ICS 27.100
P 62
Record No. J1178—2011

DL

Electric Power Industry Standard of the People's Republic of China

P DL / T 5254 — 2010

# Technical Regulation of Design for Steel Tubular Tower Structures of Overhead Transmission Line

Issue Date: January 9, 2011 Implementation Date: May 1, 2011

Issued by the National Energy Administration of the People's Republic of China

**图书在版编目（CIP）数据**

架空输电线路钢管塔设计技术规定=Technical regulation of design for steel tubular tower structures of overhead transmission line: DL/T 5254—2010：英文 / 国家能源局发布. —北京：中国电力出版社，2014.5

ISBN 978-7-5123-5579-8

Ⅰ. ①架… Ⅱ. ①国… Ⅲ. ①架空线路–输电线路–线路杆塔–结构设计–技术规范–中国–英文 Ⅳ. ①TM753–65

中国版本图书馆 CIP 数据核字（2014）第 035139 号

中国电力出版社出版

（北京市东城区北京站西街 19 号 100005 http://www.cepp.sgcc.com.cn）

北京博图彩色印刷有限公司印刷

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2014 年 5 月第一版 2014 年 5 月北京第一次印刷

850 毫米×1168 毫米 32 开本 2.875 印张 70 千字

# Contents

# Foreword

This regulation is formulated summarizing and integrating the experience in application of new technologies, new processes and new materials emerging in recent years in design, construction and operation of steel tubular tower structures of overhead transmission lines and incorporating the established provisions in GB 50545—2010 *Code for Design of 110 kV–750 kV Overhead Transmission Line* and DL/T 5124—2002 *Technical Regulation of Design for Tower and Pole Structures of Overhead Transmission Line*.

Appendices A and C to this regulation are informative; Appendix B is normative.

This regulation is proposed by China Electricity Council.

This regulation is interpreted and managed by the Technical Committee on Overhead Transmission Line Standardization.

This regulation is mainly prepared by East China Electric Power Design Institute.

Organizations which participate in the drafting include China Power Engineering Consulting Group Corporation, China Electric Power Research Institute, Weifang Chang'an Steel Tower Co., Ltd., Changshu Fengfan Power Equipment Co., Ltd. and Zhejiang Shengda Steel Tower Co., Ltd.

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Any opinions and suggestions raised during the implementation of this regulation are to be referred to the Standardization Center of China Electricity Council at the following address: No. 1 Ertiao Lane, Baiguang Road, Xuanwu District, Beijing, 100761 China.

# 1 Scope

This regulation specifies the basic principles and relevant methods for the design of steel tubular tower structures of overhead transmission lines.

This regulation applies to the design of newly-built steel tubular tower structures of 110 kV–750 kV overhead transmission line.

The renovation and expansion of transmission lines in operation can be performed according to the specific situation and operation experience in reference to relevant provisions in this regulation.

# 2 Normative References

The following references are essential to the application of this regulation. For dated references, only the edition cited applies to this regulation. For undated references, the latest editions (including all amendments) apply to this regulation.

GB 1200 *Zinc-Coated Steel Wire Stands*

GB 1300 *Steel Wire for Melt Welding*

GB/T 3098.1 *Mechanical Properties of Fasteners-Bolts, Screws and Studs*

GB/T 3098.2 *Mechanical Properties of Fasteners-Nuts Coarse Thread*

GB/T 5313 *Steel Plates with Through-Thickness Characteristics*

GB 50009—2001 *Load Code for the Design of Building Structures* (2006)

GB 50017—2003 *Code for Design of Steel Structures*

GB 50135—2006 *Code for Design of High-rising Structures*

GB 50205—2001 *Code for Acceptance of Construction Quality of Steel Structures*

GB 50545—2010 *Code for Design of 110 kV–750 kV Overhead Transmission Line*

GB/T 699 *Quality Carbon Structural Steels*

GB/T 700 *Carbon Structural Steels*

GB/T 1591 *Low Alloy Structural Steels*

GB/T 3077 *Alloy Structural Steels*

GB/T 5117 *Carbon Steel Covered Electrodes*

GB/T 5118 *Low Alloy Steel Covered Electrodes*

GB/T 5293 *Carbon Steel Electrodes and Fluxes for Submerged Arc Welding*

GB/T 12470 *Fluxes for Submerged Arc Welding of Low Alloy Steel*

JGJ 81—2002 *Technical Specification for Welding of Steel Structure of Building*

DL/T 646—2006 *Manufacturing Technical Requirements for Transmission and Substation and Steel Tubular Structures*

DL/T 764.4—2002 *Cold Forging Hot Dip Galvanizing Bolt and Nut for Tower and Hardware of Transmission Lines*

DL/T 5154—2002 *Technical Regulation of Design for Tower and Pole Structures for Overhead Transmission Line*

DL/T 5440—2009 *Technical Code for Designing of Overhead Transmission Line in Medium & Heavy Icing Area*

CECS 236: 2008 *Technical Specification for Steel Communication Monopole*

# 3 Terms and Symbols

The following terms and symbols apply to this regulation.

## 3.1 Terms

3.1.1

**Steel tubular tower**

A spatial tower structure with main members of its body composed of steel tubular members and other members composed of steel tubes, steel round bars, profiled steel or guys.

3.1.2

**Stub**

A steel tubular element used to connect the leg of a steel tubular tower with the foundation. The upper part of it connects to main leg of tower, and the lower end is buried in the chimney of foundation.

3.1.3

**Unequal leg extension**

Legs of different lengths designed to accommodate the differences of elevation between legs.

3.1.4

**Seamless steel tubes**

Steel tubes formed by hot rolling without welds in their walls.

3.1.5

**Steel pipes with a longitudinal weld**

Steel pipes with a longitudinal weld manufactured by means of electric resistance welding (ERW) or submerged arc welding (SAW).

3.1.6

**Type of flange**

Stiffened flange—a type of flange, the flat face flange plate of which is connected to the steel pipe with additional stiffeners through T-type weld connection, also known as rigid flange.

Non-stiffened flange—a type of flange, the flat face flange plate of which is connected to the steel pipe only with the inside and outside circular welds, also known as flexible flange.

Welding neck flange–a type of flange with hubbed flange plate and connected to the steel pipe through circular butt welds.

## 3.2 Symbols

$A$—outline area of steel tubular tower or gross cross-sectional area of member;

$A_s$—calculated projected area of wind pressure bearing parts of member;

$A_n$—net cross-sectional area of member;

$A_{nu}$—net cross-sectional area of single-limb of latticed member;

$A_u$—gross cross-sectional area of single-limb of latticed member;

$A_I$—calculated value of wind pressure bearing area of insulator string;

$a$—width of windward area of steel tubular tower; distance between centers of batten plate;

$B$—wind load amplified factor of member when coated with ice;

$BR$—effective bending radius;

$b$—distance between windward area and leeward area;

$C$—specified limit for crack width or deformation of structure or member, or distance from the neutral axis to the design point;

$C_X$, $C_Y$—distance from the neutral axis to the projections of design point on axis $X$ and axis $Y$;

$C/J$—parameter used for determining the maximum torsional shear stress;

$D$—average diameter of the section of round members;

$D_0$—outside diameter of round tube, outside diameter of circle or the distance between the outside sides of corresponding sides of polygon;

$d$—outside diameter of conductors or ground wires, or their calculated outside diameter when coated with ice (for a bundled conductor, its outside diameter shall be the sum of outside diameters of all sub-conductors), or diameter of bolt shank, member with round section, outside diameter of main tube of steel tube;

$d_i$—outside diameter of branch of steel tubes;

$d_e$—effective diameter of bolts or anchor bolts at the thread;

$e$—Eccentricity;

$E$—Elastic factor of steel;

$f$—Design value of strength of steel or design value of tensile strength of bolts or anchor bolts;

$f_c^W$, $f_t^W$—Design value of compressive strength and tensile strength of butt welds;

$f_f^W$—design value of strength of fillet welds;

$f_v^b$, $f_c^b$—design value of shear strength of bolts and compressive strength of members;

$f_t^b$, $f_t^a$—design value of tensile strength of bolts and anchor bolts;

$f_y$—yield strength of steel;

$f_u$—tensile strength of steel;

$f_v$—design value of shear strength of steel;

$G$—shear modulus of steel;

$G_K$—characteristic value of permanent load;

$H$—total height of steel tubular tower;

$h$—height from the ground surface to the calculated point of steel tubular tower;

$h_e$—effective thickness of fillet weld;

$h_f$—weld leg size of fillet weld;

$I_X$, $I_Y$—moment of inertia about axis $X$ and axis $Y$;

$J$—polar moment of inertia of polygon or round section;

$K$—correction factor of slenderness ratio of member;

$K_\lambda$—equivalent slenderness ratio of member;

$L_0$—calculated length of member;

$L_p$—wind span of tower;

$L_W$—calculated length of weld;

$M$—design value of moment;

$M_{max}$—maximum moment in flange plate;

$M_X$, $M_Y$—section moment about axis $X$ and axis $Y$;

$m$—reduction factor of member strength due to eccentricity;

$m_N$—reduction factor of stability strength of compression members;

$m_M$—reduction factor of stability strength of member in bending;

$N$—design value of axial tension or compression;

$N_{tmax}^{b}$—tension on the bolt on flange subject to maximum tension;

$N_{cX}^{pj}$, $N_{tX}^{pj}$, $N_{cT}^{pj}$, $N_{tT}^{pj}$, $N_{cK}^{pj}$, $N_{tK}^{pj}$, $N_{cTT}^{pj}$, $N_{tTT}^{pj}$, $N_{cKK}^{pj}$,

$N_{tKK}^{pj}$—design value of bearing capacity at main pipe joint during the calculation for intersecting welding of steel pipes;

$N_{EX}$—Euler's critical load;

$N_V$, $N_t$—shear or tension borne by each bolt;

$N_t^a$—design value of tension bearing capacity of each anchor bolt;

$N_v^b$, $N_t^b$, $N_c^b$—design value of shear bearing load, tension bearing load or compression bearing load of each bolt;

$n$—the number of bolts, number of single limbs on section of a built-up member;

$N_m$—the axial force in single limb of a built-up member due to section moment;

$n_v$—the number of shear bearing planes;

$Q_{ik}$—characteristic value of the $i^{th}$ variable load;

$Q/I_t$—parameter used for determining the maximum bending shear stress;

$q$—load uniformly distributed on flange;

$R$—design value of resistance of structural member;

$R_f$—jacking force between flanges;

$r$—gyration radius;

$r_2$—radius of the outside wall of steel tube;

$S$—distance between axial lines of limbs of built-up member, distance between bolts;

$S_{GK}$—effect of characteristic value of permanent load;

$S_{QiK}$—effect of characteristic value of the $i^{th}$ variable load;

$S_{GE}$—effect of representative value of gravity load;

$S_{Ehk}$—effect of characteristic value of horizontal seismic action;

$S_{EVK}$—effect of characteristic value of vertical seismic action;

$S_{EQK}$—effect of representative value of the variable load of tensions of conductor and shield wire;

$S_{wk}$—effect of characteristic value of wind load in seismic calculation;

$T$—tension or moment of torsion;

$t$—thickness of member;

$V$—speed of wind and shear force at reference height;

$V_1$—shear force distributed on one batten plate;

$V_{cr}$—critical wind speed for vibration starting of steel tube member;

$W_{1x}$—bending modulus of gross cross section;

$W_I$—characteristic value of wind load of insulator strings;

$W_n$—bending modulus of net cross section of members;

$W_o$—characteristic value of reference wind pressure;

$W_s$—characteristic value of tower wind load;

$W_{sa}$, $W_{sb}$—characteristic value of wind load on tower when wind is perpendicular to the side and front of the tower;

$W_{sc}$—characteristic value of wind load on cross arm when wind is perpendicular to the front of it;

$W_X$—characteristic value of horizontal wind load perpendicular to the direction of conductor and shield wire or bending modulus of section relative to axis $X$;

$W_Y$—bending modulus of section relative to axis $Y$;

$Y_i$—distance from the center of bolt to the rotating axis;

$Y_1$—distance from the center of bolt subject to the maximum force to the rotating axis;

$\alpha$—uneven factor of wind pressure or angle between axis $X$ and vertex angle of polygon;

$\beta_c$—adjustment factor of wind load applied on conductors and shield wires of 500 kV and 750 kV power lines;

$\beta_f$—amplification factor of design strength of front fillet weld;

$\beta_z$—adjustment factor of wind load applied on steel tubular tower;

$\beta_{mx}$—equivalent moment factor of member in the action plane of the moment;

$\theta$—angle between the wind direction and conductor or shield wire, degree; or central angle between two bolts, radian;

$\theta_i$—angle between the axis line of branch tube and the axis line of main tube;

$\eta$—load reduction factor of leeward side of steel tubular tower;

$\mu_s$—shape factor of members of steel tubular tower;

$\mu_{SC}$—shape factor of conductor or shield wire;

$\mu_z$—factor of wind pressure change as a function of elevation;

$\sigma$—normal stress in weld;

$\tau$—shearing stress in weld;

$\sigma_f$—stress perpendicular to the length direction of weld;

$\tau_f$—shearing stress in the length direction of weld;

$\psi$—combination factor of variable loads;

$\psi_{VE}$—combination factor for wind load in seismic basic combination;

$\psi_h$, $\psi_d$, $\psi_a$—parameter used for calculating the bearing capacity at the intersecting welded joints of steel tube;

$\phi$—stability factor of axially compressive member;

$\delta$—thickness of flange or specified limits for deformation;

$\delta_5$—tensile elongation rate of steel;

$\gamma_0$—importance factor of steel tubular tower;

$\gamma_G$—partial factor of permanent load;

$\gamma_{Qi}$—partial factor for the $i^{th}$ variable load;

$\gamma_{EG}$—partial factor for gravity loads;

$\gamma_{Eh}$, $\gamma_{EV}$—partial factor for horizontal and vertical seismic action;

$\gamma_{EQ}$—comprehensive partial factor for variable loads of tension of conductor and shield wire;

$\gamma_{RE}$—adjustment factor for seismic capacity.

# 4 General

4.0.1 This regulation is prepared based on the design principles given in GB 50545—2010.

4.0.2 Limit state design method based on probability theory is adopted in the design of steel tubular tower structures of overhead transmission lines, and reliability of structures is measured by reliability index. Requirements for safe operation of transmission line are satisfied under specified load combinations or limit condition of various deformations or cracks.

4.0.3 The design should be in compliance with the national capital construction strategy and technical and economic policies, and be safe, reliable, economic and environmentally friendly.

4.0.4 In design, new technologies, materials, processes and structure types shall be adopted and promoted actively and prudently in line with the actual conditions and in combination with regional characteristics. When practical experience is insufficient, they shall be proven by tests before application.

4.0.5 In design, the current relevant national standards and industrial standards must also be complied with in addition to this regulation.

# 5 Loads

## 5.1 General Provisions

5.1.1 Load types:

1 Permanent load: gravity load of conductor, shield wire, insulator (and its accessories), steel tubular tower structures, various fixtures, foundation and earthwork; load of initial tension of guys or towlines, soil compression and pre-stress.

2 Variable load: wind and ice (snow) load; tension of conductor, shield wire, and guy; additional loads during installation and maintenance; secondary load due to deformation and vibration loads.

5.1.2 Direction of load action:

1 Loads acting on a steel tubular tower are classified as transverse load, longitudinal load and vertical load.

2 Wind load on a steel tubular tower shall be calculated based on the following wind directions.

1) For suspension towers, wind direction of three basic wind speeds with an angle of 0°, 45° (or 60°) and 90° to the axis of the line direction shall be calculated;

2) For tension towers, in addition to 90° wind direction, the necessity of loads from other wind directions shall be comprehensively determined according to their deviation angles, tower heights, cross arms and conductors;

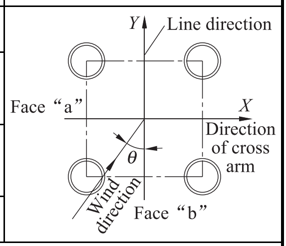
3) For terminal towers, in addition to 90° wind direction, the adverse condition of 0° wind direction shall also be calculated;

4) For suspension angle towers and minor angle tension towers, the wind direction opposite to the lateral component of tension of conductors and shield wires shall be considered;

5) For special towers (such as branching towers), the most adverse wind direction shall be determined according to the actual conditions.

5.1.3 While the wind direction has an angle to the direction of conductor, shield wire or tower, the component of wind loads on conductors and shield wires perpendicular to or along the line directions and the components of wind loads on tower and cross arms in two directions perpendicular to the tower can be determined according to Table 5.1.3.

**Table 5.1.3 Distribution of wind load due to angle winds**

| Wind Angle $\theta$ (°) | Wind Load on Line | | Wind Load on Tower | | Wind Load on Horizontal Cross Arms | | Remarks |
|---|---|---|---|---|---|---|---|
| | $X$ | $Y$ | $X$ | $Y$ | $X$ | $Y$ | |
| 0 | 0 | $0.25W_X$ | 0 | $W_{sb}$ | 0 | $W_{sc}$ |  |
| 45 | $0.5W_X$ | $0.15W_X$ | $0.424\times(W_{sa}+W_{sb})$ | $0.424\times(W_{sa}+W_{sb})$ | $0.4W_{sc}$ | $0.7W_{sc}$ | |
| 60 | $0.75W_X$ | 0 | $0.747W_{sa}+0.249W_{sb}$ | $0.431W_{sa}+0.144W_{sb}$ | $0.4W_{sc}$ | $0.7W_{sc}$ | |
| 90 | $W_X$ | 0 | $W_{sa}$ | 0 | $0.4W_{sc}$ | 0 | |

Notes: 1. $X$, $Y$ stand for the components of wind load perpendicular to and along the conductor and shield wire directions respectively;

2. $W_X$ is the characteristic value of wind load on conductors and shield wires when wind is perpendicular to the conductors and shield wires. $W_X$ can be calculated using formula 5.8-1;

3. $W_{sa}$, $W_{sb}$ are the characteristic values of wind load on tower when the wind is perpendicular to face "a" and face "b". They can be calculated using formula 5.7-1;

4. $W_{sc}$ is the characteristic value of wind load on the cross arms when the wind is perpendicular to them. It can be calculated using formula 5.7-1.

5.1.4 For each kind of steel tubular tower, the load combination shall be calculated under normal operation, line breakage (including unbalanced longitudinal tension when bundle conductor is used), uneven ice coating and installation. If necessary, rare conditions such as earthquake shall be checked.

5.1.5 In calculation for curved steel tubular tower, the adverse condition of non-simultaneous occurrence of maximum wind speed along the direction of tower height shall be considered.

5.1.6 For conical member and cylinder steel tube member with an outer wall slope less than 2%, lateral aeolian vibration effect shall be considered; when necessary, appropriate protection measures shall be adopted.

5.1.7 For various towers, the breakage tension (or longitudinal unbalanced tension) under line breakage condition and unbalanced tension under uneven ice coating shall be calculated on basis of static load.

5.1.8 For reinforced towers against consecutive collapse, in addition to calculations based on the conditions for conventional suspension towers, the condition that line breakage tension (or unbalanced tension) occurs on the same side of all conductors/shield wires shall be considered. The line breakage tension (or unbalanced tension) shall be taken from Table 5.3.3.

5.1.9 In this regulation, only the ice coating load on conductors in light ice areas with a design ice thickness of 10 mm and below is considered. For a design ice thickness above 10 mm, the requirements of DL/T 5440—2009 shall be met.

## 5.2 Normal Operation

5.2.1 The following load combinations shall be calculated under normal operation of various kinds of steel tubular towers:

1 Basic wind speed, no ice, and no line breakage (including combination of minimum vertical load and maximum lateral load);

2 Design ice coating, corresponding wind speed and temperature, and no line breakage;

3 Lowest temperature, no ice, no wind, and no line breakage (applicable to terminal and angle towers).

## 5.3 Line Breakage

5.3.1 The following load combinations shall be calculated for line breakage (including unbalanced longitudinal tension when bundle conductor is used) of suspension tower (excluding large crossing transmission towers) based on the meteorological conditions of –5℃, with ice and no wind:

1 Single-circuit tower: any conductor breaks (or any phase of conductor is subject to unbalanced tension) and no shield wire breaks; or, any shield wire breaks and no conductor breaks.

2 Double-circuit tower: in the same span, any two conductors break (or any two phases of conductor are subject to unbalanced tension); or, any shield wire breaks and any conductor breaks (or any phase of conductor is subject to unbalanced tension).

3 Multi-circuit tower: in the same span, any three conductors break (or any three phases of conductor are subject to unbalanced tension); or, any shield wire breaks and any two conductors break (or any two phases of conductor are subject to unbalanced tension).

5.3.2 The following load combinations shall be calculated for line breakage (including unbalanced longitudinal tension when bundle conductor is used) of tension tower based on the meteorological conditions of –5℃, with ice and no wind:

1 Single-circuit tower and double-circuit tower: in the same span, two shield wires break and no conductor breaks; or, any shield wire breaks and any conductor breaks (or any phase of conductor is subject to unbalanced longitudinal tension); any two conductors break (or any two phases of conductor are subject to unbalanced longitudinal tension) and no shield wire breaks.

2 Multi-circuit tower: in the same span, two shield wires break and any conductor breaks; or, any shield wire breaks and any two conductors break (or any two phases of conductor are subject to unbalanced longitudinal tension); any three conductors break (or any three phases of conductor are subject to unbalanced longitudinal tension) and no shield wire breaks.

5.3.3 For conductors and shield wires in areas where the ice coating thickness is 10 mm or less, the breakage tension or unbalanced tension shall be no lower than the values in Table 5.3.3 and the vertical load shall be taken as 100% of the design ice coating load.

**Table 5.3.3 Breaking tension (or unbalanced longitudinal tension of bundle conductor) for conductors and shield wires in areas where the ice coating thickness is 10 mm or less, %**

| Breaking Tension or Unbalanced Longitudinal Tension of Bundle Conductor (Percentage of The Maximum Working Tension) | | | | | | |
|---|---|---|---|---|---|---|
| Landform | Shield wires | Suspension tower conductor | | | Tension tower conductor | |
| | | Single conductor | Double bundle conductor | More than double bundle conductor | Single conductor | Double and more bundle conductor |
| Flat and hilly areas | 100 | 50 | 25 | 20 | 100 | 70 |
| Mountainous ground | 100 | 50 | 30 | 25 | 100 | 70 |

## 5.4 Uneven Ice Coating

5.4.1 For various steel tubular towers with uneven ice coating in 10 mm icing areas, the uneven tension that occurs simultaneously on all the conductors and shield wires in the same direction, which causes the load combination with maximum moment on the steel tubular towers shall be calculated. Under the meteorological conditions of –5℃, with uneven ice and 10 m/s wind speed, the uneven tension shall not be lower than the corresponding values in Table 5.4.1. The vertical load is calculated as not less than 75% of the design ice coating load.

**Table 5.4.1 Unbalanced tension of conductors and shield wire with uneven ice coating, %**

| Unbalanced Tension of Conductors and Shield wire with Uneven Ice Coating (Percentage of The Maximum Working Tension) | | | |
|---|---|---|---|
| Suspension towers | | Tension towers | |
| Conductor | Shield wire | Conductor | Shield wire |
| 10 | 20 | 30 | 40 |

5.4.2 For various steel tubular towers in 5 mm icing areas and ice free areas, the calculation of uneven ice coating can be ignored.

## 5.5 Installation

5.5.1 For installation of various steel tubular towers, the following load combinations shall be considered under condition of 10 m/s wind speed, no ice and corresponding temperature:

1 Installation loads of suspension tower:

1) Load caused by lifting of conductor, shield wire and accessories. This load comprises weight of conductor,

shield wire, insulator and hardware fittings (generally considered on basis of 2.0 times), and the additional weight of installation stuff and related tools. A dynamic coefficient of 1.1 shall be considered during lifting. Additional load can be chosen from Table 5.5.1.

**Table 5.5.1 Characteristic value of additional load, kN**

| Voltage, kV | Conductor | | Shield Wires | |
|---|---|---|---|---|
| | Suspension towers | Tension towers | Suspension towers | Tension towers |
| 110 | 1.5 | 2.0 | 1.0 | 1.5 |
| 220–330 | 3.5 | 4.5 | 2.0 | 2.0 |
| 500–750 | 4.0 | 6.0 | 2.0 | 2.0 |

2) Load caused by anchoring conductors and shield wires. The anchorage cable shall have an angle of not larger than 20° to the ground. A dynamic coefficient of 1.1 shall be considered for the tension of the phase being anchored. The vertical load at hanging point is the sum of vertical component of tension of anchorage cable, gravity load of conductors and shield wires and additional load. The unbalanced longitudinal tension is respectively the difference between the tension of conductor/shield wire and the longitudinal component of tension of anchorage cable.

2 Installation loads of tension towers:

1) Load brought by conductor and shield wire:

Tower for anchorage: during anchoring of shield wire, conductors and shield wires of adjacent spans are not erected; during anchoring of conductor, shield wires within the same span have been erected.

Tower for carrying out stringing: during stringing shield wire, shield wires of adjacent spans have or have not been erected, and conductors within the same span have not been erected; during stringing conductors, shield wires within the same span have been erected, and conductors of adjacent spans have or have not been erected.

2) Load brought by temporary guy:

Temporary guy, with an included angle not greater than 45° to the ground, and the direction along that of the conductor and shield wire, can be considered for anchor tower and stringing tower, and the tension of temporary guy can be considered as 30% of tension of conductor and shield wire. For quad bundle conductors, the maximum balanced tension of temporary guy is considered to be the standard value of 30 kN; for six and above bundle conductors, the maximum balanced tension of temporary guy is considered to be the standard value of 40 kN. For the temporary guy of shield wire, the maximum balanced tension is considered to be the standard value of 5 kN.

3) Load produced by stringing traction rope:

The angle between the stringing traction rope and ground is taken as not larger than 20°. In calculation of stringing tension, factors such as initial elongation of conductor and shield wire, construction error and excessive traction shall be considered.

4) Additional load during installation:
See Table 5.5.1.

5.5.2 Conductors and shield wires shall be sequentially erected phase-by-phase in a top-down order. The erection of tower with double and multiple circuits may be performed in phases in accordance with actual requirements.

5.5.3 Steel tubular members which have an angle not greater than 30° to the ground and are accessible to human shall bear a design load of 1,000 N. This load is not combined with other loads.

5.5.4 For terminal towers, the conditions with the conductor and shield wire on the substation (booster station) side erected or not erected shall be considered.

## 5.6 Checking

5.6.1 For various steel tubular towers located in areas with seismic fortification intensity M9 or above, seismic checking shall be carried out. Conditions for checking: with wind, without ice and line breakage.

5.6.2 The checking of ice coating load for various steel tubular towers is performed based on ice thickness, temperature at –5℃, with wind and without line breakage, taking into account the unbalanced tension of conductors and shield wires caused by elevation difference of tower location and span difference.

## 5.7 Characteristic Value of Tower Wind Load

The characteristic value of wind load applied on steel tubular towers shall be calculated as follows:

$$W_s = W_o \mu_z \mu_s \beta_z B A_s \quad (5.7\text{-}1)$$

$$W_o = V^2 / 1600 \quad (5.7\text{-}2)$$

Where,

$W_s$—characteristic value of wind load on tower, kN;

$W_o$—characteristic value of reference wind pressure, kN/m$^2$, which shall be calculated based on the wind speed V at reference height;

$\mu_z$—altitude variation coefficient of wind pressure; $\mu_z$ at reference height of 10 m shall be determined based on Table 5.7-1;

$\mu_s$—shape factor of structural member [for the tower composed of shaped steel members (like angle steel, channel steel, I-shaped steel and square steel), $\mu_s$ is taken as $1.3(1+\eta)$; for the tower composed of members with circular section, when $\mu_z W_o d^2 \leqslant 0.003$, $\mu_s$ equals the $\mu_s$ value of tower composed of shaped steel members multiplied by 0.8; when $\mu_z W_o d^2 \geqslant 0.021$, $\mu_s$ equals the $\mu_s$ value of tower composed of shaped steel members multiplied by 0.6; when $0.003 \leqslant \mu_z W_o d^2 \leqslant 0.021$, $\mu_s$ is calculated with method of interpolation];

$d$—diameter of members with circular section, m;

$\eta$—load reduction factor for the lee side of tower which can be determined according to Table 5.7-2;

$\beta_z$—adjustment factor of wind load applied on steel tubular tower (for towers with the overall tower height not exceeding 60 m, it shall be selected as per Table 5.7-3. In the case that the overall tower height exceeds 60 m, it shall be increased section by section from bottom to top according to the current national standard GB 50009—2001 *Load Code for the Design of Building Structures*, but the weighted average shall not be lower than 1.6. For foundation of the tower with height not exceeding 60m, it shall be 1.0; for foundation of the tower with height exceeding 60 m, it shall be increased section by section from bottom to top, but the weighted average shall not be lower than 1.3.);

*B*—amplified factor for wind load when the tower is coated with ice (1.1 for 5 mm icing area, 1.2 for 10 mm icing area);

$A_s$—calculated projected area of the wind pressure bearing parts of members, $m^2$;

*V*—wind speed at the reference height, m/s.

**Table 5.7-1 Height variation coefficient of wind pressure $\mu_z$**

| Height above Ground or Sea Level, m | Class of Terrain Roughness | | | |
|---|---|---|---|---|
| | A | B | C | D |
| 5 | 1.17 | 1.00 | 0.74 | 0.62 |
| 10 | 1.38 | 1.00 | 0.74 | 0.62 |
| 15 | 1.52 | 1.14 | 0.74 | 0.62 |
| 20 | 1.63 | 1.25 | 0.84 | 0.62 |
| 30 | 1.80 | 1.42 | 1.00 | 0.62 |
| 40 | 1.92 | 1.56 | 1.13 | 0.73 |
| 50 | 2.03 | 1.67 | 1.25 | 0.84 |
| 60 | 2.12 | 1.77 | 1.35 | 0.93 |
| 70 | 2.20 | 1.86 | 1.45 | 1.02 |
| 80 | 2.27 | 1.95 | 1.54 | 1.11 |
| 90 | 2.34 | 2.02 | 1.62 | 1.19 |
| 100 | 2.40 | 2.09 | 1.70 | 1.27 |
| 150 | 2.64 | 2.38 | 2.03 | 1.61 |
| 200 | 2.83 | 2.61 | 2.30 | 1.92 |

**Table 5.7-1** (continued)

| Height above Ground or Sea Level, m | Class of Terrain Roughness | | | |
|---|---|---|---|---|
| | A | B | C | D |
| 250 | 2.99 | 2.80 | 2.54 | 2.19 |
| 300 | 3.12 | 2.97 | 2.75 | 2.45 |
| 350 | 3.12 | 3.12 | 2.94 | 2.68 |
| 400 | 3.12 | 3.12 | 3.12 | 2.91 |
| ⩾450 | 3.12 | 3.12 | 3.12 | 3.12 |

Notes: class of terrain roughness:
A: offshore sea surface, sea islands, seashore areas, lakeshore areas and desert regions;
B: fields, country areas, jungles, hills and towns and suburban areas where houses are sparse;
C: downtown area of cities where dense building complexes are built;
D: downtown areas of cities where dense and high building complexes are built.

**Table 5.7-2 Wind load reduction factor of lee side of steel tubular tower $\eta$**

| $b/a$ \ $A_s/A$ | ⩽0.1 | 0.2 | 0.3 | 0.4 | ⩾0.5 |
|---|---|---|---|---|---|
| ⩽1 | 1.0 | 0.85 | 0.69 | 0.54 | 0.39 |
| 2 | 1.0 | 0.92 | 0.77 | 0.62 | 0.46 |

Notes: 1. $A$—outline area of steel tubular tower; $a$—width of windward side of steel tubular tower; $b$—distance between the windward side and lee side of steel tubular tower.
2. Intermediate values can be calculated with linear interpolation method.

**Table 5.7-3 Adjustment coefficient of tower wind load (for tower only)**

| Total Height of Tower $H$, m | 20 | 30 | 40 | 50 | 60 |
|---|---|---|---|---|---|
| $\beta_z$ | 1.0 | 1.25 | 1.35 | 1.5 | 1.6 |

Notes: 1. Intermediate values can be calculated with linear interpolation method.
2. The values in this table are applicable to towers with the ratio of height to base width ranging from four to six.

## 5.8 Characteristic Value of Wind Load on Conductor and Shield wire

The characteristic value of wind load applied on conductors and shield wires shall be calculated as follows:

$$W_X = \alpha W_o \mu_z \mu_{SC} \beta_c d L_p B_2 \sin^2 \theta \qquad (5.8\text{-}1)$$

Where,

$W_X$—characteristic value of horizontal wind load perpendicular to direction of conductors and shield wires, kN;

$\alpha$—uneven coefficient of wind pressure, which shall be determined based on the design reference wind speed in accordance with Table 5.8-1 and Table 5.8-2;

$\beta_c$—adjustment coefficient of wind load of the conductor and shield wire for 500 kV and 750 kV transmission lines, only used for calculating the wind load of conductor and shield wire imposed on towers (excluding the tension sag and wind deflection angle calculation of conductor and shield wire). It shall be determined in accordance with the requirements of Table 5.8-1. The $\beta_c$ of lines with other voltage classes shall be 1.0.

$\mu_{SC}$—shape factor of conductor or shield wire, which shall be 1.2 when the wire is less than 17 mm in diameter or is coated with ice (regardless of diameter), and shall be 1.1 when wire diameter is no lower than 17 mm.

$d$—outer diameter of conductors or shield wires, or their calculated outer diameter when coated with ice. For a bundle conductor, its outer diameter shall be the sum of outer diameters of all sub-conductors, m;

$L_p$—wind span of towers, m;

$B_2$—increasing coefficient of wind load applied on members when the tower is coated with ice (1.1 for 5 mm icing areas, 1.2 for 10 mm icing areas);

$\theta$—angle between the wind direction and that of conductors or shield wires, degree, (°).

**Table 5.8-1 Wind pressure uneven coefficient $\alpha$ and wind load adjustment coefficient $\beta$ for conductor and shield wire**

| Wind Speed $V$, m/s | | ≤20 | 20≤V<27 | 27≤V<31.5 | ≥31.5 |
|---|---|---|---|---|---|
| $\alpha$ | calculating load on steel tubular tower | 1.00 | 0.85 | 0.75 | 0.70 |
| | designing steel tubular tower (used in calculating wind deflection angle) | 1.00 | 0.75 | 0.61 | 0.61 |
| $\beta_c$ | Calculating load on 500 kV, 750 kV steel tubular towers | 1.00 | 1.10 | 1.20 | 1.30 |
| Note: In calculation of wires with small spans, such as jumpers, $\alpha$ should be 1.0. | | | | | |

When checking the electrical clearance of steel tubular towers, the value of wind pressure uneven coefficient $\alpha$ changing with wind span can be looked up in Table 5.8-2.

**Table 5.8-2 Value of wind pressure uneven coefficient $\alpha$ changing with wind span**

| Wind span, m | ≤200 | 250 | 300 | 350 | 400 | 450 | 500 | ≥550 |
|---|---|---|---|---|---|---|---|---|
| $\alpha$ | 0.80 | 0.74 | 0.70 | 0.67 | 0.65 | 0.63 | 0.62 | 0.61 |

## 5.9 Characteristic Value of Wind Load of Insulator String

The characteristic value of wind load applied on insulator string shall be calculated as follows:

$$W_I = W_o \mu_z B_3 A_I \qquad (5.9\text{-}1)$$

Where,

$W_I$—characteristic value of wind load of insulator string, kN;

$A_I$—calculated value of wind pressure bearing area of insulator string, $m^2$;

$B_3$—coefficient for wind load increase of insulator string when the string is coated with ice, 1.1 for 5 mm icing areas and 1.2 for 10 mm icing areas.

# 6 Materials

6.0.1 The steel material shall be reasonably selected according to the importance of structure, type of structure, connection type, steel thickness, environment and ambient temperature, etc. Q235, Q345, Q390 and Q420 steel should be used, and Q460 may be used if condition permits. The quality of steel shall meet regulations specified in GB/T 700, GB/T 1591 and GB/T 3077.

6.0.2 The quality of steel shall not be lower than grade B. When steel with thickness of 40 mm or above is used for welding, measures shall be taken to prevent lamellar tearing in steel.

6.0.3 Hot dip galvanizing bolts of grades 4.8, 5.8, 6.8 and 8.8 should be used in structure connection. Bolts of grade 10.9 may be used if condition permits and their material and mechanical properties shall be in compliance with the specifications in GB/T 3098.1 and GB/T 3098.2.

6.0.4 Electrodes for manual welding of steels shall comply with GB/T 5117 and GB/T 5118 and low hydrogen electrodes are preferred.

6.0.5 In automatic welding and semi-automatic welding, solder wire and welding flux suitable for metal strength of the main body shall be used. Measures shall be taken to ensure that the tensile strength of deposited metal is not lower than that of the manual welding electrodes. When steels of different strengths are welded, the welding materials can be selected according to the steel of lower strength and the welding environment can be selected according to the welding process requirements of steel of higher strength. The selection of welding wire and flux shall comply with the regulations in relevant current national standards.

6.0.6 The design strength of steel, bolts and anchorage bolts shall be determined in accordance with Table 6.0.6.

**Table 6.0.6 Design strength of steel, bolts and anchorage bolts, N/mm²**

| Material \ Categories | | Thickness or Diameter, mm | Tensile Strength | Compression Bending Strength | Shearing Strength | Hole Wall Pressure[a] |
|---|---|---|---|---|---|---|
| Steel | Q235 | ≤16 | 215 | 215 | 125 | 370 |
| | | >16–40 | 205 | 205 | 120 | |
| | | >40–60 | 200 | 200 | 115 | |
| | | >60–100 | 190 | 190 | 110 | |
| | Q345 | ≤16 | 310 | 310 | 180 | 510 |
| | | >16–35 | 295 | 295 | 170 | 490 |
| | | >35–50 | 265 | 265 | 155 | 440 |
| | | >50–100 | 250 | 250 | 145 | 415 |
| | Q390 | ≤16 | 350 | 350 | 205 | 530 |
| | | >16–35 | 335 | 335 | 190 | 510 |
| | | >35–50 | 315 | 315 | 180 | 480 |
| | | >50–100 | 295 | 295 | 170 | 450 |
| | Q420 | ≤16 | 380 | 380 | 220 | 560 |
| | | >16–35 | 360 | 360 | 210 | 535 |
| | | >35–50 | 340 | 340 | 195 | 510 |
| | | >50–100 | 325 | 325 | 185 | 480 |
| Galvanized black bolt (Class C) | Class 4.8 | Nominal diameter D≤39 | 200 | — | 170 | Pressure bearing of screw 420 |

**Table** 6.0.6 (continued)

| Material \ Categories | | Thickness or Diameter, mm | Tensile Strength | Compression Bending Strength | Shearing Strength | Hole Wall Pressure[a] | |
|---|---|---|---|---|---|---|---|
| Galvanized black bolt (Class C) | Class 5.8 | Nominal diameter D≤39 | 240 | — | 210 | Pressure bearing of screw | 520 |
| | Class 6.8 | Nominal diameter D≤39 | 300 | — | 240 | | 600 |
| | Class 8.8 | Nominal diameter D≤39 | 400 | — | 300 | | 800 |
| Anchor bolt | Q235 steel | Outer diameter ≥16 | 160 | — | — | — | |
| | Q345 steel | Outer diameter ≥16 | 205 | — | — | — | |
| | #35 high-quality carbon steel | Outer diameter ≥16 | 190 | — | — | — | |
| | #45 high-quality carbon steel | Outer diameter ≥16 | 215 | — | — | — | |

Notes: 1. The design strength of #20 seamless steel tube can be Q235.
2. High-strength bolt of class 8.8 shall have the qualification certificate for tests in class A (plastic property) and class B (strength).

a Applicable when the end to end distance of bolts on the member is greater than 1.5*d* (*d* is the bolt diameter).

6.0.7 The guys shall be stranded galvanized steel wire, the design strength of which shall be determined according to Table 6.0.7.

**Table 6.0.7 Design strength of stranded galvanized steel wire, N/mm²**

| Number of Strands | Standard Value of Tensile Strength of Hot Dipped Galvanized Steel Wire | | | | |
|---|---|---|---|---|---|
| | 1175 | 1270 | 1370 | 1470 | 1570 |
| | Design Tensile Strength of the Whole Stranded Galvanized Steel Wire | | | | |
| 7 strands | 690 | 745 | 800 | 860 | 920 |
| 19 strands | 670 | 720 | 780 | 840 | 900 |

Notes: 1. The design value of tension of the whole stranded galvanized steel wire equals the product of total area and design value of strength.
2. The design value of strength has been taken account into the conversion coefficient: 0.92 for seven strands and 0.9 for 19 strands.

6.0.8 The design weld strength shall be determined according to Table 6.0.8.

**Table 6.0.8 Design weld strength, N/mm²**

| Welding Method and Mode of Electrode | Steel of Members | | Butt Weld | | | | Fillet Weld |
|---|---|---|---|---|---|---|---|
| | Symbols | Thickness or diameter, mm | Compressive strength $f_c^w$ | Tensile strength $f_t^w$ for welds in the following quality grades | | Shear strength $f_v^w$ | Tensile strength, compressive strength and shear strength $f_t^w$ |
| | | | | Grade 1, 2 | Grade 3 | | |
| Automatic welding, semi-automatic welding and manual welding with E43 type electrodes | Q235 steel or #20 steel | ≤16 | 215 | 215 | 185 | 125 | 160 |
| | | >16–40 | 205 | 205 | 175 | 120 | |
| | | >40-60 | 200 | 200 | 170 | 115 | |
| | | >60–100 | 190 | 190 | 160 | 110 | |

**Table** 6.0.8 (continued)

| Welding Method and Mode of Electrode | Steel of Members | | Butt Weld | | | | Fillet Weld |
|---|---|---|---|---|---|---|---|
| | Symbols | Thickness or diameter, mm | Compressive strength $f_c^w$ | Tensile strength $f_t^w$ for welds in the following quality grades | | Shear strength $f_v^w$ | Tensile strength, compressive strength and shear strength $f_t^w$ |
| | | | | Grade 1, 2 | Grade 3 | | |
| Automatic welding, semi-automatic welding and manual welding with E50 type electrodes | Q345 steel | ≤16 | 310 | 310 | 265 | 180 | 200 |
| | | >16–35 | 295 | 295 | 250 | 170 | |
| | | >35–50 | 265 | 265 | 225 | 155 | |
| | | >50–100 | 250 | 250 | 210 | 145 | |
| Automatic welding, semi-automatic welding and manual welding with E55 type electrodes | Q390 steel | ≤16 | 350 | 350 | 300 | 205 | 220 |
| | | >16–35 | 335 | 335 | 285 | 190 | |
| | | >35–50 | 315 | 315 | 270 | 180 | |
| | | >50–100 | 295 | 295 | 250 | 170 | |
| | Q420 steel | ≤16 | 380 | 380 | 320 | 220 | 220 |
| | | >16–35 | 360 | 360 | 305 | 210 | |
| | | >35–50 | 340 | 340 | 290 | 195 | |
| | | >50–100 | 325 | 325 | 275 | 185 | |

Notes: 1. For welding wire and welding flux used in automatic welding and semi-automatic welding, the mechanical properties of their deposited metal shall be not be inferior to those specified in GB/T 5293 and GB/T 12470.

2. The quality grade of welds shall comply with the specifications in GB 50205. For butt welds with a thickness of less than 8 mm, ultrasonic inspection shall not be adopted in determining the quality grade of welds.

3. The design bending strength of butt welds is $f_c^w$ in compression zone and $f_t^w$ in tension zone.

4. The thickness in this table refers to the steel thickness at the design point. For members subject to axial tension and axial compression, the thickness refers to that of the members with thicker sections.

# 7 General Provisions

## 7.1 Provisions for Calculation

7.1.1 Limit state design method based on probability theory shall be adopted in the design of steel tubular tower structures, and the reliability of structures is measured by reliability index. The limit state design expressions are described by characteristic values of load, material properties, geometry parameter as well as a variety of partial coefficients.

7.1.2 The limit state of a structure refers to the critical state in which the structure or members can meet the safe operation requirement under various specified load combinations, or under various limit conditions for deformations or cracks. The limit states may be divided into load-bearing capacity limit state and serviceability limit state.

1 Load-bearing capacity limit state refers to the state when the structure or member reaches the maximum load-bearing capacity or reaches a deformation that it is no longer suitable for bearing loads.

2 Serviceability limit state refers to the state that the deformation or crack of the structure or member reaches the limit value specified for normal service.

7.1.3 Strength, stability and connection strength of a structure or member shall be calculated as per limit state of bearing capacity by adopting design value of load and material strength. Deformation or crack of structure or member shall be calculated as per requests of regular service limit state by adopting characteristic value of load and regular service limit value.

## 7.2 Calculation Expressions for Load-Bearing Capacity and Serviceability limit states

7.2.1 The load-bearing capacity limit states of structures or members shall be calculated with the following expression:

$$\gamma_0\left(\gamma_G S_{GK}+\psi\sum\gamma_{Qi}S_{QiK}\right)\leqslant R \qquad (7.2.1)$$

Where,

$\gamma_0$—importance factor of steel tubular tower structure, not less than 1.1 for important routes, 0.9 for temporary powerlines and 1.0 for other routes;

$\gamma_G$—partial coefficient of permanent load, taken as 1.0 if favorable for load bearing of structure and 1.2 if adverse for load bearing of structure;

$\gamma_{Qi}$—partial coefficient of the $i^{th}$ variable load, can be taken as 1.4;

$S_{GK}$—effect of characteristic value of permanent load;

$S_{QiK}$—effect of characteristic value of the $i^{th}$ variable load;

$\psi$—combination coefficient of variable loads, taken as 1.0 in normal operation, 0.9 in breakage, installation and with uneven ice coating, 0.75 in checking;

$R$—resistance design value for structural members.

7.2.2 The serviceability limit states of structures or members shall be calculated with the following expression:

$$S_{GK}+\psi\sum S_{Qik}\leqslant C \qquad (7.2.2)$$

Where,

$C$—specified limits of crack width or deformation of structures or members, mm.

7.2.3 The seismic checking for load-bearing capacity of structures or members shall be performed with the following expression:

$$\gamma_{EG} S_{GE} + \gamma_{Eh} S_{Ehk} + \gamma_{EV} S_{EVK} + \gamma_{EQ} S_{EQK} + \psi_{VE} S_{wk} \leqslant R / \gamma_{RE} \tag{7.2.3}$$

Where,

$\gamma_{EG}$—partial coefficient of gravity load, taken as 1.0 if favorable for load bearing of structure and 1.2 if adverse for load bearing of structure;

$\gamma_{Eh}$, $\gamma_{EV}$—partial coefficient for horizontal and vertical seismic actions which shall be adopted according to Table 7.2.3.

$\gamma_{EQ}$—comprehensive coefficient for variable loads of tension of conductor and ground wire , $\gamma_{EQ}$ equals 0.5;

$S_{GE}$—effect of representative value of gravity load;

$S_{Ehk}$—effect of characteristic value of horizontal seismic action;

$S_{EVK}$—effect of characteristic value of vertical seismic action;

$S_{EQK}$—effect of representative value of the variable load of tensions of conductor and shield wire;

$S_{wk}$—effect of characteristic value of wind load;

$\psi_{VE}$—combination coefficient for wind load in seismic basic combination, can be taken as 0.3;

$\gamma_{RE}$—adjustment factor for seismic capacity, 0.80 for structural members and 1.00 for welds and bolts.

**Table 7.2.3 Partial coefficient of earthquake action**

| Considering Earthquake Action | | $\gamma_{Eh}$ | $\gamma_{EV}$ |
|---|---|---|---|
| Considering only horizontal earthquake action | | 1.3 | Ignored |
| Considering only vertical earthquake action | | Ignored | 1.3 |
| Considering horizontal and vertical earthquake actions at the same time | when horizontal earthquake action prevails | 1.3 | 0.5 |
| | when vertical earthquake action prevails | 0.5 | 1.3 |

## 7.3 General Provisions for Structures

7.3.1 The deflection of tower (excluding the foundation deflection) calculated under the long-term combination effect (free of ice, wind speed of 5 m/s and annual average ambient temperature) of loads shall not exceed the values in Table 7.3.1.

**Table 7.3.1 Deflection of tower**
**(excluding the foundation deflection and displacement of guy point)**

| Item | Calculated Deflection Limits of Towers |
|---|---|
| Suspension linear towers | $3h/1000$ |
| Suspension angle towers | $5h/1000$ |
| Tension tower and terminal tower | $7h/1000$ |
| Notes: 1. "$h$" is the height from the ground surface to the calculated point;<br>2. Construction pre-deviation requirement shall be proposed in the design as per characteristics of steel tubular tower. | |

7.3.2 Maximum allowable slenderness ratios of structural members are given in Table 7.3.2.

**Table 7.3.2 Maximum allowable slenderness ratio of structural member**

| Item | Maximum Allowable Slenderness Ratio of Structural Member |
|---|---|
| Main compression members | 150 |
| Compression members | 200 |
| Redundant | 250 |
| Tension members (the tension members with pretension are not restricted by slenderness ratio) | 400 |
| Note: Calculation of slenderness ratio shall include the correction coefficient $K$ of slenderness ratio of members. See Appendix B. | |

7.3.3 The inner force for steel tubular towers should be analyzed using a three-dimensional model. Processing drawing of steel tubular tower structures shall be consistent with the calculation model of internal force.

7.3.4 When the length-diameter ratio of main members of steel tubular tower is not less than 12 and that of its bracing members not less than 24, the internal force of tower can be analyzed as the hinged system of space truss. Otherwise, the adverse influence of secondary moment of steel tube caused by the rigidity of joints shall be considered.

7.3.5 The projection of joint supporting provided by the redundant bracing members on the direction perpendicular to the axis of supported members shall not be less than 2% of internal force of supported materials and not less than 5% of internal force of supported bracing members.

7.3.6 Corrosion protection measures such as hot-dip galvanizing or other equivalents shall be provided for iron parts of tower.

7.3.7 For narrow-base steel tubular towers, the non-linear effect caused by deformation shall be considered.

# 8 Member Calculation and Section Selection

## 8.1 Member Calculation

8.1.1 The strength of steel tube subject to axial force shall be calculated using formula 8.1.1:

$$N/A_n \leqslant mf \tag{8.1.1}$$

Where,

$N$—design value of axial tension or axial compression, N;

$A_n$—net sectional area of member, mm$^2$;

$f$—design value of tensile strength of steel, N/mm$^2$;

$m$—reduction coefficient of member strength due to eccentricity: when there is eccentricity, m is taken as 0.85; when there is no eccentricity, m is taken as 1.0.

8.1.2 The stability of steel tube members subject to axial compression shall be calculated using formula 8.1.2:

$$N/(\phi_x A) \leqslant f \tag{8.1.2}$$

Where,

$\phi_x$—stability coefficient of member subject to axial compression, determined according to Appendix B;

$A$—gross cross-sectional area of member, mm$^2$.

8.1.3 The steel tube members subject to bending can be calculated using the following formula:

$$\frac{M_X}{W_X}+\frac{M_Y}{W_Y} \leqslant f \tag{8.1.3}$$

Where,

$M_X$, $M_Y$—design value of bending moment about axes $X$ and $Y$, N • mm;

$W_X$, $W_Y$—Sectional bending modulus in relation to axes $X$ and $Y$, mm$^3$.

8.1.4 The stability of steel tube members subject to compression bending can be calculated using the following formula:

$$\frac{N}{\phi A}+\frac{M}{W}\leqslant f \tag{8.1.4}$$

Where,

$M$—design value of moment, N·mm;

$W$—bending modulus of cross section, mm$^3$.

8.1.5 The steel tube members subject to tension bending shall be calculated using the following formula:

$$\frac{N}{mA_n}+\frac{M}{W_n}\leqslant f \tag{8.1.5}$$

Where,

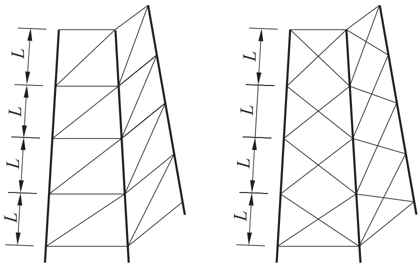
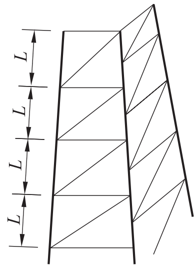
$W_n$—bending modulus of net section of members, mm$^3$.

8.1.6 The vibration critical wind speed ($V_{cr}$) of steel tube members can be calculated based on the slenderness ratio and connection at both ends of steel tube members by referring to Appendix A. The first order vibration critical wind speed shall not be less than 8 m/s.

8.1.7 The selection of calculated length and restraint conditions of members of steel tubular tower shall be determined based on the following principles:

1 The calculated length of main members is selected according to Table 8.1.7-1.

**Table 8.1.7-1 Calculated length of main members**

<table>
<tr><td>No.</td><td>1</td><td>2</td></tr>
<tr><td>Illustration</td><td></td><td></td></tr>
<tr><td>Calculated length</td><td>$L_0 = 1.0L$</td><td>$L_0 = 1.2L$</td></tr>
</table>

2 The calculated length of bracing members or redundant is selected according to Table 8.1.7-2.

**Table 8.1.7-2 Calculated length of bracing members**

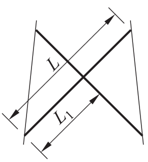
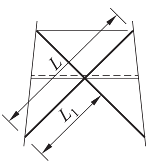
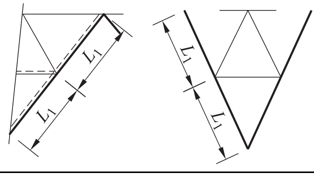
<table>
<tr><td>No.</td><td colspan="2">1. Crossed Bracing Members</td><td>2. Bracing Members of Leg</td></tr>
<tr><td>Illustration</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Calculated length</td><td>One for tension and one for compression: $L_0 = 1.0L_1$ Both for compression: $L_0 = 0.8L$</td><td>One for tension and one for compression or both for compression: $L_0 = 1.0L_1$</td><td rowspan="2">$L_0 = 1.2L_1$</td></tr>
<tr><td colspan="2">Note: with one for tension and one for compression, the ratio between tension and compression is not less than 20%.</td></tr>
</table>

**Table** 8.1.7-2 (continued)

| No. | 1. Crossed Bracing Members | 2 Bracing Members of Leg |
|---|---|---|
| Selection of correction coefficient | 1. When $0 < L_0/r < 120$, No.1 in Table B.2 in Appendix B applies;<br>2. When $120 \leqslant L_0/r \leqslant 220$, and there is no constraint at both ends, No.4 in Table B.2 in Appendix B applies;<br>3. When $120 \leqslant L_0/r \leqslant 231$, and there is a restraint at one end, No.5 in Table B.2 in Appendix B applies;<br>4. When $120 \leqslant L_0/r \leqslant 242$, and there are restraints at both ends, No.6 in Table B.2 in Appendix B applies. | |

3 For intersection welding and cruciform gusset connection, it may be considered that the joints have end restrictions. For U-type, T-type or grooved gusset plate connection, it may be considered that the joints have end restrictions in the plane of bracings, and they have no end restrictions out of the plane of bracings.

## 8.2 Selection of Section

8.2.1 In the selection of cross-section of steel tubes, hot-rolled seamless tube, longitudinally-welded steel tube, or other commonly used types specified in relevant national standards shall be considered as priority. When the diameter of a tube is large, non-standard welded steel tubes rolled or pressed by manufacturers can also be adopted.

8.2.2 When used as bracing members, the ratio between section outside diameter and wall thickness should not exceed 100 ($235/f_y$); when used as main members, considering a certain degree of plastic reserve, it should not exceed 70 ($235/f_y$).

8.2.3 The material of steel tubes should be steel with a yield strength not exceeding 345 N/mm$^2$ and yield ratio not exceeding 0.8. The wall thickness of steel tube should not be larger than 25 mm. Steel tubes made of steel with Q390 and above strength or wall thickness larger than 25 mm can also be used if experience is available.