Automation and the Future of Structural Engineering – Installment 5

By Eytan Solomon, P.E., LEED AP

Concluding our series on automation – December 2021 (Installment 1), March 2022 (2), June 2022 (3), September 2022 (4) – I sat down (virtually) in July 2022 with two more industry experts in innovation: **Dr. Erica Fischer**, *Assistant Professor of Civil Engineering at Oregon State University; and* **Ilana Danzig**, *Associate Principal at Aspect Structural Engineers. Below are highlights from our discussion.*

You two were on a panel at the Structures Congress about innovation within the AEC sector. Erica, you alluded in the panel to efforts at your university for corporation-funded research. Do you think that is a growing opportunity for innovation in the future? What motivates corporations to support that innovation?

Erica Fischer: Corporate-funded research through the university can occur in several ways. One method is where a consortium of companies come together, pull money, and sponsor research to see something come out of it. There is one within the College of Engineering called the Cascadia Lifelines Program, where a lot of the utility firms from around Oregon are sponsoring research regarding seismic mitigation on utilities and how to get their utilities ready for the Cascadia Subduction Zone earthquake. There is another one that Ilana is familiar with, which is called the REACTS consortium. It is through the TallWood Design Institute, which is Oregon State University's College of Engineering, College of Forestry, and the University of Oregon's College of Design. It fosters innovation and is an interesting way of ensuring the latest knowledge is getting directly into practice. We, as professors, get to see what is being used in the industry and where their challenges are. And then, on the flip side, the industry professionals get to be involved in research and be able to partner in the development of this new data, this new knowledge, and also help with the mentorship of the graduate students. And, maybe because it's the Pacific Northwest, we see more industry-sponsored research on mass timber. We see a lot more collaboration across structural engineering companies in mass timber. I also think the younger generation of researchers and engineers are just more comfortable in the collaborative space than keeping information to themselves.

Ilana Danzig: I agree. In this field, not much hoarding of knowledge is possible because once you produce a design that gets built, it is out there and open to inspection for anyone who wants to see it and learn from it. Usually, we accept and invite that we are all looking at what everybody's doing and building off what we see. This is because all structural design grows out of past innovation. It is why creative engineering is not about solving any one particular problem: it's about the innovative approach to solving problems so we can make incremental progress together as an industry.

Ilana, you made the great observation on the panel that "innovation needs space for failure." But, of course, there's a tension between that and the fact that structural design projects like a building or bridge are usually single instances, or as Zak Kostura put it in my first session, "we're expected to make a profit for the owner on a first prototype." So how and where do we find that space for innovation, i.e., space for failure?

Ilana Danzig: First and most importantly, there needs to be room for failure within the group you're working with and collaborating with internally – it starts with colleagues. There needs to be room to explore ideas and make suggestions, even bad ones, that can get debated and discussed, and you need to be allowed to get it wrong. But, even on a project team, if the team's shared goal is innovation, the team must have space to explore a path that might lead nowhere. That process has to be done within limits – most clients are not OK with signing a blank cheque for a prototype that is thrown out, for example. But in solving novel problems, there must be a culture of trust, where challenging each other on key ideas is expected, and the best ideas can be surfaced. Otherwise, everyone's protecting themselves the whole time, and you don't get anywhere. There is no real growth and learning without space for this, but you need trust within the team, and you need a shared goal of trying to innovate toward a tangible outcome.

I think that's the greatest part about structural engineering today: we have tools to automate the simple and repetitive, which frees us up to dig deep into the challenging and creative (the fun parts)!

Ilana Danzig

Erica, your research includes numerical modeling approaches for steel and composite structures and connections. Do these approaches employ automation tools?

Erica Fischer: We are setting up numerical methods for automation, just as we see in industry. In academia and research, we are examining how to link different computer simulation tools together such that the research is more streamlined. We accomplished this by linking BIM with a fire dynamics simulator so that we could look at building fires in different stages of construction. Still, there are many other examples of researchers who are doing this. Regardless of the automation we are employing in the research or in industry, it all has to be validated and verified through our more traditional analysis measures; otherwise, you can get whatever you want from these computer simulations.

Ilana, you alluded to your work with CLT box modules in the panel. Do you employ automated design tools for those projects?

Ilana Danzig: Here is what I have found on mass timber projects, especially on this volumetric modular work: Automation helps us shortcut to the meat of the problem-solving. It is relatively easy to create a program or tool to set up a model based on input parameters and do a bunch of basic analyses that can spit out member sizes, maybe with some material optimization. That's an easy problem to solve. The hard problem is how do we put it all together? How does the system work for connections, transportation, lifting or fire requirements, and so on? There's so much more to structural design than sizing members, and computationally speaking, sizing members is the simplest thing we can do and automate. But that barely scratches the surface of the design and coordination required on these volumetric modular projects. The juicy part of these problems is solving how it works together as a system, and that's where we still need human creativity, problem-solving, and intense multi-disciplinary collaboration. We need to zoom out a little bit, zoom in really close to a connection, and then zoom out again. It is a dynamic and creative process.

Erica Fischer: To add to that, we've been performing volumetric modular research here with mass timber, and I think if you are going to look at panelized and modular buildings versus beam-column volumetric modular (e.g., steel modular), these are two different animals. Panelized systems are often these flat-pack operations: how do we flat pack it out to the site and pop it up for rapid construction? But then, specifically, when getting into high-rise buildings, there are still questions such as: what are the implications of having a rigid diaphragm versus a flexible diaphragm, because you can have either in a mass timber building. What are the implications and demands on intermodular connections (module-to-module)? How do you create a continuous diaphragm?

Modular buildings tend to have first-story mechanisms, so how do we design our mass timber modular buildings so that we don't have a first-story mechanism? I can go on and on with the issues; there are still so many questions. But unfortunately, the research on high-rise mass timber buildings is in its infancy, and we don't even have the answers to many of these questions.

Ilana Danzig: And I think that's the greatest part about structural engineering today: we have tools to automate the simple and repetitive, which frees us up to dig deep into the challenging and creative (the fun parts)! Figuring out how much volume of wood is in a mass timber building, a prefab building, or a modular building is a relatively easy task. The move into offsite-prefabrication and modular systems is really about the speed of construction: how efficiently buildings can be delivered and whether you can get all the different parts to work together within a system. It's a new frontier and a quantum leap away from just material takeoffs.

I think we will begin to see automation to make building design and construction more affordable. There's automation that desperately needs to happen for our industry to be more efficient and for us to deliver more reasonably priced products.

Erica Fischer

Could you envision that someday, many years in the future, those parameters about constructability, fire design, and so forth can get understood and codified and laid out into computer code, so it does approach automation?

Ilana Danzig: Yes, and then we will solve new and different problems. After the creative and collaborative work of system development comes the opportunity to automate design. In fact, for individual systems, that is already happening now. Once a modular system is developed with reasonable confidence, we have the system's rules, which can then be automated for further use in future builds. Some of those rules will come from code updates, like fire requirements for concealed spaces and diaphragm design, and sometimes those rules are from testing or engineering analysis. Either way, the system design establishes a set of rules to essentially get the designer out of the way so production can happen. This is a simplification, of course, but I think that is what's interesting and different about this manufacturing approach to buildings: It separates design into development and production, and we, as structural engineers, are not used to thinking like that; it is a paradigm shift. Design is not something that is easily automated, though tools can help. But production could and should be automated, even on the engineering side. Of course, the real gains of modular work are the automation opportunities at the fabrication and construction levels. The savings on design are quite small relative to that.

Do you have a vision of the future of our profession?

Ilana Danzig: In the Structures Congress panel that Erica and I were on earlier this year, someone referenced the airline industry and the kind of advances in automation that happened in that industry. Those kinds of advances haven't happened in the buildings industry yet, but many companies and groups are putting much effort towards getting there, and I think off-site and modular are going to form part of those major advances. Along with the more common and expected advances in building heights and technologies, I think there's a shift coming to automating at a building level. Still, it is not a shift that will impact all buildings and all structural designs. However, I believe it will change how we think about design for standard and repetitive types of projects like low-rise multifamily, student residences, hotels, etc. I'm curious to see how that progresses over the next 10 years, because over the last 15 years, I have watched how design has changed and sped up amazingly with the software tools and the automation we have. And the result of this speed-up has not been that engineers aren't needed anymore or as much. Instead, the results seemed to be that engineers are used more for problem-solving than pure analysis and computation.

Erica Fischer: I think we will begin to see automation to make building design and construction more affordable. There's automation that desperately needs to happen for our industry to be more efficient and for us to deliver more reasonably priced products. As a profession, we could be more integrated. However, I think we will always need an engineer to oversee a lot of this automation. We saw the emergence of Katerra and the failure of Katerra, but I don't think we should see this as a failure of our industry. Let's see this as a success that someone tried to disrupt it. It got people thinking. [*Katerra was an American technology-driven off-site construction company founded in 2015 and filed for bankruptcy in 2021.*]

When I graduated from my undergraduate studies, everyone wanted to design the next tallest building. Now, if I give seniors in my class a survey on the first day and ask them what their career goals are: out of approximately 80 students, maybe one will say they want to design tall buildings. Most everyone else is thinking about societal issues. That's where their passion lies. We see this echoed in our professional societies at conferences and webinars. There are many more presentations and webinars about simulating a whole community. We, as structural engineers, are bridging the gap between the traditional engineer, technical knowledge, and larger society.

Ilana Danzig: Sustainability is also a huge part of the conversation now. I see more and more that it's a major driver for new grads who join us. As structural engineers, we have an enormous opportunity for positive impact in many more ways than traditionally thought. And looking at those newly graduated and the issues they care most about, I have a lot of hope for the social and societal role we engineers can and will play.▪

It's interesting. I started this series with the theme "automation and the future of structural engineering," but where we've ended up is "the human factor and the future of structural engineering." If the engineer working on a project feels ownership of the project and is passionate about it, that is the best chance for success: It's not about just putting the numbers into the computer and seeing what gets spit out. Instead, it's taking the care to look at load path, complex connections, coordination, and so forth: the "non-computable" things that sometimes get missed.

I want to thank Erica, Ilana, and all the past interviewees of this series, for giving their time and insights. I hope our readers feel better prepared and inspired about the exciting future of our profession. Don't hesitate to contact me or STRUCTURE magazine if you want to share your thoughts!

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