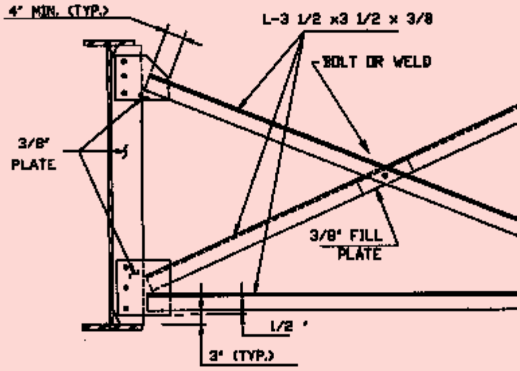


BRIDGE CROSSINGS

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Practical Information For The Bridge Industry

# Erection Engineering For Steel Bridge Superstructures

**By Steven A. Weinhold, P.E.**

In the past, bridge engineers have been primarily responsible for the structural integrity of the completed structure, not for the partially completed structure or "erection stage" of the job. This responsibility is changing rapidly as new specifications now require the design engineer to investigate the structural stability of the bridge superstructure while the bridge deck is being cast. Due to the competitiveness of designs between steel, concrete and various composite materials, designers are constantly striving for longer spans, lighter girders and wider girder spacings (to name a few). However, these factors may create stability and accessibility problems for shipping and erection that weren't of great concern in the past.

We all live in a competitive bidding environment. The design engineer needs to understand the implications of these new designs and factors. They may create additional costs for the shipping and erection phases of the project: What is saved on material and fabrication costs may not offset the additional costs of shipping and erection of the steel bridge superstructure.

The intent of this article is to give a brief introduction to the world of steel bridge erection engineering and to provide information for design engineers so that they may have a better understanding of what is involved in some of the planning used to create an erection procedure.

## Crane Information

There are three basic types of cranes used to erect steel bridges. All three have advantages and disadvantages. Choosing a particular crane or cranes for a project depends on several conditions. These include: the sizes and weights of the girders being erected; availability of equipment; and site conditions.

- Conventional truck crane with lattice boom. This is probably the most popular and practical crane to use on construction projects that have a sizeable duration due to the crane's lifting and reaching capacities. The crane can be moved from job-to-job under its own power, but the boom sections and counter weights must be hauled separately on trucks. Also, most of these cranes require an assist crane to assemble them on-site. Truck cranes can pick the load either over the rear or side of the machine depending upon which counterweights are used. They transmit the load to the earth via the outriggers. Outriggers are designed for vertical loads only and therefore should be placed on a level surface.
- Hydraulic crane with telescopic boom. This type of crane usually requires less assembly than the conventional truck crane but has approximately one-half the capacity of similar conventional cranes. In other words, a 70-ton conventional crane has similar reaching and lifting capacities as a 140-ton hydraulic crane. Hydraulic cranes are good for both short-duration jobs, due to the low shipping costs, and for jobs with tight quarters in which the telescopic boom becomes advantageous versus the fixed length of a lattice boom.
- Crawler crane with lattice boom. This type of crane runs on tracks or "crawlers" that are spread far enough apart that they don't have to use outriggers as do the truck cranes. Crawler cranes have big mobilization costs due to the number of truck loads required to move all the components. There are, however, advantages to using a crawler crane. First is its ability to move while picking up a load. The crawlers can handle lateral loads, unlike the outriggers on the truck cranes. Also, the cranes can rotate 360 degrees while picking up a load.

## Site Conditions

Site conditions usually dictate how the bridge will be erected and how the steel will be delivered. Site conditions can be improved by the general contractor if the contract documents allow them to do so. However, conditions such as overhead power

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lines, roads, navigable canals, rail roads, streams, rivers or wetlands often won't allow for adjusting the site conditions. If the site conditions cannot be adjusted, then the contractor must work around all of these in order to erect the bridge, which adds to the cost of the project. Fortunately, proper planning during the design stage of the project may eliminate some or all of these costs. Consultants should remember that the most cost-effective solution for girder erection is to deliver each girder segment to the erection site on a truck loaded at the fabricator's shop, pick the girder directly from the truck with a single crane at the premarked center of gravity without any temporary reinforcement, and put it into its final position without any falsework or temporary support. Therefore, it is imperative that proper planning be done (preferably at the design stage) to provide access for both the crane and the delivery truck at the same time and in the same area in order for the crane to immediately pick the girder directly off the truck. Also, the design engineer can possibly eliminate the need for falsework or temporary support if they consider this condition during the design stage and make the girder sections large enough to withstand the imposed stresses.

## How Big Can I Make This Girder?

A properly designed steel bridge is very strong and stable when it is fully erected and all the bolts are installed. But take a individual, long member that has a small compression flange and a relatively large bending moment due to its self weight and there might be a problem. How can it be shipped? How can it be erected? A principle consideration is the lateral stability of girders due to their large unsupported length during shipping and erection. Consultants often ask: "What's the smallest size flange I can use on a girder?" I don't believe there is an exact answer to that question. Rather, it has to be investigated on an individual basis. However, there are some guidelines:

## Shipping:

**Length—**up to 150' is preferred. Longer girders are possible but must be examined on an individual basis. Most states allow up to 80' without restrictions.

**Height—**a load height of up to 14' is possible. Most trailers are approximately 4' high. Add approximately 6" for dunnage. Therefore, overall girder height should not exceed 8'-6".

**Width—**widths up to 16' may be possible with permits and police escorts. If girders must be laid down (on their axis) they must be fully supported along their entire length.

**Weight—**Pieces up to 40 tons are commonly accomplished with permits. Weights up to 100 tons are possible, but require cooperation with all states along the route.

**Flange Size—**try not to use less than a 14" width. Remember: the wider the flange width, the easier it is to ship and erect the girder. This is especially true with curved girders.

Want to know if the girder you designed can be shipped? Refer to Figure 1, which represents a two-support condition that commonly occurs when shipping large girders. Put your girder on the truck and see if it works. The girder is laterally supported only at its reaction points. When calculating the actual stresses, you need to add 200% to the actual stress to account for impact; that is, $f_b + 2f_b = 3f_b$, which must be less than the allowable stress, $F_b$.

## Erection:

The possibility of lateral buckling of girders during erection must be investigated when long, slender girders are involved. Many girders are designed to be stable only when their compression flanges are supported laterally. An approximate determination of the stability of a girder may be made by taking the ratio of the overall length of the girder (in inches) to the compression flange width (in inches), or simply $l/b$. Experience has indicated that, as a general, rule girders with an $l/b$ of less than 60 will be stable during erection. For values between 60 and 80, stability is questionable, but may be OK, though further investigation of stresses is required. For values over 80, the girder will be unstable and will require some sort of temporary support.

## Rigging, Stresses And Stability:

Girders are erected by either one or two cranes.

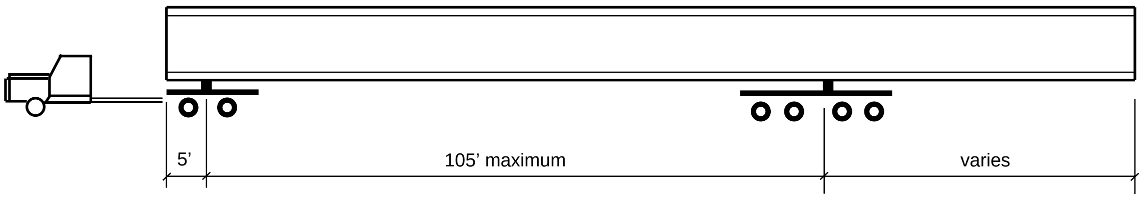


*Figure 1: How Big Can I Make This Girder?*

When one crane is used, the girder can have one pick point or two. When two lifting points are required, but only one crane is available, a spreader beam can be used in order to avoid putting compression forces into the girder being lifted. A spreader beam is designed as a beam-column that resists the horizontal force component of the wire ropes that connect to the crane hook. The angle of these wire ropes should be greater than or equal to 45 degrees.

When two cranes are used to connect, the girder can have two, three or four pick points, depending on whether spreader beams are used by one or both cranes. When utilizing two cranes, the load that each crane picks is determined knowing the distances from the center of gravity of the girder to each of the pick points.

Two basic devices are used to connect the girder to the crane hook. One is wire rope slings that can be used in a vertical, chocked or basketed arrangement. The chocked arrangement has approximately three-quarters the capacity of a vertical arrangement, and the basketed sling capacity has twice that of the vertical sling. When picking beams and girders, the vertical load is applied to the edge of the vertical sling. Therefore, bending stresses in the bottom flange and web buckling may need to be checked. Temporary hardwood stiffeners can be used between the flanges to help reinforce the girder if required. The other lifting device commonly used is a beam clamp. Beam clamps connect directly to the top flange of the girder. When using beam clamps, the bending stresses in the top flange of the girder must be checked as well as the stresses in the flange-to-web connection. The load can be distributed along the flange a distance equal to the width of the beam clamp plus twice the distance from the bearing point to the face of the girder web.

One of the primary goals of the erector is to get two lines of girders erected with crossframes attached in order to achieve stability and eliminate the possibility of the girders overturning. Once two girders are in place with the diaphragms connected, stability concerns relative to steel erection usually are eliminated. With the addition of the second girder line and crossbracing between them, the governing instability mode changes from torsional-flexural buckling of the single girder to primarily flexural buckling of the two girders acting as a unit. Another alternative is to erect the girders in pairs with their corresponding crossframes attached. Once the pair of girders is erected, the remaining girders can be set as single units. However, paired girder erection isn't always possible due to the large crane required to lift the unit. While sometimes paired girders can be lifted using two cranes, often access for both cranes to setup near the girder pair is a problem.

Curved girder erection does not differ greatly from straight girder erection except that temporary shoring or a holding crane may be necessary to stabilize the first girder until the second girder can be erected with its corresponding crossframes. This isn't always possible and is dependent on if there is an area to either setup this shoring or mobilize a holding crane. The center of gravity of a curved girder is not in the plane of the web, which creates a tendency for the girder to want to rotate or "roll". Upon the erection of the second girder and the attachment of crossframes, the two-girder unit is now located between adjacent supports, which creates positive reactions at all the bearing locations and therefore eliminates this tendency to roll.

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*The mission of The National Steel Bridge Alliance (NSBA), which was formed in 1995, is to enhance the art and science of the design and construction of steel bridges. Its activities include organizing meetings, conferences and national symposia, conducting the Prize Bridge Awards competition, supporting research, developing design aids, and providing assistance to bridge owners and designers. The NSBA membership includes representatives from all aspects of the steel bridge industry.*