Ancillary Structures Inspection Reference Manual

U.S. Department
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FOREWORD

Ancillary highway structures are unique because the dynamic loading they experience differs from bridges or statically loaded structures, and their inspection involves knowledge that is somewhat specialized. The number of these structures far exceeds other types of highway structures, and they are more visible to the traveling public. No Federal regulation governs the inspection of ancillary structures; however, most States have developed some level of inspection for their various classes of ancillary structures. As a result, there is a need for greater consistency relative to inspection procedures and practices.

This *Ancillary Structures Inspection Reference Manual* addresses inspection and maintenance issues related to a wide range of ancillary highway structures, with a focus on steel and aluminum structures. It is intended for Federal, State, local Agency, and consultant structural engineers, materials engineers, traffic engineers, field inspectors, construction supervisors, maintenance personnel and other technical personnel involved in the installation, inspection, and maintenance of ancillary highway structures.

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16. Abstract

This *Ancillary Structures Inspection Reference Manual* addresses inspection and maintenance issues related to a wide range of ancillary highway structures, with a focus on steel and aluminum structures. It provides inspection, maintenance and management personnel with the basic information they may need to manage and implement an ancillary structure inspection program, addressing inspector qualifications, inspection types, procedures, new technologies, reporting and maintenance. The manual is intended to supplement two National Highway Institute courses, "Inspection of Ancillary Highway Structures" (FHWA-NHI-130087), and "Inspection of Ancillary Highway Structures WBT Prerequisite" (FHWA-NHI-130087A).

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL L
gal ft^3	gallons	3.785	liters	m^3
yd^3	cubic feet	0.028	cubic meters	m^3
	cubic yards	0.765	cubic meters NOTE:	
	volumes greater than 1000 L should be shown in m^3			
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9	Celsius or (F-	°C
		32)/1.8		
		ILLUMINATION		
fc fl	foot-candles	10.76	lux	lx cd/m^2
	foot-Lamberts	3.426	$candela/m^2$	
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc fl
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003).

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CHAPTER 1. INTRODUCTION

The Ancillary Structures Inspection Reference Manual (ASIRM) addresses inspection and maintenance issues related to a multitude of ancillary highway structures. This manual focuses on structures designed to share the common trait of supporting highway safety and traffic management appurtenances, such as signs, luminaires, traffic signals, cameras or Intelligent Transportation System (ITS) equipment. To support such devices, structural designs use members such as round or square tubes, rolled channels or angles, which are welded or bolted together.

This manual focuses on structures made from steel or aluminum. Other materials such as timber, concrete, fiber-reinforced polymers, and wire rope, may also be used to build ancillary highway structures, but are not specifically covered in this manual, though some of the information presented may be useful. Other highway structures may be used to support ancillary highway structures, such as retaining walls, sound walls and culverts; these are also not covered in this manual.

Until the American Association of State Highway and Transportation Officials (AASHTO) published the fourth edition of its *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals* (2001 AASHTO Specifications), many of these structural supports were designed as economically as possible, and did not address service life issues such as fatigue.(1) For example, the use of low fatigue resistant materials, such as aluminum; materials susceptible to corrosion under continuously wet conditions, such as weathering steel; and designs susceptible to vibration and resonance, presented safety issues. Additionally, many of these supports featured connection details that did not properly consider the stress ranges and number of stress cycles applied to those components. These practices have resulted in failures and, in some cases, highway fatalities.

In the late 1990s, many Agencies initiated their own ancillary structures inspection programs. In 2005, the Federal Highway Administration (FHWA) released Publication No. FHWA-NHI-05-036, *Guidelines for the Installation, Inspection, Maintenance and Repair of Structural Supports for Highway Signs, Luminaires, and Traffic Signals*.(2) This manual provides information about the state of current practice regarding inspector qualifications, inspection types, procedures, new technologies, reporting and maintenance. While not intended to serve as a policy document, the ASIRM provides inspection, maintenance and management personnel with the basic information to manage and implement an ancillary structure inspection program.

Design standards have improved since the publication of the 2001 AASHTO Specifications and continue to evolve as further research is conducted to better understand how these structures behave under wind loads. Fabrication and erection details have also been improved to increase the fatigue life of these structures, and Agencies have become more knowledgeable of the maintenance activities needed to address corrosion. Information regarding these details can be found in the AASHTO publication, *LRFD Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals*.(3)

The National Highway Institute (NHI) offers the following two courses related to the information contained in this document. Information regarding enrollment and hosting opportunities can be found on the NHI website.

- FHWA-NHI-130087A–Inspection of Ancillary Highway Structures Web-based Training Prerequisite (4 hours).
- FHWA-NHI-130087–Inspection of Ancillary Highway Structures Instructor-led Training (1 day).

CHAPTER 2. NOMENCLATURE AND STRUCTURE TYPES

2.1 STRUCTURE TYPES

Sign structures come in a variety of configurations. Since national standards do not exist for sign structures, each Agency may have its own "standards." Other Agencies may provide general requirements by which a fabricator can modify the structure to suit the design criteria. Regardless of the individual Agency standard, structure types and nomenclature tend to be generally consistent across Agencies. Specific nomenclature should abide with the governing Agency's practices.

In the absence of Agency-defined nomenclature, refer to the Glossary for nomenclature used in this manual for various components of overhead sign structures.

2.1.1 Span Structures

An overhead span is a general term used to describe a full span structure supporting sign panels or other devices, such as variable message signs. Overhead span structures are supported on either side of the roadway by a single post end support or a framed double post end support.

Overhead spans are constructed of steel, uncoated weathering steel, or aluminum. The primary configurations of overhead spans are four-chord, three-chord, two-chord, single chord, and monotube overhead span structures. Due to construction, galvanizing tank size and delivery limitations, bolted connections are commonly used to splice together several sections of trusses to create longer trusses needed to span wider roadways. The following sections describe each individual structure, including specific nomenclature for each.

2.1.1.1 Multiple Chord Overhead Span

The horizontal structure for a four-chord overhead span is comprised of four primary horizontal members, typically called the upper front chord, lower front chord, upper back chord, and lower back chord (various Agencies use rear chord rather than back chord). The sign panels are mounted to the front chords for structures over one direction of travel.

The horizontal structure for a three-chord overhead span is comprised of three primary horizontal members, typically called the upper front chord, lower front chord, and middle back chord.

On four-chord and three-chord overhead spans, the chords are connected to each other along their length by secondary diagonals and struts, which are welded or bolted to the chords. Refer to Figures 1 through 4 for views of four-chord and three-chord overhead span configurations.

The horizontal structure of a two-chord overhead span is comprised of two primary horizontal members, typically called the upper chord and lower chord. Depending on the design, the two chords may be connected to each other along their length with diagonals and struts welded or bolted to the chords. Some designs eliminate these secondary members. Refer to Figure 5 for a view of a two-chord overhead span configuration.

Refer to section 5.4.1 Orientation/Numbering Conventions for the numbering conventions on various types of overhead span structures.

Figure 1. Photo. Four-chord full span.

Figure 2. Photo. Four-chord full span.

Figure 3. Photo. Three-chord full span.

Figure 4. Photo. Three-chord full span.

Figure 5. Photo. Multi-post Two-chord full span.

2.1.1.2 Single Chord Overhead Span

A single-chord overhead span structure is supported on either side of the roadway by a single post end support. The horizontal structure is comprised of a single chord. Refer to Figure 6 for a view of a single-chord overhead span configuration.

Figure 6. Photo. Overhead span, single chord and pole structure.

2.1.1.3 Monotube Overhead Span

A monotube structure incorporates the post end support into the main horizontal member. The horizontal structure is comprised of a single chord. Refer to Figure 7 for a view of a monotube overhead span configuration.

Figure 7. Photo. Two monotube overhead span structures.

2.1.2 Cantilever Structures

A cantilever sign structure is typically supported by a single post end support on one side of the roadway. Unlike an overhead span, a cantilevered structure only extends partially across the roadway. Similar to overhead span sign structures, cantilever sign structures support sign panels or other devices, such as variable message signs. Cantilever sign structures are constructed of steel, uncoated weathering steel, or aluminum. The primary configurations of cantilever sign structures are four-chord cantilever, three-chord cantilever, two-chord cantilever, mast arm, and monotube. The following sections describe each cantilever sign structure, including specific nomenclature for each.

2.1.2.1 Multiple Chord Cantilever

The horizontal structure for a four-chord cantilever is comprised of four primary horizontal members, typically called the upper front chord, lower front chord, upper back chord, and lower back chord (various Agencies use rear chord rather than back chord).

The horizontal structure for a three-chord cantilever is comprised of three primary horizontal members, typically called the upper front chord, lower front chord, and middle back chord.

For four-chord and three-chord cantilevers, the chords are connected to each other along their length with secondary diagonals and struts, which are welded or bolted to the chords. Refer to Figure 8 and Figure 9 for views of four-chord and three-chord cantilever configurations.

The horizontal structure of a two-chord overhead cantilever is comprised of two primary horizontal members, typically called the upper chord and lower chord. The structure may be designed with or without secondary members. Refer to Figure 10 for a view of a two-chord cantilever configuration. Refer to section 5.4.1 Orientation/Numbering Conventions for the numbering conventions on various types of cantilever structures.

Figure 8. Photo. Four-chord cantilever.

Figure 9. Photo. Three-chord cantilever.

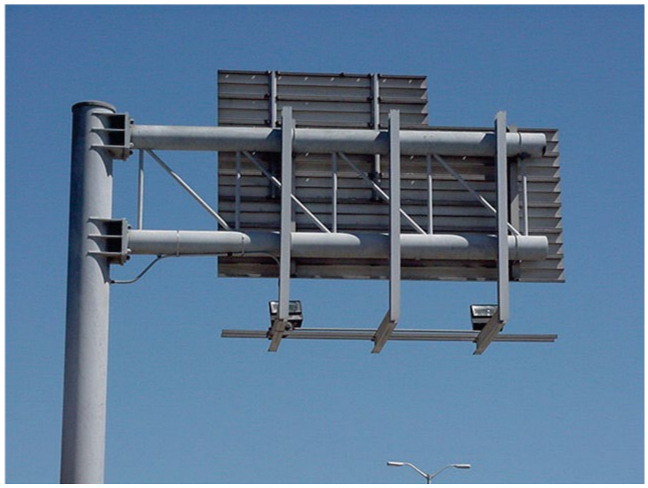

Figure 10. Photo. Two-chord cantilever.

2.1.2.2 Mast Arm

A mast arm consists of a structure that cantilevers over traffic with a single chord. Similar to cantilever structures, mast arms are supported on one side of the roadway by a single post end support. A mast arm usually supports a combination of small signs, traffic signals, cameras, and sensors. Mast arms can come in various configurations, including a single arm in one direction and two arms connected to the post at 90-degree or 180-degree angles. Luminaires are commonly attached to the top of the end support. Refer to Figures 11 through 13 for views of a single arm mast arm, a double mast arm at 90 degrees, and a double mast arm at 180 degrees.

Figure 11. Photo. Single mast arm.

Figure 12. Photo. Double mast arm at 90 degrees.

Figure 13. Photo. Double mast arm at 180 degrees.

2.1.2.3 Monotube Cantilever

A monotube cantilever consists of a structure that cantilevers over traffic with a single chord. Similar to cantilever structures, monotube cantilevers are supported on one side of the roadway by a single post end support; however, the design of a monotube incorporates the post end support into the main horizontal member. A monotube cantilever is capable of supporting larger highway signs and variable message signs. Refer to Figure 14 for a view of a monotube cantilever configuration.

Figure 14. Photo. Monotube cantilever.

2.1.2.4 Butterfly Structures

Butterfly structures consist of a single vertical post support with horizontal arms or trusses cantilevered off the post support in opposing directions, sometimes referred to as balanced butterfly structures. The cantilevered arms can be two-chord (trussed or untrussed), three-chord trusses, or four-chord trusses. Single arm configurations are typically considered mast arm structures and are not given the butterfly designation. Refer to Figure 15 and Figure 16 for views of butterfly structures.

Figure 15. Photo. Untrussed, two-chord butterfly.

Figure 16. Photo. Four-chord truss butterfly.

2.1.3 Span Wire Structures

A span wire structure is supported on both sides of the roadway by a single post end support. Span wire end supports are constructed of steel, uncoated weathering steel, aluminum, concrete, or timber. If timber is used for supporting the span wire structure, additional guy wires typically provide additional support. Metal end supports are typically attached to a drilled shaft or foundation.

The horizontal components of a span wire structure consist of one or two horizontal multi-strand cables denoted as the span wire (upper wire) and sway wire (lower wire). The span wire carries the load while the sway wire adds stability to the attachments. Single wire structures do not have a sway wire. The appurtenances are affixed to the wires of the system to provide support. The wires are connected to the end supports by eyehooks, which are bolted or clamped to the end support. Refer to Figure 17 for a view of a span wire structure.

Figure 17. Photo. Span wire structure.

2.1.4 Pole Structures

Pole structures consist of a single vertical pole supported by a foundation with no arm or a short luminaire arm connected to the top of the pole. Single poles structures without arms are typically used for supporting traffic cameras or other various ITS attachments. The attachments (including the luminaire arms) are typically affixed to the top of the pole by a bolted connection or a clamping device. The attachments vary greatly with pole structures, and the name of the pole structure is usually dictated by what is attached to the pole. Pole lengths vary, but they are usually less than 50 feet tall and typically contain one continuous fabricated section of pole made of aluminum or steel. In certain circumstances, two sections are used to obtain the desired height. If two sections are combined, the bottom of one section is slipped over the top of another section, creating a slip joint. Refer to Figure 18 for a view of a pole structure.

Figure 18. Photo. Camera pole structure.

2.1.5 High Mast

A high mast lighting tower is a pole structure that has a single pole supported by a foundation. Usually at least 55 feet tall, high masts can reach heights exceeding 200 feet. Several segments of the pole are fabricated and attached to one another by slipping the bottom of one end over the top of another to create the desired height. These slip joints may or may not be welded together. Aside from the noticeable height difference, the primary difference between a high mast lighting tower and a pole structure is that a high mast has a light ring affixed to a winch system, which can be raised and lowered to allow maintenance personnel to access the luminaires without the use of a lift. Refer to Figure 19 through Figure 21 for views of a high mast lighting tower, a high mast light winch system, and a high mast lighting tower luminaire ring.

Figure 19. Photo. High mast light structure.

Figure 20. Photo. High mast light winch system.

Figure 21. Photo. High mast light ring.

2.1.6 Structure Mount

A structure-mounted sign structure is constructed of an aluminum or steel frame typically mounted to the fascia of a bridge to provide information to vehicles passing under the structure. These structures can also be mounted to a retaining wall or other roadway structure in areas of limited horizontal roadway clearance that do not allow room for a ground mounted foundation.

When a structure-mounted sign structure is mounted to the fascia of a bridge, the upper connections are embedded or anchored into the concrete parapet or deck of the bridge typically using adhesive anchors, expansion anchors, or through-bolt connections. The lower connections to a steel girder are either bolted to the fascia girder web or clamped to the lower flange to eliminate welding in the tension area of the girder. The lower anchorages to a concrete girder are typically clamped to eliminate drilling into the tension area of the girder.

When a structure-mounted sign structure is attached to a retaining wall, the upper and lower connections are typically embedded or anchored to the wall by adhesive anchors, expansion anchors, or through-bolt connections. Refer to Figure 22 and Figure 23 for views of structure-mounted sign structures.

Figure 22. Photo. Bridge-mounted structure.

Figure 23. Photo. Retaining wall mounted structure.

2.2 STRUCTURE ELEMENTS

2.2.1 Foundations

Foundations for large overhead span structures need to transmit large forces and moments to the soil. Drilled shafts or driven steel piles typically support larger overhead span foundations. The steel piles and drilled shafts are buried and should not be visible for inspection. In certain instances where piles or shafts cannot be used, spread footings with a pedestal or riser can be installed to transfer the forces when high torsional forces are expected. The anchor rods are placed in the foundation or pedestal riser.

Larger cantilever structures have similar construction to that of overhead span structures. Various cantilever structure designs use overturn wings oriented parallel to the roadway below the ground line. These “wings” are installed to resist torsional movements and prevent the structure from leaning towards the roadway. By design, the wings are completely buried and should not be visible for inspection. Refer to Figure 24 for an illustration of a foundation with wing walls.

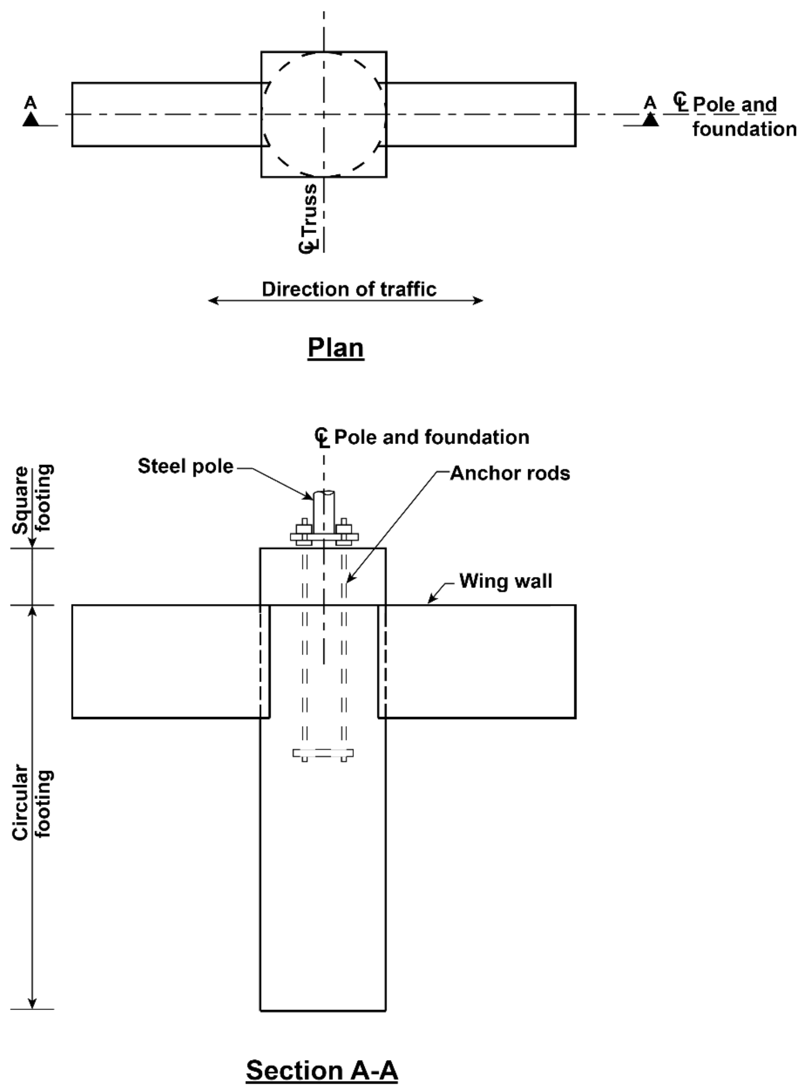

Figure 24. Illustration. Cantilever structure foundation with wing walls.

Smaller overhead span structures, smaller cantilever structures, and pole structures are typically supported by a single drilled shaft at the base support. In these cases, the drilled shaft acts as the top of the foundation of the structure. The anchor rods are placed at the top of the drilled shaft. Refer to Figure 25 for a view of a drilled shaft footing.

Figure 25. Photo. Drilled shaft footing.

In addition to sign structures founded in the ground, overhead span structures and cantilever structures may also be mounted on bridge structures to provide information to vehicles traveling across the bridge. Ideally, the sign structure should be anchored into the ends of a pier cap, but structures have been constructed where the foundation is incorporated into the parapet or attached to corbels on the exterior girders of a bridge. Refer to Figure 26 and Figure 27 for views of a bridge mounted overhead span, and a sign structure attached to a bridge fascia girder.

Figure 26. Photo. Bridge-mounted full span structure.

Figure 27. Photo. Structure attached to bridge fascia girder.

2.2.2 Base Supports

Base supports have three main components: the welded connection to the base plate, the base plate, and the anchor rods. Ancillary structures generally utilize one of two options for a welded post to base plate connection: full penetration welded (post set on top of and welded to the base plate) or socketed (post is set inside a hole in the base plate and fillet welded on the inside and outside). Refer to Figure 28 and Figure 29 for illustrations of these two welded base plate connections. Due to fatigue issues, full penetration welded base plate connections are preferred and are typically incorporated into the design of new structures.

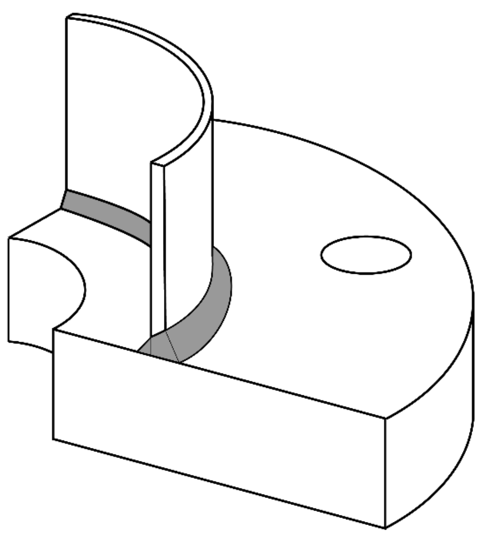

Figure 28. Illustration. Full penetration welded post to base plate connection.

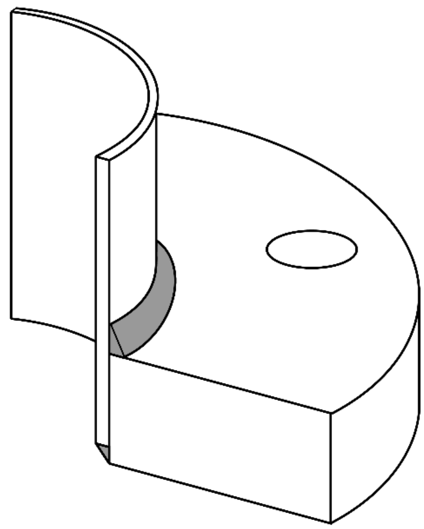

Figure 29. Illustration. Socketed post to base plate connection with fillet welds.

The base plate is connected to the foundation using anchor rods. The anchor rods are embedded in the concrete foundation at a length designed to prevent pullout. The base plate can be set on top of the leveling nuts or directly on top of the concrete surface. If the base plate is placed on top of the leveling nuts, then the top nuts are tensioned. This develops a clamping tension in the anchor rod between the leveling nut and top nut (in the region of the base plate) to help reduce fatigue stresses and prevent loosening of top nuts. Older structures may have grout pads installed between the bottom of the base plate and top of the foundation, but this increases the potential for rod deterioration and moisture retention inside the post. Refer to Figure 30 for an illustration of a base plate with leveling nuts.

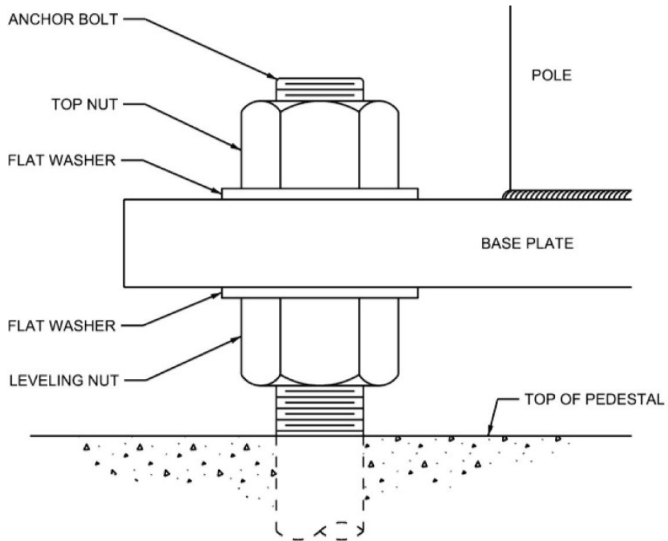

Figure 30. Illustration. Base plate with leveling nuts.

If the base plate is placed directly on top of the concrete foundation (i.e., no leveling nuts or grout pad), the top nuts are tightened to the base plate in lieu of tensioning. Since the anchor rod nuts are tightened, the structure will not have a clamping force developed in the region of the base plate and will be more susceptible to bending forces and fatigue issues. Overtightening the anchor rod nuts can induce distortion of the base plate due to unevenness of the concrete surface, which can cause additional stress in the welded base plate-to-post connection. Refer to Figure 31 for a view of a base plate mounted directly to the footing without leveling nuts.

Figure 31. Photo. Base plate mounted directly onto concrete without leveling nuts.

Aluminum casting clamps are still in service on older structures but have been phased out on new designs. Casting clamps are designed to set the vertical post in the aluminum casting. This casting is clamped to the bottom of the post support with horizontal bolts, and then secured to the foundation with vertical anchor rods. Casting clamps are susceptible to fatigue and cracking due to its low fatigue resistance, and the connection is susceptible to over-tightening by the installer. Refer to Figure 32 for a view of an aluminum casting clamp.

Figure 32. Photo. Cracked aluminum casting clamp.

2.2.2.1 Breakaway Base

Breakaway bases are used at the base of an ancillary structure when it is in the clear zone and vulnerable to a vehicle striking them. Their function is to provide a weak point in the structure for failure to occur, reducing the forces on the striking vehicle. They are typically designed from cast aluminum or a brittle material so that they fracture upon impact. Breakaway bases are typically found on smaller ancillary structures, such as pole structures, luminaire poles, and traffic signals. Two primary types of breakaway bases are used on ancillary structures: transformer bases and breakaway couplers.

Transformer bases are trapezoidal boxes typically made from cast aluminum. The transformer base is connected to the foundation using anchor rods, and the base plate for the ancillary structure is bolted to the transformer base. The transformer base has an access door to allow maintenance and electricians access for wiring signals and lights. These panels also allow for interior base inspections. Refer to Figure 33 for an illustration of a transformer base.

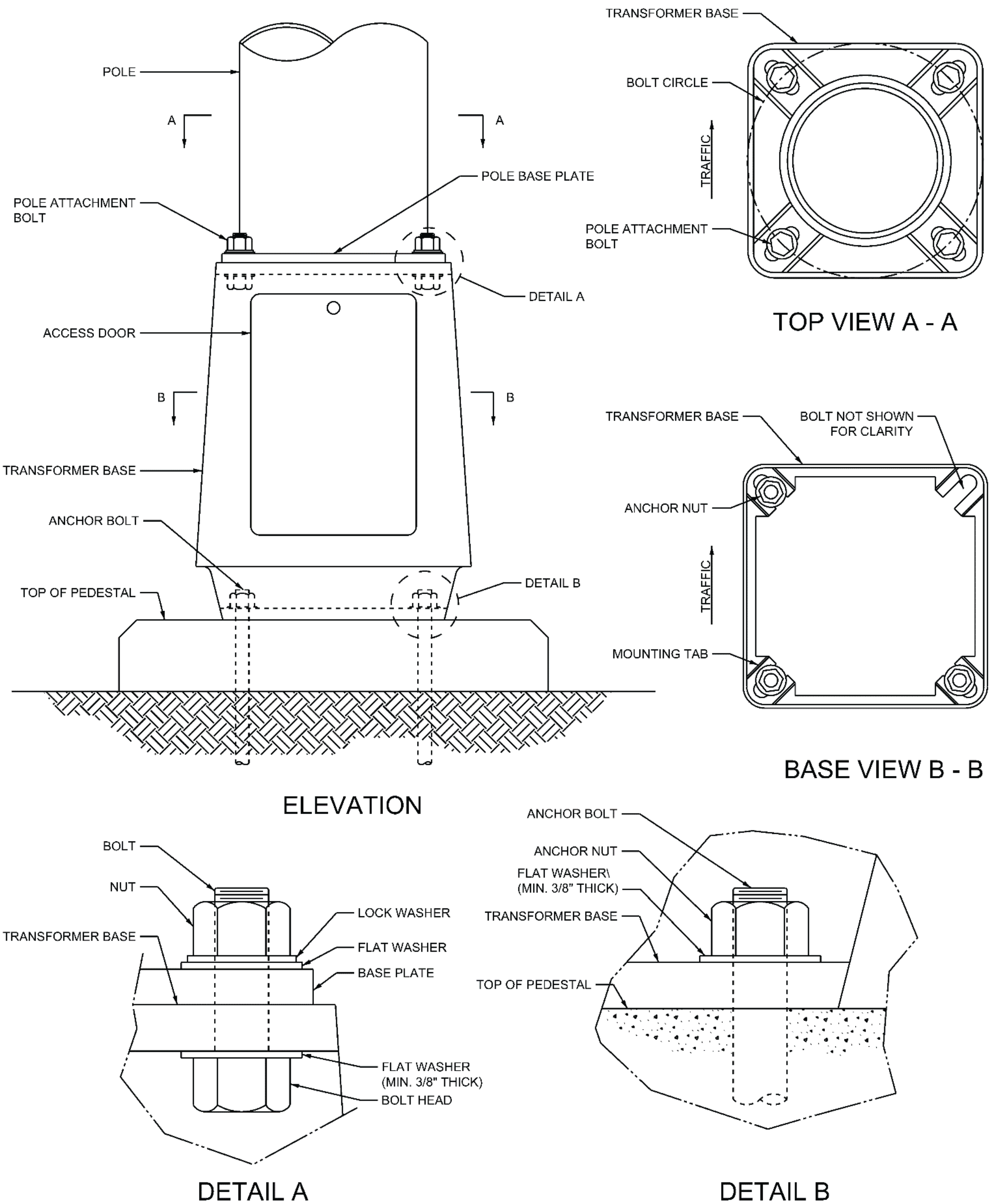

Figure 33. Illustration. Transformer base breakaway assembly.

Breakaway, or frangible, couplers are placed between the structure base plate and the foundation. One coupler is bolted to each foundation anchor rod. The couplers are designed with a reduced section (necked down cross-sectional area), which is designed to fracture on impact. The couplers are typically protected from the weather by a shroud placed around the structure base plate. Refer to Figure 34 and Figure 35 for illustrations of breakaway coupler assemblies.

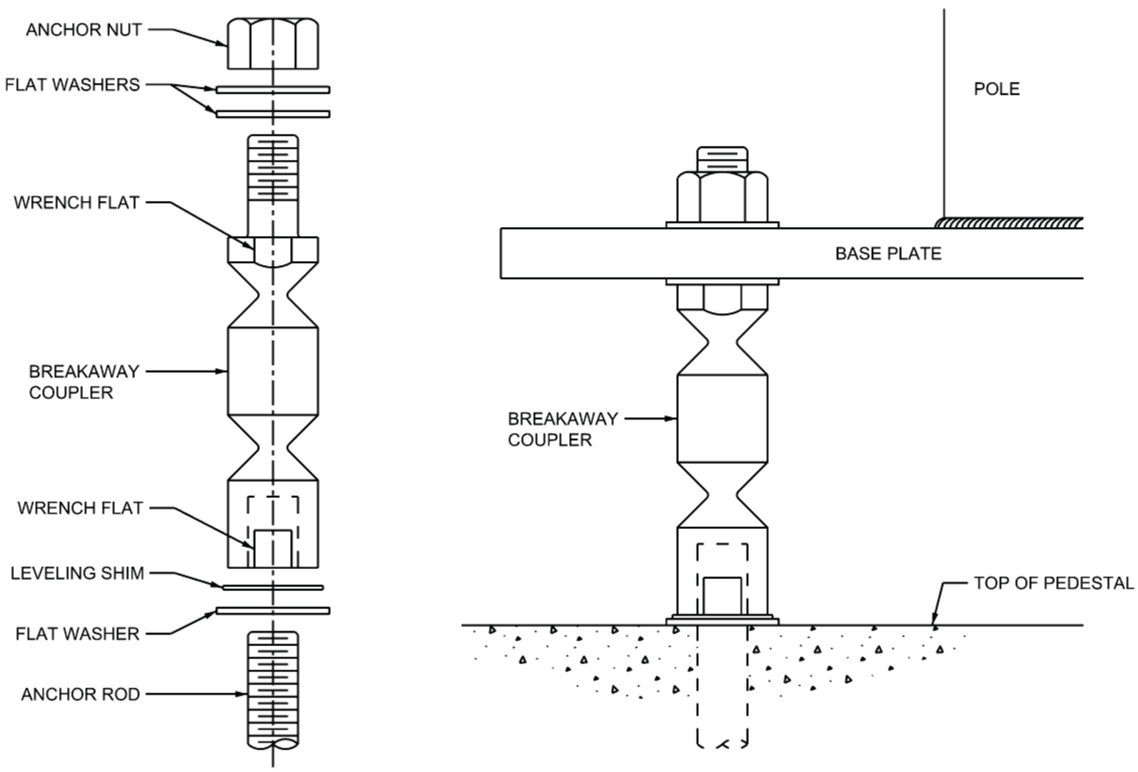

Figure 34. Illustration. Steel double neck breakaway coupler assembly.

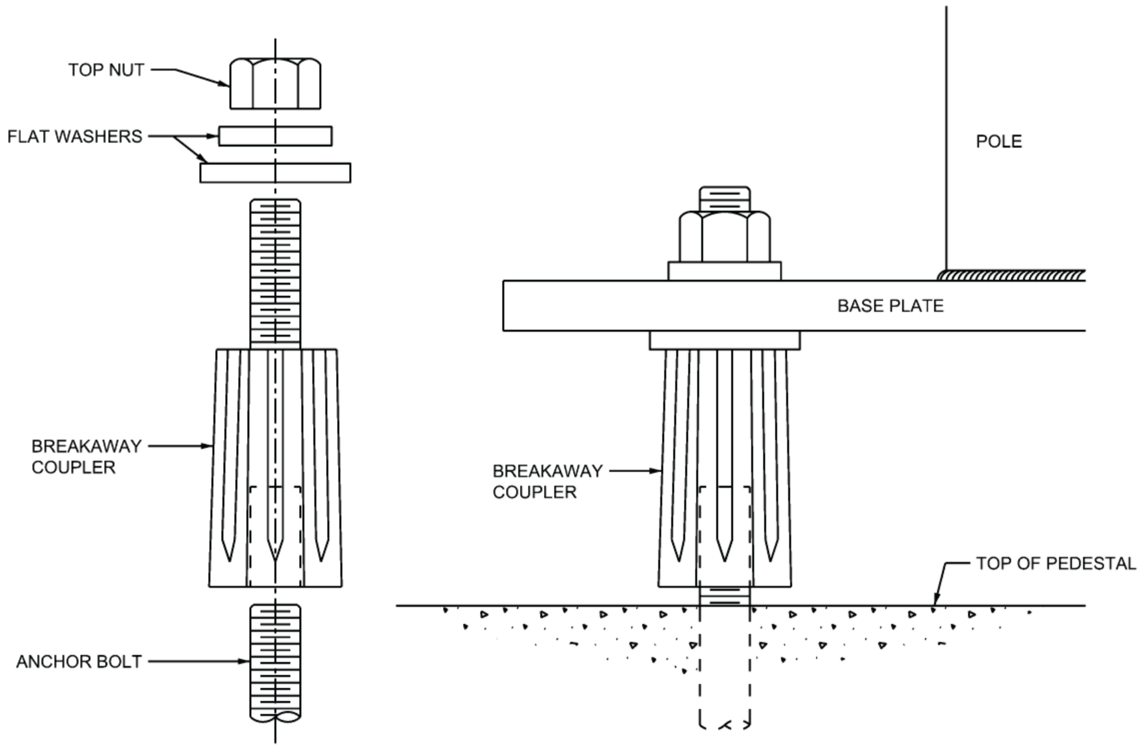

Figure 35. Illustration. Cast aluminum breakaway coupler assembly.

2.2.3 End Supports

Overhead span structures (four-chord span and three-chord span) are supported by a single post or a dual post end support frame. Dual post supports have secondary framing members connecting the two posts. Single post end supports resist lateral load as a beam-column. Dual post end support frames resist lateral loads as a cantilevered truss. Depending on the design needs, handholes may be fabricated near the top and or bottom of the post to allow for electrical access. Refer to Figure 36 and Figure 37 for views of a dual post end support with framing members, and a single post end support.

Figure 36. Photo. Dual post with framing members.

Figure 37. Photo. Single post structure.

2.2.4 Span-to-Post Connections

Span-to-post connection types vary greatly depending on the type and design requirements of the connection being detailed. Common details for overhead span structures include saddle connections, clamped connections, and moment resisting connections. In most instances, the end of each chord is secured to the end support using a bolted connection assembly, which may be connected directly to the post or supported by a corbel, horizontal plate, or load beam.

Single chord overhead span structures can have a pinned connection to a post clamp. The clamp is attached to the top of the end post. Most end posts in single-chord overhead spans are tapered, which prevents the clamp from sliding down the end post. Refer to Figure 38 for a view of a clamped end post connection.

Figure 38. Photo. Pinned span-to-post clamp connection.

Corbels can be welded to the end post to create a support plate for the chord. The chord is bolted to this plate to provide the necessary connection. Refer to Figure 39 for a view of a corbel post connection.

Figure 39. Photo. Bolted corbel span-to-post connection.

Larger full span structures can use horizontal load beams to support the truss. The load beams are welded to each end post support. The chords are typically placed in saddle shims and attached to the load beam with U-bolts. Refer to Figure 40 and Figure 41 for a view of a load transfer beam configuration, and a close-up view of a saddle shim at a span-to-post connection.

Figure 40. Photo. Load transfer beams on a dual post end support frame.

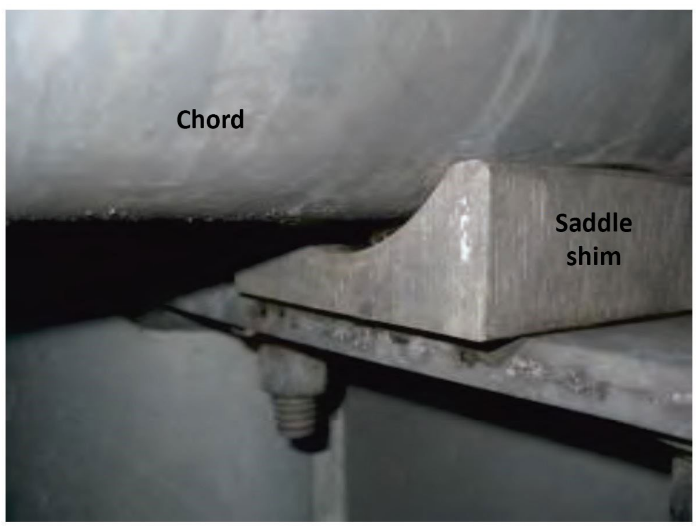

Figure 41. Photo. Saddle shim at a span-to-post connection.

Many cantilevered structures use high-strength bolted connections to attach the horizontal chords to the end supports. Cantilever structures need a moment resisting connection to support the load of the cantilever assembly. Larger cantilever spans (four-chord and three-chord) may have horizontal plates on the post support. The primary chords are connected to the plates with numerous bolts to provide the necessary connection strength. Refer to Figure 42 for a view of a four-chord cantilever-to-post connection.

Figure 42. Photo. Cantilever truss connection with horizontal plates on post support and chords.

Larger two-chord trussed cantilevers may have a splice plate type connection (refer to section 2.2.5 Splices) to connect each chord to the end support, or have a welded frame connected to the post in which the cantilever assembly is bolted to. Refer to Figure 43 for a view of a two-chord trussed cantilever post connection using a framed box connection welded to the post.

Figure 43. Photo. Bolted span-to-post connection.

Smaller cantilever spans (two-chord and mast arm) may have vertical plates on the end support and the end of the mast arm or chord. The vertical plates are attached with four or more bolts in the connection to provide the necessary strength to support the structure. Refer to Figure 44 for a view of a mast arm-to-post connection.

Figure 44. Photo. Mast arm bolted connection.

2.2.5 Splices

Mechanical splices are typically found on overhead span and monotube cantilever structures where fabrication, galvanizing, or shipping limitations cause the structure to be fabricated in numerous sections. A splice is located on each primary chord of the structure, typically in the same vertical plane. The splice plate is welded perpendicular to each chord. Each splice plate accommodates multiple bolts located around the circumference. The splice plates are bolted together in firm contact with each other.

Splices on aluminum structures should be tightened connections, while splices on steel structures should be tensioned connections. The bolts on a steel structure are typically galvanized high-strength bolts that are tensioned to produce a connection that is less susceptible to fatigue cycles. The bolts on an aluminum structure are tightened because a tensioned connection could cause deformation to the aluminum plates, causing the plates to crack or crush. The bolts found in aluminum splices are typically either stainless steel or galvanized steel with stainless fender washers to minimize dissimilar metal corrosion (premature oxidation/corrosion of the aluminum splice plates). Older aluminum structures may use aluminum bolts. Refer to Figure 45 and Figure 46 for views of aluminum and steel overhead span splices.

Figure 45. Photo. Aluminum span splice connection.

Figure 46. Photo. Steel span splice connection.

2.2.6 Sign Panels and Support Frames

Sign panels have three primary types of construction: treated plywood panels, flat stock aluminum panels, and extruded aluminum panels. Both timber and flat stock aluminum panels are bolted directly to horizontal wind beams, which are connected to the vertical sign hangers/supports. Extruded aluminum sign panels have grooved channels that accommodate sign clips that clamp the sign panel extrusions directly to the vertical sign hangers or supports. The vertical hangers can be secured to the sign structure in various ways, including, but not limited to, U-bolts, clamping devices, and banding straps. Various details of supporting the sign panels are being phased out due to fatigue issues but can still be found in the field, including sign clips with aluminum studs and threaded rods stud welded onto the back of the sign panel. Refer to Figure 47 and Figure 48 for sign panel nomenclature.

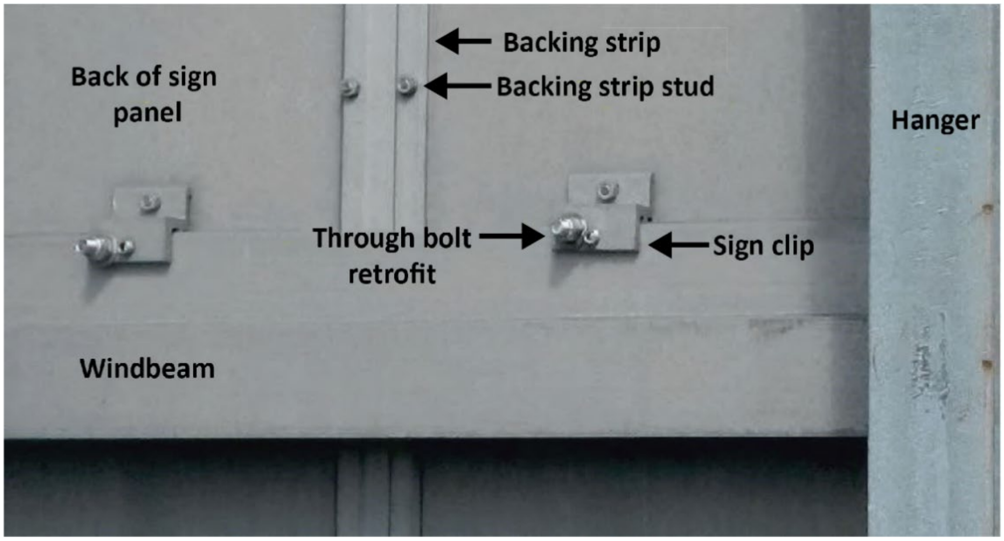

Figure 47. Photo. A sign panel and support frame with components labeled.

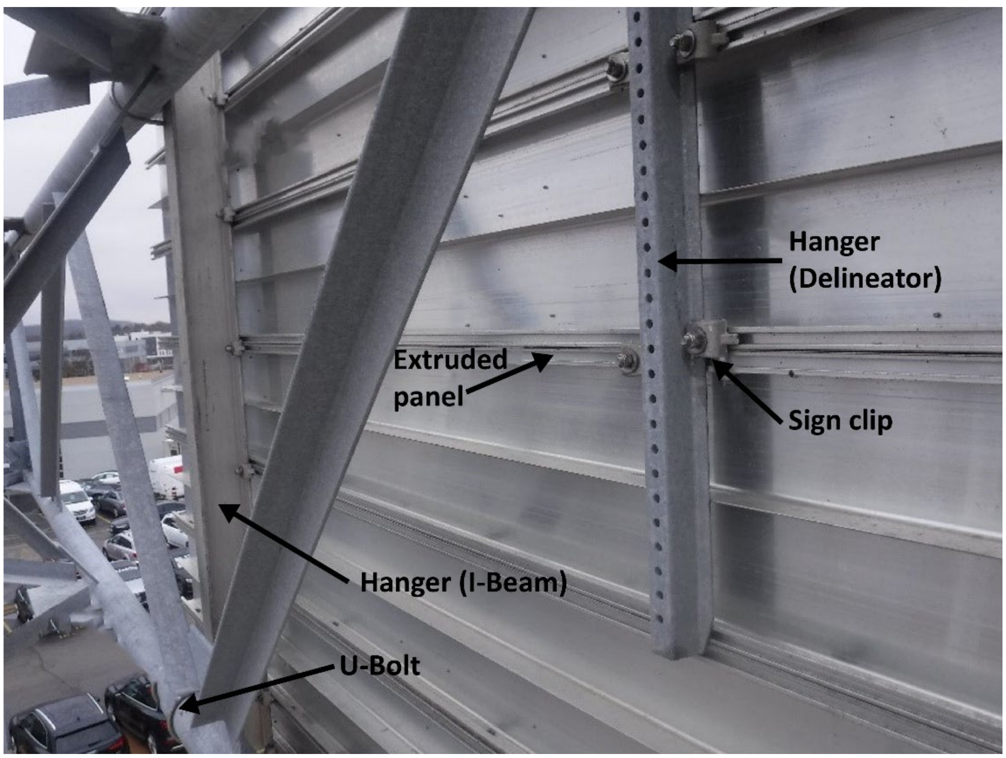

Figure 48. Photo. The back of an extruded aluminum sign panel with components labeled.

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CHAPTER 3. PERSONNEL QUALIFICATIONS

Federal regulations do not require inspection of ancillary structures; hence, there are no specific requirements for those who conduct the inspections. Just as with highway bridge inspections, inspections of ancillary structures have special circumstances that inspector personnel should address.

An inspection team usually consists of a Team Leader and a Team Member (Assistant Inspector). Team Leader qualifications may include those discussed below. Because welded members are found in most ancillary structures, at least one team member should have experience in visual weld inspection, as well as training in locating and recognizing fatigue cracking.

3.1 PROGRAM MANAGER

The Program Manager typically oversees the scoping, scheduling, cost, and quality control aspects of the inspection program. The Program Manager may delegate various tasks to others.

Program Managers should have the following minimum qualifications:

- Be a licensed Professional Engineer or have a minimum of 10 years of experience in structure inspections in a responsible capacity.
- Have completed a comprehensive training course based on ancillary structure inspections.
- Complete periodic inspection refresher training according to Agency policy.

The comprehensive training course may include both *NHI-130087A Inspection of Ancillary Highway Structures: Web-based Training Prerequisite* and *NHI-130087 Inspection of Ancillary Highway Structures: Instructor-led Training*.

3.2 TEAM LEADER

The Team Leader typically is in charge of the inspection team in the field. Team leaders should possess one of the following qualifications:

- Have a Professional Engineers registration, completed an approved comprehensive inspection-training course based on ancillary structure inspections, and have periodic refresher training.
- Have five years of structure inspection experience, completed an approved comprehensive inspection-training course, and have periodic refresher training.
- Be a certified NICET Level III or IV Bridge Safety Inspector, completed an approved comprehensive inspection training course, and have periodic refresher training.
- Have a bachelor's degree in engineering from an ABET accredited college or university, successfully pass the NCEES Fundamentals of Engineering exam, have two years of structure inspection experience, completed an approved comprehensive inspection training course, and have periodic refresher training.

- Have an associate degree in engineering from an ABET accredited college or university, have four years of structure inspection experience, completed an approved comprehensive inspection training course, and have periodic refresher training.

The comprehensive training course may include both *NHI-130087A Inspection of Ancillary Highway Structures: Web-based Training Prerequisite* and *NHI-130087 Inspection of Ancillary Highway Structures: Instructor-led Training*.

In addition to the comprehensive training course, Agencies, at their discretion, may establish additional certifications and training courses to perform ancillary structure inspections. Some of these include:

- Visual Testing I and II through the American Welding Society (AWS).
- Certified Welding Inspector through the AWS.
- Rope Access certification through the Society of Professional Rope Access Technicians (SPRAT) or the Industrial Rope Access Trade Association (IRATA).
- NHI-130078 Fracture Critical Inspection Techniques for Steel Bridges.
- Work zone traffic control through a comprehensive course such as NHI-133112 Design and Operation of Work Zone Traffic Control, NHI-133117 Maintenance of Traffic for Supervisors, or similar.

3.3 TEAM MEMBERS

A Team Member accompanies the Team Leader in the field to assist with duties needed to perform the inspection tasks. Depending on the tasks being performed, there may be more than one Team Member on site during an ancillary structure inspection. A Team Member should be able to follow the Team Leader's instructions in a safe and efficient manner. Team Members may not need specific training or experience related to inspections. However, knowledge of welding, structural bolting, nondestructive testing, climbing, and traffic control is beneficial. Safe use of inspection tools and access equipment is also advantageous.

3.4 NON-INSPECTION TEAM MEMBERS

Non-Inspection Team Members are personnel that are on- or off-site performing support duties related to ancillary structure inspections. Support duties typically include, but are not limited to the following:

- Heavy vehicle operators for vehicle mounted lifts requiring a Commercial Driver's License (CDL).
- Traffic control supervisors and technicians for setting and removing shoulder, lane, and ramp closures for ancillary structure access.
- Electricians to de-energize circuits prior to inspections.
- Personnel reporting on ancillary structure inspections.
- Personnel performing Quality Assurance (QA) on reporting.
- Project Management performed in the office.

3.5 SUPPLEMENTAL INSPECTIONS

Agencies sometimes use other Agency employees to perform supplemental inspections of structures when on site. Examples of tasks that these Agency personnel may perform, that fall outside the scope of the work performed by a typical Inspection Team, include:

- Electricians performing maintenance on traffic signals may perform a cursory inspection on the traffic signal head connection to the arm/post to ensure it is secure.
- Electricians performing luminaire replacements on pole structures may check the connections of the luminaire head and post connection.
- Electricians performing maintenance on high masts may exercise the winch system and inspect the winch cable and luminaire ring connections.
- Maintenance personnel performing routine inspection from the shoulders with binoculars check for missing sign panel connections and noticeable defects.
- Maintenance personnel may check post mounted signs for missing or loose attachments.

While these supplemental inspections by Agency personnel are invaluable to providing safety to the traveling public, it may be useful for the team to possess the qualifications described above to perform periodic ancillary structure inspections as described in Chapter 4. Inspection Types and Frequency.

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CHAPTER 4. INSPECTION TYPES AND FREQUENCY

4.1 INSPECTION TYPES

There are several potential inspection types based on the status and condition of the ancillary structure.

4.1.1 Initial Inspection

An initial inspection is typically a baseline inspection that verifies inventory data, dimensions, accuracy of installation, and notable defects from the installation. This inspection should take place immediately after the structure is erected and prior to acceptance. Performing this inspection prior to a construction project being closed out allows the erecting contractor time to address punchlist items. Coordination with the contractor and resident engineer may be needed to ensure safe access to the structure.

An initial inspection is generally a 100 percent hands-on inspection (i.e., within arm's length) in which every welded and bolted connection is verified. Plans and specifications are reviewed to verify the as-built condition matches what is shown in the plans and shop drawings. It is common for bolts on sign structures to become loose shortly after installation. The erecting contractor typically rechecks bolted connections, but they can be verified as part of an initial inspection.

4.1.2 Routine Inspection

A routine inspection generally occurs at regularly scheduled intervals. The scope of a routine inspection includes a 100 percent hands-on inspection of all welded and bolted connections. A routine inspection can also be used to update Agency inventory data. A combination of visual and nondestructive evaluation methods can be employed during a routine inspection.

4.1.3 Service Inspection

A service inspection is typically a cursory inspection that uses Remote Visual Inspection (RVI) methods, such as walking around the structure while using binoculars or a scope with a minimum 10 times magnification from the ground. Unmanned Aerial Systems (UAS) and telescoping camera poles may also be used for service inspections. This type of inspection is used to update Agency inventory data or to assess a structure after high winds or a severe weather event to quickly assess the structure for deficiencies.

Structural deficiencies, such as weld cracks in an overhead truss, are difficult to identify from a ground level inspection; therefore, a service inspection should not be performed on consecutive inspection cycles but may supplement regularly scheduled routine inspections.

4.1.4 In-Depth Inspection

An in-depth inspection generally involves a detailed inspection of one or more structural members using nondestructive evaluation methods, such as magnetic particle testing, dye penetrant testing, or ultrasonic testing. An in-depth inspection typically includes accessing and inspecting (visually and tactically) specific elements or connections of the structure and updating the condition and inventory information as necessary.

4.1.5 Damage Inspection

A damage inspection should be performed after a structure is damaged. This damage could be due to errant vehicle, mowing impact, an over height hit of the truss or sign panels, etc. Detailed documentation of the damage may be prepared with proposed follow-up actions and repairs.

While the point of impact may be isolated to a specific component, the damage inspection should be performed on all elements and attachments at a minimum 25-ft distance surrounding the area of damage and following the load path to the ground. The controlling load path component may not be near the point of impact. Damage inspections generally do not affect the normal routine inspection frequency.

4.2 FACTORS IN FREQUENCY DETERMINATION

Inspection frequency varies by Agency, generally from 12 to 72 months, with 48 months and 60 months being the most common.

Determining the frequency for ancillary structure inspections depends on several factors. Certain defects, materials, configurations, or conditions may cause inspections to be performed on a more frequent basis. Access and user costs may also affect the inspection frequency. Specific factors that may be used to determine inspection frequency include:

- Material Issues
    - Aluminum structures have a lower fatigue resistance than steel structures.
    - Uncoated weathering steel structures in moist or polluted environments are more susceptible to corrosion issues.
- Age
    - Older structures may be nearing the end of their fatigue life; fatigue prone details may be focal points of crack initiation.
    - Structures designed using older (pre-2001 edition) AASHTO design specifications did not account for fatigue loading. Some Agencies have not adopted the current AASHTO design specifications as listed in the Code of Federal Regulations, 23 CFR § 625.4(d); as a result, their full inventory may not account for fatigue loading, regardless of age.
- Redundancy
    - Structures with load path redundancy typically are less susceptible to sudden failure.
    - Structures with four bolts in the base plate or post-to-mast arm connection are more susceptible to sudden failure.
- Historical Issues
    - Problematic details with a history of premature deterioration or failure may be susceptible to failure.

- Loose anchor rod nuts and structural bolted connections can lead to fatigue issues of the connection.
- High strength anchor rods and other connections using high strength steel may be susceptible to hydrogen embrittlement or brittle fracture.
- Structures mounted on bridges may be more susceptible to fatigue due to the extra fatigue cycles caused by the bridge structure's repeated deflection/movement.
- Structures mounted to the concrete parapet with adhesive anchors under sustained tension can be subject to creep of the adhesive material.

- Cost
  - The Agency may assess risk versus cost of inspection resources.
  - The Agency may consider all costs, including inspection and maintenance.
  - The Agency should consider user costs associated with traffic delays and risk of accidents due to traffic control and work zones.

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CHAPTER 5. INSPECTION PROCEDURES

5.1 PLANNING

Initial program planning involves a general knowledge of the assets in the Agency's ancillary structure inventory.

5.1.1 Screening

Structure inventory data (section 6.1 INVENTORY DATA) is typically collected at the beginning of an inspection program to screen and prioritize the proposed inspection activities. Inventory data collection can be achieved through a combination of record plan review, maintenance record review, and routine inspection mobilizations. The following data points can be helpful in the planning, prioritization, and scheduling of an inspection program:

- Structure location (GPS coordinates, route, direction, location, and mile marker)
- Structure type (span, cantilever, mast arm, span-wire, pole, high mast, or structure mount)
- Mounting (ground mount or on-bridge span)
- Age
- Span material (aluminum, steel, or span wire)
- Material coating (painted, galvanized, or uncoated weathering steel)
- Primary member dimensions (span length, vertical clearance, or lateral clearance)
- Number of primary members
- Number of end supports
- Number of anchor rods per end support
- Sign panel area (per as-built or in-service)
- Access difficulties
- Traffic control

After the initial inventory data set is collected, a random sampling of structures can be scheduled for an In-Depth inspection (section 4.1.4 In-Depth Inspection) to identify common defects and problematic details that may be present in the Agency's ancillary structure inventory. A minimum sample size of 10 percent is suggested. This sample size should include a diverse set of structures to capture an inclusive collection of structure types, materials, and details.

5.1.2 Prioritization

At the beginning of an inspection program, structures with the highest probability of critical defects should be inspected first. The collected inventory data can be used to prioritize the inspection activities for the initial and subsequent years.

The following list includes some example priorities:

- Aluminum sign structures.
- Uncoated weathering steel high-mast lighting structures.
- Bridge-mounted span and cantilever structures.

- Sign structures more than 30 years old.
- Four-anchor rod cantilever structures.
- Structures with details found to be problematic during the initial sample round of inspections.
- Sign structures where the sign panel area exceeds the original panel or design panel dimensions.

Cost data from the sample inspection program can be used to program the necessary funding to execute the long-term inspection program.

5.2 SAFETY

Every ancillary structure inspection program should have an approved, detailed safety plan prior to beginning work. Sign structure inspections are one of the most hazardous types of structural inspections because they usually occur near live traffic. In addition, the inspector may need to climb the structure, which can be difficult due to angled and slippery structural members.

Listed below are typical contents of a safety plan:

- Safety Plan Officer for the Agency or consulting firm performing the inspection.
- Safety organization.
- Safety incident report procedures and forms.
- Fall protection procedures.
- Operation of aerial lift procedures.
- Hospital locations.
- Latest *Manual of Uniform Traffic Control Devices* (MUTCD).[4]
- Specific work zone traffic setups.
- Personal safety equipment.
- First aid kit.

5.2.1 Safety Equipment

Each inspector working on an inspection team should be supplied with the proper personal protection equipment (PPE) based on the hazards that may be encountered during a mobilization. Common PPE for ancillary structure inspection personnel may include a safety vest, hardhat, safety glasses, hearing protection, and gloves. Good gripping boots with ankle support, similar to ones a mountain climber would use, are recommended. Since the inspector may be climbing the structure or working out of an aerial lift, he or she should be trained in lift operation and rescue, fall protection, and the use of a harness and a "Y"-lanyard system. Flotation devices and rescue skiffs may be appropriate for instances in which an inspector is climbing over or adjacent to a waterway. Refer to Figure 49 for a view of an inspector wearing PPE.

Figure 49. Photo. Common inspector safety equipment.

Nighttime work may be necessary to reduce traffic congestion. Several inherent hazards exist when working at night, including visibility (workers and motorists), higher speeds, impaired drivers, and alertness (workers and motorists). The inspection team should take the necessary precautions to protect themselves and may implement the following to assist in mitigating potential hazards:

- Extra reflective clothing (pants, full-length shirt, or striping on hardhat).
- Headlamps.
- Larger channelizing devices, such as barrels used for traffic control.
- Arrow boards.
- Additional strobe lights.
- Mobile light plants/towers.
- Truck Mounted Attenuators (TMA).

5.2.2 Working Close to Live Traffic or Inspections with No Traffic Control

Working close to live traffic poses numerous inherent dangers to the traveling public, as well as the inspection team. The inspection team may have inattentive drivers passing their work zone. Inspectors should do their best to stand behind guardrails when feasible, as well as face traffic to view passing vehicles. Traffic control and work zone protection should follow the MUTCD and the governing Agency's safety regulations and guidelines for highway work zones.(4) Inspection activities should not occur without proper traffic control and work zone protections in place.

5.2.2.1 Climbing a Sign Structure

When climbing a sign structure, the inspector typically uses a “Y”-lanyard system with one lanyard always secured to the structure, thus creating a 100 percent tie-off condition. The inspector should secure the lanyard system to the structure on the upper members, while walking along the bottom members. Care should be taken by the inspector to ensure that lanyards are attached to members of sufficient strength to support a fall. Smaller secondary members may not be adequate for an anchor point. Traditional climbing techniques involve using lanyards attached to the dorsal connection of the harness. If a fall were to occur using a dorsal connection, self-rescue would be difficult, if not impossible. A fallen worker would be exposed to hanging harness syndrome, which is a serious and life-threatening condition. Therefore, each inspector should have fall suspension trauma straps attached to their harness that can be deployed in the event of a fall and utilized until the rescue plan can be implemented. When working overhead within the work zone, everything worn or carried should be tethered to the climbing inspector to protect personnel who may be working below and the traveling public.

Rope access methods may also be incorporated into accessing or climbing a sign structure by use of sternal attachments. This should be accomplished by using a specialized harnesses and equipment. Self-rescue is more practical if a fall were to occur using rope access methods; however, a rescue plan should still be in place ready to be implemented. Refer to Figure 50 for a view of an inspector using rope access methods to access the structure.

Figure 50. Photo. Inspector climbing using rope access equipment.

5.2.2.2 Climbing over Live Traffic

Some Agencies may permit climbing a sign structure over live traffic. When an Agency permits climbing a structure to inspect welds and attachments, the inspector can leave the aerial lift to do so. Depending on the structure dimensions between the top and bottom chords, climbing may not be feasible. Typically, an inspector can safely climb structures with a distance of 6-ft or less between the top and bottom chords. Larger structures become unsafe to climb, and inspections should be conducted from an aerial lift.

While working overhead, everything worn or carried should be tethered to the inspector so nothing can drop into traffic or hang below the bottom of the structure. Inspection findings may be reported using a radio attached to the climbing inspector, so inspection findings can be relayed to a note taker on the ground. Since the traveling public may be concerned when observing someone climbing a sign structure, some States place roadside or variable message signage stating “Workers Overhead” as an informational aid.

5.2.2.3 Working from Within an Aerial Lift

The inspector may need to work from an aerial lift to inspect smaller sign structures and when Agencies do not allow climbing over live traffic. In addition, the inspection of structure-mounted sign structures is typically performed from an aerial lift due to the low clearance over the roadway and the limited space between the structure-mounted members and the bridge parapet or fascia girder. It is good practice to have all tools and equipment tethered to the inspector or aerial lift to prevent items from dropping into the work area below. The inspector should take care to position the lift boom so that in the event of a hydraulic failure, the aerial lift does not lower into live traffic. Refer to Figure 51 for a view of an inspector using an aerial lift to access an overhead span.

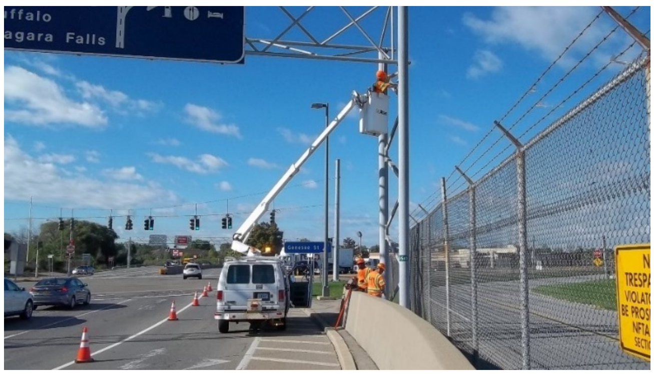

Figure 51. Photo. Performing inspection from within the bucket.

5.2.3 Traffic Control

Obtaining access for inspection personnel is one of the most difficult challenges for the inspection and evaluation of overhead sign structures. This challenge arises from the need to satisfy an Agency's Maintenance and Protection of Traffic safety requirements while controlling costs. If road closures are necessary, they may be in the form of stationary closures or rolling closures. Governing Agencies often require permits for lane and shoulder closures. Regardless of the type of closure used, all closures should conform to the MUTCD and the governing Agency's traffic control standards.(4) Inspection personnel should be trained in the proper design and implementation of highway work zones. The Team Leader should check the signage, lane tapers with traffic control channelizing devices, and lighting (night work) prior to occupying the work zone.

Depending on the location of ancillary structure inspections, Agencies may restrict traffic control closures to off-peak hours. These restrictions may prohibit closures during morning and afternoon rush hour commutes or may limit closures to nighttime hours. Inspection teams should coordinate traffic control efforts with the governing Agency.

5.2.3.1 Stationary Closures

Stationary closures generally consist of shoulder, ramp, and lane closures that are in place for up to one work shift period. Agencies commonly have approved details for stationary work zones.

Work within complicated roadway geometries or interchanges may need a unique traffic control plan to guide traffic safely through the closure. The governing Agency should review and approve the traffic control plan. Refer to Figure 52 for a view of channelizing devices used to perform a left lane closure.

Figure 52. Photo. Stationary left lane closure.

5.2.3.2 Rolling Closures

Rolling closures are commonly short duration closures where truck-mounted attenuators and arrow boards are used to redirect traffic to adjacent lanes. The governing Agency may limit stationary time at one site prior to the closure moving forward to the next work location. Rolling closures are often used when the amount of inspection time does not exceed the Agency's stationary time limit. Refer to Figure 53 for a view of a rolling closure using a truck-mounted attenuator.

Figure 53. Photo. Rolling left lane closure.

5.2.4 Electrical Safety

Sign structures that support variable message signs, luminaires, high-mast lighting towers, and traffic signal structures usually have electrical wires running through the foundations, end supports, conduits, and trusses. Over time, unprotected wires can wear due to the vibratory nature of these structures. If wires wear through the protective coating, electricity can arc to the structure itself and become electrified. It is important for the inspection team to protect themselves from electrocution. Prior to inspecting a structure with electricity, the inspection team should use a voltage detector to check the sign structure for potential voltage and stray currents due to an arced wire. If voltage is detected, the inspection team should not inspect the structure and should notify the Agency to have maintenance personnel de-energize the structure prior to inspection. At that point, Agency maintenance personnel should repair the arced wire.

Adjacent electrical utilities are another form of an electrical safety hazard. Prior to inspecting a sign structure, the inspection team should be aware of their surroundings and identify all overhead wires adjacent to the structure. If overhead utility lines are identified, the inspector should treat all power lines as if they are energized. The ground inspector should act as a spotter and notify if the inspector is getting close to power lines. The inspector should maintain a safe working distance as described in *Occupational Safety and Health Administration (OSHA) 29 CFR 1926.1408*.[(5)] Refer to Figure 54 and Figure 55 for views of overhead wires in contact with, and adjacent to, a sign structure.

Figure 54. Photo. Exposed wires due to wear.

Figure 55. Photo. Overhead lines near structure to be inspected.

5.2.5 Other Potential Safety Hazards

When an inspection team arrives at a sign structure, each member should be aware of their surroundings and attempt to identify other, less obvious potential hazards. Some potential hazards are listed below:

- Poisonous plants
- Excessive heat or cold
- Slippery conditions
- Allergen exposure
- Biting or stinging insects
- Animal or snake holes
- Garbage or waste
- Cell equipment

5.3 TOOLS AND EQUIPMENT

Each inspection team should be fully equipped to perform the structural inspections. Because it is common for inspectors to also be responsible for minor repairs, additional equipment may be necessary. Such minor repairs may include tightening bolts, replacing fasteners, paint touchup, replacing missing end support caps, replacing anchor rod nut covers, and replacing handhole covers.

5.3.1 "Tools of the Trade"

The list below would be considered "Tools of the Trade" for the sign structure inspector:

- Work-zone protection and traffic control equipment, including signs, traffic cones, and flags (in compliance with the MUTCD and Agency requirements).[4]
- Personal safety equipment, including hard hats, reflective high-visibility vests, safety glasses, hearing protection, gloves, harnesses, and lanyards, all conforming to applicable OSHA standards and Agency requirements.
- Basic access equipment, such as an extension ladder and rope.

- Tools for performing the inspection, including voltage detector, chipping hammers, pocketknives, screwdrivers or awls, magnifying glass, wire brushes, magnet, flashlights, and mirrors.
- Tools for measuring, such as a plumb bob, levels, folding rulers, tapes, calipers, and thickness gauges.
- Wrenches and screwdrivers for removing access panels and bolt covers. Penetrating lubricant may assist in removing corroded hardware.
- A torque wrench for bolt tightening or checking bolt tension.
- A digital camera for documentation. Cameras with built in GPS can be used to verify the location and orientation of photographs taken.
- Shovels, whisk brooms, and brush cutters for removing debris.
- Marking utensils, such as paint sticks (preferred), lumber crayons, soapstone, and center punch.
- GPS units: phone app or handheld depending on the precision needed.
- An electronic device for measuring distance.
- Equipment to number each sign structure, either paint stenciling, adhesive tape, paint markers, etc. if identification plaques are not installed.
- Nondestructive testing equipment, such as D-meters, ultrasonic testing units, dye penetrant, or magnetic particle.

5.3.2 Specialized Equipment

5.3.2.1 Aerial Lifts

Climbing the framed end support can provide access to many sign structures; however, the structures with a single post end support are typically accessed by using an aerial lift. These vehicles are commonly used by cable and telephone companies and are readily available for rent. For most ancillary structures, an aerial lift with a 30-ft boom is adequate. For many aerial lifts of this size, a CDL driver's license is not needed. Vehicle mounted lifts should be operated in accordance with safety procedures. Refer to Figure 56 for a view of an inspector using an aerial lift.

Figure 56. Photo. Vehicle mounted lift.

5.3.2.2 Spotting Scopes

Spotting scopes are routinely used on high mast lighting towers to view the post support, slip joints on the post support, and the luminaire ring. Spotting scopes should have variable power ranging from 10x to 50x magnification. This magnification can be adjusted as the inspector scans from the base of the post support to the top. The spotting scope should be supported by a sturdy tripod to ensure stability during the inspection process. This also allows the inspector to stop on a suspected defect to inspect using different magnifications. Spotting scopes can also be used for viewing sign structures during a service inspection from the shoulder. Refer to Figure 57 for a view of a spotting scope used to inspect a high mast lighting tower.

Figure 57. Photo. Spotting scope utilized for viewing the top of a high mast light tower.

5.3.2.3 Unmanned Aerial Systems (UAS)

Unmanned Aerial Systems (UAS), often referred to as drones, are becoming a viable alternative to spotting scopes for the inspection of high mast lighting towers. UAS with high-definition cameras can provide better coverage and angles of slip joints. While operating UAS over live traffic or pedestrians is not permitted without a Federal Aviation Administration (FAA) waiver, operating over stationary vehicles or pedestrians under a protective structure is allowed per FAA regulations (refer to the Code of Federal Regulations, 14 CFR § 107.39(b) and § 107.200(a) and (b)). Currently, implementing UAS into sign structure inspection over traffic is not a viable option without FAA waivers, but it may be feasible for high mast lighting towers located in lawn areas a sufficient distance away from travel lanes. Due to the evolving nature of UAS regulations, inspectors should verify appropriate regulations prior to using a UAS. Inspection teams should include a Certified Remote Pilot meeting the eligibility requirements listed in 14 CFR § 107.61. Alternatively, Government Agencies able to receive an FAA certificate of authorization (COA) to function as a “public aircraft operator” can self-certify their UAS and

UAS pilots (refer to 49 USC § 40102(a) and § 40125). Refer to Figure 58 for a view of a UAS used to inspect a pole structure.

Figure 58. Photo. UAS mobilized on a high mast light pole.

5.3.2.4 Robots

Robots with video and still cameras have been used to assist in high mast lighting tower inspections since the early 2000s. Earlier versions of these inspection tools clamped onto the lighting ring and used the light ring winch system to raise and lower the cameras to the desired locations. Newer robots clamp onto the high mast and can be raised and lowered independently. These robots can help inspectors determine the extent of deterioration in an elevated section of the pole or slip joint instead of using expensive lifts to access the deterioration area. Refer to Figure 59 for a view of a remote climber used to inspect a high mast lighting tower.

Figure 59. Photo. Remote high mast lighting tower climber.

5.4 INSPECTION ORIENTATION AND SEQUENCE

When performing ancillary structure inspections, all structures should follow the Agency-defined orientation and numbering convention. The following sections outline general orientation and numbering conventions various Agencies use to develop their programs.

5.4.1 Orientation/Numbering Conventions

Sign support structures can have sign panels facing one or both directions of travel on a roadway. When a structure only supports sign panels facing one direction of travel, as shown in Figure 60, then the side of the structure facing that direction of travel is identified as the "Front," with the other side of the structure identified as the "Back." When a structure supports sign panels facing both directions of travel, as shown in Figure 61, then the side of the structure facing the northbound or eastbound lanes of travel is identified as the "Front," and the side of the structure facing the southbound or westbound lanes of travel is identified as the "Back."

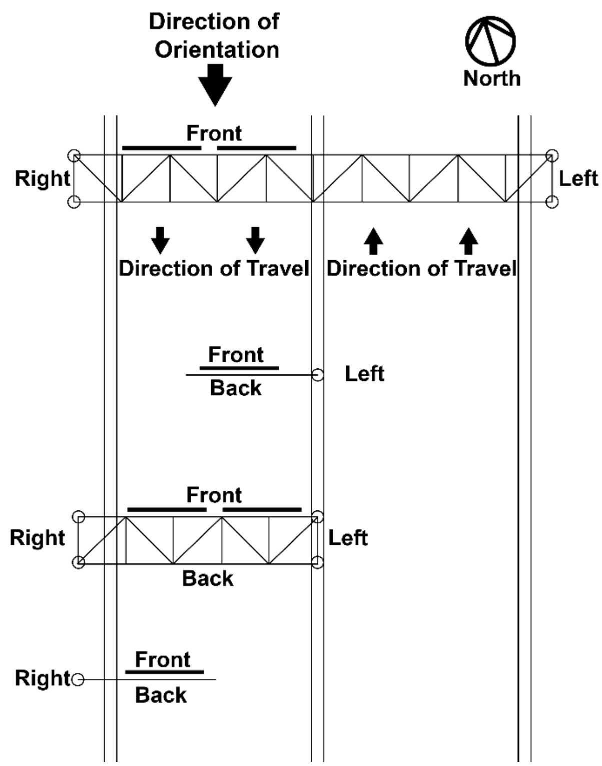

Figure 60. Illustration. Structure orientation examples with sign panels facing only one direction of travel.

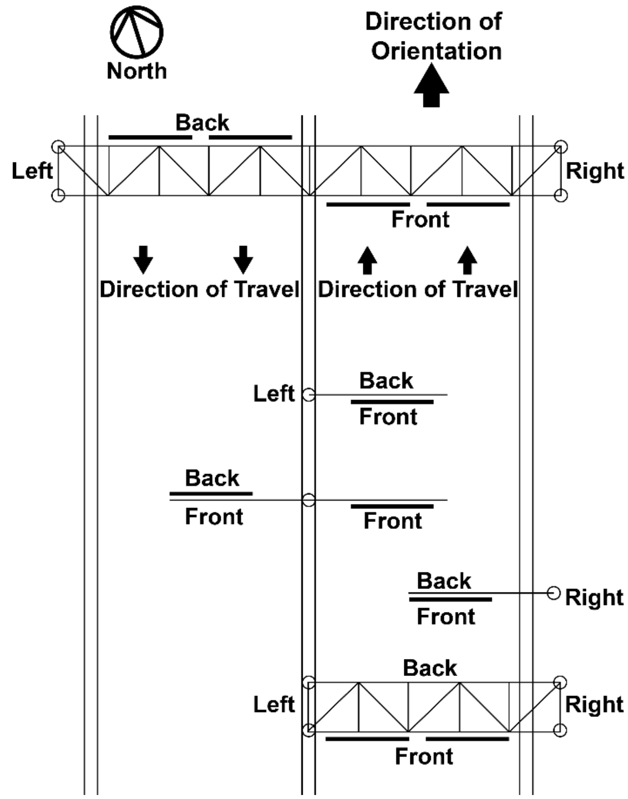

Figure 61. Illustration. Structure orientation examples with sign panels facing both directions of travel.

Secondary diagonals and struts for ancillary structure trusses usually follow common truss nomenclature. Panel points are labeled across the truss, and the members are labeled according to their beginning and ending panel point nodes. Panel points are numbered sequentially from left to right, as viewed from the front of the structure. Chords and end supports are labeled as "Front," "Back," "Right," and "Left" as looking at the front of the sign structure.

It is also important to identify the orientation of the anchor rods on each base plate for consistency between structures. Each base plate should be numbered in the same direction regardless of the structure or base plate type. A suggested practice is to number the anchor rods using the primary direction of travel as a reference point. Refer to Figure 62 for an illustration of common anchor rod numbering conventions.

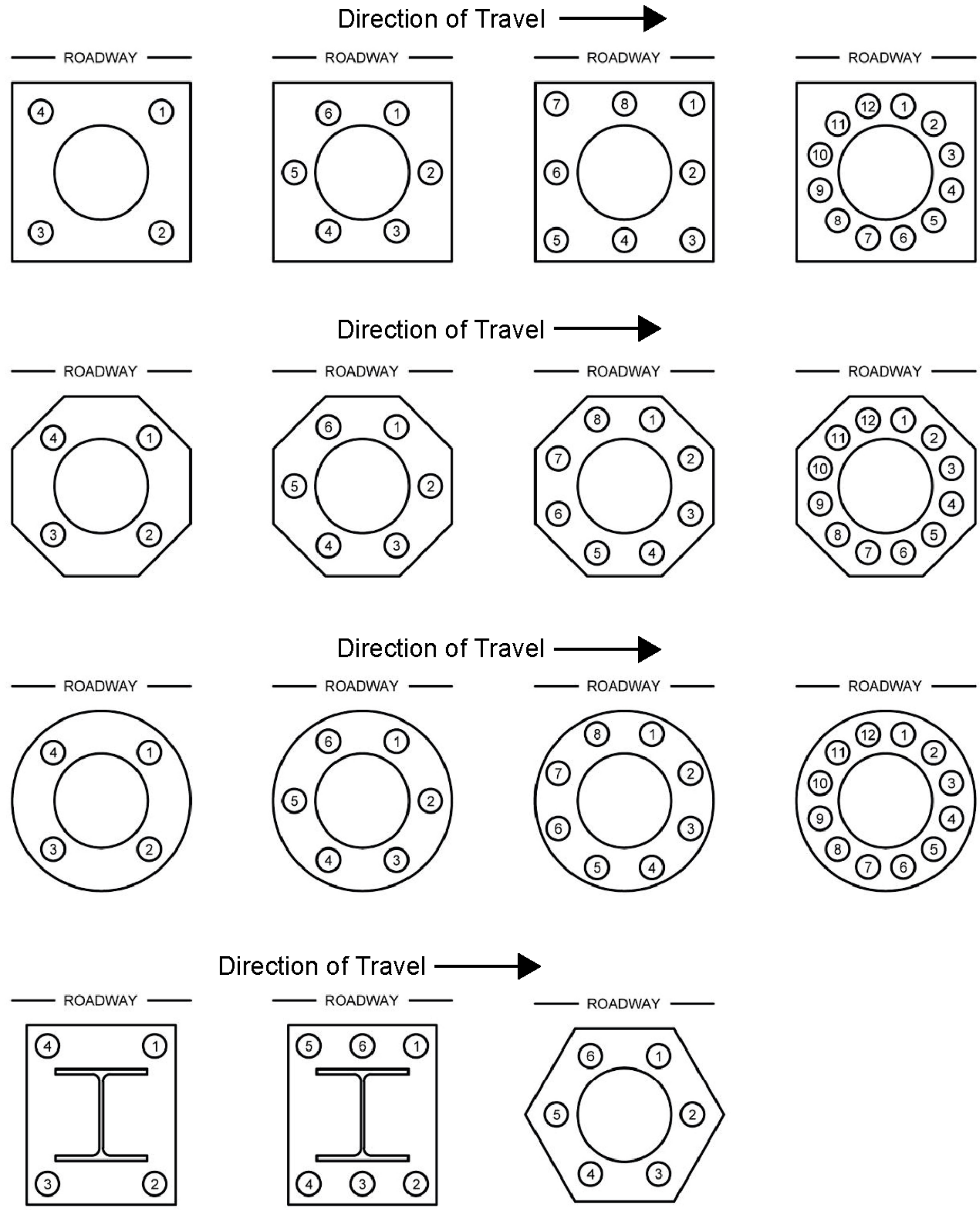

Figure 62. Illustration. Anchor rod numbering methodology.

5.4.1.1 Four-Chord Overhead Spans

When looking at the front of a four-chord full span structure, each panel point (vertical plane where secondary members connect to the chords) should be numbered from left to right, typically starting at Panel Point 0 or 1. Each chord has a separate node within the panel point. For example, when looking at Panel Point 3, there are Upper Front 3 (UF3), Lower Front 3

(LF3), Upper Back 3 (UB3) and Lower Back 3 (LB3) connections. Each secondary truss member can be identified by this nomenclature (e.g., the diagonal connected at UB3 and LB4 can be identified as Member UB3-LB4). When four-chord overhead span structures are spliced together, the two panel points on either side of the splice should be numbered separately. Refer to Figure 63 for an illustration of typical nomenclature and numbering conventions for a four-chord overhead span structure.

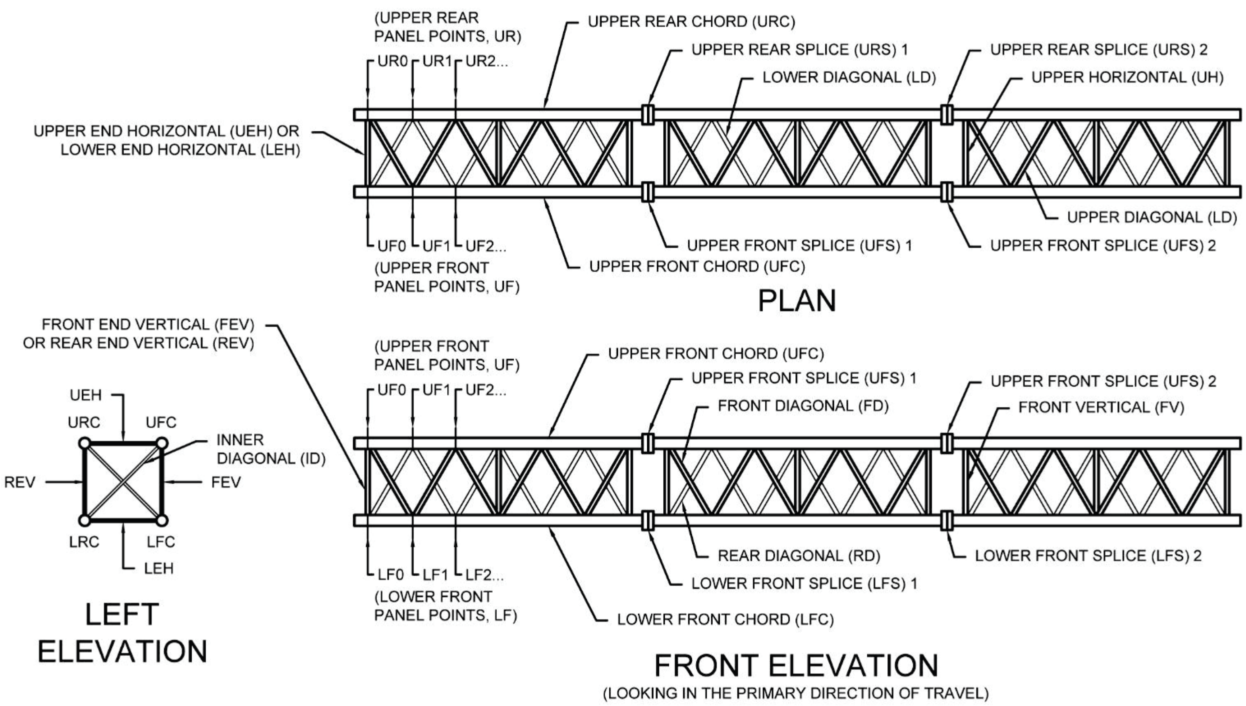

Figure 63. Illustration. Typical four-chord overhead span numbering convention and nomenclature.

5.4.1.2 Three-Chord Overhead Spans

When looking at the front of a three-chord full span structure, each panel point (vertical plane where secondary members connect to the chords) should be numbered from left to right, typically starting at Panel Point 0 or 1. Each chord has a separate node within the panel point. For example, when looking at Panel Point 6, there are Upper Front 6 (UF6), Lower Front 6 (LF6), and Middle Back 6 (MB6) connections. Each secondary truss member can be identified by this nomenclature (e.g., the diagonal connected at UF1 and MB2 can be identified as Member UF1-MB2).

When three-chord overhead span structures are spliced together, the two panel points on either side of the splice should be numbered separately. Refer to Figure 64 for an illustration of typical nomenclature and numbering conventions for a three-chord overhead span structure.

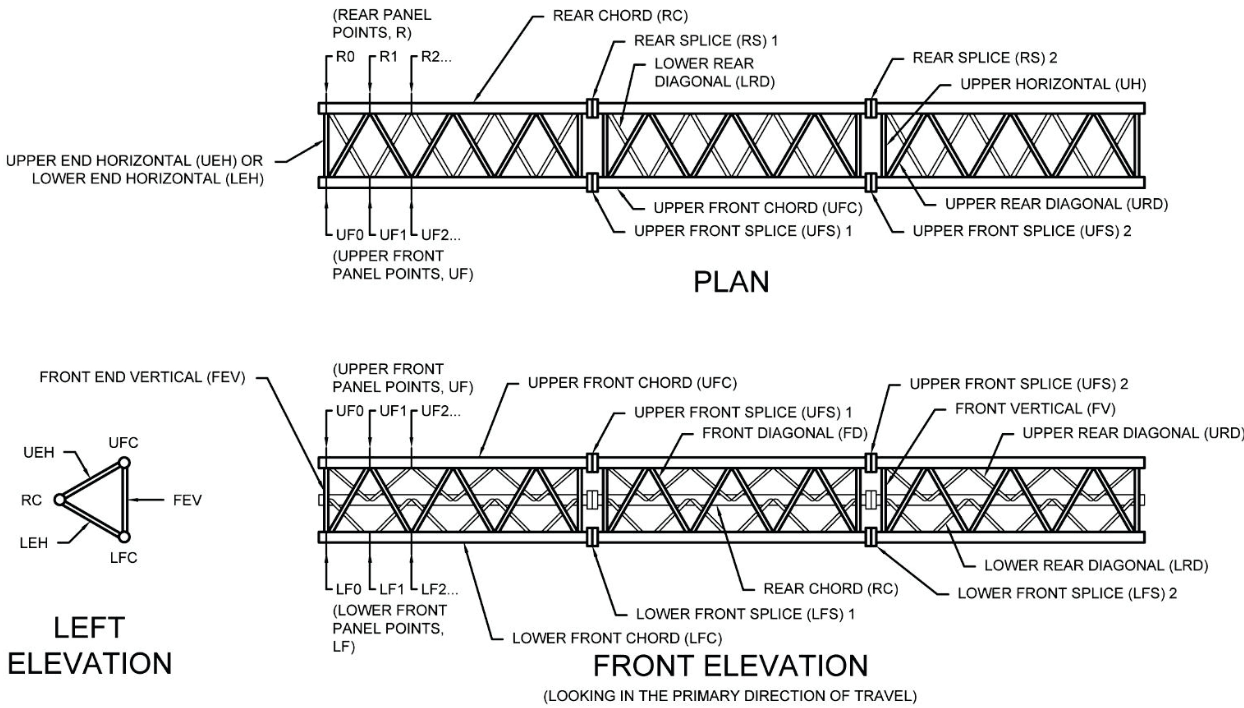

Figure 64. Illustration. Typical three-chord overhead span numbering convention and nomenclature.

5.4.1.3 Two-Chord Overhead Spans

Since two-chord full span structures may be built up with secondary diagonal and strut members, each member should specifically be identified with truss nomenclature. When looking at the front of a two-chord full span structure, each panel point (vertical plane where secondary members connect to the chords) should be numbered from left to right, typically starting at Panel Point 0 or 1. Each chord has a separate node within the panel point. For example, when looking at Panel Point 4, there are Upper 4 (U4) and Lower 4 (L4) connections. Each secondary truss member can be identified by this nomenclature (e.g., the diagonal connected at U4 and L5 can be identified as Member U4-L5).

When two-chord overhead span structures are spliced together, the two panel points on either side of the splice should be numbered separately. Refer to Figure 65 for an illustration of typical nomenclature and numbering conventions for a two-chord overhead span structure with secondary members incorporated into the design.

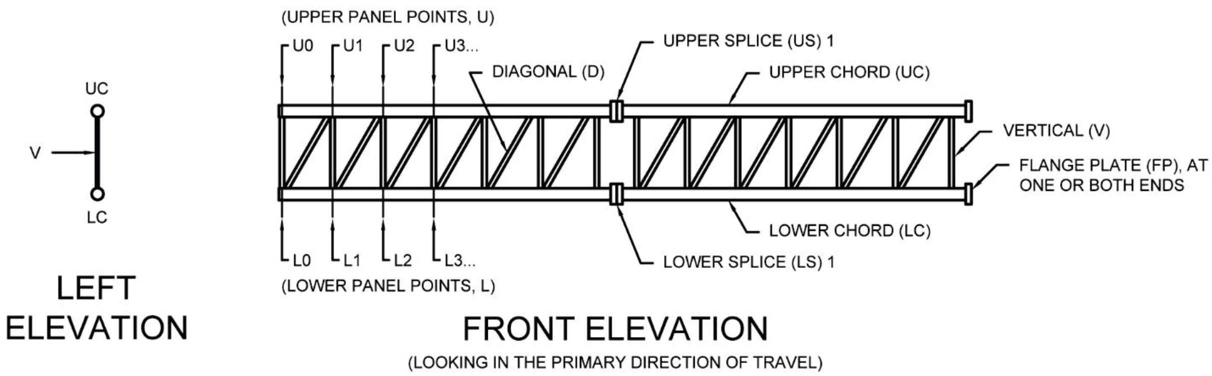

Figure 65. Illustration. Typical two-chord overhead span numbering convention and nomenclature.

5.4.1.4 Trussed Cantilever Structures

When looking at the front of a trussed cantilever structure, each panel point should be numbered from left to right, typically starting at Panel Point 0 or 1, regardless of which side of the roadway the end support is located. The numbering convention should be similar to that of the overhead span structures. Refer to sections 5.4.1.1 Four-Chord Overhead Spans, 5.4.1.2 Three-Chord Overhead Spans, and 5.4.1.3 Two-Chord Overhead Spans for numbering conventions. Refer to Figure 66 for an illustration of typical nomenclature and numbering conventions for a two-chord cantilever structure.

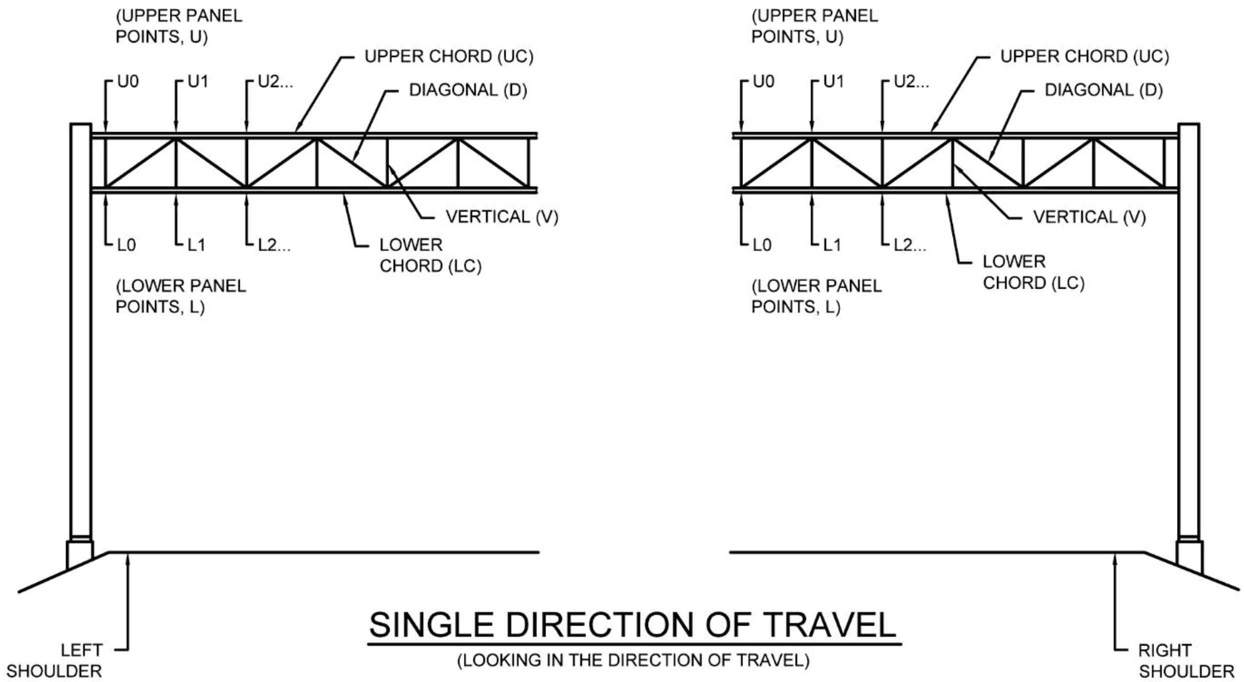

Figure 66. Illustration. Typical trussed cantilever structure numbering convention and nomenclature.

5.4.1.5 Structure Mount

In the case of structure mounted support, the primary members connecting the sign panel hangers should be denoted as the front connections (upper and lower), while the connections to the bridge should be the back connections (upper and lower). The connections should be numbered left to right starting at Panel Point 0 or 1, similar to other structure types. Depending on the size of the structure-mounted support, secondary members between the primary supports may be added to provide additional rigidity to the structure.

5.4.1.6 Butterfly Structures

When looking at the front of a butterfly structure with secondary members, each panel point should be numbered from left to right, typically starting at Panel Point 0 or 1. The numbering convention should be similar to overhead span structures. Refer to sections 5.4.1.1 Four-Chord Overhead Spans and 5.4.1.3 Two-Chord Overhead Spans for numbering conventions.

5.4.1.7 End Supports

The frame panel points are generally labeled from top to bottom starting at zero. Each horizontal plane where a welded connection occurs should be considered a separate node. Refer to Figure 67 for an illustration of dual end supports with framing members.

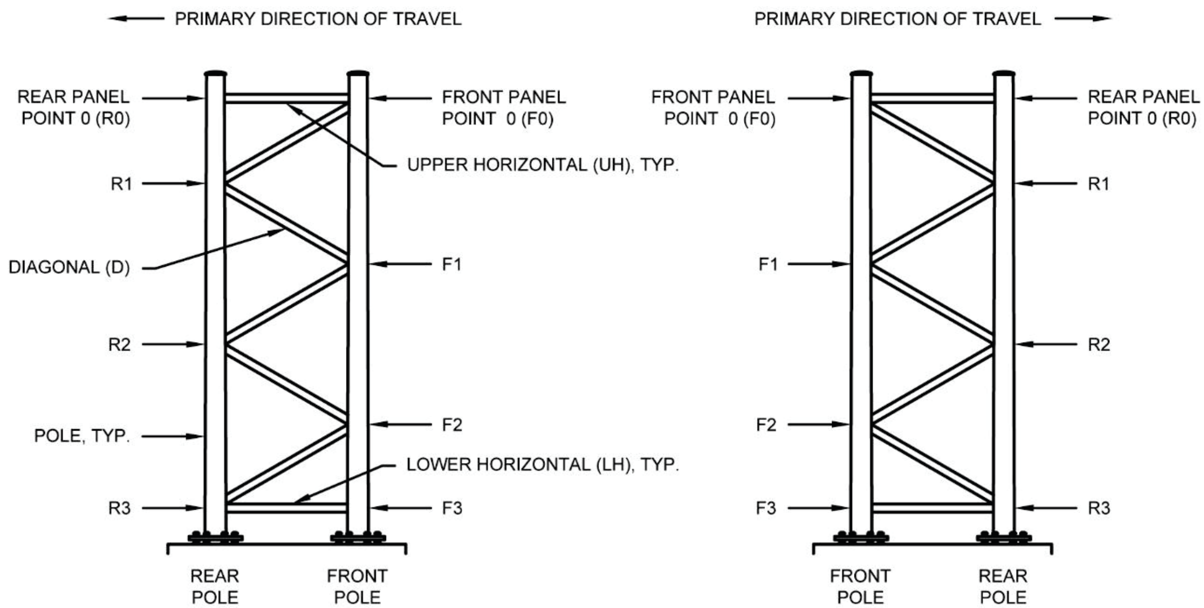

Figure 67. Illustration. Typical end support numbering convention.

5.4.2 How to Conduct an Efficient Inspection

Prior to starting an ancillary inspection, each team member should be familiar with the structure to be inspected. Each team member should review previous inspection reports, maintenance logs, as-built plans, and other information available pertinent to the structure.

A typical hands-on inspection of a sign structure starts at the foundation and works upward through the load path of the structure.

5.4.2.1 Foundation Inspection

The foundation, typically made of concrete, should be checked for cracks, spalls, and other signs of deterioration. Drainage pathways between the base plate and foundation should be checked for debris accumulation that may restrict drainage from the inside of the post. Many older structures have grout pads placed between the base plate and the foundation that should be sounded with a hammer to identify deterioration. All concrete and grout pad deterioration should be documented. Refer to Figure 68 for a view of a foundation with cracks propagating from the anchor rods.

Figure 68. Photo. Foundation cracks protruding into foundation from anchor rod.

Foundations placed on top of drilled shafts, spread footings, or piles typically protrude above the ground line. The adjacent fill material should be checked for settlement, erosion from roadway runoff, and rodent holes. Structures with the top of the foundation near the ground line should be clear of debris, and the adjacent fill material should be sloped away from the top of the foundation to prevent water accumulating on top of the foundation. All adjacent fill deficiencies should be documented. Refer to Figure 69 for a view of water ponding on a foundation due to improper grading.

Figure 69. Photo. Foundation with grading sloped towards foundation.

5.4.2.2 Anchor Rod Inspection

The anchor rods should be centered on the foundation. The exposed portions of the rods can become corroded over time or fail under fatigue loading. Anchor rods that were not properly tensioned may also become loose. Loose leveling nuts, as well as top nuts, can lead to load redistribution and overstressing of anchor rods. All accessible anchor rod top nuts, leveling nuts, and washers should be sounded with a hammer to verify tightness, and the extent of corrosion should be documented. Other deficiencies, such as lack of top nut engagement, rod plumbness, and oversized base plate holes should be documented. Shake tests may be used to assess the condition of tension rods on flexible cantilever and mast arm structures. The distance between the bottom of the leveling nut and top of foundation should be measured to verify it is less than one anchor rod diameter. Excessive standoff should be documented for further analysis. Refer to Figure 70 for a view of excessive standoff.

Figure 70. Photo. Anchor rod unsupported length above tolerance.

5.4.2.3 End Support Inspection

The end support base plate(s) should be checked to ensure they are level and not dished, as the base plates can dish over time if the anchor rods are loose and inadequate drainage can lead to advanced corrosion. Oversized anchor rod holes in the base plate should be noted, as the bearing area between the nut and base plate may not be adequate to support the structure. Refer to Figure 71 for a view of a base plate with oversized holes. The end support to base plate weld should also be examined for cracking. Cracking may be found at the termination of stiffener plates, as well. All cracks found during the inspection should have the crack tips marked on the structure along with the date of inspection using a paint stick for repeatability during future inspections. A cracked weld may also qualify as a critical finding. Refer to section 6.3 CRITICAL FINDINGS for additional information about the notification and reporting of such findings.

Figure 71. Photo. Oversized holes in base plate.

End support post handholes should be inspected around the reinforcement ring weldment for cracking. Handhole covers should be removed to allow access for inspectors to see the inside of the post. Corrosion on the inside of end support posts is a common occurrence as water and debris accumulate to form a corrosive environment. The handhole, usually located up to 3-ft above the base, should be removed to view potential corrosion. Visual inspection should be supplemented with an ultrasonic thickness meter (D-meter) to check critical areas for reduced section area. Additional common defects found with handholes are missing covers, sheared attachment hardware, or covers that cannot be removed due to seized hardware. Refer to Figure 72 for a view of internal corrosion at the base plate-to-post interface.

Figure 72. Photo. Corrosion to uncoated weathering steel post interior.

The end support inspection includes inspecting gusset plate bolts and weldments, verifying plumbness, identifying areas of impact damage, ensuring post caps and conduit plugs are installed, and identifying proper ventilation to remove any buildup of condensation. Because many steel posts are galvanized and over time, the coating begins to be consumed, coatings should be inspected for signs of failure and base metal corrosion. End support plumbness can reveal foundation problems, past vehicular impacts, or initial erection errors. Out-of-plumb measurements should be compared to prior inspections for signs of progression. Refer to Figure 73 for a view of impact damage to the end support.

Figure 73. Photo. Impact damage to end support.

5.4.2.4 End Support to Horizontal Member Connection Inspection

The end support to horizontal member connections should be checked for corroded, loose, and missing fasteners, misalignment and loss of bearing, and load transfer. Full span structures often have saddles and U-bolts at the truss to end support connections. These should be examined for missing or loose nuts and cracked castings. Cantilever trusses are generally connected with high strength bolted flange connections. The vertical welds connecting these assemblies to the post are fatigue sensitive and should receive hands-on inspection. The plates should be examined for fit-up, gaps, and loose or missing bolts. Isolation pads should be located between dissimilar metal components. The pads should be checked for integrity. Refer to Figure 74 for a view of a cracked weld at an end support welded saddle connection.

Figure 74. Photo. Cracked weld at end support connection weld.

5.4.2.5 Overhead Span and Cantilever Inspection

Once the post support is inspected, the process moves to the horizontal truss or mast arm. Truss span components can be welded or bolted. Most span weld configurations are fatigue sensitive and should be checked for cracking, while the bolted connections should be checked for loose or missing hardware. Refer to Figure 75 for a view of a cracked weld on a horizontal truss. Telescoping mirrors can be helpful for inspecting hard to reach areas. Failed welds in aluminum structures may indicate the start of fatigue failure. All cracked welds should have their crack tips marked with a paint stick and compared to prior reported lengths. A cracked weld may also qualify as a critical finding. Refer to section 6.3 CRITICAL FINDINGS for additional information about the notification and reporting of such findings.

Defects along the horizontal chord can be located by identifying the panel points on truss structures, or by stationing from the left end support on single chord overhead span and monotube overhead span structures.

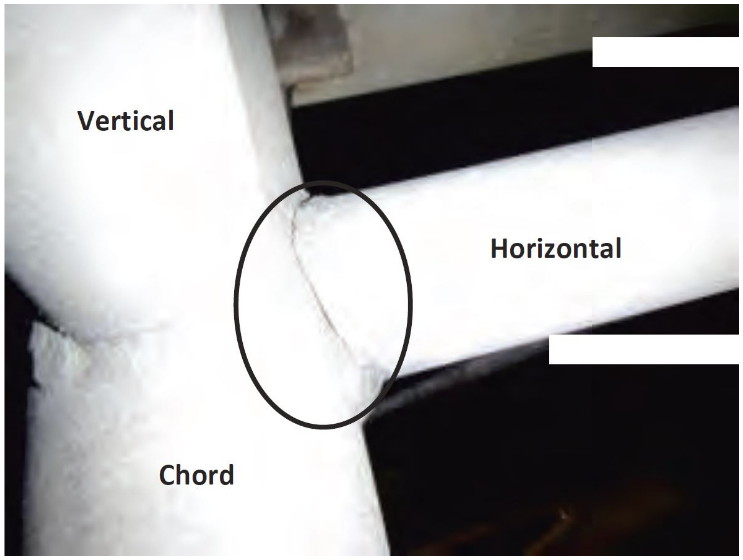

Figure 75. Photo. Cracked weld on a horizontal truss.

Sign trusses are usually fabricated into smaller sections and erected at the site. A flanged splice connection contains both bolted (plate-to-plate) and welded (chord-to-plate) connections. Flanged splice plates should be inspected for connection fit-up, faying surface gaps, loose and missing bolts, and weld cracks. Various full span structures have been designed to place shim plates in the top chords only, thus creating a camber in the structure. If installed, these shim plates should be in firm contact with the adjacent plates. Refer to Figure 76 for a view of a loose overhead span splice connection.

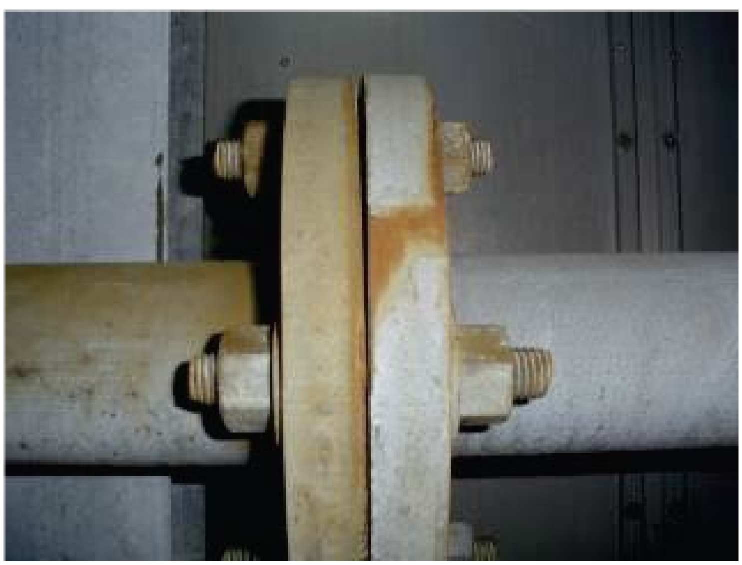

Figure 76. Photo. Gap in splice connection.

5.4.2.6 Sign Panel Inspection

Sign panels and support frames should be inspected. Sign panel connectors (bolts or clips) should be hand verified as the connectors can become loose, brittle, or fatigued over time. U-bolts and hanger-to-chord connections should be inspected for loose and missing connections. The reflective material of the sign panel should also be inspected for defects such as fading, crazing, or other damage. Refer to Figure 77 for a view of damaged reflective material on the face of a sign panel. The locations and dimensions of sign panels and other attachments should be noted so they can be compared to original design conditions.

Figure 77. Photo. Damage to reflective coating of overhead sign panel.

5.4.2.7 Traffic Signal Inspection

Traffic signals are typically attached to a mast arm or span wire structure by a bracket, clamping device, or hanger. The connection should be inspected for loose or missing hardware. Clamping devices that have been overtightened crack over time from structure vibrations. All cracking should be noted with crack tips marked. Refer to Figure 78 for a view of a cracked aluminum clamp.

Figure 78. Photo. Crack to cast aluminum clamp supporting a traffic signal.

5.4.2.8 Span Wire and Pole Structure Inspections

For span wire structures supported by steel poles, the steel poles should be inspected in a manner similar to other end supports (see section 5.4.2.3 End Support Inspection). Concrete poles should be inspected for cracking, spalling, delamination, and exposed steel reinforcement. Timber poles should also be inspected for typical timber deficiencies, including checks, shakes, decay, and rot.

If guy wires are installed, the upper and lower attachments should be inspected for loose and deteriorated hardware. All guy wires should be checked for tautness. All poles should be checked for plumbness, regardless of the material used.

The span wire connections and pole structure attachments should be inspected for loose and deteriorated hardware. Span wires should be inspected along the length of the wire for frayed and corroded wires, while all attachments to the wires should be inspected for damaged, loose, missing, and deteriorated hardware. Refer to Figure 79 for a view of broken wires at the pole connection.

Figure 79. Photo. Broken wires at span wire connection to post.

5.4.2.9 High Mast Lighting Tower Inspection

The portions of the high mast lighting tower at eye level and below should follow the inspection concepts described earlier in this section. A spotting scope is typically used for a visual inspection of the remainder of the high mast pole, slip joints, and upper attachments. When using a spotting scope, three setups should be used around the structure to ensure complete coverage of the pole. Additional setups may be needed depending on the structure's orientation with respect to the roadway, or if defects are suspected. If defects are suspected during the visual inspection, other methods may be warranted, such as UAS or robot inspection. Refer to Figure 80 for a view of a crack at the slip joint on a high mast lighting tower. Refer to section 5.3.2.2 Spotting Scopes for suggested criteria related to spotting scopes, and sections 5.3.2.3 Unmanned Aircraft Systems (UAS) and 5.3.2.4 Robots for more information about UAS and robots, respectively.

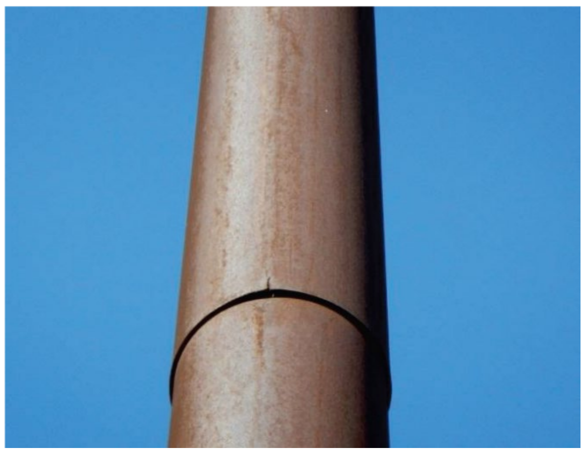

Figure 80. Photo. Crack at high mast light pole slip joint.

The inspection team should open the handhole cover to access the interior of the post. Any rodent debris present should be noted. Additionally, the interior base plate weld should be inspected for cracking, corrosion, and pack rust. The winch system connections should also be inspected for cracked welds, as well as loose and deteriorated hardware. The inspection team typically does not operate the winch system, but a visual inspection of the visible portions of the cables and electrical wires should be performed. The Agency may require the inspection team to coordinate with maintenance to operate the winch system while the inspection team is on site. The inspection team can then inspect all aspects of the cables, winch operation, and luminaire ring.

5.4.2.10 Structure Mount Inspection

When inspecting a structure mounted to the fascia of a bridge, the lane underneath the structure is typically closed to traffic for the inspector's safety. Climbing on structure-mounted sign supports can be complicated due to the concentration of secondary bracing members, limited space between the structure and bridge, and low clearance over the roadway. The upper connections to the parapet and deck should be checked for anchorage tightness and creep of concrete adhesive or expansion anchors. Gaps between the anchorage plate and the concrete surface should be noted for comparison to future inspections. The lower anchorages should be inspected for loose, missing, or deteriorated hardware. Fascia-mounted sign structures can induce torsional forces on the exterior beam of the bridge structure. The torsional rotation of the exterior beam and all adjacent bracing members on the bridge needed to mitigate these forces should be inspected during the biennial bridge inspection and are not part of the ancillary structure inspection. The remainder of the structure follows the typical inspection conventions outlined in section 5.4.2.5 Overhead Span and Cantilever Inspection, as well as 5.4.2.6 Sign Panel Inspection. Refer to Figure 81 for a view of two fascia-mounted sign structures.

Figure 81. Photo. Fascia-mounted sign structures.

5.4.2.11 Supplemental Attachment Inspection

After the inspection of all structural members is complete, the inspection should proceed to supplemental elements, such as catwalks, electrical components, guiderails, and other elements that do not comprise the actual structural system. Defects with supplemental elements should be documented in the inspection report.

5.4.3 Roles and Responsibilities of Each Inspector

Inspection teams are typically comprised of two members. When performing an inspection, it is most efficient if one inspector performs the base inspection (ground inspector) and one inspector performs the upper inspection (lift or climbing inspector). The Team Leader should assign roles for each inspection, and verify all tasks performed by team members.

The ground inspector is typically responsible for inspecting the foundations, anchor rods, base plates, handholes, and the bottom of the post supports. Depending on the time constraints, the ground inspector may also climb trussed end support assemblies. The ground inspector may also verify that all inventory information is correct, including horizontal clearances, span lengths, GPS coordinates, accuracy of location description, base and anchor rod patterns, etc. All missing and incorrect information should be updated on the inspection form. Typically, the ground inspector performs the note taking duties as well.

The lift or climbing inspector is typically responsible for the inspection of all elements not accessible by the ground inspector. This includes end support connections, overhead span and cantilever inspection, sign panel inspection, and miscellaneous attachment inspection. In addition, the lift or climbing inspector is typically responsible for verifying the vertical clearance, sign dimensions, and other inventory information not accessible to the ground inspector. Refer to Figure 82 for a view of two inspectors climbing on a four-chord overhead span.

Figure 82. Photo. Inspectors climbing a four-chord full span structure.

Once all inspection activities are complete, it is prudent for the inspection team to review the field notes for accuracy, update the inventory data, assign element ratings or condition states, and consider necessary repairs and critical findings. Photo logs should be written in the field notes. All inaccurate and incomplete data should be corrected or completed prior to leaving the site. Checklists can be a useful tool when reviewing inspection data. Checklists can assist the inspection team in ensuring all data has been collected and coded.

5.5 NONDESTRUCTIVE TESTING

Nondestructive Testing (NDT) is used for the inspection of ancillary structures. While visual inspection is the primary inspection method, it cannot detect all structural deficiencies, such as small surface fatigue cracks in welds, subsurface defects, section remaining, corrosion occurring on the interior of a structural element, and cracked anchor rods. A list of NDT methods and their application to ancillary structures is given below.

5.5.1 Ultrasonic Thickness Measurement (D-Meter)

Ultrasonic thickness “D-Meter” gauges are used to determine the remaining thickness of steel members when the other side of the member is inaccessible. This is one of the most critical NDT methods for ancillary structures because failures have been attributed to interior element corrosion that cannot be visually detected. These gauges can be used on vertical end support posts near the base plate where corrosion has been a common problem. When measuring steel thicknesses of poles near the base plate, the inspector should review plans if available as high mast lighting tower structures have been fabricated with double walls. When a double wall is encountered, only the thickness of the outer wall will be measured, as the air gap between the inner wall and outer wall does not allow sound to penetrate and obtain the thickness of the inner wall.

Readings should be taken immediately above the base plate weld, 1 inch above the base plate, and at a known full thickness reference location (6 to 24 inches above the base plate). Readings should be taken at circumferential quarter points around the post at a minimum. If readings are not consistent, additional locations can be added. Refer to Figure 83 for a view of a typical D-Meter.

Figure 83. Photo. Typical ultrasonic thickness meter (D-Meter).

5.5.2 Magnetic Particle Testing

Magnetic Particle Testing (MT) is a form of NDT that can detect surface or near-surface discontinuities in ferrous materials (not applicable for aluminum structures). MT can be used to test welds for suspected cracking. When testing on a painted surface that has suspected cracking, it is good practice to remove the painted coating to expose the bare metal. The painted coating can also trap MT particles, creating a false indication. When performing this test on a galvanized steel structure, MT can be used through the coating so long as the galvanized coating is thin and intact. If the galvanized coating is cracked, the coating should be removed as the cracked coating can trap MT particles creating a false indication. Refer to Figure 84 for a view of an inspector performing MT.

Figure 84. Photo. Inspector using Magnetic Particle Testing equipment.

5.5.3 Dye Penetrant Testing

Dye Penetrant Testing (PT) can be used on non-porous materials (steel and aluminum) to detect or confirm surface discontinuities. Prior to performing PT, the inspector removes the painted coating and galvanizing around the suspected crack and clean the bare metal to remove as much corrosion or oxidation as possible. Failure to remove the coatings and corrosion may result in trapped penetrant, which, after being drawn out by the developer, may result in a false indication. Refer to Figure 85 for a view of a cracked weld after PT has been conducted.

Figure 85. Photo. Dye penetrant used to highlight cracked connection.

5.5.4 Other Ultrasonic Testing

Ultrasonic Testing (UT) flaw detection equipment is typically used to examine anchor rods for possible cracks and determine the embedment length of the anchor rods. It is difficult to determine the length of anchor rods with 90-degree or 180-degree bends on end of the bolt, since UT relies on sound to reflect off a surface perpendicular the direction of sound travel. UT units are more sophisticated than D-meters and involve extensive training to properly calibrate the unit and test the anchor rods. Refer to Figure 86 for a view of an inspector performing UT on anchor rods.

Figure 86. Photo. Inspector utilizing ultrasonic testing equipment.

5.5.5 Qualifications

The person conducting NDT and the personnel interpreting the testing data should be trained in the applied method. Additional qualifications should include both an understanding of the theory behind the test and practical experience. It is also suggested that inspectors pass a yearly visual acuity test. All inspection methods should be conducted in accordance with applicable American Society for Nondestructive Testing (ASNT) procedures, ASTM International standards, and AASHTO specifications.

Inspectors should have formal training in the specific NDT method being performed. The ASNT developed the SNT-TC-1A practice of three certification levels for nondestructive testing for each method: Level I, Level II, and Level III. A Level I inspector can carry out calibration and tests under the direct supervision of a Level II or III inspector. A Level II and III inspector can perform NDT calibrations and tests without additional supervision. Agencies may pre-qualify inspectors or specify the level of certification required to perform NDT services on their ancillary structures.

5.6 QUALITY CONTROL

Every ancillary structure inspection program should include a Quality Control Plan. The list below details some suggested Quality Control Plan contents:

1. Listing of applicable manuals, reference materials, and technical standards.
2. Submittal requirements and schedule.
3. Personnel qualifications and responsibilities (Team Leader, Quality Control Engineer, or Owner’s Representative).
4. Record keeping and electronic file formatting standards.
5. Field auditing and corrective action process.

Checklists are helpful tools for both Team Leaders and Quality Control Engineers. When properly designed, they can 1) improve inspection quality, 2) ensure that all the essential field information is collected, and 3) standardize reporting and recommendation procedures. The Agency's inspection scope, inventory manual, and reporting requirements are good sources of information for creating project checklists.

All deliverables should be reviewed by the Quality Control Engineer to ensure 1) technical accuracy, 2) conformance with Agency program requirements, and 3) consistency in the reporting and rating of common structural element defects.

Field audits can be performed to evaluate an inspection team's procedures and understanding of key concepts. Audit results can be shared with all inspection teams to improve performance. Quality Assurance entails the verification that the Quality Control Plans are being followed at all stages of the project execution. These audits may be performed by the Agency or their designated consultants. See APPENDIX A. QC CHECKLISTS for an example of a quality control checklist.

CHAPTER 6. INSPECTION REPORTING AND INVENTORY DATA

6.1 INVENTORY DATA

Inventory data is a collection of information used to describe and identify the assets by the maintaining Agency. This section details the collection of such information and development of a useful database.

An inventory-numbering scheme is used for all types of structures to assign each structure a unique identifier in the database. Inventory numbering can be sequential along a route and contain information relevant to location, such as County Coding. After a sign structure number is assigned, the number should be stenciled onto the existing sign end support with paint or affixed on a permanent identification plaque. The structure number should be documented with the Agency so new structures are not assigned an existing inventory number.

6.1.1 Collection of Inventory Information

Prior to the start of an inspection program, the collection of historical information assists the Agency in identifying ancillary structures in their inventory. Records, such as plans, specifications, shop drawings, as-built drawings, and maintenance records should be reviewed. Historical records on ancillary structures may not be readily available. All available records should be cataloged and filed with the corresponding ancillary structure once inspected. To supplement these historical records, the inspection team gathers all pertinent data and measurements on an ancillary structure.

6.1.2 Example Inventory Checklist

The checklist below is a sample of typical inventory data fields that Agencies use to track their assets. Data fields involve the physical location of the structure, the personnel involved with the inventory or inspection, specifics about the structure itself, important dimensions, and specific attachments:

- Structure Number
- GPS Coordinates
- County
- Route
- Milepost
- Location Description
- Inspection Date
- Previous Inspection Date
- Inspection Type
- Inspection Frequency
- Team Leader
- Team Member(s)
- Access Methods
- Traffic Control Requirements

- Structure Configuration
- Material Type (Truss or End Support)
- Material Coating
- Number of Truss Sections
- Overall Span Length
- Minimum Vertical Clearance
- Minimum Lateral Clearance
- Number of Travel Lanes
- Installation Year
- Number of Signs
- Area of each Sign
- Walkway (yes or no)
- Lighting (yes or no)

6.1.3 Database Development

Databases are used to maintain the collected data. The database system should be capable of sorting and prioritizing the data sets to maximize its usefulness for all potential users of the data, such as field inspectors, program managers, maintenance personnel, and others.

6.2 CONDITION RATING DATA

It is important to have a consistent and well-defined condition rating system to assist the inspection team in assigning consistent ratings from structure to structure. While Agencies may develop their own condition rating data, AASHTO has developed information on the collection of element-level ancillary condition rating data, which can be found in AASHTO, *LRFD Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, First Edition,* Appendix D.(3) Each element in the structure would have quantities assigned to one of four conditions states: Condition State 1 (Good), Condition State 2 (Fair), Condition State 3 (Poor), and Condition State 4 (Severe). Each condition state has associated criteria that is used to determine how conditions observed during the inspection are assigned to corresponding condition states, providing rating uniformity between structures.

6.2.1 Common Elements

The elements identified in the AASHTO, *LRFD Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, First Edition,* Appendix D have been broken out into two primary categories: The National Ancillary Structure Elements (NASE) and the Ancillary Structure Management Elements (ASME).(3) Smart Flags are also incorporated into the condition rating data. Each element is broken into six areas, which can be used to identify and code each element: Description, Quantity Calculation, Condition State Definitions, Feasible Actions, Element Commentary, and Element Definitions. Some Agencies develop their own element definition system to suit their inventory needs.

6.2.1.1 National Ancillary Structure Elements (NASE)

The NASE represent the primary structural components necessary to determine the overall condition and safety of the various types of ancillary highway structures. These elements include the foundation, anchor rods, base plate, end supports, end support to chord connections, chords, trusses, and splices. NASE elements are further established by material type. Some elements are relevant to specific types of structures, including high masts, span wires, and structure mounts.

6.2.1.2 Ancillary Structure Management Elements (ASME)

The ASME represent the non-structural components of ancillary structures that Agencies may want to evaluate in support of their management system. These elements include sign panels, sign facing material, catwalks, signals, electrical and mechanical systems, dampeners, etc. These elements are described in generic terms and can be modified to suit the Agency's inventory and maintenance needs.

6.2.1.3 Smart Flags

Smart flags are used in conjunction with NASE and ASME elements to draw attention to common defects and areas of concern. The list of smart flags identified in Appendix D are:

- Steel Cracking or Fatigue
- Aluminum Cracking or Fatigue
- Anchor Rod Standoff
- Impact Damage
- Undersized Components or Elements
- Grout Pads
- Guardrail or Protection
- Distortion
- Non-Foundation Concrete Cracking
- Non-Foundation Concrete Efflorescence
- Settlement
- Misalignment
- Steel Section Loss
- Steel Out-of-Plane Bending
- Erosion

6.3 CRITICAL FINDINGS

A critical finding represents a damaged or deteriorated structural condition of a member or component of the structure that poses an immediate threat to the traveling public.

Agencies may provide specific guidance for qualifying conditions, or they may leave the determination up to the inspector's judgment. The following are examples of conditions that may qualify as critical findings:

- Advanced deterioration of a non-redundant load path member.

- Advanced deterioration of a redundant load path member, a failure of which could lead to a cascade failure.
- Advanced deterioration of an elevated component that could fall onto traffic.
- Initial and propagating fatigue cracking.
- Electrocution hazards.

Notification, reporting, and response procedures should be developed for critical findings prior to the start of a sign structure inspection program.

6.3.1 Notification

Agencies may require timely verbal and or written notification of critical findings prior to the submission of a critical finding report. Inspection personnel may need to immediately notify Agency personnel, maintain access equipment, or both until Agency personnel arrive on-site to observe the critical condition. Inspection personnel may be given the authority to temporarily close facilities or contact police forces to assist in closing facilities.

6.3.2 Reporting

The preparation and submission of a Critical Finding Report should follow the standards and protocols defined by the Agency's ancillary structure management program. Critical Finding Reports should clearly locate, describe, and quantify the observed conditions related to the finding. Any progression from prior observations should be specifically noted. The reports are typically supplemented with sketches, photographs, and the results of any nondestructive testing performed.

6.3.3 Response

Agency policy dictates how the Agency responds to the Critical Finding Report and describes what action has been taken or will be taken to address the reported condition. The following is a list of actions that may be taken:

- Structure or component removal.
- Structural repairs.
- Increased inspection frequency.
- Certification based on analysis.

6.4 INSPECTION REPORTS

Reporting of deficiencies, condition ratings, and notification of critical conditions and repair needs are an important component of a structure management plan. Many Agencies have opted for an electronic process, either using hand-held devices or laptop computers to record information directly in the field. Whether using a paper reporting procedure or an electronic system, all data should be collected before leaving the site.

Ancillary structure reporting can be broken into two main categories: Standard Reports and User Defined Reports. Agencies use Standard Reports throughout their inventory processes, while they may create User-Defined Reports to help execute their program needs.

6.4.1 Standard Reports

Agencies typically develop standard forms and reports to present the data collected as part of an ancillary structure inspection program in a consistent format. Typical standard reports include the inspection report, critical findings report (see section 6.3.2 Reporting), repair recommendations, and program summary.

6.4.1.1 Inspection Report

Inspection Reports typically contain the inventory data for a sign structure as outlined in section 6.1.3 Database Development. This report may also contain standard photographs or sketches to assist the inspection team in identifying the structure and its elements. Structure nomenclature and orientation should be identified for each structure and should be consistent between structures. Inspection reports also commonly contain element data, condition ratings, defect photographs, and maintenance recommendations. See APPENDIX A. QC CHECKLISTS for an example of this type of report.

When documenting defects in an Inspection Report, the defect should be properly quantified and located on the structure. Photographs and sketches can be used to substantiate the defect documentation. Proper documentation helps future inspections in identifying defect progression and can assist maintenance personnel with defect repairs.

6.4.1.2 Repair Recommendations Report

A Repair Recommendation Report may be a standalone report or incorporated into the primary inspection report. The Repair Recommendation Report documents areas of deterioration on a structure that do not rise to the level of a critical finding. These repairs can be categorized as low, medium, and high repairs (see section 7.1 PRIORITIZATION). Agencies typically have a predetermined timeframe in which each level of maintenance should be completed.

When advising repairs to an ancillary structure, the location and materials needed to complete the repair should be identified (e.g., U-bolt sizes, number of sign clips, anchor rod diameter for tensioning, etc.). Identifying traffic control needs also assists maintenance personnel in completing the repair. Refer to Chapter 7. Maintenance and Repair for common repair techniques.

6.4.1.3 Program Summary Report

Management personnel can use Program Summary Reports to see the global view of the ancillary structure management program. This report can be used to identify problem structures and problem details. It can also be used to program funding for inspection, maintenance, and management needs.

6.4.2 User-Defined Reports

Most Agencies have specific databases that are used to house the inventory and inspection data. Through the database, responsible parties can use queries to identify specific structures and sort the associated, relevant data into easy-to-interpret reports. Queries can include geographical locations, material types, structure-specific details, etc. These reports are customizable to the person performing the query and are unique from query to query depending on the specific needs of the user. These generated reports can then be used by numerous departments within an Agency when planning for structure inspection, maintenance, or replacement.

CHAPTER 7. MAINTENANCE AND REPAIR

7.1 PRIORITIZATION

Inspectors may be requested to recommend and prioritize ancillary structure repairs. When prioritizing repair needs, an inspector should consider the defect's effect on public safety, load carrying capacity, and service life.

A sample repair prioritization protocol is presented in Table 1. Repair Priority Rating.

Table 1. Repair Priority Rating

Priority	Description	Repair Timeframe
Critical	Items, if not corrected immediately, threaten the continued safe operation of the structure	3 days
High	Items that significantly reduce the load carrying capacity or service life of the structure	As soon as is practical
Low	Items that can be corrected during normal maintenance operations.	During the next scheduled maintenance operation

Critical priority repair needs represent observed conditions, which threaten public safety or present a reasonable risk of near-term, partial, or catastrophic structure failure. Critical repair reporting protocols may involve immediate verbal notification and the maintenance of lane closures until Agency personnel are available to visit the site and observe the condition. If emergency repairs cannot be made within a reasonable timeframe, temporary removal of the ancillary structure, or a portion of it, may be warranted to eliminate the hazard.

High priority repair needs represent observed conditions, which are determined to reduce the load carrying capacity or the structure's expected service life. These conditions should be addressed as soon as possible and may need special planning, mobilization and deferral of less critical scheduled repairs.

Low priority repair needs represent observed conditions that slightly reduce the performance or service life of the structure. If left unaddressed, deterioration may be expected to become more critical over time.

The cost effectiveness of repairs performed late in a structure's service life need to be considered. Ancillary structure replacement costs vary between $30,000 and $500,000 (2018) depending on the structure's size and complexity. Since repairs are commonly needed late in a structure's life cycle, replacement may be a cost-effective option.

7.2 ROUTINE MAINTENANCE

Routine maintenance is also known as preventive or cyclical maintenance. These activities are commonly performed on a repeated frequency to keep an ancillary structure inventory in a state of good repair. The frequency for each routine maintenance activity varies, but the ultimate purpose is to delay the onset of more significant deterioration. The following list includes examples of routine maintenance activities:

- Replace components with shorter life cycles than the main structure components.
- Miscellaneous connection hardware
- Isolation pads between dissimilar metals
- Caps and plugs
- Sign panels
- Regrade around buried bases.
- Prune encroaching vegetation.
- Repair deteriorated coatings or galvanizing.
- Tighten loose hardware.
- Clear post drainage holes or remove debris from posts.

Routine maintenance activities may involve lane closures and disruption of traffic flow to access the portions of the structure needing repair. To eliminate multiple disruptions, Agencies may ask inspectors to perform various minor routine maintenance tasks at the time of the inspection. Inspectors therefore need to maintain common tools and materials in their inspection vehicle. Inspection teams performing routine repairs should document the repairs in the inspection report so that the Agency has a record of when the repairs were performed and remove them from future maintenance actions.

7.3 TYPICAL REPAIRS

There are many defects that are commonly observed during ancillary structure inspections. These defects may be caused from fabrication and erection errors or in-service environmental exposure. Repair techniques have been developed for various common defects. Some of these repairs can be performed by the inspection team during inspection mobilization, but others may need specialized equipment and training.

7.3.1 Foundation Repairs

Ancillary structure foundations are typically constructed with reinforced concrete. Typically, only the top of the pedestal or shaft is visible for inspection.

7.3.1.1 Concrete Repairs

Ancillary structure foundations are susceptible to common concrete deterioration mechanisms such as spalling, cracking, scaling, freeze-thaw, and volumetric expansion. Refer to Figure 87 for a view of a deteriorated concrete foundation.

The common repair techniques listed below are typically beyond the capabilities of what an inspection team can complete during an inspection mobilization:

- Sealers and coatings
- Thin repair
- Deep repair
- Crack Sealing

Figure 87. Photo. Deteriorated foundation showing crack and edge spalling.

A typical concrete repair consists of the following steps:

1. Determine the cause of the damage.
2. Evaluate the extent of the damage.
3. Select the appropriate repair method and material.
4. Prepare the concrete component for repair.
    a. Saw cut around the perimeter.
    b. Remove all unsound concrete and remaining concrete to the necessary depth.
    c. Clean and prepare exposed rebar and concrete surfaces to receive the repair.
5. Apply the repair material.
6. Cure the repair material.

Many concrete repair materials are proprietary formulas, and the application techniques are specified by the manufacturer.

Several methods are available to seal cracks:

- Pressure injection: Liquid resins (epoxy or polyurethane) are injected through drilled ports to penetrate and seal the crack as the material cures.
- Rout and Seal: A groove is cut along the surface of the crack and filled with a suitable joint sealant. Bond breakers should be considered if the crack is expected to undergo expansion and contraction.
- Stitching: Holes are drilled on both sides of the crack. U-shaped metal stitches are inserted and grouted into the holes to span the crack.

- Gravity Filling: Low viscosity resins can be applied to cracked horizontal faces. The width of the crack that can be sealed is dependent on the viscosity of the resin. Refer to Figure 88 for a view of a gravity filled crack on a concrete foundation.

Figure 88. Photo. Gravity filled crack on the top face of a foundation.

7.3.1.2 Drainage Repairs

When base plate anchorages are placed directly on top of the foundation(s) or grout pad extension(s), drainage is commonly provided by forming a drainage groove immediately below the base plate. If the drainage groove is omitted, improperly formed, or becomes clogged with debris, moisture cannot escape from the interior of the support post. Condensation can then accumulate inside the base of the post leading to corrosion. Refer to Figure 89 for a view of moisture accumulated in a post interior.

Figure 89. Photo. Standing water accumulated inside a vertical support.

Clogged drain grooves can be cleared of debris using an awl, small probe rod, or compressed air. Omitted or improperly formed drain grooves can be recreated by a combination of saw-cutting and drilling. A sump may need to be cut inside the post interior to ensure that the new groove intercepts the post opening. Screening may be needed to discourage animal entry.

Buried foundations should be uncovered and the area around them regraded. Buried foundations should be exposed below the top of the foundation (preferably 1 foot). A drainage path away from the foundation should be provided. In instances when the area around the foundation is unable to be re-graded to provide proper draining, the top of the foundation and anchor rods should be cleaned of soil to prevent trapped moisture, regraded with gentle slopes, and vegetated with grass to prevent soil from washing back on top of the foundation. When steep slopes prevent highway geometry regrading, pipe half sections can be used as retaining structures to keep the top of the foundations clean of debris. Refer to Figure 90 for an example of a pipe half section used to protect a foundation which is located below finished grade.

Figure 90. Photo. Pipe half section retaining structure repair.

Debris from construction, nesting, and animal remains can accumulate inside the posts, which retains moisture and restricts drainage flows. Refer to Figure 91 for a view of rodent nesting debris inside the base of a post. Accumulated debris should be removed from the post interior. Sources of animal and debris entry should be addressed, such as missing post caps, missing conduit plugs, and missing rodent screens at the base plate.

Figure 91. Photo. Rodent nesting debris inside the base of a vertical end support.

7.3.1.3 Grout Pad or Anchor Rod Cover Removal

Some Agencies have implemented maintenance programs to remove installed grout pads and anchor rod covers from ancillary structure bases. These features have limited functionality and tend to trap moisture and debris, leading to premature corrosion of the post interiors and anchorage hardware. Prior to grout pad removal, the following criteria should be verified:

- Leveling nuts are present to support the base plate (review design drawings if available, or probe with masonry drill bit in the field).
- The base plate is rigid enough to transfer loads directly to the leveling nuts.
- Newly exposed rods are not susceptible to bending (exposure below the leveling nut is equal to or less than the rod diameter).

7.3.2 Base Repairs

Ancillary structure base components include anchor rods, base plates, and base castings. Anchor rods and base plates are typically fabricated from galvanized steel. Base castings are fabricated from either aluminum or steel.

7.3.2.1 Anchor Rod Repairs

7.3.2.1.1 Loose Nuts

Loose anchor rod top nuts and leveling nuts can be a serious problem since the intended load is then redistributed to the adjacent bolts. This is especially problematic on single base structures where different bolts are in compression and tension. Damaged top nuts should be replaced, and loose nuts should be properly rotated to tension the bolt. Refer to Figure 92 for a view of a loose leveling nut.

Figure 92. Photo. Gap between leveling nut and base plate.

Due to galvanized thread seizing, tightening with a cheater bar extension is not recommended as this may risk shearing the anchor rod. In addition, corroded anchor rods may prevent proper tensioning due to the friction created by corrosion, even if properly cleaned and lubricated. Corroded nuts should be replaced with new nuts.

The following is a possible repair process for improperly tensioned anchor rods:

1. Support the superstructure to eliminate dead load moments and uplift forces during the repair.
2. Snug tighten the leveling nuts or insert finger shims so that all are in firm contact with the bottom of the base plate.
3. Replace the top nuts one at a time.
    a. Verify that the rod threads are not damaged.
    b. Remove the nut (run off or hydraulically split).
    c. Clean the rod and nut threads with a wire brush or angle grinder with wire wheel attachment. Repair thread damage with a die as needed.
    d. Lubricate the threads with bee's wax or a comparable material.
    e. Snug tighten the nut - refer to Minnesota Department of Transportation (MnDOT) Report No. 2018-27 for state of practice.[6]
4. Turn the nut (turn-of-the-nut or DTI washer) to the necessary tension for the rod size and material - refer to MnDOT Report No. 2018-27 for the state of practice for nut rotation and angle recommendations.[6]
5. Re-tension after 48 hours.

The current state of practice in this area is reflected in a 2018 in-depth research study conducted by MnDOT and Iowa State University.[6,7] The study suggests snug-tight controls, turn-of-the-nut rotation angles, and maximum torque values for common anchor rod diameters and material grades used in ancillary structures. MnDOT is continuing to monitor rods tensioned under these conditions. At the time of printing, the MnDOT developed procedures have not been adopted by AASHTO.

When the anchor rod material is not known, conservative assumptions should be made, or the Agency's suggested practices should be followed to prevent anchor rod damage.

7.3.2.1.2 Out-of-Plumb Anchor rods

Anchor rods which are out-of-plumb are subject to bending stresses during axial loading. When anchor rods are found to be out-of-plumb by more than a ratio of 1:40, the loose nut tensioning procedure discussed in section 7.3.2.1.1 Loose Nuts should be used with the insertion of a beveled plate washer under the nut (Step 3). The washer should be sized to create full bearing at the nut face. Initial tensioning of the nut (Step 4) should be limited per engineering best practices for previously tensioned anchor rods. Step 5 should be eliminated. Refer to Figure 93 for an example of a beveled plate washer used to repair an out-of-plumb anchor rod.

Figure 93. Photo. Out-of-plumb anchor rod repaired with a beveled plate washer.

7.3.2.1.3 Cracked or Fractured Rod

When an anchor rod is found to be cracked or fractured, it can be supplemented with an adjacent threaded stud which is drilled and grouted into the foundation. The new threaded stud should have a tensile capacity equal to the original anchor. This may present geometric problems for large diameter rods. Anchor grouts are proprietary and should be installed per the manufacturer's recommendation to ensure tensile failure of the grouted stud controls the design. The grouting system should be chosen to minimize the necessary hole diameter and to follow current FHWA information about chemically cured anchors in sustained tensile loading situations.[(8)] The following describes a possible procedure:

1. Drill a hole through the base plate near the existing rod. (Size to accommodate the drill bit for Step 2.)
2. Drill a hole in the foundation (diameter and depth should follow the grout manufacturer's recommendation).
3. Install the grout per the manufacturer's recommendation.
4. Insert threaded stud per manufacturer's recommendation. (If the base is elevated above the foundation, a new washer and leveling shoulder nut may be needed.)
5. Cure the new anchor grout.
6. Snug tighten the leveling shoulder nut.
7. Snug tighten a top shoulder nut (size to accommodate base plate hole).
8. Tension per the threaded stud material standards.

Alternate repairs include removing the damaged section of the rod, expose and clean the embedded rod threads and install a coupling device to extend the rod.

7.3.2.1.4 Excessive Standoff Repairs

When the exposed anchor rod length (the top of the foundation to the bottom of the leveling nut) exceeds one anchor rod diameter, lateral forces can induce unintended bending stresses into the anchor rod. Repair techniques for this condition can be expensive. Therefore, it is suggested that the in-service anchor rod stresses be analyzed before proceeding with repairs. If it is found that the anchor rod is experiencing unacceptable bending stresses, solutions include these three repair options:

1. Lowering the structure - This repair technique is complicated by the need to either support or remove the span. Because anchor rods should not be re-tensioned, nuts should either be run down below the area of initial tensioning or re-tensioned to a substantially lower stress. Engineering review should be conducted when considering re-tensioning of previously tensioned anchor rods.
2. Extending the foundation - This repair technique removes the top of the existing foundation, exposing the top layer of reinforcing, and potentially adding a new top reinforcing mat. Special care should be taken to avoid damage to the existing anchor rods. A concrete extension is placed to reduce the rod exposure.
3. Installing a grout pad - An engineered grout pad installation may be a feasible repair technique. The grout pad design should consider the material's anchorage to the substrate and the ability of the grout placement to restrict bending in the originally exposed portion of the rods without cracking.

7.3.3 Post Repairs

7.3.3.1 Handhole Post Cap and Conduit Access Repairs

Missing handhole covers can be a safety concern, especially if electrical power is inside the post. Moisture, animals, birds, and garbage can enter the handhole. Missing handhole covers should be replaced. If the securing hardware has been damaged, it may be necessary to drill and re-tap the receiving threads. Covers can be fabricated to fit the opening or off-the-shelf replacement covers can be used. Refer to Figure 94 for an example of an aftermarket hand hole cover.

Figure 94. Photo. Aftermarket hand hole cover.

Posts may have threaded nipple extensions intended to receive flexible electrical connections to the main structure span or control cabinets. If there is no electric service at the nipple location, these openings may present an opportunity for bird entry. Entering birds are not able to perch in the post, and carcasses can accumulate inside the base of the post, trapping moisture and accelerating corrosion. Polyvinyl chloride plumbing caps and plugs can be installed on the threaded nipples to prevent bird entry. Refer to Figure 95 and Figure 96 for a view of accumulated bird remains inside a post and an example of a damaged post conduit nipple with an aftermarket plug installed.

Figure 95. Photo. Accumulated bird remains inside an end support post.

Figure 96. Photo. Damaged conduit nipple with aftermarket polyvinyl chloride plug.

Missing or damaged post caps should be replaced to prevent bird and precipitation entry. Metal and rubber replacement alternatives are available.

7.3.3.2 Post Interior Corrosion

When moisture and debris are permitted to accumulate inside the posts, the galvanizing or painted coating prematurely fails and leads to base metal corrosion. Moisture inside of an uncoated weathering steel pole does not allow the steel to develop the natural protective patina and leads to premature steel corrosion. After the drainage restrictions are corrected, corrosion can be arrested with cleaning and overcoating. The following procedure should be followed:

1. Remove accumulated debris and improve drainage (see section 7.3.1.2 Drainage Repairs).
2. Clean and prepare corroded surfaces. The performance of the repair depends on the level of surface preparation.
3. Brush coat with cold galvanizing primer paint system.

Refer to Figure 97 for an example of a painted post interior repair.

Figure 97. Photo. Interior of a vertical end support showing painted repair and inspector's probe rod.

When the corrosion has led to unacceptable post section loss, structural repairs can be designed to restore the post's structural capacity. The addition of exterior stiffener plates and sleeve-plating have been effectively used to add strength to the base of a corroded post. Refer to Figure 98 through Figure 100 for examples of structural post repairs.

Figure 98. Photo. Plating repair of a vertical end support column.

Figure 99. Photo. Stiffener addition repair at the base of a vertical end support frame.

Figure 100. Photo. Clamshell repair at the base of a high mast light pole.

7.3.4 Span to Post Connection Repairs

Agencies use various configurations to connect the span assemblies to the vertical end support assemblies. The connections are intended to transmit the loads, torques, and moments which are applied to the span. If contact is lost at one of the supports, the span loads are redistributed to the remaining chord connections, likely in excess of what they may have been designed for.

Saddle type connections use U-bolts and machined mating saddles to transmit forces through direct bearing. Tightening hardware may be effective in restoring bearing at a loose saddle. When this is not sufficient or could result in unacceptable residual stresses in the chord, shim plates and finger shims may be installed to restore load transfer. Refer to Figure 101 and Figure 102 for views of improperly seated connection saddles.

Figure 101. Photo. Gap between horizontal saddle and support beam.

Figure 102. Photo. Gap between vertical saddle and chord.

Clamping type connections use clamps and pins to secure the chord and transmit loads to the vertical end assembly. Improperly sized clamping assemblies should be replaced. Loose hardware should be tightened. Corroded hardware should be replaced. Refer to Figure 103 for an example of a non-performing clamp-type chord to post connection assembly.

Figure 103. Photo. Gap between chord and clamp assembly.

Plate bearing connections are commonly used on cantilever type structures. The chord end plate can warp during fabrication if care is not taken to prevent distortion during welding. Refer to Figure 104 for an example of warped plates creating a gap between faying surfaces. If it is determined that enough bearing area is present between the plates, the open top edges can be sealed with caulk. The caulk is typically extended down one-third of the length of the vertical seam.

If the post to mast arm connection is framed to create a connection box with holes facilitating drainage and nut tightening, then these assemblies can fill with nesting debris, as shown in Figure 105. Debris should be periodically cleared to prevent premature corrosion inside the assembly.

Figure 104. Photo. Gap between faying surfaces.

Figure 105. Photo. Nesting debris accumulation inside the connection assembly.

7.3.5 Span Repairs to Address Excessive Vibration

Excessive span vibration can reduce the fatigue life of the structure. Vibrations can be controlled through the addition of damping devices. Dog-bone type dampers are the most commonly encountered systems used on ancillary structures, but proprietary damping systems are also available. They should be installed at mid-span for span structures and at the free end for cantilever structures. All deteriorated and missing hardware should be replaced in-kind. The weights should be clear of obstructions so that they can move freely in all directions. Refer to Figure 106 and Figure 107 for examples of dampers with restricted movement.

Figure 106. Photo. Damper on aluminum span. Left weight is in contact with the diagonal member.

Figure 107. Photo. Damper at mast arm end span. Chains restrict full motion.

7.3.6 Sign Panel Repairs

7.3.6.1 Sign Panel Hardware Repairs

The numerous fasteners that connect sign panels to the structure can loosen or crack and fall off. Missing fasteners should be replaced in-kind to prevent components from falling onto traffic. Refer to Figure 108 through Figure 110 for views of missing fasteners.

Figure 108. Photo. Missing wind beam to hanger connection bolts.

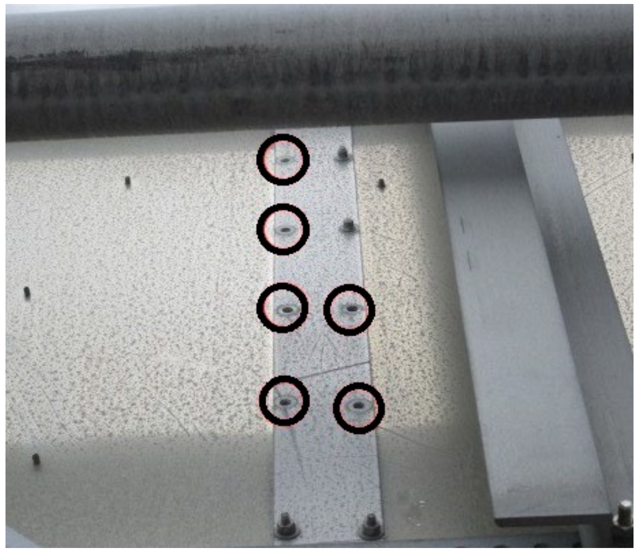

Figure 109. Photo. Broken flat panel splice bolts.

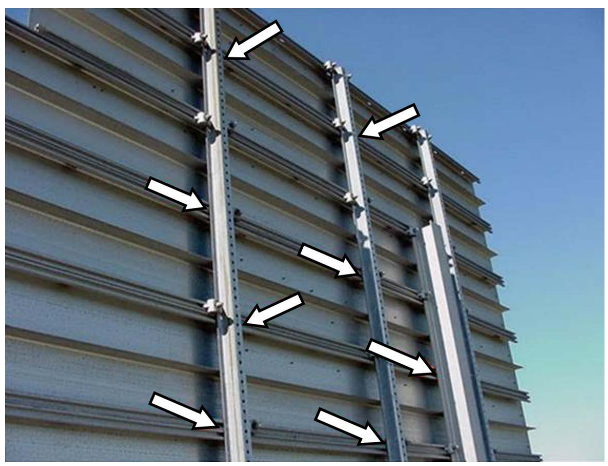

Figure 110. Photo. Missing extruded panel clips.

7.3.6.2 Dissimilar Metal Repairs

Aluminum flat sign panels are commonly mated with aluminum structural frames and supported by galvanized steel chords. Isolation pads placed between the dissimilar metals should be periodically replaced.

7.3.6.3 Impact Repairs

Panels and support frames can become damaged due to over-height vehicle impact, such as the examples shown in Figure 111 and Figure 112.

Figure 111. Photo. Impact damage to flat panel and wind beam.

Figure 112. Photo. Impact damage to sign panel.

Sign panels degrade over time due to environmental exposure; an example is provided in Figure 113. Pursuant to the Code of Federal Regulations, 23 CFR § 655.603, sign panels should either be illuminated, or Agencies should use an assessment or management method that is designed to maintain sign retroreflectivity at or above minimum levels. These minimum levels are established in Table 2A-3 of the MUTCD.(4) FHWA-HRT-08-026 *Methods for Maintaining Traffic Sign Retroreflectivity* provides suggested practices for panel maintenance.(9)

Figure 113. Photo. Faded sign panel.

7.3.7 Miscellaneous Repairs

7.3.7.1 Crack Repair

A drilled hole can be used to arrest a crack and prevent propagation. The hole diameter should be sized in accordance with FHWA-IF-13-020 *Manual for Repair and Retrofit of Fatigue Cracks in Steel Bridges*.(10)

The strength of the remaining net section should be checked. The inside of the hole should be tested with dye penetrant (aluminum or steel) or magnetic particle (steel only) to ensure that the end of the crack has been removed.

If the net section is not adequate after hole drilling, welding is an alternative repair method. Weld repairs may be made in-place or the portion of the structure can be removed from service to be repaired. Weld repairs should be properly detailed and follow AWS D1.1 *Structural Welding Code—Steel* for steel structures or AWS D1.2—*Structural Welding Code—Aluminum* for aluminum structures.(11,12)

Water-cured, fiber wrapped polymer (FRP) repair systems are presently available from multiple manufacturers and can be used in place of welding; an example of an FRP repair is shown in Figure 114. These systems are intended to bridge the crack defect and provide an alternate load path. These proprietary systems should be installed per the manufacturer's recommendations after the crack ends have been drilled out. Figure 115 shows that radiographic testing of a prior FRP repair indicated that no crack propagation had occurred after the repair had been in service for several years.

Figure 114. Photo. FRP wrap repair on an aluminum span.

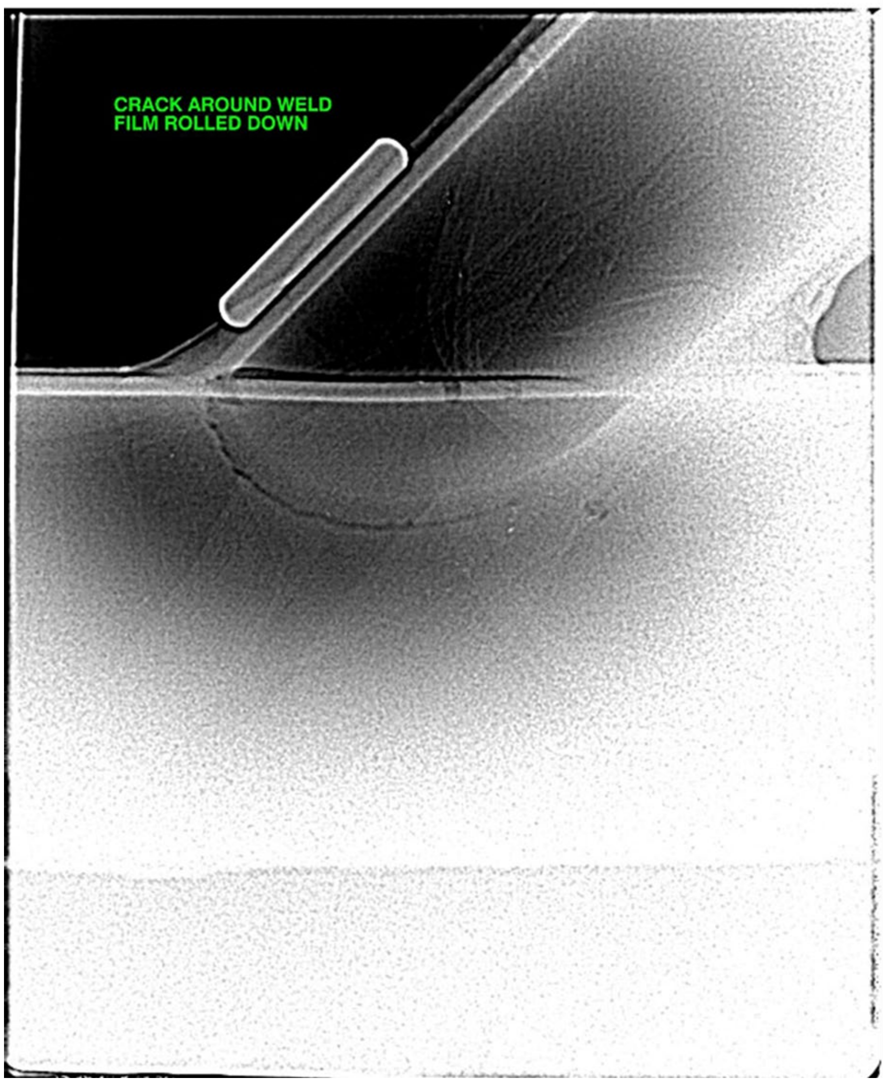

Figure 115. Photo. Radiographic examination of a weld crack under an FRP repair.

7.3.7.2 Minor Coating Repair

Many steel structures have been galvanized to slow the corrosion process. Over time, the galvanized layer is consumed and becomes ineffective. Impact damage can also remove the protective coating. If there is minor loss of galvanization, a touch up may be needed. Total loss of galvanization may not be an immediate problem if there is no visible corrosion or section loss, but it may result in a shorter structure service life. Galvanizing repair procedures are specified by ASTM A780 *Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings.*(13) The following list includes acceptable repair methods:

- Zinc-based solder
- Zinc-rich paints
- Zinc spray (metallizing)

Damaged painted and powder coated structures can be field repaired with liquid applied coating systems. Surface preparation should at a minimum remove all oils and loose materials. More rigorous hand tool, power tool, or abrasive cleaning methods may improve the performance of the repair. The repair paint chemistry should be checked for compatibility with the existing system. Adhesion and laboratory testing of the existing system may help to assure a successful repair.

7.3.7.3 Bolted Connections

Plate connections are found on ancillary structures in various splice and end support connections. Loose or missing bolts should be replaced in-kind and properly tensioned (high strength steel) or torqued (stainless steel and aluminum). Plate connections with gaps in the faying surface should be analyzed to ensure that the current bearing area is sufficient. If not, shims can be inserted to increase the bearing area.

7.3.7.4 Traffic Signal Repairs

Most repairs for traffic signal support structures are identical to those described in the previous section above. However, some additional repairs may need to be completed.

Span wires which become frayed or have loose anchorages should be replaced.

Signal head supports are typically non-redundant. Failure can be a significant safety hazard when located above an active travel lane. Replacement of support assemblies can be performed as routine maintenance under a predetermined frequency or as part of a regular inspection program.

Orbital bracket type signal supports are susceptible to cracking when the straps are overtightened. Cracks can propagate and lead to failure during the cyclical loading associated with mast arm galloping. Refer to Figure 78 for a view of a cracked orbital bracket.

7.3.7.5 High Mast Light Structure Repairs

Most repairs for high mast lighting structures are identical to those described above.

Winch and lighting rings are typically exercised by maintenance personnel, and routine maintenance can typically be performed from the ground. The access costs associated with elevated repairs for defects, like vertical tears at slip joint locations (see Figure 80), should be compared against the structure replacement costs.

7.4 ENGINEERED REPAIRS

For repairs that are not performed by the inspection team, a repair recommendation report can be useful so that the responsible parties are specifically notified of the needs. Repair recommendation reports should locate, describe, and prioritize the repair needs. Photo-documentation and measurements that would be helpful for material ordering should be included in the report.

Structural repairs should be designed by a licensed Professional Engineer. The design should utilize Agency standards and the version of design code (AASHTO *Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals*) active at the time of the original structure's design.(3)

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APPENDIX A. QC CHECKLISTS

Ratings:

Ratings	Unit	Total Quantity	C.S.1 Good	C.S.2 Fair	C.S.3 Poor	C.S.4 Critica	C.S.5 Unkn.
S.01 Foundation	EA						
S.02 Anchor Bolts	EA						
S.03 Base Plates	EA						
S.04 Column Support	EA						
S.05 Col. To Arm Conn.	EA						
S.06 Arm / Chord Memb.	LF						
S.07 Chord Splice Con.	EA						
S.08 Span Truss Memb.	LF						
S.09 Sign Frames	EA						
S.10 Sign Panels	EA						
S.11 Catwalk	LF						
S.12 Luminaire	EA						
S.13 Sign Attach.	EA						
S.14 Slip Joint	EA						

Lane Closures:

Date:	Lane(s):	Times/Weather:	Equipment	w/ SIN(s)
		To deg. C / PC / MC / OC		
		To deg. C / PC / MC / OC		
		To deg. C / PC / MC / OC		
		To deg. C / PC / MC / OC		

Flag	Condition/Location	Contact & Time:
	PIA? Y/N	

Flag	Condition/Location	Contact & Time:
	PIA? Y/N	

Flag	Condition/Location	Contact & Time:
	PIA? Y/N	

Sin: ______________________ Team Leader: ______________________

ATL: ______________________

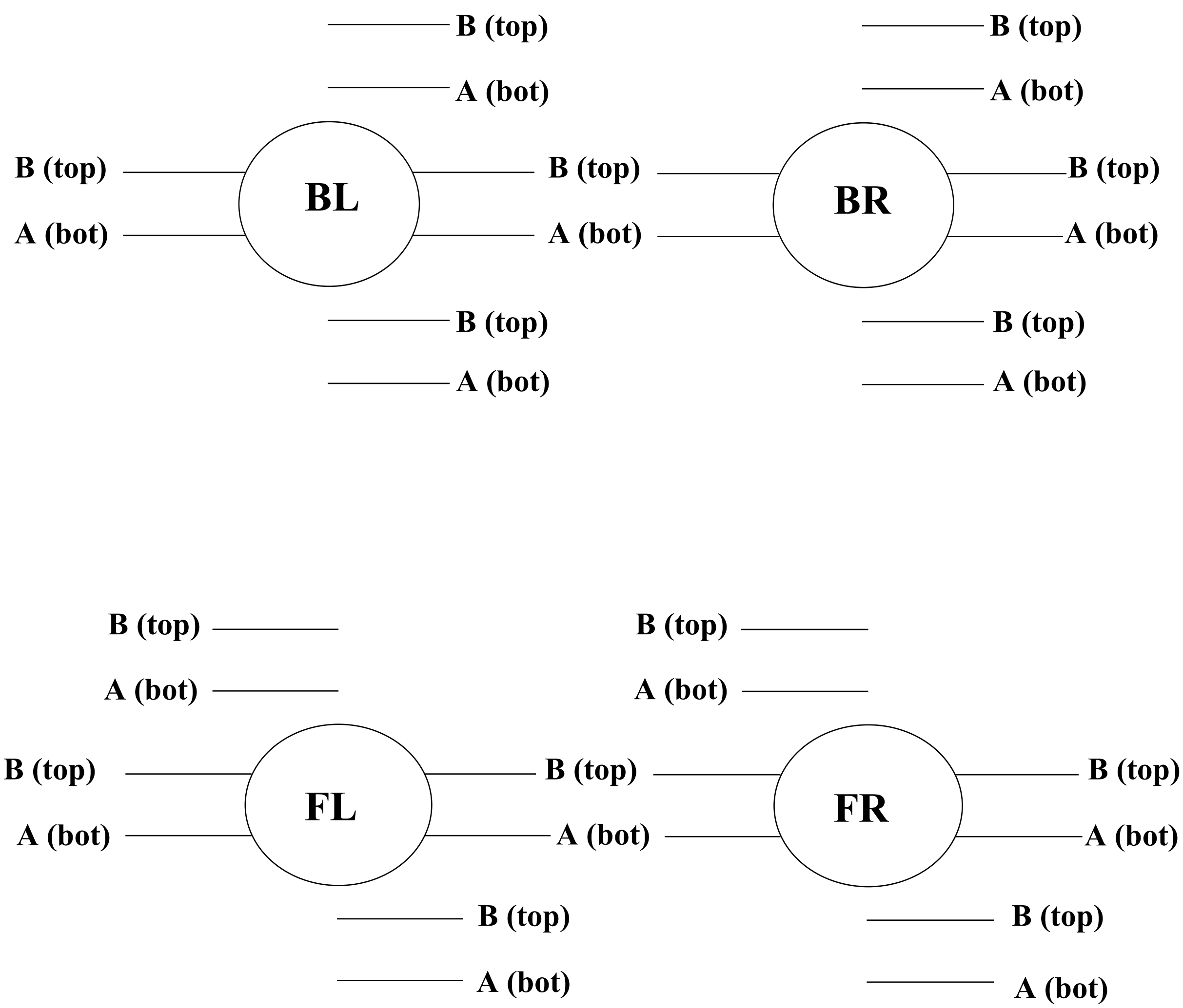
Job #: ______________________ M&PT: ______________________

Location: ______________ Route: ______________ @ ______________

	setup 1	setup 2	setup 3	setup 4
M&PT Check				
Harness/ Lanyard				
1st Aid Kit/Fire Ext.				
Lift check				
D-meter Test Block				

Notes/Sketches **Insp. Freq. change? / RFI? / Rec. repair procedures? / Notes for next inspector?**

D-Meter:



Traffic Direction = ______________ bound

Inspection Checklist:

Photos:

Front	______	**Inside post(s) – if mortar pads**	______ Left / Right
Back	______	**Defects (Rated ¾)**	______ Left / Right
Base(s)	______ Left / Right	**RR & Flag**	______ Left / Right
Connection(s)	______ Left / Right		

Coordinates: **Lat.** ______ **Long.** ______

Mile Marker: ______

Clearances: ______

(Draw Bolt Pattern here):

Bolt Pattern: LT ______

Bolt Diameter: RT ______

Bolt Diameter: ______

Span Length: ______

Verify Inventory:	**SP text**			
Post Welds	**FL:**	**BL:**	**FR:**	**BR:**
Post Plumb Offset	**L:**	**R:**	**VMS Test Pattern**	
Dims. (if no GR; road edge of post to travel lane)	**L:**	**R:**	**Shake Test**	

APPENDIX B. SAMPLE INSPECTION REPORT

CANTILEVER, OVERHEAD, BUTTERFLY, OTHER SIGN STRUCTURES
INSPECTION REPORT[14]

Structure Number:		**Date of Inspection:**	

COVER SHEET

County		**Inspection Type**	
City		**Longitude**	
Route ID		**Latitude**	

Location Description

Lead Inspector	
Additional Inspectors	

Attachments:

☐ Underclearance Sheet

☐ Location Sheet

☐ Sketches

☐ Other

Signature of Inspector **Date**

Reviewed By **Date**

CANTILEVER, OVERHEAD, BUTTERFLY, OTHER SIGN STRUCTURES
INSPECTION REPORT

Structure Number: **Date of Inspection:**

GENERAL DATA

OVERALL STRUCTURE COMMENTS

SIGN TEXT

Frequency of Inspection (Months)	
Number of Signs	
Total Sign Area (s.f.)	
Walkway Length (ft.)	
Span Length (ft.)	
Data Structure Modified	
Data Structure Erected	
Contractor	
Fabricator	

WORK PERFORMED SINCE LAST INSPECTION

CANTILEVER, OVERHEAD, BUTTERFLY, OTHER SIGN STRUCTURES
INSPECTION REPORT

Structure Number: **Date of Inspection:**

STRUCTURE DATA

Structure
Type
Comments

CODE=

Message
Type
Comments

CODE=

VMS
Type
Comments

CODE=

Material
(Pole and Chord)
Comments

CODE=

Chord
Type
Comments

CODE=

Pole
Type
Comments

CODE=

Foundation
Type
Comments

CODE=

CANTILEVER, OVERHEAD, BUTTERFLY, OTHER SIGN STRUCTURES
INSPECTION REPORT

Structure Number: **Date of Inspection:**

CLEARANCE DATA

(All clearance data in feet)

Minimum Vertical Clearance

Lane 1	**Lane 2**	**Lane 3**	**Lane 4**	**Lane 5**	**Lane 6**	**Lane 7**	**Lane 8**

Far Left Shoulder	Left Center Shoulder	Right Center Shoulder	Far Right Shoulder

Clearance Comments	

CANTILEVER, OVERHEAD, BUTTERFLY, OTHER SIGN STRUCTURES
INSPECTION REPORT

Structure Number: **Date of Inspection:**

SUBSTRUCTURE DATA

Overall Substruct.
Rating

RATING=

General
Appearance
Comments

RATING=

General Alignment
Comments

RATING=

Sign Attachment to Structural
Member
Comments

RATING=

Walkway
Comments

RATING=

CANTILEVER, OVERHEAD, BUTTERFLY, OTHER SIGN STRUCTURES
INSPECTION REPORT

Structure Number: **Date of Inspection:**

POLE DATA

Base Plate
Comments

RATING=

Slip Joint
Comments

RATING =

Trussing
Comments

RATING =

Welded Joints
Comments

RATING =

Cable Attachment to Pole
Comments

RATING =

Vertical Support
Comments

RATING =

Structure Number: **Date of Inspection:**

CHORD

Attachment to Pole/Other
Structural Member Comments

RATING =

Chord
Comments

RATING =

Splices
Comments

RATING =

Trussing
Comments

RATING =

Structure Number: **Date of Inspection:**

FOUNDATION

Overall Foundation Rating

RATING =

Anchor Bolts Comments

RATING =

Concrete Pedestal Comments

RATING =

Erosion/Undermining Comments

RATING =

Grout Comments

RATING =

Structure Number: **Date of Inspection:**

RECOMMENDATION

Signs (Sign Panels, Etc.)	
Anchor Bolts PRIORITY=	
Chords (Including Trussing) PRIORITY =	
Connections	
Poles, Vertical Supports PRIORITY =	
Footings (Including Pedestals) PRIORITY =	
Walkway	

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GLOSSARY

Agency	Organization responsible for the inspection and maintenance of ancillary structures
Adhesive anchor	A post-cure mechanical connection to a concrete surface which uses a chemical adhesive to secure an anchor point
Anchor rod	The rod that connects the sign structure base to the foundation
Ancillary highway structure	Structures maintained by highway Agencies other than bridges, culverts and retaining walls. Qualifying structures typically consist of overhead sign support, lighting support and traffic signal support structures.
Base plate	The plate used to connect the post base to the foundation.
Beam-column	A structural member which is subjected to both axial and bending stresses
Butterfly	Type of structure where a single vertical post support with horizontal arms or trusses cantilevered off the post support in opposing directions
Cantilever	A structural configuration in which one end is unsupported and the other end is moment and laterally restrained
Cascade failure	A system failure in which the failure of one component leads to failure of other interconnected components, and so on
Casting	A part manufactured by pouring molten metal into a mold
Catwalk	The walkway maintenance personnel use, usually located in front of the sign or adjacent to variable message boards
Chord	The primary horizontal member(s) of an overhead sign structure connected to the end assemblies
Clear zone	The total roadside border area, starting at the edge of the traveled way, available for safe use by errant vehicles.

Corrosion	A chemical reaction which transforms a refined metal to a lower energy / chemically stable form through an electrochemical reaction
Critical finding	A deteriorated structural condition of a member or component of the structure that poses an immediate threat to the traveling public
Culvert	A small crossing under a roadway, less than 20 feet long per AASHTO
D-meter	An ultrasonic devise used to measure the thickness of metal parts
Damage inspection	An inspection performed after a structure is damaged, involving detailed documentation of the damage with proposed follow-up actions and repair recommendations
Damper	A device designed to counteract resonant vibration
Dead load	The weight of the structure and any permanent attachments
Deck	The structural component of a bridge of which vehicles are in direct contact
Deflection	Deformation of a structural component due to applied forces
Diagonal	The secondary diagonal members of the truss
Drilled shaft	A deep foundation system constructed by the excavation of a cylindrical shaft which is filled with concrete
Dye penetrant testing	A non-destructive testing method which utilizes the capillary action of a low-viscosity liquid to highlight surface discontinuities in non-porous materials
Element	Terminology used to split a complex structure into manageable parts which serve a specific function
End support	The vertical supporting members of a sign structure comprised of the post(s) and secondary framing members between the posts
Erosion	The loss of material due to wind or moving water

Expansion anchor	A post-cure mechanical connection to a concrete surface which uses friction to secure an anchor point
Fatigue	Weakening of a material due to cyclical loading
Fatigue life	The number of load cycles at a known stress range that a component can be expected to endue before the initiation of cracking
Foundation	The portion of the structure that directs the load into the ground
GPS	Acronym for Global Positioning System which entails the use of satellite-based radio signals for positioning and navigation
Galvanization	A fabrication process in which a thin layer of material (typically zinc) is applied to a thicker base metal (typically steel) with the intent of protecting the base metal from corrosion
Girder flange	Extensions on a moment resisting structural member which are typically oriented perpendicular to the applied load and located at the top and /or bottom of the member
Girder web	The portion of a moment resisting member which is oriented in line with the applied load
Guardrail	A structural system designed to protect vehicles from roadside hazards (also guiderail)
Handhole	An opening in a sign structure member for access; usually located in the end assembly 1-ft to 3-ft above the base plate
Hands-on inspection	Visual examination from no further than an arm's-length distance
High mast light	A pole structure that has a single pole supported by a foundation
In-depth inspection	A detailed inspection of one or more structural members using nondestructive evaluation methods, such as magnetic particle testing, dye penetrant testing, or ultrasonic testing
Initial inspection	A baseline inspection that verifies inventory data, dimensions, accuracy of installation, and notable defects from the installation

Inventory data	A record of the data set maintained by an Agency on a particular asset
Lateral clearance	The smallest horizontal distance between two items
Leveling nuts	The lower nut component of a tensioned anchor rod system used to support the base plate and create an anchor for the tensioning process
Luminaire	A lighting component including a lamp and housing
Magnetic particle testing	A non-destructive testing method which utilizes magnetic fields and dyed iron filings to highlight surface and near-surface discontinuities in ferromagnetic materials
Mast arm	A mast arm consists of a structure that cantilevers over traffic with a single chord
Moment	The application of a force over a distance from a support, resulting in bending or torque
Overhead sign structure	A structure used to support signage over highway travel lanes
Overhead span	A structure that is supported on both sides of the traveled way by an end support and foundation
Parapet	A protective vertical barrier at the edge of a bridge deck
Pedestal	A compression element extending vertically from a spread footing
Piles	A long structural member that is pushed / driven into the ground to provide support for a structure
Post	The vertical member of an end assembly above the base plate
Program Manager	Team member who oversees overall inspection program and specifically oversees the scoping, scheduling, cost and quality control
Punchlist	A listing of non-conforming items to be addressed before final payment on a construction project

Quality assurance	A component of a quality management process related to providing confidence that quality measures are being properly employed
Quality control	A component of a quality management process focused on implementing the quality measures
Redundancy	The inclusion of more structural members and load paths than is needed for stability so that if one member was to fail, the structure would not collapse
Resident Engineer	An engineer employed by an owner to represent their interests and provide documentation during a construction project
Routine inspection	A type of inspection that occurs on a regularly scheduled interval; can also be used to update Agency inventory data
Saddles	Bearings that support the chords of the truss structures.
Section loss	A measure of the deterioration of member related to its ability to resist applied stresses
Safety plan	A written plan documenting the anticipated hazards and safety procedures for protection against these hazards during the execution of a project
Service inspection	A cursory inspection, typically employing Remote Visual Inspection (RVI) methods, that is used to update Agency inventory data, or assess a structure after high winds or a severe weather event to quickly assess the structure for deficiencies
Shim plates	Metal plates used to account for elevation differences in tower to truss supports
Sign panel	Sign panels can be made from flat panels or partial extruded units joined together with bolts. The front face of the panel is covered with reflective sheeting and information for motorists. Structural frames are used to connect the panels to the sign structure.
Slip joint	When two sections of a pole structure are combined, the bottom of one section is slipped over the top of another section, creating a slip joint

Span	The distance between adjacent supports
Span wire	A span wire structure is supported on both sides of the roadway by a single post end support. Span wire end supports are constructed of steel, uncoated weathering steel, aluminum, concrete, or timber.
Splice	Usually referred to as the connection between the truss chords (usually bolted field connections); may also occur in long mast arms and poles
Stress cycle	a loading period traversing the maximum and minimum stress level encountered
Strut	The secondary vertical and horizontal members of the truss
Sway wire	The lower wire of the horizontal multi-strand cables
Team Leader	Team member that oversees the inspection team in the field
Truss	The superstructure composed of truss members that can be tubular or angular
Truss seat	The member that supports the vertical load of the truss
U-bolt	Bolts shaped like the letter "U" used to attach sign framing brackets to the sign truss or to attach the truss to the end supports
Ultrasonic testing	A non-destructive testing method which utilizes reflected sound waves to identify material discontinuities
Uncoated weathering steel	A group of steel alloys that have been developed to corrode slowly without the need for additional corrosion protection
Vertical clearance	The vertical distance between the structure span and the roadway
Vertical hanger	A vertical structural member which connects the sign frame to the horizontal sign structure chords
Work Zone Traffic Control	The process of providing signage, delineation devices and physical barriers in order to create a safe work area along or adjacent to an active highway

IMAGE SOURCES

The following Agencies and organizations granted permission to include figures in this reference manual:

- Colorado Department of Transportation.

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- Fickett Structural Solutions, Inc.

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- Florida Department of Transportation.

  Figure 9. Photo. Three-chord cantilever.

- Greenman-Pedersen, Inc.

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- Infrastructure Preservation Corporation.

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- U.S. Army Corps of Engineers.

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- Virginia Department of Transportation.

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- Wisconsin Department of Transportation.

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