TIA-222-G Code Outline for Telecom Infrastructure

PREPARED FOR DESIGN COMPETITION

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Table of Contents

1 Introduction

This Standard provides the requirements for the structural design and fabrication of new and the modification of existing structural antennas, antenna-supporting structures, mounts, structural components, guy assemblies, insulators and foundations.

2 Objective

The objective of this Standard is to provide recognized literature for antenna supporting structures and antennas pertaining to: (a) minimum load requirements as derived from ASCE 7-02, *"Minimum Design Loads for Buildings and Other Structures"*, and (b) design criteria as derived from AISC-LRFD-99, *"Load and Resistance Factor Design Specification for Structural Steel Buildings"* and ACI 318-05, *"Building Code Requirements for Structural Concrete"*.

This Standard provides the requirements for the structural design and fabrication of new and the modification of existing structural antennas, antenna-supporting structures, mounts, structural components, guy assemblies, insulators and foundations.

This Standard is based on limit states design.

3 Combination of Loads

3.1 Symbols and Notation

D=	Dead load of structure and appurtenances, excluding guy assemblies;
D_g=	Dead load of guy assemblies;
D_i=	Weight of ice due to factored ice thickness;
W_o =	Wind load without ice;
W_i =	Concurrent wind load with factored ice thickness.

3.2 Strength Limit State Load Combinations

Structures and foundations shall be designed so that their design strength equals or exceeds the load effects of the factored loads in each of the following limit state combinations:

1. $1.2\,D + 1.0\,D_g + 1.6\,W_o$ (1)
2. $0.9\,D + 1.0\,D_g + 1.6\,W_o$ (2)

3.3 Definitions

Dead load, **D:** the weight of the structure, and appurtenances, excluding guy assemblies, and for foundation design, the weight of soil and substructure.

Guy assembly dead load, **Dg:** the weight of all guy assemblies, including guys, end fittings, and insulators.

Appurtenances: items attached to the structure such as antennas, antenna mounts, transmission lines, conduits, lighting equipment, climbing devices, platforms, signs, anti- climbing devices, etc.
Basic wind speed, V: 3-second gust wind speed at 33 ft [10 m] above the ground in exposure category C for a 50-year mean recurrence interval.
Height of structure, h: the height of a structure, including latticed or tubular poles mounted on the structure, but excluding lightning rods and similar appurtenances.
Importance factor, I: a factor that accounts for the degree of hazard to human life, damage to property and reliability of service.
Guyed mast: a latticed or pole structure with supporting guys.
Antenna supporting structure: A structure, including guy assemblies, guy anchorages and substructures that support antennas or antenna arrays.

4 Classification of Structures

The Standard establishes three classifications of structures based on reliability criteria. The default Structure Classification is Class II.

Table 1: Classification of Structures

Description of Structure	Class
Structures that due to height, use or location represent a low hazard to human life and damage to property in the event of failure and/or used for services that are optional and/or where a delay in returning the services would be acceptable.	I
Structures that due to height, use or location represent a substantial hazard to human life and/or damage to property in the event of failure and/or used for services that may be provided by other means.	II
Structures that due to height, use or location represent a high hazard to human life and/or damage to property in the event of failure and/or used primarily for essential communications.	III

The following descriptions indicate the appropriate Classification for a new structure based on the type of service to be provided:

Class I: Structures used for services that are optional or where a delay in returning the services would be acceptable such as: residential wireless and conventional 2-way radio communications; television, radio and scanner reception; wireless cable; amateur and CB radio communications.

Class II: Structures used for services that may be provided by other means such as: commercial wireless communications; television and radio broadcasting; cellular, PCS, CATV, and microwave communications.

Class III: Structures used primarily for essential communications such as: civil or national defense; emergency, rescue or disaster operations; military and navigation facilities.

5 Wind Loads

When structures block the flow of wind, the wind's kinetic energy is converted into potential energy of pressure, which causes a wind loading. The effect of wind on a structure depends upon the density and velocity of the air, the angle of incidence of the wind, the shape and stiffness of the structure, and the roughness of its surface.

5.1 Basic Wind Speed and Design Ice Thickness

Wind shall be considered to come from any horizontal direction. Ice shall be considered to be glaze ice. The Standard is based on 3-second gust wind speeds and radial glaze ice thicknesses. Wind speeds averaged over different time periods are to be converted to 3-second gust wind speeds for use with the Standard.

Ice may be ignored for structures located in regions where the design ice thickness is less than or equal to 0.25 inches (6 mm)

Table 2: Wind Speed Conversions

3-sec gust (mph)	Fastest-mile		10-min avg. (mph)	Hourly mean (mph)
	Wind speed (mph)	Averaging period (sec)		
60	50	72	42	40
70	58	62	49	46
80	66	55	56	53
85	70	51	59	56
90	75	48	62	60
95	78	46	66	63
100	80	45	69	66
105	85	42	73	70
110	90	40	76	73
115	95	38	80	76
120	100	36	83	79
125	105	34	87	83
130	110	33	90	86
135	115	31	94	89
140	120	30	97	93
145	125	29	101	96
150	130	28	104	99
155	135	27	108	103
160	140	26	111	106
165	145	25	115	109
170	150	24	118	113

Notes: 1. For conversion to [m/s] multiply the above values by 0.447.
2. Linear interpolation may be used between the values shown.

5.2 Wind Speed Conversions (Normative)

Table 2 provides conversion of wind speeds based on various averaging periods to the 3-sec gust wind speed. Wind data based on other averaging periods are to be converted to a 3-sec gust wind speed for use with the Standard.

6 Topographic Categories

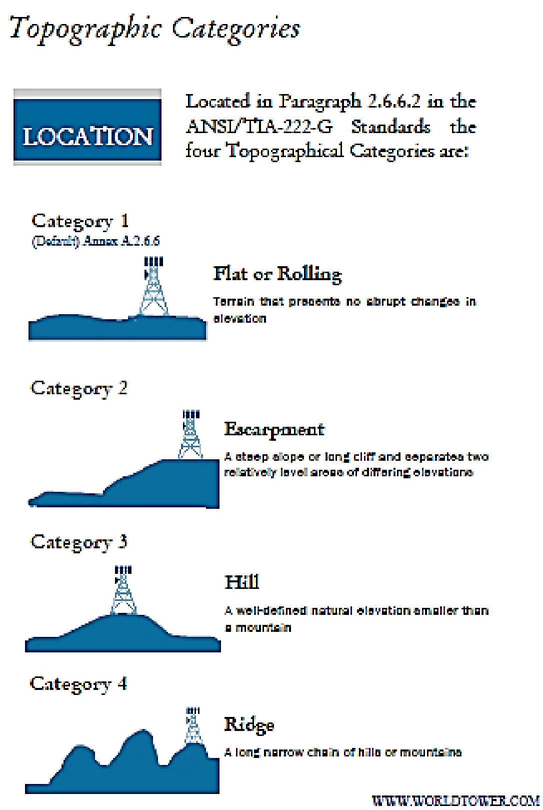


Figure 1: Topographic Categories

The topographic category for a structure shall be assessed as being one of the following:

Category 1: No abrupt changes in general topography, e.g. flat or rolling terrain, no wind speed-up consideration shall be required.

Category 2: Structures located at or near the crest of an escarpment. Wind speed-up shall be considered to occur in all directions. Structures located on the lower half of an escarpment or beyond 8 times the height of the escarpment from its crest, shall be permitted to be considered as Topographic Category 1.

Category 3: Structures located in the upper half of a hill. Wind speed-up shall be considered to occur in all directions. Structures located in the lower half of a hill shall be permitted to be considered as Topographic Category 1.

Category 4: Structures located in the upper half of a ridge. Wind speed-up shall be considered to occur in all directions. Structures located in the lower half of a ridge shall be permitted to be considered as Topographic Category 1.
Category 5: Wind speed-up criteria based on a site-specific investigation.

The default Topographic Category is Category 1.

6.1 Topographic Factor

The wind speed-up effect shall be included in the calculation of design wind loads by using the factor Kzt:

$$K_{zt} = [1 + \frac{K_e K_t}{K_h}]^2 \qquad (3)$$

where: Kh = height reduction factor given by the following equation:

$$= e^{(f*z/H)} \qquad (4)$$

e = natural logarithmic base = 2.718
K_e = terrain constant given in Table 6
K_t = topographic constant given in Table 3
f = height attenuation factor given in Table 3
z = height above ground level at the base of the structure
H = height of crest above surrounding terrain
K_{zt} = 1.0 for topographic category 1.

For topographic category 5, K_{zt} shall be based on recognized published literature or research findings.

Table 3: Topographic Category Coefficients

Topographic Category	**K_t**	**f**
2	0.43	1.25
3	0.53	2.00
4	0.72	1.50

7 Exposure Categories

An exposure category that adequately reflects the characteristics of ground surface irregularities at the site shall be determined. The exposure category for a structure shall be assessed as being one of the following:

Exposure B

Exposure C

Exposure D

1. **Exposure B:** Urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger. Use of this exposure shall be limited to those areas for which terrain representative of Exposure B surrounds the structure in all directions for a distance of at least 2,630 ft [800 m] or ten times the height of the structure, whichever is greater.
2. **Exposure C:** Open terrain with scattered obstructions having heights generally less than 30 ft [9.1 m]. This category includes flat, open country, grasslands and shorelines in hurricane prone regions.
3. **Exposure D:** Flat, unobstructed shorelines exposed to wind flowing over open water (excluding shorelines in hurricane prone regions) for a distance of at least 1 mile [1.61 km]. Shorelines in Exposure D include inland waterways, lakes and non-hurricane coastal areas. Exposure D extends inland a distance of 660 ft [200 m] or ten times the height of the

structure, whichever is greater. Smooth mud flats, salt flats and other similar terrain shall be considered as Exposure D.

The default Exposure Category is Exposure C.

8 Velocity Pressure

The velocity pressure, q_z, evaluated at height z shall be calculated by the following equation:

$$q_z = 0.00256\, K_z\, K_{zt}\, K_d\, V^2\, I \ (lb/ft^2) \quad (5)$$

$$= 0.613\, K_z\, K_{zt}\, K_d\, V^2\, I \ [N/m^2] \quad (6)$$

where:

K_z = velocity pressure coefficient from 8.1 which is a function of height and depends upon the ground terrain

K_{zt} = topographic factor from 6.1 that accounts for wind speed increases due to hills and escarpments. For flat ground, $K_{zt} = 1.0$

K_d = wind direction probability factor from Table 5

V = the basic wind speed for the loading condition under investigation, mph [m/s]

I = importance factor from Table 6

8.1 Velocity Pressure Coefficient

Based on the exposure category, a velocity pressure coefficient (Kz) shall be determined as follows:

$$K_z = 2.01(z/z_g)^{2/\alpha} \quad (7)$$

$K_{zmin} \le K_z \le 2.01$

where: z = height above ground level at the base of the structure

z_g, α and K_{zmin} are tabulated in Table 4.

Table 4: Exposure Category Coefficients

Exposure Category	**Zg**	α	**K_{zmin}**	**K_e**
B	1200 ft [366 m]	7.0	0.70	0.90
C	900 ft [274 m]	9.5	0.85	1.00
D	700 ft [213 m]	11.5	1.03	1.10

Table 5: Wind Direction Probability Factor

Structure Type	**Wind Direction Probability Factor, Kd**
Latticed structures with triangular, square or rectangular cross sections	0.85
Tubular pole structures, latticed structures with other cross sections appurtenances	0.95

Table 6: Importance Factors

Structure Class	**Wind Load Without Ice**	**Wind Load With Ice**	**Ice Thickness**	**Earthquake**
I	0.87	N/A	N/A	N/A
II	1.00	1.00	1.00	1.00
III	1.15	1.00	1.25	1.50
Note: Ice and earthquake loads do not apply to Class I structures				

9 Gust Effect Factor

9.1 Self-Supporting Latticed Structures

For self-supporting latticed structures, the gust effect factor shall be 1.00 for structures 600 ft [183 m] or greater in height. For structures 450 ft [137 m] or less in height, the gust effect factor shall be 0.85. The gust effect factor shall be linearly interpolated for structure heights between 450 ft [137 m] and 600 ft [183 m].

These conditions are expressed by the following equations:

$$G_h = 0.85 + 0.15 \left[\frac{h}{150} - 3.0\right] \quad \text{h, in feet} \qquad (8)$$

$$G_h = 0.85 + 0.15 \left[\frac{h}{45.7} - 3.0\right] \quad \text{h, in meters} \qquad (9)$$

$0.85 \leq G_h \leq 1.00$

where: h = height of structure

9.2 Guyed Masts

For guyed masts the gust effect factor shall be 0.85.

9.3 Pole Structures

For pole structures the gust effect factor shall be 1.10

10 Design Wind Load

The design wind load shall include the sum of the horizontal design wind forces applied to the structure in the direction of the wind and the design wind forces on guys and appurtenances. All appurtenances, including antennas, mounts and lines, shall be assumed to remain intact and attached to the structure.

The design wind load, F_W, shall be determined in accordance with the following:

$$F_W = F_{ST} + F_A + F_G \quad (10)$$

where:

F_{ST}= design wind force on the structure from 10.2

F_A = design wind force on appurtenances from 10.3

F_G = design wind force on guys from 10.4

10.1 Design Ice Thickness

The design ice thickness, t_i, shall be escalated with height when calculating ice weight and wind on ice loads in accordance with the following equations:

$$t_{iz} = 2.0\, t_i\, I\, K_{iz}(K_{zt})^{0.35} \quad (11)$$

$$K_{iz} = \left[\frac{z}{33}\right]^{0.10} \leq 1.4 \qquad z\text{, in feet} \quad (12)$$

$$K_{iz} = \left[\frac{z}{10}\right]^{0.10} \leq 1.4 \qquad z\text{, in meters} \quad (13)$$

where:

2.0 = limit state conversion factor

t_{iz} = the factored thickness of radial glaze ice at height z

t_i = design ice thickness

I = importance factor for structure from Table 5

K_{iz} = height escalation factor for ice thickness
z = height above ground level at base of structure
K_{zt} = topographic factor from 6.1

For purposes of calculating the additional projected area of ice, ice thickness shall be considered to accumulate with a uniform thickness around the exposed surfaces of the structure, guys and appurtenances (refer to Figure 2). The additional projected area of ice may be considered round when calculating wind on ice loads even though the bare projected area is flat.

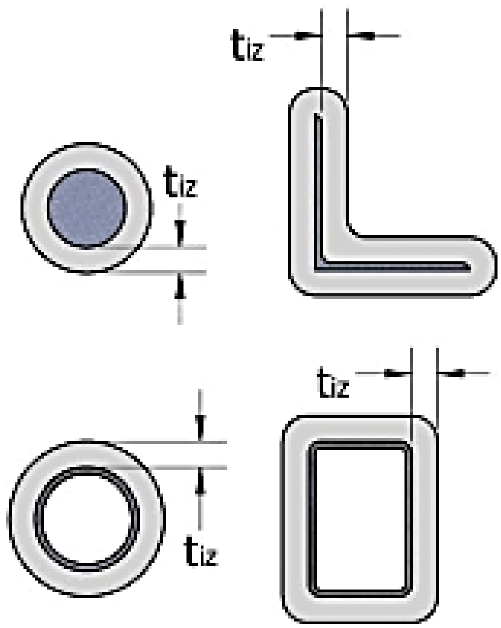


Figure 2: Projected area of ice

10.2 Design Wind Force on Structure

The design wind force, F_S, applied to each section of a structure shall be determined in accordance with the following:

$$F_{ST} = q_z G_h (EPA)_S \quad (14)$$

where:
F_S = horizontal design wind force on the structure in the direction of the wind
q_z = velocity pressure from 8
G_h = gust effect factor from 9
$(EPA)_S$ = effective projected area of the structure from 10.2.1 or 10.2.2

10.2.1 Effective Projected Area of Latticed Structures

The effective projected area of structural components for a section, $(EPA)_S$, shall be determined from the equation:

$$(EPA)_S = C_f \; [D_f \, \Sigma A_f + D_r \, \Sigma(A_r \, R_r)] \qquad (15)$$

where:

$C_f = 4.0\varepsilon^2 - 5.9\varepsilon + 4.0$ (square cross sections) (16)

$C_f = 3.4\varepsilon^2 - 4.7\varepsilon + 3.4$ (triangular cross sections) (17)

ε = solidity ratio = $(A_f + A_r)/A_g$ (18)

A_f = projected area of flat structural components in one face of the section

A_r = projected area of round structural components in one face of the section including the projected area of ice on flat and round structural components in one face for loading combinations that include ice

A_g = gross area of one face as if the face were solid

D_f = wind direction factor for flat structural components determined from Table 7

D_r = wind direction factor for round structural components determined from Table 7

R_r = reduction factor for a round element

$= 0.57 - 0.14\varepsilon + 0.86\varepsilon^2 - 0.24\varepsilon^3 \leq 1.0$ when $C < 32$ [4.4] (19)

and for all iced conditions (subcritical flow)

$= 0.36 + 0.26\varepsilon + 0.97\varepsilon^2 - 0.63\varepsilon^3$ when $C > 64$ [8.7] (20)

for no-ice conditions (supercritical flow)

where:

$C = [I \, K_Z \, K_{ZT}]^{1/2} \; V \, D$ (21)

I = importance factor from Table 5

K_Z = velocity pressure coefficient from 8.1

K_{ZT} = topographic factor from 6.1

V = the basic wind speed for the loading condition under investigation, mph [m/s]

D = outside diameter of the structural component without ice, ft [m]

Table 7: Wind Direction Factors

Tower Cross Section	**Square**		**Triangular**		
Wind Direction	Normal	45°	Normal	60°	±90°
D_f	1.0	1 + .75ε (1.2 max)	1.0	0.80	0.85
D_r	1.0	1 + .75ε (1.2 max)	1.0	1.0	1.0
Wind directions measured from a line normal to the face of the structure					

Notes:

In order for a structural component to be considered as a round structural component, the component must have a round profile on the windward and leeward sides of the component. (Formed U-shaped angle or channel members shall be considered as flat structural components.)

10.2.2 Effective Projected Area of Pole Structures

Table 8: Force Coefficients (C_F) for Pole Structures

C (mph.ft) [m/s.m]	Round	18 Sided	16 Sided	12 Sided	8 Sided
< 32 [4.4] (subcritical)	1.2	1.2	1.2	1.2	1.2
32 to 64 [4.4 to 8.7]	$38.4/(C)^{1.0}$ [$5.23/(C)^{1.0}$]	$25.8/(C)^{0.885}$ [$4.42/(C)^{0.885}$]	$12.6/(C)^{0.678}$ [$3.26/(C)^{0.678}$]	$2.99/(C)^{0.263}$ [$1.77/(C)^{0.263}$]	1.2 [1.2]
> 64 [8.7] (supercritical)	0.60	0.65	0.75	1.0	1.2

$C = (I\ K_{zt}\ K_z)^{0.5}(V)(D)$ for D in ft [m], V in mph [m/s]

V is the basic wind speed for the loading condition under investigation.

D is the pole outside diameter for rounds or the outside point-to-point diameter for polygons.

Notes:

1. When linear appurtenances such as ladders, waveguides, coax, brackets, or other similar projections are attached on the outside of the pole shaft, effective projected areas shall be calculated as follows:

(a) When $R_a \leq 0.1$, the projected areas of the attachments may be ignored.

(b) When $0.1 < R_a \leq 0.2$, the value for C_f shall be multiplied by $1.0 + 3(R_a - 0.1)$, and the projected areas of the attachments may be ignored.

(c) When $R_a > 0.2$, or alternatively for any value of R_a, the value of C_F for subcritical flow shall be used. The projected areas of the attachments shall be considered separately in addition to the structure using appropriate force coefficients for appurtenances.

Where R_a is the ratio of the projected area of the attachments (perpendicular to the wind direction) to the projected area of the structure without the attachments for the portion being considered. For iced conditions, the ice thickness need not be included in the determination of R_a.

2. For iced conditions, C_f shall be based on subcritical flow for all values of C.

3. Linear interpolation, based on the inscribed angle of each side, between the values shown, may be used for other cross-sections. The inscribed angle for a round cross-section is 0 degrees.

The effective projected area of a pole section, $(EPA)_S$, shall be determined from the equation:

$$(EPA)_S = C_f * A_P \quad (22)$$

where:

C_f = force coefficient for cantilevered pole structure from Table 8

A_P = actual projected area based on the pole outside diameter (for rounds), the outside point-to-point diameter (for polygons), or overall width, including ice thickness for load combinations that include ice

10.2.3 Effective Projected Area for Symmetrical Frame/Truss Platforms

The effective projected area, $(EPA)_A$, of frame/truss triangle or square symmetrical platforms (refer to Figure 3) that are continuous around the perimeter of a structure (or with a horizontal gap between the corners of adjacent faces less than or equal to 10% of the width of the platform) shall be determined as if the platform were a section of a latticed structure in accordance with 2.6.9.1 using directionality factors D_F and D_r = 1.0. The projected area of all supporting members for the entire platform shall be projected onto a plane parallel to a face without regard to shielding or overlapping members of the platform or the supporting structure. A drag factor of 2.0 for flat members and a drag factor of 1.2 for round members shall be applied to the projected areas of the supporting members. Fifty percent of the total effective projected area of the supporting members shall be added to the effective projected area of the platform. The resulting total effective projected area shall be used for all wind directions. No shielding shall be considered for the supporting structure. Antennas and mounting pipes supported on the platform shall be considered as generic appurtenances with a value of K_a equal to 0.75.

10.2.4 Effective Projected Area for Symmetrical Circular Ring Platforms

The effective projected area, $(EPA)_A$, of symmetrical circular ring platforms (refer to Figure 3) that are continuous around the perimeter of a structure shall be determined by considering the supporting members of the platform and the ring members as individual members. The projected area of each ring member shall be equal to the product of the diameter of the ring and the projected vertical dimension of the ring member exposed to the wind. The projected area of all supporting members for the entire platform shall be determined by projecting all supporting members onto a vertical plane without regard to shielding or overlapping members of the platform or the supporting structure. A drag factor of 2.0 for flat members and a drag factor of 1.2 for round members shall be applied to the projected areas of the supporting members and the ring members. A 0.50 factor shall be applied to total effective projected area of the supporting members and a 1.75 factor shall be applied to the total effective projected area of the ring members. The resulting total effective projected area shall be used for all wind directions. No shielding shall be considered for the supporting structure. Antennas and mounting pipes supported on the platform shall be considered as generic appurtenances using a value of K_a equal to 0.8.

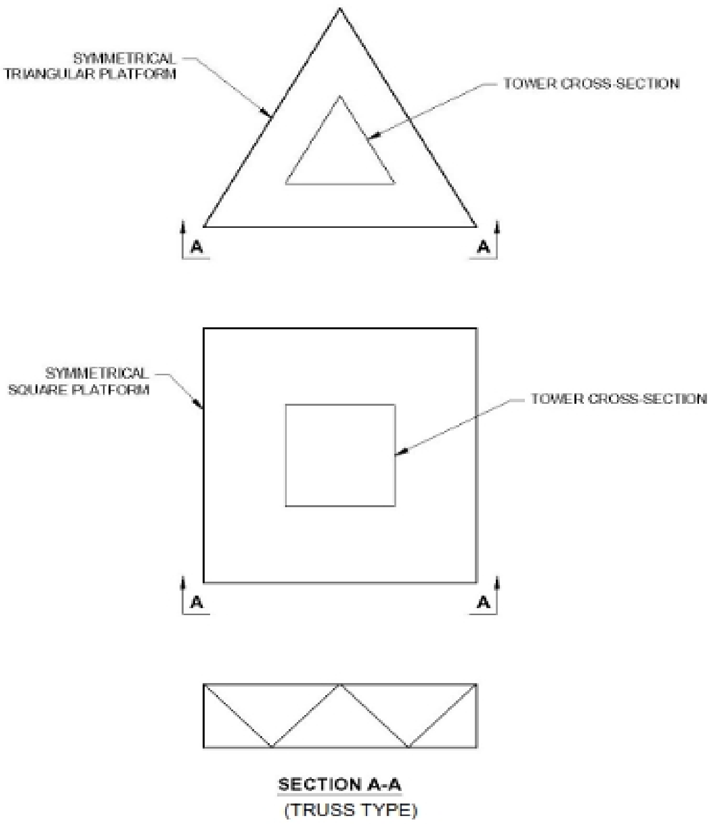


Figure 3: Symmetrical frame/truss platforms

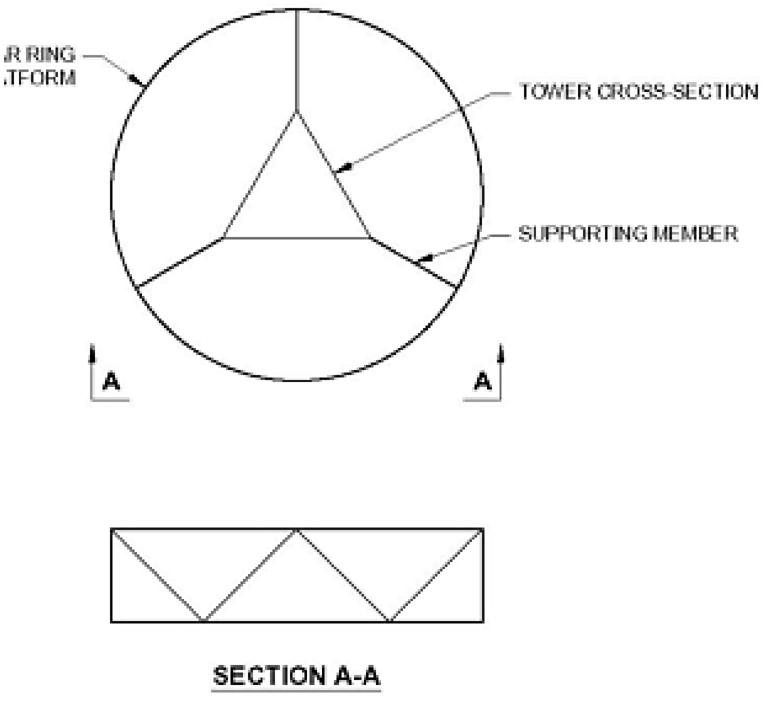


Figure 4: Circular Ring Platform

10.3 Design Wind Force on Appurtenances

The design wind force on appurtenances (either discrete or linear but excluding microwave antennas), F_A, shall be determined from the equation:

$$F_A = q_z G_h (EPA)_A \tag{23}$$

where:

q_z = velocity pressure at the centerline height of the appurtenance from 8

G_h = gust effect factor from 9

$(EPA)_A$ = effective projected area of the appurtenance including ice for loading combinations that include ice.

In the absence of more accurate data specifying effective projected area values for each critical wind direction, the effective projected area, $(EPA)_A$, of an appurtenance shall be determined from the equation:

$$(EPA)_A = K_a[(EPA)_N \cos^2(\Theta) + (EPA)_T \sin^2(\Theta)] \tag{24}$$

where:

K_a = 1.0 for round appurtenances under super critical flow conditions

= (1- ε) for appurtenances, entirely inside the cross section of a latticed structure or outside the cross section entirely within a face zone as defined in Figure 6, where ε is the minimum solidity ratio of the structure considering each face for the section containing the appurtenance. K_a need not exceed 0.6. (25)

= 0.8 for antenna mounting configurations such as side arms, T-arms, stand-offs, etc.

when 3 or more mounts are located at the same relative elevation

= 1.0 for other appurtenances unless otherwise specified in this section

(Notes: 1. K_a = 1.0 may be conservatively used for any appurtenance

2. The value of K_a is constant for all wind directions)

Θ = relative angle between the azimuth associated with the normal face of the appurtenance and the wind direction (refer to Figure 7).

$(EPA)_N$ = effective projected area associated with the windward face normal to the azimuth of the appurtenance.

$(EPA)_T$ = effective projected area associated with the windward side face of the appurtenance.

The larger value of $(EPA)_N$ or $(EPA)_T$ may be conservatively used for $(EPA)_A$ for all wind directions.

Figure 5: Different types of antennas

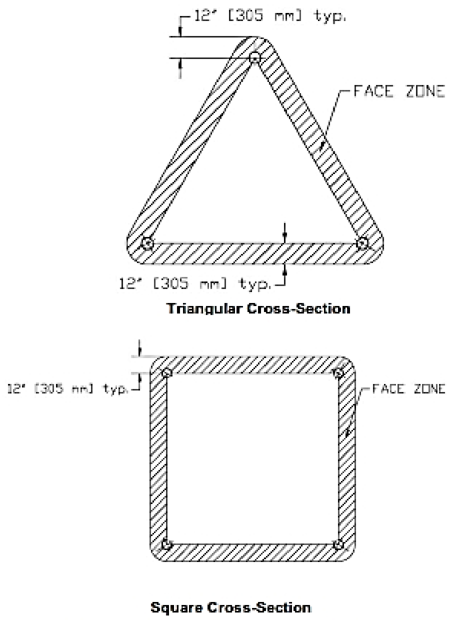
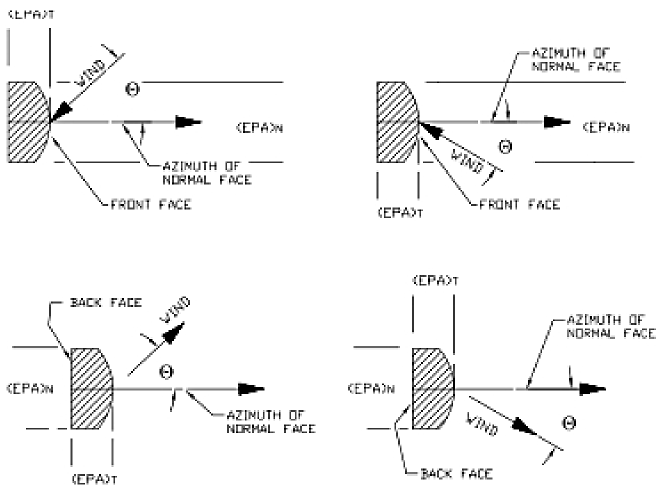


Figure 6: Face zone for appurtenances



NOTE: $(EPA)_N$ AND $(EPA)_T$ REPRESENT THE EFFECTIVE PROJECTED AREAS OF THE APPURTENANCE FOR THE WINDWARD NORMAL AND TRANSVERSE FACES OF THE APPURTENANCE.

Figure 7: Wind forces on appurtenances

In the absence of more accurate data, an appurtenance shall be considered as consisting of flat and round components in accordance with the following:

$$(EPA)_N = \Sigma (C_a A_A)_N \quad (26)$$

$$(EPA)_T = \Sigma (C_a A_A)_T \quad (27)$$

C_a = force coefficient from Table 9

A_A = projected area of a component of the appurtenance. The additional projected area of ice shall be considered as a round component for loading combinations that include ice

Table 9: Force Coefficients (C_a) For Appurtenances

Member Type		Aspect Ratio ≤ 2.5	Aspect Ratio = 7	Aspect Ratio ≥ 25
		C_a	C_a	C_a
Flat		1.2	1.4	2.0
Round	C < 32 [4.4] (Subcritical)	0.70	0.80	1.2
	32 ≤ C ≤ 64 [4.4 ≤ C ≤ 8.7]	$3.76/(C)^{0.485}$ [$1.43/(C)^{0.485}$]	$3.37/(C)^{0.415}$ [$1.47/(C)^{0.415}$]	$38.4/(C)^{1.0}$ [$5.23/(C)^{1.0}$]
	C > 64 [8.7] (Supercritical)	0.50	0.60	0.60

Where:

$C = (I\ K_{zt}\ K_z)^{0.5} (V)(D)$ for D in ft [m], V in mph [m/s]

V is the basic wind speed for the loading condition under investigation.

D is the outside diameter of the appurtenance.

Aspect ratio is the overall length/width ratio in the plane normal to the wind direction. (Aspect ratio is independent of the spacing between support points of a linear appurtenance, and the section length considered to have uniform wind load).

Notes:

1. For iced conditions, C_a shall be based on subcritical flow for all values of C.
2. Linear interpolation may be used for aspect ratios other than those shown.

The horizontal design wind force, F_A, for appurtenances shall be distributed to each leg joint according to the location of the appurtenance (i.e. lateral load and torsion considered).

10.4 Design Wind Force on Guys

The design wind force on guys, F_G, shall be determined in accordance with the following equation:

$F_G = C_d \, d \, L_G \, G_h \, q_z \sin^2 \Theta_g$ (28)

where:

F_G = force applied normal to the chord of the guy in the plane containing the guy chord and the wind, refer to Figure 8.

C_d = 1.2, drag factor for guy

d = guy diameter including ice for loading combinations that include ice

L_G = length of guy

G_h = gust effect factor from 9

q_z = velocity pressure at mid-height of guy from 8

Θ_g = true angle of wind incidence to the guy chord

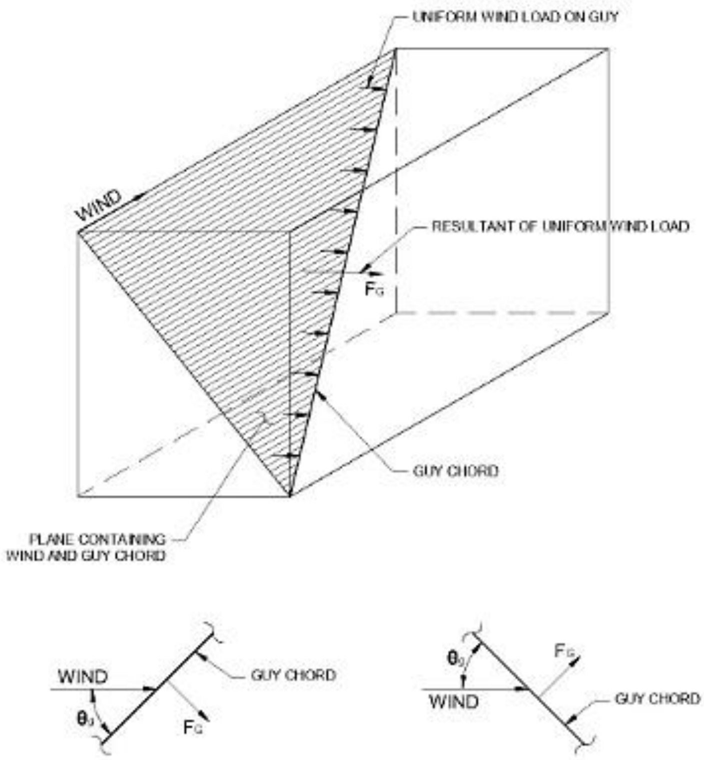


Figure 8: Wind forces on guys

11 Serviceability Requirements

11.1 Definitions

Displacement: the horizontal displacement under service loads of a point from the unfactored no-wind load position.

Service loads: the loading combination used to calculate serviceability limit state deformations.

Sway: the angular rotation under service loads of an antenna beam path in the local vertical plane of the antenna from the unfactored no-wind load position.

Twist: the angular rotation under service loads of an antenna beam path in the local horizontal plane of the antenna from the unfactored no-wind load position.

11.2 Limit State Deformations

The deformations under service loads at any point on a structure, unless otherwise required, shall not exceed the following:

1. A rotation of 4 degrees about the vertical axis (twist) or any horizontal axis (sway) of the structure.
2. A horizontal displacement of 5% of the height of the structure.
3. For cantilevered tubular or latticed spines, poles or similar structures mounted on latticed structures, a relative horizontal displacement of 1% of the cantilever height measured between the tip of the cantilever and its base.

11.3 Slenderness Ratios

The slenderness ratio, L/r, shall preferably not exceed:
(a) 150 for leg members,
(b) 200 for main compression members other than leg members,
(c) 250 for secondary members, and
(d) 300 for tension members, except for tension rod bracing and cables.

11.4 Design Values for Yield and Tensile Strength

For design purposes, the minimum nominal values for the yield strength and ultimate tensile strength for the type and grade of steel specified shall be used.

The width to thickness ratio (w/t) shall not exceed 25 for angle members.
For tubular round members, the diameter to thickness ratio (D/t) shall not exceed 400.

11.5 Tolerances

Overall Height

The overall height of an assembled structure shall be within +1% and -1/2% of the specified height, not to exceed +5 ft [1.5 m] or -2 ft [0.6 m].

Guy Tensions

The maximum deviation from the design initial tension shall be (i) ± 10% for guys up to and including 1 in. [25 mm] diameter and (ii) ± 5% for guys greater than 1 in. [25 mm] diameter, of the specified design initial tension at an anchorage, corrected for the ambient temperature.

Plumb

The horizontal distance between the vertical centerlines at any two elevations shall not exceed 0.25% of the vertical distance between the two elevations.

Twist

The twist between any two elevations shall not exceed 0.5 degrees in 10 ft [3 m]. The maximum twist over the structure height shall not exceed 5 degrees.

12 Tower Plans

The tower plans shall detail the following data for the site specified used in the structural analysis:

1. Basic wind speed (3 second gust, 50 year return period) without ice.
2. Basic wind speed (50 year return period) with ice.
3. Design ice thickness (50 year return period).
4. Exposure category (B, C or D) for the site specified.
5. Structure classification (I, II, or III) used to classify the structure.
6. Topography category (1,2, 3,4, or 5).

13 Documentation Guideline: (to be submitted by students)

There will be 2 submission as below –

1. Regular Telecom Tower for urban and rural areas
2. Street Furniture or Lamp pole for future smart cities

Documentation needed for both as below –

S/N	Document Details	Evaluation
1	3D rendered animation and detail AutoCAD drawing (Plan & elevation) of the design including all equipment and accessories.	3D drawing - Optional, 2D drawing - Mandatory
2	Structural detail calculation documents and drawings for civil structural works (Foundation, Slab etc.)	Mandatory
3	Structural detail calculation and drawings for tower or pole.	Mandatory
4	BOQ (Bill of Quantity) of materials - steel, concrete, sand, earth and other materials	Mandatory
5	Cables and wiring details	Optional
6	Executive Summary and Highlights of the idea in power point	Mandatory

Note: Additional document and presentation might have to be submitted if it appears necessary to management committee.

14 Layout Details

The tower is 3-legged, with outdoor BTS room. The BTS room contains three equipment cabinets, two battery cabinets, one solar battery and one switchboard. Students can propose modified layout drawing if that provides cost efficiency.

15 Alternate Materials to be Proposed by Students

Students are encouraged to consider alternative or composite material other than steel. For example, Aluminum is a relatively lightweight metallic element that provides high toughness at moderate strength levels. With the addition of copper, aluminum alloys can be heat-treated for higher hardness and greater strength. Carbon and alloy steels offer high toughness and good weldability. Plastic products and fiber reinforced polymers (FRP) provide alternatives to metal materials. Some plastics offer strong dielectric and nonreflective characteristics. Others provide good electrical insulation and are relatively safe for use as mounting brackets or cross arms on power pole lines or towers. Though more costly than traditional plastic materials, fiberglass-reinforced plastic is stronger than wood and easier to maintain. Pressure-treated wood is used mainly for structural or building applications but is also used for utility poles and lighting applications. Any other materials not mentioned here can also be considered.

However, Students need to check if the following material specifications meet the desired values when proposing alternate or composite material:

1. Yield strength
2. Moment capacity
3. Ductility
4. Creep behavior
5. Fatigue
6. Toughness
7. Related hardness
8. Longevity
9. Elasticity
10. Section modulus
11. Method of jointing
12. Reduction in global carbon emission footprint

15.1 Implementation of Bamboo Tower in Bangladesh

Bamboo, which is a renewable material, has already been utilized in construction of rooftop telecom towers in Bangladesh. Studies indicated untreated bamboo to have the ability to bear weight as well as possess the rigidity and tensile strength to support its own weight. It has an expected lifespan of approximate 10 years with proper maintenance. A bamboo tower takes around 12 days to construct and consumes less energy to manufacture compared to traditional steel towers. In addition to that, bamboo is inherently light which allows for easy transportation and installation of structures on rooftops putting no additional stress on the building.

15.2 Implementation of Carbon Fiber Pole (CFP) in Bangladesh

edotco Bangladesh has successfully installed the first rooftop-based carbon fiber tower in Bangladesh, in 2016. The inherent properties of carbon fiber makes it an ideal solution for rooftop-based installations as it results in a structure 70% lighter than conventional steel but with up to ten times the tensile strength. Its light weight also translates to ease of transporting the structures to the rooftop, on one's shoulders. This in turn contributes to faster installation time; almost half as compared to steel. In addition to that, carbon fiber is also highly corrosion resistant. This characteristic, along with its other properties, contribute to a longer perpetuating lifespan in which maintenance costs are also greatly reduced over time. In totality, carbon fiber structures are a greener solution due to the reduced usage of steel and carbon emissions in its manufacturing, with close to 40% reductions on like-to-like structure basis.

16 Evaluation Criteria

No.	Category	Criteria to evaluate
1	**Resource Optimization**	Is less steel required?
		Is less concrete required?
		Is new material used which is cheaper than concrete and steel?
2	**Feasibility, Practicality and Functionality**	Has design met all specs. provided in technical framework?
		Is local aspect considered - i.e. availability of the material?
		Does local firm have the technical competency to implement such design?
		Is land usage optimized?
		Does the design discourage theft, pilferage and increase safety and security?
3	**Environmental Impact**	What will be the carbon footprint reduction?
		What will be lifetime of the structure?
		What are the maintenance cost and frequency?
		What is positive impact to environment? How you measure the impact?
		Is it camouflaged? Does it have aesthetic appeal?
4	**Originality of the design**	Is it based on any old design?
		Is similar design implemented anywhere in the world?
		Is it completely out of the box thinking?

17 Design Boundary

- For Regular Telecom Tower in urban and rural areas

No.	Design Criteria	Design Value
1	Wind Speed	210 kph as design wind speed
2	Large Ancillaries/Apparatus Load	15 sqm (EPA) at top 6m of the structure
3	Soil Bearing Capacity	Minimum Soil bearing Capacity at 5m depth is 150 kN/M2
4	Exposure Category	Category-C (as per TIA)
5	Structural Class	Class-II (as per TIA)
6	Topography	Topography-I (as per TIA)
7	Equipment Cabinet Space	Minimum 3 x 2200 x 850 x 850 mm (H x W x D) footprint
8	Structure Height	35 meters
9	Structure Rotation Limit	Within 1 degree at 70% of design wind speed

- Street Furniture or Lamp pole for future smart cities

No.	Design Criteria	Design Value
1	Wind Speed	180 kph as design wind speed
2	Large Ancillaries/Apparatus Load	4 sqm (EPA) at top 3m of the structure (Camouflaged)
3	Soil Bearing Capacity	Minimum Soil bearing Capacity at 3m depth is 100 kN/M2
4	Exposure Category	Category-C (as per TIA)
5	Structural Class	Class-II (as per TIA)
6	Topography	Topography-I (as per TIA)
7	Equipment Cabinet	1 x 1000 x 600 x 500 mm (H x W x D-Camouflaged) Can be indoor or outdoor, Floor mount or pole mount
8	Structure Height	12 meters (Should be Aesthetic)
9	Structure Rotation Limit	Within 1 degree at 70% of design wind speed
10	Smart Accessories Accommodation	Streetlamp, CCTV, Air Quality Sensor, Wifi Router, Solar Panel, Panic Button, LCD Display, Phone Charging Station, Smart BIN etc. can be considered.