journal of Structural Engineering*, Vol. 134, No. 8, pp. 1334-1342, ASCE.

[2] NIST (2011), *Research Plan for the Study of Seismic Behavior and Design of Deep, Slender Wide Flange Structural Steel Beam-Column Members*, NIST GCR 11-917-13. Report, prepared by the NEHRP Consultants Joint Venture for the National Institute of Standards and Technology, Gaithersburg, Maryland. Available online at http`://nehrp-consultants.org/publications/download/nistgcr11-917-13.pdf.

Direct Strength Method (DSM) Prediction of Cold-Formed Steel Beam-Columns

Shahabeddin Torabian, Baofeng Zheng & Ben Schafer, Johns Hopkins University



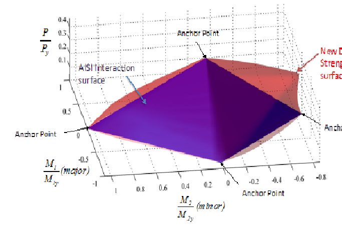
600S137-54 (AISI-S200-12 nomenclature) lipped channel sections (length = 48 in.): eccentricity in major axis= 5.5 in.; in minor axis= 0.0 in.

While the DSM implementation for beam-columns in AISI-S100-12 employs a simple linear interaction equation for strength prediction, a new DSM formulation has been proposed to determine the member stability and strength for the actual applied actions.

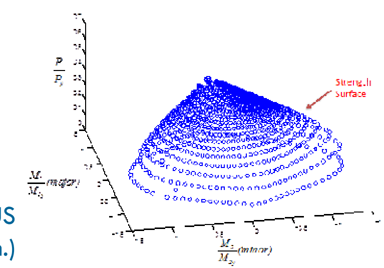
Beam-columns under biaxial moments and axial force have been tested in the Thin-Walled Structures Group at the Johns Hopkins University in order to study the structural strength and stability of cold-formed beam-columns and to validate the newly proposed DSM formulations. The combined axial force and biaxial bending moments are applied via a special test rig designed to apply axial load with eccentricities.

Fifty-three 600S137-54 lipped channel sections at a length of 12, 24, or 48 inches are tested so far and other cross-sections including Zees and Eave Struts are potentials for further testing. The results show a considerable potential for improvement in the current specification approach that utilizes a simple interaction equation.

Shell finite element models including material behavior, residual stresses and strains, and geometric imperfections; as well as, basic member properties including cross-section dimensions, member length, and boundary conditions are validated against the tested specimens and used to explore the results to the other cross-sections.



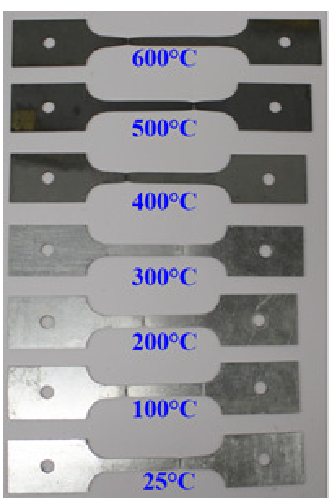
Proposed DSM strength surface vs. AISI linear interaction surface



Strength surface via collapse analyses in ABAQUS (600S137-54 lipped channel sections, length= 12 in.)

Fire Performance of Cold-Formed Steel Thin-Walled Systems

Jean Batista Abreu, Luiz Vieira Jr., Ben Schafer, Johns Hopkins University



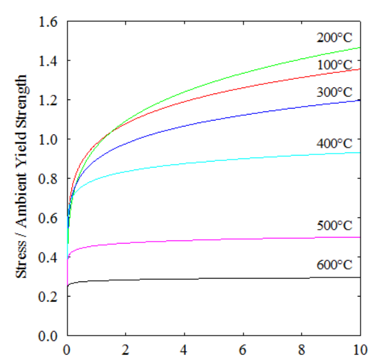
CFS specimens after high-temperature tensile test

Fire resistance of cold-formed steel (CFS) thin-walled systems is currently based on prescriptive design and costly standardized tests. Ongoing efforts seek to advance fire engineering of CFS framed structures, enabling engineers to rationally design complete structures and optimize occupant protection and structural reliability.

As part of the experimental plan, mechanical characterization tests were conducted at temperatures up to 600°C to better understand the behavior of CFS materials at elevated temperatures (left figure). The steady state tensile test method was adopted, at a strain rate of 0.003/min. Prediction equations are been developed to estimate CFS temperature-dependent constitutive relations, and strength retention factors (right figure).

Experimentation will continue at member and subsystem scales, complemented by computational analysis. Compression tests on isolated and sheathed CFS members will be conducted soon, at University of Campinas, in Brazil. The objectives of these tests are to study the fire response of CFS columns and wall assemblies and ultimately enable the vision for fire performance-based design.

Temperature dependent stress-strain relationship for CFS



SSRC Task Group 5 - Thin-Walled Structures

Cris Moen, Virginia Tech

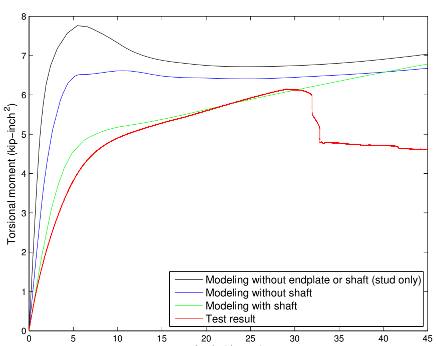
The SSRC Task Group 5 - Thin-Walled Structures recently formed a SPEC team to highlight promising methods in current thin metallic shell design practice and to define a future needs framework from which future research can launch. Thin shell structural members are a staple in many industries – from aerospace, ship building, to offshore oil and gas to residential and commercial buildings. Shell types and geometries are numerous including ship hulls, silos, tanks, pipelines, chimneys and wind turbine towers.

Watch for our paper and presentation at the SSRC Annual Conference in Toronto!

Twists of Cold-Formed Steel

Guanbo Bian, Kara Peterman & Ben Schafer, Johns Hopkins University

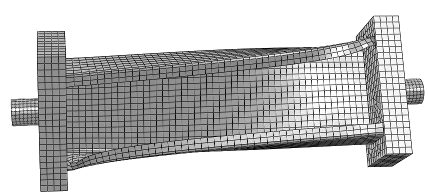
In general, cold-formed steel beams consist of open sections where the centroid and shear center do not coincide. Therefore when the transverse load is applied away from the shear center, torsion occurs. While the theory for elastic torsional response of thin-walled cold-formed steel lipped channel member is well-developed, little exists in terms of experimental benchmarks that test this theory and even less exists for situations beyond the elastic theory, including torsional buckling, torsional yielding, and full plastification in torsion.



Comparison between FE analysis and test results

The Thin-walled Structures Group at Johns Hopkins University currently conducts research addressing this topic. A typical cold-formed steel lipped channel member (upper right figure) is loaded experimentally in direct torsion, which is applied directly to a plate welded to the ends of the lipped channel. Since warping is the primary deformation mode resisting torsion, members with different end conditions are tested. In addition to end fixity, the effect of standard punched holes and member length are also being explored. Based on experimental results, shell finite element models (lower left and right figures) are constructed in ABAQUS® to further explore the effect of end fixity on torsional behavior, as well as torsional yielding, full plastification and torsional buckling for the member. Classical expressions for torsional stiffness and yielding are also compared with the experiments and models. These results will be important for future DSM-based design of the torsional, as well as combined bending and torsional response of cold-formed steel members.

Test specimen under direct torsion



Finite element model in ABAQUS

Initial Imperfections in Cold-Formed Steel Structural Members

Lauren McAnallen, Virginia Tech

In a collaboration between Virginia Tech and Johns Hopkins University, new methods were proposed for measuring, defining, and organizing initial geometric imperfections in cold-formed steel structural members. This collaborative study presents a comparison of measurement methods, a full-field imperfection characterization method, and a communal database format for imperfection measurements. This research is motivated by the need to accurately model geometric imperfections in structural members and to increase the quantity of cold-formed steel imperfection measurements available.

The results will be summarized and presented at the SSRC Conference in March 2014!

CFS-NEES Update: Testing Complete, Data Analysis and Model Calibration Underway

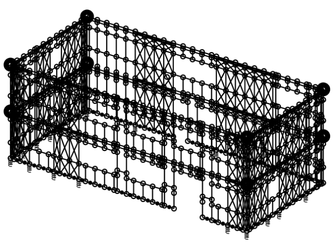
Kara Peterman & Jiazhen Leng, Johns Hopkins University

CFS-NEES buildings on the shake tables at SEESL (a) Phase 1 building, structural system only and (b) Phase 2e building, fully-finished with nonstructural elements and weatherproofing (above)

The Johns Hopkins University project, "NEESR-CR: Enabling the Performance Based Seismic Design of Multi-Story Cold-Formed Steel Structures" or, CFS-NEES, is in its final year. Full-scale shake table testing of two cold-formed steel-framed buildings (upper left figure) took place in the summer of 2013 at the Structural Engineering and Earthquake Simulation Lab (SEESL) at the University at Buffalo. Now complete, the dynamic tests have already revealed insights as to how CFS structural systems resist seismic demands, and the design assumptions and stability behavior that contribute to structural performance. Overall, the finished building (Phase 2e) exceeded expectations under both design basis and maximum considered earthquakes (DBE and MCE).

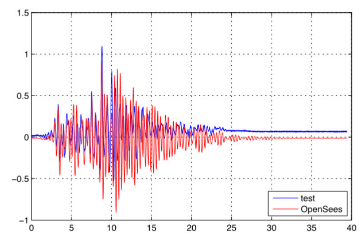
Extensive computational simulations are also underway to capture CFS system seismic behavior. A 3D finite element model (lower left figure) in OpenSees was calibrated according to shake table test result of phase 1 building.

Results of free vibration analysis of the tuned model matches closely with tests. Time history analysis was performed and the deflection of roof corner drift was compared with test output (lower right figure). More structural and nonstructural components, including semi-rigid diaphragms, gravity walls and interior walls will be added subsequently into the model for comparison with other phases of test.



3D model of Phase 1 test building in OpenSees (left)

Corner lateral displacement comparison between simulation and nondestructive seismic test of Phase 1 building (right)



Creep Buckling Behavior of Steel Columns Subjected to Fire

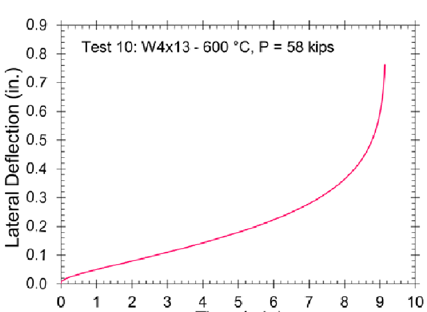
Mohammed Morovat, Michael Engelhardt, Todd Helwig, & Eric Taleff, The University of Texas at Austin

A column specimen after buckling test at 600°C

One of the critical factors affecting the strength of steel columns subjected to fire is the influence of material creep. Under fire conditions, steel columns can exhibit creep buckling, a phenomenon in which the critical buckling load for a column depends not only on slenderness and temperature, but also on duration of applied load.

The objective of this project is, therefore, to better understand and characterize the phenomenon of creep buckling of steel columns at high temperatures due to fire. To meet this objective, analytical solutions using the concept of time-dependent tangent modulus are developed to model creep buckling behavior of steel columns at elevated temperatures. Computational creep buckling analyses are also performed in Abaqus®. As part of the experimental program, material characterization tests have been conducted at temperatures up to 1000 °C to evaluate tensile and creep properties of ASTM A992 steel at elevated temperatures. The creep buckling tests on wide flange columns (W4x13) under pin-end conditions are currently underway to further verify analytical and computational predictions.

The creep buckling phenomenon can be visualized by plotting lateral deflection versus time curves, a sample of which is presented for a creep buckling test under the applied load of 58 kips at 600 °C. As can be seen, the rate of change of deflection with time increases very slowly at the beginning and then increases more rapidly until the column no longer can support its load. The time at which the displacement-time curve becomes nearly vertical represents the failure time.



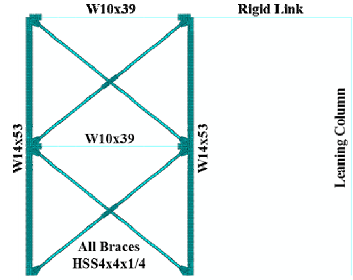
Lateral deflection as a function of time, representing the creep buckling phenomenon at high temperatures (W4x31, 51 in. long)

Three-Dimensional Finite Element Simulation of the Seismic Behavior and Performance of Multi-tier Braced Frames

Christopher Stoakes, University of Iowa & Larry Fahnestock, University of Illinois

Multi-tier braced frames (MTBFs) are used in many types of construction: industrial buildings, performing-arts centers, stadiums, and convention centers. A multi-tier braced frame is created when a braced frame with a large aspect ratio is subdivided into braced tiers with intermediate struts. No out-of-plane bracing is provided at the tier levels. Typically, a wide flange shape with weak axis oriented in the plane of the frame is used for the braced frame columns. During a seismic event, brace inelasticity can result in differential tier drifts that induce weak-axis flexural yielding of the braced frame columns. This inelasticity is not accounted for in current column design specifications.

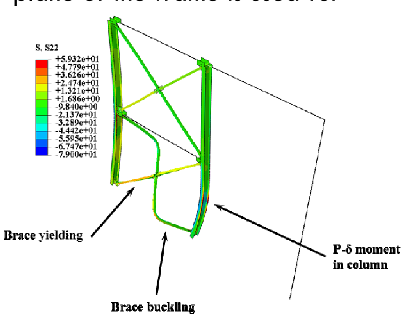
To facilitate development of design guidelines for multi-tier braced frames, their inelastic stability behavior is being explored with three-dimensional finite element analysis. Four multi-tier braced frames with single tier X-bracing were designed as SCBFs according to the 2010 AISC *Seismic Provisions*. The frame heights ranged from 9 m to 24 m, and the number of tiers varied from 2 to 5. The MTBFs were modeled with four-node shell elements in Abaqus® FEA. Whole frames were modeled to accurately simulate torsional deformation of the columns, axial load patterns in the columns, and behavior of the column-strut-brace connections. Static pushover (SPO) analyses were conducted to determine the frame limit states and the axial force and moment demands in the columns. The SPO data will be coupled with the results from nonlinear response history analyses to generate seismic design guidelines for MTBFs.



Two-tier braced frame design and FE mesh

Funding for this research was provided by AISC.

The multi-tier braced frame designs were provided by Robert Tremblay and Ali Imanpour (École Polytechnique).



Two-tier braced frame SPO deformed shape with normal stress contours (ksi)

Cyclic Lateral-Torsional Buckling Behavior of Web-Tapered I-Shaped Members

Chia-Ming Uang, UC San Diego & Matthew Smith, US Army Corps of Engineers

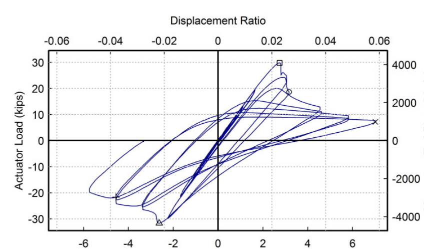
Metal Building Systems comprise a large portion of low-rise steel construction in the U.S. including areas of high seismicity. Typically the frames are composed of web-tapered I-shaped members that are proportioned for economy. Based on shake table testing, it was envisioned that lateral-torsional buckling (LTB) in the rafter may be a potential mechanism of energy dissipation for those types of moment frames.

Ten full-scale web-tapered rafter specimens were subsequently tested to investigate the cyclic post-buckling behavior of LTB. It was found that web-tapered members can undergo several large cycles of LTB without brittle failure. It was observed that LTB lead to flange local buckling (FLB) of the compression flange. In addition, this data provided valuable information concerning the need for higher lateral bracing strengths for cyclic LTB.

The experimentally observed buckling loads were used to validate current design strength equations for LTB from AISC/MBMA Design Guide 25. LTB strength is significantly affected by unbraced segments adjacent to the critical segment. These effects can be included through the use of numerical techniques to estimate the elastic critical buckling strength, along with Design Guide 25, for determining the LTB member strength for all common member geometries, including members with changes in taper and plate thickness, with a high degree of accuracy.

New beam-column finite elements are currently being derived which include member and local buckling behavior. These elements will be incorporated into OpenSees and will be useful for seismic simulations of metal building frames.

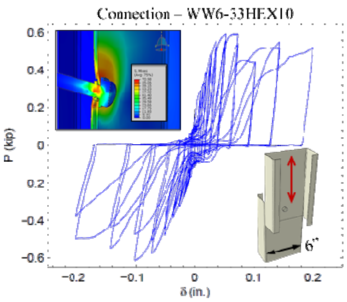
LTB failure



Typical cyclic response

Energy Dissipation of Cold-Formed Steel Framing Members and Connections

David Padilla-Llano, Cris Moen & Matthew Eatherton, Virginia Tech



Single fastener CFS connection response

Computationally efficient and accurate simulation models that can predict the nonlinear cyclic behavior of cold-formed steel (CFS) components and connections are necessary to facilitate performance-based seismic design of CFS buildings. This research program undergoing at Virginia Tech seeks to characterize the cyclic behavior and develop a toolbox of nonlinear hysteretic models for CFS framing members and screw-fastened CFS connections that can be used for seismic analysis and design of cold-formed steel buildings.

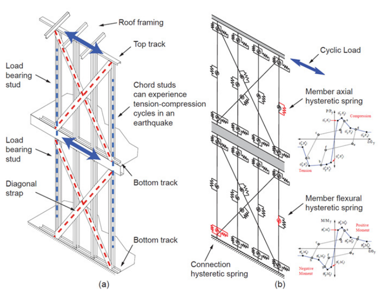
Hysteretic models have been calibrated for thin-walled CFS axial and flexural members susceptible to global, distortional and local buckling. Previous cyclic tests showed that energy dissipation vary depending on the buckling mode, effective/unbraced length and cross-sectional slenderness. The calibrated models capture the energy dissipation, strength and stiffness degradation of observed experimental responses (lower right figure).

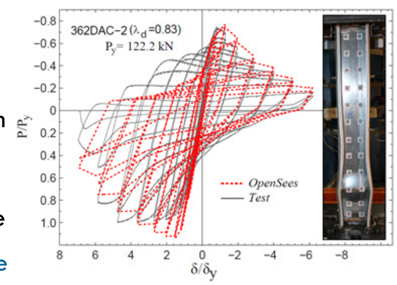
Hysteretic models will be developed for CFS screw-fastened connections. An experimental program is undergoing to investigate the cyclic behavior and energy dissipation of single screw-fastened connections for the tilting, bearing, tilting+bearing, and shear limit states (upper left figure).

The last phase of this research program will pursue the generalization of the calibrated hysteretic models such that the backbone and degradation rules are function of the slenderness and hysteretic energy dissipated in the case members. For connections, the backbone and degradation rules will be generalized as function of the screw, diameter, ply thickness and edge distance.

The hysteretic models toolbox will be used to develop a seismic analysis protocol for CFS shear walls systems and compared to results from full scale CFS sheathed shear walls from the CFS-NEES building (lower left figure).

(a) Cold-formed steel strapped shear wall, and (b) the corresponding phenomenological model





Hysteretic model and response

Calculation-Based Design of Metal Building Wall and Roof Systems

Lucas Cotterell & Cris Moen, Virginia Tech

We will be presenting our method for continuous spans at the 2014 SSRC Stability Conference in Toronto.

To get updates on our current progress, check out our blog:
http://dsmsystemdesign.blogspot.com

In Dr. Cris Moen's research group at Virginia Tech, we've been working to improve prediction methods for calculating the strength of metal building systems. Current empirical methods require extensive testing for validation, and are not able to accommodate changes in variables brought about by adding rigid insulation or a change of fasteners. Looking at roof and wall members with laterally unbraced compression flanges, we have been able to characterize the restraint provided by the sheeting system as translational and rotational distributed springs that are then applied to the cross section for analysis of the components.

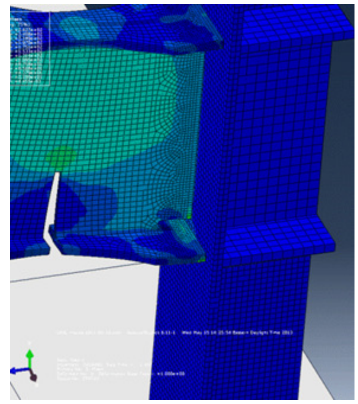
In addition to giving us a reliable mechanics based approach to calculating system capacity, this approach allows us to incorporate the Direct Strength Method (DSM) into system design. We calculate critical global, distortional, and local buckling loads for the components with springs considered and use these values to compute load capacity.

Over the past few years, we have developed and validated this method for through-fastened simple span systems, and for systems with rigid board insulation. We are currently developing methods that work for continuous spans and for standing seam roofs. For the purpose of validating a continuous span prediction method, we have assembled a database of full scale tests of through fastened C- and Z-sections with continuity over multiple spans.

An Integrated Platform for Validated Prediction of Collapse of Structures

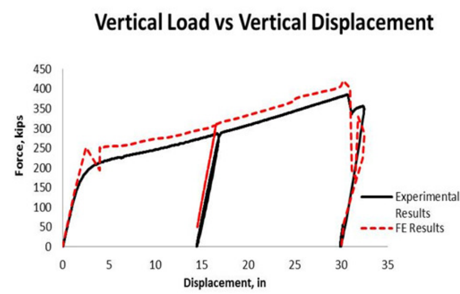
Junho Song & Derya Deniz, University of Illinois; Jerome Hajjer & Vitaliy Saykin, Northeastern University; Tam Nguyen, KTP Consultants Pte Ltd., Singapore

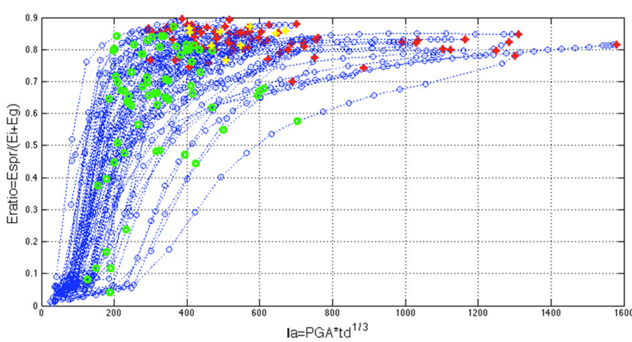
The prediction of collapse of buildings, bridges, industrial facilities, and other large structures has gained growing attention in recent years. The current work entails the development of approaches to modeling collapse of steel structures through micro- and macro - finite element models. The micro-model research incorporates micromechanical fracture models to account for material softening followed by subsequent deletion of finite elements to simulate fracture and disassociation of steel frame components. The macro-model research includes the development of a new beam element suitable for simulating fracture and member disassociation for steel frames based on the use of a bounding surface plasticity model coupled with material softening leading to element deletion. Once the parameters of these models are calibrated to experimental test results of circumferentially notched tensile (CNT) coupon specimens, they are validated through comparison with a broad array of experimental test results of steel structures, ranging in complexity from tensile coupons to moment-resisting beam-to-column connections and complete steel frame structures (figures to right). These proposed approaches are shown to be accurate, and thus enable parametric simulation capabilities of interest to researchers, practitioners, and code developers who address collapse of structures. In addition, the current work includes developing a stochastic framework to identify collapse limit states from dynamic instability along with key parameters that govern collapse capacity through nonlinear dynamic collapse analyses. A new energy-based collapse criterion to identify collapse limit states of frame structures has been developed (lower left figure). Extensive parametric analyses are now being performed to develop a collapse prediction framework for a wide class of frame structures and to identify important performance measures that contribute to accurate prediction of collapse.



Fracture occurs in the FE model in the same location as in the original experiment

Force-displacement comparison with experimental results





Relationship between ground motion intensity and energy-based damage measure (e.g., maximum ratio of strain energy to the sum of input and gravity energy), identified by nonlinear dynamic analysis for 78 strong ground motion records from PEER database. Note: + and o indicate collapse and non-collapse cases; green and yellow represent original scales; blue and red indicate scaled ground motions during incremental dynamic.

Bond Enhancement in Curved Sandwich Shells

Peter Marshall, MHP Systems Engineering, Houston, Texas; Lamar University (Texas); Center for Offshore Research & Engineering, NUS, Singapore

As follow-up to the 2009 SSRC paper by Marshall et al, research on steel-concrete-steel shells for Arctic offshore structures continues at two universities. Normally, the interface bond strength cannot be relied on at all – only contact friction and mechanical interference. National University of Singapore is testing heavy transverse reinforcement which ties the outer steel plates together. Lamar University in Texas is investigating surface treatment with a size-tiered gradation of mini-studs, macro fibers (steel) and micro fibers (synthetic), intended to develop the full bulk properties of the Fiber Reinforced Concrete core in radial tension and beam shear. The steel shell serves as prefabricated permanent formwork, and the arched vaults resist external ice loading mainly by compression, provided the sandwich does not disintegrate in an unstable fashion.

Contact: mhpsyseng@aol.com

2014 Annual Stability Conference Advanced Program
Tuesday, March 25 (annual meeting) through Friday, March 28

Nearly 60 outstanding abstracts were submitted for consideration for the Annual Stability Conference that is part of the North American Steel Construction Conference. Due to time limitations, not all of the abstracts could be accepted for the final program; however the conference planning committee wants to encourage SSRC membership to continue to submit abstracts for the upcoming technical programs.

In addition, there are numerous outstanding opportunities to interact with other SSRC members in the technical program listed in the following pages. In keeping with the format of the recent programs, the task group meetings will be held on Tuesday along with the SSRC Business Meeting and two technical sessions. We strongly encourage all of our members to attend the Tuesday sessions. In addition, please encourage your students that are attending the SSRC/NASCC conference to attend the Tuesday sessions so that they can become familiar with the SSRC Task Groups.

TUESDAY, MARCH 25 - SSRC ANNUAL MEETING

SS1 — Tu 2:00-3:30pm
Technical Presentations: Topics in Structural Stability
Moderator: Todd Helwig, University of Texas, Austin, TX

Analysis and Design of Noncompact and Slender Rectangular and Circular Concrete-Filled Steel Tube (CFT) Beam-Columns

Z. Lai and A. Varma, Purdue University, West Lafayette, IN

Behavior and Stability of Double-Coped Beam-to-Girder Connections under Combined Loading

G. Johnston and R. Driver, University of Alberta, Edmonton, Canada

Experimental Tests on Hot-Rolled Rectangular Hollow Sections

A. Liew and L. Gardner, Imperial College, London, England; N. Boissonnade and J. Nseir, University of Applied Sciences of Western Switzerland, Freiburg, Switzerland

Design and Analysis of Linear Forms for Shaft Sinking

H. Haydl, Cementation Canada, Inc., North Bay, Ontario, Canada

A New Analytical Method for Solving Nonlinear Stability Problems of Framed Structures

Kevin K. F. Wong, National Institute of Standards and Technology, Gaithersburg, MD

SS2 — Tu 3:45-5:15pm
Technical Presentations: Stability of Thin-Walled Members - Part 1
Moderator: Benjamin Schafer, Johns Hopkins University, Baltimore, MD

Analysis and Design of Thin Metallic Shell Structural Members - Current Practice and Future Research Needs

C. D. Moen, Virginia Tech, Blacksburg, VA; H. Foroughi, Isfahan University of Technology, Iran ; A. Myers, Northeastern University, Boston, MA; M. Tootkaboni, University of Massachusetts, Dartmouth, MA; L. C. M. Vieira, Jr., Universidade Estadual de Campinas, Campinas, Sao Paulo, Brazil; B. W. Schafer, Johns Hopkins University, Baltimore, MD

Direct Strength Method for Web Crippling of Cold-Formed Steel C- and Z-Sections Subjected to Two-Flange Loading

M. Y. Choy, X. F. Jia, X. Yuan, J. Zhou and H. S. Wang, Tsinghua University, Beijing, China; C. Yu, University of North Texas, Denton, TX

Optimization of Open Cold-Formed Steel Sections Based on Shape Grammar

J. Moara Santos Franco, E. de Miranda Batista, A. Landesmann, Federal University of Rio de Janiero, Brazil

Cylindrical Shell Buckling Strength According to the “Overall Method” of Eurocode 3 - Background and Applicability to the Design of High Strength Steel Slender Circular Hollow Sections

A. Taras, Graz University of Technology, Austria; N. Boissonnade, Ecole d’ingenieurs et d’architectes de Fribourg, Switzerland

SS3 Tu 5:30-6:15pm — Task Group Meetings (Parallel Breakout Sessions for Task Groups)

TG02 Members: Stability of Steel Members

Chair: Craig Quadrato, United States Military Academy, West Point, NY

TG03 Systems: Stability of Steel Systems (Frames)

Chair: Chris Foley, Marquette University, Milwaukee, WI

SS4 Tu 6:25-7:25pm — Task Group Meetings (Parallel Breakout Sessions for Task Groups)

TG04 Stability of Metal Bridges and Bridge Components

Chair: Dan Linzell, Pennsylvania State University, University Park, PA

TG05 Stability of Thin-Walled Metal STructures

Chair: Cris Moen, Virginia Tech, Blacksburg, VA

TG06 Stability Under Extreme Loads, Seismic, Fire

Chair: Amit Varma, Purdue University, West Lafayette, IN

SS5 Tu 7:30-7:40pm — SSRC Annual Business Meeting

Presentation of the 2014 Vinnakota Award

SS6 Tu 7:40-8:30pm — SSRC Social Hour

WEDNESDAY, MARCH 26 - ANNUAL STABILITY CONFERENCE

S1 W 3:15-4:15pm — Stability Under Fire Conditions - Part 1 (1.0 PDHs)
Moderator: Todd Helwig, University of Texas, Austin, TX

Welcome to the 2014 SSRC Annual Stability Conference

Benjamin Schafer, Johns Hopkins University, Baltimore, MD

Stability of Continuous Steel Column Members at Elevated Temperatures

Corbin St. Aubin, Amit H. Varma, Purdue University, West Lafayette, IN

Cold-Formed Steel Lipped Channel Beams Under Fire Conditions: Distortional Response, Failure and DSM Design

Alexandre Landesmann and Vinício Avelino, Federal University of Rio de Janeiro, Brazil; Dinar Camotim, University of Lisbon, Lisbon, Portugal

Stability and Load-Carrying Capacity of Cold-Formed Steel Compression Members at Elevated Temperatures

J. C. Batista-Abreu and B. W. Schafer, Johns Hopkins University, Baltimore, MD

S2 W 4:30-6:00pm — Stability Bracing (1.5 PDHs)
Moderator: Benjamin Schafer, Johns Hopkins University, Baltimore, MD

Stiffness and Strength of Shear Diaphragms Used for Stability Bracing of Slender Steel Beams

O. Ozgur Egilmez, Andac Akbaba and Mustafa Vardaroglu, Izmir Institute of Technology, Izmir, Turkey

Application of Diaphragm Stiffness and Strength Equations to Bridge Metal Deck Forms

O. Ozgur Egilmez, Izmir Institute of Technology, Izmir, Turkey; Todd Helwig, The University of Texas at Austin, Austin, TX

The Interaction of Stability and Fatigue Related Brace Forces in Cross Frame Members of Steel I-Girder Bridge Systems

Anthony Battistini, Sean Donahue, Weihua Wang, Todd Helwig and Michael Engelhardt, The University of Texas at Austin, Austin, TX; Karl Frank, Hirschfeld Industries, Austin, TX

Lateral Bracing Requirements for H-Section Beams with Supports Attached to Top Flange Subjected to Cyclic Antisymmetric Moment

Ryota Matsui and Toru Takeuchi, Tokyo Institute of Technology, Tokyo, Japan; Yuka Yamaura, Yamashita Sekkei Inc., Japan

THURSDAY, MARCH 27 - ANNUAL STABILITY CONFERENCE

S3 Th 8:00-9:30am	Advances in Analysis and Design for Stability (1.5 PDHs) Moderator: Clarence Miller, Consulting Structural Engineer

Stiffness Reduction Method for the Design of Columns and Beam-Columns

Merih Kucukler, Leroy Gardner and Lorenzo Macorini, Imperial College, London, UK

An Alternative Approach for Prediction of Hollow Structural Shapes Cross-Sectional Resistance: The Overall Interaction Concept

J. Nseir, E. Saloumi, M. Hayeck and N. Boissonnade, University of Applied Sciences of Western Switzerland, Freiburg, Switzerland; A. Taras, Institute for Steel Structures, TU Graz, Austria

Determining Critical Unbraced Lengths in Continuous Girders Subjected to Warping Restraing

Liutenant Colonel Craig Quadrato and Major Kevin Arnett, United States Military Academy, West Point, NY

Experimental and Computational Analysis of Direct Torsion in Cold-Formed Steel Lipped Channel Members

Kara D. Peterman, Guanbo Bian and Benjamin W. Schafer, Johns Hopkins University, Baltimore, MD

S4 Th 10:00-11:30am	Stability of Thin-Walled Members - Part 2 (1.5 PDHs) Moderator: Peter Birkemoe, University of Toronto, Ontario, Canada

Constrained Finite Strip Method Stability Analysis of Thin-Walled Members with Arbitrary Cross-Section

Sandor Adany, Budapest University of Technology and Economics, Budapest, Hungary; Benjamin W. Schafer, Johns Hopkins University, Baltimore, MD

Experiments on Cold-Formed Steel Lipped Channel Beam-Columns

Shahabeddin Torabian, Baofeng Zheng and Benjamin W. Schafer, Johns Hopkins University, Baltimore, MD

On the Relevance of Local-Distortional Interaction Effects in the Behavior and Design of Cold-Formed Steel Columns

André Martins, Pedro Borges Dinis and Dinar Camotim, Technical University of Lisbon, Lisbon, Portugal; Paulo Providência, University of Coimbra, Coimbra, Portugal

A Novel DSM-Based Approach for the Rational Design of Fixed-Ended and Pin-Ended Short-to-Intermediate Angle Columns

Pedro Borges Dinis, Dinar Camotim and Nuno Peres, Technical University of Lisbon, Lisbon, Portugal

S5 Th 1:15-2:15pm	Stability of Joists and Truss Systems (1.0 PDHs) Moderator: Donald White, Georgia Tech University, Atlanta, Georgia

Effective Length K-Factors for Flexural Buckling Strengths of Web Members in Open Web Steel Joists

Ronald D. Ziemian, Bucknell University, Lewisburg, PA; Sugyu Lee, University of Texas-Arlington, Arlington, TX

Analytical Investigation of the Stability and Post-Buckling Behavior of Large-Scale Truss Assemblies used to Support Modular Construction of Long Span Floors

Hunter Brown, Perry Green, Damon Reigles and Jim Ryan, Bechtel Power Corporation, Frederick, MD

Behaviour of LSF Floor Systems with Improved Joist Sections Under Fire Conditions

V. Jatheeshan and M. Mahendran, Queensland University of Technology, Brisbane, Australia

S6 Th 3:00-4:00pm	Studies on Post Buckling Strength (1.0 PDHs) Moderator: Perry Green, Bechtel Power Corporation, Frederick, MD

Influence of the Cross-Section Geometry on the Distortional Post-Buckling Strength of Cold-Formed Steel Columns

Cilmar Basaglia, University of Campinas, Brazil; Alexandre Landesmann, Federal University of Rio de Janeiro, Brazil; Dinar Camotim, Technical University of Lisbon, Lisbon, Portugal

Web Post Buckling Resistance of Longitudinally Stiffened Plate Girders

L. P. Subramanian and D. W. White, Georgia Institute of Technology, Atlanta, GA

Experimental Investigation on Post-Buckling Strength of End-Web Panels Strengthened with CFRP Laminates

Sherif S. Safar and Mohamed N. Abou-Zeid, American University, Cairo, Egypt

S7 Th 4:15-5:15pm	Measurement and Impact of Imperfections on Member Stability (1.0 PDHs) Moderator: Dinar Camotim, Technical University of Lisbon, Lisbon, Portugal

Non-Contact Measurements and Characteristics of Initial Geometry Imperfections in Cold-Formed Steel C-Section Structural Members

Lauren E. McAnallen, David A. Padilla-Llano, Matthew R. Eatherton and Cristopher D. Moen, Virginia Tech, Blacksburg, VA

Effect of Imperfections on the Flexural and Shear Ultimate Strengths of Web-Tapered Plate Girders

Metwally Abu-Hamd, Cairo University, Giza, Egypt; F. F. F. El Dib, Steel Construction Institute, Cairo, Egypt

Imperfection Analysis and Optimized Design of Tapered Spirally-Welded Wind Turbine Towers

Angelina Jay and Andrew T. Myers, Northeastern University, Boston, MA

FRIDAY, MARCH 28 - ANNUAL STABILITY CONFERENCE

S8 F 8:00-9:30am	Stability Under Fire Conditions - Part 2 (1.5 PDHs) Moderator: Leroy Lutz, Computerized Structural Design, Milwaukee, WI

Axial Compression Resistance of Cold-Formed Steel Lipped Channels at Elevated Temperatures

Armando Aguiar de Souza Cruz Neto, Francisco Carlos Rodrigues, Rodrigo Barreto Caldas, Alexandre Acipreste Rodrigues Costa and Possidonio Dantas Almeida Neto, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil

Modeling of Shear and Moment Steel Connections for Structural Fire Analyses

M. Seif, T. McAllister, J. Main and W. Luecke, National Institute of Standards and Technology, Gaithersburg, MD

Effect of Shear on Stability of Girders Under Fire Conditions

M. Z. Naser and V. K. R. Kodur, Michigan State University, East Lansing, MI

Experimental Studies of Cold-Formed Steel Hollow Section Columns at Elevated Temperatures

M. Balarupan and M. Mahendran, Queensland University of Technology, Brisbane, Australia

S9 F 10:00-11:30am	Beedle Presentation Session (1.5 PDHs) Moderator: Benjamin Schafer, Johns Hopkins University, Baltimore, MD

Beedle Presentation: “Inelastic Stability of Steel Members and Frames Using Computers with Vacuum Tubes in the ‘60s to Supercomputers in the ‘90s”

Sriramulu Vinnakota, Marquette University, Milwaukee, WI

A Comparison of Stability Design Requirements

Andrea E. Surovek, South Dakota School of Mines and Technology, Rapid City, SD; Larry Fahnestock, University of Illinois, Urbana-Champaign, IL

S10 F 2:15-3:15pm	Topics in Structural Stability (1.0 PDHs) Moderator: Donald Sherman, University of Wisconsin, Milwaukee, WI

New Proposal for Classification of Steel Flexural Members Based on Member Ductility

Mehdi Shokouhian and Yongjiu Shi, Tsinghua University, Beijing, China

Analysis and Design of Steel Plate Shear Walls with Column Restrainers

Mostafa A. Amer and El-Sayed B. Machaly, Cairo University, Giza Egypt; Sherif S. Safar, American University, Cairo, Egypt

Stability and Service Consideration for Steel Bridge Orthotropic Deck Panels

Mark WanChun Jen, New York, NY; Ben T. Yen, Lehigh University, Bethlehem, PA

S11 F 3:30-4:30pm	Stability of Frames and Systems (1.0 PDHs) Moderator: Ronald Ziemian, Bucknell University, Lewisburg, PA

Stability of Energy Dissipating Steel Fuses in an Innovative Seismic System for Cold-Formed Steel Structures

R. Comini and B. W. Schafer, Johns Hopkins University, Baltimore, MD

Experimental Seismic Response of Full-Scale Cold-Formed Steel Framed Buildings

K. D. Peterman, M. Stehman, N. Nakata and B. Schafer, Johns Hopkins University, Baltimore, MD; M. Pitman, University of Buffalo, Buffalo, NY; S. Buonopane, Bucknell University, Lewisburg, PA; R. Madsen, Devco Co.

Calculation-Based Design of Through-Fastened Metal Building Wall and Roof Systems for Wind

L. S. Cotterell and C. D. Moen, Virginia Tech, Blacksburg, VA

2013 Beedle Award Winner: Professor Sriramulu Vinnakota

Sriramulu Vinnakota, currently Professor Emeritus at Marquette University, Milwaukee, USA received his B.Sc. in Civil Engineering from Andhra University, India in 1957. After graduation he worked with the Central Water and Power Commission, Ministry of Irrigation and Power, New Delhi, India for 5 years on the design of various gate and power house structures. In 1962 he received a Swiss Government Scholarship for higher studies in Switzerland. Vinnakota obtained his D.Sc. in Structural Engineering in 1970 from the Swiss Federal Institute of Technology in Lausanne (EPFL). Subsequently he worked with Prof. J. C. Badoux at the Institute of Steel Construction of EPFL, where he was named *Professor Titulaire* in 1978 by the Swiss Federal Council of Ministers. After spending a year at Cornell University, Ithaca, NY and 2 years at the University of Wisconsin, Milwaukee as Visiting Associate Professor, he accepted a faculty position at Marquette University in 1981. During his stay at Marquette, from 1981 to 2012, Vinnakota concentrated his teaching and research in structural engineering in the areas of steel design, connections, and structural stability.

Professor Vinnakota has made important contributions in the area of stability of steel members and frames through the publication of numerous papers in the professional journals of international reputation.

Dr. Vinnakota is a Life Member of the SSRC and served as Chairman of its Task Group on Beams from 1982 to 2003. Since 1997, he has been a member of the Task Committee 4: Member Design of the AISC Committee on Specifications, and a corresponding member of its Committee on Manuals and Textbooks. In the 1970s he had the privilege of being the Swiss Delegate to the Commission 5 Plasticity of the European Convention for Constructional Steelwork (ECCS); and a member of the ECCS Working-Group 8-1: Stability. He is a Fellow of the American Society of Civil Engineers. Dr. Vinnakota contributed to several chapters of the fourth and fifth editions of the SSRC Guide to Stability Design Criteria for Metal Structures (Edited by Prof. T. V. Galambos). Vinnakota authored a text book: “Steel Structures: Behavior and LRFD” published by McGraw-Hill in 2006 and the book was translated into Spanish.

Vinnakota and his wife, Sreedevi, have two children: Rajiv and Jyothi; and three grandchildren: Annabelle, Heidi Sharada and Flynt Rajiv, with whom he spends most of his retired life.

Professor Vinnakota will give his Beedle Award Presentation: “Inelastic Stability of Steel Members and Frames Using Computers with Vacuum Tubes in the '60s to Supercomputers in the '90s” in the SSRC Track of the Conference, Session S9 on Friday at 10:00 a.m.

Beedle Award Details: The award has been established in honor of the late Lynn S. Beedle, an international authority on stability and the development of code criteria for steel and composite structures. He was a leader and outstanding contributor to the work of the Structural Stability Research Council for a period of more than 50 years, establishing the council as the preeminent organization worldwide in the area of structural stability. Through Lynn Beedle’s dedicated work and leadership in the national and international arenas, the structural engineering profession has seen advanced concepts developed into practical engineering tools. He consistently and successfully endeavored to advance collaboration between researchers, engineers and code writers worldwide. Recipients of the Lynn S. Beedle Award must meet the following criteria:

- Longtime member of SSRC.
- A worldwide leading stability researcher or designer of structures with significant stability issues.
- A leader in fostering cooperation between professionals worldwide.
- Significant contributions to national and international design code development.

The SSRC Executive Committee serves as the award committee. The award may be presented as frequently as annually. An individual can only receive the award once. The award is presented at the SSRC Annual Stability Conference. It consists of a framed certificate, signed by the SSRC Chair and Vice Chair.