ONE YEAR AFTER HARVEY

Hard lessons in Houston

NV5: 2018 Top Hot Firm
Improving federal project delivery
Repairing 100-year-old concrete structures
Principles of photogrammetry and LiDAR
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The Houston metro area has experienced three, greater-than-100-year floods in the last five years — story on page 41.
Photo: Adobe Stock.

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Utilizing geosynthetics to build a concrete ski jump. PAGE 40
The American Concrete Institute introduces the ACI Collection of Concrete Codes, Specifications, and Practices (formerly the Manual of Concrete Practice). With nearly 50 codes and specifications and more than 200 practices—the ACI Collection is the most comprehensive and largest single source of information on concrete materials, design, and construction.

The ACI Collection includes ACI 318-14, ACI 301, and ACI 562. The ACI Collection also covers concrete materials, properties, design, construction, reinforcement, repair, structural analysis, and innovation—plus popular topics such as slabs, formwork, masonry, and more.

The ACI Collection is available in three formats—an online subscription that is always up-to-date and includes historic editions of codes and specifications; a USB drive for convenient digital access anywhere, with or without an internet connection; and an eight-volume set of books.

Please visit www.concrete.org to subscribe or purchase.
I WAS TALKING THIS MORNING with my primary business partner at Zweig Group, Chad Clinehens, about Zweig Group’s new thrust to “elevate the industry.” Being an engineer himself, he gets it. The problem in our business is one of public relations. Engineers do so many great things, but their status isn’t what it should be. Why is that? I think there are many reasons, some of which include:

Stereotyping — Engineers in movies or on TV programs are often shown as “nerds” who are good at math but lack social skills or act like they are socially inept in some way. This fact doesn’t enhance the image of the profession.

Introversion — There is some truth to the generalization that engineers are introverts. That means that engineers aren’t always the best at tooting their own horns and selling their many accomplishments and contributions to society. Engineers aren’t braggarts. Engineers are too quiet!

Weak marketers — Our industry and firms are predominated by weak marketers who are not getting the word out about the amazing stuff their firms produce. So once again, the word doesn’t get out.

Let’s face it, it is in all of our collective interests to make engineering more interesting and more exciting. That’s how we will attract the new talent we need to the profession. It is also how we will increase the compensation for engineers in all specialties.

Elevating the professions of civil and structural engineers is what Civil + Structural Engineer magazine is all about. It’s our reason for existence. We’re here to support you and help make you more successful! Let us know any ideas you have on how to make that more of a reality.
Civil + Structural Engineer provides news and articles online to supplement content in this print issue. Visit csengineermag.com daily for the latest news and check out the following articles posted online with the September 2018 issue:

**CALIFORNIA WILDFIRES: GIS TECHNOLOGY HELPS REBUILD LIVES**

By JoAnne Castagna, Ed.D., U.S. Army Corps of Engineers, New York District

In October 2017, numerous, fast-moving wildfires erupted and spread throughout Northern California, burning more than 245,000 acres of land, killing 43 people, and destroying or damaging more than 10,000 structures. This created the largest debris cleanup in California’s history since the 1906 San Francisco earthquake. The Federal Emergency Management Agency called on the U.S. Army Corps of Engineers (USACE) to execute the massive debris-removal mission. To assist with the debris-removal process, Marzena Ellis, an hydraulic engineer with the USACE, created maps and performed critical analysis using GIS in collaboration with Arcadis U.S., Inc.. This information was used by decision makers in every stage of the mission to perform environmental assessments, debris hauling, and the final cleanup.

Read the entire article at [http://tinyurl.com/wildfires-sept18](http://tinyurl.com/wildfires-sept18).

**PROJECT PROFITABILITY: TRANSITIONING PROJECT MANAGERS TO FIRM LEADERS**

By Howard Birnberg, Association for Project Managers

Effective project managers have the communications skills, financial insights, people skills, and other capabilities that allow them to successfully manage profitable projects. These same skills also equip them to be future firm leaders. What do current leaders need to do to help to make this transition happen?

Read the entire article at [http://tinyurl.com/projectprofit-sept18](http://tinyurl.com/projectprofit-sept18).
EXPECTATIONS OF A PRINCIPAL should be higher, not lower. If you have the perception that getting to the top means you finally get a break and can put your feet up on the desk and start “managing,” you are incorrect.

Although some principals set the wrong example, being a principal means that you need to work harder to drive success in the firm. The benefits of that hard work should accrue more directly to you as value in the firm drives your stock value up. This is a key mechanism in ownership; the direct benefit of experience and hard work incentivizing greater performance.

Certainly, it doesn’t always work that way. This is why it is important for firm leaders to define the “brand of ownership,” being selective as to who represents this group and what it says to the rest of the firm. Here are some stats from Zweig Group’s recently published 2018 Principals, Partner, and Owners Survey of the AEC industry:

- Typical principal workweeks are 50 hours long; average is 45 hours for all other staff.
- 75 percent frequently or occasionally work on weekends and/or holidays.
- The typical principal gets 24 paid vacation days off per year but uses only 18.
- Only 43 percent of firms establish any specific minimum eligibility criteria for becoming a principal.

Of those that do, criteria focus on the following:

- Business development/sales abilities: 49 percent
- Professional registration/licensure: 46 percent
- Staff management responsibilities: 38 percent
- Project management experience: 33 percent
- Years of experience: 31 percent
- Education minimum: 8 percent

Of those firms that use experience:

- 14.9 years of career experience is the average to become an owner and
- 9.9 years with the firm is the average to become an owner.

The conclusion of this part of the series is that being a principal translates to performing at a higher level. Anyone can “act like an owner,” which means taking ownership of something bigger than just yourself. For those who can break out of the 8-to-5 mentality and work hard to create value in an organization, public or private, bigger and quicker career opportunities await. If you believe you are principal material, find out the qualifications in your firm and then demonstrate that you are an owner.

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I AM IN ISTANBUL meeting with the director of construction from Turkish Airlines, which is one of the largest airlines in the world. They are building the largest airport in Europe, and the second largest airport in the world, expected to serve 150 million passengers annually when it is complete. This will be Istanbul’s third “new” airport and will replace the current Atatürk International. His mission is to complete this airport by October 2018. In a live aerial picture of the construction, the runway is largely bare ground and the access road is a mound of soil. At that time, they had only three months before an opening ceremony led by Turkey’s Prime Minister. “We shall overcome,” the director said.

This project is enormous. Construction cost is US$8 billion. The terminal building area alone has 1.4 million square meters. Total project duration is 42 months — blazing speed. When I was here two years ago, the state of the airport was barely a digging ground.

What makes this project so unique is not only the size and speed of construction, but that it is 100 percent privately financed — a giant public-private partnership (P3). The government provided land and license, and the private sector consortium designed, is building, and will operate it for 25 years, while paying a $1 billion license fee per year to the government. The airport will be owned by the Turkish government.

It is not only a huge engineering feat, but also P3 at its best. The Turkish government’s political will to modernize and build the country is bar none. It all comes down to the fact that there’s large public support behind it.

Ten years ago, I was embedded in the Istanbul government to assist a $1 billion seismic risk reduction program financed by the World Bank. My job was to work with the Istanbul government to build international technical capacity in the project management unit called IPCU. Their job was huge — 2,000 schools and hospitals needed to be seismically strengthened as soon as possible. Initially, IPCU had a team of about 20 engineers and administrators. But these guys were motivated, smart, and efficient. They worked day and night to manage the $1 billion project. Public support and pressure was tremendous after the 1999 Istanbul earthquake, which collapsed scores of large schools. When it was complete, it was considered to be one of the most successful projects the World Bank had ever done. And it was on time and under budget.

During the project, after every lunch meeting, my Turkish colleagues and I would go to an ancient religious school, which converted to a tea shop, to smoke some water pipe. As Inman sang prayers, we contemplated how we could make Istanbul safer from the earthquake devastation. These engineers were good men.

All these great projects are possible because of public support. Without it, nowhere to go.

Turkey is currently going through an extremely tough economic and political period. The coup d’état two years ago stopped economic expansion, and conflicts with the West on political differences are deep. Its currency is dropping value exponentially. But I see a bright future in Turkey. It is one of few countries in the world that really understands West and East, and they sincerely want to be a part of a global solution. With its incredible public support for infrastructure construction and powerful private sector, Turkey will build its own way back economically.

H. KIT MIYAMOTO, PH.D., S.E., is the CEO and a structural engineer for Miyamoto International (http://miyamotointernational.com), a California seismic safety commissioner, and president of the technical nonprofit Miyamoto Relief. He specializes in high-performance earthquake engineering and disaster mitigation, response, and reconstruction.
At Legacy Building Solutions, we custom design, engineer, manufacture and install fabric structures worldwide, including in the U.S., Canada, South America, Europe, Africa and the Middle East. Each building is engineered to meet precise project specifications and building regulations. Solid steel I-beams allow wider, taller and safer clearspan buildings; hanging loads from mezzanines, conveyors, catwalks, shelving and cranes; and overhead or oversized doors. Legacy’s experienced team works with customers from pre- to post-construction to save time and money while providing custom solutions for your project.

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Thornton Tomasetti appointed four executives to three newly created positions. Managing Principals Gary F. Panariello, Ph.D., P.E., S.E.; and Peter DiMaggio, P.E., SECB, have been named managing director. Principal Robert K. Otani, P.E. LEED AP BD+C, becomes the firm’s first chief technology officer, and Principal Carol A. Post, P.E., S.E., LEED AP, has been promoted to chief quality assurance officer. As managing directors, Panariello and DiMaggio will focus on the strategic growth of the firm’s practices through collaboration and talent development. Otani has played a key role in the development of CORE studio, Thornton Tomasetti’s research and development incubator. Post has served as a leader in the firm’s standards and quality assurance/quality control committees and has played a key role in the development of the QAQC protocol in the Structural Engineering practice.

Khalil Saba joined EXP as sector leader, transportation, based in Southern California. He has more than 39 years of experience in civil engineering and program/project management, including 13 years with Caltrans serving as a deputy director for Caltrans District 8. EXP appointed Robert Andrews as sector leader, Ontario infrastructure. His project experience includes program management and engineering of many of the largest infrastructure systems in the world.

KZF Design hired Terrance J. Dull, P.E., as director of its Transportation & Infrastructure Group. He has more than 30 years of experience and has managed projects and designed facilities for Metropolitan Sewer District of Greater Cincinnati, Greater Cincinnati Water Works, and Ohio Department of Transportation, as well as county agencies and municipalities throughout Ohio, Kentucky, and Indiana.

Steve Hyman, P.E., was charged with managing H2M architects, engineers’ regional office expansion, leading coordinated management of H2M’s office locations in New York City, Westchester, Suffern, Albany, and New Jersey. Dennis Kelleher, P.E., is assuming the newly created role of principal market director. Joseph Mottola, R.A., is assuming the role of deputy COO, working with Gary Loesch, P.E., the firm’s current and longtime COO. With H2M for 30 years and the second architect hired in 1987, Mottola is credited in large part with the growth of the firm’s architectural practice. H2M named James J. Roberts, P.E., vice president and Water/Wastewater Market director. He has more than 35 years of experience in engineering, construction, and the operations and maintenance of New York City’s water supply, distribution, wastewater collection, and stormwater management systems. Other transitions at H2M include James Neri, P.E., vice president, to division director of Water Resources; Christopher Weiss, P.E., to vice president and director of Wastewater; Joseph Manzella, P.E., LEED AP, to vice president; Jay Pisco, P.E., to vice president; and William Rockensies, P.E., to vice president.

JQ hired Bryant De La Cruz, P.E., as a structural project manager in the firm’s Austin, Texas office. His structural design experience includes work on commercial, corporate, medical, multifamily, education, and hospitality structures in multiple regional markets and utilizing multiple structural systems.

Lance Taylor, P.E., joined Neel-Schaffer, Inc. after retiring from the Alabama Department of Transportation (ALDOT). Taylor will manage the firm’s Alabama operations. He spent nearly 26 years with ALDOT, serving in various capacities, including assistant region engineer for pre-construction for the East Central Region.

Parsons announced Patrick Cassity, P.E., as its new Construction Group executive vice president of Business Development and Design-Build Delivery. He will be responsible for working with Parsons’ Infrastructure, Federal, and Construction units to foster integration and innovation and drive growth and operational excellence in alternative project delivery. Parsons also appointed Rida Hamza, Ph.D., as vice president for Business Development, Critical Infrastructure Protection. He will be responsible for international growth and operational excellence in critical infrastructure protection and large-scale physical and cybersecurity project delivery, with focus in the Middle East Africa region, as well as other high-growth regions.
How is Leadership Measured?

<table>
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<th>Projects</th>
<th>Countries</th>
<th>Monthly Business Process Automations</th>
<th>Audit Trail Records</th>
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<td>1M+</td>
<td>100+</td>
<td>1M+</td>
<td>10B+</td>
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1 Connected Data Environment

Industry-leading Digital Project Collaboration

The most competitive project delivery organizations, no matter what their size, know that success depends on efficient project collaboration, streamlined work processes, and disciplined information management. And the numbers tell the story – they rely on ProjectWise.

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SEPTEMBER 2018

33RD ANNUAL WATEREUSE SYMPOSIUM
SEPT. 9-12 — AUSTIN, TEXAS
Learn what’s working, what’s new, and what’s next in water reuse at the nation’s only conference dedicated solely to advancing the policy, technology, innovation, and public acceptance of water reuse. https://wateruse.org/news-events/conferences/annual-wateruse-symposium

2018 ZWEIG GROUP HOT FIRM + A/E INDUSTRY AWARDS CONFERENCE
SEPT. 20-21 — DALLAS
Comprehensive business conference for leaders and aspiring leaders of AEC firms in the U.S. includes topics on technology, leadership challenges, business planning, marketing methods, recruiting and retention, and growth strategies, as well as success stories of Zweig Group award winners. https://zweiggroup.com/2018-hot-firm-conference

PLASTICPIPES XIX
SEPT. 24-26 — LAS VEGAS
Organized in collaboration with the PE 100+ Association, Plastics Pipe Institute, Inc., and The European Plastic Pipes and Fittings Association, a technical program will cover emerging innovations, case studies, key industry research, environmental aspects of the industry, processing, standards development, testing, and regional/country updates. www.ppxix.com

WEFTEC
SEPT. 29-OCT. 3 — NEW ORLEANS
Water Environment Federation annual water quality technical conference and exhibition, providing extensive educational opportunities and access to the field’s most cutting-edge technologies and services. www.weftec.org

OCTOBER 2018

DESIGNING CITIES 2018
OCT. 1-4 — LOS ANGELES
An expected 800 officials, planners, and practitioners will meet to advance the state of transportation in cities. https://nacto.org/conference/designing-cities-2018-los-angeles

NEWFORMA WORLD USER CONFERENCE
OCT. 2-4 — TUCSON, ARIZ.
General and customer-led sessions include Project Center V12, alternative ways to use workflow, document control vs. document sets, techniques to drive user adoption, mobile apps, and more. www.newformaworld.com

RESILIENCE INNOVATIONS SUMMIT AND EXCHANGE (RISE)
OCT. 9-10 — DENVER
Managing the impact of natural and man-made disasters on infrastructure, bringing together transportation leaders from around the country. http://transportationrisenumerum.com

ASCE CONVENTION
OCT. 12-15 — DENVER
Annual American Society of Civil Engineers flagship membership event offers a state of the industry and profession, professional development, multidisciplinary technical education, strategic issues/public policy discussion, and significant projects. www.asceconvention.org

ACI CONCRETE CONVENTION AND EXPOSITION
OCT. 14-18 — LAS VEGAS
Attendees collaborate on concrete codes, specifications, and practices. Technical and educational sessions provide the latest research, case studies, best practices, and the opportunity to earn Professional Development Hours. www.aciconvention.org

THE YEAR IN INFRASTRUCTURE 2018 CONFERENCE
OCT. 16-18 — LONDON
Bentley Systems’ annual event featuring industry specific forums, keynotes, and technology updates. Plus, The Year in Infrastructure Awards finalist presentations showcasing more than 50 infrastructure projects worldwide and an awards banquet. https://yii.bentley.com

GEODALLAS
OCT. 16-17 — DALLAS
Short courses, panel discussions, case studies, and technical lectures all fitting the theme, Geosynthetics in Transportation and Environmental Applications. Conference is co-located with the IFAI Expo and CAMX, the Composites and Advanced Materials Expo. https://geodallas.com

WE 18
OCT. 18-20 — MINNEAPOLIS
Organized by the Society of Women Engineers, the largest gathering of women engineers across all major engineering disciplines features the theme, Let’s Break Boundaries. Tracks include career management, entrepreneurship, leadership, and more. https://we18.swe.org

ICC ANNUAL CONFERENCE, CODE HEARINGS, AND EXPO
OCT. 21-31 — RICHMOND, VA.
Education programs for building safety professionals at all levels of their career that cover the I-Codes, disaster response, leadership, new technologies, and more. www.iccsafe.org/conference

THE PRINCIPALS ACADEMY
OCT. 25-26 — CHARLESTON, S.C.
Intensive course in all aspects of managing a professional service
firm, including business planning, marketing/business development, accounting, financial management, project management, leadership, mergers and acquisitions, ownership transition planning, and recruitment and retention.

https://zweiggroup.com/seminars/the-principals-academy

WATER INFRASTRUCTURE CONFERENCE
OCT. 28-31 — ATLANTA
Program topics include asset management practices, aging and inadequate infrastructure, resiliency to climate events, emergency preparedness, cybersecurity, protecting critical infrastructure, controlling water loss, new technology, intelligent water systems, and more.

www.awwa.org/conferences-education/conferences/water-infrastructure.aspx

NATIONAL DISASTER RESILIENCE CONFERENCE
NOV. 7-9 — CLEARWATER BEACH, FLA.
Focus on the latest in science, policy, and practice to create more resilient buildings and disaster-resilient communities in the face of earthquakes, floods, hail, hurricanes, lightning, tornadoes, and wildfires, as well as human-caused disasters.

http://flash.org/nationaldisasterresilienceconference

AUTODESK UNIVERSITY
NOV. 13-15 — LAS VEGAS
Annual Autodesk users conference attracts 10,000 professionals from the architecture, design, manufacturing, and media industries for classes, workshops, presentations, and interactive galleries.

http://auautodesk.com

LEADERSHIP SKILLS FOR AEC PROFESSIONALS
NOV. 14-15 — SAN FRANCISCO
Specifically developed to provide design and technical professionals with the skills to become more competent leaders, including strategies and techniques that will help them grow personally and professionally.

https://zweiggroup.com/seminars/leadership-skills-for-aec-professionals

EXCELLENCE IN PROJECT MANAGEMENT
NOV. 28 — ATLANTA
Tutorial and case study workshop sessions present critical areas every project manager should know from the perspective of architecture, engineering, and environmental consulting firms.

https://zweiggroup.com/seminars/excellence-in-project-management

DBIA DESIGN-BUILD CONFERENCE AND EXPO 2018
NOV. 7-9 — NEW ORLEANS
Workshops, panel discussions, and keynotes by industry leaders addressing the real-world challenges that America’s design-build teams and owners face across all sectors.

www.designbuildexpo.com

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FOR THE SECOND YEAR IN A ROW, NV5 sits atop Zweig Group’s Hot Firm list of the 100 fastest-growing AEC firms in the nation. Powered by a 2,000-person workforce, a well-oiled system of mergers and acquisitions, and a global presence, NV5 is a company over which the sun never sets.

Amid a banner year — the firm reported first quarter (Q1) total revenues of $95.5 million — NV5 is active from Massachusetts to Macau, and is involved with projects in the multi-millions to the multi-billions. A publicly traded company, NV5 (NASDAQ: NVEE) competes with the industry’s titans — AECOM, Jacobs, and Hill International, to name a few — and is more than holding its own.

Dickerson Wright, the firm’s chairman and CEO since 2009, has been in the business for four decades, giving him a profound understanding of both his company and the industry at large. The Zweig Letter reached out to Wright with questions about various topics. Here is his response.

The Zweig Letter (TZL): NV5 was featured on the NASDAQ Tower Marquee at Times Square on June 12. How did this come about, and tell us about the feedback your firm received from clients, potential clients, and across your marketing and social media channels?

Dickerson Wright: There is a very interesting story behind our name appearing on the NASDAQ Tower Marquee. Actually, the catalyst was the Zweig Group Hot Firm award. NASDAQ contacted our internal public relations person, Jenna Carrick, and said they would like to display this on their marquee. Publicity is always positive, and we have been contacted and asked to do many interviews as a result.

TZL: Hot Firm No. 1 for the second year in a row. Tell us about the strategy that has fueled the firm’s sustained growth over the last few years.

Wright: We have a very simple strategy. We are an organization of key engineering consultants to our clients. Our best people must be the face to the client. When you are perceived to add value, you grow along with your clients.

TZL: There are currently over 100 job openings posted on the NV5 website. In a tight labor market, all firms are having trouble hiring the people they need. What are the key challenges in recruitment and retention for NV5, not just domestically, but globally?

Wright: We look at the openings as something positive. It is very basic: If you want to attract people, your organization must be attractive. We want partners, not just key employees. We therefore distribute stock as equity deep into our organization. Every employee has the readily available opportunity to be an owner of NV5.

2018 Best Firms To Work For List
Zweig Group’s Best Firms To Work For Awards honor outstanding workplaces at architecture, engineering, and environmental consulting firms. Firms that applied were evaluated on firm culture, workplace practices, employee benefits, employee retention rates, professional development, and more — from both management and staff perspectives. Rankings for the Best Firms To Work For are compiled in seven sub-markets/disciplines: Architecture, Civil Engineering, Environmental Services, Geotechnical Engineering, Landscape Architecture and Planning, Multidiscipline, and Structural Engineering.

TZL: NV5 had a fantastic Q1 — $95.5 million in total revenues, a 47 percent increase year-over-year. You mentioned two key indicators of why the firm was so successful and why the 2018 outlook was raised — cross-selling within existing offices and an optimized integration process for acquisitions. Can you elaborate on those two points and discuss how they work, and the processes that are in place that make cross-selling and acquisition integration so important for your business model?

Wright: Cross-selling is a key process of NV5, not only to drive organic growth, but to promote a team concept with all of our offices. We structure bi-weekly conference calls with all offices and the services they offer. Cross-selling is not only promoted but rewarded. The office with the highest organic growth through cross-selling is recognized and awarded.

Integration of new companies is essential to the success of NV5. Prior to the acquisition, the culture of the acquirer and the acquired must match. NV5 believes in a culture of partners and fellow shareholders aligned with the same goals.

TZL: NV5 acquired Butsko Utility Design Inc. in January and followed that up with the acquisition of CSA in February. In 2017, your firm reported seven acquisitions. Since at least 2015, the aggregate value of acquisitions has seen a dramatic increase. What is the M&A outlook for the rest of 2018 and 2019?

Wright: The M&A outlook for our market and sector remains robust. The valuation when the reduced tax rate is taken into consideration remains basically stable. There still tends to be a good market for viable buyers that do not require external financing. We envision this continuing through the remainder of 2018 and 2019.

TZL: Through Q1, the firm has also grown organically by 10 percent, a huge increase compared to organic growth through Q1 2017. Why has organic growth been so strong?

Wright: Our organic growth has been driven principally by three factors: our intentional integration of all our offices by a pragmatic cross-selling initiative; our purposefully flat organization that insists on our key leaders being the direct contact with clients; and benefits derived from a strong backlog and project weather delays that spilled over to Q1.

TZL: NV5 has specialized capabilities across five verticals: construction quality assurance; infrastructure; energy; program management; and environmental. What segment is the firm's bread-and-butter? Which segment do you see increasing in the future, and what area might cool down?

Wright: Our organization is structured to embed ourselves with our clients. We feel that infrastructure design is the first interface with the client and feeds other support verticals. We see an increasing demand for infrastructure improvement projects. Infrastructure in turn supports the organic growth of all our verticals, in particular, program management and energy verticals. Some of our verticals will grow faster than others, but we do not see a decreasing or cooling down of our offerings.

TZL: The majority of NV5's contracts originate in the public sector and the quasi-public sector. However, NV5 has also expressed an interest in obtaining more private work. What's the broad-brush strategy to gain more private-sector clients?

Wright: We have found that a healthy mix of public and quasi-public and private clients allows for continuity of revenue and organic growth. However, we feel that public and quasi-public clients are not as susceptible to down cycles in the economy. We also strive to be an organization built on clients and client relationships, not just projects.
Having a strong civil engineering and survey practice as well as geotechnical and material testing gives visibility with the private sector client base.

TZL: For a firm like NV5, integration of acquired companies is crucial. Communications, logistics and marketing, employee morale, culture, client relationships, and geography all figure into the equation. Based on your experience, what is the single most difficult aspect of integrating an acquired firm?

Wright: Integration of acquired companies just doesn’t happen on its own. From experience, we know that you must have a process that is clearly understood by the acquired firm. We have to be perceived as approachable, as well as transparent, and convey that the integration is a collaborative effort.

The most difficult aspect is developing a relationship of trust, that we do not have all the answers, and that change that may include their recommendations would be positive.

TZL: As the owner of approximately 20 percent of the firm’s stock, you have a great amount of influence on the direction of the firm. What’s your leadership style?

Wright: I must convey to every employee that we are in this together. We are all shareholders and partners. I must be approachable. I find my No. 1 responsibility is to convey a message of inclusion to every employee of NV5.

TZL: NV5 went public in 2013. How has being a publicly traded company affected the firm’s access to capital and growth trajectory? Privately held firms have to play by a different set of rules than those with publicly traded stock. Would you recommend going public to other industry titans that are generating over $100 million in revenue?

Wright: A publicly traded company has much easier access to capital than a private company. We continually strive to utilize this capital to grow in a non-dilutive way. Publicly traded firms have many shareholders that are uniformly interested in growth and profitability, both of which are good for all companies.

Revenue of $100 million, though large for a private company, is considered relatively small for a public company. A company must want to grow if they wish to be publicly traded. Going public must be viewed as an entrance for a company, not a means for an exit.

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2018 Hot Firms
At a black-tie awards ceremony during the 2018 Hot Firm and A/E Industry Awards Conference (https://zweiggroup.com/2018-hot-firm-conference), Sept 20-21, 2018 in Dallas, Zweig Group will honor the fastest-growing architecture, engineering, and environmental consulting (AEC) firms. The 2018 Hot Firm List ranks AEC companies on three-year growth in revenue, by both percentage and dollar growth.

“It is important for us to celebrate growth and success in this industry,” said Zweig Group CEO Chad Clinehens. “This list recognizes those firms that are achieving a real metric of business success: growth, which fuels job creation and builds the communities they serve.”

Following are the top 25 firms on the 2018 Hot Firm List:
1. NV5 Global, Inc.
2. CMTA
3. CRB
4. Ardua-King
5. Hargrove Engineers + Constructors
6. McMillan Pazdan Smith
7. Huckabee
8. Ware Malcomb
9. Partner Engineering and Science, Inc.
10. VHB
11. WGI
13. VLK Architects
14. ISG
15. LJA Engineering, Inc.
16. Rincon Consultants, Inc.
17. BKF Engineers
18. Woolpert Inc.
19. McClure Engineering Company
20. Ross & Baruzzini, Inc.
21. Maser Consulting P.A.
22. EN Engineering LLC
23. Patel, Greene and Associates, PLLC
24. Long Engineering, Inc.
25. Environmental Partners Group, Inc.

The complete list of winners is available at https://zweiggroup.com/about-hot-firm.
Build your network at the largest design and construction industry event in the Northeast where you will design your future through trends, new technologies and educational workshops relevant across all AEC disciplines.

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Enter ADG during the online registration process when prompted to enter a discount code.
On July 14, 2015 in a planning commission meeting in Springfield, Neb., a bit of history was made. We were presenting a plan for Springfield Pines, on a site that was also the location of the Lady Gaga music video “Nebraska,” featuring a large barn and cornfield that was soon to be a coved neighborhood. The developer was Graves Development Resources (GDR). What made history was that it was the first time virtual reality (VR) was used at a public meeting where commission members put on a headset to transport themselves into the completed development!

This amazing technology, originally intended for the video gaming industry, will soon have a major impact on the land development process and how cities grow.

The following groups benefit from VR:
- everyone who judges submittals, be it a shed or addition in someone’s yard, to a new neighborhood submittal;
- developers who commission a site plan and need to fully understand its implications prior to construction;
- builders (and their clients) who need to visualize a home to assure maximum curb appeal and to ensure premium views are actually premium; and
- planners/designers who want to “feel” the result of their work as if it were already constructed.

In other words, about 99 percent of those involved in development and redevelopment can benefit from VR in a major way.

Turning site data into VR
The headset used in the Springfield planning commission meeting was a prototype of the Oculus Rift. We do not use CAD in our consulting business because it is difficult to go from a 2D to a usable 3D live action environment. LandMentor, which we developed and use, (and which easily reads or writes in CAD (.dwg) format if requested), solves these issues.

Our goal was to eliminate the time and complexity going from a site plan to a virtual environment. We spent more than two years so far (the process is ongoing) on the VR aspect of the technology to eliminate
this complexity and make the process as painless as possible. Also, if something is difficult to use and time-consuming, it pretty much translates to being expensive, which we wanted to avoid.

The entire virtual process only adds an hour or two to the planning process — an insignificant cost compared with the tremendous benefit of experiencing firsthand how the neighborhood feels.

We then continued to use VR at several other meetings, such as Pulte Homes’ Territorial Coves in Dayton, Minn., which no doubt expedited the approval process.

Development challenges

Communicating space — Looking at a 3D image of a development is like looking at a picture. With people and cars in the frame, you have some information to judge space, but it is not the same as being there. A video of a development is somewhat better, such as The Chandler in Frankfort, Ky. (http://www.rhsdplanning.com/TheChandler.mp4). However, an image or video cannot replicate the sense of space that VR provides.

Eliminating time-consuming tasks — With LandMentor, creating the 3D site plan is quick, often taking less than an hour’s effort, but even on large sites, no more than two hours.

Making VR flexible to site plan changes — A video game in VR has a known “environment” that does not change. A site plan during the design and approval process undergoes various iterations; thus, the environment changes. Standard VR engines (software that drives the hardware) are not set up for this flexibility, so we had to develop it.

Adopting simple hardware — The first VR headsets had complex interfaces, but last year we received a prototype from Microsoft to begin our VR software development. These headsets are simple, perform well, and most important, are affordable.

Reducing motion sickness — Some people take to VR, some don’t. It seems age is not a factor. We learned not to use motion (moving about), but instead, set fixed positions to explain points. At any time, we can interactively move anywhere on the site, above it for fly overs, or even below to see utility conflicts. If someone reacts negatively to motion, we simply do not use that ability. It is also the reason why we do not support the VR motion controllers that come with the headsets and instead use standard X-Box360 controllers.

For example, if during a public meeting someone complains about how the development will ruin the view from their home, we still can move about to experience how the proposed submittal affects the neighbor — or not.

We also learned several methods to reduce queasiness. For example, instead of viewing from above, we place the viewer inside the cockpit of a Cessna and have them look out the window, which is more comfortable.

An image or video rendering cannot replicate the sense of space that virtual reality provides.

Making reality appear real — For those who have used SketchUp, it is an amazing software accomplishment from an ease-of-use and overall performance perspective that works well on a variety of computer platforms. VR requires a tremendous refresh rate (speed) to operate. SketchUp does not, and because it can work on slow computers well, the compromise is that the 3D appears somewhat cartoonish.

LandMentor previously used a higher-quality 3D engine for better realism than SketchUp but was nowhere near the realistic quality of a high-level software such as Lumion. The 3D engine that drives the headset is also used for all the 3D functions, and while still not as photo-realistic as Lumion, it’s getting much closer.

LandMentor is a system specifically for land development design and construction. It blends land surveying, civil engineering, planning, and site architecture into a single core technology. Because it is a precision analytical tool, many of the spatial or geometric functions communicate directly with its 3D, thus expanding VR beyond a view.

For example, we used it to determine if a site could support three-story buildings without a shadow being cast over the proposed single-family homes. Because the positioning of the sun on a location on the planet is a function of video gaming, and accurate, we tapped into its power.

RICK HARRISON is president of Rick Harrison Site Design Studio (www.rhsdplanning.com). He can be contacted at rharrison@rhsdplanning.com.
The Baise-Jingxi Expressway in Baise City, China plays an important role in the highway network in the Guangxi region, delivering improved traffic conditions and promoting economic development. Along the expressway, the Bageng Bridge provides a transportation route over a traversing railway line and through the area’s mountains. MCC TianGong Group (MCC) was retained as the main construction contractor for the CNY 140 million bridge project, which posed numerous engineering challenges.

Situated amid mountainous terrain with soft soil subgrade and high slopes prone to rock fragmentation, the narrow bridge construction site and railway traffic affected the prefabricating gridirons and scaffolding and presented safety risks for onsite workers. In addition to the geological challenges, MCC was faced with technical difficulties in coordinating and processing data and information among the multiple disciplines. The project team was distributed; while many worked at its main office, others were split across branch locations or at the project site.

“To solve the difficulties, MCC developed a BIM team of designers and engineers and relied on Bentley software to provide information and support for construction management,” said Kun Jiang, manager of technology center at MCC TianGong Tianjin Corporation Limited.

3D modeling facilitates safety
Using OpenRoads technology, MCC generated a digital terrain model from site survey data and performed earthworks analyses, enabling construction planning at an early stage. With AECOsim Building Designer, the team used the model to simulate vehicle paths and the layout of temporary facilities, including the steel-bar processing and prefabrication field. Integrating the BridgeMaster bridge model, the team was able to set up a T-beam vertical lifting station and optimize its design.

Simulation of the vertical lifting station and erection of the precast beam, as well as construction of special equipment, were critical for safe bridge engineering. The project team avoided accidents due to the scale and height of the project by applying BIM strategies to simulate construction procedures. The team imported the structural model of the
hanging baskets into STAAD, where they performed finite element and load analyses and studied stress and deformation for the main truss to ensure structural integrity.

Using Bentley modeling capabilities, the team optimized the design of the anti-electric shed across the railway using a concrete foundation, a steel support system, and an insulated roof to accommodate the hanging basket construction and train traffic. Modeling of the guardrail and safety ladder for the edge of the 30-meter-high structures also reduced associated construction risks. Bentley’s integrated 3D design technology avoided repeat modeling, verified structural stability, and satisfied safety requirements.

Collaborative construction management
MCC used ProjectWise as its collaborative platform to share documents and data among the multiple disciplines and configured personnel permissions to ensure secure access and standardized workflows. The team created a customized component library, enabling tag management of each construction part and establishing a construction process management file of components. Through ProjectWise, the information was viewed in real time and managing documents and uploading contracts, material quantities, and construction standards into the same platform was simple.

Integrating mobile applications and iModels enhanced and accelerated information sharing. Bridge models were loaded onto mobile devices for onsite comparison with actual construction scenes. Using hyperlinks on the models, onsite workers could enter additional traceable information in the construction process, ranging from material type to construction time. With traceable data and information links accessible in real time via ProjectWise, the team achieved dynamic synchronization and management of the construction process, plus improved quality control.

Integrated BIM technology delivers savings
Implementing a collaborative BIM approach with Bentley’s integrated technology, the team modeled and simulated the entire construction process, chose the optimal construction scheme, and kept the project on schedule. Optimizing design of the construction scenario saved CNY 150,000 in construction costs and reduced construction time by 56 days. Bentley software improved engineering quality, enhanced productivity, saved time and money, minimized errors, and eliminated risks associated with elevated bridge engineering amid the terrain constraints.

In addition, the team’s BridgeMaster model not only assisted in bridge modeling, but also provided accurate material takeoffs to avoid unnecessary and costly material loss. Using OpenRoads technology facilitated precise earthworks calculations, minimizing environmental impact and reducing overall project costs. When compared with traditional methods, MCC was able to optimize delivery of the Bageng Bridge project, managing time and costs through the application of BIM and ProjectWise for information management and sharing.

Implementing a collaborative BIM approach to the Bageng Bridge project facilitated successful construction management, enabling process control. The BIM strategy also improved traceability of project information, accelerating project delivery and enhancing site performance for the infrastructure. Upon completion, the 3D models and documents will be transferred for the owner to use for complete life cycle operations and management.

The application of BIM strategies in bridge engineering not only improved project management, but also increased MCC’s reputation. MCC accumulated and analyzed the relevant processes for an optimal BIM methodology that will establish it as a standard for future projects based on the success of the Bageng Bridge project. MCC looks to continue using BIM strategies to complete more projects in its region.

STEVE COCKERELL is director of industry marketing — Road and Rail, with Bentley Systems (www.bentley.com). He joined Bentley Systems in 2002 through the company’s acquisition of Infrasoft. At Infrasoft, Cockerell served as channel marketing director where he helped develop and launch Arenium, an engineering collaboration product that enabled multi-user access to MX 3D design models. Recently, Cockerell was involved in the launch of Bentley’s OpenRail solution.
THE SCRIPT IS COMMON. A major project is announced with the expectation that the project will be delivered on time, on budget, and will meet the needs of taxpayers. Then months or oftentimes years later, costs are more than anticipated and the project is nowhere near completion. The federal agency that announced the project is frustrated that its day-to-day operations are impacted or, worse yet, the original project promises are unachievable.

At the same time, design and construction costs balloon, resulting in claims for additional compensation or extensions of time, further slowing down the project. The taxpayer, who ultimately foots the bill, is left to wonder: Are my tax dollars being used wisely?

Cost overruns and delays are not new to our industry. Recent research by McKinsey shows nearly 98 percent of mega projects (projects valued at more than $1 billion) suffer cost overruns of more than 30 percent, and the federal marketplace is no different. For example, the costs to build a Department of Veterans Affairs hospital near Denver, scheduled to open this year, has ballooned from $600 million to $1.7 billion, while the consolidation of the Department of Homeland Security headquarters in Washington, D.C. is still ongoing — 15 years behind schedule.

It is never the goal of an AEC firm to deliver work late or incur cost overruns, but major federal projects are multifaceted endeavors. Federal projects feature numerous stakeholders, which can complicate even the simplest tasks, and risks are often not properly accounted for, stakeholder alignment is weak, and communication and decision-making are hamstrung by bureaucratic red-tape. Add to this a byzantine labyrinth of laws, rules, and procedures unique to the federal sector and you have a recipe for construction delays and cost overruns.

Adapt commercial sector concepts

So, what can be done to improve the process? The answers may lie in the commercial sector.

Unlike in the federal sphere, dynamics that figure prominently into the commercial approach to the planning, procurement, design, and construction phases of a major or complex project include the following:

- The project is likely revenue-generating and therefore owners are motivated to work closely with the AEC team to eliminate delays and inefficiencies.
- Long-term cost considerations that affect the owner’s future profitability and competition for project end-users play prominently in the design and procurement process.
- Risk-sharing among project team members, coupled with incentive-based completion provisions for project delivery, help to bring alignment and focus to the team.
- Early identification of a single, dedicated, and often integrated project team, including procurement, owner’s representative, designer, and contractor who oversee the work from start to finish.

While we cannot add revenue-generating aspects into every government project or eliminate federal regulations and laws, we can certainly adapt many commercial-sector concepts and approaches to our federal projects.

Implement procurement strategies

One of the most impactful lessons from the commercial sector that can be applied begins with choosing an appropriate procurement strategy and methodology. Unlike the commercial market, where we are seeing growth in inclusive procurement methods and considerations, including total cost of ownership, performance-based contracting, integrated project delivery and public-private partnerships (P3s), we’ve seen the opposite in the federal market with a drive toward simplification, standardization, and commoditization. The net effect is the transfer of most of the risks to the AEC firms. Combine this with a reliance on firm-fixed-price contracting and the procurement environment is difficult.

Given these dynamics, project scopes are rarely well-defined, resulting in overreliance on the government’s independent estimate. This creates a competitive model focused solely on low price, which increases the risk to the federal contractor. In other words, a responsive bidder is often caught in a “Catch-22” — having to decide between adding contingencies into their bid to account for ill-defined or unknown risks or developing an unrealistically low bid to win the job. This has project delivery ramifications that often manifest themselves in delays, claims, and requests for equitable adjustments.
Institute robust partnering

Another major concept is alignment of project staff with agreed-upon and shared programmatic goals. With commercial projects there exists a growing preference for cooperative sharing of capabilities and risks. While advanced forms of these structures (such as P3s) are less common on federal projects, the partnering concept of these structures can still be applied in the federal sector. This can be accomplished through robust partnering sessions involving the full gambit of project participants, including the federal contracting officer, program team, third-party stakeholders, and the design/construction contracting team.

The advantage of a partnering session includes clear and early identification of project goals as well as risks, and formulation of a plan to allocate or mitigate those risks. The goal should be to memorialize the decisions made during the session and develop a protocol document or a “project charter” that addresses handling of risks or other issues that arise. Establishing a charter can greatly improve and simplify communication, as well as the speed at which decisions are elevated. The result is faster decision-making and avoidance of impacts to project timetables.

Streamline and improve communications

Other practices that serve commercial organizations well include a dedicated and integrated project team, resulting in better communications between the owner and their AEC contractors. In commercial projects, there is obviously no contracting officer entrusted with managing the contract on behalf of the owner. This means that communication between commercial owners and the project team are usually direct — allowing decisions to be made in real time. Though eliminating the contracting officer position for federal projects is impossible, making the contracting officer truly a part of the team results in faster, more direct lines of communication with the federal agency’s key decision-makers and helps to ensure projects stay on track and ultimately within budget.

With a Congressional budget finally settled through September 2019, we are likely to see an increase in the number of complex or major projects across the federal government. As such, federal projects that apply these commercial concepts — thoughtful implementation of procurement strategies that match project goals and risks; using robust partnering sessions and project charters that define project risks; and developing project processes and communication with less bureaucracy and an overall streamlined approach — can greatly improve the odds that those projects will be delivered on time and on budget.


A BETTER WAY TO BUILD

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DESIGN-BUILD used to be considered an “alternative” way to build. New research shows it’s now the fastest-growing and most popular method of delivering construction projects in America.

Industry analysts at FMI completed a comprehensive assessment of the nonresidential, highway/street, and water/wastewater construction markets. This research details how design-build is, literally, changing the way America builds.

“This research is incredibly important as design-build transitions from what used to be considered an ‘alternative delivery’ process, not so many years ago, to the preferred delivery method for a growing number of public and private owners. Collaboration and innovation are delivering better projects that also achieve cost and schedule savings, which is especially important as cash-strapped states and communities have to do more with less,” said Lisa Washington, executive director/CEO, Design-Build Institute of America.

Data show design-build is helping deliver vital infrastructure in all sectors and regions of the United States. Respondents report saving time and money, while more innovation and collaboration delivers better projects and leads to high design-build satisfaction and increased usage.

Highlights from the FMI Design-Build Market research report include the following:

• Overall, design-build is anticipated to account for 44 percent of construction spending in the assessed segments (nonresidential, highway/street, and water/wastewater), delivering $1.2 trillion in construction put in place by 2021.
• Design-build spending is anticipated to grow 18 percent overall, with the highway/street and water/wastewater sectors experiencing 30 percent growth by 2021.
• Design-build spending in manufacturing (16 percent), highway/street (14 percent), and educational (15 percent) sectors represent the greatest percentage of design-build construction spending by segment during the 2018-2021 period.
• Experience with design-build was rated highest across all project delivery methods, with 76 percent reporting very good and excellent experiences.
• Opportunities to innovate and the ability to fast track a project were identified as top benefits associated with design-build.


Information provided by the Design-Build Institute of America (www.dbia.org).
With growing interest in taller wood-frame buildings — many with five stories of wood on podiums with wood-frame mezzanines — there has also been interest in the use of brick veneer at greater heights.

For designers interested in brick veneer as an exterior finish, some publications and design guides reference using steel studs and non-combustible supports. However, there are in fact code-compliant methods for using brick veneer over the entire height of a mid-rise wood-frame structure. Options include a prescriptive approach for the use of brick veneer up to 30 feet in height and an alternate design approach for its use above 30 feet.

A publication by the Brick Industry Association (BIA; Reference 1) gives direct guidance for the application of brick veneer on wood backing above the 30-foot prescriptive height limit. As this paper explains, one approach is to stack the brick veneer at full height off the foundation without shelf angles or intermediate support by the wood framing. Another is to support the brick veneer off shelf angles that are attached to the wood framing at desired intervals. Both require the use of Section 12.2.1, Alternative design of anchored masonry veneer in the masonry code (Reference 2).

This excerpt of a WoodWorks technical paper focuses on these approaches. For engineers considering the use of brick veneer on a wood-frame building, the complete paper, available at www.woodworks.org/options-brick-veneer, also includes design considerations.

Prescriptive requirements

The masonry code’s prescriptive height limitations for brick veneer on wood construction allow veneer up to 30 feet above the veneer support, which could be interpreted as a foundation or an alternate location of support. This is based on Section 12.2.2.3.1.2, which states: “Anchored veneer with a backing of wood framing shall not exceed 30 feet, or 38 feet at a gable, in height above the location where the veneer is supported.”

However, this is followed by Section 12.2.2.3.1, which also requires that the weight of the veneer be supported on concrete or masonry foundations or some other non-combustible construction. In a wood-frame building, a steel shelf angle is often cited as this non-combustible support.

Under prescriptive requirements of Section 12.2.2.3.1.3, the code says that, when anchored veneer exceeds 30 feet or 38 feet at a gable, in height above the location where the veneer is supported, the weight of the veneer can be supported by cold-framed steel studs at each story above the 30-foot height limit. This prescriptive provision is the reason many code officials struggle with the use of wood-frame structures supporting brick veneer.

However, further inspection of Section 12.2.2.3.1.5 and its commentary reveals an exception to that prescriptive provision which explicitly
allows veneer to be supported on and by wood construction provided
the installed weight is 40 psf or less and the supported height is equal to
or less than 12 feet:

12.2.2.3.1.5 Exterior masonry veneer having an installed
weight of 40 psf or less and height of no more than 12 feet shall be
permitted to be supported on wood construction. A vertical movement
joint in the masonry veneer shall be used to isolate the veneer sup-
ported by wood construction from that supported by the foundation.
Masonry shall be designed and constructed so that masonry is not in
direct contact with wood. The horizontally spanning element supporting
the masonry veneer shall be designed so that deflection due to dead plus
live loads does not exceed 1/600 or 0.3 inch.

This series of code sections has been used to allow the framing details
shown in Figure 1 and support condition shown in Figure 2 on projects
across the U.S. Details published in a BIA technical note (Reference 3)
confirm that multiple support conditions are permitted. These details
and others (Reference 4) are allowed provided their design is based on a
rational analysis and complies with the requirements of the Alternative
design of anchored masonry veneer of Section 12.2.1.

Brick veneer applications exceeding 30 feet in height exist all over the
country. One example of brick veneer applied on wood framing beyond
the 30-foot height limitation can be referenced in a WoodWorks case
study of the University of Washington West Campus Student Housing
project (Reference 5).

“They code allows you to go up 30 feet [prescriptively] but we did not go
that high,” said Chris Duvall, with structural engineering firm, Coughlin
Porter Lundeen. “We isolated the brick panels at each level by using
veneer ledger angles hung from the rim board at each floor above the
podium. So, the first story of brick sits on top of the concrete foundation;
it is re-supported at the concrete podium slab and then at every level of
wood floor framing above. We then detailed the brick to allow the wood
framing to shrink behind it while the brick veneer panel moves with the
building.”

**Alternative design requirements**

Common practice when exceeding the prescriptive 30-foot height
limitation for brick veneer on wood framing has been to follow Sec-
tion 12.2.1 of the masonry code. This approach requires that the veneer
support system be based on a rational engineered solution. Code com-
mentary notes that there are no rational design provisions for anchored
veneer stipulated in any code or standard. However, some guidance is
provided in this document and in Designing Anchored Brick Veneer
above 30 Feet with a Backing of Wood Framing, published by the BIA.
The intent of Section 12.2.1 is to allow the designer to use alternative
means of supporting and anchoring masonry veneer. Section 12.2.1
requirements are as follows:

a. The forces applied to the veneer are distributed through the veneer to the
anchors and the backing using the principles of mechanics.
b. Out-of-plane deflection of the backing is limited to maintain the stability of
the veneer.
c. The veneer is not subject to either the flexural tensile stress provisions of
Section 8.2, or the nominal flexural tensile strength provisions of Section
9.1.9.2.
d. The veneer must meet the General veneer provisions Section 12.1, the prescriptive requirements for stack bond Section 12.2.2.9, and the prescriptive requirements for higher seismic areas Section 12.2.2.10.

Conventional brick veneer

According to Section 1.6 of the masonry code, conventional brick veneer is plain unreinforced masonry (see Figure 3). Veneer is not allowed to be load bearing and only supports self-weight and out-of-plane loads. Out-of-plane bending loads are transferred through the masonry ties into the backing material or studs, where it is resisted.

Section 12.2.1(c) of the masonry code states that the veneer is not allowed to be subjected to the flexural tension stress provisions of Section 8.2 or Section 9.1.9.2. Contrary to Section 12.2.1(c), commentary states that the designer may choose not to consider stresses in the veneer or may limit the flexural stresses to ASD values, the anticipated cracking stress or some other limiting condition. Flexural tension stresses and cracking can be limited by controlling the deflection of the backing material. Current deflection limits for walls supporting brick veneer are subjective, with recommendations varying from L/180 to L/720, or greater, based on limiting the crack width (Reference 6). The IBC prescribes a minimum of L/240 for brittle finishes. The University of Washington Student Housing in Seattle phase one includes five buildings, each with five stories of Type VA wood-frame construction over a two-story concrete podium. Under the Seattle Building Code, Type VA wood buildings are permitted to be five stories. Architect: Mahlum; Structural engineer: Coughlin Porter Lundeen. Photo: Benjamin Benschneider

BIA recommends a limit of L/360.7

As part of the design, the designer should also consider the following:
- Provide horizontal in-plane, out-of-plane, and vertical support for the veneer.
- Control deflection of the backing material.
- Allow for differential movement between the veneer and the wood framing, including vertical shrinkage and lateral drift.
- Develop anchor loads through the connections into the backing, providing adequate strength and stiffness.
- Account for water penetration expected through the brick veneer in the building envelope system.
- Account for air and vapor transmission expected through the brick veneer in the building envelope system.

Reinforced brick veneer

Reinforced brick veneer provides an alternate option for an exterior veneer system or cladding. This brick veneer system follows the definition in Section 1.6 in that it is non-load bearing and only supports self-weight and out-of-plane loads. It does not replace the wood-frame walls or lateral-resisting elements.

The structural brick veneer (Reference 8) is hollow, similar to concrete masonry units (CMU blocks), which allows for the installation of vertical and horizontal reinforcement (see Figure 3). The veneer thus becomes a

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you’ll get up to speed in a few short days—and that will translate to more efficient, more cost-effective and safer operations.
Solar Ship, Inc. is a Canadian company that develops hybrid aircraft designed to provide access to remote locations worldwide. The Solar Ship aircraft operate using solar power — an ideal the company is committed to maintaining in the design of its assembly facilities and hangars. In 2014, Solar Ship contacted Legacy Building Solutions to engineer, install, and provide project management services on a new hangar in Brantford, Ontario.

Space was a primary consideration for the new hangar. The largest craft Solar Ship manufactures has a 100-foot wingspan. To accommodate this, the hangar has more than 50,000 feet of clear area, measuring 176 feet by 231 feet. This allows the ships to park inside the building for storage, maintenance, and charging. The building is also formidably tall, with a sidewall height of 60 feet, soaring to 82 feet high at the peak.

Rooftop solar panels were another top-level requirement for the hangar. Solar Ship operates off the grid except for a small generator used to store power for overcast days. The top of the structure features a rooftop array consisting of photovoltaic cells as well as 1.18 kPa roof rain-on-snow load.

“We’re not connected at all to Brantford Power,” said Lewis Reford, partner at Solar Ship. “We charge during sunny days and can work the next two or three days if we need to. We don’t need the grid and we’re not held ransom by electricity prices. We know the cost of our electricity for the next 20 years.”

The hangar has more than 50,000 feet of clear area, allowing the airships to park inside the building for storage, maintenance, and charging. The building has a sidewall height of 60 feet, increasing to 82 feet high at the peak.

“The frames run parallel to the solar panels, which prevents uplift.

The natural properties of a fabric structure enhance the efficiency of the solar panels. The fabric roof and walls allow natural light into the building, eliminating the need for electric lights on most days.

“We really appreciate the translucency of the fabric,” said Reford. “During the day, there is enough sunlight inside the building to operate without additional lighting. It’s like getting the benefit of a skylight without the added cost.”

The fabric is also non-conductive, maintaining a consistent interior temperature rather than magnifying the outside conditions on espe-
cially cold or hot days. The fabric seals tightly around openings and features a continuous liner with thermal break on the interior, which has been shown to reduce air leakage to a minimum.

One of the most visible features of the hangar is the extra-large door. The sliding door measures 164 feet by 59 feet. When open, the door extends beyond the width of the structure and is supported by a special frame that was designed by Legacy. Personnel access the buildings via separate doors.

“Legacy Building Solutions has given Solar Ship more than just a state-of-the-art hangar and assembly building,” Reford said. “Through our close collaboration, their design incorporates a self-reliant photovoltaic power package that sits above the fabric roof, allowing our building operations to be entirely off-grid. In addition, Legacy’s foundation design allowed us to reuse an existing concrete pad, saving us time and money during construction. These innovations were part of our top-level requirements and delivering on them really sets Legacy apart from the traditional building segment.”

The innovative design and sustainability of the hangar have received recognition beyond Solar Ship as well. In May 2016, the hangar was awarded Game Changer Project of the Year by the Canadian Solar Industries Association (CanSIA) for using a reliable and cost-effective system that advances the future of building-integrated distributed generation.

The University of Massachusetts (UMass) wanted to bring its design programs — Architecture, Landscape Architecture and Regional Planning, and Building and Construction Technology — together in one creatively designed building exemplifying sustainable construction practices. While a steel- or concrete-framed structure would be conventional for this building’s size and use, the new John W. Olver Design Building features a timber-framed superstructure with an innovative composite floor system. The exposed wood structure emphasizes the potential of engineered wood elements while complementing and influencing the aesthetics inside and out.

Creative solution
Simpson Gumpertz & Heger Inc. (SGH) worked closely with Equilibrium Consulting, Inc. to design an 87,000-square-foot attractive, functional, and innovative structure. One challenge was designing open floor plates, originally conceived as a steel structure, with a mass-timber system. Historically, heavy timber buildings were constructed with large, closely spaced beams spanning 25 feet or less. Steel and concrete structures are commonly arranged in 30-foot bays, but easily allow engineers and architects to achieve longer spans. For the Design Building, the gravity system was changed to glue-laminated (glulam) beams and columns with an innovative approach for the floor system to construct the reimagined structure.
The solution was a composite cross-laminated timber (CLT) and concrete floor system. CLT, developed in the early 1990s, is a wood technology where sawn lumber from smaller trees are glued together in perpendicular layers to form large, mass-timber panels. Although CLT has been popular in Europe for longer than 20 years, it is a relatively new product for the United States. Taking this innovation one step further, perforated steel plate shear connectors were embedded into both the CLT panels and glulam beams and bonded with epoxy resin. A 4-inch-thick concrete slab was then placed on top of the CLT, which bonded to the steel plates and allowed the wood elements to act compositely with the concrete slab. This composite action greatly increases the strength and stiffness of the floor system, allowing the design team to achieve the required spans of up to 26 feet, typically reserved for concrete and steel construction.

The wood-concrete composite floors have excellent acoustics and dynamic damping properties. They also experience smaller deflections and limited potential for long-term creep effects as compared with a non-composite CLT floor. The steel reinforcement contained in the concrete topping helps mitigate concrete cracking and also facilitates transferring shear forces at diaphragm connections. Aesthetics were another important consideration in the development of the composite floor system. The underside of the CLT floor decks are mostly exposed, offering a warm and attractive ceiling, while the concrete slab is polished, providing a modern-looking and durable floor finish.

Dramatic design details
A defining feature of the Design Building and the showcase for its use of mass timber is the multi-story atrium. The atrium roof spans up to 56 feet to create a wide-open space below and an outdoor classroom/green roof above, complete with large pyramid skylights. A system of 3D “spider trusses” — consisting of composite concrete-glulam top chords, round glulam struts, and steel tension rods — creates a visually striking perspective from inside the space. The structural elements are left exposed as a visual demonstration of the efficient use of wood in compression and steel in tension. While one end of the spider trusses bears on typical glulam and steel columns, the other end bears on a story-deep steel truss that is visible from the atrium roof through the glass façade.

A suspended CLT stair complements the exposed structural elements in the atrium. In a hybrid use of materials, the CLT stair is suspended via steel rods from the steel story-deep truss that is in turn supported by two large glulam columns.

The structure’s lateral system is composed of CLT shear walls and exposed glulam braced frames. The vertical CLT panels compose the walls of the building’s stair towers, elevator core, and mechanical shafts. They presented an additional design challenge with their tall, narrow layout and relatively small gravity loads, which resulted in significant uplift forces from wind and seismic forces. Similar to the composite slab connectors, the shear wall hold downs are composed of steel plates embedded into the CLT panels, secured to the wood with epoxy, and welded to a conventional steel connection plate anchored to the concrete foundation.

The glulam braces are connected to the glulam columns by a series of embedded knife plates and tight-fit steel pins. The steel plates come
together to form a true pin connection that is left exposed to provide unique aesthetic that honors the connection’s structural function.

**Secrets to success**
As part of the design effort, SGH vetted production quality of the epoxy CLT connections by load testing one-fourth-scale mockups of the shear wall hold downs to confirm their strength and ductility. Additionally, SGH demonstrated to Massachusetts Department of Public Safety (DPS), the authority having jurisdiction, that this structural design meets the current building code’s general intent. The design team developed a design basis with supporting standards, testing data, and proposed future code language for DPS’s review.

Creative systems integration and willingness to try something new drove this project’s success. With an exposed structure, the layout directly affects the building’s aesthetics. Successful implementation required close coordination with architecture, and creative detailing of the wood connections to accentuate the visual appearance of the exposed wood framing. The design and fabrication team developed a variety of connections using embedded steel plates and dowels, tight-fit pins, screws, shear keys, and specialty cast steel clevises. These unique connections allowed the design team to cleverly hide some elements, such as beam-to-column connections, and emphasize others, such as the center hub of the spider trusses.

Engineered mass-timber structures employing CLT and glulam components allow for precision fabrication in a controlled factory environment. Computer numeric control (CNC) machining decreases wasted material volumes while increasing productivity and precision. This type of controlled fabrication ensures components fit together when delivered onsite and reduces field equipment needs and labor. Even with a moderate learning curve facing the small crew of timber erectors, construction schedules realized approximately 10,000 square feet of floor installation per week.

Several of the structural elements composing the large atrium space required additional onsite assembly and coordination. The steel truss was shipped to the site in pieces, assembled in the staging area, and lifted into place in two crane picks. The atrium roof was shored while the spider truss elements were connected to the center hub and the concrete topping was placed. Once the concrete topping achieved sufficient strength, the shoring was carefully removed. The stair was shipped to the site in large sections and erected by first suspending it from the steel rods and then field-connecting the pieces together with steel plates and epoxy in a carefully monitored procedure.

Factory fabrication also facilitated the use of the shear connectors for the composite slabs and hold downs for the shear walls, which both rely on epoxy to anchor embedded connections. The epoxy required strict conformance with environmental temperature, humidity, and volume tracking to ensure fabrication consistency and engagement within fabricated grooves — all of which were able to be carefully monitored and controlled in the factory. Most of these anchors were embedded during the shop fabrication process, with the CLT stair being the one exception.

The exposed structure required collaboration among the mechanical, electrical, plumbing, and fire protection (MEP/FP) systems. CLT shaft
walls provide attractive enclosures for the MEP/FP chases, serve as bearing walls to support the floor and roof decks, and contribute to the structure’s lateral force-resisting system. Openings in the CLT walls and decks were designed and detailed to allow MEP/FP systems to pass through the structure as needed. Electrical conduit buried within the composite CLT decks required additional coordination to maneuver the runs around the composite CLT-concrete shear connectors but allowed for a cleaner-looking ceiling in the end.

### A striking example

As one of the larger modern mass timber buildings in the United States, and a first of its kind in Massachusetts, the Design Building uses wood products in new and creative ways to serve as a positive example for future work and provides a collaborative learning space for UMass’s design programs. The Design Building offers a striking, first-of-its-kind example of many uses for mass construction methods and successfully provides an inspiring space for students, faculty, and visitors.


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**GREGGREY COHEN** is senior principal, **JEFFREY LANGLOIS** is senior project manager, and **NANCY VARNEY** is senior staff I with Simpson Gumpertz & Heger Inc. ([www.sgh.com](http://www.sgh.com)).

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**EVALUATION AND REPAIR OF 100-YEAR-OLD CONCRETE STRUCTURES**

**CAREFULLY CONSIDER MATERIALS, DETAILING, AND HISTORIC CONSTRUCTION TECHNIQUES TO DESIGN APPROPRIATE REPAIRS.**

By David Schnerch, Ph.D., P.E.

### The Current Trend

toward revitalization of many cities’ downtown districts has resulted in change in use of reinforced-concrete industrial buildings to condominiums or office buildings. Many cities also have bridges and other civil engineering structures that are approaching 100 years in age. Evaluation of these structures is necessary due to this change of use, particularly when additions or alterations result in increased stresses or different load paths. Additionally, repair may be necessitated by the deterioration of reinforcement or concrete over time, variation in the original quality of the materials, or deleterious degradation mechanisms caused using unsuitable materials.

### History of Reinforced Concrete Structures

Although concrete technology was developed and used since Roman times, reinforced concrete structures were uncommon in the United States before 1905, but the use of reinforced concrete for large structures quickly became an economic means of construction ([Gaudette and Slaton, 2007](http://www.sgh.com)). Additionally, more and more factories, warehouses, and agricultural facilities began to use this “new” material in the 1910s and 1920s to avoid flammability issues ascribed to timber structures.

Development of standards and material specifications occurred in parallel with increased use of reinforced concrete. The Joint Committee on Reinforced Concrete was established in 1904 before the founding of the National Association of Cement Users (later to become the American Concrete Institute (ACI) ([Kerekes and Reid, 1954](http://www.sgh.com))) to organize the various entities researching concrete properties, develop uniform methods for analysis and testing, and support research.

The first attempt to develop a code for reinforced concrete occurred in 1907. By the 1920s, codes established by the ACI were being routinely discussed and revised based on the assemblage of applied research and developing industry practice. Additionally, local building codes, such as those available for Boston, New York, and Chicago, provided allowable concrete stresses together with minimum design loads that would have been utilized in the respective jurisdictions.

Concrete reinforcement became readily available beyond 1900 and specifications for these bars were developed by the Association of American Steel Manufacturers in 1910 and were later adopted by the American Society for Testing and Materials in 1911 ([CRSI, 2001](http://www.sgh.com)). Steel reinforcing was available in round and square bars with deformed round bars available from 1/4- to 1-inch diameter and square bars available in 1/2-, 1-, 1-1/8-, and 1-1/4-inch sizes (Figure 1). Wire fabric of cold-drawn steel and other proprietary systems were also commonly available for the reinforcement of concrete floors.

### Evaluation of Existing Concrete Structures

The ACI developed ACI 562 ([ACI, 2016](http://www.sgh.com)) to provide minimum requirements for evaluating existing concrete structures and subsequently developing repairs. This document has not yet been adopted as part of the building code but in the interim can be used by design professionals to provide guidance on evaluation of existing and historic reinforced concrete structures. The exact evaluation process undertaken will depend on the planned use for the building, the extent of deteriorated conditions, and the impact of changes to the load path.

Evaluation of a structure generally includes a review of the available...
documents, if available. Construction documents may provide useful information about the size and spacing of reinforcement, basic geometry, and detailing at connections. Review of historical building codes and standards applicable at the time of construction can also provide information useful to evaluation of the structure.

It is important to consider that changes may have been made during or subsequent to the original construction such that the available construction drawings are no longer accurate. Information about the original construction may have also been lost over time, such that verification of the original structure is required. This may require one or more evaluation methods, including visual inspection, measurement, and ferromagnetic or ground penetrating radar surveys of the reinforcement. Any non-destructive technique to assess conditions that cannot be directly observed at the surface should also be verified by a more limited number of destructive investigation openings that can be repaired as part of a subsequent phase.

The evaluation onsite should determine the extent of problems and the corresponding extent of required repairs. Close-up visual inspection is the most frequently used evaluation technique and provides a great deal of information about the condition of the structure but is limited to exposed and accessible surfaces. Visual observation techniques can be supplemented with mechanical sounding to identify locations of underlying shallow concrete distress, such as delamination occurring due to corrosion of the underlying reinforcement.

Concrete cores may be obtained and tested in compression to assess the concrete strength (Figure 2). Minimum values of concrete compressive strengths are provided in ACI 562. Similar information is available to determine the minimum tensile yield and ultimate strength of reinforcing bars. Tensile testing may be warranted if an accurate assessment of the structural capacity is required.

There are multiple field and laboratory tests that can be applied to historic concrete structures to identify potentially problematic conditions. This includes carbonation testing, chloride testing, and petrographic analysis. Carbonation testing can be used to assess the potential for accelerated corrosion of the reinforcement. Carbonation is a slowly occurring process whereby concrete (in the presence of moisture) reacts with carbon dioxide in the air, thereby reducing the pH of the concrete.

Over a century, the carbonation depth may be on the order of several inches depending on the quality of the concrete. If reinforcing bars are present within the carbonated concrete, the protective oxide film normally present in concrete is absent, leaving the surface of the steel potentially active for corrosion.

Chloride testing may be performed using powder or core samples so that the chloride content can be determined at multiple depths. If the chloride content is relatively uniform at each depth, this may suggest that the chloride may have been included as an admixture or introduced through the materials. A decreasing chloride profile with depth would suggest that the chlorides are being introduced over time from the surface by sea spray or deicing salts. Guidelines are available to identify if the level of chloride at the depth of the reinforcement is sufficient to result in corrosion.

Petrographic analysis of lapped core samples may be used to identify many types of concrete material distress including alkali-aggregate reactions and sulfate attack, among others. It can also be used to qualitatively assess the presence of entrained air. Air entraining admixtures were not developed until the mid-1930s (Portland Cement Association). For older concrete structures or structures where air-entraining admixtures were not used, much of the void structure of the concrete is due to entrapped air rather than entrained, and the ability to resist freeze-thaw distress is diminished.

**Common issues**

Reinforcement — Corrosion of the existing reinforcement is the most commonly encountered condition in historic reinforced concrete structures. Corrosion of the reinforcement can result in delamination and spalling of the concrete, particularly where the reinforcement has minimal cover. A thorough understanding of the cause of the corrosion and whether the rate of corrosion is likely to increase is important to develop repairs that will reduce the rate of corrosion.

Concrete aggregates and admixtures — Early concrete structures often utilized aggregates found locally. The ability of the concrete to protect the reinforcement from corrosion was not fully understood when rein-
forced concrete structures began to be widely constructed and sodium chloride present in batching water or fine aggregate was not limited by initial building codes provided that the chlorides did not reduce the compressive strength of the concrete, as can occur at very high concentrations. Calcium chloride was also widely used because it drew moisture from the air to assist with curing and also accelerated the rate of strength increase of the concrete.

Aggregate gradation was not as closely controlled as in current practice. Very large aggregate, including baseball size or above, is sometimes observed in reinforced concrete structures from a century ago, though ACI limited the maximum size of aggregate (the size of which 95 percent by weight of the material can be passed) to not larger than one-fifth of the narrowest dimension between forms or three-fourths of the minimum clear spacing between reinforcing bars (ACI, 1925). Aggregate gradation can also affect the relative proportion of cement paste.

Placement — Placing concrete was performed without internal vibration. As such, consolidation of the concrete through spading or tamping was required periodically throughout the concrete placement. Together with variation in aggregate gradation, this placement method can result in significant regions of voids or honeycombing. Honeycombing can result in discontinuity of the load path if the size of the voided region is significant. Additionally, the voids result in less concrete cover over the reinforcing bars and can cause increased moisture retention.

Construction joints are frequently observed in historic concrete structures at locations where they may not be typically found today. Although available codes required that laitance and unsound material be removed before placing new concrete in contact with previously placed concrete, cracking, leaks, and efflorescence are frequently observed along these joints.

Reparis
There are multiple considerations with regard to repair design. These considerations reflect not only the technical constraints but also the cost and the appropriate level of durability of the repair that is desired by the owner. Too often, the compressive strength, and particularly achieving a high strength at an early age, is given too much importance. While restoring the overall capacity of the structure is important, it is generally not necessary to use very high-strength (and correspondingly high-stiffness) repair materials that are not compatible with the existing historic concrete. The selection process for a repair material must consider the transfer of stresses through the bonded interfaces at the perimeter of repairs, the potential for shrinkage of the repair mortar, and the ability of the new repair mortar to protect the reinforcement.

Reinforcement that is exposed during the repair process may be protected, supplemented, or replaced depending on its condition. There are many methods for protecting existing reinforcing bars from additional corrosion. Each method must be considered based on the properties of the concrete, the exposure of the building to the environment, the current level of chlorides, and the depth of carbonation. Establishing procedures for maintaining continuity of the existing reinforcement must also be considered during the design process, particularly since the use of smooth (or non-deformed) reinforcing bars were much more prevalent.

The aesthetics of the repairs may be of more concern in a historic structure than a modern structure. Irregular boards and light gauge metal forms were frequently used. Modern form materials, which are generally much smoother, may not be appropriate. Use of historically appropriate form materials will result in the repair locations being much less evident but will add to the overall repair cost. Concrete colors can also be adapted if carefully controlled.

Summary
Evaluation of historic concrete structures requires careful consideration of the material, detailing, and construction aspects as reinforced concrete technology was quickly emerging in the last century. A thorough evaluation is necessary to develop appropriate repairs. The longevity of these structures demonstrates the suitability of reinforced concrete as a building material. Appropriately designed repairs should ensure that these impressive structures can be maintained well into the future.

DAVID SCHNERCH, PH.D., P.E., is an associate principal with Wiss, Janney, Elstner Associates, Inc. (www.wje.com) in Boston.

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EXPANDING LAKE OSWEGO’S WATER SOURCE
A $69 MILLION PROJECT MORE THAN DOUBLES CAPACITY AND INCORPORATES ENERGY-EFFICIENT AND SUSTAINABLE FEATURES.
By Steve Flett and Jeff Wall

CONSTRUCTED IN 1968, the original Lake Oswego Water Treatment Plant treated water from the Clackamas River in Oregon at a capacity of 10 million gallons per day (mgd). Periodic updates were made to the facility, with an expansion to 16 mgd in the 1980s, but it still lacked the size and technology to meet the growing needs of the cities of Lake Oswego and Tigard.

To improve overall water supply, the two Oregon cities devised a plan to upgrade and expand the wastewater treatment facility that would produce a larger quantity of high-quality drinking water and incorporate energy-efficient and sustainable features and operations.

At 16 mgd, the City of Lake Oswego’s existing treatment plant was undersized for present and projected future growth in the two communities, making expansion to 38 mgd capacity necessary. Working in collaboration, the two cities developed a plan for upgrading and expanding the facility and created a process for engaging nearby community members. Seeking their ongoing feedback and ensuring it was considered in the plan were critical pieces of the project’s success.

Maintaining existing plant operations during construction was another top priority for the project team, as it would require careful planning and considerations throughout the course of the project to ensure the community’s water supply remained consistent and properly treated.

Additionally, the plant needed to implement an updated treatment process, increased energy efficiency, incorporate renewable energy components, and address the plant’s seismic vulnerability.

Forging a partnership
In 2008, the communities of Lake Oswego and Tigard formed a partnership with the intent to share drinking water resources and the project cost. Tigard had previously leaned on the City of Portland for water, but long sought ownership of its own secure water source to maintain control over the price it paid and to ensure an adequate water supply for the future. In an effort to keep water rates affordable for residents in both communities, the Lake Oswego Tigard Water Partnership was formed. Dividing the cost of planning, designing, and constructing a new water treatment plant secured the long-term water needs at a more manageable cost for both cities.

Under the partnership agreement, the City of Lake Oswego managed and built the water improvements with oversights from a combined Lake Oswego and Tigard Council Committee, providing guidance when necessary.

Following the design phase with Stantec, the partnership contracted with Slayden Constructors, part of Stantec Construction Group, to build the expanded and upgraded plant via a $69 million budget.

Incorporating community feedback
The partnership collaborated with local neighborhood associations to develop a Good Neighbor Plan to ensure consideration of community feedback during each of the project phases — design, construction, and ongoing operations — and a process for two-way communications.

The plan was developed during a 20-month period and incorporated more than 20 community meetings, tours, and open houses. Efforts to mitigate the impacts on nearby neighbors during construction and ongoing operations phases were identified and implemented into the
Aesthetically pleasing buildings, landscaping, and visual buffers — like planting more than 300 trees and 25,000 native plants and shrubs — gave the facility a residential look and feel. Integration of public amenities, such as pathways, a two-acre park-like setting, and rain garden, improved the area’s interconnectedness and encouraged ongoing public access at the site. The final product was an expanded wastewater treatment plant that truly blended with the neighborhood and incorporated innovative community features.

The plan and its purpose to create a more collaborative process played a significant role in the final output of the treatment plant, with much of the community feedback incorporated throughout the project’s life.

**Maintaining existing operations**

The new facilities were constructed around the existing facilities through a three-phase process. After completion of each phase, demolition of existing structures occurred, all while ensuring the existing plant remained operational. Construction of the numerous water-holding structures required considerable modifications and additions to buried process pipe throughout the site. As a result, all connections had to be carefully sequenced and planned to ensure existing processes were not interrupted. Many of the new buildings were constructed only several feet away from existing structures, requiring constant coordination between teams.

To plan for this careful coordination of the interconnections between the old and new buildings, the structures were 3D modeled in Revit, which allowed the team to virtually simulate how the two structures would coexist. Working from the Revit model, Slayden developed a set of sequence drawings that mapped out the key requirements for each phase of the project. The owner, contractor, and engineering teams used these documents to coordinate the work.

**State-of-the-art water treatment system**

The new plant incorporates a state-of-the-art water treatment process known as conventional filtration plus ozone. The ozone used in the process removes more impurities from the water supply than traditional treatment methods. It effectively eliminates taste- and odor-causing compounds and provides an additional barrier for protecting public health.

Additional benefits of the process include:
- produces pleasant tasting water year-round;
- reduces the amount of chlorine needed for disinfection; and
- meets emerging concerns for pathogens, algal toxins, and pharmaceuticals

**Energy efficient and seismically reliable features**

Energy efficient elements such as LED lighting and solar panels were installed at the plant to meet the partnership’s desire to utilize green design features. The addition of garden roofs, swales, and pervious surfaces reduce stormwater runoff and lower heating and cooling costs at the facility.

During construction, the partnership, Slayden, and other contractors utilized sustainable operational practices when available to mitigate the project’s impact on the environment and nearby neighbors.

Studies predicting a major earthquake in the Pacific Northwest led the partnership to design and construct more seismically sound infrastructure throughout the facility. Facilities and associated pipelines at the treatment plant are supported by 1,150 deep reinforced concrete piles — 56,000 linear feet of support — making the facility able to withstand most earthquakes.

Slayden Constructors worked closely with the partnership, design engineer, and other contractors to ensure the project met the appropriate needs and time requirements. The solutions-driven approach adopted by all parties was crucial in making the overall Lake Oswego Water Treatment project a success.

**Steve Flett**, vice president – preconstruction services at Slayden Constructors, Inc. (http://slayden.com), has more than 26 years of experience in construction. He is responsible for marketing and oversight of project pursuits for new opportunities leading to preconstruction tasks including but not limited to design and constructability reviews, value engineering, work strategies and sequencing, estimating, work package development, and client relations. **Jeff Wall**, construction manager at Slayden Constructors, Inc., has more than 25 years of experience. He has estimated and managed construction in Oregon, California, and Washington, including responsibility for the scheduling, planning, opening, and closing projects. His past projects include heavy civil, water and wastewater treatment plants, and fish facilities. Wall has completed 26 water and wastewater treatment plants totaling more than $300 million.
Receiving calls to solve unique and challenging site problems is common for Presto Geosystems’ engineers and network representatives. In the Spring of 2017, Utah Olympic Park’s mountain manager contacted Presto for assistance with designing a new concrete ski jump for freeskiers and snowboarders to practice their jumps in the summer.

The site is an official United States Olympic Committee (USOC) training facility used by the Olympic Ski and Snowboard teams. Built for the Salt Lake 2002 Olympic Winter Games, this dynamic multi-use facility focuses on developing and growing winter sports in Utah and hosts ski jumping, Nordic combined, bobsled/luge, and skeleton events.

Presto’s 3D GEOWEB system was chosen as the concrete support system because of its ability to help resist settlement cracking. In other concrete applications, the system can outperform standard reinforced concrete and can reduce the normal 6-inch depth of reinforced concrete to 4 inches.

The concrete ski-jump was to be built on a 1.7H:1V slope, 160 feet long, and approximately 30 feet wide. With a 4-inch depth and a 150-pound-per-cubic-foot unit weight of the concrete, this meant that approximately 250,000 pounds of concrete had to be held in place on the slope. To accomplish this, a 6-inch-diameter pipe was buried 5 feet below grade at the crest, serving as a deadman anchor for heavy-duty tendons, secured to the pipe and to the GEOWEB panels.

“Ski tiles,” 4 inches by 36 inches, were attached to the concrete ramp with ramset anchors, overlapped from top to bottom, similar to shingles on a roof. An even surface from tile to tile is critical to give the athletes the perfect run on a snowboard or pair of skis to practice their skills. In order to achieve the required level surface, it was critical that the subgrade be graded precisely because any imperfections in the subgrade would be transferred to the surface of the concrete.

Presto’s experienced construction field representative was onsite for the GEOWEB installation and concrete infilling — and to ensure the subgrade was graded to precision standards.

Overcoming difficult site challenges takes careful planning, collaborative engineering, and construction experience. Geosynthetics can offer consultants innovative ways to solve complex site problems. Presto’s assistance — from preliminary design support through final construction — allowed for a successful completion of this challenging, high-profile project.

Information provided by Presto Geosystems (www.prestogeo.com).
FLOOD PROTECTION INFRASTRUCTURE alone does not — and cannot — mitigate flood risk. Every post-event flood review (PERC) conducted by the Zurich Flood Resilience Alliance (www.zurich.com/en/sustainability/flood-resilience) contains examples of flood protection infrastructure that has incentivized bad behavior and/or failed catastrophically during floods. The response to these failures is often to allocate large sums of recovery funding to construct more protective infrastructure without asking why there was failure in the first place. Even within the disaster risk management and disaster risk reduction communities, there seems to be unquestioned faith in the ability of protection infrastructure to protect people.

The newest PERC of Hurricane Harvey in Houston, released June 21, 2018 (www.i-s-e-t.org/houston-hurricane-harvey), looks closely at some of the issues with flood protection infrastructure and provides clear ways forward to develop smarter infrastructure that will support greater flood resilience.

Hurricane Harvey in Houston

Houston is highly flood prone. The Houston metro area has experienced three, greater-than-100-year floods in the last five years alone, with the third being Hurricane Harvey. Harvey made landfall near Rockport, Texas on Aug. 25, 2017. Over the next four days, Harvey dropped more than 40 inches of rain over eastern Texas. The resulting floods inundated hundreds of thousands of homes, forced more than 30,000 people into shelters, and prompted more than 17,000 rescues. Total damage is estimated at $125 billion, making it the second-costliest tropical cyclone on record after Hurricane Katrina.

Harvey broke nearly all of the continental U.S. rainfall records, so it is understandable that it overwhelmed drainage systems, caused overbank flooding, and prompted emergency releases from all water storage and flood control reservoirs in the greater Houston area. What is concerning, however, is that more than 9,000 homes and businesses were badly flooded because they were located within river floodways, flood control reservoirs, and emergency release areas. Furthermore, home and business owners lost assets and property in spite of the fact that the filling of the reservoirs and emergency releases were relatively predictable and entirely forecastable.

Missed opportunities for mitigation

This highlights how disasters are anything but natural; there is an enormous man-made component. There were numerous points at which these impacts could have been mitigated:

- when land was initially purchased for Houston’s two flood control reservoirs, but the dams were sized to impound water beyond the boundaries of the purchased land (see Figure 1);
- when construction of homes and businesses within the reservoirs and their delineated floodways was approved in the 1990s/2000s, despite knowing they would be flooded if the reservoirs were to fill;
- when those homes were sold without adequate disclosure to either real estate agents or buyers regarding the risk;
- when areas upstream of the reservoirs were permitted for development, contributing to increased upstream runoff;
- when flood maps were developed and disseminated by county and national authorities that failed to show the full potential extent of flood risk;
- when authorities failed to evaluate, well in advance of an event, the possible impacts of floodwater within the reservoir and of emergency releases downstream, so they would be prepared to warn residents at risk; and

Figure 1: Dams for Houston’s two flood control reservoirs were sized to impound water beyond the boundaries of government-owned land. Image: Harris County Flood Control District
• when, as the reservoirs began to fill rapidly during Harvey, the potential for in-reservoir and downstream flooding was not immediately communicated to the public with warnings to protect their assets.

Many residents and business owners inside the reservoirs were in fact unaware that they were located in a flood zone. “When I started to rent this house, nobody told me. Even the insurance company told me that it was not a flooding area,” said Jeremy Boutor, an Addicks Reservoir resident.

This list is not exhaustive, yet it points to just how broad responsibility often is and how many opportunities there are for protection infrastructure to fail. Interestingly, none of these modes address physical failure caused by design thresholds being overwhelmed or a lack of maintenance, though that has also been a recurring theme in Alliance PERC studies.

Instead, this example highlights the ways in which simply building and maintaining flood protection infrastructure is not enough. Ensuring the integrity, functionality, and operability of flood protection infrastructure also requires substantial efforts to develop appropriate regulatory systems and build public awareness of the risk landscape.

Learning from the past: mix the hard with the soft

In the post-Harvey recovery phase, a leading solution being proposed to address flooding in Houston is the construction of a third reservoir. This is expected to cost more than $500 million. However, there has been little discussion of the regulatory landscape that gave rise to the flooding at the existing two reservoirs. Unless the issues revealed by Harvey are addressed, a third reservoir is also likely to eventually fail.

Large-scale infrastructure projects — such as levees, canals, and reservoirs — are expensive yet arguably important solutions to flood threats to development. However, it must be highlighted that these threats are substantially caused by the development itself, both in how and where it is built. In addition, all flood protection infrastructures come with residual risk and storm thresholds beyond which they will fail. Protecting these investments and dependent lives and assets requires parallel investments in soft solutions based on an understanding of how people interact with protection infrastructure.

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Post-Harvey report provides inundation maps and flood details for the largest rainfall event recorded in U.S. history.

NINETEEN INUNDATION MAPS and detailed flood information from Hurricane Harvey are now available from the U.S. Geological Survey (USGS), in cooperation with the Federal Emergency Management Agency (FEMA). Hurricane Harvey was the most significant rainfall event in U.S. history, both in scope and peak rainfall amounts, since records began in the 1880s.

Hurricane Harvey’s widespread eight-day rainfall, which started on Aug. 25, 2017, exceeded 60 inches in some locations (see Figure 1), which is about 15 inches more than average annual amounts of rainfall for eastern Texas and the Texas coast. The second largest rainfall event recorded in continental U.S. history was during Tropical Storm Amelia in 1978, which left Texas Hill Country with 48 inches of rain. Not only were rainfall totals exceptional during Hurricane Harvey, the area affected was also larger than previous events.

In the immediate aftermath of Harvey, the USGS and FEMA initiated a study to evaluate the magnitude of flooding, determine the probability of future occurrence, and map the extent of the flooding in Texas. USGS field crews collected 2,123 high-water marks in 22 counties in southeast Texas and three parishes across southwest Louisiana. Although parts of central Louisiana experienced Harvey-related flooding, the report only documents the extent of flooding in southwest Louisiana along the Sabine River. High-water mark data, along with flood flow information from USGS streamgages, were used to create 19 inundation maps to document the areal extent and depth of the flooding.

FEMA requested time-perishable high-water marks, updated water-level records, and Harvey inundation maps, which are key materials that will be used by state and local resource managers. The data and records will assist officials in updating building codes, planning evacu-
Flooding, on the rise due to climate change, can devastate urban areas and result in drawn-out, costly repairs. Cities are in dire need of new strategies to manage the influx of stormwater. An interdisciplinary team of engineers and urban planners at MIT has now developed a solution — multifunctional urban stormwater wetlands and ponds that seamlessly integrate the control and cleaning of stormwater with ecological and recreational benefits.

Stormwater flooding in cities is exacerbated by urban infrastructure, as many of the natural ecosystems that would absorb rainfall have been replaced with pavement, which greatly limits an area’s infiltration capacity. This keeps stormwater on the surface, where it picks up all kinds of pollutants — trash, heavy metals, industrial chemicals — that are eventually carried into nearby bodies of water, often including the local water supply.

Many cities do not have adequate systems in place to handle stormwater runoff, the largest single cause of stream impairment in urban areas. Stormwater treatment plants are large investments that need to be integrated into existing drainage and water treatment systems. Without spaces or processes that can sequester and purify contaminated water before it reenters circulation or the natural environment, urban centers lose fresh water that could be available for drinking and groundwater recharge, among other ecosystem needs.

Natural stormwater management systems — engineered green spaces — are becoming more popular options for cities, in part due to their affordability. The MIT team’s wetlands have been designed to be much more than just stormwater treatments. They are also recreational green spaces that provide ecological benefits, such as filtration and purification of water, improving water quality in nearby bodies of water. The interdisciplinary approach to urban storm flooding, with its focus on integrating stormwater management with environmental and recreational benefits, represents a promising solution for cities facing the challenges of climate change and urban development.
more effective than existing designs, such as simple basins and serpentine, at controlling water circulation and purifying stormwater, while also delivering ecosystem and recreational benefits.

The MIT team released the details of their study in a freely available report, Design Guidelines for Urban Stormwater Wetlands, in the hope that cities will adopt this approach. The report is based on two years of research funded by a seed grant from MIT’s Abdul Latif Jameel World Water and Food Security Lab (J-WAFS) and further supported by the MIT Norman B. Leventhal Center for Advanced Urbanism (LCAU) in MIT’s School of Architecture and Planning. These guidelines are based on physical experiments undertaken in the MIT Nepf Environmental Fluid Mechanics Lab and recently published in the journal Ecological Engineering.

“The goal of our study is to help cities mitigate their own problems in the face of rapidly changing climates, large storms, and a lack of economically feasible solutions,” said co-author Alan M. Berger, the Norman B. and Muriel Leventhal Professor of Advanced Urbanism and LCAU co-director.

Berger and his co-authors welcome interested city representatives to reach out to them to discuss how to implement their designs. In May, the group conducted an outreach campaign to ensure that these open-sourced designs reach urban stakeholders such as government officials and regional planners across the U.S.

The guidelines combine engineering, urban planning, and landscape architecture expertise to design a versatile green space. On top of managing stormwater, the wetland or pond creates greenery for the city, recreational space for the community, and valuable wildlife habitats.

The designs, which feature a series of clustered islands, are modular and scalable, so they can be tailored to fit the needs and resources of varying urban settings. The work was developed with two specific case studies, Houston and Los Angeles, to help ensure the adaptability of the guidelines to different localities.

“We picked L.A. and Houston because they are both large cities in warm climates, rapidly growing, mostly suburban, with good prospects for green space,” said lead researcher and lead author Celina Balderas Guzmán. “Moreover, one is very dry and one is very wet. We wanted to show our design’s adaptability to different conditions.”

Balderas Guzmán, then an LCAU member and now at the University of California at Berkeley, is an alum of MIT’s School of Architecture and Planning, where she developed a master’s thesis on stormwater wetlands that eventually led to this collaborative, interdisciplinary project.

The guidelines have yet to be used in practice. However, the team is currently in contact with city leaders in several locations about the prospect of building a pilot wetland system. Unaffiliated members of the research community speak positively about the merit of the guidelines.

“As far as I know, there is nothing available to the practitioner community that translates research findings from engineers and landscape architects into reality so cleanly,” said David L. Sedlak, professor of environmental engineering at UC Berkeley and co-director of the Berkeley Water Center.

To develop the guidelines, researchers in the Environmental Fluid Mechanics Lab, led by Heidi Nepf, the MIT Donald and Martha Harleman Professor of Civil and Environmental Engineering, tested more than 30 wetland system designs. They monitored water circulation through sculpted models to determine which topography was most effective in slowing down the stormwater and evenly distributing its flow, in order to best enable the natural processes that cleanse the water of pollutants. This comprehensive testing strategy led to designs based on clusters of streamlined islands placed close together near the wetland inlets.

Controlling the water’s movement so it lingers in the wetland is crucial to give the ecosystem time to improve water quality. Wetlands purify water through a combination of biological and chemical processes,
including giving contaminants time to settle out of the water. Wetland vegetation is another good filter, as plant surfaces and the biofilms they support are very effective at capturing pollutants and excess nutrients.

Determining the most effective design for stormwater treatment was a key aspect of the project, but the team emphasized that the value of their wetland system is more than its water management functionality. Collaboration between engineers and urban planners led to a design that maximized efficiency without sacrificing aesthetic, ecological, or recreational quality.

“Stormwater management guidelines are typically written by engineers and they are very prescriptive. They are not traditionally designed to promote ecology or facilitate recreation,” Balderas Guzmán said.

The team was able to create multifaceted wetland system designs thanks to its unique interdisciplinary makeup. Nepf, co-author of the study, said the engineers contributed hydraulic function innovations while the landscape architects envisioned how to make the wetland a valued part of the fabric of the city.

Sparking interdisciplinary collaborations is a goal of J-WAFS seed grants, and Nepf credited J-WAFS with helping the engineers and urban planners to work together, bridging their different design processes and “different languages.” “J-WAFS provided a place where we could learn how to talk to each other,” Nepf said.

Because of this unique collaboration, the guidelines offer a rich variety of benefits. They include recreational trails, which bridge the island clusters and connect city streets to inviting green space. The largest islands can hold event spaces for public programming, while floodplains beside the wetland can be used as sports fields, picnic areas, or playgrounds. The islands provide multiple ecological habitat zones, from dry upland to shallow and then deeper water. This habitat could be especially valuable to wetland species as natural wetlands disappear.

The multiuse designs have a political advantage as well. They can help cities win public approval to implement stormwater wetlands, which have often proved to be challenging projects to get local residents to support. Communities unaware of the extent to which stormwater pollutes their water supply may not support using a space that could be a park or a playground for such a project. The addition of recreational features makes artificial wetlands an easier sell.

“I hope these guidelines open people’s eyes to how they can multi-purpose land in urban areas,” Nepf said. “I hope we make them think, ‘Okay, I need something to deal with stormwater runoff, so how do I make something that might also benefit the environment and the livability of the city.’”

Greta Friar is a contributing writer with MIT’s Abdul Latif Jameel World Water and Food Security Lab (https://jwafs.mit.edu).
As one of Arizona’s main transportation hubs, the Phoenix Sky Harbor International Airport has experienced significant growth and expansion in the last five years. To meet the needs of its nearly 40 million passengers annually, the airport is working to improve services for its airlines and travelers.

The original terminal was built in 1979 and needed improvements to keep the airport competitive. The most recent work involved a $590 million design-build expansion to the existing Terminal 3, which includes a new customer processing terminal, South Concourse, and enhancements to the North Concourse. The existing South Concourse of Terminal 3 was razed, and a 15-gate concourse was constructed to replace the previous structure. The makeover also included adding windows throughout the facility and even a new garden and dog park — all to bring a more open and modern experience to its visitors. The new structures were constructed of reinforced concrete, structural masonry, structural steel moment frames, and metal decking.

To help in the expansion, Terracon’s experienced aviation and construction inspection team provided quality assurance consulting, as well as structural steel, spray-applied fire resistive materials, and nondestructive testing services on various building components.

Depth of services differentiates
For this signature project, Terracon initially provided materials testing for the City of Phoenix Aviation Department as part of the quality assurance team during construction. Terracon provided an experienced aviation technician to perform compaction verification, concrete and grout sampling, and construction observation. Earthwork was monitored for lift thickness, fill material, and suitability and tested for compliance to Federal Aviation Administration (FAA) compaction specifications using sand cone test methodology.

Due to extreme daytime temperatures in the region, most concrete placements occurred during the evening and early morning hours. Each delivery of concrete to the site was logged and verified for proper mix design and suitability for the placement. Concrete was field tested for temperature and slump, and samples were made for compressive strength verification.

Having onsite knowledge and expertise with respect to FAA specifications, materials, and typical construction practices during airport construction was an immediate benefit to the owner and contractor. In addition, our local staff was also well versed with the City of Phoenix...
How the use of geogrid materials prolongs the lifetime of recycled materials and reduces the carbon footprint of highway construction

For thousands of years, engineers have endeavored to devise better products and systems to support growth and human progress. Always thinking towards the future, engineers prioritized sustainability long before it ever became the standard for conscionable building and innovation. Today, engineers embed sustainability into every aspect of roadway construction – and they are achieving measurable results through the use of geogrid materials.

Population growth demands improved infrastructure. Existing roadways are supporting unprecedented traffic volumes, and engineering teams are continually tasked with delivering roadway reconstruction projects more quickly, efficiently and with minimal disruption to current traffic flows. Recycled asphalt has been an increasing part of the solution. A 2017 National Asphalt Pavement Association survey found that more than 76.2 million tons of reclaimed asphalt pavement (RAP) and nearly 950,000 tons of reclaimed asphalt shingles (RAS) were used in new asphalt pavement mixes in the United States during 2017. In the past, engineers and contractors have expedited roadway reconstruction projects by recycling existing road base. However, this method poses risks related to potential non-uniformities of recycled material – risks that can decrease pavement life, prolong construction efforts and create higher project costs. Eager to improve roadway performance while utilizing the environmentally friendly method of reusing aggregate base materials for improved roadway projects, Tensar International created TriAx Geogrid. When used in conjunction with recycled asphalt pavement (RAP) and other recycled materials, TriAx Geogrid provides enhanced performance beyond that of roadways only utilizing recycled aggregate base.

Manufactured from a punched polypropylene sheet oriented in multiple equilateral directions to leverage the strength of triangular geometry, TriAx Geogrid provides an enhanced level of in-plane stiffness for recycled materials. This high rib structure interlocks and confines with the aggregate base to yield a stiffer and more uniform foundation that maintains integrity over time. The confinement results in increased load capacity of the aggregate base and also reduces the potential for contamination of the aggregate base with the subgrade soil. Ultimately, the shape delivers optimal in-service stress transfer from the aggregate to the stabilizing geogrid.

Field testing substantiates sustainability of the geogrid

An independent firm recently performed a series of Automated Plate Load Tests (APLT) of roadway sections in Tulare, CA to simulate traffic loading over time per AASHTO and ASTM test methods. The APLT tested in-place aggregate base with and without the use of TriAx Geogrid. At over 10,000 cycles, the control section of recycled aggregate base experienced permanent deformation four times that of the composite section stabilized by the TriAx Geogrid.

These polymeric products support the continued use of recycled aggregate base, which reduces the amount of new material needed for the construction of new or reconstructed roadways. This reuse minimizes truck trips needed to and from construction sites, thus reducing CO2 emissions from construction traffic. Geogrids also prolong the lifetime of roadways, which reduces long-term maintenance costs and saves owners time and money while additionally limiting greenhouse gas contribution.

In roadway construction, geogrid materials offer multiple sustainable benefits to prolong infrastructure longevity and reduce maintenance requirements. Increased infrastructure lifespans eliminate related construction traffic, which results in reduced carbon emissions. As projects utilizing geogrid require less overall stabilizing materials and emit less CO2 emissions, owners benefit from improved project schedules, reduced impacts to the environment and lower materials costs to save both time and money. Ultimately, the use of geogrid materials allow engineers to embed sustainability while meeting the needs of growing populations.

About Tensar International

Headquartered in Atlanta, Tensar International is a full-service provider of specialty products and engineering services that offer innovative and cost-effective alternatives to traditional construction methods. Tensar 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 Tensar® Geogrids and Tensar’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 http://www.tensarcorp.com.
requirements, which enhanced communication and kept the project moving forward without unnecessary delays.

During initial scope development, the airport team noted the project would require visual welding inspection and ultrasonic testing of the moment connections for the structural steel welding construction. Based on the project needs, Terracon provided two experienced welding inspectors certified Level II through the American Welding Society for nondestructive testing procedures. Nondestructive observation and testing on this project included visual, magnetic particle, and ultrasonic testing. Terracon provided the structural engineer, contractor, and owner with steel erection observation reports during the construction of columns, beams, and moment frames for the new, two-story structure.

Terracon’s certified welding and nondestructive inspectors observed and tested 100 percent of the connections.

Welding procedures, welding electrodes, certification of welding personnel, and fit-up were verified during steel and welding construction. For moment connections, Terracon’s certified welding and nondestructive inspectors observed and tested 100 percent of the connections. This included a visual weld examination of each weld moment connection for size and length measurement.

Following measurements of the welds, ultrasonic testing was conducted. Ultrasonic testing equipment was used to scan each weld for indications of defects in the welded connection. This is a critical step because welds can often appear acceptable by visual observation, but beneath the surface may have weaknesses in the structural material, including inclusions, lack of side-wall fusion, weld root penetration, porosity, or cracks.

Terracon also performed special inspection of high-strength bolting connections associated with the South Concourse construction. This included pre-installation verification testing using a calibrated Skidmore-Wilhelm device on a selection of bolts for each diameter and length of bolt supplied.

During erection and bolting of the various connections, the fraying surfaces of slip-critical connections were inspected prior to assembly of the joint, and bolts were observed to be pretensioned after installation. Visual verification of completed tension-control bolts were observed and documented.

During placement of spray-applied fire-resistive materials on columns and the underside of steel decking, Terracon provided ICC-certified spray-applied fireproofing special inspectors to verify that construction met project requirements. Inspection included observation of the substrate prior to application of the materials to confirm it was properly cleaned.

After application, Terracon performed routine thickness verification of the fireproofing material. Random samples of the fire-resistive materials were collected from the structural members and tested in the laboratory to evaluate whether the density of the material applied met the minimum project requirements. Bond strength of the material was also tested using specialized field testing equipment.

**Reporting adds value**

During construction, Terracon attended several meetings to ensure that the contractor, client, and other parties all agreed on inspection methodology, identification and communication of construction defects, and schedule. Terracon provided onsite communication and verbal verification of inspection results. These were followed by daily reports and test data, including location descriptions and photos, which were rapidly shared with the project team. Most reports were delivered within 24 hours after performing the service.

This process allowed the design and construction team to quickly confirm that the information produced met project specifications and allowed the contractor to perform minor rework as necessary without losing time. Terracon tracked all non-conformances separately in a deviation log as the work continued, keeping all outstanding non-conformities at a high attention level to all concerned parties.

As airports throughout the United States prepare for update and expansion, Terracon continues to offer comprehensive services and solutions for facilities of all sizes. With a national footprint, we already serve many large and regional airports from our local offices. Our aviation team is well-versed with FAA specifications, International Building Code requirements, and specific reporting requirements, and is ready to assist with any construction facility needs.

**TRACY GROVER** is a principal and regional manager in Terracon’s Phoenix office. He is the current chair of the American Concrete Institute Committee 311, Inspection of Concrete, a registered Special Inspector, and has extensive experience in airport construction, special inspection, materials testing, and quality assurance. He has provided consulting for airport and airfield projects in Washington, Idaho, Utah, Colorado, Arizona, New Mexico, and Guam.
A POWER- AND DATA-GENERATION TECHNOLOGY built on the durability of steel is changing the way urban environments consider pedestrian foot traffic. As a concept, it is disarmingly simple. Every day, across cities, airports, and other public spaces, millions of people are performing the straightforward task of moving from point A to B. And these millions of steps can do much more than just move pedestrians — they can also become valuable electricity and data. Harnessing this untapped resource is what the Pavegen system is designed for.

Pavegen CEO Laurence Kemball-Cook, who founded the company in 2009, said, “The Pavegen system converts the weight of your footsteps into electricity. All you have to do is walk and every step you make can be converted into energy. When we get the energy, we can store it in batteries and use it to power lights in our cities.”

A step change in design
The newest model of the technology — known as V3 — is made up of interlocking triangular tiles that are installed in areas with high pedestrian foot traffic. The tiles are able to produce 5 watts of continuous power from footsteps, creating an off-grid, localized energy source.

As people step on the tiles, their weight presses them down. Steel-built electromagnetic induction generators at the point of each triangular tile convert this downward force into a rotary motion that generates electricity. Using this method, a single footstep can generate enough power to light an LED lightbulb for roughly 20 seconds.

“It’s one of the hardest engineering challenges in the world to put a product in the ground where there’s going to be significant environmental challenges, such as lots of water ingress,” said Kemball-Cook. “Things like wear and durability and environmental performance are really key to our decisions around what material we use and what finishes we apply to those materials. Fatigue resistance is really challenging too, so we had to go through a process that involved lots of testing, lots of material selection, lots of different insights, to allow us to make the product as durable as possible. We try and save costs where possible, but where we need increased performance in the product those components may be steel or they may be stainless steel.”

Pavegen aims for 100 percent of its product to be recyclable, allowing a fully integrated supply chain and fully reusable system. Infinitely recyclable without any loss of quality, steel plays a large part in helping Pavegen reach this goal.

“Everything we’re doing on the engineering side allows us to build in the highest level of durability and we’ve taken technologies from the automotive and aerospace sectors,” said Kemball-Cook. “While a Pavegen tile will never get near the billions of cycles of an automotive application, what we can do is increase its life cycle within the technology’s limits, so we can get over 20 years of performance from our product.”

Data in every step
Another key aspect of the Pavegen system is its data collection. The tiles are fitted with wireless sensors that transmit data on pedestrian movement across installation sites. This information can be used to map foot traffic and peak pedestrian flows, allowing for a real-time understanding of movement.

When deployed in retail sites, shop customers and visitors can use an accompanying app to earn digital currency for every step that they
take, redeemable against a purchase or charitable donation. Incentivizing customers to contribute to the electric powering of shop systems is the kind of integrated thinking that Pavegen hopes will inform urban planning decisions and development of smart cities.

“Smart cities are about seamless connectivity and mobility between people within that city,” Kemball-Cook said. “Sensor networks allow people to get a real-time insight into how a city is performing, and this feeds into tracks and transportation links that make it a lot easier for people to get around. What we offer is a people power solution, a decentralized power solution and also a data hub that can help cities better understand how their people are moving and behaving in those urban environments. People are the heart of any city, and adding a decentralized power network really adds to this connectivity.”

Going global
Pavegen has already delivered more than 150 projects across the world. In 2014, the technology was installed under a football pitch in Rio De Janeiro. The pitch’s six LED floodlights are now powered by players moving across the 200 Pavegen tiles installed under the playing surface.

A similar project has been lighting a football pitch in Lagos, Nigeria, while environments as diverse as festivals and marathons have been harnessing the power of their audiences and competitors.

Pavegen technology is now being used by the U.S. government, Google, Cisco, and some large real estate groups, including Westfield.

“It’s been deployed across Africa, Korea, Japan, Australia, and also Europe. Our biggest growth market is in North America and the Middle East,” Kemball-Cook said. “We see a lot of interest in the transportation sector, particularly within airports.”

Power to the people
Anywhere there are people moving, there is an opportunity to harvest the untapped energy resources produced by that motion. A fundamental shift in the relationship between citizens and their cities will not happen overnight, but Pavegen could help usher in a new era of urban planning and living.

As Kemball-Cook stresses, “The Pavegen technology can work in any transport hub, office environment, airport, public realm — anywhere there’s lots of people walking.”

The journey toward smarter urban environments and more sustainable energy production could genuinely begin with a single step.

Information provided by World Steel (https://stories.worldsteel.org), a not-for-profit organization that represents global steel manufacturers.
malleable, these tools theoretically can be made of traditional mining materials such as steel, particularly stainless steel.

Stainless steel is often selected based on its corrosion resistance. Many of these softer ground types include high levels of moisture, so choosing a material with a high corrosion resistance and varying toughness seems like an ideal fit.

To account for chance encounters with harder materials in a soft ground environment, such as a small stone deposit, alternatives such as cemented carbide — also known as tungsten carbide or hard metal — with a nickel-chromium binder can be used to balance high toughness with corrosion resistance.

The considerations are understandably different for hard rock environments, where there is less moisture and a tougher material with high impact and hardness properties is necessary. In these environments, the material of choice is cemented carbide, with a cobalt binder to bolster toughness and heat resistance. This improves performance under the high temperatures that occur when impacting hard rock surfaces.

These material differences are important to note because it’s likely that the process of tunneling under Los Angeles would involve interacting with several environments. Design engineers will struggle to find a single material that is effective in both types of soil, so specialized tools with specific materials should be incorporated into the design of a TBM.

For example, cemented carbide could in theory be suitable for such environments, but its effectiveness depends on the binding material. A tungsten carbide that uses cobalt as a binder (WC-Co) may not have sufficient corrosion resistance for soft ground applications. In these situations, the overall effectiveness and toughness of the WC-Co tool would decrease as corrosion affects the material.

Instead, tungsten carbide with nickel-chromium (WC-NiCr) may be a better fit, especially in those environments with lower pH values, where the corrosion rate using NiCr instead of Co is reduced at least by a factor of five to 10.

Since the hard phase itself does not corrode, any corrosion would occur on the binder phase to leave behind isolated particles of cemented carbide, which could not do their job properly alone. Furthermore, the addition of other refractory metal carbides influences the corrosion behavior significantly.

It’s clear there’s a lot more to material selection in designing tunneling equipment than Musk lets on. That’s why we find many designers working on these projects compare materials using Matmatch’s online database, allowing them to easily make an informed decision to develop an effective product. The material selection process might be complex, but if Musk’s vision for a subterranean transport network becomes reality, the reduction in infuriating congestion will make everybody grateful.

Information provided by Matmatch (https://matmatch.com), a search platform that connects engineers and materials suppliers through a comprehensive materials database.
In 2017, Eye-bot Aerial Solutions, a drone service company, completed a 3D reality model of cell tower antennas in Springdale, Pa. The project team at Eye-bot initiated the Springdale Monopole project to improve model fidelity, positional accuracy, and photo-realism by comprehensively modeling vertical monopole structures that feature transparent, complex cross-bracing. In the long term, Eye-bot strives to use the enhanced models to help create standardized 3D modeling workflows. The organization specializes in using unmanned aerial vehicle (UAV) photogrammetry to generate 3D models of cell towers. Based in Pittsburgh, Eye-bot has worked within several industries, including industrial manufacturing, oil and gas, telecommunication, infrastructure, construction, insurance, and power and utilities. A Federal Aviation Administration-certified company, Eye-bot can inspect, monitor, aerial survey, and 3D model a variety of locations.

Difficult modeling towers
The main challenge of the Springdale Monopole project was the characteristics of the cell tower antennas. Vertical monopole antenna towers are difficult to model solely with UAV photogrammetry and using UAV photogrammetry is even harder when the tower contains complex cross-bracing and is see through. These features are common in self-supporting, guyed towers, as was the case on this project.

Because of these conditions, the team realized that it needed to incorporate LiDAR scanning as part of the data-capture process. A software application that could accommodate both survey methods was necessary. Eye-bot combined UAV photogrammetry with LiDAR scans to easily create 3D models with Bentley’s ContextCapture.

“ContextCapture is the only software we’ve found that can use photogrammetry and LiDAR scans together, giving it a unique advantage in this application,” said Jake Lydick, founder and CEO of Eye-bot.

The application also helped the project team fully utilize all its equipment. Previously, Eye-bot had difficulty processing images greater than 40 megapixels. ContextCapture processed all high-resolution images.
images without any issues. This capability allowed the project team to experiment with new data collection procedures, ultimately yielding a better model.

Sharing modeling information
Besides the technical benefits, ContextCapture also enabled Eye-bot to share project information with prospective clients. Eye-bot made the collected data available in a variety of formats. The project team also had a 3D mesh and 2D orthomosaic available through a hosted web portal, providing global access to the information.

Additionally, clients or prospective clients can download and view the mesh and point cloud in the CAD program of their choice if they want to evaluate the models more thoroughly. ContextCapture’s interoperability makes this possible.

ContextCapture enabled Eye-bot to take and share precise measurements without visiting the site, improving safety for the project team. By using UAVs to capture the data and then inputting them into the reality modeling application, Eye-bot eliminated the danger of workers falling from the tower, which can occur using traditional climbing methods.

In addition to personnel safety, the 3D reality models allowed the project team to analyze the safety of the tower itself, checking for structural deformities and other issues. Lastly, because of the ability to easily share these detailed models and information with all parties, Eye-bot reduced travel, reducing its carbon footprint. These models will allow for better informed decisions, keeping everyone safer.

Updating model information
Eye-bot created an efficient and repeatable means of inspecting vertical monopoles, collecting more data with better accuracy in a faster and safer manner than traditional methods. The team can periodically update the models with ContextCapture to keep them current, providing accurate information about its clients’ assets.

ContextCapture increased Eye-bot’s efficiency from design and implementation to maintenance, expansion, and monitoring. By comparing 3D models, users can measure and monitor monopole alignment for any in the network. This practice helped Eye-bot and its clients create a single source of truth for their antenna data.

Also, users can perform updates on a regular basis to ensure that the equipment is in good condition as well as monitor known issues before a physical correction is necessary. Once the user determines the required repair or upgrades, workers can reference the model when performing their tasks. The model will aid in project planning and material selection, increasing overall efficiency and quality of the project and reducing resource hours.

Saving project time
Eye-bot saved time and money using many different features in ContextCapture. The application’s master-engine program allowed users to distribute the workload over the network, reducing the amount of time required between data collection and project delivery.

Also, ContextCapture’s interoperability with MicroStation allowed the team to produce a model that can be directly imported into the other application. This capability eliminated the need to convert the model to CAD format and further helped reduce the time between collection and delivery. Because the team could generate a web view of the model, Eye-bot could host its models on its own server, lowering the overall cost of service.

Additionally, these models will help Eye-bot attain more dependable wireless networks because the detailed, precise, and easily shareable models will enable technicians to catch service problems sooner. In a world that heavily depends on wireless communication, this reliability is crucial. ContextCapture’s capabilities allow the cell towers to be inspected and monitored faster, safer, and more reliably.

CHINTANA HERRIN is a reality modeling product marketing manager with Bentley Systems (www.bentley.com) primarily focused on applications pertaining to 3D photogrammetry and point clouds. She is responsible for Bentley’s ContextCapture, Descartes, and Pointools applications. Herrin has nearly 20 years of experience marketing engineering software.
The Commercial UAV Expo Americas, Oct. 1-3 in Las Vegas, is intended for professionals who are integrating or operating unmanned aerial vehicles (UAVs) in key vertical industries. In addition to industry-specific breakouts, topics will include workflow integration, security/counter-drone technology, U.S. Department of Transportation’s Integration Pilot Program, robotics, traffic management, Low Altitude Authorization & Notification Capability, and more. And, the expo offers a glimpse of what’s coming next on the technology and regulatory fronts.

Three full days of conference programming includes workshops, keynotes, and plenaries, as well as outdoor drone demonstrations, a 200-plus booth exhibit hall, and networking events. Thirty exhibiting companies are scheduled to provide product previews that highlight the newest advances and best practices for specifying, planning, and executing projects.

**Workshops**

Eight Vertical Industry Deep Dive Workshops will cover topics from platform selection to data integration, workflows, security, and more. Workshop industries include the following:

**Construction** — Aerial data obtained on construction sites via UAVs for digital elevation maps, point clouds, and other uses for efficiency and safety is increasingly being leveraged for engineering analysis and predictive analytics. This workshop will examine the best approaches from capturing information and new tools to best practices for integrating, processing, and disseminating the information, including deliverables and visualization. Scaling a UAV program and anticipating future developments will also be addressed.

**DOTs & Infrastructure** — UAVs deployed for roads, bridges, and tunnels are realizing increased value, from fault detection to asset management. But what does it take to successfully integrate a UAV program into a government agency? In-depth content in this workshop will provide practical knowledge for developing policy and guidelines for UAV programs.

**Large Installation Assets** — This workshop focuses on the use of drones from inspection and operation to maintenance of cell towers, wind turbines, solar farms, and other large installations. Key issues include appropriate sensor types and integration, safety compliance, automated systems, adjusting work processes, sharing data, progress in use of AI and autonomy, and options for the future such as swarms and utilizing large structures for drone charging.

**Mining & Aggregates** — This workshop addresses the unique challenges of terrestrial mapping and volumetric calculations above and below ground, from the appropriate sensors and platforms to compiling and analyzing the data.

**Precision Agriculture** — Experts in this workshop will cover the use of the newest technology to obtain actionable information, including drones, remote sensing, and satellites.

**Process, Power & Utilities** — This workshop will focus on the use of UAVs for applications that involve processing of fluids or gases — oil & gas, electricity, water, pharmaceuticals, and chemicals. Topics include best practices for real-time monitoring and inspection; managing and sharing data; integrating UAVs into current systems and workflows; scaling a UAV program; and leveraging information for risk mitigation and operational optimization.

**Public Safety** — Police, fire, and government entities are constrained in the use of UAVs, not only by budget but also by public perceptions and oversight. This workshop focuses on lessons learned and key factors for a successful UAV program, including mapping, reconstruction, mission overwatch, patrol uses, search and rescue, emergency management, interior tactical searching, health sciences, cybersecurity, data science operations, and other related topics.

**Surveying & Mapping** — Drones are ideal for topographic measurement, from movement monitoring, change detection, seepage detection, volumetric measurement, and more. However, determining the right sensors and tools for managing the data is not always clear-cut. LiDAR, photogrammetry, multispectral, processing/extracting the data, and appropriate deliverables will all be covered.

**Keynotes**

Daniel K. Elwell, acting administrator, Federal Aviation Administration (FAA); and Michael Perry, managing director of North America for DJI, will deliver keynotes at Commercial UAV Expo Americas. Within the FAA, Elwell is responsible for the safety and efficiency of the largest aerospace system in the world — a system that operates more than 50,000 flights per day.

At DJI, which controls the majority of drone market share, Perry has
Terrain mapping measures the shapes and features of the terrain, which is important in fields such as land development, flood control and mitigation, landslide hazard identification and monitoring, project management, and obstruction identification. Higher resolution, higher accuracy, and faster terrain mapping helps the engineering community reduce the cost to generate a good 3D representation of the terrain morphology.

Traditional topographic mapping relied mostly on total station surveys, which was slow, costly, and low in resolution. With the advancement of remote sensing technologies, especially photogrammetry and light detection and ranging (LiDAR), as well as the flourishing of unmanned aerial vehicles (UAVs) as the sensor platform, surveying is becoming easier, quicker, and achieving better resolution. This article introduces and summarizes the basic principles of surveying remote sensing techniques, compares their capabilities and limitations, and proposes broader application of these techniques in terrain mapping.

The method frequently used by drone operators is photogrammetry, which consists of making measurements, especially in exact locating of surface features. A stereo vision can be constructed when the same objects are observed from two viewing angles, just like the perception of depth from humans’ two eyes. A line of sight is constructed from the center of the camera lens to the object, then the intersection of these lines (triangulation) from multiple views reconstruct a 3D representation of the object.

For example, the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) onboard NASA’s Terra satellite has two telescopes in visible and near-infrared spectral range, one nadir-looking and one backward-looking (see Figure 1), thus allowing generation of digital elevation models (DEMs) for the entire globe, the ASTER GDEM (Hirano et al., 2003).

Many automated computer algorithms have been generated to identify common objects from multiple views, which facilitate image registration and depth recognition (Lucas and Kanade, 1981; Scharstein and Szeliski, 2002). This process is normally called “Structure from Motion” (SFM), as scene structures are derived from the movement of the camera. As the name implies, the camera should be moved to get
images from multiple observing angles and have enough overlaps between images. Commonly, cameras are mounted on a moving vehicle and take photographs automatically to obtain multi-view.

Since the features identified from photogrammetry are scale invariant, objects with known dimensions in imagery are used to provide the scale. Topographic surveyors commonly put large targets (ground control points, GCPs) on the ground and survey the geographic coordinates with RTK GPS or total stations. The targets are extracted from images, and the associated geographic coordinates are used to georeference all images into a global reference frame. These targets normally have regular geometry and are easy to identify, like squares with checkerboard patterns and circles with crosshairs.

The georeferenced point cloud is then utilized in creating DEMs and an orthophoto/orthomosaic, which is a geometrically corrected image that allows distance measurements on the image. Typically, the orthophoto has twice the spatial resolution (half the pixel size) of the DEM and has color information, which helps interpretation.

LiDAR
LiDAR sends out a light signal (typically laser) to the object and detects the reflected or scattered signal, or the induced fluorescence from the target. LiDAR measures the range between the target and the sensor; these measurements across the target form a 3D point cloud of the target.

Normally, LiDAR uses time of flight (pulse) or phase difference (continuous wave) to measure distances. For time of flight LiDAR, a high-energy laser pulse is sent out, then the reflected pulse from the target is detected. The range is then determined from the product of the speed of light times half of total time of flight (to the target and back). The ranging precision is limited by the accuracy of the internal clock and can be down to about 10 cm scale.

For phase difference LiDAR, a long wavelength sinuous waveform is modulated onto a continuous, low-energy, short wavelength carrier laser signal. Once the laser reflects from the target, the phase difference of the long wavelength signal is measured, and the range can be computed. The distance can be measured very precisely (about 2 mm), but the range is less than the range of a time of flight LiDAR.

Within typical LiDAR instruments, a mirror is used to redirect the laser toward the target. These mirrors oscillate or rotate to change the path of the laser so it can scan the target, and the mirror angles are recorded. With both angle and distance measurements, the location of the target with reference to the LiDAR is computed. The location of the LiDAR instrument can be measured from global navigation satellite system (GNSS), then the measurements can be georeferenced into a global coordinate system.

Typical LiDAR instruments make more than 100,000 measurements. GNSS, however, can never reach such a high sampling rate. This leads to a problem that when LiDAR is mounted onto a mobile platform to facilitate fast data collection, its location cannot be measured quickly enough. This problem is solved by the integration of an inertial measurement unit (IMU), which can measure the angular orientation and acceleration in a high frequency, with the GNSS, to compute the LiDAR location. The GNSS/IMU integration is performed with an automated algorithm called Kalman Filter (Kalman, 1960; Schwarz et al., 1993), which blends prediction from IMU with measurement updates from GNSS to obtain optimum estimates of coordinates.

Laser is a coherent signal with single direction and low divergence; however, the laser beam divergence cannot be infinitely low, and the footprint diameter are in centimeter to decameter scale at typical scanning ranges. Thus, laser signal can be reflected from multiple targets along its path within the footprint. If multiple return peaks can be recorded and resolved from waveform processing, then multiple targets can be registered from a single laser pulse.

The laser signal is attenuated due to scattering while transmitting in the air, and laser beam divergence reduces the laser intensity received by the detector. As a result, targets with low reflectivity or long range become hard to detect because of weaker returns. Phase difference LiDARs produce continuous waves with relatively lower energy, thus have lower detection range, while time of flight LiDARs generate short but stronger laser pulses and have higher detection range.

UAVs
UAVs, in general, can be classified into fixed-wing aircrafts that use forward airspeed to generate lift, and rotorcrafts that use rotary wings to generate lift. UAVs of both kinds have been flourishing rapidly, while most commercial UAVs used in topographic mapping are multicopters, or multicopters that have four, six, or eight rotors (quadcopter,
An advantage of multirotors is that the flight control mechanics are easy; motion control is achieved by varying each rotor’s speed.

UAVs can take various kinds of payload, including camera, LiDAR, and other remote sensors that allow mapping and surveying. GNSS/IMU can be integrated on UAVs, and their recordings can be stored in photo EXIF that can be extracted in SFM algorithms or transferred into LiDAR for georeferencing.

UA Vs are capable of low-altitude and slow flight, which is suitable for high-resolution, high-accuracy, and high-sensitivity mapping applications. Better remote sensing performances are normally achieved only with heavier instruments. For example, laser pulses of higher intensity, which are needed for longer range and better accuracy, can only be generated from larger and heavier laser sources with higher wattage. Higher weight inevitably reduces the flight time of UAVs. Most commercially available UAV systems can support 20 to 40 minutes of flight, depending on payload weight and UAV propellers.

Application of UAV photogrammetry and LiDAR has been booming (Goncalves and Henriques, 2015; Jaakkola et al., 2010; Wallace et al., 2012). Most of these applications include creation of a DEM and an orthomosaic image; sometimes vector 3D models, contour maps, and 3D point clouds are delivered to clients.

Comparisons and applications

Compared with traditional surveying methods, aerial photogrammetry allows fast, cheap, and high-resolution topographic mapping. Together with 3D point clouds, aerial photogrammetry provides high-resolution ortho-imagery, which helps data interpretation. Cameras are significantly cheaper compared with LiDAR and commonly weigh less, which makes UAV flights much easier.

Photogrammetry has its limitations. First, SIFT works well with targets that have significant contrast with their surroundings so that they can be searched automatically within the images. This raises difficulties in aligning photographs of homogeneous materials with low color contrast, surfaces with smooth texture, or moving objects. Some examples are large areas of bare ground or thick vegetation, or thin vegetation that were constantly blowing in the wind. Without easy identifiable targets, the photographs will be hard to align, resulting in low-accuracy alignments or misalignments.

Some UAVs have onboard GNSS/IMU so that the location and angle of the camera can be integrated into EXIF information of photos, relieving the worry of misalignment. However, the performances of low-cost GNSS/IMU onboard normal UAV platforms are limited. GCPs can improve the accuracy of georeferencing but do not improve the accuracy of image alignments.

Another issue with photogrammetry is the ability to sense the ground in vegetated areas. Common UAV photography can reach centimeter-level spatial resolution at flying heights of tens to hundreds of meters, and there is very little chance to see pixels of the ground through

References

• Kalman, R.E., 1960, A New Approach to Linear Filtering and Prediction Problems 1, J. Fluids Eng. 82, p. 35-45.
LiDAR, as an active remote sensing technique, is independent of natural radiation source, and allows wide application in various time of day and weather conditions. With the high intensity and priori knowledge of the stimulating signal, the sensitivity to background noise is reduced and target properties such as lithology (Franceschi et al., 2009; Hartzell et al., 2014) and vegetation indices (Li et al., 2014) can be delineated. With a low-divergence, single-direction, single-phase, and single-frequency light source, high range and spatial resolution is achieved.

LiDAR has its own disadvantages. First, the instrument cost of LiDAR is significantly greater than photogrammetry. The laser source and detector, timing electronics, mirror and its motor, and goniometer are all costly compared with photogrammetry devices. Second, LiDAR is heavier, consumes more electricity, and requires a larger UAV for heavier payload. One UAV with a camera onboard can weigh less than 1.5 kg, while the lightest LiDAR itself with enough accuracy and ranging ability can be 1.55 kg by itself, let alone the weight of the UAV and battery packs. Surveyors must carefully compare the tradeoff between cost, accuracy requirements, and technical performance.

With the remote sensing techniques onboard a UAV, surveyors can map faster and easier, and map inaccessible areas such as swamps, areas with steep slopes or vertical cliffs, and areas with safety hazards. This expands the capabilities of topographic mapping to include frequent revisiting, monitoring, and change detection, and allow better management of project progression and assessment.

This multi-target capability opens the application of laser scanning in forested areas. Signals from leaves, branches, trunk, and ground can be collected, allowing estimation of biomass. Thirdly, because of the detection and ranging rather than triangulation, LiDAR provides direct 3D point clouds without time-consuming processing of photographs.

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As a prosperous mid-sized business, TAI Engineering’s management team is always looking for new ways to compete and win additional business.

In 2016, TAI Engineering received a request for proposal from a large client that included 3D imaging services. As part of the project, the company requested a 3D rendering that would show how a facility roof would look in terms of piping and means of egress after the design work was completed. The TAI team had limited experience with reality capture technologies and contacted IMAGiNiT Technologies to discuss various options.

**Proof of concept**

Rather than immediately investing in 3D laser scanning equipment,
TAI Engineering has used reality capture to verify design documents and 3D models.

TAI decided to partner with IMAGiNiT on a reality capture proof of concept to ensure that it could deliver a return on investment. During the proof of concept, IMAGiNiT’s reality capture experts worked side-by-side with the TAI team to scan and process the data from the client site. TAI Engineering incorporated the proof of concept into its bid and won the client’s business.

“The proof of concept opened our eyes,” said Alan Miller, principal and director of projects and business development at TAI Engineering. “The speed with which we could gather data and the accuracy of the data collected helped us see the possibilities and potential uses of reality capture. We realized that 3D laser scanning would be a cost-effective means for capturing field data for our drawings.”

Based on the successful proof of concept, TAI Engineering decided to purchase its own 3D laser scanning hardware. “Since our firm does a lot of small and mid-sized projects, it made sense to purchase a scanner. It gives us greater flexibility to meet client deadlines,” Miller said. Although the team considered other vendors, TAI elected to purchase the equipment from IMAGiNiT.

TAI Engineering is already seeing direct gains from having reality capture technology. Rather than sending multiple people into the field with handheld lasers, tape measures and cameras, the firm can send a single person with the scanner and collect highly accurate field data. Thanks to training delivered by IMAGiNiT, TAI Engineering now has four people skilled at field scanning and who understand how to manipulate the resulting data.

On a recent construction project, a client asked TAI Engineering to verify the design documents and 3D model created by another firm. By scanning the building site, TAI could ensure the tie-in points for prefabricated pipes were in the right place.

“We scanned the site at the beginning of the construction process and then scanned again later,” Miller said. “Our isometric drawings now match the field. By incorporating scanning into the process, we save construction and field time by avoiding field welding.”

**Leveraging reality capture to expand the business**

TAI Engineering views reality capture and 3D laser scanning as central to its operations. According to Miller, more and more competitors are using laser scanning and it will soon become the standard way to gather field data for all size engineering firms. TAI now uses laser scanning on almost every project, instead of other measuring devices. This approach saves time, while providing accurate drawings and installations.

Reality capture is also becoming an essential part of TAI’s business development efforts. Data from laser scanning makes it possible for TAI to create visualizations quickly for clients. In addition, the firm is actively working on expanding its business to new sectors.

“This new technology and equipment is one of the primary ways that we are increasing our presence in new markets,” Miller said.

Information provided by IMAGiNiT Technologies (www.imaginit.com), a Rand Worldwide Company that provides enterprise solutions to the engineering community, including the building, manufacturing, civil, and mapping industries.
FOR NEARLY A GENERATION, the virtues and benefits of decentralized systems for water supply and sanitation have been widely recognized and approaches, devices, and technologies have been advocated as critical components for a sustainable 21st Century. Yet, the principles and practices of modern decentralized systems have not yet been broadly incorporated into curriculum within U.S. higher education.

Needs and options evolve
In the United States, systems for water supply and sanitation evolved during the 20th Century in response to a growing recognition that providing safe drinking water and adequate treatment of wastewaters were needed to protect public health and preserve water quality. During this evolution, there was a mix of systems, with the relative proportion of the U.S. population and development served by the different system types varying and evolving over time to broadly include two system types — those serving individual homes, businesses, and mixed-use developments in rural and suburban areas; and large centralized systems serving densely populated urban areas.

Today, nearly 30 percent of individual household wastewater treatment systems in the U.S. are decentralized and approximately 35 percent of new development is supported by such systems. This amounts to roughly 25 million existing systems with about 200,000 new systems being installed each year.

The growing interest in sustainability has contributed to an increasing interest in modern decentralized wastewater treatment as a more widespread solution due the significant benefits that can be realized, including:

• conserving potable water by reclaiming water for nonpotable use;
• preventing combined sewer overflow pollutant discharges;
• recharging local water resources near the point of water extraction;
• enabling recovery and reuse of wastewater resources, including water, organic matter, nutrients, and energy;
• lowering consumption of energy and chemicals;
• reducing greenhouse gas emissions;
• improving resilience to natural disasters and climate change; and
• earning points for a green building or sustainability rating.

During this period, there was also a growing recognition that the capabilities of 21st Century decentralized systems should not be judged based on the performance of older 20th Century systems. The outdated systems (e.g., cesspools, seepage pits, non-code compliant systems) were typically installed to be simple and cheap methods of wastewater disposal. During the latter decades of the 20th Century, increased water use and wastewater generation and more widespread use of disposal-based systems in a growing suburban America, contributed to occurrences of hydraulic malfunctions, groundwater contamination, and surface water quality deterioration. To properly distinguish and refer to these older disposal-based systems, they became known as “legacy systems.” In contrast to the legacy systems, modern decentralized systems can be designed for effective treatment as well as resource conservation and recovery.

Based on major research and development efforts during the last two decades or longer, modern decentralized systems have evolved to include a growing array of approaches, devices, and technologies that can be used to serve buildings and developments with design flows of less than 100 gallons per day to 100,000 gallons per day or more.

The purpose of common and emerging applications within the U.S. include to:

• provide effective wastewater treatment for homes and businesses in rural and peri-urban areas and residential, commercial, and mixed-use developments in suburban areas;
• provide nutrient attenuation in environmentally sensitive areas;
• provide effective wastewater treatment for buildings and developments while also producing a reclaimed water for nonpotable reuse purposes such as toilet flushing or irrigation;
• recover valuable wastewater resources, including nutrients, organic matter, and energy; and
• earn points for a green building or sustainability rating through the low impact water and wastewater management options enabled by decentralized systems.

Applications worldwide are similar but also encompass safe drinking water and adequate sanitation in developing regions of the world.

Engineering course delivery
Evolving the curriculum in higher education to prepare undergraduate and graduate students to be water reclamation (modern name that encompasses wastewater treatment) design professionals and decision makers is key to managing future worldwide water and wastewater challenges effectively. A keen understanding of decentralized system approaches, devices, and technologies is critical to future professionals’ ability to recommend the most advantageous design solutions to meet
individual situations and development and community needs.

During the 20th Century, U.S. higher education curriculum concerning wastewater systems engineering was predominantly focused on design and operation of wastewater collection systems and centralized treatment plants for cities and other urbanized areas. That decentralized systems education was available to a lesser extent is not surprising since the focus of federal research and educational funding was on centralized wastewater systems, and that is where careers were mostly available for university graduates.

Today, many U.S. universities offer some undergraduate and graduate curriculum addressing decentralized systems. This typically involves faculty mentoring of students involved in research or lecture delivery on water supply and wastewater treatment. In a few cases, specialty programs such as a Water and Sanitation for Health (WASH) program include lectures on decentralized water and wastewater systems. Students also receive relevant education through projects sponsored by Engineers Without Borders or other aid organizations.

Where universities have sustained decentralized system courses, they are generally offered within Agricultural and Biosystems Engineering or Civil and Environmental Engineering and cross-listed in other departments including Soil Science, Natural Resources Science, or Water Resources Management. Courses are delivered through classroom lectures complemented by laboratory or field sessions, such as those at the Colorado School of Mines, University of Wisconsin, and University of Washington. Others, including those at the University of Arizona, are delivered as online courses. All generally satisfy Accreditation Board for Engineering and Technology (ABET) criteria.

Future need
With the exploding need for wastewater treatment solutions in the U.S. and worldwide, expanding the number of universities offering decentralized systems courses is essential. This includes realizing the environmental and public health benefits of decentralized systems where little to no treatment exists and that have extremely limited resources. While it is essential that more U.S. universities offer decentralized wastewater treatment systems engineering courses, this goal is not without its challenges, including:

- engaging a faculty member with expertise in the decentralized approach;
- access to textbooks and course materials, including “real world” design experiences;
- a receptive administration that recognizes the value;
- a credit-hour space in one or more degree programs; and
- perception of career placement opportunities in the decentralized arena.

Conclusion
The virtues and benefits of modern decentralized systems have been widely recognized, and approaches, devices, and technologies continue to be advanced and promoted for widespread use across the United States and abroad. Yet, the principles and practices of modern decentralized systems have not yet been broadly incorporated into curriculum within U.S. higher education.

Existing regulations and requirements, often based on legacy system performance, is often prescriptive, constraining, and conservative. Modernized regulations and requirements will help facilitate creative engineering to realize the full benefits of decentralized systems.

Among the thousands of U.S. universities, only a few have been successful in incorporating semester-long courses focused on engineering of decentralized systems. More sustainable funding at the national, state, and local levels is needed for course offerings, grants for research, student fellowships and traineeships, and funding for new infrastructure construction and rehabilitation of aging infrastructure. Realizing this outcome is critical to develop the next generation of engineering professionals who are informed design professionals and decision makers.

ROBERT L. SIEGRIST, PH.D., P.E., BCEE, University Professor Emeritus and research professor, Colorado School of Mines (CSM), Department of Civil and Environmental Engineering, is former director of the Environmental Science and Engineering Division at CSM and founding director of the Small Flows Program. Before joining CSM in 1995, he held positions with the University of Wisconsin, Norwegian Institute for Georesources and Pollution Research, Ayres Associates Inc., and Oak Ridge National Laboratory. During his 40-year career he published more than 300 technical papers and three books and was awarded two patents. His new textbook, Decentralized Water Reclamation Engineering, was recently published by Springer (www.springer.com/us/book/9783319404714). He can be contacted at siegrist@mines.edu.
More than 130 session recordings from the 2018 NASCC: The Steel Conference in Baltimore are now available for free online viewing at www.aisc.org/2018nascconline. The recordings include a synchronization of the speakers’ voices along with their visual presentations.

The American Institute of Steel Construction (AISC) makes much of its conference material available at no charge as part of its mission to disseminate information for building and designing with structural steel. “We strongly believe that providing free access to high-quality educational material benefits everyone in the industry,” said Scott Melnick, senior vice president at AISC.

Search for conference proceedings from the last 10 years at www.aisc.org/educationarchives. The site also contains a collection of recorded webinars and articles that can be accessed at any time.

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- Analysis, design, and construction for extreme events;
- Mega-projects (projected work/risk mitigation/contractual aspects);
- Constructability issues and design aspects; and
- Other deep foundations-related topics.

The conference also includes meetings of DFI’s Board of Trustees and Committee Chairs, as well as meetings of the Technical Committees and Working Groups. Thursday through Saturday, Oct. 25-27, includes technical sessions, special lectures, networking lunches and receptions, more than 150 exhibitor displays, the Hal Hunt Lecture on Communications, the DFI Awards Reception and Banquet, and a companions’ program.

The event is expected to draw more than 1,000 engineers, contractors, government agency representatives, suppliers, manufacturers, and academics involved in the deep foundations industry from around the world to share experiences, exchange ideas, and learn about the current state of the practice.

More information and registration is available at www.dfi.org/annual2018.

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**DESIGNING WITH STRUCTURAL STEEL**

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**MORE THAN 130 SESSION RECORDINGS** from the 2018 NASCC: The Steel Conference in Baltimore are now available for free online viewing at www.aisc.org/2018nascconline. The recordings include a synchronization of the speakers’ voices along with their visual presentations.

This year’s Steel Conference attracted a record attendance of 5,175. Next year’s conference will take place in St. Louis, April 3-5, 2019. For more information, visit www.aisc.org/nascc.

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Information provided by the American Institute of Steel Construction (www.aisc.org).
Beginning in fall 2018, Purdue University’s College of Engineering and Krannert School of Management are teaming to offer a concurrent master’s degree in engineering and business administration. The new product will give students the ability to earn both degrees in two years, rather than the three it would take to earn them separately.

“Engineering students who seek a non-thesis or professional master’s degree typically plan a career that requires expertise in business and management, as well as in their technical field,” said Eckhard Groll, associate dean of undergraduate and graduate education and the Reilly Professor of Mechanical Engineering. “While many professional master’s degrees in engineering offer up to nine credit hours of management courses, many students prefer the experience of a full Master of Business Administration (MBA). Others find that their professional degrees are adequate early in their careers, but they lack the management skills they need to advance in their companies. This concurrent program meets the needs of both groups.”

Interested students must apply and be admitted to both programs. They will focus on engineering courses in the first year and then transition to the MBA the second year. Students will pay tuition costs for both programs, but several assistantships will be available through Krannert. The following engineering schools have signed on to take part in the concurrent program: aeronautics and astronautics, biomedical, chemical, civil, environmental and ecological, industrial, nuclear and interdisciplinary engineering.

“This combination will provide students both technical and interpersonal skills that will give students an edge in their organizations,” said Karthik Kannan, Thomas Howatt Chaired Professor in Management and academic director of the Krannert MBA program. “With a selection of more than 100 electives in management, economics, and organizational behavior, students are able to personalize their experience. They can complement their classroom instruction through independent studies or by getting involved in experiential projects through Purdue’s robust high-tech entrepreneurial ecosystem.”

More information about the new degree program is available at https://engineering.purdue.edu/Engr/InfoFor/DualDegrees/index_html.

Information provided by Purdue University (www.purdue.edu).
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When Building Information Modeling (BIM) was first introduced, it initially gained traction with design professionals because it enabled them to iterate more fluidly, analyze multiple options more objectively, communicate design intent more clearly, and produce more reliable and constructible documentation. As this modeling matured, contractors and fabricators have also embraced BIM for its exceptional value in downstream activities such as estimating, detailing, fabrication, installation, and handover — integrating the complete design-to-construction workflow as an efficient, collaborative digital effort.

These companies know that BIM is best played as a team sport, and that widespread adoption is key to scaling its benefits across all projects and the entire industry. But how can more firms be encouraged to get involved with BIM?

A recently published research report called Connecting Design and Construction from Dodge Data & Analytics, sponsored by Autodesk, includes an examination of two critical elements of this evolutionary process:

• Architects’ perceived level of BIM adoption and capability among the engineering firms available to them in the markets where they work; and
• Architects’ use of BIM Requirement policies to encourage or mandate its use by the engineering firms they evaluate and hire.

Architects’ perceived level of BIM engagement by engineering firms — To benchmark the current status, Dodge asked U.S. architects currently active with BIM about their perception of overall BIM adoption among five types of consulting engineers in all of the areas they practice.

• Structural engineers scored highest, with almost three-quarters (73 percent) of architects reporting either a high or very high percentage of BIM-capable firms in their market.
• High/very high ratings for mechanical, electrical, and plumbing (MEP) engineers range from 52 percent (mechanical) to 29 percent (electrical).
• Civil engineers trail, with only 15 percent of architects reporting high or very high availability of BIM skills.

These findings are not surprising, as structural firms have been working in 3D for decades, so a shift to designing with 3D intelligent objects was relatively straightforward. The higher capability levels of mechanical and plumbing engineers compared to electrical relates to the industry’s focus on BIM for clash detection, since these elements are physically larger. It also aligns with other Dodge research findings about the rapid growth of BIM among those two trades compared with electrical. Lastly, BIM practice has traditionally focused on building architecture and systems, and has only recently begun to incorporate civil considerations, so naturally, BIM-skilled civil engineers are rare by comparison.

Architects’ BIM Requirement policies for civil and structural engineering firms — In most cases, architects have a lot of control over the selection of consulting engineers for their projects and can evaluate candidates for their BIM capabilities as well as other more traditional attributes.

Dodge asked architects currently using BIM about their BIM policies for engineers, and the feedback ranged from “strict mandate that BIM be deployed” to encouraging BIM implementation, but not requiring it, and those that simply have no BIM policy in place. Data in each of these categories for civil and structural engineers is further broken down by the level of BIM engagement of the architectural firm (high-engagement, meaning more than half of their current work involves BIM, and low-engagement, meaning less than half of their current work involves BIM). More than half of high-engagement architects (53 percent) require BIM from structural firms, yet only 5 percent require it from civil. For comparison purposes, architects’ policies for MEP engineers are nearly as frequent as for structural engineers.

Future

While structural firms seem well on their way to BIM sufficiency, these findings strongly suggest that civil engineers will increasingly need to have BIM skills moving forward — so adoption, training, and skill building will be critical. For those that are already BIM-capable, they should continue to leverage it as a competitive advantage and will be best positioned for future success.

The full report is free at https://www.construction.com/toolkit/briefs/connecting-design-construction.

STEVE JONES, senior director of Industry Insights Research, Dodge Data & Analytics (www.construction.com), focuses on how emerging economic, practice, and technology trends are transforming the global design and construction industry. He produces Dodge Data & Analytics’ SmartMarket Reports on key industry trends, which are read by millions worldwide. Dodge Data & Analytics is North America’s leading provider of analytics and software-based workflow integration solutions for the construction industry.
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