cross sections

Magazine for the Structural Engineers Association of New York

2016 VOLUME 20 NO. 4

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ON THE COVER

Superior Gunite Company and Ferrara Concrete host a shotcrete demonstration for SEAoNY members.

Photo: Adrian Wright

President's Message

We are just past the midway point of our membership year. We continue to build on our success of last year. The monthly seminars continue to be engaging and attract significant audiences. Two highlights were the January evening seminar on Statutes of Limitations and the February all day seminar on Building Resilience. I encourage members to visit our website seaony.org and take a look at what's coming up next. You are bound to find something of interest to you.

Very soon a new class of engineering interns and graduates will be entering the workforce. It is important that we as professionals continue to mentor students and new graduates so that they see Structural Engineering as a viable career path. This will ensure our industry will continue to attract the best minds. SEAoNY is committed to facilitating this. Our Education and Outreach committee is doing great work engaging colleges and universities in our area.

There is always more that we can do. I urge members to consider joining one of the committees so we can continue to building SEAoNY into an even stronger organization.

Regards,
Alastair C. Elliott, PE, LEED AP

Editor's Message

Dear Cross Sections Readers,

Cross Sections is a critical component of SEAoNY. We need your help and participation to maintain its readership and circulation. It's a wonderful way to share your knowledge with the entire New York-centric Industry! Our committee is willing and eager to help you transform that topic that you've always wanted to explore into a realized, written masterpiece. Please consider contributing.

In this issue, we have three interesting articles on ranging from 3D printed structures, to welding failures, to a thought-piece on reinventing the industry's current design process. We hope that you enjoy them.

Thanks, as always, for reading!

Best,
Justin Den Herder, PE

UPCOMING EVENTS

September 27 @ 6:15-8:00 PM

SEAoNY Annual Meeting

Center for Architecture

Visit www.seaony.org/programs for additional information on these and other events!

Is 3D PRINTING the Future of Construction?

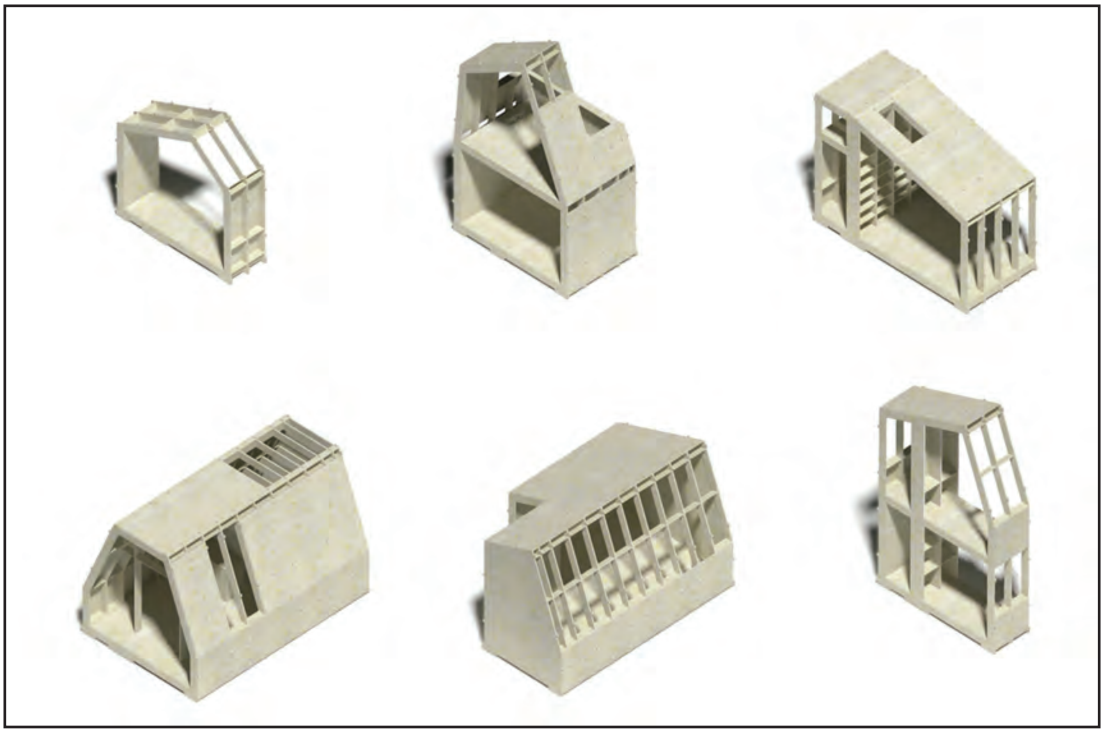
By EYTAN SOLOMON

Figure 1: Robotic technology in progress constructing a bridge over a canal in Amsterdam.

THE DUTCH COMPANY MX3D MADE WAVES THIS PAST SUMMER WHEN THEY announced their intention (and flashy renderings) to "print" in-situ a 24-foot span steel bridge over a canal in Amsterdam. Mobile robotic arms will gradually add layer upon layer of weld in an additive process to produce the branch-like truss geometry of the bridge structure. Completion of the bridge is planned for two months after commencement, once an exact site and schedule are chosen.

Three-dimensional "printing" of architectural models, made by successive layers of plastic and resin material, has been known in the A/E industry since the 1990's. But several recent innovations in the field - combining advances in computer software, fabrication hardware, and material science - are contributing to what some believe may become a revolution in design and construction. New capabilities in 3D printing are already revolutionizing other areas, from medicine (prosthetic limbs and organ replacements) to machine spare parts to everyday household goods.

The actual physical processes lumped together under the term "3D printing" are actually quite varied. Material may be extruded like icing onto a cake, or bound from granular materials in a powder bed using lasers, or laminated from very thin sheets, or traced from liquid state by photopolymerization into solid form, or deposited by welding from an electrode, and even other more obscure methods. CNC (computer-numerical control - i.e. cutting as opposed to building up) fabrication is also often grouped together under the 3D printing convention, and one fascinating example of this is the Wikihouse.



Renderings of 3D printed affordable houses made available by WikiHouse, an open source construction project.

Wikihouse is a project begun in 2011 by architect Alastair Parvin (his TED talk is recommended), whereby small structures (typically one-story but sometimes two-story) can be customized by a lay person over the internet and with the graphic program Sketchup. The information is then fed to a CNC machine which cuts "jigsaw pieces" from ordinary plywood, where the wood parts snap together with wedge and peg connections - even the mallet tools are "printed" from the plywood source material. The frame of a Wikihouse can supposedly be erected in one day by lay persons with no formal construction training. Site-specific foundations, responsibility by a design professional, and approval by the local government remain as issues requiring resolution for each individual project.

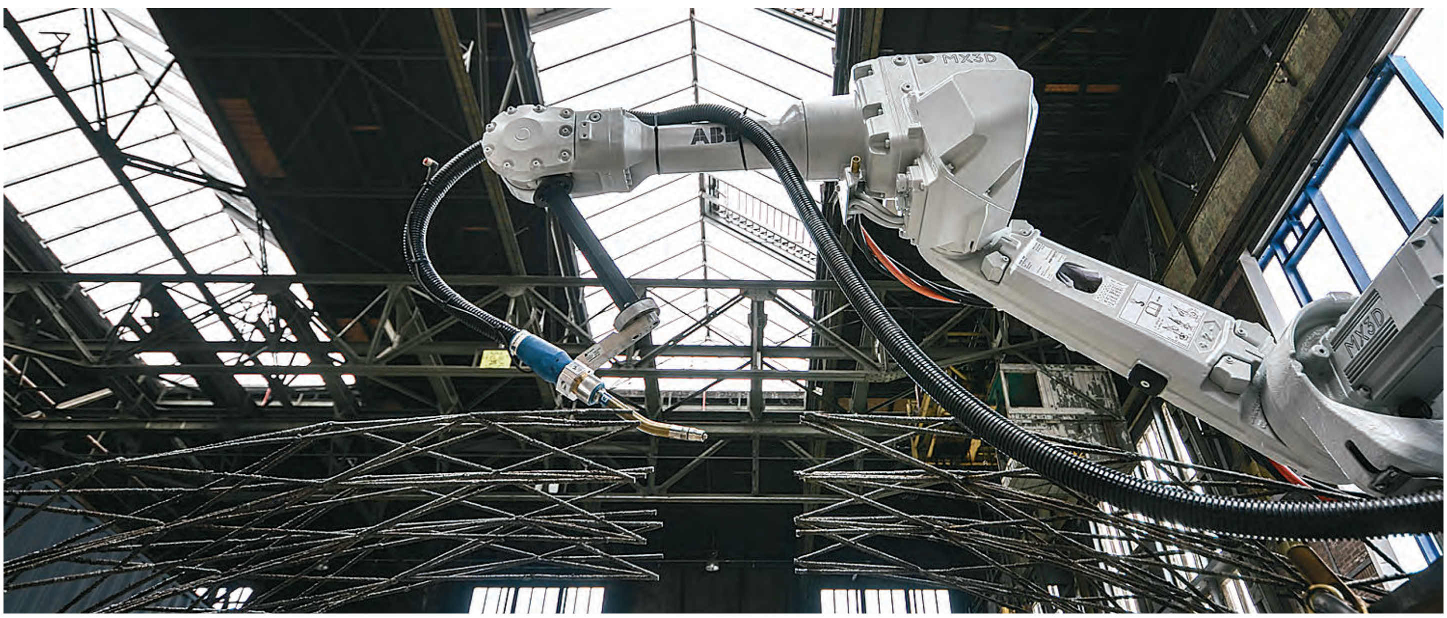
What other realms could be explored by 3D printing in architecture and structure? Certainly doors open for ambitious geometrical forms that would otherwise be difficult or even impossible to fabricate by conventional means. The safety of (human) construction workers could be improved by sending robots to do some of the difficult, dangerous, or repetitive work. Complex prefabricated connections, or complex on-site repairs, could be attacked with 3D printing solutions.

EYTAN SOLOMON is an Associate at Silman.

Figure 1: http://techxplore.com/news/2015-06-mx3d-3d-print-steel-bridge-amsterdam.html

Figure 2: http://www.gizmag.com/wikihouse-print-your-own-home-project/22548/pictures#20

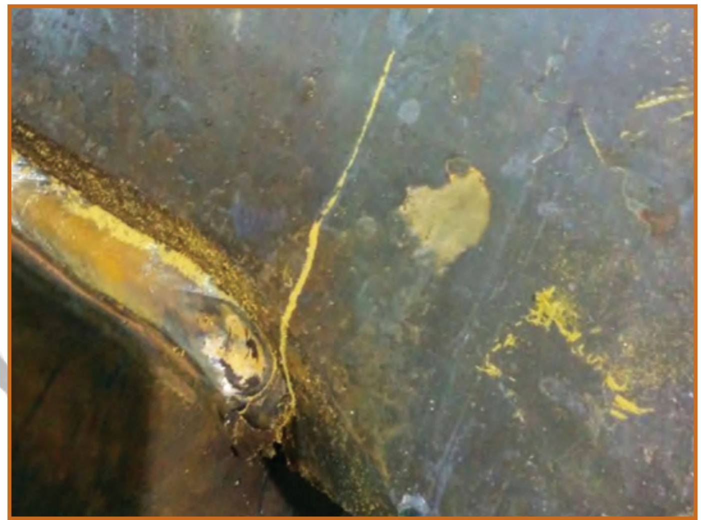
Figure 3: http://mx3d.com/projects/bridge



WHY DID IT CRACK?

THE CHALLENGE OF DETERMINING ROOT CAUSE OF CRACKING IN THICK AND RESTRAINED JOINTS

By ELIZABETH MATTFIELD



WHILE MANY CLIENTS SEEK TO PINPOINT A singular cause of cracking of welds, it can almost never be attributed to one single mistake. Most often, a crack is produced in a "perfect storm" of errors made during the design, procurement and execution phases of fabrication. Individually, these oversights would be unlikely to cause weld failures, but combined, they can cause disastrous results to any welding operation, even in very reputable shops.

Magnetic particle testing (MT) of a welded joint and surrounding base metal has revealed a crack in the photo above, with yellow powder accumulating in the cracked metal to distinguish the extent of cracking. It is clear from the powder's location that this fracture has originated in the heat affected zone (HAZ) at the weld's termination and propagated as a transverse crack into the base metal. Ultrasonic testing revealed that the crack extended 1" deep in the 3-1/4" thick material.

This fabricator had diligently monitored welding parameters in accordance with a prequalified welding procedure specification (WPS). This WPS for Group II base metal required use of a gas-shielded semi-automatic flux cored arc welding (FCAW) process with 70ksi wire. This is a process often favored by shops for both its productivity from a wire feeder as well as its penetration, attributed to its reverse polarity. The fabricator's quality manager was able to provide valuable information, such as wire diameter, shielding gas, preheat and interpass temperature, and post weld treatment (PWHT) details.

In this case, a preheat temperature of 225°F had been achieved. This is acceptable by AWS standards for Category B base and filler metal combinations in AWS D1.1:2015 Table 3.3. The FCAW wire was classified as H8, with less than 8 mL/100g of diffusible hydrogen. The double-sided tee joint had even been welded by alternating sides, a practice recommended by AWS to control thermal stresses during welding.

This prompted an investigation of the base metal by the fabricator, who assumed that since everything was prequalified and executed with good practice, there must have been some sort of flaw in the base material. The fabricator had gone so far as to hire laboratories to perform limited chemical analysis of the steel, yielding no reliable results to indicate why the cracking had occurred.

Upon first inspection of mill test certificates of the steel received, it was evident that while the WPS was perfectly acceptable for the designed ASTM A572 Grade 50 steel, it did not account for the properties of the steel that was actually received and being welded. In fact, the steel far surpassed the minimum yield and tensile strength specified for ASTM A572 Grade 50 steel, with yield values in the 62-63ksi range and tensile values in the 91-93ksi range. From a welding perspective, this steel would fall into Group III base metal, becoming undermatched by the 70 ksi filler metal being used to weld it. Undermatching of filler metal is favored where acceptable, such as in this case, where the design only demanded 50 ksi base metal. However, the extremely high tensile strength also pushed the base-filler metal combination into Category C, a category which requires a minimum preheat of 300 degrees F.

ELIZABETH MATTFIELD
is the Technical Director at Atlas Evaluation & Inspection Services.

After determination of preheat via hydrogen control method (Annex H of AWS D1.1:2015), it was verified that indeed, this base metal should have been preheated to a minimum temperature somewhere between 300 and 320°F.

One can argue that the fabricator was perfectly within his right to use AWS D1.1:2015 Table 3.3, and that the material was indeed certified as a Group II metal. But whether or not this material can be classified as a different grade by ASTM or AWS is not the point. Instead, the mill test certificate's information should have raised a flag that this material and preheat needed special consideration beyond AWS' general Table 3.3. This is confirmed in the AWS code's commentary, which advocates against the use of Table 3.3 without careful consideration of factors as covered by Annex H, used in my analysis. Simply stated, Table 3.3 is a tool that is available, but it is up to the fabricator to determine if it satisfies the conditions required to make sound welds. In case, elevated preheat beyond Table 3.3 would certainly have been warranted. Annex H of AWS D1.1:2015 is an excellent tool for structural engineers tasked with reviewing mill certification reports, since it aids in determination of preheat using a combination of factors: chemistry, restraint level and hydrogen control.

Despite its importance, insufficient preheat is rarely the sole cause of cracking. In this particular case, the weld was joining two very thick pieces of material, each 3-1/4" thick. The volume of weld metal alone produces a joint of extremely high restraint, with stresses far exceeding the tensile strength of the steel during welding and cooling occurring with each pass. The addition of stress relief holes at each end of the joint would provide a path for relief of heating and cooling stresses. Instead, the weld starts and stops abruptly at the ends of the tee joint, a perfect location for crack formation and subsequent propagation into the base metal.

Another noteworthy aspect of this operation was that the WPS did not have any provisions for post weld heat treatment. AWS D1.1:2015 does not mandate the use of PWHT, but it does repeatedly emphasize that joints must be considered on an individual basis and where needed, PWHT must be prescribed. In the case of steel over 2" in thickness, PWHT in the form of a controlled cooling rate would have been quite beneficial in relieving the stresses induced during welding.

Besides the measures above, there are other steps that can be taken by this production crews to improve the execution of this joint and prevent cracking. For example, utilization of -H8 consumables place this gas-shielded FCAW process in a low-hydrogen category, which is a good start. However, current, voltage and gas moisture contamination are variables of low-hydrogen demand projects that can be monitored and controlled to avoid increasing the amount of diffusible hydrogen in the joint.

In conclusion, finding a singular cause for weld cracking can be a near impossible task, particularly in a shop with proficient welders and established welding procedures that are rarely questioned. Fortunately, control of at least some of the most common contributing factors can often be enough to preclude weld cracking. In this case, the contractor's determination of appropriate preheat and interpass temperatures for thicknesses over 2" and providing stress relief holes in the joint would likely have been sufficient to prevent the welds from cracking.

TRANSFORMATION

of the practice of design

(AKA: Speed Kills)

By JOSEPH TORTORELLA

WHEN I ENTERED THE INDUSTRY 35 YEARS AGO, THERE WERE no desk top computers. There was no BIM. Most everything was done by hand calculation. If you had a high rise building or a particularly challenging structure that required more power to analyze, you bought computer time, wrote programs that required punch cards and spent countless hours hoping you entered every keyboard strike correctly, otherwise it was back to the beginning to search for the error. You had "job checkers". This was a person in the architect's office whose primary role was to simply continuously check the project teams drawings for coordination, completeness and constructability. Projects followed a set schedule of Schematic Design, Design Development, Construction Documents and Construction Administration. The owner had a vision and a budget and the project team designed the structure to suit both, and the construction team worked diligently to insure its success. There was no fax machine to send RFI's through quickly. No email to respond to questions instantaneously. No drop boxes or project information exchange sites. No Federal Express. There was U.S. mail, messenger services and mylars. Blueprint machines were often from a service provided by others and when they were in house, the smell of ammonia (developing solution) permeated the office. Engineers even smoked at their desks and imagine this, they wore neck ties!

> **"What started off as a brilliant idea for saving time and money suddenly became a pressure packed method of design"**

Soon, the PC came into use in our offices. The first one arrived and we all took turns experimenting with it and learning how one might implement it in our next project. Eventually, we had programs to simplify the analysis work we had for so long performed by hand. The volumes of hand calculations for each composite steel beam were reduced to data entry and output. Lateral designs were much more easily managed and more accurately completed. Suddenly, we found we could design a structure more efficiently (but not necessarily better). We could finish a project faster than before and thus, bring a greater volume of work into our respective offices. After all, faster must mean cheaper (??!!) and we would thus all need more projects to sustain our firms. This would have to lead to better designs, better cost control, faster designs and construction (thus money savings for the owner) and ultimately more elegant designs. But did this occur? Bill Gates, the great American entrepreneur said it best when he spoke of technology in today's world: "The first rule of any technology used in a business is that automation applied to an efficient operation will magnify the efficiency. The second is that automation applied to an inefficient operation will magnify the inefficiency". I believe our current inefficiencies dealing with technological advances moving rapidly ahead, has resulted in overall inefficiencies far beyond what existed 35 years ago.

Due to this new found speed enabler, owners next found the need for what we call "fast tracking" of projects. This entails completing the foundation design and/or superstructure design long before the architects, mechanical engineer and all the other trades are close to completing their designs. Before finishes (which impact loading) are even being thought about, we are issuing final foundation drawings. The owner said "we understand the ramifications" (high level of risk of cost increase and change orders as well as errors) but it is worth the risk? This also meant, bringing the general contractor on board earlier. After all, if we were issuing drawings earlier, wouldn't they need to be prepared earlier?

What started off as a brilliant idea for saving time and money suddenly became a pressure packed method of design. Job checkers became a thing of the past. At this point, who had time to actually check and coordinate projects? This is not to say that we do not today have a robust QA/QC and risk management program. Simply, the time we took to properly design and coordinate projects became greatly compressed. To assist this all, "construction managers (CM's)" and "owners Reps" were created. How could an owner manage this entire high speed process without them? Now we had compressed schedules as a result of technology, and a much larger design and construction team due to layers added to manage the process. The job of the CM or the Owners Rep was not only to insure the project would be completed within the budget and on time. They also had the role of enforcers, pressing everyone to work faster and to save money and time yet meet budgets with increasingly fewer hours and staff members to produce the project with. Not exactly a collaborative notion. Then the next big thing arrived: Computer Aided Design or CAD. How fast we could now draft our projects and how great the coordination efforts could now be given we were all on the same platform. Of course, there were many CAD software's to choose from and not all fit well within each other. Some offices grasped the concept quickly, others lagged far behind. It was never an easy transition. It is actually repeating itself yet again with the implementation of Building Information Modeling (BIM). Once again, a way to do it faster, better and more economically. Building Information Modeling (BIM) s intended to facilitate and eliminate some of the growing pains listed above. It is easier to identify design conflicts that aren't readily visible on paper if they are modeled in three dimensions from the onset. The downside of this technology is that it means every conflict becomes a design decision, during a point at which the design itself is still in iteration. For instance, if a large duct modeled by the mechanical engineer interferes with the allowable space within the dropped ceiling, the architect, structural engineer and mechanical engineer will all be involved in a discussion for how to deal with this obstruction, at a point when beam and duct sizes have yet to be determined. Coordination has the risk of being a design constraint too early on. The main benefit of a three-dimensional model will be for the contractor to use as a basis for building off of. However, the design team will often not stand behind their BIM Model as something that the contractor can build off of, either for liability reasons or fee issues. Or, the Construction team does not want to wait for the BIM model from the design team and instead, creates a separate model. Therefore it is extremely common for the design team and the construction team to have separate BIM models. Technology waits for no one.

While it seems logical, it was a recipe that changed the course of engineering forever and, set up back in our management of the process

However, the CM's and owners reps told us "we now had all of these tools available so schedules (and fees) have to be tighter". While it seems logical, thinking back, it was a recipe that changed the course of engineering forever and, I believe, set us back in our management of the process. Speed took precedence over accuracy. Elegance took a back seat to economy. Home life took a back seat to work. The result was that the engineer became a tool for the Owners reps and CM's to use to their advantage to speed the process. Camaraderie that had long been a staple of our industry was losing steam as rather than thanking the entire team for doing a spectacular job under extreme circumstances, the owner was looking for whom to blame for the delays, costs spirals and errors and omissions. It was now "every man for himself" in the endless battle of costs and delay claims and who was to blame. This was not the "master builder" at work with the entire team gathering around to learn the process; rather it was a complete loss of control over the process by the design team. This in turn created friction and stress along with reduced fees and what I believe is the "commoditizing" of our services. What was an invigorating process suddenly turned into liability control, especially in the U.S. where our legal system encourages frivolous lawsuits. Project meetings were no longer about finding success; rather they were about finding fault for failures. I understand that "time = money" but at what cost to the public. Does the speed at which we work: fast tracking and cutting corners REALLY save money? Too often, it has been proven that it does not. It is time for a change. It is time to go back to the days of collegiality and elegance in the design process…not just the design. I am not suggesting that we go back to the days of hand calculations and hand drafting or even the days of the "master builder". I simply would like to slow down, rethink fast track scheduling and reinvigorate the process. Why do we all fear asking or dictating to the owner that we need more time? The time has come for us to do things right again and take control over our lives. Could we lose the next project? Perhaps. Is it really worth what we do to our staffs on a daily basis to ignore this and keep doing things "business as usual"? I think not.

JOSEPH TORTORELLA
is President at Silman.

call for writers
(and nonwriters!)

we could use your help!

Interested in writing about our profession?

Do you have great ideas, but no time to write?

Contact us at
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seaony.org/publications

Photo of the President's Breakfast in action at the Center for Architecture on April 13, 2016.

SEAONY President's Breakfast

SEAONY President's Breakfast Roundtable occurs every spring. The event is based on a central theme and four related topics. Each topic is led by a moderator while attending members are encouraged to participate in the dialogue. This past April, the theme was Advancing in Engineering and the four topics covered were: Mentoring, Self•Marketing, Business Dvelopment, and Education. SEAoNY would like to thank the attendees and especially the moderators, Joe Tortorella of Silman, Scott Lomax of Thornton Tomasetti, Erik Madsen of Madsen Engineering, and Mohamed Arafa of Severud.

Visit the SEAoNY Events page for upcoming events!

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