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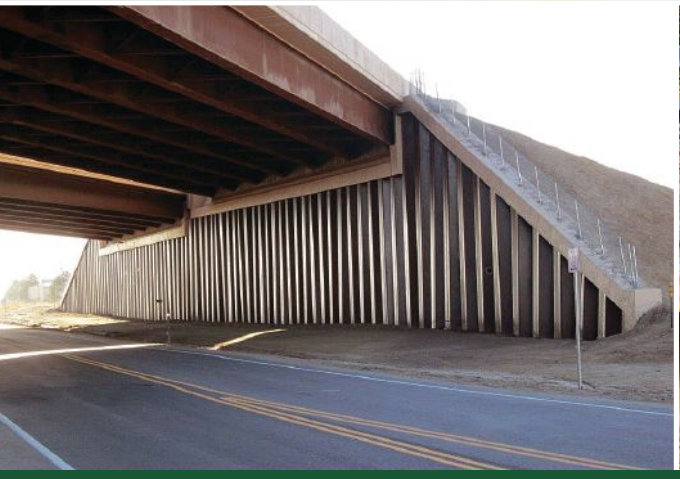

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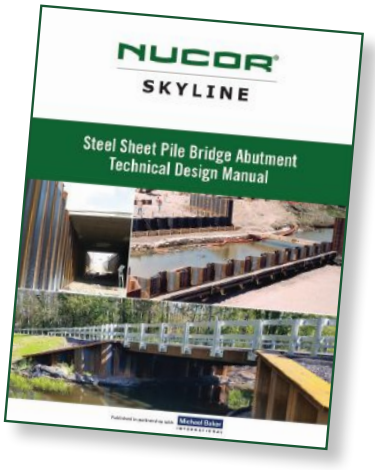

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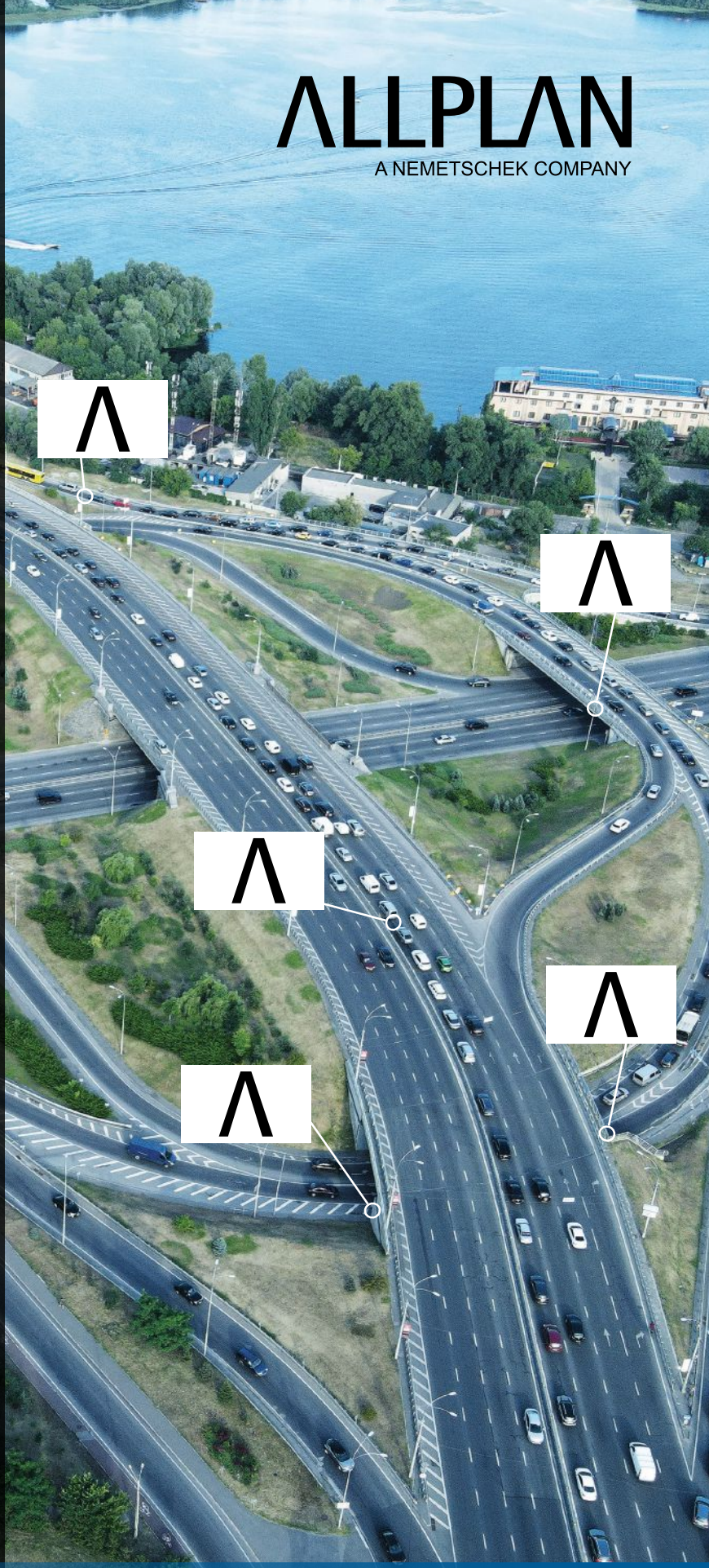

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Finally! An Infrastructure Bill Passes!

BY ROBERT SCHICKEL

"It always seems impossible until it is done." That's the quote from Nelson Mandela the *The New York Times* chose for its article about the infrastructure bill.

As I write this column, the long-awaited infrastructure bill is reality. I've been rerouting my trips on highways; waiting in lines at airports; and standing in crowded, noisy, slow-moving subways for years now. (About as long as I've been writing about the need for an infrastructure bill.)

I've only had time to read highlights of the bill, but I understand it will provide more than $500 billion in roads, bridges, rail, airports, water, dams and even broadband. In addition, it will put $47 billion toward climate-change actions. You can read more in the news section of *Informed Infrastructure* and its news website at *informedinfrastructure.com/category/news*.

I predict those who voted against the bill will be the biggest voices in taking credit for projects completed with these new funds, and I will certainly be watching how this turns out in my state. But as U.S. Transportation Secretary Pete Buttigieg said, "No matter where they live or who they voted for, all Americans deserve to have a transportation system that works for them."

Of course, this funding is spread across 10 years, so we shouldn't expect immediate results. We, as engineers, understand the development of projects takes time. But there are many projects that have been sitting on the shelf and can be "dusted off" rather quickly. The creation of jobs will be just as important for many of our citizens. This is what's important to me at the moment.

Guiding Young Engineers

I'm an adjunct instructor at Valparaiso University, guiding senior civil engineers through two semesters of their senior design project. Part of my curriculum is to help them understand what it may be like when they get their first job. Since I have experience working with engineering companies large and small as well as with government agencies of all sizes, I believe I can help them decide where they may fit in best.

Sure, some of them have been interns or had part-time jobs with engineering firms or government agencies, but we all know how we've worked with interns. They're given various assignments or tasks, but rarely left alone long enough for them to make significant decisions without additional input. Basically, you're training them and deciding whether or not they have the character, skills and potential to be an employee who will fit in the organization.

However, it has recently been a concern of mine that there wouldn't be enough funding to do the major projects, except where previous funding had already been earmarked. Government agencies, at least where I've traveled the last few years, have been able to take care of basic maintenance of roads and bridges, but not the improvements needed to increase capacity or provide appropriate safety measures. These are precisely the projects my students will want to work on.

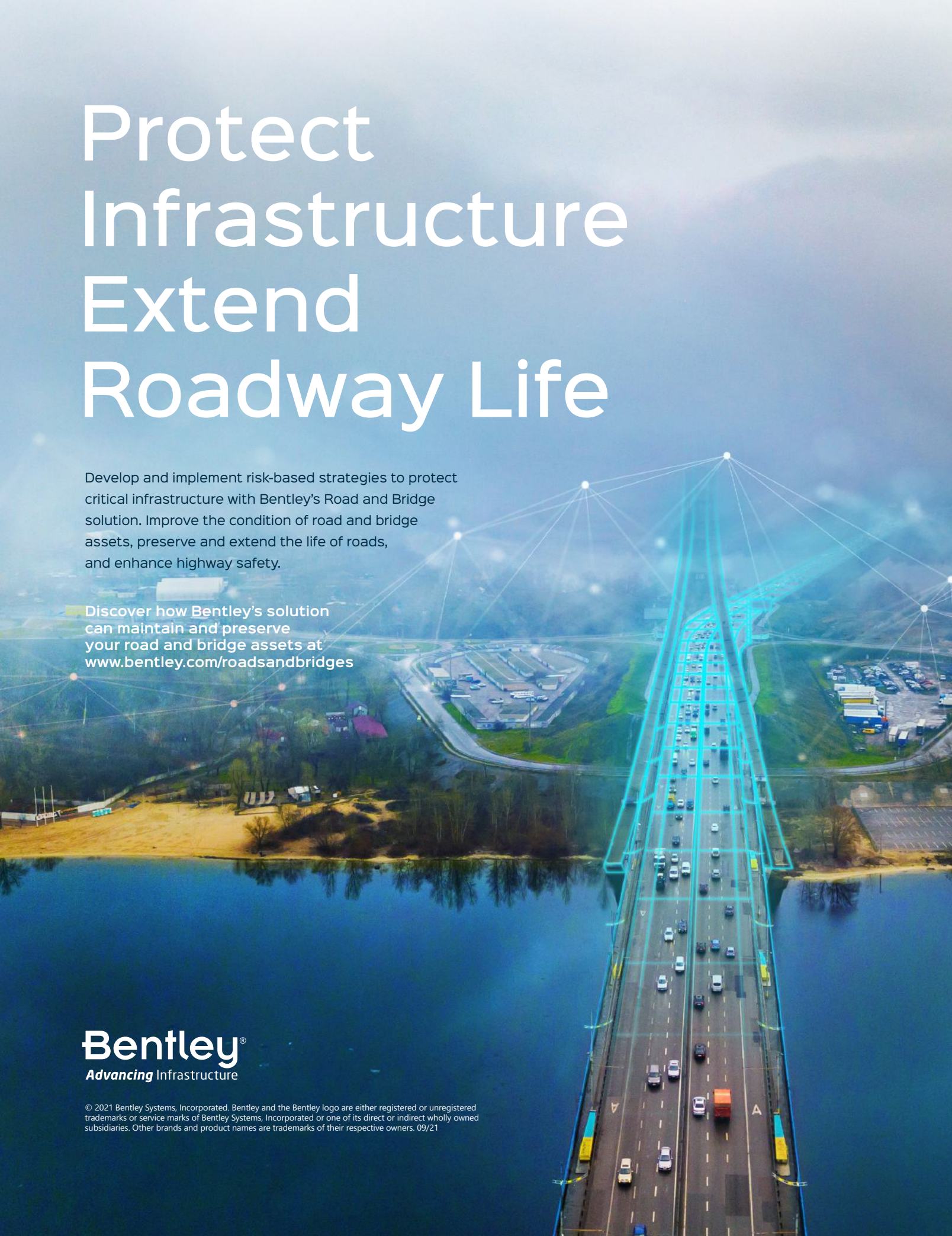
A Brighter Future

There isn't much allure in drawing up plans and specifications for the resurfacing of a county road; but adding lanes to a highway and designing a new bridge are inviting projects. Civil engineering graduates will appreciate entering a dynamic and future-oriented industry. Yes, we all will continue to maintain our facilities, but this new funding associated with the infrastructure bill will create opportunities for young engineers to complete projects they will be proud of.

There isn't much allure in drawing up plans and specifications for the resurfacing of a county road; but adding lanes to a highway and designing a new bridge are inviting projects. Civil engineering graduates will appreciate entering a dynamic and future-oriented industry.

I want my students to thrive in their careers. I want them to call me in the future and tell me about projects they've done. This new funding mechanism will create projects that will be worthy of their skills. II

Robert Schickel has more than 40 years of experience in the design of civil and transportation projects. Recently retired, he remains active as Adjunct Professor in Civil Engineering at his alma mater, Valparaiso University; email: *rschickel@v1-media.com*.



Return to Glory: Notre Dame's Restoration Is On Track

Sustainable Engineering Special Issue 2021


Return to Glory

Notre Dame's Restoration Is On Track

BY ANGUS W. STOCKING

Good afternoon, Mr. Stocking,

My husband recently attended the WEFTEC 2021 show in Chicago and returned with your article, "Return to Glory: Notre Dame's Restoration Is On Track" from the Sustainable Engineering Special Issue he picked up there. Unfortunately, he "lightened his load" and only brought back the relevant pages, not the entire magazine. I would very much like to use this article in my course at the SUNY College of Environmental Science & Forestry in Syracuse, N.Y. I teach a history of art & design class (basically an Art History survey) for the Landscape Architecture department. Your article is exactly the kind of thing I like to assign, since many of my students are in non-art majors (Forestry, Environmental Studies, Natural Resources Management). I like to give them some current outside readings that will pique their interest.

Would you be able to provide me with a PDF of your article that includes the appropriate volume and issue information?

As a frequent visitor to Notre Dame, a former French language major, and an architectural historian, I was thrilled to read of the restoration efforts.

Thank you very much for your assistance.

Dr. Sara L. French
Landscape Architecture Department
SUNY-ESF
Syracuse, N.Y.

Dr. French,

Thank you for your interest in our magazine and this article. We will happily send you a complimentary PDF of the article, and we're honored that you'll be using it in your class.

Since you're part of the College of Environmental Science & Forestry, I hope you noticed that we use high-quality paper certified by the Forest Stewardship Council (FSC), showing that it has been harvested in a responsible manner, as sustainability is at the forefront of both our magazine coverage and production.

Regards,
Kevin Carmody
Publisher
Informed Infrastructure

In this section, *Informed Infrastructure* compiles infographics from trusted sources that reveal insight on infrastructure spending. We also compile some of the top infrastructure stories that shouldn't be missed. For ongoing news coverage, turn to *Informed Infrastructure* online (*www.informedinfrastructure.com*), our Twitter feed (*@IIInfrastructure*) and our weekly e-newsletter.

Infrastructure Bill Becomes Law

On Nov. 15, 2021, the Infrastructure Investment and Jobs Act (IIJA), which was approved by Congress on Nov. 5, 2021, was signed into law by President Biden.

The infrastructure package, with $550 billion in new spending, will address the nation's core infrastructure needs, including $110 billion for highways, roads and bridges; $66 billion for passenger rail; $65 billion in high-speed internet; $55 billion for water; $39 billion in public transit; $25 billion for airports; $7.5 billion for electric vehicle charging stations; and $17 billion for ports, among other areas.

Buildings and Construction Account for 36 Percent of Global Energy Consumption

The "2021 Global Status Report for Buildings and Construction" was published on Oct. 19, 2021, by the UN Environment Programme (UNEP)-hosted Global Alliance for Buildings and Construction (GlobalABC). It found that in 2020, the sector accounted for 36 percent of global final energy consumption and 37 percent of energy-related CO2 emissions, as compared to other end-use sectors. Although the level of emissions within the sector were 10 percent lower than in 2019, reaching lows not seen since 2007, this was largely due to lockdowns, slowing of economies, difficulties households and businesses faced in maintaining and affording energy access, and a fall in construction activity. Efforts to decarbonize the sector played only a small role.

The full report can be read and downloaded at *bit.ly/3DsROQu*.

Groundwater Flow to Colorado River May Decline by a Third over Next 30 Years

A new study (available at *bit.ly/3FpuYtp*) projects that a hot and dry future climate may lead to a 29-percent decline in Upper Colorado River Basin "baseflow" at the basin outlet by the 2050s, affecting both people and ecosystems.

USGS Public Domain

Baseflow is the movement of groundwater into streams and, on average, accounts for more than 50 percent of annual streamflow in the Upper Colorado River Basin; it's vital for sustaining flows in the Colorado River during dry periods. Scientists from the U.S. Geological Survey and the Bureau of Reclamation modeled temperature, precipitation and runoff data to understand more about how baseflow may change under three future climate scenarios.

Infrastructure on the Brink

The third national risk assessment from the nonprofit First Street Foundation, "Infrastructure on the Brink," highlighted cities and counties across the continental United States whose residential properties, roads, commercial properties, critical infrastructure and social infrastructure face operational flood risk today, and how that risk is increasing during the next 30 years with a changing environment that will worsen the situation.

According to the report, about 2 million miles of road currently are at risk of becoming "impassable" due to flooding; nearly 1 million commercial properties, 17 percent of all social infrastructure facilities, and 12.4 million residential properties also have "operational risk"; and, during the next 30 years, about 1.2 million residential properties and 2,000 pieces of critical infrastructure (airports, hospitals, fire stations, hazardous waste sites and power plants) also will be at risk of becoming inoperable due to flooding from sea-level rise and/or heavy rainfall.

Access the full report at *bit.ly/3Cvl3ke*.

TOP Stories

The following are the top stories from the last few months (in terms of traffic) on the *Informed Infrastructure* website. This also reflects key coverage areas that are regularly refreshed online and via our weekly e-newsletter. Simply search key words on *Informed Infrastructure* online to find the full story.

Buildings

- SSSBA Releases Short Span Steel Bridge Technical Video Series
- Construction Sector Must 'Clean Up Its Act' on Decarbonization, Says Rocky Mountain Institute
- Sustainable New Concrete Mix from AEEE To Reduce Cement's Global Carbon Footprint
- Stantec-Designed Covina Transit Center Opens to Public
- Simpson Strong-Tie Publishes Strong-Rod Design Guide for Engineering Mid-Rise Buildings to Resist Seismic and High-Wind Forces

Transportation

- North Atlantic Rail Proposal Wins Backing from 24 Members of Congress from CT, MA, ME, NH, NY, RI and VT
- Neste and Vitol Aviation Enable Heathrow to Become First UK Major Airport to Incorporate Sustainable Aviation Fuel into Operation
- Amtrak To Invest $7.3B In New Railroad Equipment
- Americans Riding Public Transportation in Greater Numbers
- Video: Rat Creek Slide Repair

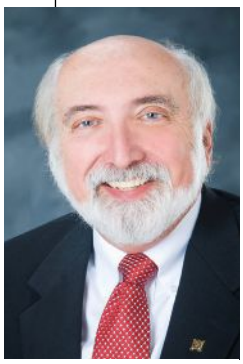
Water

- Lack of Water Linked to 10 Percent of the Rise in Global Migration
- Podcast: Technology Adoption of Water Utilities
- Plan to Strengthen the Portland Metro Levee System Approved by the U.S. Army Corps of Engineers
- Smart Sewer Technology Satisfies EPA Consent Decree, Saves City $400 Million
- New ASCE Manual of Practice 145 Provides Guidance on Liner Design for Gravity Pipes

Tools and Technology

- InEight's Fall 2021 Platform Innovations Double Down on Real-Time Capital Project Insights for Stronger Collaboration
- Idrica, Orange, Huawei Tests Connection of Millions of Devices Via 5G to Remotely Read Water Consumption In Real Time
- Over 350,000 Projects Turn to Autodesk Construction Cloud for Preconstruction Workflows
- Esri Releases ArcGIS GeoBIM, Bringing Spatial Context to AEC Operations
- Hexagon Adds England, Scotland and Wales to the HxGN Content Program

ASCE Statement on House Passage of Infrastructure Investment and Jobs Act



DENNIS D. TRUAX, P.E.

Editor's Note: *The following statement was made on Nov. 5, 2021, when the infrastructure bill was passed by Congress. ASCE issued a follow-up statement (available on* www.informedinfrastructure.com*) on Nov. 15, 2021, when the bill was signed into law by President Biden.*

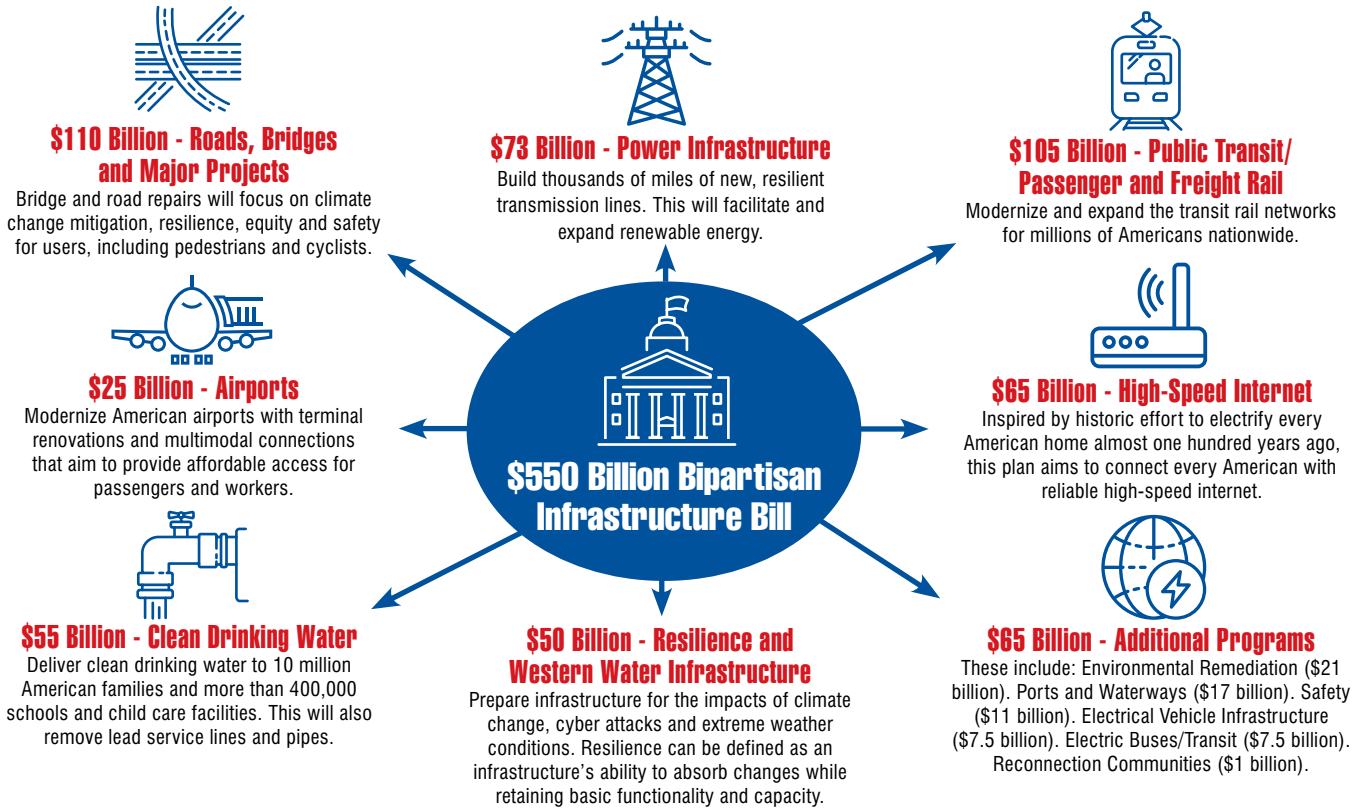
It is a great day for the nation as the U.S. House of Representatives passed the Infrastructure Investment and Jobs Act (IIJA), fulfilling President Biden's vision with a historic piece of legislation that will have monumental impacts on the economy, public safety, global competitiveness, and each American's well-being. Passage of this five-year, $1.2 trillion bill proves once again that the country can lead with infrastructure.

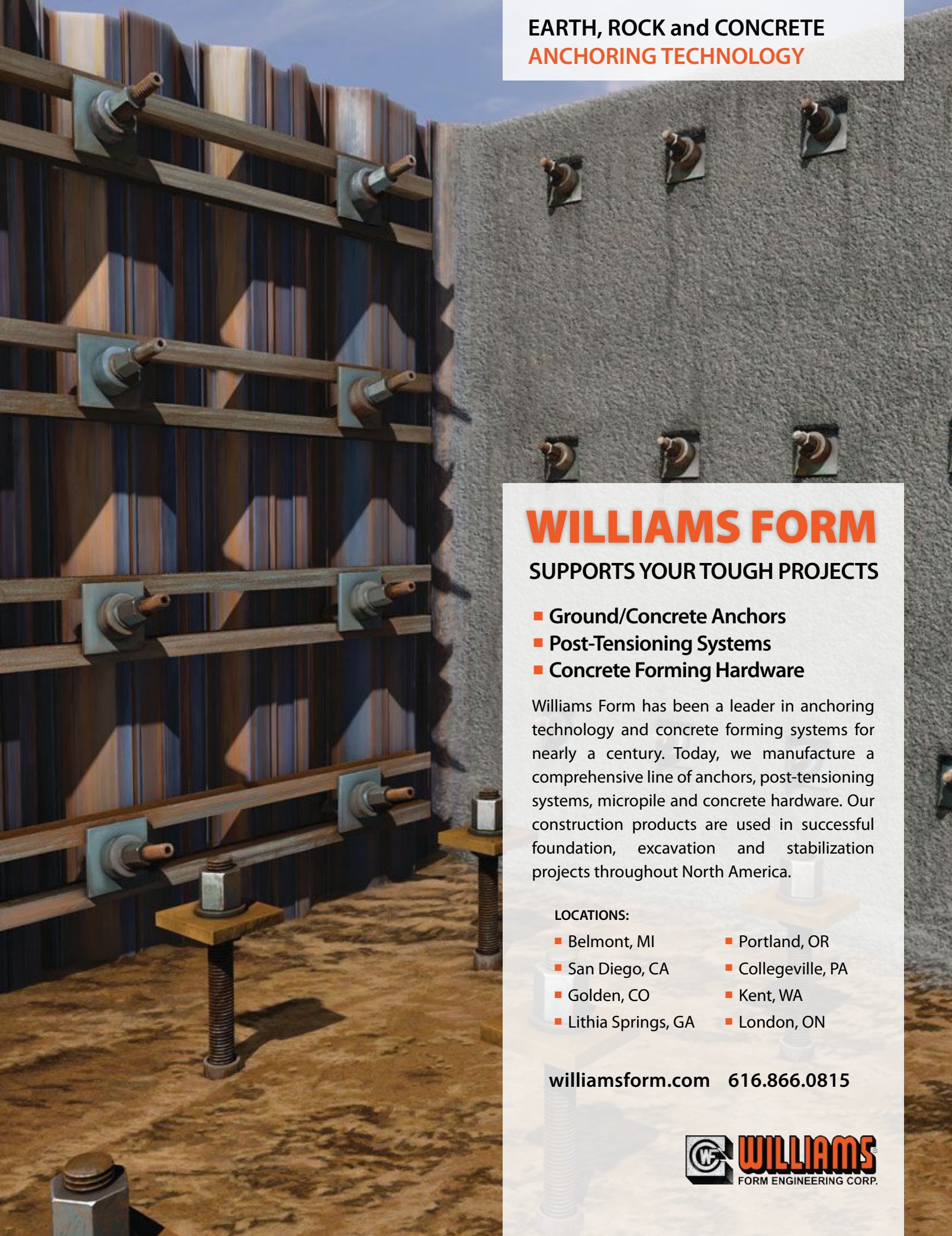
With this legislation, the federal government will restore their critical partnership with cities and states to modernize our nation's roads, bridges, transit systems, drinking water pipes, school facilities, broadband, ports, airports and more. Without a strong federal partner, local projects that are community lifelines have hung in the balance, oftentimes being paused or outright cancelled due to funding uncertainties. When this happens, American households and businesses are the ones who pay the price.

The IIJA is the culmination of decades of advocacy by American Society of Civil Engineers (ASCE) members who worked tirelessly to educate Congress about the role infrastructure plays in supporting the economy and our quality of life. ASCE's Infrastructure Report Cards have sounded the alarm on our nation's infrastructure conditions since 1998, with new reports being released every four years. While all categories of infrastructure have been the cause of some concerns, the common denominator behind each category's struggles has been a backlog of projects, overdue maintenance, and a need for resilience. This bill includes investments to repair and modernize these critical assets for almost all of the 17 categories in the 2021 Report Card for America's Infrastructure, which assigned our nation's infrastructure a cumulative grade of 'C-.'

We commend the House for joining the Senate in prioritizing American communities by passing this bipartisan infrastructure legislation, and we are encouraged that President Biden has indicated he will sign the bill quickly to ensure our communities receive these long-awaited resources soon, allowing critical projects to move forward. II

Dennis D. Truax, P.E., is president of the American Society of Civil Engineers (ASCE); email: *reportcard@asce.org*.





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Times Change: Don't Be the Cranky Old Neighbor

DOUGLAS G. FITZPATRICK, P.E.

My wife and I moved into our current home about two years after we were married and, coincidentally, just as we found out she was pregnant with our first of two daughters. It was located at the end of a street outside Charlotte in a neighborhood of 25 homes. We were the "new kids on the block" then. Almost all the families living here had already done their time; their kids were grown, and they were enjoying their "golden years."

There was an active homeowners' association. Although the community wasn't particularly old—about seven years at the time—everyone who lived here was passionate about maintaining the vision of the original developer. The covenants were geared to keep the lots heavily wooded, maintain certain color ranges and styles of homes, limit building heights, protect views of the lake, etc. We were looking for that style of community, so we fit right in.

Of course, there was an architectural committee led by homeowner volunteers charged with keeping the spirit of the covenants. For the most part, everyone seemed content with keeping things the way they were.

Change at Home

Now fast-forward 27 years. My wife and I, and a few other homeowners, now are the "old guard." It didn't happen overnight, but somehow it feels that way. During the last five years or so, there has been an influx of young families with kids, and it seems as if all the newcomers already know each other (although that's not the case).

However, all this new blood comes with unintended consequences. As these young families got settled into their new homes, eventually they wanted to make their house their home. We've all done it, and it starts small as soon as you move in: change the paint color in the living room, add wallpaper in the breakfast room, then renovate the basement, then build a family room, then start tackling the outside.

None of this is wrong; it's all pretty natural and common. But you quickly find out everyone's ideas for making their mark on their home starts to test the teeth of the covenants and the resolve of those on the architectural committee. It can turn ugly. At its ugliest, it pits neighbor against neighbor. For the old guard, it feels like no one cares the way you do. It's unsettling. It seems shortsighted. And sometimes, it feels downright rude.

Find the Wisdom, Not Rigidity, in Experience

Watching from the sidelines, however, lets you see a different picture, particularly if you're able to look at yourself and reflect on what's happening. Getting older does have its advantages. You've seen more of life, so you feel a little smarter. All the tools of life seem to work in harmony. You know a lot of people in your industry. You even get a discount at the grocery store if you shop on Thursday mornings.

But you do become handcuffed by some things, and one of them is change. Life starts moving pretty quickly as you get older, and I think it's harder to adapt to the world around you. The thought running through most folks' minds who have been in the neighborhood the longest: why can't you just do it the way it's always been done and leave things alone?

Change at the Office

Unfortunately, change is ubiquitous, and it's happening in every engineering office. As firms grow, there's a constant influx of new blood. It isn't obvious in younger firms, because everyone tends to be about the same age. But as a firm grows, the disparity in age between the old guard and the new blood widens, and so does the way we do things. There isn't an architectural committee or covenants, but we need to acknowledge the differences in styles and respect each.

As senior engineers, recognize there's a "new math" way of doing engineering now—and that's OK. There's more than one way to get from point A to point B. However, the basics of engineering will always be the same. There's always a need to understand loading, load paths, deflections, capacities, conveyance of information, visualization, application of Codes, how a building goes together, etc.

Helping young engineers tackle the basics is the only way we can keep our profession alive and moving forward. Insisting on doing it "my way" isn't productive and just makes you the old curmudgeon in the room. Help them mold their "new math" into efficient ways of accomplishing the basics and becoming good engineers in their own right. The goal is to keep them between the lines, not make them do it your way.

As young engineers, look for the hidden gems in the coaching from your more-seasoned engineers. Try not to get wrapped up in the "how to," but pay closer attention to the "why." There's no hard and fast rule for getting from point A to point B, but we do have to make sure we have all the bases covered. Your senior mentors are the fastest way to getting that firm foundation to allow you to grow professionally. II

Douglas G. Fitzpatrick, P.E., is the founder, president and practicing engineer of Fitzpatrick Engineering Group, a 17-year-old structural engineering firm specializing in commercial and healthcare building design; email: *dfitzpatrick@fegstructural.com*.

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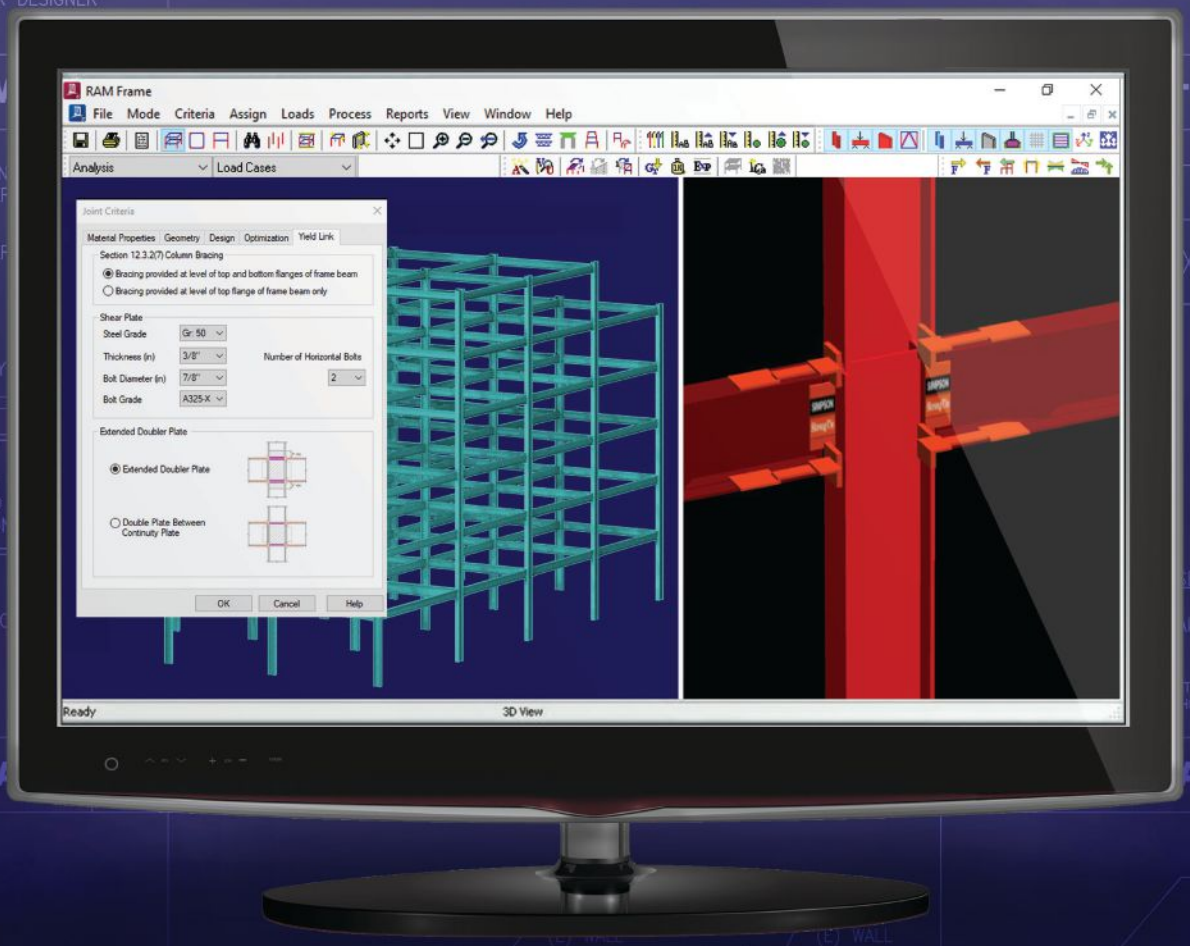

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How Private Equity Is Quietly Transforming the A/E Industry

STEVE GIDO

Whether in nature, design, health or business, lasting and significant changes seldom occur quickly, but often steadily through time. You open your eyes years later to a new paradigm or landscape that has unfolded, which ultimately requires recognition and adaptation. For the A/E industry, the most-dramatic shift in ownership models is coming from a new class of outside investors: private equity. Ten years ago, the notion of a sophisticated financial coterie joining forces with creative and cerebral A/E leaders certainly was a curious marriage. Today, these parties are rushing to the altar like never before.

In fact, almost every A/E discipline—geotechnical, civil, surveying/geospatial, MEP, environmental, construction management, forensics and architecture—has private-equity backing. More than 80 venerable industry icons now have financial sponsors, including a growing number of the ENR 500. So what's behind this, and how is private equity altering our industry? Let's go through the fundamentals and rationales.

What Exactly Is Private Equity?

Private-equity investors are seasoned financial professionals with experience in evaluating and analyzing various industries and companies. The firms they oversee raise funds of capital from institutional investors and high-net-worth families and individuals, also known as limited partners. They then will invest these proceeds in mature, privately held businesses with the goal of increasing their value through time. The private-equity managers eventually will sell the business, thus (hopefully) returning the profits at a higher yield than what these limited partners could earn in alternative asset classes.

How Does a Typical Private-Equity Investment Work?

Private-equity firms have a set of criteria for the types of "platform" businesses they seek. Some may only be interested in certain industries or just invest in distressed companies. Others may prefer to buy companies in a specific geographic region. However, most of them have minimum size thresholds regarding their desired financial characteristics, usually annual revenue and EBITDA.

After the financial sponsor has engaged with a management team and there's interest in a potential transaction, a letter of intent outlining the terms and valuation is prepared. In most cases, the private-equity firms will want to acquire a controlling stake in the target company, but some may choose to take a minority position under the right set of circumstances.

Most of these deals are funded using a combination of equity and a sizable portion of debt, which must be repaid by the target company. Thus, businesses with steady and predictable cash flow along with strong top-line prospects are sought after. Private-equity investors bring financial acumen, growth capital, and other managerial resources and ideas to help their platforms succeed. These firms will collect management fees and performance/incentive fees to cover fund-management expenses and promote future financial success.

Why Is There Serious Interest in the A/E Sector?

We live in a world today with billions of dollars available in capital circling all around the world looking for outsized returns. We also are in a period of extraordinarily low interest rates, which naturally lowers the cost of financing and can help enhance the return on investment. Historically, private equity sought deals in traditional industries such as retail, manufacturing, food and beverage, logistics, energy, etc., and others that were normally asset intensive. The idea of investing in professional-service firms, with "elevator assets" and the fickleness of company cultures and lack of tangible equipment, factories or inventories generally was avoided.

The fact that there's now so much capital chasing so few investment opportunities has pushed previously hesitant investors into exploring the merits of professional- and business-services firms. In addition, the underlying growth prospects and industry dynamics for a range of engineering and environmental services are quite favorable. Air, water and land sustainability and stewardship—in addition to a renewed push for infrastructure repair and modernization—have broad appeal and are attractive investment themes. Well-managed firms in our space generally produce steady single-digit revenue gains, attractive EBITDA margins and dependable cash-flow characteristics that appeal to investors.

Why Are More A/E Owners Choosing This Route?

With changing demographics, the A/E industry faces unprecedented ownership-transition challenges. Many baby-boomer owners are seeking the best option to successfully exit their firm, which may include an internal sale to younger employees, implementing an Employee Stock Ownership Plan (ESOP) or selling outright to a strategic buyer. But not everyone wants to sell to a 30,000-person publicly traded firm or establish an ESOP that may not bring other growth-oriented advantages.

Leaders who have gone the private-equity route often will share they enjoy a higher degree of independence and autonomy as well as "keeping our name on the door" vs. selling to a larger strategic buyer where there's potential risk of organizational change and culture conflicts. They're able to "take some chips off the table" but also rollover a portion of their equity into the new, recapitalized

platform. That may allow for a "second bite" when the private-equity firm decides to sell (to another financial sponsor or large strategic buyer), and the minority owners cash out again in a follow-up transaction. Valuations often can be higher when selling to a private-equity firm.

What Are the Ramifications to Our Industry?

Financial sponsors often can bring a more-pronounced mindset of aggressive growth compared to other conservative employee-owned design or consulting competitors. In fact, for the last decade, private-equity-backed platforms have been some of the most-prodigious buyers of smaller A/E firms (those with less than $10 million in revenue). Given the "buy vs. build" paradigm and how challenging it can be to grow professional-service practices, financial investors often are seeking to expand through multiple, synergistic acquisitions.

These platforms also actively lure other industry professionals from competitors to their leadership teams and boards. Using the prospect of direct equity, stock options, signing bonuses and future liquidity events, seasoned C-level talent and technical leaders are recruited to help transform and reorganize companies to better maximize performance and penetrate new markets.

Is that to say all these transactions work seamlessly or will achieve their desired outcomes? Not necessarily. To be sure, not all private-equity firms are alike. And like any merger, sellers need to understand the goals and motivations of their suitor as well as the short- and long-term tradeoffs of the partnership. How will the governance-arrangement work? With profits now allocated to paying off debt, what does that mean for reinvestment and incentive compensation? How will staff and clients react to the new model? What does the future hold? II

Steve Gido, CFA, is a principal, ROG+ Partners; email: *sgido@rog-partners.com*.

Select 2021 New A/E Private-Equity Recapitalizations

A/E Firm	Disciplines	Financial Sponsor
Anthesis	Environmental and sustainability consulting	Palatine Private Equity
DDCM	Civil and infrastructure engineering	White Wolf Capital
ENERCON	Engineering and environmental	AE Industrial Partners
Magnolia River	Engineering, inspection and GIS for gas/utility	Warren Equity Partners
MNS Engineers	Civil and infrastructure engineering	Long Point Capital
RATIO Design	Architecture, interiors and urban design	Hennick & Company
UniversalPegasus	EPCM for the energy sector	PMC Capital Partners
Westwood	Multidiscipline engineering	Endurance Partners
VERTEX Companies	Engineering, environmental, forensics	Wind Point Partners
YOUNG & Associates	Damage consulting and forensics engineering	CIVC Partners, L.P.

Stepping Up Source-Water Protection

CHRIS MAEDER, M.S., P.E., CFM

If a watershed was the subject of a play, this one could fill the house. Set in southwestern Wisconsin in a watershed known as Black Earth Creek, the plot has some interesting elements: a failing landfill; a Class 1 trout stream; development pressure from a bustling urban area nearby; and a cast of supporting characters that includes farmers, a few quirky residents, developers, local officials and more. But if you thought this play would be all downhill from here (no pun intended), you would be wrong. Aside from the 1980s incident involving the leaky landfill, which was capably dealt with, all other parameters indicate that Black Earth Creek—a primary source of the region's drinking water, among other uses—is on an upward trajectory in terms of the quality of its management.

The case offers some important lessons relating to source-water protection, an all-too-important topic as more communities across the United States grapple with contaminated drinking-water supplies. A recent investigation by *Consumer Reports* and *The Guardian* showed that roughly 35 percent of tap-water samples collected at random throughout the United States were found to be contaminated by PFAS, an infamous "forever chemical," and 8 percent had high levels of arsenic. Nitrate contamination is increasingly common in wells throughout Wisconsin, as is contamination by atrazine, an herbicide associated with agricultural activities. The list of similarly affected communities across the United States goes on.

As experts have lately pointed out, drinking water is a uniquely challenging resource to manage. We've created agencies and regulatory systems, and built the necessary infrastructure to protect, manage and distribute our water resources. These take the form of point-source permits for specific discharges, stormwater ordinances for polluted runoff, and infrastructure that collects and treats our waste. These systems work well—to a degree. But in most cases, these agencies and systems work independently of one another and independently of something far more basic: the raw hydrologic processes that underlie the interconnections and flow of water.

The Main Disconnect: Hydrology Does Not Follow Political Boundaries

The Black Earth Creek Watershed is a relatively small watershed that drains approximately 45 square miles of terrain consisting of steep woodland areas, agricultural lands and, increasingly, developing urban areas. The watershed is a short drive from where I live in Madison, Wis., a fast-growing metropolitan area of roughly 270,000 people. Development pressure has increased significantly in the idyllic rural communities of southwestern Wisconsin, mirroring trends apparent throughout the United States.

Black Earth Creek has been classified as an "Outstanding and Exceptional Resource Water" by the Wisconsin Department of Natural Resources and supports a self-sustaining population of roughly 1,600 wild trout per square mile. It's estimated that nearly 80 percent of the Creek's streamflow is groundwater discharge. The multiple springs in the Black Earth Creek valley are principal indicators of the strong hydrologic connections between the region's Cambrian-era aquifer and the area's lakes and rivers. The groundwater that supplies drinking water to the cities and villages in the watershed as well as the trout stream and its tributaries is one hydrologic system—plain and simple. Land-use activities that affect one element of the system will invariably affect the rest, and vice versa.

By virtue of the watershed's proximity to the University of Wisconsin-Madison as well as the state capital, and due to its status as an outstanding resource water, the watershed and its associated geophysical and biological features have been extensively studied, inventoried and mapped. These studies and the data collected guide many planning decisions in the Black Earth Creek Watershed.

Partnerships at Work

The Black Earth Creek Watershed is made up of several units of government, but one influential actor behind the management of the watershed is an entity made up of citizen-residents: the BECWA. This organization educates; facilitates communication among landowners, interest groups and municipalities; and solidifies the partnerships and trust that help the watershed work toward common goals. The BECWA was organized on the principal that management along political boundaries was inadequate to deal with a resource that moved independent of political boundaries.

The organization's positions have been controversial at times, but the group has found common ground with most interest groups, using surveys and other tools to identify overarching goals. The BECWA's mission to protect the region's water resources informs municipal land-use

plans, zoning and the siting of industrial operations, including conditions placed on residential and commercial development. Some measures include deed-mandated rain gardens for residential lots, widespread stormwater infiltration standards, and restored stream corridors fortified with vegetated swales and other green infrastructure, to name just a few. Funding on the order of $2 million also helped the sizable farming community implement measures designed to minimize risk of contamination from agricultural operations.

Land surrounding sensitive groundwater recharge areas and headwaters as well as large swathes of shoreline and wetland have been purchased outright or protected through conservation easements. A premium is placed on scientific analysis via data collection and frequent technical input from the U.S. Geological Survey, the University of Wisconsin and other consultants. Stream gages and other IoT-enabled devices gather data along the stream channel and at multiple points within the watershed; monitoring equipment is purchased on an annual basis.

Minding the Watershed

It's anyone's guess as to how the watershed will develop in the next 50 years and what—if any—will be the associated effects on the watershed's resources. It's entirely possible that in spite of the proactive approach of the watershed's municipalities, BECWA and others involved, widespread drinking-water contamination will still occur. As long as industrial, agricultural and other contaminants remain in circulation, the risk is real and ongoing.

I suspect, however, that Black Earth Creek would be in significantly worse shape if the practices reminiscent of a "business as usual" approach had dominated. After all, measures to protect source water are not a federal mandate, only a recommendation. In the end, this case demonstrates that more than a set of agencies, government units and regulatory systems is needed to protect drinking-water resources now and into the future. Strong local partnerships are needed as well as a level of oversight beyond what the status quo offers. In addition to the technical knowledge of engineers, modelers and regulators, we need the "buy-in" and partnership of citizen interests with a stake in the quality of our water resources. II

Chris Maeder, M.S., P.E., CFM, is the engineering director for CivilGEO Inc.; email: *chris.maeder@civilgeo.com.*

Solving a Decades-Old Problem: The Commute

Dartmouth Engineering

VIKRANT VAZE

It's no secret that commuter travel choices change traffic patterns and times. On-demand service providers such as Uber and Lyft have been very successful at adapting their service offerings and price points to travelers' needs and preferences. In the process, they sometimes generate trips that would otherwise not have been made; at other times they incentivize travelers to switch from traditional trains and buses to on-demand services; and in some cases they increase road traffic.

But what if we flipped the script? What if scheduled transportation providers such as buses and trains were to adapt their service offerings to commuter needs, on-demand alternatives and traffic patterns to benefit the city as a whole? What if scheduled transportation service providers used commuter and traffic patterns to identify the types of commuting options that are best for each area based on rider preferences?

New research says it could save millions of dollars daily. The work, published in the INFORMS journal *Transportation Science*, finds that a redistribution of public-transit resources to better align available transportation options with what passengers want will result in strong societal benefits, including financial savings.

How Can It Work?

So how exactly can scheduled providers of buses and trains leverage the presence of on-demand ride-hailing instead of trying to fend off on-demand services? By scaling back scheduled travel at times and on routes better served by on-demand services, scheduled service can be expanded elsewhere. This can increase operator profits and consumer welfare by millions of dollars daily, making on-demand drivers happy with the extra fare revenues, and allowing scheduled providers to add frequency and increase fleet where needed.

Some people may ask, "what's the catch?" But our work says it really can be a win-win-win, simultaneously making commuters and service providers happy while benefiting the system as a whole.

There has been speculation in popular media that rideshare services such as Uber and Lyft could make scheduled services such as trains and buses obsolete. But what we find is quite the opposite. We see synergy between these competing providers with complementary strengths and weaknesses. Travelers prefer different modes of transportation at different times for different trip purposes and destinations. Our work provides a solution so all these modes can successfully coexist and thrive.

Systemwide Cost Reduction

Using New York City as a case study, our model redistributes transit resources based on commuter preferences. From this approach, we found we could optimize transit schedules to consistently lead to a 0.4- to 3-percent systemwide cost reduction. This amounts to rush-hour savings of millions of dollars per day, while simultaneously reducing costs to passengers and transportation service providers.

When designing schedules, public-transit agencies should explicitly consider the impact of commuter-choice factors such as travel convenience, price, travel time and traffic congestion. The opposite also is true: commuters' choices in turn change traffic patterns and travel times.

Realistically looking at areas where scheduled transit can cut down and let on-demand operators take on a larger proportion of trips benefits a diverse group of stakeholders. It allows for a more-thoughtful reconfiguration, which leads to schedules that are better for passengers, transportation operators and the city as a whole—a rare win-win-win. II

Cities could save millions of dollars for scheduled and on-demand providers and riders using transit-system optimization.

Vikrant Vaze is a professor at Thayer School of Engineering at Dartmouth College, whose research focuses on data-driven optimization for design, planning and operations of large-scale, multistakeholder systems; email: *Vikrant.S.Vaze@dartmouth.edu*.

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In this issue...

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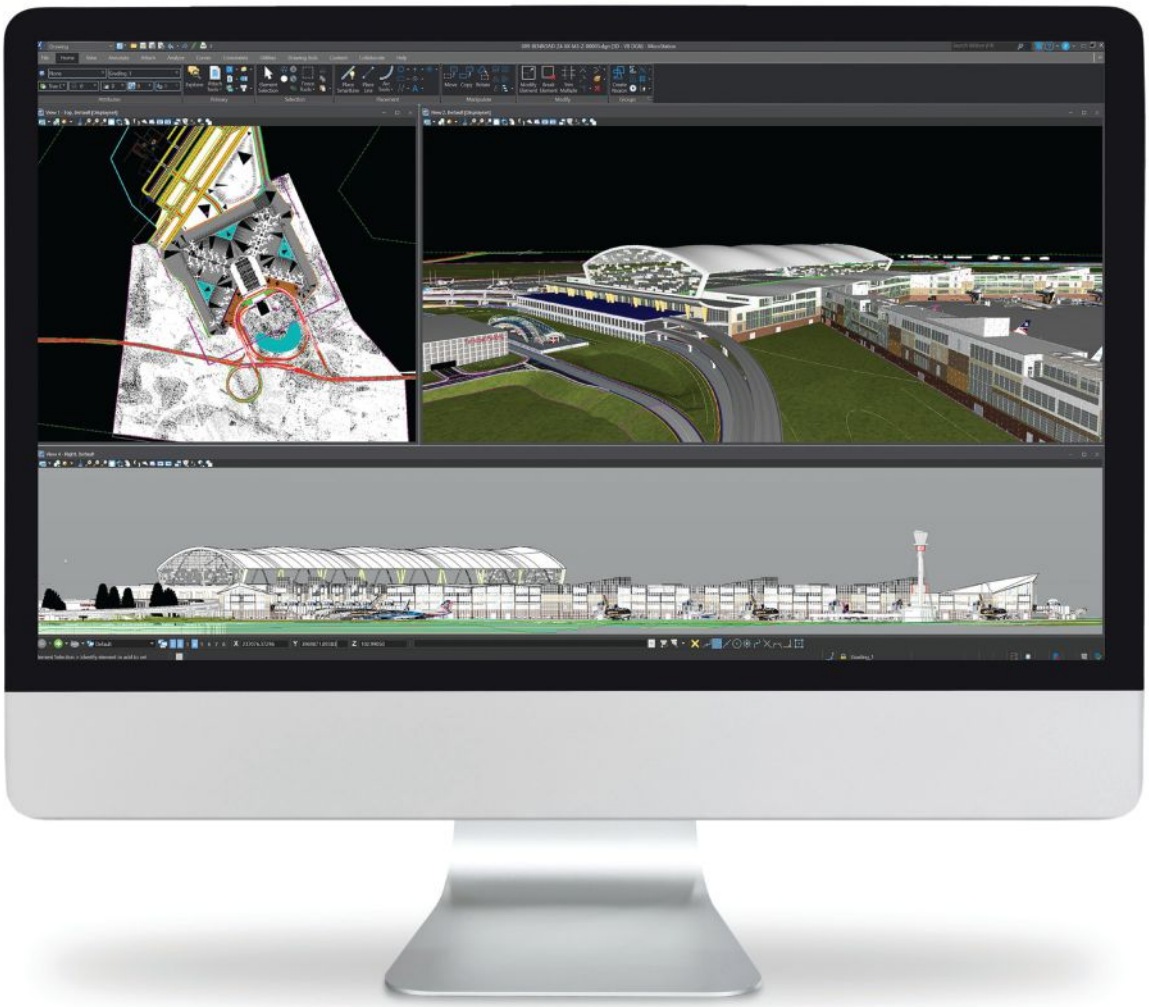

Delivering 2D and 3D infrastructure design projects has its challenges, even for small businesses. Projects are expected to be delivered on time and on budget, even as complexities and scale increase. Not to mention, many project teams are now in work-from-home environments, which can make collaboration difficult. Is your software helping you overcome these challenges?

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– Civil Engineer, G2.com Review

MicroStation Free Trial

Alex Nye

A project developed by SKS Partners and designed by Perkins&Will, this 134,000-square-foot triangular building is San Francisco's first CLT building and California's first multi-story fully mass timber building.

KNOCK ON WOOD

California's Mass Timber Regulation Changes Expand the Building Material's Viability

BY CAROL BRZOZOWSKI

Recent changes to California's mass timber regulations have expanded opportunities for building design and construction that increasingly leverage the benefits of wood.

Code changes went into effect July 2021 as an early adoption of what will be in the next formal code cycle, notes Anders Carpenter, mass timber expert and senior project manager as well as senior associate at Perkins&Will, San Francisco. Projects under the 2019 California building code could move forward on a permit pursuing the new compliance path, he adds. Type IV for heavy timber was an older construction method utilizing cut-wood members from felled trees.

"We're looking to be more sustainable in harvesting rapidly renewable resources—the smaller, growing trees—and engineering the product to use wood more efficiently," notes Matt Covall, Perkins&Will project manager and LEED AP of the new code.

Code Changes

Previous mass timber projects had restrictive height, area and fire-rating requirements, explains Carpenter, adding that it could be difficult to find compliance in some jurisdictions, necessitating more engineering judgment reports and additional testing.

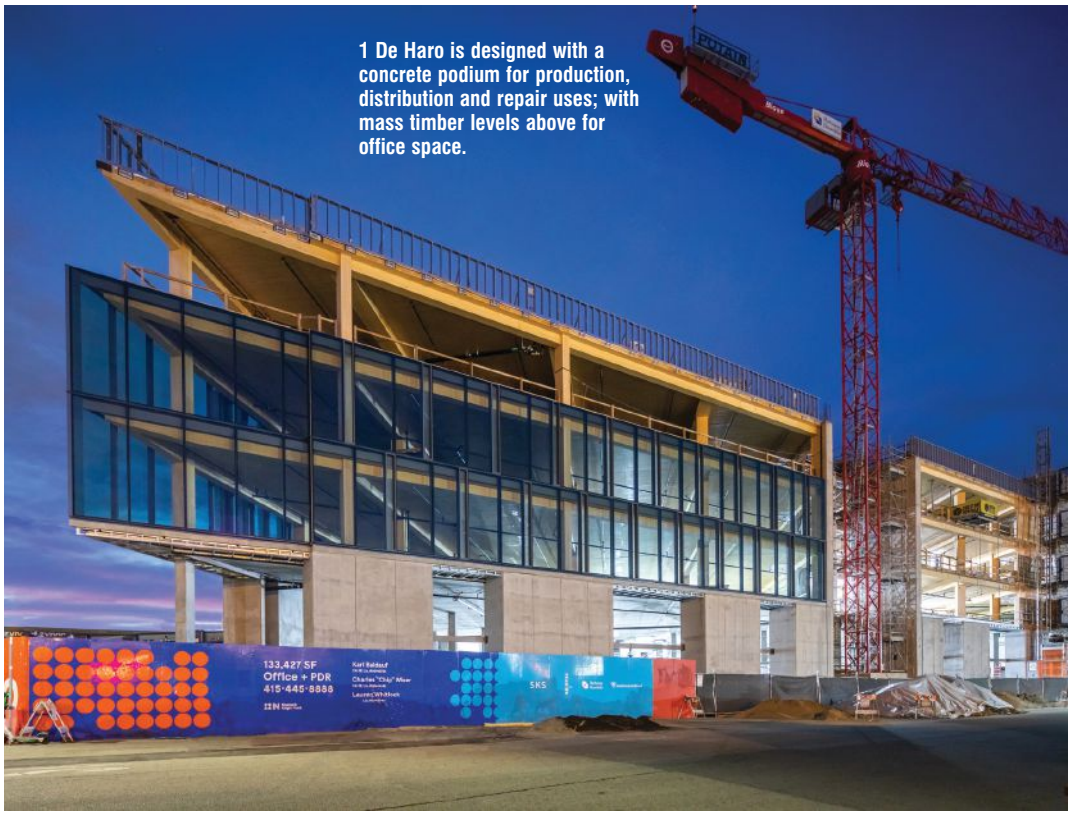
Regulation changes segment Type IV construction into three new categories: A, B and C. While minimum size requirements for columns and beams remain the same, the three new subtypes change the allowable height, and area has been increased for a tall wood building:

- Type IV A = 270-foot maximum height, 18 stories mass timber over Type IA plinth, 0-percent exposed frame
- Type IV B = 180-foot maximum height, 12 stories mass timber over Type IA plinth, 30-percent exposed frame
- Type IV C = 85-foot maximum height, eight stories residential/nine stories office mass timber, 100-percent exposed frame

For example, Perkins&Will is working on a Type IV C construction of an eight-floor mid-rise graduate student housing project that doesn't require concealment of the wood.

The new code paves the way for much greater height and stories previously not allowed in America nor in California until recently, says Covall. "Mass timber is inherently much lighter. Being able to go taller is adding more stories, allowing us to see savings from foundations being reduced substantially," he adds.

Previous codes restricted a drop ceiling from being below a mass timber panel, slab and assemblies. "They would



1 De Haro is designed with a concrete podium for production, distribution and repair uses; with mass timber levels above for office space.

Alex Nye

either have to be filled with insulation, or you couldn't run the building systems based on the limitations of doing that," notes Carpenter. "If you needed an acoustical ceiling in a space, it became difficult.

"Now the building can be sprinklered throughout; or if the concealed space uses a noncombustible installation or you line it with gypsum board, you are allowed to have something like a drop ceiling in a mass timber project," he adds.

Structural integrity is derived by wood being inherently flexible and resilient, notes Carpenter, adding that within California code, steel or concrete lateral systems need to supplement the wood.

"Concrete is being used in conjunction with the timber more often as a topping slab due primarily to vibration and acoustics," says Dalton Ho, LEED architect and senior sustainable building advisor, Perkins&Will.

Covall was lead architect for 1 De Haro, San Francisco's first cross-laminated timber (CLT) building and California's first multi-story full mass timber building, which used steel brace for the lateral component.

Regarding seismic concerns, design is driven by weight, notes Ho, adding that timber's light weight performs better because heavier buildings generate more lateral forces when they move.

Fire Hazard?

As for fire protection, misconceptions abound regarding mass timber. "Wood is thought of in black-and-white terms of being a combustible material—that it will burn easily and is less safe than a steel or concrete building," notes Carpenter. "Actually, these mass timber projects have a pretty effective resistance, even if the material is not covered up and the wood is burning or if the fire has burned through any coverage and it gets to the wood."

"Mass timber is so [dense] that you might get in the hour or two hours it's rated for, depending on the building code furnished for that specific project," says Covall. "It might smolder and char to a certain depth, but it will not fully ignite in that amount of time." That time frame enables people to exit the building and fire crews to respond, he adds.

Wood is subjected to ASTM E119 or UL 263 fire tests, Carpenter notes, adding some have demonstrated fire resistance ratings of three hours or greater.

A significant difference in the new Type IV subtypes is the elimination of the one-hour fire rating for noncombustible, non-load bearing walls and wood stud walls, which previously had to be protected with fire putty as well as fire and smoke dampers to meet the code.

"Under this new code implementation, if a partition did not require a fire rating for occupancy separation, it wouldn't need that additional treatment," adds Carpenter.

Comparisons to Other Materials

In choosing mass timber over steel or concrete, Covall notes, mass timber uses rapidly renewable materials. A recently completed project utilized trees less than 80 years old, which will be replaced by new trees.

"Since they are growing in about 80 years, the building will still be here," Covall says, adding that extraction of ore or materials for concrete or steel is not replenished.

Environmental benefits center on decarbonization and long-term carbon sequestration, notes Carpenter, with mass timber having less embodied carbon and operational carbon when placed onsite.

"There's debate about how you quantify the amount of carbon sequestration with wood because it is tied to the

Mass timber is assembled onsite, allowing for simple and fast assembly.

material's carbon lifecycle analysis: supply chain, forestry practices and material disposal," notes Carpenter, adding that each factor can lead to a better or less optimal outcome.

As the only naturally renewable building material, mass timber provides benefits in reductions in foundation, transportation, energy and installation ease, according to Ho. Perkins&Will considers salvaged wood or reuse, if possible, the best way to reduce the carbon footprint.

Timber certified by the Forest Stewardship Council, Sustainable Forestry Initiative or Programme for the Endorsement of Forest Certification (see "Editor's Note") ensures it's coming from responsibly managed forests, notes Carpenter. It also reflects positively on client projects' commitment to sustainability and innovation, "doing what's right for people and the planet through what they build on their land," he adds.

Energy benefits abound, the architects point out. "These projects, in tandem with modular mechanical, electrical and plumbing (MEP), force us to think about the systems holistically early in a project and do a lot of energy modeling and benchmarking," explains Carpenter.

"Even if you remove mass timber's sequestering potential, it's still a lower-embodied energy product compared to concrete and steel by upwards of 20 percent just in production alone," says Ho.

Timber products can be flat-packed, with transportation energy of the light material greatly reduced. "Timber naturally lends itself well to high-performance and energy-efficient buildings," says Ho. "It's naturally a more insulated material than concrete or steel. Because it's precision-manufactured offsite to very accurate dimensions, you can build buildings with a tighter building envelope with much lower air infiltration, often driving energy consumption."

Project Speed

Carpenter adds that shorter construction schedules and site logistics provide economic benefits. "The streamlined coordination and tolerances with mass timber projects as being largely prefabricated are down to a 16th of an inch compared to steel and concrete requirements, which are more like an inch," he says.

"Mass timber projects, in conjunction with a modular MEP system that can be partially prefabricated, can come together seamlessly onsite," adds Carpenter. "There's less field correction and less scheduled risk. In many cases, the final structure becomes the final finish with the wood."

For the graduate student housing project, an analysis of using mass timber vs. concrete concluded the mass timber version was 15 percent faster to build with a 25 percent savings on foundations.

"Because of some of the other nuances of building in mass timber, it leveled out to about a 10- to 15-percent savings in overall costs when compared to the concrete baseline building," notes Carpenter.

Truncated construction time helps clients' timelines. "In the case of a student housing project, a university may have a timeline to move through," says Carpenter. "If a developer's performance is directly related to a moving date, the shorter construction time equates to a more financially feasible or successful project."

Cash flow curves of mass timber projects require a shorter financing schedule, but its sequence in the overall project

timeline is more front-loaded. Carpenter says it's critical to have a predictable construction timeline for material warehousing until it's ready to be installed, as it can be challenging to get it delivered on the exact day needed. Some clients may not want to frontload costs or pay extra for warehousing.

"The material will be fabricated earlier," adds Carpenter. "An owner has to know they are bringing on the general contractor and subs earlier."

With projects coming together faster, there's less weather exposure to components onsite during construction, which means less product replacement due to weathering.

Additional Benefits

The socio-cultural benefits of using mass timber—depending on a project's location and supply chain—can help support a regional economy, Carpenter notes, adding that fabrication outside the United States negates the benefits derived by local sourcing.

In addition, occupant health can ensure better air quality, since mass timber isn't covered with interior materials that off-gas, adds Carpenter.

Construction crews—requiring fewer people with mass timber—operate with less noise and dust, which also benefits neighbors. "In many cases, CLT projects are easier to assemble and less hard on the body than a steel or concrete building, because you're assembling prefabricated components as opposed to doing tricky and time-intensive welds or concrete pours," explains Ho.

"There's also a biophilic connection to nature and the psychological benefits of being in a wood-finished space," adds Carpenter. "The celebration of that natural beauty is a big benefit for the project, because the structure in many cases becomes the final interior finish. People want to spend time in those types of spaces as opposed to maybe a concrete or steel project lined with sheetrock."

The graduate student family housing project design in San Francisco provides aesthetically pleasing benefits.

"The exterior cladding is not wood, but you would see the mass timber from outside," says Carpenter. "It would be very sensitive aesthetically to the heavily wooded site it's on. The buildings there now are wood-clad buildings. Multiple buildings on this site could be mirrored, flipped and turned with a mass timber structure in tandem with a modular MEP solution and a modular approach to the facade.

"You can build an architectural language on a site like this without having a homogenous look, where it looks like every building is the exact same," he adds.

Material Limitations

General contractors and subcontractors should be experienced in working with mass timber to avoid delays and field corrections, notes Carpenter.

Ho says the limitations of mass timber actually emanate from its benefits of being a light product. "The longer the span, the more it would be affected," he adds. "We've seen some issues with significant acoustic or vibration control, where if you're adding so much concrete in there to dampen vibration that it might not make sense to use timber."

Space constraints—such as lab spaces requiring structural grids exceeding what current mass timber manufacturing can build—may dictate mass timber can't be used, notes Ho.

Kyle Jeffers

Mass timber manufacturers produce wood panels and beams to a high level of precision according to the architect's specifications.

Some mass timber projects can face challenges in jurisdictions where the code hasn't been updated, similar to how it has been in California and other states. "Some jurisdictions may say they're still under a general Type IV heavy-timber code, but can work with you and review engineering judgments," adds Ho. "There's a high level of risk on getting your permit in time or getting a permit at all compared to it being a slam dunk with a steel or concrete project for the same design."

Ho says he and his colleagues advocate mass timber in projects "only if it makes sense. Right now, we see mass timber making sense in a lot of commercial instances." II

Editor's Note: Informed Infrastructure *now publishes entirely on paper certified by the Forest Stewardship Council and the Sustainable Forestry Initiative.*

Carol Brzozowski is a freelance journalist specializing in technology, resource management and construction topics; email: *brzozowski.carol@gmail.com*.

REALITY NOW

Turning Data into Actionable Information

BY MARK SCACCO, P.E.

Much industry media coverage has been given to the capabilities of current reality capture (recap) tools such as drones, mobile lidar scanners, handheld SLAM devices and even smartphone-based capture technology. And surely most readers of this publication are at least casually familiar with recap terminology such as point cloud, photogrammetry, orthomosaic, lidar and 3D mesh.

It seems nearly every AEC and Infrastructure (AEC/I) software and hardware vendor has joined the chorus extolling the virtues of recap and offering a product or service related to digitally capturing the real world. This is a great development for the industry, because a common vernacular is needed for conversation and widespread recap adoption to occur.

During the last few years, you've likely come across many articles, courses and webcasts about recap for AEC/I, including those from this publication. This, too, is great for elevating the industry knowledge base and advancing efforts to improve safety, accuracy and efficiency. Most of this content focuses on the capture tools themselves as well as the techniques and workflows associated with achieving these benefits. This article will not regurgitate those previous works.

Rapid advances in recap hardware and processing software—and dramatic decreases in the costs of both—have lowered, or altogether removed, many of the adoption hurdles and democratized its use. No longer the domain of a few specialists or highly trained professionals, the ability to quickly and easily collect vast amounts of highly accurate, highly detailed data has refocused the recap conversation onto the data themselves and how they are and can be used. To that end, this article will look at these data in action now and what's just over the horizon in the very near future.

A Brief Sidenote

Before jumping into the conversation about the use of data, it's worth pausing to briefly discuss a common misconception about the computer hardware needed to access and work with recap data. In the AEC/I industry, two of the most-prevalent recap methods are photogrammetry and lidar, and the resultant measurements frequently are delivered in the forms of a point cloud, high-resolution imagery and 3D meshes.

A common misconception is that high-end workstations are needed to take advantage of all these wonderful data. However, with the widespread availability of online processing and storage coupled with affordable pricing, there's no need to invest in new hardware. A modest CAD workstation (e.g., Intel Core i7 with 20GB of RAM and an Nvidia GForce GTX 960 with 1GB of VRAM) is more than adequate to effectively and efficiently work with the orthomosaics, point clouds, and 3D meshes generated by online processing services.

Furthermore, the cost of the recap hardware itself has plummeted. For example, the highly capable workhorse DJI Phantom 4 photogrammetry drone costs a bit more than $1,000; the Leica BLK combines a high-definition 360-degree camera, a laser scanner and a thermal imager for less than $20,000; and if you own an iPhone 12 or newer, you have a lidar scanner for free with your phone.

Turning Data into Actionable Information

Armed with all this powerful tech, how are the masses of designers, engineers, contractors and other professionals using the data in their everyday work lives? "Each stage [in the design, build, operate cycle] sees very important benefits of reality capture," says Benoit Fredericque, senior director of product management iTwin Context - Context RealityData and GIS with Bentley Systems. "Design sees a lot of benefits with growing use in construction and operations. Drones are increasingly used at each stage."

RealityOne Midwest

A point cloud describes highly accurate and detailed 3D mesh for earthwork volumes from drone imagery.

Esri

A cloud-hosted digital twin of a Taiwanese port incorporates GIS data, drone-captured 3D mesh and BIM models. It's used here to simulate the effects of sea-level rise.

Predesign

In fact, the base starting point for most AEC/I projects is capturing and creating a model of what *is*, whether on a site or inside a building.

"All work we do is based on a plan," says Martin Fischer, director for the Center for Integrated Facility Engineering (CIFE) and Kumagai professor in the School of Engineering at Stanford University. "That's where the biggest impact of our work happens. Recap gives us the tools to create feedback loops to more-efficiently deploy resources and optimize the design of assets and workflows." The ability to rapidly develop accurate models and plans drives the adoption of recap in the AEC/I industry.

One well-documented use is in site topographic and structural surveys. Point clouds often are captured for topographic surveys and volume calculations. This use is not new and has been around for more than a decade. The previous challenge was creating a *useful* digital terrain model (DTM) from the point cloud, as this exercise would tax the capabilities of most workstations.

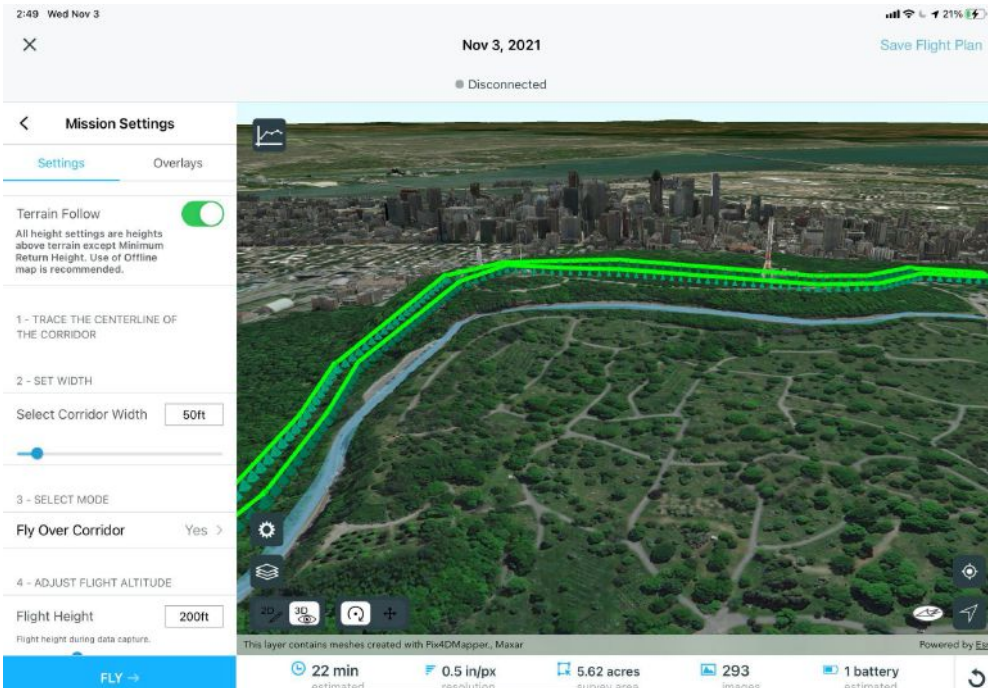
What is new(ish) is the ability to create usable analysis directly from the point clouds themselves. For example, most point cloud processing tools avoid DTM creation and directly compute differential volumes between two point clouds or between a point cloud and a design DTM. In (most) cases where a DTM of the existing ground is needed for use as the basis for further design, these same processing applications can output TIN, meshes and 3D contours that are easily handled by most design and drafting software.

Nico Bonnafoux, product manager for Esri Site Scan for ArcGIS, shares a specific example: "Arcadis, a global design, engineering and management consulting company based in Amsterdam, reduced field data collection time by a factor of 10 for recap of a 30-mile stretch of a 12-lane highway in Qatar. They did this by moving from traditional survey equipment to using drones. This is a tool that enhances the capabilities of trained and qualified staff."

Not only was field time dramatically reduced, the quantity and quality of the collected data far surpasses what's feasible with legacy tools. Better, more-thorough data lead to better decision-making, planning and design.

"Having detailed info [about current conditions] leads to better design and reduces errors during design," concurs Bryan Williams, portfolio manager for 3D capture and robotic layout at Trimble Inc. "Engineers generally consume the data and see real returns on investment [from recap] by getting things right

Esri



A Nearmap 3D mesh was used to plan an automated drone recap mission in Site Scan Flight for a road survey in Montréal.

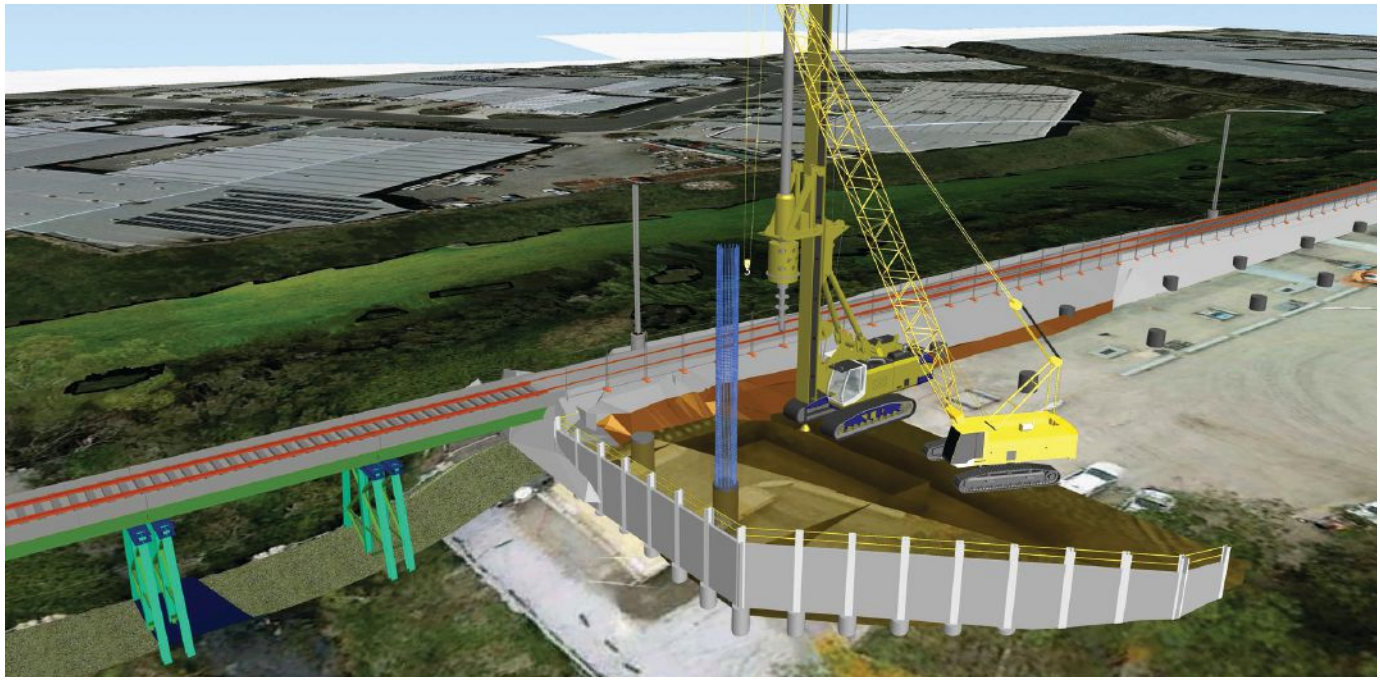
the first time without making a lot of changes; and by preparing accurate estimates and better designs, especially in an existing situation. Good 3D data help lead to better designs." The operative words here are "good data," where good applies to both the quality (high definition and accuracy) and accessibility (timeliness and usability) of the data.

DIY or DaaS?

Although do-it-yourself (DIY) recap for existing site and corridor modeling and planning now is within reach for most industry players, some want the convenience of skipping this step and instead simply licensing the data for immediate use. A benefit of using a "Data as a Service" (DaaS) provider is the data have been prepared for use in advance, saving time and costs of doing this task inhouse, and eliminating the need for purchasing or renting recap equipment.

One such DaaS provider is Nearmap, which captures high-resolution aerial imagery multiple times per year and licenses photogrammetry products to the AEC/I industry, including orthomosaic imagery, 3D meshes and point clouds.

Western Program Alliance



Western Program Alliance used reality capture with 4D construction modeling for a level crossing-removal project in Melbourne, Australia.

"Previous challenges with recap data include obtaining appropriate data and then using it in a meaningful way," says Don Weigel, global vice president of product at Nearmap. "While current recap technology has made this easier, sometimes it is preferable to simply stream current baseline model information directly into your design and analysis tools. When engineers and designers have 'analysis-ready' data, they don't have to worry about the accuracy of the inputs, its format, rotation or translation. Instead, they can make data-driven decisions and focus on engineering tasks and outcomes."

Another DaaS provider is Here Technologies, which offers several location-based products available for subscription and licensing. In addition to traditional base maps, users can access points of interest with enhanced location data; road and infrastructure data on road signage and signals, curvature and steepness, and roughness and elevations; and environmental zones data that include information on area restrictions such as vehicle class or emissions restrictions.

Power Shift

One of the most-impactful changes enabled by the democratization of recap tech is the decentralization of data capture and processing. Recent bottlenecks caused by the need for specially trained recap professionals in the field and data processors in the office are reduced or eliminated by giving more team members simpler (and more-powerful) tools to capture and work with the data at the times and locations needed. (Of course, "garbage in, garbage out" still applies.)

Perhaps the greatest benefit of this is that recap is no longer a special event that occurs at predetermined, prescheduled times. While comprehensive recap of existing conditions still are planned and scheduled ahead of time during the design phase, it's during the shift from design to construction planning and execution when the new benefits become most apparent. Says Trimble's Williams, during construction "power moves from the office to people in the field. The field team can communicate back to the engineers in the office, decreasing the communication time between identifying issues and resolving them." Movement and distribution of data models no longer is a one-way street; instead, they move freely among field and office teams and other stakeholders.

Several real-world examples at every stage of construction—from pre-construction planning to closeout and

Trimble

A scan of recently installed ductwork provides almost-immediate feedback on as-built conditions.

handover—demonstrate the versatility of recap and its expanding uses.

Pre-Construction Planning

Site logistics and pre-construction planning benefit from recap in several ways, including evaluating access to the site via public roads, rivers, etc.; and understanding and accommodating buildings, trees and other existing items either enroute to the site, adjacent to the site or on the site itself. Common uses of recap point cloud and photogrammetric data include extracting information about bridge height and width clearances along possible roads leading to the site; evaluating existing overhead wire sag elevations that may impede access to the site; and using a 3D model of the site and adjacent areas to plan for crane location and onsite material storage.

"Recap delivers a richness of data, which is used before construction even starts," explains Bentley's Fredericque. "Because the scans are so comprehensive, often contractors will collect data for a specific purpose and then return to the data for additional uses."

Construction

Once construction begins, there are almost too many uses of recap to count and certainly too many examples to list them all here. One such example is weekly construction planning and more-frequent progress validation. Capturing as-is or as-built conditions to compare against as-designed models previously required a special setup to perform the capture and then additional time in the office to process the data and overlay the information on the design model. Any deviations from the design or conflicts in the construction then would be flagged for discussion and remediation. Now these comparisons are done directly in the field.

Using tools such as the Trimble SX-7 scanner, which includes an inertial measurement unit (IMU) and advanced internal algorithms, field personnel are capturing the as-is conditions at greater frequency and directly comparing the recap scan data with the design model. On mobile devices, field personnel are making measurements, identifying missing components and verifying that items have been built in the correct locations.

"Validation during construction keeps the decision process moving by putting the data and information directly into the hands of those making decisions," explains Williams. "This reduces rework and change orders, and keeps the project moving."

With the increased practice of offsite prefabrication of components, recap provides additional value. For example, BIM design models typically are used as the basis for prefabrication models. This workflow is satisfactory until actual as-built conditions begin to deviate from the design, as often happens as construction progresses. Because of the limited space into which many MEP assets are built, even slight deviations from the design can result in prefabricated components not fitting properly. With the widespread use of recap tools during construction, contractors are scanning as-built conditions and relaying this information back to the shop to inform changes to fabrication, eliminating rework and schedule delays.

HDR

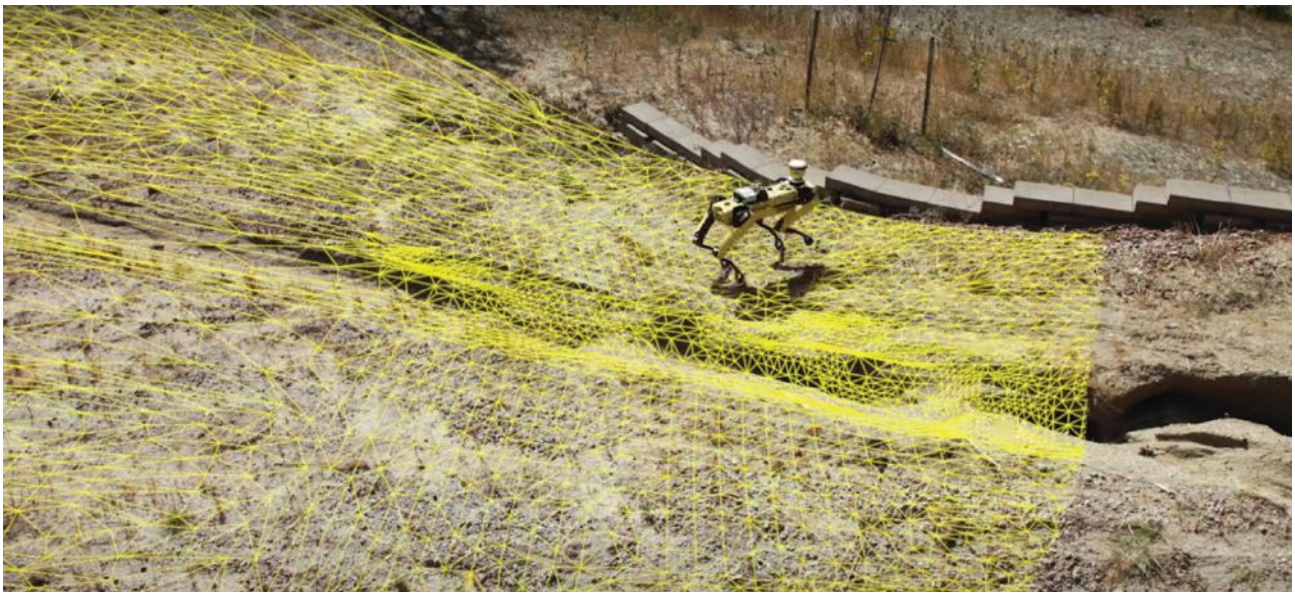
Drones were used to capture data to create this reality mesh of the Diablo Dam on the Skagit River in Whatcom County, Wash., for ongoing monitoring and maintenance.

"The general contractor and the MEP contractors are collecting this recap information," says Williams. "This is no longer a specialty service. Because the tools have been

simplified, more team members have the ability to collect the data and work with the results themselves. QA/QC tasks become decentralized."

Yet another example of the time and cost savings associated with today's recap addresses the problems of labor shortage and personnel safety. As Micah Callough, technology director, AEC, at Esri explains, "Inspections, especially specialty inspections like those done for asbestos abatement, are addressing labor shortage using recap technology. For example, demolition and construction schedules can be negatively affected by the limited number and availability of experienced inspectors."

Trimble, Inc.



A terrestrial-based robot equipped with a lidar laser scanner executes a predefined capture pattern for use in creating a digital terrain model.

However, high-resolution, high-defintion recap data captured in the field by less-experienced inspectors or laborers can be reviewed in the office by an experienced inspector. "This saves time, money and keeps the project on schedule," adds Callough.

The list of additional current uses is long and includes checking aggregate elevations prior to a concrete pour and measuring flatness after the pour; monitoring and tracking oil and other contaminants in shipping lanes to identify leaking ships using chemical IDs; and aiding in the fight against and recovery from West Coast wildfires by tracking airborne chemicals, paint, oil and other hazards kicked up by the fires.

Post Construction

Intriguingly, recap data collected for a specific present-day purpose can provide answers to as-yet-defined challenges in the future. "The raw, unfiltered data provides the opportunity to discover information 'hidden' in the data," says Fredericque. "Months or years later, a contractor, engineer, facility owner or someone yet to be identified might resolve challenges by extracting additional information that wasn't originally needed."

Benefits Today

Returns on investment are notoriously difficult to quantify, usually due to the lack of a well-defined baseline. In the AEC/I industry, the benefits realized today can easily be measured in a couple of ways.

"You can look at recap investment ROI from the cost-leadership angle and the differentiation angle," says Hesam Hamledari, associate at McKinsey & Company and recent PhD graduate from Stanford University's CIFE. "For example, in a recent study, a general contractor in the United States used robotic data capture to reduce data-capture time by 90 percent while simultaneously collecting five to six different types of data over what was required. This can significantly reduce the cost of data capture as well as a project's cost overruns due to increased situational awareness.

"The contractor now had a tangible differentiator from their competitors," he explains. "They had better data and could share 3D models of the site with the owners instead of the 2D plans used by their competitors. They could more-rapidly verify work progress, issue payments and resolve conflicts."

Reality the Day After Tomorrow

As these practical applications of recap are just gaining traction today, reality capture of tomorrow will enable more-spectacular results. In fact, we're starting to glimpse future jobsites.

In one incredible mashup of recap, robotics, AI and block-chain technology, Stanford's Fischer and Hamledari, along with their industry colleagues, used lidar-equipped unmanned ground vehicles and camera-equipped aerial drones to automatically scan a project site, document and verify construction progress, and, using a blockchain-enabled smart contract, automatically issue conditional

lien waivers from the contractor to the owner and issue payments from the owner to the subcontractors. The full details are available in the paper "Construction Payment Automation Using Blockchain-Enabled Smart Contracts and Reality Capture Technologies" by Hesam Hamledari and Martin Fischer (found at *bit.ly/31ro88c*).

Hamledari sees the future of recap developing in three areas: capturing, analyzing and using the data. He explains devices used for capturing reality will continue to expand to collect multisensory data throughout a project's lifecycle. Analyzing the data for useful information will improve with continued progress in AI and computing performance. And the way we use recap information will continue to develop to further document ROIs, integrate with other tech (such as blockchain-enabled smart contracts) and tie contract "success" to business objectives.

Expanding capture capabilities is the first step, and Esri's Callough agrees. "Once we move past the stigma of surveillance, we can capture more data and move the industry forward. One example where we've accepted this is in vehicle tracking, which has been around for a while. Soon we'll see constellations of sensors on most project sites, gathering reality data for air quality, personnel, tool location, activity, materials and more." Before this happens, however, Callough says a big increase in security is needed to reduce risks of hacking. "Security is the responsibility of everyone."

Fischer with Stanford expands the traditional concept of recap for AEC/I to include workflows and information itself. "Reality capture should extend into the supply chain to provide visibility of the reality of the material flows. For example, without a reliable sense of what materials are or will be needed, contractors must have more materials onsite and manage those materials onsite. By creating visibility into the material flow, its transit and delivery information flow, we can cut down on 'just-in-case' materials."

Developments in capturing data are not limited to what is captured but also will include how frequently the data are captured. Capture frequency will increase in many ways, including the use of terrestrial robots.

"Applying drone automation techniques to terrestrial capture technologies will greatly expand the amount of data collected for projects not suitable for drones," says Fredericque from Bentley.

Nearmap's Weigel adds, "Data changes frequently, so capturing it frequently provides insights from months to days to hours. The time from capture to desktop will reduce dramatically. This will have immediate benefits to time-sensitive uses such as search and rescue, disaster response and mitigation, and more."

The second area where recap will develop is in the analysis of the capture data. "AI will get better and help save more time, providing current, accurate and insightful analysis-ready information," says Weigel. This is a needs-driven

result in which engineers, planners, contractors and owners need to evaluate multiple scenarios and narrow their focus to a handful of good options.

"Customers will have more voice in training the AI models to answer specific questions," he adds. "For example, we envision bundles of AI attributes and layers for specific use cases, such as assessing roof condition for the insurance industry, and bundles of layers for building footprints and elevations for the telecom industry."

In addition to comprehensive recap models, Weigel also sees an increased use of "mini models" of reality. "Think traffic studies: a recap of roadway geometry provides a digital environment for modeling car and pedestrian flow."

Analysis of recap data continues to benefit from cloud-based processing, storage and collaboration. "[The] cloud has proven its ability to break down a lot of walls and enable actions that were previously impossible, especially around collaboration and data-sharing activities," says Fredericque. "Adoption of recap tools will continue to grow, with different recap technologies connecting in the cloud. As this happens, we'll start to gain real-world benefits at scale."

The capture, analysis and preparation of recap data culminates in their usage to solve real problems. The continued development of existing technologies (e.g., augmented reality, virtual reality and mixed reality (AR/VR/XR)) and the roll-out of new technology (e.g., 5G, optical fiber connections to the cloud and advanced edge computing) will further enable use of recap data whenever and wherever needed.

As the volume of data increases through time from many projects, their usefulness also increases, even if those uses currently are unclear. "Acquiring data requires investment with the idea that at some point in the future, the data will be involved. Currently, [the industry is] lacking enough historical data to prove the value of collecting data without knowing what you'll use it for," explains Bentley's Fredericque. "Many countries and asset owners are taking the initiative to capture this data for future use. One example comes from France's main natural-gas distribution system operator, GRDF. One of their initiatives is to capture all-new trenches before they are backfilled. This is owner-driven."

Bonnafoux summarizes the advances in capturing, analyzing and using recap data with a drone example. "Reality capture technology is moving from a 'toy' to a standard jobsite tool. Soon, drones will be in the hands of everyone who needs them. This is enabled by more automation, both in capture (the 'drone-in-a-box' concept) and data extraction—using AI to assist in decision making such as detecting faults, making performance predictions and automating scheduling." Widespread capture tools and advanced analysis algorithms will deliver ready-to-use recap information at an ever-increasing scale and scope.

Beyond the Day After Tomorrow

As recap tools continue to expand their capabilities, their impact on the industry also will expand, enabling workflows and outcomes heretofore impossible. These include specific advances such as improved design assistance from our applications to entirely new business models. Integrating feedback loops into the process will accelerate these future uses.

As Stanford's Fischer explains, "Current recap methodologies lack situational awareness, because they lack feedback loops. Future recap will integrate feedback loops to inform and optimize design and operations. Once we have more data, we can optimize; for example, computer tools can design optimal steel structures in significantly less time. We have tools today which help design light structures, but what if by making it heavier you reduce the complexity of the connection designs? This is not possible today, but once we have more data, we can create these automations."

The capture, analysis and use of data leads toward more-robust and accurate modeling, which enables real-time monitoring, preventive maintenance, and simulations to predict future operations and outcomes. To this end, Fischer points to an example of an industrial structure developer that simultaneously builds a digital twin along with the actual structure. "The developer requires weekly recap so the digital information can be digested into the digital twin over a longer period of time," says Fischer. "The digital twin of the asset is then available at the time of handover of the physical asset."

This type of tight integration between the physical and digital assets can change the way contracts are defined and projects delivered. Currently, contracts typically define success as the delivery of an asset such as a building, bridge or water-treatment facility. New business models will emerge, with a clearer definition between delivering a product vs. delivering an outcome. Those AEC/I players that can guarantee a desired outcome will have a distinct advantage. "In the future, success will be defined by outcomes, such as 'the building will operate at 50-percent less energy consumption' or 'the roadway will require zero maintenance for X number of years,'" forecasts Fischer.

Conclusion

The consensus is that firms which learn to adapt to the rapidly evolving recap landscape will thrive, while those which do not will struggle. Capturing reality and using the information extracted from the data is simply a means to the end of addressing efficiency problems, labor and expertise shortages, getting everyone home safely, and ultimately delivering not just a project, but results.

As Fischer summarizes, "The current feeling is that any one individual [person or entity] sees too little of the whole. Digital reality capture enables business models, workflows and outcomes to work together, so we can accelerate the development and incorporation of these new methods for greater efficiency, less waste and better results." II

Mark Scacco, P.E., is a 25-year veteran of AEC technology and design consulting. He is an AEC Industry Consultant with Scacco LLC and can be reached via email at *mark.scacco@scaccollc.com*.

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Design Considerations for Using Flexible Buried Bridges in Lieu of Conventional Bridges

BY JOEL HAHM, P.E.

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LEARNING OBJECTIVES

At the conclusion of this article, the reader should be able to understand/perform the following:

- Know what is considered a flexible buried bridge.
- Recognize applications where a flexible buried bridge can be considered.
- How to evaluate site, design and construction considerations for a flexible buried bridge.
- Benefits of a flexible buried bridge compared to a conventional bridge.

Overview

Structural-plate buried structures consist of multiple metal plates that are corrugated, shaped to a specific curvature, hot-dipped galvanized (when made of steel), and bolted together in the field to construct large culvert or clear-span arch bridge crossings. After assembly, they are backfilled using granular soil to complete the bridge crossing. They are considered flexible structures that work via soil-structure interaction, where the structure and surrounding engineered backfill work together to support the design loads.

Figure 1. Assembly for a typical bridge installation. (Massachusetts DOT; Attleboro, Mass.)

Structural plate has been in use for more than 90 years. It originally served as a large-diameter alternative to corrugated metal pipe (CMP) for use in hydraulic applications where CMP could not be efficiently built large enough to satisfy hydraulic requirements or where bottomless (arch- or box-shaped) structures were needed. Original corrugation profiles were relatively shallow (6″ x 2″ or 9″ x 2.5″), which limited the available structural-plate span length.

Since the development of deep corrugation profiles (those with greater than 5″ corrugation depth) about 40 years ago, there has been a gradual increase in the use of structural plate for longer-span hydraulic crossings and grade-separation applications where conventional bridges have historically been used. This has resulted in the emergence of "Flexible Buried Bridges," which are structural-plate structures with a span of greater than 20 feet—the AASHTO definition for the minimum span of a structure considered a bridge.

Today, flexible buried bridges are widely considered an attractive and economical alternative for short- to medium-span conventional bridge crossings. They offer a wide range

of benefits, including basic economy, construction advantages, ease of transportation, environmental benefits, low maintenance costs, increased resilience and other factors. The use of these structures has been made possible by advancements in design and analysis tools, manufacturing capabilities, materials, and development of deeper corrugation profiles to allow for longer spans, heavier loads and higher cover.

Flexible buried bridges have demonstrated excellent performance in areas impacted by seismic events. These types of structures have historically performed very well compared to other bridge types in seismic events, typically remaining functional as a lifeline and often requiring little to no repair or remediation afterward. Recent studies on seismic demands have found that seismic loading does not govern most flexible buried bridge designs.

To date, flexible buried bridges have been constructed in spans exceeding 100 feet and have been designed to carry rail loads, large agricultural vehicles, mining equipment, large off-road construction equipment, and other special loads that are much heavier than typical highway design loading. Cover can range from as low as 2 feet to more than 50 feet, depending on the structure size and shape as well as project conditions.

Figure 2. A buried bridge supports a 2.7-million-pound mining shovel and 12-foot cover. (New Mexico DOT; Grants, N.M.)

There have been several webinars, workshops and articles sponsored by a number of organizations during the last several years addressing various aspects of design, construction and performance of flexible buried bridges. This article provides guidance on the considerations for design of flexible buried bridges and how they can be considered as an alternative to conventional bridge applications.

Why Consider Flexible Buried Bridges?

There is a flexible buried bridge option for just about any short- to medium-span crossing need. The most common applications have been bridges spanning across minor natural water courses. However, because of the aforementioned recent advances, flexible buried bridges also are becoming more common for grade separations (crossings where traffic passes through the bridge and over it), wildlife crossings (wildlife crossing over the bridge with traffic passing through it or vice versa), in-place bridge replacements (building a new buried bridge beneath an existing conventional bridge without detouring traffic), bridge replacements in remote areas, and other applications.

The advantages of using flexible buried bridges will vary based on project-specific considerations. However, the most-common benefits of using flexible buried bridges as an alternative to conventional bridges tend to be lower overall project cost, better fit based on site geometric limitations, constructability, speed of construction, and design advantages. Additional benefits may include but are not limited to:

- Site geometric limitations (road alignment, right of way, grading challenges, minimizing project footprint)

Figure 3. A bridge replacement with twin-span buried bridges. (Missouri DOT; Cape Girardeau County, Mo.)

Figure 4. A bridge replacement in a remote location. (USDA Forest Service; Unity, Ore.)

- Project location (remote area, congested urban area)
- Project schedule/material availability (need to accelerate material delivery or design-submittal process)
- Skill or experience of construction labor force (desire to use local or inhouse labor)
- Completed project cost
- Long-term maintenance and inspection cost
- Construction equipment requirements (lack of space for cranes or need to reduce equipment costs)
- Design challenges and considerations (heavy loads, load rating, seismic/settlement concerns, clearance requirements)
- Speed of construction (minimize traffic disruption and/or onsite construction time)
- Aesthetics (blend with surroundings, achieve a desired look)
- Resilience and environmental factors (ability to function after an extreme event such as seismic, flooding and damage; design for future needs; sustainability)
- Improved safety (no bridge deck to ice up, wider shoulders and walkways with potential to economically increase bridge width)
- Other unique, project-specific factors

An additional advantage gaining more attention given shrinking agency budgets is lower long-term inspection and maintenance costs. Flexible buried bridges consist of two basic bridge elements: the structure plates and connecting hardware (nuts and bolts). These structures eliminate bridge decks, which are a common maintenance challenge for bridge owners and expensive to rehabilitate. There are no bearings, joints, drains, abutments or other common bridge details that need to be regularly inspected or maintained. Inspection is simple, consisting of visual observations of the condition of the structure, spot measurements of the shape and general site observations. Maintenance on the interior may involve periodic cleaning and/or removal of silt or unwanted vegetation, depending on the application (grade separation vs. hydraulic crossing). At the road level, only routine pavement maintenance is required, which is far less expensive than bridge-deck repair.

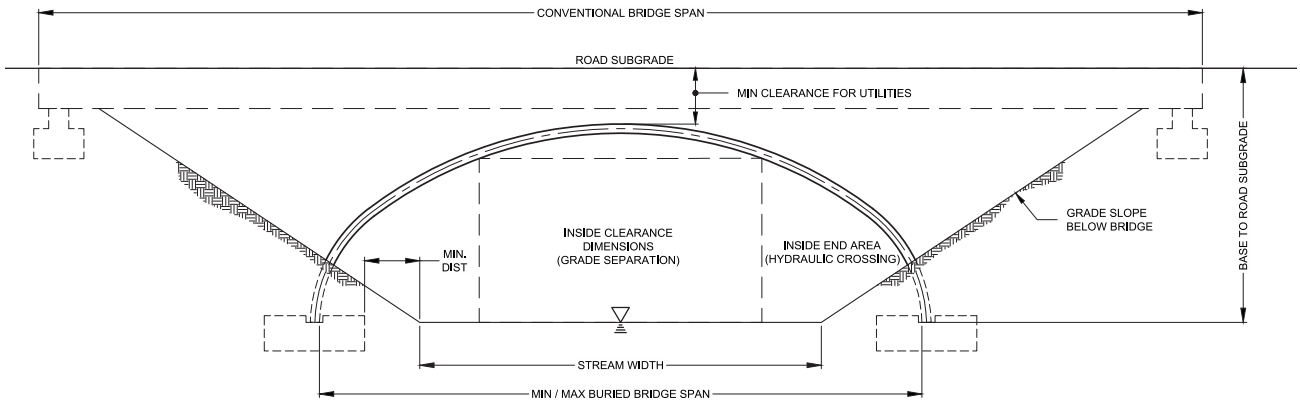
Designing a Flexible Buried Bridge Structure

Evaluate Siting Conditions and Feasibility

The first step in developing a buried bridge alternative is to determine if site geometric limitations will allow a buried bridge structure to fit at the desired location. To evaluate this, it is critical to determine how large the structure needs to be and how much room is available. For hydraulic applications, the structure size typically is determined by a hydraulic analysis that establishes a minimum inside end area or span based on the water course passing through it. For non-hydraulic applications, the minimum structure size usually is determined based on inside clearance requirements.

Maximum structure size limitations often are governed by the available vertical distance from the bottom of the structure to the top of the road grade passing over the structure as well as minimum soil cover needed to meet design requirements. Other factors that limit structure size may include a minimum depth of soil cover needed for utilities crossing over the structure, the presence of existing bridge elements (for in-place bridge replacement applications), right-of-way boundaries, foundation depth and other project-specific geometric limitations.

As a rule of thumb, the maximum span-to-rise ratio for a flexible buried bridge is on the order of 4:1 to 5:1, depending on the structure span and shape. It is important to recognize that a buried bridge alternative will rarely have the same span as the conventional bridge option. This can help reduce the footprint of the project. Figure 5 illustrates basic information that



SITE CONDITIONS AND CONSTRAINTS

Figure 5. Basic information that should be considered when evaluating geometric feasibility.

should be considered when evaluating geometric feasibility.

Engineers often approach a crossing by considering how long of a span is required to cross from "bank to bank." However, many engineers have found that by reorienting the challenge to consider how large of an opening is required to pass the hydraulics or capture the clearance box can require a much smaller opening and span. Figure 5 effectively demonstrates how a buried bridge using a much smaller span and footprint can achieve the project objectives. This will typically result in a more cost-effective solution as well.

After feasibility of a buried bridge alternative is determined, the next step is to consider structure geometry options. At this point, the project engineer should reach out to a manufacturer to evaluate the best shape to use as a starting point for a design evaluation. Most structure manufacturers will have a library of "standard" shapes that can be used as a starting point, and one of these may be a perfect fit for what is needed. If not, a custom geometry can be developed that is optimized for the project requirements.

Figure 6. Before (top) and after (bottom) images of a bridge replacement with custom geometry. (Vermont Agency of Transportation; St. Johnsbury, Vt.)

Basic Design Inputs

Buried bridge structures are designed in accordance with Section 12 of the AASHTO LRFD Bridge Design Specifications. The structure design evaluation will involve several basic inputs. Deep-corrugated buried bridge structures (corrugation depth >5") are analyzed using finite-element analysis (FEA). In addition to the structure geometry and material properties, the FEA requires inputs for foundation soil properties, engineered backfill materials (placed around the structure), and site soil properties outside of the engineered backfill materials. The engineered backfill material is specified by the structure designer based on AASHTO requirements and the FEA results.

Foundation soil and site soil properties used for FEA inputs can usually be determined based on information provided in soil boring logs, test pit data and other information available regarding site conditions. If project soil information is limited or not available, reasonable assumptions can be made. When they are necessary, the assumptions should be clearly stated by the structure designer and acknowledged by the project engineer or owner. At this stage, assumptions may result in a conservative design. It would be in the owner's best interest to obtain the needed soil information prior to final design to confirm the initial assumptions.

Backfill Considerations

The AASHTO LRFD Bridge Design Specifications include requirements for minimum soil cover above the structure and the minimum width of engineered backfill on each side of the structure. The engineered backfill zone material is typically specified as a

Figure 7. An engineered backfill zone and site soils for haul road grade separation. (Fort Knox Gold Mine; Fairbanks, Alaska)

well-graded, angular, durable, coarse granular material with low fines. Although there may be some design flexibility based on the project application and structure size, engineered backfill zone materials will usually classify as A-1 or A-2-4 soils per AASHTO M145 (AASHTO soil classification standard). Fill material in contact with the structure will also need to fall within a range of desired electrochemical properties to achieve service-life requirements. These properties include (but may not be limited to) pH, resistivity, chlorides and sulfates. It is common to import quarried or processed material to satisfy the structural and electrochemical property requirements of the engineered backfill. However, if there is a desire to use site soils, geotechnical testing may be performed to determine if the onsite material is suitable.

Minimum cover and backfill zone width requirements are based on the structure geometry—specifically the ratio of crown radius to the haunch/side radius. The crown is the top of the structure, and haunch/side is the portion of the structure immediately adjacent to the crown that will usually have a tighter radius of curvature. If the radius ratio is greater than 5:1, the minimum soil cover allowed is 2 feet, and the minimum backfill zone width is 1/5 of the structure span. If the radius ratio is less than 5:1, the minimum soil cover allowed is 3 feet, and the backfill zone width is 1/3 of the structure span. For large-span structures, the minimum backfill zone width can be capped at 17 feet if the designer determines that width is acceptable based on the FEA results. The cost and availability of suitable engineered backfill zone material varies widely based on project location, local geology, regional usage and other factors. This can be a significant or a minor cost and should be considered when evaluating structure options.

Foundation Considerations

Foundation costs are a significant consideration for both conventional and flexible buried bridge options. Flexible buried bridges have a much-higher differential settlement tolerance than most conventional bridges and rigid structures. When the higher settlement tolerance is considered in the geotechnical analysis, a much-higher allowable bearing pressure often is possible, which can result in foundation cost savings or allow for use of spread footings when deep foundations otherwise would be needed.

The foundation-bearing elevation for buried bridges usually is much deeper than where a bridge sill would be located for a conventional bridge. In many cases, this allows for buried bridges to bear directly on a stable foundation soil layer, rather than needing to extend foundations deeper, carry out a soil-improvement program or use deep foundations that might be needed for a conventional bridge. It is important for the geotechnical engineer to consider foundation requirements for the buried bridge alternative differently than for the conventional bridge. In many cases, differences in foundation costs can be a significant deciding factor in the structure type.

Construction Considerations

Construction costs and methods also should be considered and discussed with the manufacturer. Weights of individual plates typically are in the range of 350 to 1,200 pounds, depending on plate length and material thickness. This allows many structures to be assembled using a backhoe, forklift truck or other equipment already onsite for other work, keeping equipment costs down. A crane typically is not required for assembly, and there is no need for specialized labor or heavy equipment—many counties and general contractors

Figure 8. An assembly uses a backhoe (left) and forklift truck (right). (Attleboro, Mass., and Limon, Colo., respectively)

Figure 9. A staged construction with 40-foot cover. (Washington DOT; Spokane, Wash.)

prefer to use their own equipment and labor forces whenever possible. The modular nature of flexible buried bridges makes them ideal for staged construction. Part of the structure may be assembled and backfilled, and traffic put in service over the completed section while construction continues on the next.

Depending on site limitations, a new buried bridge can be built below an existing bridge without taking it out of service. Both scenarios (staged and in-place construction) can eliminate or significantly reduce the need for detours and traffic delays. Modular construction (where a buried bridge can be preassembled in large sections and set in place on the foundations) can be used in areas where only limited road closures are allowed. Each project has its own unique set of construction requirements and challenges, and those should be considered for each structure type. There can be significant differences in the time and construction effort required among the options being considered.

Conclusion

Flexible buried bridges can be an effective alternative to conventional bridges in many bridge applications. Project-specific requirements, limitations and design challenges will impact the feasibility of a buried bridge alternative, while factors such as site conditions, foundation alternatives, construction considerations and overall project cost can provide valuable data points to help make the best decision on the better bridge type for the project.

Figure 10. An in-place bridge replacement during construction (top) and finished (bottom). (Missouri DOT; Lawrence County, Mo.)

Author

Joel Hahm, P.E., Contech Engineered Solutions; email: *Joel.Hahm@ContechES.com*.

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Professional Development Series
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Design Considerations for Using Flexible Buried Bridges in Lieu of Conventional Bridges

Quiz Questions

This quiz can be completed online at *www.informedinfrastructure.com/v1education/*. Your score will be tabulated while you wait, and you will receive your certificate upon completion if you correctly answer eight or more questions.

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1) How do flexible buried bridges support design loads?
   A. The structure carries all the load.
   B. The pavement directs the load away from the structure.
   C. The structure and backfill work together to support loads through soil-structure interaction.
   D. None of the above.

2) What is a common application for flexible buried bridges?
   a. Grade separations
   b. Wildlife crossings
   c. Bridge replacements in remote areas
   d. All of the above

3) What is a common benefit of using flexible buried bridges as an alternative to conventional bridges?
   a. Speed of construction
   b. Location of manufacturing facility
   c. Delivered using oversized loads
   d. Design complexity

4) Roadway maintenance on the wearing surface above a buried bridge is limited to typical pavement maintenance because buried bridges do not have a bridge deck.
   a. True
   b. False

5) Which factors determine the minimum size of a buried bridge?
   a. Inside end area
   b. Seasonal temperature variations
   c. Inside clearance requirements
   d. A and C

6) Which is a factor that can limit the maximum dimensions of a buried bridge?
   a. Pavement type for the crossing roadway
   b. The number of bolts in the structure
   c. Available vertical distance from the bottom of the structure to the top of the road
   d. The number of plates in the structure

7) A custom geometry can optimize the geometry of a buried bridge solution while improving design efficiency compared to a standard shape.
   a. True
   b. False

8) Deep-corrugated buried bridge structures are analyzed using finite-element analysis (FEA) in accordance with AASHTO design requirements. Which design inputs are needed for the FEA?
   a. Engineered backfill material properties
   b. Foundation soil properties
   c. Structure geometry and material properties
   d. A and B
   e. All of the above

9) What determines the minimum allowable height of cover and backfill zone width of a buried bridge?
   a. Structure span
   b. Ratio of the crown radius to the haunch/side radius
   c. Foundation soil properties
   d. Level of compaction of engineered backfill soils

10) What are the construction advantages of flexible buried bridges?
   a. Specialized labor and heavy equipment are not needed for assembly
   b. Plates can get wet during construction
   c. Staged construction and in-place bridge replacement can eliminate or reduce the need for detours
   d. A and C
   e. None of the above

To complete the quiz and earn your PDH credit:
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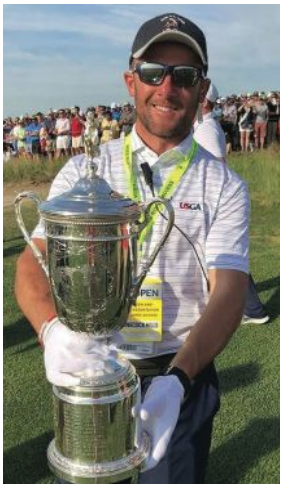
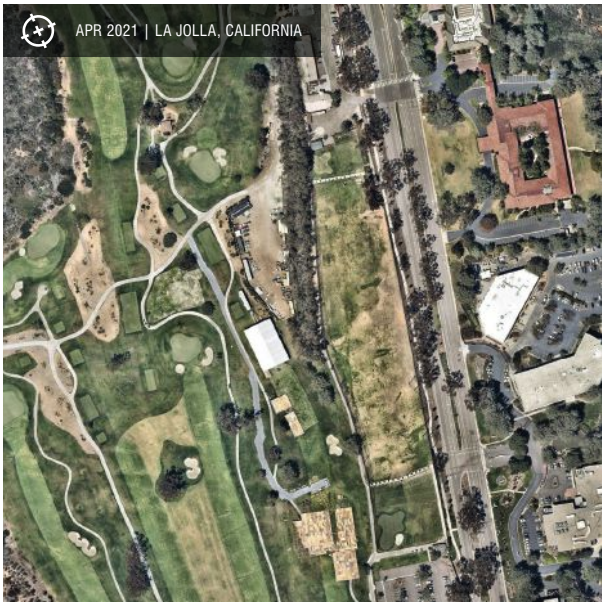
Improving on 'Par for the Course'

Aerial Imagery Helps Prepare Golf Courses for U.S. Open Tournament



Tim Lloyd
Director of Operations
U.S. Golf Association



Nearmap imagery from January 2021 (left) and April 2021 (right) show the construction progress to the course in preparing for the U.S. Open.

The U.S Open Championship has been held since 1895 and is one of the most-prestigious and difficult golf tournaments in the world. Staged by the U.S. Golf Association (USGA), it's played on a different course each year and now welcomes tens of thousands of attendees every day.

Most golf courses aren't built for such crowds or the infrastructure required to host such an event, including temporary grandstands for spectators; buildings for food, drinks and other concessions; restroom facilities; television equipment and broadcast towers; temporary parking; security and public safety; and new roads to move all the additional vehicles around.

Currently tasked with planning and executing these tournaments is Tim Lloyd, director of operations for USGA. "My team specifically is involved in the build planning and execution of the onsite venue," he explains. "Taking a golf course and turning it to a stadium."

Check out the USGA session "Line-of-site planning in a pandemic" from Nearmap's NAVIG8 conference and other sessions about how aerial technology is helping solve real-world problems now and in the future.

Watch Now

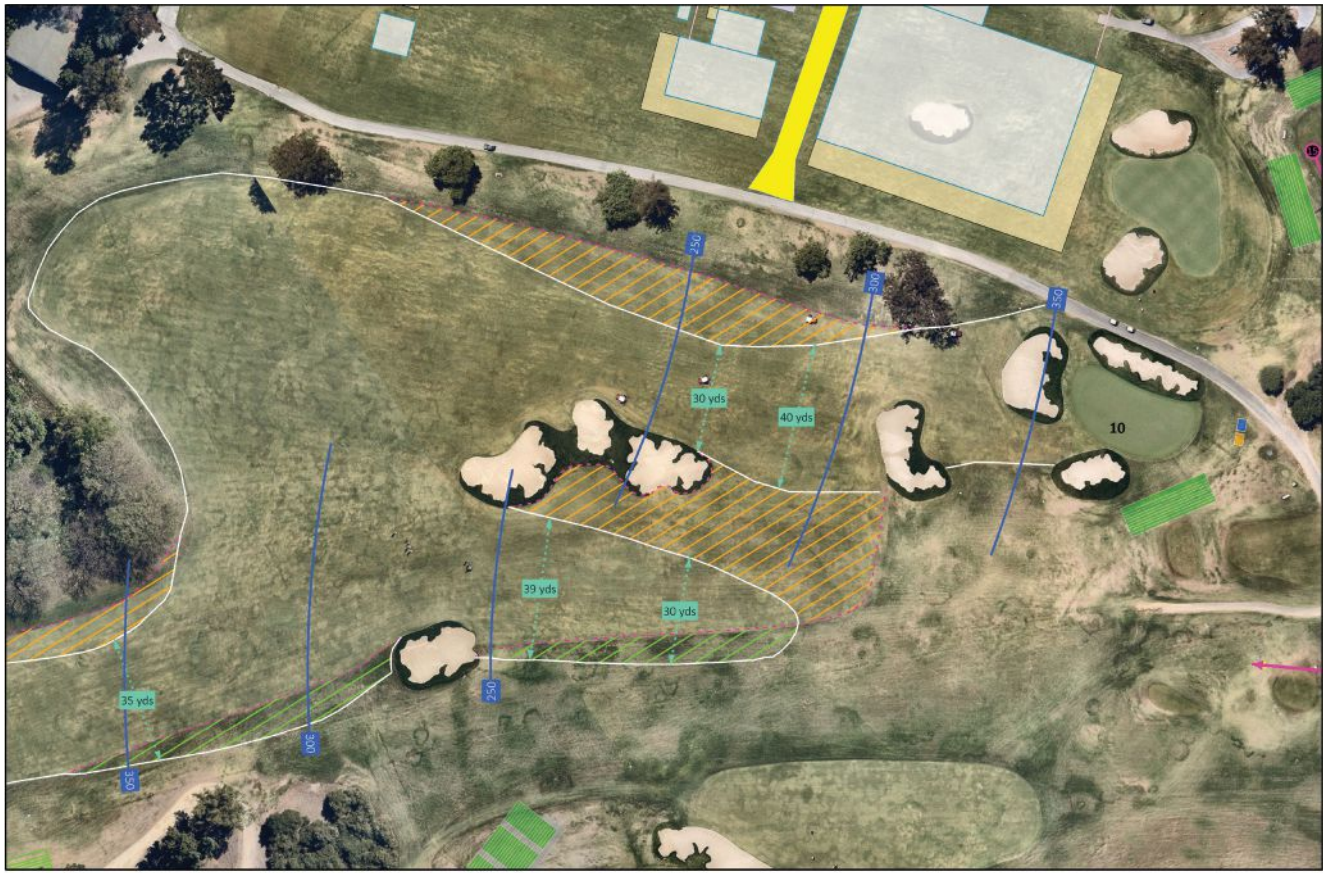
Expanding the Toolset

Such a monumental task requires a lot of people, equipment and planning, and Lloyd uses technology as much as he can to help. One of his primary resources is detailed, high-resolution aerial imagery from Nearmap, which provides content updates two to three times a year.

"We came upon Nearmap a few years ago and began to realize the benefit of having that constant update and the very crisp imagery as we look to our sites and how we overlay that two-dimensional plan on top of it," says Lloyd.

He also explains that a typical U.S. Open takes about four years to plan and build, and using Nearmap imagery taken during different seasons with varying vegetation growth is very useful.

"The ability for us to see that infrastructure as we lay it in is critical to our ability to plan accurately," he adds. Nearmap location content can be used to plan and execute the control of procurement, transport, and stationing of workers and materials in the different phases of the construction to reduce disruption to the local community and surrounding businesses.



The USGA uses Nearmap imagery as a basemap within ArcGIS to assess a course's normal layout for its members and if it needs to be modified to make it more challenging for the U.S. Open and the world's best golfers.

High resolution imagery is vital to the planning process. Nearmap's current-generation camera system captures data with a ground sample distance (GSD) of 5.5 centimeters in vertical imagery with a horizontal accuracy of 19.8 centimeters, which allows for extreme precision.

Changing Course

In addition to laying out the new infrastructure needed for every event, Nearmap imagery is used to determine if a course needs to be modified to suit the world's best golfers.

As an example, Lloyd cites the Los Angeles Country Club, which will host the 2023 U.S. Open. During planning, they realized professional golfers, who hit the ball farther than most of the regular members and can be more creative in their approaches, may try to navigate a hole more-directly by playing a shot to a different hole, and then back to the green of the original hole. They didn't want the intent of the course to be challenged, so they're redesigning those holes so the best players in the world have to stay on the hole as intended.

"This is a unique application, but without Nearmap, we wouldn't be able to show it," notes Lloyd. "Once those changes are made, we'll then get the updated aerial [imagery], and we'll be able to show it as it is in real time."

Making a Difficult Job Easier

Lloyd notes that although planning for a U.S. Open and all the changes needed on each course have been happening for more than 100 years, modern technology improves the ease and accuracy of the transitions.

"In the past, prior to our ability to use Nearmap, we'd be guessing, we'd be estimating and drawing in freehand how those buildings situated, perhaps with some blueprints and otherwise," he explains. "But now we have the ability to see it, as soon as that building was under construction and then when it was completed. We could see exactly what it looked like, and we were able to plan accordingly."

To host a U.S. Open, the USGA often needs to add temporary infrastructure to an existing course. This can include buildings for players, stands for patrons and even new roads that allow for all the additional vehicles needed for such an event.

About Nearmap

Nearmap's cloud-based geospatial information services and aerial surveys offer instant access to high-resolution vertical, oblique and panoramic aerial imagery, city-scale 3D datasets and Nearmap AI along with integrated geospatial tools. For more information, visit *www.nearmap.com*.



Plotting for Growth

Geospatial Technology Boosts Efforts to Rebuild Forests and Reestablish Landscapes

BY JOHN STENMARK

Imagine planting enough new trees to cover a plot of land the size of Switzerland. Now do it again and again, nearly 500 times, until you've covered 2 billion hectares. It's a huge, seemingly overwhelming effort. Yet a Dutch company is using advanced geospatial technologies to make it happen.

From its base in Amsterdam, Land Life Company works to restore lands degraded by natural or human activities such as wildfire, desertification, agriculture and urbanization. It's one of a small handful of companies capable of large-scale tree-planting services needed to reestablish forests and create productive landscapes. With projects in 25 countries on five continents, Land Life clients include governments and corporations seeking to reinvigorate damaged land and soils or to offset carbon released by commercial activities. Since its founding in 2013, Land Life has planted nearly 1.3 million trees.

Successful tree planting comes in bunches. At each project location, new trees are planted in groups to provide protection against the wind. The young trees spread naturally to fill in and enlarge the new forest. Eventually the soil improves to support new plant life and further aid in carbon capture.

But it's difficult to plant trees successfully on a large scale, and Land Life plants trees by the thousands. Logistics are complex; and costs for sapling trees, supplies, labor and equipment add up quickly. To optimize the cost-to-benefit ratio, Land Life needs to achieve a high rate of success for the trees it plants; the young trees need to grow and remain healthy to produce long-term benefits.

Foraging the Forests

To reach and maintain success, Land Life monitors the new trees through periodic visits to measure parameters

such as height and health. Combined with information on the tree species, location, soils and environmental conditions, the data support informed decisions in planning the next round of planting and enable Land Life to adjust variables such as soil amendments and watering approaches.

"We are gathering as much data as we can," says Tom Janmaat, a data scientist at Land Life. "We're shaving costs in the operations and using our knowledge to optimize performance. The next steps will be ecological gains: making sure you plant the right trees in the right spot at the right time. Scientific knowledge is available, and we think we can get even better. We can help improve our knowledge base by gathering data on how our trees grow: Learning what works and what doesn't."

Janmaat explains that Land Life records as much data as possible on factors that could influence the trees' growth and survival rates, then analyzes how the various parameters influence each other. Thanks to its rigorous statistical practices, Land Life needs to monitor only a fraction of its trees. On a planting of a hundred-thousand trees, they typically monitor a few thousand to produce a good sample of every combination of tree species and treatments in a given field.

Monitoring tree performance is a labor-intensive process. To control costs, the company is working to improve productivity in its monitoring efforts. For example, it developed an inhouse smartphone app to guide users through the capture of information on a tree's species, height and health. In order for the information to be useful, field teams must be sure they visit the same tree every time. When dealing with thousands of nearly identical trees, it's not a simple task. That's where GNSS comes in.

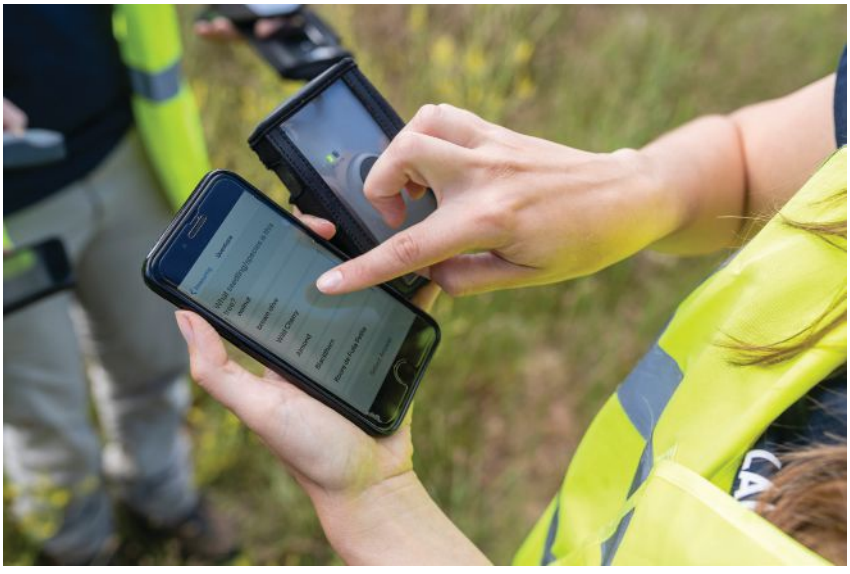
Technicians measure a tree height and record data on a smartphone. Monitoring is an essential part of successful high-volume tree planting.

For years, Land Life attached small paper tags with unique QR codes to the trees selected for monitoring. Although the codes ensured accurate identification of specific trees, they required monitoring personnel to carry a separate QR reader and crawl on the ground to reach and scan the tag. The method was further compromised by the

A Land Life technician uses a QR code reader to identify a tree. By replacing the QR codes with accurate GNSS positioning, Land Life produced a four-fold increase in monitoring productivity.

fact that some QR tags were torn off and lost each year. So Land Life turned to satellite positioning using the GPS receivers built into team members' smartphones. That decision led to a new challenge: accuracy.

In open fields and with access to a cellular network, a smartphone's built-in GPS can provide positions accurate to roughly 3 meters. The accuracy is worse when working in treed areas or locations where cellular signals are not available—conditions where Land Life does much of its work. With trees spaced 3 to 4 meters apart, the smartphone GPS can't provide the accuracy needed to confidently identify and return to the same tree repeatedly. Land Life needed the ability to measure within 1 meter.



A Land Life technician holds a smartphone and the Trimble R1 GNSS receiver while entering data. The R1, commonly carried in a pocket, provides submeter accuracy via Bluetooth connection to the phone.

Meeting the Needs

Professional-grade GPS or GNSS (Global Navigation Satellite System) receivers could easily meet the submeter requirements, but Land Life was concerned about the cost and complexity of those solutions. It had already invested in writing software for data collection, and its field teams were familiar and efficient with those inhouse apps. Land Life needed a way to blend higher-accuracy positioning into its existing workflows and Bring-Your-Own-Device (BYOD) approach to locating and monitoring the trees.

Land Life selected the Trimble R1 GNSS receiver: a device roughly the size of a pack of playing cards that can provide real-time positioning with submeter accuracy. Using a Bluetooth connection, the R1 can stream position data to apps running on iOS or Android smartphones, making it easy for field workers to carry and use. Land Life software developers incorporated the high-accuracy positions into their inhouse monitoring apps. With the position data in their familiar apps, workers could use existing workflows and smartphones; they needed very little training on the new device.

Land Life also can mount an R1 onto its tree-planting machines, enabling field teams to capture the location of each new tree when it's planted. For monitoring, the app then can guide users to specific trees.

"When you have that submeter accuracy, it's easy to find your way

back to a tree," notes Janmaat. "You walk toward the tree, you look on your phone and say, 'Oh, yeah. I see the dot of my location on my screen next to the tree that I'm looking for.' It works quite well."

Building on its experience with the R1, Land Life also is using Trimble Catalyst, which combines a small GNSS antenna with software running on an Android-based tablet or smartphone. By turning the smartphone into a GNSS system that can produce up to centimeter accuracy, the Catalyst technology further reduces the cost and complexity of accurate positioning. Like the R1, the Catalyst solution uses GNSS correction data from the Trimble RTX service to produce the needed submeter accuracy positions.

According to Jasper Schurr, the commercial manager for Geometius, a Trimble distributor in the Netherlands, receiving correction data is essential. "The RTX service is important for users like Land Life," he says. "Many GNSS correction services provide corrections using cellular phone connections. With RTX, cellular coverage isn't needed. The correction data can be delivered via both phone and communications satellites, so users can get accurate performance 24/7, even in remote locations."

Maintaining Control

Land Life already is reaping the benefits of the accurate GNSS systems for monitoring. Janmaat describes a project in Spain where they could compare the new and old approaches. "Two of us were there for two full days doing close to 20 hours of work each to monitor a thousand trees. With the Trimble system, you can do a thousand trees by yourself in one day, which has sped up monitoring by at least a factor of four."

As the forests grow, monitoring will transition from ground-based measurements to using drones to capture data over larger areas. By using accurate GNSS to locate trees during planting and maintain tight georeferencing for drone flights, Land Life will be able to identify and monitor individual trees from aerial drone images.

Janmaat used data plots from a planting project in Texas to illustrate the contribution of accurate positioning to Land Life's data-driven methods. Trees planted using accurate GNSS appear in neat rows, while those planted using only a phone GPS are uneven and more scattered.

The accurate positioning also enabled direct comparison of different treatments and watering methods to specific trees through time, including use of an automated watering solution in dry areas. The data enable Land Life to improve performance and survival rates, effectively reducing the cost per successful tree.

Looking forward, Land Life expects to use its GNSS capabilities to assist operators in guiding the planting machines, ensuring consistency and proper placement of trees. But monitoring will remain a core effort and a driver for increasing productivity and tree success rates.

Janmaat is keen to share his enthusiasm and knowledge gained about technology in forestry and agriculture in

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Speaker:
Erin Emmons, GISP
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Erin Emmons is a GIS Professional (GISP) and multimodal planner at Kimley-Horn and Associates with over 16 years of experience. Her focus is in the integration and use of GIS and geospatial technology to develop data-backed solutions to solve transportation challenges. Erin serves as Secretary of the WTS South Florida Chapter and Committee Co-Chair of the AAAE Geospatial Working group. She manages projects involving the development and implementation of web and mobile GIS-based software applications, data model design, and geoprocessing automation.

Originally aired:
November 16, 2021

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In larger areas, tree monitoring will transition from ground-based measurements to using drones to capture data.

general. He believes it provides an interesting and exciting challenge for young professionals to implement technology that enables a for-profit company to contribute to society and the Earth, while having a positive effect on our environment.

"We are doing technologically challenging stuff that we apply toward a sustainable goal," he says. "We are confident this will reduce costs in the future and make us more effective in planting trees. Apart from the cost aspect, it also enables us to reforest parts of the Earth that would otherwise be more difficult to recover. By developing our knowledge, we have greater understanding on which trees grow well in the various conditions. It enables us to work in areas where other companies might not succeed." II

John Stenmark is a writer and consultant working in the geospatial, AEC and associated industries. A professional surveyor, he has more than 25 years of experience in applying advanced technology to surveying and related disciplines; email: *john@stenmark.us*.

Two California Locations Save Space and Money with Engineered Stormwater Systems

Hub City Treatment Train

Nicknamed "Hub City," Colton, Calif., is home to the Colton Crossing, which was built in 1833 and was one of the busiest at-grade railroad crossings in the United States. Today, and less than two miles south on the Santa Ana River bank, are two developing industrial buildings. Placed between the I-10 and I-215 freeways, these buildings offer direct access to San Diego and Los Angeles Counties. The proximity to one of the largest rivers in Southern California poses the need to treat stormwater from the 16-acre site, which will house more than 200,000 square feet of warehouse space.

Challenge

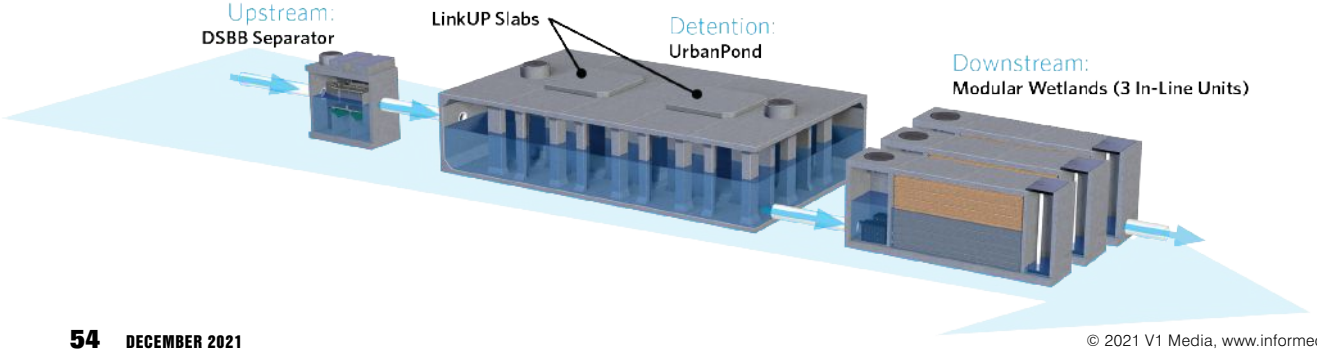
Colton's land premiums are a driving force to obtain proven stormwater solutions within a minimal footprint. Tricky soil conditions and the need to address pollutants of concern (e.g., oil, grease, total suspended solids (TSS), trash, debris, metals and pathogens) as well as meeting the regulations of the Santa Ana Regional Water Quality Board NPDES Permit and County of San Bernardino Water Quality Management Plan are not easy feats.

Solution

Thienes Engineering elected to partner with Bio Clean to engineer stormwater management for the site and provide the most-efficient solutions. This involves a treatment train of three Bio Clean devices: the DSBB Separator (hydrodynamic separator), UrbanPond® stormwater storage system and Modular Wetlands® Linear.

Conclusion

This stormwater project in Colton represents the ability to engineer a creative treatment train system that satisfies local regulations while meeting unique challenges and site constraints.



Sushi, Stormwater and Sustainability

Overlooking one of California's most-famous beaches, Nobu in Malibu, Calif., has become a model for contemporary restaurant design, service and cuisine that lives up to its demanding relationship with the sea. Although Nobu is now an operating success, the developers of Malibu's marquee restaurant had some unique challenges to address.

Challenge

Stormwater hazards impact all water bodies, and our coastlines are typically the last line of defense to prevent plastics, trash and other pollutants from contaminating these waters and harming wildlife; so there's a significant opportunity to enhance stormwater treatment and protect the ocean.

On California's coast, the densely populated county of Los Angeles produces many hazards that enter its storm drains every day. But the Nobu property is no different, and it's pointedly positioned to help address these hazards and act as stewards of the very resource that provides Nobu with quality fish every day.

Beyond the environmental concerns, Nobu is set on some of the most-valuable square footage in the world. And maximizing space and efficiency was a top priority.

Solution

The Malibu restaurant site integrated two Modular Wetlands Linear units. The Modular Wetlands is a stormwater biofilter uniquely designed to replicate natural processes to remove a variety of pollutants from stormwater runoff. Some of those pollutants include fine TSS, bacteria, oils and grease, plastics, trash, heavy metals, and harmful nutrients such as nitrate and phosphorus, which are known to overwhelm oxygen levels and devastate fish populations.

Given the value of the coastal real estate in Southern California, Nobu had an enormous incentive to maximize land usage and save space. A traditional "downward-flow" bioretention system is above ground, has a singular surface area and typically occupies an average of 1,795 square feet of space (per impervious acre). In comparison, the Modular Wetlands Linear is submerged, and this model took up a mere 63 square feet. When those estimates are applied to the Nobu site plan, the comparisons are impressive. The twin Modular Wetlands saved an estimated 3,464 square feet, representing roughly $3 million dollars of Malibu real estate value, plus returns on parking revenue.

Conclusion

Today, Nobu continues to share the atmosphere it set out to protect. The Modular Wetlands Linear biofiltration systems are saving land, yet still beautifying the landscaped areas and actively contributing to the shared mission by addressing pollutants such as TSS, nitrates, phosphorus, oils, trash and plastics before they reach the Pacific Ocean. II

2021 Guide to Concrete Product and Design Software for Buildings, Bridges and Roads

This guide briefly showcases the latest concrete product and design software used by civil and structural engineers throughout the industry. If your company should have been included, let us know at *gsolo@v1-media.com* or *jboone@v1-media.com*, and we'll add it online.

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Boral Resources

Operating coast to coast, Boral Resources is the nation's leading marketer of coal combustion products. These products—including fly ash, bottom ash and synthetic gypsum—are marketed for numerous applications in the building products industries. Boral specializes in serving concrete producers and has invested in the nation's most extensive network of distribution terminals and transportation equipment to provide reliable service to fly ash users. Boral also offers proprietary technologies such as RestoreAir and Carbon Burn-Out to ensure consistent, high-quality fly ash for its customers.

801-984-9400
www.flyash.com

Canam

Canam Bridges specializes in the design, fabrication and erection of steel bridges. Through the years, we've partnered in the construction of multiple highway, railway and industrial structures. The products we fabricate comply with established standards and customer requirements in every respect without compromising on quality, materials, design and fabrication.

Canam Bridges accompanies its customers throughout the course of their project by proposing various construction services adapted to their needs. Our objective is to help customers streamline the construction process by presenting them with a turnkey offer. Our team of experts will make every effort to provide them with optimal solutions that are in line with their needs both during the pre-project phase and in planning, designing, fabricating and erecting the bridge structure.

Tony Matutis
tony.matutis@canamgroupinc.com
603-542-5202
www.canamgroupinc.com

ChromX | An MMFX Innovation

As the nation's leading producer of rebar, Commercial Metals Company offers a variety of concrete reinforcement products at a range of corrosion resistance levels. ChromX rebar provides a high-strength, corrosion-resistant concrete reinforcing line of long steel products in various grades and levels of corrosion resistance. Martensitic Microcomposite Formable Steel (MMFX) is the innovation behind all ChromX products. It is this proprietary steel microstructure, along with a patented chemical composition, that creates corrosion resistant and high strength properties within the bar, rather than a coating.

Designers can select the appropriate level of corrosion resistance and strength needed (available in grades 100 and 120) specifically targeted to the service life for the project. High strength and corrosion-resistant properties within the steel result in a reduction in construction costs, shortened build times, reduced congestion issues and improved safety. In addition, building codes and design guides through ACI, ICC and AASHTO, among others, are available in support of high-strength designs using ChromX products.

Salem Faza
Salem.Faza@cmc.com
949-405-9161
www.cmc.com

CivilGEO, Inc.

CivilGEO develops advanced engineering and environmental modeling software for civil engineers worldwide. CivilGEO's product, GeoHECRAS, automates most of the engineering workflows required to analyze existing concrete bridge and culvert structures as well as design new roadway crossing structures. Users typically save at least 50 percent of their engineering time using the advanced automation that the software provides. The software tightly integrates with Autodesk Civil 3D and Bentley MicroStation as well as Esri's ArcGIS and ArcMap. A free demonstration version of GeoHECRAS is available for trial.

Sara Presta
sara.presta@civilgeo.com
800-488-4110
www.civilgeo.com

Commercial Metals Company-GalvaBar

As the nation's leading producer of rebar, Commercial Metals Company offers a variety of concrete reinforcement products at a range of corrosion resistance levels. This includes GalvaBar, our continuously galvanized rebar (CGR) with a pure zinc alloy coating. CGR provides the proven protection of zinc in its coating that is applied prior to fabrication and is able to be fully fabricated without specialty equipment or unique processes required. GalvaBar complies with ASTM A1094 requirements for continuous hot-dip galvanized steel bars and concrete reinforcement. It is inventoried and available from our plant in Catoosa, Okla., and can be distributed throughout CMC's supply chain and logistics network or through your current rebar supply chain.

Mike Stroia
michael.stroia@cmc.com
918-379-4808
www.cmc.com/galvabar

Concrete Reinforcing Steel Institute

Founded in 1924, the Concrete Reinforcing Steel Institute (CRSI) is a technical institute and an ANSI-accredited Standards Developing Organization (SDO) that stands as the authoritative resource for information related to steel-reinforced concrete construction. Among the nation's oldest trade associations, CRSI authors many industry-trusted technical publications, standards documents, design aids, reference materials and educational opportunities to advance and standardize the reinforced concrete construction industry.

CRSI's members represent more than 80 percent of the U.S. manufacturers, fabricators and placers of steel reinforcing bar and related products. Our professional members (architects, engineers, contractors) are involved in the research, design and construction of steel-reinforced concrete.

CRSI also has a broad Region Manager network that supports both members and industry professionals, and creates awareness among the design/construction community through outreach activities.

Dave Mounce
dmounce@crsi.org
630-380-5820
www.crsi.org

Contech Engineered Solutions

Contech Engineered Solutions is a leading provider of site solutions for the civil engineering industry. Contech is the only company that can provide bridge, drainage, erosion control, retaining wall, sanitary, soil stabilization and stormwater solutions on a national scale. Our product offering includes corrugated metal and plastic pipe; metal plate, concrete arch bridges and steel truss structures; hard armor and wall systems; and stormwater detention/retention, filtration and treatment systems. Our product portfolio is based on more than a century of research and practical field experience serving the highway, drainage, sewage and site-improvement markets. To contact one of Contech's 50 offices or 300 sales and product professionals nationwide, visit www.ContechES.com or call 800-338-1122.

Info@ContechES.com
800-338-1122
www.ContechES.com

Concrete Sealants, Inc.

Since ConSeal's founding in 1970, we've proudly served concrete producers and end-users with a full line of top-quality products. Today, ConSeal manufactures sealants, extruded sealing tapes, primers, wraps, waterstops, coatings, mastics, hot-melts, lubricants, densifying coatings and specialty admixtures. ConSeal products are used to assemble and seal precast concrete pipes, manholes, box culverts, septic tanks, burial vaults, structures, buildings and components of all types. Additionally, ConSeal products are used with poured-in-place construction joints, concrete bridge spans and decking, roadway surfaces, and more. ConSeal manufactures products for HVAC, electrical, petroleum pipe and other applications.

Hello@conseal.com
www.ConSeal.com

CONTROLS Inc.

CONTROLS Inc. is the American subsidiary for the CONTROLS company founded in Liscate, Italy. With more than 50 years' industry experience, we understand construction materials testing equipment. We are the industry leader in the design, manufacture and supply of advanced testing equipment for asphalt, concrete and soil in construction and civil engineering.

Our comprehensive range of compression testing machines satisfies all EN, ASTM and other national standards. A wide selection of accessories and upgrading options makes our concrete testing solutions flexible and modular, allowing each user to expand their testing capabilities easily and as required, from basic quality control to advanced testing. Our products are complemented by a wide range of equipment for fresh and hardened concrete testing plus Non-Destructive Testing (NDT).

brian.lins@controls-group.com
847-551-5775
www.controls-group.com

CTS Cement

CTS Cement manufactures Rapid Set fast-setting hydraulic cement and Komponent Type K shrinkage compensating cement.

Rapid Set is a full line of professional-grade cement products engineered for high performance, rapid strength gain, versatility, low shrinkage and durability. Rapid Set gains structural strength in one to two hours. You can quickly put the structure into full service, save time and money, and achieve durable, long-lasting results.

Komponent is a line of shrinkage-compensating concrete products made with Type K cement technology. Use Komponent to minimize or eliminate control joints, alleviate curling and shrinkage cracking, and reduce repair and maintenance costs. Komponent protects the integrity and durability of the concrete, extends the service life of the installation, and reduces lifecycle costs.

info@ctscement.com
800-929-3030
www.CTScement.com

Curecrete

For more than 70 years, Curecrete has focused solely on developing products to enhance concrete floors.

Ashford Formula was the first product to densify concrete, producing a dense, hard, stable surface. Water-based, non-toxic and simple to apply, it is widely specified in manufacturing plants, warehouses and distribution centers.

The RetroPlate Concrete Polishing System is a combination of diamond grinding, polishing and the RetroPlate densifier. This allows for the creation of limitless designs, polished to a marble-like sheen, along with the permanent qualities of a densified concrete floor: density, strength, abrasion resistance and dustproofing.

Curecrete products can be found on concrete floors across the globe. As the originator of the concrete densification and polishing industries, Curecrete's track record is proven and unmatched.

marketing@curecrete.com
800-998-5664
www.curecrete.com

Dlubal

Dlubal offers powerful programs for structural and dynamic analysis for multiple materials, including steel, concrete, timber, cross-laminated timber (CLT), aluminum, glass, and fabric/form-finding per the American, Canadian and other international standards.

RFEM is a nonlinear FEA program for analyzing member, plate, wall, shell and solid elements. It is one of the most highly sophisticated yet user-friendly programs, especially suitable for new users with its intuitive modeling workflow.

Due to a wide range of interfaces, RFEM also provides seamless integration between CAD and structural-analysis programs in Building Information Modeling (BIM). Bidirectional data exchange between RFEM and programs such as Tekla Structures, Autodesk Revit and AutoCAD are possible.

See why more than 5,000 engineering offices, construction companies and universities across the world trust in Dlubal Software.

Amy Heilig, PE.
info-us@dlubal.com
267-702-2815
www.dlubal.com

Easi-Set Worldwide

Easi-Set Worldwide has been developing industry-leading precast concrete products for engineering applications for more than 40 years. Easi-Set's engineers innovate, test and continually improve a full lineup of products for precast concrete companies across the globe to license for manufacture. This model allows Easi-Set to concentrate on product advancements while giving customers access to a vast network of highly qualified manufacturers.

Easi-Set's top engineer-specified products:

1. SlenderWall—a high thermal performance turnkey precast architectural envelope panel with integrated interior wall stud. www.slenderwall.com

2. Easi-Set Buildings—highly resilient all-precast concrete modular buildings. www.easisetbuildings.com

3. Beach Prisms—parabolic coastal erosion control barriers.

4. SoftSound—Superior noise wall technology for highway and commercial use. www.softsoundwall.com

5. J-J Hooks—North America's most-specified precast highway safety barrier. www.jjhooks.com

info@easiset.com
800-547-4045
www.easiset.com

Euclid Chemical

The Euclid Chemical Company, based in Cleveland, is a leading manufacturer of products for the concrete and masonry construction industry. For more than a century, Euclid Chemical has developed strong relationships with engineers, contractors, specifiers, owners, building materials suppliers and concrete producers by offering quality products and industry-leading technical support. Euclid Chemical provides concrete admixtures, grouts, concrete repair systems, architectural and waterproofing coatings, concrete flooring products, fiber reinforcement for concrete, and more. TUF-STRAND SF is a patented macro-synthetic fiber used for replacement of limited structural steel in precast, slabs on ground, pavement and shotcrete applications. The FiberCalc app is a TUF-STRAND SF fiber dosage calculator available in app stores or by visiting www.tufstrand.com.

info@euclidchemical.com
800-321-7628
www.euclidchemical.com

Integrity Software, Inc.

When you use SofTrack, you will automate your control of Bentley application usage. Enforce your licensing control with no option for the user to opt-out. Set idle activity timers to ensure your licenses are being effectively utilized. Support your Bentley ELS to E365/Connection migration.

Since 2014, SofTrack has provided unparalleled support to control Bentley Application usage by product code and feature (pipes, ponds, rails). Additionally, control Bentley Passport/Visa usage.

SofTrack provides seamless operation for local and remote application usage, including Citrix sessions and virtual desktops.

Also included is fully automatic Autodesk named-user and network license tracking and reporting.

SofTrack features include the ability to audit, control and report usage of any application and much more.

Alice Nivault
sales@softwaremetering.com
866-372-8991 ext. 612
www.softwaremetering.com

BIO-SAN® C500

For protection of concrete in severe sewage conditions

NO EQUAL

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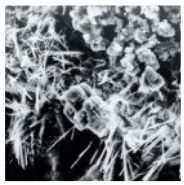
Concrete (Untreated)



Xypex Crystallization (Initiated)

Xypex Crystallization (Mature)

Xypex Bio-San C500 is a uniquely designed admixture for integral, long-term protection of concrete in harsh sewage conditions with high levels of H_2S that cause microbial induced corrosion. Bio-San C500 combines potent antimicrobial protection along with the unique crystalline technology of the Xypex Admix C-Series. Bio-San C500 prevents microbial induced corrosion, stops infiltration/exfiltration of water, and provides acid and sulphate resistance, significantly extending the service life of concrete sewage collection systems and waste water infrastructure.

Call 1.800.961.4477 or visit us at xypex.com

XYPEX®

Forterra

Forterra is a leading manufacturer of pipe and precast products throughout the United States and Eastern Canada. Forterra builds resilient and sustainable infrastructure through strategically located facilities in the United States as well as in Mexico and Eastern Canada. Since setting our foundation in 1899, we have evolved dramatically in the areas of distribution, technology and product development—not only to move water, but to employ its benefits for sustainable communities.
info@forterrabp.com
469-458-7973
www.forterrabp.com

IES – Easy Structural Software

For fast and accurate design of reinforced concrete structures, try the IES Building Suite. These tools will help you analyze and design frames, lateral systems and foundations. Engineers are more successful when they use tools they enjoy. IES structural software provides results to lift your practice to the next level. Download your free trial in 2 minutes. Get complete functionality, email support and video-based training during the trial! Solve your next problem in minutes, on IES.
Terry Kubat
info@iesweb.com
800-707-0816
www.iesweb.com

Lehigh Hanson

Lehigh Hanson, Inc. is a leading supplier of construction materials in North America. Our core activities include the production of cement and aggregates, and we also produce ready-mixed concrete, asphalt and other downstream products. With our innovative approach and extensive network of facilities, our customers trust us to provide the products, service and experience it takes to get the job done. At Lehigh Hanson, that's a trust we earn every day. For more information, visit us at lehighhanson.com.

For expertise you can count on, download i.check, Lehigh Hanson's free app that turns your smartphone into a technical resource, providing solutions for common concrete challenges.
Lori Tiefenthaler
lori.tiefenthaler@lehighhanson.com
972-653-5500
www.lehighhanson.com

MAPEI

MAPEI is a leading manufacturer of installation materials for concrete restoration solutions (CRS), including the maintenance of cast-in-place concrete. Our Admixtures division delivers innovative technologies and advanced solutions for concrete manufacturing. MAPEI also produces systems for moisture mitigation, including self-adhering sheet and cold fluid-applied waterproofing, in addition to surface-preparation products. Products include, but are not limited to, moisture barriers, concrete additives, structural strengthening and concrete repair products. The company has 18 manufacturing facilities employing more than 1,700 people throughout North America and the Caribbean. We are a member of the U.S. Green Building Council. MAPEI is certified to the stringent standards of ISO 9001 for quality management and ISO 14001 for environmental management. Visit www.mapei.us or call 800-426-2734 (800-42-MAPEI) for more information.
800-426-2734
www.mapei.us

National Precast Concrete Association

The National Precast Concrete Association (NPCA) is the trade association representing manufacturers of industrial plant-produced precast concrete products and suppliers to the industry. NPCA's more than 900 member companies manufacture products that create and rebuild infrastructure, protect the environment and offer modularity, customization and infinite creative design possibilities across all sectors of the construction industry. NPCA produces The Precast Show annually, and provides members with the latest technical and industry information through precast.org, a suite of publications, educational seminars, product committees and conferences. A cornerstone of the association is the NPCA Plant Certification program, which is recognized in 38 states and accredited by the ANSI National Accreditation Board.
800-366-7731
precast.org

Portland Cement Association

The Portland Cement Association (PCA), founded in 1916, is the premier policy research, education and market intelligence organization serving America's cement manufacturers. PCA members represent the majority of U.S. cement production capacity and have facilities in all 50 states. The association promotes safety, sustainability and innovation in all aspects of construction, fosters continuous improvement in cement manufacturing and distribution, and generally promotes economic growth and sound infrastructure investment.
Mike Zande
847-972-9138
www.cement.org

Post-Tensioning Institute

The Post-Tensioning Institute (PTI) is a nonprofit organization for the advancement of post-tensioned, prestressed concrete design and construction. PTI represents a community of businesses and professionals dedicated to expanding quality post-tensioning applications. PTI advocates the quality use of post-tensioning by providing education, certification, and codes and standards as well as promoting the industry and supporting research. Members of the Institute include major post-tensioning material fabricators in the United States, Canada and Mexico as well as manufacturers of prestressing materials in the United States, Canada, Mexico, Asia and Europe; and companies supplying materials, services and equipment used in post-tensioned construction. In addition, PTI has more than 500 professional engineers, architects and contractors.
Paulina Gomez
info@post-tensioning.org
248-848-3180
post-tensioning.org

Oldcastle Infrastructure™
A CRH COMPANY

Oldcastle Infrastructure

Oldcastle Infrastructure is the leading provider of building materials, products and services for infrastructure projects to several market sectors nationwide, including communications, energy, transportation and water.

Oldcastle Infrastructure is part of CRH's Building Products division. CRH is the leading diversified building business in the world, employing approximately 77,000 people at 3,100 operating locations in 29 countries worldwide. CRH is the largest building materials business in both North America and Europe.

With all of this on our side, it's no surprise we're able to offer the most comprehensive service solutions for engineers, contractors, distributors, utility companies, government agencies and more.

For more information, visit www.oldcastleinfrastructure.com.

888-965-3227
www.oldcastleinfrastructure.com

Precast/Prestressed Concrete Institute (PCI)

Founded in 1954, The Precast/Prestressed Concrete Institute (PCI) is a technical institute for the precast concrete structures and systems industry. PCI develops, maintains and disseminates the Body of Knowledge for the design, fabrication, and construction of precast concrete structures and systems. PCI develops consensus base standards, industry handbooks, quality-assurance programs, certification, research and development projects, design manuals, continuing education, and periodical publications. PCI members include precast concrete producers, erectors, suppliers, professional engineers and architects, educators, students, and industry consultants who complement the wide range of knowledge of precast concrete. For additional information, visit pci.org/howprecastbuilds.
pci.org/howprecastbuilds

Pre-Con Products

Based in Southern California, Pre-Con Products provides concrete precast for a number of uses including wet and dry utilities, manholes, reinforced concrete pipe, precast foundations, stormwater treatment, and custom precast pieces. Our specialty is StormPrism, a proprietary underground stormwater storage system that offers benefits that no other precast system offers. In addition, Pre-Con is a licensed general engineering contractor with a unique ability to combine construction and manufacturing within a single operation.

James Mayer
jmayer@pre-conproducts.com
602-499-5881
www.stormprism.com

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Build High-Performing Concrete 'Power' Roads and Pavements

With the flexibility of articulating permeable pavers and the strength of hard-armored concrete slabs, GEOWEB Geocell Reinforced Concrete (GRC) creates stronger roads and pavements with less concrete cross-section—and less overall construction time and cost—resulting in 15-25-percent cost savings.

The integral 3D GEOWEB confinement structure offers additional benefits—eliminates the need for formwork and reinforcement, assures uniform concrete depth, controls pavement cracking, and helps manage surface water runoff.

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Katie Bouchard
Katie.bocskor@prestogeo.com
800-548-3424
www.prestogeo.com

RISA

RISA has been developing leading-edge structural design and optimization software for more than 30 years. Our products are used around the world for buildings, stadiums, bridges and everything in between. For concrete floors, including beams and two-way slabs, nothing beats RISAFloor ES for ease of use and versatility. The design of columns and shear walls with RISA-3D offers total flexibility. RISAFoundation is the ultimate tool for analysis and design of a variety of different foundation types, including retaining wall, spread footings, mat slab or piles. If you need to design post-tensioned structures, both ADAPT-Builder and ADAPT-PT/RC offer industry-best design for even the most complex projects. Overall, RISA has the tools to help tackle your next concrete design challenge. To learn more about RISA, please visit risa.com/products.

info@risa.com
800-332-RISA
risa.com

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Concrete Foundation Design Software

Foundation Design software for footings, piles, combined footings and more, as per ACI 318, AS 3600.

Powerful analysis and design features:

- Powerful soil analysis for isolated and pile foundations
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Sam Carigliano
sam@skyciv.com
612-356-2448
www.skyciv.com

Simpson Strong-Tie

Simpson Strong-Tie has software and web applications designed to support our concrete products.

Anchor Designer for ACI 318 will quickly and accurately analyze an existing design or suggest anchorage solutions based upon user-defined design elements in various concrete conditions. This software has been updated to include the latest product launches from Simpson Strong-Tie, providing more anchor products to choose from.

Our Rebar Development Length Calculator web application supports the design of post-installed rebar in concrete applications by calculating the necessary tension and compression development lengths. The calculation methodology is based on ACI 318 requirements for cast-in-place reinforcing-bar development length.

web@strongtie.com
800-925-5099
www.strongtie.com

SpecChem

SpecChem manufactures premium concrete construction building materials for distribution throughout the United States and internationally. We manufacture a full line of liquid chemical technologies, including form release agents, paving and curing compounds, evaporation retarders, cures and hardeners, bond breakers, sealers, bonding agents, surface retarders, water and damp proofing coating, and an array of cleaning and stripping products.

Additionally, we manufacture a line of specialty epoxy products that includes adhesive bonding agents, epoxy sealers and coatings, high-strength epoxy mortars and grouts, and epoxy and polyurea control joint fillers.

Finally, our comprehensive line of cementitious grouts, repair mortars, underlayments and overlayments, and asphalt patch round out a line-up designed to provide quality, innovation, and value to distributors, specifiers and contractors.

We are members of CSI and listed in MasterSpec and BSD SpecLink.

Jay Shimmens
jshimmens@specchemllc.com
816-561-4029
www.specchemllc.com

Soil Retention Products

Drivable Grass, manufactured by Soil Retention, is a plantable, flexible and permeable concrete pavement system designed with an engineered polymer grid that allows flexibility and conformity to

irregular ground-surface contours along pre-defined linear grooves while providing the intended structural support. This unique product, whether planted or non planted, is a solution for a variety of applications for soil stabilization. Drivable Grass is an ideal solution for erosion control protection when used in bio-swales, road shoulders, roadside swales, infiltration basins, small channels and ditches. Drivable Grass is a permanent hard armor system that provides a simple solution to linear projects.

Bill Ramsay
bramsay@soilretention.com
800-346-7995
www.soilretention.com

Sprayroq

Sprayroq is a global industry leader in spray-applied resin technology for structural rehabilitation and corrosion protection of water, wastewater and other industrial infrastructure assets. With its plural-component spray technology, it is the only fast-curing structural and chemical-resistant formula that can be used for the rehabilitation and protection of underground infrastructure.

Our trenchless technology solutions extend asset life through corrosion control, abrasion resistance and structural reinforcement. For three decades, Sprayroq has provided structural rehabilitation and corrosion protection for water, wastewater and stormwater infrastructure worldwide.

Our core technology, SprayWall, is a self-priming polyurethane lining that reinstates structural integrity, superior corrosion resistance, and provides infiltration control and chemical resistance. It provides the quickest return-to-service times in the industry, saving you time, energy and money. With its 50-year design protocol, SprayWall outlasts top competitor products reporting 22-percent greater strength at the 50-year point. Contact Sprayroq today and see the long-term solutions for yourself!

info@sprayroq.com
205-957-0020
www.sprayroq.com

Steelike

Steelike, Inc. develops, produces and supplies Steelike Ultra-High Performance Concrete (UHPC). Steelike UHPC meets or exceeds the performance specifications of federal and state agencies for UHPC in transportation infrastructure projects, where UHPC is increasingly specified to connect precast bridge elements for accelerated bridge construction (ABC) and rehabilitate bridge decks. UHPC can also be used to fabricate precast structural and architectural members. Steelike UHPC is all-white mixable in a ready-mix truck, and saves the user time, labor and money. The company recently developed groundbreaking innovations including eliminating the need for expensive specialized mixers by enabling the use of ready-mix trucks to mix Steelike UHPC; and eliminating the need to overfill and grind UHPC connections. For more information, please visit steelike.com.

Chen Wang
chen@steelike.com
703-520-2763
steelike.com

Stone Strong Systems

What is it that makes Stone Strong the best block in precast? In a word: everything. Everyone knows we're the biggest block in the industry. But what they may not know is that we're the industry's most efficient, complete retaining wall system as well. Or that our big block system is the first to be fully engineered both structurally and geotechnically. So no matter what you're looking for—size, speed or strength—Stone Strong can meet your project requirements.

Nathan Gran
ngran@stonestrong.com
402-973-1294
www.stonestrong.com

Strong Products, Inc.

Biodegradable release specialists; unique water clear form, mixer and spatter releases; all contain zero water, zero evaporative solvents, zero vegetable oils; all are environmentally/worker friendly and low VOC compliant.

pkolassa@strongproductsinc.com
517-639-5650
www.strongproductsllc.com

Strata

Strata's focus on innovation and technology has allowed us to become a leader in the soil reinforcement industry. Our team includes a full research and development department that works to develop products to push the boundaries of what is possible to solve even the toughest challenges.

StrataGrid is a high-performance soil reinforcement product. It is made with polyester yarns that have a high molecular weight and extraordinary tensile strength. These yarns are then knitted into a dimensionally stable network of apertures to form the geometric grid shape that offers tensile reinforcement to the soil in both vertical and horizontal directions. StrataGrid is coated with a black saturation coating to provide further chemical and mechanical benefits that preserve its durability in any environment.

grtfmarketing@glenraven.com
800-680-7750
www.geogrid.com/en-us/products/stratagrid

STRUCTUREPOINT

Formerly the software development team of the Portland Cement Association (PCA), StructurePoint recently developed our new spLearn Education & Training Service and spConsult Specialty Engineering Service. Designed to provide continued PDH accredited education and personalized support to complement your existing StructurePoint software subscription or as a one-time service. These services include personalized webinars, onsite training and pre-scheduled webinars, along with our vast library of technical articles, design examples, case studies, and video tutorials. Our core offering remains the suite of concrete analysis and design software programs: spColumn, spSlab, spMats, spWall and spBeam. We continue to upgrade the SP software as the only tool entirely dedicated to concrete design methods, standards and code provisions relevant for every infrastructure project today.

info@structurepoint.org
847-966-4357
www.structurepoint.org

Titan Environmental Containment - Titan Environmental USA

As an industry-leading supplier of high-quality geosynthetics, Titan is proud to offer Concrete Canvas, a revolutionary new class of construction material used as an alternative to conventional concrete. Coined as "Concrete on a Roll," Concrete Canvas allows for concrete construction without the need for plant or mixing equipment—simply unroll and hydrate for quick and easy installation. This flexible concrete-filled geosynthetic mat hardens on hydration to form a thin waterproof layer for effective scour and erosion protection, weed suppression, waterflow redirection, concrete remediation and more. Common applications include slope, ditch, channel and outfall lining in a range of sectors from civil and municipal infrastructure to mining, transportation and more.

Ron Drewry
ron.drewry@titanenviro.com
866-327-1957
www.titanenviro.com

Trimble Solutions USA

Uncertainty and risk are major concerns for concrete contractors, but with the right tools you can manage these and improve your business. Tekla software allows contractors who plan and pour concrete onsite to improve productivity and quality with coordinated and timely information. With Tekla, you can make your projects predictable thanks to better planning and management. Regardless of the structure or project type, and from preconstruction to pour, concrete construction can become more productive in the office and onsite by utilizing reliable information from constructible models. Tekla's unique ability to accurately handle pours, and its intuitive information management tools help you improve project coordination and control, manage risks and plan for success.

Jodi Hendrixson
jodi.hendrixson@trimble.com
678-737-7379
www.tekla.com/us/solutions/concrete-contractors

Trinic

Trinic is a unique company. We manufacture additives, powdered admixes and premixes used for production of architectural and decorative concrete. We serve customers in more than 72 countries.

In 2010, we began with a desire to make better concrete. By listening to our customers, our dedicated team members continue to improve existing products and develop new products to better serve the industry. With a caring approach to technical/customer support, hands-on workshops and our state-of-the-art batch plant, we continue to grow.

In every interaction, we aim to leave customers, employees and vendors feeling listened to, validated, confident and so well taken care of that their heart is well settled. We hope to assist each customer in making their businesses exceed expectations and their lives exceed their dreams.

Rich Doud
rich@trinic.us
607-775-1948
www.TRINIC.us

U.S. CAD

U.S. CAD is the leading provider of architecture, engineering and construction (AEC) technology and consulting services. Founded in 1999, U.S. CAD is an Autodesk and Bluebeam Platinum Partner delivering BIM and AEC software, training, support, production and scanning services as well as virtual and augmented reality solutions designed for organizations of all sizes for better project outcomes from conception through construction. Our mission is to help clients win more, produce more and achieve more. Our products and services are ideal for those who design, engineer and build the world around us. Visit www.uscad.com.

Perla Lozano
perla.lozano@uscad.com
877-648-7223
www.uscad.com

WILLIAMS FORM ENGINEERING CORP.

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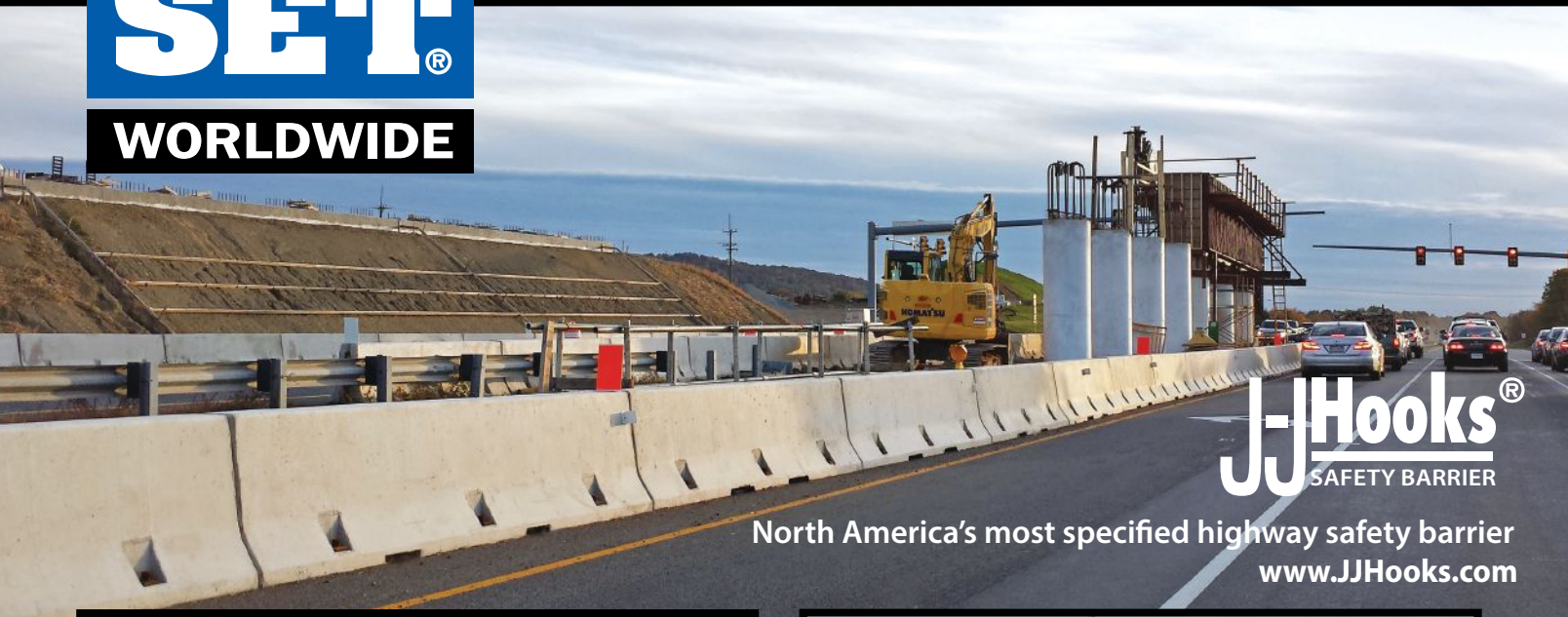

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CHANGE LEADER

The Industry Needs To Recognize Those Who Bring About Change

These profiles are based on interviews, and the opinions and statements are those of the subject and are not necessarily shared or endorsed by this publication.

Joe Cavanaugh is executive vice president of technology at Tensar.

This particular webcam interview was recorded by Todd Danielson, the editorial director of *Informed Infrastructure*. You can view a video of the full interview by visiting *bit.ly/3qiPrMu* or scanning the accompanying QR code.

Resilient Roads

Joe Cavanaugh is one of the founders of the Resilient Roads Roundtable, a group of organizations and people sharing a vision to improve the performance of roadway infrastructure. Such improvements include being more resilient—so roads last longer—and using materials that are more environmentally sensitive.

"It's a bit of a shift in thinking from an empirical-based design approach to advancing the design approaches we're using, changing the way road design and construction currently works," explains Cavanaugh.

Like many aspects of the infrastructure industry, he notes it's difficult to "do things differently" and introduce performance standards. "There's always a reluctance to change," he says. "So we felt we needed to go about this with a broader group of like-minded folks, both businesses as well as people."

The Resilient Roads Roundtable hopes to pull this group together and start to change how the industry approaches overall design and construction of road infrastructure with a keen view toward more-resilient construction.

The Power of Recognition

To spur the needed change, Cavanaugh believes an important part of the Roundtable's mission is to recognize those who are "taking chances" and leading progress, even if it can be risky. Because civil engineers create the "built infrastructure," their projects have to work, function and do the job for which they were intended. However, as infrastructure continues to degrade through time and environmental conditions worsen, the industry needs to change to be more effective.

"We need to motivate people to want to disrupt our ways of thinking, and challenge ourselves and peers, and even challenge our bosses and politicians to embrace this concept of changing, of trying to come up with better ways of doing things, and, in some cases, be willing to accept that we may not always have all the answers before we try something," adds Cavanaugh.

"There's just been a real paradigm of, 'if it isn't 100-percent proven, you can't implement it.' And that's not always the case," he says. "There are ways you can implement things, try them out, test them. And I think we don't reward folks who try things out enough."

Cavanaugh believes that some recognition of people succeeding by failing "in a safe manner" would be an effective way to let people know that innovation is appreciated and shouldn't be avoided while continuing a status quo that no longer works.

"In most other modern-day industries—and where technologies are rapidly developing—this is what people are doing," he adds. "They're trying, and they're failing, and they're learning from it. And they just keep at it and keep trying to keep getting better. If we can find ways to bring some of that into our industry, some great stuff could happen. As long as we're learning from it, then it should be celebrated and rewarded."

Sustainable and Connected

In terms of overall trends in roadway infrastructure, Cavanaugh believes they will follow patterns in many other types of infrastructure: they need to be more sustainable and better connected through technology.

This can be accomplished through better design approaches and thinking more in terms of how engineers come up with new methods of analysis, new ways to test materials and new design approaches. Then they need to take advantage of new computational capabilities.

"We're going to have to challenge ourselves to come up with ways to design so we can incorporate, perhaps, recycled materials into the constructions, or materials that last longer, and find ways to incorporate those benefits into either the design approach or the economic analysis that goes into the decision-making of what solution you choose," he says. "I think that whole concept applies very broadly to our civil infrastructure in all the physical assets we're building." II

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Informed Infrastructure Advertising Staff

Parul Dubey
Advertising and Operations Manager
pdubey@v1-media.com

Patrick Krill
Global Accounts Director
pkrill@v1-media.com
414-225-0101

Jeff Boone
Senior Project Manager
jboone@v1-media.com
630-675-3557

Geoff Solo
Senior Account Executive
gsolo@v1-media.com
805-680-3742

Shannon Burnett
Operations & Marketing Manager
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Denali Consulting Services
eldar@godenali.com

Eldar Causevic has been leveraging process innovation and technology to help build scalable professional services firms for more than 25 years. He understands what truly drives profitability and how to grow a company effectively. As an advisor, he has supported more than 100 companies in their journeys to reach new levels of growth and generate more than a billion dollars in new revenue.

Causevic began his career as a co-founder of a tech startup at the age of 17. He went on to build two professional services firms, a tech company, and also achieve multiple exits to Fortune 500 corporations.

In addition to his advisory work, Causevic has been actively involved as a board member, mentor, and advisor of innovation and professional services organizations.

Causevic earned both an engineering and an MBA degree from Washington University in St. Louis, where he also served as an associate dean for entrepreneurship and oversaw programs in project management, cyber security, construction management, and systems engineering. He also taught a "Business for Engineers" course at Washington University.

informedinfrastructure.com/v1education

FUTURE FORWARD

The Future of Downtowns Is More Inclusive and Adaptable

These profiles are based on interviews, and the opinions and statements are those of the subject and are not necessarily shared or endorsed by this publication.

Cathy Lin is the director of Research at the International Downtown Association (IDA). Jonathan Tinney is a principal with Stantec's Urban Places.

The International Downtown Association (IDA) and Stantec's Urban Places division partnered to release a new report highlighting evidence-based approaches for urban districts navigating the consequences of the COVID-19 pandemic. "Building on Recovery for Urban Place Management" features case studies of IDA member organizations, offering recommendations and detailing results for downtown and city-center recovery. The report also draws on observations from a series of focus-group sessions conducted in April 2021 of 55 CEOs from urban place-management organizations across the United States and Canada.

This particular webcam interview was recorded by Todd Danielson, the editorial director of *Informed Infrastructure*. You can view a video of the full interview by visiting *bit.ly/3C54CLg* or scanning the accompanying QR code.

"We wanted to create this report because we know downtowns and dense urban districts were disproportionately impacted by the effects of the pandemic," notes Cathy Lin, director of research at IDA. "This report presents a framework of key actions to help them navigate a successful recovery."

Although some long-term initiatives are cited, the report emphasizes short-term, tactical steps to bring people—and revenue—back into downtowns. These suggestions empower urban place-management organizations, city partners and other stakeholders with the tools to leverage new opportunities and advocate for additional funding to support current efforts.

"I think the other piece of this [report] is really about the forward planning," adds Jonathan Tinney, a principal with Stantec's Urban Places. "As we go forward, we hopefully will see a lot of investment in infrastructure within our downtowns."

Tinney hopes the report will help downtown organizations and different stakeholders position themselves to take advantage of funding as it comes forward and ensure that some of these vital investments in our downtowns are made.

Inclusivity Key

The report regularly mentions inclusion, which is another aspect where the pandemic highlighted problems and inequities.

"Downtowns are often the representative image that people have of their city," notes Lin. "So place managers and stewards of these critical gathering and civic centers are putting a new emphasis now on striving toward making downtowns inclusive of everyone in the community."

Downtowns typically offer the highest concentrations of opportunities and resources, and those need to be accessible to everyone, she explains. Place-management organizations are thinking about inclusion at all levels, sometimes internally—whether evaluating diversity within the organization itself or at the board level—but also by creating programming that's more diverse for the broader community.

An example Lin highlights is from the Downtown Partnership of Baltimore, which announced the first cohort of winners for its downtown Black Owned and Operated Storefront Tendency (BOOST) program, which is granting up to $50,000 to five black entrepreneurs to aid them in the long-term success of creative storefronts in downtown Baltimore.

Embracing Change

Another theme of the report is how willing cities were to try new things during the pandemic and how open they are to continuing programs that were successful. Tinney was impressed by several observations of place managers, including the willingness to embrace new approaches and the nimbleness of downtown organizations to take advantage of them. He cites the creation of new outdoor dining, outdoor public spaces and the reclamation of city streets as signs of a shift and focus on the public realm.

"To find that kind of connection, create some vitality, that was surprising and heartwarming at the same time," he notes.

Lin says she often heard, especially early on, that the pandemic was going to be the demise of downtowns and the end of dense cities, but that hasn't been the case.

"We've been seeing urban place-management organizations turning this crisis into an opportunity to build on downtown strengths and advocate for a better city," she adds.

Another of her favorite examples is the Downtown Austin Alliance in Austin, Texas, which created a comprehensive roadmap to recovery and resilience. The Alliance set four critical priorities: 1) addressing unsheltered homelessness, 2) activating parks and public spaces, 3) supporting small businesses and live music, and 4) promoting downtown. The Downtown Austin Alliance also is championing several opportunities that will transform downtown with infrastructure and placemaking.

"I think the key is to focus on flexibility and adaptability, and really putting the human-scale experience front and foremost," concludes Lin. II

Editor's Note: As of the time of publishing this profile, Jonathan Tinney no longer works for Stantec.

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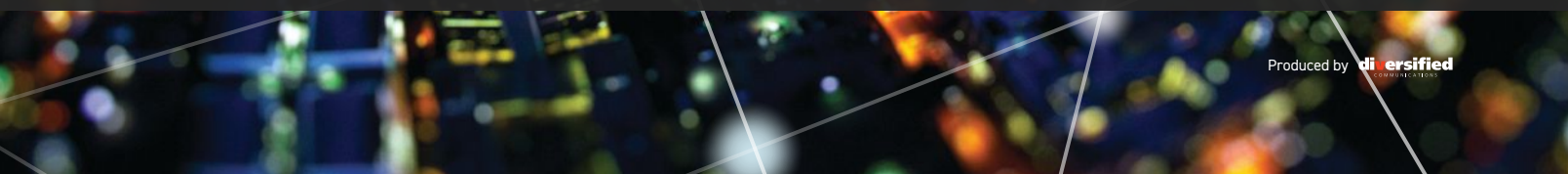

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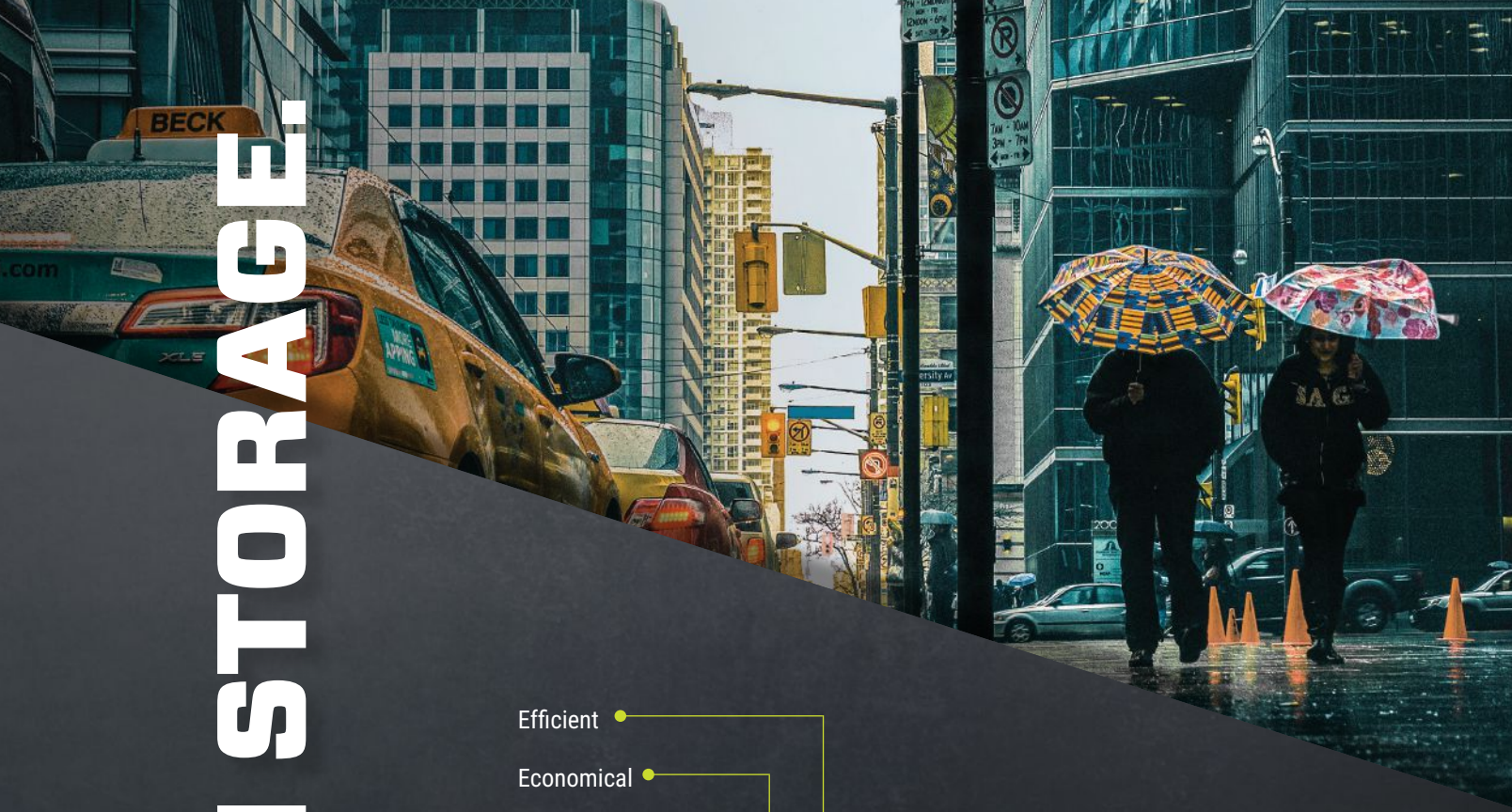

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