Piece BY Piece

BY MICHAEL P. CULMO, P.E.

Span-by-span bridge construction, using modular steel bridge elements, can serve as a viable and economical bridge-building alternative.

ACCELERATED BRIDGE CONSTRUCTION (ABC) has come a long way in the last 10 years.

And prefabricated, modular elements made with steel beams have been a big factor in making this happen, as they can be used to reduce the weight of the assemblies, thereby making crane installations more cost effective and viable.

Modular steel beam/deck elements generally consist of two or three steel beams with a composite concrete deck cast in the fabrication plant. They are erected quickly and joined with reinforced concrete closure pours made with high-early-strength concrete; a bridge superstructure can be built in as little as two days using this technique.

One of the more successful examples of this method was the 93Fast14 project in Medford, Mass. (a 2012 NSBA Prize Bridge Awards winner), which involved replacing 41 spans on 14 bridges along Interstate 93. The 14 bridge superstructures were replaced during ten 55-hour weekend work periods. The use of structural steel for the beam elements made the project possible since crane capacities controlled many of the sites.

Michael P. Culmo (culmo@cmeengineering.com) is vice president of transportation and structures with CME Associates, Inc., in East Hartford, Conn.

Span by Span

Let's take a look at the two common ABC methods to design and construct a multi-span bridge. The first is to detail multiple simple spans between supports, sometimes referred to as "span-by-span" construction. Conventional simple-span bridges require expansion joints at each pier—historically a problematic feature of many bridges—as leaking joints, considered by many to be the most common cause of premature bridge deterioration, lead to the corrosion of beam ends and deterioration of the substructures under the joints.

The second method for designing multi-span bridges is to use continuous-span beams, which do not require deck expansion joints at the interior supports, and require less structural steel for a given span arrangement.

Span-by-span beams are simply erected on the substructures without the need for splicing and shoring towers. The problem with leaking deck joints has been addressed by designing these bridges to be either joint-less or continuous for live load by using simple concrete pours at interior supports to eliminate the need for deck expansion joints. Using span-by-span techniques for the superstructure can accelerate the process by eliminating the need for welded or bolted field splices in continuous girders. Beam erection can progress very rapidly as the modular units are inherently stable. Once set, the crane can release the beam without the need for any external bracing.

One method that has been developed to eliminate deck joints on simple-span bridges is "link slab" technology. A link slab is built by simply casting the slab continuously across the pier linking the two spans. The link slab is designed to accommodate the live load rotation of the girders without significant cracking. This is accomplished by debonding a portion of the deck near the support to form the link slab, which acts as a flexible beam. The recommended

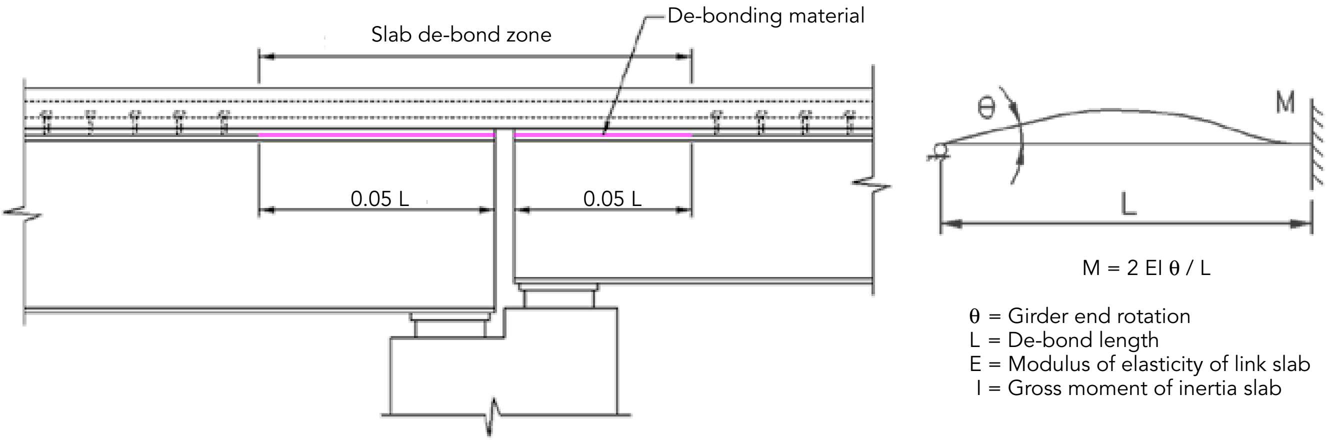
The 93Fast14 Project in Medford, Mass., demonstrated the viability of modular steel bridge construction by replacing 41 spans in ten 55-hour weekend work periods.

length of de-bonding is 5% of the adjacent span on each side of the pier. Keep in mind that link slabs are not a form of continuity. The bending moments in the link slab are much less than typical negative bending moments in continuous girder bridges; therefore, the design of the girders is based on simple-span supports.

The bending moment in the link slab can be calculated using a simple equation. Reinforcing can then be designed to resist the bending and control cracking. The bending stresses in link slabs are often less than the tension stresses that develop in continuous-span bridges. The same principals of crack control reinforcing design are applied to both.

Greater Efficiency

We are taught in engineering courses that continuous steel girders are more efficient than simple-span girders and that "least weight equals least cost." In principle, these lessons are true. But in order understand the true efficiency of steel bridge construction, the engineer needs to look at the total cost of the bridge, including the cost of connections, construction methods and deck reinforcement. In order to study the efficiency of span-by-span construction, we investigated the preliminary design of a hypothetical two-span bridge. The bridge selected is a typical expressway overpass with equal spans of 122 ft and five girder lines.



Bridge deck joints can be eliminated at piers through the use of "link slabs."

▲ Typical two-span overpass bridge.

▼ Continuous girder with bolted splices.

▼ Simple-span bridge with joint-less deck.

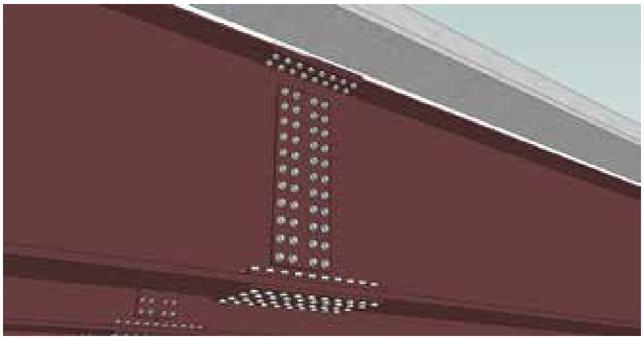
Two bridge types were studied for this structure: continuous girders and simple-supported girders. The NSBA computer program Simon was used to complete a preliminary design of the girders. (Simon is available for free at **www.steelbridges.org** and can be used to design efficient steel girders for simple- and multiple-span bridges based on the AASHTO LRFD *Bridge Design Specifications*.)

The results of the preliminary design showed that the simple-span bridge required 30 more tons of steel at a cost of $70,000 more than the continuous-span option (based on construction costs in the Northeast). The remainder of the study was dedicated to investigating the total cost of the bridge in order to determine if other factors would offset the increased cost for the structural steel.

On such factor was splicing. The 122-ft-long simple-span girders can be shipped in one piece (without field splices), where the continuous girders would need at least one field splice. The study assumed that two field splices would be required for the bridge. It may be possible to build this bridge with one splice, but the length of the pieces would be more than what some permitting agencies would allow.

Another NSBA computer program, Splice, was used to design the bolted splice for the continuous girder study bridge. This program can efficiently design a bolted field splice according to the requirements of the AASHTO LRFD *Bridge Design Specifications*. The final design of the splice included 116 high-strength bolts, and the cost for fabrication and installation of the splice was estimated to be $5,800 per splice (again, based on typical regional construction costs). By eliminating the need for bolted field splices in the span-by-span bridge, an estimated cost savings of $58,000 could potentially be realized.

The *Bridge Design Specifications* require the use of longitudinal reinforcing steel in the negative moment region of continuous girder bridges in order to control cracking due to composite dead load and live load moments. In general, the design of link slabs results in longitudinal reinforcing that is much less than that used in continuous girder bridges. In addition, the link slab reinforcing steel need only be applied over the link slab zone, which is typically smaller than the negative moment region of a continuous girder. For the study bridges, the link slab design saved considerable reinforcing steel when compared to the continuous-span bridge, which equated to an approximate savings of $22,000.



▲ Bolted field splice designed using NSBA's Splice program.

Another avenue of potential cost savings with simple-span construction is erection. Many agencies require the use of shoring towers under bolted splices. Even if shoring towers are not used, the cranes are required to hold the girders until sufficient bolts are installed in the field splices, which is a less efficient process. The potential erection cost savings for the simple-span bridge was estimated to be approximately $30,000.

When it comes to bearings, simple-span construction requires two lines of bearings at the center pier, compared to one line of bearings in the continuous girder bridge. The simple-span bearings are small but there are more to fabricate and install, and the cost of the extra bearings was estimated to be approximately $1,500.

When the above items are accounted for, an estimated net cost savings of $38,500 could be realized for the span-by-span bridge.

Item	Net Cost Savings
Structural Steel	-$70,000
Bolted Splices	$58,000
Additional Deck Reinforcing	$22,000
Steel Erection Cost	$30,000
Bearings	-$1,500
Net Savings	$38,500

Net cost savings for simple-span construction as compared to continuous bridge construction.

To recap:

1. Continuous-girder spans require less structural steel and fewer bearings.
2. The simple-span construction method may not need bolted field splices, uses less additional deck reinforcement and may be less expensive to erect when compared to a continuous girder bridge.
3. Least weight of structural steel does not always equate to least overall bridge cost.
4. By using link slab technology, simple-span construction can be accomplished with a joint-less deck that is durable.
5. Simply put, simple-span construction is a valuable tool for accelerated bridge construction projects.

This study was limited in that only one bridge was investigated. Other bridge configurations will yield different results. In some cases, a continuous-girder bridge may have a lower overall bridge cost. The conclusion of the study is that simple-span construction should not be ignored due to concerns over the structural efficiency of the girders alone. When total bridge costs are applied, this method can be competitive or even less expensive than conventional continuous-girder designs.