

AMERICAN ASSOCIATION OF
STATE HIGHWAY AND
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AASHTO
THE VOICE OF TRANSPORTATION

Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals



Sixth Edition 2013 Documents
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Foreword

The sixth edition of *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals* supersedes the fifth edition and its 2010 and 2011 interims. It includes changes approved by the Highways Subcommittee on Bridges and Structures in 2012.

Design guidelines for fatigue-critical multisided tubular sections are included in Section 5, “Steel Design.” Additional guidance is provided on longitudinal seam welds, tube-to-transverse plate connection welds, anchor bolt installation, and stiffened connections. New figures for fillet-welded gusseted box connections and ring-stiffened box connections are provided as commentary. Section 5 also includes updates to hand-hole welds, weld inspection, and provides new figures for holes and cutouts.

The scope of Section 11, “Fatigue Design,” is expanded to allow design of support structures using nominal stress-based classifications of typical connection details, or using the alternate local stress-based and/or experiment-based methodologies presented in Appendix D. New tables are provided for determining the fatigue resistance of typical connection details in support structures for finite and infinite life designs. The scope of Section 11 is expanded to include separate provisions for high-mast lighting towers, including a combined wind load for a simplified approach to derive fatigue damage from all the load effects due to natural wind.

The Specifications are based on the allowable stress design methodology and are intended to address the usual structural supports. Requirements more stringent than those in the Specifications may be appropriate for atypical structural supports. The commentary is intended to provide background on some of the considerations contained in the Specifications; however it does not provide a complete historical background, nor detailed discussions of the associated research studies. The Specifications and accompanying commentary do not replace sound engineering knowledge and judgment.

AASHTO Highways Subcommittee on Bridges and Structures

Preface

The sixth edition of *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals* supersedes the fifth edition and its 2010 and 2011 interims. It includes changes approved by the Highways Subcommittee on Bridges and Structures in 2012.

AASHTO Publications Staff

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SECTION 1

INTRODUCTION

1.1—SCOPE

The provisions of these *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals*, hereinafter referred to as the Specifications, are applicable to the structural design of supports for highway signs, luminaires, and traffic signals. The types of supports covered in these Specifications are discussed in Article 1.4. The Specifications are intended to serve as a standard and guide for the design, fabrication, and erection of these types of supports.

These Specifications are not intended to supplant proper training or the exercise of judgment by the designer, and they include only the minimum requirements necessary to provide for public safety. The Owner or the designer may require the design and quality of materials and construction to be higher than the minimum requirements.

The commentary directs attention to other documents that provide suggestions for carrying out the requirements and intent of these Specifications. However, those documents and the commentary are not intended to be a part of the Specifications.

C1.1

These Specifications are the result of National Cooperative Highway Research Program (NCHRP) Project 17-10 and the corresponding NCHRP Report 411. At the discretion of the Owner, proprietary solutions may be considered. These solutions may address both new structures and the repair or rehabilitation of existing structures. Testing of proprietary solutions shall model actual conditions as closely as possible, and the test methods and results shall be published. These Specifications are intended to replace the previous edition, *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals* (2009).

The commentary discusses some provisions of the Specifications with emphasis given to the explanation of new or revised provisions that may be unfamiliar to users of the Specifications. The commentary is not intended to provide a complete historical background concerning the development of this and previous Specifications, nor is it intended to provide a detailed summary of the studies and research data reviewed in formulating the provisions of the Specifications. However, references to some of the research data are provided for those who wish to study the background material in depth.

1.2—DEFINITIONS

Arm—A cantilevered support, either horizontal or sloped.

Bridge Support—Also known as span-type support; a horizontal or sloped member or truss supported by at least two vertical supports.

Cantilever—A support, either horizontal or vertical, supported at one end only.

Designer—The person responsible for design of the structural support.

High-Level Luminaire Support—Truss-type or pole-type tower that provides lighting at heights greater than about 17 m (55 ft), typically using 4 to 12 luminaires.

High-Mast Lighting Tower (HMLT)—Another description for a pole-type high-level luminaire support.

Luminaire—A complete lighting unit consisting of a lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps, and to connect the lamps to the electric power supply.

Mast Arm—A supporting arm designed to hold a sign, signal head, or luminaire in an approximately horizontal position.

Monotube—A support that is composed of a single tube.

Overhead Sign—A sign suspended above the roadway.

Owner—The person or agency having jurisdiction for the design, construction, and maintenance of the structural support.

Pole—A vertical support that is long, relatively slender, and generally rounded or multisided.

Pole Top—A descriptive term indicating that an attachment is mounted at the top of a structural support, usually pertaining to one luminaire or traffic signal mounted at the top of a pole.

Roadside Sign—A sign mounted beside the roadway on a single support or multiple supports.

Sign—A device conveying a specific message by means of words or symbols, erected for the purpose of regulating, warning, or guiding traffic.

Span Wire—A steel cable or strand extended between two poles, commonly used as a horizontal support for small signs and traffic signals.

Structural Support—Support designed to carry the loads induced by attached signs, luminaires, and traffic signals.

Traffic Signal—An electrically operated traffic control device by which traffic is regulated, warned, or directed to take specific actions.

Truss—A structural support, usually vertical or horizontal, composed of framework that is often arranged in triangles.

1.3—APPLICABLE SPECIFICATIONS

The following specification documents may be referenced for additional information on design, materials, fabrication, and construction:

- *Standard Specifications for Highway Bridges,*
- *AASHTO LRFD Bridge Design Specifications,*
- *Standard Specifications for Transportation Materials and Methods of Sampling and Testing,* and
- *Book of ASTM Standards.*

1.4—TYPES OF STRUCTURAL SUPPORTS

Structural supports are categorized as follows:

- Sign support structures,
- Luminaire support structures,
- Traffic signal support structures, and
- A combination of these structures.

1.4.1—Sign

Structural supports for signs include both overhead and roadside sign structures that are intended to support highway traffic signs and markers.

C1.4.1

Typical overhead and roadside sign supports are shown in Figure C1.4.1-1. Overhead sign structures are generally of the bridge or cantilever type. It is also common to support signs on existing grade separation structures that span the traffic lanes.

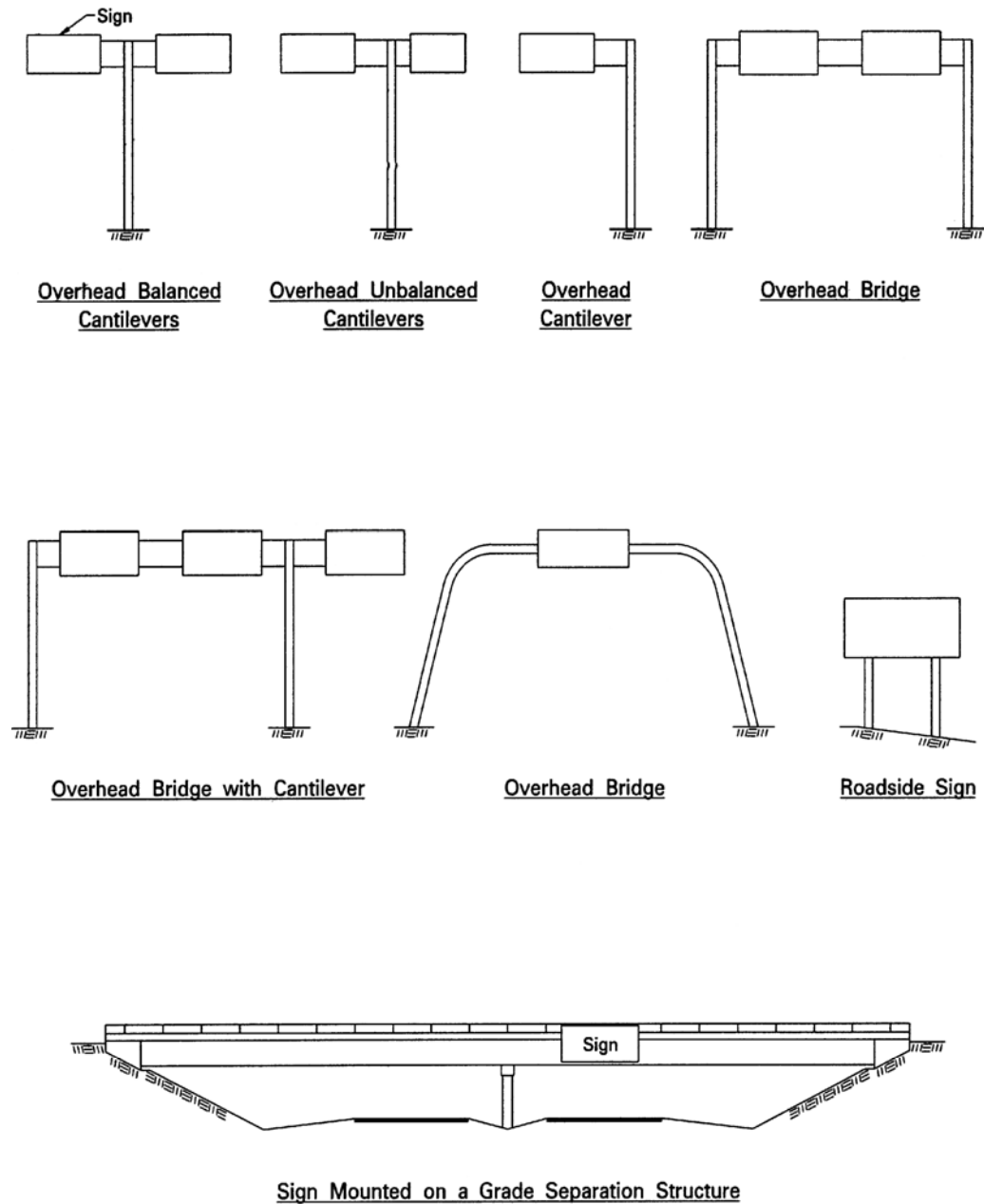


Figure C1.4.1-1—Sign Supports

1.4.2—Luminaire

Structural supports for luminaires include typical poles with luminaire arms, typical poles with luminaires mounted at pole top, and high-level luminaire supports (both truss type and pole type).

C1.4.2

The lighting of modern highways includes the use of typical lighting poles, generally tubular shafts that support one or two luminaires and range in height from about 9 m (30 ft) to 17 m (55 ft). High-level luminaire supports normally range in heights from about 17 m (55 ft) to 46 m (150 ft) or more, usually supporting 4 to 12 luminaires; they are used to illuminate large areas. Typical luminaire supports and high-level luminaire supports are shown in Figure C1.4.2-1.

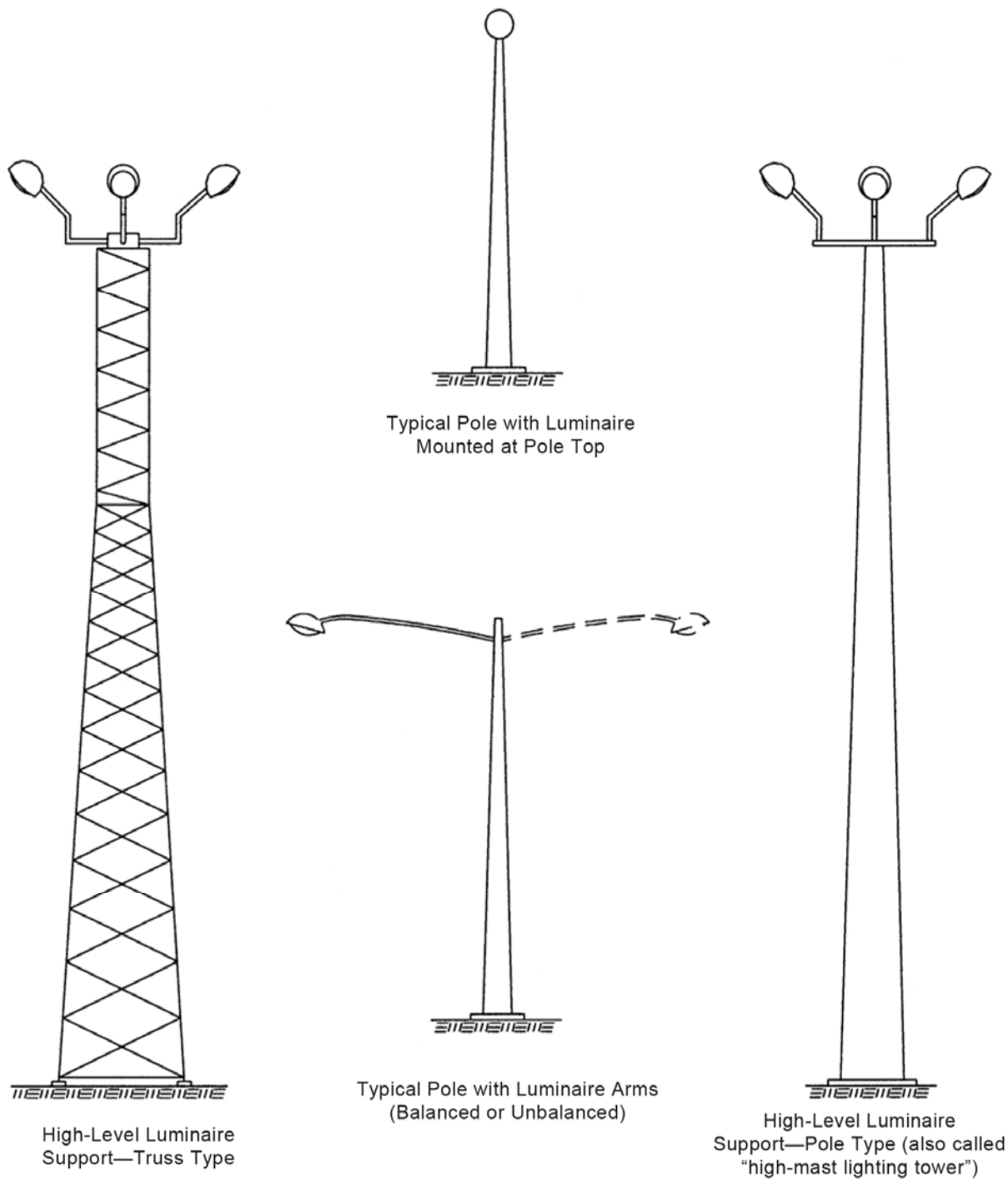


Figure C1.4.2-1—Luminaire Structural Supports

1.4.3—Traffic Signal**C1.4.3**

Structural supports for mounting traffic signals include pole top, cantilevered arms, bridge, and span wires.

Typical traffic signal supports are shown in Figure C1.4.3-1.

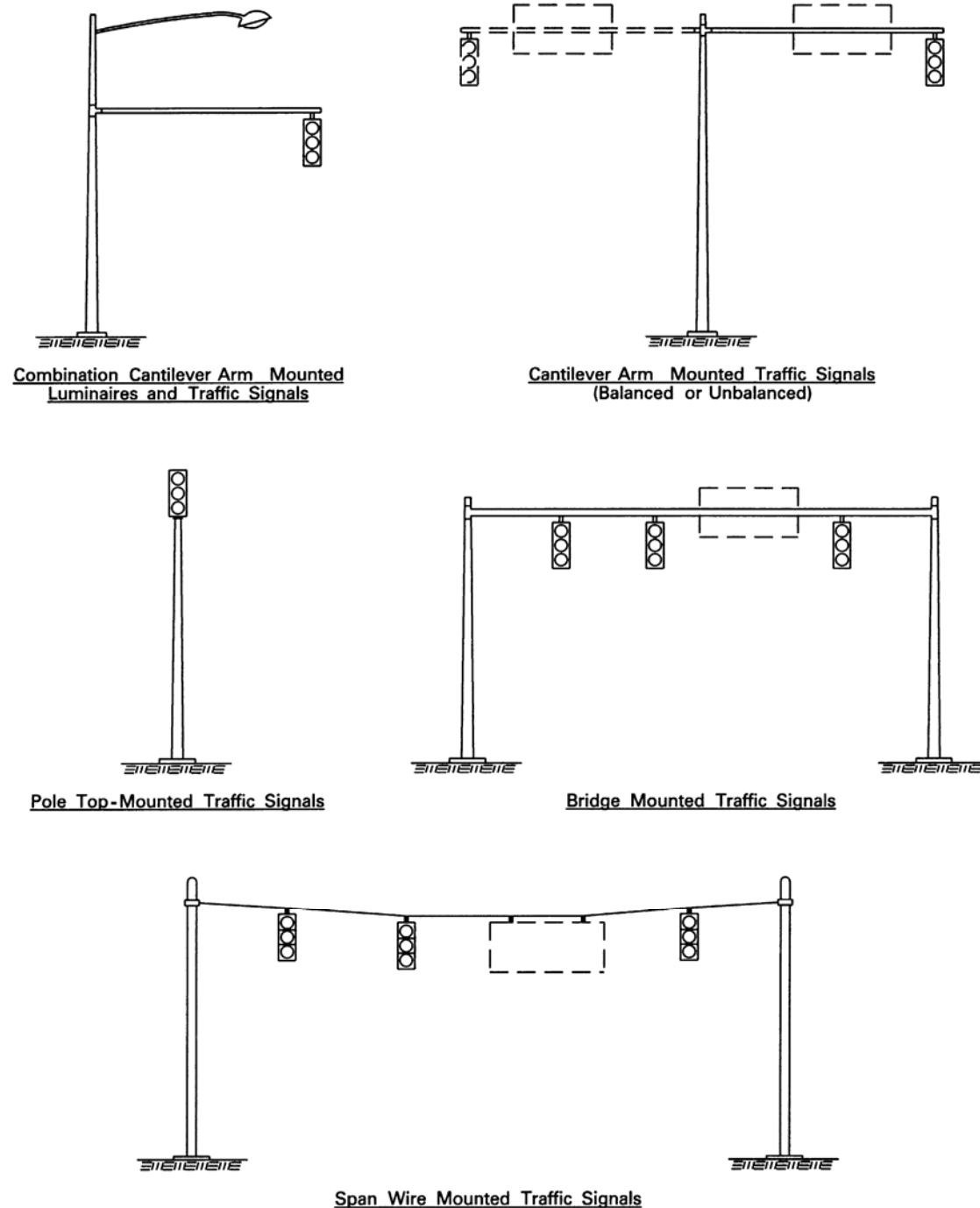


Figure C1.4.3-1—Traffic Signal Structural Supports

1.4.4—Combination Structures

Combination structures include structural supports that combine any of the functions described in Articles 1.4.1, 1.4.2, and 1.4.3.

C1.4.4

Generally, combination structures are composed of a luminaire support and a traffic signal support. Other structures may combine traffic signal or luminaire supports with those for utility lines.

1.5—REFERENCES

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SECTION 2:

GENERAL FEATURES OF DESIGN

2.1—SCOPE

C2.1

Minimum requirements are provided or referenced for aesthetics, clearances, constructibility, inspectability, and maintainability of structural supports. Guidelines for determining vertical and lateral clearances, use of breakaway supports, use of guardrails, illumination of the roadway, sizes of signs, illumination and reflectorization of signs, and maintenance are found in the following references:

- *A Policy on Geometric Design of Highways and Streets* (2011),
- *Manual on Uniform Traffic Control Devices* (2009) (herein after referred to as MUTCD),
- *Roadside Design Guide* (2011),
- *AASHTO Maintenance Manual for Roadways and Bridges* (2007), and
- *Roadway Lighting Design Guide* (2005).

This Section is intended to provide the Designer with information and references to determine the configuration, overall dimensions, and location of structural supports for highway signs, luminaires, and traffic signals. The material in this Section is broad in nature. No attempt has been made to establish rigid criteria in such areas as vertical heights of traffic signal and luminaire supports and levels of illumination. This Section provides references and considerations for the different aspects of design that should be considered in the preliminary stages of a project. In addition to the requirements provided within this Section, many Owners have their own requirements.

2.2—DEFINITIONS

Barrier—A longitudinal traffic barrier, usually rigid, used to shield roadside obstacles or nontraversable terrain features. It may occasionally be used to protect pedestrians from vehicle traffic.

Breakaway—A design feature that allows a sign, luminaire, or pole top-mounted traffic signal support to yield, fracture, or separate near ground level on impact.

Clear Zone—The total roadside border area, starting at the edge of the traveled way, available for unobstructed use by errant vehicles.

Clearance—Horizontal or vertical dimension to an obstruction.

Curb—A vertical or sloping surface, generally along and defining the edge of a roadway or roadway shoulder.

Gore—The center area immediately past the point where two roadways divide at an acute angle, usually where a ramp leaves a roadway.

Guardrail—A type of longitudinal traffic barrier, usually flexible.

Mounting Height—Minimum vertical distance to the bottom of a sign or traffic signal, or to the center of gravity of a luminaire, relative to the pavement surface.

Pedestal Pole—A relatively short pole supporting a traffic signal head attached directly to the pole.

Roadside—The area between the shoulder edge and the right-of-way limits, or the area between roadways of a divided highway.

2.3—AESTHETICS

The structural support should complement its surroundings, be graceful yet functional in form, and present an appearance of adequate strength. The support should have a pleasing appearance that is consistent with the aesthetic effect of the highway's other physical features. Supports should have clean, simple lines, which will present minimum hazard to motorists.

Structural supports should be designed and located so as not to distract the motorist's attention or obstruct the view of the highway. Supports should be placed so they do not obstruct the view of other signs or important roadway features. The effect that signing or lighting installations have on the surrounding environment should be evaluated.

2.4—FUNCTIONAL REQUIREMENTS**2.4.1—Lighting Systems**

General guidelines concerning lighting systems for highways may be found in the *Roadway Lighting Design Guide* (2005).

2.4.1.1—Vertical Heights for Luminaire Supports

The height of the luminaire support should be determined by the Designer to fit the particular need and situation.

C2.3

The appearance of ordinary structural supports should consider aesthetics and function. Combination poles, which serve multiple functions for lighting, traffic control, and electrical power, should be taken under consideration to reduce the number of different poles along the highway.

C2.4.1

The Designer should select the light source, luminaire distribution, mounting height, and luminaire overhang based on such factors as geometry and character of the roadway, environment, proposed maintenance, economics, aesthetics, and overall lighting objectives. Some communities limit the amount of surrounding glare from illumination systems, and shielding may be required. The same average level of lighting can usually be obtained by more than one installation arrangement.

The *Roadway Lighting Design Guide* (2005) provides information on level and uniformity of illuminance and luminance, quality of light, location of poles, use of breakaway devices, high-mast lighting towers, and maintenance. Similar information may also be found in *An Informational Guide for Roadway Lighting* (1984) and *A Study of Roadway Lighting* (1968). Additional information on breakaway devices for lighting poles may be found in the *Roadside Design Guide* (2011).

C2.4.1.1

Some items that should be considered by the Designer in determining the height of a luminaire support are as follows:

- Glare characteristics of the highway,
- Desired level of illumination and distribution of light over the roadway area,
- Photometric characteristics of a selected lamp and luminaire,
- Available space for placing the supports, and
- Maintenance capability (maximum attainable servicing height).



Height restrictions may be imposed by various government agencies, such as the Federal Highway Administration (FHWA) with respect to breakaway devices and the Federal Aviation Administration for aircraft considerations.

The amount of illumination that should be provided over a roadway depends on the interaction among visibility, visual comfort, light distribution, and the geometry of the lighting system. Disability and discomfort glare, pavement glare, road location, and obstructions to visibility and traffic patterns are other factors that influence the level of illumination to be provided by a lighting system.

A luminaire installation should provide a visual environment that is conducive to safe and comfortable night driving. Where pedestrian safety is not involved, there is no indication that the lighting of bridges and overpasses should be any different from elsewhere on the highway.

2.4.2—Structural Supports for Signs and Traffic Signals

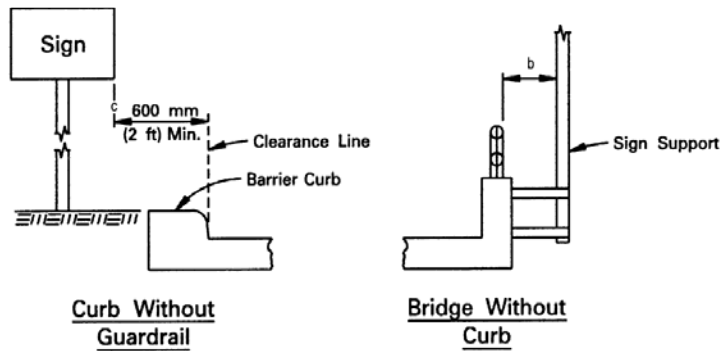
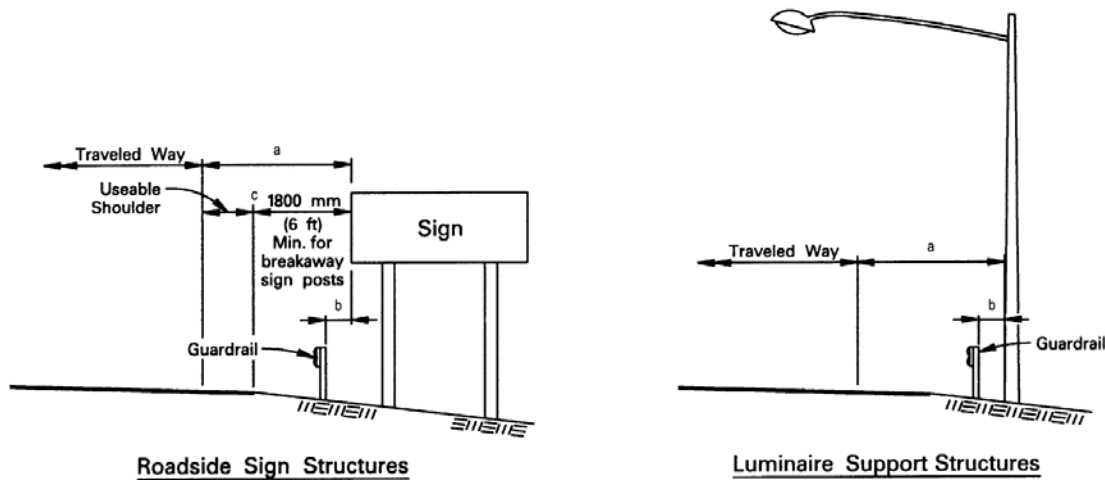
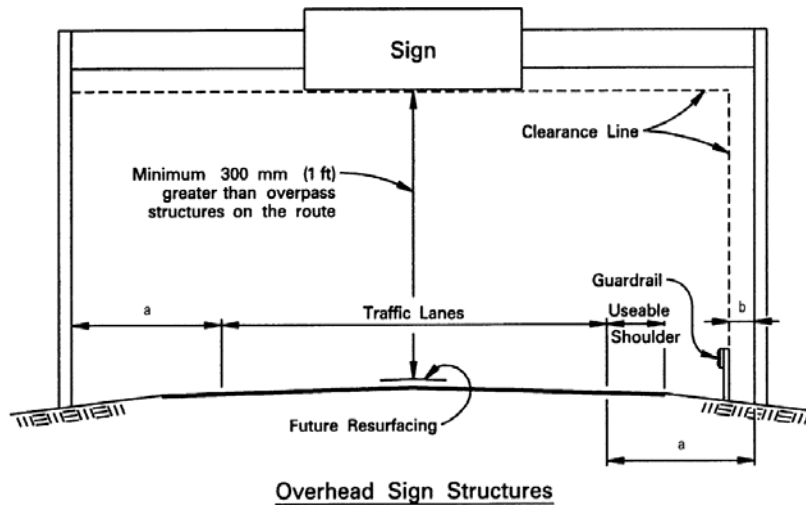
2.4.2.1—Vertical Clearances

Overhead sign and overhead traffic signal structures shall provide a vertical clearance over the entire width of the pavement and shoulders of 300 mm (1 ft) greater than the required minimum vertical clearance of overpass structures on the route. The vertical clearance shall be either in conformance with *A Policy on Geometric Design of Highways and Streets* (2011) for the functional classification of the highway, or exceptions thereto shall be justified. Possible reduction of vertical clearance should be investigated. Additional guidance on vertical clearances may be found in the MUTCD.

C2.4.2.1

The minimum clearance should include an allowance for possible future overlays.

The additional 300-mm (1-ft) vertical clearance is required so that high vehicles will strike the stronger overpass structures first, thereby lessening the chance of major collision damage to the structurally weaker overhead sign support or traffic signal support structures. A depiction of this clearance limit is illustrated in Figure 2.4.2.1-1.



Notes:

- ^a See Article 2.5.1 on "Clear Zone Distances" and Article 2.5.2 on Breakaway Supports.
- ^b See Article 2.5.3 on "Guardrails and Other Barriers."
- ^c See MUTCD.

Figure 2.4.2.1-1—Location of Structural Supports

2.4.2.2—Size, Height, and Location of Signs

The MUTCD should be consulted for the sizes, heights, and placement of signs for any installation.

2.4.2.3—Illumination and Reflectorization of Signs

Illumination and reflectorization of signs should conform with the provisions of the MUTCD.

Except where reflectorization is deemed adequate, all overhead sign installations should normally be illuminated. The lighting equipment should produce uniform illumination for the sign surface and the position of the lighting fixtures should not impair normal viewing of the sign or obstruct view of the roadway. Where internal illumination is used in conjunction with translucent materials, the colors of the sign should appear essentially the same by night and day.

2.4.2.4—Variable Message Signs

Cantilevered support structures for variable message signs (VMS) shall be designed for fatigue in accordance with Section 11, “Fatigue Design.”

The design of VMS support structures, enclosures, and connections to the support structure will normally require additional considerations that are beyond the scope of these Specifications.

2.5—ROADSIDE REQUIREMENTS FOR STRUCTURAL SUPPORTS

Consideration shall be given to safe passage of vehicles adjacent to or under a structural support. The hazard to errant vehicles within the clear zone distance, defined in Article 2.5.1, should be minimized by locating obstacles a safe distance away from the travel lanes. Roadside requirements and location of structural supports for highway signs, luminaires, and traffic signals should generally adhere to the principles given in Articles 2.5.1 through 2.5.9.

2.5.1—Clear Zone Distance

Structural supports should be located in conformance with the clear zone concept as contained in Chapter 3, “Roadside Topography and Drainage Features,” of the *Roadside Design Guide* (2011), or other clear zone policy accepted by the FHWA.

Where the practical limits of structure costs, type of structures, volume and design speed of through-traffic, and structure arrangement make conformance with the *Roadside Design Guide* (2011) impractical, the structural support should be provided with a

C2.4.2.2

The MUTCD includes information on signs for sizes, illumination and reflectorization, location, height, and lateral clearance.

C2.4.2.3

The *Roadway Lighting Design Guide* (2005) provides some information for luminance and illuminance of signs.

High-intensity reflectorized sheeting can be used to eliminate the need for sign illumination and maintenance walkways.

C2.4.2.4

VMS are composed of lamps or luminous elements that may be visible during the day as well as at night. The lamps and electronics are contained within an enclosure, which weighs significantly more than most sign panels.

NCHRP Report 411 (1998) provides some information regarding the design of VMS support structures. Additional design considerations that are not provided in the report may still be required.

C2.5

Where possible, a single support should be used for dual purposes (e.g., signals and lighting). Consideration should also be given to locating luminaire supports to minimize the necessity of encroaching on the traveled way during routine maintenance.

C2.5.1

The clear zone, illustrated in Figure 2.4.2.1-1, is the roadside border area beyond the traveled way, available for safe use by errant vehicles. This area may consist of a shoulder, a recoverable slope, a nonrecoverable slope, and/or a clear run-out area. The desired width is dependent on the traffic volumes and speeds and on the roadside geometry.

Suggested minimum clear zone distances are provided in the *Roadside Design Guide* (2011) and are dependent on average daily traffic, slope of roadway, and

breakaway device or protected by the use of a guardrail or other barrier.

2.5.2—Breakaway Supports

Breakaway supports should be used for luminaire and roadside sign supports when they cannot be placed outside the roadside clear zone or behind a guardrail. The requirements of Section 12, “Breakaway Supports,” shall be satisfied. The requirements of Articles 2.5.2.1 and 2.5.2.2 should be met for the proper performance of the breakaway support.

Breakaway supports housing electrical components shall have the use of electrical disconnects considered for all new installations and for existing installations that experience frequent knockdown.

2.5.2.1—Foundations

The top of foundations and projections of any rigidly attached anchor bolts or anchor supports should not extend above the ground level enough to increase the hazard or to interfere with the operation of a breakaway support.

2.5.2.2—Impact Height

Breakaway supports should be located such that the location of impact of an errant vehicle’s bumper is consistent with the maximum bumper height used in breakaway qualification tests.

2.5.3—Guardrails and Other Barriers

The location of roadside sign and luminaire supports behind a guardrail should provide clearance between the back of the rail and the face of the support to ensure that the rail will deflect properly when struck by a vehicle. Continuity of the railing on rigid highway structures should not be interrupted by sign or luminaire supports.

The clearance between the edge of a sign panel, which could present a hazard if struck, and the back of a barrier should also take into consideration the deflection of the rail. The edge of a sign shall not extend inside the face of the railing.

design vehicle speed. Additional discussions of clear zone distances and lateral placement of structural support may be found in the MUTCD and *A Policy on Geometric Design of Highways and Streets* (2011).

C2.5.2

Generally, breakaway supports should be provided whenever the support is exposed to traffic. Breakaway supports cannot usually be incorporated with overhead sign bridges, cantilever overhead signs, or high-level lighting supports. These structure types can often be placed outside the clear zone; however, if they are located within the clear zone, barrier protection is required.

Article 12.5.3 contains information on electrical disconnects.

C2.5.2.1

Foundations for breakaway supports located on slopes are likely to require special details to avoid creating a notch in the slope that could impede movement of the support when broken away or a projection of the foundation that could snag the undercarriage of an impacting vehicle. Foundations should be designed considering the breakaway stub height limitations of Article 12.5.3.

C2.5.2.2

The breakaway performance of most, if not all, breakaway supports degrades with an increase in impact height. Typically, the bumper center height in breakaway qualification tests is about 450 mm (18 in.). Research suggests that a breakaway support should not be located where the trajectory of an errant vehicle is likely to result in the bumper of the vehicle striking the support more than 700 mm (28 in.) above the ground line at the support. This criterion will be met where a foreslope is no greater than 1 to 6 or the face of the support is not more than 600 mm (24 in.) outside the intersection of a shoulder slope and a 1 to 4 foreslope.

C2.5.3

Guardrails, as illustrated in Figure 2.4.2.1-1, are provided to shield motorists from fixed objects and to protect fixed objects, such as overhead sign supports. The *Roadside Design Guide* (2011) provides guidelines for the provision of roadside barriers for fixed objects.

The clearance between the back of the barrier and the face of the support may vary, depending on type of barrier system used. The *Roadside Design Guide* (2011) may be used to determine the proper clearance.

2.5.4—Roadside Sign and Luminaire Supports

Roadside sign and typical luminaire supports within the clear zone distance specified in Article 2.5.1 should be designed with a breakaway feature acceptable under NCHRP Report 350, or protected with a guardrail or other barrier. Where viewing conditions are favorable, roadside sign and typical luminaire supports may be placed outside the clear zone distance.

2.5.5—Overhead Sign Supports and High-Level Lighting Supports

Overhead sign and high-level lighting structural supports should be placed outside the clear zone distance; otherwise, they should be protected with a proper guardrail or other barrier.

2.5.6—Traffic Signal Supports

Traffic signal supports that are installed on high-speed facilities should be placed as far away from the roadway as practical. Shielding these supports should be considered if they are within the clear zone for that particular roadway.

2.5.7—Gores

Where obstruction in the gore is unavoidable within the clear zone, protection should be provided by an adequate crash cushion or the structure should be provided with a breakaway device.

2.5.8—Urban Areas

For sign, luminaire, and traffic signal structures located in working urban areas, the minimum lateral clearance from a barrier curb to the support is 500 mm (20 in.). Where no curb exists, the horizontal clearance to the support should be as much as reasonably possible.

C2.5.4

Where there is a probability of being struck by errant vehicles, even supports outside this suggested clear zone should preferably be breakaway.

C2.5.5

Overhead sign and high-level lighting supports are considered fixed-base support systems that do not yield or break away on impact. The large mass of these support systems and the potential safety consequences of the systems falling to the ground necessitate a fixed-base design. Fixed-base systems are rigid obstacles and should not be used in the clear zone area unless shielded by a barrier. In some cases, it may be cost effective to place overhead sign supports outside the clear zone with no barrier protection when the added cost of the greater span structure is compared with the long-term costs of guardrail and vegetation maintenance. Some structures can sometimes be located in combination with traffic barriers protecting other hazards, such as culverts, bridge ends, and embankments.

C2.5.6

Traffic signal structural supports with mast arms or span wires normally are not provided with a breakaway device. However, pedestal pole traffic signal supports are appropriately designed to be breakaway. Pedestal poles should, if possible, be placed on breakaway supports because they are usually in close proximity to traffic lanes.

C2.5.8

The 500-mm (20-in.) offset is not an urban clear zone, rather it was established to avoid interference with truck mirrors, open doors, and so forth. The preferred location of support structures is on the “house side” of the sidewalk.

2.5.9—Joint-Use Supports

Where possible, consideration should be given to the joint usage of supports in urban areas.

2.6—CORRELATION OF STRUCTURAL SUPPORT DESIGN WITH ROADWAY AND BRIDGE DESIGN

2.6.1—Signs

Sign panels may be supported on existing or proposed grade separation structures. In these cases, the minimum vertical clearance requirements for overhead signs do not apply. A specifically designed frame shall be required to attach the sign panel to the existing structure. The overhead sign should be located as near to the most advantageous position for traffic operation as possible, but where structurally adequate support details can be provided.

2.6.2—Luminaires

The location of luminaire supports should be coordinated with the function and location of other structures.

2.7—MAINTENANCE

A regular maintenance program should be established that includes periodic inspection, maintenance, and repair of structural supports.

Provisions to perform maintenance and inspection of structural supports should include the following:

C2.5.9

Advantage should be taken of joint usage to reduce the number of supports in urban areas. For example, a traffic sign and signal support can be combined with a lighting pole.

C2.6.1

Sign installation on grade separation structures is generally acceptable aesthetically when the sign panels do not extend below the girders or above the railing. The sign panel should be placed slightly above the minimum vertical clearance specified for the grade separation structure. Close liaison between bridge and traffic engineers is essential for signs mounted on grade separation structures.

The placement of overhead signs must be considered in the preliminary design stages to avoid possibly restricting the driver's view of sign messages by other signs or structures. Signing is an integral part of the highway environment and must be developed along with the roadway and bridge designs.

C2.6.2

The location of the luminaire supports should be coordinated with the location of the sign structures so that the driver's view of sign legends is not hampered. Attention should be given to correlate interchange and structure lighting with the lighting provided on the other sections of the roadway. Where practical, high-level lighting may be used to reduce the number of supports required, present fewer roadside obstacles, and improve safety for maintenance personnel.

C2.7

The *AASHTO Maintenance Manual* (2007) includes information for scheduling, inspecting, and maintaining structures.

All structural supports should be inspected for the effects of corrosion and fatigue. Some connections, such as the slip base breakaway connection on some roadside sign and luminaire supports, may require periodic maintenance to maintain the specified torque requirements of the bolts for the connection to function properly.

Steel poles and brackets that are not galvanized should be painted as frequently as required by local conditions.

- Inspection ladders, walkways, and covered access holes, if necessary, where other means of inspection are not practical;
- The means to perform inspection, maintenance, and repair of overhead sign and traffic signal structural supports, without obstructing the traveled way on all except low-volume highways; and
- The means to perform maintenance and repair of structural supports for roadway lighting systems caused by such factors as lamp outages, destruction resulting from vehicle impact, vandalism, accumulation of dirt on luminaries, and corrosion.

Maintenance and repair of overhead sign structural supports may be done either by special maintenance equipment operated from the shoulder or by construction of a maintenance walkway on the sign structural support.

Maintenance and servicing of luminaires and lighting for signs should be considered when designing lighting systems. Most high-level lighting systems use methods and equipment that lower the luminaire assembly by means of cables and winches to ground level for servicing. Truck-mounted units are also available that allow servicing of supports up to about 30 m (98 ft) in height.

High-level lighting poles have been outfitted to accept movable video equipment for the inspection of the pole.

2.8—REFERENCES

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SECTION 3: LOADS

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SECTION 3

LOADS

3.1—SCOPE

This Section specifies minimum requirements for loads and forces, the limits of their application, and load combinations that are used for the design or structural evaluation of supports for highway signs, luminaires, and traffic signals.

Where different mean recurrence intervals may be used in specifying the loads, the selection of the proper mean recurrence interval is the responsibility of the Owner.

Fatigue-sensitive supports are addressed in Section 11.

C3.1

This Section includes specifications for the dead load, live load, ice load, and wind load.

The Specification defines wind loads in terms of 3-s gust wind speeds instead of the formerly used fastest-mile wind speeds. Use of the 3-s gust wind speed map may result in significant increases or decreases (relative to the fastest-mile) in the calculated wind loads depending on the location of the structure.

3.2—DEFINITIONS

Basic Wind Speed, V —The 3-s gust wind speed at 10 m (33 ft) above the ground associated with a 50-yr mean recurrence interval.

Design Wind Pressure, P_z —The pressure exerted on a member or attachment by wind. The pressure is calculated using appropriate design values for all variables in the wind pressure equation.

Drag Coefficient, C_d —A dimensionless coefficient that adjusts the effective velocity pressure, vp_z , for the effects of the geometry of the element and the Reynolds number.

Effective Velocity Pressure, vp_z —The pressure exerted by the effects of the wind assuming that the importance factor, I_r , and the drag coefficient, C_d , are both equal to 1.0.

Fastest-Mile Wind Speed—The peak wind speed averaged over 1.6 km (1 mi) of wind passing a point.

Gust Effect Factor, G —A dimensionless coefficient that adjusts the wind pressure to account for the dynamic interaction of the wind and the structure.

Height and Exposure Factor, K_z —A dimensionless coefficient that corrects the magnitude of wind pressure referenced to a height above the ground of 10 m (33 ft) for the variation of wind speed with height.

Importance Factor, I_r —A factor that converts wind pressures associated with a 50-yr mean recurrence interval to wind pressures associated with other mean recurrence intervals.

Mean Recurrence Interval, r —The inverse of the probability of occurrence of a specific event in a 1-yr period. (If an event has a 0.02 probability of occurrence in one year, it has a mean recurrence interval of 50 yr = 1/0.02.)

Service Life—Time that the structure is expected to be in operation.

Solidity—The solid elevation area divided by the total enclosed elevation area for a truss.

Special Wind Region—A region where the magnitude of the local wind speeds is dramatically affected by local conditions. Wind speeds in these areas should be determined by consulting the authority having local jurisdiction or through the analysis of local meteorological conditions.

Three-Second Gust Wind Speed—The average wind speed measured over an interval of 3 s.

Velocity Conversion Factor, C_v —A factor that converts 3-s gust wind speeds associated with a 50-yr mean recurrence interval to 3-s gust wind speeds associated with other mean recurrence intervals. The square of the velocity conversion factor equals the corresponding importance factor.

3.3—NOTATION

b	=	overall width (m, ft) (3.9.4.2)
BL	=	basic load (3.9.3)
C_d	=	drag coefficient (3.8.3)
C_{dD}	=	drag coefficient for round cylinder of diameter D (3.8.6)
C_{dd}	=	drag coefficient for round cylinder of diameter d_o (3.8.6)
C_{dm}	=	drag coefficient for multisided section (Table 3.8.6-1) (C3.8.6)
C_{dr}	=	drag coefficient for round section (3.8.6)
C_v	=	velocity conversion factor for the selected mean recurrence interval (C3.8.6)
d	=	depth (diameter) of member (m, ft) (3.8.6)
D	=	major diameter of ellipse (m, ft) (3.8.6)
DL	=	dead load (N, lb) (3.4)
d_o	=	minor diameter of ellipse (m, ft) (3.8.6)
G	=	gust effect factor (3.8.1)
I_{ce}	=	ice load (N, lb) (3.4)
I_r	=	importance factor based upon the r th mean recurrence interval (3.8.1)
K_z	=	height and exposure factor (3.8.1) (C3.8.4)
L_{sign}	=	longer dimension of the attached sign (m, ft) (3.8.6)
n_c	=	normal component of wind force (N, lb) (3.9.3)
P_z	=	design wind pressure (Pa, psf) (3.8.1) (3.8.6)
r	=	mean recurrence interval expressed in years for importance factor, I_r (3.8.6)
r_c	=	ratio of corner radius to radius of inscribed circle (C3.8.6)
r_m	=	ratio of corner radius to radius of inscribed circle where multisided section is considered multisided (3.8.6)
r_r	=	ratio of corner radius to radius of inscribed circle where multisided section is considered round (3.8.6)
r_s	=	ratio of corner radius to depth of square member (3.8.6)
t_c	=	transverse component of wind force (N, lb) (3.9.3)
V	=	basic wind speed, expressed as a 3-s gust wind speed, at 10 m (33 ft) above the ground in open terrain associated with a 50-yr mean recurrence interval (m/s, mph) (3.8.1)
vp_z	=	effective velocity pressure at a height z above ground (Pa, psf) (3.8.6)
W	=	wind load (N, lb) (3.4)
W_h	=	wind load on exposed horizontal support (N, lb) (3.9.2)
W_l	=	wind load on luminaires (N, lb) (3.9.2)
W_p	=	wind load on sign panel or traffic signal (N, lb) (3.9.2)
W_{sign}	=	shorter dimension of the attached sign (m, ft) (3.8.6)
W_v	=	wind load on exposed vertical supports (N, lb) (3.9.3)
z	=	height at which wind pressure is calculated (m, ft) (C3.8.4)
z_g	=	constant for calculating the exposure factor and is a function of terrain (C3.8.4)
α	=	constant for calculating the exposure factor and is a function of terrain (C3.8.4)

3.4—GROUP LOAD COMBINATIONS

The loads described in Articles 3.5 through 3.8 shall be combined into appropriate group load combinations as stipulated in Table 3.4-1. Each part of the structure shall be proportioned for the combination producing the maximum load effect, using allowable stresses increased as indicated for the group load.

The loads for Group IV, *fatigue*, shall be computed in accordance with Articles 11.6 and 11.7.

C3.4

Table 3.4-1 has been modified from the 1994 edition of the Specifications. The percent increase for group load combinations II and III has changed from 40 percent to 33 percent. The primary reason for the change is to ensure consistency with major specifications in the United States.

An additional load combination for fatigue has been added based on NCHRP Report 412.

The intent of the Specifications is to provide an adequate margin of safety against failure. For example, the minimum safety factors for bending for a steel tubular section are approximately 1.92 for Group I loading and 1.45 for Group II and Group III loadings. The safety factor may vary depending on the material and cross-section used; however, consideration has been given to ensure the equity in safety factors among different materials addressed by these Specifications. Some materials and structural shapes may warrant a higher safety factor because of inherent variability in the material or the manufacturing process.

Table 3.4-1—Group Load Combinations

Group Load	Load Combination ^a	Percentage of Allowable Stress ^b
I	<i>DL</i>	100
II	<i>DL + W</i>	133
III	<i>DL + Ice + 1/2 (W)</i> ^c	133
IV	Fatigue	^d

Notes:

- ^a See Article 3.6 regarding application of live load.
- ^b Percentages of allowable stress are applicable for the allowable stress design method. No load reduction factors shall be applied in conjunction with these increased allowable stresses.
- ^c *W* shall be computed based on the wind pressure. A minimum value of 1200 Pa (25 psf) shall be used for *W* in Group III.
- ^d See Section 11 for fatigue loads and stress range limits

3.5—DEAD LOAD

The dead load shall consist of the weight of the structural support, signs, luminaires, traffic signals, lowering devices, and any other appurtenances permanently attached to and supported by the structure. Temporary loads during maintenance shall also be considered as part of the dead loads. The points of application of the weights of the individual items shall be their respective centers of gravity.

C3.5

Dead load is to include all permanently attached fixtures, including hoisting devices and walkways provided for servicing of luminaires or signs.

C3.6

The specified live load represents the weight of a person and equipment during servicing of the structure. Only the members of walkways and service platforms are designed for the live load. Any structural member designed for the group loadings in Article 3.4 will be adequately proportioned for live load application. For OSHA-compliant agencies, additional requirements may apply.

C3.7

The ice loading is applicable to those areas shown in Figure 3.7-1. It is based on a 15-mm (0.60-in.) radial thickness of ice at a unit weight of 960 kg/m³ (60 pcf) applied uniformly over the exposed surface.

A map of the United States with state boundaries outlined. A large area in the western and central US is shaded with diagonal lines. This area includes Washington, Oregon, California, Nevada, Idaho, Utah, Arizona, New Mexico, Texas, Montana, Wyoming, Colorado, Kansas, Nebraska, Oklahoma, Missouri, Arkansas, Louisiana, Wisconsin, Illinois, Indiana, Michigan, Ohio, Pennsylvania, New York, Vermont, New Hampshire, and Maine. A legend in the bottom left corner shows a shaded box with the text 'Ice Load Region'.

Figure 3.7-1—Ice Load Map

3.8—WIND LOAD

Wind load shall be the pressure of the wind acting horizontally on the supports, signs, luminaires, traffic signals, and other attachments computed in accordance with Articles 3.8.1 through 3.8.6, Eq. 3.8.3-1 corresponding to the appropriate 50-yr mean recurrence interval basic wind speed as shown in Figure 3.8.3-1, and the appropriate importance factor selected from Table 3.8.3-1.

Design wind pressures computed in accordance with Appendix C may be used in lieu of those given above, as specified by the Owner.

3.8.1—Wind Pressure Equation

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

$$P_z = 0.613K_zGV^2I_rC_d \text{ (Pa)} \quad (3.8.3-1)$$

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

3.8.2—Basic Wind Speed

The basic wind speed V used in the determination of the design wind pressure shall be as given in Figure 3.8.3-1. For areas that lie between isotachs in Figure 3.8.3-1, the basic wind speed shall be determined either by interpolation or by using the higher adjacent isotach.

C3.8

The alternative method for the determination of the design wind pressure is the same method contained in the 1994 edition of the Specifications.

C3.8.1

The wind pressure equation is based on fundamental fluid-flow theory and formulations presented in *Minimum Design Loads for Buildings and Other Structures*, ANSI/ASCE 7-95 (1996). More recent ASCE 7 publications are available; however, this Specification largely uses ASCE 7-95 and research on which it is based.

For recurrence intervals of 10 or 25 years, the design wind pressure for hurricane wind velocities greater than 45 m/s (100 mph) should not be less than the design wind pressure calculated for V equal to 45 m/s (100 mph) and the corresponding non-hurricane I_r value (Table 3.8.3-1).

C3.8.2

Previous versions of the Specifications incorporated individual wind speed maps for 10-, 25-, and 50-yr mean recurrence intervals. These wind speed maps were developed by Thom (1968) and correspond to fastest-mile wind speeds.

The basic wind speeds in this Section are based on the 3-s gust wind speed map presented in Figure 3.8.3-1. This map is a metric conversion of the wind speed map published in *Minimum Design Loads for Buildings and Other Structures*, ASCE/SEI 7-05 (2006). More recent ASCE 7 maps may be used at the discretion of the Owner. The map is based on peak gust data collected at 485 weather stations (Peterka, 1992; Peterka and Shahid, 1993) and from predictions of hurricane speeds on the United States Gulf and Atlantic Coasts (Batts et al., 1980; Georgiou et al., 1983; Vickery and Twisdale, 1993). The map presents the variation of 3-s gust wind speeds associated with a height of 10 m (33 ft) for open terrain. In addition, the 3-s gust wind speeds presented in Figure 3.8.3-1 are associated with a 50-yr mean recurrence interval (annual probability of two percent that the wind speeds will be met or exceeded). The change to 3-s gust wind speeds represents a major change from the fastest-mile basis. It is necessary because most national weather service stations currently record and archive peak gust wind speeds and not fastest-mile wind speeds.

In Figure 3.8.3-1, the bold line that separates Washington, Oregon, and California from Idaho, Nevada, and Arizona divides the 38 m/s (85 mph) and 40 m/s (90 mph) wind regions, and should not be considered an isotach. As indicated in ASCE 7, the division between the 38 m/s (85 mph) and 40 m/s (90 mph) regions, which follow state lines, was sufficiently close to the 38 m/s (85 mph) contour line that there was no statistical basis for placing the division off state boundaries.

3.8.2.1—Elevated Locations

For site conditions elevated considerably above the surrounding terrain, where the influence of ground on the wind is reduced, consideration must be given to using higher pressures at levels above 10 m (33 ft).

3.8.2.2—Special Wind Regions

The wind speed map presented in Figure 3.8.3-1 shows several special wind regions. If the site is located in a special wind region, or if special local conditions exist in mountainous terrain and gorges, the selection of the basic wind speed should consider localized effects. Where records or experience indicate that wind speeds are higher than those reflected in Figure 3.8.3-1, the basic wind speed should be increased using information provided by the authority having local jurisdiction. Such increases in wind speed should be based on judgment and the analysis of regional meteorological data. In no case shall the basic wind speed be reduced below that presented in Figure 3.8.3-1.

3.8.3—Wind Importance Factor I_r

A wind importance factor I_r shall be selected from Table 3.8.3-1 corresponding to the specified design life of the structure. Table 3.8.3-2 provides the recommended minimum design life for various structure types. Some roadside signs that are considered to have a relatively short life expectancy may be designed with a wind importance factor, I_{10} , based on a recommended minimum 10-yr mean recurrence interval. The Owner may specify a design life for a structure other than that shown in Table 3.8.3-2 and the corresponding wind importance factor shall be used.

C3.8.2.1

It may be necessary in some cases to increase the design wind speed to account for the effects of terrain. Although most situations will not require such an increase in wind speeds, ASCE 7 presents a rational procedure to increase the basic wind speed when a structure is located on a hill or escarpment.

C3.8.2.2

If the wind speed is to be determined through the use of local meteorological data, ASCE 7 presents procedures for analyzing local meteorological data.

C3.8.3

The importance factors allow the wind pressures associated with the 50-yr mean recurrence interval (3-s gust wind speeds) to be adjusted to represent wind pressures associated with 10-, 25-, or 100-yr mean recurrence intervals. The importance factors in Table 3.8.3-1 account for the different return periods associated with non-hurricane winds, hurricane winds, and winds in Alaska. The commentary of ASCE 7 contains provisions for the determination of a separate set of importance factors for each of these categories of wind. A major reason for the incorporation of these provisions was the significant difference in design pressures between non-hurricane and hurricane winds for structures designed with an assumed design life of 10 yr, such as some roadside signs. The values for the importance factors in Table 3.8.3-1 are equal to the square of the velocity conversion factors in the ASCE 7 commentary and Table 3.8.3-3.

Although Table 3.8.3-2 provides recommended minimum design lives for structural supports, the Owner should use discretion in specifying the design life for a particular structure and location.

In critical locations, it may be appropriate to determine wind pressures based on a 100-yr mean recurrence interval.

Luminaire support structures less than 15 m (50 ft) in height and traffic signal structures may be designed for a 25-yr design life, where locations and safety considerations permit and when approved by the Owner.

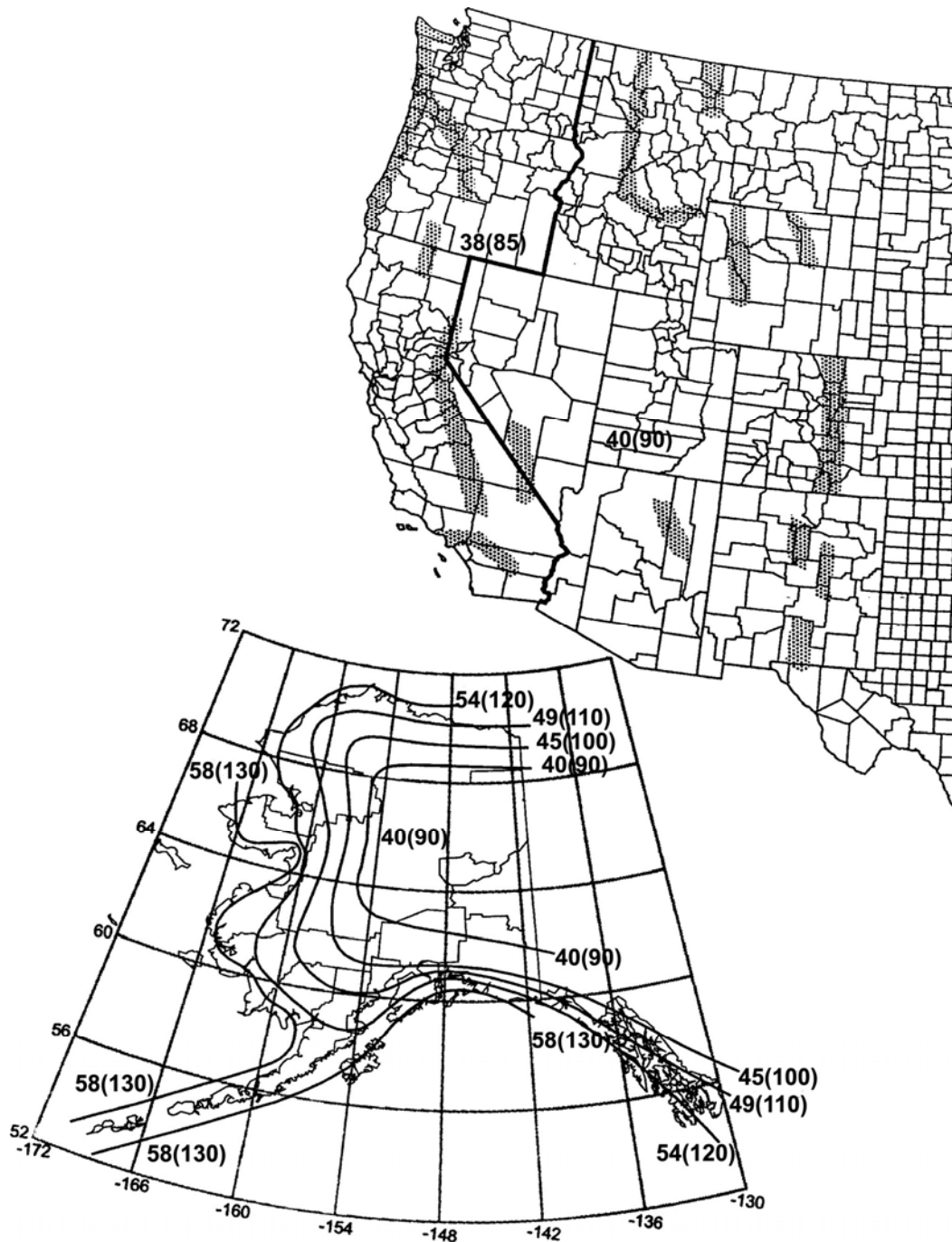
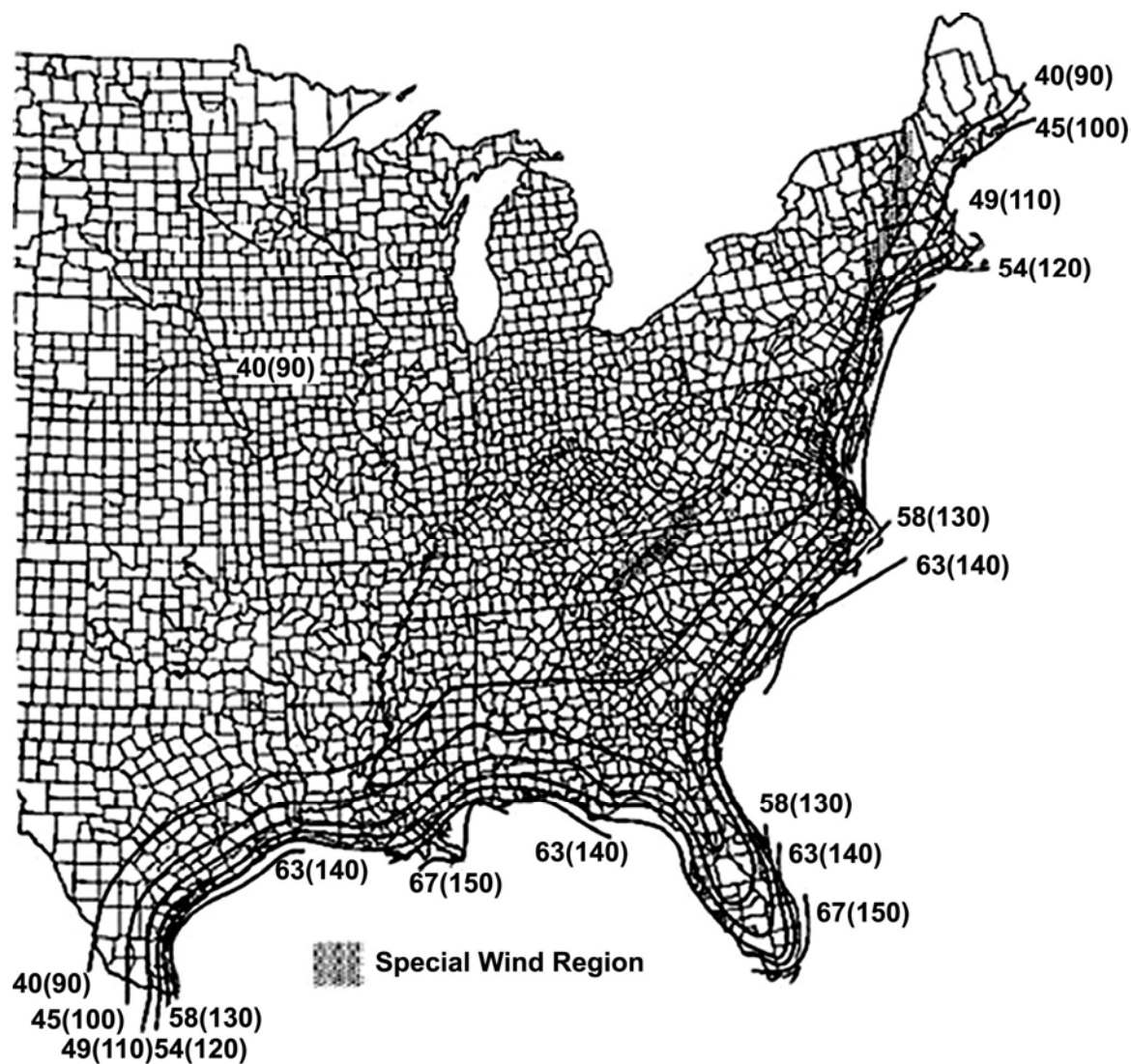


Figure 3.8.3-1—Basic Wind Speed, m/s (mph)—Western U.S. including Alaska (ASCE 7-05)

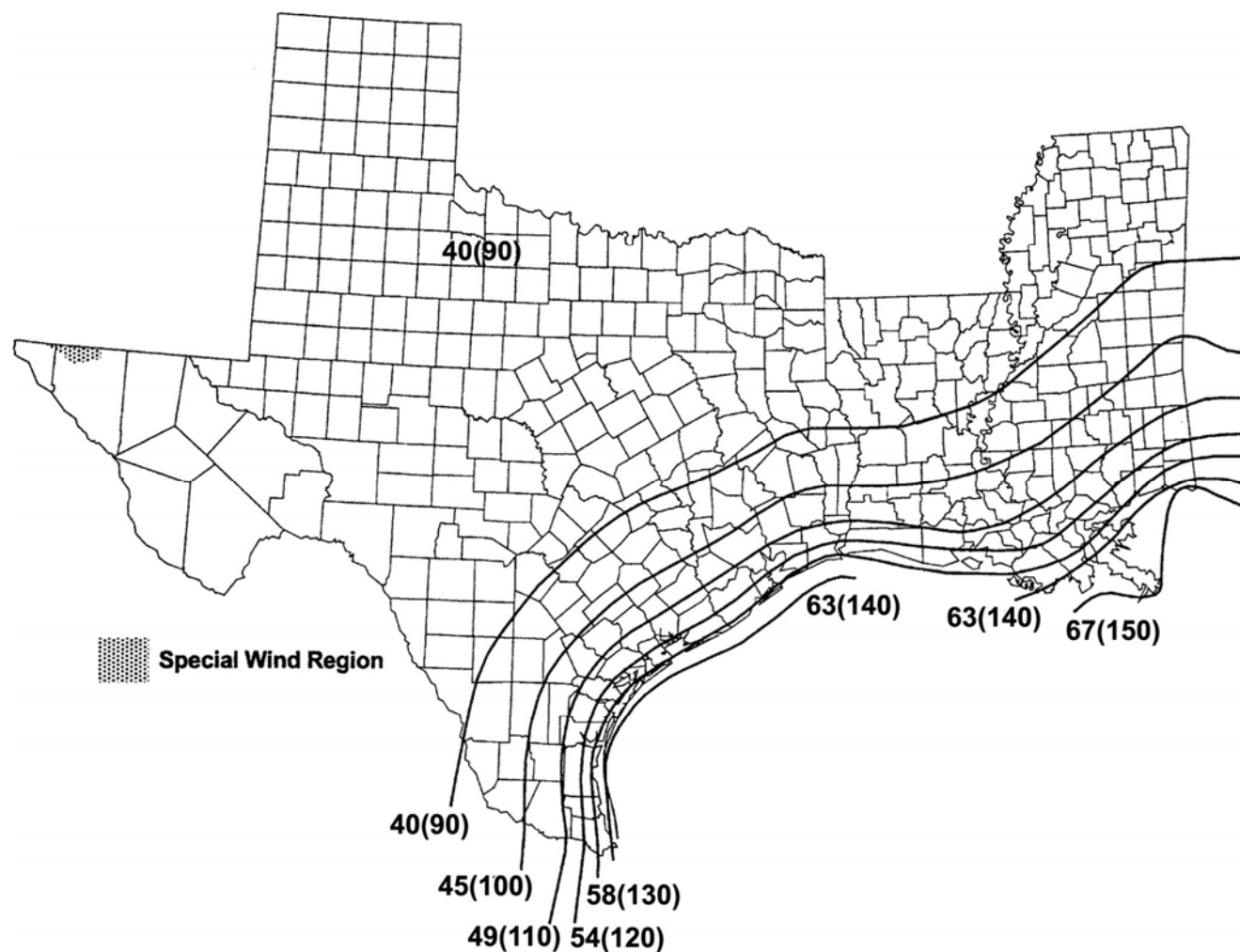


Location	Vm/s	(mph)
Hawaii	47	(105)
Puerto Rico	65	(145)
Guam	76	(170)
Virgin Islands	65	(145)
American Samoa	56	(125)

Notes:

1. Values are nominal design 3-s gust wind speeds in m/s (mph) at 10 m (33 ft) above ground for Exposure C category.
2. Linear interpolation between wind contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.

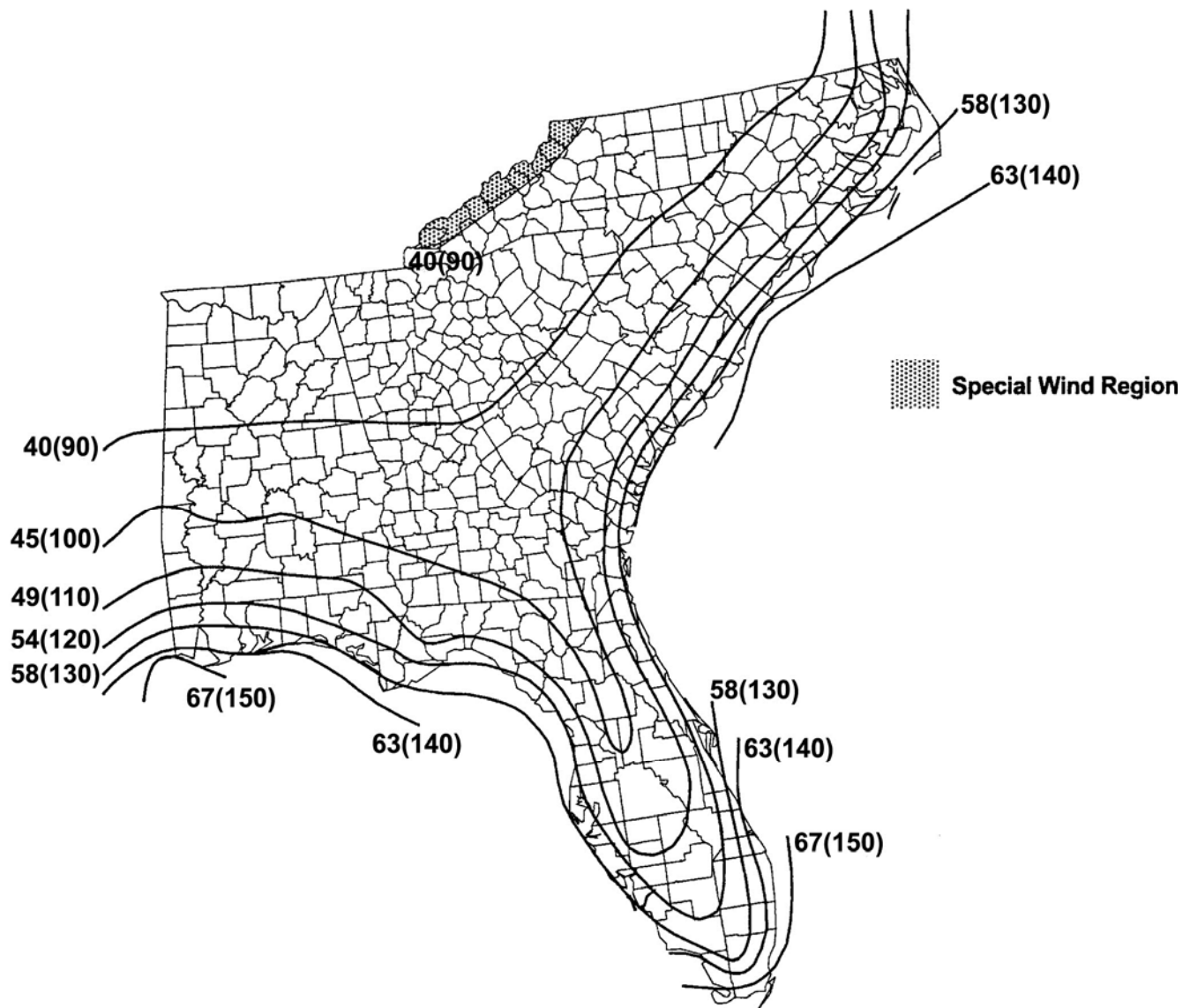
Figure 3.8.3-2—Basic Wind Speed, m/s (mph)—Eastern U.S. and Islands (ASCE 7-05)



Notes:

1. Values are nominal design 3-s gust wind speeds in m/s (mph) at 10 m (33 ft) above ground for Exposure C category.
2. Linear interpolation between wind contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.

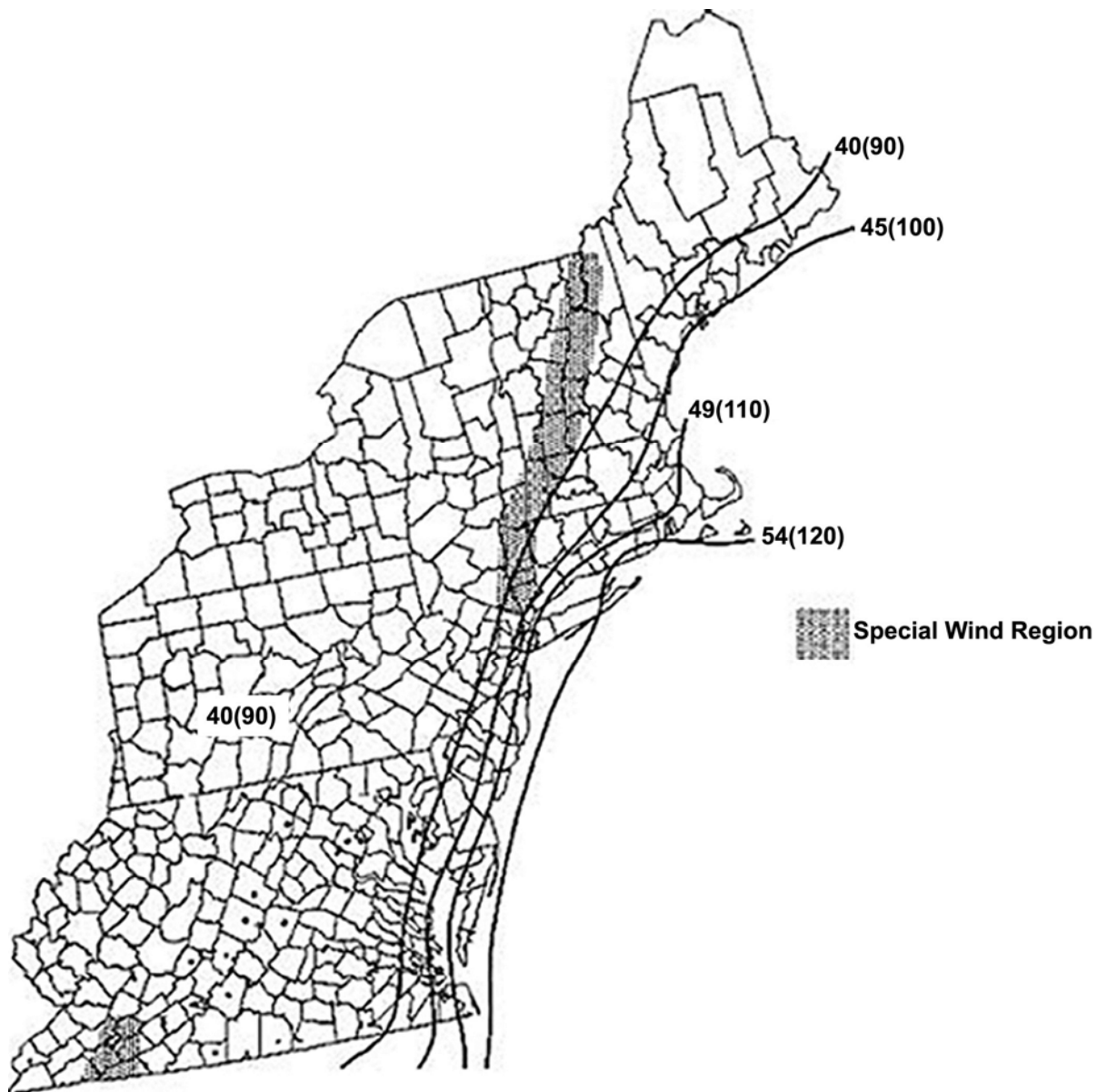
Figure 3.8.3-3—Basic Wind Speed, m/s (mph)—Western Gulf of Mexico Hurricane Coastline (ASCE 7-05)



Notes:

1. Values are nominal design 3-s gust wind speeds in m/s (mph) at 10 m (33 ft) above ground for Exposure C category.
2. Linear interpolation between wind contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.

Figure 3.8.3-4—Basic Wind Speed, m/s (mph)—Eastern Gulf of Mexico and Southeastern U.S. Hurricane Coastline (ASCE 7-05)



Notes:

1. Values are nominal design 3-s gust wind speeds in m/s (mph) at 10 m (33 ft) above ground for Exposure C category.
2. Linear interpolation between wind contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.

Figure 3.8.3-5—Basic Wind Speed, m/s (mph)—Northeastern U.S. Hurricane Coastline (ASCE 7-05)

Table 3.8.3-1—Wind Importance Factors, I_r

Recurrence Interval Years	Basic Wind Speed in Non-hurricane Regions	Basic Wind Speed in Hurricane Regions with $V > 45$ m/s (100 mph)	Alaska
100	1.15	1.15	1.13
50	1.00	1.00	1.00
25	0.87	0.77 ^a	0.89
10	0.71	0.54 ^a	0.76

^a The design wind pressure for hurricane wind velocities greater than 45 m/s (100 mph) should not be less than the design wind pressure using $V = 45$ m/s (100 mph) with the corresponding non-hurricane I_r value.

Table 3.8.3-2—Recommended Minimum Design Life

Design Life	Structure Type
50 yr	Overhead sign structures Luminaire support structures ^a Traffic signal structures ^a
10 yr	Roadside sign structures

^a Luminaire support structures less than 15 m (50 ft) in height and traffic signal structures may be designed for a 25-yr design life, where locations and safety considerations permit and when approved by the Owner.

Table 3.8.3-3—Velocity Conversion Factors, C_v

Recurrence Interval Years	Basic Wind Speed in Non-hurricane Regions	Basic Wind Speed in Hurricane Regions with $V > 45$ m/s (100 mph)	Alaska
100	1.07	1.07	1.06
50	1.00	1.00	1.00
25	0.93	0.88	0.94
10	0.84	0.74	0.87

3.8.4—Height and Exposure Factor K_z

The height and exposure factor K_z shall be determined either from Table 3.8.4-1 or calculated using Eq. C3.8.4-1 in the commentary.

C3.8.4

K_z is a height and exposure factor that varies with height above the ground depending on the local exposure conditions and may be conservatively set to 1.0 for heights less than 10 m (33 ft). The variation is caused by the frictional drag offered by various types of terrain. ASCE 7 defines acceptable wind design procedures using different terrain exposure conditions. For a specified set of conditions, the wind pressures associated with the different exposures increase as the exposure conditions progress from B to D, with exposure B resulting in the least pressure and exposure D resulting in the greatest pressure. Exposure C has been adopted for use in these Specifications as it should provide an accurate or conservative approach for the design of structural supports. It represents open terrain with scattered obstructions.

Once the terrain exposure conditions are established, the height and exposure factor, K_z , is calculated using the following relationship that is presented in ASCE 7:

$$K_z = 2.01 \left(\frac{z}{z_g} \right)^{\frac{2}{\alpha}} \quad (\text{C3.8.4-1})$$

where z is height above the ground at which the pressure is calculated or 5 m (16 ft), whichever is greater, and z_g and α are constants that vary with the exposure condition. Based on information presented in ASCE 7, α should be taken to be 9.5 and z_g should be taken to be 274.3 m (900 ft) for exposure C. These values are for 3-s gust wind speeds and are different from similar constants that have been used for fastest-mile wind speeds. Table 3.8.4-1 presents the variation of the height and exposure factor, K_z , as a function of height based on the above relation.

Table 3.8.4-1—Height and Exposure Factors, K_z^a

Height, m (ft)	K_z^a
5.0 (16.4) or less	0.87
7.5 (24.6)	0.94
10.0 (32.8)	1.00
12.5 (41.0)	1.05
15.0 (49.2)	1.09
17.5 (57.4)	1.13
20.0 (65.6)	1.16
22.5 (73.8)	1.19
25.0 (82.0)	1.21
27.5 (90.2)	1.24
30.0 (98.4)	1.26
35.0 (114.8)	1.30
40.0 (131.2)	1.34
45.0 (147.6)	1.37
50.0 (164.0)	1.40
55.0 (180.5)	1.43
60.0 (196.9)	1.46
70.0 (229.7)	1.51
80.0 (262.5)	1.55
90.0 (295.3)	1.59
100.0 (328.1)	1.63

^a See Eq. C3.8.4-1 for calculation of K_z .

3.8.5—Gust Effect Factor G

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

C3.8.5

G is the gust effect factor and it adjusts the effective velocity pressure for the dynamic interaction of the structure with the gustiness of the wind. The gust effect factor, G , should not be confused with the gust coefficient that was incorporated in earlier versions of these Specifications. Although the two factors accomplish essentially the same purpose, the gust effect factor, G , is multiplied by the pressure, whereas the gust coefficient is multiplied by the wind speed. Hence, the gust effect factor, G , is the square of the gust coefficient. The procedure to calculate either the gust effect factor, G , or the gust coefficient depends on its wind sensitivity.

Information presented in ASCE 7 states that if the fundamental frequency of a structure is less than 1 Hz or if the ratio of the height to least horizontal dimension is greater than 4, the structure should be designed as a wind-sensitive structure. Thus, virtually all structures addressed by these Specifications should be classified as wind-sensitive structures based on the height to least horizontal dimension ratio. It is not appropriate to use a nonwind-sensitive gust effect factor, G , for the design of sign, luminaire, and traffic signal structures. Special procedures are presented in the commentary of ASCE 7 for the calculation of the gust effect factor for wind-sensitive structures. The ASCE 7 calculation procedure requires reasonable estimates of critical factors such as the damping ratio and fundamental frequency of the structure. These factors are site and structure dependent. Relatively small errors in the estimation of these factors result in significant variations in the calculated gust effect factor. Therefore, even though sign, luminaire, and traffic signal support structures are wind sensitive, the benefits of using the ASCE 7 gust effect factor calculation procedure do not outweigh the complexities introduced by its use.

Previous versions of these AASHTO Specifications addressed wind sensitivity by incorporating an increased gust coefficient of 1.3. This gust coefficient corresponds to a gust effect factor of $1.69 = (1.3)(1.3)$ for use with fastest-mile basic wind speeds. The 1.3 gust coefficient has been used within these Specifications since around 1961. It was intended to reflect the wind sensitivity of the types of structures addressed by these Specifications. Its origin traces to a paper by Sherlock (1947) and subsequent wind engineering literature through the 1950s and 1960s. Use of this factor results in higher wind loads than would be expected for structures that are not wind sensitive. As discussed above, it is clear that most structures supporting signs, signals, and luminaires are wind sensitive. Thus, the types of structures addressed by these Specifications should be designed for wind loads that are higher than those used to design typical buildings, per ASCE 7. Finally, use of the traditional gust coefficient of 1.3 has resulted in successful designs. Therefore, the 3-s gust effect factor, G , derived from the traditional fastest-mile gust coefficient of 1.3 is the basis for this Specification.

The fastest-mile gust coefficient of 1.3 is converted to a 3-s gust coefficient by multiplying the gust coefficient of 1.3 by the ratio of the fastest-mile wind speed to the 3-s gust wind speed. This ratio is approximately equal to 0.82 based on ASCE 7. The equivalent 3-s gust coefficient is equal to $1.07 = (1.3)(0.82)$. The corresponding gust effect factor, G , is then found to be approximately equal to 1.14 by squaring the 3-s gust coefficient. Therefore, a gust effect factor, G , of 1.14 is recommended for the design of structural supports for signs, signals, and luminaires. Supports that have been designed with this past philosophy have performed well. Therefore, use of this philosophy is continued.

The following illustrates the relationship between the gust effect factor, G , and the fastest-mile gust coefficient. Neglecting the effects from height above ground, exposure, and drag, the use of the gust effect factor of 1.14 with an assumed 3-s gust speed results in essentially the same wind pressure as was determined by the 1994 edition of these Specifications using the 1.3 gust coefficient and the equivalent fastest-mile wind speed. The equivalent fastest-mile wind speed is 82 percent of the 3-s gust wind speed.

If the Designer wishes to perform a more rigorous gust effect analysis, the procedures presented in ASCE 7 may be used.

3.8.6—Drag Coefficients C_d

The wind drag coefficient, C_d , shall be determined from Table 3.8.6-1.

C3.8.6

The validity of the drag coefficients presented in Table 3.8.6-1 has been the subject of recent research (McDonald et al., 1995). Based on this work coupled with independent examinations of the information presented in Table 3.8.6-1, the drag coefficients were changed to account only for the use of metric units and 3-s gust wind speeds, except for square and diamond shapes. The fundamental philosophy and procedures remain unchanged.

A conversion factor, C_v , is used in Table 3.8.6-1 to convert the 3-s gust wind speed for a 50-yr mean recurrence interval, V_r , to the 3-s gust wind speed corresponding to the selected design life of the structure. The use of this conversion factor provides a proper representation of the wind flow characteristics around a multisided or round tube and a proper determination of the resulting drag coefficient for the maximum likely velocity during the selected design life of the structure.

Research concerning C_d values for dodecagonal shapes has been conducted at Iowa State University (James, 1971). The highest coefficients for the dodecagonal cylinder were measured for wind normal to a flat side. A circular cylinder was included in the testing program to allow a check on the test equipment, and boundary corrections were applied to the raw test data. All measured values for the dodecagonal cylinder with zero angle of incidence were higher than those measured for the circular cylinder. Lower shape coefficients might be justified for some velocities; however, this would require additional data for the dodecagons at lower Reynolds numbers and review of the factors specified for round cylinders.

The equation for the C_d value for an elliptical member with the narrow side facing the wind was empirically derived to fit wind tunnel test data.

The drag coefficients for hexdecagons include the effects that varying ratios of corner radius to cylinder radius have on the drag coefficient. The C_d values for $C_v V_d$ greater than 10.66 m²/s (78 mph-ft) were selected from information from wind tunnel tests on a number of hexdecagons with different ratios of corner radius to radius of inscribed circle (James, 1985).

These minimum C_d values vary linearly from 0.83 for a ratio of zero, to a value of 0.55 for ratios equal to or over 0.26. For consistency between maximum C_d values for cylinders and hexdecagons, the maximum C_d value for hexdecagons was selected to be the maximum value given for a cylinder. For a given ratio, values of C_d for $C_v Vd$ values between 5.33 m²/s (39 mph-ft) and 10.66 m²/s (78 mph-ft) vary linearly from 1.10 for $C_v Vd$ equal to 5.33 m²/s (39 mph-ft) to the minimum value at $C_v Vd$ equal to 10.66 m²/s (78 mph-ft). The wind force resulting from use of these C_d values represents the total static force acting on the member, which would be the vector sum of the actual drag force and lift or side force.

Values of C_d for octagonal shapes vary with wind velocity and orientation according to tests, but a value of 1.20 shows to be conservative over a wide range. Values of C_d for square tubing, with the wind direction perpendicular to the side of the tube, have been revised to reflect the influence from the ratio of the corner radius to depth of member (James and Vogel, 1996).

A transition in the values of C_d for multisided cross-sections (hexdecagonal, dodecagonal, and octagonal) that approach round was developed in NCHRP 494, *Structural Supports for Highway Signs, Luminaires, and Traffic Signals* (Fouad et al., 2003) and incorporated as note “e” to Table 3.8.6-1. The method uses a linear equation to interpolate between the drag coefficient for round poles, C_{dr} , and the drag coefficient for multisided poles, C_{dm} , with respect to the variable r_c . If r_c is unknown, the section can conservatively be treated as multisided using the lowest reasonable value of r_c for the section.

Values of C_d for square tubing, with the wind direction perpendicular to the diagonal axis (diamond configuration), are based on wind tunnel tests (James and Vogel, 1996).

When three members are used to form a triangular truss, the wind load shall be applied to all of the members. Even though all of the members are not in the same plane of reference, they may be seen in a normal elevation.

As provided in note “b” to Table 3.8.6-1, consideration may be given to modifying the forces applied to free-swinging traffic signals. Traffic signals are a combination of aerodynamic and non-aerodynamic shapes and open spaces; because of these factors, it is difficult to predict traffic signal wind loading, especially when the signal head is free to swing. At this time, it appears that the only practical means of predicting wind loading on free-swinging traffic signals is through wind-loading tests. More research in the area of traffic signal aerodynamics is needed.

If traffic signals or signs on span-wire pole structures are restrained from swinging in the wind, their full wind load must be applied. When agreed on between Owner and Designer, reduced forces may be used for free-swinging traffic signals when substantiated by research (Marchman, 1971; Marchman and Harrison, 1971).

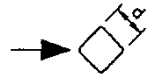
Wind loads on signs that are not restrained from swinging in the wind may be reduced with the consent of the Owner. Wind tunnel test results (Marchman and Harrison, 1971) indicate instability problems with traffic signals with certain hood configurations when not restrained from swinging. These instability problems should be considered when designing span-wire support structures.

Table 3.8.6-1—Wind Drag Coefficients, C_d ^a

Sign Panel $L_{sign}/W_{sign} =$	1.0	1.12
	2.0	1.19
	5.0	1.20
	10.0	1.23
	15.0	1.30
Traffic Signals ^b	1.2	
Luminaires (with generally rounded surfaces)	0.5	
Luminaires (with rectangular flat side shapes)	1.2	
Elliptical Member ($D/d_o \leq 2$)	Broadside Facing Wind	Narrow Side Facing Wind
	$1.7 \left(\frac{D}{d_o} - 1 \right) + C_{dD} \left(2 - \frac{D}{d_o} \right)$ 	$C_{dd} \left[1 - 0.7 \left(\frac{D}{d_o} - 1 \right)^{\frac{1}{4}} \right]$ 
Two Members or Trusses (one in front of other) (for widely separated trusses or trusses having small solidity ratios see note c)	1.20 (cylindrical) 2.00 (flat)	
Variable Message Signs (VMS) ^e	1.70	
Attachments	Drag coefficients for many attachments (cameras, luminaires, traffic signals, etc.) are often available from the manufacturer, and are typically provided in terms of effective projected area (EPA), which is the drag coefficient multiplied by the projected area. If the EPA is provided, the drag coefficient shall be taken as 1.0.	

Continued on next page

Table 3.8.6-1—Wind Drag Coefficients, C_d ^a—Continued

Single Member or Truss Member	$C_v Vd \leq 5.33 \text{ m}^2/\text{s}$ (39 mph-ft)	$5.33 \text{ m}^2/\text{s}$ (39 mph-ft) $< C_v Vd$ $< 10.66 \text{ m}^2/\text{s}$ (78 mph-ft)	$C_v Vd \geq 10.66 \text{ m}^2/\text{s}$ (78 mph-ft)
Cylindrical	1.10	$\frac{9.69}{(C_v Vd)^{1.3}}$ (SI) $\frac{129}{(C_v Vd)^{1.3}}$ (U.S. Customary)	0.45
Flat ^d	1.70	1.70	1.70
Hexdecagonal: $0 \leq r_c < 0.26$	1.10	$1.37 + 1.08r_c - \frac{C_v Vd}{19.8} - \frac{C_v Vd r_c}{4.94}$ (SI) $1.37 + 1.08r_c - \frac{C_v Vd}{145} - \frac{C_v Vd r_c}{36}$ (U.S. Customary)	$0.83 - 1.08r_c$
Hexdecagonal: $r_c \geq 0.26^e$	1.10	$0.55 + \frac{(10.66 - C_v Vd)}{9.67}$ (SI) $0.55 + \frac{(78.2 - C_v Vd)}{71}$ (U.S. Customary)	0.55
Dodecagonal ^e	1.20	$\frac{3.28}{(C_v Vd)^{0.6}}$ (SI) $\frac{10.8}{(C_v Vd)^{0.6}}$ (U.S. Customary)	0.79
Octagonal ^e	1.20	1.20	1.20
Square 		$2.0 - 6r_s$ [for $r_s < 0.125$] 1.25 [for $r_s \geq 0.125$]	
Diamond ^f 		1.70 [for $d = 0.102$ and 0.127 (0.33 and 0.42)] 1.90 [for $d \geq 0.152$ (0.50)]	

Notes:

- ^a The velocity for determining the drag factor is V , V_{mean} , or V_T , depending on whether one is trying to determine the drag factor for Wind Load (Article 3.8), Natural Wind Gust (Article 11.7.1.2), Truck-Induced Gust (Article 11.7.1.3), combined wind pressure range for design of HMLTs (Article 11.7.2), or site-specific wind or fatigue loads. Wind drag coefficients for members, sign panels, and other shapes not included in this table shall be established by wind tunnel tests (over an appropriate range of Reynolds numbers), in which comparative tests are made on similar shapes included in this table.
- ^b Wind loads on free-swinging traffic signals may be modified, as agreed by the Owner of the structure, based on experimental data (Marchman, 1971).
- ^c Current data show that the drag coefficients for a truss with a very small solidity ratio are merely the sum of the drags on the individual members, which are essentially independent of one another. When two elements are placed in a line with the wind, the total drag depends on the spacing of the elements. If the spacing is zero or very small, the drag is the same as on a single element; however, if the spacing is infinite, the total force would be twice as much as on a single member. When considering pairs of trusses, the solidity ratio is of importance because the distance downstream in which shielding is effective depends on the size of the individual members.

effect of shielding dies out in smaller spacings as the solidity decreases. Further documentation may be found in *Transactions* (ASCE, 1961).

- d Flat members are those shapes that are essentially flat in elevation, including plates and angles.
- e Valid for members having a ratio of corner radius to distance between parallel faces equal to or greater than 0.125. For multisided cross-sections with a large corner radius, a transition value for C_d can be taken as:

If $r_c \leq r_m$, then $C_d = C_{dm}$

If $r_m < r_c < r_r$, then $C_d = C_{dr} + (C_{dm} - C_{dr})[(r_r - r_c)/(r_r - r_m)]$

If $r_c \geq r_r$, then $C_d = C_{dr}$

where:

r = ratio of corner radius to radius of inscribed circle,

C_{dm} = drag coefficient for multisided section,

C_{dr} = drag coefficient for round section,

r_m = maximum ratio of corner radius to inscribed circle where the multi-sided section's drag coefficient is unchanged (see table below), and

r_r = ratio of corner radius to radius of inscribed circle where multisided section is considered round (see table below).

Shape	r_m	r_r
16-Sided, Hexdecagonal	0.26	0.63
12-Sided, Dodecagonal	0.50	0.75
8-Sided, Octagonal	0.75	1.00

- f The drag coefficient applies to the diamond's maximum projected area measured perpendicular to the indicated direction of wind.
- g A value of 1.7 is suggested for Variable Message Signs (VMS) until research efforts can provide precise drag coefficients.

Table 3.8.6-2—Effective Velocity Pressures, vp_z , Pa (psf) for Indicated Wind Velocity, m/s (mph)^{a,b}

Height, m (ft)	38 (85)	40 (90)	45 (100)	49 (110)	54 (120)	58 (130)	63 (140)	67 (150)
5.0 (16.4) or less	873 (18.2)	967 (20.4)	1224 (25.2)	1451 (30.5)	1763 (36.4)	2034 (42.7)	2399 (49.5)	2714 (56.8)
7.5 (24.6)	951 (19.9)	1053 (22.3)	1333 (27.5)	1581 (33.3)	1920 (39.6)	2215 (46.5)	2613 (53.9)	2955 (61.9)
10.0 (32.8)	1010 (21.1)	1119 (23.7)	1416 (29.2)	1679 (35.3)	2040 (42.1)	2353 (49.4)	2776 (57.3)	3140 (65.7)
12.5 (41.0)	1059 (22.1)	1173 (24.8)	1485 (30.6)	1760 (37.0)	2138 (44.1)	2466 (51.7)	2910 (60.0)	3291 (68.9)
15.0 (49.2)	1100 (23.0)	1219 (25.8)	1543 (31.8)	1829 (38.5)	2221 (45.8)	2563 (53.8)	3024 (62.4)	3420 (71.6)
17.5 (57.4)	1136 (23.7)	1259 (26.6)	1594 (32.9)	1889 (39.8)	2295 (47.3)	2647 (55.5)	3123 (64.4)	3533 (73.9)
20.0 (65.6)	1169 (24.4)	1295 (27.4)	1639 (33.8)	1943 (40.9)	2360 (48.7)	2723 (57.1)	3212 (66.2)	3633 (76.1)
22.5 (73.8)	1198 (25.0)	1327 (28.1)	1680 (34.6)	1992 (41.9)	2419 (49.9)	2791 (58.6)	3293 (67.9)	3724 (78.0)
25.0 (82.0)	1225 (25.6)	1357 (28.7)	1718 (35.4)	2037 (42.9)	2474 (51.0)	2854 (59.9)	3367 (69.4)	3808 (79.7)
27.5 (90.2)	1250 (26.1)	1385 (29.3)	1753 (36.1)	2078 (43.7)	2524 (52.0)	2912 (61.1)	3435 (70.8)	3885 (81.3)
30.0 (98.4)	1273 (26.6)	1410 (29.8)	1785 (36.8)	2116 (44.5)	2570 (53.0)	2965 (62.2)	3499 (72.2)	3957 (82.8)
35.0 (114.8)	1315 (27.5)	1457 (30.8)	1844 (38.0)	2186 (46.0)	2655 (54.8)	3063 (64.3)	3614 (74.5)	4088 (85.6)
40.0 (131.2)	1352 (28.3)	1498 (31.7)	1896 (39.1)	2249 (47.3)	2731 (56.3)	3150 (66.1)	3717 (76.7)	4204 (88.0)
45.0 (147.6)	1386 (29.0)	1536 (32.5)	1944 (40.1)	2305 (48.5)	2799 (57.7)	3230 (67.8)	3810 (78.6)	4310 (90.2)
50.0 (164.0)	1417 (29.6)	1571 (33.2)	1988 (41.0)	2357 (49.6)	2862 (59.0)	3302 (69.3)	3896 (80.3)	4406 (92.2)
55.0 (180.5)	1446 (30.2)	1602 (33.9)	2028 (41.8)	2405 (50.6)	2920 (60.2)	3369 (70.7)	3975 (82.0)	4496 (94.1)
60.0 (196.9)	1473 (30.8)	1632 (34.5)	2065 (42.6)	2449 (51.5)	2974 (61.3)	3431 (72.0)	4048 (83.5)	4579 (95.8)
70.0 (229.7)	1521 (31.8)	1686 (35.6)	2134 (44.0)	2530 (53.2)	3072 (63.4)	3544 (74.4)	4182 (86.2)	4730 (99.0)
80.0 (262.5)	1565 (32.7)	1734 (36.7)	2194 (45.3)	2602 (54.8)	3160 (65.2)	3645 (76.5)	4301 (88.7)	4865 (101.8)
90.0 (295.3)	1604 (33.5)	1777 (37.6)	2250 (46.4)	2667 (56.1)	3239 (66.8)	3737 (78.4)	4409 (90.9)	4987 (104.4)
100.0 (328.1)	1640 (34.3)	1817 (38.4)	2300 (47.4)	2727 (57.4)	3312 (68.3)	3821 (80.2)	4508 (93.0)	5099 (106.7)

Notes:

^a $vp_z = 0.613 K_z G V^2 I_r C_d$ ($vp_z = 0.00256 K_z G V^2 I_r C_d$) for I_r and C_d equal to 1.0, and $G = 1.14$ ^b Effective velocity pressures may be linearly interpolated.**3.9—DESIGN WIND LOADS ON STRUCTURES**

Figures 3.9.4.2-1 through 3.9.4.2-3 depict application of loads on various types of structural supports.

3.9.1—Load Application

The wind loads acting horizontally on a structure shall be determined by the areas of the supports, signs, luminaires, signals, and other attachments and shall be applied to the surface area as viewed in normal elevation.

The effective projected area (EPA) is the actual area multiplied by the appropriate drag coefficient. If the EPA is provided for the luminaire or attachment, the design wind

C3.9.1

Confirm with the component supplier literature and so forth regarding the incorporation of C_d in the reported EPA.

pressure (Article 3.8.1) shall be computed without incorporating the drag coefficient C_d .

3.9.2—Design Loads for Horizontal Supports

Horizontal supports of luminaire support structures and all connecting hardware shall be designed for wind loads, W_l and W_h , applied at the centers of pressure of the respective areas.

Horizontal supports of sign structures (cantilevered or bridge type) and traffic signal structures shall be designed for wind loads, W_h and W_p , applied normal to the support at the centers of pressure of the respective areas.

Horizontal supports for span-wire pole structures shall be designed for wind loads, W_h and W_p , where W_h may be applied as a series of concentrated loads along the span wire.

3.9.3—Design Loads for Vertical Supports

The vertical supports for luminaire structures, traffic signal structures (excluding pole top mounted traffic signals and post top luminaire structures), and sign support structures shall be designed for the effects of wind from any direction. An acceptable method to design for the effects of wind from any direction is by applying the following two load cases of normal and transverse wind loads acting simultaneously. This method is applicable where all signs are approximately in one plane and is not applicable for structures with arms in two or more planes.

Load Case	Normal Component (n_c)	Transverse Component (t_c)
1	1.0 (BL)	0.2 (BL)
2	0.6 (BL)	0.3 (BL)

The basic load (BL) for the structures with rigid horizontal supports shall be the effects from the wind loads, W_v , W_l , W_p , and W_h , applied at the centers of pressure of the respective areas of the structures and normal to the sign faces. Nonsymmetrical single roadside sign supports shall be designed for normal and transverse components (n_c , t_c).

Vertical supports for span-wire pole structures (provided only a single span wire is attached to each support) may be designed for the full wind loads, W_v , W_p , and W_h , applied normal to the span wire, without the application of the transverse components (t_c).

3.9.4—Unsymmetrical Wind Loading

To allow for unsymmetrical wind loading, the loading conditions stipulated in Articles 3.9.4.1 and 3.9.4.2 shall be used in conjunction with those of Articles 3.9.2 and 3.9.3 to compute the design torsional load effects. The resulting

C3.9.3

The Specifications provide a simplified means to account for the effects of wind from any direction. Other more rigorous methods that appropriately account for the effects of wind from any direction may also be used.

The transverse components may be distributed in proportion to the relative lateral stiffness and restraint conditions of the supports.

The transverse components (t_c) may be neglected for the design of typical span-wire structures (provided only a single wire is attached to each support), because the wind direction resulting in the maximum tension in the span wire should be normal to the span.

A possible exception would be if the combined projected areas of the sides of the attachments are significantly greater than their combined projected areas parallel to the span.

torsional stresses shall be included with the wind load stresses for the fully loaded structure.

3.9.4.1—Overhead Cantilevered Supports

For vertical supports with balanced double cantilevers (i.e., equal torsional load effects from each arm), the normal wind load shall be applied to one arm only, neglecting the force on the other arm. For unbalanced double cantilevers, the normal wind loads shall be applied only to the arm that results in the largest torsional load effect.

When vertical supports have more than two arms, and the arms are mounted opposite or at diverging angles from one another, the wind load shall be applied to one arm when balanced or only to the arm that results in the largest torsional load effect when unbalanced.

3.9.4.2—Concentrically Mounted Supports

For high-level (pole or truss type) luminaire supports, typical poles supporting luminaires and/or traffic signals, or roadside signs with single supports, the torsional load effect for concentrically mounted attachments shall be calculated as the wind loads, W_p , W_b , and W_h , multiplied by 0.15 b , where b is the width measured between the out-to-out extremities of the attachments.

For nonconcentrically mounted attachments, the torsional load effect shall be calculated using the net torque.

C3.9.4.2

A minimum 15 percent eccentricity is required for concentrically loaded support structures.



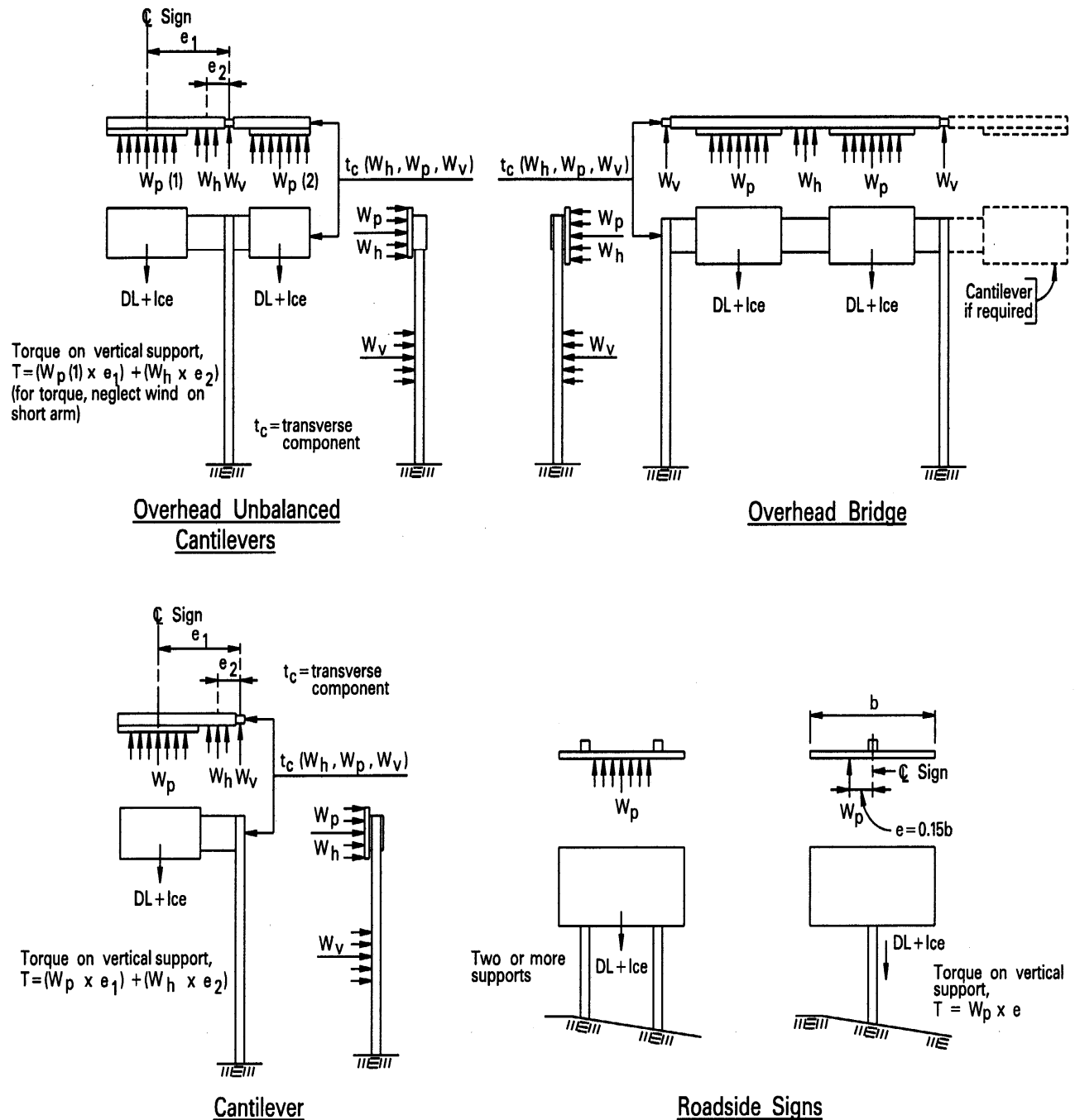


Figure 3.9.4.2-1—Loads on Sign Support Structures

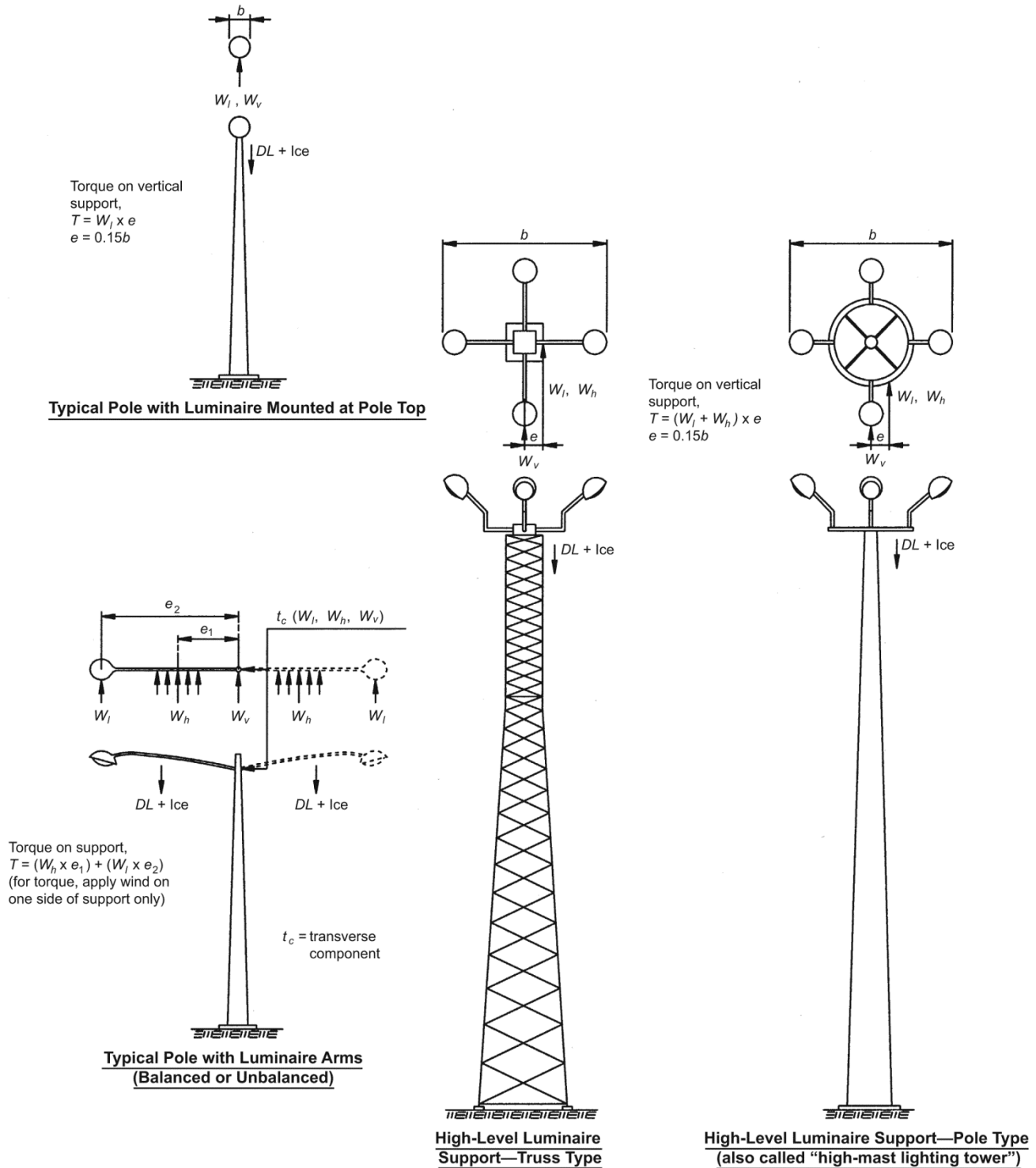


Figure 3.9.4.2—Loads on Luminaire Support Structures