

THE NEW JAMES RUMSEY BRIDGE: LONG- SPAN STEEL GIRDER BRIDGE ERECTION OVER THE POTOMAC RIVER



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BIOGRAPHY

Jared G. Fasick, PE, is a Project Manager for Bridges, Construction Services, and Forensic Investigations with the Pittsburgh office of Gannett Fleming, Inc. working almost exclusively for contractors in providing structural engineering services including design/build, alternate, and value-engineered design, as well as support of construction services for an array of structure types and sizes, including girder, truss, arch, suspension, movable, and major river crossing.

Thomas G. Leech, PE, SE, is a Vice-President with Gannett Fleming, Inc., who supervises the designs of large bridge structures, conducts forensic evaluations for failed structures, and supervises risk management studies for large and complex public works projects.

Patrick C. Carnevale is the Vice-President for Advantage Steel and Construction, LLC, located in Saxonburg, Pennsylvania, and is responsible for overall business activities, including structural steel erection procedures, business development, estimating, and safety and quality assurance. Previously, Patrick was the General Manager of Wilhelm and Kruse, Inc., responsible for the steel fabrication and erection of PNC Ballpark, portions of Heinz Steelers Stadium, the Hillman Cancer Center, and the PNC Corporate Headquarters Building. Advantage focuses on heavy highway and private client markets, targeting complex or time constrained projects.

SUMMARY

The new three-span 1,085-foot long James Rumsey Bridge over the Potomac River is a long-span curved steel haunched plate girder bridge with a maximum span length of 425-feet and a maximum web depth of 18'-4".

These long-span steel girder bridges, with spans in excess of 400-feet and web depths in the 20-foot range, are subject to pronounced out-of-plane rotations due to their scale during erection. Careful evaluation of girder stresses during erection, given the configuration of vertical and lateral erection bracing, as well as the rigidity of internal bracing elements, must be performed in developing a long-span steel girder bridge erection procedure.

This paper examines the complexities associated with erection of long-span steel girder bridges. The effects that permanent interior diaphragm type can have on girder stability during erection, specific erection challenges for long-span steel girder bridges, and a comparison of considered erection methods for the James Rumsey Bridge are discussed.

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Figure 1.

The new James Rumsey Bridge spans the Potomac River, connecting Maryland and West Virginia, at Shepherdstown, West Virginia. As can be seen in Figures 1 and 2, this new three-span 1,085-foot long curved steel haunched plate girder bridge, with a maximum span length of 425-feet and maximum web depth of 18'-4", replaces an existing adjacent six-span, 1,020-foot long Wichert Truss bridge, which is one of the last remaining in the United States.

Situated on soil rich with American history, it was at this location during

the Revolutionary War that British and German prisoners were marched across the Potomac River en route to Maryland military prison camps. During the Civil War the entire Northern Virginia Army withdrew from here into Virginia following the Battle of Antietam.

GROWING POPULARITY

Defying the history of its site, the new James Rumsey Bridge charts a course for future bridge engineering. Although still relatively rare, long-span steel plate girder bridges like the James Rumsey Bridge are increasingly being selected by Owners over more established long-span structure types such as box girders, arches, and trusses. Developments in fabrication capabilities within the United States, coupled with the economics of bridge construction, desired structural redundancy and a greater focus on bridge aesthetics for long-span structures, have resulted in an increased number of long-span steel girder bridges being constructed.

These long-span steel girder bridges (bridges with span lengths in excess of 400-feet and approximately 20-foot web depths) however are subject to pronounced out-of-plane rotations due to their scale during erection. Careful evaluation of girder stresses during erection, given the sequence of erection, configuration of vertical and lateral erection support/bracing, as well as the rigidity of internal bracing elements, must be performed in the development of a long-span steel girder bridge erection procedure. This discussion of steel erection



Figure 2.

focuses on traditional single-plate girder erection by crane and will use the James Rumsey Bridge as the primary talking point given its recent successfully completed erection.

Traditional single-plate girder erection is the most common and generally the most cost effective method of girder/beam erection. Many of the topics discussed in this paper are applicable for any plate girder or steel beam bridge during erection. However, special stability considerations that must be made for long-span steel girder erection.

SCOPE OF WORK

The general contractor for the construction of the new James Rumsey Bridge was Brayman Construction Corporation and the steel erection sub-contractor was Advantage Steel & Construction, LLC.

Gannett Fleming Construction Services was retained by Advantage Steel & Construction, LLC, to develop, as the Construction Engineer in coordination with Bill Branscome, Advantage's Operation Manager, the Girder Erection Procedure for the James Rumsey Bridge, as well as:

- Temporary Bent and Temporary Tower design
- Pier-jacking system design
- Determination of bottom of girder elevations at temporary towers
- Barge mounted crane stability evaluation
- Temporary bearing stiffener design
- Causeway temporary bridge evaluation

HEIGHTENED SENSITIVITY

Given the scale of the members involved, design and construction engineers must have a heightened sense of awareness to compression flange stability prior to deck cure. For the construction engineer, very low buckling stress limits due to long unbraced compression flange lengths for the first erected girder mandate constant awareness of structural stability. Upon completion of erection (prior to deck cure) design engineers, who are responsible for structural stability from the time erection is complete (prior to deck cure however), must properly consider compression flange lateral stability as it relates specifically to long-span steel girder bridges because of their increased web depths. Diaphragm configurations, like that shown in Figure 3 without a top horizontal member, offer acceptable lateral flange stability for shallow depth girders. However, as shown in Figure 4, when girder depths become excessive, this diaphragm configuration offers minimal lateral flange stability. As such, the brace point that the Design Engineer considered as effective during design is not a true brace point, thus permitting undesirable lateral compression flange deflections. Use of temporary top horizontal members can prevent these deflections, however upon completion of erection, these temporary top horizontal members can not be removed prior to deck cure. Removal of these temporary horizontal members would permit

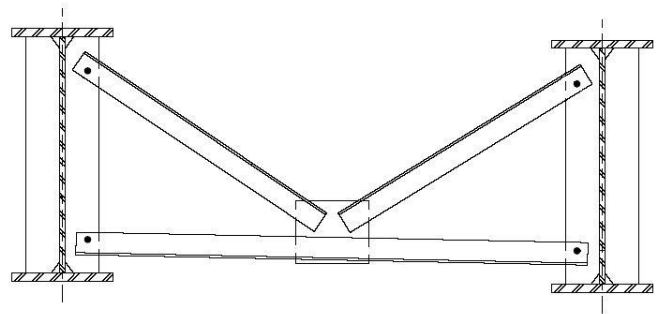


Figure 3.

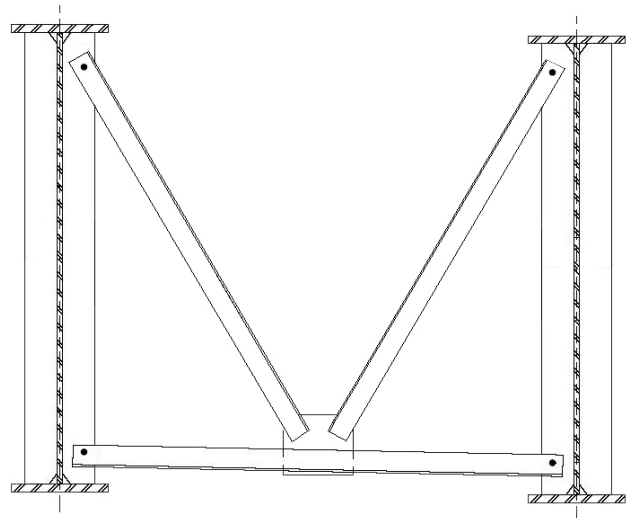


Figure 4.



Figure 5.

lateral flange displacement for deep bridges with diaphragms as shown in Figure 4. A diaphragm configuration with a top horizontal member, like that shown in Figure 5 should be utilized when web depths exceed half the girder spacing.

Construction engineers responsible for erection and control of compression flange stresses to prevent lateral-torsional buckling during erection assume significantly different risks than design engineers. Single-girder unbraced compression flange lengths for the first erected girder can be upwards of 200-feet, which is a

significant departure from the nearly 30-foot unbraced compression flange length used by the design engineer. Combine these often excessive unbraced compression flange lengths with the fact that long-span steel girder bridges commonly replace and are located adjacent to existing truss bridges and one has the recipe for using the existing structure as a lateral brace. Use of such an accessible bracing element can be very effective. However, ill-conceived lateral bracing details which a.) do not provide true lateral stability, and/or b.) do not permit vertical girder deflections without inducing lateral deflections are common. Use of these types of “adjacent structure bracing” details require special attention be paid to camber release during erection, which can be significant enough in long-span steel bridges to preclude affective use.

Lateral-torsional buckling is best controlled by reducing distances between points of contraflexure, in effect controlling strong-axis moments, either with the use of hold cranes or temporary towers. Given the spans generally associated with long-span steel bridges, temporary towers provide a better means of reducing these distances because required hold crane capacities and rental fees can become excessive. Temporary towers also permit the opportunity to introduce a brace point against wind forces, thus reducing wind stresses and lateral displacements during erection.

Figure 6 and 7 moment diagrams demonstrate the differences between the effective use of hold cranes and temporary towers in reducing distances between contraflexure points. Note the differences in the vertical

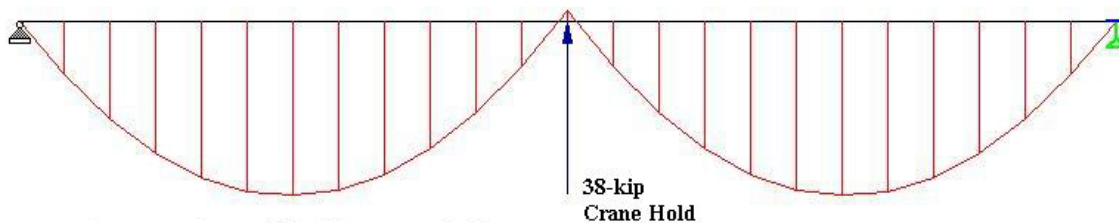
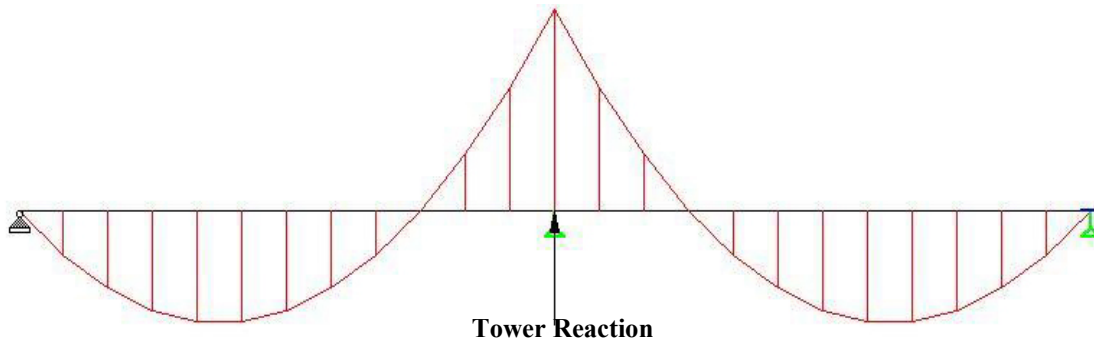


Figure 6. 250-foot span with midspan crane hold support.



Tower Reaction with midspan tem

forces applied and the differences in the distance between contraflexure points.

Frequently contractors prepare and submit erection plans that fail to properly consider lateral stability of the first erected girderline. This problem is not obvious because it occurs when the cranes sequential release from the first erected girderline to erect the second girderline without providing temporary tower or hold crane vertical support to the first girderline. The common

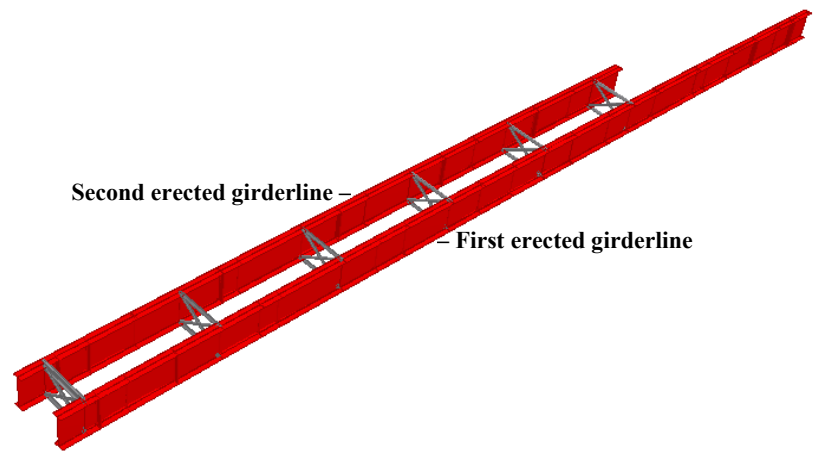


Figure 8.

The common misconception is that support of the first girderline is not necessary because you are holding the second girderline and the diaphragms are installed. The reality is that without having the second girderline fully erected, fully diaphragm connected to the first girderline, and released from the cranes, the diaphragms offer no lateral resistance to the first erected girderline; thus leaving the first erected girderline unbraced the full distance between supports. This occurs because these connected diaphragms offer no lateral stability when the second girderline is being fully supported by the erecting crane. Quite simply, because of the diaphragm effectively acting as a lever, the second girderline erecting crane can only support the weight of the second girderline. Raising or lowering of the second girderline only induces torque into the first erected girderline, which can result in failure of the first girderline during erection.

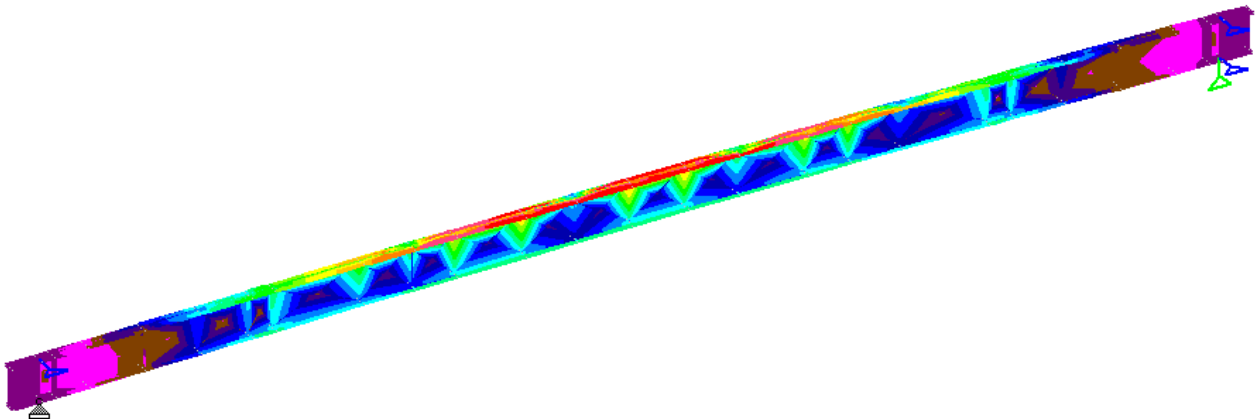


Figure 9. First erected girderline alone without intermediate support.

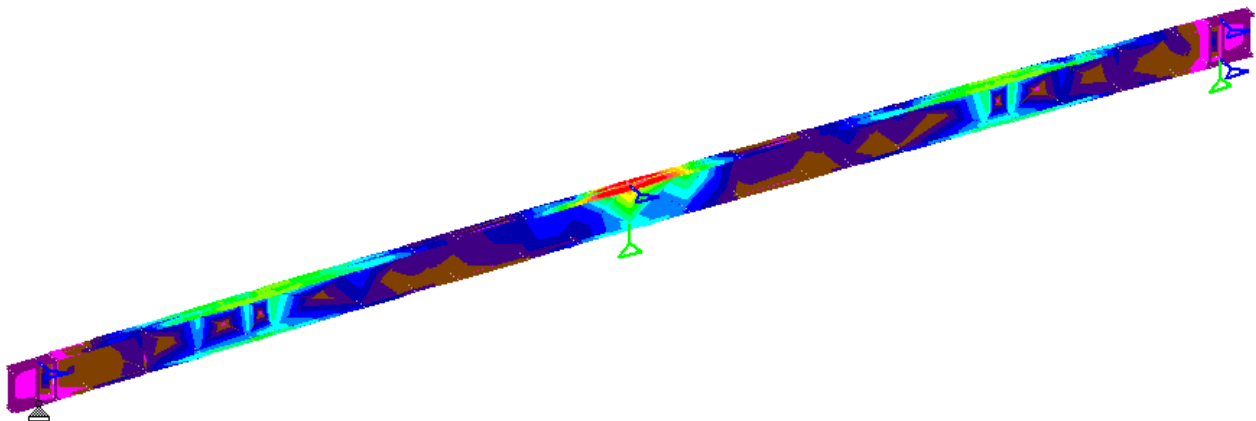


Figure 10. First erected girderline with intermediate support.

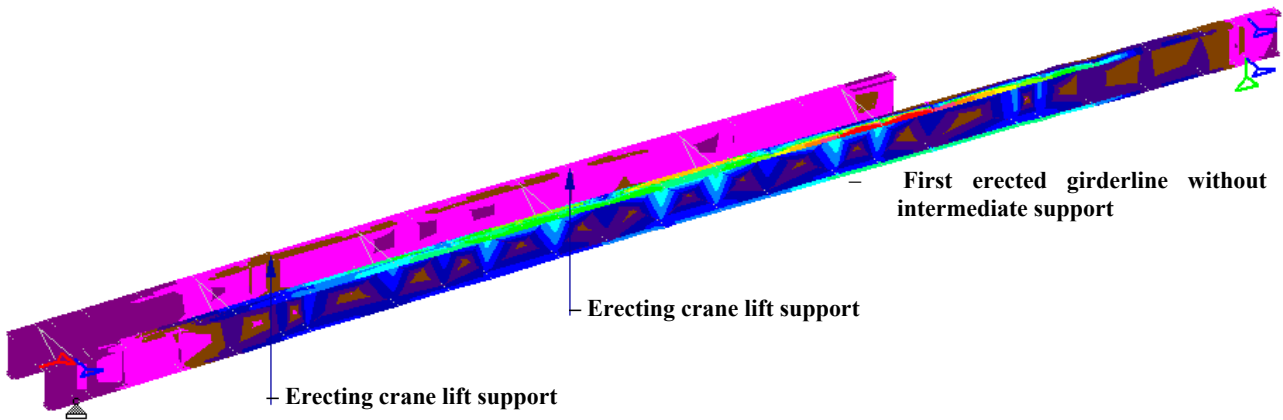


Figure 11.

Figure 8 shows the type of girder configuration discussed. Figures 9 and 10 depict the differences in magnitude of absolute plate stress in the single first erected girderline without and with temporary vertical support respectively at midspan. Figure 10 represents generally the magnitude of permissible compression flange stress between supports during long-span steel girder erection.

Figure 11 shows the magnitude of absolute plate stress in the first girderline when the initial segment of the second girderline is installed and is being fully held. Figure 12 shows the magnitude of absolute plate stress in the first girderline when the initial segment of the second girderline is installed and is being raised to 'help support' the first girderline. The resulting torque to the first girderline is shown in Figure 12, and the differences in stress magnitudes between Figures 10 and 12 are significant. The magnitude of absolute plate

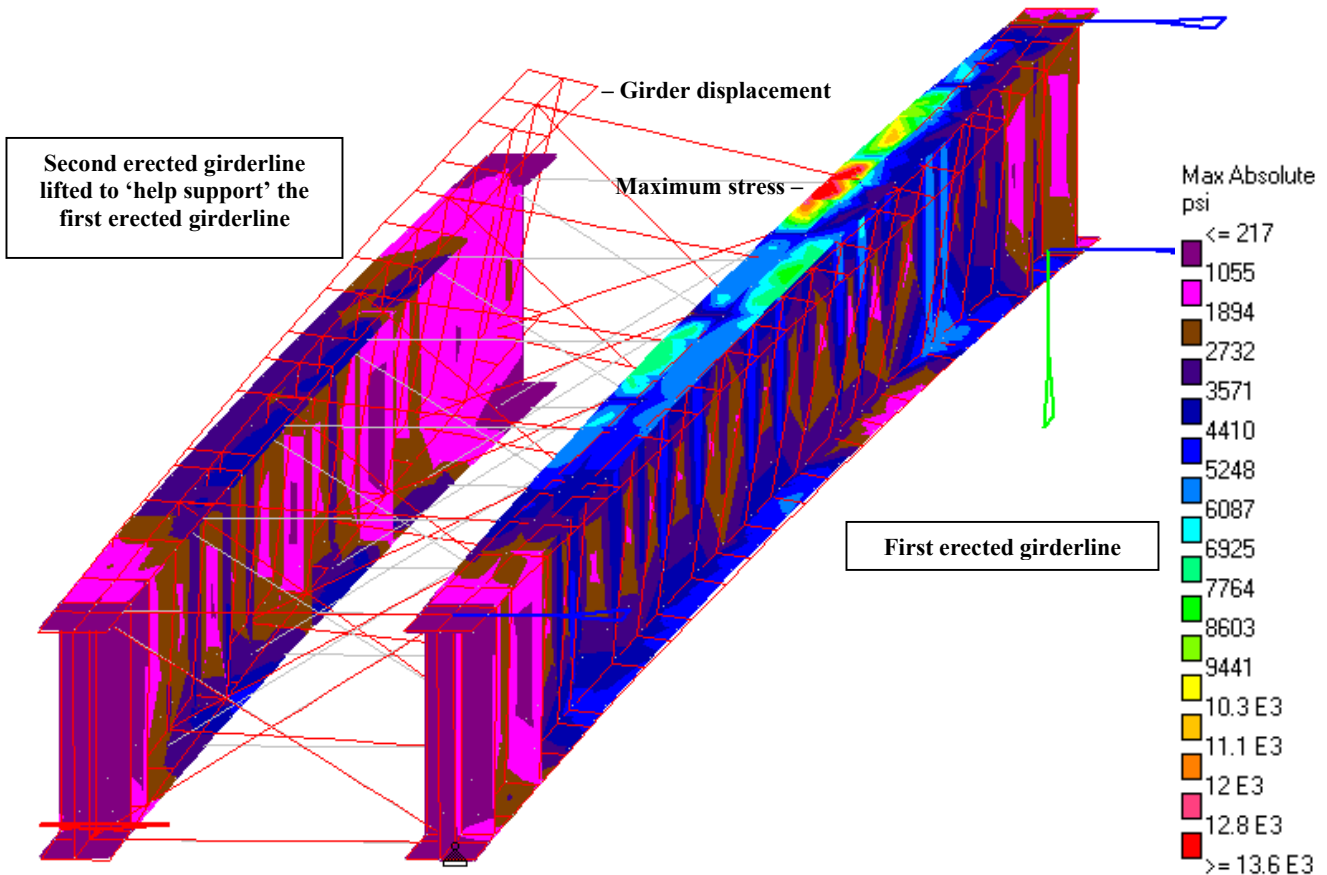


Figure 12.

stress shown in Figure 12 would greatly exceed permissible compression flange stress limits during long-span steel girder erection.

Additionally, horizontal curvature of girders and wind load effects, complicating not only design but also erection, are also generally overlooked by contractors. However, sharply curved long-span girder bridges are highly unlikely and with the appropriate control of strong-axis moments, additional wind stress effects can be accommodated. The new James Rumsey Bridge has only minor horizontal curvature at the ends of Spans 1 and 3 which was not severe enough to significantly increase erection stresses, and at critical points in the erection, wind stresses were reduced by limiting maximum wind speeds.

ERECTION CONSTRUCTIBILITY

In developing a long-span steel girder erection procedure, thought must be given to the contractor's preferred means and methods. All Contractors have their own techniques they choose to rely on in order to facilitate construction. However, all revolve around the basic concept of flexibility, which is critical in long-span erection. Construction engineers and contractors must build flexibility into bridge erection through the use of:

- Holding crane and/or vertical jacking capabilities at temporary towers (Figures 13 and 14) to aid in making field splice connections, and/or
- Pier jacking or the like, for aligning bearing stiffeners and bearings at consecutively fixed piers, thus permitting girder erection regardless of temperature effects



Figure 13.

Conceptual erection methods presented in Contract Documentation that rely on drop-in erection, pier girder-segment balancing, and barge-mounted temporary towers are recognized by construction engineers and contractors for their inherent constructability, stability, and safety issues. The most preferred and cost-effective erection will progress from one abutment to the other in a continuous manner. This eliminates temperature considerations required for drop-in erection and further facilitates field splice connection.



Figure 14.

The erection procedure developed for the new James Rumsey Bridge proceeded continually from Abutment 2 to Abutment 1, with two conceptual erection procedures being generated. The Figure 15 erection procedure, which was used for erection of the James Rumsey Bridge, utilized temporary bents (providing support to all girderlines), temporary towers (providing support to the first erected girderline only), and limited use of hold cranes (providing support to the first erected girderline only) to control unbraced compression flange lengths. Constructability was aided through the use of vertical jacking at temporary bents and pier jacking for bearing alignment.

An alternate erection procedure, initially considered but ultimately discarded, utilized

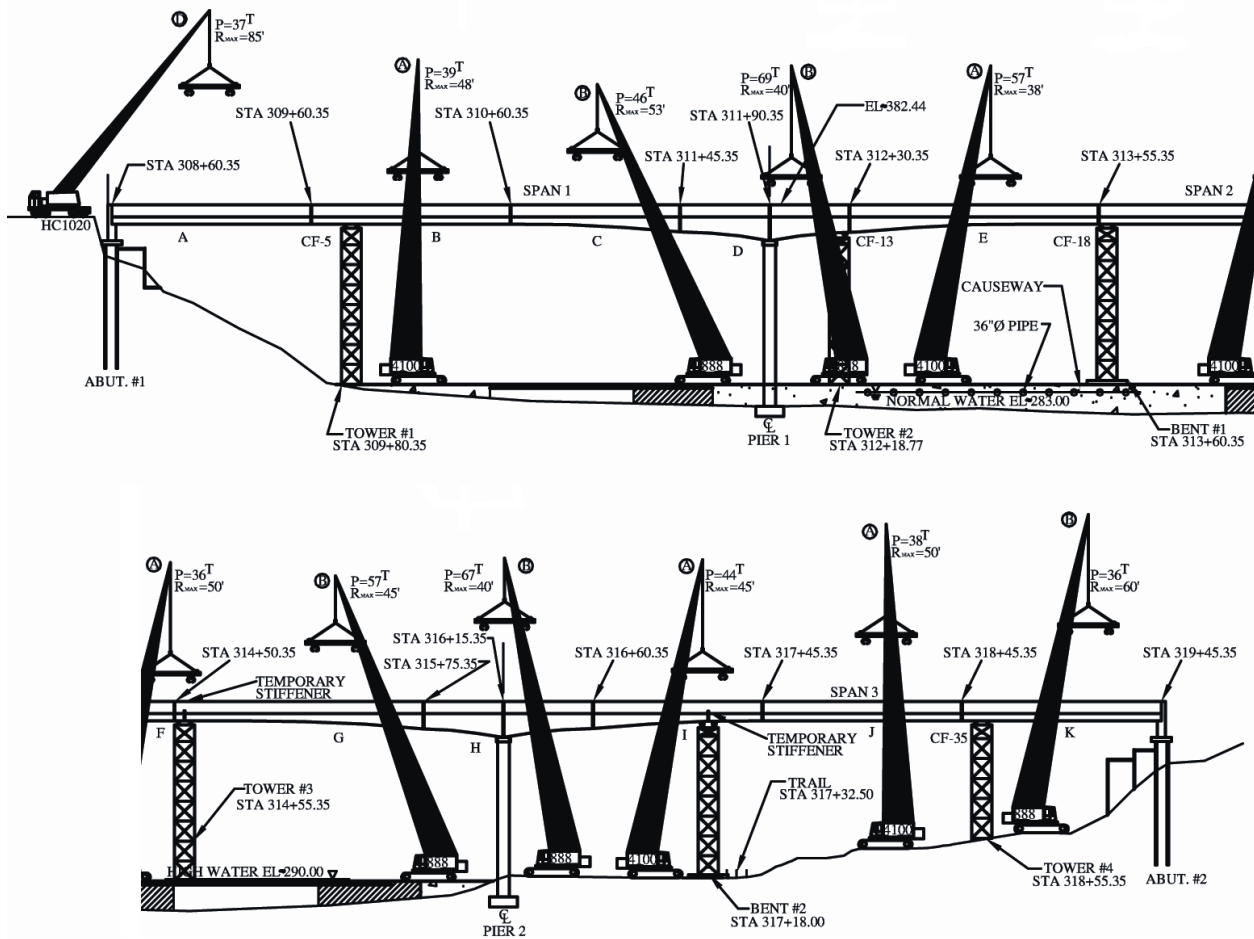


Figure 15.

temporary bents (providing support to all girderlines), and replaced the temporary towers as located in Figure 15 with the use of hold cranes (providing support to the first erected girderline only) to control unbraced compression flange lengths.

The Figure 15 erection procedure was selected for the following reasons: i.) site constraints relating to hold crane access and maneuverability, ii.) additional costs associated with hold crane duration at the project site, and iii.) use of temporary towers allow for more refined control of girder elevation, as well as frees cranes for use elsewhere on the site. Generally, where excessive use of hold cranes is required, use of temporary bents and temporary towers is more cost effective.

SUMMARY

The new James Rumsey Bridge was successfully erected from June to November 2004, and withstood the effects of Hurricanes Charley, Frances, and Ivan, as well as the resulting flood from Hurricane Ivan, which destroyed the construction causeway and two temporary bridges on the causeway.

AUTHORS

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