

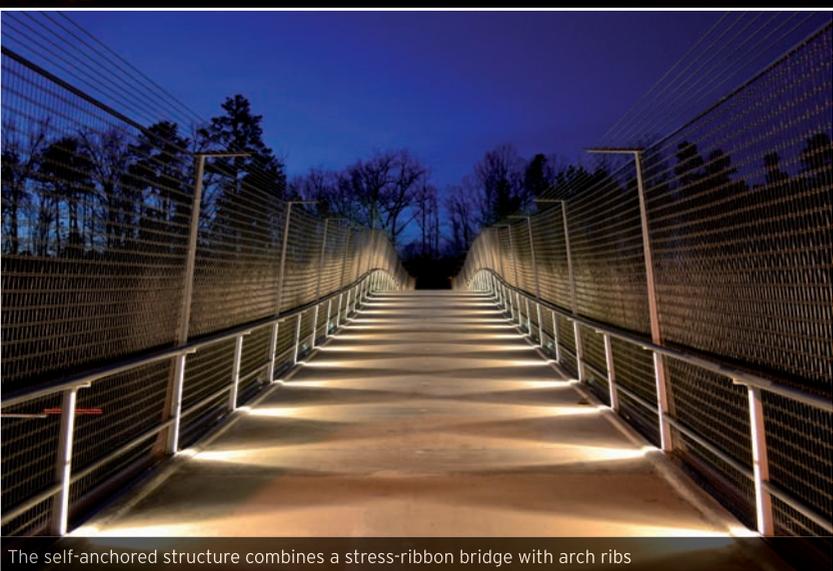
# RIBBON ROUTE

A new hybrid stress-ribbon pedestrian bridge in North Carolina is the longest span of its kind in North America, connecting two sections of a rails-to-trails project. **Tim Hayes** and **Joe Tse** explain the challenges of design and construction on this signature bridge

In order to connect two sections of a 35km-long rails-to-trails project, the City of Durham, North Carolina needed a pedestrian bridge that would provide safe, pleasant passage over the Interstate 40 highway. Pedestrians and cyclists were using a standard highway bridge which was not pedestrian-friendly to cross the road.

The new crossing was intended to be the centrepiece of an important community effort, so when City of Durham officials engaged Parsons Brinckerhoff as primary engineer for the American Tobacco Trail project, they insisted on a signature bridge design. The result is one of only two hybrid stressed ribbon pedestrian bridges in the USA; with its span of 64m between arch supports, it is also the longest of its kind in North America, and has created the longest rails-to-trails trail in North Carolina.

Parsons Brinckerhoff was responsible for planning, design, construction management and construction inspection of the trail, including the bridge, and worked with architect Steven Grover & Associates proposing several



The self-anchored structure combines a stress-ribbon bridge with arch ribs

alternatives, including the design chosen by the city.

The majority of the trail follows an abandoned railway route once used by the American Tobacco Company, which dominated the US tobacco industry in the late 19th and early 20th centuries and was headquartered in Durham through the 1980s. Other than construction of box culvert crossings over streams and wetlands, trail construction was fairly straightforward. It was the US\$5.5 million bridge - adjacent to The Streets at Southpoint Mall, a movie theatre, and other public amenities - that demanded the lion's share of attention.

The American Tobacco Trail Bridge is a self-anchored structure that combines a concrete stress ribbon deck with 760mm-diameter steel arch ribs. The anchorages - or abutments - and the deck near the mid-span are cast-in-place, while the main bridge consists of precast deck panels. Post-tensioning tendons extend from anchorage to anchorage.

The addition of the arch ribs and foundation struts eliminated the need for large horizontal forces at the abutments, the main drawback of a traditional stressed ribbon bridge. The two arches are 64m long, clearing the width of I-40 without the need for intermediate supports. The total

length of the stress ribbon deck is 82m.

The design called for the use of 12 post-tensioned tendons to support the concrete bridge deck, which created an opportunity to build a remarkably thin deck that was only 220mm thick and could still support the pedestrian and bicycle traffic.

Creating a signature structure offered an exciting opportunity, but in such situations it is not always easy to find a construction partner. The bridge design was so unusual there was some initial difficulty attracting bidders. While there are similar bridges around the world, this type of bridge had not been constructed locally before.

Prior to submission of the bids, Parsons Brinckerhoff worked with the city and the prospective bidders to resolve constructability questions. Many alternative construction sequences were explored, but ultimately it was agreed that lifting the bridge over I-40 during a seven-hour night-time closure was the preferred option.

The design team conferred with potential bidders and explored opportunities to reduce costs and enhance constructability based on the bidders' means and method without compromising the design. This interaction extended to construction details that would ensure success in lifting the structure into place during the seven-hour closure.

The dialogue helped all parties understand the constraints the contract documents placed on the contractor and why those constraints were necessary. This collaborative approach resulted in a bid from Blythe Construction that was within an acceptable range of the engineer's estimate and did not require any design compromises.

Although the final structure is self-anchoring, the need to keep I-40 open to traffic, except for very limited lane closures, meant that the arches had to be designed to function as a stable, load-carrying system before the stressed ribbon deck was erected. This was important in order to transform the arch system into the final self-anchored hybrid structure.

Among alternative foundation options that were considered, including choices of driven piles, the notable horizontal forces associated with the chosen construction sequence were found to be most effectively resisted by drilled shafts, which offered sufficient lateral capacity while providing vertical resistance.

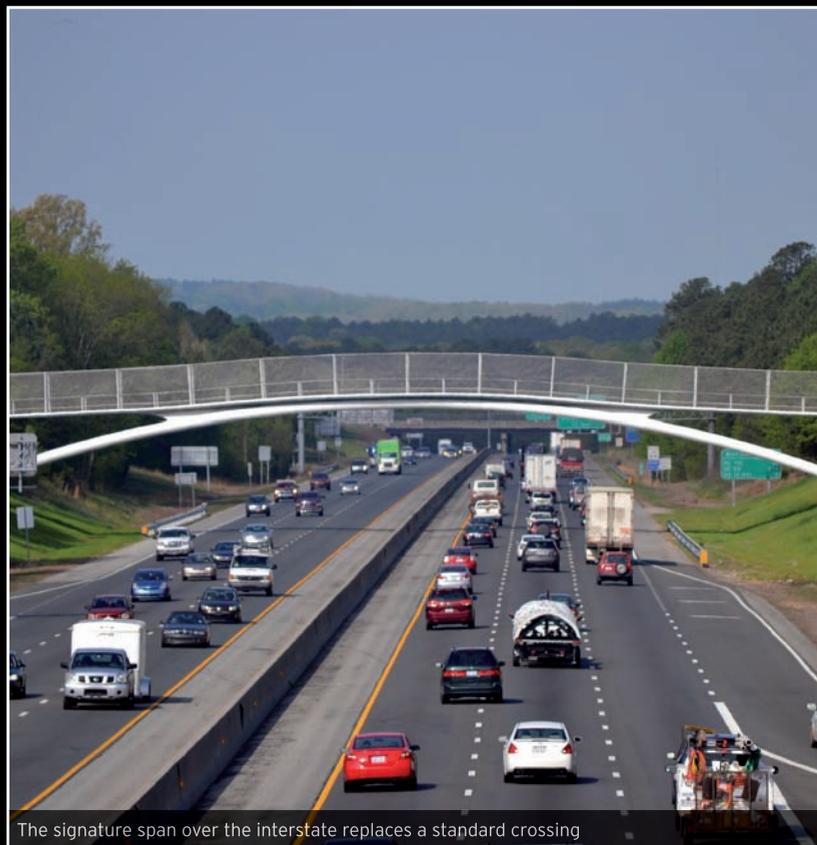
Two 1067mm-diameter shafts were used at the base of the arches, while two 600mm-diameter shafts were used as tie-down elements beneath the abutments. Vertical post-tensioning was used at each of the 600mm-diameter anchorage drilled shafts to ensure durability by maintaining compression in the concrete against uplift forces.

A geotechnical investigation indicated that the top 6m of soil at the locations of the drilled piers is a mixture of clay and sand. Beneath the mixture is weathered rock to a depth of approximately 15m.

During the design phase, a parametric study was carried out to determine the sensitivity of the structure against a reasonable range of soil stiffness in order to rule out changes to the principal features and proportions of the structure caused by potential variability in the soil conditions.

Meanwhile, plans were made to perform an on-site test of the soil stiffness against the values assumed in the design, and also to perform soil improvements if required to increase lateral stiffness of the soil around the drilled shafts.

The parametric study was conducted using computer models that included multi-linear soil springs. On-site testing results determined that the stiffness of the soil fell comfortably within the range that was considered in the design, and therefore neither design modification nor soil improvement



The signature span over the interstate replaces a standard crossing

was necessary. The field testing was simple and involved only basic instrumentation to determine loads versus displacements while pulling two of the permanent drilled shafts towards each other by means of a high-strength bar tendon.

The dynamic response of the bridge and associated pedestrian comfort were assessed using time-history analyses. Acceleration at various locations on the structure, including the centre of the stressed ribbon, was calculated by analysing groups of joggers crossing the bridge at the same time, as well as by air pressure from trucks passing underneath the bridge.

The arch ribs were fabricated in sections. Parsons Brinckerhoff worked closely with the contractor and fabricator to establish the procedure for forming and testing the steel pipes.

To start the fabrication process, 2.5m to 3m pipe sections were hot-formed out of steel plates. The 64m-long arch ribs were fabricated by welding the pipe sections together. The pipes were cold bent to a specified shape reflecting the final geometry of the ribs plus computed structural cambers. For structural performance and aesthetic considerations, the weld seams were positioned so that they were toward the inside of the bridge and on the outer edge of the bent radius.

The bridge opened to pedestrian traffic earlier this year; almost immediately, it was a hit with the community, and use has exceeded expectations. The first weekend it was open, there was so much pedestrian traffic that cyclists had to walk their bikes across the bridge

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