Movable Scaffold Systems: Gerald Desmond Bridge Approach Spans

by Jeremy Johannesen, McNary Bergeron & Associates

The opening of the new Gerald Desmond Bridge in October 2020 signified a major upgrade for the Port of Long Beach, Calif. As a key link in the port's infrastructure, this bridge plays an important part in the nation's economy as a whole—it is estimated that 15% of U.S. imports pass over, and likely under, the bridge.

With a vertical clearance of 205 ft over the water, the new bridge provides a significantly larger navigation envelope for modern shipping needs. Although easily overlooked, cast-in-place concrete box girders have been constructed on each side of the channel to make the long climb to the 1000-ft-long main span cable-stayed bridge, which is the centerpiece of the project.

The use of post-tensioned concrete box girders as the workhorse structures on the approaches was a natural fit for this project. The California Department of Transportation has used this type of construction extensively, and the structures have a reliable history standing up to two things California is famous for: traffic and earthquakes. It is for these reasons that post-tensioned concrete was used in the design-build proposal from Arup and SFI (a joint venture among Shimmick Construction, FCC Construction, and Impregilo S.p.A.) in 2012.

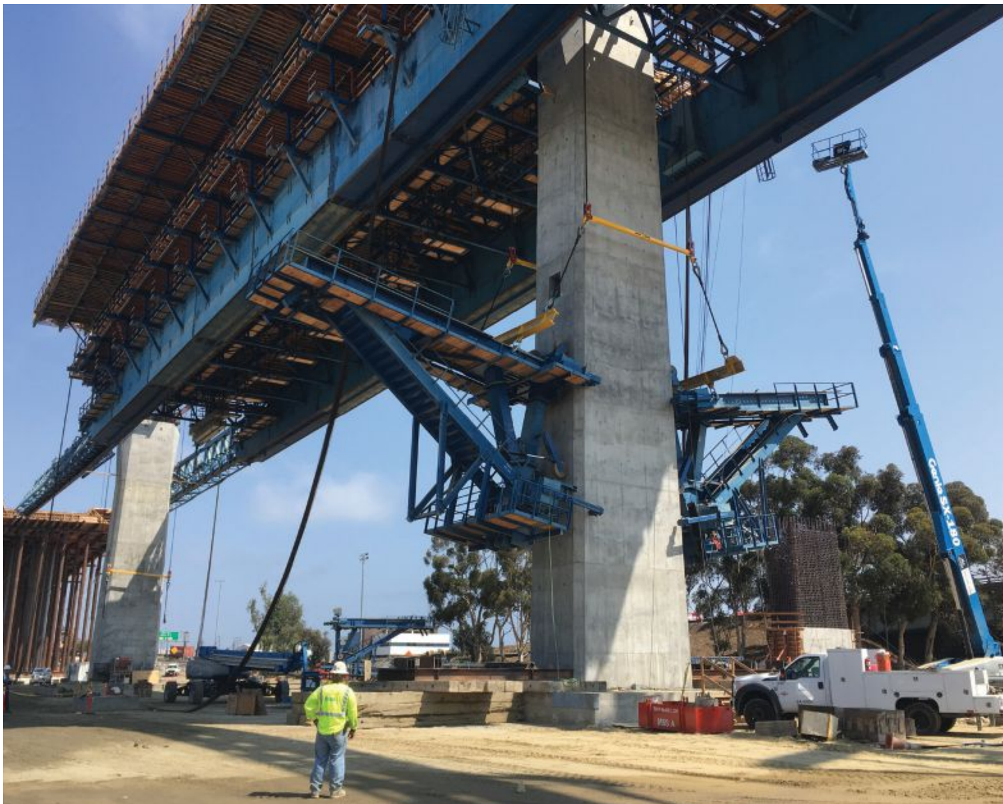
Hand-in-glove with box-girder construction has been the industry's use of what many call "California" (conventional) falsework. To the casual observer, these temporary works can appear baffling, but they are a well-understood and economical means of bridge construction on the West Coast. This type of falsework, however, is not practical for heights over 120 ft, which led the team to consider other methods for the tallest portions of the approach structures. They selected a movable scaffold system (MSS) as a means to continue conventional box-girder construction to the height of the main-span bridge.

MSSs are self-launching equipment used to support formwork and concrete for the span-by-span construction of bridges; such systems are commonly used in the construction of long, straight viaducts in Europe and Asia. Whereas launching gantries are not uncommon for the construction of precast concrete segmental bridges, there are no recent examples of MSS projects for cast-in-place work in the United States.

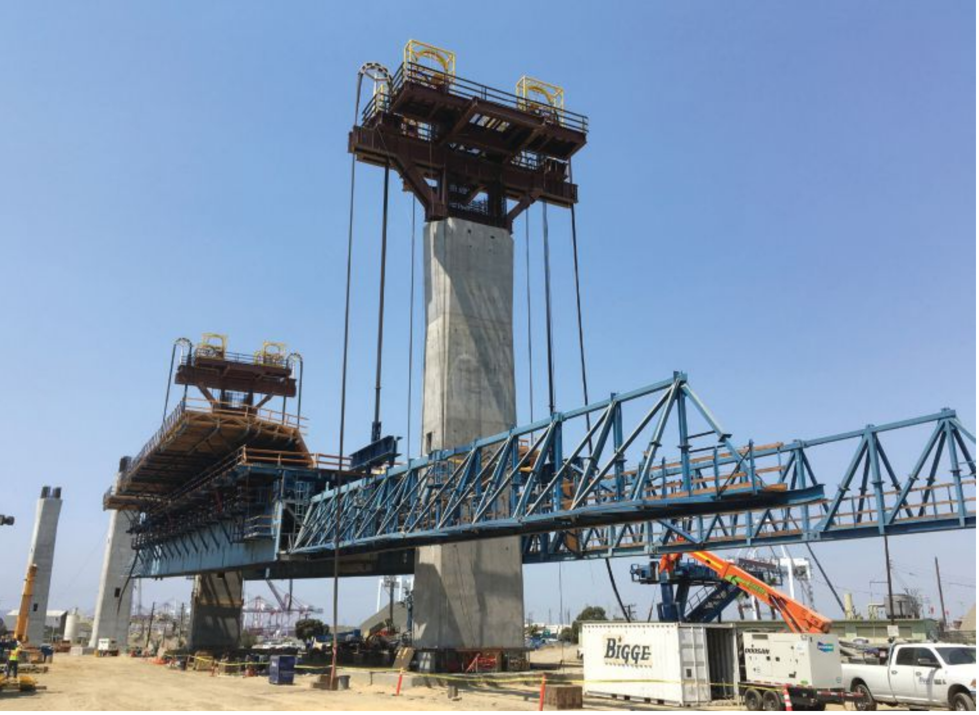
On this project, the details of this construction method were heavily influenced by the design requirements, and seismic considerations were an obvious driver in the bridge design. To that end, integral column connections were essential for seismic performance. As a result, the approach units were configured as integral frames having two to four spans of approximately 230 ft per span. Expansion and contraction between units was allowed at quarter-span hinges. This arrangement limits the amount of movement and bending in the integral columns due to creep, shrinkage, and temperature effects.

Due to schedule and logistics, the project required two MSS units; these were designed and supplied by Strukturas AS. One unit was put to work on the west approach, the other on the east.

The MSS operations required close coordination with the superstructure design. For example, the direction of construction dictated the location of construction joints and hinges, and ultimately had a strong influence on



Rigging assembly for erection of the brackets under the movable scaffold system. Each bracket supported a load of 3000 kip, which was transmitted to the pier wall by a shear lug on the bracket. Photo: SFI.



The movable scaffold system (MSS) being lifted by strand jacks. The brackets, one of which can be seen in the background on the right below the MSS, were raised in a separate operation. The MSS center section was a heavy box girder that supported the concrete span and lighter trusses at each end for launching. The total length of the MSS was over 500 ft. Photo: SFI.

the post-tensioning (PT) profile. For continuous superstructures using MSS, superstructure concrete is placed from the quarter point of one span to the quarter point of the next. This is a normal practice for many structure types because it takes advantage of an inflection point, and it had the benefit on this project of minimizing bending demands in the MSS. With the construction method having a direct influence on the design, the engineer and contractor had to commit to the construction sequence early in the planning.

The MSS was arranged in an underslung configuration, where the launching girders straddle the pier columns below the superstructure. With an empty weight of 3000 kip, each MSS could support approximately 7000 kip of concrete. At the lead pier, the two main girders were supported on brackets anchored on the sides of the pier columns, avoiding the need for temporary columns to the footings.

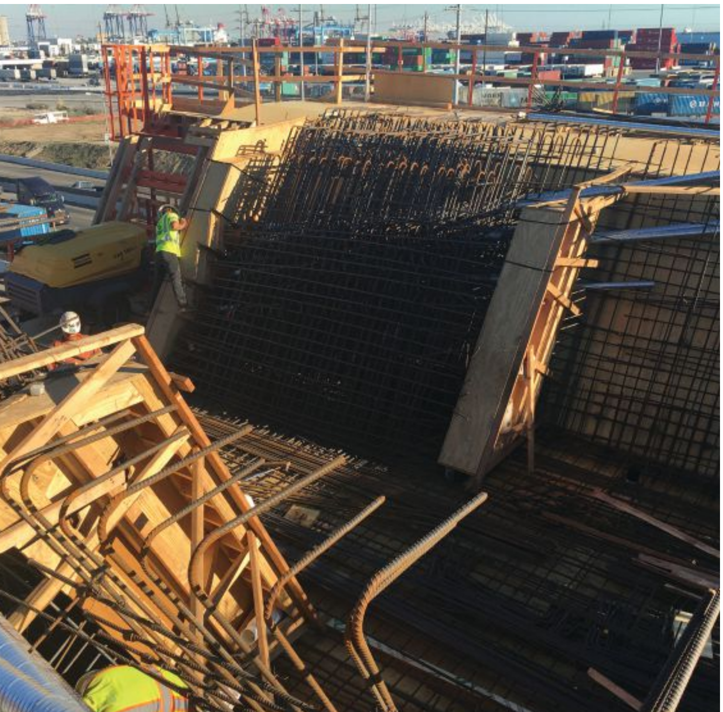
Each bracket supported a load of 3000 kip, which was transmitted to the pier wall by a shear lug on the bracket. This detail required a temporary opening in the pier wall, which was patched after the span was complete and the bracket removed.

For concrete placement, the rear of the MSS was supported near the quarter span by a "gallows" beam. This beam transferred the weight of the MSS and concrete to the webs of the box girder near the construction joint to hold the formwork tight to the completed section.

Similar to traditional box-girder construction, the spans were constructed and cast in two stages. The bottom slab and webs were cast first and partially post-tensioned before the deck slab was constructed. As with conventional post-tensioned box girders, the majority of the tendons were located in the webs and were draped between piers. With the construction joints near the quarter point of the span, where bending demands are modest, the PT anchors were spaced over the depth of the web in full-height blisters to allow access for tensioning from inside the box girder. At these blisters, tendons from adjacent spans overlap, making the tendon profile continuous from span to span.

For the deck concrete placement, the slab over the interior cell of the box girder was supported using shoring similar to that used in multistory buildings, which was

Reinforcement and formwork installed for full-height blisters where post-tensioning anchors were located. Use of blisters allowed access for tensioning from inside the box girder. Photo: McNary Bergeron & Associates.



Reinforcement configuration for bottom slab, webs, and pier diaphragm. Post-tensioning ducts are being installed at top of webs. Photo: McNary Bergeron & Associates.

Each bracket was equipped with rubber wheels to guide it up the face of the column. At the top of the lift, the wheels were retracted to place the shear lugs into the pockets on the sides of the column. Bars at the top and bottom of the bracket were then tensioned to secure the entire assembly to the column. Photo: Strukturas AS.

then stripped out for the next span. Once the span was fully cast and the concrete had reached design strength, final post-tensioning was installed and jacks under the MSS were lowered to release the load from the MSS.

With the new span supporting itself, the formwork could be unbolted along the girder centerline and the two launching girders were slid apart from each other to clear the pier column and allow launching to the next span.

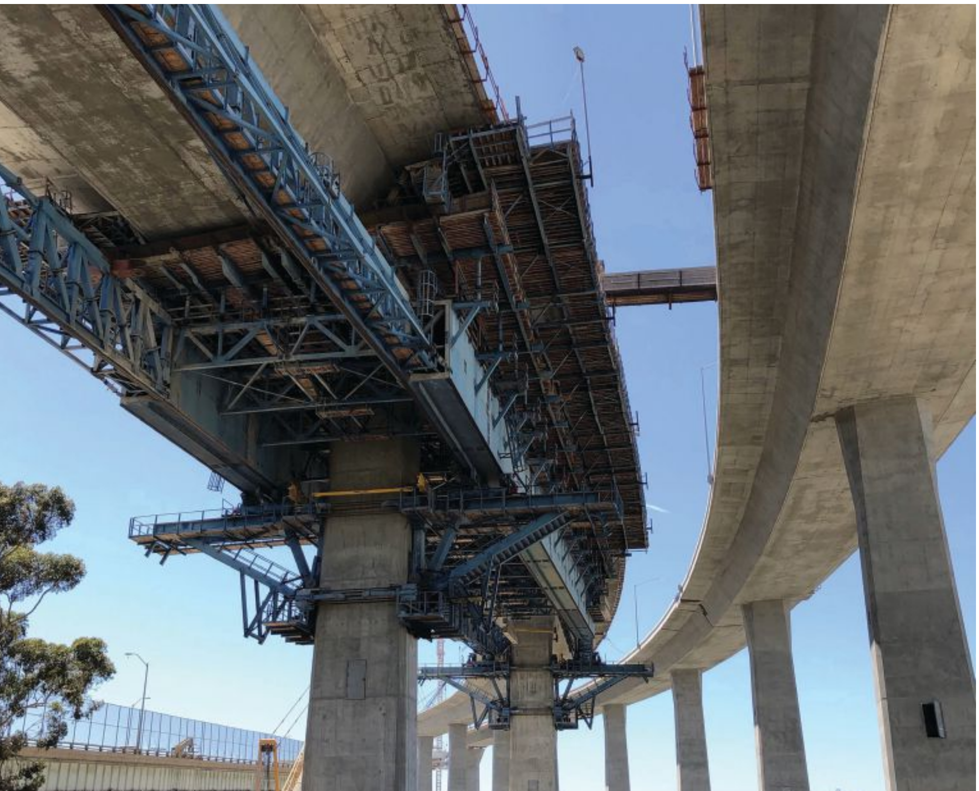
The launching girders varied in configuration and capacity along their lengths based on demands and function. The center section of each launching girder consisted of a heavy box girder to support the concrete span. At each end, the girders transitioned to a lighter truss configuration for launching. With the nose and tail required to launch 230 ft from pier to pier, the MSS measured over 500 ft long.

To support and access the MSS, assembly and disassembly were done on the ground. Each MSS unit was delivered in approximately one hundred 40-ft shipping containers and then the pieces were bolted together in the footprint of the bridge. McNary Bergeron & Associates provided construction engineering for the temporary works associated with lifting the assembled MSS into position. With the equipment assembled on the ground, strand jacks supported on temporary frames at the top of the pier columns were used to lift the MSS to height at a rate of 20 ft per hour over the duration of a work shift. Because the MSS obstructed all crane access from overhead, the support brackets were then positioned underneath for a similar lift using strand jacks.

Due to the overhead constraints, the brackets were lifted in pairs using a rigging system resembling a marionette puppet. Each bracket was equipped with rubber wheels to guide it up the face of the column. At the top of the lift, the wheels were retracted to place the shear lugs into the pockets on the sides of the column. Bars in the top chord of the bracket were then tensioned to hold the entire assembly tight to the column, and the MSS was lowered onto the launching wagons and brackets. After spans were completed, the brackets were taken down using similar methods and cycled ahead to the next pier.

Because the approach spans consisted of two girder lines, each MSS unit made two runs. After the first run, the equipment was lowered and moved to the next heading using self-propelled modular transporters.

The movable scaffold system (MSS) under the completed bridge. The formwork was shifted on the MSS to allow construction of the curved concrete box girder. Photo: McNary Bergeron & Associates.



Conclusion

With the upfront cost of the equipment, MSS is most viable on projects with a significant number of consistent span lengths and geometry. It is also a very linear method of construction that requires close coordination with the design and is best suited for design-build or alternate delivery methods.

With those constraints met, this project demonstrates that, in the right conditions, MSS is an efficient method for the construction of box-girder bridges. During the project, each MSS unit produced one span every two to three weeks, translating to approximately 90 ft of new bridge per week per heading. More importantly, the system provided an option where conventional falsework was not practical.

Compared with other construction methods, MSS has unique advantages. Geometry control and related engineering oversight are greatly simplified because spans are constructed in a single go. Similarly, the system minimizes construction joints and construction-related openings in the deck. Lastly, in the specific example of this project, MSS construction proved to be well adapted to seismic design details, including integral piers, hinges, and heavy longitudinal reinforcement.

The completion of the Gerald Desmond Bridge is a great achievement for everyone involved in the project, and the use of MSS represents the design-build team's resourcefulness in pairing industry expertise with new methods to achieve great goals.

Jeremy Johannesen is a principal with McNary Bergeron & Associates in Broomfield, Colo.