Canal Crossing

By John E. Christopher, Ph.D., P.E.

Erection challenges for a bridge replacement over the Erie Canal brought about a buoyant solution.

Floating the fully assembled bridge into place.

Erecting a Warren truss bridge over a relatively small waterway like the Erie Canal might seem routine at first. However, construction constraints during the $5.5 million replacement of the Prospect Street crossing in Lockport, NY introduced challenges that required an out of the ordinary solution.

The new bridge is located just northeast of Prospect Street, carrying Stevens Street. The canal is less than 120′ (36.5 m) wide at the original Prospect Street crossing, but the replacement bridge is oriented approximately 45 degrees to the canal. In addition, abutments are perpendicular to the axis of the bridge and set back some distance from the canal edges. This arrangement required a significant increase in span length, from the original 117′-8″ (35.9 m) at the Prospect Street crossing to 267′-8″ (81.3 m) at the new location.

The new bridge was fabricated with roughly 600 tons of ASTM A790M, Grade 345W structural steel. During new construction, many conditions had to be considered:

- The center of the span was not to coincide with the center of the canal.
- Sediment in the canal bottom contains contaminated and hazardous materials, which could not be disturbed. Considering this condition, the New York Department of Transportation restricted the contractor from any construction operation or technique that would disturb the canal bottom. This restriction clearly and specifically excluded the use of any erection bents within or upon the sediment.
- The navigation season for the canal is May 1 through November 25, which includes recreational use. At other times, the canal is drained.
- High voltage lines cross the canal adjacent to the new bridge location.
- The new bridge would support a water main and two gas lines located below, through the outboard sidewalk brackets.

These conditions presented several challenges to the erector. Elimination of temporary erection bents limited the means to erect the new bridge to only two possibilities:

1. Erect each of the two trusses separately but fully assembled, and then fill in the bracing, floor beams, and stringers.
2. Erect as much of the bridge as possible on pontoons, and then float it into place.

Land-based Erection Scheme

In order to execute the first option with any efficiency, each truss would have had to be assembled on its side, with both chords temporarily supported on skids adjacent to one of the abutments. This operation would have then required the truss to be upended, lifted into position, and placed onto the abutment seats.

A number of problems associated with this approach emerged. First, the length, weight, and lack of lateral stiffness of the trusses indicated there was insufficient resistance to lateral-torsional buckling under their self-weight. As a result, this approach would have required additional temporary stiffening elements to stabilize each truss when subjected to conditions of erection and handling. Estimates indicated the fabrication and assembly of these stiffening

John E. Christopher is president of Structural Engineering Concepts, Pittsburgh, and Adjunct Assistant Professor of Civil and Environmental Engineering at the University of Pittsburgh.

elements would have been costly.

Second, the extra weight of these stiffening elements would have increased the lift weight close to the maximum hoist capacity of the Manitowoc 2250 crawler crane with the MAX-ER 2000 selected for the project. The weight of one completed truss assembly was about 300 kips with an additional weight of about 60 kips for the stiffening elements. Depending on the weight of the rigging, the outreach capacity of the crane with this load was about 75′. A larger rig was not available. In addition, the combined weight of the lifted load and the crane weight would have placed a significant surcharge on the embankment at the edge of the canal.

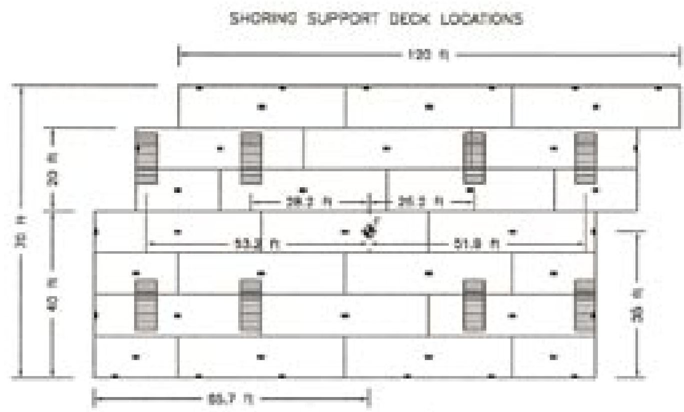
Also, the first truss would have had to safely resist lateral storm wind loads without the benefit of the second truss and the lateral bracing system in place. Moreover, the bridge bearings were located at the bottom chord. Without additional temporary supports, there would be nothing to prevent overturning from lateral wind load. This required the use of additional temporary structural elements to resist superimposed lateral forces.

The associated problems and cost of this approach indicated the need for an alternate scheme. As this approach was being considered, an ironworker at one of the planning meetings said, "This looks like a float-in job to me!"

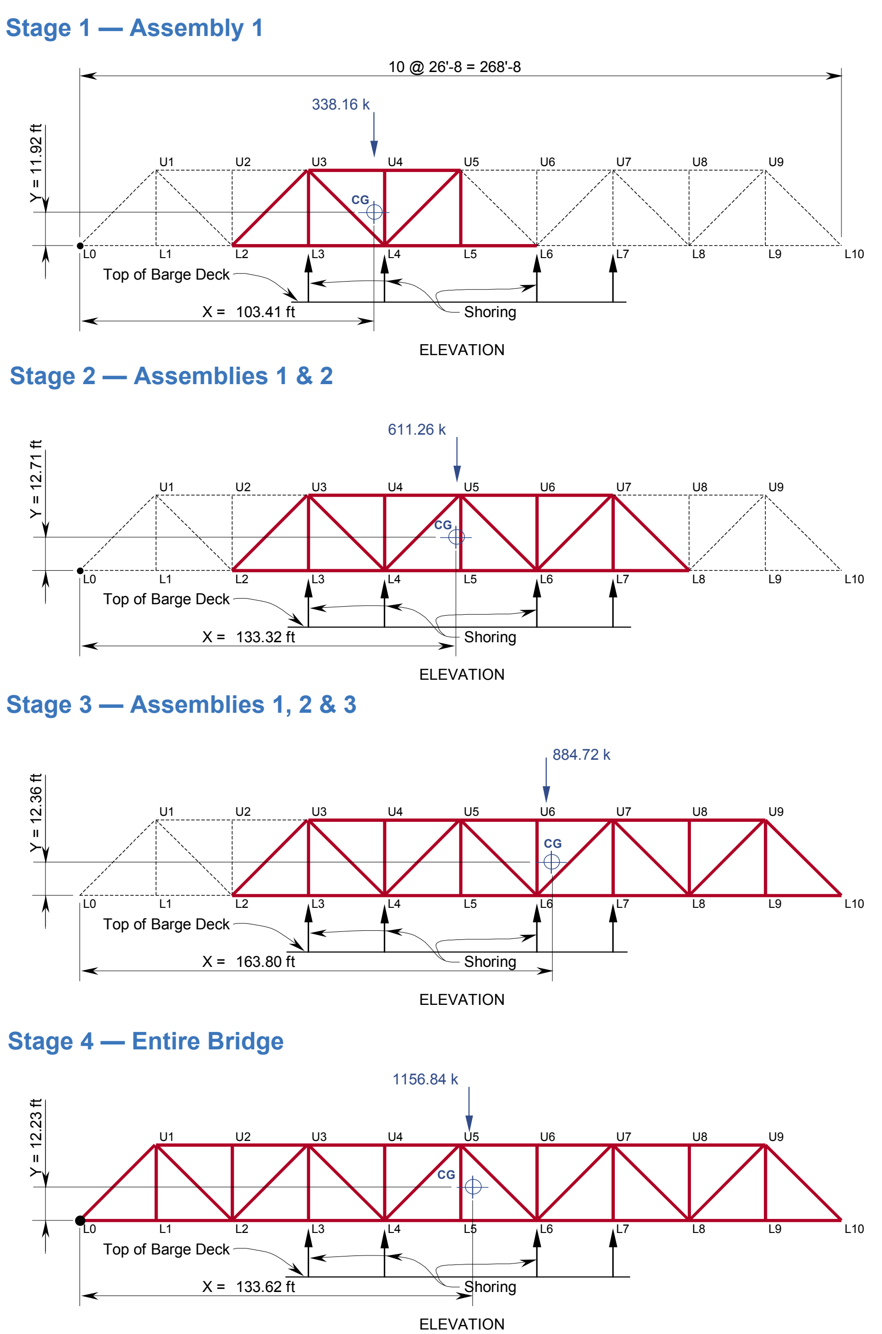
Pontoon-based Erection Scheme

Taking his suggestion, the erector contacted Robishaw Engineering in Houston to determine the feasibility of this approach using their Flexifloat sectional barge equipment. They reported that Flexifloat pontoon modules locked together could form the working surface required to carry the bridge. The interlocking arrangement of these modules had the strength and stiffness to make the pontoon assembly behave as a single unit. This characteristic provided the necessary floating capacity and stability to support the whole bridge, mounted on shoring about 30′ above the canal, when subjected to storm-level winds. It quickly became apparent that this approach was safer and more economical than the first.

Once the decision was made to float the bridge into place, execution of the plan was started with the necessary engineering. The erector selected Structural Engineering Concepts of Pittsburgh to identify the major lifts, design the rigging, design the temporary shoring that supported the bridge above the pontoons,



Flexifloat pontoon arrangement.



The stages of loading on the pontoons, starting at the center of the bridge and working outward.

and design the jacking arrangement necessary to lower the bridge onto its abutment seats.

Robishaw developed a preliminary plan for the pontoon arrangement based on the loads calculated by Structural Engineering Concepts. The plan required the use of a group of pontoons that formed a rectangular surface area 120′ long by 70′ wide. Although this defined the pontoon system needed to safely support the bridge, an accurate survey of the canal indicated the corners of the pontoon group in this preliminary arrangement would interfere with the canal edges. This problem was exacerbated by the fact that the center of the bridge span and the center of the canal did not coincide. In addition, the bridge could only be mounted eccentrically to the pontoons by no more than about 1.5′. Therefore, the pontoon arrangement required a modification.

Based on survey information, Structural Engineering Concepts suggested a revised pontoon arrangement that approximated a parallelogram. Robishaw Engineering used this suggestion to produce the arrangement shown in the figure on the previous page. With this arrangement, the pontoons supported the bridge at each stage of the erection.

In an area to the north and east of the construction site at the edge of the canal, the erector made four main assemblies of the bridge. Each assembly included the main truss members, floor beams, deck stringers, top chord and bottom chord lateral bracing, sidewalk brackets, sidewalk stringers, and utility piping. Structural Engineering Concepts compiled the weights and centers of gravity of these units for the purpose of designing the rigging and shoring. Using the Manitowoc 2250 crawler crane with the MAXER 2000, the heaviest lift was 356 kips at an outreach of 65′. The capacity of the crane allowed its position to be moved far enough away from the canal wall to avoid adding any significant lateral soil pressure on it.

The stages of loading on the pontoons, starting at the center of the bridge and working outward, is shown in the figure on the previous page. Note that the center of gravity shifts considerably as each assembly is placed on the shoring. Robishaw Engineering considered these conditions and provided ballast instructions that kept the pontoons within allowable list and trim limits.

The design of the shoring by Structural Engineering Concepts considered these loading stages, the list and trim limits, and the possibility of storm wind loads. This design kept the pontoon deck forces within the 5,000 psf deck load-bearing limit specified by Robishaw Engineering. The shoring design also included means to jack the assembly support points to facilitate making the connections between assemblies.

In addition to the shoring design, Structural Engineering Concepts planned the procedure to move the bridge into place. Because the bridge is skewed with respect to the canal, it could not be moved into place laterally without interference with the abutment backwalls. As a result, the shoring had to be high enough to allow the bearing points at the end of the bridge to swing over the high point of the abutment backwalls. The shoring height was determined using this consideration, the normal canal water elevation, and the pontoon freeboard and trim estimated by Robishaw Engineering.

The final item of consideration for the procedure was to determine how to extract the pontoons from under the bridge after it was floated into place. The depth of the canal water, plus the reserve pontoon freeboard, allowed the operation to use ballast in the pontoons to lower the bridge by about 2′. The erector also contacted the Erie Canal Authority to request a reduction in the canal water level during the final placement operation. Initially, the Authority indicated the possibility of reducing the water level by about 2′ after the bridge was moved into place. Structural Engineering Concepts specified a jacking procedure and designed the temporary 5′-high timber blocking at the abutments, considering that flooding the pontoons and draining the canal could lower the bridge by about 4′.

In October of 2004, roughly five months after the steel erection process was initiated, the bridge was ready to be moved into place. However, the previous season produced rainfall far above average, and the canal water level was about 4′ higher than normal. In addition, the Erie Canal Authority did not reduce the canal water level during the operation. These conditions required the height of the temporary blocking at the abutments to increase to about 12′. This also increased the labor necessary to jack the structure down onto the bearing seats.

In spite of the canal's unexpectedly high water level, the operation went smoothly with no other apparent problems. Once the bridge was erected on the pontoon shoring and everything was ready, it took about eight hours to float it into place and remove the pontoons and shoring. The jacking operation took place during the following week.

The use of high-strength steel made the float-in erection method possible. The steel frame was light enough to temporarily support the fully assembled bridge on pontoons and shoring. The heavier load of an alternative reinforced concrete structure would have made it impractical, or even impossible, to implement this method. As it was, there was no extra space in the canal for the additional pontoons that would have been necessary to resist the added weight of a concrete design.

Also, the restriction imposed by NY DOT to specifically exclude the use of any erection bents within or upon the canal sediments made a poured-in-place or pre-cast structure of this span impossible to erect. Aside from being specified by the Erie Canal Authority, structural steel was the optimum choice for this project in light of the construction conditions and limitations. ★

Owner
New York State Dept. of Transportation

Engineers
Hatch Mott MacDonald, Buffalo, NY (bridge design)

Structural Engineering Concepts, Pittsburgh (erection)

Robishaw Engineering, Inc., Houston (pontoon)

Engineering Software
STAAD 21.0 (bridge design)
STAAD Pro 2003 (erection)

Detailer and Fabricator
American Bridge Manufacturing, Coraopolis, PA, AISC member

Detailing Software
AutoCAD

General Contractor
Holmes & Murphy, Inc., Orchard Park, NY