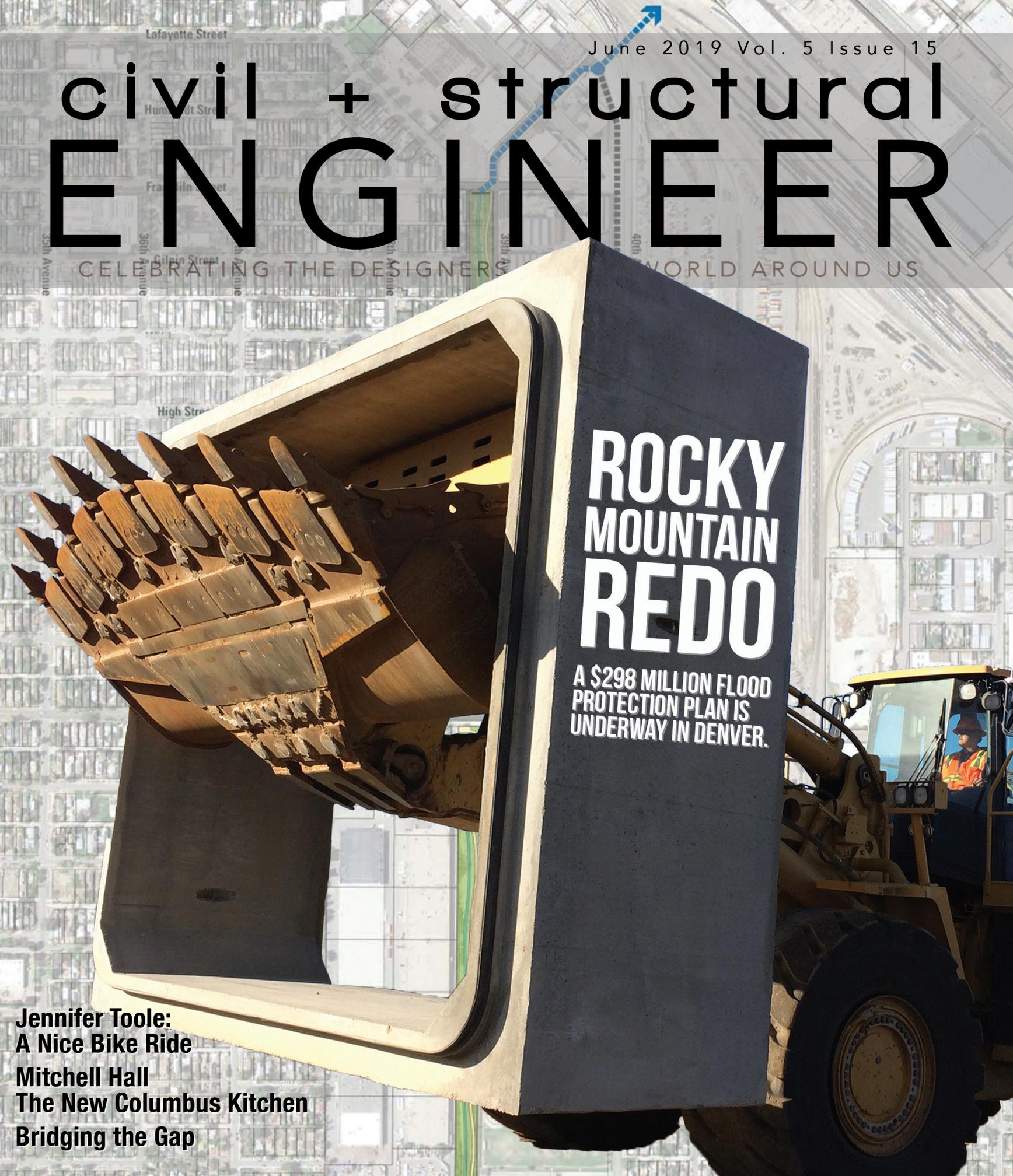


June 2019 Vol. 5 Issue 15

# civil + structural ENGINEER

CELEBRATING THE DESIGNERS OF THE WORLD AROUND US



## ROCKY MOUNTAIN REDO

A \$298 MILLION FLOOD PROTECTION PLAN IS UNDERWAY IN DENVER.

**Jennifer Toole:**  
A Nice Bike Ride  
Mitchell Hall  
The New Columbus Kitchen  
Bridging the Gap

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## CHANGE AND CELEBRATE

WOMEN ARE DOING THEIR PART,  
WE MUST DO OURS

**WHEN WE TALK ABOUT DIVERSITY AND INCLUSION**, we talk about a lot of things. Gender, ethnicity, nationality, expertise, perspective, life experience, and sexual orientation, among others. But when it comes to the engineering industry and the people who work in it, the most basic aspect of diversity and inclusion centers on men and women. Men have comprised much of the engineering field for decades and women have not. We see that legacy every day.

But the world is changing – perhaps a bit slowly for some. But change is afoot. In its mission to Elevate the Industry, Zweig Group is committed to helping bring that change about. And as it pertains to Civil + Structural Engineer magazine, it means that we run stories on the great women who we hear about through our massive data base, or who we contact through client connections and personal referrals. This is not happenstance, but an intentional effort to celebrate the women who help shape the world in which we live. While the gender gap is still large – both rank-and-file and within leadership – and though pay equity remains an issue, there’s no denying that there are plenty of women doing fantastic things in the AEC industry.

But before I get into anything specific about any particular person, let’s look at a few facts and figures.

Among those surveyed by Zweig Group through its Best Firms to Work For questionnaires, 86 percent of all women bought the maximum amount of company stock when they became principals. And nearly half of all women – 44 percent – borrowed money to ensure their ownership stake in the company. Women, the research shows, are doubling down when it comes to committing to their careers in the AEC industry.

And then there’s this statistic: 100 percent of women in the AEC industry considered leaving the profession altogether. That’s not good, but look at the bright side: 50 percent of women considered leaving their current firm to start their own firm, as opposed to 21 percent of men. This speaks to entrepreneurship – something the industry still needs more of. If women are going to be part of an innovative, disruptive future, then more power to them.

It’s easy to get mired down in statistics. Instead, I’ll just state the obvious – while a lot of work still needs to be done, there are obvious signposts pointing to a more gender-balanced future in our field. With that said, consider a few of the women who have been, or who will be, featured in the magazine.

In last month’s issue, we had Emily Herndon. The high-flying strategy consultant built a career working at two of the largest engineering firms in the world. She told the magazine that life at the larger firms gave her access to great colleagues and clients, and that the real-world education was priceless. Herndon eventually took her experience to Woolpert, where she’s building out a strategy consulting team and has the freedom to function as an entrepreneur. What’s interesting about Herndon is that she’s not an engineer or an architect. But she does have a science background, giving her the “in” she needed to otherwise do what she does best – identify big problems and offer even bigger solutions. Herndon, with 20 years on her resume, has enough experience to be part of the past, but there’s still enough in front of her to be part of the future.

In this issue, we have Jennifer Toole. The founder of Toole Design said her old bosses at the old firms where she worked didn’t know what to do with her. She didn’t see a path forward, either. So, what does she do? She starts her own firm. And she’s done a great job, too. In less than 20 years, Toole Design has grown to nearly 200 people with offices across the United States and Canada. With the emergence of micro-mobility in major cities across the nation, Toole says her firm, which specializes in urban design and greenways, has found a niche within a niche. She said she plans on growing her firm if she can find enough qualified talent in a tight labor market. That’s not going to be easy, but if history tells us anything, it’s that Toole will figure out a way to find and hire the right people to help push her firm forward.

And stick around. This fall we’re going to have a special guest in our magazine, and hopefully on the cover!

I say all this as a reminder that talk is cheap. If you’re going to help bring about change, you must do something about it. In the pages of this magazine, we’ll celebrate the women who have made themselves into industry leaders. We’ll let them tell their stories to thousands of people and, hopefully, be an inspiration for others. In the process of bringing about change, what are you going to do?

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## IN PURSUIT OF EXCELLENCE

THIS IS A CONSTANT JOURNEY THAT  
REQUIRES COMPLETE DEDICATION

**WE CONSISTENTLY HEAR ABOUT MILLENNIALS** being lazy and unfocused. This bleeds into other generational groups as well. In fact, while crafting firms' strategic plans, I often hear about QA/QC issues. Leaders in firms lament about how they must pay extra attention because the workforce today doesn't have the same attention to detail, reverence for quality, and doesn't understand how that affects client relationships. These are simply symptoms at the periphery of the core issue. What has seemed to shift is the focus on true mastery of your chosen profession and a willingness to look internally to develop an individual and collective morality in the pursuit of excellence.

Making a commitment to mastery and excellence will make your life a lot simpler. It will take away excuses and reasons for your leadership to doubt you. Filter your actions through a personally driven mission, vision, and value lens. These should align with the firm you have chosen to dedicate your time to. If it doesn't, you probably aren't working for the right firm or the right people.

I hear a lot about work-life balance and flextime policies these days which partially, in my opinion, is to pursue temporary pleasures. I'm not saying that there aren't very important reasons for having this balance as most people define it. Not only will mastery, excellence, and moral purpose help you professionally, but also in your individual pursuit of happiness. In a previous life, I started a medical device firm with the purpose of treating clinical depression. In this capacity I learned just how severe and to what magnitude people around the world are suffering.

Whether you come to the realization through a religious world view, through enlightenment reasoning, or other methods, happiness is a moral purpose. That purpose you've chosen is the profession and activities you are dedicating your life to. In fact, Aristotle defined happiness in a life well-lived. To him, something was good if it fulfilled a purpose. A human's purpose is to act with right reason which makes us unique. George Washington stated "the consideration that human happiness and moral duty are inseparably connected. ..." Austrian psychiatrist Victor Frankl wrote in his memoir about surviving the Holocaust, "Woe to him who saw no more sense in his life, no aim, no purpose, and therefore no point in carrying on. He was soon lost."

This isn't merely subjective but backed up by evidence and several studies like the one at the University of Carleton in Canada which found those who reported a strong purpose in life at the outset of the study were 15 percent more likely to be alive than those who did not – for every age group. A study of 951 patients with dementia found those who felt a sense of purpose were 2.4 times less likely to develop Alzheimer's than others. This has been replicated over and over again, so I won't belabor the point. Needless to say, I'd hire a person who's taken the time to figure out who they are, who acts with moral purpose, and is committed to excellence in their chosen discipline; someone of true character that aligns with my firm over someone with an excellent skillset on paper any day of the week.

Assuming 8 hours of sleep for each of us, that leaves us with 16 hours a day, which requires just about all our waking hours be directed towards activities that help us become professionally and personally better. The goal is to achieve mastery. This isn't working constantly for 16 hours a day. That is simply impossible. It is, however, aligning all of our activities and actions toward this goal. Leaders are readers and this is a part of your development. Developing yourself physically

---

**PHIL KEIL** is director of Strategy Consulting, Zweig Group. Contact him at [pkeil@zweiggroup.com](mailto:pkeil@zweiggroup.com).

is also key. It will help your cognition, it will help you perform at a higher level, and let's face it, this is a long-term game that we are all hoping to be involved in for some time. Given that, here are a couple of steps you can take right away to help inculcate these qualities in you.

1. Build yourself a routine that allows you to learn, reflect, gather feedback, exercise, and operate at the highest level of excellence in your daily work environment. Something you consistently follow. For me, I have several routines throughout the day. Outside of some of the topics we've discussed so far, I have three pillars, which if not in alignment, do not allow me to operate optimally in my professional life – faith, family, and fitness.
2. Develop a method that allows you to improve on moral and character issues. Benjamin Franklin was notorious for developing methods for self-betterment. He actually created a calendar of virtues, seeking to wipe out his tendency toward wrongdoing. You can find this online. He also kept a journal that allowed him to track progress.

This isn't going to happen overnight. This is a constant journey that promotes complete dedication to excellence in your professional life. As Jocko Willink says in his book, "Extreme Ownership," discipline equals freedom. It is a great concept. Don't try to do everything at once. Slowly integrate new habits and new routines into your life. Discipline is key, though. Willpower or motivation is not enough. Take these thoughts and suggestions to heart, and the probability is pretty good that you will be very successful in your career and likely make it to the Principal/Ownership level.

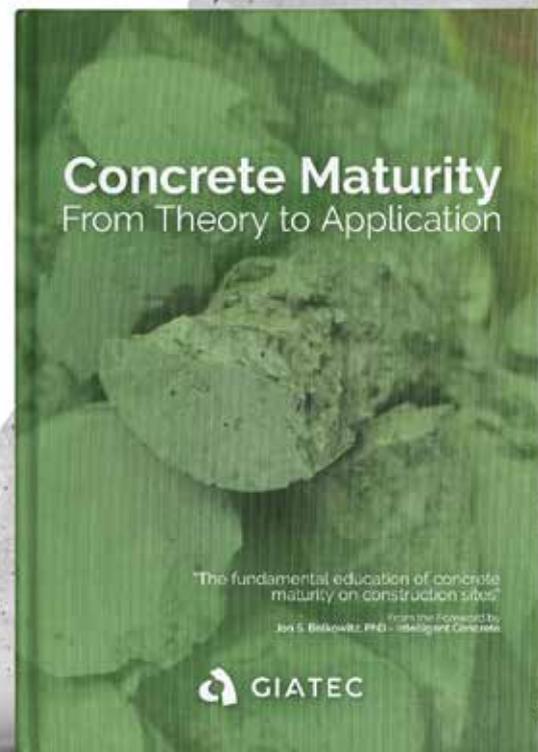
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**ROLLS-ROYCE SUPREME.** If you haven't already heard, the Guyton Collection – a famous assortment of classic American and European automobiles assembled by the late architect Fred Guyton – recently sold at auction for an astounding \$11.7 million. The auction, hosted in St. Louis by Sotheby's, saw bidders from 27 countries buy 73 cars and an assortment of art and memorabilia. The showstopper was the 1909 Rolls-Royce 40/50 HP Silver Ghost Roi des Belges in the style of Barker, which went for \$1.3 million, far outpacing the pre-sale estimate.

Other highlights included the sale of a 1938 Rolls-Royce Phantom III 'Parallel Door' Saloon Coupe at \$423,000, and a 1925 Rolls-Royce 40/50 HP Silver Ghost Piccadilly Roadster, which went for \$280,000. The auction also featured a 1927 Bugatti Type 40 Grand Sport, reportedly one of Guyton's favorite cars. It sold for \$362,500. Clearly, Guyton had a keen eye, plenty of respect for the process of car collecting, and the resources to indulge his passion.

But let's not just look at the cars. Let's look at the man. Guyton, who passed in September, was survived by his wife, seven children, and 10 grandchildren. Before serving in the US Army as a helicopter pilot, Guyton spent a year in Bogota, Colombia as a Peace Corps volunteer. He co-founded his own firm, PGAV, now a 100-plus person company which is still very much in business designing facilities for the hospitality and leisure market.

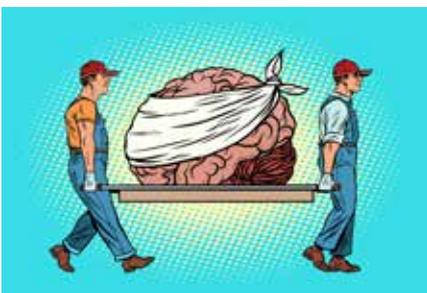
It's clear Guyton led a full life, enjoyed himself, and left behind a great legacy for a lot of people. You can't ask for more than that.



Photo: Darin Schnabel ©2019 Courtesy of RM Sotheby's

**BOSTON BEANS.** Everyone knows it's a tight labor market. So, what do you do when a large legacy architecture firm just ups and closes its doors, leaving a lot of people unexpectedly out of work? Well, if your Ozzie Nelson, Chairman and Co-CEO of NELSON, you hire them. Shortly after news of the Steffian Bradley Architects closure broke, there came another story with Nelson announcing the hire of longtime SBA architect and principal Bob Humenn. In the article, Nelson said he had plans to hire more former SBA employees to beef out the firm's Boston healthcare offerings.

But back to the shocking news. SBA, founded in 1932, closed its doors in April for no apparent reason. But we know something must have gone wrong. Try as they might, the Boston Business Journal and the Boston Real Estate Times couldn't turn up any hard dirt or smoking guns. As far as we know, it could have been a failed leadership transition. Back in March 2016, the New England Real Estate Journal published an announcement about SBA's plans. The leadership transition was supposed to take place over the course of three to five years, where one executive would increasingly assume the responsibilities of the incumbent President of US Operations. But in July 2018, a little over two years into the transition, the emerging executive took a big job with another firm, leaving SBA after nearly 20 years. So much for the three-to-five-year plan.



**GOOD OL' FLORIDA.** They say stupid things happen in Florida. Nothing could be so true.

Just this year, at least two engineers and one firm have had their licenses revoked in The Sunshine State. One engineer took partial payment from a married couple looking to add an extension to their house. The engineer drew up preliminary drawings for the house, took \$1,800 of the \$2,700 fee, but never produced the final drawings. "The homeowners tried numerous times to get a response and a timetable for completing the final drawings. The homeowners tried unsuccessfully to get respondent to complete the engineering services contracted for or to get a refund of their payment. Respondent hasn't responded to any communications," according to the case file with the State of Florida Board of Professional Engineers. For that stellar piece of customer service, the engineer had his license revoked.

Another engineer was caught practicing on a suspended license. He also happened to be the owner of the firm. With a suspended license, he could not function as the firm's principal officer, and therefore could not operate the firm. It looks like this guy was a single-shingle, meaning he was the only engineer there. When the state board asked for proof of a new principal officer, someone who could run the firm according to state law, the respondent could not, or did not, provide it. That left the board with only one solution: Revocation. According to research by Zweig Group, a civil engineer at the principal level makes as much as \$150,000 a year. Heck, even an engineer at the PM level makes as much as \$110,000 annually. That's the house, the kid's college fund, the boat, the vacation, and the retirement. It makes you wonder what's going through someone's head when they throw it all away. But as they say, stupid things happen in Florida.

If you know of an interesting or off-kilter story taking place in the AEC industry, please contact C+S at [rmassey@zweiggroup.com](mailto:rmassey@zweiggroup.com).

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06/16/2019



## A NICE BIKE RIDE

JENNIFER TOOLE, AICP, ASLA, FOUNDER AND  
PRESIDENT OF TOOLE DESIGN

By Liisa Andreassen

**WHEN SHE WAS COMING UP THROUGH THE RANKS**, Jennifer Toole said she became increasingly frustrated. There were no women in top positions at the firms where she worked and, moreover, the firms had no history or tradition of promoting women. Toole said she had a sense that her employers didn't know what to do with her. Fortunately, she knew what to do. In 2003, when she was 36, she founded her own firm, Toole Design.

"I really didn't have another choice but to start my own company," she said. "I couldn't succeed any other way."

Based in Maryland, the urban design, multi-modal and greenways firm has since grown to 17 offices throughout North America that employs over 180 people. And if Toole has her way, the firm will continue to grow like it did in 2018, when both staff and revenue increased by about 30 percent. The firm has openings for as many as 30 positions across various locations and, if the firm can find the right people, it'll make the hires.

"I want to continue to grow," she said. "There's a tremendous demand for what we do. I see a lot of need."

In a tight labor market, growth won't be easy. But Toole and her firm have an advantage. They attract people who not only like what they do, but who believe in what they do. Of the firm's 17 offices, 16 of them are located in high-density areas that are accessible by foot, bike or public transit. Ninety percent of the firm's employees either walk, ride, or take public transit to work each day.

Toole, as principal-in-charge, is in the middle of creating a 75-mile bike network in New Orleans, a town known for its trolley cars. The master plan is complete and now in the design phase. Toole Design is also a leader in the field of micro-mobility, which has seen explosive growth through dockless bikes and scooters, now ubiquitous in large cities across the nation.

"It's a brand-new way of getting around, and we are at the forefront of that movement," she said.

While Toole did not come from an entrepreneurial family – her father was a company man – she certainly considers herself to be one, as she has always been interested in the "business side of things." And like any good entrepreneur, Toole's goal is to create a legacy, something that can outlast her – when the time comes to do something else.



"I would love to be able to transition ownership to people who have been with us all along and who are just as passionate as I am about what we do," she said.

### A Conversation with Jennifer Toole

**C+S:** *How far into the future are you able to reliably predict your workload and cashflow?*

JT: Despite the unpredictable nature of our projects, we've gotten this down to a science. If you have good project managers and a solid administrative team that moves invoices out the door quickly, then workload equals cashflow. As such, we focus a lot of attention on predicting and managing workload. We use different tools for the short term (two-four weeks) versus the long term (six-12 months). We know in advance when an office or a department will either be overloaded or running light on work, and we take measures to shift workload as necessary. Finally, we don't count our chickens before they hatch. Our workload projections are only based on solid project wins – not on "maybes."

**C+S:** *How much time do you spend working "in the business" rather than "on the business?"*

JT: The best part about my job is that I get to do both. The reason I'm in this business is because I have a deep conviction in the power of walkable, bikable, transit-friendly streets to transform communities. I wouldn't be happy if I didn't get a chance to work "in the business" every day. But I also really love the nuts and bolts side of running a growing company, along with all the trials and tribulations that brings. As the company has matured, I like to think that part of my brain matured as well.

**C+S:** *What role does your family play in your career? Are work and family separate, or is there overlap?*

JT: My family is absolutely central to my ability to be a good CEO, but they aren't involved in the day to day work. I have been blessed with a wonderful husband and three children who have supported me in every way, from the moment we started the company. Their support and



Jennifer Toole, founder and president of Toole Design

encouragement gives me strength, especially during those times when I'm frustrated, worn out or discouraged. Also, I think being a working mother has helped keep my job in perspective. There is only so much time in the day, and my kids demand (and deserve) a portion of it. I'm a type A, driven person who could have easily been consumed by my job – having a family has always kept me grounded in what really matters in life.

*C+S: It is often said that people leave managers, not companies. What are you doing to ensure that your line leadership are great people managers?*

JT: We spend quite a bit of time working with managers to help them understand how to be good leaders, and coaching them as they work through the challenges that every manager faces: motivating staff to do great work, ensuring staff know their contributions are valued, building a culture within their office or department, dealing with difficult situations, etc. It frankly comes down to providing the maximum amount of support you can to managers. So far, it seems to be working – our turnover rate is low considering how competitive the market is for top talent.

*C+S: What novel approaches are you bringing to recruitment, and how are your brand and differentiators performing in the talent wars?*

JT: We aren't into gimmicks. We don't own a foosball table, we don't

offer pet insurance, or have a kitchen stocked with free snacks. What we do offer is a chance to do meaningful work for a company that has a clear mission to make communities safer and healthier places to walk, bicycle and use transit. We don't take on projects that conflict with that mission, even if it means we would make more money. We tend to attract people with similar values who appreciate that we stick to our principles.

*C+S: Is change management a topic regularly addressed by the leadership at your firm? If so, elaborate.*

JT: Change management has been a consistent topic of discussion from the beginning. Toole Design has grown at 15-25 percent per year since we opened our doors in 2003, so change is one thing we learned to embrace. Growth at that pace requires constant reinvestment, so early on we learned to run a lean operation and to invest in systems that anticipate growth. Another aspect of change management is helping our staff appreciate the opportunities that come with change. We always try to help them evolve and grow along with the company. I'm happy to say that we have a strong history of promoting from within. We have talented people who have stepped into leadership positions as the company has grown.

*C+S: How do you handle a long-term principal who is resting on his or her laurels? What effect does a low-performing, entitled principal or department head have on firm morale?*

JT: Thank goodness we have not had this problem yet. But just in case any of my long-term principals are reading this, I have a message: don't even THINK for a moment about resting on your laurels!

*C+S: You want high utilization for profitability, but that means employees are fully loaded with assignments. How do you balance growth, utilization, new clients, and new hires?*

JT: I think every company struggles with this. I'm pretty sure we are a long way from solving it. For us, it goes back to accomplishing our mission – we need our staff to remain focused on delivering outstanding projects that make cities better and safer places to walk, bicycle and use transit. I find our staff are motivated more by our mission than a profit margin – and that is OK.

*C+S: They say failure is a great teacher. What's the biggest lesson you've had to learn the hard way?*

JT: Thankfully, we have not had any big failures so far. We've never closed an office or laid off employees for lack of work. We've managed to avoid financial catastrophes. Most of my lessons have been little ones – realizing I was too cautious when I should have gone for the gusto, or didn't take quick enough action to address a brewing problem, or failed to delegate authority and let someone else have a chance to fail.

*C+S: What happens to the firm if you leave tomorrow?*

JT: I'm happy to say that Toole Design would be fine. We have been

## TOOLE DESIGN

**Year founded:** 2003

**Headquarters:** Silver Spring, MD

**Jennifer Toole:** 31 years of experience; Bachelor of Environmental Design, Landscape Architecture, North Carolina State University; American Institute of Certified Planners

**No. of employees:** 180

**No. of office locations:** 17

**Expertise:** Engineering, landscape architecture and urban design and planning

**Mission:** Creating spaces for people in motion: Their mission is to reimagine streets and transportation networks to serve every member of the community. When they put their heads together, they plan for action and turn it into reality. From Vision Zero action plans and innovative data analyses to final design and construction documentation, their engineers, designers, and planners work across disciplines to make sure that their clients can help their communities become safer and more accessible.

**Fun fact:** 90 percent of Toole's staff bikes, walks or takes transit to get to and from work.

**TOOLE**  
DESIGN

careful and deliberate to set up systems to make it possible for the company to carry on, no matter what happens to me. I am blessed with partners who are extremely smart business people, and I have no doubt that they would steer the ship on a steady course.

*C+S: Diversity and inclusion is lacking. What steps are you taking to address the issue?*

JT: The lack of diversity at Toole Design, and in our profession in general, worries me. A diversity of perspectives is critical to developing well-informed and creative solutions that are tailored to the communities we work for. This is especially true for transportation, which has a well-documented history of inequitably impacting people of different incomes and backgrounds.

About a year and a half ago, Toole Design formed a Diversity and Inclusion Committee to tackle this issue head on. This internal committee is composed of representatives from each of our offices. Over the course of about eight months, we explored what diversity means in



Jennifer Toole, third from left, with staff members from Toole Design's Portland Office on the Tilikum Bridge. Photo: Toole Design Group, LLC

each of the cities where we have offices. We looked inward and asked ourselves whether we provide a truly welcoming and inclusive atmosphere to our employees regardless of their background. We examined our own successes and failures in addressing equity in our projects.

The result was our Diversity and Inclusion Plan, which we have begun to implement. We have our own version of the "Rooney Rule" which says we will interview at least one minority candidate for every open position. We still hire the most qualified candidate no matter what their background is, but I've found we need that extra push to get diverse candidates to the table. We hired a new Director of Diversity and Inclusion who is taking our committee to the next level. We realize we will never truly be finished with this work, but it's important to start the conversation and not shy away because it's difficult.

*C+S: A firm's longevity is valuable. What are you doing to encourage your staff to stick around?*

JT: Fundamentally, it's a combination of having great projects and being a great place to work. We stay true to our mission, and focus on performing creative, high quality work. We are fortunate to work in one of the most exciting areas of transportation planning and design – and attract people who are passionate about what we do. We are on the leading edge of innovation, and our staff are driving this change.

We also focus a lot of energy on maintaining a collaborative and supportive work environment. We're always looking for new, cost-effective ways to be a better workplace through events, staff recognition, professional development, and more. We make it clear that we are invested in their success. By combining these ingredients, we have been fortunate to retain staff for the long haul.

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# INFORMED RESILIENCY

KINEMATRICS AND ITS OASISPLUS EARTHQUAKE TECHNOLOGY

LOOKING AT HOSPITAL DEPLOYMENTS

By Editorial staff

**FIRST DEPLOYED IN THE UNITED ARAB EMIRATES** at the Burj Khalifa in Dubai, OasisPlus is a piece of technology platform that provides critical information before, during, and after an earthquake, in real time, on and offsite.

Devised as a tool to save lives and minimize business disruptions, OasisPlus is perhaps getting its second wind as resiliency continues to trend upward. It doesn't hurt that OasisPlus, a product created by OSS, the system's division of Kinemetrics, is based in Southern California, ground zero for the resiliency movement.

OasisPlus and Kinemetrics are making their push into the hospital systems in California. The time is right, said Ogie Kuraica, Kinemetrics president and CEO. Via the ShakeAlertLA app, earthquake early warning has already arrived in Southern California. State officials are hoping to introduce the world's most sophisticated early-warning system, similar to systems now active in Mexico and Japan, statewide in the near future.

"We see a new wave of opportunity," Kuraica said. "We'd like to get into the major hospitals in California."

So far, so good. Kuraica said the OasisPlus system is being deployed at Seattle Children's Hospital with deals finalizing at medical centers in San Francisco and Los Angeles. Earthquakes can be particularly dangerous for those staying in hospitals as surgeries and other treatments can be disrupted during a quake and a subsequent evacuation.

In terms of minimizing business disruptions, Kuraica looks back to 2013 and finds a good reason why the OasisPlus technology is important. Earthquakes in Iran and Pakistan forced evacuations in Abu Dhabi and Dubai, but those evacuations didn't need to happen. The post-quake data available to decisions makers at the time was insufficient. And in Abu Dhabi and Dubai, both important international financial centers, evacuations can create exorbitant – and unnecessary – losses.

Kuraica wants to curb such disruptions.

"Not every earthquake deserves the same notification," he said.

For good reason, panic sets in when there is a quake. After the shaking stops, people are confused as to what they're supposed to do. Should they stay or should they go? That's the big question OasisPlus, Kuraica, and chief designer Mauricio Ciudad-Real seek to answer, and



Ogie Kuraica, President & CEO, Kinemetrics, Inc. Photo: Kinemetrics

**OasisPlus is a technology platform designed to provide the tools and information you need before, during, and after an earthquake to control impact and ensure business continuity.**

- Avoid unnecessary evacuations and business process interruptions to secure ongoing critical operations
- Enable better-informed decision making during an earthquake to assure continuity of operations
- Protect your brand from damage associated with mishandling of emergency situations
- Minimize expensive downtime and distress

**OasisPlus empowers response teams to:**

Understand how the earthquake has affected their building  
 Know the location and condition of building occupants  
 Target their emergency response to the areas that need it most  
 Communicate instructions directly to occupants via the smart phone app



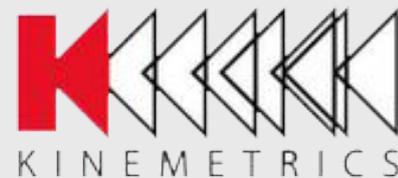
Mauricio Ciudad-Real, senior program manager, OSS. Photo: Kinematics

**“WHEN YOUR BUILDING SHAKES, SENSORS MEASURE THE MOVEMENT, AND OASISPLUS EVALUATES THE RESULTS BASED UPON DETAILED UNDERSTANDING OF YOUR BUILDING’S PERFORMANCE AGAINST THE TYPE OF MOTION MEASURED.**

**“THIS EVALUATION IS TRANSLATED INTO A SET OF ALERT LEVELS THAT INDICATE THE IMPACT YOU SHOULD EXPECT IN THE DIFFERENT AREAS OF YOUR BUILDING.” — OASIS PLUS**

When an earthquake hits, we all feel a moment of panic. As soon as your building moves, OasisPlus sends a Building Alert to each occupant who uses the mobile app. This alert snaps them out of that momentary panic, and reminds them of the proper response: Do Not Evacuate – Drop, Cover, and Hold On.

A detailed SAFE Report is automatically sent out to your designated list of recipients. This can be your leadership, response team, or even your structural engineering firm. The SAFE Report includes information on the alert levels across your building, as well as detailed building response information such as inter-story drift that your engineers will find helpful in assessing your structure. – OasisPlus



in the shortest amount of time possible. Post-quake inspections can take weeks, or even months, to conclude. In regard to mission-critical structures like schools and hospitals, or a vital business district, that’s too long.

But most of the time, a quake does not do enough damage to warrant an evacuation or an assessment, said Kuraica, citing a statistic that 80 percent of quakes cause no damage.

“A decision has been made without understanding what happened to the building,” he said, referring to the distinct lack of post-quake knowledge available to stakeholders.

The OasisPlus system is autonomous, meaning it is installed – sensors throughout the building and a console – then organization staff that is onsite as well as offsite (including remote leadership and consultants) are trained on how to monitor the system, so they are self-contained and can function on their own.

“It provides enough information to save a human life,” Kuraica said. “Sometimes staying is much safer than going.”

# HAVING A FIELD DAY

GEOTHERMAL SYSTEM COOLS AND WARMS ATLANTA BRAVES SUNTRUST PARK TURF, ADDITIONAL PIPE SYSTEMS DRAIN AND RECYCLE STORMWATER.

By Steve Cooper

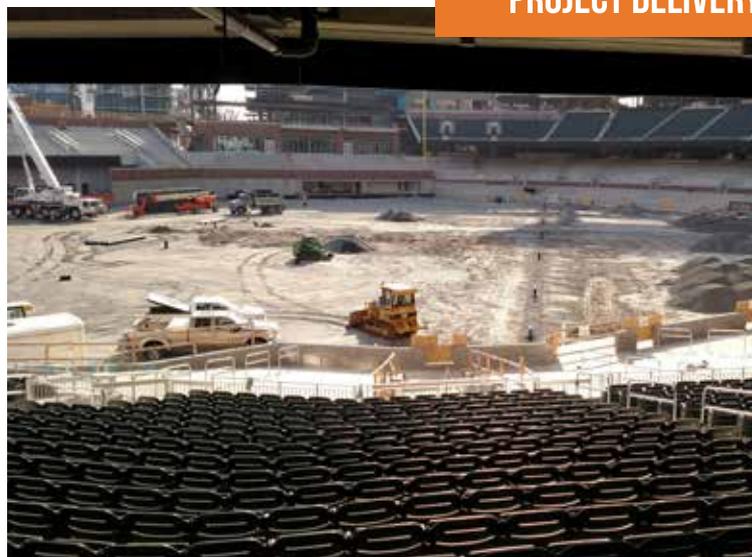
**DESIGNING A NATURAL TURF FIELD** for major league stadiums has been done since the game began. But figuring out a way to naturally heat and cool the grass while providing optimum drainage is new. And for the just-built Atlanta Braves stadium, failure of the turf management system would have meant the loss of games plus \$400,000 to replace the sod.

The \$672 million Atlanta Braves SunTrust Park features an innovative design for the drainage, aeration, and geothermal-fed temperature moderation of the root zone for the nearly 130,000 square feet of sod. The design objectives were to remove rainfall at a high rate, reuse stormwater and uniformly distribute air to provide moderate cooling or warming of the root zone. To meet those goals, some 20,600 linear feet of drainage pipe and 4,100 linear feet of irrigation pipe were installed along with more than a thousand feet of pipe for the geothermal system.

In November 2013, the Atlanta Braves announced the move from Turner Field in downtown Atlanta to a site in nearby Cobb County, Georgia. The new stadium would seat 42,000 and would be available to host other events. It had to be ready for the start of the 2017 major league baseball season.

Just about 20 years before, the Braves converted the Olympic Stadium into the Turner Field baseball stadium. The Motz Group, LLC (Cincinnati) constructed the field drainage system and the Braves asked Motz to do the same for the new stadium, SunTrust Park, but with some added features.

According to Mark Heinlein, senior vice president of Motz, "We installed our PAT system at Turner Field in 1996. When we learned that the Braves would be building a new stadium, I talked with Ed Mangan, who is the Head Groundskeeper, about whether there would be an opportunity for Motz to build that field for them. He said 'Well, I really like the PAT system, I've had it for 20 years. What I really need to do is to be able to move air not only down through the field with vacuums, but back up through the bottom of the field with forced air'. We had thought about doing that for some time and said if you're willing to give us some time we'll do the research to prove that we can move air from the bottom of the field in a more efficient and more sustainable manner than other systems currently out in the market. So we built a 'to scale' section with our standard PAT system out in our research area and I hired Jim Goddard, and also Dr. Issam Khoury from Ohio University to help us figure this thing out. Our team did a lot of testing of things like pipe spacing, perforation patterns in the pipe, percentage of openings in the pipe, looked at moving hot and cool air through the system, and did a lot of data collection and analysis. This became our AirPAT root zone management system."



The SunTrust Park playing field under construction. Photo: The Motz Group

AirPAT captures the water with either gravity or a vacuum chamber to accelerate drainage and will also move air into the turf's root zone. The SunTrust system goes a step further by tapping the earth to provide the correct air temperature.

The mandate to Motz was to maintain turf temperatures above 39°F in order to avoid freezing of the grass root zone. The key component would be networks of thermoplastic pipes. Rain water would trickle down into one that would also provide a pathway for the temperature controlled air to heat or cool the root zone, another would use the collected rainwater for field irrigation, and another would be buried deeper to gather air for the geothermal system.

"Then, we got the idea of incorporating geothermal principles to provide the warm or cool air to the root zone in an underground loop of pipe." Heinlein said. "This had never been done before. Other systems had basically used giant furnaces to heat the air before blowing it into the system. Our test site confirmed that we could get warmer air in the winter and cooler air in the summer with the geothermal pipe system. We then went back to the drawing board and looked very closely at what kind of temperature differentials can we get from the ground 10 feet below, how much air do we have to move, how long does the air have to be 10 feet below the ground before we get that energy transfer of the warm winter air or cool summer air. And at that point we could effectively moderate the temperature of the root zone."

At SunTrust Park the Motz AirPAT system will keep a constant level of moisture available to the Seashore Paspalum Platinum TE grass in the playing area. AirPAT has a series of sensors that enable the grounds crew to monitor and control the oxygen and moisture levels along with the temperature under the field to keep the sod healthy even in winter and during extremely warm summer months.

The geothermal system is made up of 1,100 feet of 10-inch diameter, single wall, corrugated high-density polyethylene (HDPE) pipe with airtight joints from Advanced Drainage Systems, Inc. (ADS) (NYSE: WMS). "This pipe came in continuous coils of 300 feet," explained

Goddard, who retired as ADS' Chief Engineer and is now a well-known industry expert and consultant. "We wanted to have as few joints as possible for the runs to right and left fields, which is the longest at more than 450 feet to behind home plate. Air that is either cool or warm due to the temperature of the surrounding soil and depending on the time of the year, is fed through these pipes that are buried from nine to ten feet deep on a slope so that any condensation will drain. That depth was chosen because the ground temperature in the Atlanta area at that depth is historically between 64- and 67-degrees F.

"The air is then blown through AdvanEDGE® flat, perforated pipes, and moves into the gravel then the sand level and into the root zone of the turf. The system is designed to replace all the air moving into the field every 10 minutes."

The gravel layer is the equivalent of American Association of State Highway and Transportation Officials (AASHTO) #89 crushed gravel with limited fines. The sand layer meets United States Golf Association (USGA) standards. There were 14,300 cubic yards of stone backfill and 4,500 cubic yards of root zone sand.

The AdvanEDGE pipe being used for both gathering rain water and heating or cooling the root zone is 12 inches wide and meets ASTM D700. It is also a product of ADS and was developed primarily for highway storm water drainage. The perforated pipe was designed to be installed on its edge to provide the largest possible drainage profile while reducing the width of the trench. At SunTrust Park AdvanEDGE is laid flat. This permits the pipe to be installed to drain water near the roots than would be possible with round pipe. Special fittings designed by ADS and Motz connect the flat AdvanEDGE pipe to the round ADS, N-12®, six-inch check pipe.

"We used the AdvanEDGE pipe because it is so very efficient," Heinlein stated. "What we determined in our research plot is that the standard ADS product wouldn't work for us, only because the standard perforations in a 12-inch AdvanEDGE pipe were not optimal for what we wanted to do. This was the first step in the research project. We took pipe that had no perforations, and manually drilled holes of various sizes and in different patterns. Those test pipes were put out in the research trial and we monitored what happens to the air as it moves through these different size holes and perforation patterns. We were able to determine the exact perforation pattern that we wanted for this system. It's now a custom perforation that ADS does exclusively for the AirPAT system."

## Field Drainage

The rate of storm water drainage under gravity flow is 2.7 to 3.5 inches per hour. The rain water percolates through the ground and into the AdvanEDGE pipe, and conveyed into a 30,000-gallon underground detention unit for reuse

"The system is built like a giant bathtub," Heinlein explained, "with the field wrapped in an impervious liner so every drop of water that falls on that field can be managed. No water goes into the ground – no water gets lost – every bit of it is captured. One of the benefits of doing that is to be able to take that water and do whatever you want with it.



Screenshots of the OasisPlus dashboard. Photo: Kinemetrics

When there is need for that water stored in the underground cistern system, it's brought through a series of particulate filters and UV filters that sanitize it and is ready to be reused. Ed uses that water for things like landscape irrigating, or for a quick wetdown of the infield before a game, watering down the warning track, washing down all of his equipment. It's all recycled water. Plus, the other benefit of the system is that the Braves can really conserve the water that gets put on that field because it can also be sub-irrigated using the captured storm water. As a water management system, it is extremely sustainable and very efficient, especially with Atlanta's history of severe drought conditions."

Additional information can be found at the ADS website: [www.ads-pipe.com](http://www.ads-pipe.com).

**STEVE COOPER** has reported on a variety of water, conduit and gas pipeline projects for several decades. Based in New York, he has traveled extensively to conduct on-site news interviews with professional engineers, contractors, government officials and representatives of major companies supplying the industry. He can be reached at 516/623-7615 or [steve@scacommunications.com](mailto:steve@scacommunications.com).

# A CONTAINERIZED ENVIRONMENT

TRINITY PRIVATE EQUITY GROUP INVESTS IN FALCON STRUCTURES, A CONTAINER-BASED STRUCTURE MANUFACTURER OUT OF AUSTIN, TEXAS.

By Editorial Staff

**TRINITY PRIVATE EQUITY GROUP** has made a substantial growth capital investment in Falcon Structures, a manufacturer of container-based structures. With this capital infusion, Falcon expects to double its number of employees by 2021 and ramp up the company's production capacity.

"Trinity's investment enables us to scale our business in order to dependably serve the rapidly expanding container-based structures market," said Stephen Shang, Falcon Structures CEO and co-founder.

The capital will fuel growth initiatives in Falcon's existing business of space augmentation using container-based structures, such as offices and storage units to re-purpose under-utilized space, field operations (mobilizing container-based structures to serve as working and living units for industrial field work), and equipment enclosures (containerizing high-value equipment to keep it secure and mobile).

Furthermore, as a premier private equity firm, Trinity recognized Falcon's potential to revolutionize the development and construction industry with fast, modular, container-based structures. This new partnership will leverage Trinity Private Equity Group's real estate experience to catalyze Falcon's entry into the modular construction market.

"Trinity is an exceptionally good fit for Falcon's strategic direction. They're bringing invaluable real estate resources to the table that will be instrumental in forging the future for container-based structures," said Shang.

Sanjay Chandra, managing partner at Trinity Private Equity Group and co-founder of American Leather is joining the board of directors, bringing extensive real estate and manufacturing experience to Falcon Structures. Alan Blake, co-founder of GloFish, is also joining Falcon's board of directors and lending his entrepreneurial experience to guide Falcon's growth.

"We see Falcon as a disrupter in construction technology with great opportunity for growth and setting a new standard in container-based construction," Chandra said.

Founded in 2003, Falcon can provide AC462 compliant containers fit for use as building materials. Every modified container is manufactured in Falcon's controlled facility to create a product that consistently exceeds customer expectations. Falcon's growing client base includes



Fortress Obetz, made out of more than 120 containers, in Central Ohio. Photo: Falcon Structures

major energy corporations, defense contractors, construction firms, and the US Department of Defense.

Founded by entrepreneurs in 2006, Trinity's current holdings exceed two billion dollars and are comprised of traditional private equity, real estate, energy, and growth investments. Trinity's array of analysts and expansive network of advisors allows it to evaluate opportunities across many industry sectors.

In an interview with C+S, Shang said interest in container-based structures has been on the rise.

"In the last five years, people have started seeing the benefits of starting with shipping containers,"

Over the last 15 years, the company has developed a sophisticated supply chain. The company works with two container sizes: 8 X 40 X 8.5, and 8 X 20 X 8.5. More than 120 containers were used on one structure, Fortress Obetz, in Central Ohio.

"These are big Legos," Shang said.

Containers make sense for multifamily construction, schools, and office-sharing facilities. The trend is one of growth, Shang said.

In the wake of the big investment from Trinity, Shang is hitting the speaking circuit, and will even do a bit of advocacy – lobbying the International Code Council to address guidelines for building with containers.

He describes the container market as a Blue Ocean, a market defined by opportunity and creativity, as opposed to a Red Ocean, one characterized by saturation and cut-throat competition.

"Now is not the time to be fighting over the pie, but to expand the pie," Shang said.

# Stray Current Induced Corrosion in Reinforced Concrete Parking Garage

By Sara S. Tabatabaei and Alfredo Bustamante

A new five-level parking garage is constructed in Arizona and located adjacent to multiple high voltage transmission lines. The contractor first experienced electrical shocks as they started construction of the third level. For obvious safety concerns, construction phasing was altered and an electromagnetic consultant was hired to provide a thorough investigation.



The electromagnetic specialist measured electrostatic and magnetic induced voltage/current and recommended installing a grounding system to resolve the electrical shock issue. The grounding system is designed to establish a low resistance path to ground. When metals are placed in the electromagnetic field, they act like an antenna picking up a voltage related to the magnetic flux, or the rate of change in the magnetic field. If the induced voltage on metal discharges through an electrolyte, such as concrete, the result can be corrosion. To minimize the effects of corrosion, a piece of metal is completely electrically isolated or connected to the grounding network so that the induced current discharges directly to the ground.

Next step after installing a grounding system, was to determine the amount of current that is flowing into the steel reinforcement of the parking structure (both mild steel and post-tensioning steel). A corrosion consultant was hired to assess the potential impacts from induced voltage in the steel reinforcement and metal elements of the building because of the electromagnetic field surrounding the transmission lines.

## Field Testing

The corrosion consultant performed four different field testing; grounding conductor measurements, prestress tendon tail voltage to ground, potential gradient survey of each deck, and antenna voltage to ground tests. A summary of each test is presented below:

1. **Grounding Conductor Measurements:** This test verified that grounding conductors are attached to the reinforcement and that conductors running from the columns to the ground rods were exposed to obtain the alternating current (AC) current flowing through them. The data collected from this test indicated that ground conductor current measurements vary from 0.55 A to 1.68 A.
2. **Pressure Tail Voltage to Ground:** The voltage between the primary slab tendon tails at level 4 and 5 to the ground rod were measured. Pressure tendon tail voltage varied from 0.24 to 24.5 at Level 4 and 5. The current to ground for these two levels varied from 0.05 mA to 0.19 mA.
3. **Potential Gradient Survey of Each Deck:** A potential gradient survey was conducted to test the voltage differences between two identical reference electrodes placed in contact with a wetted concrete surface. This test confirms that the grounding system is minimizing the potential differences that occur naturally.
4. **Antenna Voltage to Ground:** The antenna test consisted of a reinforcing bar oriented parallel to the transmission lines and was connected through a voltmeter to the ground rod in the building. The collected data indicates that significant voltages can be imparted to metallic objects near transmission lines, and that the voltages drop off significantly as the antenna moved away into the structure.

## Discussion

Stray currents are defined as electrical currents flowing through electrical paths other than the intended paths. Stray currents can arise from railways, cathodic protection (CP) systems, high-voltage power lines, or other resources. Stray currents can deviate from their intended path because they find a lower resistance, parallel and alternative route to flow.

Stray current interference can result in localized corrosion of reinforcing bars when current leaves or, in some cases, enters the steel. Reinforcing steel in concrete is susceptible to stray current because concrete is an electrolyte, thus a conductive medium, that supports the pickup onto and subsequent discharge of stray current from the embedded steel.

Stray current effects do not always result in corrosion of the embedded reinforcing steel. The damage to the reinforcing steel depends on several parameters, such as the type of current (AC or DC); the current strength; the presence of interruptions in the circulation of current; and the chloride content in the concrete.

The risk of corrosion induced by stray currents on steel embedded in sound, alkaline, and chloride free concrete can be extremely low. However, the presence of small amounts of chloride can lead to a noticeable decrease in the charge required to initiate corrosion. In the case of concrete structures contaminated by chloride, stray currents may have very serious consequences, even if the levels are too low to initiate pitting corrosion. Chlorides in concrete reduce its resistivity facilitating the circulation of stray currents<sup>1</sup>.

Stray AC currents are known to be much less damaging to steel than stray direct currents (DC). The effects of stray AC currents are more complex than the effects of stray DC currents. It has been proposed that by application of an AC current with a density less than 1.9 A/ft<sup>2</sup> on bare steel, there is likely no risk of corrosion, between 1.9 and 9.29 A/ft<sup>2</sup>, corrosion is possible, and at current densities greater than 9.29 A/ft<sup>2</sup>, corrosion damage is likely<sup>2</sup>. For the studied parking structure, based on the corrosion consultant's report, measurements of the grounding conductors current showed a range of 0.3 A to 1.68 A meaning that there was a low risk of corrosion of the steel in this structure.

The electrical resistivity of concrete is an important parameter for corrosion of embedded steel because it can facilitate or hinder the circulation of stray currents. Concrete with high resistivity provides protection for the embedded steel from stray current corrosion because it reduces the current flow<sup>3</sup>. Waterproofing membranes and coatings on the concrete surface can also provide an electrical barrier to the flow of stray currents.

The tail voltage measurement data indicated relatively small current values ranging from 0.05 mA to 0.19 mA AC. In addition to that, the post-tensioning system at the parking garage is electrically isolated because it is a fully encapsulated system. Therefore, it is unlikely that corrosion of the post-tensioning system will develop from an induction based current.

### Recommendations

We recommended to apply a protective top deck traffic coating to the Level-5 slab and to the outermost 18 feet perimeter of parking garage floor slab at all supported levels to avoid any water/chloride intrusion into the slab, early corrosion, and accelerate of corrosion by stray currents. All exposed metals on level-5 should be connected to the grounding system. This parking garage needs an annual periodic inspection of the grounding rods including stray current measurements.

### Conclusion

A good grounding system can minimize the effects of stray current and the potential differences that occur naturally. The risk of corrosion induced by stray currents on steel embedded in sound, alkaline, and chloride-free concrete can be extremely low. At low and moderate potentials and in the absence of chloride, steel corrosion caused by stray currents is unlikely. Waterproofing membranes and coatings on the concrete surface provide an electrical barrier to the flow of stray currents.

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Mitchell Hall is expected to anchor not only the Columbus State campus, but development in the surrounding area. *Photo: Design Group*

## MITCHELL HALL

NEW CULINARY CENTER EXPECTED TO SERVE UP FOOD, FELLOWSHIP, AND NEW DEVELOPMENT

By Richard Massey

**THE NEW HOSPITALITY MANAGEMENT AND CULINARY ARTS BUILDING** at Columbus State Community College in Ohio is just about done. The facility, named Mitchell Hall after lead private donor Cameron Mitchell, will increase culinary enrollment and elevate the quality of instruction.

Designed by Design Group and built by Gilbane, Mitchell Hall is the first major capital project on the Columbus State campus since 2006. The three-story building will be nestled in a green space, formerly a parking lot and a through street, and will feature a balcony overlooking the nearby Columbus city skyline. Conceived as the front door to campus and the surrounding Discovery District, Mitchell Hall is expected to be a catalyst for further development over the next two decades.

Chief Designer Mike Bongiorno, a managing director and design principal at DesignGroup, said the project was pure pleasure, but that doesn't mean there wasn't a certain amount of pain. As a Public-Private Partnership, the project had a large cast of stakeholders – Columbus State Community College, the city of Columbus, the state of Ohio, the Columbus Downtown Development Corporation, and private donors

### Features of the 80,000-square-foot, three-floor facility include:

- Doubling Hospitality and Culinary Arts enrollment capacity to more than 1,500 students.
- A professionally managed, student-staffed 50-seat sit-down restaurant and bar and 20-person retail café and bakery, both with outdoor seating.
- A 400-plus seat banquet-capacity conference center with onsite catering and a sweeping balcony overlooking downtown.
- Onsite farm-to-table food production gardens.
- A 100-seat culinary theater.
- \$33 million project cost

SOURCE: Columbus State Community College



The Culinary Hub under construction. *Photo: Design Group*

that include the American Electric Power Foundation, Cameron Mitchell Restaurants, Crane Group, and The Columbus Foundation.

“We had to make a lot of people happy along the way,” he said. “There were a lot of eyes on this. A lot of pressure.”

The scale of the project speaks for itself. The new facility replaces a two-kitchen setup located in a basement with an 80,000 square-foot showcase that features 11 teaching kitchens and labs, a restaurant, bakery, culinary theater, conference room and classrooms. The new building is expected to support a doubling of enrollment capacity to 1,500 students.

Bongiorno focuses on impact-driven, mission-driven architecture. His approach to his craft is full throttle, and while he values subject matter expertise – and used it on the Mitchell Hall project – he values innovative thinking – which he also employed for Mitchell Hall – even more. Born and raised in Brooklyn, NY, he is a cum laude graduate of the prestigious Pratt Institute School of Architecture in New York City. He is managing principal at Design Group.



The Culinary Hub is the heart and soul of Mitchell Hall. *Photo: Design Group*

Among the biggest challenges, Bongiorno said, was shoehorning as much program space into the building as possible without making it look institutional. That was achieved, he said, with the Culinary Hub, a central interior feature that ties all the building’s elements together, and makes the facility look big and welcoming. He wants students to enter Mitchell Hall and say to themselves, “Wow, this place is for me.”

With the abundance of cooking facilities, and the need for interactivity and documentation, the building, compared to a standard campus facility, is equipped with a “disproportional” amount of MEP and AV technology.

Bongiorno, prone to colorful analogies, had this to say about Mitchell Hall: “Just like any good party, everyone should end up in the kitchen. [Mitchell Hall] is going to be the campus’ kitchen.”

Soft openings for Mitchell Hall begin in August.

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**RICHARD MASSEY** is managing editor of Zweig Group publications. He can be reached at [rmasse@zweiggroup.com](mailto:rmasse@zweiggroup.com).

# CURVILINEAR GEOMETRIES

POST-TENSIONED CONCRETE ALLOWS BUILDERS TO DO MORE WITH LESS

By Kristin E. Dispenza

**ENGINEERS FACE A PARADOXICAL CHALLENGE:** making skyscrapers ever taller, yet making them lighter-weight and less material-intensive. One solution has been the increased use of post-tensioned concrete. Post-tensioning is a method of reinforcing concrete (or other materials) with high-strength steel tendons, improving the performance of the concrete by taking advantage of concrete's high compressive strength characteristic to provide additional tensile strength. Cast-in-place post-tensioned concrete is as durable as traditional concrete but is more structurally efficient.

“The high-strength steel and concrete that are necessary for stressing also increase the member capacity, resulting in a reduced amount of required conventional reinforcement,” explained Michael Hopper, Associate, LERA. “The result is shallower structural members, compared to conventional reinforced concrete systems.”

Longer, thinner slabs allow for reduced floor-to-floor heights, optimizing the number of building stories that can fit within a given height limit. Fewer column supports are required, so design flexibility and usable space are maximized.

## Post-Tensioning: Why Now?

Curvilinear geometries, stories that are offset from floor to floor, and transparent facades are all characteristics of contemporary skyscrapers. The open spaces and long spans that facilitate this type of design rely on fewer interior columns, more frequent use of cantilevered floors, and flexibility in load distribution.

“Designers have known for quite some time that cast-in-place, pre-stressed (post-tensioned) concrete was the most effective way to build offices, residential towers and parking structures,” said Russell L. Price, executive vice president, Suncoast Post-Tension, Ltd. “And as floor slab profiles become more complex, with fewer rectangular shapes, floor slab edges on many newly-designed structures vary widely, not only from project to project but even between floors on the same project. Prior to the availability of design software, design analysis was complex enough to discourage the use of post-tensioning. Once computers could support the designing of floor systems, post-tensioning went from being the design teams' third or fourth choice to being their first choice because designers understood the benefits that cast-in-place post-tensioned concrete brought to high rise building construction.”

A striking illustration is the Seminole Hard Rock Hotel & Casino, currently under construction in Hollywood, Florida. The building will stand at 450 feet tall and will be shaped like the body of a guitar. To replicate the curvature of a guitar, floor slabs are deeply set back from floor to floor and columns could not be arranged in a grid. Nevertheless, post-tensioning offered the flexibility to “sweep” or curve the tendons



The Roy and Diana Vagelos Education Center at the Columbia University Medical Center. Photo: Post-Tensioning Institute



The Seminole Hard Rock Hotel & Casino in Hollywood, Florida. Photo: Post-Tensioning Institute

to follow the column lines and limited the deflection of the long slab cantilevers necessary to meet the changing shape at each floor. This allowed the curtain wall system to fit the curved shape of the structure. The vision for the Roy and Diana Vagelos Education Center at the Columbia University Medical Center – a 107,000 square-foot, 15-story medical education facility – was to provide an interdisciplinary learning environment. Architects designed a cascade of spaces across the building’s southern façade, which required vertical load paths that would leave the stacked spaces intact. The engineering solution includes an architecturally exposed pair of inclined composite concrete columns to support the cascade floors. The sloping columns create thrusts that are resisted by in-floor trusses constructed with post-tensioning and high-strength rebar. Cantilevered floor plates up to 26 feet in length leave the façade column-free, allowing building edges to be defined by specially-designed glass plates that do not align in plan.

“In complex structural systems such as this, engineers must coordinate expected deflections with the other building systems, such as facade attachment locations or other exterior enclosure requirements, moveable partitions, or equipment that is impacted by motion,” said Hopper. “Using post-tensioning, LERA’s engineers were able to confidently calculate the expected deflection of the slabs in the Education Center, ensuring that the glass panels would not break due to unexpected building movement. Post-tensioning offers a reduction in long-term creep deflections because of its tuned load balancing.”

“Using post-tensioning improves calculations of deflection in two ways,” said Carol Hayek, Chief Technical Officer, CCL. “Firstly, through load balancing, actual deflections are reduced. Secondly, there is less uncertainty in the calculations. This is because reinforced con-

crete slabs are always designed as a cracked section. To calculate a cracked section, one has to consider many different properties, such as variations in the mix, differences in curing, and so on, so the resulting deflection calculation is an estimate. But post-tensioning calculations are limited to an uncracked section; one can use the full section to reduce load.”

Post-tensioning reduces or eliminates cracking by pre-compressing the cross-sectional areas that would otherwise experience large tensile stresses when loaded (if the post-tensioning were not present). Designers can use post-tensioning to control and limit tensile stresses to ensure that concrete sections remain uncracked.

The architectural trend of using exposed concrete as a finish surface also benefits from post-tensioning. Exposed concrete is not only the finish surface for the mixed-use Reston Station OB1 located in Reston, Virginia, but expresses the building’s structural system. Exoskeleton columns slope at 11 degrees from vertical and around this exoskeleton a transparent, “glass box” aesthetic was desired by the designer. Thin, cantilevered floors and concealed anchors minimize the amount of structure visible in these glazed areas. The building’s floor slabs contain distributed tendons in the east-west direction; these tendons are crossed at midspan to conceal dead-end anchors inside the exterior columns and allowed the tendons to be stressed at the spandrel beams. Post-tensioned slabs help resist thrusts created by the inclined columns. Post-tensioned concrete also offers cost savings because it is quicker to construct. For the Address Boulevard Hotel in Dubai, UAE, indirect cost savings were achieved through an accelerated construction program that included the ability to remove formwork every three days as opposed to the 15 days for traditional methods. These indirect savings were in addition to direct cost savings associated with reduced material usage and reduced loads, which engineers at StrongForce estimate to be approximately 20 percent for the slab system in its entirety.

### Wind and Seismic Loading

Upon its completion in 2019, NEMA Chicago will be one of the tallest unbonded post-tensioned towers in the United States, standing at 76 stories and 887 feet (270.4 m).

“Post-tensioning provides tall buildings like NEMA Chicago with the strength necessary to resist lateral forces from wind loads,” explained Neel Khosa, vice president, AMSYSCO, Inc.

Some areas are starting to use post-tensioning for seismic resistance. Post-tensioning cables remain elastic under loading and their self-centering behavior limits deformation, keeping buildings from overturning, according to Hayek.

“An increasing number of buildings in California are using hybrid systems of vertically-placed post-tensioning cables combined with rebar (which helps dissipate energy) to improve seismic performance. Vertical applications of post-tensioning can even be used to correct tilting buildings. Additionally, adding compression to the system for resisting lateral loads results in thinner walls—another material-saving, square-foot-increasing benefit of post-tensioning,” said Hayek.

## Urban Site Constraints

Hudson Yards is a 28 acre (11.33 ha) mixed use development on the west side of Manhattan that is expected to be complete in 2024. For much of the site's history it was occupied by rail yards and it will again be an active rail hub once the Hudson Yards development is completed. A centerpiece of the development is 55 Hudson Yards, a 51-story commercial office building that is one of the first fully concrete framed high-rises of its class in New York City.

"Until recently, the use of unbonded PT has been almost non-existent in New York City – the largest construction market in the United States," said Khosa. "55 Hudson Yards has paved the way for a few other skyscrapers that utilize unbonded post tensioning."

"Concurrent with the Hudson Yards development, New York's Metropolitan Transportation Authority installed a new subway station as part of the Number 7 Line Subway Extension," said Florian B. Aalami, President and CEO, ADAPT Corporation. "The station was built with an arrangement of caissons that, it was anticipated, could carry loads consistent with steel tower construction. Developers of Hudson Yards, however, desired the speed and cost advantages of concrete construction."

This presented engineers with the challenge of transferring loads away from caissons in the center of the building footprint, which were inadequate to support the weight of concrete. They developed a unique arrangement of "draped," post-tensioning tendons that use hyperstatic reactions to counteract the weight of the concrete structure and reduce natural load paths. Tendons were anchored between the 10th floor (at locations near the exterior columns) and the 8th floor (at the building's

two interior columns), across a distance of 98 horizontal feet. Tendons were stressed from the 10th level.

Developers of 55 Hudson Yards also desired multiple areas across the floor plates that could be cut by building tenants during renovations in order to achieve double-height spaces. Tendons laid in a uniform arrangement (spaced at regular intervals in both directions) would have made it impractical to cut through slabs. Therefore, a flat-slab floor system was designed that arranged post-tensioning cables in a banded radial configuration, leaving large areas within the slab cable-free.

Enormous flexibility in transferring loads is another benefit of post-tensioning. When the layout of columns in a building's base (or any other vertical section) can't directly transfer loads from upper floors, a transfer slab can be created using post-tensioning, with the slab effectively supporting building levels above it.

Parking, loading docks, city utility easements and more posed limitations on structural support placement at the base of the Ritz-Carlton Residences Waikiki Beach (Phase 1), in which opened in 2016. To support seven floors of podium structure, four post-tensioned transfer girders and a two-story post-tensioned concrete truss were designed by Baldrige & Associates Structural Engineering to span 120 ft (37 m). Post-tensioning was used in the top and bottom chords of the truss to help control deflections and vibrations. Throughout the building, more than 50 major transitions were required for the vertical elements. With no columns going to the ground in their original location and some elements shifting in plan several times throughout the height of the building, offset foundations and columns, as well as sloping columns, were used to shift support locations through varying floor layouts.

With skyscraper cities continuing to grow, there will be an ongoing demand for architecturally varied skylines and structurally efficient buildings. Cutting-edge engineering techniques such as post-tensioning can help design teams meet these demands.

*Structural Engineers Axiom #7*

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## ROCKY MOUNTAIN REDO

HAMMERED BY A MAJOR FLOOD EARLIER IN THE DECADE, DENVER DECIDED TO DO SOME DIGGING.

By Sam Stevens

**SEVERE FLOODING IN COLORADO** caused the loss of lives, destruction of property and the evacuation of more than 11,000 people in 2013. Following this and numerous other instances of flooding, the City and County of Denver committed to an ambitious, \$298 million stormwater infrastructure initiative – Platte to Park Hill: Stormwater Systems Project. The coordinated and community-led approach consists of a series of engineering-focused projects that will address flood protection in northeast Denver neighborhoods.

Denver's Montclair Basin, which encompasses the area affected, experiences a high flood risk given it lacked an adequate drainage system and is the City's largest watershed basin. It is also challenged from a water treatment perspective, with no open waterway to allow natural or man-made facilities to address water quality. Stormwater modeling and evidence from previous storms shows that during moderate to large storm events, the existing pipe systems reached capacity quickly and the excess runoff is carried into neighborhoods at depths of three feet or more – causing a many issues for these at-risk communities.

In order to address these flooding and environmental issues, as well as improve community amenities, multilayered goals for the project were established early, including providing critical flood protection, improving water quality, increasing neighborhood connectivity, enhancing public spaces, and upgrading infrastructure with green elements.

The three projects are currently underway with expected completion of the water treatment elements by Fall 2019 and the entire project by the end of 2020. The projects include:

- City Park Golf Course Redesign
- 39th Avenue Greenway and Open Channel
- Globeville Landing Outfall and Park

### Integrating a 200-acre-foot detention basin into an urban golf course

To begin, the City knew it needed to uncover existing storm canals and drainageways that had been buried under 150 years of urban development, forcing stormwater into pipes. The “daylighting” of buried channels started at the golf course — cutting through pavement and re-engineering old streams and canals to ultimately create over a mile and a half of naturalistic riparian corridors across the three projects – and allowing the team to create natural bioswales throughout.

The first part of this takes place at City Park Golf Course, where 800 linear feet of brick pipe installed in the early 1900s was removed, opening up the system to a 1,200-linear foot meandering stream. The stream was then seamlessly integrated into the golf course – control-



Photo: City and County of Denver



Precast, reinforced concrete boxes were installed underground on both sides of the greenway, connecting the overall system and allowing for future extension further into the basin. Photo: City and County of Denver

ling stormwater and enhancing playability of the course. A trash vault was also installed offline of the storm system, intended to collect debris picked up by stormwater during rainfall events, and up to 2,200 cubic feet of trash prior to emptying.

Another essential part of the course redesign was the inclusion of a 200-acre-foot detention basin. Golf courses have a proven track record of providing neighboring communities with effective water quality and flood control protection and integrating stormwater detention basins into golf courses allows the course to capture and temporarily hold floodwater, slowly releasing it over time.

The new regional trash vault, forebay and wetland channel form the



December 2018 aerial view of the City Park Golf Course. Photo: Rocky Mountain Photo

first treatment train in the re-engineered Montclair Basin, enhancing the quality of the water as its conveyed to the South Platte River.

While the treatment train is essential to the Platte to Park Hill project, the City was challenged with smartly integrating these elements into a beloved City course. Through a collaborative design process, the drainage improvements, including re-grading of 200 acre-feet of detention, were integrated in such a way as to become part of the course itself. Playability is now enhanced and challenged by the drainage and stream features.



The Platte to Park Hill: Stormwater Systems Project is a coordinated and community-led approach to a series of engineering-focused projects that will address flood protection in northeast Denver neighborhoods. Photo: Design Workshop, Inc.

## Using green infrastructure in an urbanized area to capture a 100-year storm

Even with the City Park Golf Course redesign to integrate these stormwater features, the Montclair Basin still lacked the infrastructure for handling the water produced during a 100-year flood event. Therefore, the City opted to combine a greenway and stormwater pipe system to create the backbone of the needed drainage system.

At a location lower in the basin where stormwater concentrates, an East-West corridor extending from 39th Avenue was selected for the greenway. This greenway will both intercept overland flows in larger storms and help naturally clean stormwater in smaller events as it flows and conveys to a river. A key challenge with the project was completing the project in a tight urban corridor with businesses and residents surrounding the two-mile-long project site. Therefore, a robust community outreach process was established, enabling the City to uncover design aspects most important to the community which included gathering and recreational spaces, incorporation of native landscapes and materials, and increased connectivity for pedestrians, drivers and bikers.

The City reconstructed the urban landscape where possible, slowing down and filtering the water through vegetation to remove contaminants, all while controlling storm runoff and nourishing greenery to help residents endure the climate shift toward droughts and rising temperatures. Greenways help remove waterborne contaminants by exposing them to sunlight and slow and control stormwater across wider channels and gentler banks. To further the treatment process, over 50 street side stormwater quality planters were installed to collect and filter water through various layers of vegetation and soils. Additionally, two new trash vaults add 1,000 cubic feet of trash collection in the basin

Precast, reinforced concrete boxes were installed underground on both sides of the greenway, connecting the overall system and allowing for future extension further into the basin. Storm flows will be intercepted and directed from newly constructed boxes on one end through the greenway and back through additional new boxes and pipes leading to the Globeville Landing Outfall – which ultimately empties into the



At a location lower in the basin where stormwater concentrates, an East-West corridor extending from 39th Avenue was selected for the greenway.  
 Photo: City and County of Denver

South Platte River. Another key component was careful planning and designing around an existing 100-year-old, 120-inch brick pipe. The existing pipe was inspected and found to be in good condition, allowing for reuse. The reuse of this pipe helps convey a significant portion of the stormwater to the South Platte River and reduces the need for another bored tunnel under the Union Pacific Railroad.

The new greenway project will replace the City’s aging infrastructure with nearly 12 acres of new recreational open space and increased connectivity. Three vehicular and two pedestrian bridges will connect people across the channel, and the site will feature the first shared street in Denver. The new green infrastructure will better control stormwater, improve water quality and public safety, increase plant diversity, and improve natural ecosystems – all of which were top priorities for the City and community. Once complete, the new space will include more pathways and bridges, 5,000 square feet of community gardens and an outdoor amphitheater.

### Engineered outfall within Superfund site and railyard

Globeville Landing Park is the final stop for stormwater traveling from northeast Denver to the South Platte River. Five hundred linear feet of large diameter pipes were installed to carry stormwater under 17 freight train tracks and two heavy commuter rails, and through an existing Superfund site, before it rises to the surface at a natural open channel with a capacity of 2,300 cubic feet per second.

The City opted to design an open, natural stormwater drainage system, a nationally recognized best practice for moving stormwater, and also a way to provide habitat for wildlife and ecosystem restoration while improving overall water quality. The outfall is in a key location, where

much of the water from the Montclair Basin naturally enters the South Platte River. It is designed to dissipate the high-energy stream of water and features a separate and stable, impermeable lining installed three feet below the finished open channel, protecting groundwater at the outfall. It also contains a UV vault that treats low flow stormwater prior to discharging it into the South Platte River.

Next to the outfall, the new community park will feature active play areas, grassy areas for sports and recreation, multiple bike and pedestrian paths, outdoor seating and shaded gathering places for families, access to the river, and improved safety and visibility of the park. Upon completion, Globeville Landing Outfall and Park will not only move stormwater, it will become a desired and safe place for families to gather within the community.

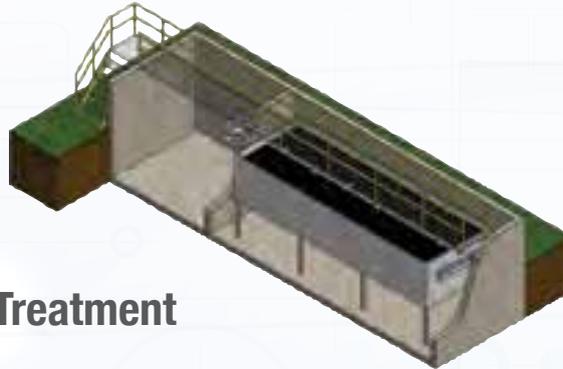
All aspects of Platte to Park Hill: Stormwater Systems Project are currently underway with drainage functions operational and expected completion of each project throughout the next year and a half. Beyond providing flood protection for more than 5,000 residences and establishing the first inhabitable stormwater outlet structure, the project will create 12 acres of new parkland in communities, add three miles of pedestrian facilities, increase open space, and breathe new life into one of Denver’s beloved golf courses.

**SAM STEVENS**, engineering supervisor, infrastructure project management, City and County of Denver. Stevens is an Engineering Supervisor with the Infrastructure Project Management team at the City and County of Denver. He has over 17 years of experience as a Civil Engineer working for the Los Angeles County Department of Public Works, several consulting firms in the Denver Metro area and in various divisions within the City and County of Denver.



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# Wastewater Solutions

## Activated Sludge Sewage Treatment Plants with Extended Aeration Used for Community Wastewater Treatment

By Brenda Martinez



Truck loaded with lift station and ancillary equipment for Indiana Coal Plant wastewater treatment system. *Photo: Delta Treatment Systems*

### Overview

Activated sludge sewage treatment plants utilize the extended aeration method of biological waste reduction. These extended aeration plants are characterized by the introduction of raw wastewater directly into the aeration tank, long term aeration (usually 24hrs.), high mixed liquor suspended solids, high sludge return ratio, and low sludge wastage. This system design is generally used to serve populations of 20,000 people or less in applications including subdivisions, multiple family dwellings, mobile home parks, shopping centers, commercial offices, industrial facilities, motels, schools, and recreation areas. The long detention time in the aeration tank permits the plant to operate effectively even though flows and strengths vary widely. The plant can be divided into three main units of operation: aeration, clarification, and disinfection.

### History of Extended Aeration Package Plants

Modern decentralized activated sludge wastewater treatment plants, also known as package plants, were developed in the 1960s. The process was developed to mimic the natural breakdown of domestic waste in nature. For many years, domestic wastewater was discharged into open waterways and streams. As this waste entered the waterway, the dissolved oxygen in the stream decreased and microbiological activity increased near the area of discharge. Waste material in domestic wastewater is generally organic, meaning it is biodegradable and serves as a food source for bacteria in the water.

This food source coupled with dissolved oxygen present in the water and added nutrients causes a rise in microbiological population. The bacteria are quick to degrade the organics and essentially, treat the wastewater. As the waste moved downstream, the bacteria eventually consumed the organic material, which would lead to a decrease in population. In moderation, this process proved to be a good natural process for treatment. As these discharge points started to move closer and closer together, growing steady in discharge quantity and loading, the dissolved oxygen was not recovering quickly enough, leading to a decline in water quality. This negatively impacted both human and ecosystem health, leading to a need to for change in wastewater treatment practices.

### Process Summary

There are three main processes in extended aeration technology: aeration, clarification, and disinfection. Each step is critical to the success of the treatment process, and each process should be designed based on influent concentration loading and effluent quality expectations. Detention time, aeration criteria, and equipment are all important design considerations.

### Aeration

The aeration basin mimics the point of the stream where raw wastewater first enters. In a natural water body, the amount of dissolved oxygen is sufficient and the consistent movement of water from the discharge pipe into the stream causes a "mixing" action; allowing constant contact between the microbes and the organics in the wastewater. In an extended aeration package plant, raw wastewater enters a basin, typically sized at 1x the average daily flow rate of the site it is servicing. It flows first through a bar screen, which allows the removal of large debris from the waste stream. The bar screen is manually cleaned by the operator during routine maintenance



Example of above grade double hopper clarifier for extended aeration package plant. *Photo: Delta Treatment Systems*



Top view of Washington Resort, completely covered, with aluminum hatches for service access points, tertiary filter blower and control panel.  
*Photo: Delta Treatment Systems*

visits. The wastewater is then introduced into an oxygen rich environment, provided by an external air compressor and distributed evenly throughout the basin via air distribution system. This air distribution system serves two purposes: to provide the necessary oxygen to the natural microbiology and to provide sufficient movement in the chamber to keep the aerobic bacteria in constant contact with the organics for biodegradation. The goal of this chamber is to reduce organics in the wastewater, therefore lowering Biochemical Oxygen Demand (BOD); the main analysis used today to determine water quality.

### Clarification

The second step of the extended aeration process is clarification. Following treatment of the wastewater in the aeration basin, it flows into the clarifier.

The clarifier is a quiescent zone with no agitation or aeration. The clarifier, whether circular or cone shaped, allows for solids to settle to the bottom of the tank, and a clear supernatant to form at the top. The tank is typically sized for four hours of detention time, which may vary based on local regulatory or project specific requirements. The purpose of this chamber is to reduce Total Suspended Solids (TSS), another parameter used to determine water quality. Fats, oils, and greases are skimmed off the top of the clarifier chamber and settled solids are removed and returned to the aeration basin for further treatment. As sludge builds up at the bottom of this tank, it is periodically manually or automatically removed, and hauled off for disposal.

### Disinfection

The final step of extended aeration is disinfection. The disinfection chamber follows clarification and is typically sized for 15-30 minutes of detention at 2.5 times the average daily flow for proper detention. Disinfection can be accomplished either by liquid chlorine, tablet feed chlorinators, or ultraviolet light. The goal of this chamber is to kill coliform bacteria that could be harmful to human and environmental health before it is finally discharged into the environment.

### Technology in Action

#### Indiana Coal Fired Power Plant Extended Aeration Package Plant

A five-unit, 3,145 MW coal-fired power plant located in southern Indiana required a new wastewater treatment system. The former sewage treatment facility was installed in 1982 and required replacement. The plant is a zero-liquid discharge facility and all plant waste water streams are returned to the 3,000-acre cooling pond, which is an industrial surface impoundment. The plant was installed below grade at a design flow rate of 40,000 GPD. The system was designed to treat domestic wastewater to effluent levels of CBOD, TSS, and fecal coliform down to less than 25 mg/L, 30 mg/L and 125 cfu/100 mL respectively. Delta Treatment provided a sanitary lift station with duplex pump system, and an extended aeration package plant for wastewater treatment. This includes flow equalization, UV disinfection, and a control panel that would be able to communicate with the operations room located on-site. All equipment necessary for proper operation and function was supplied. The system was started up in the Spring of 2016 and has continued to meet effluent quality requirements to date.

#### Washington Vacation Resort Activated Sludge Wastewater Treatment Plant

A vacation resort facility located off the coast of Washington State was operating an on-site activated sludge wastewater treatment plant servicing 47 individual condominium units at the resort and several privately-owned lots in a nearby subdivision. The system was installed in the 1970s. It required a structural upgrade and the resort was issued a more stringent permit that required total nitrogen discharge levels at 10 mg/L or less monthly average. The system was designed with a flow equalization chamber to handle the variable flow that accompanies vacation rentals, as well as a tertiary sand filter to meet the required total nitrogen limit. The unit provided by Delta Treatment was sized at 16,000 GPD daily flow. The system was installed in late 2015 and has consistently met regulatory permit limits.

### Conclusion

Activated sludge and extended aeration sewage treatment plants provide communities with populations of 20,000 or less an effective wastewater treatment solution. They are a particularly effective option where flows vary widely, such as in shopping centers, commercial offices, industrial facilities, motels, schools, and recreation areas. Where BOD and TSS levels are of concern, these package plants excel.

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**BRENDA MARTINEZ** has been the Commercial Project Manager for Delta Treatment Systems (formerly Delta Environmental) for three years. Brenda assists developers and engineers in designing wastewater treatment systems that will optimize treatment performance for their projects. Prior to working for Delta, Brenda spent 15 years in the environmental testing industry, doing bench scale treatability studies for municipal wastewater plants as well as standard analytical testing for soils and waters under both Standard Methods and ASTM methodologies. Brenda holds a Bachelor's Degree in Environmental Science from Texas A&M University, a Master's Degree in Environmental Management from the University of Maryland University College, and is currently a PhD student at Louisiana State University in the Environmental Science program. [bmartinez@deltatreatment.com](mailto:bmartinez@deltatreatment.com).

## GOOD CONSUMPTION

THE MILAN TRIENNALE'S USA PAVILION, CURATED BY TWO ENGINEERS, ASKS US TO RETHINK OUR USE OF MATERIALS

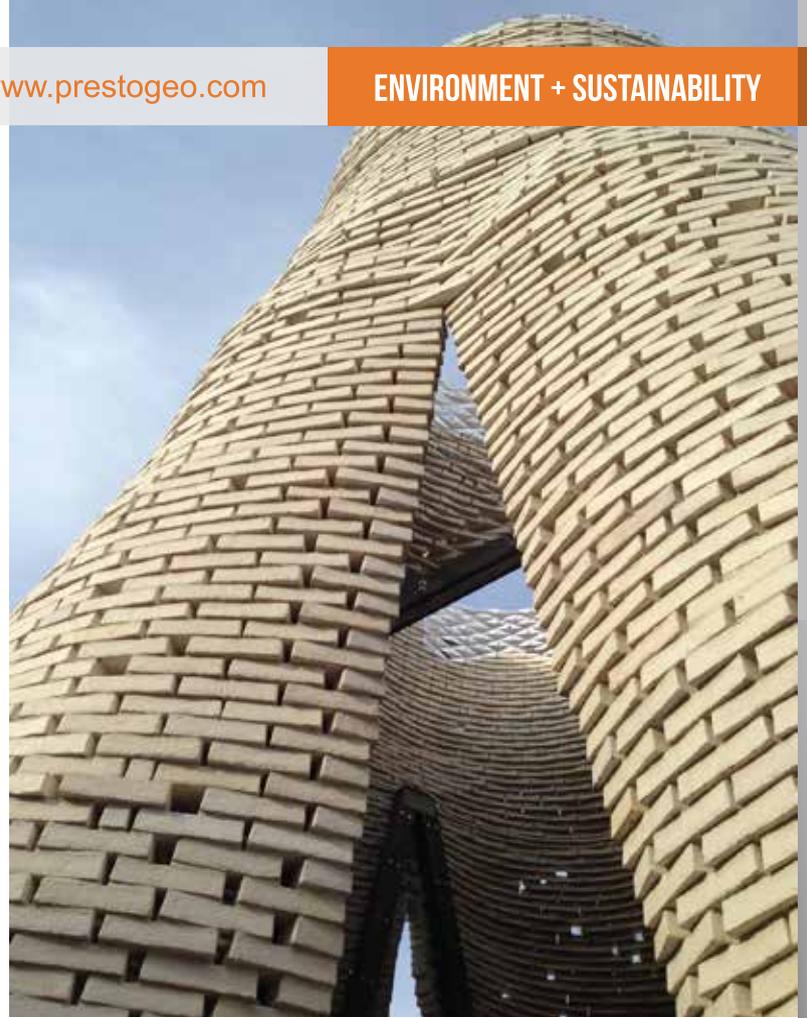
By Russell Fortmeyer and Frances Yang

**IT TURNS OUT EFFICIENCY IS NOT ENOUGH.** If engineering has primarily concerned itself with optimizing the quantity of material, energy, or water used in our built environment – designing artificial systems to efficiently address natural phenomena – the current global situation of climate change, resource scarcity, and stressed nature demands that we change engineering. We have to ask ourselves: how can design transform the landscape of consumption?

For Broken Nature: Design Takes on Human Survival, the international design exhibition that kicked off the XXII Milan Triennale in March and runs through the summer, Arup curated an exhibition for the United States pavilion called **RECKONstruct** that argues for a radical overhaul of how architects, designers, engineers, and contractors create the built environment.

In the United States, construction and demolition waste from buildings accounts for over 20 percent of total solid waste generated in the country. In 2015, the last year the US Environmental Protection Agency publicly assessed the industry, that amounted to more than 160 million tons of debris. More generally, the country is on track to produce more than a billion tons of solid waste every year, with an average national rate of recycling of only 35 percent. At the other end of our industry, demand for new materials for construction exceeds 2.2 billion tons per year and growing, by far the largest consumer of raw materials in the country. We cannot recycle our way out of this – we have to find ways to use much less.

This massive materials economy exceeds our borders, exacting an enormous toll on environmental, economic, and social systems across the planet. Very little of it is quantified, tracked, or even generally understood in terms of how it fuels resource depletion, carbon emissions, or impacts to public health and ecosystem viability. Yet, we find that from academia to design, government to industry, the forces shaping the built environment in the United States increasingly acknowledge the expansive system boundaries governing the circulation of materials in the economy. Our industry must now consider boundaries beyond the project site, where the installation of materials as part of a project is viewed as merely one point along the systemic value chain of consumption, rather than the only point we value. Rapidly growing programs like the Carbon Leadership Forum, Cradle to Cradle, the American Institute of Architects' Materials Matter initiative, mindful MATERIALS, International Living Future Institute's Living Product Challenge, and Environmental and Health Product Declarations, are galvanizing our domestic industry toward integration of life-cycle considerations into design.



MoMA PS1 Young Architects Program Installation. Photo: Arup



Bio-fabricated stool created using mycelium mushroom and agricultural waste. Photo: Arup



RECKONstruct US Pavilion Triennale XXII International Exhibition. Photo: Arup

With our exhibition in Milan, we wanted to take stock of the opportunities these new developments present to engaged designers and engineers. Many manufacturers are developing new markets for materials to redirect waste toward new products. Our exhibition highlighted three stools designed and manufactured by the furniture company Humanscale that explored three different models of sustainable practice. The UBQ stool relies on post-consumer landfill waste (think diapers and potato chip bags) combined with recycled plastic to create a hard substrate for the stool, which is then topped with a felt pad made of recycled garment scraps. Another approach, which Humanscale called the Venus stool, used plastic to feed a three-dimensional print from a design based on mimicking nature's minimalist constructs, in this case the Venus's flower-basket sea sponge. In sustainable design, this tactic is called biomimicry, or using inspiration from nature. While this version of the stool focused on material efficiency, the designers envisioned the plastic could be replaced with recycled nylon from ocean-harvested fishing nets to further reduce impacts.

But we can also scale up these approaches. Developing biological material loops creates new categories for design engagement. In 2014, Arup collaborated with the New York-based design studio the Living to use the firm's mushroom bricks, made with Ecovative Design's mycelium biofabrication platform, to create a durable, freestanding tower capable of occupancy. A similar approach was taken with Humanscale's mycelium stool on exhibit in Milan. Both the tower and the stool can be disassembled and composted, returning nutrients to the earth when they are no longer needed. Today – by design, not necessity – very little of our existing built environment can be treated similarly. How is it possible to know whether these radical design changes are



The Venus Stool, inspired by the Venus Flower Basket sea sponge. Photo: Arup

making a difference? How do we take a quantifiable pulse of the planet? Life-cycle assessment (LCA) is the scientific means of tracing back the history of how our building products were made, how they were transported from one stop to the next, and what toll they took on our environment in getting to us. It accounts for the raw materials and their spoils that need to be extracted from the earth, or for the waste picked out of material graveyards and made good for a new life. It considers whether the energy used comes from dirty or clean sources, and whether the mode of travel emitted heavy pollutants over many miles or merely hitched a short zero-emissions ride across town. It also reflects if the material itself has helped to clean the air during its growth from a small seedling or if it displaces climate-warming emissions emanating daily from landfills and incinerators.

LCA is the big data problem of the century for the built environment, and we have a lot of work to do. And this type of life-cycle accounting is only as reliable as the data, and only as useful as it is accessible. Tools like openLCA give us the power and the knowledge to test if new design approaches lead to smaller environmental footprints. The data are on par with those of commercial LCA tools, while the open-source, free-access attributes break down normal barriers to entry. Using openLCA on the three Humanscale design concepts led to deeper understandings, as well as some surprising results.

Not surprising was that all three concept stools had lower environmental impacts than a generic metal stool with a composite agrifiber seat. The impact reductions varied from 20 to 90 percent, with the largest reductions in energy consumption, marine and freshwater toxicity, waste, fossil fuel use, and carbon emissions. Surprisingly, water con-



A still from the RECKONstruct immersive film. Photo: Arup

sumption did not improve much for the mycelium and Venus designs because they relied on plant oils that still incurred high agricultural water demands. LCA on the Venus stool design showed that material efficiency isn't necessarily good in and of itself – the material still needs the ability to serve a second life if it is to stay out of a landfill. If we substituted recycled nylon fishing nets for the virgin plastic, while also ensuring a means for recycling that plastic again after the use life of the stool, we could reduce impacts by a remarkable 90 percent when compared to the conventional 3-D printing materials.

It was also not surprising that developing a robust LCA for three simple stools took a lot of time. We interrogated data we didn't trust, compared alternative data sets, and debated what the results meant to understand what we could have changed to effect greater reductions. With the current state of the LCA process, it's unreasonable to think we could do this for everything we consume, hence we have to start with the materials, assemblies, and products that account for the biggest impacts.

The LCA process we undertook was developed in collaboration with the Massachusetts Institute of Technology's SHINE program—Sustainability and Health Initiative for NetPositive Enterprise—which used what we call a regenerative LCA process to confirm and quantify the impacts. While a sustainable approach to materials LCA would result in a neutral outcome—doing less harm—the challenges we collectively face require a more progressive approach. Materials consumption could capture and store carbon in circulation already, creating a net positive impact.

In the logic of SHINE, if we can know our footprint in terms of the impact we leave, can we start to know our handprint—the intentional mark we make to positively affect the planet?

In a state of broken nature, transforming America's entrenched market is not an easy task. It requires thinking beyond recycling or merely reducing consumption. We must usher in a new circular economy by constantly reimagining the nature of “raw” materials as the availability of whatever stock of ingredients is already in play. Simultaneously, we must account for the full impact of materials use, whether that is valuing the health of an ecosystem, registering the carbon emissions associated with the life of a product, or forcing the elimination of hazardous materials from supply chains. The material life cycle and material choice offer us massive hidden opportunities and a collective call to action to design for and with nature.

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**RUSSELL FORTMEYER**, chief curator of RECKONstruct, is an associate principal and sustainability consultant who leads the consulting practice in Arup's Los Angeles office. Trained both as an engineer and architect, Russell addresses issues including climate change, resilience, resource scarcity, and social equity in the context of creating healthy and efficient buildings and cities.

**FRANCES YANG** leads the sustainable materials practice in the Americas region for Arup, a global design and engineering firm. Frances has more than 12 years of experience in green building design, engineering, and sustainable materials strategies across global projects. She is coauthor of [Prescription for Healthier Building Materials: A Design and Implementation Protocol](#).



## ORANGE COUNTY GREAT PARK

GRASSCRETE: MEETING CALIFORNIA'S DEMANDING STORMWATER RETENTION REQUIREMENTS HAS NEVER BEEN EASIER

By Sean O'Keefe

**IN CONSTRUCTION, INNOVATION IS ESSENTIAL** and, as the needs of the industry have changed, so too have the means, methods, and materials employed to solve challenges.

Florasource Ltd. is a California horticultural supply firm founded in 1985 by owners Tom and Nancy Hawkins, who met while pursuing

degrees in Environmental Horticulture at UC Davis. Today, the company provides a steady supply of young plants to commercial growers, grower-retailers and low water lawn alternatives to the landscape contractor industry.

Expanding on their interest in environmental horticulture, the company also represents a range of innovative landscape products, including green roof, green wall, and living hardscape systems. As such, when design firms were working on the Orange County Great Park in Irvine,



Grasscrete's proprietary molded pulp-formers dissolve naturally after the concrete hardens leaving a monolithic slab of reinforced concrete able to achieve a compressive strength of up to 12,000 psi.

Florasource was able to meet some of their project needs with the right combination of products.

"The Orange County Great Park project is the ongoing transformation of Marine Corps Air Station El Tora, in southern California," Hawkins said.

Spanning some 1,300 acres, Orange County Great Park is a public-private partnership between the City of Irvine and developer Five Point Communities, and takes aim at becoming one of the largest and best metropolitan parks in the world. A nearly limitless list of in-park amenities includes the Great Park balloon, carousel, kids rock play area, walkable historical timeline, historic Hangar 244, Palm Court, Farm + Food Lab, and the recently opened 53-acre sports complex. Future assets in the five-year development include a 179-acre wildlife corridor, 71 acres of agricultural areas, and an 18-hole golf course and clubhouse.



By regulatory standards, a drivable surface means being able to support the weight of a fire truck in an emergency. Grasscrete's lattice-like structure combines solid and void and becomes virtually undetectable until it's needed.

Designing and building-out an appropriately vegetated park of this magnitude while meeting California's water conservation in landscaping requirements for new development was no small order. Passed in 2006, the state's requirements include establishing a maximum amount of supplemental site irrigation and encouraging the capture and retention of 100 percent of stormwater on site. In conjunction with landscape contractor Brightview Landscape Development, Florasource has supplied several stages of park buildout with a combination of materials ideally suited for California's unique low-water climate and stormwater retention expectations.

"We provided UC Verde Buffalograss for lots of areas at the park" Hawkins said. "It's a great low-water lawn option that was bred specifically to grow well in California and other drought-prone areas, including the desert valleys in Phoenix and Tucson, Arizona."

Bred by UC Davis and introduced commercially in 2003, UC Verde Buffalograss requires as little as a fourth of the amount of water of traditional turf grasses, and peaks at a growth height of only six inches, meaning much less need to be mowed regularly. On the hardscape side, Florasource also had a ready response to the stormwater retention requirements in permeable paving solution – Grasscrete.

"Grasscrete is an incredibly durable, permeable paving product that allows grasses or other vegetation to be planted within it," Hawkins said. "We had experience working with Brightview on a large Grasscrete installation for Hyundai's US Headquarters in Fountain Valley, CA. There it was used for emergency fire lanes and was also planted with UC Verde Buffalograss."

Grasscrete is a proprietary blend of product, service, and technique manufactured by Sustainable Paving Systems of Fair Oaks, California. As the manufacturer's representative for the state, Hawkins joins other distributors across the country and specialty concrete contractors under the Bomanite brand in having exclusive rights to this innovative concrete system in development since the mid-1970s.



Planted with UC Verde Buffalograss, grasscrete allows rain and supplemental irrigation to return to the water table naturally, making the combination of materials ideal for low-water climates.

At the Orange County Great Park Grasscrete has been used primarily to create hard, drivable surfaces for utility access roads, emergency vehicle fire lanes, and in allowing drivable shoulders for several of the roundabouts in the bordering residential neighborhoods. By forming a concrete lattice of solid and void, Grasscrete combines the strength and rigidity of a single, structural framework while still providing enough access to soil, water, and sunlight to support sustained vegetation. The result is a vegetated permeable surface that remains drivable when needed, capable of supporting the parked weight of a fully loaded fire truck.

“The fire department doesn’t take these things lightly,” says Hawkins. “In 2014, we were required to set up a formal test installation for the City of L.A., to get approval for the newly designed, biodegradable Grasscrete former. They drove one of their biggest trucks out on it, put down the stabilizers and raised the ladder up just like they would in a fire. The Grasscrete surface never moved.”

The Grasscrete system differs from other types of pervious paving systems in the incorporation of molded-pulp formers that allow cast-in-place flatwork to be placed monolithically. Made from recycled paper, the pulp-formers are biodegradable and will slowly begin to dissolve as the concrete hardens. By reinforcing the forms continually with #4

rebar, builders can achieve a compressive strength of between 4,500 and 12,000 psi depending on the specific mix of materials.

“The planting depth with Grasscrete is also a differentiator compared to other permeable paving systems,” Hawkins said. The formers produce an internally reinforced concrete pan that is a stout 5 ½ inches thick and provides deep, well-protected voids for plants to root within. Despite a strength that is identical to other solid concrete flatwork or any other permeable pavement systems, Grasscrete delivers an astounding 37.5 percent non-solid surface, allowing whatever is planted within to truly blanket the concrete.

“Grasscrete seems to check all the boxes related to California’s storm-water retention requirements,” Hawkins said. “But it’s also very flexible in terms of how it can be used: as a drivable, planted lawn-like surface, or a hill stabilizer, a solid surface bottom for detention ponds, for high-end driveways, planted or unplanted, straight or curved, unfinished or polished. There are endless possibilities.”

**SEAN O'KEEFE** writes *Built Environment* stories for publications, architects, builders, and product manufacturers based on 20 years of experience in the design and construction industry. He can be reached at [sean@sokpr.com](mailto:sean@sokpr.com).

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# Designing Sustainable Ports & Yards with 3D Geocells

## Stabilization for Higher-Performing Pavements

Ports and intermodal yards in coastal areas are more prone to pavement problems due to inherent soft, unsupportive soils and high water levels. Heavy traffic patterns and the constant weight of loaded parked trailers and stacked containers at these facilities can accelerate the degradation of the paved or unpaved surfaces and subbase materials. The repeated pressure over poor soil conditions results in settlement, ruts, potholes, and even pavement failure. These surface problems require continual, costly maintenance and interruptions to facility operations. But the problem isn't at the surface—it's a base stabilization problem.

### Transforming Base Materials through 3D Confinement

Creating and ensuring a stable surface supportive of the long-term, heavy traffic needs starts with better stabilization of the base materials. The GEOWEB® 3D confinement system is built for this function. The system's deep, cellular network controls both the horizontal and vertical movement of unstable base soils. When vertical loads are applied, active earth pressures in the loaded GEOWEB® cells push against passive earth pressures in adjacent cells to form a stable system. The benefits of confining fill are applied to both base reinforcement and unpaved surface applications.



### Permeable Unpaved Pavements

Utilizing the GEOWEB® 3D system at the surface, unpaved yards and roads may be designed with highly-permeable, open-graded aggregate (low fines).



There is a notable environmental benefit with this approach. The pavement layer and base materials perform as an on-site stormwater detention basin, where it can store water in the void spaces for natural infiltration. The storage capability can reduce stormwater infrastructure and storm water pond volumes. Without fines in surface layer, drainage is also greatly improved. Water can flow freely through the system preventing pore pressure build up and global failure of the cross section. Where clean aggregate sources are not available, salvaged or low-quality aggregate material may be used to reduce material and hauling costs.

### Base Reinforcement Under Paved Surfaces

In the base layer, GEOWEB® confinement is beneficial under asphalt, reinforced and rolled compacted concrete, especially in areas with low CBR subgrades and drainage issues. Reducing stress on the subgrade allows a thinner pavement layer. Differential and long-term settlement is also reduced—resulting in extended pavement life.

### Design Pavements for Better Performance.

Selection of the GEOWEB® pavement solution is influenced by loading, subgrade soils, traffic frequency and infill type. A free project evaluation from the manufacturer utilizing the AASHTO design method helps determine design feasibility.



## BRIDGING THE GAP

LARGE-SCALE INFRASTRUCTURE IMPROVEMENTS, DONE PROPERLY, CAN INCORPORATE BOTH THE FUNCTIONAL AND RECREATIONAL

By James Pezzotti and Jennifer Reigle

**DESIGNING AND CONSTRUCTING** large-scale transportation projects in urban, multi-use environments can present unique challenges due to their multifaceted nature. Challenges vary from city-to-city, but many include managing high traffic volumes, limiting or eliminating disruptions to large events planned by the city and/or city stakeholders, the need to accommodate pedestrian and cyclist access and safety, site access, public and private utility coordination, and environmental and cultural resource clearances. These challenges may seem daunting; however, these projects are extremely important to cities, especially those looking to attract more foot traffic, pedestrian use, and smoother traffic conditions, and the result can be tremendously rewarding.

Pennoni encountered many of these challenges and several other complexities beyond those of a typical urban environment with our I-676 Vine Expressway Reconstruction project, which involved superstructure replacement of seven aging bridges, but we ultimately finished ahead of schedule while also increasing pedestrian safety and creating beautiful spaces for citizens and tourists to enjoy.

I-676 is an integral part of Philadelphia's traffic system and carries approximately 106,000 vehicles per day across its 1.75-mile length. The Pennsylvania Department of Transportation (PennDOT) District 6-0 retained Pennoni to lead with six design sub-consultants responsible for replacing seven structurally deficient superstructures over I-676 from 22nd Street to 18th Street. The project site was in a culturally-sensitive urban area, which provided the opportunity to improve pedestrian and vehicular traffic safety, increase access to local businesses, and enhance public spaces.

The seven existing bridges consisted of five vehicular bridges and two pedestrian walkway bridges, all with substandard vertical clearance that required rectification during design. All the existing bridge superstructures, which were two-span, non-composite, prestressed concrete adjacent box beam structures varying in length from 96 feet to 135 feet, were replaced with single-span composite steel girder superstructures, which improved the vertical clearance over I-676. The existing center piers were removed, which increased visibility along the highway, and the existing reinforced concrete abutments were retrofitted and reused.

Ensuring ongoing engagement and coordination with stakeholders and city representatives throughout the entirety of the project is one challenge that will arise. To successfully complete this project, coordination with over 40 stakeholders was crucial. The project stakeholders included local business associations, neighborhood groups, institutional neighbors and city departments including: The Parkway Council



View of the completed 20th Street Bridge, looking west. Photo: Kazi Hassan

Foundation, Logan Square Neighborhood Association, The Franklin Institute, The Philadelphia Streets Department, and Parks and Recreation. Each project stakeholder was engaged during the entire design and construction process to ensure all concerns were heard, considered, and incorporated as needed and the needs of motorists, pedestrians, and cyclists were accounted for.

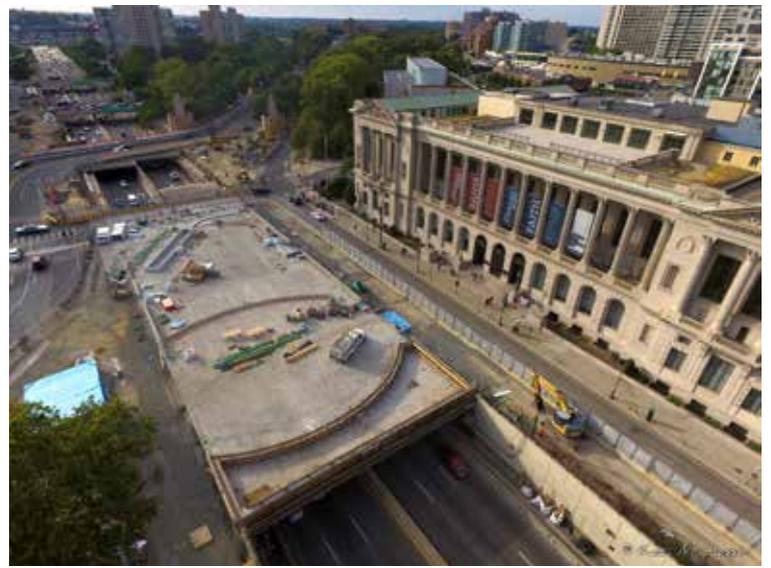
Within this project boundaries and adjacent to the bridge construction are two large Civil War memorials and three sculptures: the Shakespeare sculpture, the General PennyPacker sculpture, and the Francisco DiMiranda sculpture. The city and other project stakeholders were concerned about the protection and preservation of these pieces during construction. To alleviate concerns, special provisions were included in the contract to build protective shelters around each memorial and sculpture, seismographs were installed to monitor construction vibrations, and the statues were cleaned and refurbished prior to the completion of the project.

Accounting for large events around the project site, both planned and unplanned at the start of the design process, was another challenge. The planned events included the Democratic National Convention in July 2016, the NFL Draft in April 2017, the Parkway's Centennial kickoff celebration in Fall 2017, annual Welcome America events, annual Made in America concerts, and the annual Philadelphia Marathon. In addition, an announcement was made that the city would host the World Meeting of Families and Papal visit in September 2015. At this point, the engineering plans and construction package for the project were nearly complete and required major revisions. The project was revised to be completed in two stages and multiple phases to accommodate this event. Major events are a regular occurrence in cities. It's important to keep this in mind when developing the project plan and timeline. Breaking the project down in stages can help alleviate the extra challenges big events can bring on.

Splitting the project into two stages helped solve another complexity. Traffic control was established to minimize disruptions for the high-volume of vehicular and pedestrian traffic. Stage 1 included 20th Street/Parkway/Free Library, 19th Street and Family Court bridges,



View of the completed 21st Street Bridge. Photo: Joe Gidjunis



View of 20th Street Bridge during construction. Photo: Kazi Hassan



View of the completed Family Court Bridge, showcasing the increased public space and greenery. Photo: Kazi Hassan

while Stage 2 included 22nd Street, 21st Street, and 18th Street bridges. The 22nd Street, 21st Street and 20th Street/Parkway bridges remained partially open to vehicles and pedestrians during reconstruction while the remaining bridges were closed to traffic with detours posted.

Expressway traffic control was a separate challenge. Based on the existing roadway configuration, only seven feet adjacent to the abutments was provided to the contractor for a long-term work zone. Short-term construction, such as removing or placing the bridge beams, was completed during overnight closures of I-676 from 11 p.m. to 5 a.m.; detours were determined to guide motorists around the construction during those closures. PennDOT provided construction updates, including road and bridge closures on the project website, and press releases so that it was easily accessible to motorists and pedestrians.

With pedestrians in mind, we implemented several safety improvements. The intersection of 20th Street and the Parkway were reconfigured to remove an existing leg of the intersection and an island was installed to allow for shorter pedestrian crossings across the Parkway and to reduce pedestrian/vehicular conflicts. Along the western edge of 20th Street, the crossing length for the Parkway was reduced by 54 percent. Traffic and pedestrian safety improved through the addition of

62 traffic signal posts and 67 traffic signal post pedestrian countdowns. Pedestrian refuge islands were redesigned at the Parkway at 20th Street and pedestrian bump-outs were added along Vine Street to assist with creating a shorter and safer pedestrian crossing. Access and visibility were improved with the addition of 87 ADA sidewalk ramps and 84 street lights.

For projects in urban environments, incorporating elements beyond the functional ones are important to take into consideration. Increasing and enhancing public spaces with numerous beautification elements such as lawn areas, trees, raised planters, and benches, were designed and installed as part of this project. The area between the existing 20th Street/Parkway bridge and the Free Library bridge was capped to create an expanded Shakespeare Park. Additional green space was added to Pennypacker Park with the installation of a large grass oval in the middle of the bridge. These public parks are now used to host events, such as live entertainment, book signings, and cocktail events.

The primary goal of the project, replacing the structurally deficient bridges, was accomplished along with the pedestrian safety improvements and beautification of the area which have not only made this area more attractive for the residents and tourists, thus increasing pedestrian traffic and use of the facilities nearby, but it has become integral for larger Parkway events, like annual festivals and even special events such as the Eagles Super Bowl Championship Parade in early 2018.

Construction was completed a year ahead of schedule in the fall of 2018. This was possible because of the successful coordination between the owner, contracting team, and design team, as well as the technical expertise to replace the poor-condition superstructures, improve pedestrian and vehicular safety, and incorporate public green spaces, all while maintaining traffic during construction.

**JAMES PEZZOTTI, PE**, is an Associate Vice President, Project Manager/Senior Engineer at Pennoni in Philadelphia, PA.

**JENNIFER REIGLE, PE**, is a Senior Engineer and Project Manager at Pennoni in Philadelphia, PA.

# First-of-Its-Kind Interactive Calculator Enhances Tensor SpectraPave Software

Tensor International has released a major update to its established SpectraPave Software that lets designers, contractors and owners assess the complete short and long-term costs of pavement design options. SpectraPave's updated Pavement Optimization module is intended to help engineers, public agencies, owners, and contractors better understand the true value of using TriAx geogrids in their pavement sections. That value can be determined by examining pavement life extension, reduction of initial construction time and cost, reduction of life cycle costs, reduction of fuel and water consumption during construction, just to name a few.

Key features in the latest release of SpectraPave include:

- Ability to design for a specific level of performance
- Comparison of a variety of support and loading conditions and serviceability limits
- Evaluation and comparison of designs and costs for both unbound aggregate and mechanically stabilized aggregate layers
- Calculators for estimating construction time, reduction of dump truck trips, and fuel and water requirements to construct a project
- Calculators for assessing the cost of traffic delays due to congestion on surrounding public roadways
- Visual enhancements to clearly communicate the estimated initial construction cost and life cycle cost of unstabilized and TriAx stabilized pavement sections
- Assurance that the underlying structural calculations are based on the high-quality research and trusted product that has been proven in the market for many years

Development of the new SpectraPave tool was grounded in Tensor's belief that true value engineering is not simply a matter of cutting costs, but requires giving careful consideration to all options, always with the project's goals in mind. A well-planned and well-executed value-engineering process can improve a project without sacrificing its essential integrity. It may even improve construction quality.

"We've been hearing more and more from designers, owners, and contractors, that they want to better understand the actual cost of constructing and owning a pavement section, looking beyond the initial construction cost. The new SpectraPave value calculator allows them to do this," said Joe Heintz, P.E., Product Manager with Tensor International Corporation. "The new SpectraPave solution also makes this information understandable and usable for all stakeholders – not just folks with pavement design backgrounds," he added.

This comprehensive, systems-based design software suite offers the full benefits of Tensor's knowledge, research and experience in analyzing both subgrade stabilization and pavement optimization applications. No previous knowledge or experience in pavement design is required to benefit from using the software. Pavement designers, contractors and owners can learn more or download the free SpectraPave Software here: <http://info.tensorcorp.com/tensor-spectrapave>.

## About Tensor International

Headquartered in Atlanta, Tensor International is a full-service provider of specialty products and engineering services that offer innovative and cost-effective alternatives to traditional construction methods. Tensor solutions are based on advanced soil stabilization and reinforcement technologies and incorporate unique, engineered applications for commercial, industrial, municipal, residential and transportation infrastructure site development. The company specializes in solutions for common site development challenges, including grade changes requiring retaining walls and poor soil conditions affecting the cost of roadways, parking lots and building structures. Patented, polymeric Tensor® Geogrids and Tensor's Geopier® foundation reinforcement piers are the primary components of the company's systems, offering reliable strength and durability. Contracted services include site evaluation, conceptual engineering, design, value engineering and installation advice. For more information, visit [tensorcorp.com](http://tensorcorp.com).

# PRECISE POSITIONING

TECHNOLOGICAL ADVANCES BRING NEW LEVELS OF PERFORMANCE TO PRECISE GNSS POSITIONING.

By Mark Richter

**SINCE THE EARLIEST DAYS** of satellite-based positioning, surveyors, mappers and other geospatial professionals have sought the holy grail of geolocation: Achieving centimeter-level accuracy whenever and wherever it is needed. Activities such as cadastral or engineering surveys, construction, monitoring and infrastructure management demand high accuracy regardless of project location.

The push for accuracy led first to real-time kinematic (RTK) solutions and then to real-time GNSS networks (RTN). These solutions could provide positions at the centimeter level in real time, which gave users an enormous step forward in productivity and flexibility.

More recently, precise point positioning (PPP) – in which a single GNSS rover can produce accurate results without RTK or an RTN – is addressing the need for accurate geolocation in remote regions. For example, in South Australia surveyors working for Fyfe Pty Ltd (a major Australian consultancy) have used PPP for cadastral surveys in regions not served by GNSS networks. Fyfe crews used Trimble® CenterPoint® RTX positioning service to capture real-time positions on cadastral markers. As a check, they also captured static GNSS data on 40 of the markers. The positions obtained using Trimble RTX agreed with the post-processed static measurements to within 2 cm horizontal. The work demonstrated that they could meet local accuracy requirements while significantly reducing the time spent on site compared to other real-time techniques.

RTK and RTN serve their users well and will continue to do so. But the approaches come with limitations. RTK users need to manage their own reference stations and stay within radio range of control points or establish new ones when needed. RTN eliminates the need for individual reference stations and allows users to cover larger – but still limited – areas. Both approaches rely on radio or cellular communications to deliver data to the GNSS rover. If a data communications link is interrupted, precise real-time positioning stops.

Precise point positioning (PPP) can solve the issues of geographic constraints and communication outages. Until recently, however, it has come with its own limitations in accuracy and time. Users often needed to wait 30 minutes or more to obtain a higher-accuracy GNSS position, which would still be sub-decimeter. That accuracy may be sufficient for a number of uses, but it's not enough for many applications in surveying and construction.

Fortunately the limitations are fading. Improved PPP techniques are providing new levels of accuracy, flexibility and reliability. Recent advances in Trimble's CenterPoint RTX positioning service illustrate the new capabilities.



Surveying with Trimble GNSS at a wind farm in South Africa. By using advanced PPP technologies, surveyors can achieve high accuracy without any local positioning infrastructure. *Photo: Trimble*

## From Good to Better

In contrast to the differential techniques used in RTK and RTN, PPP develops positions by modeling and correcting for three main error sources: satellite orbits, clock offsets and atmospheric effects. The correction data is delivered to a GNSS rover, which combines the information with its own satellite observations to produce accurate positions. Users who subscribe to a positioning service receive the corrections via communications satellites. Depending on the provider, PPP accuracy is typically in the decimeter to meter range.

With the introduction of CenterPoint RTX, Trimble implemented a commercial service to provide high-accuracy PPP corrections. A service of Trimble's RTX platform for global real-time positioning, CenterPoint RTX focuses on applications and users that require centimeter accuracy.

Introduced in 2011, Trimble RTX has provided reliable correction services for users on seven continents. In May 2018, Trimble released updated performance specifications for CenterPoint RTX: The system can produce horizontal accuracy of 2 cm RMS with a convergence time of 15 minutes. (In regions where Trimble CenterPoint RTX Fast service is available, convergence can take as little as one minute.) Once the solution converges, crews can use standard RTK workflows for data collection and setting out.

The improved performance is achieved through several factors. First, Trimble operates a network of more than one hundred GNSS tracking stations around the world that provide continuous GNSS observation data to the Trimble RTX servers. Second, Trimble RTX is not limited to GPS and GLONASS. It also utilizes signals from BeiDou, Galileo to provide a true multi-constellation solution, thereby enabling more robust modeling of error sources. Third, Trimble engineers and scientists have developed enhanced modeling techniques used for PPP. Improvements were also made to the correction streams carrying data



Coverage map of Trimble CenterPoint RTX service. Users can achieve 2-centimeter positions over most of the planet. *Photo: Trimble*

to servers and GNSS rovers. With more data from more stations fed into ever-improving algorithms, overall system performance improves.

For example, Trimble can now model satellite orbits with accuracy of one to two centimeters in real time. Compare this to the broadcast orbit data that is accurate to roughly one meter. Precise orbit data from International GNSS Service (IGS) gives centimeter accuracy, but that information is not available for 10 to 15 days after fieldwork.

The computations for atmospheric modeling and clock offsets are also improved. The atmospheric modeling works by analyzing the radio signals sent from known locations of a satellite to a known ground station. This approach, which leverages the high accuracy models for orbits and clock biases, is essentially a direct measurement of the atmosphere at a specific location. As the density of stations increases, the model can become more accurate. As a result, instead of using only global atmospheric models, Trimble RTX can also develop regional atmospheric models (RAM). In areas such as much of Europe and portions of North America where the density of tracking stations is sufficient, the regional atmospheric models are very accurate and provide higher resolution, thereby allowing significantly faster convergence times. Rapid convergence also utilizes the higher bandwidth available in these areas for transmitting correction data from communications satellites to the GNSS rovers. Positions can be obtained in these regions in less than one minute using CenterPoint RTX Fast.

The ability to provide high-accuracy positioning also relies on increasing capability of hardware in the field. New generation GNSS rovers such as the Trimble R10 have the ability to track all available signals as well as the PPP corrections, which are delivered on L-band transmission. The new rovers also provide the computing horsepower needed to handle the volume of data and complex computations on the fly.

During the convergence period, CenterPoint RTX users can see the accuracy estimates displayed on the controller in a manner based on the patented HD-GNSS approach used by Trimble, which doesn't require traditional ambiguity fixing as in previous RTK positioning techniques. This allows the system to no longer be vulnerable against 'wrong' fixes and leads to a more reliable solution. Also similar to RTK, crews can occupy a known position and use the Quick Start technique to reduce convergence time to less than five minutes in areas where CenterPoint RTX Fast is not available.

## Complementary Technologies

It's important to note that Trimble CenterPoint RTX is not a replacement for RTK or RTN. Rather, it is a complementary technology intended to support those users by providing increased flexibility and reliability. For example, when working with RTK or RTN (including those powered by Trimble VRS (Virtual Reference Station) technology, users may encounter dead spots where the radio link to the base station or cellular connection with the VRS server is blocked or interrupted. In these cases, Trimble CenterPoint RTX provides a backup solution called Trimble xFill®. With xFill, real-time positioning continues to function for up to five minutes after loss of data link, enabling the user to continue operations such as stakeout with 2 cm accuracy. The five-minute coverage is provided with no fee; users who need more time can benefit from a subscription to Trimble xFill Premium.

Geospatial professionals who work in regions served by RTN or VRS may not need Trimble RTX. But for those who encounter limitations in RTK range and reliability, Trimble RTX provides an efficient, reliable alternative or backup that can keep field crews productive and on schedule.

For locations that lack sufficient ground control for GNSS surveying, PPP lets users bypass the need to establish local control points with suitable accuracy and density. That task can involve time-consuming static observations and processing before any real-time work can begin. This benefit was illustrated in South Africa, where surveyors from Cape Survey Ltd. used Trimble CenterPoint RTX to locate access roads serving a new wind farm. Even with on-site control points from earlier static GNSS surveys, crews planned for three days of work, much of which involved moving RTK base stations on a site more than 25 km across. Instead the crew used Trimble CenterPoint RTX to reduce time on site by at least two-thirds while collecting data with 2-cm accuracy.

In Australia, the accuracy demonstrated by Fyfe enabled the company to work with local authorities to enhance the accuracy of the digital cadastral database. By using Trimble CenterPoint RTX, Fyfe could establish positions on cadastral marks more quickly and at significantly lower cost than static or RTK GNSS. The project delivered reliable, spatially correct data for use by planners, engineers, utilities and the general public. Immediate improvements could be seen in corrected property boundaries overlaid on aerial and satellite imagery.

As the density of ground stations increases, performance of RTX will also improve. We may see increased regional modeling, which can directly affect convergence time in those areas. As a result, Trimble RTX users in remote locations around the world will be able to work faster and with survey-grade accuracy.

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## PT. Wijaya Karya leveraged Bentley solutions to save on construction costs and meet deadlines

Two months before the annual Indonesian Homecoming Festival in West Java, a catastrophic landslide affected the main road between Bogor and Cianjur, worsening the already terrible traffic situation. PT. Wijaya Karya was retained to provide an effective feasibility study while performing preventive measures with a strict project deadline. The team investigated the site and captured images to make a digital terrain model with ContextCapture. The organization used OpenRoads and AECOsim Building Designer to design the site, corridor, and ancillary structures and receive automatic concrete volumes. This accurate quantification saved the team up to 20 percent in construction costs.

[Learn more about this project.](#)

### Project

Two months before the annual Indonesian Homecoming Festival in West Java, a catastrophic landslide affected the road between Bogor and Cianjur, worsening the already terrible traffic situation on West Java's main thoroughfare. The Ministry of Public Works retained PT. Wijaya Karya (WIKA) to provide an effective feasibility study while performing preventive measures on the site. The estimated USD 2.9 million project presented numerous site and environmental challenges that required the implementation of integrated design technology to meet the strict, five-month delivery deadline.

### Solution

WIKA implemented a digital 3D BIM and reality modeling solution using Bentley® technology for data capture, design, and construction management. Using unmanned aerial vehicles coupled with ContextCapture, the team surveyed the site, performed ground extraction from a reality mesh, and generated a digital terrain model. Leveraging the capabilities of OpenBuildings™ Designer (formerly AECOsim Building Designer) and OpenRoads™, the team quickly designed the site, corridor, and ancillary structures and used Navigator for clash detection to identify and resolve issues prior to construction. ProjectWise® served as the connected data environment to share information and optimize coordination among the team.

### Outcome

Bentley's integrated technology solution reduced design and construction time by 30 percent, saving three months to help WIKA meet the accelerated five-month deadline. Working in a connected data environment streamlined design workflows to reduce project design time by up to 20 percent. Providing a digitally integrated modeling environment saved USD 660,000 in design costs. The collaborative digital BIM approach improved design quality by 95 percent.

### Software

Using aerial photography and ContextCapture for reality modeling enabled WIKA to save six days capturing existing site conditions compared to traditional survey methods. Given the landslide-prone site conditions, PLAXIS® was instrumental in performing geological analysis to determine soil-bearing properties for structural design. OpenRoads and ProStructures optimized roadway design and reinforcement detailing to accommodate the foundation conditions, while OpenBuildings Designer helped manage accurate 2D and 3D drawing outputs. Utilizing Bentley Navigator for clash detection and construction simulation minimized design errors and enabled real-time construction monitoring to save a total of USD 158,000 in costs.



Designed and engineered by Newtecnic, TechHub is a groundscraper accommodating easily modifiable and therefore futureproofed lab, office and workshop spaces that benefit from natural ventilation. Shown undergoing reconfiguration and maintenance in 2039, TechHub's automated building control unit is temporarily located externally while the internal system is put on hold. A 3D model corresponding to the building assists reconfiguration through augmented reality (AR). *Photo: Newtecnic*

## DIGITAL PATTERN BOOKS DISRUPT CONSTRUCTION INDUSTRY

**BUILDING-DESIGN PATTERN BOOKS THAT HAVE BEEN OUT OF FAVOR FOR DECADES ARE NOW FINDING A NEW DIGITAL LIFE THAT IS DISRUPTING THE GLOBAL CONSTRUCTION INDUSTRY.**

By Andrew Watts

**IN THE PAST**, construction pattern books that allow designers to develop and popularize building styles, were widely used to let clients see what they were buying. With easy to understand images, customers could request changes to layouts and finishes to get a 'mass customized' building to suit their needs.

The great advantage of pattern books was that the designs were tried and tested – known to work. There were no surprises, and each stakeholder understood exactly what the outcome would be. Mixing and matching details was simply achieved.

Pattern books fell out of favor, especially with architects who saw them as un-creative and limiting their design options. Digitalization, however, has changed pattern books updating the concept and positively disrupting the processes of designing, engineering, constructing and maintaining 21st century buildings.

### Generative Design Changes Everything

One of the main drivers for this radical change in construction has been the evolution of Generative Design (GD) technology. This automatically and semi-autonomously creates designs based on the physics related to the functions of buildings. This process of form finding often copies nature's solutions by developing organic shapes that would not be possible without the use of the algorithms that drive designs. These develop through many iterations and output designs that are optimised for their functions.

This means that a digitalized pattern book can have almost infinite design variations and like its historical counterpart each option has assured and verified characteristics that make it perfectly suited to its function. Designs generated by algorithms turn engineering requirements into unique and often very beautiful designs that have never been seen before. Each time changes are required. The design re-generates around the engineering inputs to produce technically warranted outcomes. Algorithms ensure that mechanical electrical and plumbing components and systems along with all other aspects of the building are automatically re-configured and optimized. This is achieved parametrically so that, for example, air-conditioning ducts, and pipes or cable runs are automatically re-drawn to fit the modified structural specification.

### Optimised Everything

One of GD's enabling technologies is Topology Optimization (TO). This optimizes designs within a space envelope and to a set of boundary conditions including geophysical parameters, stress, lighting, heating and ventilating, human usage and traffic flows.



Designed and engineered by Newtecnic, TimberPort S.E. Asia is a highly adaptable, pre-fabricated live/work system that can be simply and safely assembled onsite by local contractors. A drone-based GPS checks the position of each module for accurate location. *Photo: Newtecnic*

Topology optimisation is not a new technology but with the evolution of 3D design simulation, and recent advances in 3D printing hardware, it has helped make GD practical for many manufacturing and construction applications. In the past TO on its own could create optimised shapes for components and assemblies but often it was not possible to turn these designs into real-world geometry. In other words, while the digital output may have been theoretically perfect it was not possible to produce it as a physical product.

GD has changed that situation because it automatically creates 3D computer aided design (CAD) geometry from the outputs that TO generates. This is a game changer because now it is possible to know that optimised design outputs from GD are practical to manufacture. This advance allows designers to not only digitally modify designs using CAD but also to check that any modifications still fall within the required condition boundaries.

These technologies change not just the designing and making process but how people think. Instead of being restricted to “design,” “engineering” or “manufacturing,” GD is helping skilled people break-out of their departmental ‘silos’.

## Role Changes

Because this technology automatically generates optimised and fully proven designs the role of the architect has changed. Masterplans and programs are increasingly integrated with zoning, social and engineering design aspects of the project.

In many instances the productivity enhancement and efficiency that this technology offers meets a bottleneck at the early design stage. But, using the digital tools that are now available, building designs are increasingly being generated and optimized using this method. The implications, not just on productivity, but also on costs, are profound because many more final design options can be quickly generated and validated by design engineers without the need for architectural input.

To handle this engineering-led building design process, Newtecnic is working with several universities in the US to educate a fresh generation of engineers who can work with the newest technologies, and

design and making processes. Working alongside more experienced engineers they can analyze and verify individual components, fabrications and whole buildings that are based on the firm foundation of physics. The technology ensures that while the visual style reflects today’s most advanced aesthetic the engineering design is guaranteed to optimally perform its functions.

## Building the Future

This way of operating solves two significant problems encountered on many construction projects, namely interrupted and fragmented workflows, and a shortage of skilled workers.

Integrated workflows are achievable when projects are fully engineered in advance of any physical construction. Too often decisions are made using only partial information. This means that decisions are taken on unreliable information that does not reveal the complete picture.

On projects that Newtecnic engages with, every aspect of the enterprise is simulated using advanced 3D visualization combined with design engineering based on physics. Not only the building and its construction workflows, but its situation and environment are analyzed and incorporated into the design. This means that any potential interruptions to the project are revealed and overcome in advance. Rationality is brought to projects and this increases productivity while significantly reducing waste. Designs are informed with the full knowledge of how components will be manufactured. This leads to better and more practical solutions which are elegant, both procedurally and in aesthetic terms.

With these methods each participant in a project is able to access the information needed to become an efficient and well-informed player. They can see the detailed information that they need in the context of the whole project and thereby understand their place and responsibilities in the workflows.

## The Answer to Skills Shortages

One of the biggest issues facing the construction industry is a skills shortage. Recent figures show that 90 percent of US construction companies surveyed are concerned about labor and skills shortages with around 50 percent expecting that this will not improve in the short term. This drives up wages but still does not tackle the fact that it is expected that by 2022 there will be 1.5 million vacant construction industry positions in the U.S. However, through technology, multi-level responses to the skills shortage are causing a significant closing of this looming gap.

An industry that makes its processes simpler reduces the need for skills which are applied with the traditional approach. In partnerships with American universities that are engineering exemplars, Newtecnic is assisting in the setting up of design engineering courses that lead to university qualifications for students. This is a fast track alternative to a 4-year engineering degree, much of which has little relevance to today’s industry needs. With the self-explanatory title ‘Learning to Work’ students learn through doing.

Meanwhile, the universities' specialist resources for physical testing of new types of components are utilized to ensure that digital designs are verified for their real-world roles.

Using the pattern book concept as a platform, very ambitious construction projects are quickly being engineered from concept to delivery. Each step is examined, analyzed and optimized for efficient productivity that reduces risk, cost and waste. A new breed of engineers has entered the industry with contemporary ideas, fresh imaginations and the skills to make best use of the most advanced technology available.

### Digital Learning

The work being currently conducted optimizes logistics and construction processes so that buildings are simpler to assemble. This means that workers with different skills and experience can take on appropriate roles while industry specialists develop careers on jobs requiring their own particular expertise.

More complexity can be easily added, and further parameters related to location, usage and services, incorporated into the design, while individual components and assembly processes are optimized. Local workers learn processes from 3D animations ensuring they can become skilled at their required tasks in the virtual world before they reach the worksite.

Pre-solving problems this way through digitalized design engineering overcomes one of the most significant barriers to innovation in our industry, i.e. leaving it until the building stage to resolve problems. This now allows contractors to do what they do best – building. Additionally, engineering led design makes contracts much clearer so the interface between designing and making (which is where many disputes can occur) is clearly understood by both disciplines.

### Evolving the Industry

Engaging fabricators, contractors, clients and design engineers in this technically driven process removes egos and grievances from the mix by enabling greater integration than has previously been possible.

More options and better choices emerge when the digitized engineering route is taken. The consequences of this move support society – which benefits from a more robust and well-organized industry capable of producing environmentally and economically sustainable buildings and infrastructure.

Construction is being revolutionized from within, producing opportunities for innovation and advancement through replacing outmoded practices and stagnation, with new ideas and technologies based on proven principles. This is an exciting time to be in the industry during a period of profound and welcome disruption.

### Actions for getting the most from Industry disruption

1. Change the "silo mind-set" by knocking down barriers between designing and making.
2. Design, engineer and make on one unified digital platform.
3. Avoid mistakes and plan better by simulating processes in advance.
4. '3D Print to perform' ensuring that product function is the number one priority.
5. Leverage science by using materials libraries.
6. Create a digital thread and pattern book so people can focus on their work and not on software applications.
7. Simulate to optimise not just products but also their manufacture and printing.
8. Mesh departments and people so they can collaborate and innovate together.
9. Connecting design to manufacture is the key to efficiency.
10. Future proof production by using an extended enterprise platform that links all processes and stakeholders.
11. Have a holistic approach by using one full solution not 20 different software tools.
12. Predict outcomes through 3D simulation.

About Newtecnic:

Newtecnic is an international world leader in the engineering design of complex highly ambitious construction projects and advanced building envelope systems. The company is an engineering design house that undertakes the engineering design of building structures, façades, and MEP (Mechanical Electrical and Plumbing) installations in partnership with leading international developers, architects and contractors. Founded in 2003, Newtecnic's design professionals team is completely and solely dedicated to the design and engineering of structures, façades and MEP. In partnership with the Engineering Departments of Cambridge University, and UCLA in Los Angeles, Newtecnic's R&D team analyses, develops, tests, validates and specifies new building technologies and methods. Newtecnic has offices in the USA, UK and Saudi Arabia. The company is owned, directed and managed by long-established and experienced engineers. Newtecnic holds the ISO 9001:2015 certification with the British Standards Institution (BSI)

For further information: <http://www.newtecnic.com/>

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# Insulating Concrete Forms for Multifamily Residential Construction

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Credit: 1 LU/HSW

Course Number: ZG062019CS

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Build with Strength, a coalition of the National Ready Mixed Concrete Association, educates the building and design communities and policymakers on the benefits of concrete, and encourages its use as the building material of choice. No other material can replicate concrete's advantages in terms of strength, durability, safety and ease of use.

## Course Overview:

This article provides guidance for architects and engineers on how to design and build high performance reinforced concrete multifamily residential buildings using Insulating Concrete Forms (ICFs). Combining the strength and durability of reinforced concrete with rigid insulation, ICFs provide ideal solutions for apartments, condos, hotels, dormitories and assisted living facilities. With increased attention to occupant safety and comfort, design professionals can take advantage of concrete's inherent fire resistance and noise reduction qualities. This article addresses how the thermal properties of ICFs offer building owners significant energy savings over the long term. The article also provides guidance on how to minimize the cost of ICF concrete construction to take full advantage of these benefits.



Apartment building using Insulating Concrete Forms (ICFs) technology. Photo: Nudura

## Learning Objectives:

1. Understand the basic design criteria and construction elements of Insulating Concrete Forms (ICFs) for multifamily residential projects
2. Demonstrate the economic benefits of building multifamily projects with ICFs
3. Recognize the energy performance characteristics of ICF for multifamily construction
4. Understand the contribution concrete makes to a building's resilience to fire, flood, wind and earthquakes

### Introduction

Insulating Concrete Forms, or ICFs for short, combine two well-established building products, reinforced concrete for strength and durability, and expanded polystyrene (EPS) insulation for energy efficiency. ICF walls are made up of two layers of rigid insulation held together with ties to form ICF form units with a cavity in the center. The ICF form units are stacked in the shape of the wall, reinforcing steel is added into the form cavity and then concrete is placed into the form. The result is a reinforced concrete wall with a layer of insulation on each side. What makes ICFs different than traditional concrete construction is that the forms remain in place after the concrete is cured to provide thermal insulation. The combination of reinforced concrete and insulation provides an ideal load bearing wall, thermal envelope, fire barrier and sound barrier.

In addition to ICF walls there are also ICF concrete floor and roof systems. The concept is similar in that the ICF form is made with rigid insulation to function as a one-sided form at the bottom surface. The forms are installed to span between concrete walls, reinforcing steel is placed and then concrete is placed over the forms. The result is a reinforced concrete floor or roof with rigid insulation on the bottom.

ICF wall systems have been used for building applications ranging from single story buildings to 20+ story high-rise buildings and everything in between. There are examples of ICF buildings all over the U.S. and Canada including single-family residential, multifamily residential, hotels, dormitories, assisted living facilities, offices, healthcare facilities, manufacturing and warehouse buildings. Schools built with ICF are popular due to low- or net-zero energy use. Theaters are also trending towards ICF construction for superior sound attenuation. For this article we'll focus on multifamily occupancies including apartments, condos, hotels, dormitories and assisted living facilities.

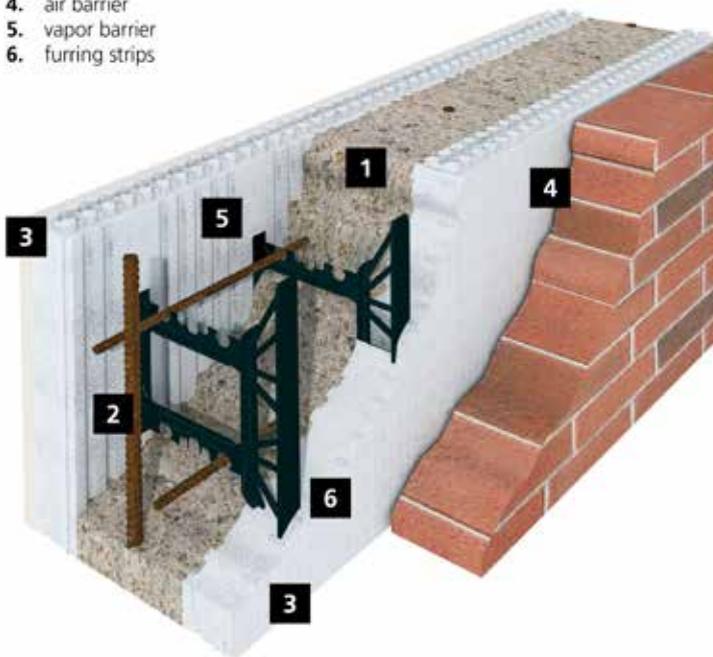
What makes ICFs so attractive for multifamily construction is that they are cost competitive with wood frame, steel frame and masonry construction. A building owner gets a building that is more disaster resilient and energy efficient at or nearly the same cost. Fire safety is a key element of multifamily construction since occupants sleep in these buildings and are often challenged to evacuate during a fire. Concrete walls and floors provide the fire resistance needed to not only allow occupants to evacuate, but contain the fire within a single unit, imposing less risk to fire fighters and property.

### ICF Wall Systems

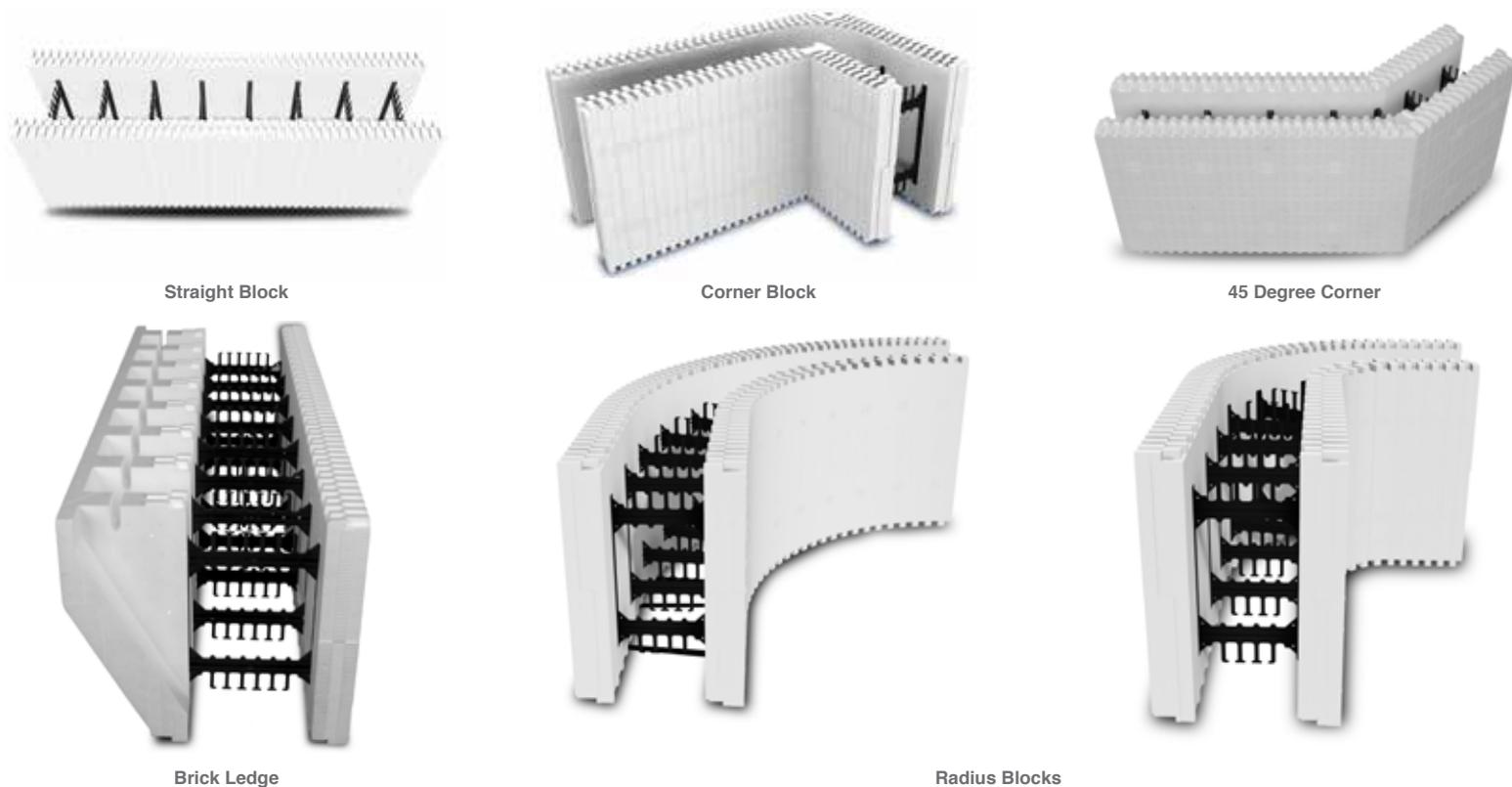
Typically, ICF wall units are comprised of large molded EPS blocks, similar to Lego® blocks with a cavity for concrete in the center. Blocks are manufactured in an EPS manufacturing facility. The blocks range in size from 48 to 96 inches long and 12 to 24 inches high depending on the manufacturer. The most common configuration of an ICF unit is made up of two layers of 2-3/8- to 2-5/8-inch-thick EPS spaced 4, 6, 8, 10 or 12 inches apart depending on design requirements. The most common cavity is 6 inches or 8 inches for most low to mid-rise buildings,

### 6 construction steps in 1 simple package.

1. concrete
2. steel reinforcement
3. insulation
4. air barrier
5. vapor barrier
6. furring strips



Typical ICF concrete wall components. Photo: Logix



Examples of ICF wall block configurations. Photo: Buildblock

but for taller buildings, taller walls, or exceptionally large loadings, thicker walls are necessary. For simplicity, ICFs are generally called out by the width of cavity, hence an ICF with a 6-inch cavity is called a 6-inch ICF and an ICF with an 8-inch cavity is called an 8-inch ICF and so forth.

The blocks are designed to have interlocking teeth that hold the forms together much like Legos®. Most manufacturers not only supply straight blocks but have corner blocks, angled blocks, t-blocks and some even have curved blocks. Most even provide special blocks with brick ledges. Most companies supply blocks that are fully assembled and ready for installation, but some ship blocks that are folded into a flat configuration and then unfolded for installation. One manufacturer ships blocks and ties separately that are assembled on site. Many have special window and door bucks along with other accessories such as bracing, clamps and scaffolding to make the construction process more efficient.

There are some ICF forming systems that are made of other insulating materials and with slightly different configurations and shapes, but flat-wall ICF systems dominate the marketplace. This can be attributed to the fact that flat-wall ICF form units are designed to create standard reinforced concrete structural elements, using well-documented design criteria, such as ACI-318.

There are at least a dozen companies that manufacture flat-wall ICF systems that can deliver their product throughout the U.S. and Canada and many are members of the Insulating Concrete Form Manufacturers Association (ICFMA). For more information visit [www.icf-ma.org](http://www.icf-ma.org).

EPS insulation used for ICFs is governed by ASTM C 578, Type II closed cell foam with an R-value of 4 per inch. Polystyrene beads are first expanded with steam forming high density beads, which are injected into a mold to form the desired shape. Once removed from the molds and cured, EPS is a stable and durable material ideal for construction. No chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs) or formaldehydes are used in the manufacturing process and there is no off-gassing. EPS is moisture resistant, non-absorbent and resistant to mold and rot. EPS contains a flame retardant and the smoke from burning is non-toxic. In addition, EPS is recyclable at its end of life.

The plastic ties that hold the two wythes of the block together are generally made with polypropylene plastic, but it does depend on the manufacturer. They are designed to withstand the liquid concrete pressure during construction. Most manufacturers



Concrete being pumped into an ICF wall. Photo: Quad-Lock

design their ties to secure horizontal and vertical reinforcing bars into notches in the ties to minimize the need to use tie wire. Although different manufacturers provide a wide range of spacing for ties, the most common spacing is 6 or 8 inches. The ties have no thermal bridging, they do not degrade or rot over time, and all ties have furring strips embedded in the EPS for screw-on attachment of exterior or interior finishes.

Reinforcing steel used in ICF walls is the same used for any other type of concrete structure. Typically, smaller diameter bars are used such as #4, #5 or # 6, but thicker bars can be used for higher loading, concentrated loads and pilasters. In most cases, reinforcing steel is placed in one layer in the center of the wall at wide a spacing as permitted by code, especially for above-grade walls built using 6- or 8-inch ICFs. For 10-inch

and larger ICFs, one can consider using 2 layers of reinforcing on each face. The objective is to minimize congestion and facilitate concrete placement. In some cases, steel fibers have been used in place of reinforcing steel in ICF walls, but most common applications use both horizontal and vertical steel reinforcement.

Concrete is typically placed in ICF walls using a boom-type concrete pump, though line-pumps or even conveyor belt equipment can be used. Specified compressive strength used in ICF walls can be whatever is required to resist structural loading, but most common are a 3000 psi or 4000 psi concrete pump mix. The recommended maximum aggregate size should be ½-inch aggregate for 4- and 6-inch cavity forms and ¾-inch aggregate for 8-inch and larger cavity forms. The required concrete slump is 6 inches but could be up to 8 inches or more to accommodate pumping using high-range plasticizers and mid-range water reducing admixtures to achieve necessary flowability.

Concrete is typically placed one level at a time. In other words, ICF blocks are stacked in the shape of the wall for a single story. Reinforcing steel is installed as the forms are stacked. Bracing, scaffolding, window and door bucks are installed. Once the ICF wall is plumbed and straight, concrete can be placed in 4-foot lifts. For a wall that is 12 feet tall, concrete would be placed in 3 different lifts by placing 4 feet of concrete at one time for the entire length of wall. By the time pump reaches the starting point, the concrete is usually stiff enough to place the second lift and so on.

As construction continues, electrical and plumbing lines can be embedded into the interior layer of foam by cutting channels with a hot-knife or other tool. Interior or exterior finishes can be applied directly to the surface by screwing into the plastic furring strips. Gypsum wall board on the interior, and stucco, brick or siding on the exterior are common finishes ideally suited to ICF construction but nearly any finish can be applied.

**Click Here to Finish This Continuing Education Piece and to Take the Quiz**

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# Insulating Concrete Forms for Multifamily Residential Construction Quiz

## BUILD WITH STRENGTH

A COALITION OF THE NATIONAL READY MIXED CONCRETE ASSOCIATION

### 1. What materials make up an insulating concrete form wall?

- a) Structural insulated panels
- b) Expanded polystyrene
- c) Reinforced concrete
- d) Fiberglass insulation
- e) Both B and C

### 2. A typical 6-inch insulating concrete form wall easily achieves an STC rating of \_\_\_\_\_.

- a) 55
- b) 75
- c) 150
- d) 300

### 3. For multifamily construction, ICFs are cost competitive with

- a) Wood frame
- b) Steel frame
- c) Masonry
- d) All the above.

### 4. EPS used for ICFs is typically ASTM C 578, Type II closed cell foam with an R-value of:

- a) 4 per inch
- b) 2 per inch
- c) 1 per inch
- d) 10 per inch

### 5. Concrete used for ICF walls typically has specified compressive strength of:

- a) 1,000 or 2,000 psi
- b) 2,500 psi
- c) 3,000 or 4,000 psi
- d) 5,000 psi

### 6. ICF floors and roofs can span up to about \_\_\_\_\_, depending on the depth of each joist.

- a) 10 feet
- b) 16 feet
- c) 20 feet
- d) 30 feet

### 7. Which systems offer the advantage of having space for mechanical and electrical within the floor cavity?

- a) Precast hollow-core plank
- b) Concrete on metal deck combined with steel joists or cold formed joists
- c) ICF floor and roof systems

### 8. Maximum aggregate size for 6-inch ICF walls should be:

- a) 1/4"
- b) 1/2"
- c) 3/4"
- d) 1"

### 9. Which of the following performance benefits do ICFs have?

- a) Noise attenuation
- b) Fire resistance
- c) Energy efficiency
- d) Strength
- e) Durability
- f) All of the above

### 10. ICFs are considered by the IECC and ASHRAE 90.1 as mass walls with continuous insulation and typical whole wall ICF assemblies have an R-value between \_\_\_\_\_ depending on the exterior and interior finish materials.

- a) R-11 and R-19
- b) R-20 and R-23
- c) R-24 and R-26

### 11. Which hazard kills more Americans each year:

- a) Earthquakes
- b) Tornadoes
- c) Floods
- d) Fires
- e) Hurricanes

### 12. A 6-inch ICF wall will typically achieve a fire rating of:

- a) 1 hour
- b) 2 hours
- c) 3 hours
- d) 5 hours

**Click Here to Take the Quiz!**

# Managing Stormwater through LID and GI

## Attendees will learn:

1. Learn what Low Impact Development and Green Infrastructure means for residential and commercial project sites.
2. Cover the regulations governing these practices and how they have been met with traditional construction methods.
3. Learn about porous pavement options and their benefits and limitations related to infiltration, runoff reduction, traffic and performance.
4. Understand how to manage urban stormwater through design of vegetated channels that replace hard surface systems and mitigate flooding potential.
5. Explore different applications for low-impact products, and understand how they fit with the goals of LID and GI.

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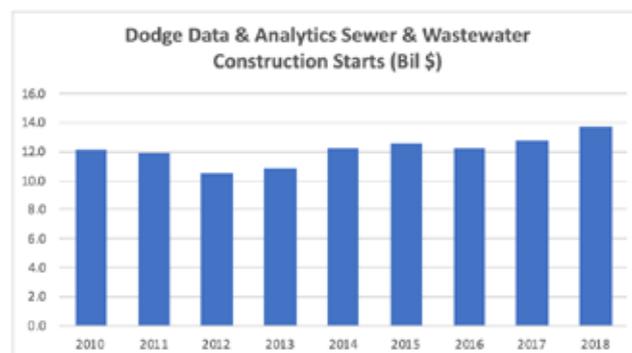
**WATER**

**SEWER AND WASTEWATER CONSTRUCTION** got off to a strong start in 2019 with a 34 percent increase in the first four months of the year. Levels have slowly been edging upwards over the past two years, possibly as a result of the numerous environmental disasters – hurricanes, flooding, and so forth – that have occurred in recent years. Other support is coming from America’s Water Infrastructure Act (AWIA), signed into law in 2018. AWIA included a reauthorization of the Water Resources Development Act (WRDA) that authorized \$3.7 billion in federal funds for the Army Corps of Engineers for dredging, flood control, and other projects. AWIA also authorizes funding for the state revolving loans, subject to the annual appropriations process.

## Dodge Data & Analytics

U.S. Sewer & Wastewater Construction Starts (including hazardous waste)  
Billions of Dollars

Dodge Data & Analytics Sewer & Wastewater Construction Starts (Bil \$)		
2010	12.1	
2011	12.0	-1%
2012	10.6	-12%
2013	10.9	3%
2014	12.2	13%
2015	12.6	3%
2016	12.2	-3%
2017	12.8	5%
2018	13.7	7%



## Largest Sewer/Wastewater Projects of 2018 (Full Year)

Rank	Project Title	City, ST	Started	Mil \$
1	Los Alamos Legacy Cleanup Contract	Los Alamos, NM	2018:05	1,390.0
2	Echewater Project Tertiary Treatment Facilities	Elk Grove, CA	2018:08	299.3
3	Tomahawk Creek WWTP Facility Improvements	Leawood, KS	2018:02	250.0
4	Southeast Plant Headworks Facility (SEP)	San Francisco, CA	2018:07	225.0
5	SW Bergen Point Wastewater Treatment Plant Outfall Replacemt	West Babylon, NY	2018:03	187.8
6	Wastewater Treatment Plant	Logan, UT	2018:12	135.0
7	Midland Secondary Wastewater Treatment Plant	Midland, TX	2018:09	133.5
8	Franklin WRF Modifications & Expansion	Franklin, TN	2018:09	132.9
9	Riverside Park Water Reclamation Facility	Spokane, WA	2018:01	119.0
10	Logan Regional Wastewater Treatment Facility	Logan, UT	2018:07	107.0

## Largest Sewer/Wastewater Projects of First Two Months of 2019

Rank	Project Title	City, ST	Started	Mil \$
1	WWTP Secondary Treatment Phase 1B	Ewa Beach, HI	2019:02	267.2
2	Outfall Low Flow Pump Stations/SCADA Systems Network Upgrade	Huntington Beach, CA	2019:02	90.2
3	Beaumont WWTP Salt Mitigation Upgrade	Beaumont, CA	2019:01	64.3
4	Westminster WWTP ENR and Biosolids Upgrades	Westminster, MD	2019:02	60.8
5	Wastewater Treatment Facility	Richland, MS	2019:01	53.0
6	Wet Weather Combined Sewer Storage-Phase 1	Chattanooga, TN	2019:02	48.6
7	Secondary Treatment & Recycled Water Plant Upgrade	San Rafael, CA	2019:01	46.4
8	Southington Water Pollution Control Plant Phosphorus Upgrade	Plantsville, CT	2019:02	45.0
9	Infrastructure - Koa Ridge Development	Waipahu, HI	2019:01	40.0
10	Plum Creek Water Purification Facility	Castle Rock, CO	2019:01	32.2

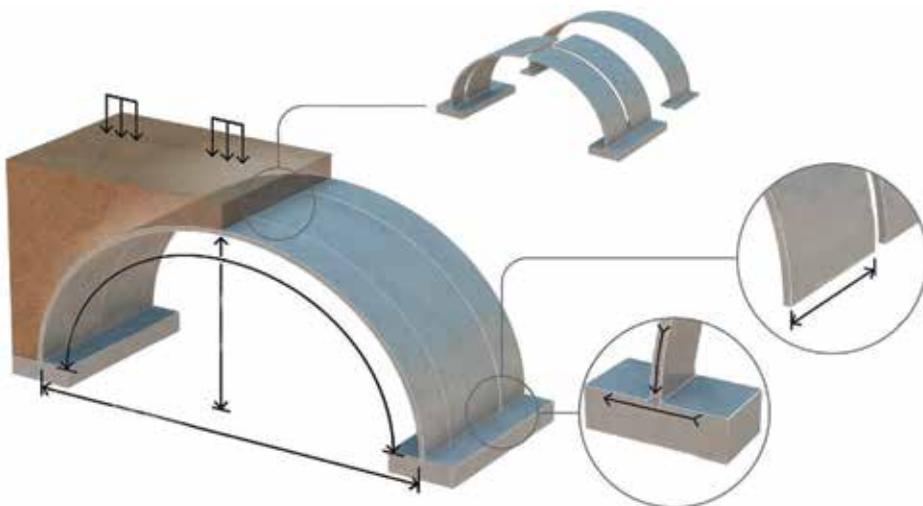


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The bottom course of facing panels are set and braced around the trestle.

## MODIFIED MSE WALL CONSTRUCTION MINIMIZES RAILROAD DOWNTIME

**MERCHANTS BRIDGE**, constructed in the late 1800's, is the oldest rail structure crossing the Mississippi River, and is still used as a major route for freight. The bridge is currently being renovated to increase capacity and meet new engineering standards. Due to the high volume of freight traffic, it is a priority that the project optimizes construction schedule and minimizes track downtime. In the early stages of construction, The Reinforced Earth Company provided the contractor with a unique solution for renovating the bridge's approach on the Missouri side. The solution used a modified MSE wall design that would allow for the existing trestle to be left in place so that the railroad could continue to operate during most of the construction.

The trestle volume was filled from the bottom-up with low-density cellular concrete (LDCC), enclosed by concrete panels, which were anchored to the fill with steel MSE soil reinforcements. MSE walls are typically constructed using granular backfill, however in this case the use of a conventional MSE wall would require more labor and time to compact the fill inside the volume around the existing trestle. The LDCC was flowable, required no compaction effort, and was placed in



A portion of the completed wall joining the existing structure.

vertical lifts larger than a granular backfill would be. After the walls were constructed to the required grade, rail traffic was stopped, and new tracks were installed. The modified MSE walls with LDCC fill do not behave as a typical MSE wall, but on this project, it provided the needed benefit to the railroad's schedule.

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