Truss or Cantilever Sign Foundation Design

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Division of Bridges - INDOT

February 7th, 2018

Overview

• Design Criteria
• Current Design Policy, Codes, IDM, Specifications, Standard Drawings.
• Geotechnical Requirements.
• Foundation Types, Selection, Location, Constraint
• Practice Pointers
Sign Support Structures

• Types, IDM:

1. box truss;
2. sign cantilever structure;
3. tri-chord truss structure;
4. butterfly sign cantilever structure;
5. dynamic message sign structure;
6. monotube bridge sign structure;
7. bridge-attached sign structure for large panel signs;
8. bridge bracket for crossroad signing; and
9. cable span sign structure.

Box Truss Structures

17'-6" Min. Vert. CL
Cantilever Structures

AASHTO Specifications

- Current Design Code – ASD Design

Abbreviated Table of Contents

Design

Appendices

Appendix A. Analysis of Span-wise Structures
Appendix B. Design AEA
Appendix C. Alternative Method for Wind Pressures
Appendix D. Alternative Method for Fatigue Design
AASHTO Specifications

- Future Design Code

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**Appendices**

- Appendix A: Analysis of Span-Wide Structures | A.4
- Appendix B: Design AIDS | B.4
- Appendix C: Alternative Methods for Fatigue Design and Stabilization | C.4
- Appendix D: Detailed Element Descriptions | D.4

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ASCE/ SEI & ACI Codes

**ASCE/SEI 7-10**

**ACI Building Code**

An ACI Standard and Report

Building Code Requirements for Structural Concrete (ACI 318-14)

Commentary on Building Code Requirements for Structural Concrete (ACI 318R-14)

Revised by ACI Committee 318
Current Policy


- Sign Foundation: Should be Designed per LRFD Bridge Design Specifications IDM 502-1.01(12)

- Standard Drawings for Foundations are designed per LRFD Bridge Design Specifications.

Current Policy

- Shop Drawings for signs in the standard drawings should be submitted to Traffic Division for review and approval.

- Design calculations and shop drawings should be submitted for approval: for signs that require design and are not detailed in the standard drawings in geometry

- Geotechnical Investigation is required for overhead sign structures
Design Criteria - Loads

AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, & Traffic Signals

Table 3.4-1---Group Load Combinations

<table>
<thead>
<tr>
<th>Group Load</th>
<th>Load Combination</th>
<th>Percentage of Allowable Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>DL</td>
<td>100</td>
</tr>
<tr>
<td>II</td>
<td>DL + W</td>
<td>133</td>
</tr>
<tr>
<td>III</td>
<td>DL + Ice + 1/2(W)</td>
<td>133</td>
</tr>
<tr>
<td>IV</td>
<td>Fatigue</td>
<td>4</td>
</tr>
</tbody>
</table>

- **Dead Load**: IDM 502-1.01(11)
  - Dead Load:
    - Aluminum: 169 lb/ft³
    - Steel: 490 lb/ft³
    - Traffic message panel sign: 2.48 lb/ft², aluminum extruded panels 12-in. height.
    - Traffic message sheet sign: 2 lb/ft²

- **Live Load**: Standard Specification Section 3.6 → Live Load of 550 lb distributed over 2ft for walkway design only.

- **Ice Load**: **Shall Be** 3 lb/sft (~ 0.65”) around all elements, one face of sign panel.
Design Criteria - Loads

AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, & Traffic Signals

• Wind Load: Basic Wind Speed 90 mph, 50 Year Service Life.

• Seismic Design: NOT Required

• Fatigue: Not required for Foundation.

Design Criteria - Loads

AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, & Traffic Signals

3.8.1—Wind Pressure Equation

The design wind pressure shall be computed using the following equation:

\[ P_z = 0.613K_zGV^2I_rC_d \text{ (Pa)} \]  \hspace{1cm} (3.8.3-1)

\[ P_z = 0.00256K_zGV^2I_rC_d \text{ (psf)} \]

• \( I_r \) = Importance factor Table 3.8.3-1
• \( K_z \) = Height Exposure Factor Table 3.8.4-1
• \( G \) = Gust Effect Factor = 1.14
• \( C_d \) = Drag Coefficient Table 3.8.6-1
Design Criteria - Loads

LRFD Specifications for Structural Supports for Highway Signs, Luminaires, & Traffic Signals

• Limit States
  • Service Limit State  ➔ Stress Limits, Cracking, & deformations (Wind)
  • Strength Limit State  ➔ Strength & Stability (No Wind)
  • Extreme Limit State  ➔ Survival of the structure under extreme (Wind)

• Seismic Design: NOT Required  LRFD 1.1

Design Criteria - Loads

LRFD Specifications for Structural Supports for Highway Signs, Luminaires, & Traffic Signals

500 lbs/sft on walkways only
## Design Criteria - Loads

**LRFD Specifications for Structural Supports for Highway Signs, Luminaires, & Traffic Signals**

### Ice Load:

- **LRFD:** Ice Load due freezing rain and in-cloud icing may be applied:
  - Around the surfaces except one face of sign panels.
  - Owner shall specify special icing conditions.
  - LRFD Commentary: For extreme cases specified by the owner use ASCE/SEI 7-10.

### Diagram:

- ASCE/SEI 7-10
  - 1” Glazed ice (~4.6 lb/sft)
  - 0.75” Glazed ice (~3.46 lb/sft)
  - > Standard Specification (3 lb/sft)
### Design Criteria - Loads

**LRFD Specifications for Structural Supports for Highway Signs, Luminaires, & Traffic Signals**

- **Wind Load:**

  **3.8.1—Wind Pressure Equation**
  The design wind pressure shall be computed using:

  \[ P' = 0.00256K_sK_wG^2C_d \]  

  where
  
  - \( P' \) is the basic wind speed (mph).
  - \( K_s \) is the height and exposure factor defined in Article 3.8.4.
  - \( K_w \) is the directionality factor defined in Article 3.8.5.
  - \( G \) is the gust effect factor defined in Article 3.8.6.
  - \( C_d \) is the drag coefficient defined in Article 3.8.7.

### Table 3.8-1—Mean Recurrence Interval

<table>
<thead>
<tr>
<th>Traffic Volume</th>
<th>Typical</th>
<th>High</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADT&lt;100</td>
<td>300</td>
<td>1700</td>
<td>300</td>
</tr>
<tr>
<td>100&lt;ADT≤1000</td>
<td>700</td>
<td>1700</td>
<td>300</td>
</tr>
<tr>
<td>1000&lt;ADT≤10000</td>
<td>700</td>
<td>1700</td>
<td>300</td>
</tr>
<tr>
<td>ADT&gt;10000</td>
<td>1700</td>
<td>1700</td>
<td>300</td>
</tr>
</tbody>
</table>

*Typical:* Failure could cross travelway  
*High:* Support failure could stop a lifetime travelway  
*Low:* Support failure could not cross travelway  
Roadside sign supports: use 10-yr MRL, see Figure 3.8-4.
Design Criteria - Loads

LRFD Specifications for Structural Supports for Highway Signs, Luminaires, & Traffic Signals

• Wind Load


Design Criteria - Loads

LRFD Specifications for Structural Supports for Highway Signs, Luminaires, & Traffic Signals

• Basic Wind Speed
• (Extreme Event Limit State)

• MRI 300 Yr
Design Criteria - Loads

LRFD Specifications for Structural Supports for Highway Signs, Luminaires, & Traffic Signals

- Basic Wind Speed
  (Extreme Event Limit State)

- MRI 700 Yr

Design Criteria - Loads

LRFD Specifications for Structural Supports for Highway Signs, Luminaires, & Traffic Signals

- Basic Wind Speed
  (Extreme Event Limit State)

- MRI 1700 Yr
Design Criteria - Loads

LRFD Specifications for Structural Supports for Highway Signs, Luminaires, & Traffic Signals

- Basic Wind Speed
- (Service Limit State)

- MRI 10 Yr

Design Criteria - Loads

LRFD Specifications for Structural Supports for Highway Signs, Luminaires, & Traffic Signals

- Height Factor, Kd

- LRFD

3.3.4 - Height and Exposure Factor $K_d$

$$K_d = 2.0 \left( \frac{z}{H} \right)$$

The height and exposure factor $K_d$ shall be determined either from Table C3.3.4-1 or calculated using Eq. 3.3.4-1.

<table>
<thead>
<tr>
<th>Height, z (ft)</th>
<th>$K_d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-10 (2-4 m)</td>
<td>0.85</td>
</tr>
<tr>
<td>11-20 (4.6-6.1 m)</td>
<td>1.00</td>
</tr>
<tr>
<td>21-40 (6.4-12.2 m)</td>
<td>1.30</td>
</tr>
<tr>
<td>41-80 (12.4-24.4 m)</td>
<td>1.75</td>
</tr>
<tr>
<td>81-120 (24.6-36.5 m)</td>
<td>2.25</td>
</tr>
<tr>
<td>121-160 (38.1-48.8 m)</td>
<td>2.85</td>
</tr>
<tr>
<td>161-200 (48.8-60.9 m)</td>
<td>3.55</td>
</tr>
</tbody>
</table>

- Standard Specs

<table>
<thead>
<tr>
<th>Height, z (ft)</th>
<th>$K_d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-10 (2-4 m)</td>
<td>0.85</td>
</tr>
<tr>
<td>11-20 (4.6-6.1 m)</td>
<td>1.00</td>
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<tr>
<td>21-40 (6.4-12.2 m)</td>
<td>1.30</td>
</tr>
<tr>
<td>41-80 (12.4-24.4 m)</td>
<td>1.75</td>
</tr>
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<td>81-120 (24.6-36.5 m)</td>
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</tr>
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<td>161-200 (48.8-60.9 m)</td>
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</tr>
</tbody>
</table>

* See Eq. C3.3.4-1 for calculation of $K_d$.
Design Criteria - Loads

LRFD Specifications for Structural Supports for Highway Signs, Luminaires, & Traffic Signals

• Directionality Factor, $K_d$

<table>
<thead>
<tr>
<th>Support Type</th>
<th>Directionality Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Round</td>
<td>0.95</td>
</tr>
<tr>
<td>Square</td>
<td>0.90</td>
</tr>
<tr>
<td>Octagonal</td>
<td>0.95</td>
</tr>
<tr>
<td>Dodecagonal</td>
<td>0.95</td>
</tr>
<tr>
<td>Hendecagonal</td>
<td>0.95</td>
</tr>
<tr>
<td>Traffic Signal</td>
<td>0.85</td>
</tr>
<tr>
<td>Dynamic Measure Sign</td>
<td>0.85</td>
</tr>
<tr>
<td>Overhead Frame/Truss</td>
<td>0.85</td>
</tr>
<tr>
<td>Support with horizontal arms or members supporting sign and/or signals</td>
<td>0.85</td>
</tr>
</tbody>
</table>

• Wind Gust Factor, $G$

3.8.6—Gust Effect Factor $G$

The gust effect factor, $G$, shall be taken as a minimum of 1.14.

• LRFD Commentary: Follow ASCE/SEI 7-10 if:
  • Structure is Gust Sensitive:
    • Panel Height/Length > 4
    • Fundamental Frequency < 1.0 Hz
Design Criteria - Loads

LRFD Specifications for Structural Supports for Highway Signs, Luminaires, & Traffic Signals

- Wind Drag Coefficient, $C_d$

![Table](image)

Design Criteria - Loads

LRFD Specifications Vs Standard Specifications

$P_z = 0.00256K_2 K_d G V^2 C_d \text{ (psf)}$

- Basic Wind Speed, $V$ $\uparrow$ for Extreme $\downarrow$ For Service
- Importance Factor, $I_r$ $\cancel{\text{(1.0)}}$
- Height Factor, $K_z$ Unchanged
- Directionality Factor, $k_d = 0.85$ for overhead signs New
- Gust Wind Factor, $G$, Unchanged
- Drag Coefficient, $C_d$, Unchanged
Design Criteria - Loads

Wind Load Application – Box Truss Sign

\[ t_c (W_h, W_p, W_v) \]

\[ W_h \]
\[ W_p \]
\[ W_v \]

\[ DL+Ice \]

\[ Cantilever if required \]

\[ Wh = \text{Wind on Horizontal Components} \]
\[ WP = \text{Wind on Sign Panel} \]
\[ Wv = \text{Wind on Vertical Supports} \]

Overhead Bridge Structures

Design Criteria - Loads

Wind Load Application – Cantilever Sign

\[ t_c = \text{transverse component} \]

\[ W_p \]
\[ W_h \]
\[ W_v \]

\[ DL+Ice \]

\[ \text{Torque on vertical support, } T = (W_p \times e_1) + (W_h \times e_2) \]

\[ Cantilever \]

\[ Wh = \text{Wind on Horizontal Components} \]
\[ WP = \text{Wind on Sign Panel} \]
\[ Wv = \text{Wind on Vertical Supports} \]
Design Criteria - Geotechnical

Geotechnical Requirements - IDM CH 502

- Soil Borings **Will be** required for overhead structures to determine:
  - Soil Type: Sandy or Cohesive
  - Soil Bearing Capacity
  - Soil Friction Coefficient

- Foundations in Standard Drawings Reflects Minimum of:
  - Undrained Shear Strength 750 psf for Clay
  - Friction Angle of 30° for Sand

Design Criteria _ Geotechnical

- Broms’ Method for Cohesive or Cohesionless Soil for Drilled shafts
Design Criteria - Types

- Types in the Standard Drawings
  - Drilled Shaft or Spread Footing for Box Truss Structures
  - Drilled Shafts for Cantilever Structures

Design Criteria - Standard Drawings

- Sign Box Truss Structure

![Diagram of Sign Box Truss Structure]

Indiana Department of Transportation
SIGN BOX TRUSS STRUCTURE
TRUSS SECTIONS IN ELEVATIONAL VIEWS, TABLE WITH MEMBER SIZES
SEPTEMBER 2013
STANDARD DRAWING NO. E 002-5875-03

[Diagram showing typical exterior and interior truss sections]
Design Criteria – Standard Drawings

• Sign Box Structure

Spread Footing

Design Criteria - Standard Drawings

• Sign Box Structure
Design Criteria - Standard Drawings

- Sign Box Structure
  
  Drilled Shaft

Design Criteria - Standard Drawings

- Sign Box Structure – Spread Footing

  Advantages
  
  - Better for new roadway construction
  - Can be installed outside travelway limits

  Disadvantages
  
  - Requires bigger area of roadway disturbance.
  - Requires longer construction time (excavation, forms, backfill, paving, forms, MOT...)

Truss or Cantilever Sign Foundation Design
Design Criteria - Standard Drawings

- Sign Box Structure – Drilled Shafts

  **Advantages**
  - Less roadway disturbance – Space Limitation
  - Better for existing roadway/median or tight locations
  - Shorter construction time

  **Disadvantages**
  - Require Casing if water table or caving soil encountered
  - More Expensive: Mob & Demob for drilling equipment

If Both can be used, Use cost to determine Foundation Type

Design Criteria - Standard Drawings

- Cantilever Structure – Double Arm

![Diagram of Cantilever Structure]

Drilled Shaft

<table>
<thead>
<tr>
<th>TYPE</th>
<th>MAX SPAN (FT)</th>
<th>MAX SIGN AREA (FT²)</th>
<th>MAX MOUNTING HEIGHT (FT)</th>
<th>Chord Diameter (IN)</th>
<th>Wall Thickness (IN)</th>
<th>Vertical Diameter (IN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>10</td>
<td>100</td>
<td>24</td>
<td>7.5</td>
<td>6.0</td>
<td>4.0</td>
</tr>
<tr>
<td>B</td>
<td>15</td>
<td>200</td>
<td>24</td>
<td>10.5</td>
<td>6.0</td>
<td>3.0</td>
</tr>
<tr>
<td>C</td>
<td>20</td>
<td>300</td>
<td>24</td>
<td>14.0</td>
<td>6.0</td>
<td>6.0</td>
</tr>
</tbody>
</table>
Design Criteria - Standard Drawings

• Cantilever Structure – Quadri Chord

Truss or Cantilever Sign Foundation Design

Design Criteria - Standard Drawings

• Cantilever Structure – Foundation
Design Criteria - Standard Drawings

• Cantilever Structure – Median Installation

Design Criteria - Standard Drawings

• Cantilever Sign – Outside Shoulder Installation
Design Criteria

- Anchorage Design/ Code Check – ACI Appendix D
  - Steel Strength of Anchor in tension
  - Concrete Breakout Strength in tension
  - Pullout Strength of Anchor in concrete
  - For headed Anchor: Concrete Side-Face blockout Strength of Anchor in tension
  - Steel Strength of Anchor in Shear
  - Concrete Breakout Strength in shear
  - Concrete Pryout Strength of Anchor in shear
  - Interaction of Tensile and Shear Forces

Design Criteria – Standard Drawings

- Anchorage – Sign Box Truss Structures
Design Criteria – Standard Drawings

- **Anchorage – Cantilever Sign**

![Diagram of Anchorage - Cantilever Sign Foundation Design]

<table>
<thead>
<tr>
<th>BASE PLATE DIMENSIONS</th>
</tr>
</thead>
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<tr>
<td>COLUMN DIAMETER</td>
</tr>
<tr>
<td>18&quot;</td>
</tr>
<tr>
<td>20&quot;</td>
</tr>
<tr>
<td>24&quot;</td>
</tr>
</tbody>
</table>

- **Design Criteria**

  - **Specifications/ Material Properties**  Section 700, 800, 900
  - Concrete: Class A for Spread Footing & Drilled Shaft Foundation
  - Reinforcing Steel: Grade 60 Epoxy Coated
  - Anchor bolts, Nuts, and washers: ASTM F1554 Grade 36
  - Top End of Anchor bolts: Coated or Galvanized
  - Surface Seal Top Surface and Sides of foundation above the ground
Practice Pointers

- General Requirements IDM 502-1.01(10)

  - On Barrier Wall: Transition Taper = 30:1 to connect to adjacent barrier wall.
  - Provide expansion Joints at the transitions and pavement joint locations within the transition area.
  - Drainage shall be accounted for in the vicinity of the structure. IDM 502-1.01(10).

Practice Pointers

Summary/ Recommendations

- Coordinate with other roadside safety elements
- Pay attention to tight location in urban areas.
- Properly quantify Wind & Ice loads,
- Pay attention to anchorage design and details.
- Proper load path and proper load analysis.
- Try not to use soil borings from another location
- Pay attention to excavation limits adjacent to travelway, mainly for spread foundation
- Structural elements do not fit/ Anchor bolts or positioning plate not oriented properly.
Truss or Cantilever Sign Foundation Design

QUESTIONS

?