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Standard for design of steel structures

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Standard for design of steel structures

1 General provisions

1.0.1 To implement the national technical and economic policies in the design of steel structures, to achieve advanced technology, safety and application, economic rationality, and quality assurance, this standard is hereby formulated.

1.0.2 This standard applies to the design of steel structures for industrial & civil buildings as well as general structures.

1.0.3 In addition to complying with this standard, the design of steel structure shall also comply with the provisions of relevant national standards.

2 Terms and symbols

2.1 Terms

2.1.1 Brittle fracture

The sudden fracture of structure or member which does not exhibit a plastic deformation of alarming nature under the tensile stress.

2.1.2 First-order elastic analysis

The establishment of balancing conditions in accordance with the undeformed structure as well as the analysis of structure's internal force and displacement by elastic phases, which does not consider the impacts of the geometric nonlinearity on the structure's internal force and deformation.

2.1.3 Second-order P- Δ elastic analysis

The establishment of balancing conditions in accordance with the displaced structure as well as the analysis of structure's internal force and displacement by elastic phases, which only considers the impacts of the initial overall defect of the structure and the geometric nonlinearity on the structure's internal force and deformation.

2.1.4 direct analysis method of design

The design method of using the overall structural system as an object to perform the second-order nonlinear analysis, which directly considers the factors of initial geometric defects, residual stress, material nonlinearity, joint stiffness and so on that have significant influence on structural stability and strength performance.

2.1.5 Buckling

Another state of significant deformation of the structure, member or steel plate along the direction of weaker stiffness which reaches the critical state of bearing.

2.1.6 Post-buckling strength of steel plate

The capability of steel plate to continuously withstand larger load after it is buckled.

2.1.7 Normalized slenderness ratio

A parameter, of which the value is equal to the square root of the quotient of the bending, shearing or compressive yield strength of the steel AND the

corresponding flexural, shear or compressive elastic buckling stress of the member or steel plate.

2.1.8 Overall stability

The capability of a member or structure to remain stable as a whole under load.

2.1.9 Effective width

When calculating the post-buckling ultimate strength of the steel plate, the resulting reduced width which is obtained by using the uniformly distributed yield strength to equivalent the width of the steel plate which is subject to the non-uniformly distributed ultimate stress.

2.1.10 Effective width factor

The ratio of the effective width to the actual width of the steel plate.

2.1.11 Effective length ratio

Coefficients associated with the buckling mode of the member and the rotational constraints at both ends.

2.1.12 Effective length

The length used to calculate stability, the value of which is equal to the product of the geometric length of the member between its effective constraint points and the effective length ratio.

2.1.13 Slenderness ratio

The ratio of the effective length of the member to the turning radius of the member section.

2.1.14 Equivalent slenderness ratio

In the overall stability calculation of the axially loaded members, in accordance with the principles of equal critical force, the slenderness ratio corresponding to the calculation which converts the lattice members to solid-web members, or the calculation which converts the bending torsional and torsional instability into bending instability calculations.

2.1.15 Nodal bracing force

The lateral force which is used for bracing along the buckling direction of the braced members (or the compressed flange of the member), at the lateral support which is provided to reduce the free length of the compressed member (or the compressed flange of the member).

2.1.16 Unbraced frame

The structure which uses the bending resistance of the joint and the member to resist the load.

2.1.17 Bracing structure

In the plane in which the beam-column members are located, the structure which has the obliquely-arranged bracing member to support the axial stiffness and to resist the lateral load.

2.1.18 Frame-bracing structure

The structure of the anti-lateral force system which is composed of a frame and a bracing.

2.1.19 Frame braced with strong bracing system

In the frame-bracing structure, if the bracing structure (bracing truss, shear wall, cylinder, etc.) has a large lateral stiffness resistance, the frame can be regarded as a frame without lateral displacement.

2.1.20 Leaning column

The column which is designed only to be axially loaded but does not consider the lateral stiffness.

2.1.21 Panel zone

The region of the rigid joints of the frame beam-column and the column webs which are provided with stiffeners or partitions on the upper and lower sides of the beam height range.

2.1.22 Spherical steel bearing

The hinged bearing or movable bearing the steel spherical surface of which can be rotated in any direction at the bearing.

2.1.23 Steel-plate shear wall

A steel plate which is placed between the frame beam-column to withstand the horizontal shear in the frame.

2.1.24 Chord member

In a steel tubular structure member, a tube member which is continuously cut through at the joint, such as a chord in a truss.

2.1.25 Branch member

In a steel tubular structure, a tube member that is disconnected at a joint and connected to a chord member, such as a web member in a truss to connect to a chord member.

2.1.26 Gap joint

A tube joint the two branch members of which depart for a certain distance.

2.1.27 Overlap joint

At the steel-tube joint, the joint where the two branch members overlap each other.

2.1.28 Uniplanar joint

A joint in which the branch member and the chord member are connected to each other in the same plane.

2.1.29 Multiplanar joint

A tube joint formed by connecting a plurality of branch members in different planes to a chord member.

2.1.30 Welded section

A section made of a steel plate (or profile steel) through welding.

2.1.31 Composite steel and concrete beam

A beam which is formed by the concrete flange and steel beam through the shear connections and can be integrally loaded.

2.1.32 Bracing system

An anti-lateral force system which consists of beams (including foundation beams) and columns that support and transmit their internal forces.

2.1.33 Link

In an eccentric bracing frame structure, a beam section which is located between the two oblique bracing ends or a beam section which is located between an oblique bracing end and the column.

2.1.34 Concentrically braced frame

A frame whose oblique bracing intersects with the frame beam-column at one point.

2.1.35 Eccentrically braced frame

4 Material

4.1 Structural steel designations and standards

4.1.1 Steels should be Q235, Q345, Q390, Q420, Q460 and Q345GJ steels. The quality shall comply with the provisions of the current national standards “Carbon structural steels” GB/T 700, “High strength low alloy structural steels” GB/T 1591, and “Steel plates for building structure” GB/T 19879. The specifications, shape, weight and allowable deviation of steel plates, hot-rolled I-beams, channel steels, angle-steels, H-shape profile steels, steel-tubes, and other profiles for structural use shall comply with the provisions of relevant national standards.

4.1.2 When the welded load-bearing structure uses the Z-direction steel to prevent laminar tearing of steel, the quality shall comply with the current national standard “Steel plates with through-thickness characteristics” GB/T 5313.

4.1.3 For load-bearing structures that are exposed in open-air and have special requirements for corrosion resistance or are in an aggressive medium environment, it may use the weather-proof structural steel of designation Q235NH, Q355NH and Q415NH, the quality of which shall comply with the current national standard “Atmospheric corrosion resisting structural steel” GB/T 4171.

4.1.4 The quality of steel castings for non-welded structures shall comply with the current national standard “Carbon steel castings for general engineering purpose” GB/T 11352. The quality of steel castings for welded structures shall comply with the current national standard “Steel casting suitable for welded structure” GB/T 7659.

4.1.5 When using the steels of other designations which are not listed in this standard, it should perform statistical analysis in accordance with the current national standard “Unified standard for reliability design of building structures” GB 50068, to study and determine its design indicators and scope of application.

4.2 Connections and fasteners materials and standards

4.2.1 Welding materials for steel structures shall comply with the following requirements:

- 1** The electrodes used for manual welding shall comply with the current national standard “Covered electrodes for manual metal arc welding of non-alloy and fine grain steels” GB/T 5117, the selected electrode model

its quality shall comply with the industry standard “Hot-rolled round carbon steel bars and rods for standard parts” YB/T 4155-2006.

4.3 Selection of materials

4.3.1 The selection of structural steel shall follow the principle of reliable technology and economic rationality, comprehensively consider the importance of structure, load characteristics, structural form, stress state, connection method, working environment, steel thickness and price, etc., select suitable steel designation and material guarantee items.

4.3.2 The steel used for the load-bearing structure shall have the qualification guarantee of yield strength, tensile strength, elongation after fracture and the content of sulfur and phosphorus. For the welding structure, it shall also have the qualification guarantee for carbon equivalent. The steel used for the welded load-bearing structure and the important non-welded load-bearing structure shall have the qualification guarantee for the cold-bending test; the steel used for the member directly subjected to the dynamic load or the fatigue verification shall also have the qualification guarantee for impact toughness.

4.3.3 The selection of steel's quality grades shall comply with the following requirements:

- 1** Grade A steel can only be used for structures that have a working temperature above 0 °C and do not require fatigue verification. Q235 steel should not be used for welding structure.
- 2** The steel for welding structures which require fatigue verification shall meet the following requirements:
 - 1) When the working temperature is higher than 0 °C, its quality grade shall not be lower than grade B;
 - 2) When the working temperature is not higher than 0 °C but higher than -20 °C, the Q235 and Q345 steel shall not be lower than grade C; the Q390, Q420 and Q460 steel shall not be lower than grade D;
 - 3) When the working temperature is not higher than -20 °C, the Q235 steel and Q345 steel shall not be lower than grade D; the Q390 steel, Q420 steel, and Q460 steel shall be grade E.
- 3** For the non-welded structure which requires fatigue verification, the steel's quality grade may be reduced by one grade as compared with the above-mentioned welded structure, but it shall be not lower than grade B. For crane beam of the intermediate working-system which has a lifting weight

11 Connections

11.1 General requirements

11.1.1 The method of connection of steel structural members shall be selected in accordance with the conditions of the construction environment and the nature of the force.

11.1.2 At the same connection location, it shall neither use common bolts nor the connection which shares the pressure-type high-strength bolt and welding; as the reinforcing measures in the reconstruction and expansion projects, it may use the bolting-welding combined connection which may use the friction-type high-strength bolts and the weld to jointly withstand the same action force, its calculation and construction should comply with the provisions of clause 5.5 of "Technical specification for high strength bolt connections of steel structures" JGJ 82-2011.

11.1.3 Grade C bolts should be used for the connections that are tensioned along their bar axis, or may be used for shear connections in the following cases:

- 1 The secondary connection in a structure subjected to static loads or indirectly subjected to dynamic loads;
- 2 The connection of a detachable structure subjected to static loads;
- 3 The mounting connection used for temporary fixing members.

11.1.4 Countersunk head and semi-countersunk head rivets shall not be used for the connection which is tensioned along its bar axis direction.

11.1.5 The design of welded-connection construction of steel structure shall comply with the following requirements:

- 1 Minimize the number and size of welds;
- 2 The arrangement of welds should be symmetrical to the centroid of the member's section;
- 3 The joint area has enough space for welding operation and post-weld testing;
- 4 It shall avoid dense weld and two-way, three-way intersections;
- 5 The weld position shall avoid the maximum stress area;
- 6 Weld connection shall be selected to ensure equal-strength matching;

when steels of different strengths are connected, it may use the welding materials which match the low-strength steel.

11.1.6 The quality grade of the weld shall be selected based on the importance of the structure, load characteristics, weld form, working environment and stress state in accordance with the following principles:

1 In the members that are subjected to dynamic loads and require fatigue verification, the welds that require equal-strength connection with the base metal shall be welded through, the quality grade shall comply with the following requirements:

1) For the lateral butt weld or the combined weld of T-butt joint and the angle joint whose force is perpendicular to the weld's length direction, it shall be grade I when it is tensioned, or not be lower than grade II when compressed;

2) The longitudinal butt welds whose force is parallel to the weld's length direction shall not be lower than the stage II;

3) The weld at the T-shaped connection part between the web and the upper flange of the crane beam of heavy-duty working-system (A6 ~ A8) and the medium-duty working-system (A4, A5) which has a lifting weight $Q \geq 50t$, as well as between the upper chord of the crane truss and the joint plate shall be welded through, the weld form should be combined weld of butt joint and angle joint, the quality grade shall be not lower than grade II.

2 In areas where the operating temperature is equal to or lower than $-20\text{ }^{\circ}\text{C}$, the quality grade of the member's butt weld shall not be lower than grade II.

3 In the members that do not require fatigue verification, the butt welds that are required to have equal-strength with the base metal should be welded through, the quality grade shall not be lower than grade II when tensioned, and shall not be lower than grade II when compressed.

4 For the partially weld-through butt welds, the angle weld, the T-shaped connection location of the butt-joint and angle-joint combined weld, and the angle weld of overlapped connection, the quality grade shall comply with the following provisions:

1) For the structure which is directly subjected to dynamic load and requires fatigue verification, the beam of the medium-duty working-system crane which has a lifting weight equal to or greater than 50 t, the beam-column, the bracket, and the other important joints, it shall be not lower than grade II;

4 The stiffener or partition of the column's web at the joint area of the beam-column shall comply with the following requirements:

- 1) The cross-section size of the lateral stiffener shall be determined by calculation, its thickness should not be less than the thickness of the beam's flange; its width shall meet the requirements of force transmission, construction and limit slenderness ratio of the plate;
- 2) The upper surface of the lateral stiffener should be aligned with the upper surface of the beam's flange, and connected to the column's flange by a penetrated T-shaped butt weld. When the beam is connected to the column of H-shaped section along the weak axis direction, that is, it is perpendicularly connected to the web to for rigid connection, the connection between the lateral stiffener and the column's web should use the penetrated butt weld;
- 3) The connection between the lateral partition and the column's flange in the box-shaped column should use the penetrated T-shaped butt weld. For the weld which cannot use arc welding and the thickness of the column's wall panel is not less than 16 mm, it may use the fusion nozzle electroslag;
- 4) When using the oblique stiffeners to reinforce the panel zone, the stiffener and its connection shall be able to transmit the other shear force than that can be undertaken by the column's web; its section size shall comply with the requirements for the force transmission and the limit slenderness ratio of plate.

12.3.6 The beam-column's rigid joint which uses the end-plate connection shall comply with the following requirements:

- 1** End-plate should be the overhanging-type. The thickness of the end-plate should not be less than the bolt diameter;
- 2** The thickness of the end-plate and the diameter of the bolt at the joints shall be determined by calculation, it should take into account the influence of prying force in the calculation;
- 3** For the column's web in the joint area which is corresponding to the location of the beam's flange, it shall provide the lateral stiffener, the panel zone which is surrounded by it and the column's flange shall be subject to the verification of shear strength in accordance with clause 12.3.3 of this standard, it should provide the oblique stiffener for reinforcing purpose when the strength is insufficient.

12.3.7 The joints connected by end-plates shall comply with the following provisions:

12.4.6 The casting process shall ensure that the internal texture of the cast steel joint is dense and uniform, the steel castings should be subjected to normalizing or quenching-tempering heat treatment. The design documents shall indicate the tolerance of the skin size of steel castings.

12.5 Pre-stressed cable joints

12.5.1 Tensile joints of prestressed high-strength cables shall ensure that the joint tension zone has sufficient construction space for ease of construction operation and reliable anchoring. The connection between the tensioned joint of the prestressed cable and the principal structure shall consider the over-tensioning as well as the actual stress of the cable at the loading phase, to ensure safe connection.

12.5.2 Prestressed cable's anchoring joints shall adopt anchorages with reliable force transmission, low prestress loss and convenient construction, it shall ensure the local compressive strength and stiffness of the anchorage zone. The principal stressed bar and plate zone in the anchoring joint area shall be subjected to stress analysis and connection calculation. The joint area shall avoid overlapping welds, openings, etc.

12.5.3 The prestressed cable's turning joints shall be provided with chutes or channels. It may apply lubricants or gaskets in the chutes or channels, or use materials with low friction coefficient; it shall verify the local compressive strength of the turning joint, and take reinforcing measures.

12.6 Bearings

12.6.1 For the beam or truss whose flat-plate bearing braced on the masonry or the concrete, it shall verify the compressive strength of the lower masonry or concrete, the base-plate's thickness shall be calculated in accordance with the bending moment produced by the bearing's reaction force against the base-plate, and it should be not less than 12 mm.

When the end of the beam's end bracing stiffener is calculated in accordance with the design value of the end surface's compressive strength, it shall be planed and jacked tightly, wherein the overhanging length of the flange's stiffener shall be not more than 2 times its thickness, and it should take position-limit measures (Figure 12.6.1).

core, the base and the box on the spherical bearing shall be processed by cast steels, the sliding plane shall take the corresponding lubricating measures, the bearing as a whole shall take dust-proof and rust-proof measures.

12.7 Column footing

I General provisions

12.7.1 The column footing of multi-floored high-rise structural frame columns can be buried column footing, plug-in column footing and outer-wrapped column footing. The multi-floored structural frame columns can also adopt exposed column footings. The single-floored workshop's rigidly connected column footing may be the plug-in column footing and exposed column footing; the hinged column footing should be exposed type.

12.7.2 For the outer-wrapped, buried and plug-in column footing, it shall not apply paint within the range of contact between steel column and concrete; when installing the column footing, it shall use the grinding wheel to clean the soil, oil stain, rust, and welding slag from the surface of the steel column.

12.7.3 When the end of the axial compression column or the bending-flexural column is a milling-flat end, the maximum pressure of the column body shall be directly transmitted by the milling-flat end. The connection weld or bolt shall be subject to shear calculation in accordance with 15% of the maximum pressure and the maximum shear force, whichever is larger. When the bending-flexural column has tensioned zone, the connection of such zone shall be calculated in accordance with the maximum tensile force.

II Exposed column footing

12.7.4 Column footing anchors should not be used to withstand the horizontal reaction force at the bottom of the column footing. This horizontal reaction force is undertaken by the friction force between the base-plate and the concrete foundation (the friction coefficient is 0.4) or by setting the shear key.

12.7.5 The size and thickness of the base-plate of the column footing shall be determined in accordance with the bending moment at the column end, the axial force, the bracing condition of the base-plate, the reaction force of the concrete under the base-plate, and the structure of the column footing. The anchor of the exposed column footing shall be determined by calculation based on the environment in which it is used.

12.7.6 Column footing anchors shall have sufficient burial depth. When the burial depth is limited or the anchorage of the anchor bolt is relatively long in concrete, it may set the anchor plates or anchor beams.

- 3 The anchor bolts of column footing shall be set in accordance with the constructional requirements, the diameter should not be less than 16 mm, the anchorage length should not be less than 20 times its diameter;
- 4 It shall provide the horizontal stiffener or lateral diaphragm for the columns at the top stirrups of the outer-wrapping concrete, its slenderness ratio shall comply with the relevant provisions of clause 6.4 of this standard;
- 5 When the frame column is a round tube or a rectangular-tube, it shall pour concrete in the tube, the strength grade shall not be less than that of the foundation concrete. The concrete pouring height shall be higher than that of the outer-wrapping concrete, meanwhile it should be not less than the diameter of the round-tube or the long side of the rectangular-tube;
- 6 The verification of the bending and shear capacity of the outer-wrapping reinforced concrete as well as the constructional requirements for the tensioned rebar and stirrup shall comply with the relevant provisions of the current national standard "Code for design of concrete structures" GB 50010. The length of the main rebar extending into the foundation shall not be less than 25 times the diameter, both ends of the main rebar at four corners shall be hooked, the length of the lower bend shall not be less than 150 mm, the lower bend segment should be welded with the steel column, the top stirrup shall be reinforced and densified, and shall not be less than three grade HRB335 hot rolling rebar of diameter 12 mm.

IV Buried column footing

12.7.8 Buried column footing shall comply with the following requirements:

- 1 The main rebars and stirrups placed around the buried part of the column shall, based on the bottom bending moment and shear force of the column footing, be determined by calculation in accordance with the current national standard "Code for design of concrete structures" GB 50010, and it shall comply with the relevant constructional requirements. The thickness of the concrete protective layer at the column's flange or the outer edge of the tube column (Figure 12.7.8), as well as the distance from the flange of the side-row of columns or the outer edge of the tube column to the end of the foundation beam shall not be less than 400 mm. The distance from the middle column's flange or the outer edge of the tube column to the intersection line of the foundation beam's edges shall not be less than 250 mm. The angle of the intersection line of the foundation beam's edges shall be made into obtuse angle, the slope shall not be greater than the oblique angle of 1:4. At the edge of the foundation's protective raft slab, it shall provide the horizontal U-shaped stirrup to resist the horizontal punching from the column;

14 Composite steel and concrete beams

14.1 General requirements

14.1.1 The provisions of this clause apply to composite beams that are not directly subjected to dynamic loads. For composite beams directly subjected to dynamic loads, it shall follow the requirements of Appendix J of this standard to carry out fatigue calculation, the bearing capacity shall be calculated in accordance with the elastic method. The flange of the composite beam may be made of cast-in-place concrete slab, concrete composite slab or profiled steel-plate concrete composite slab. The concrete slab shall, in addition to the provisions of this clause, also meet the relevant provisions of the current national standard "Code for design of concrete structures" GB 50010.

14.1.2 When carrying out the verification of the composite beam section's bearing capacity, the effective width b_e of the concrete slab at the mid-span and the middle bearing (Figure 14.1.2) shall be calculated as follows:

$$b_e = b_0 + b_1 + b_2 \quad (14.1.2)$$

Where:

b_0 - The width of the top of the plate bracket: when the plate bracket's inclination angle $\alpha < 45^\circ$, it shall be calculated as $\alpha = 45^\circ$; when there is no plate bracket, it takes the width of the upper flange of the steel beam; when the concrete slab and the steel beam are not in direct contact (for example, there is profiled steel plate to separate them), it takes the lateral spacing of the stud; when there is only one row of studs, it takes 0 (mm);

b_1, b_2 - The effective width of the outer and inner flanges of the beam. When the plastic neutral axis is located within the concrete slab, it takes 1/6 of the equivalent span l_e of the beam, respectively. In addition, b_1 shall also not exceed the actual overhang width S_1 of the flange; b_2 shall not exceed 1/2 of the clearance S_0 between the upper flange or the plate bracket of the adjacent steel beam (mm);

l_e - Equivalent span. For the simply braced composite beam, it takes the span of the simply braced composite beam; for the continuous composite beam, the mid-span's sagging moment zone takes 0.6 l , the side-span's sagging moment zone takes 0.8 l , where l is the composite beam's span; the bearing's hogging moment zone takes 20% of the sum of the adjacent two spans (mm).

14.1.3 When the composite beam is subjected to the verification of the limit state of normal use, it shall comply with the following provisions:

shrinkage may be calculated in accordance with the temperature difference between the concrete slab of the composite beam and the steel beam minus 15 °C;

- 5** When considering the effect of concrete creep, it may double the elastic modulus ratio of steel to concrete.

14.1.4 When constructing a composite beam, the material weight and construction load before concrete hardening shall be borne by the steel beam. For the steel beam, it shall follow the actual temporary bracing conditions as well as the provisions of clause 3 and clause 7 of this standard to verify its strength, stability, and deformation.

When calculating the deflection of the composite beam as well as the cracking width of the hogging moment zone, it shall consider the effects of construction methods and procedures. When calculating the deflection of the composite beam, it shall superimpose the deflection at the construction phase with the deflection which is generated by the continuous load during the use phase. When there is temporary brace under the steel beam, it shall consider the additional deformation which is produced when removing the temporary brace. When calculating the cracking width of the hogging moment zone of the composite beam, it may consider only the hogging moment value which is introduced after forming the composite section.

14.1.5 When the strength and deformation meet the requirements, the composite beam can be designed as a partial shear connection.

14.1.6 For composite beams designed in accordance with this clause, the slenderness ratio of the plates in the compressive zone of steel beams shall comply with the relevant provisions of the plastic design in clause 10 of this standard. When the compressive upper flange of the composite beam fails to comply with the limit slenderness ratio of the plate as required by the plastic design, but the connectors comply with the following requirements, it may still use the plastic method to carry out design:

- 1** When the concrete slab is in contact with the composite beam along the full length (such as cast-in-place floor slab), the maximum spacing of the connector is not more than $22t_f\varepsilon_k$; when the concrete slab and the composite beam are partially in contact (for example, the lateral ribs of the profiled steel plate are perpendicular to the steel beam), the maximum spacing of the connectors is not more than $15t_f\varepsilon_k$; ε_k is the steel number's correction coefficient, t_f is the thickness of the compressed upper flange of the steel beam.
- 2** The distance between the outer edge of the connector and the edge of the steel flange is not greater than $9t_f\varepsilon_k$.

15 Concrete-filled steel tubular columns and joints

15.1 General requirements

15.1.1 This clause applies to the design and calculation of concrete-filled steel tubular columns and joints that are not directly subjected to dynamic loads.

15.1.2 Concrete-filled steel tubular columns can be used for frame structures, frame-shear wall structures, frame-core tube structures, frame-brace structures, tube-in-tube structures, partial frame bracing-shear wall structures, and tower structures.

15.1.3 In industrial and civil buildings, the frame-beam connected to the concrete-filled steel tubular columns should use the steel beam or steel-concrete composite beams or cast-in-place reinforced concrete beams.

15.1.4 The selection of steel tubes shall comply with the relevant provisions of clause 4 of this standard. The strength grade of concrete shall be matched with the strength of steel. It shall not use admixtures that have corrosive effects on steel tubes. The compressive strength and elastic modulus of concrete shall be used in accordance with the current national standard "Code for design of concrete structures" GB 50010.

15.1.5 The calculation of concrete-filled steel tubular columns and joints shall comply with the relevant provisions of the current national standard "Technical code for concrete filled steel tubular structures" GB 50936.

15.1.6 For the concrete-filled steel tubular column, in addition to the bearing capacity design of the use phase, it shall also carry out the bearing capacity verification of the construction phase. When verifying the bearing capacity of the construction phase, it shall use the void steel tube section. The axial stress of the void steel tube section shall not be more than 60% of the design value of its compressive strength, and meanwhile satisfy the stability requirements.

15.1.7 When pouring concrete in steel tube, it shall take effective measures to ensure the compactness of the concrete.

15.1.8 Concrete-filled steel tubular columns should consider the adverse effect of concrete creep on the stable bearing capacity.

15.2 Rectangular concrete-filled steel tubular members

15.2.1 Rectangular steel tubes may be cold-formed straight-seam steel-tubes or spiral-seam welded-tubes and hot-rolled tubes, or otherwise cold-formed

steel section or hot-rolled steel plate and steel section welded rectangular-tubes. Connections can be made by high-frequency welding, automatic or semi-automatic welding and manual butt welds. When a rectangular steel-tube concrete member is made of steel plate or steel section combination, the connection weld between the wall panels shall use the full penetration weld.

15.2.2 The side length of the rectangular concrete-filled steel tubular members should not be less than 150 mm, the wall thickness of the steel tube shall not be less than 3 mm.

15.2.3 Rectangular concrete-filled steel tubular member shall consider the weakening effect of the corners on the concrete's restriction action. When the long-side size is larger than 1 m, it shall take the constructional measures to enhance the restraining effect of rectangular steel tube on concrete and reduce the impact of concrete shrinkage.

15.2.4 When the rectangular concrete-filled steel tubular member is subjected to compressive calculation, the dependency ratio of the axially compressed bearing capacity of the concrete may be distributed considering the deformation coordination of steel tube and concrete; in case of tensioned calculation, it may not consider the action of concrete, but only calculate the tensioned bearing capacity of the steel tube.

15.3 Round concrete-filled steel tubular members

15.3.1 Round steel tubes may be welded round steel tube or hot-rolled seamless steel tube.

15.3.2 The diameter of the round concrete-filled steel tubular member's section should not be less than 180 mm, the wall thickness shall not be less than 3 mm.

15.3.3 The round concrete-filled steel tubular member shall take effective measures to ensure the hoop effect of steel tubes on concrete; when the diameter is greater than 2 m, it shall take effective measures to reduce the impact of concrete shrinkage.

15.3.4 In the tensioned elastic phase calculation of the round concrete-filled steel tubular member, it may not consider the action of concrete, but only calculate the tensioned capacity of the steel tube; after the steel tube is yield, it may consider the co-work of steel tube and concrete, whilst the tensioned capacity may be appropriately increased.

15.4 Beam-column joints

15.4.1 The connection joint of rectangular concrete-filled steel tubular member

18 Protection of steel structures

18.1 Fire-resistance design

18.1.1 Steel structure's fire protection measures and its construction shall be determined in accordance with the actual conditions of the project, considering the structural type, fire endurance requirements, working environment and other factors, in accordance with the principles of safety, reliability and economic rationality.

18.1.2 The designed fire endurance of building steel members shall comply with the relevant provisions of the current national standard "Code of design on building fire protection and prevention" GB 50016.

18.1.3 When the fire endurance time of steel members cannot meet the requirements of the specified design fire endurance, it shall make the fire protection design. The building steel structure shall be subjected to the fire resistance verification in accordance with the provisions of the current national standard "Code for fire safety of steel structures in buildings" GB 51249.

18.1.4 In the steel structure design document, it shall indicate the designed fire endurance rating of the structure, the designed fire endurance of the member, the required fire protection measures, and the performance requirements of the fire protection materials.

18.1.5 When the member uses the fireproof coating for fire protection, the thickness of coating at the high-strength bolted connection shall be not less than the thickness of the coating of the adjacent member.

18.2 Corrosion prevention design

18.2.1 Steel structure shall follow the principle of safety, reliability and economic rationality, and carry out anti-corrosion design in accordance with the following requirements:

- 1** For the steel structure's anti-corrosion design, it shall be based on the importance of the building, environmental corrosion conditions, construction and maintenance conditions, etc., to reasonably determine the anti-corrosion design period;
- 2** Anti-corrosion design shall consider the requirements of environmental protection and energy conservation;
- 3** In addition to the anti-corrosion measures that must be taken in the steel

structure, it shall also avoid the poor design which may accelerate corrosion as much as possible;

- 4 In the anti-corrosion design, it shall consider the inspection, maintenance and overhaul of the steel structure throughout its life.

18.2.2 Steel structure's anti-corrosion design shall consider the corrosiveness of the medium in the environment, environmental conditions, construction and maintenance conditions, etc., in accordance with local conditions, comprehensively choose the anti-corrosion scheme or combination thereof from the following schemes:

- 1 Anti-corrosion coating;
- 2 Metal protective layers such as zinc and aluminum formed by various processes;
- 3 Cathodic protection measures;
- 4 Weathering steel.

18.2.3 For the parts which endanger personnel safety and is hard to repair, as well as the important load-bearing structure and member, it shall enhance protection. For the principal load-bearing steel structure member which is in the seriously corrosive use environment and cannot be effectively protected only by coating, it should use the weathering steel or be wrapped by concrete.

When the design service life of some secondary members is different from the design service life of the principal structure, the secondary members shall be easily replaced.

18.2.4 Structure's anti-corrosion design shall comply with the following requirements:

- 1 When using steel-section combined-type bar, the width of the gap between the steel sections should meet the requirements for construction, inspection and maintenance of the protective layer;
- 2 When contact with different metal materials accelerates corrosion, it shall take the isolation measures at the contact points;
- 3 The corrosion resistance of connecting members such as welding rods, bolts, washers and joint plates shall not be lower than that of the main material; the diameter of the bolt shall not be less than 12 mm. The washer shall not be a spring washer. Bolts, nuts and washers shall be protected by galvanizing, etc., and take the anti-corrosion schemes same as the main structure after installation;

- 4** For the buildings which have a design service life of greater than or equal to 25 years, the protection of structure which is hard to repair shall be enhanced;
- 5** Avoid places where it is difficult to inspect, clean and paint, as well as the dead corners or grooves that can accumulate warm air and a large amount of dust; the closed section members shall be closed along the entire length with the end weld;
- 6** The column footing below the ground shall be wrapped with concrete of lower strength grade (the thickness of the protective layer shall not be less than 50 mm), the wrapped concrete shall not be less than 150 mm above the outdoor ground, the indoor ground should not be less than 50 mm, and it shall take measures to prevent residual moisture. When the bottom of the column footing is above the ground, the bottom of the column footing shall be not less than 100 mm above the outdoor ground, not less than 50 mm above the indoor ground.

18.2.5 The original corrosion grade of steel surface and the grade of steel rust removal shall comply with the provisions of the current national standard "Preparation of steel substrates before application of paints and related products - Visual assessment of surface cleanliness" GB/T 8923.

- 1** Steel which has a surface original corrosion grade of grade D shall not be used as structural steel;
- 2** Surface treatment materials such as abrasives which are used for sand blasting or shot blasting shall meet the requirements for surface cleanliness and roughness of anti-corrosion products, and meet environmental protection requirements.

18.2.6 The matching scheme of steel structure's anti-corrosion coating may be designed in accordance with the requirements of environmental corrosion conditions, anti-corrosion design life, construction and maintenance conditions, and so on. The repair and the primer for the weld parts shall be able to adapt to the conditions of surface treatment.

18.2.7 In the design documents of the steel structure, it shall indicate the anti-corrosion scheme. If using the coating/plating, it shall indicate the required steel de-rusting grade as well as the paint and thickness of the coating/plating to be used, and indicate the requirements for the user organization for regular inspection and maintenance of steel structure's anti-corrosion during use. It is recommended to develop anti-corrosion maintenance plan.

18.3 Temperature insulation

18.3.1 For steel structures in high temperature working environments, it shall consider the effect of high temperature on the structure. The design state of the high temperature working environment is a permanent state, the high temperature action is a variable load, which shall be designed in accordance with the limit state of bearing capacity and the limit state of normal use.

18.3.2 When the temperature of the steel structure exceeds 100 °C, in the verification of the bearing capacity and deformation of steel structure, it shall consider the impact of the long-term high-temperature action on the steel material and the connection performance of steel structure.

18.3.3 When the temperature of the steel structure under high temperature environment exceeds 100 °C, it shall verify the structural temperature action, and shall take protective measures based on different conditions:

- 1** When the steel structure may be damaged by hot molten metal, it shall use the thermal insulation layer which is made of masonry or thermal-resistant solid materials to protect it;
- 2** When the steel structure may be directly affected by the short-term flame, it shall take the thermal-insulation protection measures such as thermal-resistant thermal-insulation coating and heat radiation shielding, etc.;
- 3** When the bearing capacity of the steel structure in the high temperature environment does not meet the requirements, it shall take the thermal-insulation temperature-reduction measures such as increasing the member's section, using fire-resistant steel or thermal-resistant thermal-insulation coating, heat radiation shielding, water jacket thermal-insulation & cooling measures;
- 4** When the high-strength bolt connection is heated for more than 150 °C for a long time, it shall take such thermal-insulation protective measures as thermal-resistant thermal-insulation coating or heat radiation shielding, etc.

18.3.4 The thermal-insulation protection measures of steel structures shall be durable in the corresponding working environment and compatible with the anti-corrosion and fire protection measures of steel structures.

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