CATENARY STRUCTURE LOADING, DESIGN CRITERIA, AND STANDARDS FOR USE ON THE NORTHEAST CORRIDOR AND KEYSTONE BRANCH

National Railroad Passenger Corporation

AMTRAK

Purpose:

This document outlines the requirements for the structural design of railroad catenary structures. The intent of the information contained herein is to provide general guidelines for the uniform and consistent design of these structures where practicable.

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Revision Record

Revision Number	Date	Description	By	Checked
1	9/27/10	Changed 336.4 MCM ACSR & 9/16 CW wire weights	DPT	RGN

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SECTION 1 – GENERAL

A. INTRODUCTION AND SCOPE

1. This chapter prescribes criteria for the design and detailing of railroad catenary (support) structures. The design and construction of new and replacement catenary structures as well as the analysis and modification of existing structures for new loads or loading conditions shall conform to the minimum design requirements specified here-in.

2. Exemptions or exceptions to any provisions contained in this document must be authorized by Amtrak's Director of ET Design & Standards.

3. The basis for design of railroad catenary support structures shall be in accordance with AREMA Manual for Railway Engineering Chapter 33 Part 4, the National Electric Safety Code, Amtrak's AED-1, and as modified here-in.

4. Structures shall be detailed to accept Amtrak's standard catenary hardware.

5. All structures shall be grounded per NESC and NEC code requirements.

B. DESIGN CODES AND REFERENCES *(latest editions)*

1.	AREMA	Manual of Railway Engineering, Chapter 33
2.	AISC 310	Hollow Structural Sections Connections Manual
3.	AISC 325	Steel Construction Manual– 13th Edition
4.	AISC 326	Detailing for Steel Construction – 2nd Edition
5.	AISC 348	Specification for Structural Joints Using ASTM A325 or A490 Bolts
6.	NEC	National Electric Code
7.	NESC	National Electric Safety Code
8.	IBC	International Building Code
9.	ACI 318	Building Code Requirement for Structural Concrete
10.	ASCE 7	Minimum Design Loads for Buildings and Other Structures
11.	AWS D1.1	American Welding Society: Structural Welding Code – Steel

END OF SECTION

SECTION 2 – LOADING REQUIREMENTS

A. *BASIC LOADS*

1. The basic loads applied to new catenary structures shall be in accordance with AREMA Chapter 33 Part 4, Amtrak's AED-1, and as modified by this document. The loads include:

   (a) Dead weight of wires, wire supports, and supporting structure

   (b) Curve pull forces and dead end loads

   (c) Ice loads on the wires only

   (d) Wind loads on the wires and structure

   (e) Wire break loads

   (f) Live loads (from cat walks, ladders, etc - refer to ASCE 7)

   (g) Other loads as may be specific to the location and structure

2. Unless otherwise specified to be greater, an importance factor (I) of 1.0 shall be used for determining wind pressure on structures and supported facilities per NESC Section 25. Wind loading shall be in accordance with the provisions and requirements stated in the NESC.

3. Five (5) load conditions shall be reviewed:

   (a) Icing Condition (Or NESC Rule 250 B)
   - Temperature = 0ºF
   - 40 mph wind
   - ½ inch radial ice on all wires
   - Maximum lateral pole deflection at contact wire height = 6 inches*

   (b) Design Condition (Or NESC Rule 250 C)
   - Temperature = 60ºF
   - 90 mph wind
   - All structures and their supported facilities shall be designed to withstand the Basic Wind Speed in accordance with ASCE/SEI 7, *Minimum Design Loads for Buildings and Other Structures*, Chapter 6.0 and the National Electric Safety Code, Section 25. Based upon ASCE 7-02, Figures 6-1 and 6-1c, the basic wind speed (3 second gust) for the majority of Amtrak's Northeast Corridor is 90 mph.

   (c) Operating Condition
   - Temperature = 60ºF
   - 60 mph wind
   - Maximum lateral pole deflection at contact wire height = 4 inches*

- This combination is not used to compute member stresses, rather to compute lateral catenary support and wire deflections for the interface with the vehicle/pantograph system.

(d) Wire Break Condition

- Portal structures shall be designed to resist the unbalanced forces in the direction of the line resulting from broken wires. Two such wire break loads of not less than 1,000 pounds each shall be assumed as acting on any pole carrying transmission or signal wires or one wire break load of not less than 2,000 pounds shall be assumed as acting at any catenary attachment point to a steel member of a supporting structure. Both conditions shall be checked individually.
- Wire break loadings need not be considered as acting in conjunction with longitudinal wind forces.
- Special provisions for Cantilever Catenary Structures: Arms and arm/column connections need not be designed to resist wire break conditions. However, columns shall be designed to resist wire break loads applied to the section at the messenger wire height. Large deflection and non-elastic deformation to the arm is to be expected, however, overall structural failure shall be prohibited.

(e) Construction Condition

- The wind pressures calculated under the "Design" load case (b) shall be applied to the entire structure and supporting facilities without ice or wire wind loads. Any support or restraint provided by a wire must subsequently be removed.

**Deflection limitations stated pertain to lateral deflections at contact wire supports as it relates to pantograph registration. Overall structural deflections shall follow the recommendations and limitations stated in AISC.*

4. When modifying an existing structure the design criteria applicable to the period when the structure was originally designed may be used in lieu of requirements outlined in Part 2, Section 3.

B. WIRE DEAD LOADS

1. For the purposes of structure design, wire size and weights noted in Table 2.B-1 (following page) shall be assumed as a minimum unless larger wire sizes or heavier loads are required.

Table 2.B-1 Wire Sizes and Weights					
Wire	**Size**	**Material**	**Nominal Diameter (in)**	**Dead Load Wt lbs/linear foot**	
				Bare @ 60°F	**½" ice @ 0°F**
Messenger	5/8"	stranded bronze	0.625	0.905	1.616
	5/8"	copper weld comp.	0.613	0.848	1.53
	7/16"	bronze	0.4375	0.453	1.05
	300 MCM	copper	0.630	0.926	1.63
Trolley	4/0	solid bronze	0.482	0.642	1.260
	336.4 MCM	bronze	0.680	1.02	1.690
	300 MCM	silver copper	0.574	0.908	1.575
Auxiliary	4/0	Copper	0.482	0.642	1.260
Hangers – clips					
2 wire systems				0.120	0.120
3 wire systems				0.080	0.080
Catenary Feeders	300 MCM	copper	0.714	0.945	1.70
	400 MCM	copper	0.728	1.235	1.985
	636 MCM	ACSR	0.990	0.874	1.80
	750 MCM	copper	0.998	2.316	3.25
	1000 MCM	copper	1.152	3.088	4.12
Transmission	250 MCM	copper hollow core (Type A)	0.731	0.783	1.55
	250 MCM	copper hollow core (Type NH)	0.818	0.803	1.62
	250 MCM	copper hollow core, hollow tube	0.731	0.844	1.61
	250 MCM	copper spiral I beam	0.731	0.803	1.57
	4/0	7 strand copper	0.522	0.653	1.29
	477 MCM	ACSR (26/7 "Hawk")	0.858	0.656	1.50
Signal Power	1/0	7 strand copper	0.368	0.326	0.866
Static	336.4 MCM	ACSR	0.741	0.527	1.30
	4/0	7 strand copper	0.522	0.653	1.29
	9/16"	Copperweld	0.572	0.700	1.37

C. WIND PRESSURES ON WIRES AND STRUCTURES

1. Basic wind loading equation:

   (a) Wind Pressure (lbs/ft^2) = $0.00256*(V^2)*(k_z)*(G_{RF})*(I)$
   (b) V = Basic Wind Speed for a 3s Wind Gust
   (c) k_z = Velocity Pressure Exposure Coefficient (See Table 2.C-1)
   (d) G_{RF} = Gust Response Factor (See Table 2.C-2)
   (e) I = Importance Factor (1.0)

Table 2.C-1
Velocity Pressure Exposure Coefficient, k_z

Height(ft)	k_z (Structure)	k_z (Wire)
≤ 33	0.90	1.00
33 to 50	1.00	1.10
50 to 80	1.10	1.20
80 to 115	1.20	1.30
115 to 165	1.30	1.40
165 to 250	1.40	1.50
>250	Use Formulas	Use Formulas

Formulas:

Structure: $k_z = 2.01 \times (0.67 \times h/900)^{(2/9.5)}$
Wire: $k_z = 2.01 \times (h/900)^{(2/9.5)}$

Note: *Minimum Value for k_z is 0.85*

Table 2.C-2
Gust Response Factor, G_{RF}

Height	Structure	Wire G_{RF}, Span Length, L (ft)			
h (ft)	**G_{RF}**	≤ 250	250<L<500	500<L<750	500<L<750
≤ 33	1.02	0.93	0.86	0.79	0.75
33 to 50	0.97	0.88	0.82	0.76	0.72
50 to 80	0.93	0.86	0.80	0.75	0.71
80 to 115	0.89	0.83	0.78	0.73	0.70
115 to 165	0.86	0.82	0.77	0.72	0.69
165 to 250	0.83	0.80	0.75	0.71	0.68
>250	(1)	(1)	(1)	(1)	(1)

Note (1): *Use applicable formulae provided in NESC.*

D. LOAD COMBINATIONS AND FACTORS

1. Load combinations shall be generated to meet the five (5) load conditions outlined in Section 2.A.3. Load factors need not be applied when using ASD allowable factors (see Section 3.A.1).

2. The general load combinations shall be as noted in Table 2.D-1 (following page). Other load combinations may be required by Amtrak for special structures.

Table 2.D-1 Load Combinations		
Load Case	**Combination**	**Description**
1A	0 degree F, ½" Ice, 40mph Wind Perpendicular to Tracks	Structure DL + Wire DL with 1/2" Ice + Curve Pull @ 0 deg. + Dead-end @ 0 deg. +/- 40mph wind perpendicular to tracks
1B	0 degree F, ½" Ice, 40mph Wind Parallel to Tracks	Structure DL + Wire DL with 1/2" Ice + Curve Pull @ 0 deg. + Dead-end @ 0 deg. + 40mph wind parallel to tracks
2A	60 degrees F, Bare Wire, 90mph Wind Perpendicular to Tracks	Structure DL + Bare Wire DL + Curve Pull @ 60 deg. + Dead-end @ 60 deg. +/- 90mph wind perpendicular to tracks
2B	60 degrees F, Bare Wire, 90mph Wind Parallel to Tracks	Structure DL + Bare Wire DL + Curve Pull @ 60 deg. + Dead-end @ 60 deg. +/- 90mph wind parallel to tracks
3A	60 degrees F, Bare Wire, 60mph Wind Perpendicular to Tracks (for deflection only)	Structure DL + Bare Wire DL + Curve Pull @ 60 deg. + Dead-end @ 60 deg. +/- 60mph wind perpendicular to tracks
3B	60 degrees F, Bare Wire, 60mph Wind Parallel to Tracks (for deflection only)	Structure DL + Bare Wire DL + Curve Pull @ 60 deg. + Dead-end @ 60 deg. + 60mph wind parallel to tracks
4A	0 degree F, 40mph Wind Perpendicular to Tracks, wire break	Structure DL + Wire DL + Curve Pull @ 0 deg. + Dead-end @ 0 deg. +/- 40mph wind perpendicular to tracks + 2000 pound wire break load on the beam at a catenary support that generates the worst case stresses
4B	60 degrees F, Bare Wire, 90mph Wind Perpendicular to Tracks, wire break	Structure DL + Bare Wire DL + Curve Pull @ 60 deg. + Dead-end @ 60 deg. +/- 90mph wind perpendicular to tracks + 2000 pound wire break load on the beam at a catenary support that generates the worst case stresses
4C	0 degree F, 40mph Wind Perpendicular to Tracks, wire break	Structure DL + Wire DL + Curve Pull @ 0 deg. + Dead-end @ 0 deg. +/- 40mph wind perpendicular to tracks + (2) 1000 pound wire break loads on the **pole** at a height to generate the worst case stresses (but must be where one of the crossarms are located)

4D	60 degree F, 90mph Wind Perpendicular to Tracks, wire break	Structure DL + Wire DL + Curve Pull @ 60 deg. + Dead-end @ 60 deg. +/- 90mph wind perpendicular to tracks + (2) 1000 pound wire break loads on the **pole** at a height to generate the worst case stresses (but must be where one of the crossarms are located)
5A	60 degrees F, No Support, 90mph Wind Perpendicular to Tracks	Structure DL +/- 90mph wind perpendicular to tracks (no wire support)
5B	60 degrees F, No Support, 90mph Wind Parallel to Tracks	Structure DL +/- 90mph wind parallel to tracks (no wire support)

3. Based upon the requirements of AREMA, load factors (overload) shall be applied for steel design as noted in Table 2.D-2.

Table 2.D-2
Load Factors (Overload for LRFD design)

Overload Factor	Description
1.5	Dead Load Structure including supports, signals, etc
1.5	Dead Load wires
1.0	Ice load on wires (1/2" radial)
1.65	Transverse Force due to bearing change of wires
1.65	Dead End Force
2.5	Transverse wind load on structure
1.1	Longitudinal wind load on structure
2.5	Transverse wind load on wires
1.0	Force created by wire breaking
1.6	Live Load (person on fixed ladder or platform)

4. Based upon the requirements of AREMA, wind loading shape factors C, shall be applied for steel design as noted in Table 2.D-3 (following page).

Table 2.D-3 Shape Factors, C	
Factor C	**Description**
1.0	Wires
0.8	Cylindrical Sections
1.2	H Sections
1.8	Lattice Structures
1.4	Flat Surfaces

5. Based upon the requirements of AREMA, wind loading exposure factors, E shall be applied for steel design as noted in Table 2.D-4.

Table 2.D-4 Exposure Factors, E	
Factor E	**Description**
1.25	Operating Load Condition Factor (Flat exposed areas, high embankments, viaducts)
1.5	Design Load Condition Factor (Flat exposed areas, high embankments, viaducts)
0.8*	Design & Operating Condition Factor (Sheltered areas, deep cuts, deep forests)

* *Transverse (perpendicular to tracks) wind loads only*

6. Where the combination of vertical, transverse, or longitudinal loads may act simultaneously, the structure shall be designed to withstand the simultaneous application of these loads.

END OF SECTION

SECTION 3 – STRUCTURAL DESIGN REQUIREMENTS

A. GENERAL REQUIREMENTS

1. Structural steel analysis and design shall be per AISC Manual of Steel Construction, 13th edition (or latest). Either ASD or LRFD may be used.

   (a) If ASD is used, use ASD allowable limits with no overload factors.
   (b) If LRFD is used, use AREMA/NESC overload factors and AISC LRFD reductions.

2. Structural members shall be designed with consideration for additional future loading. Excess capacity to allow for such loading shall be determined using good engineering judgment.

3. Design modifications to existing structures shall be conducted using the original loading criteria. The allowable stresses shall not be greater than the design criteria in place at the time of the original design and construction. All structural members shall be designed with consideration for additional future loading based on good engineering judgment.

4. Allowable stresses shall not be increased one-third above stress values given in specifications when produced by wind loading unless it is approved by Amtrak's Director of ET Design and Standards

5. Structural Erection Diagrams (SED's) shall include a loading diagram. Loading diagrams should show Icing (0 degree, 40mph wind, ½" ice) condition along with reactions at foundation(s) and down guy(s) for both loading conditions.

6. Static wires which are permanently attached to the top of the column section are permitted (when required) to be considered a support in the longitudinal direction of the structure. The static wire shall not provide any structural support in the transverse direction.

B. BASIC DESIGN VALUES

1. Design values (taken from AISC) for structural steel design shall be used as shown in Table 3.B-1 (following page).

Table 3.B-1 Basic Steel Design Values					
Condition			***ASD***	***LRFD***	***Related Info.***
Tension			$0.6F_YA_g \leq 0.5F_UA_e$	$0.9F_yA_g \leq 0.75F_UA_e$	*For A_e, see LRFD Equation D3-1*
Bending	Strong Axis	$L_b \leq L_p$	$0.66F_YS_X$	$0.99F_YS_X$	See Note 1. $L_p = 300r_y/(F_y)^{1/2}$ L_r and strengths when $L_b > L_r$ are given in the AISC Manual
		$L_p < L_b \leq L_r$	*Use linear interpolation between L_p & L_r*		
		$L_b = L_r$	$0.42F_yS_X$	$0.63F_YS_X$	
	Weak Axis		$0.9F_YS_Y$	$1.35F_YS_Y$	
Shear (strong axis)			$0.4F_YA_W$	$0.6F_YA_W$	See Note 2.
Compression		$Kl / r \leq 800/\sqrt{F_Y}$	$0.6F_YA_g \times 0.658^P$	$0.9F_YA_g \times 0.658^P$	$P = F_Y (Kl/r)^2 / 286,000$ See Note 3.
		$Kl / r > 800/\sqrt{F_Y}$	*150,000*$A_g/ (Kl/r)^2$	*226,000*$A_g/ (Kl/r)^2$	

Notes:

1. *Multiply equations given for $L_b \leq L_p$ by value in parentheses for W14x90 (0.97), W12x65 (0.98), and W6x15 (0.95).*
2. *Multiply equations given by 0.9 for W44x230, W40x149, W36x135, W33x118, W30x90, W24x55, W16x26, W12x14 and all C and MC-shapes. In weak axis, equations given can be adapted by using $Aw = 1.8b_ft_f$*
3. *Not applicable to slender shapes. For slender shapes, use QF_Y in place of F_Y, where $Q = Q_sQ_a$ from Section E7. For C- and MC-shapes, also check Section E4.*

2. Design equations (taken from AISC) for structural steel in combined bending and compression shall be used as shown in Table 3.B-2.

Table 3.B-2 Combined Bending and Compression Stress Design Values			
Condition		***Equations***	***Related Info.***
LRFD	$P_u / \Phi_CP_n \geq 0.20$	$(P_u / \Phi_CP_n) + \{(8/9)(M_{u,x}/\Phi_bM_{n,x} + M_{u,y}/\Phi_bM_{n,y})\} \leq 1.0$	See LRFD H1-1a
	$P_u / \Phi_CP_n < 0.20$	$(P_u / 2\Phi_CP_n) + (M_{u,x}/\Phi_bM_{n,x} + M_{u,y}/\Phi_bM_{n,y}) \leq 1.0$	See LRFD H1-1b
ASD	$f_a / F_a > 0.15$	$(f_a / F_a) + \{(C_{mx}f_{bx})/[(1- f_a/F_{ex})(F_{bx})] + (C_{my}f_{by})/[(1- f_a/F_{ey})]\} \leq 1.0$	See ASD H1-1
		$(f_a / 0.6F_y) + (f_{bx}/F_{bx}) + (f_{by}/F_{by}) \leq 1.0$	See ASD H1-2
	$f_a / F_a \leq 0.15$	$(f_a / F_a) + (f_{bx}/F_{bx}) + (f_{by}/F_{by}) \leq 1.0$	See ASD H1-3

2. Design values for connection design (Values taken from AISC) shall be used as shown in Table 3.B-3.

Table 3.B-3
Basic Connection Design Values

	Condition		***ASD***	***LRFD***	***Related Info.***
Bolts	Tension		$0.38F_uA_b$	$0.56F_uA_b$	---
	Shear (N bolts, per shear plane)		$0.2F_uA_b$	$0.3F_uA_b$	Mult. by 1.25 for X bolts
	Slip Resistance (Class A, STD holes)		$0.14F_uA_b$	$0.21F_uA_b$	Per slip plane (see Note 1)
	Bearing		$0.6F_uL_ct \leq 1.2F_Ud_bt$	$0.9F_uL_ct \leq 1.8\ F_ud_bt$	See Note 2.
Welds	Shear (all welds except CJP)		$0.3F_{EXX}A_w$	$0.45F_{EXX}A_w$	See Note 3.
	PJP Groove Welds	Tension	$0.32F_{EXX}A_w$	$0.48F_{EXX}A_w$	See AISC Section J2.1a.
		Compression	$0.48F_{EXX}A_w \leq 0.6F_YA_{BM}$	$0.72F_{EXX}A_w \leq 0.9F_YA_{BM}$	Joint not finished to bear.
	CJP Groove Welds		Strength equal to base metal		---
Connected Parts	Tension		$0.6F_YA_g \leq 0.5F_UA_e$	$0.9F_YA_g \leq 0.75F_UA_e$	*For A_e, see LRFD Equation D3-1*
	Shear		$0.4F_YA_g \leq 0.3F_UA_n$	$0.6F_YA_g \leq 0.45F_UA_n$	---
	Block Shear		$0.3F_YA_{nv}+0.5U_{bs}F_UA_{nt}$	$0.45F_YA_{nv}+0.75U_{bs}F_UA_{nt}$	See Note 4.
	Compression	Kl/r ≤ 25	$0.6F_YA$	$0.9F_YA$	---
		Kl/r > 25	Same as for W-shapes with A_g = A.		

Notes:

1. *Slip checked as a serviceability limit state using ASD load combinations for ASD, LRFD load combinations for LRFD. For Class B surfaces, multiply by 1.43. For OVS or SSL holes, multiply by 0.85. For LSL holes, multiply by 0.7.*
2. *For LSL holes parallel to the direction of load, multiply by 0.83.*
3. *For fillet welds, multiply by 1.5 for transverse loading (90-degree load angle). For other load angles, see Section J2 of AISC Manual of Steel Construction.*
4. *For calculation purposes, F_uA_{nv} cannot exceed F_YA_{gv}. U_{bs} = 1 for a uniform tension stress; 0.5 for non-uniform tension stress.*

C. STANDARD COMPONENTS

1. Columns

(a) Columns shall be made from standard wide-flange or HSS sections.

(b) Built-up wide-flange sections with the use of angles can be used in overbuild design cases to strengthen weak-axis bending (improving the L/r_Y ratio) due to longitudinal wind loading. They can also be used in cantilever structure cases to strengthen regions where the in-plane wind loads create excessive torsion forces in the member. Built-up sections shall be limited to the regions of the structure where the previously mentioned design cases dictate they be used.

(c) Pole steps shall be provided 20'-0" above top of foundation and shall be spaced 1'-3" apart to the top of the column.

(d) The columns shall be designed with a full moment base plate or direct embedment in a reinforced drilled concrete pier.

2. Catenary Beams

(a) Catenary cross beam members used in portal frame structures shall be made from standard wide flange sections or HSS sections.

(b) Cantilever arms shall be made from either WT sections or back to back angle sections.

(c) Sag braces and struts shall be used where required and should be made of back to back angles.

(d) Beams shall be shop cambered to negate the effects deflection due to self weight.

3. Signal Bridges

(a) Signal bridges shall consist of box-girder sections with a non-skid surface provided as the top plate.

(b) Handrails, ladders, and fall protection shall be designed and provided per applicable Amtrak and safety standards and codes.

4. Foundations

(a) Design per ACI 318 and the International Building Code Chapter 18.

(b) In general, foundations shall be of the drilled pier type (caisson). The use of a permanent steel casing (pipe steel) with a minimum 3/8" skin thickness and a yield strength of 35,000 psi is required for all catenary column foundations. Typical foundations shall be 48" diameter, having a depth ranging from 15'-0" to 30'-0", as required.

(c) Exploratory trenches are to be hand dug in accordance with the approved construction drawings to determine the presence of any underground installation before proceeding. These trenches are to be backfilled and immediately compacted (See Section IV of Amtrak's AED-1 for more information).

(d) Locate a 3' deep x 15" wide exploratory trenches on the design drawings. The extent of each trench shall be in the form of an "H" whose outside dimensions match the extent of the outside face of the foundation dimensions.

(e) The permanent steel casing shall extend from the bottom of the excavated hole to 0'-6" above proposed grade. Temporary forms (Neat Forms preferred) shall be used which extend from a minimum of 0'-6" below grade to the finished top of concrete. Normally, the top of concrete shall be even with the top of high rail.

(f) In foundations where solid bedrock is encountered, the use of a reduced pile diameter (rock socket) is permissible. In these conditions the reinforcing steel in the rock socket portion of the pile shall extend into the larger section such that a full tension lap splice occurs. Shear at the socket/caisson interface must be checked.

(g) Finished concrete shall slope away from the steel with a 1% to 2% slope.

(h) Pier foundations shall contain reinforcing steel to withstand flexural bending forces created by active earth pressures. Rebar shall be deformed (uncoated) unless directed otherwise.

(i) Piers shall contain confinement reinforcing. Typically, confinement steel consists of #4 ties with a maximum spacing of 1'-0" below grade, and 0'-6" above grade. Two (2) additional #4 ties shall be placed at the top and bottom of the foundation at a maximum spacing of 4". Continuous hoops (spiraled) cages are preferred. When a continuous hoop is not used, separate hoops shall have extra ties and hoops to ensure ease of placement. Tacks welds are allowed to be used near the outer ends of the cage to assist in the rigidity of the cage, however the designer must consider the effects of embrittlement when using this method.

(j) For cast-in-place caissons, provide 3" clear cover to all reinforcing bars.

(k) Pile head deflection and slope shall be considered as it pertains to the overall structure deflection. See Section 2.A.3 for structure deflection limitations.

(l) In lieu of using foundation software (i.e. L-Pile) to determine the effects of a foundation on an embankment, the depth of foundations shall be increased per AREMA Chapter 33 Section 4.2.8.2.1. The required increase shall also be determined by calculations.

(l) Ineffective soil depth shall be taken as a minimum of 2'-0" unless soil boring information is provided which shows otherwise.

(m) Foundation design shall be done using the worst case loading condition (service loads) with a 1.5 safety factor (overturning) for caissons.

(n) Design of anchor rods shall be in accordance with the ACI-318, Building Code Requirements for Reinforced Concrete (latest edition). The minimum embedment depth for anchor rods is 6'-0".

5. Guy Anchors and Assemblies

(a) Guy anchors shall be designed using the worst case loading (service loads) with a 1.75 safety factor (sliding and uplift).

(b) Type A-1, A-2, B-1, B-2, and caisson type guy anchors are preferred.

(c) All components which come into contact with the earth or concrete shall be galvanized.

(d) Guy anchors shall be placed in a vertically dug hole which is approximately the same dimensions as the anchor. In typical soil conditions, the minimum anchor embedment depth is 10'-0". In unstable conditions, areas of weak soil, high water tables, and/or areas susceptible to erosion a more detailed analysis must take place to determine the required embedment depth.

6. Cross Arms

(a) 132-kV Transmission Arms are generally single 4x4x1/2" single steel angles for suspension assemblies and double 4x4x1/2" angles for dead-end assemblies and shall be bolted to the pole. 7/8" diameter steel sag rod shall be provided for all arms and shall be clamped to the pole.

(b) Signal Power Feeder Arms are generally single 4x4x1/2" single steel angles for suspension assemblies and double 4x4x1/2" angles for dead-end assemblies and shall be clamped to the pole. 7/8" diameter steel sag rod is not required.

(c) Cross Track Feeder Arms are generally double 4x4x1/2" angles, with struts, clamped to the pole.

(d) Catenary Power Feeder Arms are generally double 4x4x1/2" angles. 7/8" diameter steel sag rod shall be provided for all arms and shall be clamped to the pole.

(e) Double dead-ends shall always be provided for long-term flexibility unless directed otherwise.

(f) All parts shall be galvanized.

7. Overhead Bridges

(a) Wherever possible catenary connections to overhead bridges should be avoided. If required, they should consist of a 4" diameter galvanized steel pipe clamped by u-bolts to dropper brackets which are welded or bolted to the bridge. Prior approval from Amtrak's Engineering Department must be granted prior to attaching any catenary to an overhead bridge.

8. Miscellaneous Steel

(a) Ladders for plain poles shall be provided when required. Anti-climb gates shall be provided on all ladders and shall extend fifteen-feet above the top of foundation or grade, whichever is higher.

(b) Railings shall meet all current safety regulations.

D. MATERIALS

1. The steel material requirements of AREMA Chapter 15 Section 1.2 apply to railroad catenary structures as modified here-in. All other steel structures shall comply with AISC requirements except as modified here-in.

2. Fabrication of steel structures shall be in accordance with AISC as modified here-in. Third party fabrication shops shall be AISC certified or have demonstrated experience with the fabrication of catenary structures.

3. Galvanized steel is the preferred material for exposed applications.

4. The recommended steel material specifications are listed in Table 3.D-1.

Table 3.D-1
Steel Material Specifications

Shape/Item	Material Specification
W- Shapes	ASTM A992 Grade 50 Hot Dip Galvanized
Hollow Structural Shapes	ASTM A500 Grade B Hot Dip Galvanized
Shapes and plates not embedded in concrete	ASTM A36 Hot Dip Galvanized
Shapes and plates embedded in concrete	ASTM A36 Hot Dip Galvanized
Welding Electrodes	E70xx low hydrogen (tensile strength F_{EXX} = 70 ksi)
High Strength Bolts	ASTM A325 Type 1 galvanized
Standard Hardened Washers	ASTM F436 Type 1 Hot Dip Galvanized
Heavy Hex Nuts	ASTM A563 Grade DH galvanized
Anchor Bolts or Rods	ASTM A449, Hot Dip Galvanized
Hardware	AISI C-1035 for clevises and turnbuckles. Turnbuckles shall be manufactured per ASTM F1145. AISI C-1030 for eye nuts and steel eye bolts. AISI C-1018 grade 2 for sleeve nuts. Cotter pins shall be stainless steel or bronze. All shall be Hot Dip Galvanized

5. Concrete shall be 4000psi at 28 days with a minimum w/c ratio of 0.45 minimum 5½% air content (if required).

6. Reinforcing steel shall be grade 60.

E. STEEL DESIGN DETAILS

1. Minimum plate thickness and member thickness is ⅜ inch.

2. Anchor Rods and Base Plates

   (a) Holes in base plates for anchor rods shall be oversized. Recommended oversize is 5/16” but shall not exceed AISC Code of Standard Practice.

   (b) Minimum diameter of anchor rods is 1¼ inch. The recommended diameter is 2 inches.

   (c) Each anchor bolt shall include two heavy hex nuts and a leveling nut.

   (d) Provide plate washers where oversize holes are provided.

(e) Welding on anchor rods will only be allowed in the bottom 12 inches.

(f) The minimum embedment length of anchor rods is 6'-0".

(g) Anchor rods shall be threaded at the top end a distance sufficient to provide for leveling or raking of the structure

(h) The minimum thickness of base plates is 1". For cantilever structures, the minimum thickness is 1½". The recommended baseplate thickness is 2".

F. MISCELLANEOUS

1. All steel structures shall be grounded.
2. Galvanized coating thickness for structural members shall not be less than 2.3 oz/sf.
3. Provisions for the attachment of a static wire shall be provided on the top of all columns.
4. The catenary structure number shall be permanently marked on the inbound and outbound faces of all columns at four feet above groundline using reflective paint or signs.
5. Cadwelded grounding is an acceptable alternative to the grounding pad/lug.
6. The location of structures shall not violate the minimum railroad clearance requirements per MW1000.

END OF SECTION

Appendix A

Index of Tables