Are Young Engineers Unprepared?

A Young Engineer Answers

By Eytan Solomon, P.E., LEED AP

Debate over the perceived inadequacies of structural engineering graduates has reached a fever pitch. Pick up just about any issue of *Civil Engineering* or *STRUCTURE®* from the last two years and you'll find contributions to the discourse. Some say that young engineers today are not technically competent, that they have no engineering judgment or intuition, and that these deficiencies will manifest through poor designs into an increase in structural failures and collapses. To these ominous claims I offer not quite a rebuttal, but a reasonable continuation of the discussion from the viewpoint of that brash young engineer for whom everyone fears. I question how the profession has changed from past generations of engineers to the present, how it has in fact stayed the same, and what we should do to approach a better future.

How Have Things Changed?

Few will deny that the engineer of today is faced with more information than 100, 50, or even 5 years ago. High-strength steel, and concrete, prestressed concrete, fiber-reinforced concrete, and structural glass are just *a few* of the new construction materials of our generation; finite element analysis (FEA), building information modeling (BIM), and sustainability are just *a few* of the new design paradigms; and globalization, intelligent technology, and digital fabrication are just a few of the new industry standards.

Similarly, the codified laws by which we create structures have also expanded and sharpened. The bureaucratic, legalistic, rule-fixated demeanor of our society – a character that does not necessarily yield negative results – has given rise to building codes and design guidelines that are voluminous and complex without precedent. We have all heard engineers and professors pine for the old days when an entire code book was thinner than a sheet of plywood, while the rest of the design process was left to the engineer's scientific principles and experience.

Clearly structure geometries today are more complicated than before. Increasing computer sophistication is both a cause and effect of the ever-more "funky" designs that come across our desks. I once sat with the president of my firm – an engineer who has seen it all in his 50-odd years of practice – to look over the latest geometrically complex proposition from a certain *starchitect*. "Why do they want to do this?" he implored sincerely before we realized it was a rhetorical question, "I guess because they can." While the Empire State Building is often cited as "proof" that super-sized engineering was and can be performed by hand, in fact there is no better example of contrast to today's structures that are not allowed – by design and economics – to be nearly as simple, heavy, stiff, robust, and logically programmed as the Empire State Building.

In the Frank Gehry age of architecture, it is simply impossible to design many buildings without a computer and, in fact, it is impractical without a tremendous reliance on computer analysis. We feel sorry for our architect friends who log endless hours on AutoCAD, but many engineering students come out of school to work as "desk monkeys" on Revit, RISA or SAP models for geometrically complex projects. How much "intuition" can one really attain in such an assembly-line environment? And does this inherently disconnect the "first principles" learned in school from a young engineer's day-to-day practice? When our elders went to school, the truss and beam designs of steel and concrete were perhaps closer to what they would actually work with after graduation. Now the 3-D modeling program is absolutely essential to an engineer's ability to analyze and design complex structures efficiently, and is very often linked directly with drawing production and construction logistics as well.

As a result of the increased complexity in materials, codes, and geometries, engineering educators find themselves scrambling to catch up with the pace of industry, while at the same time struggling to retain the fundamental courses in mechanics, analysis and design. A special education committee for ASCE recently noted that: "Students earn at least 20 fewer credits than did their counterparts in the 1920s. While they take comparable proportions of mathematics, science, and general education, today's students complete, on average, 18 fewer credits of engineering topics…. How can tomorrow's civil engineers design safe, cost-effective projects, accounting for greater complexity and uncertainty with less formal education?"

Schools have responded to these seemingly impossible demands with a variety of solutions: Many offer classes with more direct preparation for industry practice such as computer design and drafting, or group work and project presentations. Some schools have increased the time to complete the engineering degree from four years to five years. And some programs have actually reacted by cutting back on the computer and construction oriented courses, so that the undergraduate curriculum can concentrate on fundamentals of analysis and design.

How Have Things Stayed The Same?

Before we throw up our hands in fatalistic surrender, allow me to suggest that beneath the bells and whistles of the computer age, the same timeless principles of engineering, experience, and management apply as much now as ever before. As a preamble, let us concede that the computer as an engineering tool is here to stay, until an as yet unknown technological evolution replaces it. I agree wholeheartedly that our practice very often demands "back of the envelope" decision-making, but do not mistake that for ubiquitously casting computers as a plague or curse.

Some structural engineers, young and old, believe – whether consciously or subconsciously – that the way to gain engineering judgment is by performing long hours of calculations by hand. I contend that while doing hand calculations is undeniably important, it is equally necessary to cultivate engineering judgment and intuition by walking construction sites, collaborating with architects, hearing war stories from contractors and older engineers, seeing how project after project is "solved". A legendary professor at Columbia

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University used to say, "The best engineer is the one with grease under his fingernails." With a constant objective of educating oneself, every moment of every workday can be a learning experience practically regardless of the actual task: every drawing glanced at, or conversation overheard, can be another bit of experience gained, with the right attitude.

My next contention is that the image of past generations of engineers working exclusively in an "ivory tower" of first principles must be a myth. Automation and "short-cut" methods have been part and parcel of structural engineering for over a century, and the computer is no more inherently evil than its predecessors. In his excellent essay *Don't Blame the Computer for Mistakes!*, Bashar Altabba "vividly remember[s] the days when similar arguments [about computers] were being made about handheld calculators – back when these were first introduced. Some schools even banned their use… At that time, the proposed solution for complex calculations was a simple one: just use a slide rule like 'real engineers' do! Does anyone today still hold this view about handheld calculators?" And what about when the slide rule itself was introduced to cut down longer, pure-hand calculations?

As an illustration, vector-point "graphic statics" was a popular method for designing wood, iron, and steel trusses from the 1900s and earlier, up to at least the 1970s, whereby complex analysis could be performed by non-engineer technicians (who merely had to draw a series of straight lines between dots); in theory, the results were checked by a supervising engineer. Is this fundamentally so different from our modern practice whereby a junior engineer and computer model the structure, and a senior engineer checks the results? I do not deny that over-reliance on computer output without proper care can be gravely dangerous; however, I do question whether design automation is truly an entirely new problem. One of my superiors says that no computer program, ultimately, is anything more than a "glorified spreadsheet."

I next take issue with our elders' fear of declining competence and intelligence in young engineers. I will not argue against individual anecdotal claims such as, "I have seen engineers with 8 or more years of experience with no engineering intuition or common sense." There are, have been, and will be good engineers and bad engineers, just as there are, have been, and will be good doctors and bad doctors, good lawyers and bad lawyers. And like any other business, the engineering "org" chart is a triangle with few at the top and many at the bottom. I'm sure the harbingers of doom know at least a handful of good young eggs, and might these be the few to ultimately succeed those at the top? And isn't that the way it has always been? The senior people at my firm encourage thinking of recent graduates as apprentices, with the idea that one's first office should provide that link between the university and the workplace.

On a deep philosophical level, it is not surprising for our elder engineers to fear the future. A professor at the University of Buffalo noted that "it is natural that older engineers have a lack of confidence in younger engineers." Ours is a serious and difficult, but rewarding profession; the responsibility should instill pride and confidence. Like King Lear, we want to see our realm passed on to proper hands and we hope for a brighter outcome than he found. It is easy to fear that one's successors may be unprepared if they do not follow exactly in one's footsteps. Machiavelli said that people naturally remember the past better than it was, and I suspect that most successful engineers tend to feel that his or her own path was the best one. However, difference does not imply inferiority.

What Should We Do?

Many have offered solutions, for instance ASCE's policy 465, which proposes to expand and deepen civil engineering education at the university level. In theory this will bolster the engineering student's body of knowledge to a level, certainly not yet on par with, but closer to that of a medical or law student. While there are countless outstanding engineers who never pursued a master's degree (as well as the inverse), there may be no realistic way to demonstrate to the lay public the educational rigor of the engineering profession without raising the bar of degree-attainment.

Previously I touched on the rise of the unconventional, computer-enabled, "funky" architectural schemes with which we structural engineers are compelled to work. But truly, are any of today's designs more geometrically audacious than the old masterpieces of Eduardo Torroja's fantastic concrete thin-shells, or Eladio Dieste's incredible prestressed masonry creations? Frank Gehry and Zaha Hadid's daring forms have their aesthetic place, of course, but I contend that structural engineers must "take back the funk". We must lead in this geometric revolution, in step or ahead of the *starchitects*, because we ultimately hold the keys to the realities of strength and stability. Besides Santiago Calatrava, I fear that engineers have fallen into the complacency of merely reacting to the architects' dreams, while it rarely occurs to us to have the dream first.

Another suggestion, made publicly by Ed Huston, is to dig up – out of books, notes, and individual experience – all the "rules of thumb" and "reality checks" engineers have acquired over the years and circulate them among peers, both young and old. I could not agree more. No matter how complicated an analysis becomes, it is practically guaranteed that at some point in the process you will need to "prove" your design succinctly, in the space of a single page, to someone: a client, a colleague, a contractor, a senior or junior co-worker, or – above all – your own conscience. Under these challenges is where you learn what cannot be taught.

I encourage employers to ponder the true nature of our profession: Does anyone really start with intuition, or is this cultivated slowly over time? Is the computer really evil, or does it in fact *help* the engineer develop understanding because it challenges one's conventional thinking? Should an engineering firm be a hierarchy of those who "have" knowledge and those who simply run models, or should it be a place of continuing education between masters and apprentices? Even if we do "clean our own house," how do we deal with architects who produce foolish designs in CAD, and construction managers who churn out schedules from Primavera without any intuition of their own? And what do we do about that elephant in the room: The declining fees for our services!

As a final illustration, let us recall the story about William LeMessurier re-analyzing the entire Citicorp Building by himself in a cabin during the post-erection crisis concerning bolted versus welded connections, under the previously unconsidered effects of quartering winds. While his application of first principles in hand calculation is magnificent, the more important moral of this story is LeMessurier's global thinking, humanistic conscience, creative problem-solving, and having the right priorities.

Let us too have the right priorities: Look inward, and march forward!▪

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