A Vision for the Future of Structural Engineering and Structural Engineers: A case for change

A Board of Governors
Task Committee Paper
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PART I - Introduction and Goal

BACKGROUND

The Structural Engineering Institute (SEI) of the American Society of Civil Engineers (ASCE) is a unique and vibrant community of more than 20,000 members. The mission of SEI is to advance and serve the structural engineering profession. To that end, the SEI Board of Governors (the Board) believes that serving the profession includes stewardship of its future—establishing a vision and acting upon that vision to ensure the health and vitality of the profession through carefully selected strategic initiatives.

The path to the future of the structural engineering profession includes defining the vision for the future, understanding the current practices and challenges, and identifying the way forward to bridge the gap.

THE 2008 SEI VISION STATEMENT

In 2008, the Board met and put forth the following strategic vision for the profession 25 years into the future:

In 2033, the Structural Engineering profession will be:

- A unique, fully engaged profession with a strong identity;
- Recognized for the contribution the profession makes to
  - public safety and risk management,
  - economic and sustainable use of resources,
  - the use of innovative technologies, and
  - the creation of inspiring structures;
- Stewards of the built environment; and
- Attractive to the best and brightest.

At that time, the goal was to envision the desired characteristics for the structural engineering profession at large. The stated vision statement represented the long view of 25 years into the future. Three years after it met to establish the above statement, the Board met again to build upon the strategic vision of 2008 and specifically to identify topics and strategic issues that it would like to consider for action.

That effort produced the following four main strategic areas within the broad purview of *The Future Structural Engineer*, which constitute high-priority initiatives for the Board:

(1) Expectations and Role of the Future Structural Engineer

- Strategic Issue: *The tools available to structural engineers are rapidly replacing workforce with automation in many tasks traditionally done by structural engineers. This evolution presents an opportunity, if not a mandate, to transform structural engineering education, training, and practice in ways that will foster an enduring and creative profession.*
- Desired Outcome: Explore and define what the structural engineering profession looks like for the next generation of structural engineers, including the path for education, practical knowledge gain, and technology applications that will and should exist throughout a career.

(2) Structural Engineer Licensing

- Strategic Issue: *Increases in complexity of structural design responsibility, including advances in building codes and standards, design aids and tools such as computer programs, project delivery methods, and construction materials, could undermine the profession's ability to protect the health, safety, and welfare of the public from unqualified and inexperienced professionals designing inadequate structures.*
- Desired Outcomes: Enact legislation for structural engineering licensure requirements in all jurisdictions by creating a plan for working proactively with local engineers, stakeholders, and engineering organizations, and developing resources such as statistical data, white papers, and case studies to support the efforts of local structural engineers.

(3) Continuing Education

- Strategic Issue: *Lack of a governing body and inconsistencies in continuing education offerings and mandatory requirements dilute the benefits of continuing education for practicing structural engineers.*
- Desired Outcome: Outline a comprehensive approach to education after graduation, including expectations for mentoring and formal courses.

(4) International Links and Globalization

- Strategic Issue: *Advances in technology and increasingly interdependent economies have changed the way structural engineers deliver their services; the rate of change is accelerating, and SEI needs to develop a proactive approach to educate, train and accredit structural engineers in this changing global environment.*
- Desired Outcomes: Establish an international and diverse working group to develop a path towards global structural engineering accreditation standards. Develop a series of short white papers on the opportunities and constraints for structural engineering projects in emerging markets, as well as opportunities for American structural engineers pursuing work internationally. Provide leadership for the

development of a strong structural engineering community in Africa.
Maintain/strengthen the SEI/ASCE brand name internationally.

The Board recognized that the strategic areas are interrelated; all of them demanding a clear picture of the qualifications future structural engineers will need to function effectively in a vibrant profession. To investigate those qualifications, the Board appointed a Task Committee to study changes impacting the structural engineering profession, and to provide background and present ideas for change, as well as recommendations for action by the Board.

The members of the *Task Committee on the Qualifications of Future Structural Engineers* (the Task Committee), and the authors of this paper, are as follows:

Stan Caldwell, P.E., Stan R. Caldwell, P.E., SECB
Donald Dusenberry, P.E., Task Committee Chair, Simpson Gumpertz & Heger Inc.
Jennifer Goupil, P.E., Structural Engineering Institute of ASCE
Cherylyn Henry, P.E., T.Y. Lin International Group
Keith Hjelmstad, Ph.D., Arizona State University
John Hooper, S.E., Magnusson Klemencic Associates
Jim Malley, S.E., Degenkolb Engineers

The Task Committee convened its first meeting at the 2012 Structures Congress in Chicago, IL on March 29, 2012. It met in person five additional times and conducted five conference call meetings. In addition, the Task Committee conducted two industry surveys.

The Firm Leader Survey was open to structural engineering firm leaders, and was designed to test hypotheses of some of the current practices and assumptions about the following topics: internships, mentoring/coaching, training, professional registration exams and organization membership, current academic training, post-academic training, and hiring trends, as well as expectations for change in industry in the next 10-30 years.

This was an online survey that the Task Committee developed and deployed to 2,258 members of SEI who self-identified as president, owner, vice-president, director, principal, chief engineer, or similar. Additionally, NCSEA deployed the survey invitation to 7,807 members who self-identified as the above categories as well as project manager, project engineer, and senior structural engineer. In total, 10,065 members were invited to participate and the survey received a total of 352 completed responses, which is a 3.5% response rate.

Our interpretation of the results of this survey is in Appendix A to this paper.

The Design and Construction Leader One-on-One Interviews surveyed design and construction industry leaders from all regions of the United States to obtain their vision of the future of the overall design and construction industry as well as the future of the structural engineering profession.

The Task Committee developed the list of potential interviewees to represent leaders from structural engineering and architecture, as well as owners, developers, contractors, industry representatives, and a municipal building official. In all, the Task Committee interviewed thirty-three individuals over a two-month period. The interviews were generally conducted by telephone after the Task Committee provided the interviewees with a brief summary of the Task Committee's efforts along with a list of interview questions.

Our interpretation of the results of this survey is in Appendix B to this paper.

The Task Committee used its research into trends impacting the profession, interview results, and its own deliberations to develop a picture of qualifications structural engineers of the future will need in order to respond to changes that are happening now and will continue in the future. The Task Committee developed this picture into the recommendations contained herein for action by the Board.

PART II - The Challenges Going Forward

Structural engineering has enjoyed a brilliant and iconic past. Signature bridges, high-rise buildings, and long-span roofs over sports facilities stand as testaments to the work of structural engineers. However, much of the work of structural engineers is hidden by façade or otherwise exists so commonly in our experience that we do not notice it.

As a mature profession, we have been subject to the subtle and not-so-subtle forces that have shaped the nature of the work we do and the work we aspire to do. The profession of structural engineering, like many others, has endured extraordinary challenges in recent years, both within the United States and world-wide. That pressure has served to expose some of the vulnerabilities of the profession and to open a new willingness to imagine the future. Today we see ourselves in a shrinking space because many of the technical tasks that a structural engineer used to do are now being done automatically by computers or completed overseas. We have further limited the space by developing standards and codes that attempt to define the design parameters of upwards of 95% of the structures being built today. Some engineers have developed niche specialties in areas outside the scope of prescriptive standards and codes, such as performance-based design, multi-hazard design, and performance monitoring. They will enjoy bright futures if they are able to maintain cutting-edge skills that continue to be in demand. Other niche specialties will emerge as technology evolves.

Compounding the shrinking space, the educational system has not changed much in the past several decades and, therefore, new graduates entering the profession today are not ideally prepared. Additionally, there is palpable concern that the best and brightest young people are becoming less interested in structural engineering as a career.

As a result of the path taken thus far, the structural engineering profession currently faces many challenges in areas such as education, licensure, technology, globalization, innovation, and leadership. Those challenges are also avenues of great opportunity. The current state in each of these areas is outlined below as a preamble to the discussion of how we may move forward.

Education: Undergraduate education of engineers has evolved under a tension created by an increasing body of knowledge pulling against a steady drive to grant undergraduate degrees in all academic majors within a period of only four years. This evolution has taken place while the profession has become detached from the formal educational process. Nearly two-thirds of senior structural engineers have no knowledge of any academic programs beyond their own personal experience.[1] This disconnect is further exacerbated by the primacy of the research mission at top universities that has distanced the research frontier from mainstream professional practice and has left undergraduate curricula largely unchanged for decades. The

[1] 2013 Firm Leader Survey Summary, Appendix A

drive to reduce degree requirements has been met more with resistance than with innovation; the process of curricular change has been more like chiseling than reinvention.

The accreditation process has been a double-edged sword for engineering, but has seen some major improvements over the past decade through outcomes-based accreditation. ABET has become a driving force for curricular change and is likely the sole reason that any educational breadth, or focus on "soft skills," is present in engineering education today. The relationship between the top engineering research universities and ABET has been strained. Consequently, many curricular changes are implemented through forces or fears associated with losing accreditation and, as such, are often not embraced by the faculty that must implement them.

Structural engineering as an identifiable profession suffers from there being few formal programs at either the undergraduate or graduate level with the name *Structural Engineering*[2]. Structural engineering is traditionally a subset of civil engineering. Many civil engineering graduate programs have identifiable structural engineering focus areas at the master's level. The requisite level of education in structural engineering has long been dictated by market demand. Structural engineering firms with more than 10 employees tend to hire primarily at the master's degree level, although the bachelor's degree continues to be a hiring target for very small firms (fewer than 10 employees) and very large firms (greater than 500 employees)[3].

With all of the factors taken together, there is evidence that the entry level of education for a structural engineer may rest more comfortably in the neighborhood of six years rather than four. Because other areas of engineering are not likely to abandon the notion of a four-year degree to enter the profession, structural engineering has the opportunity to pioneer a professional degree program.

Education of structural engineers in the workplace is limited.[4] Most structural engineering consulting firms do not have internship programs, and those that do focus on recruiting rather than training. Very few firms have formal mentoring programs. While younger engineers clearly want more mentoring, their leaders generally have little interest in providing it. Most firms do offer training, especially in-house training, but this is focused almost entirely on technical skills related to production of the firm's work. Very few firms offer training in soft skills like business, communications, and leadership.

Licensure: Licensure is a mechanism used by many professions to regulate membership and the domain of action of the profession. Licensure is the spur into the legal system that provides a

[2] The University of California at San Diego is the only known ABET-accredited undergraduate structural engineering program in the United States, and the program earned its ABET accreditation using the ABET General Criteria. ABET criteria for a structural engineering program does not currently exist, however an SEI Task Committee is exploring the validity of such criteria at the master's degree level only.

[3] 2013 Firm Leader Survey Summary, Appendix A

[4] ibid

basis for regulation of the industry. Of those who participate in the profession of structural engineering, most are licensed generically as “professional engineers,” rather than as “structural engineers.” Only a few states currently offer structural engineering licensure that restricts the practice or title of structural engineering to those who are qualified. In the remaining states, every licensed professional engineer is generally free to practice structural engineering if they themselves feel that they are competent to do so. In a world where structural engineering is clearly not a part-time profession, this does not protect the public health, safety, and welfare. Even for licensed structural engineers, the requirements for licensure continue to vary significantly from one state to another. Consequently, achieving comity to practice in another state based upon current licensure continues to be much more difficult for structural engineers than for other engineering disciplines.

Technology: Structural engineers have long been leaders in technological solutions to engineering problems. In the 1970s, structural engineers were among the first professionals to adopt computer analysis. In the 1980s, they were among the first to adopt automated design. In the 1990s, they were among the first to transition to computerized drafting and detailing. In the 2000s, they were among the first to embrace building information modeling. Many believe that structural engineers will soon be among the first to enter the brave new world of automated production of construction based on electronic models rather than printed documents.

Technology has opened the door of innovation for structural engineers by enabling modeling and design exploration unheard of in the past. Technology always holds the promise of freeing up the human mind for more lofty thoughts, especially once routine tasks become automated. Structural engineers can and will lead in the implementation and use of automation technologies in the future. However, key areas need attention so that the opportunities of technology are leveraged while recognizing that much traditional structural engineering work will be replaced by automation. First, academic education of structural engineers needs to evolve to better prepare for this future. Students who will leverage technology for analysis must find a different mechanism for mastering the key concepts behind the tools used for analysis. Second, firms need to make sure that business practices (such as cost-plus billing) do not set up technological advancement as impediments to financial success. Finally, structural engineers need to perpetually refine and redefine their value in the light of technology, to participate in its advancement—either as drivers, or creators, or creative users—and to seek a natural equilibrium between human and machine.

Globalization: While American higher education remains the envy of the world, engineers are being educated in increasing numbers in developing nations, especially in China and India. The existence of more engineers means there is more competition. Work that can be done remotely and shipped electronically can be done for a lower price. Globalization did not seem like much of a threat to structural engineers in developed nations a decade ago. Foreign engineers could not reasonably provide local services such as timely design coordination meetings and site visits.

In addition, licensing boards in the United States enforced rigorous “direct supervision” regulations. But the competitive landscape has simply changed worldwide. No amount of regulation will ultimately stem the tide of entrepreneurs offering good service at a low price, nor should it.

To lead in the global marketplace, structural engineers must differentiate themselves from others. The best bet has always been, and will continue to be, innovation. SEI engineers, among them some of the most engaged researchers in the world, can and should lead the way in establishing global standards of practice, including the responsibilities of the “engineer of record.” To do these things we must make a commitment to this purpose. To succeed we must embrace the international challenges that range from differences in engineering and business approaches, to local capabilities and resources, to cultural and linguistic contexts. To impact competitiveness in the global market, SEI engineers must not only lead the way to the most innovative and effective structures, we must also develop and influence international codes and standards related to structural engineering.

Globalization also means more opportunity. As nations emerge economically they bring huge demand for the development of infrastructure. As an example, a century ago Britain’s core infrastructure was largely in place. Lacking adequate domestic opportunities, British structural engineers successfully sought large new projects worldwide; they are still doing so. American structural engineers face a similar situation today: America’s core infrastructure is largely in place. There will always be a need for ongoing repair, replacement, and expansion of existing structures. There will also continue to be many large new projects in the United States. However, there will be more and larger projects abroad. The need for new infrastructure in parts of the world that are undeveloped or underdeveloped will emerge as a major opportunity for structural engineers worldwide. Structural engineers with adequate language and cultural skills, and an understanding of indigenous construction materials and techniques, can look forward to tremendous opportunities in places like Asia, South America, and Africa.

Innovation: Structural engineering is a high-liability profession—a profession where mistakes can result in the loss of life and property. Operating in an environment of high consequence tends to breed conservatism. Further, we have created a prescriptive environment with our many building and bridge codes and standards. Most engineers will elect to operate to the letter of the prescription in such an environment. It is not surprising, then, that structural engineering has become a profession that is very averse to risk.

We must manage this risk better to enter a more creative and innovative future. We must find a way to curb our impulse to put our every technical thought into a code or specification. We must find a way to return engineering judgment to the top of the list of reasons why structural engineers are valuable and why creative people aspire to be structural engineers.

Leadership: A century ago, many structural engineers worked as "master builders." They took responsibility for all aspects of their projects, including planning, design, financing, construction, and maintenance. Eventually, in part due to liability concerns, they began to shed key responsibilities. Project management shifted to architects for buildings and to civil engineers for bridges. Construction planning, scheduling, and execution shifted to contractors. This included the means and methods of construction as well as jobsite safety. Today, architects expect to manage building projects and they expect to be involved in the high-level decision making. The same is generally true for civil engineers with respect to infrastructure projects. By contrast, structural engineers have developed an expectation to serve as specialists who, led by others, produce safe structural designs.

With some notable exceptions, structural engineers do not view themselves as leaders and have not developed the skills and abilities that are characteristic of leadership. There is no route to a future vision of the profession except through embracing leadership as a fundamental obligation. Students need to learn it in school. Firms need to develop and promote it. And all must practice it.

SUMMARY

This synopsis of the challenges the structural engineering profession faces with education, licensure, technology, globalization, innovation, and leadership remind us that these important issues play different roles in professional advancement. Education and licensure provide tools to shape the profession. Technology and globalization represent the ever-changing landscape of the work environment for engineers; they embody challenge and opportunity. Innovation and leadership are the goals.

In many ways our route to the present has put us at a crossroads. Electing to continue on the current path without change is to elect a supporting role in building the future, a shrinking profession ever more bound by prescriptive design environments, and a future where risk management is the province of lawyers, not engineers. No structural engineer wants that future. At the crossroads we also have the opportunity to advance a future built on leadership and innovation. The future will require change. Our task is to find a way to leverage the current conditions to bridge the gap to the future.

PART III - Vision of the Future

After considering our assessment of the current status, the foreseeable evolution of the profession, and the traits desired for successful structural engineers in the future, the Task Committee identified the following features as enhanced abilities to satisfy the vision of structural engineering in 2033 and beyond:

A **unique, fully engaged profession with a strong identity** will be realized when structural engineers:

- Are viewed as an integrating factor in a project rather than a support cast;
- View policy, aesthetics, and finance as important details of the structural engineering task rather than vice versa;
- Are able to articulate the vision of the profession in a way that is understood, embraced, and admired by the public;
- Are renowned for their curiosity and commitment to learning;
- Are considered as the most likely member of any group to take a leadership role; confidence in that leadership is based upon deep understanding of the myriad issues at stake, keen appreciation of the other disciplines involved, and well-developed collaboration skills;
- Are among the first chosen as policy leaders in matters regarding infrastructure and sustainability;
- Cease the practice of using building codes and standards as the primary means to communicate the technical details of the profession;
- Cease to view disciplines such as construction, economics, architecture, and public policy as “other disciplines”;
- Are acknowledged as experts in structures of all shapes, sizes, and scales, in addition to traditional buildings, bridges, and tunnels; and are eager to embrace the next new thing as a structure in need of engineering; and
- Reimagine how structural engineers are educated and successfully execute that new vision. The new image of engineering education is considered bold and enlightened by educators outside of engineering and eagerly imitated by educators inside of engineering.

In order to be **recognized for the contribution the profession makes to public safety and risk management, economic and sustainable use of resources, and the creation of inspiring structures**, structural engineers will need to be able to demonstrate the following:

- Technical competence appropriate to the advancing state of knowledge;
- The ability to productively use innovative technologies from other fields *and* the ability to develop innovative technologies within the province of structural engineering, especially but not exclusively in use of new materials, to advance the capabilities of structural engineering;
- A broad vision of infrastructure and its role in advancing the objectives of civilized society; a willingness and commitment to add value to every professional conversation on projects related to infrastructure development; and
- An ability to not simply adapt to changing design environments, new technologies, and fickle economic forces, but also to leverage those changes in moving toward the future.

As **stewards of the built environment** structural engineers will develop their vision by recognizing the following trends:

- A significant part of future structural engineering work will concern rehabilitation, reuse of existing infrastructure, and sustainability (especially in the U.S. market);
- New markets will be primarily outside the U.S. and new construction opportunities will increasingly be international;
- Growth will occur for specialty niche firms and beyond-code practices; and
- Some portion of the traditional structural engineering portfolio can, should, and will become commoditized.

Accordingly, for the profession to be **attractive to the best and brightest,** the structural engineering profession will need to do the following:

- Play an essential role in the conception, influence, and leadership in daring designs for the built environment of the future;
- Embrace and articulate a passion to address the world's key infrastructure and environmental challenges with particular emphasis on sustainability;
- Rely on a demonstrated broad set of interests and abilities requisite to carry out the work of structural engineering;
- Become globally competitive and collaborative by fully embracing multiple languages and cultures:
- Lead the development, implementation, and use of new technologies in solving problems old and new;

- Establish a readily identifiable professional development mechanism that seamlessly progresses from formal education to professional employment to leadership, and includes authentic mentoring at all levels, including added value through sharing of experience (such as with other technologies); and
- Demonstrate that structural engineers are motivated by a sincere drive to develop creative and innovative solutions to both traditional and non-traditional problems.

These attributes will lead the structural engineering profession to a successful future.

A SUCCESSFUL VISION REALIZED

When we define the vision and identify the strategic issues as well as the characteristics we seek for success—relative to the profession as a whole, to individuals, and to structural engineering firms—how will we know we have arrived?

When the vision is realized, the following will be true of the profession:

- Structural engineering is among the top choices of educational pursuit for the best and brightest of the next generation.
- Structural engineering is known as a professional (post-baccalaureate) degree that serves as an aspirational goal of many undergraduate majors.
- Other professions routinely seek to hire structural engineering graduates because they combine the extraordinary problem-solving abilities of engineers with the broad knowledge and appreciation of issues that face the world.
- Earning a structural engineering license is viewed as a major achievement and aspirants would willingly rise to the challenge to earn the distinction.
- High-level, critical project meetings with key decision makers will not start until the structural engineer has arrived because no one would imagine making a decision without this voice.
- Books are written and movies are made about structural engineers or structural engineering. Structural engineers show up on annual lists of “people who made an impact.”

This assessment of the state of affairs, when viewed through the lens of the SEI Vision, leads us to conclude that the strategic issues identified for the purposes of addressing the qualifications of future structural engineers are as follows:

(1) Education

- Strategic Issue: *The traditional models for educating structural engineers are obsolete. The pressure to decrease time to graduation coupled with the tether to professional outcomes is no longer able to prepare the next generations of structural engineers.*

- Desired Outcomes: Revolutionize how structural engineers are formally educated and then naturalize the mechanism for academia and practice to interact and to embody innovation and leadership in both education and practice.

(2) Technology

- Strategic Issue: *The increased rate of development and advancement of technology has surpassed the profession's ability to leverage it. Teaching methods have been slow to evolve to adequately meet the needs of a profession in which computations are routinely done with advanced software.*

- Desired Outcomes: Fully leverage the computational ability of technology and develop new learning methodologies that glean wisdom and experience from its use. Drive the technology changes needed to creatively advance structural engineering.

(3) Globalization

- Strategic Issue: *Increases in competition for structural engineering services coming from outside the U.S. have challenged the way that structural engineers deliver services.*

- Desired Outcomes: Create a demand for expertise in the world market by honing a new capability to serve different cultures. Be the global leader in structural engineering.

(4) Innovation

- Strategic Issue: *The development of and reliance on codes and standards that govern structural engineering designs, as well as, the practice of risk management have stymied innovation within our profession. This, coupled with absence of training on how to be innovative, has stifled the development of new or existing building materials or advancement of structural engineering in non-civil structures.*

- Desired Outcomes: Bold leadership will drive innovation in performance based design approaches and push the advancement of new materials and markets.

(5) Leadership

- Strategic Issue: *The current muted respect within the project team as well as lack of a public identity limits the potential for increased influence of the structural engineer to impact individual projects and society.*

- Desired Outcomes: Project stakeholders will seek input from the structural engineer for critical decisions on technical and business matters and the structural engineer will be viewed by society as essential for the welfare of the public.

Engineers always have had strong technical abilities. This is not likely to change. However, our research suggests that the principal qualities that the profession needs to reinforce going forward can be summarized in two words: innovation and leadership. Without creating new opportunities to express our skills, and without taking charge of our future, the structural engineering profession will fall victim to outside forces and be marginalized. The ability for the structural engineering profession to address these strategic issues will define how the profession will look and function in the future.

PART IV - Bridging the Gap

To get to a future where structural engineers are leaders and innovators we will need to move forward with a purposeful and strategic effort. While people have different views of the future of the profession, we tend to agree that structural engineers of the future will not be engaged in the same technical tasks that they have been in the past. Some see the future as advancing the technical aspect by declaring the common work, perhaps 95% of the projects we have done up to this point, to be the work of technicians or automation, leaving the truly unusual structural engineering tasks, perhaps the remaining 5%, as the definition of structural engineering. In this view, structural engineers will need to be very technically able—more than is common today. Others see the future through the lens of "master builder" where the structural engineer of the future will require more organizational and management abilities. In both futures there is general agreement that the structural engineer should lead in more circumstances than generally happens today and that the work that occupies the structural engineer should be more innovative. The question is "How do we get there from here?"

SKILLS AND ABILITIES NEEDED TO INNOVATE AND LEAD

It is rare to voice a view of the future without hearing an echo from the past. And yet the circumstances change and with them the motives, drives, and needs. So it is with the skills and abilities that will be required by structural engineers in the future. A consensus is emerging that within the broad context of what has long been valued or sought from engineers, we must shift the emphasis to strike a new balance of technical skills and soft skills to develop engineers with broad professional ability and broad professional commitment driven, above all, by curiosity and creativity. What needs to change?

Technical Skills: The one constant of engineering over time is the expectation of strong technical skills. That will continue to be true in the future, but the professional environment, the capabilities of computers, as well as other influences, suggest that we must constantly update our expectations on technical skill. Whereas in the past technical skill implied an ability to calculate something by hand, in the future technical skill will almost always involve the interpretation of a computation done by a computer. Our ability to process large amounts of information is not merely a speedup of the old hand calculations but rather a new paradigm for fundamental thinking about engineered systems.

Engineers of the future will be better served by a firm grasp of conceptual engineering fundamentals than they will by recalling detailed factual knowledge (such as that which is buried in design standards and specifications). We will redefine technical skill and we will reimagine how we teach new engineers those skills. At present we are caught in transition—the computational tools are available and advancing, but most education has not evolved to a productive pedagogy centered on those tools. We will advance on this issue not by mourning

the limited ability of new engineers to think in the mold of the past generation, but rather by embracing a new kind of engineer who is trained to draw insight from the modern tools of the trade.

The current education process is not being leveraged against current tools to provide opportunity for "intuition" to develop among young structural engineers. We move forward not by trying to recapture the methods of the past, but by reconsidering what we mean by "intuition" and recasting the result in the context of current tools.

Technical ability today is defined more by a body of knowledge than it is an ability to create. Structural engineers of the future will bend their technical skill toward innovation; they will develop substantially different frameworks for developing intuition about structural systems; and they will make engineering judgments on a considerably different input stream. The education of engineers capable of bridging this gap must focus on discovery, validation, exploration, and conceptual design rather than the small deterministic tasks that are the staples today. Even for those technical topics that do not change, we must reform our pedagogy to acknowledge the vast knowledge of how people learn so that we can develop deep competence in foundational ideas.

Soft skills: For many years the profession has said that too many engineers lack a fully-developed set of skills outside of the technical domain. People have often tied this over-focus on technical skill, and associated paucity of soft skills, as a key reason that structural engineers often do not get a seat at the big table.[5]

The structural engineering profession of the future must welcome those who possess robust soft skills and seek to improve the soft skills of those who do not come by those skills naturally. These skills include the traditional communications abilities—including speaking, writing, and presentation skills—along with a full complement of the modern soft skills related to a high emotional intelligence quotient—such as an engaging personality, flexibility, adaptability, self-direction and self-control, and perseverance.

As software used by our profession increases the automation of our work, it is likely that structural engineers relatively new to the profession will be directing a staff of technicians running that software. To be effective in this role, structural engineers will need to develop management skills much earlier in their careers than they do now.

[5] The term "big table" broadly refers to the place where high-level decisions are made on projects. The failure to be at the big table, then, suggests more of a service role for structural engineers—structural engineers are told what to do and will get it done.

Getting to a profession with enhanced soft skills[6] may be a heavy lift, but it is essential. We must first recognize that natural selection through a lens focused exclusively on math and science ability has given us what we have today. What we seek cannot be satisfied through better training of this traditional input stream. We must change the input to include more individuals who possess strength in these other areas and allow those individuals to have an influence on others through appropriate success.

In a nutshell, this is the diversity problem that has limited the engineering profession from successfully moving to a better place. First, we must realize the need for diverse abilities in our profession. Second, we need to honestly embrace a solution that includes people who might list math and science second or third on their list of passions. Third, we need to adjust the educational system ("look to the right; look to the left…") to assure that these newcomers are not immediately eliminated from the pipeline through a sense of unwelcome or a sense of boredom with what we do. Finally, we need to adjust the mindset of the workplace to embrace a more diverse workforce. Our focus should start with reforms of the educational system because if these new souls do not show up in the pipeline they will never show up in the firm.

Broad professional ability: We generally acknowledge the need for broad professional ability in the next generation of structural engineers, but that means different things to different people—from a few things one might learn in business school to a true liberal arts education. The engineers that have these skills will be equipped to interact with everyone associated with a project. They will have knowledge of constructability, cost estimation, finance, public policy, and law. They will know the language of the contractor as well as the language of the lawyers and politicians. They will have broad knowledge of other cultures, other political systems, and they will speak multiple languages.

The structural engineer of the future will be equipped and eager to take the lead on project teams. Structural engineers will be groomed from early in their formal education to take on leadership roles. They will be taught, they will be encouraged, and they will be expected to lead.

Those who demonstrate these attributes today are self-ignited to get there. In the future we must teach these skills—we know it is possible because it is done routinely outside of engineering schools. This training may come at the expense of technical training—a compromise that engineers have been loath to make from time immemorial. Rather than calcify the debate over the divisions of an already small pie, we must liberate the curriculum, possibly through a revolution of the educational model, as discussed in the next section.

[6] Let us distinguish between a profession with enhanced soft skills and an individual with enhanced soft skills. There is no need to have every member of the profession able to achieve a higher ability level of soft skills. There will not be enough opportunity to justify that. On the other hand, we need some and we need a lot more than we currently have.

Creativity and curiosity: Young engineers need more encouragement to be creative and better training to help them get there. Respected educationalist Kenneth Robinson has said, "Creativity is more important than literacy in education today."[7] Albert Einstein once said, "Imagination is more important than knowledge." Today knowledge can be captured by the computer and reproduced and transmitted at light speed. We all carry a device in our pockets that can find information any time and almost anywhere, instantly, and have the computational power of the largest computers available to engineers a generation ago. Ironically, in the knowledge economy knowing facts is not an advantage; however, the ability to synthesize known facts is powerful.

In the past we placed an extraordinary emphasis on problems with exact and unique answers some of which have complex and sophisticated paths to get there. Engineers need this skill, but they need much more than this skill. It is not an all or nothing proposition, but rather a question of balance. It is also a significant question of whether current engineering faculties are even equipped to teach outside of the current canon.

Structural engineering has operated almost exclusively at the knowledge end of the spectrum. To thrive we must move to the creative end. The future structural engineer will be driven by curiosity and by a desire to learn new things; he will be impervious to disciplinary boundaries; she will think of her role as creating. The future structural engineer will learn in environments that promote creativity and will practice creatively.

BOLD NEW MECHANISMS FOR CHANGE

Our universities hold the key to changing the profession because the profession will never be better than the people that are flowing into it and all of those people get there through the university. But universities do not hold the only key. The practice owns the power to veto any change promoted by the universities or to encourage or discourage any person the university allows to get through. The only route to change the profession lies in collaboration between the educational sector and the practice sector.

Out beyond the details, the singular good ideas, and pet peeves, there has emerged the notion that the future of structural engineering is about two basic things: Innovation and leadership. Further, it is evident that our recommendations could be organized in two natural strands: (1) Innovation and leadership in structural engineering practice and (2) education for innovation and leadership needed to support the new vision.

We need bold new mechanisms to get to the future vision. The following paragraphs describe some mechanisms and some ideas that might help us to make tangible progress toward the future.

[7] *Out of our Minds: Learning to be creative*, Kenneth Robinson, 2001

INNOVATION AND LEADERSHIP IN STRUCTURAL ENGINEERING PRACTICE

We want a profession for the future built to innovate and lead. The profession is the sum total of what we, as the participants in that profession, actually do. As we explored the current state of the profession and the forces that are bearing down on it, we realized that our past has been a journey that has limited opportunity for innovation and leadership in many ways—from creating design standards and specifications that have discouraged creativity to the educational pipeline that is set up to select people at the purely technical end of the spectrum. To create a vibrant future we must act to change the current mechanisms. The future of the profession must be framed around a new set of propositions.

The opportunities for change in practice come from a variety of sources; some are listed below.

Promote performance based design. The drive to develop codes and specifications has led to the outcome that many of the tasks previously done by structural engineers could be and have been automated. Adding "code checks" to structural analysis software was a natural evolution. In the future we must curb our tendency to codify our design decisions and leave those decisions in the province of qualified structural engineers. If we mandate how a structure must perform, but leave freedom to how the engineer provides that performance, we open the possibilities for amazing solutions to presently unsolvable problems.

One avenue for change that has emerged in recent years is the notion of performance-based design. This design philosophy invites fundamental thought about structural performance that returns advanced computation technology to the structural engineer as a tool rather than as a faster and more accurate replacement. Refocusing the profession on performance-based design would increase the importance of sound engineering judgment in the design process, rely on better technical knowledge, require the use of more sophisticated technology in problem solving, result in more efficient structures, and place the structural engineer in a better position to drive technological change.

ASCE 7 seems to be moving in this direction. The 2010 edition now provides for determination of loads following performance-based procedures[8]. The trend in ASCE 7 is likely to continue and expand, and should extend to other codes and standards as well.

Champion the trend toward performance-based design.

Bring materials science into structural engineering practice. The traditional education of structural engineers has not focused on fundamental behavior of materials. Research breakthroughs have been sparse, and material properties that have limited our designs continue to constrain us. Innovations in building materials have not been a driving force in the practice of

[8] Section 1.3.1.3 of ASCE 7-10 Minimum Design Loads for Buildings and Other Structures

structural engineering. We need to understand the materials we use better, and we need better materials.

In the future the education and practice of structural engineering should be built around efforts to improve the mechanical performance and sustainability of materials. We might start by providing a better foundation in materials science for future structural engineers, but ultimately we must embrace innovation in materials as a key part of what it means to be a structural engineer.

Advance new structural materials.

Apply skills beyond traditional construction. When we say we engineer structures, we almost always mean buildings, bridges, tunnels, and other civil works. By doing this, we have adopted a very narrow view about what can constitute a structure. The principles that govern structural engineering are applicable to all types of structures—from aerospace structures to packaging. It is time that we embrace all of these activities as "structural engineering" and to seek out other applications that would benefit from the professional perspective of the structural engineer.

If the problem involves managing force and motion, we can solve it. And we should.

Apply skills beyond structural engineering for traditional construction. Structural engineers have evolved into a role that is largely technical support. In the future structural engineers need to be a voice in the key decision processes for building projects. To be that voice we must be conversant with all aspects of the building challenge, both through adequate education and through active pursuit of that role as professionals.

As a first step, engineers should be better prepared in business and leadership when they enter the profession. Further, we should embrace a more diverse set of thinkers in the practice of structural engineering than we currently do—people with primary strengths in areas other than the purely technical.

If we embrace the task of solving the business risk issues associated with building infrastructure, we can bring so much more to the table during project conception, development, design, and construction. Structural engineers should be fully conversant on matters of financing, land use, construction costs, constructability, and means and methods. There will be new roles for us as delivery methods evolve, and there will always be better ways for us to contribute to the process. The more we bring and the better we can interact with our partners in the process, the higher we will be valued and respected, and the better will be the outcome for the project.

Play a larger role on the construction project team.

Lead sustainability. The world needs sustainable solutions to advance civilization. The building and renewal of infrastructure creates an opportunity for structural engineers to lead efforts in sustainability. If we see our role through the lens of sustainable infrastructure lifecycle then we can see a way to both drive innovation of sustainable solutions as well as lead the project teams to adopt them.

Future structural engineers will consider the carbon footprint of new construction, efficient use of materials, and de-constructability. Creative reuse of existing buildings offers huge opportunities for structural engineers to mitigate the impact of construction on the environment. Structural engineers will play lead roles in the development and implementation of adaptive reuse strategies for existing buildings. When we have expert understanding of material behavior and are liberated by performance-based codes, our role in stretching the most value from resources at the least cost to the environment will skyrocket.

Structural engineers need to embrace designing for sustainability as a consideration equal to designing for cost efficiency.

Encourage participation in society enhancing activities. The members of a profession are responsible for promoting the profession—if not they, then who? Structural engineers of the future will have the ability to speak and represent the profession to all segments of society and will eagerly take up the challenge of doing so.

We build structures where people can find shelter, nourishment, employment, and transport. We do this in support of, in the midst of, and in spite of human activity. What we do impacts society on all levels, from providing essential services to potentially being an unbearable nuisance. We need to be cognizant of our role and our influence, and strive to make our impact positive in all aspects. We need to do this in our professional activities of course. But we also should do it in ways that exploit and leverage our talents for endeavors that are beyond our daily professional responsibilities.

Engineers in general are far too sparsely represented in leadership roles in politics, philanthropy, and volunteerism. As a group we could offer our talents and abilities to the improvement of the quality of life of others through activities that are outside of our traditional professional role. Benefit flowing inward would then be derived from the publicity and respect the profession would get by the successful application of our skills to the solution of a vast array of important problems facing society.

Let’s make a positive difference.

Drive the process of technology development. Structural engineers were among the first to embrace many of the computer innovations that are now ubiquitous in the profession.

Somewhere along the way structural engineers became “subjects” of technology more likely to have the next innovation thrust upon them than to create the next technological innovation.

We need to return to our roots as the creators of the technology that drives our profession. The structural engineer of the future will have a strong background in advanced technologies and the profession will welcome those with the entrepreneurial spirit required to lead the way in development of the technologies, and the means to manage those technologies, that will enable the creation of the next generation of infrastructure.

We should push for the creation of design and analysis software more capable than what currently exits. We should participate in the development of sensors and systems that help us to monitor and diagnose structural problems before they result in catastrophe. We should develop tools that are suited to the task of rehabilitating, retrofitting, or extending existing infrastructure.

Where we see need we should imagine new technology.

Embrace other cultures. Globalization is a fact of the future. We need to move beyond the idea of simply advancing business in other parts of the world. In order to lead the world in structural engineering we must embrace globalization and immerse ourselves in other cultures. Engineers who work on projects in other parts of the world should speak the language and understand the people they serve.

We start by advancing an initiative to have multilingual engineers and we may be able to realize that goal through educational reforms. We extend by engaging in exchange programs that instill an understanding of culture, professional practice, legal and contractual standards, and the realities of the construction industry in foreign locations. We complete by becoming fully comfortable working on projects on the other side of the world.

Think globally, act globally.

Be global leaders in structural engineering. The route to the future for leadership in structural engineering is through creativity and innovation, not through labor. The leader in creativity will lead all others in defining and advancing the profession throughout the world.

In order to set the international model for structural engineering we must lead the way toward innovation. Among the many possibilities to lead we can have the best structural engineering research and develop in university and private laboratories, vigorously pursue performance-based design as the predominant framework for structural engineering, develop and advance of codes and standards that are emulated across the globe, seek ways to positively impact developing nations through structural engineering, and define the role of the structural engineer in developing sustainable infrastructure.

SEI members will function in the global market for so long as we are leaders in the ability to develop and implement the standards and technology that leads the world. That requires mastery and leadership of both. Researchers and engineers associated with SEI presently are among the best in the world. As such, we are uniquely positioned to be the leaders in the development of standards, codes, and practice. In fact, many ASCE and SEI documents presently set the standard for world practice.

We can continue our leadership role into the future, but many regions of the world now look to our counterparts from other developed professional societies for guidance on structural design. This has been the case for a very long time, and will continue. In addition, as new regions of the world elevate to progressive and economically strong societies there will be new competition. SEI members will remain influential, and extend their influence, by association with a progressive and productive SEI, and through the promotion of SEI and its products worldwide. We need to engage the world so everyone understands the value SEI members bring to the solution of structural engineering problems everywhere.

Think like a world leader, act like a world leader, be a world leader.

Commit to life-long learning and professional advancement. The education and credentials we acquire during our professional lives are important and meaningful. As we progress through our careers our roles change and our profession changes. We have a responsibility to stay current with changes, and to be effective in our changing roles. This requires a commitment to developing the skills we need to have at all stages of our careers, and to help those that follow us to develop their skills.

Overlaying the system of formal education and practice of structural engineering are the mechanisms for licensure and continuing education. Bold changes in education and practice will need to be met with equally bold efforts relative to licensure and continuing education.

Ongoing efforts by national associations and local structural engineering groups continue to support changes to structural engineering licensure in a state-by-state fashion. The newly created Structural Engineering Licensure Coalition (SELC) is a first step in a unified approach to the disjointed efforts of achieving specialty licensure nationwide. Such an innovative effort by the profession defines its leadership in this area. But, there is much work to be done and complementary efforts and successes will be required to realize the Board's Vision and address the strategic issues defined by this committee.

In the future, all individuals practicing in the field of structural engineering should be licensed as structural engineers based on the ANSI-approved *NCEES Model Law Structural Engineer*, which should include a continuously evolving examination that properly evaluates the skills necessary to be a structural engineer as those skills evolve.

The demand for continuing education was created by the requirements for licensure renewal and currently represents a system that is begging for innovative change. The profession has a real opportunity to define what continuing education will mean relative to structural engineering licensure and create a thirst for quality continuing education throughout the profession of structural engineering.

A robust future for the profession also includes deep and authentic mentoring. There was a time when the development of engineers happened in an apprentice system. Apprentices learned from masters in a highly personal and interactive exchange. The demand for efficiency has brought hierarchy in almost all parts of our profession, from the educational domain to the structure of companies. Today it is difficult for young engineers to learn directly from our most gifted senior engineers. The cost of missing this connection is enormous and multiplies over the generations. The structural engineer of the future will have access to the senior members of the profession because we will value it and we will find innovative new ways to let it happen.

Commit to developing and implementing uniform and meaningful requirements for professional licensure, continuing education, quality control, and training of the next generation of engineers.

EDUCATION FOR INNOVATION AND LEADERSHIP

One of the keystone ideas for change in the profession of structural engineering is to change the way we educate structural engineers. Educational reform in engineering has been wedged in by many constraints—from accreditation procedures to management of a system that includes community colleges and transfer students. Our surveys showed that most senior engineers in practice know little of the educational environment beyond their own experience[9]. The educational system is far from agile; curricular reform is more like chiseling stone that it is molding clay. Furthermore, education is seldom acknowledged as a system and hence most change is piecemeal. To change the outcome we need to change the system.

If we could start from a blank piece of paper today, how would we imagine the ideal education for structural engineers? Would we create the undergraduate experience we have today? Would we teach math, physics, and engineering fundamentals in the manner that we currently do? Would we envision general education as we do currently? Would we align structural engineering with civil engineering? Would we build graduate programs as we do today? It is not likely that anyone who is aware of the research on how people learn, the needs of the profession, or the aspirations of many students would create anything remotely close to what we have today. Our current system is a product of incremental evolution, founded in the

[9] 2013 Firm Leader Survey Summary, Appendix A

industrial revolution, refocused on science in the post WWII era, and now weighted down by an incredible number of constraints.

If anything, engineering education has become far too parochial. The drive to get students committed to certain branches of engineering as early as possible and to get them ready in four years has all but eliminated the breadth that we believe is essential for the future of the profession.

We need to re-envision the formal education of structural engineers. What we propose here is to embrace the concept that the preparation of engineers is a process that cannot be addressed by fiddling with certain parts of the system. We need to re-imagine the entire process. This re-imagination of formal education has three main parts: (1) decouple undergraduate education from the professional training[10], (2) develop a professional school model with an associated internship mechanism and a correlated transition to practice, and (3) create a more fluid and engaged connection between the practice and the academy.

Reform undergraduate education: The discussions about educational reform in engineering have gone from the faint drumbeat of a few in decades past to an audible noise that is impacting universities in a way that is harder and harder to ignore. While the trenches of tradition remain fairly deep, the knowledge of how people learn will soon transform engineering colleges in the United States. The pressure to generate well-rounded engineers and the cost of education will drive that effort. The combination of available technology, the high price of college, and increased awareness of good educational practice is pushing American higher education to a tipping point.

There are at least two routes forward for the reform of undergraduate engineering education: one choice could create general engineering programs that aim to provide foundational preparation and broad education for all engineers, but little parochial professional knowledge; and a second route could move to a pre-engineering strategy typical of the professional schools in law and medicine. These approaches represent dramatic change that might allow movement toward a better overall model for the formal education of engineers. While these concepts are worthy of consideration by all engineering fields, structural engineering is in a good position to actually implement these ideas.

If we loosen the coupling between the undergraduate education and the outcome of being a professional structural engineer, we can create avenues to promote the development of soft skills, broad knowledge, and skills that will enhance professional ability in ways that we are simply not able to do under the current constraints. If we improve the technical foundation of the lower division and exchange parochial professional training in the upper division with a

[10] The undergraduate degree is not designed to be the primary place for professional training in engineering. Professional training would include those subjects that are specifically related to professional practice.

broader sort of preparation for additional study, then the undergraduate path to engineering will be more attractive to more students, a better education for those who follow that path, and will leave the task of professional education at a preparation level and maturity level that could significantly enhance the overall outcome of the education.

Create professional schools: The reform of the undergraduate experience for structural engineers is predicated on the notion that something else follows. We might best image the next phase to be a professional school model rather than the current graduate school model. Currently, graduate education in structural engineering is usually built on the traditional civil engineering degree, with an expectation that students have a background in structural analysis and design. Much of the graduate education might be characterized as "what you learned before, only more and better."

The professional school model would create new opportunities depending upon how the entrance requirements were administered. Entrance requirements similar to law school or medical school would simply articulate a core set of courses required to start (and a standard exam). If we envisioned structural engineering school in a similar manner we might specify courses in math and science and possibly even engineering mechanics. That would open the possibility of many majors leading to structural engineering school. This model opens the door to a broader group of students to consider the profession.

One might envision admission from <u>any</u> undergraduate degree in engineering. No longer would civil engineering be the primary route to structural engineering, but so would mechanical, electrical, aerospace, and others. A far more innovative approach would be to abandon the traditional undergraduate engineering degrees for a specially designed general engineering degree that advanced students through foundational engineering courses, creative design experiences, and a significant set of liberal arts courses to round out the education[11].

The undergraduate degree would be about foundational knowledge and breadth; the professional school education would be about depth and specific knowledge in structural engineering. We would no longer need to worry about the adequacy of the few courses provided in the undergraduate education; they would no longer be viewed as entry-level professional requirements. The undergraduate degree could be designed as preparatory to a broad array of professional possibilities. The broader undergraduate degree would serve well as a preparation for a vast set of outcomes outside of engineering, establishing the "liberal arts education of our technical future."

Coordinate internships: Internships have been a staple opportunity at most engineering schools for a very long time. Due to the nature of the structural engineering business, structural firms

[11] There are models currently available that are close to this model, e.g., Olin College.

have played a relatively minor role in the internship universe, and in fact many admit to only using the process for recruiting.[12] There is a remarkable lack of communication about the concept of internships among stakeholders, even though they could function as a very important part of the educational process. Internship programs are constantly in the process of being invented (or re-invented) and there is no effective mechanism to share best practices.

We could develop a profession-wide process for the creation and administration of internships in structural engineering that would make it easier for firms to participate and easier for students to find opportunities. We could take what is now a very substantial, but quite dissipated part of our professional universe and make it into something effective, exciting, and vital to our future.

If you will, imagine a national clearinghouse for structural engineering internships. No individual school has to create the idea or the infrastructure. No individual school has to hire a professional in a position with zero upward mobility to manage the local program. No firm has to invent a concept of internship. No firm is obligated to participate except as laid out in a multi-year agreement that commits to a number of slots, a threshold of training, and to educational objectives that are generally acceptable to the academic community—which would grant academic credit for the experience in a uniform way. The national clearing house could also have bricks and mortar for developing the core skills of students who enter the program (much like study abroad programs attend to language acquisition and cultural education for students who will study at a foreign institution). The “bricks and mortar” might be electronic or a distributed responsibility of the member universities.

At the core, the program must be an integrated and effective, but narrowly targeted, entity supported and endorsed by the profession. Students would view the program as essential to professional development and future employment. The national clearinghouse might also function as employment agency (similar in effect to how interns are placed in medical schools or how graduate schools who use the common application process function). The value of the program would rise and fall on economies of scale and would survive if the outcome hit a target set by the profession.

A variation on this idea could begin with a nationally-executed internship scholarship program in which the top 50-100 structural engineering students compete for a spot to participate. These students could be placed with firms participating in the program and earn a demarcation in a vein similar to a Rhodes Scholar.

Re-invent the engineer-in-training concept: Currently, engineers enter a period we call “engineer in training” after graduation from their formal education. Perhaps it is time to revisit

[12] 2013 Firm Leader Survey Summary, Appendix A

the concept. Imagine, if you will, a completely new entity—neither structural engineering firm nor university. By analogy with the teaching hospital let us call this new entity the "teaching firm" or the "practice arm of the university"—in the former some senior members of the firm are trained educators responsible for the development of new engineers, in the latter some of the faculty are responsible for engaging in the practice of engineering while mentoring their students in the practice. Either way, the goal would be to provide the education needed by all new structural engineers that is not currently provided by academic curricula and is not reliably provided by in the current workplace environment.[13]

All prospective structural engineers would pass through this system. It would be an opportunity for development far beyond the academic setting and it would provide a more reliable and robust education than even the best firms can currently provide. Of course, the logistical tasks we face in realizing such an entity are enormous. However, it would not be more complicated than setting up a new university (which has been done, of course, but is not the province of amateurs). Ultimately, the support of an adequate number of leading firms—at least through their hiring practices—would be essential to the survival of such an innovation. The effort might start as a collaboration of leading structural engineering schools with leading structural engineering firms.

Faculty in Practice, Practitioners on Faculty: The survey of top practicing engineers reveals that very few know much about the educational environment beyond their own time at their alma mater.[14] By the same token engineering faculty members have grown distant from the practice of structural engineering because the reward system of university employment does not encourage the connection.

Some of the innovations described previously create new avenues to reconnect the academy with practice, and in fact rely on this linkage for success. That connection is vital to the future. Every opportunity to create pathways across this divide should be explored in our future. Universities could lead the way by reforming promotion and tenure practices and by employing practicing professionals in the delivery of engineering education. Professional associations could pave the way by building the mechanisms for engagement.

SUMMARY

SEI has committed to its vision for the profession. We know where we are and how we have arrived here. The path forward is ours to decide, should we choose to pursue it. We recognize the path may change, and progress will need to be shepherded. The SEI Board of Governors will

[13] We acknowledge that good firms are in the "teaching" business and that some university programs provide elements of the education sought here. Rather it is a suggestion that we need to move beyond an ad hoc, haphazard approach to this part of the education as a profession, if these things are truly important.

[14] 2013 Firm Leader Survey Summary, Appendix A

continue to press forward with careful consideration and purposeful initiatives and activities to achieve this vision.

PART V - Recommendations for SEI Board of Governors Action

This paper asserts that structural engineers of the future will need to be innovators and leaders to respond to our changing working environment. While much of the evolution of structural engineering is beyond the influence of SEI, there are certain actions that SEI can take to help mold the profession's future. The following recommendations are starting points that the Board should implement.

EDUCATION FOR INNOVATION AND LEADERSHIP

- Establish a standing committee composed of academics and practitioners with experience related to the educational process. Charge this committee with developing and advocating for a fundamentally new system for the undergraduate and professional education of structural engineers so that new structural engineers are trained in skills that support innovation and leadership on the world stage. This change is needed to position structural engineers of the future to be highly valued partners in the construction industry world-wide and to be able to blaze new paths as the profession responds to the changing professional environment.

- Establish a committee with like-minded organizations to study the state of continuing education for structural engineers; to recommend enhancements that ensure that providers offer only meaningful, high quality courses for study; and recommend industry-wide mechanisms and processes to make continuing education consistent and effective for all structural engineering professionals. This initiative is needed so that structural engineers develop and maintain the skills necessary for their practice and keep abreast of changes impacting our profession.

PROFESSIONAL PRACTICE FOR INNOVATION AND LEADERSHIP

- Promote the structural engineer as a leader and innovator by designating a champion to solicit authors and speakers for white papers, magazine articles, conference sessions, public media interaction, and/or other means, to make the case for structural engineers to broaden their skill sets and to attract persons with new and diverse talents to the profession. Provide SEI staff to support this effort and facilitate placement of publications and presentations. This change is needed so that structural engineers will acknowledge the need to have new and broader skills to respond to the changing professional environment, and the public will appreciate the structural engineer's critical role in society.

- Establish the *International Activities Division* (IAD) with designated support staff within SEI to advance the role of SEI members on the world stage and facilitate the

development of skills that allow SEI members to thrive in the global market. IAD activities could include: marketing efforts to promote SEI, its publications, and its members worldwide; identifying and sponsoring SEI members to serve in prominent roles at foreign professional meetings and conferences; operating a clearinghouse for foreign exchange programs for our best and brightest young engineers; establishing foreign chapters; fostering ways for SEI members to contribute to beneficial development in disadvantaged societies; and others. This change is needed to broaden the impact of SEI structural engineers in other cultures, provide opportunities for education and learning that will benefit the participating engineers and our profession, and position SEI engineers to compete in the global market.

- Promote structural engineering licensure by supporting the Structural Engineering Licensure Coalition and its mission to advocate for structural engineering licensure in all jurisdictions. This continuing initiative is needed to promote public safety in the built environment.

- Establish a standing committee to champion performance-based building and bridge design codes and standards and the reduction of unnecessary constraint on design. This committee should be composed of representatives of SEI and other standard-development organizations to collaborate in the development of codes that focus on essential standardization, supported by appropriate guidance, rather than complete regulation. This change is needed to encourage creative thinking to achieve innovative, cost-efficient, environmentally-sensitive, and sustainable designs, while blunting the ongoing trend toward codes that marginalize our profession.

- Implement a series of summits on a regular interval to engage the leading related organizations to identify areas of mutual interest and bases for collaboration in education, training, and partnership for the development of technologies that promote the interests of structural engineers. The first summit should address behavior of materials, development of new materials, and application of novel materials and techniques for the solution of engineering problems. Subsequent summits could address issues such as sustainability, information technology, and structural health monitoring, among others. This change is necessary to identify solutions to emerging issues that impact our profession, pool resources for the advancement of technologies to solve engineering problems, help to direct research money to the solution of problems important to the profession, and position structural engineers to be at the forefront of relevant technology.

- Create a new forum that showcases structural engineers in non-traditional roles and solving problems outside the construction industry. This change is needed to inspire structural engineers to reach beyond the traditional boundaries of our profession,

identify the skills we will need in the future, and visualize new and exciting ways to apply those skills. This could also be used to promote the profession externally.

- Create the equivalent of an Opal Award to recognize structural engineering firms that excel in leadership and innovation. This change is necessary to inspire structural engineering firms to enhance their culture to respond to changes emerging in our profession.

- Encourage all SEI members to become involved with philanthropic work, community leadership, political advocacy, professional society activity, media interaction, and other outwardly-focused activities that leverage our skills for the betterment of society. Establish a publication forum to recognize and publicize accomplishments beyond the workplace, and expand the SEI award program for the most outstanding accomplishments. This change is needed to enhance the ways structural engineers' skills are applied to the betterment of society, open new possibilities for structural engineers to practice their profession, and increase the public's awareness of the significance of the profession.

APPENDIX A - 2013 Firm Leader Survey

The members of the Task Committee on the Future Qualifications of Structural Engineers conducted a survey of structural engineering firm leaders to test hypotheses of some of the current practices and assumptions about the following topics: internships, mentoring/coaching, training, professional registration exams and organization membership, current academic training, post-academic training, and hiring trends, as well as expectations for change in industry in next 10-30 years.

PROCESS

This was an online survey that the Task Committee developed and deployed to 2,258 members of SEI who self-identified as president, owner, vice-president, director, principal, chief engineer, or similar. Per the analytics, 697 opened the email (a 31 % open rate) and 156 clicked on the survey (a 22% click through rate). Additionally, NCSEA deployed the survey invitation to 7,807 members who self-identified as the above category as well as project manager, project engineer, and senior structural engineer. This invitation resulted in 2,061 opened emails (a 30% open rate) and 393 clicks to survey (a 20 % click through rate).

In total, 10,065 members were invited to participate and the survey received a total of 352 completed responses, which is a 3.5% response rate.

DEMOGRAPHICS

The survey collected demographic information from the respondents and key characteristics are noted as follows:

Nearly half (48%) of respondents were from firms with fewer than 25 employees in total (small firms); and the majority of the respondents (84%) are employed in firms with 25 or fewer structural engineers. About a quarter (27%) were from firms with 26-200 employees. The last quarter (24%) were employed at firms with greater than 200 employees.

Half of respondents (50%) self-identified their employer as a Structural Engineering Design Consulting Firm – Primarily Buildings; the next largest demographic was employed by a Civil Engineering Firm with a Structural Group (8.5%), and the other respondents were spread among nine other organization types with fewer than 5% per category.

Most (88%) are employed with private companies.

The majority of the respondents (70%) are senior firm leaders (such as President/VP/Owner/Principal/Chief or Lead SE/Director), with a quarter of the respondents (25%) identified as Associates/Project Manager/Project and Structural Engineer.

Respondents practice in all market sectors; and the most common clients included building owners (72%), contractors (68%); architects (63%), state/local government (50%), developers (43%), federal government (35%), and educational facilities (34%).

SUMMARY OF SIGNIFICANT FINDINGS

The survey was constructed into two sections: first, a series of questions evaluated the current practices of education and training to become a practicing structural engineer, and second, a series of matrix questions rated expectations for change in the profession.

Current practices—In addition to identifying current practices, the evaluation questions also asked respondents to consider a need for changes to individual firm programs as well as industry wide changes. In summary, the following were revealed:

If used, which most firms do not, *internship programs* in the structural engineering profession are generally used for recruitment, and therefore not generally perceived as needing improvements.

Formal mentoring is not common in structural engineering firms. While split fairly evenly between those in agreement that improvements in mentoring are necessary with those who do not, it is interesting that the most senior staff participating in this survey was slightly less inclined to perceive a need for improvements in mentoring (as compared to whole group, which generally represents senior staff as a whole).

Most common *training* for structural engineering firms is in-house, but without a defined budget amount; training is generally geared toward design and production skills. It appears that firms are more likely to grow business skills through on-the-job activities than through organized training. Respondents were relatively evenly split on the need for improvements to training programs.

Most respondents are supported by their firms for fees and dues, and most are satisfied with their current level of funding for *professional activities* (associations and licensure), therefore they do not see need for improvements.

The current population of practitioners does not keep up with *academic programs* and what knowledge they may have is of their own program at the time of their studies; only a third of respondents are aware of their Alma mater's current academic program. Knowledge is primarily gleaned from recruiting and observing new hires. Very few practitioners communicate regularly with academic faculty. Despite direct knowledge of academic programs, there is general agreement that the current structure of formal education does not provide requisite skills in an undergraduate degree program.

While there is mild support for *post-academic training* (consisting of external courses for credit) that includes technical design courses, there is little support for business courses and most respondents do not see a need to change this.

One question in particular was included in the survey to reveal hiring practices relative to degree level such as Bachelors of Science degree (BS) versus a Master's of Science degree (MS). Overall, there appeared to be a balance between hiring graduates with a BS and MS graduates. Hiring levels reported as BS of 28%, BS or MS was 41%, and MS only was 27%. Upon further analysis of the data using cross-tabs (See Figure 1), the following was correlated:

- Smaller firms (10 employees and fewer) generally hire the largest proportion of BS;
- Mid-sized SE firms (26-200 employees) generally hired MS more than BS;
- Large firms (200 and more) generally hired MS and/or BS relatively equally; and
- All size firms hired MS.

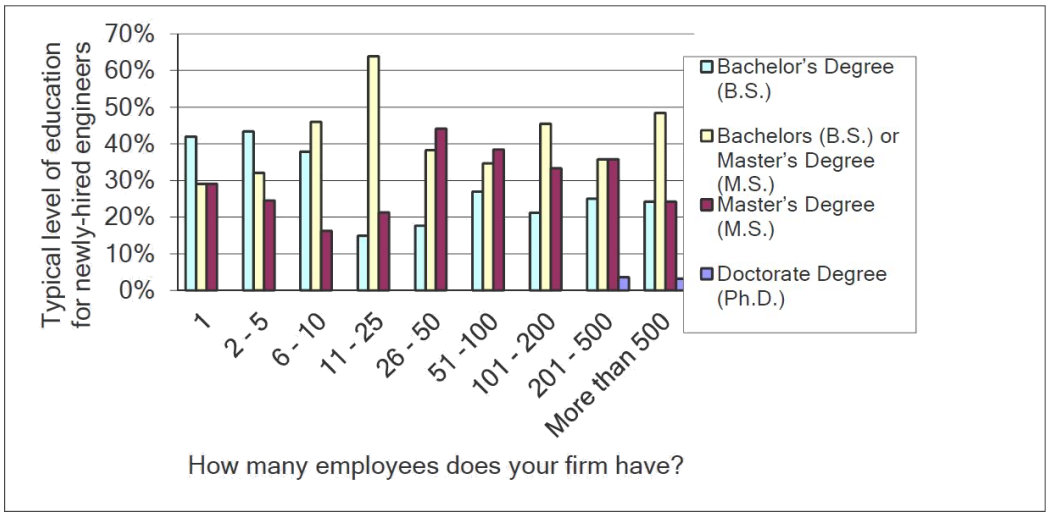

Figure 1: Cross-tab correlation between firm size and hiring degree (Q47 vs. 35)

Firm size generally correlates with geographic reach of work with small firms engaging mostly in local or regional work and more international work being done by larger firms. Firms of 100 or more employees generally diversify equally local-regional-national-international; see Figure 2.

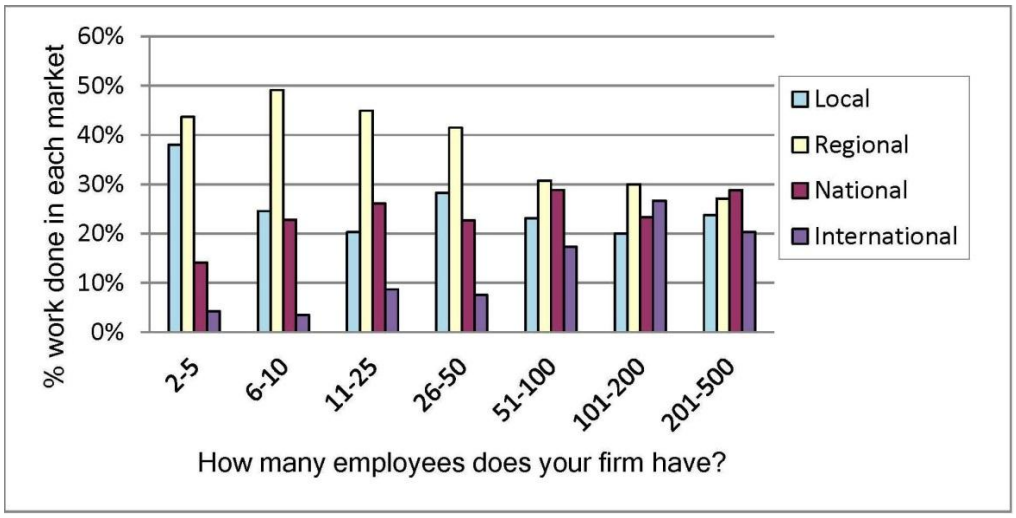

Figure 2: Cross-tab correlation between firm size and markets served (Q47 vs. 45)

There appears to be a correlation between the complexity of the structure and the hiring trend: for instance, firms that design high-rise and stadium structures are more likely to hire MS students; see Figure 3.

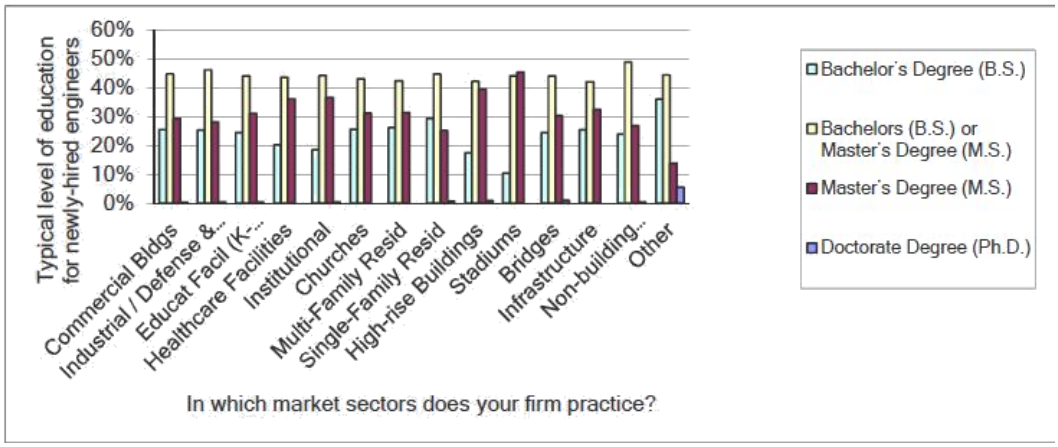

Figure 3: Cross-tab correlation between market sector and hiring degree (Q53 vs. 35)

Expectations for change—The second part of the survey revealed respondents' opinions on the future of the profession. The survey asked: "Please rate your agreement with the following statements on how you expect to see your specific profession change in the next 10-30 years." The responses revealed several trends.

Respondent generally agreed that the structural engineering profession will increase in size and that the industry will provide more interesting work. While respondents expressed that the profession will not necessarily decrease in stature or influence, it wouldn't increase either. The respondents did see the profession as changing its role (or at least not remaining the same as it is currently) and that it will impact other professions.

Relative to how the profession will change, respondents indicated the need for change in the following:

- 73% training,
- 69% academic education,
- 64% continuing education,
- 54% licensure, and
- 42% internships (recall, this is most commonly used for recruiting).

When asked to rate the influence of each of the following on the potential to drive change in their profession in the next 10-30 years, the following percentages of respondents identified the drivers as:

- 94% technology
- 73% delivery methods
- 71% education
- 63% globalization
- 51% environmental
- 45% political
- 35% social

Further questions revealed that while slightly more than half (53%) believe that structural engineers will have wider responsibility, only slightly less than half (48%) believe that structural engineers will have expanded roles. The majority (60%) believe that automation threatens to commoditize the profession; and more than half (54%) believe globalization and contractor led procurement are threats.

Final thoughts were collected in the open-ended question, "What opportunities are created or challenges are caused by changes in your profession?" The top three responses correlate very well with earlier responses as follows:

1. Technology
2. Globalization
3. Delivery methods/Procurement
4. Regulations/Codes
5. Licensure
6. Commodity
7. PE/SE Exams

8. Need to adapt to changing AEC profession

SUMMARY

In summary, respondents appear to be satisfied with current programs except for formal education. Hiring relative to degree level appears to correlate to firm size and type of work performed.

When asked about the next 10-30 years, technology, delivery methods, education, and globalization were repeatedly identified as drivers of change; and current practitioners see these drivers as threats more than opportunities.

APPENDIX B - 2013 Design and Construction Leader One-on-One Interviews

The members of the Task Committee on the Future Qualifications of Structural Engineers conducted one-on-one interviews with design and construction industry leaders from all regions of the United States to obtain their vision of the future of the overall design and construction industry as well as the future of the structural engineering profession.

PROCESS

The Task Committee assembled a list of potential interviewees that represented leaders from structural engineering and architecture, as well as owners, developers, contractors, industry representatives, and a municipal building official. In all, thirty-three individuals were interviewed over a two-month period. The interviews were generally conducted by phone and the interviewees were provided a brief summary of Task Committee's efforts along with a list of interview questions.

DEMOGRAPHICS

Table 1 identifies the profession of the thirty-three individuals interviewed.

Table 1: Types of Professionals Interviewed

Employer	Number of individuals
Structural Engineering Firm	7
Architectural/Engineering Firm	2
Specialty Firm	1
Architect	7
Contractor	3
Developer	1
Owner	1
Building Official	1
Software Developer	3
Concrete Industry	1
Steel Industry	2
Other	4

In order to acquire a broad perspective, the interviewees were selected from different sized firms (small, medium, and large) with practices that ranged from local to international. As indicated in Table 2, the interviewees' practice covers the full range.

Table 2: Interviewees' Location of Work

Practice	Number of Responses
Local	22

Regional	25
National	19
International	12

SUMMARY OF SIGNIFICANT FINDINGS

Technology (software)—The use of integrated design, BIM in particular, is on the rise and is elevating the influence of the contractor at the expense of the engineer. This is happening concurrently in the architecture field, though to a lesser extent. Automation is diminishing prestige and authority of the engineering community, and digital coordination is changing the way the industry operates. This challenge offers an opportunity to engineers. Those who adapt and who are flexible, proactive and not reactive, in this environment will thrive.

Expanded role of the structural engineer—The future structural engineer will experience a higher level of collaboration with other industries (fabricators, contractors, etc.). This will in part be driven by technology. Material selection and detailing could be done through modeling software, as opposed to traditional shop drawings. There will likely be more prefabrication. Artificial intelligence could be present on the job site. Advancing technology could mean greater commoditization.

In terms of collaboration, the question becomes how blended of a future is the industry trying to reach? The preservation of the structural engineer is at the forefront of discussion; how much collaboration can be done without fully giving away the profession? Each team member will bring varying talents, but who ultimately will be responsible for developing the form of the project? Will it be the architect, the structural engineer, or a collaboration of the two?

Niche roles will increase for engineers who want to specialize. Examples include façade design, cable-supported structures, and pre-fabricated modular components.

Alternative roles for the structural engineer—Future employment opportunities for the structural engineer will likely expand. Today, there are few structural engineers working ‘in house’ for contractors, but this type of position is increasing in numbers. Contractors may establish full structural engineering and architecture departments within the same company, particularly as alternative delivery methods (i.e. design-build and public-private partnerships) become more prevalent and contractors take on more vertical construction projects. This will compel structural engineers to become part of a large corporation instead of being their own entity, such as employees of a structural engineering firm. Delivery methods have a great impact on the profession. Methods like integrated project delivery (IPD) and design-build (DB) are generally viewed negatively by structural engineers, though they are rapidly gaining popularity among contractors and government agencies.

Many structural engineers could also work with manufacturers of proprietary building products. There will likely be more structural engineers working for architecture firms, so long as they exist in their current form. There may also be more structural engineers working for owners who do not necessarily want a full in-house design staff, but a project consultant to keep the owner's interests at the forefront.

While individual structural engineers may have more opportunities, these opportunities place pressure on the tradition structural engineering design firm. Structural engineering firms will need to be able to distinguish themselves to remain competitive.

Cross-education for the structural engineer—Engineers must become more visionary. They require more business skills and must be better leaders. Not only must they be better leaders, they must be perceived as leaders. Additional skill sets (oral and written communication, business strategies, and leadership techniques) can be incorporated with coursework already present in the university curriculum.

Structural engineers are trained in two dimensions, but architects think in three dimensions. This must be altered so that structural engineering students more readily can imagine structures in three dimensions. Structural engineers should have more training in construction topics, like cost estimating and scheduling. Understanding construction practices is critical for structural engineers.

A different school model should be considered. A general engineering undergraduate degree, with additional coursework in oral and written communication and business courses could be paired with a focused graduate degree program in structural engineering.

Continuing education—With technological and engineering changes that will continue to occur, continuing education opportunities will become increasingly important. State and national structural engineering licensure will require continuing education units in order to maintain licensure. More formal and standardized continuing education programs will need to be developed to provide the necessary on-going training of the engineering profession.

Collaboration between educators and practitioners—There is currently a disconnect between academia and practice. Practitioners feel that more practical engineering material should be covered in the classroom, while educators feel that practitioners should take a greater responsibility in mentoring their young employees. More collaboration between educators and practitioners is necessary. Different teaching methods should be investigated, and post graduate education is a must. With the decrease in credit hour requirements for the undergraduate degree, academic requirements for practice and/or licensure require further investigation. SEI could strongly impact this area.

Sustainability—Structural engineers typically feel that they do not play a large role in sustainable design. However, the structural engineer can assist the architect with material selection and these decisions will impact the economy of the design. Traditionally, the structural engineer does not base material selection on environmental factors, though this will change as younger engineers who enter the building industry are highly conscious about sustainable design.

Sustainability must be better defined. Currently, sustainability is defined in terms of time. Questions such as "how long will this material last" or "what is the long-term environmental effect of using this product" are becoming more important. Sustainability is much broader than new construction; renovations and retrofits also require sustainable design approaches. Sustainability doesn't equate to LEED. This program will decrease in importance.

There must be flexibility in original design in terms of use. Most buildings are torn down not because they are functionally obsolete or structurally deficient. Owners believe that there is a better use of the land on which the building sits (i.e. the owner needs a 35-story building instead of a three-story building). A 'historical' designation is typically the only way to salvage a building from demolition. How can structural engineers collaborate as a team to make the entire package sustainable?

Most building materials are already recyclable or renewable. Wood, recycled steel, or concrete crushed to create aggregates are common. The structural engineer must also have a better understanding of materials, an understanding and vocabulary that goes beyond tradition concrete and steel.

Government regulations—An increase in regulations would impact the profession. More regulations would produce more prescriptive designs. Safety measures and laws could also become stricter. Changes in OSHA requirements could dictate designs. Also, taxes on materials or tariffs on products brought in from overseas would impact material selection. Product or material subsidies may be present. Patents and regulations could interfere with the propulsion of the industry. New materials and specifications could be developed, but it would take years to implement them because of prescriptive limitations or legal road blocks.

Risk allocation—Structural engineering is a risk a~~d~~verse profession, for good reason, but this needs to change in order for the profession to thrive. Buildings may become more modular, there may be a design template or a kit-of-parts, and adaptive reuse may be commonplace. However, risk aversion is a large impediment to structural engineers. It constrains creativity, as the profession will err on the side of caution out of the concern for professional liability.

"You learn much more from failure than success, and I'd much rather it be someone else's mistake."

If structural engineers truly want to be key players, they must be willing to undertake more risk. Risk must be dealt with more quantitatively. Following codes and prescriptive design does not necessarily free the designer from risk. The codes are continuously changing, and the industry only has a vague understanding of these changes, not a deep understanding.

International licensure—Several interviewees mentioned international licensure as a means to function more efficiently in the global market.

Globalization—Globalization is already driving change in the profession. For some firms, it provides additional project opportunities even though most of the effort involves only the initial design. Other foreign opportunities will likely occur in the current under-developed countries for companies who want to grow their practices. However, globalization will provide opportunities for engineers in other countries to compete in the United States, potentially causing an erosion of design while further commoditizing our design practice.

Globalization is currently being affected by national security issues and will be affected in the future by trade tariffs and the licensing process in the United States.

New perspectives—In general, the thoughts and opinions of the interviewees were fairly consistent and congruent. There were, however, a few ideas mentioned that strayed from the overall consensus of the group.

Many interviewees see BIM and other computer methods as the future of the industry. One interviewee countered, stating that performing hand calculations and learning classical analysis methods is the key to developing young engineers. One concern of senior engineers today is that students are not learning enough in school, and do not necessarily understand exactly what a computer model is doing. The ‘garbage in versus garbage out’ adage comes to mind.

All of the interviewees agreed that the industry needs to find a way to branch out, to encompass more roles and characteristics beyond that of what is considered traditional for a structural engineer. A small subset of interviewees indicated interest in seeing structural engineers become more involved in the building envelope design, and not leave this portion of building design in the architect’s or contractor’s hands. In addition to having a better understanding of materials, one interviewee suggested structural engineers become better versed in fire protection of buildings, and that material science and fire protection go hand-in-hand.

Lastly, one interviewee suggested that the structural engineer be more involved in the means and methods of construction. Presently, structural engineers stay clear of means and methods because interfering in this area is seen as a liability and is solely the contractor’s responsibility. Perhaps, however, being included in this aspect of construction could prevent constructability problems and time delays.

SUMMARY

The interviewees were passionate about the future of the design and construction industry. They see significant change in the future, with both the industry itself and the professionals who make up the industry. Technology, various roles the structural engineer will play, education, collaboration, sustainability, risk allocation, and globalization are at the forefront of the discussion. Overall, structural engineers must be leaders of change in order to be leaders in the industry.