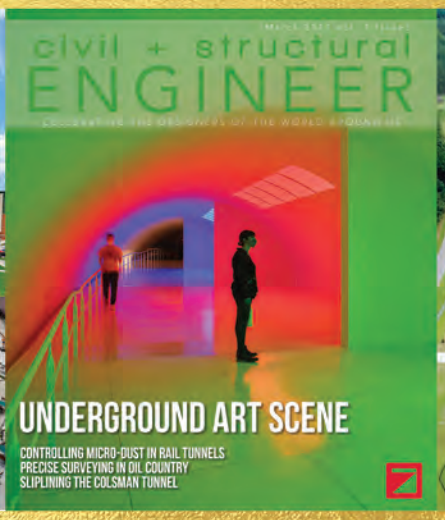
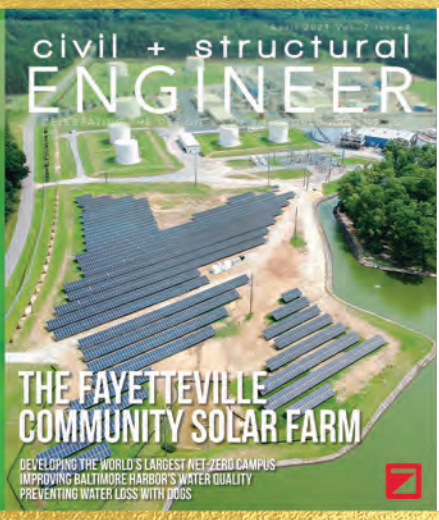








January 2022 Vol. 8 Issue 1

civil + structural ENGINEER

CELEBRATING THE DESIGNERS OF THE WORLD AROUND US





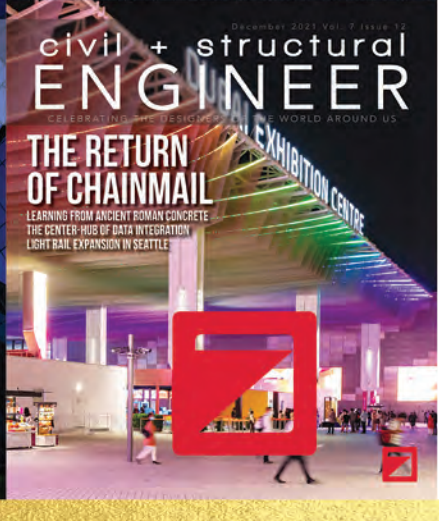












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AIA Continuing Education Provider



A CELEBRATION OF 2021

Luke Carothers

When 2021 began, there were a lot of questions floating around the industry–questions about sustainability, questions about the ongoing pandemic, questions about digitization, and more. Our responses to these questions have shaped not only the current state of the AEC industry, but also its future.

Projects like the Fayetteville North Carolina Solar Farm and habitat restoration in Minnesota's Kingsbury Bay demonstrate a growing push in the industry to incorporate a sustainable mindset towards environmental resources. This push was also echoed in several of our stories about unmanned systems and drones, discussing the capability of drones to completely alter our approach design, construction, and stockpile management. However, this is but a fraction of the topics and projects covered by us in the last twelve months.

To celebrate the thinkers that have shaped the AEC industry's discourse over the past year, this issue features some of the best pieces from Civil+Structural Engineer Magazine. These projects and ideas are foundational to how we see and shape the world moving forward.

It is our goal to both elevate the AEC industry and celebrate the people who design the world around us. From Dubai to Alaska and back again,this publication has spanned the globe, covering those tackling the problems our industry faces with ingenuity and collaboration. By looking back and curating the best of the past, it is our hope that this issue shines a light into the unknowing of a new year.

LUKE CAROTHERS is the Editor for Civil + Structural Engineer Media. If you want us to cover your project or want to feature your own article, he can be reached at lcarothers@zweiggroup.com.



JANUARY 2022

COMMERCIAL UAV EXPO EUROPE
JANUARY 18-20 — AMSTERDAM

As drones move from being optional extras to essential tools, benchmarking the value associated with creating and maintaining a commercial drone program is critical. Professionals need to understand how drones have proven to enable countless tasks to be performed in faster, cheaper and safer ways that can sometimes vary from region to region all across Europe. At Commercial UAV Expo Europe, we carefully develop conference topics in cooperation with an Advisory Board of esteemed professionals to focus on these kinds of real-world results. We thoroughly vet prospective presenters to ensure they are the best in their topic area and region. The goal: to provide outstanding, actionable information on the critical issues industrial users face integrating or operating UAS to showcase what innovations are making a bottom-line difference today while also providing a glimpse at what's coming next for UAS across the entire continent and beyond.
https://www.expouav.com/europe/

AMSTERDAM DRONE WEEK
JANUARY 18-20 — AMSTERDAM

Amsterdam Drone Week is the global platform for sharing knowledge on current air solutions, potential innovations and vital regulations. A top-level meeting point where all key players, big and small, commercial and non-commercial, from various industries, knowledge institutes and authorities, gather to co-create and co-operate. Creating urban air solutions together.
https://www.amsterdamdroneweek.com/

APPLICATION ARCHITECTURE SUMMIT
JANUARY 27 — VIRTUAL

Application Architecture Summit is a multi-vendor virtual event where experts explore application platforms, frameworks and tools for low-hassle and light-speed app development, testing, delivery and security.
https://www.idevnews.com/registration/?event_id=523&code=23400

ICCCE 2022: 16. INTERNATIONAL CONFERENCE ON CIVIL AND CONSTRUCTION ENGINEERING
JANUARY 28-29 — NEW YORK, NY

The International Research Conference is a federated organization dedicated to bringing together a significant number of diverse scholarly events for presentation within the conference program. Events will run over a span of time during the conference depending on the number and length of the presentations. With its high quality, it provides an exceptional value for students, academics and industry researchers. International Conference on Civil and Construction Engineering aims to bring together leading academic scientists, researchers and research scholars to exchange and share their experiences and research results on all aspects of Civil and Construction Engineering. It also provides a premier interdisciplinary platform for researchers, practitioners and educators to present and discuss the most recent innovations, trends, and concerns as well as practical challenges encountered and solutions adopted in the fields of Civil and Construction Engineering
https://waset.org/civil-and-construction-engineering-conference-in-january-2022-in-new-york

FEBRUARY 2022

GEO WEEK
FEBRUARY 6-8 — DENVER, CO

Geo Week is the intersection of geospatial + the built world. The event brings together AEC Next Expo & Conference, SPAR 3D Expo & Conference and the International Lidar Mapping Forum into a single powerhouse event. Industries covered include Architecture, Engineering & Construction; Asset & Facility Management; Disaster & Emergency Response; Earth Observation & Satellite Applications; Energy & Utilities, Infrastructure & Transportation; Land & Natural Resource Management, Mining & Aggregates, Surveying & Mapping, and Urban Planning/Smart Cities.
https://www.geo-week.com

THE 5TH INTERNATIONAL CONFERENCE ON MATERIALS ENGINEERING AND APPLICATIONS
FEBRUARY 12-14 — NHA TRANG, VIETNAM

It provides an opportunity for the delegates to meet, interact and exchange new ideas in the various areas of Materials Science especially on materials engineering and application. ICMEA 2022 aims in proclaim knowledge and share new ideas amongst the professionals, industrialists and students from research areas of materials engineering and application to share their research experiences and indulge in interactive discussions and special sessions at the event.
http://www.icmea.org/

LEADERSHIP SKILLS FOR AEC PROFESSIONALS
FEBRUARY 17-18 — NEW ORLEANS, LA

Practical leadership skills are vital to the health and success of every company in any industry. Effective leaders motivate their teams to achieve exceptional results, inspire others to be better than they thought possible, and create an environment where their team is focused and working towards a common vision. Zweig Group's team of management experts – who have extensive experience working with AEC firms providing solutions to the challenges facing AEC firms today – deliver practical solutions that technical professionals can put to work immediately to lead their firms to success.
https://shop.zweiggroup.com/collections/seminars/products/leadership-skills-for-aec-professionals?variant=34602098360471

6TH INTERNATIONAL CONFERENCE ON SUSTAINABLE ENERGY ENGINEERING (ICSEE 2022)
FEBRUARY 18-20 — HOBART (TASMANIA), AUSTRALIA

2022 will offer an extensive program of interest to academia, government and industry. It will include several distinguished keynote speakers and three conference days full of papers, posters, etc. A series of exciting speeches to develop skills and advance awareness of requirements engineering practices are of particular interest to industry.
http://www.icsee.org/

MARCH 2022

PROJECT MANAGEMENT & ADVANCED PM FOR AEC PROFESSIONALS

MARCH 10-11 – TAMPA, FL

This one-day training course covers the critical focus areas every AEC Industry project manager should be familiar with and is presented in lecture, tutorial, and case study workshop sessions. Attendees will leave armed with a comprehensive understanding of the characteristics, skills, and techniques successful project managers must have to flourish in their role. Each team member brings their own unique experiences and skillset to project teams. Effectively leveraging the talents of your team can optimize team effectiveness. Project Management for AEC Professionals provides people-focused, science-driven practical skills to help team leaders harness the power of their team. By addressing the most important aspects of any project – the people – this course will provide practical techniques that can be immediately implemented for a positive impact on any AEC team or business.

https://shop.zweiggroup.com/collections/seminars/products/excellence-in-project-management?variant=34602103013527

ELEVATING DOER-SELLERS

MARCH 30-31 – SCOTTSDALE, AZ

Elevating Doer-Sellers: Intensive 2-Day Workshop is a two-day seminar specifically developed to help design and technical professionals in architecture, engineering, planning, and environmental firms become more comfortable managing clients and promoting the firm and its services. Led by two retired and current CEOs with extensive experience from the design desk to the board room, this one-of-a-kind seminar presents business development techniques proven to drive real growth and value in your AEC firm. Beyond the buzzword heavy, ra-ra approach of other business development and sales training seminars, Elevating Doer-Sellers: Intensive 2-Day Workshop focuses on what really works in today's AEC firm utilizing practical and proven techniques that resonate across the organizational chart.

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APRIL 2022

ELEVATEHER KICKOFF

APRIL 6-7 – DALLAS, TX

More information coming soon.

https://zgelevateher.com/

CEO ROUNDTABLE

APRIL 21-22 – NAPA VALLEY, CA

The CEO Roundtable Retreat is a unique opportunity for AEC firm leaders to engage and interact with industry peers to discuss current issues facing firms today, explore industry trends and next practices, and confront the biggest challenges they face leading their firms. Zweig Group's CEO Chad Clinehens, PE, moderates the program guiding group conversations, encouraging integration and networking, and ensuring attendees gain valuable insight, new ideas and tools – and a new network of colleagues – to foster effective leadership at their respective firms. Come prepared to discuss your biggest challenges and successes during this highly interactive session. With you in control of the subject matter, roundtable discussions strike at the heart of what you need to effect change in your organization.

https://shop.zweiggroup.com/collections/seminars/products/ceo-roundtable?variant=30872181014563

SEPTEMBER 2022

COMMERCIAL UAV EXPO

SEPTEMBER 6-8 – LAS VEGAS, NV

Commercial UAV Expo Americas is the definitive event for professionals integrating or operating commercial UAS. With top-notch education, thousands of attendees, and more exhibitors than any other commercial drone event, it's the best opportunity of the year for anyone who needs to keep up with commercial UAS technology, trends, and developments.

https://www.expouav.com/

ELEVATEAEC CONFERENCE & AWARDS GALA

SEPTEMBER 14-16– LAS VEGAS, NV

The 2022 ElevateAEC Conference and Awards Gala registration is open for the annual in-person conference in Las Vegas, September 14-16. Celebrate the iconic black-tie awards gala 2022 winners of the Hot Firm list, Best Firms To Work For, Marketing Excellence, Rising Stars, Top New Ventures and the Jerry Allen Courage In Leadership Awards. Register now for the AEC industry's top IN-PERSON learning and networking event of the year.

https://zweiggroup.com/pages/annual-in-person-elevate-leadership-summit

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CLIMATE PLEDGE ARENA

AN ENVIRONMENTAL AND ENGINEERING MARVEL

By Greg Huber

BEING CHOSEN BY OAK VIEW GROUP, a Seattle public-private partner and developer, to redevelop the former Key Arena into a brand-new, best-in-world venue and the future home of National Hockey League's Seattle Kraken and Association's Seattle Storm, all while keeping its historic landmarked roof intact, has been one of Mortenson's most challenging and rewarding undertakings.

As if this alone wasn't enough of a challenge, a whole new bar was set when Jeff Bezos from Amazon tweeted in June 2020, "I'm excited to announce that Amazon has purchased the naming rights to the historic Seattle arena previously known as Key Arena. Instead of calling it Amazon Arena, we're naming it Climate Pledge Arena as a regular reminder of the urgent need for climate action. It will be the first net zero carbon certified arena in the world, generate zero waste from operations and events, and unclaimed rainwater in the ice system to create the greenest ice in the NHL. #ClimatePledge."

At the time of that announcement, the project team had already carefully planned every aspect of the arena. The structural foundations and building excavation were well on their way, the procurement team was ordering necessary construction components and discussions with local utility companies were underway about how to power the building's operational needs.

Although sustainability was always an important feature to be incorporated into the project, this new goal – to create the first net Zero Carbon certified arena in the world – was the biggest challenge yet. Luckily, Mortenson and the entire team's passion and competitive spirit drove them to determine how – not if – this could be done. The certification by the International Living Futures Institute is the most rigorous benchmark of sustainability in the building environment. It is the gold standard against which all others are measured. People from around the world use its regenerative design framework to create spaces that give more than they take.



Structural Challenges

The first major challenge was determining how to "recycle" the 44-million-pound historic roof (designed by Seattle architect Paul Thiry. Meanwhile, the construction crew excavated 600,000 cubic yards of dirt underneath to substitute for the arena's Y-column and buttresses that held up the historic roof. This was held by seventy-two temporary roof support (TRS) steel columns; each founded 70 to 90 feet below the existing arena floor level. The TRS system also had to resist seismic loads and limit movement to a quarter inch. Mortenson used water jets to remove concrete from the base of the old columns which exposed the steel rebar to allow the team to safely cut and extend the column foundations that were supported nearly 100 feet below grade.

The process occurred during most of 2019 and used nearly the amount of steel equal to a modern-day Major League Soccer stadium. Mortenson relied on intense team collaboration, top-down construction, and digital tools to simulate the built environment. And today, Climate Pledge Arena is standing on the original 20 Y-columns and four pronged-buttresses to hold up the roof, originally built for the 1962 Seattle World's Fair.

In addition to maintaining the roof, Mortenson was charged with saving the iconic glass curtain wall that every fan, visitor, and Seattleite will see walking by Climate Pledge Arena, while preserving the view of the Space Needle, cityscape, and more. To accomplish this, each glass panel had to be carefully marked, catalogued, and stored before reinstallation in its original location.





Working towards Net Zero

Climate Pledge Arena is working to be the first net Zero Carbon arena in the world, powered exclusively by renewable energy rather than natural gas. The arena will run solely on electric power for daily operations, eliminating all fossil fuels from the building and utilizing the first all-electric dehumidification systems in the NHL. This meant Mortenson had to replace natural gas infrastructure with electrical systems. From kitchen systems and concessions, to air handling units, and building conditioning – all systems were changed to be served by electricity instead of natural gas.

Overall water usage is critical to limiting energy use and sustainability goals. Rainwater will be stored in a 15,000 gallon below-grade cistern and filtered as needed for the "rain to rink system." Waterless urinals and low flush fixtures were added to increase water usage efficiency.

The mechanical, electrical and plumbing (MEP) system was also designed with efficiency in mind. Energy recovery ventilators, serving all the locker rooms, collect 100 percent of the air that is exhausted and use the captured energy to preheat or cool the incoming air streams.

Changing out gas to electrical conversion substations almost doubled the amount of electricity coming into the building, requiring more electrical equipment. With equipment in order, immediate decisions were needed. Luckily important changes were able to be made at the fabrication stage, and the custom electrical equipment production stayed on schedule.

Next, situating heavy electrical gear presented a real space utilization conundrum. Mortenson and the design team needed to determine where the equipment was going to live. Typically, it's located on the first floor, but construction sequencing hindered that possibility. The entire construction and design team needed to find the best location that was cost and schedule efficient and required the least amount of rework, which resulted in a substation on an elevated metal deck.

Renewable Energy

The original 160,000 square-foot arena roof is historic and, as such, could not be used to host solar panels. Instead, solar panels are planned to be installed on the roof of the new atrium building entrance and on the facility parking garage. The energy generated by the solar arrays will be used to power to arena alongside additional renewable energy sources.

Project Delivery

The construction and design team used several tools to ensure design, construction and marketing efforts dovetailed together to create a seamless project delivery. Mortenson used 4D building information modeling (BIM) as a basis for multi-trade coordination and scheduling. The entire building was constructed virtually to aid with major trade system coordination. For instance, the steel team could use the model to track fabrication and installation tasks. Color coding was used to aid schedulers while tracking procurement, upcoming tasks, and completed work. Using the 4D model, the MEP systems were modeled to not only assist in clash detection (field installation coordination) but also in prefabrication efforts.

Changing horses in midstream to create a net zero arena was a major effort by the entire team. Mechanical and electrical contractors were essential in giving their input, as were the architecture and engineer teams that jumped in to determine construction sequencing.

Climate Pledge Arena will be a beacon of corporate responsibility across the sports landscape. Together, Mortenson and Oak View Group are setting new sustainable standards for the built environment and inviting others to join The Climate Pledge to reduce carbon emissions for a better future.

GREG HUBER is Project Executive at Mortenson.

UNDERWATER VISUALIZATION DRIVES TIMELY, SUCCESSFUL HABITAT RESTORATION PROJECT

THE MINNESOTA DEPARTMENT OF NATURAL RESOURCES (DNR) is facilitating the multi-year, $18-million Kingsbury Bay – Grassy Point Habitat remediation and restoration, a site located in St. Louis County, Minnesota. The goal of the project is to restore 240 acres of fish and wildlife habitat within a part of the St. Louis River Area of Concern (AOC). Critical to the project is to excavate and reuse excess sediment, remediate and reuse legacy wood waste and remove non-native vegetation.

Minnesota DNR contracted Barr Engineering Co. to manage the engineering and design, construction administration, and quality control oversight and Veit & Company, Inc. for the construction effort.

Begun in 2019, the restoration effort includes:
- The removal of invasive cattail from Kingsbury Bay to an offsite disposal location
- The removal of legacy wood waste from Grassy Point and reuse of waste to construct small islands in the area
- Sediment dredging from Kingsbury Bay and reuse of sediment to restore aquatic and upland habitat

The Veit crews also installed in-water stream control structures at the inlets of Kingsbury and Keene Creek, with a little help from technology.

Underwater Visualization

Founded in 1928, Veit & Company, Inc. has long been a technology leader in the Upper Midwest's site prep and civil works market segment. Its technology-enabled fleet includes dozers, excavators, motor graders, and skid steers all equipped with 3D machine control systems, as well as rovers, base stations and total stations—all connected to the cloud, enabling the easy transfer of 3D project files to field crews.

For the Kingsbury Bay – Grassy Point Habitat project, GPS-guided machine control on excavators was particularly valuable, especially when combined with a Trimble Marine Construction System to track underwater material removal in real time.

One of the most challenging tasks in the marine construction environment – whether for dredging, building, or demolition – is working in turbid water including suspended sediments and materials, making it impossible to accurately monitor progress. Conventional practice is for a contractor to estimate the approximate amount of material to be removed or placed on a given site based on experience and pre-construction hydrographic surveys. Once the operator has reached an estimated point of completion, they conduct a post-construction survey for verification and certification, and almost always, the operator must return to the site for rework.



The Trimble Marine Construction System can be integrated with a single beam echo sounder (SBES) to acquire pre-/post-dredge survey data from below the water and then quickly identify high and low spots, calculate progress volumes and send grid model updates to both the office and the dredge vessel.

"We use the Trimble Marine Construction System to track the bucket location in real-time in 3D—a huge advantage in water," said Britton Lawson, Director of Construction Technology at Veit. "Essentially, the 3D map created by Trimble is the only eyes for the excavator operators to know where they've been and where they need to go. Project managers are also able to track progress and material quantities moved."

Customer Profile: Veit & Company, Inc. is a leading, technology-progressive specialty contractor with corporate offices in Rogers, Minnesota. The company specializes in earthwork, utilities, foundations, demolition, dredging and industrial cleaning. With an annual revenue of more than $200 million and 100-120 projects running at any one time, approximately 75 percent of the company's earthwork projects rely on technology including machine control, rovers, total stations and base stations.

Business Challenge: Efficiently remove and reuse sediment, legacy wood waste and non-native vegetation to restore the Kingsbury Bay – Grassy Point Habitat.

Solution
- Trimble Marine Construction System
- Trimble Earthworks Grade Control Platform
- Trimble Business Center
- Trimble TSC7 Controller/SPS986 Antenna
- Trimble Siteworks Positioning System
- Trimble Remote Assistant



Dredged with Accuracy

For the Grassy Point job, Veit used two Liebherr excavators with clamshell buckets on barge spreads. Each was equipped with the Trimble Earthworks Grade Control Platform using the Minnesota Department of Transportations' MnCORS VRS Virtual reference station network for instant access to RTK positioning services.

"One machine would excavate to design and load the material. Two tugboats moving four hopper barges were used to transport the material to the placement site. The other unit would unload the material, placing it on the seabed to a design grade. This was all achieved with Trimble guidance," Lawson said. "We also had a Trimble Siteworks Positioning System with a TSC7 Controller that was performing quality control/quality assurance checks behind both spreads." The Veit team relied on a remote connectivity cloud platform to remotely manage the units.

Bi-weekly as-built progress surveys were completed by survey crews using a single beam sonar. The subsequent surveys were then uploaded to the machines for reference.

"The data from the single beam echo sounder was compiled in Trimble Business Center and sent out with plan sheets," said Lawson. "We used aerial drones to gather topographic data of the island surface above the water and then combined those surveys with the machine mapping data. That process helped significantly to reduce rework. We never had to go back because it was field-verified right away."

The Trimble Marine Construction System makes the process much faster and more accurate. Lawson estimates that the initial excavation is about 50 percent quicker than traditional methods because operators know where the bucket has been and where it needs to go. Lawson added, "With the 3D visualization, we have greater assurance that cut depths are accurate as compared to a mark on the stick. Reducing the time spent returning to a site for rework is invaluable."

Enabled by technology, Veit crews worked 24-hours a day, Monday-Saturday, to complete the required tasks from June to September 2020. Summer 2021 will conclude the restoration project, finishing the cap on the Grassy Point islands using clean sediment removed from Kingsbury Bay, dredging remaining excess sediment from open water



portions of Kingsbury Bay, restoring Grassy Point wood removal areas using sediment from Kingsbury Bay and restoring and reseeding disturbed areas.

Lawson concluded, "I cannot imagine performing this project without 3D positioning technology. Using the Trimble workflow greatly contributed to our success and reduced our rework to almost none. We would not want to tackle this type of project without the 3D tools we had available to us from Trimble."

HUDSON COMMONS: HISTORIC FOUNDATION MEETS MODERN ENGINEERING IN AN INNOVATIVE MANHATTAN OVERBUILD

By Joseph Provenza, AIA, P.E., LEED AP BD+C; Jeffrey Smilow, P.E., F. ASCE; Yujia Zhai, P.E., Motaz Elfahal, Ph.D., P.E.; and Gerardo Aguilar, Ph.D.



WHAT BEGAN IN 1962 as a functional-but-unassuming eight-story warehouse on Manhattan's West Side has become the foundation of one of the most unexpected and fascinating projects in New York City today – the 26-floor Hudson Commons building.

Over the years, the cast-in-place concrete building at 441 Ninth Avenue has been reimagined; notably in the 1980s when it was converted into an office building that retained most of the architectural character from its original era.

But it never experienced anything quite like its most recent transformation.

When Cove Property Group acquired the commercial property in 2016, they envisioned a vertical expansion of the site to capitalize on the 2005 rezoning of Manhattan's west side. That left the developer with a decision to make on the fate of the former warehouse: Would they demolish the old building and rebuild from a clean slate, or would they find a way to reposition the existing structure to meet their needs?

Early site investigations showed that the robust structure was in good structural condition making it suitable for reuse. Thus, after weighing their options, Cove selected the most cost-efficient solution that would achieve the maximum rentable area: the rehabilitation, retrofitting and reuse of the existing structure. The existing building would add 17 floors and 300,000 square feet of commercial space, creating a sleek new steel and concrete office tower.

Now that its transformation is complete, Hudson Commons emerges as a 26-floor, LEED Platinum Class A property that provides 700,000 square feet of rentable office space, topping out at 421 feet.

The architect of the renovation and addition is Kohn Pederson Fox Associates (KPF), with WSP USA serving as the engineer of record. Mueser Rutledge Consulting Engineers (MRCE) served as the geotechnical consultant. The construction manager is Pavarini McGovern (PMG).

Best of Both Worlds

For the project to succeed, several challenges had to be addressed, from precise demolition procedures without the use of interior shoring, and retrofitting of the existing columns, slabs and foundation systems; to the articulation of the new building core.

Shoring can be costly, so it was important to the owner that the project included a plan for shoring-free demolition of a 125- by 25-foot area throughout the existing building to accommodate the new core. In lieu of shoring, the existing slabs were reinforced with a combination of temporary and permanent steel members that provided the required support of the structure.

The original structure is comprised of two-way concrete slabs on a 24- by 28-foot grid with drop panels, "mushroom" capitals, and a masonry core providing lateral stability. The low-rise, massive building is representative of the 1960s.

The addition takes the form of a sleek modern office tower, which speaks to the 14-acre Hudson Yards megaproject development rising to the west of Hudson Commons. By contrast, the subtle renovation of the original building, which reuses the existing wrap-around brick façade while upgrading the structure to meet current design and construction codes, will keep the project grounded in the context of the neighborhood and its 1960s roots.

WSP faced several unprecedented challenges that demanded highly innovative structural solutions if the vision developed by Cove and KPF was to be realized. The existing cast-in-place columns and footings required sizeable retrofits for the gravity loads imposed by the new tower above, and the existing roof slab required extensive retrofitting to accommodate a heavily landscaped amenity space.

The most invasive feature, however, was the addition of a new reinforced concrete core linking existing and new construction that would provide the required lateral stability and stiffness for the new taller building.



The addition of a 17-story tower to the original building has resulted in Hudson Commons emerging as a 26-floor building with 700,000 square feet of rentable office space in Manhattan. *Photo: ©2017 NEOSCAPE, INC.*

A Solid Foundation

Although the existing structure was bearing on the good-quality substrate typical of Midtown Manhattan, the geotechnical composition of the site and its existing foundation elements presented a significant engineering challenge.

The bearing capacity of the structure ranged from 20 to 40 ton/ft2, and there was a steep drop-off throughout the site. In addition, the constraints of working within the confines of an existing structure were immediately evident, particularly for the use of deep foundation elements and the equipment required for their construction.

The reinforced concrete core is supported by a new 48- to 72-inch-thick mat foundation bearing directly on sound bedrock. With the core walls in-line with existing columns, consideration of existing column foundations added another layer of complexity. While some column foundations were narrow piers reaching the bedrock, a few columns were supported by larger pile caps. The latter were treated as local interruptions in an otherwise continuous mat foundation with cold joints only.

The small footprint of the new core in combination with its eccentric location translated to large overturning moments, which were addressed by providing 45 600-kip anchors socketed 45 feet into rock. MRCE specified 450-ton micropiles socketed 15 feet into sound bedrock to achieve the required load demand.

From these constraints emerged the development of three types of foundation retrofits:

- piers-to-rock encapsulating and tied into existing piers-to-rock,
- new caisson caps encompassing existing piers-to-rock, and
- enlarged caisson caps articulating existing pile caps.

Concrete Jackets

One major challenge was the original building columns insufficient



Photo: Copyright Neoscape, Inc. 2017

capacity to accommodate 17 additional floors. To achieve expansive column-free areas, large spans in the office tower – some reaching 48 feet – amplified the demands at the base of the building where higher loads go to fewer columns. Conversely, a smaller number of original columns required retrofitting for the project.

The solution implemented by WSP was the retrofitting of existing concrete columns employing new reinforced concrete jackets.

The first task was the assessment of existing conditions and the study of available construction documents. Although some original drawings were available, core samples were extracted from various locations to determine the in-situ compressive strength of concrete.

WSP provided 3D laser scanning services for the entire structure, yielding an accurate representation of as-built column dimensions and locations, the latter being critical to tie in the column grid of the tower above. To minimize potential compatibility problems, concrete compressive strength for the retrofitting jackets matched the one determined through the coring campaign (approximately 5,000 psi). Furthermore, to minimize the increase in column size, large diameter high-strength rebar was used.

Reinforcement continuity was critical to maintaining a consistent load path. Ground Penetrating Radar scanning was performed around each column, allowing WSP to map and coordinate locations for holes to be drilled for reinforcement to pass through the existing slabs. Large diameter (#14 bars) and high-strength (Gr 75) reinforcement were used to maintain jacket thicknesses under 12 inches, resulting in 60-inch-maximum-diameter columns. Column capitals were removed to achieve the desired reinforcement continuity and full column bearing but were rebuilt during the cast operation to maintain the original aesthetic, which was important to KPF's vision.

The forming and casting of circular columns in the building's constrained environment presented a potentially costly and troublesome prospect, so shotcrete was used for columns and capitals. Concrete was placed, compacted and consolidated all at the same time due to the design pressure with which the shotcrete was sprayed.

The final layer of concrete was applied by a skilled technician using a hand trowel, an aesthetic treatment that left the final appearance indistinguishable from traditional methods. This application by the construction team was a genuinely innovative feature of Hudson Commons.

Lateral-Load Performance

To provide stability to both the existing structure and the new tower, a full upgrade of the Hudson Commons lateral force resisting system was required. WSP collaborated closely with KPF on an architectural design that included a new circulation and mechanical core eccentrically placed along the north side of the property that would maximize the building's rentable area.

One notable feature of the building's core is its prominence in the architectural expression of Hudson Commons as it rises above the existing building. The new spine of the building uses exposed architectural concrete as a tribute to the historic architecture of the neighborhood.

The new reinforced concrete core runs from foundation to the top of the building and is comprised of 10,000-psi concrete shear walls ranging from 12 to 24 inches in thickness. WSP envisioned a box-like configuration wrapping the entire mechanical and circulation program that would counteract the torsional effects associated with an eccentric core. In this closed-box layout, the core is placed along existing column lines, and the existing columns create breaks in the shear walls analyzed by considering individual piers at the base building.

One intrinsic benefit of this approach was the absence of link beams in the base building, which allowed maximum flexibility with regards to routing services out of the core. Above the existing roof, the walls were connected through reinforced concrete link beams to provide adequate lateral stiffness. Per industry standards, three-dimensional finite element analysis software was used to model both the existing and new structure, allowing for an optimized and efficient structural design.

WSP's retrofitting approach for the gravity system included the reinforcement of existing concrete slabs with steel members around the perimeter of the area to be demolished for the new core. Steel members were installed above and below the slab following the bending moment demand associated with gravity loads. Top steel members were removed after casting the core walls, while steel members below the slab were fitted with studs to trigger composite action and remained as permanent bracket connections between the new core walls and the existing slab.

This innovative solution resulted in significant savings in terms of both cost and schedule.

Green Showcase

Another feature included in the project is the potential to turn outdoor open areas on the ninth and 25th floors into green spaces for the tenants.

The existing structure has been reinforced and designed to allow for landscaping that could include grass, trees and other green uses. It will be the decision of the tenants on those floors, but the structure has been designed to allow for the creation of something quite elegant on those spaces.

WSP worked closely with PMG (Construction Management) to determine the most cost-effective approach to accommodate green spaces on the existing roof. The final structural solution was a secondary support system of steel beams installed under the existing slab to support the significant load of a fully landscaped area on the original building's roof. The structural solution was detailed in such a way as to not penetrate the existing roof, which would have added significant cost to the project.

New steel members were designed as non-composite sections to eliminate the need to perforate the roof for stud installation, while clips were installed along the beams to prevent lateral-torsional buckling.

Nearly every level of the new building features terraces or balconies providing remarkable views of the city and river. Vertical integration between floors is promoted by the exposed stairway, which also allows for an exceptional naturally-illuminated interior. Floor-to-ceiling windows further welcomes daylight coverage on each floor.

The green roof, daylighting architecture and plans for efficient energy and water systems are features that lead to Leadership in Energy and Environmental Design (LEED) Platinum certification from the U.S. Green Building Council, and Wired Platinum certification.

Vertical Vision

Hudson Commons was completed in March of 2020 and tenants are now occupying a building that challenged conventional engineering and construction practice. The building has become one of the most innovative adaptive-reuse projects in New York City.

This reimagined commercial building demonstrates the potential for large-scale vertical expansion when innovative solutions are applied. With developers and cities striving towards sustainable solutions, the relevance of projects like Hudson Commons is clearly recognized.

One rarely comes across a project like Hudson Commons, mixing steel and concrete in a way that perfectly blends the two, taking advantage of the benefits each material offers economically and in an engineering sense. This project provides developers with a methodology and alternative cost-effective, sustainable solutions that could change the way existing structures are upgraded for future use.

JOSEPH PROVENZA is a senior associate at WSP USA Buildings Inc. and served as the firm's project manager for Hudson Commons.

JEFFREY SMILOW served as the principal-in-charge.

YUJIA ZHAI was the project director.

MOTAZ ELFAHAL served as the structural analysis manager.

BUILDING VALUE INTO SPORTS FACILITIES

RIGID-FRAME FABRIC BUILDINGS OFFER A HIGH-QUALITY SOLUTION FOR BUDGET-MINDED PROJECTS.

By Shannon Humbert and Eric Donnay

WE LIVE IN A WORLD where spending power can create some pretty wide disparities. Gawdy mansions and luxury cars exist because somebody can afford them, even if most of us are quite comfortable and happy living in a family-friendly house and driving a reliable, modestly-priced vehicle.

Similar gulfs in wealth are evident in the sports facility market, where professional franchises and the top major college athletic programs can rely on massive television contracts and booster funds to construct any type of building they deem necessary, with every bell and whistle included to play games, train athletes, or attract recruits.

In most of the sporting world, there exists a similar goal of designing the best athletic facility money can buy – it's just that the amount of money to actually work with is much lower. For the majority of universities, schools, communities, or recreation clubs in the process of procuring a new athletic facility, finding the best value is paramount.

Cost-Effective Sports Architecture

The conversation for many entities naturally begins with traditional brick-and-mortar buildings. This makes sense, since it's the construction option with which most people are familiar, and there are usually very few question marks about how such a building would look and function.

In reality, though, not everyone is in a financial position to spend money on traditional construction. Many organizations have instead turned toward more affordable alternatives, such as tension fabric buildings. However, even this building category alone offers some drastic differences when it comes to engineering, quality, and longevity.

First of all, it's important to establish how fabric structure styles have evolved in the past decade. More than 10 years ago, Legacy Building Solutions introduced rigid-frame, structural steel engineering to fabric building design. Prior to this development, fabric structures were mostly built with web truss framing, a system still prevalent among many suppliers today.

By utilizing I-beam frames, fabric buildings instantly achieved more universal credibility. From an engineering perspective, rigid-frame design was a known and proven method. From an end user viewpoint, it essentially provided a conventional approach to building construction, just with fabric material as a more cost-effective cladding for the roof and sidewalls.

Custom Fit

Besides inspiring more structural confidence, rigid-frame design also opened up a new world of possibilities by providing much more design



flexibility, allowing users to customize their fabric buildings to the precise dimensions necessary for the sports or activities taking place inside.

When web-truss fabric buildings first became available to the athletics and recreation market – and even to this day – they were typically supplied in standard, pre-engineered sizes. Therefore, if a certain length and width were needed, for example, customers would have no choice but to go up to the nearest available standard size. Another feature of this building style is its curved frames, which can create unusable space along the sidewalls. The end result is that users often have to find ways to fit their building, rather than designing the building to fit their actual needs.

With structural steel design, purchasers can start out with a clean sheet and develop a custom building plan from the beginning of the process. If the plan calls for basketball or volleyball to be played near a sidewall, the wall and roof slope can be built high enough to accommodate that activity. If the plan calls for tennis courts, the structure can be designed to USTA guidelines for building peak height and allow for the necessary space around each court.

Ultimately, the rigid-frame design provides the ability to value-engineer a fabric building. By having their exact specifications met, users can get the space they truly need without paying for excess space or construction materials.

Of course, fieldhouses and practice facilities for sports like football and soccer typically do require a lot of space, another area where rigid-frame fabric buildings prove cost-effective. The inherent strength of these I-beam structures, combined with lightweight fabric cladding, allows for long clear span roofs with no support beams.

Old-school fabric structures lack the true engineering integrity necessary for really long spans. Brick-and-mortar buildings are structurally sound, but the larger the building needs to be, the greater the price difference between traditional construction and rigid-frame fabric buildings, which can be installed at a fraction of the cost.

Interior Environment

Another construction option that has long been popular, due to its price tag, is steel buildings. While steel-sheeted structures can help fill a certain niche in the industry, their cost-saving advantage gradually disappears as the building dimensions become larger. And no matter

what size structure is required, steel buildings tend to fail the aesthetics test, generally offering poor lighting and acoustics.

By contrast, the interior environment inside a fabric building offers a softer feel, better acoustics with less echo, and much improved lighting due to the reflective properties of the fabric material. People who've never set foot inside a fabric sports structure often comment that the atmosphere exceeds their expectations.

While having an attractive venue is certainly beneficial to those using or visiting the building, engineers and architects will also take notice that the same materials used to create that welcoming atmosphere are actually serving another purpose in helping to meet building codes.

For projects where state or local energy codes must be met, a rigid-frame design allows building suppliers to easily apply insulation – typically with R values ranging from R-19 to R-30 – along the interior of the structure. The insulation is secured and then covered with a fabric liner that is actually the same type of fabric used for the exterior cladding.

Polyvinyl chloride (PVC) has the been the primary fabric of choice for sports facilities for many years because of its durability. The fact that users can select different colors of fabric to match their team, school or organizational branding is also a selling point for fabric in general. Legacy Building Solutions offers a newer fabric called ExxoTec™ PVC that delivers more durability and a longer life expectancy, due to the added layers of primer and lacquer around its high-strength woven fabric.

To install the fabric, Legacy relies on its patented fabric attachment system that uses half-inch diameter bolts to clamp a keder rail to the top flange of the structural steel frame. Fabric panels are then slid through the keder channel to connect to each beam. This process allows fabric panels to be pulled into place with the properly calculated horizontal and vertical tensions.

Wider fabric panels are used for the interior than the exterior of the building, but otherwise the process is the same both outside and inside. With the interior liner tightly secured, maintenance concerns for the fabric cladding itself are practically nonexistent.

Behind the Scenes

For many industries, the I-beams in a fabric building are left exposed and may require some kind of treatment to protect the steel. Since the structural frames in most fabric-cladded sports facilities are encapsulated by insulation and liners, typically a primer coating is all that needed to treat the beams.

That said, building users in coastal locations or who experience high humidity conditions due to their facility application – such as a swimming pool – could consider epoxy paint for I-beam treatment to protect against corrosion. Because the steel beams are permanently out of view, some users might choose this option purely for the peace of mind of knowing that the structural frame is well protected.

It is worth noting that the rigid frame building design allows for effective passive ventilation within the walls. Ridge and soffit vents use the natural movement of warm airs to help remove moisture from the insulation cavity, another key piece in meeting building codes for a given environment.

Hanging Tough

Because of the airtight nature of a lined fabric building, air flow is very important, and passive ventilation alone is not enough for most athletic structures. Users will need some sort of mechanical means to at least move air, if not also heat or condition it. Often this means the inclusion of fans or an HVAC system suspended from the building frame above.

For a rigid-frame design, supporting hanging loads like HVAC, fire suppression systems and lighting isn't difficult, although it does need to be considered in the original design. Engineers use finite element analysis software to calculate the stresses for each individual I-beam, rather than over-engineering the entire structure and adding unnecessary cost.

Likewise, many sports facilities need to accommodate items such as scoreboards, video platforms, court dividers and netting. Some will even need to add mezzanines for spectator seating. By working with the customer to account for every potential collateral load, building designers can simply modify the rigid frame to add the necessary strength for those loads.

Added Touches

While project managers may be primarily focused on getting the most bang for the buck from a fabric building, of course it's also common to need to appease certain stakeholders with additional flourishes, such as exterior facades containing brick or stonework. While these elements will add cost, the straight sidewalls of a rigid-frame structure do make it possible to easily include these types of touches.

Another possibility with I-beam design is adding a fabric-clad addition to the gabled end of an existing structure. Designers need to consider snow loads and rain runoff for the original building and new addition, among other compatibility factors, but for situations where expansion is a more cost-effective solution than new construction, it often can be done.

Built Fast, Built Right

Rigid-frame fabric buildings can also be completed in far less time from start to finish than traditional brick-and-mortar buildings. While the time to build the framework is similar for a fabric building and a metal-clad structure, fabric panels can be applied in one-third the time needed to screw down metal siding.

A big reason for the overall reduction in fabric building lead time is that companies like Legacy are full-service suppliers who can handle every step in the process from start to finish. By employing their own design engineers, manufacturing fabric panels and I-beams in their own facilities, and sending their own in-house professional installation crews to every jobsite, these companies can ensure full quality control and constantly keep projects moving, without any of the unexpected delays experienced by those relying on outside vendors.

All things considered, tension fabric structures offer exceptional value for sports venues large and small. From proven structural integrity to a high level of interior finish and craftsmanship, rigid-frame fabric buildings make it possible for any entity to obtain a facility they can be extremely proud of, without breaking the bank.

ENGINEERING TITLETOWN

By Luke Carothers

FOR WELL OVER 100 YEARS in the American Midwest, football has been as much a part of life as death and taxes. In Green Bay, Wisconsin, this seems to be doubly true. Often billed as the last of the "small" NFL franchises, the Packers and the people of Green Bay have a unique relationship in the modern climate of professional sports.

This relationship began around the turn of the 20th century when several small semi-professional football teams combined and secured $500 for equipment and uniforms from a local meat packaging company. Thus, the team the NFL now known as the Packers was born on the shores of Lake Michigan.

These early Packers teams won often, securing 6 NFL championships while playing their games in the small, 25,000 seat wooden City Stadium. Their success, however, outmatched their seating capacity, and in the 1950s the NFL threatened to move the franchise to Milwaukee if a new stadium wasn't built in Green Bay. Fearing the loss of a franchise that had given much to the identity of the small town, the city built the first stadium exclusively for an NFL franchise.

In 1957 the new stadium was completed (originally called New City Field), and was renamed to honor the late Curly Lambeau in 1965. Originally built to hold around 32,000 spectators, it has since been expanded to hold just under 73,000 screaming fans for Packers' home games.

Construction is underway for this multi-family apartment building.
To say that Green Bay is football-obsessed is an understatement. Since 1960, every single Green Bay Packers home game has been sold out, and, to add to that, they still have roughly 115,000 people waiting in line to receive season tickets.

With so much focus on one place and one team, it is no wonder there have been numerous improvements to not only the stadium, but also the areas immediately surrounding it. In addition to upgrading seating, adding field lights, and other stadium improvements aimed at cultivating the flow of football-crazed fans, several improvements have been made to the infrastructure in the surrounding areas to ensure they have capacity to handle high-volume crowds at distinct and predictable intervals.

In early 2015, coming at the end of a 3-year stadium renovation that gave the stadium new infrastructure and lighting, the Green Bay Packers announced plans for an innovative project that would transform 35 acres of land just west of Lambeau Field. The plan–dubbed "Titletown"– was to build an innovative, mixed-use development aimed at accommodating not only the fans and visitors who flock to the area, but also local residents.

Subsequently, an initial plan for the project was made by Rossetti Architects, Sterling Project Development, and Titletown Development.



The plan was to create a space that could incorporate several different groups of end-users. As such, space was planned for a number of different activities that both supported game-day activities as well as encouraging year-round tourism. The original development plans included space for things like a brewery, a luxury hotel, and a health clinic as well as a sledding hill and 10-acre park and plaza, all of which is featured at the final space.

From playing to dining, visitors enjoy scores of activities at Titletown. At the initial stages of development, there was a strong need to bring in a civil and structural engineering team with a strong background in working on mixed-use developments, and raSmith was brought on board. They were tasked with evolving the site. More specifically, they had to develop the plan in a way that provided access to the site, balanced parking with developable building area, and provided space for a public plaza.

When raSmith joined the Titletown Design Team, the development space was not yet defined. Using public input sessions, the development team was able to determine how the space was being used through Phase I of development. After gathering input from the public, it was decided that Phase I would consist of buildings such as Hinterland Brewery, Lodge Kohler, Bellin Health, and Titletown Tech as well as a





From playing to dining, visitors enjoy scores of activities at Titletown.



Titletown is within walking (or leaping) distance to Lambeau Field.

plaza that features a sledding hill, skating rink, playground, a full size football field, activity area, and a lot of open space.

Additionally, according to Senior Project Manager Ryan J. Lancour, the project faced constraints based on scope when the project acquired land, eventually growing by approximately a third and incorporating the re-construction of two public roadways.

Initial plans were also made for a second phase of development that would create a more pedestrian-friendly experience. Phase II was focused on increasing the number of townhomes and reconstructing a major public roadway; it also includes the construction of a podium that significantly increases the development's parking capacity while keeping open space above.

From a structural perspective, the team was able to overcome challenges posed by varying soil bearing conditions underneath the site of the Bellin Clinic. In addition, the site was further complicated by the inclusion of a partial basement that would be constructed below the water table. To overcome this, raSmith constructed an augercast pile system to support the at-grade portion of the building in order to provide the best value while also minimizing construction impact for the residential building adjacent to the site.





Capturing the spirit of Green Bay, Titletown is a destination for any season.

In winter, the plaza area features an ice-skating rink and tubing lanes. From a use perspective, the team also had concerns about sound- and foot-induced vibrations coming from the Bellin Health Clinic's second floor, which was designed for activities such as running, jumping, and freeweight use. Based on owner and architect concern for those noisy activities being noticed on the first level offices and exam rooms, raSmith recommended that a roll-out floor isolation system be incorporated into the design.

As time passes, the Titletown project continues to grow. From the first announcement of Phase I in 2015 until now, this project has seen a high level of development from the perspectives of both form and function. raSmith's Structural Project Manager Steven Roloff, P.E, LEED AP, notes his team's ability to achieve "flexible design solutions" as a way to create fewer issues during the construction process. According to Roloff, his team was able to lessen these construction issues by incorporating details that allow for larger field tolerances than normal.

While work still continues on Titletown's Phase II, it is expected to be completed by the end of 2021.

LUKE CAROTHERS is the Editor for Civil + Structural Engineer Media. If you want us to cover your project or want to feature your own article, he can be reached at lcarothers@zweiggroup.com.

UNDERGROUND ARTS SCENE: UPDATING THE MUSEUM OF FINE ARTS, HOUSTON

By Luke Carothers

THE OLD SAYING IS TRUE when it comes to the Museum of Fine Arts in Houston (MFAH): everything is bigger in Texas. One of the largest museums in the United States, MFAH services the fourth largest city in the country, with its wide array of programs being utilized by a staggering 1.25 million people every year.

The oldest museum in the State of Texas, it was first constructed in 1917 and in 1924 it allowed its first visitors through the doors. Since then, the site has seen its fair share of construction.

MFAH has recently undergone renovations in the way of new building construction. In December 2020, construction was completed on the Nancy and Rich Kinder Building on the MFAH campus. The project was split into two phases with the first focusing on construction of the 102,500 square foot Glassell School of Art; this phase nearly doubled the space available for the school, which currently serves 7,000 students per year. The teaching arm of MFAH, this space allows the Glassell School of Art's students to access fully digital workspaces and classrooms as well as expanded exhibition space. This space replaces the previous building that housed the school since 1979.

Phase two of the project consisted of the construction of the Nancy and Rich Kinder Building, a 183,500 square foot exhibition space to house modern and contemporary art made after 1900. The building features a translucent glass cool jacket exterior, three-floors of galleries circling a three floor atrium, a 225-seat theatre, a street-level cafe, a restaurant overlooking the sculpture garden, an underground parking garage with 115 spaces, and tunnels connecting the building to both the Glassell School of Art as well as the Caroline Weiss Law Building. When completed, this building increased exhibition space at the MFAH by 75 percent.

One of the more interesting aspects of the project was the construction and utilization of an underground tunnel that connects the new building to the older parts of the campus. The plan was to create a 150-foot tunnel to connect the Nancy and Rich Kinder Building to the Caroline Wiess Law Building. This tunnel, while primarily designed to facilitate pedestrian traffic between the buildings, also serves a gallery space for the MFAH. The building site itself included a number of unique obstacles that required the team at McCarthy to come up with creative solutions and utilize innovative techniques to complete the project.

Plans for these tunnels had to account for several challenges that are posed by the site's unique human environment. Being located in one of the oldest parts of the city of Houston, this meant that there was a possibility the team would encounter an unmarked, buried utility line. Winston Hesch, project director for McCarthy, says ground utilities in this part of town can "sink over time". Additionally, because the tunnel



is located 2-3 feet underground, engineers had to waterproof the site not only for rainwater, but also for ground water.

Typically, tunnelling in the Houston-area is done a particular way: a trench is dug then a cover is added, thus forming a tunnel. However, because the City of Houston would not allow the team to close Bissonnet Street for an extended period of time, as well as underground utilities, the team opted for a different, more traditional route: excavating the tunnel six inches at a time.

This process proved time consuming, taking the team six and a half months to complete while excavating the tunnel six inches at a time. Additionally, in order to connect the two buildings, the tunnel had to change in elevation and offset horizontally. In order to achieve these parameters while also keeping a shape with a curved top, straight sides, and flat bottom the team opted to install a series of interconnected plates approximately every six inches of excavating. To support this plate system, the team installed an I-beam approximately every six feet and injected the system with grout.

Challenging this process was the high presence of water at the site. The team had to deal not only with rainwater, but also groundwater as the tunnel was constructed close to the water table in the area. They were able to overcome these challenges by using PREPRUFE 400T, which is a Grace Waterproofing Project. In order to account for the thousands of anchor bolts being drilled through the waterproofing every day, McCarthy's team met with manufacturers to come up with a plan of action. The result was a hand check of every seam and penetration of the system to ensure proper installation. Once the system was fully completed, the team encountered no leaks.

The months of excavating and tedious checking have paid off. Unlike most tunnels, this project has systems like mechanical, electrical, and lighting installed. More than just a pedestrian walkway and art gallery, the space and project have become a work of art of themselves, adding yet another dimension and element to one of the most storied public institutions in Texas.

LUKE CAROTHERS is the Editor for Civil + Structural Engineer Media. If you want us to cover your project or want to feature your own article, he can be reached at lcarothers@zweiggroup.com.

WHEN CRANES FLY

WHEN NEW YORK CITY SPACE CONSTRAINTS LIMIT CRANE CONSTRUCTION OPTIONS, SET YOUR SIGHTS SKY-HIGH

By Jon Skinner, PE

A MONUMENTAL CRANE LIFT to support Tiffany & Co.'s iconic flagship retail store renovation took place to expand the landmark 1940 Art Moderne building on Fifth Avenue. The luxury brand, currently undergoing a holistic, multi-year upgrade, sought to replace a former 1980s vertical rooftop expansion that housed three levels of office space with a new tri-story modern addition. Designed with double-height and column-free spaces wrapped in two different glass facades, the newly constructed addition would create more interest from the street while maintaining energy efficiency. However, constructing this in the heart of the congested City would require innovative solutions to configure crane space that would not take a large footprint and minimize road closures for the duration of the build.

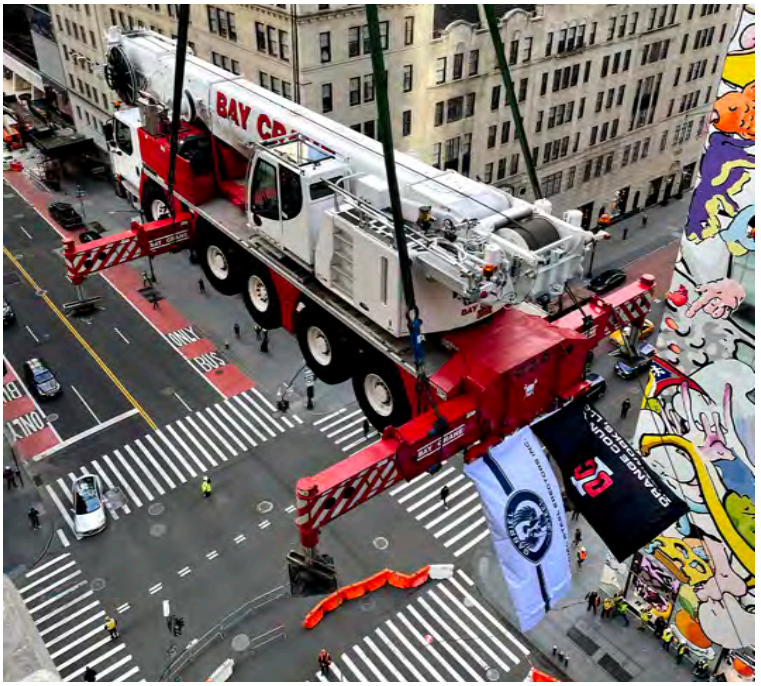
Taking space, time, and budget into consideration, McLaren Engineering Group's construction team turned to unconventional methods of crane engineering to figure out how to work within NYC's tight building constraints. The solution was as iconic as the retail brand itself: a crane would pick up another crane and fly it atop the Tiffany & Co. building in the heart of Midtown where it would commence work on the build.

The lift of an LTM 1130 mobile crane was engineered onto the roof of Tiffany's utilizing a giant 500-ton Liebherr LTM 1500 crane. The fully assembled LTM 1500 (utilizing the y-guy superlift kit) required eight trucks delivering over 363,800 lbs of counterweight. As a result, McLaren also provided the crane engineering for a Tadano TR450XL that assisted in putting the LTM 1500 together. With speed and cost in mind, the team provided crane plans, permitting, and the structural engineering necessary for the lift itself and to support the crane once placed.

The LTM 1130 weighing approximately 205,000 lbs, fully counterweighted, was lifted seven stories over the streets of Manhattan to begin work on the new three-story (8th, 9th, and 10th-floor) glass-walled addition that sits atop the existing historic limestone-and-granite building.

During the pre-bid process, McLaren worked with the contractor, Orange County Ironworks (OCI) vetting a geometry and capacity checks concept for the cranes and then a preliminary look into building reserve capacity. This solution saved several months on the project schedule, allowing OCI to work around the clock through Holiday Embargo. New York City prohibits cranes and work in the streets in most areas starting the week before Thanksgiving until after the beginning of the new year. Getting the rooftop crane in place allowed Orange County Ironworks to continue uninterrupted through the holidays, saving time and millions of dollars on the project.

This heavy lift required the construction engineering team to put together a total of 7 different crane plans (5 CN Applications with NYC DOB) for the project, design rigging to lift the crane, design rooftop





dunnage to support the crane on the roof, and to analyze the building for imposed loads. This additionally led to reinforcement design of a couple of existing building columns.

Construction topped out in March of 2021, and the smaller crane has since been safely returned to the ground. Tiffany & Co. has temporarily relocated its flagship to an adjacent storefront at 6 East 57th Street until completion of the construction project, which is planned for Spring 2022.

JON SKINNER, PE, McLaren Engineering Group Vice President of Construction Engineering, is an nationwide leader revolutionizing the industry by providing specialized services and innovative solutions to assist developers, contractors, fabricators, and erectors from design to completion. From crane engineering services to construction support, his team determines optimal and cost-effective means and methods for building construction, provides the design of temporary support, bracing, and construction sequencing, the conventional design of steel structures and connections, the design of delegated primary and secondary structural elements and everything in between.

HERNANDO DE SOTO BRIDGE EMERGENCY REPAIRS: CRITICAL, COMPLEX, COLLABORATIVE

By Aaron Stover, P.E., S.E., Ted Kniazewycz, P.E., and Rick Ellis, P.E.

SPANNING THE MISSISSIPPI RIVER with a distinctive profile, the Hernando de Soto bridge not only carries Interstate 40 (I-40) across the Mississippi River between Memphis, Tennessee and West Memphis, Arkansas, but also serves as an iconic landmark for the region. As one of only two crossings of the Mississippi River in the Memphis area, the steel-tied arch bridge is a vital transportation, commerce, and defense link.

On May 11, 2021, inspectors from Michael Baker International were conducting a routine inspection of the upper portions of the Hernando de Soto Bridge (areas of the bridge below the deck are the responsibility of Arkansas Department of Transportation (ARDOT) inspectors and outside of Michael Baker's scope of work) when a fracture was observed in the tie girder of the arch over the primary navigation channel. Initial shock and disbelief quickly turned into swift action to ensure the safety of the traveling public and the 18 rope access inspectors climbing the upper portions of the bridge. The team confirmed the critical finding and from there, moved quickly, focusing on doing the next right thing at each step. ARDOT, Tennessee Department of Transportation (TDOT), and 9-1-1 were immediately contacted by Michael Baker staff to alert them of the situation and request support to close the bridge to both automobile traffic moving across the bridge and river traffic on the Mississippi River below.

The next few minutes were critical. Michael Baker's rope access inspectors were called down and as the team awaited support from local authorities to close the bridge, they moved off the structure down each of the westbound and eastbound lanes dressed in neon colors, waving their hands and stopping traffic. With the assistance of the Memphis police, the bridge was quickly evacuated.

As I-40 stood empty, much was unknown, but one thing was certain: the team's #1 objective at all times was safety.

Initial Assessment

The fracture critical tie girder, the main tension element in the tied-arch bridge, left the structure in a precarious state. Both vehicular and barge traffic were immediately halted. With nautical traffic paused for three days, initial physical and analytical assessments were completed. Once the structure was deemed stable, the U.S. Coast Guard decided to reopen the river for navigation. Vehicular traffic across the structure remained halted for the duration of the repairs.

The Michael Baker team first leveraged their considerable experience with unmanned aircraft systems (UAS) – or drones – to fly the fracture location to inform ARDOT and TDOT of the apparent extent of the damage. The initial UAS video confirmed that the fracture included the



Hernando de Soto Bridge. *Photo: Michael Baker International*

complete loss of one of the two web plates, one of the two flanges, and partial fracture of the second flange. More than 50 percent of the member cross-section was lost in the fracture. Within hours, engineers from ARDOT, TDOT, and Michael Baker were working toward the ultimate goal of safely repairing the fractured tie girder. At this time, Michael Baker was contracted for design of an emergency repair by TDOT.

Thorough analysis and evaluation of the bridge began immediately. Within a single day, Michael Baker assembled teams across numerous offices to gather data, perform calculations, and increase the team's understanding in order to better evaluate the bridge's condition. Engineers generated detailed finite element models of the bridge and the local fracture to begin to shed light on the criticality of the bridge's condition. Field inspection teams assisted with obtaining critical information to support early investigative efforts obtained by UAS. Michael Baker, alongside ARDOT's UAS pilots, monitored the fracture to track any changes during those first critical hours. To support the initial temporary repairs, additional measurements of the crack, tie distortion, and other critical field measurements were needed.

This information was gathered by a Michael Baker rope access inspector on the bridge. During the inspection, Michael Baker established a live feed via UAS video linked to a web meeting. This allowed design engineers in multiple locations to communicate in real-time with the inspector while he took measurements and allowed them to request additional information and clarifications as needed. This creative use of technology gave designers real time results and a first person understanding of the implications of the distortion that would need to be considered in the repair design.

A Collaborative Process

The team recognized that collaboration and efficiency in design and schedule would be important to repairing the fracture and reopening the bridge as quickly as could be properly accomplished. TDOT selected the Construction Manager/General Contractor (CM/GC) project delivery method, recognizing the benefit to the project as it allowed owners, engineers, and contractor to collaborate on repairs. As lead designer for all phases of repair, Michael Baker called on more than 60 engineers from 20 of the firm's offices around the country to contribute to the project in design and review/oversight roles to ensure that timely and prudent decisions were made at all phases of the work and that



Initial Find. *Photo: Michael Baker International*

multiple phases could be advanced in parallel to minimize the overall project schedule. Within a week of the fracture being discovered, General Contractor Kiewit Infrastructure South Co. had also been brought onboard. All partners on the project proceeded in lockstep as repairs commenced, with daily working meetings to resolve challenges and frequent status meetings held throughout the entirety of the project. The Federal Highway Administration (FHWA) was also a key partner throughout the project, aiding with the repair plans.

Three-Phase Design

With the team in place, ARDOT and TDOT collaborated on a three-phase repair plan – created and executed in collaboration with Michael Baker and Kiewit – with design and construction overlapping between the phases. The plan included:

Phase 1: Stabilization

The team took a "do no harm" approach to the initial repairs as there was concern that the bridge was severely compromised. The initial evaluations found the remaining section was dangerously close to yielding. The team found no evidence from the structure that the load had not found an alternate path beyond the opposing web and remaining flange. Stabilizing the member was not a long-term fix, but it was the first step toward the repair, ensuring the safety of subsequent phases of work. The Michael Baker team established safe working load levels for construction crews and equipment staged on the bridge. Within the first week of the closure, a stabilization splice was designed to temporarily restore the capacity of the fractured section of the tie and the fabrication of roughly 30,000 lbs. of structural steel plates began by Stupp Bridge. To install the splice, Kiewit assembled a suspension platform and secured the plating with nearly 450 temporary bolts. The splice provided additional redundancy to the partly severed member without applying any corrective twist or loading to the damaged tie. The suspended platform allowed the contractor greater access to establish a more permanent repair in Phase 2.

Phase 2: Member Repair

Knowing that time was of the essence to get this vital transportation link re-opened, analysis and design of the longer-term fix began immediately with Michael Baker engineers evaluating ways to repair this bridge. Faced with a range of potential repairs from reconstruction of the bridge to temporarily supporting the structure for the repair, the



Inspection. *Photo: Michael Baker International*

project participants found a creative solution to repair the structure in place and collectively cut significant cost and schedule impacts out of the project timeline. Advancements in the understanding and application of concepts in fracture mechanics and redundancy allowed for the fractured member to be repaired rather than completely replaced.

The last solution consisted of using external post-tensioning to reduce tension in the existing tie, lessening its level of stress and possibility for further damage. Eight 3" diameter high-strength steel bars were connected to steel weldments at either end of the fractured tie. High-pressure rams were utilized to deliver the required force to partially de-tension the tie. Extensive real-time monitoring of the post-tensioning operations was implemented to ensure success. While the tie was partly unloaded, the temporary Phase 1 stabilization plates were removed and new strengthening plates were installed that have nearly the capacity of a completely intact tie by themselves.

These new plates, acting in tandem with the existing steel, provided a redundant load path in the unlikely event of future fracture. The team worked closely with Kiewit and fabricators W&W/AFCO and G&G Steel to design the repair around readily available HPS70W material. During the completion of the work, an 18" section of the tie containing the fractured web and flange plates was removed for further forensic examination. Once the strengthening plates were installed and fully bolted, the post tensioning was removed, signifying successful repair of the damaged tie girder.

Phase 3: Overall Tie Girder Repair

While Phase 2 repairs were going on, extensive nondestructive testing (NDT) of all similar welds in the tie girders was completed and provided information leading to what became the Phase 3 repairs of the tie. NDT discovered indications ranging from very small to very large. The remedy for many of these smaller indications was to either core or grind them out, thereby removing the potential flaw. Larger indications were plated over to provide a redundant solution. The details used in Phase 2 were readily adaptable for Phase 3 and Kiewit worked with supplier AFCO/W&W Steel to obtain the necessary HPS70W plate.



Michael Baker rope access and UAS bridge inspectors.
Photo: Michael Baker International

Tests were conducted on a portion of the damaged member that was removed as part of the Phase 2 repairs. The removed portion is currently undergoing forensic examination at the labs of Wiss Janney Elstner Associates Inc. (WJE) in Northbrook, Illinois. The WJE team is conducting various tests on the material to document its properties, as well as microscopically examining the weld and the fractured surfaces to determine where and how the fracture began. By having the fractured component in their possession, the engineers at WJE were able to provide guidance for field-testing of other welds that were completed as part of the inspection in Phase 3.

All Eyes on Memphis

The emergency closure quickly gained attention across the country from the public, media outlets, and politicians alike. Tennessee Governor Bill Lee, Arkansas Governor Asa Hutchinson, and U.S. Secretary of Transportation Pete Buttigieg all visited the bridge in the days following the closure, with Secretary Buttigieg noting "We want to make sure that national attention and resources are available to help the state and local authorities who are resolving this and working toward a safe reopening of the bridge…Even for people outside this region, it is important that we restore this connection quickly because like so much about the Memphis region, it is an area of national logistical importance."

The impact of the shutdown of the Hernando de Soto Bridge on the economy was felt almost immediately. River traffic below the bridge had resumed by May 14, 2021, but all automobile traffic had to be diverted to the nearest crossing on Interstate 55 (I-55). The added traffic resulted in bottlenecks and delays, with the Arkansas Trucking Association estimating that the additional travel time attributed to the closure was costing the trucking industry more than $2.4 million each day that the bridge was not in operation. This further reinforced that the timely, proper, and safe completion of the repairs was critically important.

As the team moved through the initial find and into inspection, design and repair, it was of the utmost importance to maintain transparency and communication with the public impacted by the closure. A public awareness campaign was carried out in conjunction with the bridge's repair activities. Project information and updates were shared via media efforts (press releases and press conferences), as well as daily across the TDOT and ARDOT websites and social media channels. To support this, Michael Baker developed a 3D visualization of the repairs as they were being developed.

Reopening the Hernando de Soto Bridge

For several weeks, activities progressed 24-hours a day, supported by extended shifts. Initially, the eastbound and westbound lanes of I-40 crossing the bridge were initially scheduled to open on August 2 and August 6, 2021 respectively, but the eastbound lanes were opened ahead of this date on July 31, 2021, while the westbound lanes opened on August 2, 2021 – traffic was again flowing 83 days after the fracture was discovered.

The project highlighted the importance of transparency, accountability and collaboration and exemplifies how two DOTs can work together to accomplish a common goal. All agencies and firms involved in the project brought a deep understanding of structural engineering to the work, and the commitment and partnership amongst them facilitated the analysis, design and construction needed to safely, effectively, and efficiently repair the fracture.

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BUILDING TOWARDS THE SUN: VERTICAL CONSTRUCTION IN THE MIDDLE EAST

By Luke Carothers



LED BY CITIES LIKE DUBAI, the Middle East has seen an enormous growth in large scale construction projects over the last twenty years, particularly in the realm of skyscrapers. Iconic structures such as the Burj Khalifa in Dubai and the Ethiad Towers in Abu Dhabi have become synonymous with the vertical expansion of Middle Eastern skylines. Abdo Kardous, President of Hill International Middle East, says the increase in tall building projects in the area is a result of two factors: population growth and wealth gained from oil.

In recent decades, several cities in the region have exploded in population, particularly in the United Arab Emirates (UAE). In 2000, Dubai was home to less than 900,000 people; today, Dubai is home to more than 3.3 million people. Kardous also points out that, unlike in places like the United States and China, there is little to no developed rural land surrounding these cities. Whereas in China, the US, and other similar countries populations migrate from rural areas for work, the working population of many Middle Eastern cities is located within the city itself. This places an even greater emphasis on housing development within the larger cities, which is a viable use for high rise structures in urban areas.

Silhoute Towers

Combined with capital from the oil industry, population growth is fueling an expansion of real estate investment within the region. This influx of real estate development is further influenced by the availability of buildable land, the lack of which has driven the price of land steadily upward. According to Kardous, this has caused developers to develop their properties vertically to maximize the available space. In addition, thin, vertical structures are a viable option because there are little to no seismic considerations that have to be made. Even in the areas where there is seismic activity, it is to a much lesser degree than areas such as the West Coast of the United States. Kardous also believes there is another aspect coming into play that is fueling vertical expansion beyond what the economic factors dictate–prestige.

The desire to create a landmark structure is demonstrated by projects like the aforementioned Burj Khalifa, which is almost 200 meters taller than the second tallest building in the world, Merdeka 118 in Kuala Lumpur. The construction of the Burj Khalifa, despite numerous setbacks, resulted in an iconic landmark at a staggering price. Aside from cost, there is also instability in some of these projects as a result of shifts in international markets. If international economic markets experience low or stagnant rates, these projects are often affected by way of project delays and cancellations.

In addition, there are several considerable challenges associated with construction in hot climates that projects must contend with while remaining safe and on-schedule. According to Kardous, the use of concrete is among the most important considerations for high rise projects in the Middle East. Projects must find ways to keep their ready-mix concrete below a certain temperature. One of the more creative solutions includes using ice to cool the water that mixes with the concrete. To ensure that these solutions are practical, there is considerable logistical planning that needs to take place. This means planning to ensure that there is sufficient time to transport the concrete from the production facility to the construction site as well as enough time to pour the concrete. This becomes critical when it comes to pouring concrete to the project's upper stories. As such, Kardous notes that the efficient planning not only places the production facility as close to the construction site as possible, but also that the concrete's transportation route avoids delays from cities and densely trafficked areas. Once the concrete reaches the construction site, these logistical considerations must also contend with the further challenge of pumping concrete higher and higher as the building extends vertically. The extra time afforded by this planning is especially crucial for projects that reach 300 meters or higher, where Kardous notes that additives must be mixed in with the concrete to keep it malleable.



Another challenge to tall construction projects is the vertical transportation of both workers and materials, which can become one of the biggest time consumers on these construction projects. Again, this involves considerable logistical planning to ensure that construction activities such as inspections and maintenance are ordered in such a way that they do not require multiple trips up and down the structure. When it comes to the vertical transportation of materials, Kardous says there are never enough tower cranes and hoists for the project, but, by optimizing their usage, materials can be efficiently transported to their appropriate levels. This optimization usually comes by extending the usage cycle of the lifting equipment from a standard 8-hour work window to a full 24 hours. While this results in longer hours for contractors and workers, it ensures that materials are moved efficiently and the project is completed on time.

Sky Sun Towers

However, even with potential complications with these prestige-driven projects as well as challenges building in the hot climate, more and more tall buildings are being constructed throughout the Middle East. Led in part by firms such as Hill International, tall buildings such as the Silhouette Tower in Doha, Qatar where they provided construction and project management services. Kadous believes that this trend will only continue. Currently, the UAE is leading the way in terms of vertical building with both Dubai and Abu Dhabi leading the way for the Gulf Region.

Sky Sun Towers

Kardous believes that in order for this trend to continue, there needs to be an emphasis on both safety and fire protection. To place a stricter emphasis on safety, there are a few smaller categories into which the subject is divided. Life safety focuses on the means of egress for the occupants of any building or project. This means paying attention to the distance between occupants and their means of escaping in the event of fire or structural damage; it also means including design elements such as refuge floors into buildings. According to Kardous, life safety is directly tied to both the building codes of each country as well as the capacity of the local authorities. Wherever a high-rise building is proposed, the local fire department must have the ability to help the people on the highest floors in the event of a fire. In some places, this greatly limits the available height of new building projects. Once a focus on life safety is established, then the next area of focus becomes protecting the building and its systems. Once all the occupants are safely evacuated, the emphasis becomes protecting the structure, systems, and installations within the building. Although there is a focus on these safety elements during the occupation of the building, Kardous believes that there needs to be a greater emphasis on providing fire safety during the construction phase where there are additional dangers from things like welding and electrical work.

There appears to be no slowing down when it comes to the pace of new vertical construction projects in the Middle East. As more projects are scheduled and completed, there will not only be challenges associated with construction and logistics, but also with the use of these buildings. How this challenge is met will define the landscape of how these projects are handled in the coming years.

LUKE CAROTHERS is the Editor for Civil + Structural Engineer Media. If you want us to cover your project or want to feature your own article, he can be reached at lcarothers@zweiggroup.com.

GONDOR TO DUBAI: CHAINMAIL AS A STRUCTURAL SOLUTION

By Luke Carothers

DURING THE IRON AGE (1200-300 BCE), nobility and royalty as well as their protectors began wearing shirts of interwoven metal rings to protect themselves. Known as chainmail, this technological improvement vastly improved the wearer's chances of surviving a blow from a sharpened weapon. The earliest versions of chainmail were formed when leather or cloth shirts had overlapping rings of iron sewn onto them, but by the 10th century smiths were fashioning divided chainmail suits that covered the head, neck, and torso while also facilitating use from horseback. In addition, improvements in industrial practices meant that chainmail was cheaper and easier to produce, meaning that it was no longer exclusively for nobility and their protectors.

However, chainmail began to fall out of favor starting around the 14th century with the introduction of plate armor, and fell largely out of use until the late 20th century when it was found to be incredibly useful when diving with sharks. Now, thanks to Kayne Horsham and his company Kaynemaile, chainmail is making its way back into the conversation.

Horsham and his team at Kaynemaile, based in New Zealand, have developed a chainmail material made from lightweight polycarbonate that protects buildings as well as bodies; this update from the iron and steel of centuries past makes the material incredibly robust while still being lightweight. When Kaynemaile is used in place of steel sheets or mesh, it presents several key advantages. For example, Kaynemaile reduces the static load on buildings and cuts down on installation time and costs. Furthermore, Kaynemaile reduces the solar energy and sunlight entering a building, which has been one of its earliest applications in parking garages.

Horsham first became familiar with chainmail when he served as an artistic director for the creatures, weapons, and armor department on the set of the iconic Lord of the Rings trilogy. When he was initially approached for the film, Horsham knew he had to not only make the materials look good on film, but also stand up to the rigors of moving to different filming locations over years of shooting. The first material they tried to use was steel, which looked beautiful, but weighed too much. Because the material was to be worn by actors and not battle hardened knights, Horsham knew he had to find a lighter material. Strict requirements set out by director Peter Jackson set aside the possibility of using some sort of painted material.

Horsham's solution was to create a set of plastic rings then coat the rings with pure silver and copper using a process called electroforming. The resulting mesh very closely resembled the medieval chainmail with the pure silver adding a necessary element of fantasy. While this product looked good on film, the labor of creating it was intensive. Each of the links were hand welded individually, which took thousands





of hours for Horsham and his team. Additionally, because the material was used in all the stunts throughout the film, Horsham and the team constantly had to replace torn or broken pieces. It was during this time that Horsham began to think about ways to make his chainmail, dubbed "Kayne's-maile" by actor Viggo Mortensen, both stronger and easier to manufacture.

After filming wrapped, Horsham briefly worked in miniatures before he started working on a machine to assemble this material. Once this machine was assembled, it was fully automated to create the material, but it still took a lot of time and cost a lot of money. Coming to the realization that he was making chainmail the same way it had been made for thousands of years, Horsham changed direction and focused on creating the rings already assembled. Thus, the liquid state assembly (LSA) system was created. Horsham likens it to part printing rather than layered printing in that it "prints a part at a time in a desired position and [builds on] that."

According to Horsham, this paradigm shift in the assembly process alleviated quality control issues because he no longer had to worry about the strength of each assembled link. With quality control assured, Horsham began experimenting with different materials to build the links with. Because of his previous work, he originally intended to use this new process and material in the fashion and costuming industry. Developing the world's first liquid state assembly process allowed Horsham to develop his mail with modern materials such as polycarbonate, which has a high strength to weight ratio and could give the material applications in the architecture and engineering fields.



Once Horsham and his team focused on the architecture and engineering markets, the material applications of Kaynemaile soon became evident. After Kaynes maile became an established company in 2006, their lightweight polycarbonate mesh soon began to feature in art installations and architectural designs. Kaynemaile also poses significant advantages from an environmental perspective. Unlike other materials, Kaynemaile is fully recyclable and is created using a "nil-waste" process. Due to this and other structural advantages, Kaynemaile is being used in projects across the world.

A few years ago, the Kaynemaile team was approached by architecture firm Woods Bagot who was familiar with the material from a number of projects throughout the United States as well as Mace Engineering. Woods Bagot was working with the Dubai World Trade Center on a project to create a new exhibition space. Part of this project involved the space between the train station and the new exhibition space. This space would not only need to capture the imagination of crowds entering the exhibition space, but it also needed to shade users from the harsh desert sun. Woods Bagot and Mace had struggled to find a permanent material to serve as a canopy for the space; they built three test structures using different materials, but none of the three traditional shading methods could stand up to the desert sun and wind. Based on their previous work, the teams decided to use Kaynes maile as the shading material for the project.

Horsham traveled to Dubai and began working with the teams to fit the material to the specific designs necessary for the project. It soon became clear that Kaynes maile was able to outperform the other materials due to its unique design and construction. Its seamless design allowed the material to respond to wind force smoothly as the rings are able to move independently from one another. This also means that no one area of the canopy is subject to more constant force than another. In addition, Kaynes maile has unique shading properties that made it the perfect material for the project. The material's three dimensional design simultaneously creates shadow and circulates air, which allows it to function as a radiator and keep the entire structure cool.

While this structure had to perform in the desert heat, it also needed to capture the imaginations of the people entering the exhibition space. In this regard, Kaynes maile stood out immediately. The over 120,000 square feet of material dazzles in four colors overhead the entrance to the expo. Wind moves through the overlaid mesh screens, causing shadows and light on the ground to move, breathing life into the space. Horsham and his team call this the "Wondercool Effect". Kaynesmaile also worked with CD+M Lighting Design Group to use dramatic lighting effects to further add to the sensory experience.

Kaynemaile's canopy structure is debuting at the Dubai World Expo 2020. This event, which was postponed due to the pandemic, features exhibits from 192 countries and only happens every five years. Kaynemaile also worked on the New Zealand pavilion for the World Expo. For the pavilion, which is located in the sustainability district, Horsham and his team conceptualized, designed, and created a living building facade.

Horsham believes that the uses for Kaynemaile are only limited by the creativity of the user. For example, several parking garages throughout the United States have turned to Kaynemaile in part to combat the heat island effect. Furthermore, because each solution can be customized, Kaynemaile is a scalable solution for a variety of project sizes and needs. As exemplified by Kaynemaile's selection as a shade canopy for the Dubai expo space, the future uses of this material will be determined by the problems architects and engineers seek to fix.

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CONNECTING JACKSONVILLE WITH THE FUTURE

By Brian Russell, P.E., David Tudryn, AIA, and Andrew C. Rodgers, P.E.

GRAND CENTRAL TERMINAL in New York City, Union Station in Denver, 30th Street Station in Philadelphia: These iconic facilities transcend generations and are destinations in and of themselves. The Jacksonville Transportation Authority (JTA) set out to join this list with the new Jacksonville Regional Transportation Center at LaVilla (JRTC). The JTA's goal with this project was to centralize their dispersed connection hubs and services into one multi-functional facility that would become a model of transportation efficiency, signature aesthetics and community-serving features.

This ambitious project began in an unconventional fashion, with a design competition. The JTA challenged entrants to create a facility that would simultaneously serve the core functions of transportation and JTA offices while helping to build connections and revitalize the region. Many designs were submitted, but only one hit the mark: timeless and modern, effective and innovative. The winning firm, a joint venture between Michael Baker International and Pond & Company (officially known as the Pond|Michael Baker International JV), put forth a 67,000-square-foot facility that realizes complete-streets connections within an historic Jacksonville district.

The project was completed using construction-manager-at-risk delivery, with the Pond|Michael Baker International JV serving as the project's lead designer and providing community coordination and outreach, architecture, interior designs, structural engineering, civil engineering, M|E|P|FP engineering, landscape architecture, right-of-way and utility coordination, geotechnical engineering and construction management services. Balfour Beatty Construction provided general contractor services.

A Uniting Force

Connections are at the heart of the JRTC and to that end, the design process reflected the importance of community. The facility is located in Jacksonville's LaVilla neighborhood, an area that has long been regarded as an important center for African American culture and commerce but in recent years has seen economic activity decline. The JTA saw the design and construction of the JRTC as an opportunity to reinvigorate the once-multicultural district. So, when it came to design, the team began by imagining the area as a whole, envisioning the surrounding parcels and how they would interact with the structure, rather than using the structure as its starting point. At the same time, the needs of JTA's individual departments and operations were taken into account, particularly the bus routes and schedules. The team designed the facility to balance the center's layout between public and private transit entities and ensure the safety of all visitors and passengers, as much of the site was devoted to vehicular circulation.



Skyway at JRTC – April 2020

TOD strategies were employed in the design of the JRTC and the finished product is more than somewhere to catch a bus – it is a destination with centralized local, intercity regional transit networks (including 21 bus bays and seven staging bays), paratransit services, alternative mobility solutions, an elevated automated people mover (APM) system called the Skyway and space for future services. Inside, the JRTC consists of five floors of JTA office space, with two of the floors offering public space for riders and boarding and circulation spaces for buses, taxis, rental car services and an elevated rail system. The third floor includes an executive Board Room for regularly scheduled Board meetings and other large public meetings. Distinct elevator lobbies at each public level separate the public areas from JTA administrative functions but offer enough access to experience the views of Jacksonville and create a sense of community. The JRTC has become a hub of activity for the community, even hosting regular events such as farmer's markets, and its interior spaces include significant contributions from local Jacksonville artists, which honor and memorialize the LaVilla Neighborhood's music, heritage and transportation history.

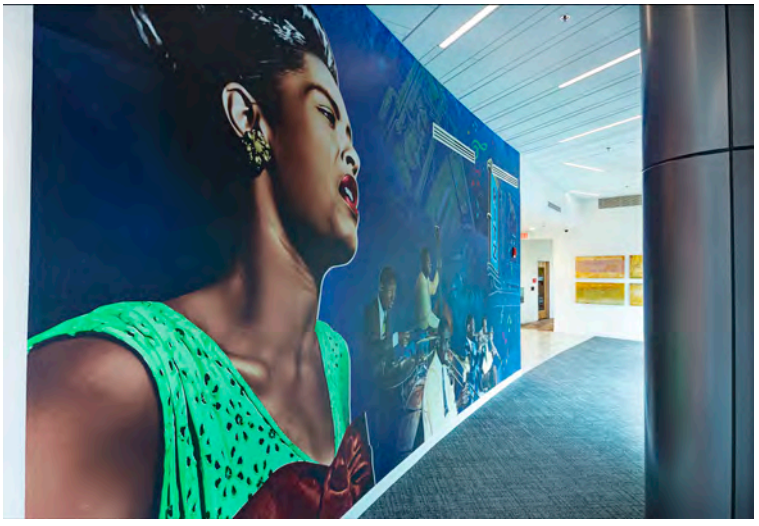
The team also wove the JRTC's exterior into the fabric of the neighborhood by providing gathering spaces, sidewalks, bike-sharing and business space. To further improve safe access to transit, the team designed and constructed an inviting pedestrian bridge that links the JRTC to the Intercity Bus Terminal, unifying the campus. The bridge spans 280 feet over LaVilla's Stuart Street and West Forsyth Street and features a canopy with a design that extends the language of the triangulated curtain wall. The bridge serves as a new gateway to downtown Jacksonville for passenger cars exiting I-95.

Eye on Aesthetics and Sustainability

The iconic, crescent-shaped structure is divided into public terraces with a glass curtain wall on one side to convey a sense of movement. The curtain wall, a progressive design hallmark envisioned to express acceleration and mirror the JTA's philosophy of transportation, is the central artistic and architectural innovation of the JRTC. To achieve this look, the team worked with a specialized glazing manufacturer, creating a unique and aesthetically striking interlocking design of







triangular and trapezoidal shapes that were printed on the glass. The coloring process involved printing the ink on the glazing to achieve two separate colors on the same piece of glass, an uncommon feature. The panels were assembled in a factory, accelerating construction and reducing costs, then hung like puzzle pieces on the façade.

In addition to aesthetics, the curtain wall enhanced sustainability, allowing for natural daylighting. The team used energy analysis modeling to determine the percentage of insulation needed behind the curtain wall panels and in another effort to improve sustainability, performed building information modeling on the exact construction materials to design more efficient HVAC systems. The administrative building is currently pursuing LEED Gold Certification, while the adjacent Greyhound Terminal successfully achieved LEED Silver Certification.

Future-Focused Design

The team made conscious design decisions with an eye to the future, ensuring that the facility is adaptable to new transportation technology. The skyway beam can be converted to an autonomous vehicle space with the removal of the monorail beam and conversion of the Skyway Terrace floor. Additionally, there is space for future micro and e-mobility solutions. In this way, the facility can continue to grow and change as the transportation needs of Jacksonville evolve.

Among the most important and lasting benefits of the JRTC has been its impact on its host community. The commitment by the JTA to bring the intermodal center to LaVilla has greatly improved community access to the greater Jacksonville area for jobs while offering it as a convenient destination for future arts and entertainment venues, as well as the adjacent convention center.

In the end, the JRTC checked all of the JTA's boxes: improve safety and access; provide highly-functional transit connections; be an icon for the City of Jacksonville; contribute to rejuvenating the adjacent neighborhoods; serve as a catalyst for Transit-Oriented Design (TOD) and demonstrate leadership in sustainability, energy and environmental design. However, the primary achievement of the JRTC is gathering the city's formerly fragmented transit services into a centralized modern hub, enabling riders to easily and safely transfer between modes of transportation both internal and external to Jacksonville. The facility opened in May 2020 at a cost of $59.5M. Today, the JRTC is bustling, serving about 18,500 people per day.

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REIMAGINING RESIDENT TRANSPORTATION: NYC FERRY SYSTEM

By Stephen A. Famularo, PE, D.PE



AN INCONSPICUOUS TRANSPORTATION revolution is taking advantage of one of New York City's greatest attributes: its robust waterways. With pre-pandemic subways and buses at near or full capacity and the highest commute time of any major U.S. city, New York sought options to bring the best service and quality-of-life to residents and commuters at the water's edge. Placing priority on expanding citywide connectivity and modernizing infrastructure across all five boroughs, the waters around New York City have become integral to the solution. The strategic expansion of ferry-based infrastructure solves for a historically overburdened transportation network and, in a post pandemic world, offers commuters an open-air option capable of better ensuring social distancing measures.

The NYC Ferry expansion project, originally named by the NYCEDC as the Citywide Ferry Service, was announced by Mayor Bill de Blasio's administration in 2015 with goals to relieve part of the load of the city's transportation system while connecting 20+ waterfront communities, many of which had historically been considered "transit deserts". The plan would provide affordable and convenient transit options for communities, support growing neighborhoods, connect people to jobs and economic opportunities throughout the city, and increase the resiliency and redundancy of its transportation network.

Until this recent expansion effort, the City's ferry service had two main roles within the transportation system: (1) providing additional commuter capacity in routes that had become overcrowded with prohibitive traffic/delays, and (2) providing targeted relief for commuters affected by an abrupt loss in ground transportation service (situations like 9/11 and Hurricane Sandy).

NYCEDC launched the first phase of NYC Ferry system in May of 2017 with McLaren Engineering Group contracted to provide engineering consulting services for the development, investigation, planning, design, coordination, permitting, procurement, and construction administration of 11 new ferry landings and the restoration of two others.

The project came with a strict construction deadline and a few unique challenges. First, the team would be working on 13 landings with separate owners, meaning 13 individual approvals, inspections, and permitting processes to coordinate should the ferries be constructed upland. Second, prefabricated barges were already in the process of being constructed prior to the team's involvement, making the design dependent on specifications created by other entities. Third, the entire structure needed to be resilient and adaptable in order to make the ferry system work as a mass transit hub and an emergency relief service option. To combat these challenges and create a unified ferry system that was adaptable and resilient, McLaren developed an innovative standardized system consisting of a prefabricated floating barge, canopy, steel piles, fenders, gangway, and passenger amenities.

To reduce coordination with individual property owners, the gangways were designed not connected to land, but instead sitting on an independent pile cap. This reduced the need for coordination, inspection, drawing research, and analysis of each site, enabling the team to remain on track with time. The connection from the barge to the upland, by a gangway, is independent of the existing bulkhead, esplanade, or platform. By installing a mini-platform adjacent to the land, all loads are isolated away from the existing structure. This small footprint also allows the landings to be easily removed and relocated if ridership demands suggest adjustments to the route.





The design also upgraded NYC Ferry System's ability to withstand extreme environmental events and facilitate quick responses due to its inherent flexibility – from both an engineering standpoint and an operational one. The isolation of the floating barge structure from upland components, design of minimally restrained gangways, and inclusion of contingency features all contribute to improving functionality and durability when faced with extreme conditions. The floating barge is the primary means of protecting the terminal against damages that could jeopardize ferry service after extreme storm events. The most recent FEMA Flood Insurance maps available identify that the water levels anticipated with a 100-year storm would overtop the seawall at all the terminal locations considered. Thus, any non-watertight electrical or mechanical components located on land or a fixed pier at the upland elevation would be subject to severe water damage that would make the terminal inoperable for several days to weeks. By providing a floating barge structure and hinged gangway seated on this barge, the barge deck and portions of the gangway become safe surfaces to mount.

The new design and construction of all 11 landings including Astoria, Roosevelt Island, Long Island City North, Atlantic Ave/Brooklyn Bridge Park, Red Hook/Atlantic Basin, Bay Ridge, Rockaway, Soundview, East 90th Street, Stuyvesant Cove/East 20th Street and Corlears Hook/Grand Street, were completed on time and are ready to connect residents and commuters across the city as post-pandemic activities begin to resume.

Currently, McLaren is working on the next round of NYC Ferry System improvements including renovation of two facilities and the design and installation of three additional landings. They are also leading the development of a new homeport and maintenance facility for the fleet at Atlantic Basin in Red Hook, Brooklyn. The development of this new site (Homeport II) will provide proper care and protection for approximately 40 vessel slips, and include utility and finger piers for fleet maintenance, and offer repairs and inspection with an additional travel lift. This centralized location will offer protection from vessel traffic in the Buttermilk Channel.

For the feasibility phase of the Homeport II project, marine engineers and in-house divers deployed an Acoustic Doppler Current Profiler (ADCP) to measure the waves, wakes, and current velocities caused by environmental conditions and passing vessels. This in-house tool collected information for two months and relayed detailed site data that McLaren's design team used to develop the facility layout for both day-to-day serviceability and long-term resiliency.

Planned completion of the landings for the NYC Ferry System expansion is set for 2022 with the first phase of Homeport II (19 Slips) coming online in Spring of 2023.

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CHONGQING AND GUIZHOU ORGANIZATIONS ADVANCE CONSTRUCTION OF TAIHONG YANGTZE RIVER BRIDGE

BENTLEY'S INTEROPERABLE REALITY MODELING APPLICATIONS HELP TO SAVE CNY 1.8 MILLION IN CONSTRUCTION MANAGEMENT COSTS

By Amy Heffner



The Taihong Yangtze River Bridge is a CNY 900 million construction project along the 77-kilometer highway linking the Nanchuan District and Lianjiang New Area in Chongqing. Image courtesy of China Railway Changjiang Transport Design Group Co., Ltd.

New Bridge Completes Economy Boosting Expressway

The Taihong Yangtze River Bridge is a CNY 900 million construction project along the 77-kilometer highway network linking the Nanchuan District and Lianjiang New Area in China's Chongqing municipality. The 1,436-meter-long bridge crosses the Yangtze River and is the final component of the expressway, which is expected to reduce travel time between the two districts to 50 minutes and boost Chongqing's economic development.

The bridge features a two-way, six-lane roadway with a width of 39.6 meters. Designed as a suspension bridge, it includes an 808-meter steel box beam with a complex structure required to sustain a high-load capacity amid complicated terrain. The scale and complexity of the project necessitated pushing the boundaries of engineering data to ensure construction quality and safety.

Manual Processes Undermine Dynamic Bridge Construction

Recognizing that bridge construction is a dynamic process, the project owner hired China Railway Changjiang Transport Design Group (CRCTDG). Working with Guizhou Communications Construction Group and Guizhou Bridge Construction Group, as well as numerous other components and contributors in various disciplines, CRCTDG had to determine how they could use the engineering information to increase the performance, quality, safety, scheduling, and cost of each stage of the life cycle. They also realized that they needed to digitize engineering workflows and avoid irreversible and costly errors. CRCTDG knew that traditional manual and paper-based data exchange and construction methods would not be sufficient to achieve the accuracy and public safety they targeted. "Traditional infrastructure-related data mainly uses estimation statistics, manual compilation and reports, and document transmission," explained Fengmin Chen, head of CRCTDG's BIM technology department.

They explored using 3D BIM methodologies and reality modeling to perform construction simulation and enable seamless, real-time data exchange and intelligent information management. More specifically, during the design stage, they sought to achieve parametric modeling, improve design efficiency, integrate multidiscipline data, and generate a unique data source. CRCTDG desired digital pre-assembly of steel box beams during construction and 3D laser scanning to monitor construction progress for high-precision quality control. However, they faced data collection, integration, and coordination challenges associated with incorporating digital survey methods and BIM modeling. They also needed to overcome software incompatibility to simulate construction and establish a digital foundation for lifecycle operations and management.

With Bentley's open applications, CRCTDG established digital workflows and a construction management platform that eliminated information silos caused by traditional construction methods. Image courtesy of China Railway Changjiang Transport Design Group Co., Ltd.

Leveraging Bentley Applications for Construction Management

CRCTDG selected ContextCapture to process unmanned aerial survey data and establish a highly precise 3D model. They also used the application to create a terrain model of the bridge site, display contours as lines or triangular meshes, and produce effective elevation and slope analysis. The use of high-precision orthophoto maps, point clouds, or reality scanning technologies generated terrain models of the bridge site and greatly improved the efficiency and accuracy of the work. MicroStation was used to streamline and integrate models from multiple software applications, providing a single data source throughout the entire project lifecycle. They performed 3D laser scanning of the complicated terrain via unmanned aerial vehicles for rapid and detailed data collection.

Using ContextCapture, they processed the point clouds and survey data to generate geological models of the bridge site. These digital survey and 3D modeling methods also helped them obtain accurate 3D measurements of the steel box girder components to simulate assembly, helping intelligently manufacture the steel box beam. They continually collected point cloud data throughout the bridge construction process to visually monitor progress. "Reality scanning technologies are used to regularly collect site data during construction to record project construction at different construction periods," commented Chen. Using LumenRT, CRCTDG integrated the reality and BIM models to simulate the construction process and monitor progress, optimizing construction through effective planning.

With Bentley's open applications, CRCTDG established digital workflows and a construction management platform that eliminated information silos caused by traditional construction methods. The interoperability of MicroStation helped streamline and integrate models from multiple applications, providing a single data source throughout the project lifecycle. By employing iModels, they enabled digital delivery and a cloud-based platform, resulting in mobile review and enhanced cost control. The digital workflow allowed them to combine construction process data with the BIM model to achieve high-precision construction quality control and create a unified, intelligent bridge model that can be used through operations and maintenance.

Industrializing Chongqing's Bridge Infrastructure Industry

By establishing a 3D BIM-based construction management platform to monitor construction of the Taihong Yangtze River Bridge, CRCTDG improved construction management quality and efficiency, eliminated the information silos and bottlenecks of conventional construction, and established lifecycle BIM operations and maintenance. Having a visual representation of the project provided all participants with an experience that simulated being on site, regardless of their location. The improved visualization helped reduce the time spent traveling to the site by 23 days, as well as optimized planning and scheduling. Through parametric modeling and automated processes, they improved design efficiencies, reducing bridge design time by 300 hours and saving CNY 500,000. Establishing digital workflows streamlined communication and collaboration to help complete the bridge design 30 days ahead of schedule.



With Bentley's open applications, CRCTDG established digital workflows and a construction management platform that eliminated information silos caused by traditional construction methods. Image courtesy of China Railway Changjiang Transport Design Group Co., Ltd.

Bentley's solutions provided dynamic digital management of construction planning and resource allocation to effectively carry out progress control and lower construction costs. Working in the digitally simulated construction environment, as well as predicting and overcoming potential problems in advance, saved nearly CNY 1.8 million in construction management costs and shortened the construction period by 47 days. Applying BIM modeling methods, CRCTDG established a 3D digital context to clearly communicate the development process and manage engineering information throughout the entire project lifecycle, ensuring quality and safety. The complete visual model lays the foundation for the intelligent manufacturing and construction management of similar large steel bridge projects. "[Using Bentley applications], lean construction, precise management, and control of modern infrastructure have been truly enabled, which promotes industrialization of the infrastructure industry," said Chen.

Project Summary

Organization: China Railway Changjiang Transport Design Group Co., Ltd.
Solution: Bridges
Location: Chongqing, China

Project Objectives:

- Apply intelligent 3D BIM methodologies to streamline workflows and generate a single data source for lifecycle bridge management.
- Simulate construction progress and achieve high-precision construction quality control.

Project Playbook: ContextCapture, LumenRT, MicroStation, OpenBridge Modeler, OpenRoads ConceptStation, ProStructures, RM Bridge

Fast Facts

- The six-lane, 1,436-meter Taihong Yangtze River Bridge will cross the Yangtze River in Chongqing.
- The team proposed methods for intelligent information management and collaboration.
- Simulated construction monitoring and digital workflows streamlined communication and planning.

ROI

- ContextCapture and MicroStation reduced bridge design time by 300 hours, helping complete design 30 days early and save CNY 500,000.
- Establishing digital construction management saved CNY 1.8 million in management costs and shortened construction by 47 days.
- The virtual 3D model ensures quality and safety throughout the project and will promote the industrialization of Chongqing's bridge infrastructure industry.

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LIGHT AT THE END OF THE TUNNEL: HOW TECHNICAL INNOVATION AND COMMUNITY BUY-IN TURNED A 5.6 KM MICROTUNNELLING PROJECT INTO A HUGE SUCCESS

NEW SEWAGE FORCEMAIN RUNS BELOW DENSE URBAN AREA INCLUDING 11 RIVER CROSSINGS, THREE RAILWAY CROSSINGS, PARKS, AND MAJOR CITY STREETS

By Bradley Marin, Tom Casher, and George Godin



THE YORK DURHAM SEWAGE SYSTEM FORCEMAIN TWINNING PROJECT (YDSS) is a sustainable sewage servicing solution undertaken in the summer of 2019 by the Regional Municipality of York, located north of Toronto, to provide relief for the Town of Newmarket's original forcemain, as well as resiliency for the area's overall conveyance sewage system. As the lead design firm on the project, GHD was tasked with all of the pre-design investigation as well as the design, bid, and build process, and coordination of all activities related to approvals and construction.

The work involved mining through highly variable ground conditions so concrete forcemain could be laid for a 5.6 km-long sewage pipe running parallel to an existing 36-year-old forcemain through the heart of Newmarket, a city of 85,000. The objective was to provide a dual forcemain system to ensure resiliency in operations and maintenance for the system.

A key requirement was to use a construction method that would have the least social and environmental impact due to the area's highly congested urban setting and natural environment. The solution was microtunnelling construction of a two-pass system consisting of a new forcemain within a micro-tunnel carrier pipe.

Part of the initial investigations included a phased geotechnical program to evaluate ground conditions and later identify where additional geotechnical information was needed to mitigate risk during construction. Part of the process also included establishing value engineering sessions with construction leaders for guidance on the capabilities of the tunneling equipment and procedures to be specified within the design.

Project Scope

The project's engineering scope included all preliminary geotechnical, hydrological, and archaeological site investigation and environmental studies, route evaluation and selection, constructability reviews, geotechnical data, and geotechnical baseline reports. GHD was also tasked with hydraulics modelling, geotechnical settlement analysis, noise impact assessment and attenuation, detailed design, environmental management, and a comprehensive public engagement program.

From a design perspective, GHD was responsible for all approvals, contract document specifications, development of cost estimates, tendering and construction contract award, review of shop drawings, contract administration, and construction site inspections. GHD was also responsible for administering the commissioning and warranty of approximately 5.6 kms of 1,050-millimetre diameter concrete forcemain to be installed via microtunnelling in a 2,250-mm diameter tunnel.

Public Engagement

Mitigating the impact of the YDSS Project on the community was a high priority in the planning process. Since the project included crossing several regional roads and three live regional transit railway lines, accommodating daily high traffic and rail times was paramount to keep residents getting to work and school on time.

A robust stakeholder engagement program involving agencies, landowners, town staff, Indigenous Peoples, and the general public was implemented to ensure all residents were aware of times when their travel would be impacted. The stakeholder program was also used to communicate the measures being taken to mitigate the impact on the area's various water crossings and local conservation lands such as Fairy Lake and Bailey Ecological Park, a 10-hectare bird and animal sanctuary.

Project Legacy

Having a new forcemain in place allows York Region, for the first time in over 40 years, to inspect and maintain the original forcemain when repairs are needed.

This fast-paced project included the successful construction of two of the longest curved microtunnel drives in North America, measuring 820 m and 1,132 m in length respectively. In less than a year, the project team successfully completed all eight micro-tunnelling drives, including installation of carrier pipe and construction of chambers.

Complexity and Challenges

The proximity to conservation land, numerous water bodies, and adjacent critical infrastructure were some of the many challenges faced by GHD.

In order to access the launch and retrieval shafts, a number of temporary roads and bridges had to be built. The shaft locations were constructed of crushed stone, filter fabric, and cellular web product to account for soils with low bearing pressure. In addition, these materials would help ensure storage volumes for flood events within the watershed were maintained.

It was initially estimated the project would take more than four years from start to finish if tunnelling operated within York Region's standard construction hours of 7 am to 7 pm with the use of a single machine. A number of accommodations – from carefully placed shielded lights, sound walls, and silenced generators, to restricted nighttime deliveries to and from tunnelling shafts – resulted in favorable community sentiment and support for the project. This eventually led to construction being allowed to take place 24 hours a day, six days a week, with multiple tunnelling machines. As a result, the project was completed in just over one year.

Details as the Baseline for Quality

Careful consideration was given to the design of the tunnel's alignment. The appropriate tunnel easement width and horizontal curves were selected to allow the use of precast tunnel segment without the need for hydraulic joints. Vertical curves were selected in certain areas to promote clearance to existing natural water bodies and minimize the depth of shaft construction. Curve radii, while employed within the design, were kept to a minimum deflection angle to maximize forward thrust from the jacking frame hydraulic cylinders. Hydraulic pressure within the jacking frame was monitored continuously, as was the sampling of the soil to ensure consistency with the geotechnical condition stated within the geotechnical baseline report.

Utilizing the latest technology, the microtunnelling machine was operated in a manner that allowed for the monitoring of continuous face pressure. This meant the earth could be excavated in a controlled manner, minimizing face loss and settlement to the utilities beside and above. The face of the tunnelling equipment was armed with rear loading cutting disks and tools that would accommodate for the excavation of the highly varied soils with the potential for cutting through large cobbles and boulders. The tunnelling equipment was specified with face access as a mitigation measure to accommodate changing out of disk cutter should it become necessary. Hyperbaric intervention was also used to give workers safe access to the face of the tunnelling equipment under pressure.

Technical Excellence and Innovation

It was critically important for the project to have as little impact as possible on the surrounding area's urban setting, and to ensure protection of the East Holland River floodplain and natural environment setting, which cuts through the heart of Newmarket. As a result, the 5.6 km pipeline was constructed with a limited number of shafts and with the rare use of back-to-back microtunnel drive lengths in excess of 500 meters. Extensive geotechnical analysis, along with value engineering consultation and risk mitigation actions, provided the Region with added confidence for the project to proceed as designed.

The placement of shafts was key to productive mining, so shaft sites were selected using a carefully established decision matrix. These sites allowed for the delivery of material along a controlled haul route to minimize community traffic and noise impact. All equipment and material entered the shaft and was installed within the shafts and the newly constructed tunnelled sections. Even though microtunnelling took place 24 hours a day, traffic to the shaft locations was restricted to regular construction hours. This required all excavated material and new precast tunnel segments to be supplied strictly within a 12-hour window.

Constructing the forcemain within the tunnel also required a unique approach. This meant using pre-stressed cylinder pipe segments within the precast tunnel sections to address the internal pressures from the forcemain as well as the external soil loads. Pipe segments had to be carefully placed within the tunnel to account for both horizontal and vertical curves and all connection points. Pipe segments would need to be interconnected, blocked in place, tested and then the annular space filled with grout to ensure system reliability.

It Takes a Village

The planning efforts of York Region leading up to the project were critical in laying an important foundation for success. Up-front community consultation, engineering studies, and quality assurance efforts all contributed to the successful completion of the project—ahead of schedule, within budget, and mindful of the needs of the community.

York Region listened to community concerns and responded with practical solutions to address traffic concerns, noise, vibration and light issues, tree and wetland protection, as well as minimizing disturbance to existing utilities. The project minimized the number of tunnel shafts to ensure community services would not be adversely affected.

The natural environments of the Town and the East Holland River Flood plain were protected by reducing shaft compound size, selecting locations outside the flood plain and maximize the spacing between shafts. With microtunnelling being used as the construction method, long distances of forcemain could be installed between shafts. This meant trees and vegetation were not disturbed and parkland remained in use throughout construction.

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LIVING WITH WATER IN NEW ORLEANS

By Luke Carothers

THE CITY OF NEW ORLEANS in Louisiana is among the most revered cities in the world for its rich history and vibrant, diverse culture. A strong component of this cultural tradition is a sense of enduring resiliency, which is demonstrated through continually rebuilding after large-scale weather events. With much of the city located below sea level, it is no wonder that the citizens of New Orleans are experienced in dealing with floods brought on by hurricanes.

One New Orleans neighborhood–known as Gentilly–has seen more flood damage than most. The first residential neighborhoods in the Gentilly area were constructed in the early 20th century when residents piled earth on top of swamp land to create terraced homes. With Lake Pontchartrain bordering it to the north and Bayou St. John to the west, Gentilly is uniquely susceptible to intense flooding events. During Hurricane Katrina in 2005, Gentilly was among the hardest hit areas of the city when the London Avenue Canal Floodwall was breached in two places.

As a result, subsequent improvements in disaster preparedness have been proposed and undertaken by the City of New Orleans to improve the safety of the people living in the neighborhood. In 2015, the U.S. Department of Housing and Urban Development introduced the National Disaster Resilience Competition. The City of New Orleans participated by submitting a proposal to create the City's first Resilience District in the Gentilly neighborhood.

Known as the Blue and Green Corridors project, the City's proposal focuses on overarching goals such as: reducing flood risk, reducing subsidence, improving the community's quality of life, and encouraging economic growth and social revitalization. To achieve these goals, there will be a combination of projects and efforts within the community that focus on innovative solutions to water management.

The City's proposal was accepted and they were awarded $141 million in funding in addition to funding previously allocated through the U.S. Federal Emergency Management Agency's Hazard Mitigation Grant Program. The City chose Stantec to lead the project, and they have developed a number of solutions that improve the area based on a triple bottom line analysis–flood reductions, healthier lifestyles, and economic activity. By building a team that includes engineers, landscape architects, and planners, it is clear the project was approached from a more holistic perspective. More specifically, a triple bottom line analysis not only looks at the cost of completing a project, but also value added by factors such as air & water quality, public health outcomes, public education, and heat island effect.

According to Bernadette Callahan and Dan Grandal, much of the work surrounding this project represents a "paradigm shift toward what it truly means to live with climate change…providing an example of a path to success to communities aspiring to resilient and sustainable living."

This paradigm shift also applies to changing from the traditional approach to water management to something called "Living with Water". Traditionally, cities such as New Orleans rely on a water management system that collected stormwater runoff in pipes that led to pump stations. Despite having some of the largest pumping facilities in the world and making improvements such as high levees, the area still struggles to deal with over 60 inches of rainfall annually as well as rising water from climate change.

"Living with Water" aims to lessen the burden on the City's stormwater system by introducing "infiltration-based green infrastructure practices and strategic storage solutions", according to Callahan and Grandal. More specifically, this means constructing, planting, and growing vegetated systems that are capable of managing stormwater runoff. Consisting of elements such as stormwater bumpouts and rain gardens , this green infrastructure "mimics the natural environment and predevelopment flow patterns by slowing stormwater runoff and giving it a chance to infiltrate back into the ground". In an area such as New Orleans, re-introducing water into the ground is particularly important due to the high clay content. Keeping the clay-based soil consistently wet helps prevent soil subsidence.

The team at Stantec also had the community in mind when working on the Blue and Green Corridors project, employing a concept known as the "Complete Streets" approach. In essence, the "Complete Streets" approach is predicated on designing streets that prioritize safety, comfort, and access for everyone who uses a street: walkers, runners, bikers, and vehicles. Because the team at Stantec completed extensive community outreach in the planning stages for the project, they were able to design in such a way that puts the community first. This includes steps such as including high visibility crosswalks and accessible curb ramps, but it also includes strategically placed infrastructure, such as the stormwater bumpouts, to slow vehicle speeds and reduce the distance between crosswalks.

According to projection models, improvements made by the Blue and Green Corridors project even have the potential to reduce flooding, even in the areas surrounding the project, by up to six inches. This highlights the potential of the system, and it demonstrates a path forward to reducing flooding in the City of New Orleans by building new systems that work in tandem with the old.

In a community where flooding is at the forefront of concerns, the Blue and Green Corridors project is proof that we can use new, innovative techniques to supplement our previous understanding in order to improve the lives of those who live in the community.

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CALLING IN THE K-9 UNIT FOR WATER LOSS: TENNESSEE HOME TO NATION'S FIRST PRIVATE WATER LEAK DETECTION DOG FOR HIRE

By Esme Rye

MEET GAUGE RYE, the first privately-owned leak detection dog in the United States. In January of 2020, Seth Rye of Rye Engineering PLC, a Tennessee engineering company specializing in water loss management was forwarded an article by two utility district clients. The article featured a leak detection dog that was trained for Central Arkansas Water. From there, Seth's wife, Pam took over and began researching this wonderful development in water loss management.

Pam was able to contact Carrie Kessler and Tracy Owen of "On the Nose" Water Leak Detection Dogs of Roland, Arkansas who agreed to complete the training of a rescue dog named Gauge as a leak detection dog for Rye Engineering. When the Rye's first met Gauge in March of 2020, he was already trained for obedience and imprinted for leak detection by On the Nose with help from a prison program in Arkansas known as "Paws in Prison". This program allows for training of dogs by inmate handlers working alongside professional animal trainers like Carrie and Tracy.

Since Gauge's training was completed and he was delivered to the Rye Engineering on January 24, Pam Rye has taken the role of Lead Handler for Gauge with Seth taking the role of Co-handler. "I schedule a working session for Gauge each weekday. Sometimes it is 15-20 minutes and other times it is closer to an hour. This keeps his skills sharp and reinforces what he already knows about finding water leaks. Seth takes him on a Saturday hunt and is getting him ready for upcoming scheduled leak detection activities this spring," said Pam Rye.

Canine leak detection is a method where specially trained dogs are used to detect the smell of Chlorine in potable water. The dogs are imprinted with tiny amounts of chlorinated water when they are young. "We imprinted Gauge by introducing exceedingly small amounts of tap water to him. The first samples were on a Q-tip," said Kessler.

After imprinting, the dogs undergo regular training. "Its important to constantly vary their exposure to leak situations. Proper training will ensure that the animal knows its job is to find leaks," explained Kessler.

Rye Engineering plans to use Gauge in a wide variety of leak detection situations including but not limited to the following:

1. Cross-country water lines
2. Water transmission mains
3. Follow-up surveys to satellite leak detection
4. Emergency leak detection
5. Quiet leaks



"Gauge has been well trained, but it will be up to us to figure out where he can be used most effectively," said Pam Rye. "He is more than just a tool for leak detection. What sets him apart from conventional leak detection tools is the fact that he can think, he can adapt, and he has a real drive for what he is doing," explained Rye. The company plans to introduce him into a variety of situations this spring where he will supplement the efforts of the leak detection crews.

Gauge will have the same range as Rye's existing array of water loss services as he is used to car travel and is a trained service dog with public access. "Because of his public access training, Gauge can enter public buildings, hotels, airports, and other areas with his handler. This will make traveling hours from home and staying out of town for water loss projects very practical," said Rye. We can easily take him all over Tennessee and the surrounding states by car and to farther jobs by airplane if needed," she explained.

So why do all of this when there are already proven methods of water loss control? "The water loss industry is relatively young in the United States and it is developing rapidly and continually evolving. As practitioners, we have a duty to explore the latest technologies and methods as they become available. The introduction of canine leak detection into the industry is truly one of the most exciting and potentially satisfying developments that I have encountered since we've been in business," said Seth Rye. Rye also believes that dogs can fill an important void that to date even the most sophisticated leak detection technologies have struggled with, leak detection on PVC water mains. "We train the dogs to detect by smell. A dog's nose is so much more powerful than its ears," explains Carrie Kessler of On the Nose. Since PVC water mains do not conduct sound very effectively, Rye believes that a new approach using scent is very promising to the industry.

For now, Gauge is happy to do the job he was born for. His people believed in him and believed that his special nose knows how to help save our most precious natural resources. He can't wait to get to work for you.

For more on dogs preventing water loss, see our article about Vessel.

A TEXAS-SIZED ENDEAVOR

HOUSTON PUBLIC WORKS' NORTHEAST TRANSMISSION LINE TAKES SHAPE

By Christine Kirby and Kevin Tran

THINGS ARE INDEED BIGGER IN TEXAS. And Houston's Northeast Transmission Line is no exception. After a decade of astonishing 21.6 percent population growth, the Houston region is expected to double its current population by 2050. To keep up with projected water demands, and in response to the Harris-Galveston Subsidence District mandate to reduce groundwater pumping along the Texas coastal region, the City of Houston partnered with regional water authorities to build the Northeast Transmission Line (NETL).

The NETL program, Houston's largest water transmission program yet, is full steam ahead. The project will convey 365 MGD of treated surface water from the newly expanded Northeast Water Purification Plant (NEWPP) through 16.5 miles of primarily 108-inch steel water line from Lake Houston to west of IH-45 with various take-points and interconnections along the way. The water line will also provide redundancy for areas serviced by the existing 66-inch waterline along the Greens Road corridor.

"Houston Public Works is integrating multiple segments into one massive pipeline. Once complete, the City will be able to increase surface water usage to help minimize subsidence and flooding," said Panduranga P.K. Kuruva, P.E., managing engineer for Houston's surface water program. "Increasing water capacity is vital to meet Houston's growing demand."

By the Numbers

Houston Public Works divided the 16.5 miles into 13 construction contracts. With most of the line being 108-inch diameter, the projects also included 120-inch, 96-inch, 84-inch, 66-inch, 54-inch and 42-inch diameter interconnections. All 16.5 miles of steel water line was manufactured in Texas factories with more than 21,700 metric tons of domestically sourced steel coil. The total construction cost is nearly $450 million, with 26 large diameter isolation valves, more than 17,000 linear feet of tunnels, and over 100 easement parcels. Once the Northeast Water Purification Plant (NEWPP) Expansion is completed, the NETL will serve more than 900,000 homes in Harris County.

"A project of this magnitude required years of planning and extensive collaboration," said Mackrena Ramos, P.E., vice president at Lockwood, Andrews & Newnam, Inc. (LAN), a national planning, engineering and program management firm that is serving as the technical advisor. "Just the sheer size of the project makes it unique, but the number of individuals it took to make it a reality is quite amazing. From the City team to their partners, engineers, utility coordinators, manufacturers, and contractors' workforce, we all had a vested interest to meet the water needs of Texans."

Texas-Sized Challenges

For a project of this scale, challenges of equal magnitude were faced throughout the design and construction process.



The 13 segments were organized in three phases, known as the eastern projects, the western projects, and the "workaround solution". The workaround solution – three projects which fell in the middle of the alignment – was designed and built first as it could be placed in service with interconnections to the existing system on each end. This created a long bypass for a segment of the existing 66-inch water transmission main along the Greens Road corridor. The first of the projects began construction on summer 2018, and the workaround solution was placed in service by fall 2020. The City was able to isolate part of the existing 66-inch main for condition assessment and rehabilitation, all while the eastern and western segments were still in construction. By the spring of 2021, a much-needed repair was successfully completed on the existing 66-inch water line, which is a major source of water for the City and surrounding areas, including George Bush Intercontinental Airport.

"The internal repair of the existing 66-inch main was crucial to restoring service to an essential line within the NEWPP service area. The interconnection between the 108-inch and 66-inch was on the critical path during design and construction. Now complete, the interconnect and repair provide operational flexibility and longevity to the two systems," said Ramos.

Part of the workaround solution included a 1,163-foot tunnel under IH-69 at Aldine Bender Road. The freeway consists of 15 elevated

main lanes and eight frontage road lanes at this crossing location. The tunnel alignment stretched between bridge columns, and soil conditions included fine sand and silty sand under the groundwater table. Harper Brothers Construction, LLC procured an earth pressure balance machine (EPBM) and successfully completed the tunnel between January to March 2020.

Another challenging aspect of this large-scale waterline project was construction staging and access within an urbanized area. Easements ranged in width from 50 feet to 90 feet, with many of the parcels on developed land. Existing utilities, surface features such as driveways, parking lots, trees, landscaping, and monument signs were within close proximity to the proposed construction work. Contractors needed every inch of space for equipment and material staging, and this was a major consideration during the design phase. Design engineers identified conflicts and worked with private utility owners to relocate overhead and buried utilities to make way for construction. Relocations of easement encroachments, such as monument signs, landscaping and fences, were identified by the design engineer and coordinated through the City in advance of construction.

The City's public engagement team's primary goal is to engage, educate, and inform the community. They conducted community meetings to provide information to residents and business owners for the upcoming construction work. The meetings, held after the contractor was selected but before construction work began, allowed attendees to interface directly with the design team and contractor's representatives.

"Transparency is key for any large project like this. Houston Public Works relies on the community's support to ensure success throughout construction and implementation," said Kenya Williams, public engagement team for Capital Projects. "Our engagement team made sure to address any challenges and concerns before construction began."

Each standard 40-foot-long pipe segment, weighing 35,000 pounds, arrived on site on an 18-wheeler truck. Once the pipe arrived, it was offloaded in a location as close as possible so that the excavator could reach it without having to travel a long distance. To lift and move this pipe, a 70 metric-ton excavator was needed. Harper Brothers Construction used a Hitachi 870, a slightly larger tracked excavator, to perform the double duty of lifting the pipe and excavating a deeper trench. Stabilized construction roads were built within easement areas so that 18-wheelers, dump trucks and other vehicles could enter and exit the job site. Where pipe and materials could not be stored on site, a secondary laydown area was used.

"One of the biggest challenges with construction projects in urban or semi-urban settings is the logistics. To overcome the space constraints on site, we had to have a thorough site plan. We staged our materials in a way that allowed for fluid movement of the crew through the line. The key to a successful project is a solid plan," said Jon Harper, CEO of Harper Brothers Construction, LLC.

When the COVID-19 pandemic struck the Houston area in March 2020, quick thinking was needed on the part of the City's team. Two of the western projects had advertised for bids, but the mandatory pre-construction meeting had not yet been held. There was no room for delay, so the team quickly converted the meetings to a virtual format, and attendees were able to call in by phone or log in through a computer. Monthly progress meetings were converted to a virtual format as well and are still being conducted this way today. Safety of the field crews and support staff, all considered as essential workers, were of the utmost priority. Face coverings and hand sanitizer were provided, along with implementing social distancing and contact tracing for crews. Teams quickly adapted to new restrictions and safety protocols, and field activities never missed a beat.

"For the NETL project, all the materials were local and made in Texas. Therefore, we didn't have major delays. We were fortunate that we did not have any severe cases in our workforce," said Harper.

On February 15, 2021, temperatures across the state plunged into record-setting, sub-freezing conditions, resulting in widescale electricity outages that lasted for several days. In a matter of hours, chemical plants along the Texas Gulf Coast underwent swift unplanned shutdowns, disrupting global supply chains, and triggering a shortage of raw materials, including polypropylene and polyethylene. As a result, a shortage of materials such as PVC pipe and protective coatings for pipelines is looming over the NETL and the construction industry. So far, manufacturers and suppliers have met commitments, but impacts from the Texas freeze will be felt for months to come.

Where We Are, and Where We're Going

To date, seven segments have been completed and placed in service. Six segments are currently in construction, and the entire NETL is expected to be completed by late 2022.

"The Northeast Transmission Line is more than ten years in the making and will be the largest water line for the City of Houston," says Kuruva. "Our purpose is 'Together we create a strong foundation for Houston to thrive' and the Northeast Transmission Line embodies our goal for improved water service across the area."

Houston's legacy continues with its trail-blazing water infrastructure expansion initiatives. Thanks to these initiatives, the City of Houston's drinking water system maintains a "Superior" rating, the highest rating for water quality issued by the Texas Commission on Environmental Quality.

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WASHINGTON PROJECT RESTORES WATER FOR FARMERS

EXCESSIVE PUMPING CREATED 200 FOOT FALL OF REGION'S VITAL AQUIFER

By Thomas Renner

RESIDENTS OF THE UNITED STATES are faced with a number of concerns, particularly issues with the nation's crumbling infrastructure. One resource that is of particular distress, especially in the western U.S., is water availability. There are multiple reasons why some communities are water-starved, including drought.

Groundwater depletion also contributes to water shortage issues. The U.S. Geological Survey reports several regions have seen shrinking levels of groundwater. In New York, counties on Long Island have seen the water table lowered and saline groundwater has moved inland. Land subsidence issues extend from West Central Florida to the Southwest desert and even into the Pacific Northwest.

A recently completed project in Washington, however, aims to restore the precious resource that people, especially the region's widespread farming community, depend upon. The first pumping station of the Odessa Groundwater Replacement Project will provide water for up to 10,500 acres. The project, called EL47.5, includes nearly nine miles of pipes. The $20.8 million project started in 2016, and was redesigned in 2017-2018 after a grant allowed for additional capacity. Construction was completed in late summer 2020 and became operational in the spring of 2021.

The project will eventually include nine systems to offset the rapid decline of the Odessa Aquifer, which has fallen more than 200 feet since 1980. For a community wrestling with water issues for more than 40 years, the project will bring much-needed relief.

"It's nearly 200,000 people and over a dozen, maybe two dozen small communities that really represent the fiber and the structure of the Columbia Basin and agriculture and farm communities as we know them," said Vicky Scharlau, Executive Director of the Columbia Basin Development League.

Unique Solution

EL47.5, which is named for its distance from the start of the East Low Canal, includes six pumps and a pump house. It is the first of nine proposed pressurized pipeline systems being built to deliver Columbia Basin Project surface supplies to replace groundwater use on 87,000 acres across Grant, Adams, and Lincoln counties.

"Water is ordered daily, conveyed through the East Low Canal and delivered on a 24-hour basis," Scharlau said. "The water is sent down the canals and the pumping station is just one of many outlets that takes water from the canal and distributes it to the different lands."

EL47.5 is one cog in the Odessa Groundwater Replacement Program.



The systems are part of the larger Columbia Basin Project, which currently serves approximately 680,000 acres.

The scope of work for the Odessa Groundwater project is far-reaching. Workers widened 46 miles of the East Low Canal, constructed seven siphons, will add seven radial gates and replace 12 bridges.

"Lands are all upslope from the East Low Canal, so pumping is a necessity," Scharlau said. "Open channel flow deliveries were financially prohibitive and would require a new canal system to be built. Besides regulatory hurdles, costs were estimated in the billions. For this situation, this was the best option for water delivery to farmers."

EL47.5 is the first pumping station in the expansive Odessa Groundwater system, and teams faced a series of challenges that hopefully will be reduced in subsequent stations. "Regulations, costs, and easement issues were overcome by time and perseverance," Scharlau said. "Along with typical construction issues. Once it was designed, construction was pretty smooth. The pandemic occurred during construction of the plant, and that certainly didn't help."

Powerful Pumping Station

Water is pumped through the system via a 12,800 square feet pump station, which will push out up to 73 million gallons per day.



The station includes one pump of 700 horsepower, and 5 pumps of 1,250 hp. The powerful system can deliver more than 63,000 gallons per minute. The station has a delivery capacity of 10,500 acres, pumping water at 140 cubic feet per second at 345 feet total dynamic head. The pumps pull water out of the canal and are delivered based on daily orders of irrigators who bought water on long term contracts.

The intake structure includes a sump that is 35 feet to 86-feet wide, 80 feet long and 18 feet deep. It includes 820 cubic yards of concrete and 145,000 pounds of rebar. The pumps deliver water to 46,892 feet (8.88 miles) of pipelines that are 14 to 60-inch in diameter with 15 turnouts.

"This is the first pumping plant in the project and the lands that it serves is what makes this pump station unique," said Jon Erickson of the East Columbia Basin Irrigation District and project manager of the Odessa Groundwater Replacement Project. "This is an important step in getting water to the farmers that need it."

The ECBID designed the pumping station, which was built by Goodman & Mehlenbacher Enterprises, Inc.

Accessing Pumps

The pumps are an important part of the project, but installing and accessing the pumps when they eventually need replacement was one of the important design considerations in the station's construction.

Teams will access the pumps through six roof hatches manufactured by The BILCO Company. The custom hatches, 6-feet, 6-inches x 7-feet, are fabricated with polycarbonate dome covers for natural daylight and engineered lift assistance for easy, one-hand operation. They are also modified for hand winch operation, allowing them to be easily opened and closed from inside the building.

The aluminum hatches, which were supplied by Anderson Specialties, were custom-fabricated to meet unique size requirements. "They were proposed by the contractor and met the specs that we required," Erickson said. "They were also important because they allowed pump and motor access by crane."

Subsidence Issues

The issues with groundwater depletion that Washington is encountering is common throughout the United States. The problems, however, go deeper than the lack of water.

Sustained groundwater pumping also leads to a multitude of other issues. Deterioration of water quality, increased pumping costs, drying up of wells, and reduction of water in streams and lakes are some of the consequences of overreliance on aquifers. So too is land subsidence, which is the gradual settling or sudden sinking of the Earth's surface due to removal of subsurface materials.

Subsidence occurs when large amounts of groundwater have been withdrawn. The layers within an aquifer compact and settle, resulting in lowering the ground surface.

A study this year reported that 19 percent of the world's population will be affected by land subsidence by 2040, accounting for 21 percent of the global GDP. One of the most extreme examples of land subsidence has occurred in California's San Joaquin Valley, a large farming community. Since the 1920s, excessive pumping of groundwater at thousands of wells has caused land to sink as much as 28 feet (8.5 meters).

Eastern Virginia has also experienced land subsidence with overuse of the Potomac Aquifer. Like the Odessa project, officials have executed a plan to enhance sustainability of the region's long-term groundwater supply.

The solution, however, is dramatically different as it uses highly treated water that would otherwise be discharged into the Elizabeth, James, or York Rivers and treats it to meet drinking water quality standards. The water is then added to the Potomac Aquifer, which is the primary source of groundwater throughout eastern Virginia.

A report in 2020 from Old Dominion University and NASA's Jet Propulsion Laboratory found that Norfolk and Virginia Beach are subsiding at the rate of approximately 3.5 millimeters every year. The report confirmed less technical observations, but also delivered one surprise. The rate of subsidence varies by neighborhood, sometimes by as much as 15-20 percent.

Critical Industry

As an important economic driver in the region, water from EL47.5 and the Odessa Groundwater project will be critical to the farmers, families and businesses. Maybe farmers could have continued to draw water from the aquifer. Maybe, though, the aquifer might eventually go dry. That's not a chance the region is willing to take.

"It is only speculative what and when would have happened without the project," Scharlau said. "However, trends have shown a consistently declining aquifer."

The U.S. Bureau of Reclamation said more than 700 irrigation wells were drilled in the Odessa region. In June 2017, the Washington Department of Ecology issued cease and desist orders requiring landowners to stop pumping groundwater. In December 2017, the Department fined landowners for illegally pumping more than 500 million gallons of groundwater from the aquifer to water 530 acres of crops that included potatoes, alfalfa, and timothy hay.

Agriculture is an important component in the Washington state economy. The state is the third largest food and agricultural exporter in the United States, generating $10.6 billion in revenue across 39,500 farms and ranches. Water is a critical resource, and the Odessa Groundwater Replace Project will be instrumental in helping farmers maintain their livelihood.

While a labor intensive and sophisticated solution, the project illustrates a creative solution toward solving an infrastructure problem that faces many U.S. communities.

THOMAS RENNER writes on building, construction, engineering, architecture, and other topics for trade industry publications throughout the United States.

LANDFILL OR STORMWATER DETENTION?

THE CHOICE IS OBVIOUS ACCORDING TO THIS P. E.

MANY TIMES, a site will need to be drastically excavated and sculptured to meet the building requirements. This naturally includes leveling but also importing soil to fill voids. Grooming the site can be used to great advantage to meet the continuing importance of controlling water flow and quality according to Bill Shelton, P.E. Senior Civil Engineer at ZMM Architects & Engineers (Blacksburg, VA).

Primarily focused on projects in Virginia, Shelton works to help his clients meet the Virginia Department of Environmental Quality's regulations for stormwater. "The Department of Environmental Quality has some pretty stringent guidelines for water quality and quantity," he said.

In early 2021, Shelton and his team completed a project that required a stormwater management system that could handle up to nearly 2.5 million gallons of water. "This system is one of the largest we've designed. It can manage a 100-year storm with the volume capacity it has."

"According to the plans, this new construction would increase the amount of impervious area to nearly 25 acres, which included all the associated loading docks and employee parking lots and road paving, plus there would be a 350,000 square foot building on the property. This all added up to a significant impervious area and meant that we had quite a bit of water to control and store. It's a pretty substantially sloped area which would require a lot of cut and fill. I figured that since the area would need to be filled in, we might as well use the storm water detention system to help bring it up to grade."

"The way our system works is that we collect all the water, run it though a water filtration units for pre-treatment and then into the chamber units that have an added section to trap additional sediment."

The stormwater management system consists of four beds of underground detention chambers to handle 330,000 CF of storage. More than 1,700 ADS StormTech® MC-4500 chambers were utilized to improve water quality and for storage. For the removal of total suspended solids (TSS), the StormTech Isolator® Row was incorporated into each unit. "StormTech with the Isolator row gives us a leg up on meeting the quality and quantity requirement," Shelton stated.

For pretreatment, each of the units in the system is equipped with an ADS Barracuda® Hydrodynamic Separator in either four, six or eight-foot diameter. The fourth unit, a 3K ADS BaySeparator® water quality unit with a 60-inch diameter and an eight-foot depth and two 60-inch manholes, was placed upstream for additional treatment due to the volume of the water entering that particular chamber unit. The BaySeparator utilizes three flow paths to route stormwater between the precast structures and trap pollutants, keeping them separate until they are removed during routine maintenance.

The Barracuda is a high-performance vortex hydrodynamic separator designed to remove 80 percent of total suspended solids to protect the public waterways. It does this by using density differences and gravity to remove suspended solids and floatables from stormwater runoff. Named for its "teeth", the Barracuda mitigates turbulence in the sump area to prevent resuspension of captured contaminants.

The chamber units drain to a common point using ADS N-12 corrugated HDPE pipe for conveyance of the water to the pond. ADS Nyloplast® Water Control Structures were used for the stormwater basins. A key feature is the ability for the installer to make changes "on the fly", which was important given the terrain. For example, if the inlet is sitting above grade, the PVC riser can easily be cut flush to grade. Or if the riser ends up sitting below grade, the inlet can be raised up using extension pieces. The project utilized 30 ADS Nyloplast® PVC curb/drop inlets.

Because mostly in-fill material was used and there were concerns of infiltration of fines into the conveyance pipeline, Shelton specified 9,000 linear feet of ADS N-12® corrugated high-density polyethylene (HDPE) pipe with watertight connections. The storm water system used InsertaTee® for lateral connections.



"The StormTech system combined with the Barracuda is a great combination that addresses stormwater quantity and quality on all sizes of projects," he offered. "The StormTech online design tool, specifications, details, and knowledgeable engineering staff made this one of the easiest and cleanest systems to design."

"This chamber system is just such an easy system to model on the computer, it's easy for reviewers to understand and wrap their heads around, easy to maintain for the owner at the end of the day," Shelton explained. "So, we just really like using these systems. And because of the quantity of the water and the different areas the water was coming from, we decided to break it up into the four beds, which we located under employee parking areas. But we still didn't meet the DEQ requirement and so the water actually discharges from that system into an aboveground, extended detention basin that offers another amount of water quality and quantity to meet those requirements."

"The water does sit there for a while to settle out any remaining sediments, which would be minimal, if any. The pond holds the water and lets sediments settle out so that cleaner water will discharge through the upper layers of the pond. The pond does have a clay liner so there's really not much infiltration, but it does permit any sediments to settle out."

Selecting the Proper Systems

"We have used some different systems before. This included permeable pavements to other underground storage like the milkcrate container-type boxes. They all work. But what we found is that the StormTech and Barracuda for most of the clients we work for, especially a lot of school systems, they don't have the time and energy and the personnel to maintain these things. So, the ease of maintenance and inspection is huge in our minds particularly for our school clients because typically they are usually running on a tight budget and they can't really hire someone to inspect it all the time. So, they can just open an inspection port and look down in, stick a measuring rod in to see if the sediment has built up and that's it. It's easy. You don't have change the filter like you would in a cartridge system and you're not relying on plants that may live or die and need frequent replacement. Maintenance on the entire underground systems can be performed using a using a vacuum truck or comparable equipment."

"Typically, if we are going to do an underground system, it just makes sense to use the Isolator Row because the DEQ allows a 40 percent preliminary reduction, which can be accomplished just by putting that in. You're going to put in the underground detention so, you might as well get 40 percent of your water quality requirement while you're at it. A good design practice in an underground detention system is to filter out the water sediments and trash and everything, and the Barracudas are built for that in regard to getting the bigger stuff out before it even gets to into the underground system. "

"When doing an underground detention system anyway and you have to have the pretreatment using the Barracuda, why not add what little it takes to add an Isolator Row, and then you have around 60 percent of your pollutant removal level right there. It's a win-win. And it's usually pretty easy to convince the owners that it's a good way to go."



Filling in the Requirement Gap

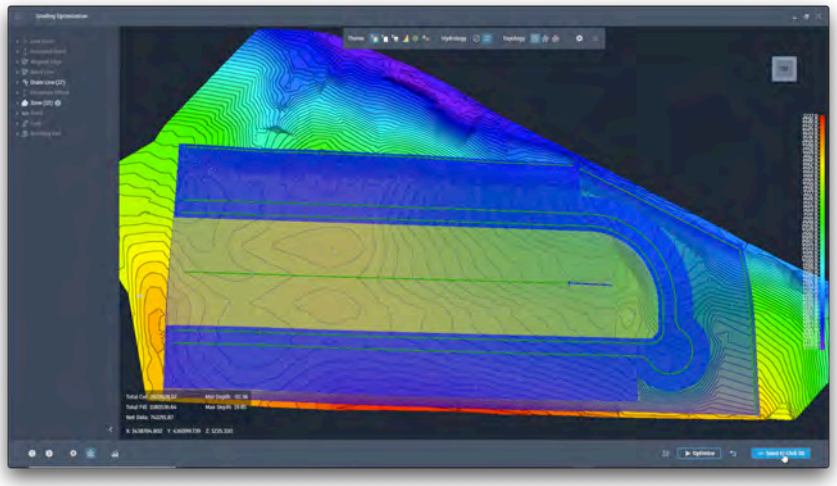
"A lot of times the owners can buy pollutant credits from a nutrient bank. Even when we have the Barracuda and the Isolator Row combination, for whatever pollutant removal that's left the owner can buy nutrient credits, even when those sediments or TSS are negligible. Unfortunately, as design engineers we're bound by the percentages that the regulatory agencies allow. Even when a lot of these systems can get up to 80 percent removal, the regulatory agencies only allow a certain percentage. But in reality, the water is coming out of there real clean."

About the Company

Advanced Drainage Systems is a leading provider of innovative water management solutions in the stormwater and on-site septic wastewater industries, providing superior drainage solutions for use in the construction and agriculture marketplace. For over 50 years, the Company has been manufacturing a variety of innovative and environmentally friendly alternatives to traditional materials. Its innovative products are used across a broad range of end markets and applications, including non-residential, residential, infrastructure and agriculture applications. The Company has established a leading position in many of these end markets by leveraging its national sales and distribution platform, overall product breadth and scale and manufacturing excellence. Founded in 1966, the Company operates a global network of 63 manufacturing plants and 32 distribution centers. To learn more about the ADS, please visit the Company's website at www.ads-pipe.com.

DESIGN AUTOMATION IS THE NECESSARY FUTURE FOR CIVIL INFRASTRUCTURE

By Theo Agelopoulos



A SERIES OF MOTIVATING FACTORS is incentivizing the rapid digitization of civil infrastructure design, engineering, and construction, as well as operations and maintenance. The cumulative events of global population expected to reach 10 billion people by 2050, climate change, and the recognition of the need to foster greater industry resiliency because of the COVID-19 pandemic, demand a more rapid digital transformation of the industry we all serve.

To put a finer point on this, the G20 nations-backed Global Infrastructure Hub estimates that by 2040, the world must invest some $94 trillion in roads and rails, homes, commercial sites, and other built structures to keep society functioning.

As countries emerge from the pandemic, now is the time to fundamentally rewrite the script for how civil infrastructure projects are delivered. To realize the ambitious targets for high-quality, resilient, and sustainable infrastructure, will require the acceleration of digital transformation in the industry.

Emerging technology drives better outcomes

Emerging technologies in design automation and generative design offer the civil infrastructure industry, including both the public and private sectors, new potential to deliver infrastructure projects more effectively. Outcome based design automation enables designers and engineers to set specific goals from the start – for example, saving time, optimizing costs, reducing materials usage, or improving sustainability – and increases the likelihood of meeting them upon completion.

Combined with setting parameters, design automation tools reduce repetitive, manual work, and are already demonstrating operational efficiency for designers and engineers, allowing them more time to innovate and to focus on design reviews for accuracy and quality, improving business growth and profitability.

Generative Design, another example of design automation, helps users explore solutions to complex design problems. Using cloud computing and artificial intelligence, it augments a designer's ability to optimize and validate design options, helping them make a more informed final design decision.

At global infrastructure firm Gannett Fleming, for example, the use of Dynamo for Autodesk® Civil 3D® on rail yard projects has slashed design time by generating the best site layouts for buildings and rail alignments.

"Conceptual design is a manual, tedious and time-consuming process. We automate the design process to get as close to the final design as possible at the beginning of the project, " says Stacey Morykin, Engineering Technology Manager at Gannett Fleming. "Generative design enables us to optimize a project and provide more value to our clients."

Optimizing the site design process

Infrastructure projects, regardless of type, often require leveling or contouring of the existing ground necessary to meet project specifications. This grading design is typically a manual, time-consuming process.

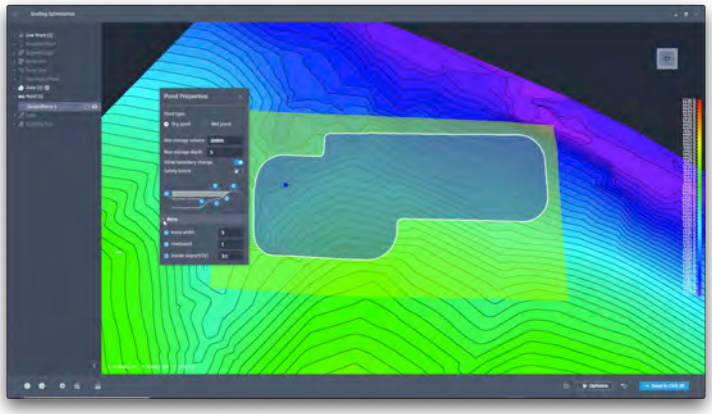
Automated grading design tools, which Autodesk unveiled in spring 2021, work with user-defined constraints, such as allowable elevations and slopes, to process a series of iterations to generate the optimal design proposal.

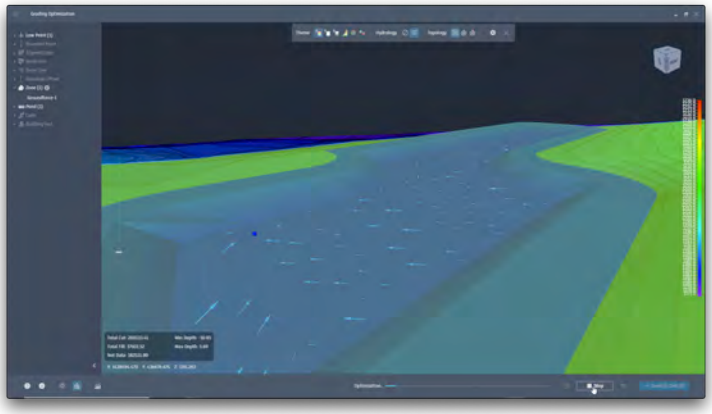
"Being able to define assets like parking areas, buildings and ponds, and assign grading criteria and let the computer provide options is a game changer," says Charles D'Errico PLS, IT Systems Analyst at Thomas & Hutton. "Traditionally, once the first grading solution was achieved, no other options would be considered due to time and budget limitations. Now, designers can evaluate multiple grading schemes, instead of the first valid solution."

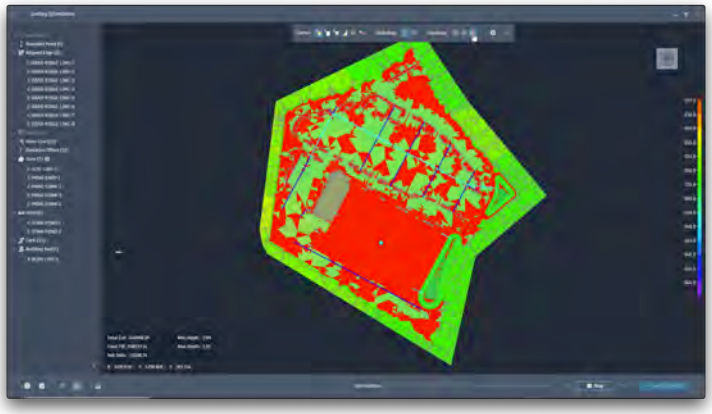
In a subdivision plan, automated grading design can help engineers more easily establish a balanced preliminary surface based on allowable slopes to zones within the roadway, roadway to building setbacks, and across building areas. They can efficiently generate a design proposal for the grading of a water detention or retention pond based on minimum and maximum storage depths and other constraints to accommodate storm water runoff. The technology also facilitates the identification of constraint violations between building pads, curb islands, parking lots, and other use requirements.

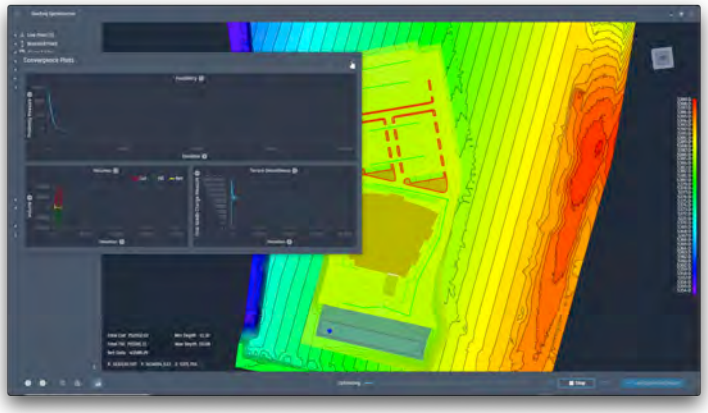
According to Gannett Fleming, they estimate that time saved by automating the grading design process could clock in at up to 50 percent.

"Grading is a labor-intensive and complex process. We have seen significant advantages when collaborating with vertical teams", says









Morykin. “We can share the terrain data quickly, enabling vertical teams to continue their design and allowing all stakeholders to make better and more timely decisions about the project.”

Enabling engineers to arrive at best-fit solutions earlier, automation and generatively designed terrain grading improves project outcomes while reducing costs and material waste.

What is next and how do we get there?

We understand the digital transformation of the civil infrastructure industry along the entire project lifecycle is now a must-do rather than a nice-to-do. Further, it is time to recognize we cannot tackle the challenges ahead by working in silos and relying on the status-quo approach to design, engineering, and construction of capital projects.

The first step is for the entire industry to embrace the inevitability of the transformation already underway and to also embrace automation as a partner for the work of industry professionals. We know it saves time and money and for the challenges ahead, we do not have much of either. Importantly, the evolution of our industry requires collaboration between the private sector and the public sector at all levels of government.

While the private sector continues to innovate and provide the opportunity to stretch limited natural and financial, the federal government can support the digitization effort by providing incentives for the advancement of technology in civil infrastructure. Earlier this year, Autodesk CEO Andrew Anagnost offered support to the new administration and Congress for this purpose in a series of policy suggestions to spur economic and job growth, and to speed up the pace of transformation.

Grading optimization is important not only for the efficiency it provides but also because it demonstrates the value of automated design in one specific component of a civil infrastructure project. Imagine the potential design automation offers across the entire lifecycle of a project.

This is the change we need and the change we require for the industry and for the public. Change is inevitable and it is time to look ahead to the future so as not to become overwhelmed by the challenges it will certainly bring.

THEO AGELOPOULOS serves as Senior Director for Autodesk’s infrastructure business, including industry, partnership, and M&A strategies. Theo played a key role in Autodesk’s business model transformation – specifically in Autodesk’s Architecture, Engineering and Construction business – and he has extensive experience enabling digital transformation. He is recognized for his leadership of technology-based disruptions impacting the AEC industry, including CAD, BIM, GIS, Cloud, Reality Capture, and AI/ML. Today, Theo’s team leads the design automation evolution, including the release of Autodesk Grading Optimization for Civil 3D, a tool supporting engineers in a more efficient, rapid, and accurate approach to terrain grading.

CUTTING THE COST AND TIME FOR STOCKPILE SURVEYS IN HALF WITH DRONES

By Sally Huynh

TODAY, DRONES ARE DELIVERING survey-grade accuracy in a fraction of the time at half the cost of conventional inspections. State transportation agencies are discovering that the return on investment in drone technology is attractive regardless of state geography and size, from populous states like Ohio and Minnesota to small, rural states like West Virginia.

Other common department of transportation uses for drones include traffic monitoring, disaster response, construction progress updates, ice control, snow removal, and inspections of pavement, high-mast light poles, and bridges. When West Virginia's transportation department started to consider using drones for some of their work, they had to overcome some objections. "Just three or four years ago, if you were working with photography drones for mapping, you were finding the data to be what we called geographic information system (GIS) at best," says Travis Long, chief of surveys at West Virginia Department of Transportation (WVDOT).

But West Virginia's Environmental Protection Agency (EPA) was already delivering impressive results with drones and it caught WVDOT's attention. "Between 2017 and 2019 things greatly improved with the mapping software," Travis notes. "The accuracy and the ways to verify the data have become easier."

Since WVDOT launched a proof-of-concept program in 2018, the early skepticism about drones has given way to enthusiasm. The agency reports it is achieving remarkable gains in accuracy, efficiency, cost savings, and safety for one of its most onerous tasks. Here's how the department of transportation transformed what has always been expensive, accident-prone work—surveying aggregate stockpiles—for the better with drones.

Replicating Drone Use Established by the State EPA

In many states, the gateway agency for drones is the department of transportation. In West Virginia, the state EPA was the early adopter, turning to drone operations for watershed delineation and reclamation work estimates.

To cut the cost of acquiring high-quality GIS data as part of reclamation site surveys, West Virginia EPA (WVEPA) started using survey-grade GPS and advanced photogrammetry software to analyze images captured by drones. The high-resolution data on reclamation sites they produced quickly proved the accuracy and value of the drone program.



As an early adopter, West Virginia's Environmental Protection Agency found use for drones in watershed delineation and reclamation work estimates.

It also created a much more efficient workflow. "We record video showing before and after shots of reclamation sites, and we save a lot of time going back and forth to sites, because decision-makers can review the drone HD video remotely," says Mike Sheehan with the Office of Special Reclamation.

Getting Buy-In for Drones at the DOT

Management at the transportation department was nevertheless wary about the potential risks and liability of using drones. "If someone on a road crew dropped a wrench off a bridge and it busted a windshield on a car below, everybody knows our insurance would pay for that," explains Travis. "And other than that person's supervisor and maybe one level higher, no one would hear about it. But if I did the same amount of damage to the same windshield with my drone, the incident's going to go all the way up the chain to management, and it's probably going to make the news because it's a new technology."

With this kind of attention on the program, Travis and his team put a big emphasis on making sure they had the right pilots. It brought up a question many government agencies face early on: whether to hire new or outside drone pilot talent or train in-house experts on how to fly.

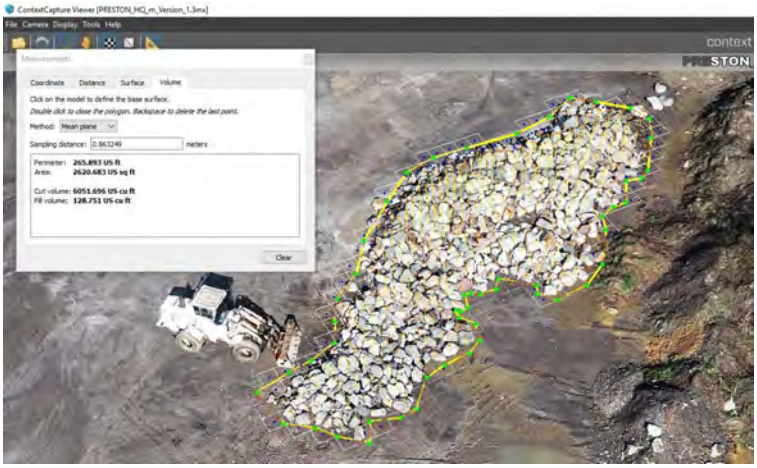
While both approaches have worked well in other states, the West Virginia leaders wanted to handpick their team. Some had lots of flight hours and some had none. Pilots were paired with experienced surveyors and as the program continues to mature, WVDOT is moving toward cross-training surveyors as pilots.

The WVDOT drone team also emphasized starting small and not reinventing the wheel to gain initial approval. "Get through the part that none of us likes to do—the policy and the standard operating procedures—and get that done quickly. Borrow from what others have done and make sure you tailor it to what fits your program."

Mitigating Public Misperceptions About Drones

"Here in West Virginia, if people don't know what something is, they tend to shoot it," says Travis. "One of the frequently asked questions on the state EPA site was, 'what happens if I shoot this drone down?'"

To get ahead of public misconceptions of what they were doing with drones, WVDOT also published a FAQ. Despite this and other public



West Virginia Department of Transportation began using drones to survey 177 aggregate stockpiles, analyzing nearly a dozen classes of materials.

information efforts, "In our first six months, we were hit with a Freedom of Information Act request from a property owner who asked for all of our drone footage. We had to give them all of the data, some 25,000 JPEG images."

Surveying Stockpiles with Increased Accuracy, Speed and Safety

That was one of a few bumps in the road during the agency's three-month trial stage. Surveying some of WVDOT's 177 aggregate stockpiles was the department's first use case. State highway departments store large piles of crushed rock, sand, salt, and gravel for road building, maintenance, and winter traction. Constructing a two-lane asphalt highway requires nearly 25,000 tons of crushed stone per mile.

West Virginia's stockpiles include roughly a dozen classes of materials. These stockpiles must be physically surveyed annually to get an inventory. Until drones, such volumetric calculations have been completed in a few ways. One involves counting the number of trucks carrying bulk material, a method that one company found can cause inaccuracies of as much as 20 percent. Alternatively, crews relied on surveyors to measure the piles, which required them to climb around hazardous stacks of shifting material.

"It's always been a project that none of our surveyors like to do, because walking on gabion piles is a good way to get your ankle broke or break some piece of equipment. And then nobody believes the data because they've been counting trucks or tonnage," explains Travis. The WVDOT survey team recognized potential for drones to speed up this process, reduce risk, and increase accuracy.

Travis' team made a small $25,000 investment in equipment and pilots. They set up a data model to verify the data they collected. Crews flew drones around stockpiles and quickly captured extensive imagery. These images were stitched together with software that builds 3D models of the piles. These models can easily calculate the volume of stockpiles nestled against hillsides or inclining slopes, a task that's difficult to do accurately using traditional methods. The team compared the data collected by drone to ground control points, and checked physical measurements in the model to confirm data accuracy.

"We were so impressed," says Travis. "Surveys of stone and dirt, stockpiles that have a lot of differential in photos, were far more accurate than we could have gathered from surveying." The work was also completed more than twice as fast. "We would typically have 21 survey crews working on this project, and it would usually take us more than two weeks to complete it. When we took it on with drones, it only took us nine days to collect this data, process it, and report results. This is the best way to survey stockpiles."

Calculating ROI for Drone Stockpile Surveys

The strong return on investment the West Virginia team demonstrated early on really gave the program traction. WVDOT calculated it by comparing the cost of conventional surveying of stockpiles with surveys using drone technology. The conventional method took 42 surveyors 15 workdays, at a cost of about $378,000. With drones, the same workload took seven drone pilots only nine workdays, costing nearly $35,000. The department saved more than $343,000 in a single month.

Expanding to Other Use Cases

Considering aggregate is one of the biggest materials used in construction projects, stockpile inspections are a logical first drone use case for many public agencies. In fact, about 50 percent of all aggregate is used for publicly funded construction projects. That includes highways, water and sewer systems, public buildings, airports, and other county and municipal public works projects.

Today, WVDOT is considering expanding its drone programs to uses they think could provide more efficiencies and greater accuracy for the department:

- Construction material cost estimates such as quantity takeoffs
- Surveying and topographical maps as part of designing new road routes
- Road safety assessments using point clouds
- Drone-based LiDAR surveys to discover delamination of roadbeds undetectable to the naked eye

From surveying aggregate stockpiles to inspecting bridges, drones are transforming what have often been expensive, accident-prone tasks for state transportation agencies. In spite of initial uncertainty, WVDOT's experiment of using drones quickly expanded to a department-wide program, demonstrating benefits ranging from increased speed and accuracy to substantial cost savings early on. Drone advancements will continue to unlock new and more powerful use cases and following WVDOT's steps of generating positive public perception and taking after other transportation agencies' drone programs will help ensure your team is well positioned for growth and innovation in the future.

SALLY HUYNH is the Senior Customer Marketing Manager at Skyward, a Verizon company. Sally is a professional marketing manager with a history of delivering successful programs that support company goals for customer acquisition, cross-selling, and retention. She also specializes in customer-focused marketing activities that build advocacy and loyalty while creating a world-class experience through the entire customer journey. When Sally is not being a fierce advocate for Skyward customers, she enjoys hikes with her best four-legged pal, Kona, and flies her Mavic to capture the beautiful Pacific Northwest.

PRECISION AND STORYTELLING: REID HU'S "AFTER THE MUDSLIDE" WINS 2021 ENGINEERING DRONE VIDEO OF THE YEAR

By Luke Carothers

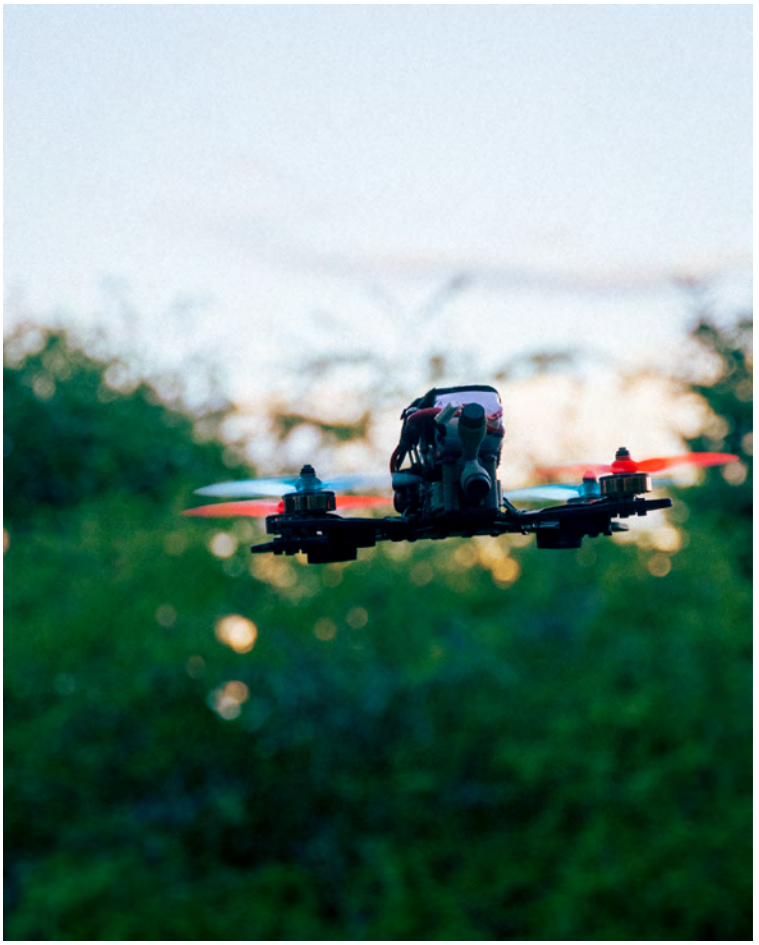
THE 2021 ENGINEERING DRONE VIDEO OF THE YEAR CONTEST (EDVY) reached new heights this year with 68 videos entered from across the globe. With more than 14,300 votes cast during the initial voting round, the competition was stiffer than ever. Three finalists emerged from this intense voting period: "Bois d'Arc Lake Project" by Freese and Nichols, "Interstate 74 Bridge Corridor" by IMEG Corp, and "After the Mudslide" by Reid Hu. In addition, this year featured an inaugural partnership with SPH Engineering who offered several impressive prize packages to the top three finishers that included their flagship software.

The final round consisted of a review from our prestigious panel of judges. After much deliberation and intense discussion, the panel came to the conclusion that Reid Hu's "After the Mudslide" is the unanimous winner of the 2021 Engineering Drone Video of the Year Contest.

Hu, a student from the Pacific Northwest in the United States, was drawn to shoot his project through family ties. His uncle worked as a structural engineer on the project, and he approached Reid about flying his drone through the building. Reid jumped at the chance, and, ever mindful of the power of storytelling, seized the opportunity to incorporate cinematic elements to contextualize the project.

Located in the Pacific Northwest, the subject of the video is a residential construction project. The house that previously stood on the site was washed away in a landslide two years prior. The impetus for rebuilding this particular house is seamlessly blended in the video as the camera navigates the steel beams sunk deep in the ground to prevent the house from washing away in the next landslide.

The video begins low, rising through a truck before skimming over some timber and rising behind the retaining wall above the house. This opening shot sets the stage for the building narrative tension as the point of view is rapidly pulled back through the building being constructed. The viewer is given a wide view of the project including the completed house to the left, the project being worked on, and the wreckage of the previous house strewn in the water. The point of view then shifts again, bringing the viewer back through the construction and turning to pan over the watery horizon. This demonstrates an ability to give the viewer "different information than what is usually available," something that judge Alexey Dobrovolsky, CTO of SPH Engineering, commented on during the judging process.



The video also stood out from the competition in terms of both its use of narration and natural noise. By employing construction noises such as a truck backing up, a generator running, and a hammer pounding, the video is given its first layer of context. Simultaneously, Reid's voice narrates the project, telling the story behind the site and its importance in being rebuilt. This aspect in particular stood out to judge Margot Moulton, who said these elements made the video feel, "very human and personal."

According to the panel of judges, "After the Mudslide" was the most technically advanced entry of the finalists. Panelist Jean-Louis Weemaes noted the blending of technical skill and storytelling to create a powerful final video. This technical skill is evident in numerous places throughout the video, but perhaps nowhere better than when the drone is flown backwards through the beams of the house.

Reid credits his use of FPV drones for this ability to navigate tight spaces and create stunning shots. FPV in this instance means First Person View, meaning Reid's drone has a small camera mounted on the front. This small camera transmits real time images to the drone operator, giving them direct control of the flight. This also means that FPV drones, according to regulations, cannot be operated without having another pair of eyes on the drone. For this video, Reid employed his father as the visual observer. Their work on this project consisted of first planning the video. This ensures not only clean, effective shots, but also the safety and security of everyone working on the project.



According to Reid, after the planning was done, he "went for it." Although several shots took multiple attempts, the most difficult, according to Reid, was the backwards flight through the building. To accomplish this shot, Reid and his father had to work together, first planning the correct site lines, then giving audible feedback as the shot progressed. It was this creativity in blending short technical maneuvers with long creative shots that impressed judge Vincent Haldy during the judging process. Judge Will Anderson also took note of this ability, calling it, "seamless."

In addition to demonstrating breathtaking skill and control in shooting the video, Hu's entry demonstrated the power of drones to highlight the humanity and necessity of engineering projects. Panelist Caitlin Burke noted Hu's storytelling ability, saying that the video has the ability to "inspire young people, and women, to enter the industry or become drone pilots."

"After the Mudslide" certainly stands as a testament to the multiplicity of uses for drones within the AEC industry. While drones and other UAVs are capable of performing complex and intense tasks that are vital to sectors such as infrastructure and agriculture, they are, at the same time, capable of revealing a very human element that is often lacking in discussions of projects within the AEC industry. Reid Hu's video and capacity for storytelling offer a glimpse of the power for drones to open a new pathway into the industry.

Watch the winning video and visit Reid's website if you are interested in working with him to create a video of your own project.

LUKE CAROTHERS is the Editor for Civil + Structural Engineer Media. If you want us to cover your project or want to feature your own article, he can be reached at lcarothers@zweiggroup.com.

VIDEO

NEW WAYS CONTRACTORS ARE LEVERAGING DRONE DATA FOR JOBSITE MANAGEMENT

By Troy Dahlin



THE ADOPTION OF DRONE TECHNOLOGY has increased rapidly in heavy construction over the last three years, with systems becoming easier to use while providing more data at higher accuracies.

Today, there are more than 1.7 million drones, or unmanned aerial vehicles (UAVs), in use, and 203,000 remote pilots are registered with the Federal Aviation Administration (FAA). Moreover, those numbers are almost certain to increase in the years ahead.

Recent data from The Civil Quarterly (TCQ), a quarterly research report on the current business health of contractors from Dodge Data & Analytics, revealed that the heavy civil sector has widely adopted many advanced tools and digital processes. For example, more than half of contractors said they used drones and ruggedized tablets.

Drones are used in nearly every industry, not just construction. But they are the natural next step in the technological evolution for heavy construction companies, as they offer a cost-effective way to use technology to tackle long-standing needs, such as safely capturing the accurate and robust data needed to make real-time decisions that can make or break a project's bottom line.

In addition to fast and flexible data collection, drones deliver reduced worker costs, enhanced jobsite safety, and faster surveying and construction time than traditional data capture techniques. But perhaps more than any other benefit, drones enable the collection of improved and more accurate data without disrupting jobsite operations.

There are many opportunities on the modern jobsite where drones are of particular benefit. For example, drones enable heavy construction contractors to capture data from hard-to-reach, potentially hazardous or otherwise inaccessible locations that would be too risky or expensive to capture traditionally.

Heavy construction contractors need solutions that allow them to leverage vast amounts of data to make actionable decisions. Here are a few new ways we're seeing contractors benefit from drones on their commercial projects.

More accurately tracking progress throughout construction

When it comes to drone data, much of the attention in heavy construction has been quantifying earthwork volumes. This takes the form of pre-bid analysis to ensure correct quantities are known so that optimal designs can be created and efficient haul plans can be implemented.

Drones are then used to track earthwork volumes throughout the construction process to provide feedback on what has been completed and the amount of work remaining to inform project plans and allow for faster replanning cycles.

Processing a drone's images — known as orthomosaic images — into three-dimensional points on the ground can be combined with three-dimensional points from other collection sources. Those points can be used in computer-aided design (CAD) to create three-dimensional surfaces, contour lines, surface features, three-dimensional models, site progressions documentation, and volumetrics for earthwork calculations.

A worker can capture more data during a 20-minute flight than through a week of traditional terrestrial measuring.

For example, the Leica Aibot SX intelligent aerial surveying solution captures a digital data set more efficiently. Additionally, it adds a fully integrated UAV solution into existing Leica Geosystems surveying and engineering workflows.

The Leica Aibot workflow is based on Leica Geosystem's trusted product portfolio. It seamlessly integrates with the Leica Infinity software suite to capture, process, merge, store, and analyze data. Leica Aibot skyCAPP is the professional flight execution software supporting all your missions, especially when you need actionable data.

Save money and improve safety as a result of better data

As a reality capture tool, drones provide the ability to capture an aerial "snapshot" of a project at any time. More data can be captured in a twenty-minute flight than during a week of traditional terrestrial measuring.

Additionally, because the data set is much denser and richer, it allows for a more detailed analysis and improved accuracy for some applications. One of the unexpected benefits is improved client visualization by showing overall site progress against the design, translating into quicker and more complete decision-making at the project management level.

With the economy rebounding, post-COVID construction projects are commencing rapidly, and material prices are at an all-time high, requir-



ing extra attention to optimize the procurement and use of precious and expensive resources.

Jobsites are constantly changing, but using a drone's orthomosaic images, coupled with the derived point clouds, provides a wealth of information of what materials have been put in the ground and what is remaining.

This can lead to lean procurement management, ensuring what is needed on site is available when needed and stored in the correct location. This is particularly important for paving and utility construction, extending the benefits of drones past simply validating the amount of dirt moved.

It also enables a team to monitor a jobsite to gather intel for progress reporting and stockpile management. For example, operators can use drones to monitor equipment to ensure it is appropriately utilized and take quick action should they find unsafe or out of compliance conditions, further enhancing the job site's safety.

Better informed decisions to increase efficiency

After capturing the data, it's imperative to get the correct data in the hands of the right people on-site so they can make informed decisions on the most efficient way to complete the project.

To overcome, AGTEK has created a suite of tools that allow users to quantify both earthwork and material quantities directly from their phone or tablet, measuring directly against orthophotos, detailed point clouds and digital elevation models (DEMs), putting the data's power to work in the field.

This provides a feedback loop for the field to the office and back again to merge drone data with design, as-built, and on-site progress updates captured with photos, notes, and machine tracks.

Verify assets and simplify workflow

Contractors can also use drones to validate and hand over the asset to the owner, helping reduce the time needed with manual approaches. In addition, taking this approach ensures the final product is constructed within specification, eliminating the need for costly fixes.

The goal is to deploy a solution that simplifies the workflow of this process to move it from the realm of the specialist to enabling generalists to take advantage of drone technology and data. This can save both time and money on key projects.

Drones can play an instrumental role in verifying assets in locations where verifying data is particularly challenging, such as urban environments or heavily canopied construction sites.

For example, the Leica Aibot CX aerial digitization solution allows users to easily compare as-designed and as-built. This enables a transparent view of a site's progression at every step of the project lifecycle of planning, design, construction and hand-over.

Solutions today are making jobsites safer while saving contractors money. Yet, despite their proliferation, many contractors are unaware of the profound benefits drones bring to the modern jobsite.

Many construction companies initially operated drones with the intent of always having them on hand at a site. However, they work best when they are not a 24/7, anywhere, anytime tool.

Over time, companies' plans for drones evolved into having a dedicated team of professionals who travel from site to site where their drone operating services are needed.

Technology today should be the professional partner contractors deploy to save time and money, guarantee accurate data and drive projects forward. When implemented correctly, they provide another powerful tool in contractors' arsenals.

TROY DAHLIN is vice president, heavy construction segment, US/CAN of Leica Geosystems, part of Hexagon. For more information, please visit www.leica-geosystems.com.

ENGINEERING EXPERTS HELP COMMUNITIES PREPARE FOR WICKED WEATHER

By Spencer Francis, PE

AS WE ROUND OUT another active hurricane season, Bowman, a growing multidisciplinary professional services firm based in Reston, Va., is busy improving community infrastructure nationwide and assessing areas of future risk.

President Biden released the Build Back Better Framework, a trillion-dollar infrastructure package, and Bowman's team of experts have long been at work on our country's infrastructure, from utilities to land developers. Our services run the gamut, from civil, MEP and transportation engineering, to surveying, mapping, land acquisition, right of way, and other areas.

While we're past the hurricane season, it was on everyone's mind throughout the summer and fall. Hurricane Elsa came through the Atlantic in July and luckily didn't do extensive damage. But all these extreme weather events demonstrate the need for continued diligence in making our infrastructure more resilient.

Bowman (Nasdaq: BWMN) offers a broad range of real estate, energy, infrastructure, and environmental management solutions to public and private clients across the country. Our engineers and planners design community infrastructure to be more resilient to increasingly severe hurricanes and other major weather events.

We also know how to quickly and safely survey the damage using the most high-tech methods available.

Much of my job and that of my team is working with energy companies and communities to harden or relocate power lines and microgrids underground. This helps communities become more resilient in extreme weather situations, such as this year's severe storms, flooding, as well as 2020's active hurricane season. We work closely with utility contractors and utility company engineers to move hundreds of miles of electric lines and microgrids underground every year. This, in turn, positively affects tens of thousands of properties a year. One such company is Pike Electric Corporation.

"Our clients are increasingly focused on the reliability and resilience of their electric grids. Pike's strategic partnership with Bowman allows us to seamlessly integrate their right-of-way and survey services with our workflows. We value this approach because it combines our strengths to provide safe, efficient, and customer-focused results for our clients," says Luis Ordaz, Vice President, Engineering, Pike Electric Corporation, a national provider of engineering and construction services to the electric utility industry.

My team also works closely with Bowman's surveyors on similar projects but in addition to power lines outside of homes and neighborhoods, the surveyors frequently use 3-D scanning technology to survey and properly secure electrical substations. The improved technologies improve accuracy and safety.

Jason Reynolds is a Registered Professional Land Surveyor (RPLS), Bowman Principal and 30-year veteran of the survey industry based



This is the kind of typical storm damage Bowman survey and infrastructure resiliency teams see and address after hurricanes and other extreme weather events.

in Austin, Texas. He works with his survey team to utilize thermography video and drones to assess post-storm damage. They also look for vulnerable infrastructure. In 2017, Reynolds and his team responded to Hurricane Harvey to assist with the identification of both damaged transmission and distribution lines.

According to Reynolds, the transmission lines and majority of distribution lines post-Harvey were flown over a wide area with a manned helicopter with an onboard video camera with embedded GPS positions across a three-county area. Unmanned Aerial Systems (drones) equipped with GPS, video, and thermal cameras flew over distribution lines that were in heavily vegetated areas. A utility representative subject matter expert accompanied all crews.

When a downed line or a line that was not functioning was identified, the coordinates were called into the damage response center via satellite phones to dispatch the available repair crews to the location for repair or rebuild. After a formal 'lessons learned' meeting about the project with internal and external stakeholders, Reynolds' team formalized a 'readiness condition plan' for future storms.

This included triggers to prepare for an assessment program as the hurricane was developing, gather response assets, mobilize crews to a safe area near the anticipated impact point before the hurricane made landfall, followed by deployment to the damage assessment rally point when conditions indicated it was safe to begin flight operations. This plan was also utilized in 2019 during Hurricane Dorian.

Flight crews and 20 land-based crews accompanied the assessment team and were deployed days before the storm and were ready to assist the utility providers, but the storm was downgraded and there was minimal damage.

Bowman is at the forefront of the turnkey approach to electric distribution storm hardening as utilities race to redesign and harden their systems. With our program approach, we work directly with contractors and other engineering partners to expedite project delivery and improve our storm hardening program's efficiency.

To handle the sheer magnitude of data and complex moving parts of these large programs, Bowman consistently works to improve processes and procedures for efficiency and accuracy. Among these improvements was the development of an online database that provides for real-time project tracking and reporting utilizing the latest cloud-based and geographic information system (GIS) technology. The Bowman team can literally have a drone out in the field while a client sees what the drone sees from wherever they are and can advise of their needs and priorities in real-time.

Bowman also has significant augmented reality capabilities so owners can now be in a "situation room" after a storm to view the live feed from the drone to assess the storm or other type of damage situation and deploy crews to the areas of the most urgent need.



This screen grab shows a thermal inspection of a power line.

Reynolds also noted that from surveying to undergrounding power lines, our strength is in our technology and how easily we collaborate to find the right solution for the client. On any given day we're working with people in 8-10 regions solving different problems. We understand what the client needs, it's part of our culture to know it and maximize the technology to provide the best possible solution. We have experts in a wide variety of disciplines so we can determine what needs to be put in place.

In addition to the high-tech focus at Bowman, we also have a high-touch approach among our more than 850 employees across the country.

When we're not preparing for and surveying damage from storms, much of our work is directly with landowners during fair weather as our team works to storm-harden power lines in subdivisions and rural areas. I remember one instance on a project in Florida where we worked with an out-of-town landowner living in a very rural part of Mexico with no phone, no internet, and no mail service. We negotiated through the landowner's cousin who then visited his relative via donkey so that we could complete the project. It's also about building relationships and more personal transactions, which are emotional and different from traditional engineering work.

SPENCER FRANCIS, PE, EVP - REGIONAL MANAGER, is a licensed professional civil engineer with comprehensive technical and leadership experience and expertise in a wide variety of markets including economic development, transportation, stormwater, water/wastewater, energy, and land development. He oversees right-of-way and land services, civil engineering, transportation engineering, and water/wastewater engineering operations throughout the U.S. for Bowman. His ability and knowledge in leading projects from inception through construction helps develop successful projects with regard to their development challenges, the time necessary to overcome those challenges, and how creative and cost-saving solutions may be brought to bear.

MAPPING THE SMART PATH TO HAPPINESS

HOW ONE CITY IS USING GEOSPATIAL DATA TO IMPROVE THE QUALITY OF LIFE

By Mary Jo Wagner



Dubai's downtown waterfront. *Photo: Olga Ozik, Pixabay*

THE CITY OF DUBAI takes its smartness and its happiness very seriously. In fact, happiness is the stated end goal of all the ambitious and clever initiatives the city launched since the start of its Smart Dubai program in 2013. The all-encompassing strategy influenced the creation of the United Arab Emirates' (UAE) first-ever Minister for Happiness and Wellbeing, and it's ultimate aim is to transform Dubai into the smartest and happiest city on Earth.

A significant part of Smart Dubai has been GeoDubai, a comprehensive scheme managed by Dubai Municipality's GIS Center to collect and provide all geospatial data and related services to government, educational and private entities within the entire UAE.

"The Dubai government believes that geospatial data is one of the core elements of creating the happiest and smartest city in the region," says Maryam Obaid Almheiri, the GIS Center's Director. "Geospatial data is essential for effective urban planning, infrastructure, security and health, all of which contribute to smart services that make Dubai a livable, sustainable, innovative, and growing hub of happiness. The key for us has been the ability to accurately map the city as fast as it develops."

To give them both the mapping speed and precision it needs, the GIS Center acquired a vehicle-mounted mobile mapping system that captures centimeter-grade spatial data at highway speeds without sacrificing data quality or crew safety. The new system has not only enabled the group to image all the major roads, landmarks, and buildings in the emirate in record time, it's driving them toward successfully supporting Dubai Municipality's ultimate smart goal of building Dubai's "Digital Twin," an entire 3D model of the city's exterior and interior infrastructure.

Keeping Pace

The GIS Center has been collecting and processing geospatial data of the whole emirate of Dubai since 2001, when His Highness Sheikh Maktoum bin Rashid Al Maktoum, Vice President and Prime Minister of the UAE and Ruler of Dubai, issued a law proclaiming Dubai Municipality's GIS Center as the sole official body responsible for the task.

As such, it has routinely acquired aerial photography and satellite imagery of the emirate and created 3D models and topographic maps using photogrammetric techniques. It also has, on a nearly daily basis, used traditional total stations and GNSS RTK technology to survey roadways, parks, and street furniture as well as collect as-built surveys. For street-view imagery, it has previously turned to commercial vendors. All the data sources are offered through a centralized portal to support a host of public services such as civic planning, building design and legislation, transportation, addressing, and utilities.

Keeping pace with its ever-changing city, however, hasn't been easy, especially in the area of urban development.

"In Dubai, it seems there is a new feature or development added every day," says Almheiri. "We can't get aerial photography and satellite imagery fast enough, commercial vendors don't provide blanket coverage, and capturing construction with traditional survey technology is time consuming. Setting up total stations and GNSS receivers along active roadways is also a constant risk for our crews. With the launch of GeoDubai, we knew we'd need an inhouse mapping system that would allow us to control our data-acquisition program, coverage and accuracy requirements, and would give us the means to safely and precisely capture Dubai's infrastructure as it's changing."

In late 2018, the GIS Center acquired the Trimble MX9 mobile mapping solution, a field-to-finish system that combines high-density laser scanning, one spherical and three planar cameras for panoramic and multi-angle imagery, and a high-precision Applanix GNSS (IMU) component.

"The MX9 has four cameras that capture panoramic and multi-angle images, and two laser scanners that each capture 1 million points per second as you drive," says Mohamed El Mustafa, the GIS Center's MX9 project manager. "That gives us an incredibly high-density point cloud as well as incredibly rich images of every feature on the road. Nothing's missed. And we can acquire those significant data volumes in a fraction of the time of a traditional survey. It's the key to us successfully achieving the goals of GeoDubai."

As the first government department in the emirate to own a mobile-mapping system, the GIS Center began using the MX9 in a number of parks and exhibition areas to familiarize themselves with the technology and calibrate it to provide the functionality and data quality they require. By mid-2019, the Center had initiated its first major mobile-mapping project: imaging and scanning the emirate's roads and urban infrastructure.

Dubai in 3D

To begin, teams first focused on Dubai's roughly 12,000 kilometers of

roads, targeting major routes and landmarks such as the Global Village festival and amusement park, the Old Souk markets, and Dubai's downtown. The aim was to capture every existing feature on and along the road to create 360-degree street views, point clouds, and 2D and 3D base maps of the 60- by 60-kilometer Emirate.

To provide geospatial referencing to the MX9 system, the Dubai Municipality Survey Department has a network of roughly 12,000 existing ground control points (GCPs) to provide centimeter-accuracy control for the mobile mapping. The department also has a network of Virtual Reference Stations (VRSs) to support RINEX post-processing for the MX9's GNSS.

With the MX9 mounted on top of their SUV, a two-person crew drove the roadway in two directions. Traveling at 80 kilometers/hour, the system scanned road furniture such as road signs, light poles, stop lights, markings and medians—any feature within 400 meters of the road—and captured nine images (panoramic and multi-angle) every 5 seconds. Simultaneous to the image capture, the system collected a point cloud of the AOI at 2 million points per second. On average, it took the team two to three hours to acquire 100 kilometers of data per day on both sides of the roads.

"A notable benefit of the MX9 is not only that it has two scanners, but also their positioning angle, which allows us to capture features that could potentially be blocked if we only had one scanner," says El Mustafa. "Dubai, for example, has heavy traffic, so it would be easy to miss a feature because a car passes you. Two scanners ensure that if one is momentarily blocked, the other will scan those points. In addition, the MX9's overhead reach is up to 400 meters high, so we can capture nearly all of Dubai's tallest buildings to create an accurate and true 3D model of the city."

The GIS Center completed its first project phase of capturing all of Dubai's major roadways, landmarks and buildings in 3D in April 2020. For the remainder of 2020, teams were focusing on collecting the rest of the road network, landscapes, and infrastructure to complete the 3D mapping of the entire emirate.

"We wouldn't have been able to finish this major achievement this quickly without the MX9," says El Mustafa. "A surveyor using conventional technology would likely need nearly two months to cover the same amount of distance we collect in one day. And they'll maybe acquire about 200 points a day. We get 360-degree panoramas every five seconds and two million 3D points per second of everything that's there. There's no comparison."

No Need To Explain

After each data acquisition, a team used a suite of Trimble software tools to process the data. When the MX9's GNSS and inertial data were processed with POSPac, Trimble Business Center software integrated the trajectory information and control-point measurements to georeference the data collected from the MX9 cameras and scanners. They also processed and colorized each point cloud. And from the 3D view, they extracted a host of features such as road furniture, signs, houses, and building outlines to produce vectorized maps for GIS-based analyses.

The street view, panoramic images, point clouds, and base maps then were published to the GIS Center's GeoDubai advanced geospatial portal, giving public and private end users the ability to view, measure and study any feature or structure in the city. And at the end of June 2020, the 3D mobile mapping data was integrated with the GIS Center's latest smart innovation: Dubai Here, a Web browser system that offers access to geospatial data, including maps of Dubai's landmarks, commercial and residential structures, parks, trees, bridges, tunnels, and transit network.

"What makes the mobile mapping data so effective is that no explanation is needed," says El Mustafa. "Unlike with a singular GNSS survey point, with the MX9 street views, users can see the whole city in front of them, not just a point or polygon. A photo gives 1,000 explanations. And that makes it so much easier to use."

In addition to providing precise panorama and measurable 3D views of the city, the GIS Center is also capturing and mapping the interiors of commercial and public buildings to bring that same 3D view and analysis inside. Using the Trimble Indoor Mobile Mapping Solution (TIMMS), the cart-mounted lidar and camera systems scan and image every room and object in an interior space—including desks, chairs, stairs, doors, plants, sprinklers, and vents—and provide real-world positions of each area of the building and its contents.

Integrating the MX9 data with the internal TIMMS data will not only offer end users a holistic view of Dubai's buildings and landmarks, it will provide the foundation to ultimately create the city's Digital Twin, a complete 3D model of the whole city. That model, enhanced with Internet of Things technologies and linked to real-time information, will provide the essential information for planning and managing the city and providing effective, smart services.

"Data-rich images and 3D maps give decision makers precise, up-to-date and dynamic information to support and effectively manage our core city functions," says Almheiri. "For example, in emergency response, civil defense can immediately know the height, accessibility and complexity of a burning building's shape, giving them the knowledge to plan the most effective response. Planners can use 3D maps to monitor and assess building ages and develop effective demolition strategies. Engineers can develop road design or maintenance in 3D. This is the kind of data depth and innovation we need for Dubai's future Digital Twin and, most importantly, to build the smartest and happiest city."

And in the end, that's what it's all about for Dubai: being smart and happy. It may have a penchant for creating a city of "ests"–tallest, largest, fastest, easiest, cleanest–but the most important "est" for the Dubai government is being the smartest and happiest city. And that's no laughing matter.

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MAR 10-11	Project Management & Advanced PM for AEC Professionals *Tampa, FL*
MAR 30-31	Elevating Doer-Sellers *Scottsdale, AZ*
APR 7-8	ElevateHER Kickoff *Dallas, TX*
APR 21-22	CEO Roundtable *Napa Valley, CA*
APR 28-29	M&A Next *Charleston, SC*
MAY 19-20	CFO Roundtable *TBD*
JUN 23-24	The Principals Academy *Miami, FL*
SEP 14-16	ElevateAEC Conference & ElevateHER Symposium *Las Vegas, NV*

*All events subject to change

VIRTUAL SEMINARS

JAN 18, 20, 25, 27	Project Management *Time TBD*
FEB 1, 8, 15, 22	Elevating Doer-Sellers *11am-1pm CT*
FEB 22, 24, + MAR 1, 3, 8, 10	The Principals Academy *Time TBD*
JUL 12, 19, 26 + AUG 2	Leadership Skills for AEC Professionals *11am-12:30pm CT*
APPROX. ONCE A MONTH	Survey Report Webinar *Time TBD*

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