Launching Gantries for Bridge Erection in Difficult Terrain

In areas with limited ground access, the use of an overhead launching gantry may offer an economical solution for the construction of segmental concrete bridges.

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Precast segmental bridges are being built in greater numbers and under increasingly difficult site conditions across the United States. These structures are often the last and sometimes most difficult sections of the Interstate highway system to complete. Overhead launching gantries provide a practical and environmentally sensitive solution to constructing bridges in areas where ground access is limited. These specialized pieces of equipment allow precast balanced cantilever construction entirely from above the structure, even under difficult geometric restraints such as urban alignments and tight radius curves.

Methods of Segmental Erection

The first precast concrete segmental bridge was erected in France under the direction of Eugene Freyssinet between 1945 and 1948. The bridge crosses the Marne River, located near Paris. In 1956 the first segmental bridge in the United States was erected near Shelby, New York.

There are three main configurations of segmental concrete bridges that are generally identified by the method of erection:

- Span-by-span;
- Incremental launching; and,
- Balanced cantilever.

Span-by-Span Erection. This type of bridge is erected one span at a time on a supporting structure. Post-tensioning is placed at midspan as well as over the piers in order to make the structure continuous.

The span-by-span erection method utilizes an underslung or assembly truss that supports concrete segments between two piers. Segments are placed on the truss using a crane. After all of the segments have been placed, post-tensioning tendons are installed and stressed so that the segments are self-supporting. The truss is then moved ahead to the next span. The truss may be launched or rolled ahead to the next span. In some cases, the truss may have to be partially disassembled, lowered to the ground and then moved ahead. After adjacent spans have been erected, post-

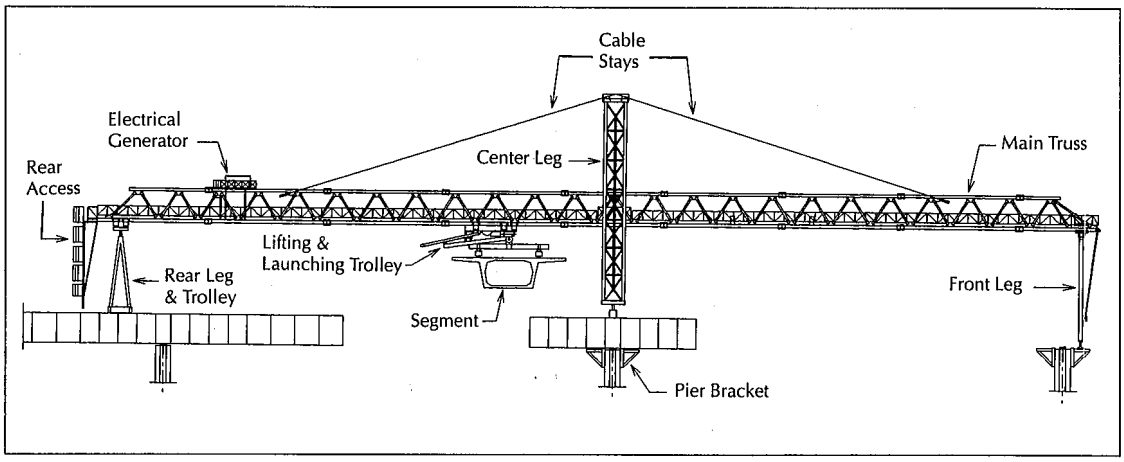


FIGURE 1. Schematic of a fixed-leg cable-stayed gantry.

tensioning is placed over the pier, making the two spans continuous.

The span-by-span method enables erecting the structure completely from above, which is especially important in difficult terrain or where ground access is limited. Due to economic considerations, span-by-span erection is typically used on structures with span lengths less than 150 feet. The method is also limited to structures with straight or large radius curved alignments.

Incremental Launching. The incremental launching method was developed in the early 1960s by two German engineers. This method involves setting up a casting bed at one of the abutments, where segments are match cast against a previously poured segment. Once the segment in the forms has reached sufficient strength, it is post-tensioned to the ahead segments and pushed or launched towards the ahead pier. This sequence continues until the structure reaches the opposite abutment.

The incremental launching method is limited to constant depth sections as well as constant radius curves. It has been successfully used on spans up to 200 feet without the need for temporary bents. The longest span built utilizing temporary bents was 550 feet and the longest structure has 23 spans with a total length of 3,400 feet. This method is a viable alternative for structures built in difficult terrain.

Balanced Cantilever. This type of bridge is built by alternately placing segments on either side of a supporting pier, thus forming a balanced cantilever. Negative moment post-tensioning is stressed during erection and positive moment post-tensioning is placed at mid-span to make the structure continuous with the previously completed structure.

Cantilever post-tensioning is placed and stressed during erection. When the cantilever is complete, a closure pour makes it continuous with the previously completed structure. Continuity post-tensioning is then placed at mid-span between the two structures.

There are three primary ways to erect a balanced cantilever bridge using:

- Crane;
- Beam and winch; or
- Launching gantry.

A land-based or barge-mounted crane can be used to erect segments. This method is suitable and versatile at sites where ground or water access is not a problem.

The beam and winch method involves supporting a winch on fixed beams, which are mounted to the leading edge of the completed portion of the cantilever. Segments are transported and positioned directly below the end of the cantilever. They are then lifted using the winch assembly and secured to the previously erected segment. Typically, one beam and winch setup is located at either end of the cantilever. As segments are placed, cantilever post-tensioning is installed and stressed. The beam

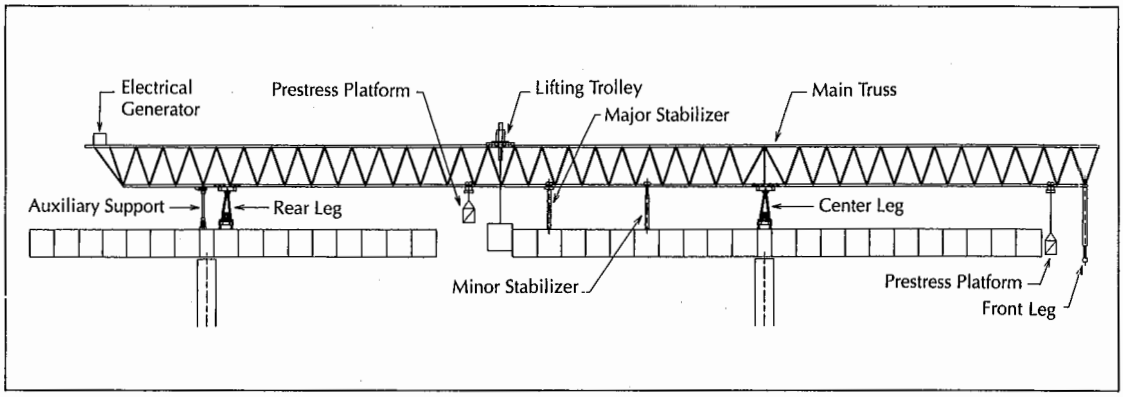


FIGURE 2. Schematic of a moveable-leg gantry.

and winch setup is then moved ahead to the end of the cantilever and positioned to lift the next segment. This versatile method can be used with virtually any alignment configuration. However, ground or water access is required to position segments directly below the lifting equipment.

The final method of erection used in balanced cantilever construction incorporates the use of a launching gantry, or an overhead truss, that is used to place the segments. Once a cantilever has been completed, the gantry has the capability to launch itself forward to the ahead pier to begin the erection of the next cantilever. One major benefit of this method is that it can be carried out entirely from above with no ground access required. This feature alone makes the launching gantry an excellent choice for bridges that have to be built in difficult terrain.

Launching Gantry Configuration

Launching gantries typically have one of two configurations. The gantry shown in Figure 1 has a single horizontal steel truss that is supported by cable stays. The cables transfer load from either side of the main truss to a center tower. The center tower is supported on the bridge deck. A mobile rear leg is also used to support the truss. A front leg is used to support the gantry during the launching and placing of pier segments. The front and center legs are fixed in position relative to the horizontal girder. The rear leg can move along the length of the girder. A lifting trolley rides along the bottom chord of the truss. Segments are lifted at the rear of the truss and delivered into position.

The gantry shown in Figure 2 has three support legs: a front, rear and center. The legs support the horizontal truss. The front leg may or may not be fixed in position, while the center leg and rear leg are free to move relative to the space truss. Segments are delivered to the rear of the truss. The lifting trolley that is used to place segments rides along the chord of the truss.

History of the Erection Method

The use of a launching gantry to erect a segmental bridge is not a new concept. The first bridge to be built employing a launching gantry was the Oleron Viaduct in France. The bridge connects mainland France with the island of Oleron, which is situated off the west coast roughly 80 miles north of Bordeaux. Erection of this 9,390-foot structure began in August 1964 and took 19 months to complete.

The structure is situated entirely over water. Traditionally, this type of structure would consist of concrete arches or steel structures, built using floating barges and cranes. However, due to wide tidal ranges in that area, the use of floating equipment would have substantially increased the time of erection and added to the project's cost.

In addition to these considerations, the erection of the bridge from the water and the low-lying marshes would have had a significantly adverse environmental impact on the nearby fragile Marennes oyster beds. The use of overhead erection equipment allowed this viaduct

to be built with minimal environmental intrusion.

The first bridge to be built in the United States that utilized an overhead launching gantry was over the Kishwaukee River near Rockford, Illinois. It was erected between 1978 and 1979. The bridge's twin structures provide a supplemental river crossing parallel to U.S. Highway 51. The total length of the bridge is 1,090 feet. It is composed of two 170-foot spans and three 250-foot spans. In order to protect the environmentally sensitive river valley, the design specifications required that the structure be erected completely from above. During the preliminary design phase, both steel and concrete structures were considered. The concrete alternative proved to be the most economically feasible solution.

The Hanging Lake Viaduct

The Hanging Lake Viaduct serves as an excellent example of a structure built over difficult terrain. This precast segmental bridge was erected in a narrow canyon that accommodates the Colorado River as well as two lanes of traffic on U. S. Highway 6. The Hanging Lake Viaduct completes the last remaining link of Interstate 70 in western Colorado.

After years of study, it was decided to construct I-70 through the scenic and environmentally sensitive Glenwood Canyon. Pressure from the public required that the design of the highway through the canyon disturb the natural terrain of the canyon as little as possible. In addition, there were no alternate routes available for detouring the traffic from I-70 at either entrance to the canyon.

Therefore, the Colorado Department of Transportation (CDOT) made it a design requirement that the Hanging Lake Viaduct superstructure be constructed from above. This mandate prohibited the use of any conventional ground-based equipment, falsework or temporary bents during construction that would adversely affect traffic and the environment.

Two complete designs were prepared to meet these unusually stringent but necessary restrictions. A precast concrete segmental box girder alternate was designed as well as a steel box girder alternate. The concrete alternate received the lowest bid at $34.1 million and was selected. Construction began in late 1989. The total project included 8,400 lineal feet of bridge. The typical span length was 200 feet, with parallel 300-foot spans over the Colorado River. The majority of the structure followed the river alignment on steep, rocky talus slopes.

The precast concrete segmental alternate was designed to be built using the balanced cantilever method with an overhead launching gantry. The contractor decided to use a gantry that had recently been used to build the French Creek Viaduct, located adjacent to Hanging Lake and separated from it by only a short tunnel. The gantry that was used on the project had been used to build several structures in Europe. The gantry was brought to the U.S. specifically to build the French Creek Viaduct.

The gantry is referred to as a "60/60 gantry." This designation is given to indicate that the gantry can be used to erect 60-meter (197-foot) spans and that it has a lifting capacity of 60 metric tons (132 kips). The gantry used on the project is similar in configuration to the gantry shown in Figure 1.

Special consideration was made during the bridge design to account for the erection method. Temporary cantilever post-tensioning tendons were added over the pier as well as negative moment post-tensioning at the midspan closure joints. This additional post-tensioning was added to accommodate launching the gantry onto the completed cantilever. In addition, a 60-ton counterweight was placed over the closure pour during launching.

The design specified that construction begin at a point where access by truck could be facilitated. This enabled all segments to be trucked to the gantry over the completed section of the new structure. Again, this eliminated the need for any ground-based cranes and kept the construction traffic off the sensitive terrain below.

Typical Erection Cycle. During a typical erection cycle, precast segments were symmetrically placed on either side of the pier using the gantry. The segments were then transported over the completed structure to the rear of the gantry. After that, the lifting trolley was used to place each segment in its final position. Segment weights varied from 40 to 55 tons and lengths ranged from five to eight feet. After

each segment was placed, six 1⅜-inch post-tensioning bars were stressed. The post-tensioning bars were used to suspend the segment while a matching segment was placed in the opposite position on the cantilever. After two pairs of segments were hung, a pair of tendons (12 by 0.6 inch or 19 by 0.6 inch), one located above each web, were stressed.

Once the cantilever was completed, closure beams were placed between the down station end and the previously completed structure, and the cantilever was adjusted for line and grade. A one-foot closure segment was then poured, making the just-completed cantilever continuous with the finished structure. Once sufficient strength was obtained (3,000 pounds/square inch) in the closure, the bottom slab continuity tendons were stressed. After closure, the gantry was launched ahead to the next pier. Prior to moving the gantry, temporary post-tensioning tendons were stressed.

The launch sequence is illustrated in Figure 3. Figure 3a shows the gantry position at the completion of cantilever erection. The rear leg has been moved forward as the gantry is being supported by the center leg and the stanchion. While the gantry is supported on the stanchion and the rear leg, it is launched ahead so that the center leg can be supported on the cantilever and the front leg can be supported on a steel pier bracket that is attached to the ahead pier (see Figure 3b). The pier bracket also resists the overturning moment during cantilever erection.

Next, the stanchions are retracted and the gantry is supported by the rear, center and the front legs as shown in Figure 3c. Once the gantry is in this position, it is used to place the pier segment. The pier segment is supported on temporary shims on the pier bracket. To complete the launching sequence, the gantry is supported on its front and rear legs, and the horizontal truss is launched ahead until the center leg is positioned over the pier as shown in Figure 3d. The gantry is lowered onto the center leg and stabilized by the rear leg.

The gantry was designed to build span lengths of approximately 200 feet. To enable the gantry to build the 300-foot spans over the Colorado River, a temporary bent was placed in the river. First, the maximum cantilever length possible was constructed with the gantry center leg in its typical position over the pier. Next, a support was installed under the leading edge of the cantilever. The gantry was then launched ahead so that the center leg was in position over the temporary support (see Figure 4). Cantilever construction could then continue for an additional 60 feet until the gantry could be launched to the next permanent pier.

The typical erection and launching cycles took anywhere from one to two weeks depending on the number of segments in the cantilever and the number of tendons to be stressed. The contractor was able to place approximately four segments (two pairs) during an eight-hour day. A typical cantilever contains 13 pairs of segments; therefore, segment placement took approximately six eight-hour days. The contractor was able to complete one 200-foot span every seven days over the last half of the project. This rate exceeded the contractor's own predictions and allowed the project to be completed four months ahead of schedule.

At the completion of erection, the gantry was disassembled and shipped to a storage facility for use on another job in the near future.

The New Baldwin Bridge

The new Baldwin Bridge was the first concrete segmental bridge to be built by the Connecticut Department of Transportation. It carries eight lanes of traffic across the Connecticut River between the towns of Old Saybrook and Old Lyme on the heavily traveled Interstate 95.

The new Baldwin Bridge's twin structures are 2,528 feet long and consist of eleven spans ranging in length from 177 to 275 feet. Its 488 precast trapezoidal box segments have a constant depth of 12 feet and a typical length of ten feet and seven inches. The eastbound structure has a deck width of 74 feet and eight inches, and the westbound structure has a deck width of 83 feet and nine inches. Segment weights range from 140 to 160 tons.

The original contract plans specified an erection technique employing two beam and winch setups to place the precast segments using the balanced cantilever method. Segments would have been transported directly below their intended erected location and hoisted into position. Segments would have been delivered by

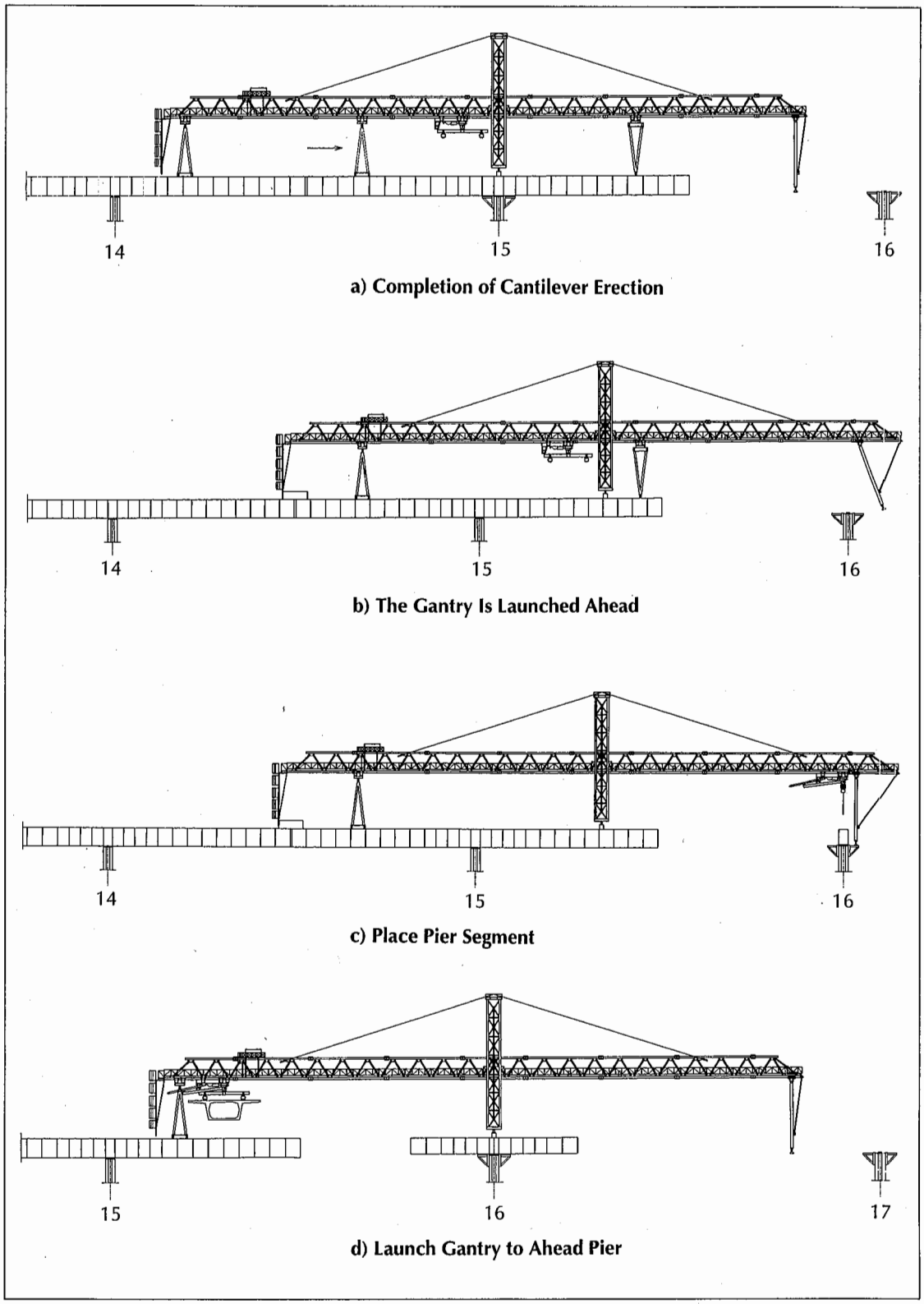


FIGURE 3. Hanging Lake Viaduct gantry launch sequence.

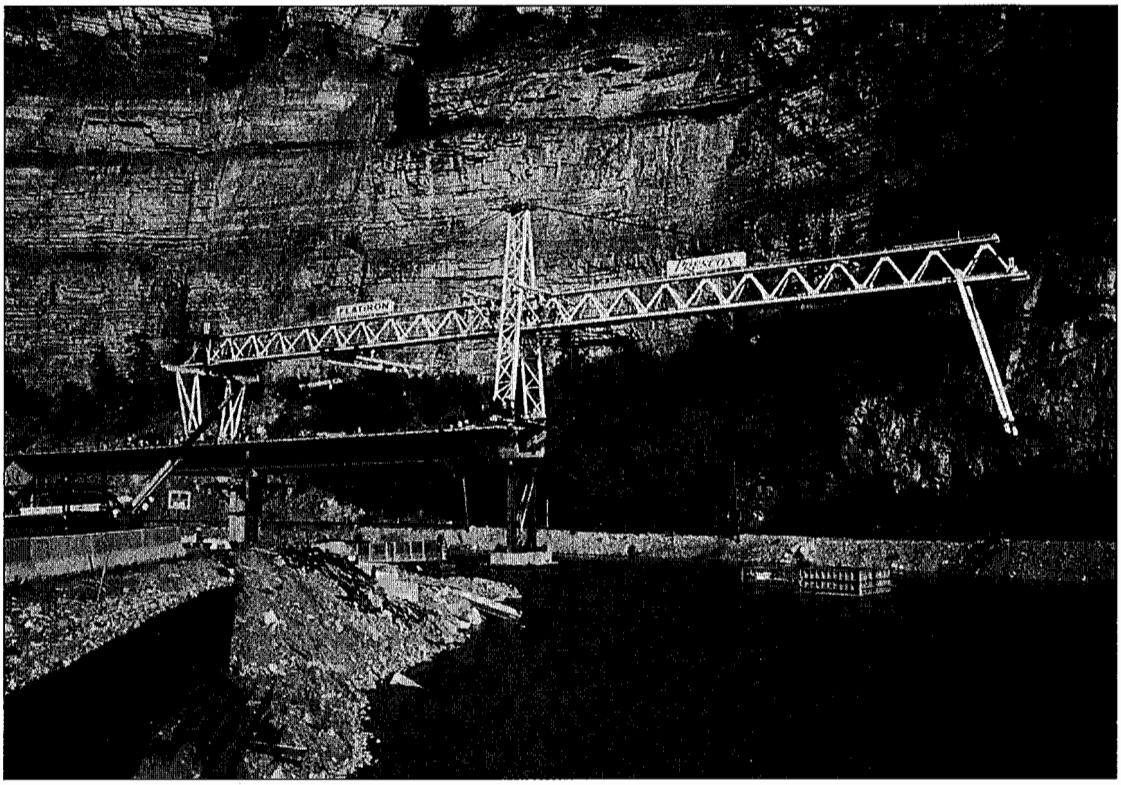


FIGURE 4. Hanging Lake Viaduct gantry launch over the Colorado River.

barge to the spans over the Connecticut River and by truck for the end spans over land. The contractor was concerned about the large amount of waterborne equipment required for this scheme. These concerns were based on having to work in strong tidal currents, satisfying the strict conditions of the environmental permit, having to keep the navigation channel open and being prohibited from dredging between April 1 and November 30. The use of large falsework bents also was a concern, particularly because of the varying height of each pier.

Because of these constraints, the contractor opted to explore the use of an overhead gantry system. This system would allow the erection of the structure with virtually no waterborne equipment, resulting in a significant time savings over the original scheme. The Baldwin Bridge gantry, shown in Figure 5, has an overall length of 435 feet and weighs approximately 600 tons (it is also similar to the gantry shown in Figure 2). It consists of twin triangular space trusses that have a depth of 17 feet. A twin truss design was chosen because of the structure's straight alignment as well as the weight of the segments.

The contractor wanted a piece of equipment with as much versatility as possible to allow for future use. The truss was supported on two legs, and moves with respect to these legs when launching. There was an auxiliary support located at the rear of the truss and a front leg at the nose of the truss. These supports were used to hold the truss up during the movement of the rear and center legs. The segment-lifting trolley rode on the top chord of the truss and employed a unique hydraulic jack with a 17-foot stroke and 200-ton capacity to hoist and position the segments. The overturning moment encountered during cantilever erection was resisted by the stabilizer arms that connected the deck to the truss as the cantilever was built. The stabilizer arms eliminated the need for falsework at the piers. Additional equipment attached to the gantry included two movable work platforms that were used for prestressing and an

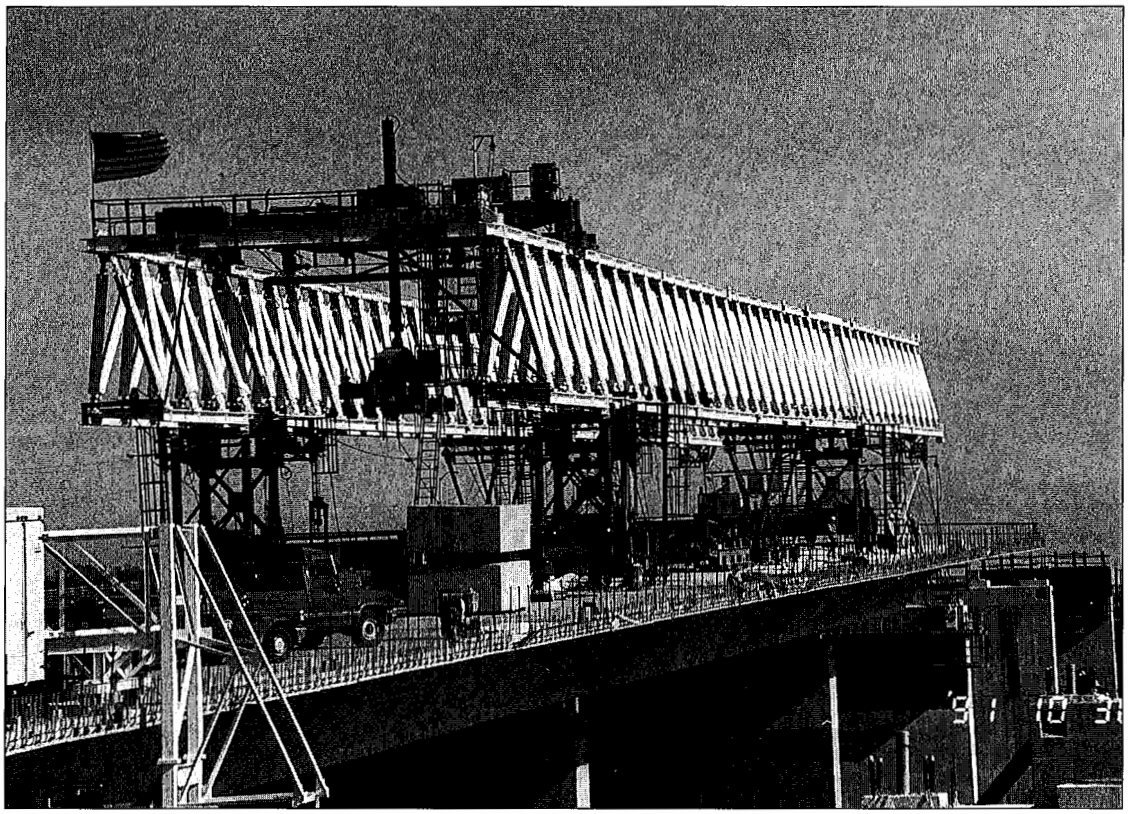


FIGURE 5. A view of the new Baldwin Bridge launching gantry.

electrical generator that was used to power the gantry.

The gantry was fabricated in Canada and trucked to the site in pieces. It was assembled and load tested on the western approach of the westbound structure. The truss was designed to be easily transportable with pinned connections between the chords and diagonals.

Erection began on the westbound side of the bridge. The gantry worked its way to the eastern side, using the already completed structure to provide access for the 12-axle segment hauler. Once the westbound structure had been completed, the entire gantry was loaded onto two special hauling rigs and moved back over the completed bridge into position to repeat the process for the eastbound structure. After the eastbound structure had been completed, the gantry was disassembled and trucked to storage to await its next assignment.

The bridge was designed to resist the loads of a comparatively small beam and winch placed at the ends of the cantilever. Though the loads from the erection gantry were much greater, the structure was able to resist the weight of the gantry with minimal modifications. The most significant of these modifications were the addition of external post-tensioning and a counter-weight over the middle of the previously erected span used during launching.

Typical Erection Cycle. The gantry was launched ahead so that the front leg was resting on the ahead pier. Jacks under the front leg were activated and the segments directly over the pier were erected as shown in Figure 6. The center leg was then moved to the pier and the rear leg to the end of the previous cantilever. This alignment allowed the truss to be launched ahead into the cantilever erection position. As the segments were erected, the stabilization arms were attached to the deck in order to resist overturning moments. Two stabilizer arms were required during this operation. The major stabilizer was used to resist any unbalanced moment, and the minor stabilizer was

used only when the cantilever was in a balanced position and the major stabilizer was being moved ahead. A counterweight was also used on the cantilever to reduce the unbalanced moment.

Each segment was epoxied to the previous segment. The epoxy was squeezed and the segment temporarily suspended using post-tensioning bars that were coupled at the face of the previous segment. After each pair of segments had been erected, several post-tensioning tendons were stressed in the top slab. Once all segments were placed, a one- to three-foot closure joint was poured to join the cantilever and the previously erected span. Continuity tendons were stressed after the closure had reached sufficient strength. The gantry was then launched ahead to begin the erection of the next cantilever. A typical cantilever required two to three weeks to erect.

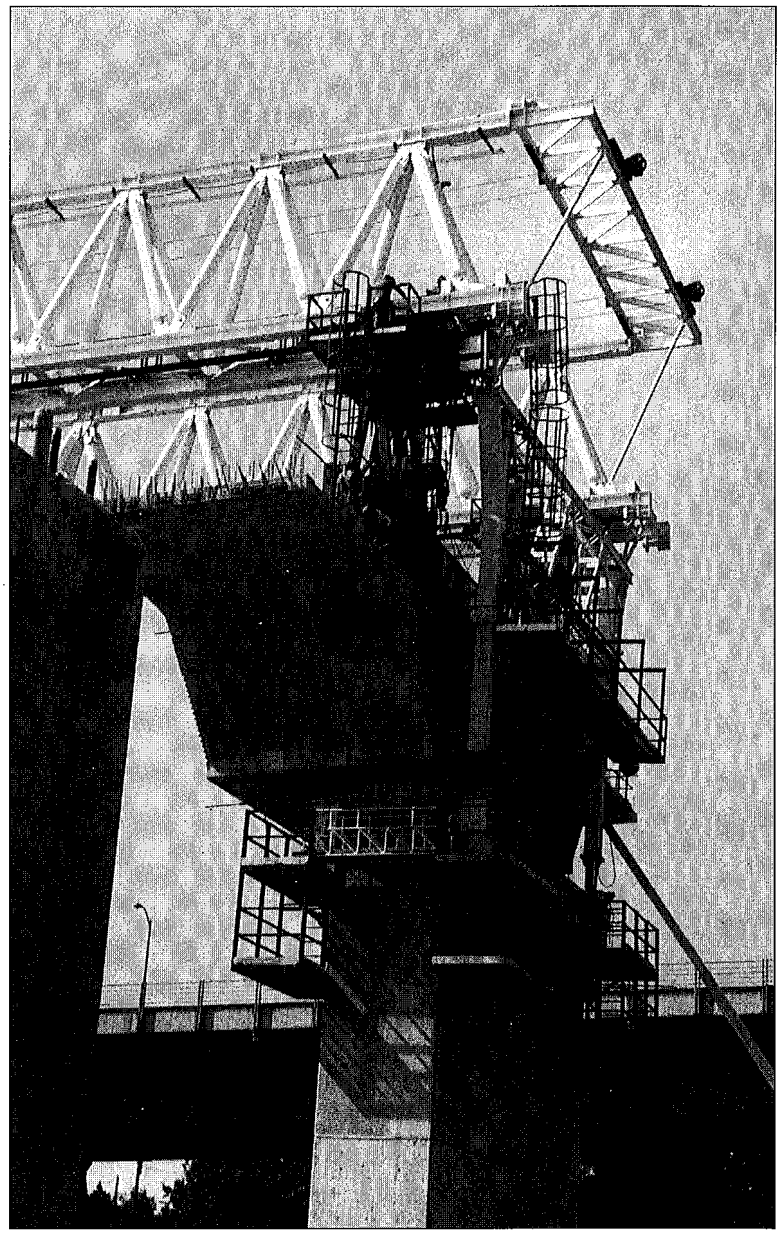
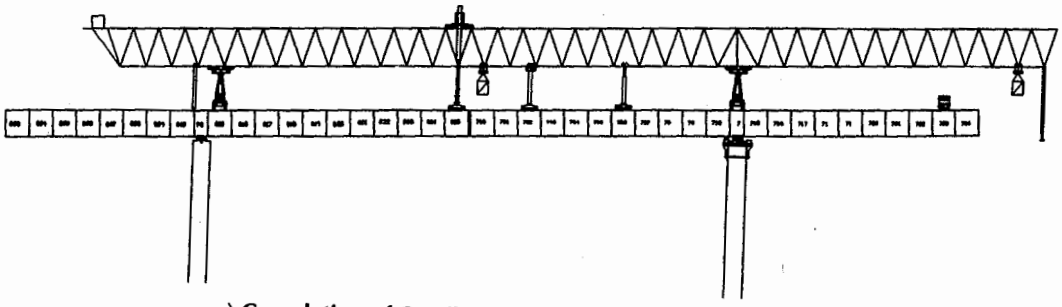


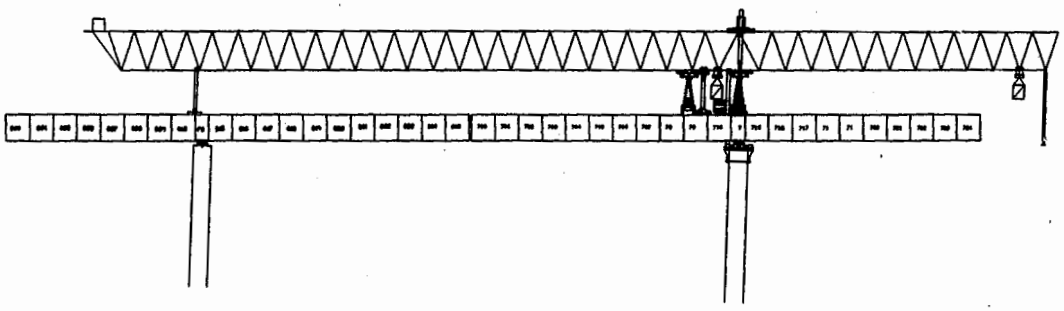
FIGURE 6. Pier head erection on the new Baldwin Bridge.

After a cantilever was completed and the back closure had been made, the gantry was positioned as depicted in Figure 7a. Figure 7b shows the gantry supported on the center leg and the auxiliary support. The rear leg is moved ahead. In Figure 7c and 7d the gantry is supported on the rear or center leg and the auxiliary support. The rear and center legs are repositioned in preparation for launching the gantry. Figure 7e shows the launching of the gantry to the ahead pier. In Figure 7f the gantry is supported on the auxiliary support, the front leg and the center leg. The rear leg is repositioned and two segments are placed over the ahead pier. Figure 7g shows the center leg being moved to the ahead pier where it is supported on the pier segment. The final launch step is illustrated in Figure 7h. With the gantry supported on the rear and center legs, the truss is rolled ahead into the pier erection position.

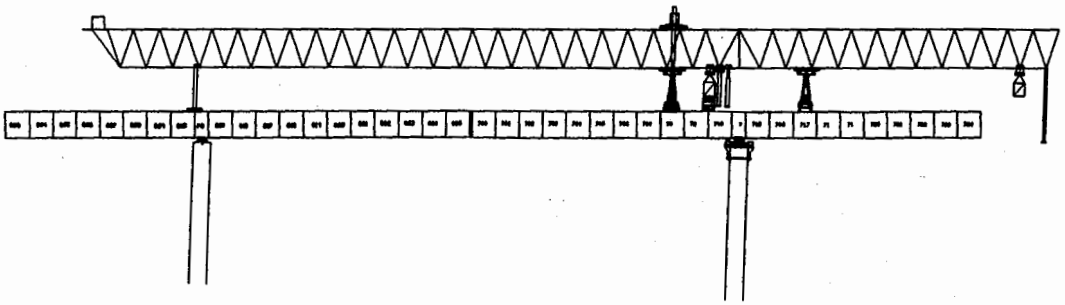
The new Baldwin Bridge serves as an excellent example of a structure built in difficult terrain where an overhead launching gantry was used. The erection of the new bridge was



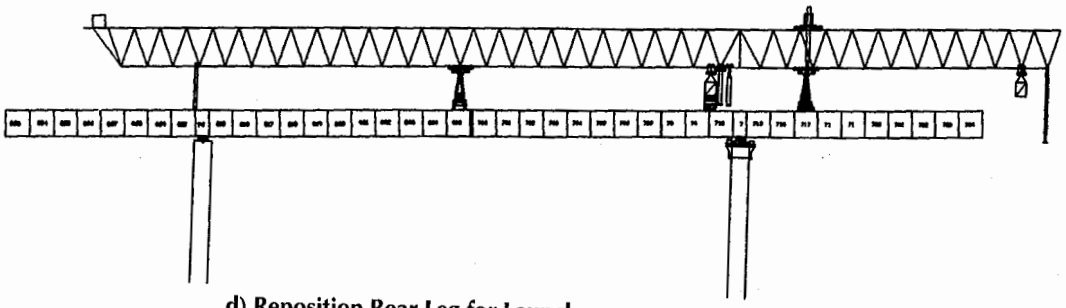
a) Completion of Cantilever Erection



b) Reposition Rear Leg So That Center Leg Can Be Moved Ahead



c) Reposition Center Leg



d) Reposition Rear Leg for Launch

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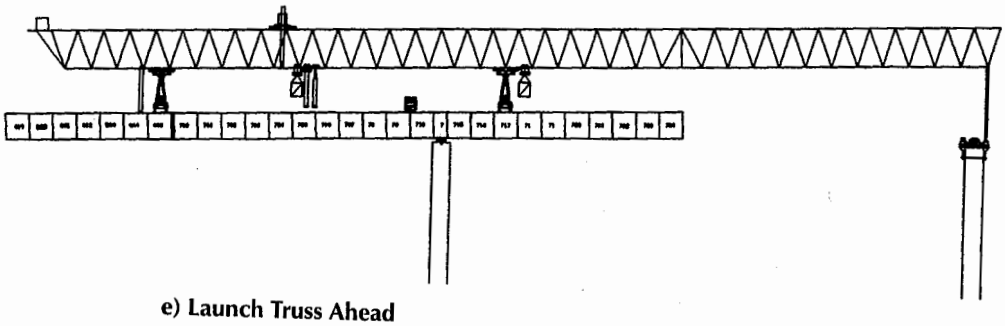
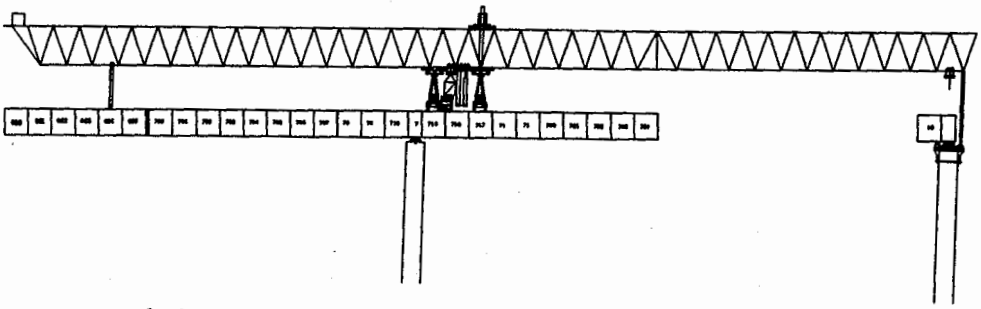
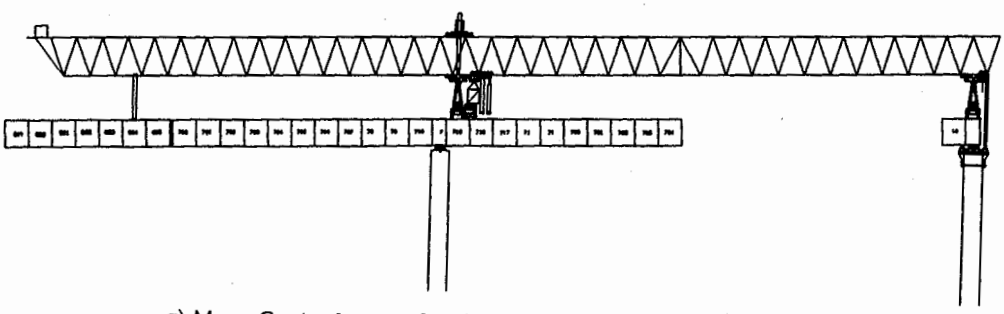
FIGURE 7. The new Baldwin Bridge gantry launching sequence.



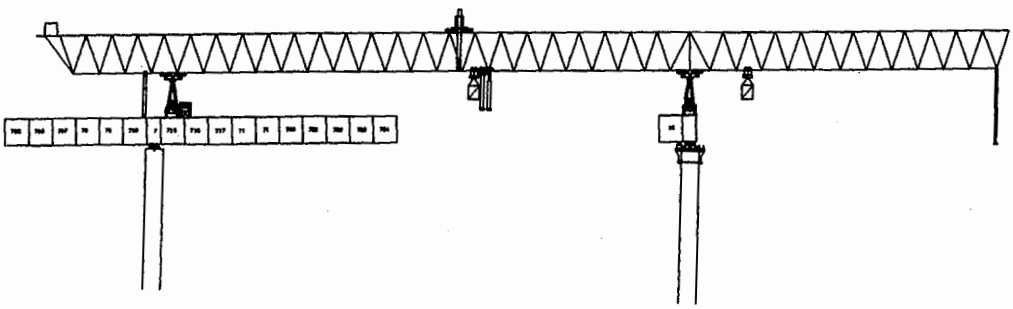
e) Launch Truss Ahead



f) Place Pier Segment



g) Move Center Leg to Ahead Pier



h) Launch Truss Ahead Into Cantilever Erection Position

completed in the spring of 1993, six months ahead of the contracted schedule. The contractor was able to surpass the contract schedule in large part due to the use of the overhead launching gantry. The up-front investment required for this specialized piece of equipment resulted in time and cost savings in the end. This gantry can be modified to meet many different bridge configurations and should be considered for use in any situation where site constraints limit access from the ground.

Conclusion

As more and more bridges are built over increasingly difficult terrain and under strict environmental constraints, the idea of building entirely from above becomes more of a necessity than a luxury. The overhead launching gantry allows concrete segmental bridges to be erected entirely from above, which is a necessity given certain site parameters. The two case studies presented here — the new Baldwin Bridge and the Hanging Lake Viaduct — are both excellent examples of the use of this erection method. They demonstrate how the use of an overhead launching gantry can save time and, therefore, money on projects built in difficult terrain.

ACKOWLEDGMENTS — *The Flatiron/Prescon Joint Venture was the contractor for the Hanging Lake Viaduct project. The gantry for that project is owned by Prescon Corp. and was used by Campenon Bernard in Europe. The contract for the new Baldwin Bridge project was the joint venture of Perini, PCL and O&G.*

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