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Note that this section is based on both the 2013 AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals,* 6th Edition (allowable stress design) and the 2015 AASHTO *LRFD Specifications for Structural Supports for Highway Signs, Luminaries, and Traffic Signals,* 1st Edition.

10.2 Sign Support Structures

This series of articles replaces previous Bureau documents for overhead sign truss design criteria.

In the following articles [AASHTO-LTS-6 article, table, or figure] refers to the 2013 AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals,* 6th Edition. [AASHTO-LRFDLTS-1 article, table, or figure] refers to the 2015 AASHTO *LRFD Specifications for Structural Supports for Highway Signs, Luminaries, and Traffic Signals*, 1st Edition. The Bureau generally follows the AASHTO sign support specifications but modifies some provisions based on experience and local fabricating practice.

10.2.1 General

In the past, highway sign support structures usually were designed by the Bridges and Structures Bureau (BSB). Currently these structures are designed by consulting engineers with BSB oversight. As much as possible, the Bureau has developed standard plans, which then can be used by the Traffic and Safety

Bureau for typical projects. Past standards have included both aluminum and steel components but, because of fatigue concerns, the Bureau now uses all-steel structures.

The Bureau currently utilizes the following types of sign support structures:

- Overhead bridge-type sign trusses (BSB SS SOST-01-11 to SOST-21-11 which includes trusses for dynamic message signs (DMS)),
- Overhead cantilever-type sign trusses (BSB SS SCST-01-17 to SCST-09-17),
- Roadside DMS supports (BSB SS RDMS-01-13 to RDMS-06-13),
- Bridge-mounted sign supports, and
- Barrier-mounted sign supports

When signs on existing support structures are updated, the Traffic and Safety Bureau submits the changes for review by the Bridges and Structures Bureau.

10.2.1.1 Policy overview

The design of sign support structures has changed in recent years for several reasons. In the 1994 AASHTO sign specifications there was little information on fatigue design other than reference to the AASHTO *Standard Specifications for Highway Bridges*, but since 2001 the sign specifications have had detailed fatigue requirements that may control the design. The 2001 sign specifications required detailed fatigue design only for overhead cantilever-type sign trusses, but then the 2009 sign specifications extended those requirements to overhead bridge-type sign trusses. The detailed fatigue requirements are more favorable for steel than for aluminum, allowing significantly larger stresses for steel connections.

Increases in required lettering sizes and the amount of information to be communicated has necessitated larger signs. In 2000 the Bureau designed standard overhead sign structures for signs 10 or 12 feet tall, but currently there sometimes is need to design for signs over 20 feet tall. Another trend that has affected design is the state program to construct a network of dynamic message signs (DMSs) throughout the state supported on overhead bridge-type sign trusses, as well as on roadside supports.

The Bureau typically designs overhead bridge-type sign trusses in a four-chord box truss configuration with galvanized steel pipe or hollow structural sections. The trusses generally are sized for center-to-center chord spacings of 5 feet horizontal by 6 feet vertical. The overhead trusses are based on a Warren configuration on all four sides, with panel points at 5 feet along the length and an internal diagonal at each set of panel points. For ease of shipping and galvanizing, the trusses are designed with separate sections 20 to 40 feet long bolted together at chord splices.

Researchers at the Bridge Engineering Center at Iowa State University have tested a corroded and damaged galvanized steel overhead bridge-type sign truss, and researchers at Purdue University have tested two damaged aluminum overhead bridge-type sign trusses [BDM 10.2.1.5]. All of the testing has indicated that the Warren, four-chord configuration is robust. Typical trusses will not deflect excessively or fail to carry design loads, even with noticeable corrosion or fatigue damage to one chord.

Past sign truss inspections have indicated that aluminum overhead bridge-type trusses supporting DMS cabinets have a larger percentage of cracked connection welds than trusses supporting static signs. Many of the fractures are at redundant internal diagonals. Examination of the fractures suggests poor fabrication rather than fatigue.

Due to changes in the AASHTO sign specifications, the need for larger signs, the need to design for fatigue, and the apparently poor performance of aluminum trusses carrying DMSs, the Bureau no longer permits the use of new aluminum sign support structures without approval of the Chief Structural Engineer. With few exceptions, standards for 50- to 130-foot span galvanized steel overhead bridge-type sign trusses (BSB SS SOST-01-11 to SOST-21-11) are currently used for both static signs and dynamic message signs. Standards for 30- to 40-foot span galvanized steel overhead cantilever-type trusses (BSB SS SCST-01-17 to SCST-09-17) also are used for static signs. Due to vibration and fatigue concerns, a DMS placed in an overhead position must be supported on a steel bridge-type truss unless permission is granted by the Chief Structural Engineer to place the DMS on a steel cantilever-type truss. To meet AASHTO sign specification fatigue resistance requirements and make fabrication easier, the preceding structures are to be fabricated with gusset-and-slotted-pipe connections.

The Bureau requires a vertical clearance of 17.5 feet below the bottom edge of the sign support angles attached directly to the sign panels. This clearance is one foot more than that for typical bridge overpasses. Bureau guidelines for zone of intrusion can be found in BDM 3.14. The Bureau prefers that static signs and DMSs be centered vertically on a sign support structure so that wind will not cause a significant torsional moment about a horizontal axis.

The Bureau standard sign structure plans show foundations for overhead bridge-type sign trusses consisting of a stem wall on a spread footing and foundations for overhead cantilever-type trusses consisting of a pedestal on a spread footing. For poor soil conditions, locations above utility lines, and other special site conditions the office prefers steel H-piles with footings instead of drilled shafts. Drilled shaft foundations may be used only with permission of the supervising Unit Leader.

Due to potential fatigue damage from traffic vibrations, overhead cantilever-type sign support structures shall not be located on highway bridges. The Bureau also strongly recommends that overhead bridge-type sign support structures not be located on highway bridges but, if a sign support structure must be located on a bridge, the structure shall be located at or very near a pier.

Although the Bureau no longer needs to add outriggers to sign trusses for lights that provide night-time illumination of signs, the Bureau does provide runways and ladders for service of overhead DMSs. These service aids need to be considered in the loading of a DMS support structure, and they need to be planned with respect to Occupational Safety and Health Administration (OSHA) rules and security needs.

The Bureau makes limited use of bridge-mounted sign supports (i.e., supports for signs that supply traffic information to motorists traveling on the roadway that passes under the bridge). Due to concerns about adhesive anchors in sustained tensile-load applications, extreme care should be taken when this anchor type is utilized to mount sign supports on the side of an overhead bridge. When designing adhesive-anchor attachments, designers shall follow the recommendations in 2018 FHWA Technical Advisory T5140.34 *Use and Inspection of Adhesive Anchors in Federal-Aid Projects*. Designers also shall explicitly require that (1) the adhesive anchor installer hold current ACI Adhesive Anchor Installer Certification credentials and (2) the anchor installation be performed in the presence of an inspector with current ACI Post-Installed Concrete Anchor Installation Inspector Certification credentials.

10.2.1.2 Design information

The Traffic and Safety Bureau determines the need for signing on the state highway system and establishes sign sizes and locations. When standard plans and specifications for sign support structures do not cover given situations, the Bridges and Structures Bureau either approves standard plans with exceptions or specially designs the supports. For approving new signs on existing overhead structures, the Bureau has a relatively simple checking procedure covered in subsequent articles [BDM 10.2.4.2 – 10.2.4.5].

For use of standard spread footing foundations for overhead sign support structures, the soil is assumed to have a net allowable soil bearing pressure (for settlement) of 2.0 ksf or greater. Generally, the locations of spread footing foundations are within the prepared base for the highway where soils have reasonable capacity, and no specific soil information is needed. However, in the following cases the designer shall consult with the Design Bureau Soils Design Unit:

- Spread footing foundations need to be placed where there is uncertainty regarding soil capacity (e.g., at a location in or near a river floodplain),
- Spread footing foundations need to be located farther than usual from the roadway,
- Foundation footings need to be placed on piles, or
- Structures need to be placed on drilled shaft foundations.

10.2.1.3 Definitions

Reserved

10.2.1.4 Abbreviations and notation

[AASHTO-LTS-6 3.3, 3.8, 5.3, 5.10, 6.2, 6.4, 11.6; AASHTO-LRFDLTS-1 3.3, 3.8, 5.3, 5.10, 5.12, 6.3, 6.5, 6.7, 11.6]

AA, Aluminum Association
ACI, American Concrete Institute
AISC, American Institute of Steel Construction
API, American Petroleum Institute
ASTM, American Society of Testing and Materials
C_d, drag coefficient [AASHTO-LTS-6 3.8.6, AASHTO-LRFDLTS-1 3.8.7]
CRSI, Concrete Reinforcing Steel Institute
DMS, dynamic message sign, also called changeable message sign (CMS) or variable message sign (VMS)
G, gust effect factor [AASHTO-LTS-6 3.8.5, AASHTO-LRFDLTS-1 3.8.6]
I_F, fatigue importance factor [AASHTO-LTS-6 11.6, AASHTO-LRFDLTS-1 11.6]
I_r, wind importance factor [AASHTO-LTS-6 3.8.3]
k, effective length factor for a compression member [AASHTO-LTS-6 5.10, 6.4; AASHTO-LRFDLTS-1 6.5, 6.7]
K, effective length factor for a compression member [AASHTO-LRFDLTS-1 5.10, 5.12]
K_d, (wind) directionality factor [AASHTO-LRFDLTS-1 3.8.5]
K_z, height and exposure factor [AASHTO-LTS-6 3.8.4, AASHTO-LRFDLTS-1 3.8.4]
L, unbraced length of a compression member [BDM 10.2.4.1.1]; span length [BDM 10.2.4.1.2]
MRI, mean recurrence interval [AASHTO-LRFDLTS-1 3.8]
OSHA, Occupational Safety and Health Administration
r, radius of gyration [AASHTO-LTS-6 5.3, 6.2, AASHTO-LRFDLTS-1 5.3, 6.3]
V, basic wind speed [AASHTO-LTS-6 3.8.2, AASHTO-LRFDLTS-1 3.8.2]
Δ_{Beam}, deflection of a beam with the moment of inertia of the truss chord configuration
Δ_{DL}, dead load deflection at midspan
Δ_{Truss}, approximate deflection of the truss

10.2.1.5 References

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10.2.2 Loads

10.2.2.1 Dead

[AASHTO-LTS-6 3.5, AASHTO-LRFDLTS-1 3.5]

The dead load (designated as permanent load in AASHTO-LRFDLTS-1) shall include all permanent parts of the structure; all attachments such as signs, runways, and ladders; and temporary dead loads during maintenance [AASHTO-LTS-6 3.5, AASHTO-LRFDLTS-1 3.5].

Weight of a typical aluminum sign panel with back framing, not exceeding 20 feet tall may be taken as 6 psf. (This weight assumes the use of vertical steel L6 x 3½ x ½-inch sign support angles horizontally spaced at 4 ft on center and excludes the weight contribution of sign-support-angle-to-truss-chord connections.) The designer shall determine the unit weight of taller aluminum signs with back framing and signs of other materials with framing.

The designer shall determine and use the actual weight of dynamic message signs (DMSs) and other special sign types.

The designer should note that a runway for service of a DMS has significant weight. The runway may weigh nearly as much per foot of length as a DMS.

10.2.2.2 Live

[AASHTO-LTS-6 3.6, AASHTO-LRFDLTS-1 3.6]

For the typical unlighted overhead bridge-type and cantilever-type sign truss there is no runway or platform, and therefore no live load.

In cases where a runway or platform is attached to an overhead sign truss, a single 500 lb load shall be applied to each runway or platform member, distributed transversely over 2 feet [AASHTO-LTS-6 3.6, AASHTO-LRFDLTS-1 3.6]. The live load also shall be applied for design of the connections to the overhead sign truss structure but need not be applied to the truss structure itself because the design group load combinations [BDM 10.2.3] will ensure adequate strength for the temporary live load.

10.2.2.3 Ice

[AASHTO-LTS-6 3.7, AASHTO-LRFDLTS-1 3.7]

For designs using AASHTO-LTS-6, an ice load of 3 psf [AASHTO-LTS-6 3.7] shall be applied to the following:

- The entire surface of each member and gusset plate in a sign support structure,
- One side of ordinary signs,
- The top, ends, and one face of a DMS,
- The nominal plan area (neglecting openings) of a runway grate, and
- The entire surface of runway rails, runway supports, and ladder members.

For designs using AASHTO-LRFDLTS-1, ice load need not be applied as it has been determined that ice and wind on ice do not practically control the critical load effect [AASHTO-LRFDLTS-1 C3.7].

10.2.2.4 Wind

[AASHTO-LTS-6 3.8.1, 3.8.3, 3.8.6, 3.9.3; AASHTO-LRFDLTS-1 3.8.1, 3.8.7, 3.9.3]

Design wind pressure in the AASHTO sign specifications is determined as the product of several factors.

For designs using AASHTO-LTS-6, the design wind pressure is computed using:

$P_z = 0.00256 K_z G V^2 I_r C_d$ (psf) [AASHTO-LTS-6 Eq. 3.8.3-1]

For designs using AASHTO-LRFDLTS-1, the design wind pressure is computed using:

$P_z = 0.00256 K_z K_d G V^2 C_d$ (psf) [AASHTO-LRFDLTS-1 Eq. 3.8.1-1]

In most cases the basic height and exposure factor, K_z = 1.00 will suffice, but when signs taller than 20 ft are placed on an overhead sign truss or a sign truss is located near or on a highway bridge, the designer needs to check the maximum sign elevation with respect to the surrounding ground or water level. The height and exposure factor may need to be increased, which will result in a design wind pressure increase.

For structures on the state highway system the wind importance factor, I_r, shall be taken as 1.00 when using AASHTO-LTS-6 [AASHTO-LTS-6 3.8.3]. This I_r value of 1.00 corresponds to a minimum structural design life of 50 years.

AASHTO-LRFDLTS-1 does not use a wind importance factor, but instead adjusts the basic wind speed, V, according to a mean recurrence interval (MRI) based upon the highway traffic volume and risk category [AASHTO-LRFDLTS-1 3.8, Table 3.8-1]. For structures on the state highway system, the MRI shall be taken as 1700 years for the Extreme I limit state (120 mph basic wind speed) and 10 years for the Service I limit state (76 mph basic wind speed).

The (wind) directionality factor, K_d, accounts for the reduced probability that the design event wind direction aligns with the most aerodynamically vulnerable direction of the sign support structure. When using AASHTO LRFDLTS-1, the designer shall apply an appropriate K_d value to each support structure component (e.g., truss member, column/post) and attached signs (both static signs and DMS cabinets) [AASHTO-LRFDLTS-1 3.8, Table 3.8.5-1]. The directionality factor is not considered in AASHTO LTS-6 but implicitly set as 1.0 for all support structures.

Design wind pressures on sign structure components are dependent on their respective drag coefficients, C_d. The AASHTO sign specifications follow traditional drag coefficients. These coefficients likely will be revised in the future to be consistent with those in the ASCE/SEI-7 standard [BDM 10.2.1.5] and reflect more accurate information obtained through National Cooperative Highway Research Program (NCHRP) Project 15-67: Wind Drag Coefficients for Highway Signs and Support Structures. Currently the Bureau uses the following AASHTO-specified drag coefficients [AASHTO-LTS-6 3.8.6, AASHTO-LRFDLTS-1 3.8.7]:

- Typical signs with aspect ratios of 1.0 to 5.0: 1.2
- DMSs: 1.7
- Unshielded tubular sign structure members: 1.2

When following AASHTO-LTS-6 for typical structures where the weighted-mean average of the sign centroid heights is less than 32.8 feet (10 m) above the roadway, the Bureau has customarily used the following wind pressures determined from a basic wind speed of 90 mph associated with a 50-year recurrence interval:

- Signs: 30 psf
- DMSs: 40 psf
- Unshielded sign structure members: 30 psf

Structures carrying signs with heights exceeding 20 feet, structures with gusset plate connections, and structures elevated above the surrounding ground or water level usually will need to be designed for larger wind loads.

Member shielding in truss frameworks is interrelated with the drag coefficient. In applying the wind pressure to truss members the Bureau has the following policies, which generally give conservative results.

- For wind normal to a truss [AASHTO-LTS-6 3.9.3, AASHTO-LRFDLTS-1 3.9.3], consider members facing the wind on both the front and back of the truss to be loaded. Consider members between front and back that would be hidden in an elevation view and members parallel with the wind to be shielded from wind load.
- Apply normal wind to the sign structure from the back, considering all members in the back face to be loaded and the members in the front face directly behind a sign or DMS to be shielded.
- For wind transverse [AASHTO-LTS-6 3.9.3, AASHTO-LRFDLTS-1 3.9.3], consider the horizontal and vertical members at 5-foot intervals to be loaded and all horizontal and vertical diagonals behind those members to be shielded.

The AASHTO specifications likely will provide more rational guidance for applying wind pressures to shielded truss members sometime after NCHRP Project 15-67 is completed in 2022.

In lieu of rigorously analyzing the effects of wind from any direction, the designer may use the load cases for simultaneous normal and transverse wind loads given in the AASHTO sign specifications [AASHTO-LTS-6 3.9.3, AASHTO-LRFDLTS-1 3.9.3]. The load cases apply to the typical sign support structure with signs in approximately one plane but do not apply to unusual structures with major components oriented in two or different planes. Note that the “basic load” is applied differently in AASHTO-LTS-6 than in AASHTO-LRFDLTS-1. In AASHTO-LTS-6, the single basic load (BL) is based upon wind load effects applied normal to the sign faces. In AASHTO LRFDLTS-1, two separate basic loads are used: BL_n is the basic load for wind load effects applied normal to the plane of the structure and BL_t is the basic load for wind load effects applied transverse to the plane of the structure.

10.2.2.5 Fatigue

[AASHTO-LTS-6 11.6, 11.7.1, 11.9; AASHTO-LRFDLTS-1 11.6, 11.7.1, 11.9]

Design for fatigue in the AASHTO specifications involves use of fatigue design loads to determine nominal stress ranges at member connections in the structure and ensure that those stresses are less than the appropriate fatigue limits for the connection details [AASHTO-LTS-6 11.9, AASHTO-LRFDLTS-1 11.9].

Three types of equivalent static loads are required for overhead structures:

- Galloping [AASHTO-LTS-6 11.7.1.1, AASHTO-LRFDLTS-1 11.7.1.1],
- Natural wind gust [AASHTO-LTS-6 11.7.1.2, AASHTO-LRFDLTS-1 11.7.1.2], and
- Truck-induced gust [AASHTO-LTS-6 11.7.1.3, AASHTO-LRFDLTS-1 11.7.1.3].

All three loads apply to overhead cantilever-type structures, but only natural wind gust and truck-induced gust loads apply to overhead bridge-type structures.

Each of the loads is multiplied by the fatigue importance factor, I_F [AASHTO-LTS-6 11.6, AASHTO-LRFDLTS-1 11.6]. For structures on the state highway system, the designer shall take the fatigue importance factor as 1.00.

The natural wind gust and truck-induced gust loads also depend on the drag coefficient. The designer shall select the drag coefficient and apply shielding using the wind load guidelines in the preceding article [BDM 10.2.2.4].

In determining the nominal stress ranges at a connection, the designer shall add the axial stresses to the combined bending stresses, if the connection is assumed to be rigid. The designer need not separate tension from compression stresses because stresses usually reverse with opposite wind direction or oscillation of the structure.

Under the fatigue design loading and fatigue resistances in the AASHTO sign specifications, the design of typical overhead structures will be at least partially controlled by fatigue rather than by structural design.

10.2.3 Load combinations and application to signs and supports

[AASHTO-LTS-6 3.4, AASHTO-LRFDLTS-1 3.4]

The AASHTO-LTS-6 specifications identify four group load combinations to be used in design [AASHTO-LTS-6 3.4]. The first three combinations are for structural design. Because Group Loads II and III are to be used with a 133 percent allowable stress it may be easiest to multiply those two load combinations by 0.75 during analysis so that the results of all three load combinations can be compared directly at 100 percent allowable stress.

The AASHTO-LRFDLTS-1 specifications identify seven load combination limit states [AASHTO-LRFDLTS-1 3.4]. The first five combinations are for structural design.

AASHTO-LTS-6 Group Load IV and AASHTO-LRFDLTS-1 load combination limit state Fatigue I are for fatigue design.

Live load is not included in any of the AASHTO-LTS-6 group load combinations or AASHTO-LRFDLTS-1 load combination limit states but is to be considered locally for service facilities such as runways or platforms [BDM 10.2.2.2].

10.2.4 Analysis and design

[AASHTO-LTS-6 4.4, 4.5, 10.4, 10.5; AASHTO-LRFDLTS-1 4.4, 4.5, 10.4, 10.5]

Methods of analysis that satisfy the requirements of equilibrium and compatibility and use the linear stress-strain relationship for the material may be used [AASHTO-LTS-6 4.5, AASHTO-LRFDLTS-1 4.5]. AASHTO-LTS-6 design of metal members and reinforced concrete components of sign support structures shall follow the allowable stress design (ASD) method [AASHTO-LTS-6 4.4]. AASHTO-LRFDLTS-1 design of metal members and reinforced concrete components of sign support structures shall follow the load and resistance factor design (LRFD) method [AASHTO-LRFDLTS-1 4.4].

The designer should use the following assumptions for typical truss connections:

- Welded tube-to-tube or pipe-to-pipe, chord-to-web member connections are rigid with respect to both axes.
- Welded gusset plate, chord-to-web member connections are rigid in the plane of the gusset and pinned out of plane.
- Bolted gusset plate, chord-to-web member bearing connections are pinned with respect to both axes.
- Bolted gusset plate, chord-to-web member fully tightened connections are rigid in the plane of the gusset and pinned out of plane.
- Shop welded, field bolted splice plate, chord-to-chord connections are rigid with respect to both axes.
- Shop welded, field bolted base-plate-to-anchor-bolt connections are rigid with respect to both axes.

The designer may utilize commercial finite element software such as STAAD.Pro to analyze and design sign support structures. The software normally will consider all members to be rigidly connected about both axes and thus automatically will determine secondary bending stresses in trussed portions of the structure. Where the rigid connections are not appropriate, the designer has the option of specifying releases to simulate pinned connections.

Usually the software also will consider all members fully braced at each end, and that assumption will need to be corrected for compression and bending in posts composed of more than one finite element member and possibly for other conditions in the structure. In the typical overhead bridge-type sign truss, upper U-bolt connections between post and truss chord can carry only tension, and the designer needs to model the connections carefully. The designer shall verify the finite element analysis and design computations for critical members by hand computations.

For an overhead bridge-type sign truss, the midspan deflection under AASHTO-LTS-6 Group I dead load plus ice load or AASHTO-LRFDLTS-1 Service I dead load shall not exceed 1/150 of the span length [AASHTO-LTS-6 10.4.1, AASHTO-LRFDLTS-1 10.4.1]. For hand computations the truss deflection may be determined as for beams but with an increase of 20 percent to account for the flexibility of truss web members.

$$\Delta_{Truss} = 1.2\Delta_{Beam}$$

Where:

Δ_{Truss} = approximate deflection of the truss

Δ_{Beam} = deflection of a beam with the moment of inertia of the truss chord configuration

For an overhead cantilever-type sign truss under AASHTO-LTS-6 Group I loads or AASHTO-LRFDLTS-1 Service II loads, the horizontal deflection at the top of the vertical post shall be limited to 2.5 percent of the post height and the slope at the top of the post shall be limited to 0.35 in./ft [AASHTO-LTS-6 10.4.2.1, AASHTO-LRFDLTS-1 10.4.2.1].

Camber of overhead bridge-type sign trusses and overhead cantilever-type sign trusses shall be determined from the following equation [AASHTO-LTS-6 10.5, AASHTO-LRFDLTS-1 10.5]:

$$Camber = \Delta_{DL} + \frac{L}{1000}$$

Where:

Δ_{DL} = dead load deflection at midspan for bridge-type trusses and dead load deflection at end of span for cantilever-type trusses

L = span length

10.2.4.1 New structures

10.2.4.1.1 Steel

[AASHTO-LTS-6 Section 5, 5.4, 5.9, 5.10, 5.11, 5.12, 5.14.1, 10.4.3.1; AASHTO-LRFDLTS-1 Section 5, 5.4, 5.9, 5.10, 5.11, 5.12, 10.4.3.1]

The designer shall use the steel design provisions in the AASHTO sign specifications [AASHTO-LTS-6 Section 5, AASHTO-LRFDLTS-1 Section 5] wherever applicable. For unusual conditions where the design specifications do not apply, the designer shall follow other specifications referenced by the sign specifications. If no specifications are referenced, the AISC *Steel Construction Manual* or AISC *Hollow Structural Sections Connection Manual* [BDM 10.2.1.5] often will have more appropriate information than the AASHTO *Standard Specifications for Highway Bridges* or the AASHTO *LRFD Bridge Design Specifications*.

Unless otherwise noted on the plans, steel shall meet the following material requirements.

- Angles, bars and plates: ASTM A36, ASTM A572 Grade 50, ASTM A709 Grade 36, or ASTM A709 Grade 50
- W-sections: ASTM A992, ASTM A36, ASTM A572 Grade 50, ASTM A709 Grade 36, ASTM A709 Grade 50, or ASTM A709 Grade 50S
- Steel bar grating: ASTM A1011 Type 2
- Pipe: ASTM A53 Grade B, Type E or S; or API 5L Grade B
- Round hollow structural sections (HSS): ASTM A500 Grade B, ASTM A500 Grade C, ASTM A1085, API 5L Grade X42, or API 5L Grade X52
- Galvanized high strength bolts: ASTM F3125 Grade A325 Type 1, Class 2A. ASTM A449 Type 1 bolts or ASTM F3125 Grade A325-T Type 1 bolts may be substituted for ASTM F3125 Grade A325 Type 1 bolts where necessary to assure proper bolt length and thread length.
- Galvanized nuts: ASTM A563 Grade DH, Class 2B
- Galvanized washers: ASTM F436 Type 1
- Anchor bolts (anchor rods): ASTM F1554 Grade 55, S1*, Class 2A; or ASTM F1554 Grade 105, S4 (-20 degrees Fahrenheit),** Class 2A [IDOT SS 4187.01, C, 3, a, 2]

* S1 = supplementary requirement for chemical composition to assure weldability
** S4 = supplementary requirement for Charpy impact

Because manufacturers now can reliably produce pipe and HSS with dimensions at or near the lower limit of the tolerance range, pipe and HSS section design properties have been reduced to those listed in the AISC *Manual of Steel Construction,* 15th Edition; however, software may not be corrected for the changes. When using software for analysis and design, the designer needs to ensure that the software is using the latest pipe and HSS section properties or compensate for the differences between old and new properties.

When following AASHTO LTS-6, the minimum thickness for steel material shall be 0.1875 inches for main members and 0.125 inches for web and secondary members [AASHTO-LTS-6 5.14.1]. When following AASHTO LRFDLTS-1, the minimum thickness for steel material shall be 0.1793 inches for main members and 0.125 inches for web and secondary members [AASHTO-LRFDLTS-1 5.6.1].

All steel material with a thickness greater than 0.500 inches in main load carrying tension members shall meet current Charpy V-notch impact requirements [AASHTO-LTS-6 5.4, AASHTO-I 10.3.3, AASHTO-LRFDLTS-1 5.4, AASHTO-LRFD 6.6.2.1]. The portions of the structure required to meet impact requirements shall be designated on the plans and noted for Temperature Zone 2. The designer shall discuss any need for Charpy V-notch impact requirements with the supervising Unit Leader.

The Bureau prefers that fillet-weld size be limited to 5/16 inch, the largest weld that can be made in a single pass.

Bolts for chord splices and other truss member connections shall be ASTM F3125 Grade A325 galvanized high-strength steel bolts [IDOT SS 4153.06, B, 1] installed by the turn-of-nut method [IDOT SS 2408.03, S, 5]. Preferred bolt size is 7/8 inch.

U-bolts for attachment of aluminum signs, aluminum DMS cabinets, and other aluminum parts shall be stainless steel [IDOT SS 4187.01, C, 1]. U-bolts for connection of galvanized steel truss components, galvanized steel runways, and other galvanized steel parts may be stainless steel or galvanized steel [IDOT SS 4187.01, C, 2].

For steel truss members in tension, L/r shall not exceed 240 [AASHTO-LTS-6 5.9.2, AASHTO-LRFDLTS-1 5.9.4]. Overly slender members may vibrate individually [AASHTO-LTS-6 10.4.3.1, AASHTO-LRFDLTS-1 10.4.3.1].

Bureau policy is to use the length between working points with the following effective length factors (k-factors) for compression members:

- k = 1.0 for truss chords and web members,
- k = 1.8, minimum, for end posts in overhead bridge-type sign truss structures for the direction in which they behave as frame (rather than truss) members, and
- k = 2.1 for posts in overhead cantilever-type truss structures.

For steel truss members in compression, kL/r shall not exceed 140 [AASHTO-LTS-6 5.10.1, AASHTO-LRFDLTS-1 5.10.3].

All steel sign support components shall be galvanized after fabrication. The galvanizing is intended to include both the exterior and interior of tubular members. Because of explosive pressures generated in sealed spaces during galvanizing and restricted flow of molten zinc after hot dipping of a component, vent and drain holes are required in some cases. The designer should anticipate the need for and locations for holes and design accordingly.

Steel overhead sign trusses do not require a damping device.

10.2.4.1.2 Aluminum

[AASHTO-LTS-6 Section 6, Table 6.4-2, 6.4.3.1, 6.4.4.2, 6.5, 6.8.1, 6.9, 10.4.3, 10.4.3.1, Table B.6-4]*The contents of this article apply only to allowable stress design using AASHTO LTS-6. Because the Bureau no longer permits aluminum for new sign support structures without approval of the Chief Structural Engineer, this article is now primarily intended to be used for reference when analyzing existing aluminum structures.*

Aluminum box truss components are assembled from tubes with continuous chords connected with short web members. Except where gussets are used, the web diagonals and struts are cut to length with fish-mouth ends, which then are fillet welded to the continuous members. The diagonal and strut connections are gapped so that there is no overlap between adjacent web members. Usually the gap created at the surface of chords by aligning centerlines of all intersecting members at a point is sufficient, but occasionally it may be necessary to realign web members. If the final alignment is more than 2 inches from the centerline alignment at a point, the realignment shall be considered in the analysis.

For ease of fabrication internal diagonals usually are offset from panel points. Because internal diagonals are redundant and lightly stressed the offset need not be considered in design.

Because it is difficult to weld and inspect connections between members that intersect at small angles, the angle between any diagonal and chord shall be 35 degrees or more. Although the lower limit for end-welded tubular connections is taken as 30 degrees by some authorities, the office has set the higher limit based on the advice of aluminum sign support fabricators.

The designer shall use the aluminum design provisions in the AASHTO sign specifications [AASHTO-LTS-6 Section 6] wherever applicable. For unusual conditions where the specifications do not apply, the designer shall follow other specifications referenced by the sign specifications. If no specifications are referenced, the Aluminum Association *Aluminum Design Manual* [BDM 10.2.1.5] often will have more appropriate information than the AASHTO *Standard Specifications for Highway Bridges*.

Extruded tube, structural shapes, and plate for aluminum sign trusses shall be Alloy 6061-T6.

Minimum thickness for aluminum material shall be 0.125 inches [AASHTO-LTS-6 6.8.1].

Because welding removes beneficial effects of heat-treating and cold working, allowable stresses need to be reduced for zones within one inch of a weld as required in the AASHTO sign specifications [AASHTO-LTS-6 6.5]. Because the reductions are difficult to apply as intended by the specifications, the designer should consult tables specifically for Alloy 6061-T6 [AASHTO-LTS-6 Table B.6-4 (B.6-3)].

The designer also shall consider the locations of the welded zones in a member with respect to potential buckling or bending collapse mechanisms. The zones weakened by welding will behave as hinges under overload and lead to early collapse unless the allowable stresses are correctly evaluated with respect to member behavior.

Welding shall conform to *Structural Welding Code—Aluminum, AWS D1.2/D1.2M: 2014* [AASHTO-LTS-6 6.9 and BDM 10.2.1.5]. For the typical sign trusses, workmanship shall be Class I. The office modifies the welding code specifications as follows.

- The office prefers that fillet-weld size be limited to 5/16 inch, the largest weld that can be made in a single pass.
- Aluminum filler alloy ER5356 or ER5556 shall be used [IDOT SS 4187.01, A, 7]. Only microscopically clean welding wire (those which have been shaved after drawing) should be used, and spools of wire remaining at the end of the day's production should be sealed in polyethylene bags. Welding wire in drive rolls and gun not so protected should be discarded. With ER5356 or ER5556 electrodes allowable design stresses for welded zones do not need to be additionally reduced for member thicknesses above 0.375 inches [AASHTO-LTS-6 Table 6.4-2].
- Tubes should be milled to the required radii with the maximum gap at any point not greater than 1/16 inch. Forced fits must be avoided, and only downhand welding is allowed.
- All areas to be welded shall be brushed with stainless steel brushes immediately prior to welding. All aluminum welding shall be performed by the gas metal arc welding (GMAW) process. Only the stringer bead technique shall be used. Interpass temperature shall not exceed 200 degrees Fahrenheit. All initial root passes shall not exceed 5/16 inch and must penetrate the root. The convexity of a fillet weld shall not exceed 1/16 inch. All weld craters must be eliminated, and wherever possible welds should carry through tight areas without stopping.
- Tack-weld ends shall be filled and shall not terminate in craters. If a tack weld is cracked, the crack shall be removed before welding begins.

Stainless steel bolts [IDOT SS 4187.01, C, 1] shall be used in chord splices. Preferred size is 7/8-inch.

Stainless steel U-bolts shall be used for attachment of aluminum signs, aluminum DMS cabinets, and other aluminum parts [IDOT SS 4187.01, C, 1].

Slender aluminum truss members may vibrate individually during uniform wind conditions and eventually suffer fatigue damage. Based on satisfactory performance of Iowa DOT aluminum sign trusses in service, the Bureau prefers that the slenderness of all diagonals and struts not exceed an L/r of 150. The limit of 150 is more conservative than the recommended slenderness limit for tension members in the AASHTO sign specifications [AASHTO-LTS-6 6.4.3.1, 10.4.3.1].

Bureau policy is to use the length between working points with the following effective length factors (k-factors) for compression members:

- k = 1.0 for truss chords and web members,
- k = 1.8, minimum, for end posts in overhead bridge-type sign truss structures for the direction in which they behave as frame (rather than truss) members, and
- k = 2.1 for posts in overhead cantilever-type truss structures.

For truss members in compression, the slenderness limit, kL/r, should not exceed 120 [AASHTO-LTS-6 6.4.4.2].

To avoid damaging vibrations of an aluminum overhead truss when sign panels are not attached, a damping device shall be provided at the center of the truss [AASHTO-LTS-6 10.4.3]. The damping device shall be a 31-pound Stockbridge type (Alcoa Aluminum 1708-17.1) or approved equal.

10.2.4.2 Existing structures

When sign areas are to be changed on existing overhead bridge-type sign trusses, overhead cantilever-type sign trusses, or bridge-mounted sign support structures during signing updates, the Bureau will review the changes based on the following documents and information from the Traffic and Safety Bureau:

- A copy of the original design plans,
- The dimensions and positions for all signs that will remain on the support structures, and
- The dimensions and positions of the new signs being installed on the support structures.

There are three possible results of the review:

- Existing sign support structures are acceptable with the new signs,
- Signs need to be reduced in size, or
- Existing sign support structures need to be replaced.

10.2.4.2.1 Overhead bridge-type sign truss review

The review of an overhead bridge-type sign truss shall be based on the allowable sign area and wind load shown on the plans for the structure. If the new sign area is larger than the allowable sign area or the sign height is greater than the allowable sign height, the designer shall perform an approximate analysis.

For an approximate analysis, the designer shall assume the truss to be a simple span beam and the supports to be simple cantilevers. Place the wind loads on the allowable sign area to determine the maximum moment and shear in the truss and the maximum axial load and moment at the base of the posts. Compare these quantities to those determined using the new sign area and location. If the moments, shear, and axial load are no more than 10 percent greater than those calculated for the allowable sign area, the new sign area may be approved.

If the sign height extends above the top chords or below the bottom chords of the truss more than 5.25 feet, the horizontal spacing of aluminum 6 x 3½ x ½-inch sign support angles will need to be reduced from the 5-foot maximum. If the sign height extends above the top chords or below the bottom chords of the truss by more than 6.5 feet, the horizontal spacing of steel L6 x 3½ x ½-inch sign support angles will need to be reduced from the 5-foot maximum. The designer will need to provide the new maximum spacing to the Traffic and Safety Bureau for inclusion in their plan set. As an alternative to a reduced spacing for the sign-support angles, the designer may substitute a stronger section and U-bolt connection capable of resisting the design loads.

10.2.4.2.2 Overhead cantilever-type sign truss review

The review of an overhead cantilever-type sign truss shall be based on the sign area shown on the plans for the structure. If the new sign area is less than or equal to the sign area shown on the plans, the new sign area may be approved. If the new sign area is greater than the sign area shown on the plans, the sign area will be limited to the sizes shown in the following tables. Table 10.2.4.4-1 applies to larger aluminum-truss-with-steel-end-post structures, and Table 10.2.4.4-2 applies to smaller aluminum-truss-with-steel-end-post structures. These tables do not apply to SCST-17 standard trusses made entirely of steel. For a SCST-17 standard truss, the new sign area may be approved if it is less than or equal to the maximum allowable sign area shown on standard sheet SCST-02-17.

Table 10.2.4.4-1. Allowable sign area for larger overhead cantilever-type aluminum-truss-with-steel-end-post structures

Maximum cantilever length[(1)], feet	Maximum sign height, feet	Maximum sign area, ft^2
35.00	14.00	210
34.00	14.00	224
33.00	14.00	238

Table notes:

1. See Figure 10.2.4.4.
2. Steel pipe end post 22- or 24-inch diameter by 0.500 inch thick
3. Maximum end post (truss) height 27.00 feet. See Figure 10.2.4.4.
4. Aluminum truss chords 5½ x 5/16 inches
5. Aluminum web members 2½ x ¼ inches, 2¼ x 3/16 inches, 2 x 3/16 inches, and 2 x ¼ inches

Table 10.2.4.4-2. Allowable sign area for smaller overhead cantilever-type aluminum-truss-with-steel-end-post structures

Maximum cantilever length[(1)], feet	Maximum sign height, feet	Maximum sign area, ft^2
33.00	10.00	150
30.00	11.00	176
27.50	12.00	192

Table notes:

1. See Figure 10.2.4.4.
2. Steel pipe end post 18-inch diameter by 0.500 inch thick
3. Maximum end post (truss) height 27.00 feet. See Figure 10.2.4.4.
4. Aluminum truss chords 5½ x 5/16 inches
5. Aluminum web members 2½ x 3/16 inches, 1¾ x 3/16 inches, and 2 x 3/16 inches

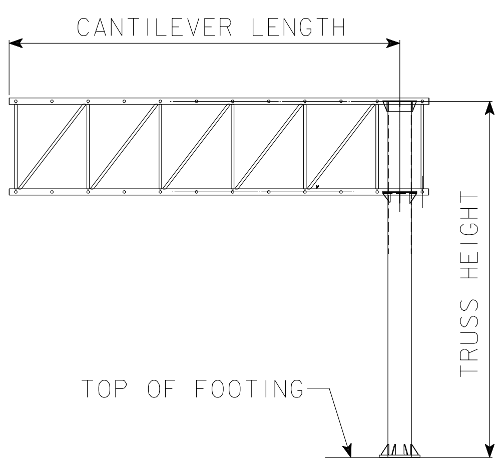

Figure 10.2.4.4. Overhead cantilever-type truss dimensions

10.2.4.2.3 Bridge-mounted sign support structure review

The designer should base review of bridge-mounted sign support structures on the limits in the original plans, carefully considering design wind pressure information obtained through National Cooperative

Highway Research Program (NCHRP) Project 15-67: Wind Drag Coefficients for Highway Signs and Support Structures. NCHRP Project 15-67 indicates that the actual average drag coefficient for a bridge-mounted sign can be much higher than what is currently specified in AASHTO LTS-6 and AASHTO LRFDLTS-1. NCHRP 15-67 also indicates that the pressure distribution on a bridge-mounted sign is nonuniform, especially when the sign extends significantly above the top of the bridge barrier rail.

10.2.5 Detailing

[AASHTO-LTS-6 6.11.1, AASHTO-LRFDLTS-1 14.5.11.1]

To prevent galvanic corrosion, contact between aluminum and dissimilar metals shall be avoided [AASHTO-LTS-6 6.11.1, AASHTO-LRFDLTS-1 14.5.11.1] except as follows. For typical sign support structures the Bureau permits contact (1) between the aluminum structure and stainless steel fasteners, and (2) between the aluminum structure and galvanized steel shapes and plates.

Anchor bolts (anchor rods) shall be galvanized and comply with ASTM F1554 Grade 55, S1; or ASTM F1554 Grade 105, S4 (-20 degrees Fahrenheit) [IDOT SS 4187.01, C, 3, a, 2]. Generally bolt size should match base plate thickness. Anchor bolt nuts shall be tightened by the turn-of-nut method and the procedure shall be given on the plans. See the commentary for this article for the procedure [BDM C10.2.5].

Bureau policy does not permit the use of grout with anchor bolts but requires space between base plate and top of foundation. To restrict entry to this space, the Bureau uses a standard rodent guard (a wire mesh that wraps the base plate) detail. This detailing that excludes grout is intended to prevent corrosion.

For an overhead bridge-type truss supporting a DMS, details for the following are required:

- Electrical access,
- Walkway, and
- Ladder.

So that the contractor and construction personnel have erection standards, the designer shall include on the plans a list of tolerances for foundations and anchor bolts and for the completed structure. Typical tolerances are given in the commentary for this article [BDM C10.2.5].

10.2.6 Shop drawings

The fabricator shall submit shop drawings for review as required [IDOT SS 2423.03, A, 1].

10.2.7 Structures and components

10.2.7.1 Overhead bridge-type sign trusses

Generally the Bureau bases overhead bridge-type sign truss structures on a 5-foot length-module and provides standard plans for structures nominally 50 to 130 feet in length. Standard overhead bridge-type trusses have center-to-center chord spacings of 5 feet horizontal by 6 feet vertical. The truss web members are arranged in a Warren pattern on all four sides, and internal diagonals are placed at each set of panel points along the truss. The truss is fabricated in 20- to 40-foot sections that are bolted together in the field. The latest standard plans make use of galvanized steel pipe (minimum yield strength of 35 ksi) for the overhead space truss and galvanized steel hollow structural sections (minimum steel yield strength of 42 ksi) for the truss supports [OBS SS SOST-01-11 to SOST-08-11]. The standards allow for substitution of hollow structural sections for pipe.

Due to fabrication- or fatigue-related cracks in welds in aluminum overhead bridge-type trusses supporting DMS cabinets, the Bureau no longer places DMS cabinets on aluminum overhead bridge-type trusses. The Bureau currently does not allow the use of new aluminum sign support structures without approval of the Chief Structural Engineer.

Overhead bridge-type sign structures generally should not be placed on highway bridges but, if a sign structure must be located on a bridge, it shall be located at or very near a pier.

10.2.7.2 Overhead cantilever-type sign trusses

The Bureau usually configures overhead cantilever-type structures on a vertical, Pratt five-panel and horizontal, Warren ten-panel truss pattern. Because the truss configuration length is limited to 40 feet but does not vary much, the Pratt panel lengths typically are in the 6- to 7-foot range. Center-to-center chord spacings are 4 feet horizontal by 7 feet vertical. Internal diagonals are placed at all of the Pratt panel points. The current standard plans make use of galvanized steel hollow structural sections (minimum yield strength of 42 ksi) and galvanized steel pipe (minimum yield strength of 35 ksi) for the overhead cantilever truss and galvanized steel pipe (minimum yield strength of 42 ksi) for the end post [BSB SS SCST-01-17 to SCST-05-17]. Prior to 2017, the standard plans made use of aluminum tubes for the overhead cantilever truss and galvanized steel pipe for the end post.

DMS cabinets shall not be placed on overhead cantilever-type sign trusses without approval of the Chief Structural Engineer.

Overhead cantilever-type sign trusses shall not be placed on highway bridges.

10.2.7.3 Roadside dynamic message sign support structures

The current standard plans for roadside dynamic message sign support structures make use of a pair of galvanized steel pipe mast arms attached to a galvanized steel hollow structural section support post with a 30-foot maximum height [BSB SS RDMS-01-13 to RDMS-06-13].

10.2.7.4 Runways and ladders

Runways, ladders, other service aids, and their connections to sign structures need to be designed for dead load, live load, ice load (as applicable), and wind load as previously indicated [BDM 10.2.2]. Sign structures then need to be designed for dead, ice (as applicable), and wind loads transmitted through the connections.

In addition to structural capacity, service aids need to be designed to meet Occupational Safety and Health Administration (OSHA) rules. The designer also must consider access restrictions to prevent unauthorized use.

10.2.7.5 Bridge-mounted sign supports

The Bureau currently utilizes unofficial working standards for bridge-mounted sign supports (i.e., supports for signs that supply traffic information to motorists traveling on the roadway that passes under the bridge) to assist in the development of site-specific designs. The sign supports consist of galvanized steel brackets with a maximum horizontal spacing of 8 ft. Each bracket is comprised of a vertical W6x15 member to which the sign panel is attached, an upper horizontal W6x15 member that mounts to the bridge concrete barrier rail, and a lower horizontal W6x15 member that mounts to the bridge exterior beam/girder. The maximum allowable sign height for the supports is 11’-10. The maximum allowable sign length is 14 ft for a 2-bracket support and 22 ft for a 3-bracket support. The maximum allowable skew angle between the sign panel and bridge barrier rail is 20 degrees.

10.2.7.6 Foundations

[AASHTO-LTS-6 13.1; AASHTO-LRFDLTS-1 13.1; AASHTO-I 4.4.7.1.1.1, 4.11.4.1.5; AASHTO-LRFD 10.6.3.3]

Generally the Bureau prefers spread footing foundations for support of overhead and roadside structures. The Bureau standard sign support structure plans show foundations for overhead bridge-type sign trusses consisting of a stem wall on a spread footing and foundations for overhead cantilever-type trusses consisting of a pedestal on a spread footing. For designs using AASHTO LTS-6, spread footings for sign support structures shall be designed according to the 2002 AASHTO *Standard Specifications for Highway Bridges*, 17th Edition as required in the sign specifications [AASHTO-LTS-6 13.1], using either allowable stress design (ASD) or load factor design (LFD). For designs using AASHTO LRFDLTS-1, spread footings for sign support structures shall be designed according to the 2017 AASHTO LRFD Bridge Design Specifications, 8th Edition using load and resistance factor design (LRFD).

The bottom of a spread footing shall be placed at least 4 feet below ground line. Unless site soil information indicates otherwise, the designer may assume the net allowable soil bearing pressure (for settlement) to be 2.0 ksf. In order to prevent overturning of footings on soil, under ASD the eccentricity of loading shall not exceed one-sixth of the footing dimension [AASHTO-I 4.4.7.1.1.1]. Under LFD the eccentricity of factored loading shall not exceed one-fourth of the footing dimension [AASHTO-I 4.11.4.1.5]. Under LRFD the eccentricity of factored loading shall not exceed one-third of the footing dimension [AASHTO-LRFD 10.6.3.3]. When checking the bearing pressure and the eccentricity, the designer should include the soil overburden.

For poor soil conditions, locations above utility lines, and other special site conditions the Bureau prefers steel H-pile foundations. Design of the piles will require information from soil borings. If soil borings are not provided, the designer should request borings from the Design Bureau Soils Design Unit. With ASD the designer should use the friction and end bearing information in the *Foundation Soils Information Chart, Pile Foundation* [BDM 10.2.1.5]. With LFD and LRFD the designer should use the information in the LRFD Bridge Design Manual [BDM 6.2.7].

Drilled shaft foundations may be used with permission of the supervising Unit Leader or Chief Structural Engineer. Overhead bridge-type sign support structures typically are designed under the assumption that the foundation between the two posts of a truss support is continuous and the base plates are not subject to relative movement, as would be the case for independent drilled shafts.