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Load Code for the Design of Building Structures

建筑结构荷载规范

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1 General Provisions

1.0.1 This code is formulated with a view to adapting the need of the building structure design and meeting the requirements of safety and usability, economy and rationality.

1.0.2 This code is applicable to the structural design of building engineering.

1.0.3 This code is formulated in accordance with the basic principles specified in the national standard "Unified Standard for Reliability Design of Engineering Structures" GB 50153−2008.

1.0.4 The actions concerned in the building structure design shall cover direct action (load) and indirect action. This code only specifies load and thermal action, and the provisions for the relevant variable load are also applicable to the thermal action.

1.0.5 The loads concerned in the building structure design shall not only comply with this code, but also those in the current relevant ones of the nation.

3 Classification and Combination of Loads

3.1 Classification of Loads and Representative Values of Loads

3.1.1 The loads of the building structures may be classified into:

1 Permanent load, including structure self-weight, soil pressure, prestress, etc..

2 Variable load, including live load on floor, live load on roof and ash load, crane load, wind load, snow load, thermal action, etc..

3 Accidental load, including explosive force, impact force, etc..

3.1.2 In the design of building structures, the different loads shall adopt different representative values according to the following requirements:

1 For permanent load, the characteristic value shall be its representative value;

2 For variable load, the characteristic value, combination value, frequent value or quasi-permanent value shall be its representative value according to the design requirements;

3 For accidental load, its representative value shall be determined according to the use characteristics of the building structures.

3.1.3 The determination of the representative value of variable load shall adopt 50-yeardesign reference period.

3.1.4 The characteristic values of loads shall be adopted according to the requirements of each chapter of this code.

3.1.5 In the design of limit state of bearing capacity or the design of limit state of normal use according to the characteristic combination, for variable load, the combination value or characteristic value shall be its representative value according to the specified load combination. The combination value of variable load shall be the characteristic value of variable load multiplied by the load combination value coefficient.

3.1.6 In the design of limit state of normal use according to frequent combination, for variable load, the frequent value or quasi-permanent value shall be its representative value; in the design according to quasi-permanent combination, the quasi-permanent value of variable load shall be its representative value. The frequent value of variable load shall be the characteristic value of variable load multiplied by the frequent value coefficient. The quasi-permanent value of variable load shall be the characteristic value of variable load multiplied by the quasi-permanent value coefficient.

3.2 Combination of Loads

3.2.1 In the design of the building structures, load combination shall be carried out according to the limit state of bearing capacity and the limit state of normal use respectively based on the loads possibly emerging simultaneously on the structure during the use process, and the respective most unfavorable combination shall be taken for design.

3.2.2 For the limit state of bearing capacity, the effect design value of load combination shall be

7 Snow Load

7.1 Characteristic Value of Snow Load and Reference Snow Pressure

7.1.1 The characteristic value of snow load on roofs in horizontal projection plane shall be calculated according to the following formula:

$$S_k=\mu_r s_0 \tag{7.1.1}$$

Where S_k——The **characteristic value of snow load (kN/m^2);**

μ_r——**The distribution factor for roof snow load;**

s_0——**The reference snow pressure (kN/m^2).**

7.1.2 The reference snow pressure shall adopt the snow pressure with 50-year recurrence interval, which is determined according to the method specified in this code; for the structure sensitive to snow load, the snow pressure with 100-year recurrence interval shall be adopted.

7.1.3 The reference snow pressure of all the cities throughout the country shall be adopted according to the value with a recurrence interval *R* of 50 years in Table E.5 of Appendix E of this code. Where the reference snow pressure of a city or construction site is not given in Table E.5 of this code, the reference snow pressure shall be determined through statistical analysis according to the method specified in Appendix E of this code, in accordance with the local annual maximum snow pressure or snow depth data, and on the basis of the definition of reference snow pressure; and the analysis shall consider the influence of sample size. In the absence of local snow pressure and snow depth data, the reference snow pressure may be determined through comparative analysis on meteorological and topographic conditions according to the reference snow pressure or long-term data specified for nearby areas, or determined approximately according to Annexed Figure E.6.1 Distribution Map of Reference Snow Pressure throughout the Country in Appendix E of this code.

7.1.4 The snow load in mountain area shall be determined through actual investigation. In the absence of measured data, the snow load may be adopted according to the snow load value of local adjacent open and flat ground surface multiplied by a coefficient of 1.2.

7.1.5 The combination value coefficient of snow load may take 0.7; the frequent value coefficient may take 0.6; the quasi-permanent value coefficient shall take 0.5, 0.2 and 0 respectively according to Zones I, II and III of snow load; the snow load zones shall be adopted in accordance with those specified in Appendix E.5 or Annexed Figure E.6.2 of this code.

7.2 Distribution Factor for Roof Snow Load

7.2.1 The distribution factor for roof snow load shall be adopted in accordance with those specified in Table 7.2.1 according to the roof type of different categories.

7.2.2 In the design of building structures and supporting members of roofs, the snow distribution condition shall be adopted according to the following requirements:

1 The roof slab and purlin shall be adopted according to the most unfavorable condition of nonuniform snow distribution;

8 Wind Load

8.1 Characteristic Value of Wind Load and Reference Wind Pressure

8.1.1 The characteristic value of wind load vertical to the building surface shall be determined according to the following requirements:

1 In the calculation of main load-carrying structures, the characteristic value of wind load shall be calculated according to the following formula:

$$w_k=\beta_z\mu_s\mu_z w_0 \tag{8.1.1-1}$$

Where w_k——The characteristic value of wind load (kN/m^2);

β_z——The dynamic response factor at z height;

μ_s——The shape factor of wind load;

μ_z——The exposure factor for wind pressure;

w_0——The reference wind pressure (kN/m^2).

2 In the calculation of enclosure structures, the characteristic value of wind load shall be calculated according to the following formula:

$$w_k=\beta_{gz}\mu_{sl}\mu_z w_0 \tag{8.1.1-2}$$

Where β_{gz}——The gust factor at z height;

μ_{sl}——The local shape factor of wind load.

8.1.2 The reference wind pressure shall adopt the wind pressure with 50-year recurrence interval, which is determined according to the method specified in this code, but shall not be less than 0.3kN/m^2. For the tall buildings, high-rise structures and other structures sensitive to wind load, the reference wind pressure value shall be increased properly, shall meet the requirements of the relevant code for the design of structures.

8.1.3 The reference wind pressure of all the cities throughout the country shall be adopted according to the value with a recurrence interval R of 50 years in Table E.5 of Appendix E of this code. Where the reference wind pressure of a city or construction site is not given in Table E.5 of this code, the reference wind pressure shall be determined through statistical analysis according to the method specified in Appendix E of this code and in accordance with the definition of reference wind pressure and the local annual maximum wind speed data; and the analysis shall consider the influence of sample size. In the absence of local wind speed data, the reference wind pressure may be determined through comparative analysis on meteorological and topographic conditions according to the reference wind pressure or long-term data specified for nearby areas, or determined approximately according to Annexed Figure E.6.3 Distribution Map of Reference Wind Pressure throughout the Country in Appendix E of this code.

8.1.4 The combination value coefficient, frequent value coefficient and quasi-permanent value coefficient of wind load may take 0.6, 0.4 and 0.0 respectively.

3 Other conditions shall be valued according to μ_{sl} of open buildings.

Note: 1 The opening ratio of dominant opening refers to the ratio of the area of single dominant opening to the whole area of this wall;

2 μ_{sl} shall take the value of corresponding dominant opening position.

8.3.6 For the wind tunnel test of building structures, the test equipment, test methods and data processing shall meet the requirements of the relevant codes.

8.4 Along-wind Vibration and Dynamic Response Factor

8.4.1 For the buildings with height greater than 30m and height-width ratio greater than 1.5 and various high-rise structures with fundamental natural period T_1 greater than 0.25s, the along-wind vibration influence of wind pressure fluctuation on structures shall be considered. The response calculation of along-wind vibration shall be carried out according to the theory of random vibration of structures. For the structures meeting the requirements of Article 8.4.3 of this code, the along-wind load may be calculated through dynamic response factor method.

Note: 1 The natural vibration period of structures shall be calculated according to the structural dynamics; the approximate fundamental natural period T_1 may be calculated according to Appendix F;

2 The acceleration of along-wind vibration of tall buildings may be calculated according to Appendix J of this code.

8.4.2 For the flexible roof structures sensitive to wind or with span greater than 36m, the wind vibration influence of wind pressure fluctuation on structures shall be considered. The wind vibration response of roof structures should be determined through calculation according to the random vibration theory based on the wind tunnel test results.

8.4.3 For general vertical cantilever structures, e.g. Tall buildings and high-rise structures such as framework, tower frame and chimney, only the influence of the first vibration mode of the structures may be considered; the along-wind load of the structures may be calculated according to Formula (8.1.1-1). The dynamic response factor β_z at z height may be calculated according to the following formula:

$$\beta_z = 1 + 2gI_{10}B_Z\sqrt{1+R^2} \quad (8.4.3)$$

Where g——The peak factor, taking 2.5;

I_{10}——The nominal turbulence intensity of 10m height, taking 0.12, 0.14, 0.23 and 0.39 corresponding to Category A, B, C and D terrain roughness respectively;

R——The resonant component factor of fluctuating wind load;

B_z——The background component factor of fluctuating wind load.

8.4.4 The resonant component factor of fluctuating wind load may be calculated according to the following formula:

$$R = \sqrt{\frac{\pi}{6\xi_1}\frac{x_1^2}{(1+x_1^2)^{4/3}}} \quad (8.4.4\text{-}1)$$

8.4.6 The space correlation coefficient of fluctuating wind load may be determined according to the following requirements:

1 The correlation coefficient in vertical direction may be calculated according to the following formula:

$$\rho_z = \frac{10\sqrt{H + 60e^{-H/60} - 60}}{H} \tag{8.4.6-1}$$

Where H——The total height of structure (m), shall not be greater than 300m, 350m, 450m and 550m corresponding to Category A, B, C and D terrain roughness respectively.

2 The correlation coefficient in horizontal direction may be calculated according to the following formula:

$$\rho_z = \frac{10\sqrt{B + 50e^{-B/50} - 50}}{B} \tag{8.4.6-2}$$

Where B——The windward side width of structure (m), $B \leq 2H$.

3 For high-rise structures with smaller windward side width, the correlation coefficient in horizontal direction may take ρ_x=1.

8.4.7 The coefficient of vibration mode shall be determined according to structure dynamic calculation. For the high-rise structures of vertical cantilever type, whose shape, mass and rigidity vary continuously and regularly along the height, and the relatively uniform tall buildings along the height, the coefficient of vibration mode $\varphi_1(z)$ may also be determined according to Appendix G of this code in accordance with the relative height z/H.

8.5 Across-wind and Wind-induced Torsional Vibration

8.5.1 For the tall buildings with obvious across-wind vibration action effect and the structures of slender circular section, the influence of across-wind vibration should be considered.

8.5.2 The equivalent wind load of across-wind vibration may be adopted according to the following requirements:

1 For the tall buildings and high-rise structures with complex plane or elevation shape, the equivalent wind load ω_{Lk} of across-wind vibration should be determined through a wind tunnel test, or determined according to the relevant data;

2 For the tall buildings and structures of circular section, the equivalent wind load ω_{Lk} of across-wind vibration caused by trans-critical strong wind resonance (vortex shedding) may be determined according to Appendix H.1 of this code;

3 For the tall buildings of rectangular section and of concave or chamfered rectangular section, the equivalent wind load ω_{Lk} of across-wind vibration may be determined according to Appendix H.2 of this code.

Note: The acceleration of across-wind vibration of tall buildings may be calculated according to Appendix J of this code.

8.5.3 For the structures of circular section, the across-wind vibration (vortex shedding) shall be checked for different Reynolds numbers *Re* according to the following requirements:

1 Where $Re<3\times10^5$ and the wind speed υ_H at the top of the structures is greater than υ_{cr}, the subcritical breeze resonance may occur. In this case, antivibration measures may be taken structurally or the critical wind speed υ_{cr} of the structures may be controlled as no less than 15m/s.

2 Where $Re\geq3.5\times10^6$ and 1.2 times the wind speed υ_H at the top of the structures is greater than υ_{cr}, the crossing critical strong wind resonance may occur; in this case, the equivalent wind load of across-wind vibration shall be considered.

3 Where $3\times10^5\leq Re<3.5\times10^6$, the wind vibration beyond critical range may not be handled.

4 The Reynolds number *Re* may be determined according to the following formula:

$$Re=69000\upsilon D \tag{8.5.3-1}$$

Where υ——The wind speed for calculation, taking the critical wind speed value υ_{cr};

D——The diameter of structure section (m), where the structure section reduces along the height (inclination not greater than 0.02), the diameter at 2/3 structure height may be approximately taken.

5 The critical wind speed υ_{cr} and the wind speed υ_H at the top of the structures may be determined according to the following formulae:

$$\upsilon_{cr}=\frac{D}{T_i St} \tag{8.5.3-2}$$

$$\upsilon_H=\sqrt{\frac{2000\mu_H\omega_0}{\rho}} \tag{8.5.3-3}$$

Where T_i——The natural vibration period of the i^{th} vibration mode of structure, taking the fundamental natural period T_i in the checking of subcritical breeze resonance;

St——The Strouhal number, taking 0.2 for the structures of circular section;

μ_H——The exposure factor for wind pressure at the top of structure;

ω_0——The reference wind pressure (kN/m^2);

ρ——The air density (kg/m^3).

8.5.4 For the tall buildings and high-rise structures with obvious wind-induced torsional vibration action effect, the influence of wind-induced torsional vibration should be considered.

8.5.5 The equivalent wind load of wind-induced torsional vibration may be adopted according to the following requirements:

1 For the tall buildings with complex shape and obviously eccentric mass or rigidity, the equivalent wind load ω_{Tk} of wind-induced torsional vibration should be determined through a wind tunnel test, or determined according to the relevant data;

determined according to the method specified in Appendix E of this code; the reference air temperature values of the cities throughout the country may be adopted according to Table E.5 in Appendix E of this code. Where the reference air temperature value of a city or construction site is not given in Appendix E of this code, the reference air temperature value may be determined through statistical analysis according to the method specified in Appendix E based on the air temperature data recorded by local meteorological station. In the absence of local air temperature data, the reference air temperature may be determined through comparative analysis on meteorological and topographic conditions according to the reference air temperature specified for nearby areas, or determined approximately according to Figure E.6.4 and Figure E.6.5 in Appendix E of this code.

9.2.2 For the structures such as metal structures which are sensitive to air temperature variation, the influence of extreme air temperature should be considered; the reference air temperature T_{max} and T_{min} may be properly increased or decreased according to the local climate conditions.

9.3 Uniform Temperature Action

9.3.1 The characteristic value of uniform temperature action shall be determined according to the following requirements:

1 For the operating condition of structures at maximum temperature rise, the characteristic value of uniform temperature action shall be calculated according to the following formula:

$$\Delta T_k = T_{s,max} - T_{0,min} \tag{9.3.1-1}$$

Where ΔT_k——The characteristic value of uniform temperature action (°C);

$T_{s,max}$——The maximum average temperature of structure (°C);

$T_{0,min}$——The minimum initial average temperature of structure (°C).

2 For the operating condition of structures at maximum temperature drop, the characteristic value of uniform temperature action shall be calculated according to the following formula:

$$\Delta T_k = T_{s,min} - T_{0,max} \tag{9.3.1-2}$$

Where $T_{s,min}$——The minimum average temperature of structure (°C);

$T_{0,max}$——The maximum initial average temperature of structure (°C).

9.3.2 The maximum average temperature $T_{s,max}$ and the minimum average temperature $T_{s,min}$ of the structures should be determined according to the heat engineering principle in accordance with reference air temperature T_{max} and T_{min} respectively. For the indoor structures with enclosure, their average temperature shall consider the influence of indoor and outdoor temperature difference; for the structures exposed outdoors or structures during construction period, the influence of solar radiation should be considered according to the structure orientation and surface heat absorptivity.

9.3.3 The maximum initial average temperature $T_{0,max}$ and the minimum initial average temperature $T_{0,max}$ of the structures shall be determined according to the structure healing or restraint forming time, or determined according to the unfavorable condition based on the possible structure temperature during construction.

10 Accidental Load

10.1 General Requirements

10.1.1 The accidental load shall cover the loads caused by explosion, impact, fire and other accidental disasters. This chapter is only applicable to explosion and impact load.

10.1.2 Where the accidental load is used as the dominant load in structural design, the structure shall be ensured without progressive collapse caused by accidental load under the condition that local member damage is allowed for the structure.

10.1.3 The design value of accidental load may directly take the characteristic value of accidental load determined according to the method specified in this chapter.

10.2 Explosion

10.2.1 The explosion load caused by explosive, gas and dust, etc. should be adopted according to the equivalent static load.

10.2.2 Under the action of dynamic explosion load of routine explosive, the characteristic value of equivalent uniformly distributed static load of structural members may be calculated according to the following formula:

$$q_{ce}=K_{dc}p_c \tag{10.2.2}$$

Where q_{ce}——The characteristic value of equivalent uniformly distributed static load acting on structural members;

p_c——The maximum pressure of uniformly distributed dynamic load acting on structural members, may be adopted according to the relevant requirements of Article 4.3.2 and Article 4.3.3 of the national standard "Code for Design of Civil Air Defence Basement" GB 50038−2005;

K_{dc}——The dynamic coefficient, determined according to the principle of equivalent maximum internal force based on the dynamic analysis result under the action of uniformly distributed dynamic load for the members.

Note: For the explosion caused by other reasons, the equivalent uniformly distributed static load may be determined according to the equivalent TNT charging quantity by reference to the method of this article.

10.2.3 For the building structures with access plate, where the ratio of the access plate area A_V to the explosion space volume V is 0.05~0.15, and the volume V is less than 1000m^3, the equivalent uniformly distributed static load p_k of gas explosion may be calculated according to the following formula and shall take the larger value:

$$p_k=3+p_V \tag{10.2.3-1}$$

$$p_k = 3+0.5p_V+0.04\left(\frac{A_V}{V}\right)^2 \tag{10.2.3-2}$$

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