Selecting the Right Bridge Type

Course Number: ST-02-204

PDH: 2

Approved for: AK, AL, AR, DE, FL, GA, IA, IL, IN, KS, KY, LA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NE, NH, NJ, NM, NV, NY, OH, OK, OR, PA, SC, SD, TN, TX, UT, VA, VT, WI, WV, and WY

State Board Approvals

Florida Provider # 0009553 License #868
Indiana Continuing Education Provider #CE21800088
Maryland Approved Provider of Continuing Professional Competency
New Jersey Professional Competency Approval #24GP00025600
North Carolina Approved Sponsor #S-0695
NYSED Sponsor #274

How Our Written Courses Work

This document is the course text. You may review this material at your leisure before or after you purchase the course.
After the course has been purchased, review the technical material and then complete the quiz at your convenience.
A Certificate of Completion is available once you pass the exam (70% or greater). If a passing grade is not obtained, you may take the quiz as many times as necessary until a passing grade is obtained).
If you have any questions or technical difficulties, please call (508) 298-4787 or email us at admin@PDH Pro.com.

1.0 INTRODUCTION

One of the initial choices to be made by the designer is to select the most appropriate bridge type for the site. While this choice is not always straightforward, selecting the right structure type is probably the important aspect of designing a cost-effective bridge.

1.1 Required Span Lengths

Various types of bridge superstructures provide efficient solutions for different span arrangements. There are many possible reasons for choosing particular span lengths for bridges, some of which are discussed below.

1.1.1 Owner Desires

In many cases, the owner's desires will drive the selection of the bridge type. Some owners tend to push their bridges toward the shortest spans possible, with an eye toward allowing a choice of materials or to prefer a specific material type.

Owners will occasionally choose a bridge because they desire to construct a specific bridge type at a location. In some cases these desires come directly from the owner, but often public opinion influences the selection of the bridge type, particularly for long span bridges.

Occasionally, an owner will prescribe a certain bridge type for reasons of perceived prestige. The choice may be made specifically to design a bridge type that has not been done by that owner, to design a certain bridge type with a record span length, or to create a signature structure.

1.1.2 Hard Requirements

One critical requirement that often controls the main span lengths for water crossings is navigational clearance. The U. S. Coast Guard is generally the controlling agency regarding required span lengths for navigable inland waterways
.
Another non-negotiable controller of bridge span lengths can be defined by environmental commitments. Given the increased sensitivity to minimizing adverse environmental impacts, there have been many cases where the span arrangements have been set to meet environmental commitments.

1.1.3 Existing Constraints

Locations of existing constraints often control the span arrangements for new structures. For new, high-level structures, the locations of existing features that are being crossed by the new structures may control certain span lengths or span arrangements. This situation may occur where expanded interchanges are being constructed on or near the site of existing interchanges where the original structures will be retained or used for staging during construction. The location of existing surface roadways often controls span arrangements for new bridges.

Occasionally it is more cost-effective to move the surface roadways to accommodate the new bridge, but in congested urban areas this is rarely possible.

Another constraint encountered by designers/owners is railroads. There are significant costs associated with moving tracks or interrupting rail service to accommodate construction of new bridges. It is often beneficial to increase span lengths to minimize impacts to the railroads. Since the railroads are for-profit enterprises, they tend to be very protective of their facilities in order to maintain profitability.

1.1.4 Other Constraints

Site access may control the choice of span arrangements for structures in certain cases. When constructing bridges over wide, deep valleys, it is sometimes advantageous to increase span lengths to eliminate costly piers. In some cases, deck structures such as trusses or arches may become economical.

Occasionally, the desired construction schedule may impact the structure type that is chosen. Certain types of structures lend themselves to short construction durations, which may be important to the owner.

Local contractor expertise may also affect the selection of the structure type. Certain types of structures are not common in certain regions. For example, while segmental structures are relatively common in the southeast, they are rare in many parts of the northeast, where many owners will not use segmental structures because of the difficulties associated with deck replacement. As a result, few contractors in the northeast region have experience in segmental construction, which will likely result in either high construction costs or out-of-state contractors winning the bid.

2.0 BRIDGE TYPES

There are many bridge types that are typical for current construction. The various types are ideally suited to different span lengths. However, there is generally significant overlap in the applicable ranges for the most common span ranges, so multiple bridge types are generally viable at most span ranges.

2.1 Rolled Beam Bridges

Rolled beam bridges using W-shapes are used in some situations, mainly for simple spans up to approximately 100' or continuous spans up to approximately 120'. They are generally made composite with the bridge deck. Rolled shapes result in bridges with higher unit weights of steel (in pounds per foot) than do plate girders. However, the unit cost of rolled shapes is significantly lower than is common for plate girders due to the simpler fabrication. The details are also generally less expensive than for plate girders since transverse stiffeners are not usually required. In addition, the diaphragms between beams usually consist of rolled shapes with channels being the most common choice. The limited amount of welding and simple diaphragm details often make rolled beam bridges more economical than plate girders in short span ranges.

2.2 Welded Plate Girder Bridges

Deck plate girders are the most common type of steel structure. As recently as the 1970s, many bridges were designed using two deck girders, transverse floorbeams at regular intervals, and longitudinal stringers either continuous over the floorbeams or framed into the floorbeam webs. However, as welded girders became the predominant method of fabrication and cracks occurred in girders due to poor fatigue details, the issue of fracture criticality became a concern to many agencies.

Through girders provide another welded plate girder option. A through girder bridge generally has two girders near the edges of the deck with shallow floorbeams connecting the bottom flanges of the girders and often will have longitudinal stringers framed into the floorbeams. The girder top flanges and much of the web extend above the top of the bridge deck. Knee braces are generally provided at each floorbeam location in order to brace the girder top flange. The use of the through girder system is generally limited to sites which must accommodate a severe superstructure depth restriction.

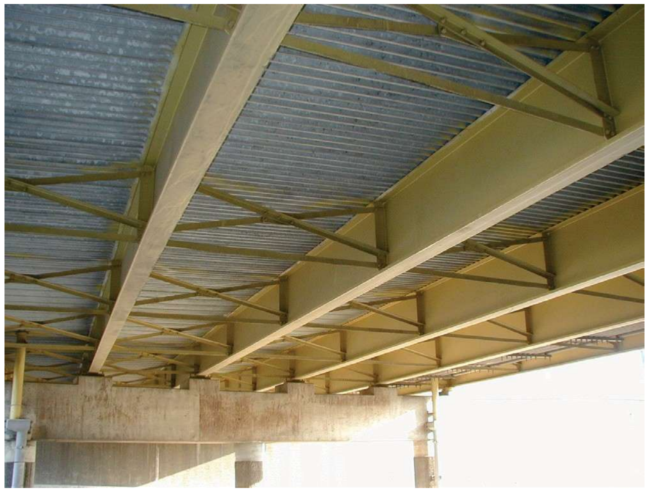

Figure 1 Photo of a typical multi girder system with x-type intermediate cross frames and stay-in-place formwork used for constructing the deck slab

There are several reasons that through girder bridges are not commonly used for highway structures. The system results in two-girder structures, which are fracture critical, meaning that the failure of one of the main girders could lead directly to the failure of the entire bridge. The main girders cannot be made composite with the bridge deck, meaning that the deck offers no strength benefit to the girders. Finally, the top flanges of the girders in the compression regions are braced only at the floorbeam spacing, rather than full length as would be the case for a composite deck girder bridge. This will require additional steel in the top flanges of the girders because of the strength reductions resulting from the unbraced length.

Eventually, multi-girder bridges became the desired deck girder bridge configuration, and composite construction became common. Designing for composite action allows the designer to account for the strength of the bridge deck in the section properties of the girders. In addition, the top flanges in the positive moment regions are fully braced in the final condition, allowing the use of higher allowable compressive stresses than are possible for flanges braced at discrete points. Deck girders also offer great flexibility to accommodate variable width roadways and horizontally curved geometry. Additionally, shop layout is generally less complex than would be the case for through girders, trusses or arches.

Deck girder designs are usually optimized for span lengths exceeding about 125 feet if the girder spacing can be set between 11 and 14 feet. For spans lengths less than 125 feet, narrower girder or beam spacing may be more economical. This minimizes the number of girder webs and the overall unit weight of steel. The cost savings for an optimum number of girders will usually offset any cost increases due to a thicker bridge deck. Some agencies still limit girder spacing to the 8 to 9 foot range that was common many years ago, although there is currently no economic reason to do so for longer span lengths.

Crossframes or diaphragms have been provided at a maximum spacing of 25 feet for many years in accordance with the provisions of the *AASHTO Standard Specifications for Highway Bridges (2002)* (1). The *AASHTO LRFD Bridge Design Specifications, 5th Edition*, (referred to herein as the AASHTO LRFD (5th Edition, 2010)) (2) has eliminated the 25 foot maximum spacing requirement and left the spacing up to the designer. While the intent was not to stretch the spacing too far, the desire was to avoid the need to add additional crossframe lines for the sole purpose of limiting the spacing to 25 feet. For a more complete discussion of crossframe spacing and configurations, refer to the Steel Bridge Design handbook module titled Stringer Bridges.

Deck girders can generally be erected with minimal amounts of falsework. Pier brackets may be necessary over the interior supports as the spans increase. Although falsework towers are sometimes used for shorter spans, only when the spans exceed about 200 feet do towers become necessary. Erection of plate girders generally proceeds quickly since there are a limited number of field sections and bolted connections that the erector needs to deal with in the field.

In certain cases, lateral bracing may be required to facilitate construction of the bridge. While this case should be rare when the girders are properly proportioned, lateral bracing may be particularly useful for spans over 300 feet or for very tall structures where winds encountered may be significantly higher than would be expected on structures close to the ground surface.

One variation of the multi-girder system is the girder substringer system. This arrangement is generally used on wider bridges with relatively long spans. As discussed earlier, fewer girders in the cross section will result in greater overall economy in the superstructure design. When the span lengths exceed approximately 275 feet, it is often economical to use a girder substringer arrangement. This system uses several heavy girders with wider girder spacing. Truss crossframes, which in many cases look like large K-frames, are used between the main girders with the rolled beam stringers supported midway between the main girders.

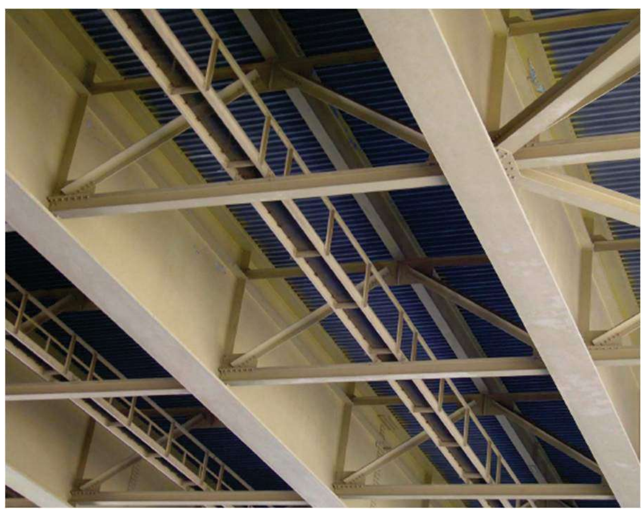

Figure 2 Photo of a typical girder substringer system showing a stringer sitting on top of cross frames

2.3 Trusses

Trusses behave as large beams to carry loads, but are comprised of discrete members that are subjected primarily to axial loads. The members are generally arranged to form a series of triangles that act together to form the structural system. The chords are the top and bottom members that behave as the flanges of a girder. Diagonals and verticals function in a manner similar to the web in a plate girder. Diagonals generally provide the necessary shear capacity. Verticals carry shear and provide additional panel points through which deck and vehicle loads can be applied to the truss. Tension verticals are commonly called hangers, and compression