

Design Considerations for Pedestrian Truss Bridge Structures

By James G. Bauer; Steven Herth, P.E.; and Adam Homelvig, P.E.



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The United States remains one of the world's fastest-growing industrialized nations. Its population is projected to increase to 392 million by 2050 — more than a 50-percent increase compared with 1990, according to the U.S. Census Bureau. This growth is expected to create increased demand for pedestrian steel truss bridges for many purposes including, but not limited to, recreational and fitness activities and tourist attractions. The most common use of prefabricated pedestrian steel truss bridges is for trail applications in park and community environments, which is the main focus of this article.

The history of prefabricated steel truss bridges dates to the 1930s when modular systems were used to meet the needs of the British military in remote locations. In the 1950s, deck/girder bridges were developed as a replacement for deteriorating timber bridges. Today, truss designs are longer, wider, stronger, and more durable. These designs, combined with technology improvements and manufacturing efficiencies, will continue to support the ever-growing and ever-chang-

ing needs of society as they relate to pedestrian, bicycle, and equestrian traffic.

This article provides an overall approach to siting and design considerations for prefabricated steel truss pedestrian bridges, but is not intended to be an all-inclusive, step-by-step tutorial on bridge design. A basic understanding of bridge components and layout, including design codes, bridge styles, and loading, is explained in general detail. Additional detailed reference materials are listed on page PDH 6.

Siting

The layout and design of a prefabricated steel truss bridge begins with a site reconnaissance to determine the bridge width and length (also known as span) dimensions. A simple site investigation — paying close attention to abutment constraints, flood marks, the size of upstream logs, streambed strata, and drift locations — is advised. A geotechnical investigation is recommended. Reference the **CE News** article titled "Articulated Concrete Block Design," dated August 2010 for more information about scour

countermeasures in those suspect locations.

Width — The most common method to specify the width of a pedestrian truss bridge is the clear width measurement between railing system elements. In the event that this dimension is "fixed," it should be highlighted on the bid plans and also in the specification documents. To control lateral deflections and "sway," the horizontal center-to-center of truss dimension should preferably be no less than 1/20th of the bridge span, but should not — except in extreme cases — be less than 1/25th of the bridge span.

Length — The length of the bridge is a function of channel geometry (elevation differences), stream geomorphology, and horizontal and vertical alignments. Typically, the most cost-effective structures are those with horizontal alignments constructed perpendicular to the stream because the result is the shortest bridge length. Bridges with a slight grade are good for surface water runoff. The Americans with Disability Act (ADA) allows for a maximum of 8.33 percent grade (1/12 slope) and 5.0 percent grade (1/20 slope) with and with-

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Learning Objectives

After reading this article, the reader should understand:

- Application options for prefabricated steel truss pedestrian bridges;
- Terminology used to describe a prefabricated steel truss pedestrian bridge; and
- Items to consider for proper layout of a trail bridge.

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This pedestrian through-truss has been custom designed for a skywalk application.

out a pipe handrail, respectively. Environmental considerations such as wetlands, endangered species, and floating debris may also play a factor in determining the length.

The most common method to specify the length of a pedestrian truss bridge is the distance between abutment backwalls. Note that the bridge bearing is typically 3 inches to 9 inches from the abutment back-wall and thermal expansion of the bridge is accounted for with slide bearings and a gap derived from the formula below, which assumes 100 degree temperature differential. Base plates with slotted holes on one end of the bridge allow for this thermal movement in the field.

$$\text{Thermal Expansion (inches)} = \text{Bridge length (in inches)} \times 0.00065$$

Functionality

Several attributes and accessories are associated with the overall functionality, aesthetics, and service of the bridge including deck type, steel finish, safety railing systems, camber, toe plates, and fencing.

Deck type — The deck type selected is a function of the bridge use and has a direct impact on the dead load of the structure. Industry

standard deck options include cast-in-place, reinforced concrete, precast planks, open grating, and composite or wood decking.

Finish — Three main finish options are typically offered for prefabricated steel truss bridges: weathering steel, paint, and galvanized. Each finish has its purpose based on the bridge application and environmental exposure.

Safety rail system — Either horizontal rails or vertical pickets are the industry standard safety systems. Horizontal rails are used most widely for economical reasons while a more costly vertical picket system is used for aesthetic reasons or, at times, safety concerns as the horizontal safety rails may act as a ladder for children to climb, creating a potential hazard. The specifier needs to consider the setting and usage of the bridge, as well as economics, when determining the appropriate safety system for the project.

Camber — Camber is put into bridges for two primary reasons: visual effect and/or to increase clearances beneath the structure.

The use of camber as a structural “arch” is virtually never considered for prefabricated bridges and

should not enter into the decision on how much to camber a bridge. Camber is typically specified in one of four ways or by some combination of the following:

1) A percentage of the dead load deflection. Bridges deemed to be “flat” are usually cambered to offset 150 percent of the full dead load deflection to ensure that there is no sag due to fabrication tolerances, et cetera. Once the bridge is in place, a slight “crown” is hardly noticeable but a small amount of “sag” in the bridge may be visually unappealing.

2) A percentage of the full bridge length (typically 1 to 2-1/2 percent).

3) A specified vertical dimension at bridge midspan.

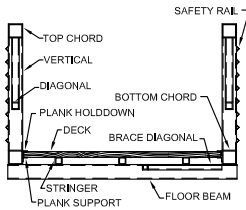
4) To produce a desired deck slope (typically in conformance with ADA where required).

Camber is typically based on a circular curve. There is minimal difference between a circle and a parabola at the typical cambers used in pedestrian structures. Also, vehicle speeds, if any, are low; therefore, the increased cost to detail and fabricate a parabolic arch is unwarranted.

Additional accessories and their general use(s) are as follows:

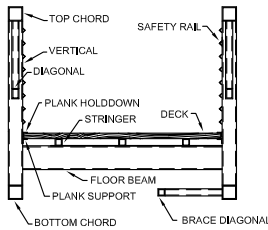
- **Toe plate** — required on all H-section bridges (Figure 1b) or whenever there is no continuous structural member at or near deck level. Used to keep people from inadvertently stepping off the bridge and to prevent objects from rolling off the bridge.
- **Fencing** — typically used on overpass structures to ensure pedestrian safety and prevent falling objects.
- **Rubrail** — typically used for bridge structures on bicycle paths. Mechanically attached at handlebar height of 42 inches from top of deck per AASHTO “Guide for the Development of Bicycle Facilities.”

Figure 1A



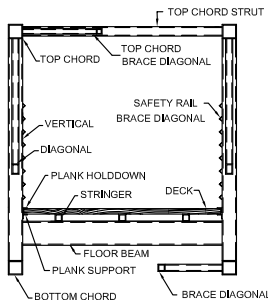
HALF THROUGH UNDERHUNG TRUSS
WITH UNDERHUNG FLOOR BEAM

Figure 1B



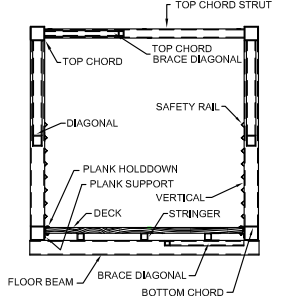
HALF THROUGH H-SECTION TRUSS
WITH RAISED FLOOR BEAM

Figure 1C



FULL THROUGH "BOX" TRUSS
WITH RAISED FLOOR BEAM

Figure 1D



FULL THROUGH "BOX" TRUSS
WITH UNDERHUNG FLOOR BEAM

Design

The design of prefabricated steel truss pedestrian bridges is based on the siting and functionality factors previously discussed combined with the loading conditions — wind, dead, live, fatigue, snow, seismic, and stream force — required for the bridge. Seismic and stream load forces are key determinations that should be addressed by the specifying engineer during the specification phase and are discussed briefly in this article.

Truss type — Often, the aesthetics of a particular truss type is the driving factor for the selection process. As previously mentioned, prefabricated truss bridges went into use in the 1930s, but the design and use of truss bridges dates to 1820 when the Town's Lattice Truss was patented, which is one of only 27 truss types in use globally. Today, one of the most common styles is the Pratt Truss, patented in 1844, which has vertical members and diagonals sloping to the center, resulting in a statically determinate structure that is ideal for long spans. This section focuses on Pratt Truss design considerations that include four basic cross section details as shown in Figure 1.

The following is a brief discussion of typical scenarios where each of the common bridge types could be utilized most efficiently. These scenarios consider shipping and fabrication costs as well as efficient structural use of materials, recognizing situations where geometry is a concern.

A *Pratt Truss with an underhung floor beam* (shown in Figure 1a)

is typically most cost-effective on relatively short-span bridges (up to about 50 feet in length) or on some longer spans where below-deck clearance is an issue. However, their economical use depends on the bridge loading and deflection requirements. Heavy loads such as large vehicles can affect the decision on when to use a Pratt Truss with underhung floor beams, which may not be the most efficient bridge type to use with heavy concentrated floor loads.

H-Sections (shown in Figure 1b) are typically most efficient on medium- to long-span structures (50 feet to 240 feet) under one or more of the following situations:

- below-deck clearance is not an issue;
- on heavily loaded structures;
- bridges with large vehicle loads or stringent deflection or vibration limitations;
- where a maximum handrail height is a limitation and a deep truss is required structurally; or
- where no overhead structural elements are a desired condition.

Through or box trusses are used on relatively long spans (100 feet to 250 feet) where below-deck clearance is an issue, where enclosing the structure with glazing or fencing is desired, or where the structure requires roofing.

The economical determination of the truss depth (center-line to center-line of chord dimension) depends on a number of factors: guardrail height, chord stress levels, shipping considerations, and lateral support of the top chord. As a

Figure 1E

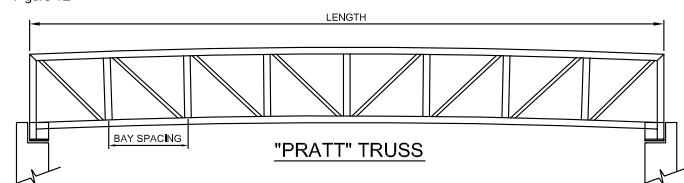


Figure 1: Pratt truss bridge cross section details

Bridge Width (w)	Two-wheel vehicle (lbs)*	Four-wheel vehicle (lbs)*
$w < 4'-0"$	1,200	NA
$4'-0" \leq w \leq 6'-5"$	1,200	4,000
$6'-6" \leq w \leq 8'-5"$	1,200	6,000
$8'-6" \leq w \leq 10'-5"$	1,200	8,000
$w \geq 10'-6"$	1,200	10,000

* Weights are minimum recommendations only; owner-specified or site-specific vehicles may be larger.

Table 1: Minimum recommended design vehicle loads

general rule, the truss depth should be no less than 1/20th of the bridge span but — except in extreme cases — shall not be less than 1/25th of the bridge span. These ratios, through usage, have proven economical in maintaining reasonable truss deflection limits (1/400 of the span length) and vibrations; however, they may not be adequate if more stringent deflection requirements or if vibration or frequency limits are a concern.

Design code — Two main design codes are used to govern prefabricated steel truss pedestrian bridge types:

1) "AASHTO Guide Specification for the Design of Pedestrian Bridges," published by the American Association of State Highway and Transportation Officials (AASHTO); and

2) "International Building Code" (IBC) for design loads in conjunction with the specification for structural steel buildings published by the American Institute of Steel Construction (AISC) for member and connection design.

In general, AASHTO Guide Specifications for the Design of Pedestrian Bridges is referenced most commonly on projects where state and/or federal funds are allocated to the bridge construction.

Dead load — Unless otherwise specified, the dead load used in the design combinations shall only be the dead weight of the superstruc-

ture and the weight of the original decking material used with no future overlays considered. These weights shall be determined by the bridge manufacturer; however, in the case of deck materials by others (usually asphalt or concrete), the specifier must indicate the weight of the decking material (typically the unit weight of normal or lightweight concrete) and the approximate deck depth. Bear in mind that as the bridge manufacturer is usually responsible for the deck design and that the deck thickness is a function of final deck support member spacing, the bridge manufacturer must be allowed to modify the depth of concrete decks — and therefore the dead load — to fit individual bridge scenarios.

Live loads — Two live loads are applicable for truss design: pedestrian and light vehicular.

Pedestrian live load — The typical pedestrian traffic live load is 85 pounds per square foot (psf). This represents an average person occupying 2 square feet of bridge deck area and is considered a reasonable, conservative service live load that is difficult to exceed with pedestrian traffic. In applications where pedestrian traffic is light (trail bridges, walkways, et cetera), live loads as low as 60 psf (see IBC Table 1607.1 (40)) have been used with approval of the owner. This reduced live loading is not acceptable for entrance or exit ways or in locations where a large number of people

are expected to congregate.

Reduction of live loads for deck influence areas exceeding 400 square feet is consistent with the provisions of ASCE 7, "Minimum Design Loads for Buildings and Other Structures," and is intended to account for the reduced probability of large influence areas being simultaneously loaded to the maximum design value.

Vehicular live load — The proposed vehicle loads listed in Table 1 are intended as minimum default values in cases where no other vehicle load is specified. Table 1 provides a recommendation of design vehicles that could commonly access a pedestrian or bicycle structure (golf carts, garden tractors, riding lawnmowers, utility vehicles, ATVs, snowmobiles, cars, pick-up trucks, vans, sport utility vehicles, and motorcycles).

Because smaller vehicles have tighter axle and wheel spacing — possibly causing their lighter wheel loads to be located nearer the midspan of a decking member — all vehicles up to and including the largest vehicle selected for design must be used in determining the critical decking member stresses. Loaded skid-steer loaders, emergency vehicles, construction equipment, and heavy trucks are all special load cases and shall be considered when there is any reason or likelihood that they could obtain access to the bridge structure. The specifier or "operating agency" shall indicate the maximum vehicle load requirements of the structure.

On all structures, including those where vehicle access is restricted from the bridge either by stairs or bollards at each end of the structure, the bridge and floor system typically are designed for a minimum concentrated load of 1,000 pounds placed on any area 2-1/2



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feet by 2-1/2 feet square. Recognizing the fact that vehicle loadings on these structure types are usually infrequent and travel speeds are low (normally less than 10 mph), an impact allowance to the vehicle load is usually deemed unnecessary.

Seismic loads — The calculation of seismic forces in areas subject to earthquakes should be as set forth in the applicable design code or specification (typically IBC/ASCE 7 or AASHTO). For states with high seismic activity, such as California, it is common to be required to meet the seismic requirements of local or state agencies (i.e., CALTRANS or the California Building Code). A geotechnical investigation to determine relevant site conditions is recommended for all bridges that may encounter high seismic forces so that an appropriate seismic evaluation can be accomplished.

Stream force loads — If the bridge is partially or completely submerged during future rain events, the specifier shall state the high water elevation, the average water velocity, and the bridge elevation in the contract documents. The stream force load is consistent with the "AASHTO Standard Specifications for Highway Bridges, Section 3.18.1.1" as it pertains to superstructure loads. When applicable, the specifier shall determine both the maximum stream flow velocity at flood stage and the height of flood waters. Once determined, the bridge can be designed for stream forces as described below or the length of the structure can be increased by raising the elevation of the bridge such that it is above the high water flood elevation.

The bridge designer will design the bridge accordingly, based on one of the following four methods:

- 1) design for no stream load on the superstructure;
- 2) design for uniform stream

force load on the superstructure, which will typically keep the bridge in place during a flood, but not necessarily usable;

3) design for uniform stream force load and debris impact loads; or

4) design the bridge anchorage as a "break-away" system, which is typically done to prevent the bridge from acting as a dam.

Conclusion

The prefabricated steel truss pedestrian bridge industry is mature with thousands of successful structures nationwide. Proper siting and design of a prefabricated steel truss pedestrian bridge requires a comprehensive understanding of many variables as explained. This

article identified a number of relevant factors; however, designers may contact a bridge manufacturer to assist with the specification process to ensure proper design for the project site in question.



For online access to all of **CE News** PDH articles, visit <http://continuingeducation.zweigwhite.com>

References

- AASHTO Guide Specifications for Design of Pedestrian Bridges, American Association of State Highway and Transportation Officials.
- Guide for the Development of Bicycle Facilities, American Association of State Highway and Transportation Officials.
- Standard Specifications for Highway Bridges, 16th edition, American Association of State Highway and Transportation Officials.
- ASCE Standard 7-95, Minimum Design Loads for Buildings and Other Structures, American Society of Civil Engineers.
- 2006 International Building Code.
- Prefabricated Bridge Elements and Systems, U.S. Department of Transportation, Federal Highway Administration, www.fhwa.dot.gov/bridge/prefab/psbsreport03.cfm.

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1. What is a good target truss depth and truss width for efficient design?

- a) Span/25
- b) Span/20
- c) Span/10
- d) Span/30

2. What truss type would be best suited for a 150-foot-long span where top of deck to low steel is not a concern and you do not need overhead fencing?

- a) Half Though Underhung.
- b) Full Though Box Truss.
- c) Half Though H-Section.

3. What would you use as a rubrail height for a bridge if you expect bicycle traffic?

- a) 3 feet-6 inches (42 inches)
- b) 4 feet-6 inches (54 inches)
- c) 4 feet-0 inches (48 inches)
- d) 3 feet-0 inches (36 inches)

4. What would be the maximum deck slope allowed by ADA if the bridge had a pipe handrail?

- a) 4 percent (1/25)
- b) 10 percent (1/10)
- c) 5 percent (1/20)
- d) 8.33 percent (1/12)

5. How much thermal expansion would you design for on a 100-foot-long bridge?

- a) 1.1 inches
- b) 0.58 inch
- c) 0.78 inch
- d) 0.33 inch

6. If dead load camber (flat) is requested by the owner, how much camber should be put into the bridge?

- a) Enough to offset 100 percent of dead load deflections
- b) Enough to offset 100 percent of dead load deflections plus 50 percent of live load deflections
- c) Enough to offset 150 percent of dead load deflections

7. What is the minimum concentrated load on a bridge if vehicular traffic is restricted?

- a) 2,000 pounds
- b) 1,200 pounds
- c) 1,000 pounds
- d) 2,500 pounds

8. What design code would you use for a bridge if the project had federal funding?

- a) AISC
- b) AASHTO
- c) IBC
- d) ASCE

9. What is the never exceed truss depth or truss width for efficient design?

- a) Span/25
- b) Span/20
- c) Span/10
- d) Span/30

10. What live load would you use for a pedestrian bridge in a park that had an annual July 4 celebration each year?

- a) 60 psf
- b) 85 psf
- c) 65psf

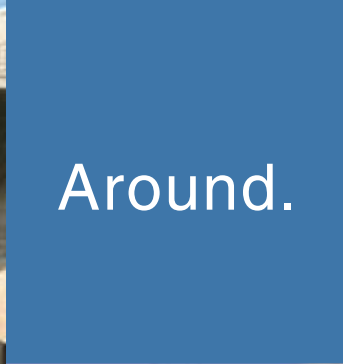
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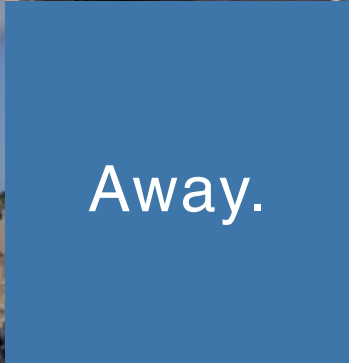
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