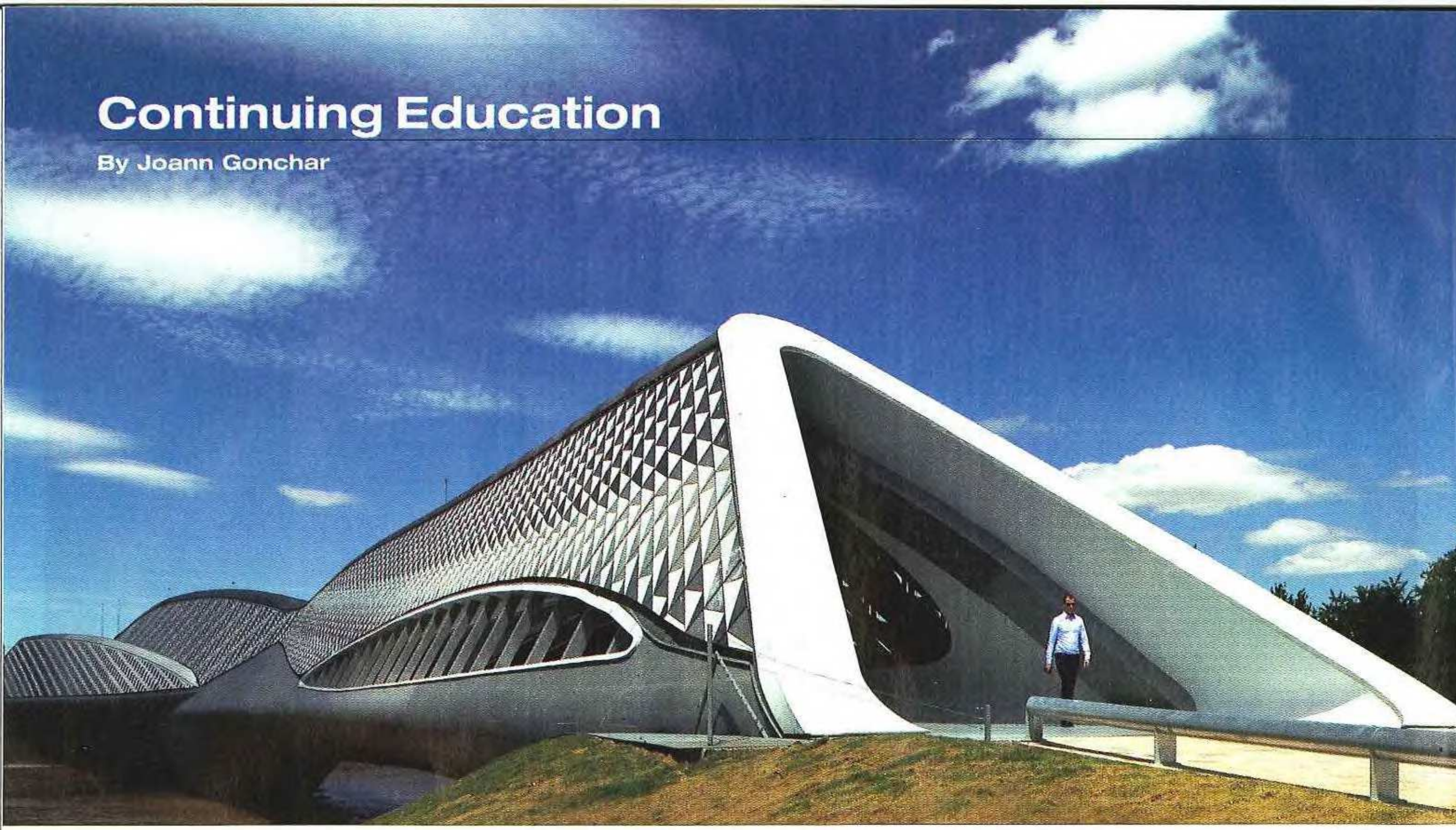
By Joann Gonchar



Not-So-Pedestrian Footbridges

A portfolio of projects demonstrates that there is more to creating signature spans than connecting point A to point B

At least on the surface, few design problems could be as straightforward as that for pedestrian bridges: The main objective is simply to provide passage for people on foot over relatively small obstacles, such as streams, narrow rivers or dangerous roadways. But architects and engineers who work on such bridges say that the most ambitious projects are rarely solely focused on moving people from point A to point B, and that well-designed pedestrian spans become destinations in and of themselves, as well as gathering places and vantage points from which to take in the surroundings.

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LEARNING OBJECTIVES

After reading this article, you should be able to:

1. *Discuss the design objectives for the four pedestrian bridges presented in this article.*
2. *Describe the structural components of each example.*
3. *Explain the fabrication and construction methods deployed.*

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Such were the goals for the combination bridge and building designed by Zaha Hadid Architects that served as the entry pavilion to this past summer's Zaragoza Expo, in Zaragoza, Spain. The London-based firm was selected through a competition in mid-2005 and proposed a more than 900-ft-long, curvaceous structure, providing both exhibition space and a pedestrian crossing over the Ebro River. The organic and flowing geometry was not a formal response to the client's competition brief, insists Manuela Gatto, project architect. Instead, its configuration is "contextual," she says. "It is intended to provide multiple ways to appreciate the river."

The steel bridge spans the Ebro in two sections—one that is about 400 ft long, and another approximately 500 ft long, separated by an island. The shorter section, on the river's north bank, is made up of three triangular tube trusses, or "pods," that merge into one toward the opposite bank. Each is a truss that includes a hexagonal box beam at its crown serving as a top chord, and a ship-hull-like

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deck structure of steel plate serving as the bottom chord. Between the two are parallel ribs connected by orthogonal diagonal members. These "diagrids" resist shear forces and form the substructure for glass-reinforced-concrete facade panels. "It is an interpretation of a traditional timber-covered bridge," says Kevin Acosta, a civil engineer with Arup, which provided all engineering services on the project.

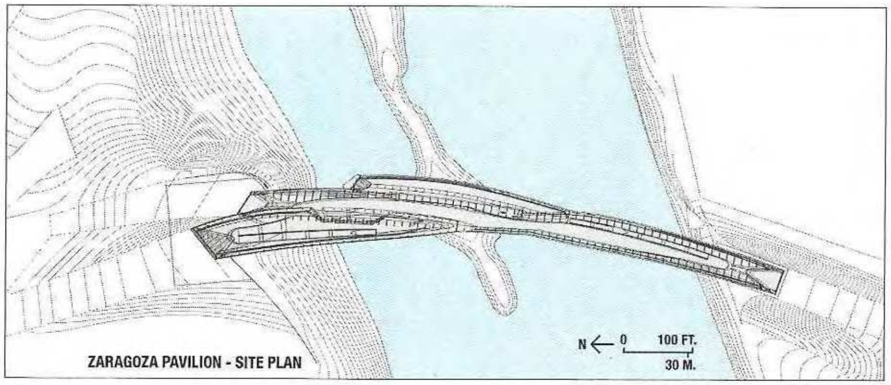
The pavilion's hybrid nature added a level of difficulty to the geometrically complex project. For example, it needed to be designed to deflect less under gravity and lateral loads than a typical bridge would. And it included other elements atypical for bridges, such as fireproofing, interior finishes and mechanical systems. Finding the best places to locate service corridors within the structure for lighting, air-conditioning, and other systems was especially challenging, says Acosta. "These openings reduce the stiffness of the structure and most times require reinforcement around them, adding to the construction complications."

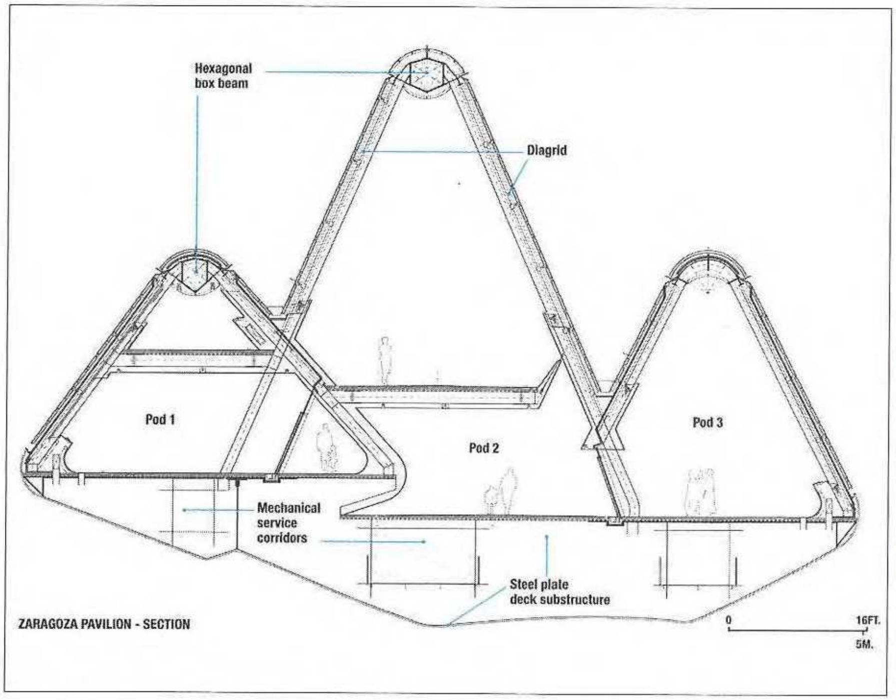
Contractors started foundation work in early 2006, extending piles more than 230 ft deep, because of the poor bearing capacity of the karstic ground below the pavilion. The steel superstructure components, begun about a year later, were fabricated in Spain's Basque region, in sections as large as road transportation limits would allow. Even so, on-site assembly and erection was labor intensive. "The asymmetric structure was a challenge to put in place," says Gatto.

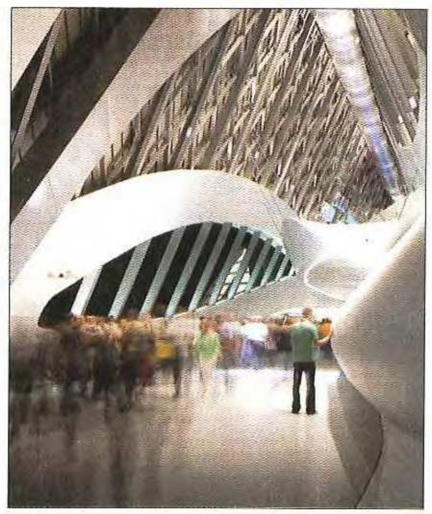
For the shorter span, contractors temporarily filled in the river between the island and the north bank, erecting the components on falsework. The second span, which weighed more than 2,200 tons, was completely assembled on the south bank and painstakingly "launched" into position on cables over about two months in late 2007. After structural completion the following January, contractors raced to complete installation of cladding, mechanical systems, and finishes just in time for the June 2008 expo opening.

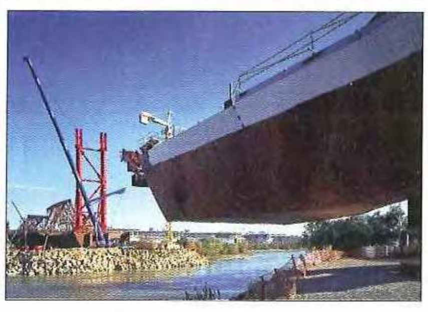
Landmark in the Landscape

Most pedestrian bridges are not as programmatically complex or as geometrically idiosyncratic as Hadid's pavilion. But many share the Zaragoza project's contextual goals. "Bridges should be particular



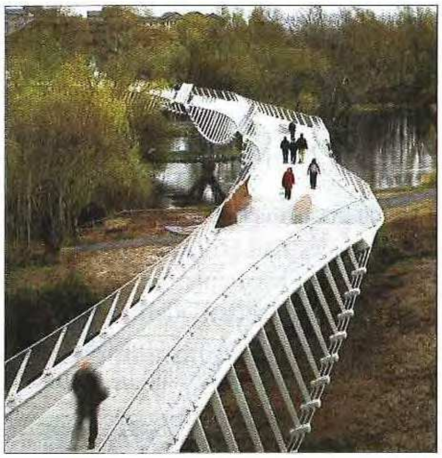




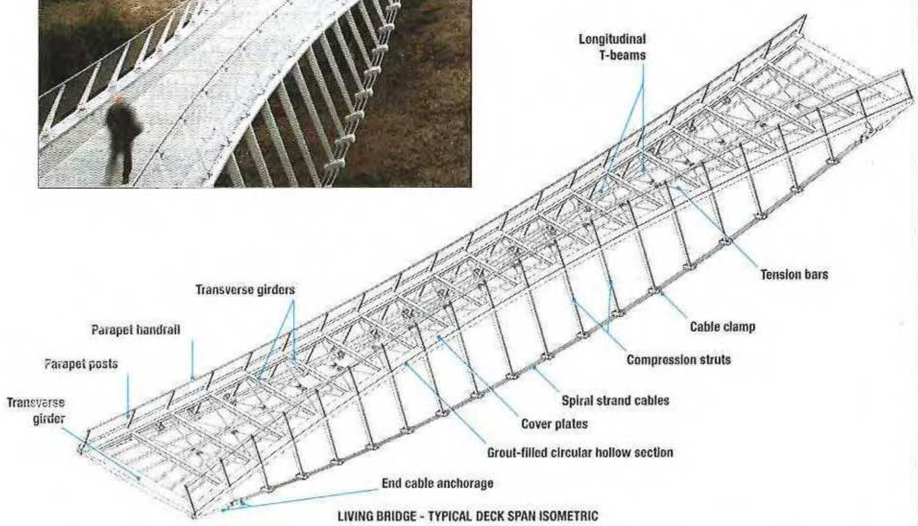


Zaha Hadid's Zaragoza Pavilion provided exhibition space and a pedestrian route (above left) over the Ebro River. It consists of three triangular tube trusses (above), or "pods," that merge into one (top). A 2,200-ton section of the bridge was assembled on land and launched into place over the river with cables (right).

PHOTOGRAPHY (TOP TO BOTTOM): LUKE HAYES; ROLAND HALBE



The Living Bridge crosses the River Shannon and connects two parts of the Limerick University campus. Its six identical spans are supported by below-deck edge-cable trusses (above). Each segment of the C-shaped crossing widens at pier locations, creating a pulsing rhythm over the river (left).

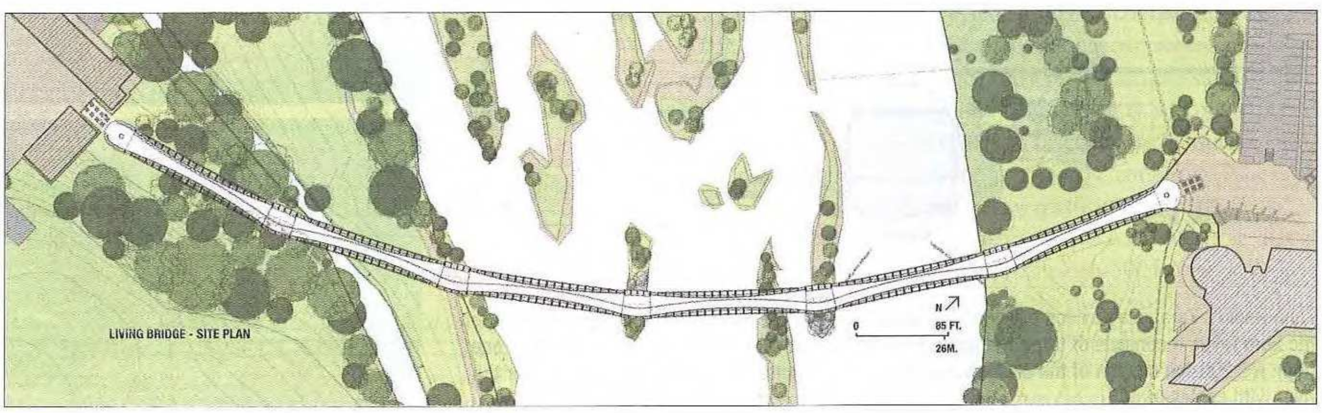


to their place," says Keith Brownlie, a director of Wilkinson Eyre Architects. The London-based firm has designed a number of pedestrian bridges, including one it completed in late 2007 called "the Living Bridge." It crosses Ireland's River Shannon and connects two parts of the Limerick University campus.

The $15.4-million bridge, C-shaped in plan, comprises a string of six independent and identical, 144-ft-long spans. The decks widen from 5 ft at midspan to 10 ft at the five supporting piers, each of which emerge from a naturally occurring island. "It is like a snake that has swallowed several ostrich eggs," says Brownlie.

The configuration provides multiple vantage points for viewing the surrounding riparian landscape and serves as a gathering place for students, says the architect. If the goal were simply to transport people from one side of the river to the other as quickly as possible, the bridge would not have a curved plan, which makes it longer, and arguably more expensive, points out Conor Lavery, an associate director in Dublin for Arup, the project's structural engineer.

For pedestrians, according to Brownlie, the experience of traveling between the islands is like traversing a clapper bridge—a primitive type of river or stream crossing constructed by placing large slabs of rock across stone piers. But the structure of the Living Bridge is much different from that of its ancient counterpart. The primary load-bearing system for the Wilkinson Eyre bridge is a pair of inclined edge-cable trusses below each span. The truss has a top compression member at deck level,



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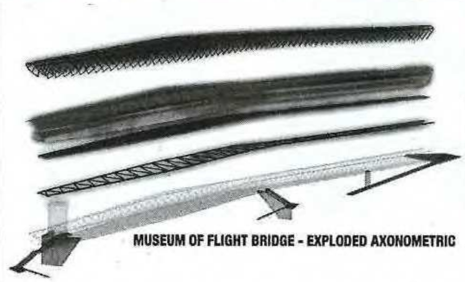

The main span of the pedestrian bridge at Seattle's Museum of Flight is made of pipe bent into pure circles but has an elliptical section (top). Fabricators completed assembly in Tacoma (right) and transported it to the site in one piece.

consisting of a grout-filled circular hollow section, and a tensile lower chord of three spiral strand cables. Steel compression struts, 7 ft on center, transfer the loads applied to the deck to the lower chord.

The "underflung" cable, as Brownlie refers to the below-deck structure, allows unimpeded views of the surrounding landscape. Use of the unusual system, with the bottom of the truss only 14 ft above the surface of the water, was possible only because this section of the Shannon is not navigable and has a dam upstream. Therefore, the designers did not need to worry about the clearance necessary for boat traffic or potential damage to the structure from flooding.

Because the river provides habitat for fish and other wildlife, the project team planned the construction to limit site disturbance. The steel components were fabricated in France and transported in modules to Limerick. Crews assembled the spans in two compounds on the river's banks that were not considered ecologically sensitive. The in-river work, such as the construction of piles and the erection of spans, was performed in only two and a half months from a temporary bridge built on gabions. "It is a tall task to push a civil-engineering structure through a natural landscape, but we came up with a minimal-impact solution," says Brownlie.

Seattle Span

Although they were working in an urban environment rather than a fragile natural landscape, project team members for a recently completed pedestrian span in an industrial section of Seattle also were concerned about the disruption associated with construction. Their scheme for installing the bridge connecting the Museum of Flight's main campus with an extension involved closing a busy roadway below the new crossing for only a day.

The accomplishment is all the more noteworthy given the $6.4-million bridge's unusual design, which was inspired by the stream of crystallized vapor created in the wake of a jet, known as a contrail. "We wanted an icon that captured the spirit of flight," says architect Rick Zieve, FAIA, who is a principal in the local office of SRG Partnership.

The bridge's primary span is a 200-ft-long tube truss, about 17 ft in diameter, tapering to about 12 ft at the ends. SRG originally hoped to construct the truss from pipe sections bent into ellipses. But working with structural engineer Magnusson Klemencic Associates (MKA), Seattle, and fabricator Jesse Engineering, Tacoma, Wash., the architect came up with a more cost-effective and constructible alternative design: The webs are made up of two sets of 5-in.-dia. pipes bent into pure circles. These bent elements, which total more than 300 pieces, all with unique profiles,

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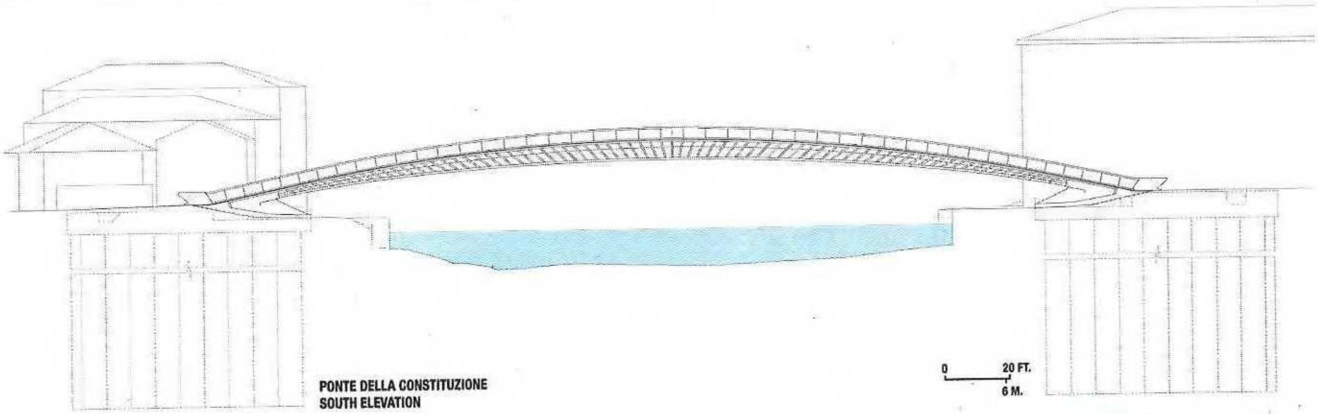

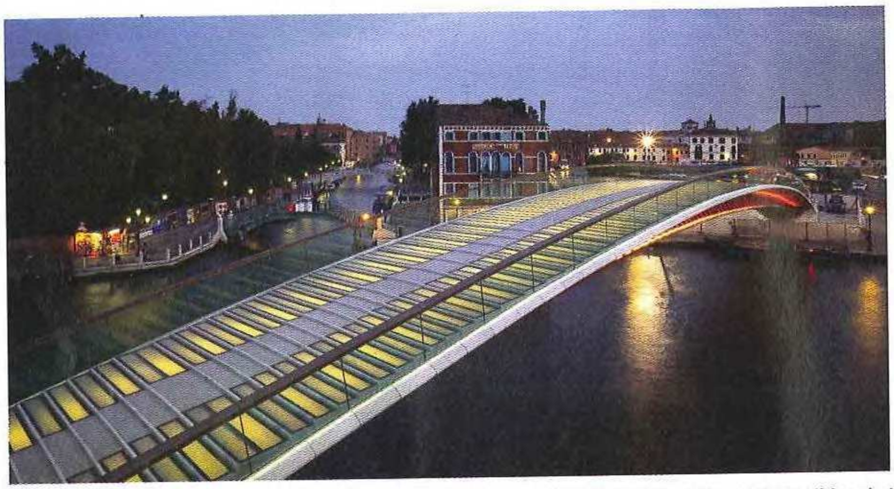

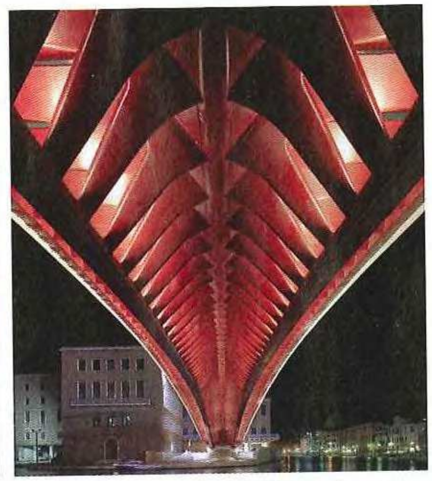

Santiago Calatrava's Ponte della Constituzione in Venice is an interpretation of the city's traditional stone arched bridges in modern materials. It has a sculptural steel skeleton (right) and a glass deck (above) that becomes a carpet of light at night.

are inclined in opposite directions so that they overlap. Set inside the hooped exterior elements are four straight, 10-in.-dia. pipes serving as top and bottom chords. This crisscrossing gives the bridge an elliptical section even though its individual elements have a more simple geometry. The configuration reinforces the flight metaphor and creates the illusion that the bridge is floating, says Zieve.

In general, individual truss components can be smaller and the overall structure lighter if the top and bottom chords are farther apart, explains Jay Taylor, MKA principal. But at the Museum of Flight, the bridge depth was limited by the need for adequate clearance from overhead high-voltage lines and the roadway below. Finding that "sweet spot" between component size and depth was challenging, he says.

The utilities also complicated installation. Jesse fabricated the main span in Tacoma, along with a less complex, 165-ft-long, trapezoid-shaped section. Crews transported the two fully assembled pieces to the site primarily by barge and then a short distance by truck, carefully lifting them into place under the powerlines by crane in only a few hours. "It was like threading a needle," says Zieve.

Contextual Crossing

Architect-engineer Santiago Calatrava deployed a similar strategy for the fabrication and installation of his Ponte della Constituzione completed last fall in Venice. The 266-ft-long span crosses the Grand Canal and connects the city's railway station with the Piazzale Roma. It was fabricated in three pieces in nearby Marghera and brought to the city by barge. Structurally, however, Calatrava's design is very different from the Museum of Flight bridge, crossing the canal with a shallow arch. The 266-ft-long span extends from stone-clad reinforced-concrete abutments and consists of a gently curved steel tube that defines the bridge's central spine and serves as the main torsion-resisting component. This central component is tied via a sculptural steel skeleton painted a bold red to an upper and lower pair of arched chords.

The bridge widens from about 18 ft where it meets the Canal quays to 20 ft at midspan, creating a platform for taking in the sites of the city, explains Calatrava. The crossing becomes especially dramatic at night, when the laminated-glass deck is illuminated from below, transforming it into "a carpet of light," he says.

The project has been plagued by controversy surrounding its reported $15.5-million price tag, construction delays and other issues. Nevertheless, it is a graceful interpretation of an ancient typology indigenous to Venice in the modern materials of steel and glass. "The city has more than 400 bridges, almost all of them arches," says Calatrava. "There was no reason to do anything differently." ■

AIA/ENGINEERING NEWS-RECORD CONTINUING EDUCATION

INSTRUCTIONS

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- **Complete the questions below, then fill in your answers on the next page.**
- **Fill out and submit the AIA/CES education reporting form or take the test online at continuingeducation.construction.com/ to receive one AIA learning unit.**

QUESTIONS

1. The Zaragoza Pavilion is an interpretation of which?
- **a.** ☐ the contrail of a jet
- **b.** ☐ traditional covered bridges
- **c.** ☐ ancient clapper bridges
- **d.** ☐ the arched bridges of Venice

2. The design for the Zaragoza Pavilion included which elements atypical for bridges?
- **a.** ☐ low limits for deflection
- **b.** ☐ fireproofing
- **c.** ☐ air-conditioning
- **d.** ☐ all of the above

3. The earth below the Zaragoza Pavilion is which type?
- **a.** ☐ sand
- **b.** ☐ clay
- **c.** ☐ karst
- **d.** ☐ silt

4. Which of the following is true regarding the Zaragoza Pavilion?
- **a.** ☐ its design was intended as a formal response to the competition brief
- **b.** ☐ it is described by its architect as a snake that has swallowed several ostrich eggs
- **c.** ☐ it has a below-deck structure of parallel ribs connected by orthogonal members
- **d.** ☐ it is intended to provide multiple ways to enjoy the river

5. All of the following are true regarding the Living Bridge edge-cable trusses except which?
- **a.** ☐ their bottom chords are in compression
- **b.** ☐ their bottom chords are in tension
- **c.** ☐ they permit unobstructed views from the bridge deck
- **d.** ☐ their below-deck configuration was possible because the river is not prone to flooding

6. In order to construct the Living Bridge, workers did which?
- **a.** ☐ filled in the river between islands
- **b.** ☐ built a temporary bridge on gabions
- **c.** ☐ launched the individual spans into place with cables
- **d.** ☐ none of the above

7. Assembly of the Museum of Flight bridge took place mostly where?
- **a.** ☐ in a parking lot near the site
- **b.** ☐ in a fabrication shop
- **c.** ☐ on falsework over the roadway
- **d.** ☐ none of the above

8. All of the following are true regarding the Museum of Flight bridge except which?
- **a.** ☐ the bridge has an elliptical section
- **b.** ☐ truss webs are made of pipe bent into pure circles
- **c.** ☐ truss webs are made of pipe bent into ellipses
- **d.** ☐ truss chords are made of straight sections of pipe

9. Which of the following would have allowed designers to make individual components of the Museum of Flight Bridge smaller?
- **a.** ☐ increasing the distance between the truss top and bottom chords
- **b.** ☐ decreasing the distance between the truss top and bottom chords
- **c.** ☐ increasing the width of the bridge deck
- **d.** ☐ decreasing the width of the bridge deck

10. The shallow, gently curved steel tube that runs down the spine of the Ponte della Constituzione serves as which?
- **a.** ☐ the main torsion-resisting component
- **b.** ☐ the main gravity-load-resisting component
- **c.** ☐ the main lateral-load-resisting component
- **d.** ☐ the main shear-resisting component

Program title: "Not-So-Pedestrian Footbridges,"Engineering News-Record (3/30/09, page 54). 049ENR01

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