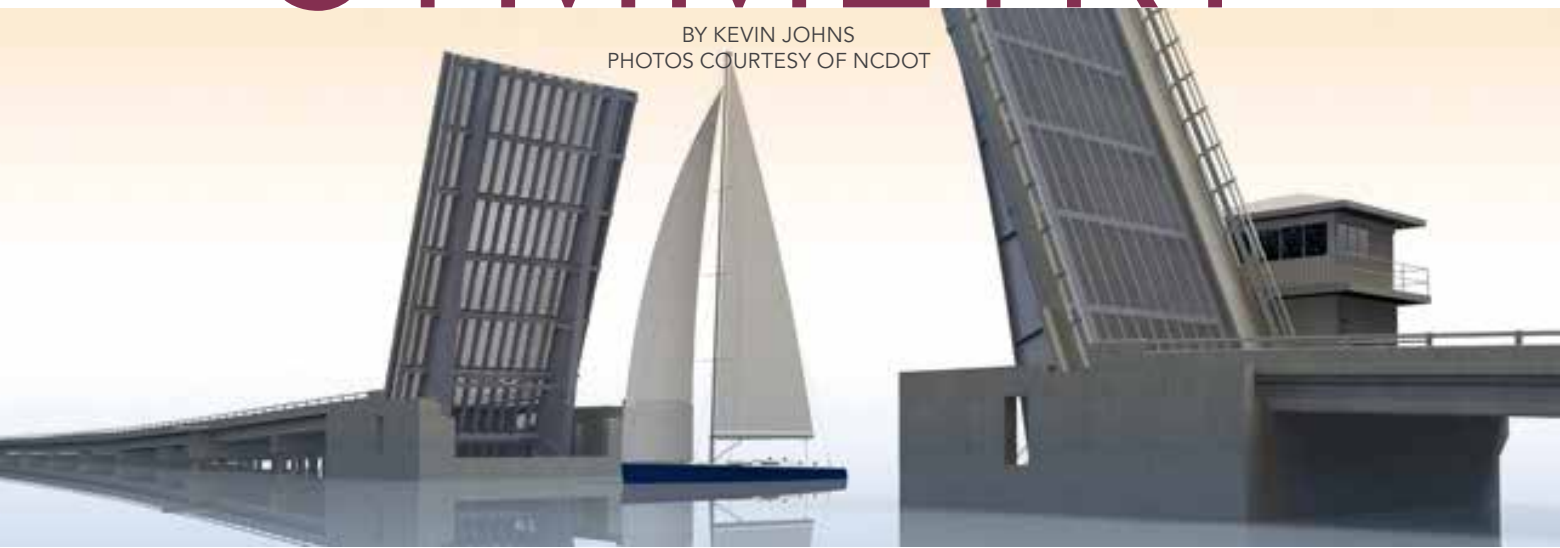


# Steel SYMMETRY

BY KEVIN JOHNS  
PHOTOS COURTESY OF NCDOT



Steel brings balance to an asymmetrical bascule leaf bridge near the mouth of the Pasquotank River in coastal North Carolina.

**ELIZABETH CITY, N.C.**, is a historic seat of transportation.

As far back as the mid-1700s, inspection stations and ferries were established along the town's waterfront a few miles upstream from the mouth of the Pasquotank River. Surrounding communities built canals to more easily ship tobacco and other goods to the town's deep-water port. In 1870, the Elizabeth City and Norfolk Railroad, precursor to the Norfolk Southern Railway, was established and its first operating line opened in 1881.

But like many towns and cities across the country, the infrastructure of Elizabeth City has aged. This includes a steel double-leaf trunnion bascule bridge that carried US 158 over the Pasquotank River through the heart of the city. Built in 1931, this bridge had reached the end of its expected lifespan.



**Kevin Johns**  
([kwjohns@modjeski.com](mailto:kwjohns@modjeski.com))  
is the movable bridge  
business unit director at  
Modjeski and Masters.

## Designs for Replacement

The Pasquotank River Bridge's eastbound span was among the 838 bridges identified by the North Carolina Department of Transportation (NCDOT) to be replaced as part of the North Carolina State Transportation Improvement Program.

The bridge consists of two double-leaf trunnion bascules, one for eastbound traffic and one for westbound traffic. The project included completely replacing both the superstructure and substructure of the older eastbound bridge with 430 ft of approach and a new 146-ft double-leaf trunnion bascule span. The new bridge will accommodate highway, bicycle and pedestrian traffic and include two 12-ft traffic lanes, an 8-ft bicycle lane and a 5-ft, 6-in. pedestrian sidewalk.

Due to parameters connected to the stimulus funds that the project would use, the engineering team was given only eight months to complete the preliminary and final designs. Plans were completed and approved for construction in February 2011, and demolition of the existing structure and construction of the new bridge began in May 2011.

The design had to incorporate several unique features and overcome engineering challenges. The asymmetrical span had to be precisely balanced while reducing overall weight of both the bascule leaves and counterweight. To promote proactive, preventive bridge maintenance, NCDOT requested that all components critical to bridge maintenance be easily accessible. Bridge engineer Modjeski and Masters accomplished this by making all areas of the structure accessible by stairs instead of ladders.

- The new Pasquotank River Bridge will accommodate highway, bicycle and pedestrian traffic and include two 12-ft traffic lanes, an 8-ft bicycle lane and a 5-ft, 6-in. pedestrian sidewalk.

### Balancing the Weight

The Pasquotank River Bridge design included an asymmetrical deck cross section, which created a challenge for the designers. To promote a greener and more pedestrian-accessible Elizabeth City, the new bridge was designed with a sidewalk and bicycle path. But incorporating these features on only one side of the span required careful accounting of the span's weight to achieve proper balance.

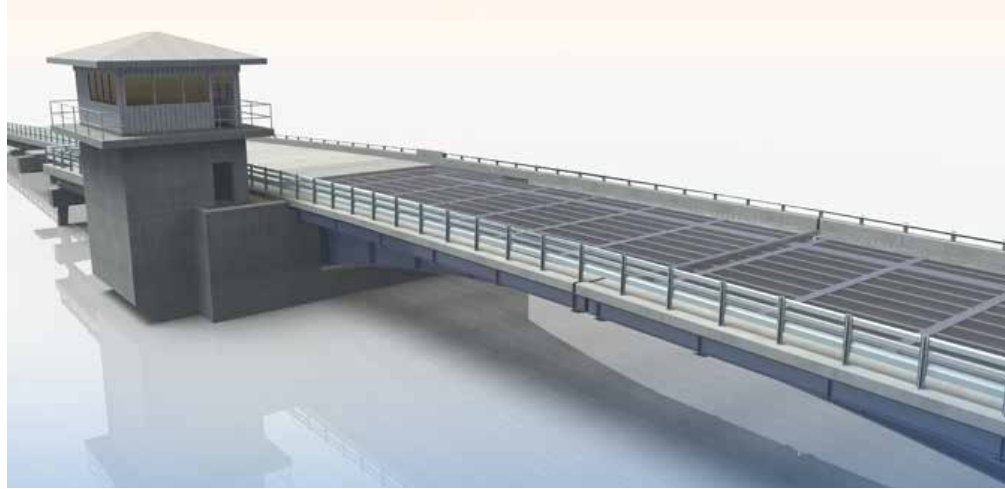
Because the span has an asymmetrical cross section, the transverse center of gravity had to be tracked as well. This required the counterweight to be designed accordingly, which was accomplished by casting voids in it to match the leaf's transverse center of gravity.

To further reduce the leaf's weight, the engineers used an open steel grating deck for the travel and shoulder lanes across as much of the span as possible using AASHTO M270 Grade 50 structural steel fabricated by Prospect Steel.

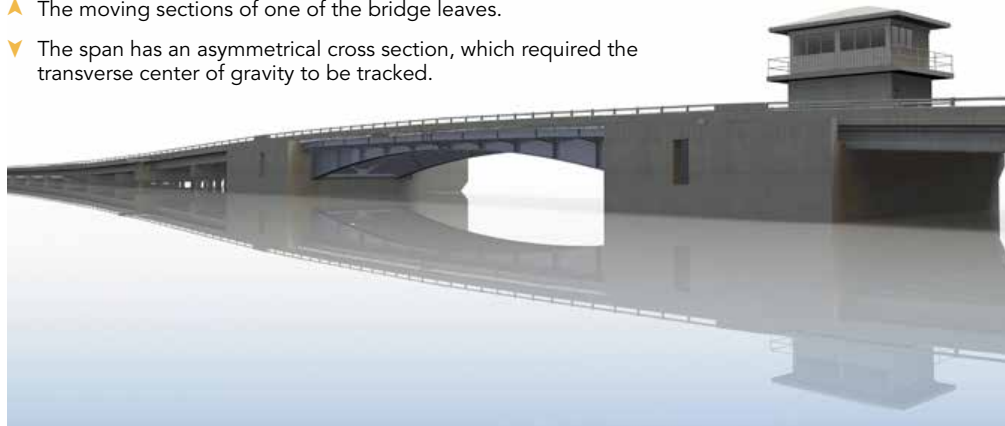
In addition to the weight of the bascule leaf, the designers were tasked with reducing the structure's overall weight. When constructing a bascule span, weight and balance are two critical issues in maintaining functionality. To achieve balance on a bascule span, approximately 3 lb of counterweight is required for every 1 lb of weight in the span, so it is important to keep the span as light as possible. A heavier span would require more expensive operating machinery for opening and closing the bridge and more expensive foundations to support it.

Like all movable bridges, bascule spans require precise balance to ensure mechanical functionality. Counterweight design and balance requires very careful accounting of the bridge's weight, including the weight of welds, bolts and even paint. Each leaf of the span weighs approximately 550 tons and after proper balancing, there will be a positive reaction of only five tons of dead load on each of the live-load bearings. This is done to ensure that the leaf stays closed when in the closed position.

- The new bridge is made up of 430 ft of approach and a new 146-ft double-leaf trunnion bascule span.



- ▲ The moving sections of one of the bridge leaves.
- ▼ The span has an asymmetrical cross section, which required the transverse center of gravity to be tracked.







- ▼ Each counterweight contains around 66 tons of steel ballast and 90 cubic yards of concrete.



- ◀ To achieve balance on a bascule span, approximately 3 lb of counterweight is required for every 1 lb of weight in the span, so it was important to keep the span as light as possible. Each leaf weighs approximately 550 tons.

However, it was also necessary to make sure that the bridge was counterweight heavy so that when it's in the open position, it stays open, and when it rotates through its full range of motion, it stays nearly balanced. This was accomplished by carefully locating the bridge's center of gravity so that it rotates from in front of the trunnion to behind the trunnion when the bridge moves from closed to open. An accurately positioned center of gravity placed less strain on mechanical components, so the bridge wouldn't need to work harder than necessary to open and close.

### A Tight Fit

For construction of the new eastbound bridge, all traffic was shifted to the westbound bridge and the existing eastbound bridge was completely removed.

One of the most challenging aspects of the project was the construction of the new bascule pier, which had only 1-ft clearance from the existing westbound bridge bascule pier. Steel sheet piles were installed to form a cofferdam, then pipe piles were installed in the wet. Next, a tremie seal was placed in the cofferdam to allow for dewatering, which allowed the new reinforced concrete bascule piers to be built in the dry.

The new bridge machinery was placed in the bascule pier and the tail portion of the bascule span was installed. A splice was introduced into the bascule girder so the toe portion could be floated into position later without blocking the navigable channel. Next, the counterweight concrete was poured and the toe portion of the bascule span was installed. The final alignment of the span to the operating machinery was made, at which point the span was fully operational.

Again, each bascule leaf weighs approximately 550 tons. Each counterweight contains around 66 tons of steel ballast and 90 cubic yards of concrete. The weight-saving measures used in the design will reduce overall machinery wear and operating costs of the bridge, allowing for reduced total cost of ownership and long-term maintenance for NCDOT.

### Access and Clearance

Ease of access required careful planning during the design phase. Enough physical space had to be provided in the bascule piers for the stairs without causing interference with the moving bascule spans and counterweights. To accomplish this, the design team created a 3D bridge information model during preliminary de-

- ◀ The bridge's opening ceremony.

sign. This ensured that the stairs did not interfere with bridge functionality or other critical design components.

NCDOT requested that the grade of the new bridge be as close as possible to the existing span. However, the elevation of low steel could not be reduced either. Because the new bridge is significantly wider than the existing one, the new girders have to support considerably more weight, which required them to be deeper. To satisfy deflection criteria, it was necessary to increase the grade by 1 ft to keep low steel at the existing elevation.

### Safety Measures

The American Association of State Highway and Transportation Officials (AASHTO) *Movable Bridge Design Specifications* indicates that movable bridges are required to use traffic gates and barriers to stop vehicular traffic when the bridge is in the open position. In Elizabeth City, traffic on US 158 stops at signalized intersections very close to the bridge. As a result, using both a warning gate and barrier was impractical because of limited space available, and would cause a significant traffic disruption through the intersections.

To meet the necessary requirements, the designers configured the bascule superstructure and piers so that when the bridge is open, the bascule leaves block the roadway, leaving only a 1-ft gap above the bridge deck. This allows the bascule leaf to act as a barrier, preventing vehicles from falling into the water.

To protect the bridge from damage caused by vessel collision, the design team turned to the AASHTO *Guide Specifications for Vessel Collision Design*, which states: “Movable bridge piers which house mechanical equipment or support movable

machinery should be fully protected from vessel contact by aberrant vessel.” Thus, marine fenders were designed to carry the entirety of the vessel collision load. They are able to withstand a head-on vessel collision load of 1,000 tons and a side loading of 500 tons.

### Grand Opening

The new Pasquotank River Bridge opened to the public in May, almost exactly four years from the start of construction. In addition to reducing long-term maintenance costs, the bridge will stimulate economic integration between neighboring Camden, Pasquotank and Perquimans Counties, improve vehicular traffic flow through Elizabeth City and make it easier for marine traffic to navigate the Pasquotank River. ■

### Owner

North Carolina Department of Transportation, Raleigh, N.C.

### General Contractor

Archer Western, Charlotte, N.C.

### Architect

Bowman Murray Hemingway Architects, Wilmington, N.C.

### Structural Engineer

Modjeski and Masters, Mechanicsburg, Pa.

### Steel Team

#### Fabricator

Prospect Steel, Little Rock, Ark. 

#### Detailer

Candraft Detailing, Inc., New Westminster, B.C., Canada 