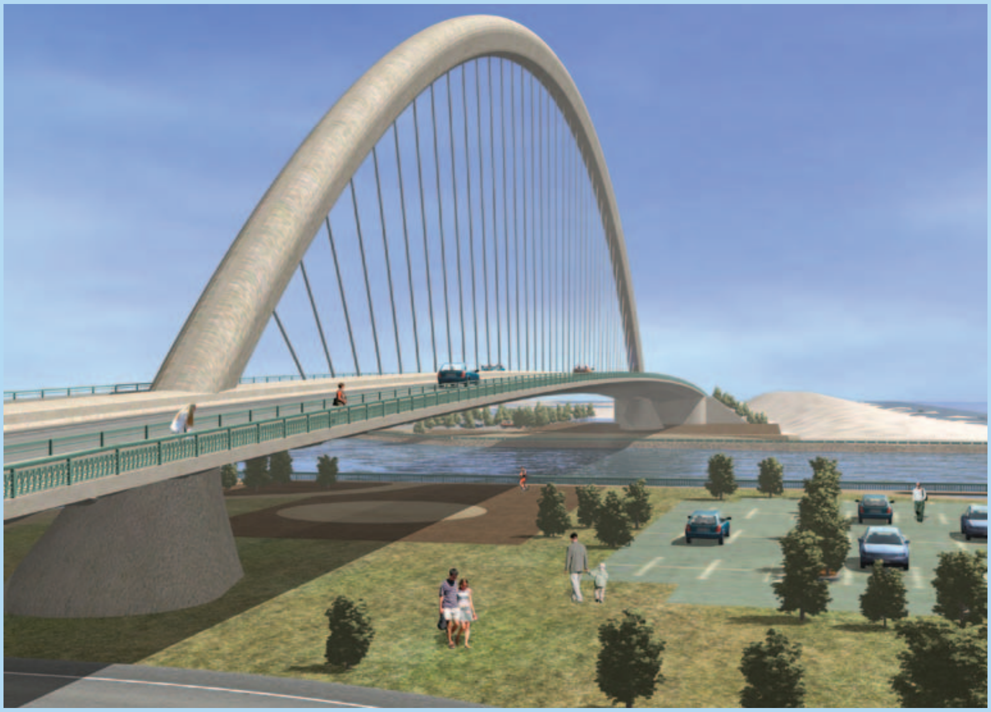
Indian River Inlet Bridge



A Community's Vision in Harmony with Nature

By: Dennis O'Shea, P.E., Delaware DOT
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With extensive community input, involving two design charettes and four public workshops, along with a community bridge design unveiling, the residents of southern Delaware, working with Delaware Department of Transportation and FIGG Engineering Group, have created a unique bridge for the 21st Century.

By empowering the citizens of Sussex County, Delaware, the Delaware Department of Transportation fostered the creation of a unique structure that will rise from the dunes surrounding the Indian River Inlet. The simple goal was to span the Inlet, carrying vehicles and pedestrians with no piers in the water. The Delaware Department of Transportation

"...the first major highway bridge of its type..."

(DelDOT), under the leadership of Nathan Hayward III, Secretary, challenged the design team to a larger vision – to replace the bridge with a world-class structure that would be embraced by the local community and the crowds of summer visitors that enjoy the Delaware State Seashore Park, which surrounds the bridge. The preferred design, believed to be the first major highway bridge of its type, was unveiled to the public at the bridge site on August 20. It received overwhelming community acceptance from the group, totaling over 500 local residents.

Background

The Indian River Inlet Bridge carries Delaware State Route (SR) 1 over the Indian River Inlet, providing a vital north-south link along the eastern seaboard of the United States. The actual location of the Indian River Inlet has moved along the coast over time. Placement of jetties that extend out into the Atlantic Ocean, and use of a sand distribution system that moves sand from south of the inlet to north of the inlet, secured the current location. In 1965, when the northbound superstructure (southbound superstructure completed in 1976) and entire substructure of the existing bridge was built, the Inlet was approximately 28-feet deep at the center and 23-feet at the piers.

"...continued scouring or erosion of the streambed."

Over the years, the Army Corps of Engineers has monitored the condition of the Inlet, for which they have jurisdiction. Regular fathometer surveys, measuring water depths of the inlet, have documented the continued scouring or erosion of the streambed. In the late 1980's, the scour had exposed the bridge's support piles. In 1989, at a cost exceeding the construction value of the second structure, DelDOT placed very large riprap, some as large as a Volkswagen, around the base of and between the existing bridge piers to minimize the continuing scour impact. However, scour erosion at the bottom of the Inlet has continued.

A 1999 survey shows the water depth near the piers varies from shallow water to depths exceeding 100', placing the stability of the previously placed riprap in jeopardy. Concerns over severe scour erosion affecting the existing structure led DelDOT to plan for replacement of the existing bridge. It became apparent that the long-term economical approach would be to span the inlet and remove all piers from the water. The solution… a 1,000-foot main span with all piers on land, providing room for possible future expansion of the inlet width to stabilize the inlet, mitigating a hazardous navigation condition, and eliminating the scour concern that plagued the previous bridges at the site.

Everyone Gets a Vote

Shortly after the selection of the design team, the team completed a listening tour, which included interviewing local residents about their concerns and desires for the new bridge. The design team used this information to develop options for the first design charette.

On the afternoon of April 8, 2003 interested local residents were invited to join the design team for a tour of the bridge site, in order to gain a clear understanding of the challenges that would be addressed during the design phase. The following morning, April 9, Secretary Nathan Hayward opened the first community design charette of 60 participants with *"…you're going to embark on what I think is a first ever in Delaware. We're going to deputize all of you who have voter's tags. We're going to turn you into design engineers."*

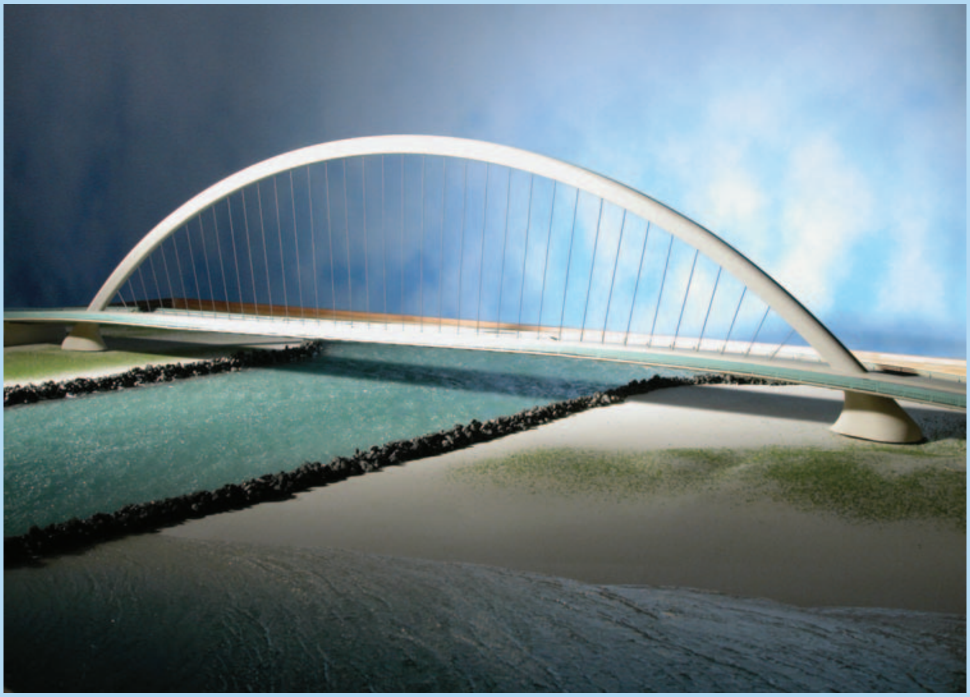
At the first charette, the participants voted as a group that the new bridge be an icon for their communities, and be beautiful. In addition to providing a transportation link, they wanted the bridge to provide pedestrian recreational activities and enhance the beach experience for residents and summer visitors. Various themes had been developed and were presented to the group, including: *Memories of the Beach, Nautical/Celestial Navigation, Diamond State, Harmony with Nature* and a historical theme of *Celebrating the Founding Spirit of Delaware*. Based on consensus voting, the group selected a combined theme of *Harmony with Nature* and *Nautical/Celestial Navigation*.

"Many participants were outspoken…"

From this, the group went on to select two bridge types: a single tower cable stay bridge and a single arch, with minimal feature lighting, necklace lighting on the pedestrian pathway and a partially open barrier traffic rail. Many participants were outspoken and expressed a desire to enhance the beach experiences that so many of the residents and visitors enjoy, especially the fantastic view of the coastline. They wanted simple shapes to provide the interpretation of the selected theme, as opposed to ornamentation, on the bridge structure.

"…the ability to fully expose the below deck arch supports."

The design team moved quickly to further develop options and direction based on the participants' selections during the first meeting. On May 7, a similar sized group met to solidify major bridge features. They finalized the structure type and voted for the single arch with a single plane of radial stays, open back spans, a tulip shape for the arch cross section, muted blue feature lighting, an ornamental pedestrian railing that incorporates natural elements and a surface for the pedestrian pathway that mimics the beach.



The grand, sweeping arch rises from the ocean shoreline dunes. The arch, with its single plane of radial stays, supports a 1000-foot span across the waterway, avoiding the need for piers in the inlet.

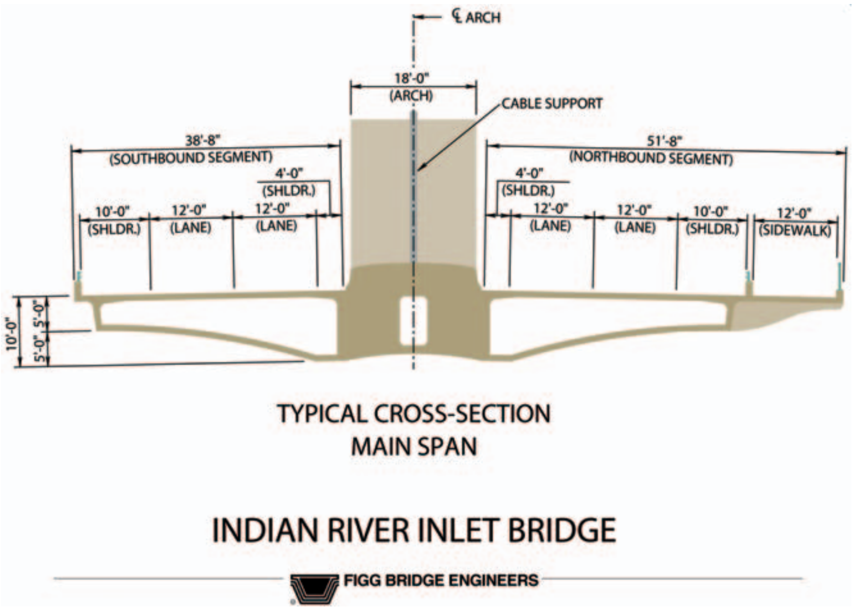
The Bridge Structure

Final design activities for this unique structure are currently underway, and will be carried out principally under the requirements of the AASHTO LRFD code.

The bridge arrangement includes spans of 150' / 1000' / 150'. The inclusion of the 150' open back-spans was a preference of the charette participants. They provide an additional visual openness below the bridge for visitors to the state park, along with the ability to fully expose the below deck arch supports. In addition, they provide for the required access roadway below the bridge to pass not beneath the main span, but rather below the back span, resulting in increased security for the bridge.

The support cables for the arch will be similar to those of cable-stayed bridges. Anchorages will be located in the upper arch and the deck level

"…a torsionally rigid deck system to resist unsymmetrical dead and live loads."



tie beam. Access to the anchorages will be provided through the internal voids of the arch and the tie beam. The use of a fully parallel system of prestressing strands for the cables, along with other details of the cable system, will allow for easy installation, stressing and removal of individual strands of any cable throughout the life of the structure.

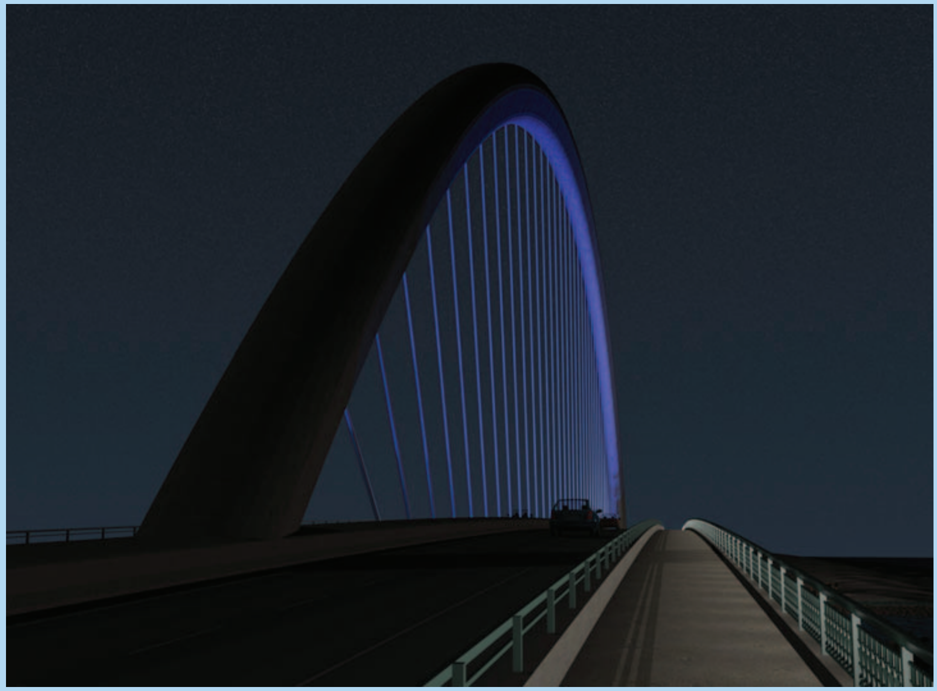
As with all bridges which use a single line of support cables, the roadway requires a torsionally rigid deck system to resist unsymmetrical dead and live loads. The torsionally rigid deck system is similarly important for wind stability of the long main span structure.

The unique cross-section of the bridge deck was selected for consistency with the project's *"Harmony with Nature"* theme. The global bridge deck cross-section consists transversely of a precast southbound box girder, the cast-in-place arch tie beam and the precast northbound box girder. The northbound box girder also includes the additional width for the 12' pedestrian sidewalk located on the east (ocean) side of the structure. The sidewalk extension is supported on transverse ribs extending beyond the web of the box girder.

The precast roadway box girder sections are significantly asymmetrical due to the addition of the pedestrian sidewalk. Therefore, the design will include a small transverse diaphragm in each segment to enhance its dimensional rigidity during the casting and transportation phases. The supports of the sidewalk are extensions of the internal diaphragms.

Global stability of the arch has been carefully considered in selecting overall member sizes. Stability analysis has included consideration of both the influence of geometric displacements (large displacement theory, P-Δ analysis) and non-linear material (loss of member stiffness due to potential cracking of the concrete) behavior. Initial analyses of the arch indicated that potential coupling of these two non-linear effects was undesirable. Therefore, the selected arch dimensions and design criteria are such that cracking level stresses ($7.5\sqrt{f'c}$) are not permitted, even under the factored load combinations.

Under transverse wind loading, the arch deflects laterally, influencing the orientation of the support cables. As the plane of the cables



At night, the stays of the arch will be softly lit in blue. Glowing against the night sky, the silhouette of the arch will guide mariners to the gateway of the inlet.

becomes non-vertical, they develop horizontal forces that directly oppose the wind loads and assist in stabilizing the arch against further displacement. Even under hurricane wind loads, the lateral displacement of the arch 220' above the deck has been calculated to be less than 20% of the width of the arch cross-section.

Foundations

Another important factor for the long-term performance is the foundation design. The geotechnical aspects of the site consist of about 30 feet of moderately dense sand, overlying approximately 35 feet of soft organic clay founded upon a thick layer of highly dense sand/gravel. Unfortunately, these conditions do not economically permit the use of a true arch, which relies upon lateral resistance from the foundations to counteract the internal arch thrust forces. Therefore, the bridge is designed as a tied arch with the thrust forces captured internal to the structure, allowing the foundations to be isolated from these effects.

"...a tied arch with the thrust forces captured internal to the structure..."

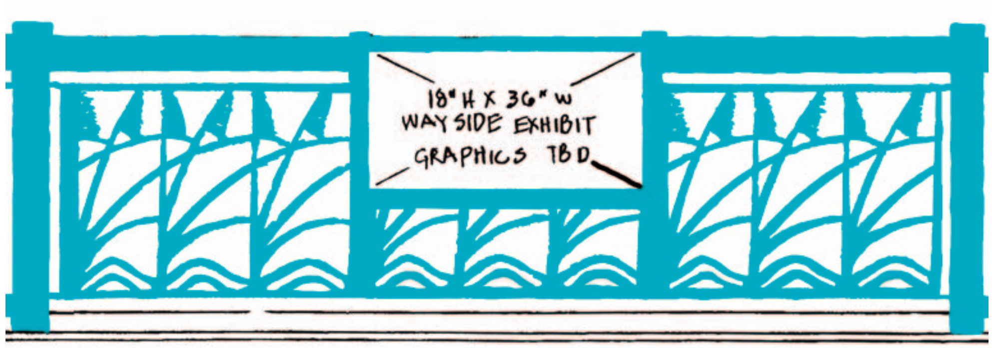
Due to the monolithic structural configuration of the arch, bridge deck and arch base, the arch foundation must move with the superstructure under creep/shrinkage/temperature effects. The foundation movement may reach as much as 6 inches.

Initial foundation studies indicate that drilled shafts are the preferred foundation type, in consideration of both the large loads imposed and to reduce installation noise within the camping and day use areas of the state park. Preliminary foundation design illustrates that approximately 60 drilled shafts of 5' diameter will be required to support each of the arch bases. As a result, the foundations tend to be very stiff in resisting the longitudinal bridge displacements that will occur. It is anticipated that specific foundation mitigation efforts will be incorporated to isolate the drilled shafts from the upper layer of sand and allow for the necessary foundation movements.

Building the Arch

The construction method for the bridge will consist of cast-in-place techniques for the upper arch and the deck level tie beam. The characteristics of the violent water flow within the inlet make it impractical to use barges or false work techniques for construction. The upper arch will be built first using incremental construction, utilizing form travelers and temporary cable stay towers for stability.

After joining the arch at the top, the horizontal tie beam construction will similarly be cast-in-place with a form traveler system, installing the permanent central arch support cables as the tie beam lengthens. Finally, the precast deck sections will be incrementally installed and connected transversally to the tie beam, which supports them from above, under deck mounted cranes. The bridge will be bid in 2004 and construction will require a two-year time frame.



Five storyboards will be positioned along the pedestrian walkway. The custom railing pattern reflects the grasses found in the dunes.

Conclusion

The Indian River Inlet Bridge aesthetic design was created by the Sussex County community through two full day design charettes and multiple public workshops. The community worked closely with bridge engineers to select preferences that will create a one-of-a-kind, world-class bridge. This intimate involvement captured the spirit of the local community. The bridge embraces a distinctive sense of place that will attract visitors to the picturesque views of the Delaware State Seashore State Park and Atlantic Ocean for years to come. The design of such a unique structure has provided for a compilation of design theory and specifications. The slenderness of the proposed structure will require innovation and a blending of techniques used in both cable stay and arch bridge construction.

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