Pittsburgh

ENGINEER

FOCUS ON PEDESTRIAN BRIDGES
SPECIAL ISSUE OF THE 2023 INTERNATIONAL BRIDGE CONFERENCE

QUARTERLY PUBLICATION OF THE ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA

SUMMARY

ON THE COVER...

Park Union Bridge
Colorado Springs, CO
Photographer: Jason O'Rear

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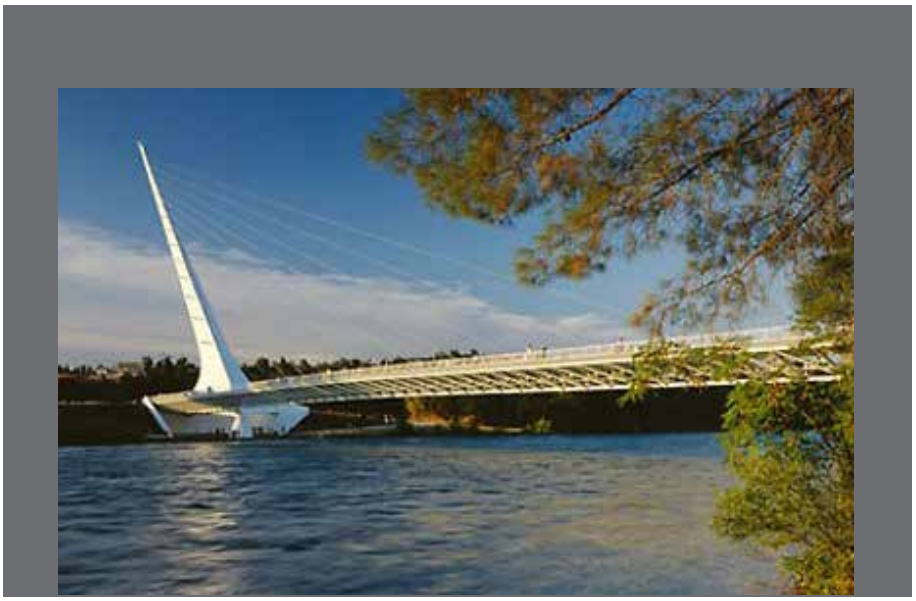
Guest Editors: Matt Bunner, Mike Cuddy, Pat Kane, Tom Leech, and Jon McHugh

EDITORIAL

PEDESTRIAN BRIDGES: the evolution of the crossing



The 2005 IBC Figg Medal Award-winning Sundial Bridge at Turtle Bay by Santiago Calatrava

The pedestrian bridge is truly a unique structure type and can be an art form all its own.

Generally, the range of loadings and geometric constraints differ from "conventional" vehicular bridges and opportunities to create new, striking forms emerge. The resulting solutions, as you will find in these pages and throughout the IBC technical program in general, are both beautiful and as varied as can possibly be as different designers and even different cultures solve the same puzzle in thousands of different ways.

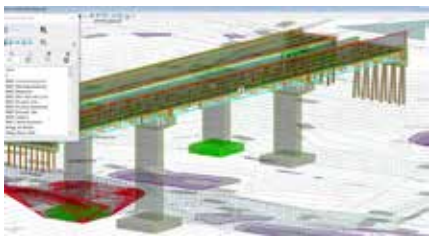
As expanded upon later in this edition, the pedestrian bridge was truly the first bridge type. The evolution of bridge design emerged from transport of people and then goods and then the various modes of transportation. People were first. People are most important.

Increasingly, with the emergence of context sensitive design and the embracing of bridges as more than merely a utilitarian crossing, these structures have become more of a destination in their own right- and truly a source of identity and pride in the communities and surroundings which they enhance.

Then… also, there is the dreaded "A" word- Aesthetics. The word too often perceived as synonymous with an increase in cost. But, as many notable bridge architects and engineers would tell you, it doesn't have to be that way if the form of the bridge truly matches and accentuates its function (Shameless plug #1: If you have not read Fred Goettemoeller's ***Bridgescape: The Art of Designing Bridges***, you definitely should).

The 2020 IBC Hayden Medal Award-winning Tanxi Mountain pedestrian Bridge is truly a unique destination in its own right.

Moreover, the "state of the art" of bridge design has truly evolved along with the needs and roles of the pedestrian bridge. The proliferation of model-based design and incorporation of artificial intelligence (AI) in our designs and workflows have truly pushed the envelope of what is possible and what is constructable. The future of the art of the pedestrian bridge may only be limited by our collective imaginations.



Bridge Modeling

All this is why, this year, we have chosen to celebrate the variety of pedestrian bridges from around the world. Throughout the years, the IBC has awarded many pedestrian and special purpose bridges from their creativity, timeless forms, community involvement, and harmony with their environment (Shameless plug #2: be sure to take the past IBC awardees quiz featured later in this edition). Giving these structures an homage of their own seemed fitting.

By marrying this years' photo contest with the theme, we have captured the passion for these structures from a wide range of different minds and viewpoints. With thirty-five amazing entries this year, it was truly challenging to narrow the list to ten (and indeed, we had to pick twelve!)

We hope that you enjoy this edition of *Pittsburgh ENGINEER* magazine and the variety of entries published herein. We again extend our gratitude to the many contributors who have made this all come together.

All of these entries have both captured and spanned our imaginations. And we truly hope that they do the same for you.

Cheers!!

Matt Bunner, Mike Cuddy, Pat Kane Tom Leech, and Jon McHugh …-the editors

Welcome to the International Bridge Conference!

It is my pleasure to welcome you to the 40th annual International Bridge Conference hosted by the Engineer's Society of Western Pennsylvania (ESWP). We have come a long way since the 1984 Conference. The first Conference featured 44 papers. At our 40th Conference, we will have 85 papers, 14 special technical sessions, and 9 workshops. There will be Bridging the Gap Presentations that are prerecorded and feature attendees talking about their ideas for the bridge industry. This will be our second year in a row with an in person conference after the COVID 19 pandemic and a sense of normality. We are returning to the Gaylord National Resort & Convention Center after holding the conferences there from 2016-2019. The schedule includes the IBC Awards Dinner on Monday evening. Our Awards Committee selected winners for 8 awards. The Magazine Theme is Pedestrian Bridges-Spanning the Imagination. There were 12 winners out of 35 entries. There will be a tour on Tuesday of the recently completed Frederick Douglass Memorial Bridge. Be sure to stop by our Exhibit Hall to welcome our exhibitors and enjoy lunch buffets and evening receptions. Stop by the Featured State Exhibit. We are pleased to announce that Colorado DOT is our Featured State.

The planning for the conference by the Executive Committee started the day after the 2022 conference. Our dedicated volunteer group of 32 voting Members, 7 Honorary Members (25 years of service), and 8 Emeritus Members (10 years of service) manage our 17 Committees. Our group will have 21 session chairs for the technical sessions, and 8 moderators for the workshops. The reliable experienced ESWP staff, headquartered in Pittsburgh, PA, of Dave Teorsky, Kristina Emmerson and Mike Gaetano ensure we meet deadlines, post notifications, put technologies in place, and make sure we abide by the Manual of Operations. The Committee meets once a month with only two in person meetings. Since our Executive Committee is made up from individuals from 19 different cities in 10 states, the virtual meeting choice has been the preferred way to meet. We are geographically diversified. Imagine policing 20+ engineers on a virtual meeting who all want to voice their opinion! I thank all of them for their effort and cooperation.

ESWP is dedicated to encouraging the "next generation" of engineers through innovative, enjoyable, and hands on learning opportunities. At the IBC, a Student Poster Competition is conducted. Students submit on any topic relating to their bridge engineering experience. Stop by their posters near the Exhibit Hall as they will answer any questions you may have about their poster. A Special Session will feature four Young Attendee Presentations.

The financial success of our conference is due to our Exhibitors and your registration fees. Thanks for attending and hope you enjoyed the content we provided. Last year's conference survey question, "Would you recommend IBC to others" garnered a 98.3% "yes" answer. We are working for the same response for this year's conference.

Kevin E. Duris, P.E.

General Chair IBC 2023

Kevin is Assistant Chief Estimator for Trumbull Corporation based in Pittsburgh, PA

Kevin E. Duris, P.E.

Remembering Herb Mandel

Herb Mandel, pictured center with red necktie, surrounded by professional colleagues in 2013

IBC, ESWP and the bridge community at large lost a dear a true friend and colleague, who at age 98, passed away on Saturday, March 11, 2023. He leaves behind a wonderful family of children, grandchildren and great grandchildren.

With close to 40 years of service to IBC, many of us on the executive committee remember Herb for his sharp intellect, wit and faithful attendance at all executive committee meetings, even during his advancing years. Never at a loss of words for a quote for the magazine or for an award winner, Herb had one famous saying which he repeated at executive committee meetings, and which many of us now repeat, as Herb would often say: "Never say no to a volunteer!"

He enjoyed an interesting and meaningful life. With this college education interrupted by WWII, as a Pfc. U.S. Army, in 1945, Herb participated in the Liberation of the Langenstein-Zwieberge Concentration Camp. After WWII, his education continued and at Yale University graduate school, he became a pupil of Hardy Cross – one of the most renown and honored Civil Engineers of his time. Herb went on to design and supervise many notable projects such as the Pell Bridge across the Narragansett Bay in Newport, Rhode Island, the Williamstown-Marietta Bridge across the Ohio River and the PRT (formerly PAAC) Stage I, Light Rail Transit Project. Many of us, in Pittsburgh, who have prepared subsequent rehabilitations and transit upgrades have commented on his P.E. seal on the design plans for the Mt. Lebanon Tunnel. Never at a loss for words, Herb is known to have said:

> "Never say no to a volunteer!"

"I had the best career in the world; I feel like someone gave me a giant erector set to play with for my whole life."

The best tribute to Herb's legacy with IBC and ESWP is reflected in his words, authored some 10 years ago, when he wrote:

"After attending the 1983 PennDOT conference, my own work began on the IBC began with the fourth conference when I joined the executive committee. Two years later I was the general chairman of the sixth conference, and service on the executive committee has been continuous ever since … Watching the conference grow, working on the executive committee, making friends both within the committee and at the conference, and getting to know some of the greatest bridge engineers in the world are all the things that make me continue to be active in IBC. I realize that IBC is much more than a meeting. It is a celebration of bridges and the people who design and build them. I am so glad that while all this was going on, I was not a bystander ..." from The International Bridge Conference and How it Grew by Herb Mandel, published by ESWP in Reflections …, June 2013.

We, as members of the editorial staff and members of the executive committee of IBC are also glad, that our colleague and friend, Herb Mandel, chose not to be a " … bystander …" – the editors

Bridging the Gap Between Art and Engineering:
The Evolution of Iconic Pedestrian Bridges

Bridges have been a means to connect people in the presence of dangerous or insurmountable obstacles. Whether of wood or stone humans have built structures to provide the means of linking their communities for trade, resources, and travel. The first bridges were unquestionably pedestrian bridges. It is quite ironic that now with the invention of the automobile a bridge must be identified as a pedestrian bridge when it does not accommodate vehicular traffic. Regardless of what it is called, pedestrian bridges have undergone a vast transformation in form and function through history. From modest forms to iconic structures, society has redefined what the pedestrian bridge is and can be.

Arkadiko Bridge in Greece; Designed circa 1200 BC (Courtesy Wiki Commons)

For much of history the pedestrian bridge connected two points in as short of a distance as possible. Defined by historic travel routes and topography, engineers, before they were known as such, would use whatever means at their disposal to span the gap before them. Aesthetics was rarely, if at all, a consideration in the bridge's layout or design. With limited resources and the possibility of a bridge being destroyed regularly by flood or war, the need to consider aesthetics was low on the priority list for builders.

When art and aesthetics began to be incorporated into bridges, it was an addition to the structure, rather than the purpose of the structure. Dramatic pilasters and sculptures were incorporated into railings and columns. Bridges such as the Rialto and the Ponte Vecchio in Italy were utilized for additional building space which utilized the contemporary architecture at the time. While engineers appreciate the form of classic bridges for their elegance in form and design, there has been a distinct pivot in the purpose in some modern pedestrian bridges. The desire for an iconic structure has become the purpose of the bridge with the function taking a back seat in the design.

Iconic Desire

Why has this come about? It has become recognized by owners that bridges create a sense of place for a community. This can be readily seen with timeless bridges like the Golden Gate Bridge and Brooklyn Bridge. Each is synonymous with San Francisco and New York respectively, creating a touch stone for the world to identify each city. The reality is that not every city or community has a bay or river to justify the extraordinary effort and expense to construct a mega bridge. Instead, owners have now turned to the pedestrian bridge as the infrastructure element of choice to be the icon of the community .

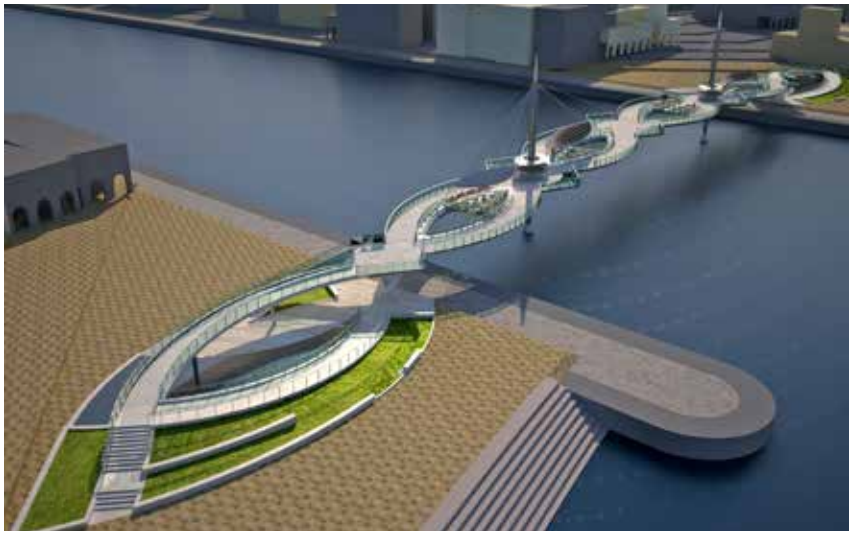
The pivot in design is based on a fundamental perspective change in the purpose of a pedestrian bridge. The objective with an iconic bridge is to create a place of gathering instead of a place of transport. The intention of owners is for their community to have a bridge that is an experience for pedestrians. A place of interaction with the form of the bridge and the setting. The end goal being a bridge that attracts the community and tourists alike to a location of commerce or beauty.

A prime example of this is the Sundial Bridge in Redding, California. Constructed over the Sacramento River in 2004, this cable stayed design by Santiago Calatrava is a bridge which places aesthetic form before utility. The bridge provides users the opportunity to interact with the Sacramento River and the bridge night and day. This iconic bridge is a tourist attraction and brings travelers on Interstate 5 to the downtown of Redding, providing tourists a reason to stop when they otherwise may not have.

A Leap Forward

The new appetite for iconic pedestrian structures has increased with the advancements of computational analysis methods available to engineers and architects alike. Owners in this new wave of pedestrian bridge design have pushed architects to create stunning structures that cannot be ignored and challenged engineers to make the designs work. Architects and engineers have long had the wherewithal to conceive dramatic forms and analyze complex structures, but the ever-increasing access to personal computing power has lowered the barrier to entry for creating, analyzing, and constructing complex geometric elements that make up iconic pedestrian bridges. Modern engineers and architects can leverage this computational power to generate and analyze more complex geometry faster and more accurately than ever before. The onus of understanding the flow of forces and behavior of structural materials remains on the engineer, but the tools

The Harbor Drive Pedestrian Bridge in San Diego, CA: Designed in 2006. Photo credit Brooke Duthie Photography



Necklace Bridges near Doha, Qatar: Designed in 2014. Image credit Safdie Rabines Architects

The Dublin Link Bridge in Dublin Ohio; Designed in 2016. Photo credit Corey Klein Photography

available allow the engineer to focus on the principles of design rather than spending their time with the tedious aspects of data entry and manipulation.

Several modern examples of iconic pedestrian bridges designed by TYLin which demonstrate the evolution of leveraging computational power are the Harbor Drive Pedestrian Bridge (San Diego, California), the twin Lusail City Pedestrian Bridges (Lusail, Qatar), and the Dublin Link Pedestrian Bridge (Dublin, Ohio). The Harbor Drive Pedestrian Bridge is a signature pedestrian crossing in San Diego that was designed early in the evolution of computational design tools. The architect's model was fully realized in 3D and information from this model was useful in creating 4D finite element models (FEM) that closely tracked time dependent effects as the 4th dimension. Additional 3D models of specific complex elements were derived by the design engineers to ensure constructability and mitigate conflicts but overall, the process mostly relied on brute force, and plan preparation was done using conventional 2d methods. At the time, this level of effort in design was reserved for the very few signature projects being developed. Fast forward several years to the design of twin Lusail City pedestrian bridges that were a centerpiece of the World Cup in Qatar. While the architectural and FEM models were the same as described for Harbor Drive, full structural 3D models of the bridges were developed containing all elements constructed in the bridge. These were used heavily in plan production and were instrumental in minimizing geometric conflicts. This level of effort was, at the time, still reserved for the select few projects, however, the improvement in the development of models was marked. Moving ahead to the design of the Dublin Link pedestrian bridge more advances were realized. Architectural, FEM, and 3D Structural models were all used heavily as in Lusail, but by this point the design methodology had evolved such that the various models could talk to each other. Geometry from the architectural models informed the structural 3D models and data from them was used in part to generate the FEM models and produce portions of the plans. This represented a seismic shift in the value of each of the models and, more importantly, reduced the ramifications of dreaded late-stage changes. The Dublin Llink served as a springboard for this type of design ideology within TYLin to the point where all signature projects utilize linked models, and our most complex projects have FEM models and plan production driven from a single parametric 3D model. This progression highlights the steps the industry has taken in advancing computational design to keep up with, and in some instances drive, desire for more iconic structures.

The Next Step

Engineering and architectural design have advanced with technology, while construction and fabrication have undergone similar advances. Although the advances in design technology seem to be well on their way while advances in fabrication and construction technology are still in their infancy. Most of the important advances in bridge technology throughout history have been due to economic necessity. Expect the

3D Printed Steel Bridge Concept in San Diego, CA: Designed in 2020

same to be true as we move into the future. Increased desire for signature structures is happening faster than the increase in budgets to pay for them. The same way design technology has allowed for efficiencies in the analysis and design of iconic structures, construction technology can make way for more efficient fabrication and construction of these structures. While there are many construction technologies to be excited about, 3D printing jumps to the foreground. The winning concept for the 2021 AISC Forge Prize was a full-scale steel pedestrian bridge 3D printed in place over a canyon in San Diego. While technology won't allow that just yet, we aren't far off. The additive robotic manufacturing company MX3D has already successfully printed a steel pedestrian structure in the Netherlands and Autodesk in collaboration with DAR Group has prototyped numerous 3D printed GFRP pedestrian structures. There are other successful 3D printed structures out there as well. The next step in advancing iconic pedestrian bridges will likely come from 3D printed construction and manufacturing which will allow architects to pursue more ambitious and organic designs, leaving engineers with more challenges to solve.

Conclusion

At their core, bridges provide connection. The initial driver for bridge construction was connecting a community with their basic needs. Societal evolution provided the next step of bridge construction providing convenience, bridging gaps so a neighborhood could be a seamless whole. Over the past several decades the newest driver has been the desire to connect people with the bridge and surrounding environment. To create a place of experience where the bridge itself is artwork which compliments the setting it is constructed in. The iconic pedestrian bridge has become a place of being instead a place of passing.

This new level of design is sure to challenge engineers and architects in the coming years in unexpected ways. Already designs are pushing the envelope such that what is defined in contemporary design codes does not apply and engineers must rely instead on first principals to solve engineering problems. Juxtaposed with this is the use of advanced FEM and parametric modeling to understand and define the structural behavior. Add in the limitless possibilities provided by 3D printing and the idea of what is possible is shattered completely. How engineers adapt to this brave new world will shape the future of iconic bridges and what is constructed for generations to come.

About the Authors...

Jeremy LaHaye, P.E.

Jeremy has been with TYLin for 18 years serving as a project manager and designer for a myriad of bridge projects. He enjoys a good challenge and thrives on delivering projects that are iconic or challenging by nature.

Bobby Sokolowski, P.E.

Bobby is a Lead Bridge Engineer for TYLin specializing in parametric modelling and design of bridges. He has developed a suite of tools that are used within the bridge design group and are pushing design technology forward in the industry.

Dan Fitzwilliam, P.E.

Dan is the Bridge Sector Manager for the Southwest at TYLin. He has been designing complex bridges for over 25 years. His recent works include a series of architecturally unique pedestrian bridges.

Parametric Pursuit: Groundbreaking Digital Design and Delivery from Concept to Completion

Delivery of Green Street Bridge became an opportunity for technical innovation: Balancing the pragmatism of Design Build procurement with a community's aesthetic ambitions.

Parametric Model Juxtapositioned with Completed Bridge

"Parametric modeling allows complex elements to be edited easily without the need to be manually rebuilt. For example, the parameters used to create an object may be changed afterward to achieve a different result without manually rebuilding the element…. – Bentley"

The $2.9 million Green Street Pedestrian Bridge, located in downtown Winston-Salem is a unique, multi-ribbed, unbraced tied-arch structure spanning the newly reconstructed Salem Parkway. It is a focal point of an award-winning, $99.2 million North Carolina Department of Transportation U-2827B I-40 Business Reconstruction Design-Build Project completed in 2021. The project had an ambitious design-build delivery schedule and comprised of a wide array of project elements, ranging from roadway improvements to sound walls and numerous new vehicular bridges: All competing for limited resources to deliver a major public infrastructure project in less than two years.

The added aspiration for the Green Street pedestrian bridge was to meet the community's vision for a signature bridge – an aesthetic goal triggering a fundamentally different design approach for the structure from a very early stage to ensure this could be achieved. Generating fast-track results to meet the aesthetic goals for a competitive pursuit required leverage of parametric design tools and expertise: At the time, a giant leap forward for digital design delivery on a DOT project.

RFP Phase

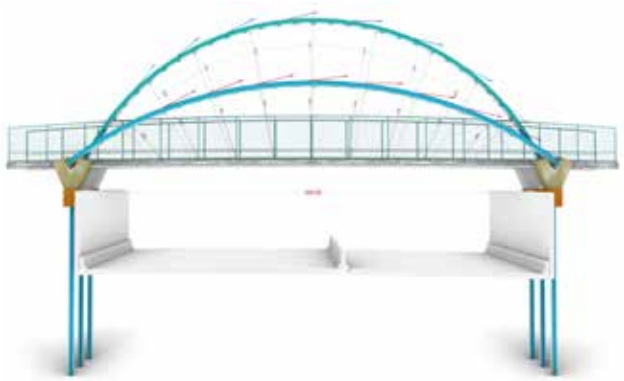
Green street's delivery and trajectory for success started a few weeks before the pursuit submittal deadline in 2016 when a handful of DB teams were finalizing their competitive Joint-Venture bids for the overall I-40 design-build project. The RFP didn't just require any conventional beam bridge across I-40 Business for Green Street—it specifically required a competitive technical submission meeting the creative intent of the community which was articulated in the aesthetic guidelines. The challenge was to provide a unique geometric design at the pursuit stage consisting of a multi-ribbed, true tied arch that was unlike any other in the region. Quite the stretch for committing to a buildable design and subject to a competitive Joint-venture pursuit at a very early and marketing stage.

Bounded by limited and competing resources at the pursuit stage and with only six weeks remaining to wrap up the technical content by the submittal deadline, a timely and effective design solution for Green Street was also critical for the success of the overall project bid package. By leveraging parametric bridge design tools and expertise as early as possible, the team was able to efficiently develop a unique structural concept which enabled key early insights and built necessary technical confidence for a unique, four-unbraced arch ribs and genuine tied-arch concept in a very short window of time.

This allowed for the validation of the structural configuration using structural analysis models and provided critical early insights that built higher confidence in selecting the primary load-carrying steel shapes for rolling availability and pricing. Providing this early confidence in the structural and geometric solution to the team was paramount, especially at the rib crossover locations where the constructability focus was amplified. A 3D parametric model helped verify critical aspects and provided the geometric framework for the stunning visual submitted as part of the pursuit. A few months later, the team was selected for the project.

Design Phase

The design phase picked up directly from where the pursuit-level parametric model had ended so that design



Elevation View of Parametric Geometry Model

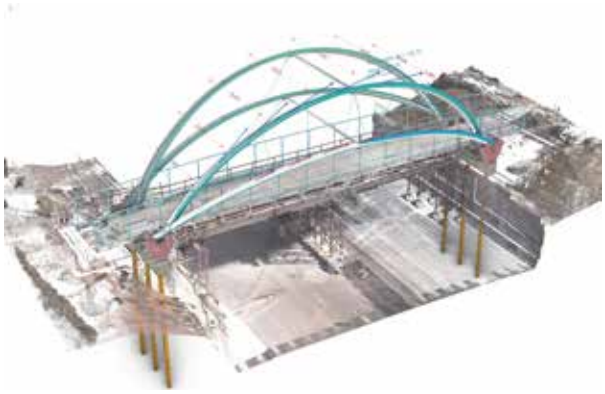
development efficiency and effectiveness could propel forward at NTP and could capitalize on the digital design investment made. The centralized real-time parametric model was used to refine the design and explore opportunities for refinements and cost-effectiveness along the project's lifecycle and for key deliverable milestones. By changing key aspects of the bridge's definition and geometric relationships, the team could explore form and fit directly without redrawing or rebuilding the analysis and geometric models, since they were all parametrically connected.

Improved form finding was essential at this critical early stage when design and constructability decision-making is driving the structure's design trajectory. Form-finding helped identify optimal design and constructability solutions throughout the bridge structure by balancing forces with materials and other performance-based constraints. The parametric model provided the opportunity to evaluate infinite parabolic and radial arch rib configurations and rib tilt angles in addition to hanger splaying in minimal amounts of time: Key to comparing material savings with aesthetic and visual implications or determining optimal splice locations that balanced slenderness ratios with shipping-to-site geometric limitations. Balancing demand and realizing optimized biaxial flexural demands of various rib tilt angles, strengthening the case for the 13- and 33-degree angles seen in the final design. The overall arch heights were checked to compare the effects of compressive thrust and tie forces in the deck and to identify sweet spots for structural design.

Ultimately, form-finding provided a basis for understanding efficient structural solutions which had to be evaluated against constructability and, in the case of Green Street, visual impact on the aesthetics. Integrating the parametric design methodology marks the most exciting and powerful change to engineering since computer-aided design replaced drawing on vellum and are powerful tools that compliment expertise when exploring and evaluating unique structural forms, function, and design possibility in the early stages of concept development.

Construction Phase:

The availability of the parametric model was pivotable towards understating how field adjustments would affect the design and behavior of the bridge. Fabrication tolerances are typically within an eighth of an inch for steel, yet, much larger for concrete: Especially at the substructure level or anywhere fabricated steel elements interface with cast-in-place elements and reinforcing.



Parametric Model Juxtapositioned with Surveyed Bridge Prior to Completion

The beauty of the parametric bridge engineering model is that it constantly forms the basis of the underlying design even into construction: Similar to the design phase, it will adapt to implemented field conditions or changes just as elegantly. Given site survey data, the point cloud can be overlayed on the parametric bridge model to assess field conditions and the potential for impact on design due to tolerance limits being pushed.

For example, the team explored adjustments for embedded gusset plates to work with blocked out as-built reinforcing conditions, checking if the adjustable stainless-steel hangers would still accommodate the fit-up angle and length tolerances.

The parametric bridge model allowed the design team to instantly shift components in real-time to understand the implications. An elevated understanding of field issues improves outcome opportunity when working with the Contractor to assess and recommend field adjustments: Aspects providing critical timely insights during construction.

Conclusion

Initialized early and at the pursuit stage in 2016, the centralized parametric design workflow for the Green Street bicycle and the pedestrian bridge became the pivotal part of the project's design trajectory for delivery success and continued to adapt through the design lifecycle and into the construction phase.

The built structure's completed form validates the early insights gained from a combination of expertise and the leverage of a ground-breaking parametric model: Certainly, one of the first DOT bridge projects to successfully apply parametric engineering from concept to completion. In effect, ensuring that what was structurally conceptualized to meet the aesthetic requirements of the RFP and proposed in the competitive pursuit submittal would become a reality.

The arching structure serves as an artful, iconic gateway into downtown along I-40 Business, re-connecting adjacent communities previously bifurcated by the highway, and represents groundbreaking advancements for the digital delivery of a bridge leveraging innovative parametric design and technology.

About the author...based out of HDR's Portland, Oregon office, Michael Roberts is a Senior Bridge Engineer specializing in the design of footbridges across the USA.

Completed Green Street Pedestrian Bridge

The South Street Pedestrian Bridge Extension

Ahcène Larbi, Ph.D., P.E. & Joseph Sullivan, P.E.
WSP USA

Introduction

The design of a new extension to the South Street pedestrian bridge to span Christopher Columbus Boulevard (CCB) in Philadelphia has been completed and its construction has begun. With a total length of 611'-3", the structure includes a 258'-0" asymmetrical steel tied arch main span, an 88'-9" west approach tying it to the existing South Street pedestrian bridge and 264'-6" long corkscrew shaped east approach connecting it to the Delaware waterfront and Delaware River trail. The west approach curves at the tie-in at South Street to allow the main span to cross the CCB at approximately 40 degrees in a northeasterly direction. The bridge has a 14 ft pathway to provide pedestrian and bicycle access to the waterfront.

WSP was the engineer of record for the South Street Pedestrian Bridge, serving as a sub-consultant to Pennoni & Associates. The South Street bridge extension is a component of the larger project of I-95 Central Access Philadelphia project (I-95 CAP), which includes the construction of a new Penn's Landing Cap structure, that creates an 11-acre park over I-95, and Christopher Columbus Blvd. The I-95 CAP project is part of the Master Plan for the Central Delaware adopted by the Philadelphia Planning Commission in 2012 and validated by the 2014 Delaware River Waterfront Corporation (DRWC) Feasibility Study. The project promotes multi-modal access to the Penn's Landing waterfront for the City of Philadelphia.

Goals of the Project

The goals of the project were to extend an existing South Street Bridge, that abruptly ended with a set of stairs and switchback ramp, with a signature pedestrian structure that will link South Street to the Delaware River waterfront. This bridge is intended to be a landmark structure with unique architecture that will become identifiable with Penn's Landing. A minimum vertical clearance of 17'-6" over Christopher Columbus Blvd. was required. The project also aimed to minimize right of way acquisitions and impacts to third parties in the area. The type of structure envisioned would consider ease of fabrication and construction and minimize long term maintenance and operational costs.

Constraints

The alignment of the new South Street bridge had to be positioned in a manner that accommodates several constraints:

- At the tie-in to the existing South Street Bridge a small portion of the overlook will be removed to allow the structure to receive the new structure.
- The new structure must have sufficient room under its first span to accommodate a future I-95 exit ramp.
- The foundations of the new structure must avoid an 84" diameter sewer line running on a southeasterly direction across the parking lot and Christopher Columbus Blvd.
- An existing bulkhead supported on timber piles on the west bank of the Delaware River also must be avoided.
- Finally, the bridge must span the new proposed Delaware River Trail that will be built on the east sidewalk of Christopher Columbus Blvd. by the river.

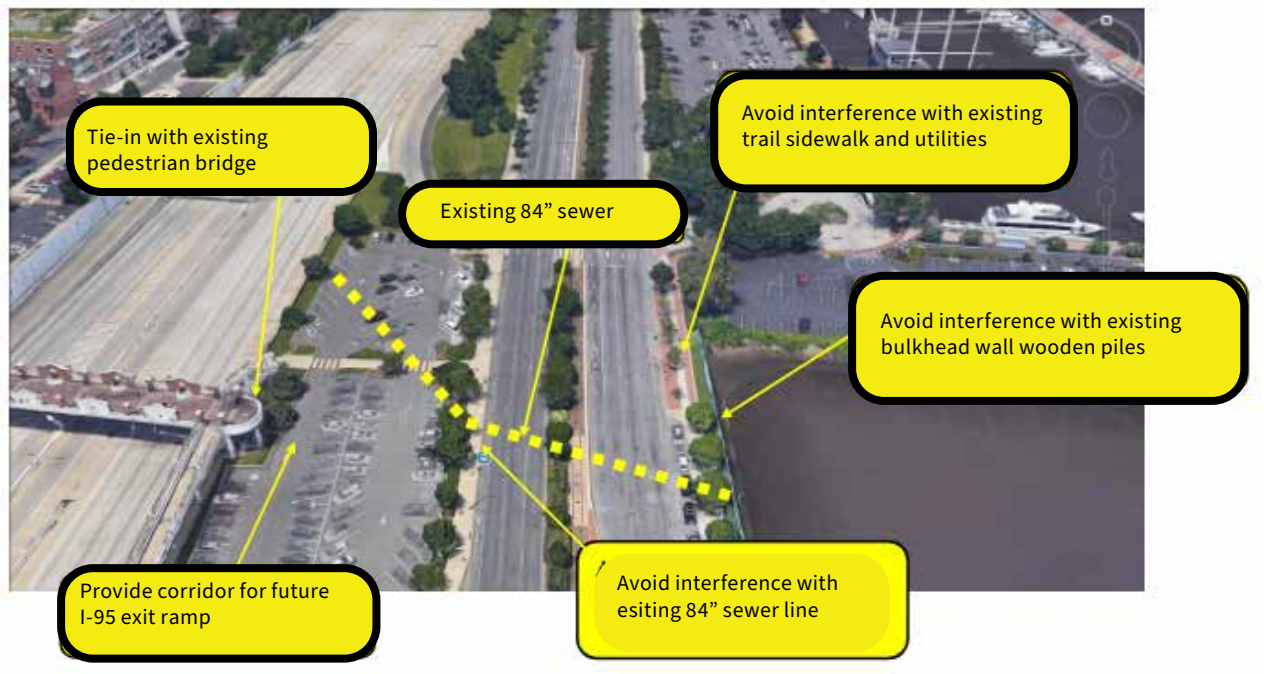


Illustration of the various constraints

A landmark Structure

The selected structure alternate is an asymmetrical steel tied arch bridge with a 258 ft long span. The arch rises 80 ft above the pathway and the arrangement of the suspenders in a radiating configuration give the arch the look of a basket. The number of cross frames bracing the two arch ribs is kept to a minimum for a more minimalist shape emphasizing the arches and allowing more natural light through the structure.

The arches are supported on reinforced concrete piers with a curved shape to maintain continuity of the arch curves emphasizing the load path as if the arch was fixed on the ground.

The approach structures are made of 3-girder plate girder spans, two spans for the west approach tying the arch span to the existing South Street Bridge and a 5-span circular east approach carrying to walkway down to the Penn's Landing and the Delaware River Trail. The girder spans are supported on slender hammerhead piers. Architectural texturing is used on all piers to give them a unifying theme.

The two western piers are supported on spread footings, while the rest of the piers are supported on friction piles driven approximately 40 feet below the bottom of foundation. The main span piers, the east abutment, and the wingwall piles are kept vertical to minimize conflict with the existing 84" diameter sewer line, bulkhead and utilities buried in the Christopher Columbus Blvd. sidewalks. The remainder of the piers used both vertical and battered piles.

The stainless-steel mesh railing mounted on the deck curbs is leaning outward to provide a sense of openness for the pedestrians. Its height varies to accommodate the required heights over Christopher Columbus Blvd and the Conrail track runs down the middle of the roadway. Rather than providing two distinct heights on the approaches and main span, a variable height following a gentle parabolic curve to provide a profile in elevation that does not clash with the arch curve. the fence height rises as it comes into the main span and then decreases until it reaches the constant height provided on the approaches.

Architectural lighting is very important for this area of the city as it is the locus of many cultural and recreational activities all year round. The light beams placed at each suspender cable will light the arch with different color schemes to complement the events taking place at the waterfront. Lighting of the walkway is incorporated in the handrails of the pedestrian railing.

Design

In addition to meeting the requirements of the 8th edition of the AASHTO Bridge Design Specifications and PennDOT's Design Manual, the design meets additional requirements established in a design criteria developed to meet the demands of such a complex structure. A LARSA-4D finite element model was put together to analyze the structure under all phases of construction. The structure was analyzed for loads during construction, and in its completed configuration, the accidental loss of a suspender, the failure of a floor system element or the tie girder. An important aspect of the design was the investigation of vibrations due to wind and pedestrians. While wind did not pose a problem for the structure, tuned mass dampers (TMD) had to be considered to mitigate some cases of pedestrian vibration. The addition of these TMDs will be finalized after testing of the completed structure.

Constructability

Maintenance and protection of traffic on Christopher Columbus Blvd. throughout construction is one of the key factors in the construction staging of this structure. Pedestrian traffic on the existing South Street Bridge will be maintained as well as the stairs and ramps will remain in place. In addition, all utilities along Christopher Columbus Blvd. must be kept in service during construction and impact on them from construction minimized.

Two construction methods have been developed in the final plans. One of them uses cranes for an erection on alignment and the other self-propelled mobile transporters for erection off alignment. Both methods will require the usage of a good portion of the existing parking lot on the west side of Christopher Columbus Blvd.

The I-95 CAP project will undoubtedly transform Penn's Landing and the waterfront with the construction of the cap over I-95 adding 11 acres of green spaces and park amenities, providing venues for many activities on the waterfront. Access to the area is then paramount for vehicles, pedestrians, and bicycles. The South Street Bridge extension will not only improve access from the bustling Center City neighborhood, but it will become a centerpiece of the waterfront in this area of Philadelphia. With it 100 ft rise over Christopher Columbus Blvd., it will be visible from afar, its lighting during events will be a rallying point for all visitors and residents alike.

A rendering of the completed South Street Pedestrian Bridge Extension

Bridge Quiz – Some IBC Award Winning Pedestrian Bridges

Each year, IBC annually awards bridge medals for outstanding bridges, of which some of the most unique are pedestrian bridges. These bridges have an international flavor, feature signature architectural elements and receive strong acceptance by the public.

Can you match the IBC Judge's Quote with each unique pedestrian bridge?

QUOTE #1 "The willingness of the project planners to embrace technology for each stage of the project has resulted in an aesthetically pleasing, light structure that belies its marine environment." Eugene C. Figg, Jr. Medal Winner, 2022

QUOTE 2: "With its sleek lines and sculpted shape, the bridge's tower evokes the needle though whose eye, pedestrians can traverse the sleek, sinuously curving deck." Eugene C. Figg, Jr. Medal Winner, 2021

QUOTE 3: "To gasp (in admiration) is fitting for this structure, perhaps even poetic. One can imagine gasping while looking through the glass deck and taking the view from the bridge at approximately 400 feet above the valley floor." 2020 Arthur G. Hayden Medal

QUOTE 4: "The iconic bridge includes the use of signature color, special lighting and elegant detailing. The sinuous crossing is perfectly integrated into the landscape due to its transparency and lightness." - 2019 Arthur G. Hayden Award

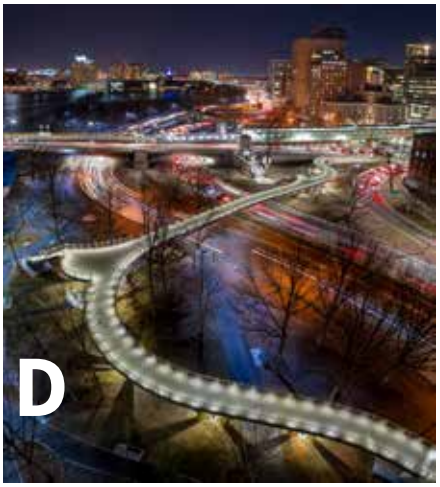
QUOTE 5: "The bridge connects the east and west canyons, giving the impression that one is floating on air. The span provides a unique vantage point, incorporating the surrounding landscape into an extraordinary experience."- 2018 Arthur G. Hayden Award.

QUOTE 6: "An innovative context sensitive solution … With its steep descent, the aesthetic, sculpted profile represents a nautilus shell emphasizing the bridge's proximity to the Pacific Ocean ." 2017 Arthur G. Hayden Award

QUOTE 7: "The expertise displayed by all stakeholders resulted in a unique preservation of the 90-year-old historic bridge as a linear park, that will enable this river crossing to serve the community for many years to come." 2017 Abba G. Lichtenstein Medal Arthur G. Hayden Award

QUOTE 8: "Bridges of Prosperity is doing great things in South America without the rest of the world knowing. This… bridge shows what can be done to help local people be able to cross rivers and creeks in a functional way." 2017 Award of Merit

Bridge Quiz - cont'd.



QUIZ ANSWERS

Quote 1 – Bridge H - the Varvsbron, Helsingborg, Sweden

Quote 2 – Bridge C - the Dublin Link, Dublin, Ohio, USA

Quote 3 – Bridge A - the Tanxi Mountain Sky Bridge, Shanghai Province, Peoples Republic of China.

Quote 4 – Bridge D - the Frances Appliegate Pedestrian Bridge, Boston, MA, USA

Quote 5 – Bridge G - the Zhangjiajie Grand Canyon Glass Bridge, Zhangjiajie Central Forest Park, Peoples Republic of China

Quote 6 – Bridge F - the Idaho Avenue Pedestrian Overpass, Santa Monica, CA, USA.

Quote 7 – Bridge B - the Corning Centerway Arch Bridge, Coring, New York, USA

Quote 8 – Bridge E - the Paso Real Suspension Pedestrian Bridge, Condega, Nicaragua

#

Paradoxically Pedestrian – Three footbridges defying conventional solutions

Written and Photographs by: Michael Roberts, P.E., S.E., P.Eng., ENV-SP

Three unique European pedestrian bridges are highlighted from over a dozen visited, each offering insight into a wide range of structural adaptions and forms possible for even the simplest of bridges located at key cultural centers.

These bridges stood out from their nearest neighbors and did much more than get people from point A to point B, providing a structural solution beyond that of an off-the-shelf design and raising integral questions. When balancing structural forces in contextually sensitive locations, can aesthetics go too far and can a pedestrian bridge overstep its function and intent?

This photo essay highlights three pedestrian bridges discovered on a recent visit to London and Madrid, the result of a personal pilgrimage by the author to Footbridge 2022.

Esperance Bridge, London, UK, 2021 Lat: 51.5347 Lon: -0.1253

Question: Can a prefabricated truss design work for a high-profile development in the heart of London to cross a canal located at a cultural and historic nexus?

A welded steel plate warren thru-truss adaption offering an inspirational and modern-take on the bridge's 1821 rail bridge ancestor, the Esperance Bridge clear spans 25m (82 ft) over Regents Canal.

A bold structural and geometric form incorporating stainless steel elements and specialty fabrication, the bridge is the final of three canal crossings offering pedestrian accessibility within a landmark development adjacent to Kings Cross and St. Pancreas railway stations.

Project Team: Arup/Moxon Architects

Matadero Shell Bridge, Madrid, Spain. 2010 Lat: 40.3911 Lon: -3.7001.

Question: Can a modern pedestrian bridge's structural design simultaneously provide a canvas for its community's artistic expression while providing shelter from the sun as it makes its impact and adding to a collection of nearby pedestrian bridges spanning over six centuries?

A 6-inch-thick reinforced concrete compression arch surface is resisted by a composite steel tension deck-tie spanning 43.5m (143 ft) over Madrid's Manzanares River.

One of two identical bridges, the Matadero Bridge was designed with community involvement and ownership: Local residents provided photos that were digitally converted into a tile mosaic expression that adorns the interior surface of the shell and is protected from the sunlight.

Project Team: FHECOR/Burgos & Garrido Arquitectos/West 8 Urban Design & Landscape Architecture b.v.

Arganzuela Park Monumental Bridge, Madrid, Spain. 2011 Lat: 40.3977 Lon: -3.71177.

Question: Can a pedestrian bridge become a recognizable icon reconnecting riverbank parks and have programmatic goals of improving local area residents' quality of life, urban connectivity, and recovery of the natural environment?

Designed by French Architect Dominique Perrault, the Arganzuela is a double metal spiral in the form of a ringlet with two arms, covered by a metallic mesh which reflects the sunlight during the day and is illuminated at night.

Bicyclists are provided with a designated path over the bridge which connects the park's bicycle path network and pedestrians can stroll over the bridge on a separated path providing benches for a slower and more restful crossing of this Madrid Rio Icon.

Project Team: MC2 Estudio de Ingenieria, S.L./Architect: Dominique Perrault Architecture

About the author...Michael Roberts, P.E., is a Senior Bridge Engineer specializing in the design of footbridges across the USA and is based out of HDR's Portland, Oregon office: Recently travelling to Europe to attend the Footbridge conference and connect with an inspiring community of pedestrian bridge designers.

Featured State for IBC 2024: Texas

Texas has more than 55,000 bridges that carry vehicular traffic — about 28,000 more bridges than any other state in the nation, and more than the combined inventories of 17 states.

Of those, nearly 36,000 Texas bridges are on the state system, and the remaining 19,000 bridges are off the state system (city streets, county roads, etc.) TxDOT routinely inspects bridges in accordance with the National Bridge Inspection Standards and conducts additional reviews as part of the Maintenance Bridge Inspection Tracking System. This ensures all bridges open to vehicular traffic in Texas are safe.

Texas has 33 international bridges open to traffic between Mexico and Texas, six of which are federally owned and the other 27 owned by TxDOT or local governments.

The average age of Texas bridges is 48 years for bridges on the state highway system and 34 years for bridges off the state highway system.

Contracts were awarded to replace, widen, repair, rehabilitate, or construct 740 bridge-class structures in fiscal year 2022.The San Antonio Riverwalk (https://www.thesanantonioriverwalk.com/) - hugely popular, and particularly noteworthy since we are headed to San Antonio

Featured Texas Bridges:

The Ann W. Richards Congress Avenue Bridge, Austin, TX -
Home to a colony of over a million Mexican Free-Tailed Bats who eat 10k to 30k lbs of bugs each night; just up the road from San Antonio; you can stand on the bridge each evening at dusk and watch them come pouring out.

Photo Credit :Stuart Seeger from San Antonio, Texas, USA - Congress Avenue Bridge, CC BY 2.0, https://commons.wikimedia.org/w/index.php?curid=23105923

Fred Hartman Bridge, Baytown, TX -
the longest cable-stayed bridge in Texas, and one of only four such bridges in the state. The bridge replaced the Baytown Tunnel (of depth clearance 40 feet)

Photo Credit: United States Coast Guard, PA2 James Dillard, Public domain, via Wikimedia Commons

Waco Suspension Bridge, Waco, TX -
Roebling bridge built in 1870, built on the Chisholm Trail for cattle; wide enough for two stagecoaches to pass each other (provided there was not a cattle drive on the bridge) (https://www.waco-texas.com/Departments/Parks-Recreation/Suspension-Bridge-Riverwalk-Area).

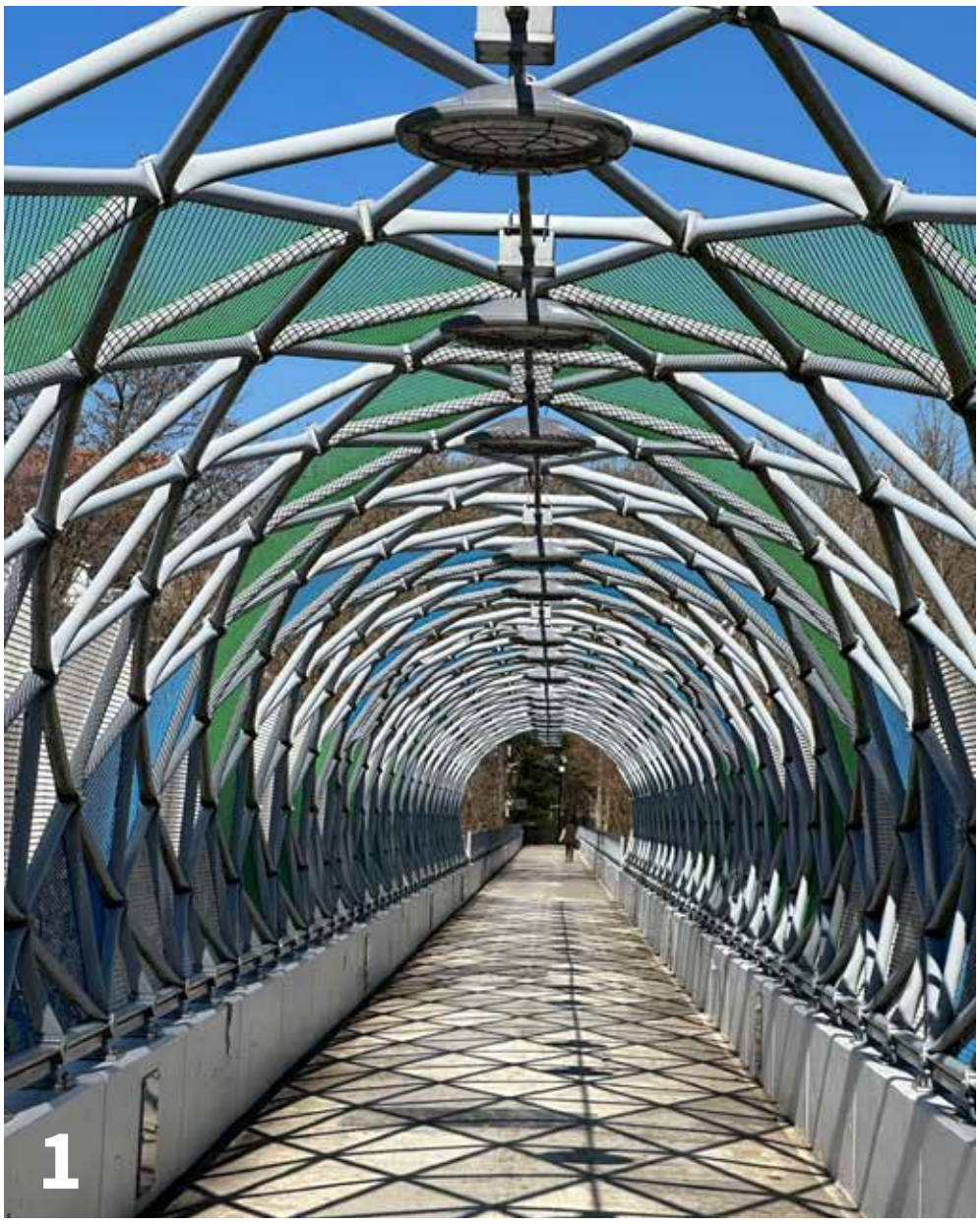
Photo courtesy Wikipedia (Creative Commons)

ALSO, REMEMBER THE ALAMO IN DOWNTOWN SAN ANTONIO

ALL PHOTOS COURTESY WIKIPEDIA COMMONS

IBC's 12th Annual Photo Contest

This year we highlight pedestrian bridges. Our artists are professional photographers, bridge professionals, and bridge enthusiasts who share their love of bridges by entry into our annual contest. The executive committee of IBC has reviewed many entries and after a difficult selection process has voted the following as the ten best entries of 2023 – enjoy the results of our contest along with comments from the judges.



1. US 29 Pedestrian Bridge; US 29 - Villages of Oakland Mills and Town Center Columbia; Submitted by: Laura Magoon

"Fascinating image of light and shadow"

2. Capital Cascades Connector Bridge; Tallahassee, Florida, over S. Monroe Street;
Submitted by: Adam Cohen

"Great use of perspective and lighting"

3. North Bank Bridge; The North Bank Bridge is a pedestrian walkway under the cable stayed Zakim Bridge in Boston. Spanning 690 feet, it crosses the MBTA rail tracks;
Submitted by: Damian Silverstrim

"great capture of shadow and light illuminating a novel, latticed structural form"

4. Trestle Trail; Des Moines, Iowa
Submitted by: Richard Cochrane

"Great view and perspective since view conveys movement with the steel overhead."

5. Kinzua Skywalk;
Kinzua State Park;
Submitted by: Brandon Lankey:

"One may be saddened by the setting, yet portions of the iconic and majestic structure endure"

6. Umtanum Suspension Bridge; Trail Bridge crossing of the Yakima River, Washington;
Submitted by: Michael Roberts

"Great use of perspective and lighting."

7. Pasarela de Arganzuela; Manzanares, Madrid, Spain;
Submitted by: Dennis Smith

"Fascinating visual perspective"

8. Manting Imperial Garden; Xishuangbanna, Yunnan, China; Submitted by: Xiyu Li

"a timeless treasure captured in striking lighting"

9. Southside Hot Metal Bridge - Trail Bridge; Great Allegheny Passage Submitted by: Stephen Shanley, P.E.

"Delightful illustration of the center of perspectivity"

10. Canal Place, Cumberland, MD; Hiker-Biker Trail over C&O Canal; Submitted by: Michael Good

"a tranquil setting and timeless image when captured in black and white"

Congratulations to our Top-10 selections, and thanks to all who submitted an entry into the IBC Photo Contest! Let's do it again next year!

The 2023 IBC Awards

The International Bridge Conference® annually awards medals and awards of distinction to many projects of eminence and distinction from the world-wide engineering community. This year is no exception – enjoy this year's award winners.

ROEBLING MEDAL

Dr. Dan A. Brown, Ph.D., P.E.

Dan A. Brown has provided many distinguished contributions and achievements in bridge engineering over his 45-year professional career. Over that time span, Dan Brown has served prominently in professional organizations, design consulting work, construction practices consulting, collaborative research and education. His expertise blends the requirements of design with the realities of construction. From 1987 to 2009, Dan was an engineering professor at Auburn University. In 2005, he started his consulting firm, Dan Brown and Associates.

Dan has served as a design and construction foundation consultant for dozens of large-span and signature bridges across the U.S. including, the Gordie Howe, Goethals, Schuyler Heim, Tilikum Crossing, Stan Musial over the Mississippi, I-15 Beck Street, Kit Bond over the Missouri River, John James Audubon in Louisiana, replacement I-35W Bridge in Minnesota, light rail system in Honolulu, Hawaii, Gerald Desmond Bridge in Long Beach, California, Tappan Zee Bridge in New York City, Champlain Bridge in Montreal, Huey P Long Bridge in New Orleans, and new Goethals Bridge in New York City.

Dr. Brown served on the faculty at Auburn University for over twenty years where he conducted extensive research related to bridge foundations. Throughout both his consulting and academic careers, Dan has continuously demonstrated the unique ability to be innovative yet practical, and to effect positive change in both the state-of-the-art and state-of-the-practice of foundation design and construction for bridges.

Examples of innovations that Dan Brown has fostered and facilitated include use of bi-directional and static load testing for bridge foundations, post-grouting for drilled shafts, rational integrity testing practices including the use of in-situ load cells, use of self-consolidating and other highly workable concrete mixes for challenging placements, and use of continuous-flight auger (CFA) piles for bridge foundations.

Dan has led and contributed to many of the most significant manuals published by the Federal Highway Administration addressing design and construction of foundations for bridges including manuals and other publications addressing drilled shafts, driven piles, and CFA piles. He has served as an instructor for the FHWA sponsored NHI course on "Drilled Shafts: Construction Procedures and Design Methods".

The Award's Committee comments include: "Dan Brown is eminently deserving of the John A. Roebling Medal. Over Dan's lifetime, he has demonstrated the essence of Roebling's ability to blend material science and design into practical construction practices. Dr. Dan Brown is an innovator, designer, and educator in the field of bridge foundations. He is recognized throughout North America for his geotechnical and foundation subject matter expertise and for his ability to provide constructable design solutions as evident in his design consultant services for many major bridges. He has regularly shared his knowledge with the bridge industry as an educator in a university setting and through FHWA sponsored NHI course offerings."

LINDENTHAL MEDAL

Pelješac Bridge

Owner: Hrvastske Ceste
Designer: JV: Pipenbaher Consulting Engineers, Ponting Bridge, Faculty of Civil Engineering of Zagreb University
Contractor: China Road and Bridge Corporation (CRBC)

The Pelješac Bridge is located at the southern end of Croatia, in the Mali Ston Bay Nature Reserve in the west Adriatic Sea. The bridge established the connection between the northern territory of Croatia and the southern Dubrovnik - Neretva province, avoiding border crossing with Bosnia and Herzegovina on land. It is a steel box girder extra-dosed cable-stayed bridge with 6 pylons and a total length of 2440m. The average sea depth along the bridge alignment is 27 m. The required minimum navigation clearance was 200m x 55 m. The contractor China Road and Bridge Corporation (CRBC) signed the commercial contract with the client Hrvastske Ceste under the terms of the FIDIC red book with a total cost of 2.08 billion Kuna. The construction started in August 2018 and it opened on 26 July 2022.

The 2023 IBC Awards

FIGG MEDAL

Frederick Douglass Memorial Bridge

Owner: The District Department of Transportation
Designer: BEAM Architects + AECOM
Contractor: Archer Western Construction LLC (Walsh Group) and Granite Construction Co

The Frederick Douglass Memorial Bridge (FDMB) is a 1200ft (365m) long three span bridge over the Anacostia River, replacing the adjacent structurally obsolete South Capitol St. Bridge. The triple through-arch arrangement provides a dynamic gateway to the historic monumental core of Washington DC and provides a rare and significant alteration to the Capitol skyline. The cable-supported design is in the spirit of the city's historic multi-arch form bridges but evolves the type with bold over-deck structure to create an iconic visual signature. With interventions including large park-like transit ovals at each end the project completely transforms the South Capitol Street corridor into a grand urban boulevard that reinforces the iconic L'Enfant Plan of the city and is central to the revitalization of neighborhoods on both sides of the river. The $453 million FDMB is the largest public works project in the history of the District of Columbia.

LICHTENSTEIN MEDAL

Town Bridge Road over Farmington River

Owner: Town of Canton, CT
Designer: TranSystems
Contractor: ROTHA Contracting Company, Inc.

The existing 1895 Berlin Iron Bridge Company Parker thru truss bridge was structurally deficient and functionally obsolete. The 160' long single-span bridge had a narrow 14'-3" roadway width to accommodate alternating one-way traffic. The project goal was to develop an optimum solution to improve the geometric and capacity issues while preserving the National Register listed historic truss bridge. The local residents, through the public involvement process, expressed overwhelming support to maintain the existing bridge in its original configuration and rehabilitation plans were prepared to repair and sensitively strengthen the bridge to HS-20 load capacity. The trusses were removed, match marked, disassembled, and shipped to a shop to be repaired and "duplex" coated with paint over hot dip galvanizing before being reassembled on-site. Missing or damaged historic features, such as lattice railings and decorative finials, were repaired or replaced.

The 2023 IBC Awards

RICHARDSON MEDAL

Todd Helwig for his work on NCHRP Project 12-113: Proposed Modification to AASHTO Cross-Frame Analysis and Design. (NCHRP Report 962)

Owner: AASHTO
Designer: Todd Helwig
Contractor: Not applicable

Professor Todd Helwig is awarded the 2023 George Richardson Medal for his work leading the NCHRP 12-113 Research Project entitled Proposed Modification to AASHTO Cross-Frame Analysis and Design. This project included field instrumentation, laboratory experiments, and extensive parametric finite element analysis on over 4000 bridges including extreme geometrical effects of support skew and/or horizontal curvature. This project resulted in balloted and approved provisions in the AASHTO Design Specifications that filled a major void on the design provisions for cross-frame and diaphragm systems in steel bridges. The provisions include guidelines on truck placement and load factors for cross frame fatigue, recommendations on modification factors accounting for eccentric connections in cross-frame members, and stability bracing provisions for cross-frame systems. These recommendations will enhance and improve the design of every single steel bridge system in the United States.

COOPER MEDAL

Merchants Bridge Main Span Trusses & East Approach Replacement

Owner: Terminal Railroad Association of St. Louis
Designer: TranSystems
Contractor: The Walsh Group

Merchants Bridge was built in 1890 and had exceeded its design life. As a result, one of the nation's primary east-west rail corridors was operating under a variety of speed, clearance, and load restrictions, all of which led to increased costs for the owner, Terminal Railroad Association of St. Louis (TRRA), as well as for the six Class I freight railroads that relied on the crossing. To bring the bridge back to an acceptable level of service, the structure was completely rehabilitated. The three main aspects included the removal and replacement of the three 520-foot river-span through trusses, seismically retrofitting the four existing river piers, and significantly improving the east approach.

The 2023 IBC Awards

AWARD OF MERIT – EMERGENCY RESPONSE

Fern Hollow Bridge

Owner: Pennsylvania Department of Transportation / City of Pittsburgh
Designer: HDR
Contractor: Swank Construction Company, LLC

Less than a year after its tragic collapse, the Fern Hollow Bridge in Pittsburgh, Pennsylvania is once again connecting the communities that rely on it. The collaborative effort between governments, engineers, constructors, and stakeholders transforms a tragic incident into a source of community pride. The team kept the bridge's four vehicular lanes, while maintaining the existing right of way, expanding multi-modal capacity by 50%, increasing safety, and integrating public art. The herculean effort required designing multiple critical components — foundation, substructure, superstructure, utilities, environmental and aesthetics — simultaneously, using available materials and equipment, consolidating reviews, avoiding adjacent historic masonry structures, and constructing new abutments on drilled piles. The project became a public event for the community, who lined up to watch and applaud the parade of bridge beams traverse the city, which were often followed by news helicopters streaming video. The historic project is a testament to collaboration, innovation, and community willpower.

HAYDEN MEDAL

The Pihe Aqueduct

Owner: Anhui Provincial Group Limited for Yangtze-to-Huaihe Water Diversion
Designer: Anhui Transport Consulting & Design Institute Co., LTD & Anhui Surver & Design Institute of Water Resources & Hydrpower Co., LTD
Contractor: China Railway Construction Bridge Engineering Bureau Group Co., LTD & Steel Structure Construction Co., LTD of China Railway No. 4 Engineering Group

The Pihe Aqueduct is a river relocation project that carries the Pihe River over another grand canal. The main structure is a steel beam-arch composite bridge with a span configuration 68m+110m+68m. Its main span is the world's longest for navigable aqueducts. Corrugated stainless-steel webs are used on its water trough, which is the first of its kind in the world. A new structure with outer truss and inner trough, which is verified by over 30 reduced scale model tests and water filling tests on the as-built bridge, is designed to meet challenges such as special loads caused by waterflow and temperature field, requirements of navigation and water quality protection. Theoretical and practical breakthroughs in structure's compatible deformation under temperature field, water body's flow field effect and fluid-solid coupling have been achieved. Environmental and ecological protection were stressed in the project.

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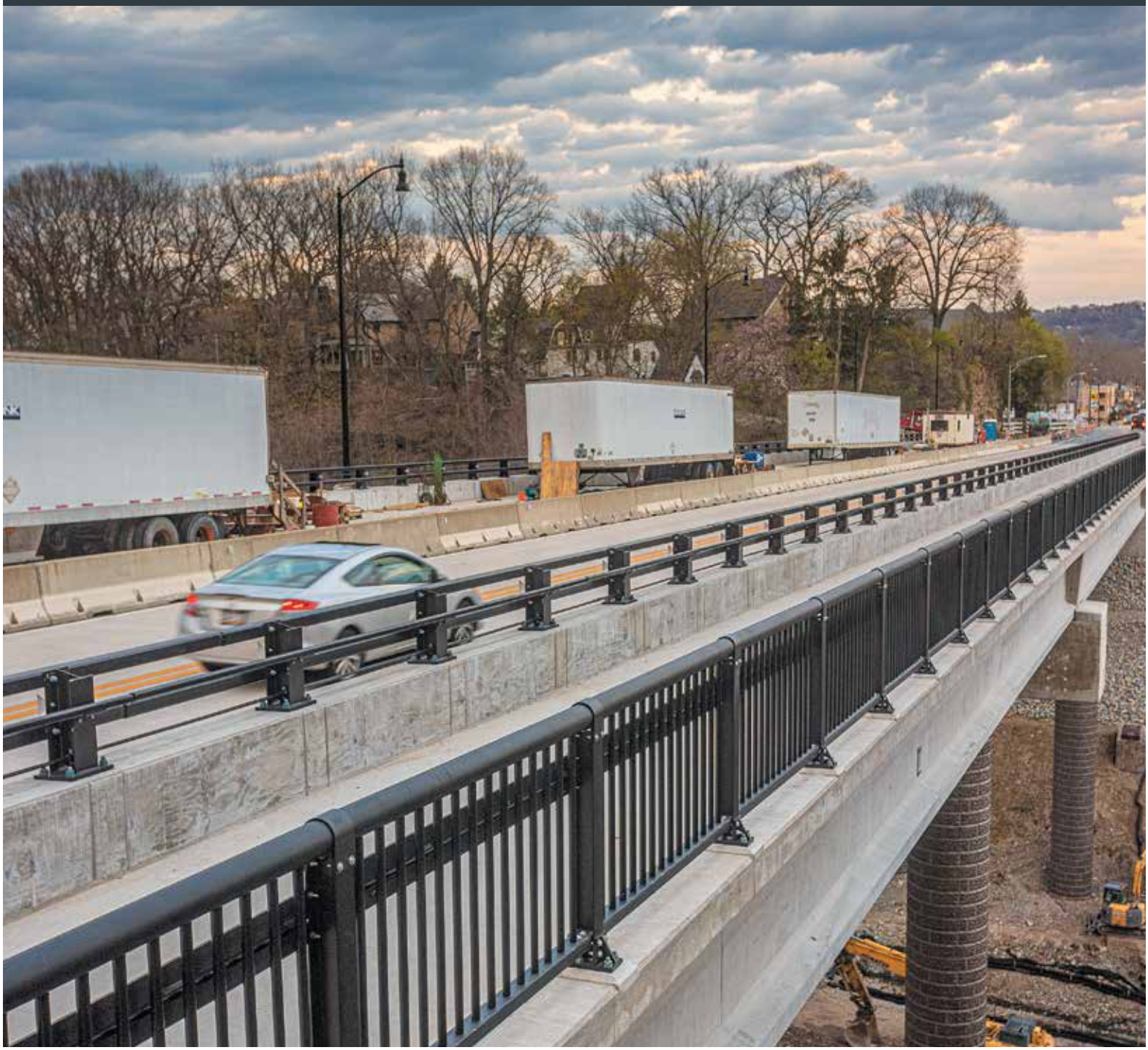
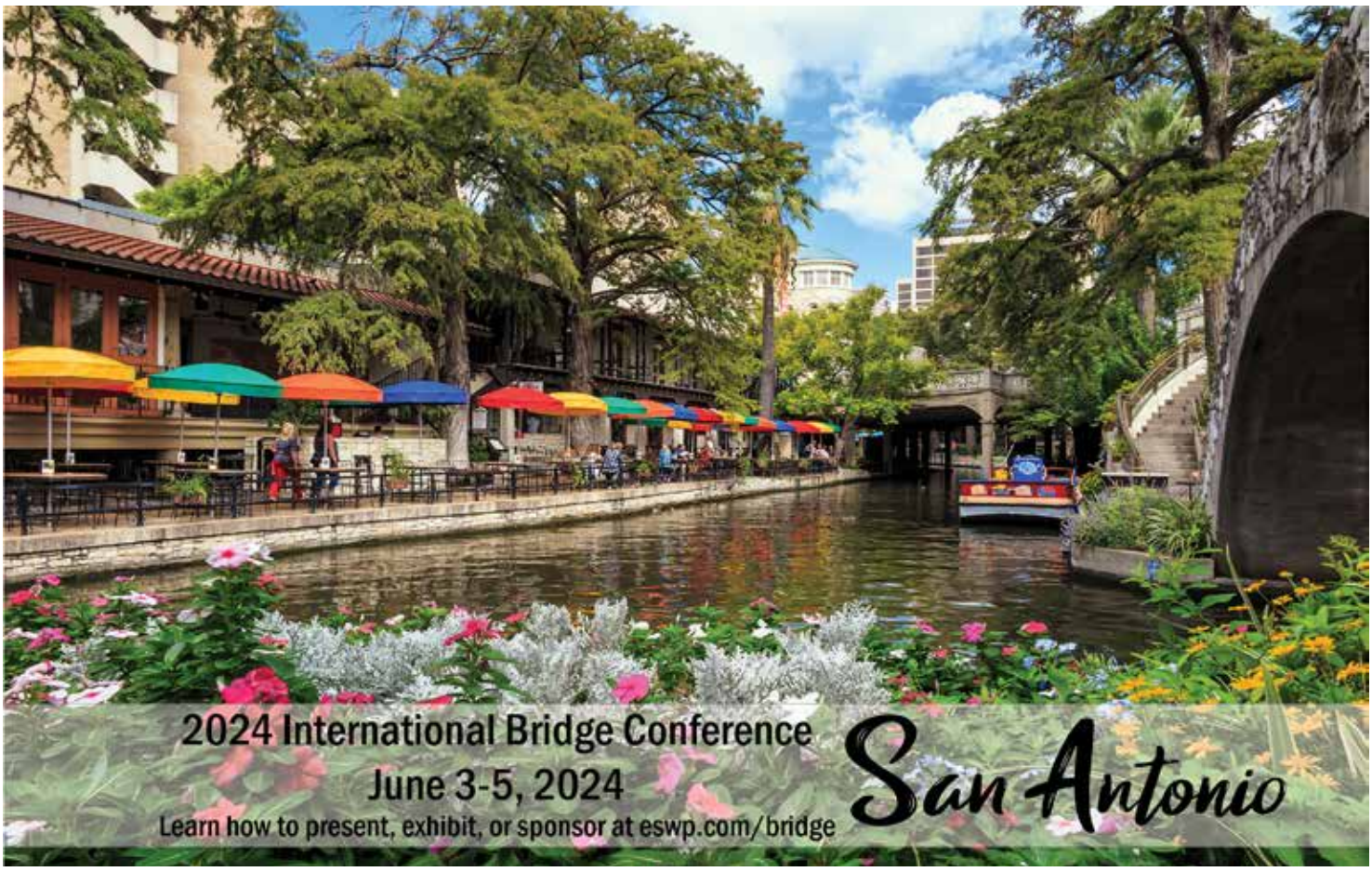
Fern Hollow Bridge Emergency Replacement Project, Pittsburgh, PA

hdrinc.com

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