UDC

# GB

NATIONAL STANDARD

OF THE PEOPLE'S REPUBLIC OF CHINA

P **GB 50011-2010** (GB 50011-2016)

# Code for Seismic Design of Buildings

## 建筑抗震设计规范

(2016)

**Issued on: May 31, 2010** **Implemented on: December 1, 2010**

**Jointly Issued by** **the Ministry of Housing and Urban-rural Construction of the People's Republic of China and the General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China**

National Standard

of the People's Republic of China

Code for Seismic Design of Buildings

# GB 50011-2010

Developed by:

Ministry of Housing and Urban-rural Development of the People's Republic of China

Approved by:

Ministry of Housing and Urban-rural Development of the People's Republic of China

Implementation Date:

December 1, 2010

China Architecture & Building Press

**2010 Beijing**

# Announcement of Ministry of Housing and Urban-rural Development of the People's Republic of China

No.609

## Announcement on Publishing the National Standard –Code for Seismic Design of Buildings"

The standard –Code for Seismic Design of Buildings" has been approved as a national standard with the serial number of GB 50011-2010 and shall be implemented on December 1, 2010. Therein, Articles 1.0.2, 1.0.4, 3.1.1, 3.3.1, 3.3.2, 3.4.1, 3.5.2, 3.7.1, 3.7.4, 3.9.1, 3.9.2, 3.9.4, 3.9.6, 4.1.6, 4.1.8, 4.1.9, 4.2.2, 4.3.2, 4.4.5, 5.1.1, 5.1.3, 5.1.4, 5.1.6, 5.2.5, 5.4.1, 5.4.2, 5.4.3, 6.1.2, 6.3.3, 6.3.7, 6.4.3, 7.1.2, 7.1.5, 7.1.8, 7.2.4, 7.2.6, 7.3.1, 7.3.3, 7.3.5, 7.3.6, 7.3.8, 7.4.1, 7.4.4, 7.5.7, 7.5.8, 8.1.3, 8.3.1, 8.3.6, 8.4.1, 8.5.1, 10.1.3, 10.1.12, 10.1.15, 12.1.5, 12.2.1 and 12.2.9 are compulsory ones and must be enforced strictly. The former standard –Code for Seismic Design of Buildings" GB 50011-2001 shall be abolished simultaneously.

Authorized by the Research Institute of Standard and Norms of the Ministry, this code is published and distributed by China Architecture & Building Press.

**Ministry of Housing and Urban-rural Development of the People's Republic of China**

May 31, 2010

# Foreword

According to the requirements of Document Jian Biao [2006] No.77—“*Notice on Printing and Distributing the Development and Revision Plan of Engineering Construction Standards and Codes in 2006 (Batch 1)*” issued by the former Ministry of Construction (MOC), this code was revised from GB 50011-2001 “*Code for Seismic Design of Buildings*” by China Academy of Building Research (CABR) together with other design, survey, research and education institutions concerned.

During the process of revision, the editorial team summarized the experiences in building seismic damages during Wenchuan Earthquake in 2008; adjusted the seismic precautionary intensities of the relevant disaster areas; added some compulsory provisions on the sites in mountainous areas, the arrangements of the infilled wall in frame structure, the requirements for staircase of masonry structure and the construction requirements of seismic structure; and raised the requirements for the details of the precast floor slab and for the reinforced elongation. Hereafter, the editorial team carried out studies on specific topics and some tests concerned, investigated and summarized the experiences and lessons from the strong earthquakes occurred in recent years home and abroad (including Wenchuan Earthquake), adopted the new research achievements of earthquake engineering, took the economic condition and construction practices in China into account, widely collected the comments from the relevant design, survey, research and education institutions as well as seismic administration authorities nationwide. Through a multi-round discussion, revision, substantiation, and with pilot designs as well, the final version has been completed and reviewed by an expert panel. This newly-revised version comprises 14 Chapters and 12 Appendixes. Besides remaining those provisions partially revised in 2008, the main revisions at this edition are:

1. supplementing the provisions on the seismic measures for areas with the seismic precaution Intensity 7 (0.15*g*) and Intensity 8 (0.30*g*),
2. adjusting the Design Earthquake Groups of Main Cities in China in accordance with GB18306-2001 “*Seismic Ground Motion Parameter Zonation Map of China*”,
3. improving the soil liquefaction discriminating equation;
4. adjusting the damping modification parameter of design response spectrum,
5. modifying the damping ratio and the seismic adjusting factor for load-bearing capacity of steel structure,
6. modifying the calculation methods of the horizontal seismic-reduced factor of seismically isolated structure,
7. supplementing the calculation method for horizontal and vertical earthquake action of large-span buildings;
8. raising the seismic design requirements for concrete frame structure buildings and for masonry buildings with RC frames on ground floors.
9. proposing the classification method for the seismic grades of steel structure buildings, and adjusting the provisions on seismic measures, correspondingly;
10. improving the seismic measures for multi-storey masonry buildings, concrete

wall buildings and reinforced masonry buildings;

11. expending the application scope of seismically isolated and energy-dissipated buildings;
12. adding the principles on performance-based seismic design of for buildings as well as the seismic design provisions for large-span buildings, subterranean buildings, frame-bent structure factories, buildings with composite steel brace and concrete frame structures, and buildings with composite steel frame and concrete core tube structures.
13. canceling the contents related to multi-storey masonry buildings with inner frames.

The provisions printed in bold type are compulsory ones and must be enforced strictly.

The Ministry of Housing and Urban-Rural Development of the People's Republic of China is in charge of the administration of this code and the explanation of the compulsory provisions hereof. China Academy of Building Research (CABR) is responsible for the explanation of specific technical contents. All relevant organizations are kindly requested to sum up and accumulate your experiences in actual practices during the process of implementing this code. The relevant opinions and advice, whenever necessary, can be posted or passed on to the Management Group of the National Standard "*Code for Seismic Design of Buildings*" of the China Academy of Building Research (Address: No. 30, Beisanhuan East Road, Beijing City, 100013, China; E-mail: GB50011-cabr@163.com).

Chief Development Organization: China Academy of Building Research (CABR).

Participating Development Organizations: Institute of Engineering Mechanics (IEM) of China Earthquake Administration, China Architecture Design & Research Group, China Institute of Building Standard Design & Research, Beijing Institute of Architectural Design, China Electronics Engineering Design Institute, China Southwest Architectural Design and Research Institute, China Northwest Architectural Design and Research Institute, China Northeast Architecture Design and Research Institute, East China Architectural Design and Research Institute, Central-South Architectural Design Institute, the Architectural Design and Research Institute of Guangdong Province, Shanghai Institute of Architecture Design and Research, Institute of Building Design and Research of Xinjiang Uygur Autonomous Region, Yunnan Province Design Institute, Sichuan Architectural Design Institute, Shenzhen General Institute of Architectural Design and Research, Beijing Geotechnical Institute, Shanghai Tunnel Engineering and Rail Transit Design and Research Institute, China Construction (Shenzhen) Design international, Architecture Design General Institute of China Metallurgical Group Corporation, China National Machinery Industry Corporation, China IPPR International Engineering Corporation, Tsinghua University, Tongji University, Harbin Institute of Technology, Zhejiang University, Chongqing University, Yunnan University, Guangzhou University, Dalian University of Technology and Beijing University of Technology

Chief Drafters: Huang Shimin, Wang Yayong

(The following is according to the Chinese phonetic alphabetically)

Ding Jiemin, Fang Taisheng, Deng Hua, Ye Liaoyuan, Feng Yuan, Lu Xilin, Liu Qiongxiang, Li Liang, Li Hui, Li Lei, Li Xiaojun, Li Yaming, Li Yingmin, Li Guoqiang, Yang Linde, Su Jingyu, Xiao Wei, Wu Mingshun, Xin Hongbo, Zhang Ruilong, Chen Jiong, Chen Fusheng, Ou Jinping, Yu Yinquan, Yi Fangmin, Luo Kaihai, Zhou Zhenghua, Zhou Bingzhang, Zhou Fulin, Zhou Xiyuan, Ke Changhua, Lou Yu, Jiang Wenwei, Yuan Jinxi, Qian Jihong, Qian Jiaru, Xu Jian, Xu Yongji, Tang Caoming, Rong Baisheng, Cao Wenhong, Fu Shengcong, Zhang Yiping, Ge Xueli, Dong Jincheng, Cheng Caiyuan, Fu Xueyi, Zeng Demin, Dou Nanhua, Cai Yiyan, Xue Yantao, Xue Huili and Dai Guoying

Chief Examiners: Xu Peifu, Wu Xuemin, Liu Zhigang

(The following is according to the Chinese phonetic alphabetically)

Liu Shutun, Li Li, Li Xuelan, Chen Guoyi, Hou Zhongliang, Mo Yong, Gu Baohe, Gao Mengtan, Huang Xiaokun and Cheng Maokun

# Contents

# 1 General

**1.0.1** This code is formulated with a view to implementing the relevant laws and regulations on construction engineering and protecting against and mitigating earthquake disasters, carrying out the policy of “prevention first”, as well as alleviating the seismic damage of buildings, avoiding casualties and reducing economic loss through seismic precautionary of buildings.

The basic seismic precautionary objectives of buildings which designed and constructed in accordance with this code, are as follows:

1) under the frequent earthquake ground motion with an intensity being less than the local Seismic Precautionary Intensity, the buildings with major structure undamaged or requiring no repair may continue to serve;
2) under the earthquake ground motion with an intensity being equivalent to the local Seismic Precautionary Intensity, the buildings with possible damage may continue to serve with common repair; or
3) under the rare earthquake ground motion with an intensity being larger than the local Seismic Precautionary Intensity, the buildings shall not collapse or shall be free from such severe damage that may endanger human lives.

If the buildings with special requirements in functions or other aspects are carried out with the seismic performance-based design, more concrete and higher seismic precautionary objectives shall be established.

**1.0.2 All the buildings situated on zones of Seismic Precautionary Intensity 6 or above must be carried out with seismic design.**

**1.0.3** This code is applicable to the seismic design and the isolation and energy-dissipation design of the buildings suited on zones of Seismic Precautionary Intensity 6, 7, 8 and 9. And the seismic performance-based design of buildings may be implemented in accordance with the basic methods specified in this code.

As for the buildings suited on zones where the Seismic Precautionary Intensity is above Intensity 9 and the industrial buildings for special purpose, their seismic design shall be carried out according to the relevant special provisions.

Note: For the purposes of this code, “Seismic Precautionary Intensity 6, 7, 8 and 9” hereinafter is referred to “Intensity 6, 7, 8 and 9”.

**1.0.4 The Seismic Precautionary Intensity must be determined in accordance with the documents (drawings) examined, approved and issued by the authorities appointed by the State.**

**1.0.5** Generally, the seismic precautionary intensity of buildings shall be adopted with the basic seismic intensity (the intensity values corresponding to the design basic acceleration of ground motion value in this code) determined according to the “*Seismic Ground Motion Parameter Zonation Map of China*”.

**1.0.6** In addition to the requirements of this code, the seismic design of buildings also shall comply with the requirements specified in the relevant current standards of the State.

# 2 Terms and Symbols

## 2.1 Terms

**2.1.1** Seismic precautionary intensity

The seismic intensity approved by the authority appointed by the State, which is used as the basis for the seismic precaution of buildings in a certain region. Generally, it is taken as the seismic Intensity with a 10% probability of exceedance in 50 years.

**2.1.2** Seismic precautionary criterion

The rule for judging the seismic precautionary requirements, which is dependent on the Seismic Precautionary Intensity or the design parameters of ground motion and the precautionary category of buildings.

**2.1.3** Seismic ground motion parameter zonation map

The map in which the whole county is divided into regions with different seismic precautionary requirements according to the ground motion parameter (that is the degree of earthquake ground motion intensity indicated by acceleration).

**2.1.4** Earthquake action

The dynamic response of structure caused by earthquake ground motion, including horizontal and vertical earthquake action.

**2.1.5** Design parameters of earthquake ground motion

The parameters of earthquake ground motion used in seismic design, including the acceleration (velocity or displacement) time history of the earthquake ground motion , the acceleration response spectrum and the peak value of ground acceleration

**2.1.6** Design basic acceleration of earthquake ground motion

The design value of seismic acceleration with a 10% probability of exceedance in the 50-years design reference period.

**2.1.7** Design characteristic period of earthquake ground motion

The period value corresponding to the starting point of the descending section of the seismic influence coefficient curve used for seismic design, that is dependent on the earthquake magnitude, epicentral distance, site class and etc. For convenience, it is named as “characteristic period” for short.

**2.1.8** Site

Locations of the project colonies, being with similar characteristics of response spectra. The scope of site is equivalent to plant area, residential area and natural village or the plane area no less than 1.0km$^2$.

**2.1.9** Seismic concept design of buildings

The process of making the general arrangement for the buildings and structures and of determining details, based on the fundamental design principles and concepts obtained from the past experiences in earthquake disasters and projects.

**2.1.10** Seismic measures

The seismic design contents except earthquake action calculation and member resistance calculation, including the details of seismic design.

**2.1.11** Details of seismic design

All the detailed requirements that must be taken for the structural and nonstructural components according to seismic concept design principles and require no calculation generally.

## 2.2 Symbols

**2.2.1** Actions and effects

$F_{Ek}$, $F_{Evk}$——Standard values of total horizontal and vertical earthquake actions of structure respectively;

$G_E$, $G_{eq}$——Representative value of gravity load of structure (or component) and the total equivalent representative value of gravity load of a structure ,respectively;

$w_K$——Standard value of wind load;

$S_E$——Seismic effect (bending moment, axial force, shear, stress and deformation);

$S$——Fundamental combination values of the effects of earthquake action and other loads;

$S_k$——Effect of the standard value of action or load;

$M$——Bending moment;

$N$——Axial force;

$V$——Shear;

$p$——Pressure on bottom of foundation;

$u$——Lateral displacement;

$\zeta$——Storey drift

**2.2.2** Material properties and resistance

$K$——Stiffness of structure (member);

$R$——Resistant capacity of structural component;

$f$, $f_k$, $f_E$——Design value, standard value and seismic design value of various material strength (including the bearing capacity of soil) , respectively;

$[\zeta]$——Allowable storey drift.

**2.2.3** Geometric parameters

$A$——Cross-sectional area of member;

$A_s$——Cross-sectional area of reinforcement;

$B$——Total width of structure;

$H$——Total height of structure, or the column height;

$L$——Total length of structure (unit);

$\alpha$——Distance;

$a_s$, $a'_s$——Minimal distance from the force point of the longitudinal tensile and compressive reinforcements to the margin of section, respectively;

$b$——Sectional width of member;

$d$——Depth or thickness of soil layer, or the diameter of reinforcement;

$h$——Depth of cross-section of member;

$l$——Length or span of member;

$t$——Thickness of wall or floor slab.

**2.2.4** Coefficients of calculation

$\alpha$——Horizontal seismic influence coefficient;

$\alpha_{max}$——Maximum value of horizontal seismic influence coefficient;

$\alpha_{vmax}$——Maximum value of vertical seismic influence coefficient;

$\gamma_G$, $\gamma_E$, $\gamma_W$——Partial factor of action;

$\gamma_{RE}$——seismic adjusting factor for load-bearing capacity;

$\delta$——Calculation coefficient;

$\varepsilon$——Enhancement or adjustment coefficient of earthquake action effect (internal force or deformation);

$\lambda$——Slenderness ratio of member, or the proportionality coefficient;

$\xi_y$——Yield strength coefficient of structure (member);

$\rho$——Reinforcement ratio or ratio;

$\phi$——Stability coefficient of compressive member;

$\psi$——Combination value coefficient or the influence coefficient.

**2.2.5** Others

$T$——Natural vibration period of structure;

$N$——Penetration resistance (in blow number);

$I_{lE}$——Liquefaction index of soil under earthquake;

$X_{ji}$——The coordinate of modal displacement (relative displacement of the $i^{th}$ mass point of the $j^{th}$ mode in $x$ direction);

$Y_{ji}$——The coordinate of modal displacement (relative displacement of the $i^{th}$ mass point of the $j^{th}$ mode in $y$ direction);

$n$——Total number, such as number of storeys, masses, reinforcements and spans, etc.;

$\upsilon_{se}$——Equivalent shear wave velocity of soil layer;

$\Phi_{ji}$——The coordinate of modal rotation (relative rotation of the $i^{th}$ mass point of the $j^{th}$ mode around the z axial direction).

# 3 Basic Requirements of Seismic Design

## 3.1 Category and Criterion for Seismic Precaution of Buildings

**3.1.1 The seismic precautionary category and the seismic precautionary criterion of buildings shall be determined in accordance with the current national standard GB 50223 "*Standard for Classification of Seismic Protection of Building Constructions*".**

**3.1.2** Unless otherwise specified in this code, Categories B, C and D buildings with seismic precautionary intensity 6 may not be carried out the calculation of earthquake action.

## 3.2 Earthquake Ground Motion

**3.2.1** The earthquake ground motion of the zones in which buildings are suited shall be represented by design basic acceleration and characteristic period of earthquake ground motion corresponding to the seismic precautionary intensity.

**3.2.2** The corresponding relationship between the seismic precautionary intensity and the design basic acceleration of ground motion shall be in accordance with those specified in Table 3.2.2. Unless otherwise stated in this code, the buildings in such zones where the design basic acceleration of ground motion is 0.15$g$ and 0.30$g$ shall be carried out with seismic design respectively according to the requirements of seismic precautionary intensity 7 and 8.

**Table 3.2.2 Corresponding Relationship Between Seismic Precautionary Intensity and Design Basic Acceleration of Ground Motion**

| Seismic precautionary intensity | 6 | 7 | 8 | 9 |
|---|---|---|---|---|
| Design basic acceleration value of ground motion | 0.05$g$ | 0.10 (0.15)$g$ | 0.20 (0.30)$g$ | 0.40$g$ |

Note: $g$ is the gravity acceleration.

**3.2.3** The characteristic period of earthquake ground motion shall be determined according to the design earthquake groups and the site class of the building site. The design earthquakes in this code are totally divided into three groups, and their characteristic periods shall be adopted according to the relevant provisions in Chapter 5 of this code.

**3.2.4** The seismic precautionary intensity, design basic acceleration of ground motion and design earthquake groups of the central areas in the main cities in China may be adopted according to Appendix A of this code.

## 3.3 Site and Soil

**3.3.1 During the selection of a building site, a comprehensive assessment to the region shall be made according to the project demand and the relevant information on the seismicity, engineering geology and seismogeology of the region, and the assessment result such as the favorable, common, unfavorable or hazardous section shall be given simultaneously. At the unfavorable section, the building site shall be avoided to locate or be treated with some effective measures if unable to avoid. In the hazardous sections, the buildings assigned to Category A or B must not be constructed and the buildings assigned to Category C shall not be constructed.**

**3.3.2 If the building site is of Class I, it shall be permitted to adopt details of seismic design according to the requirements of local seismic precautionary intensity for the buildings assigned to Category A and B, and to the requirements of the reduced Intensity that shall be taken as one grade less than the local seismic precautionary intensity, but not less than Intensity 6, for the buildings assigned to Category C.**

**3.3.3** If the building site is of Class III or IV, in the areas where the design basic acceleration of ground motion is 0.15*g* and 0.30*g*, unless otherwise stated in this code, buildings should be adopted with details of seismic design according to the requirements of the seismic precautionary intensity 8 (0.20*g*) and 9 (0.40*g*), respectively.

**3.3.4** The design of base and foundation shall meet the following requirements:

**1** Foundation of one same structural unit should not be built on the soils with entirely different features.

**2** One same structural unit should not be adopted with natural subsoil and pile foundation partially. If different types of foundations are adopted or the buried depth of foundation is different obviously, corresponding measures shall be taken at the relevant positions of foundation and superstructure according to the differential settlement of these two parts of foundations under earthquake.

**3** To the subsoils consisted of soft clay, liquefied soil, newly filled soil or extremely non-uniform soil, the corresponding measures shall be taken according to the non-uniform settlement and other adverse impacts of foundation under earthquake.

**3.3.5** The site and foundation of buildings in mountainous areas shall comply with the following requirements:

**1** For the buildings in mountainous areas, the slop stability evaluation and prevention and treatment scheme suggestions shall be made during geotechnical investigation, and the slope project meeting the requirements of seismic precaution shall be set up in accordance with the geologic and orographic conditions, usage function requirements and local conditions.

**2** The slope design shall meet the requirements of the current national standard GB 50330 "*Technical Code for Building Slope Engineering*"; and the relevant friction angle shall be corrected according to the precautionary intensity during the slope stability evaluation.

**3** The building foundation near to slope shall be carried out with seismic stability design. An adequate distance with proper measures that shall be determined according to the precautionary intensity, shall be left at the edge of the soil or severely weathered rock slope and building foundation to avoid the foundation failure under earthquake.

## 3.4 Regularity of Building Configuration and Structural Assembly

**3.4.1 The building design shall specify the regularity of building configuration according to the requirements of seismic concept design. For irregular buildings, strengthening measures shall be taken as required; for especially irregular buildings, special strengthening measures shall be taken through special study and demonstration; severely irregular buildings shall not be built.**

**Note: The building configuration refers to the variations in the plane, elevation and vertical section of a building.**

**3.4.2** The building design shall attach great importance to influences of the regularity of its plane, vertical plane and vertical section on the seismic performance and economical rationality, and the regular building configuration should be as a matter of priority. And at the same time, the arrangement of the lateral-force-resisting components should be regular and symmetrical in plan with respect to two orthogonal axes, the lateral stiffness of the lateral-force-resisting system should vary uniformly along the vertical direction, the sectional dimension and material strength of the vertical lateral-force-resisting components should be reduced gradually from bottom to top to avoid the sudden changes of lateral stiffness and load-bearing capacity.

The seismic design of irregular building shall comply with those specified in Article 3.4.4 of this code.

**3.4.3** The horizontal and vertical irregular classification for the building configuration and its structural assembly shall be carried out according to the following requirements:

**1** The concrete structure building, steel structure building or steel-concrete structure building, having one of horizontal irregularity types listed in Table 3.4.3-1 or one of vertical irregularity types listed in Table 3.4.3-2 or other similar irregular types, shall be designated as irregular building.

**Table 3.4.3-1 Horizontal structural Irregularities**

| Type of irregularity | Description and reference index |
|---|---|
| Torsional irregularity | Under the action of specified horizontal force with accidental eccentricity, the ratio between maximum and average of elastic horizontal displacement (or storey drift) of lateral force-resisting members at two ends of the storey is larger than 1.2. |
| Reentrant Corner irregularity | Both projections of the structure beyond a re-entrant corner greater than 30% of the plan dimension of the structure in the given direction |
| Diaphragm discontinuity Irregularity | Diaphragms with abrupt discontinuities or variations in stiffness, including those having cutout or open areas greater than 30% of the gross enclosed diaphragm area, or effective width less than 50% of total width of diaphragm, or with floors staggered greatly in the vertical direction. |

**Table 3.4.3-2 Vertical structural Irregularities**

| Type of irregularity | Description and reference index |
|---|---|
| Stiffness-Soft Storey Irregularity | The lateral stiffness in the storey is less than 70% of that in the storey above or less than 80% of the average stiffness of the three storeys above; or the horizontal dimension of the storey is less than 75% that of next storey lower except the top storey or the small buildings outside roof. |
| In-plan Discontinuity in vertical lateral-force-resisting component Irregularity | The internal force of vertical lateral-force-resisting components (columns, seismic walls and seismic bracing) is transmitted downward through horizontal transmission components (beam and truss) |
| Discontinuity in Lateral Strength-Weak Storey Irregularity | The storey lateral strength of lateral-force-resisting structure is less than 80% of that in the storey above. |

**2** The horizontal and vertical irregular classification for masonry buildings, single-storey factory buildings, single-storey spacious buildings, large-span roof buildings or subterranean buildings shall meet those specified in the related chapters of this code.

**3** A building, with several irregularity types or one certain irregularity type exceeding the reference index greatly, shall be designated as especially irregular building.

**3.4.4** Provided that the building configuration and its structural assembly are irregular, the earthquake action calculation and internal force adjustment shall be carried out in accordance with the following requirements and the weak positions shall be taken with effective details of seismic design:

**1** For buildings having horizontal irregularities and vertical regularities, calculation shall be carried out using spatial structural models l and the following requirements shall also be met:

**1)** For buildings having torsional irregularity, the torsion effects shall be considered; under the action of specified horizontal force with accidental eccentricity, the ratio between maximum and average of elastic horizontal displacement (or storey drift) of lateral force-resisting members at two ends of the storey should not be larger than 1.5; and if the maximum storey drift is far less than the specified limit, the requirement of 1.5 times above may be loosened properly;

**2)** For buildings having reentrant corner irregularities or diaphragm discontinuity irregularities, the analysis model including the actual stiffness changes in the floor plane shall be used; and the influence of the local deformation of floor slab should also be taken into account for high seismicity cases or larger irregularity index cases; and

**3)** For planar asymmetric buildings having reentrant corner irregularities or diaphragm discontinuity irregularities, the whole structures in plan may be divided into number of blocks according to actual situation, and the torsional displacement ratio of each block may be calculated separately, and a local internal force enhancement coefficient shall be adopted for the seismic design of the members located at the position with large torsion effects.

**2** For buildings having horizontal irregularities and vertical irregularities, the calculation shall be carried out using spatial structural models, the seismic shear of storey with smallest lateral stiffness shall be multiplied by an enhancement coefficient no less than 1.15, the elasto-plastic deformation analysis for the weak stories shall be carried out according to the relevant regulations of this code, and the following requirements shall also be met:

**1)** For buildings having in-plan discontinuity in vertical lateral-force-resisting component Irregularity, the seismic internal force transferred from the vertical component to the horizontal transmission components shall be multiplied by an enhancement coefficient of 1.25~2.0 according to the seismicity, type of horizontal transmission component, mechanical conditions and geometrical sizes, etc.;

**2)** For buildings having stiffness-soft storey irregularity, the lateral stiffness ratio between adjacent stories shall comply with those specified in the relevant chapters of this code; or

**3)** For buildings having discontinuity in lateral strength-weak storey irregularity, the shear capacity of the weak storey shall not be less than 65% of that of the storey above.

**3** For buildings having horizontal irregularities and vertical irregularities, the pertinence seismic measures no less than requirements of Item 1 and Item 2 in this article shall be adopted according to the quantity and degree of the irregularities. For especially irregular buildings, special studies on the seismic design shall be made, and much more efficient strengthening measures shall be taken or the corresponding seismic performance-based design method shall be used for the weak portions of structures.

**3.4.5** For buildings having complex configuration and irregular plan or elevation, the arrangement of the seismic joints shall be determined according to the results of the a comparative analysis of those factors such as degree of irregularity, condition of foundation and technical economy, and the following requirements shall be met respectively:

**1** For the complex building with no seismic joints, the mathematical model of the structure shall be consistent with the actual, and the vulnerable portion where stresses concentrated, deformations concentrated or torsional effects were obvious, shall be distinguished so as to adopt corresponding strengthening measures;

**2** For building with seismic joints at proper positions, multiple regular and independent lateral-force-resisting structural units should be formed. The seismic joint with adequate width shall be arranged according to the seismic precautionary intensity, structural material, structure type, height and height difference of structural units as well as the possible condition of earthquake torsional effects, in order to separate the structures on both sides of the seismic joint completely; or

**3** For the expansion joints and settlement joints, their width shall comply with the requirements of seismic joints.

## 3.5 Structural System

**3.5.1** The structural system shall be determined through comprehensive comparison in technology, economy and application conditions based on such factors as precautionary category, seismic precautionary intensity, height, site conditions, foundation, structural materials and construction of the building.

**3.5.2 The structural system shall meet the following requirements:**

**1 The structural system shall have clear analysis model and reasonable paths for the transmission of seismic forces.**

**2 The structural system shall have adequate robustness to avoid the losses of seismic capacity or gravity load-bearing capacity due to the failure of portion of structure or components.**

**3 The structural system shall have necessary seismic capacity, favorable deformation ability and seismic energy dissipation ability.**

**4 For the weak portions that may appear, necessary measures shall be taken to improve the seismic capacity.**

**3.5.3** The structural system should also comply with the following requirements:

**1** The structural system should have multi-layered seismic energy dissipation subsystems.

**2** The structural system shall have a reasonable distribution of stiffness and resistance to eliminate the occurrence of weak portions where excessive concentrations of stress or plastic deformation might be produced due to local weakening or abrupt changes.

**3** The structure should have similar dynamic characteristics in the directions of two main axes.

**3.5.4** The structural members shall meet the following requirements:

**1** The masonry structures shall be constructed with the arrangements of reinforced concrete ring-beams, tie-columns and core–columns in masonries according to relevant provisions, or with constrained masonries and reinforced masonries, etc.

**2** The concrete structure members shall be designed with reasonable cross sections and proper arrangements of longitudinal bars and hoops, in order to avoid the failure modes that the shear failure is prior to flexural failure, concrete crush is prior to reinforcement yielding, and the anchorage and bond failure of reinforcements is prior to member damage.

**3** The prestressed concrete members shall be arranged with adequate non-prestressed reinforcements.

**4** The steel structure members shall be designed with reasonable sizes to avoid the local and whole buckling failure.

**5** The floor and roof of multi-storey and tall buildings should be preferred with cast-in-situ RC (reinforced concrete) slabs. For the precast concrete floor or roof, measures of the floor system and details shall be taken to ensure the integrity of connection between precast concrete slabs.

**3.5.5** The connection between members of the structure shall meet the following requirements:

**1** The connection failure shall not be prior to that of the connected members.

**2** Anchorage failure of embedded elements shall not be prior to the connection failure.

**3** The connections of precast structural members shall ensure the integrity of the structure.

**4** Prestressed reinforcements of prestressed concrete members should be anchored beyond the core of joint.

**3.5.6** The seismic brace systems of single-storey fabricated factory building shall ensure the integrity and stability of the whole structure during earthquake.

## 3.6 Structural Analysis

**3.6.1** Unless otherwise provisions are issued in this code, the analysis for internal force and deformation of building structures under frequent earthquake ground motion shall be carried out. In this analysis, it may be assumed that the structure and members are working at elastic state, so that the linear static analysis method or linear dynamic analysis method may be used.

**3.6.2** For irregular building structures with obvious weak portions that may result in serious seismic damage, the elasto-plastic deformation analysis under the rare earthquake ground motion shall be carried out according to relevant provisions of this code. In this analysis, the non-linear static (pushover) analysis method or non-linear time history (dynamic) analysis method may be used according to the structural characteristics.

Where the specific provisions are specified in this code, the elasto-plastic deformations of the structure may also be calculated by the simplified methods.

**3.6.3** When the gravity additional bending moment of structure under frequent earthquake ground motion is greater than 10% of original bending moment, the second-order effect of gravity shall be taken into account.

Note: The gravity additional bending moment is the product of the total gravity load at and above any one storey by the mean storey drift of this storey under earthquake ground motion; the original bending moment is the product of the seismic shear force of this storey by the storey height of the building.

**3.6.4** In seismic analysis of structure, the floor and roof shall be taken as being rigid, block rigid, semi-rigid, local elastic and flexible diaphragm according to the plane shapes and the deformation in-plane, then the cooperative working mechanisms of lateral-force-resisting components shall be determined according to the arrangement of lateral-force-resisting system and the floor diaphragms rigidity, and then, the analysis of seismic internal forces of these components shall be carried out.

**3.6.5** For the structures having nearly symmetric distribution of masses and lateral stiffness and rigid floor and roof diaphragms as well as the structures with specific provisions of this code, the seismic analysis may be performed using planar structural models. For other structures, the seismic analysis shall be performed using spatial structural models.

**3.6.6** The seismic analyses of structures by computers shall meet the following requirements:

**1** The determination of mathematical model as well as necessary simplified calculation and treatment shall comply with the actual working condition of the structure, and the effects of stair components shall be involved in calculation.

**2** The technical conditions of computer software shall comply with this code and those specified in the relevant standards, and the contents and reference of special treatment shall also be clarified.

**3** For complex structures, the analysis for internal force and deformation under frequent earthquake action shall be performed using at least two different mechanical models, and the analysis results of these two models shall be compared.

**4** The rationality and validity of all the analysis results from the computer shall be analyzed, judged and affirmed, and after then they are permitted to be used in the project design.

## 3.7 Nonstructural Components

**3.7.1 Nonstructural components, including the nonstructural components and the auxiliary mechanical and electrical equipments of buildings, and the connections to the main structures shall be designed and constructed to withstand seismic action.**

**3.7.2** The seismic design of nonstructural components shall be performed by relevant professional personnel respectively.

**3.7.3** The nonstructural components attached to floor and roof structures as well as the non-bearing wall of the staircase shall be reliably connected or anchored to the main structure to avoid collapsed during earthquake that may induce human injury or damage of important equipments.

**3.7.4 For frame structures, the unfavorable effects of infilled walls including enclosure walls and partition walls on seismic performance of structure shall be estimated and taken into account, and the irrational arrangement of infilled walls that would cause damage to main structure shall be avoided.**

**3.7.5** Curtain wall and veneers shall be reliably connected to the main structure to avoid falling during earthquake that may induce human injury.

**3.7.6** The supports and connections of the auxiliary mechanical and electrical equipments installed at the buildings shall meet the functional requirements during earthquake and shall not result in any damage to relevant portions.

## 3.8 Isolation and Energy-Dissipation

**3.8.1** The isolation and energy-dissipation design may be applied to the buildings which have higher or special requirements on seismic safety and function.

**3.8.2** The seismically isolated and energy-dissipated buildings may be designed according to the seismic precautionary objectives that should be higher than the basic seismic precautionary objectives stated in Article 1.0.1 of this code.

## 3.9 Materials and Construction

**3.9.1 The special requirements of seismic structures on materials and construction quality shall be clearly stated in the design documents.**

**3.9.2 The property indexes of structural materials shall meet the following minimum requirements:**

**1 The materials of masonry structure shall meet the following requirements:**

**1) The strength grade of common brick and hollow-brick shall not be less than MU10 and the strength grade of mortar for the bricks shall not be less than M5;**

**2) The strength grade of small-sized concrete hollow block shall not be less than MU7.5 and the strength grade of its masonry mortar shall not be less than Mb7.5.**

**2 The materials of concrete structures shall meet the following requirements:**

**1) The strength grades of concrete for frame-supported beams and columns as well as frame beams and columns and connection cores assigned to seismic grade 1 shall not be less than C30; and the strength grades of concrete for tie-columns, core columns, ring-beams and other members shall not be less than C20;**

**2) For the ordinary reinforcements used as the longitudinal reinforcements of frames and diagonal bracing members (including the stair) assigned to seismic grade 1, 2 and 3, the ratio of the measured tensile strength to the measured yield strength shall not be less than 1.25, the ratio of the measured yield strength to the standard value of yield strength shall not be larger than 1.3, and the measured overall elongation under the maximum tensile stress shall not be less than 9%.**

**3 The materials of steel structures shall meet the following requirements:**

**1) The ratio of the measured yield strength to the measured tensile strength shall not be larger than 0.85;**

**2) The steels shall have obvious yield steps and their elongation rate shall not be less than 20%; and**

**3) The steels shall have good weldability and qualified impact ductility.**

**3.9.3** The property indexes of structural materials should also meet the following requirements:

**1** The ordinary reinforcements with better ductility, tenacity and weldability should be preferred. For the longitudinal reinforcements, the hot rolled reinforcements with strength grade no less than HRB400 that meet the requirements of seismic performance index should be used, in additional, the Grade HRB335 hot rolled reinforcements that meet the requirements of seismic performance index may also be used. For the hoops, the hot rolled reinforcements with strength grade no less than HRB335 that meet the requirements of seismic performance index should be used, in additional, in additional, the Grade HPB300 hot rolled reinforcements that meet the requirements of seismic performance index may also be used.

Note: The inspection method of reinforcements shall comply with those specified in the current national standard —Code for Acceptance of Constructional Quality of Concrete Structures" GB 50204.

**2** The concrete strength grade of concrete structures, should not exceed C60 for seismic wall, and for other components, it should not exceed C60, C70 for Intensity 9 and Intensity 8,respectively.

**3** For the steel type of steel structures, s the Q235B, Q235C and Q235D carbon structural steels and Q345B, Q345C, Q345D and Q345E high strength low alloy structural steels should be used; in additional, other types and grades of steels may also be used when reliable references are available.

**3.9.4 During the construction, if the longitudinal reinforcements in original design have to be replaced by those with higher strength grade, the conversion shall be made according to the principle of equal tensile capacity design values of reinforcements, and shall also comply with requirement of minimum reinforcement ratio.**

**3.9.5** For steel structures adopting welded connections, if the welding restraint degree of joints is relatively big, the thickness of steel plate is not less than 40mm and the steel plates bear the tensile force along the plate thickness direction, the contraction rate in the thickness direction shall not be less than the allowable value of Grade Z15 specified in national standard GB/T 5313 —*Steel Plate with Through-thickness Characteristics*".

**3.9.6 During the construction of the masonry seismic walls in buildings adopting reinforced concrete tie-columns or masonry buildings with RC frames on ground floors , the masonry walls shall be laid out prior to casting the tie-columns and concrete frames..**

**3.9.7** The horizontal construction joints of concrete wall and frame column shall be taken with measures to strengthen the bonding property of concrete. For the seismic wall assigned to Grade I and the zone of the seismic wall continuous to ground where the transition storey slab meets the wall, the shear bearing capacity of horizontal construction joint shall be checked.

## 3.10 Seismic Performance-Based Design of Buildings

**3.10.1** When a building structure is designed using the seismic performance-based design method, the technical and economic feasibility comprehensive analysis and argumentation on the selected performance objectives shall be made according to the following factors:

precautionary category, precautionary intensity, site conditions, structure type and irregularity, requirements of functions of building and ancillary facilities, investment size, earthquake loss and reconstruction cost.

**3.10.2** According to the actual demand and possibility, the seismic performance-based design of building structure shall have pertinency and may be implemented respectively for the whole structure, partial or key zones, critical components, important components and secondary components of the structure, building components and supports for mechanical and electrical equipments.

**3.10.3** The seismic performance-based design of building structure shall meet the following requirements:

**1** Determination of earthquake hazard levels.

For the structures with 50-years design life, the three earthquake hazard levels in this code: frequent earthquake, precautionary earthquake and rare earthquake may be selected, thereinto, the design basic acceleration of the precautionary earthquake shall be determinate according to those listed in Table 3.2.2 of this code, and the maximum seismic influence coefficient of the precautionary earthquake may be taken as 0.12, 0.23, 0.34, 0.45, 0.68 and 0.90 for Intensity 6, Intensity 7 (0.10*g*), Intensity 7 (0.15*g*), Intensity 8 (0.20*g*), Intensity 8 (0.30*g*) and Intensity 9, respectively.

For the structure with a design life more than 50 years, the desired earthquake parameters should be determined from that of the three earthquake hazard levels of this code, by proper adjustment through special study based on the actual demand and possibility.

For structures located within 10 km of the fault rupture, the near-source influences shall be taken into account, and the ground motion parameter should be multiplied by an enhancement coefficient of 1.5 and no less than 1.25 for the distance from fault within 5 km and outside 5km, respectively.

**2** Selection of performance objectives

The selected performance objectives, that are defined as the expected damages or functional status of buildings under different levels of earthquake ground motion, shall not be lower than basic precautionary objective specified in Article 1.0.1 of this code.

**3** Selection of the design performance indexes

During the seismic performance-based design of a building, the specific design performance indexes for the whole structure or the vital zones shall be selected to improve the seismic bearing capacity and deformability, respectively or simultaneously. and meanwhile, the uncertainty of seismic action shall be considered and proper clearance shall be left.

During the design, the requirements of the bearing capacity (including not occurring brittle shear failure, forming plastic hinge, yielding or maintaining elasticity, etc.) for horizontal and vertical members located at different zones of a structure under different ground motion levels should be determined; the expected elasticity or elasto-plastic deformation status for different portions of a structure under different ground motion levels should be selected, and the detail requirements for high, medium and low ductile demand of the corresponding members should be determined. If the bearing capacity of member is Significantly higher than the demand, the corresponding detail measures for ductility may be reduced properly.

**3.10.4** The calculation for the seismic performance-based design of building structure shall meet the following requirements:

**1** The analytical model shall correctly and reasonably reflect the transmission paths of seismic forces and the actual working status of floor diaphragm whether the integral or partial floor is at elastic under different ground motion levels.

**2** For elasticity analysis, the linear method may be used. For elasto-plastic analysis, the equivalent linear method with damping increasing, static or dynamic nonlinear method may be used according to the elasto-plastic state of structure determined by the performance objectives, respectively.

**3** The nonlinear analysis model for the structure may be simplified properly relative to the elastic analysis model, but the linear analysis results of above two models under frequent earthquake shall be basically consistent. During the calculations, the gravity second-order effect shall be considered, the elasto-plastic parameters of members shall be determined reasonably, and the bearing capacity of member shall be calculated according to the actual section and reinforcement. The nonlinear analysis of the structure shall be performed to find out the possible damaged zones and the elasto-plastic deformation degree of the members by the comparisons with the ideal elastic analysis results.

**3.10.5** The reference objectives and calculation methods for the seismic performance-based design of the structure and its members may be adopted according to those specified in Section M.1 of Appendix M in this code.

## 3.11 Seismic Response Observation System of Buildings

**3.11.1** For the large public buildings with height exceeding 160m, 120m and 80m for seismic precautionary intensity of 7, 8 and 9 respectively, the seismic response observation system of building structures shall be installed as required, and the building design shall leave spaces for the observation instruments and relevant circuits.

# 4 Site, Soil and Foundation

## 4.1 Site

**4.1.1** During selecting the building site, the region shall be classified as favorable, common, unfavorable or hazardous section to the seismic capacity of buildings according to Table 4.1.1.

**Table 4.1.1 Classification of Favorable, Common, Unfavorable and Hazardous Sections**

| Section type | Geological, topographical and geomorphic description |
|---|---|
| Favorable section | Stable rock bed, stiff soil, or dense and homogeneous medium-stiff soil located at wide-open and even field, |
| Common section | Sections not belonging to the favorable, unfavorable and hazardous sections |
| Unfavorable section | Soft soil, liquefied soil; stripe-protruding spur; lonely tall hill, steep slope, steep step, river bank or boundary of side slops, soil having obviously plan heterogeneous distribution on the cause, characteristics and state (including abandoned river beds, loosened fracture zone of fault, and hidden swamp, creek, ditch and pit, as well as base formatted with excavated and filled), plastic loess with high moisture, ground surface with structural fissure, etc. |
| Hazardous section | Regions where landslide, collapse, subsidence, ground fissure and debris flow may occur during earthquake, as well as the zones in causative fault where ground dislocation may occur during earthquake. |

**4.1.2** The building site shall be classified according to the equivalent shear wave velocity of soil and the thickness of overlaying layer of site.

**4.1.3** The measurement of the shear wave velocity of soil shall meet the following requirements:

**1** At the stage of primary investigation of the site, for the same geologic units with large area, the number of drilling holes for the shear-wave-velocity tests of soil should not be less than 3.

**2** At the stage of detailed investigation of the site, for every building, the number of drilling holes for the shear-wave-velocity tests of soil should not be less than 2; if the data varies significantly, the number may be increased properly. For the crowded building complex in one community, which are built in one same geologic unit, such number may be reduced properly but shall not be less than one for each tall building or each large-span spatial structure.

**3** For buildings assigned to Category D or buildings assigned to Category C with no more than 10 storeys or no more than 30m in height, if the measured data are not available, the shear wave velocity of each soil layer may be estimated within the range as per set in Table 4.1.3 based on the geotechnical description of soil, the soil type and the local experiences.

**Table 4.1.3 Classification of Soil Types and Range of Shear Wave Velocity**

| Soil type | Geotechnical description | Shear wave velocity of soil layer (m/s) |
|---|---|---|
| Rock | Stiff rocks, hard and complete rocks | $\upsilon_s$>800 |
| Stiff soil or soft sock | Broken and comparatively broken rock; soft and comparatively soft rock; compact gravel soil | 800≥$\upsilon_s$>500 |
| Medium-stiff soil | Medium dense or slightly dense detritus; dense or medium-dense gravel; coarse or medium sands; cohesive soil and silt with $f_{ak}$>150kPa; hard loess | 500≥$\upsilon_s$>250 |
| Medium-soft soil | Slightly dense gravel; coarse and medium sands; fine and mealy sands (excluding the loose sand), cohesive soil and silt with $f_{ak}$≤150kPa; filled soil with $f_{ak}$>130kPa; plastic young loess | 250≥$\upsilon_s$>150 |
| Soft soil | Mud and muddy soil; loose sand; new sedimented cohesive soil and silt; filled soil with $f_{ak}$≤130kPa; flow plastic loess | $\upsilon_s$≤150 |

Note: $f_{ak}$ is the characteristic value (kPa) of base bearing capacity obtained through load test or other methods; $\upsilon_s$ is the shear wave velocity of rock-soil.

**4.1.4** The thickness of the overlaying layer of the building site shall be determined according to the following requirements:

**1** Generally, this thickness shall be taken as the distance from the ground surface to the top surface of the soil layer which has a shear wave velocity more than 500m/s and under which the shear wave velocity of any soil layer is no less than 500m/s.

**2** If there is such soil layer 5m below ground surface that has a shear wave velocity more than 2.5 times of that of the soil layers above and the shear wave velocities of this soil layer and those under it are not less than 400m/s, the thickness of the overlaying layer may be taken as the distance from the ground surface to the top surface of this soil layer.

**3** The lone-stone and lentoid-soil with shear-wave velocity greater than 500m/s shall be deemed the same as surrounding soil layer.

**4** The hard volcanic inter-bedded rock in the soil profile shall be deemed as rigid body and its thickness shall be deducted from the thickness of overlaying layer.

**4.1.5** The equivalent shear wave velocity of soil profile shall be calculated according to the following equation:

$$\upsilon_{se}=d_0/t \tag{4.1.5-1}$$

$$t=\sum_{i=1}^{n}(d_i/\upsilon_{si}) \tag{4.1.5-2}$$

Where $\upsilon_{se}$——Equivalent shear wave velocity of soil profile (m/s);

$d_0$——Calculation depth (m), which shall be taken as the minor between the thickness of overlaying layer and 20m;

$t$——Transmission time of the shear-wave from the ground surface to the calculated depth;

$d_i$——Thickness (m) of the $i^{th}$ soil layer within the range of calculation depth;

$\upsilon_{si}$——Shear wave velocity (m/s) of the $i^{th}$ soil layer within the range of calculation depth;

$n$——Number of soil layers within the range of calculation depth.

**4.1.6 Based on the equivalent shear wave velocity of soil profile and the thickness of**

**overlaying layer, the site shall be classified as Site Class I, II, III or IV in accordance with Table 4.1.6, wherein the Site Class I consists of two subclasses: $I_0$ and $I_1$. If reliable shear wave velocity and thickness of overlaying layer are available and their values are near to the divisional line of site class listed in Table 4.1.6, the design characteristic period used in earthquake action calculation shall be permitted to determine by interpolation method.**

**Table 4.1.6 Thickness of overlaying layer for Site Classification, in m**

| Shear wave velocity of rock or equivalent shear wave velocity of soil (m/s) | Site Class | | | | |
|---|---|---|---|---|---|
| | $I_0$ | $I_1$ | II | III | IV |
| $v_s$>800 | 0 | | | | |
| 800≥$v_s$>500 | | 0 | | | |
| 500≥$v_{se}$>250 | | <5 | ≥5 | | |
| 250≥$v_{se}$>150 | | <3 | 3~50 | >50 | |
| $v_{se}$≤150 | | <3 | 3~15 | 15~80 | >80 |

**Note: In the above table, $v_s$ refers to the shear wave velocity of rock.**

**4.1.7** If causative fault exists in the site, the impact of causative fault on the project shall be evaluated and the following requirements shall be met:

**1** For the conditions meeting any one of the following requirements, the impact of causative fault dislocation on the surface structures may be neglected:

**1)** The seismic precautionary intensity is less than 8;

**2)** Fault has been no activity since the Holocene;

**3)** The thickness of the soil layers overlying the hidden fault is greater than 60m and 90m for Intensity 8 and 9, respectively.

**2** In the event that the situation does not conform to the provisions in Item 1 of this article, the main fault zone shall be avoided in the selection of site. The avoidance distance should not be less than the minimum avoidance distance for causative fault specified in Table 4.1.7.

If the scattered, less than 3 storeys buildings assigned to Category C or D are needed to be built within the scope of avoidance distance, the seismic measures of one intensity higher shall be taken, the integrity of foundation and superstructure shall be improved, and the building must not cross over any fault trace.

**Table 4.1.7 Minimum Avoidance Distance of Causative Fault (m)**

| Intensity | Precautionary category of building | | | |
|---|---|---|---|---|
| | A | B | C | D |
| 8 | Special study | 200m | 100m | — |
| 9 | Special study | 400m | 200m | — |

**4.1.8 When buildings assigned to Category C or A or B are needed to be built in unfavorable sections such as stripe-protruding spur, lonely tall hill, non-rocky or highly weathered rocky steep slope, river banks or boundary of slopes and so on, the stability of foundations under the earthquake ground motion shall be guaranteed, and meanwhile, the possible amplification effects of unfavorable sections to the design parameters of ground motion shall be estimated, and the maximum value of horizontal seismic influence coefficient shall be multiplied by the enhancement coefficient which shall be determined from 1.1 to 1.6 depending on the specific conditions of the unfavorable**

**section.**

**4.1.9 The geotechnical engineering investigations of the site shall include the following works:**

**1 According to the actual demand, to classify the region as favorable, common, unfavorable or hazardous sections;**

**2 To provide the Class of the site;**

**3 To evaluate the geotechnical stability under earthquake ground motion (including landslide, collapse, liquification and seismic subsidence characteristics);**

**4 For buildings that the time history analysis method needs to be used as the supplement of the modal response spectrum analysis, the soil profile, the thickness of overlaying layer and the relevant dynamic parameters shall also be provided according to the design requirements.**

## 4.2 Natural Soil and Foundation

**4.2.1** For the following buildings, the seismic bearing capacity check of natural soil and foundation may not be carried out:

**1** The buildings that seismic check for the upper-structure may not be carried out according to those specified in this code.

**2** The following buildings without soft cohesive soil layer within the main load-bearing layer of subsoil:

**1)** Ordinary single-storey factory buildings and single-storey spacious buildings;

**2)** Masonry buildings;

**3)** Ordinary civil frame or frame-wall structure buildings not exceeding 8 storeys and 24m in height;

**4)** Multi-storey frame factory buildings and multi-storey concrete wall buildings, of which the foundation load is equivalent to those specified in Item 3).

Note: The soft cohesive soil layer refers to the soil layer with characteristic value of base bearing capacity less than 80, 100 and 120 respectively for Intensity 7, 8 and 9.

**4.2.2 During seismic checking for the natural soil and foundation, the characteristic combination of earthquake action effects shall be used, and the seismic soil bearing capacity shall be taken as the product of the soil bearing capacity characteristic value and the seismic adjustment coefficient of soil bearing capacity.**

**4.2.3** The seismic soil bearing capacity shall be calculated according to the following Equation:

$$f_{aE} = \zeta_a f_a \tag{4.2.3}$$

Where $f_{aE}$——Seismic soil bearing capacity;

$\delta_a$——Seismic adjustment coefficient of soil bearing capacity, which shall be determined from Table 4.2.3;

$f_a$——Soil bearing capacity characteristic value after depth and width correction, which shall be determined according to the current national standard –Code for Design of Building Foundation" GB 50007.

**4.2.4** While checking the vertical bearing capacity of natural soil under the earthquake ground motion, the mean pressure and the maximum pressure on foundation bottom under the characteristic combination of earthquake action effects shall comply with the requirements of the following Equations:

**Table 4.2.3 Seismic Adjustment Coefficient of Soil Bearing Capacity**

| Name and character of rock-soil | $\delta_a$ |
|---|---|
| Rock, dense detritus, dense gravel, course and medium sands, cohesive soil and silt with $f_{ak}$≥300kPa | 1.5 |
| Medium dense and slightly dense detritus, medium dense and slightly dense gravel, course and medium sands, dense and medium dense fine and mealy sands, cohesive soil and silt with 150kPa≤$f_{ak}$<300kPa, and hard loess | 1.3 |
| Slightly dense fine and mealy sands, cohesive soil and silt with 100≤$f_{ak}$<150, and plastic loess | 1.1 |
| Mud, muddy soil, loose sand, miscellaneous fill soil, newly piled loess and streamed loess | 1.0 |

$$p \leq f_{sE} \tag{4.2.4-1}$$

$$p_{max} \leq 1.2 f_{sE} \tag{4.2.4-2}$$

Where $p$——Mean pressure on foundational bottom under the characteristic combination of earthquake action effects;

$p_{max}$——Maximum pressure on foundation bottom under the characteristic combination of earthquake action effects.

For the high-rise buildings with height-width ratio greater than 4, the foundation bottom should have no zero stress zone under the earthquake ground motion; for the other buildings, the area zero stress zone shall not exceed 15% of the area of foundation bottom.

## 4.3 Liquefied Soil and Soft Soil

**4.3.1** The liquification discrimination of saturated sandy soil and saturated silt (excluding loess) and the corresponding soil treatments should comply with the follow requirements:

**1** For Intensity 6, the liquefaction discrimination and the mitigation measures need not be considered generally, but for the building which is assigned to Category B and sensitive to liquefaction settlement, the liquefaction discrimination and the mitigation measures should be carried out according to the requirements of Intensity 7.

2 For Intensity 7 to 9,the liquefaction discrimination and the mitigation measures for building assigned to Category B, may be considered according to the requirements of local seismic precautionary intensity.

**4.3.2 For the subsoil including saturated sand and saturated silt, liquefaication discrimination shall be made except for Intensity 6. And for the subsoil including liquefied soil, corresponding measures shall be taken according to the precautionary category of building, the liquification grade and other actual conditions.**

**Note: The requirements for the liquification discrimination (identification) of saturated soil specified in this article do not include loess and powdery clay.**

**4.3.3** If one of the following conditions is satisfied, the saturated sandy soil or silt (excluding loess) may be preliminarily evaluated as non-liquefied soil, or the influence of liquification may be neglected.

**1** If the geologic time of soil is Epipleistocene of Quaternary ($Q_3$) or earlier, it may be evaluated as non-liquefied soil for Intensity 7 and 8.

**2** If the percentage content of sticky particles (particles with grain size less than

0.005mm) in silt is not less than 10%, 13% and 16% for Intensity 7, 8 and 9 respectively, the soil may be evaluated as non-liquefied soil.

Note: The sticky particle content used for liquification evaluation is measured by hexametaphosphate used as dispersion agent, and it shall be converted according to relevant regulations if other measured methods are used.

**3** For buildings with shallowly-buried natural foundations, if the thickness of upper covered non-liquefied soil and the ground water level meet any one of the following conditions, the liquification influence may be neglected.

$$d_u > d_0 + d_b - 2 \tag{4.3.3-1}$$

$$d_w > d_0 + d_b - 3 \tag{4.3.3-2}$$

$$d_u + d_w > 1.5d_0 + 2d_b - 4.5 \tag{4.3.3-3}$$

Where $d_w$——Ground water level (m), which should be taken as the mean annual highest water level within the design reference period or the annual highest water level in recent years;

$d_u$——Thickness of upper covered non-liquefied soil layer (m), in which the thickness of mud and muddy soil layers should be deducted;

$d_b$——Embedded depth of foundation (m), which shall be taken as 2m if it is less than 2m;

$d_0$——Characteristic depth of liquefied soil (m), which may be taken from Table 4.3.3.

**Table 4.3.3 Characteristic Depth of Liquefied Soil (m)**

| Type of saturated soil | Intensity 7 | Intensity 8 | Intensity 9 |
|---|---|---|---|
| Silt | 6 | 7 | 8 |
| Sandy soil | 7 | 8 | 9 |

Note: If the ground water level in this regions is under variable condition, the characteristic depth shall be considered according to unfavorable conditions.

**4.3.4** If the preliminary discrimination of saturated sandy soil and silt indicates that the further liquification evaluation is necessary, the standard penetration test method shall be used to evaluate the liquification of the soils within evaluated depth, which shall be taken as 20m generally, and 15mfor the buildings that the seismic loading-capacity checking of natural soil and foundation may not be performed as specified in Article 4.2.1.

If the standard penetration blow count of saturated soil (without pole length correction) is less than or equal to the critical value of that for liquification evaluation, the soil shall be evaluated as liquefied soil. If mature experiences are available, other evaluation methods may also be used.

Within the depth range of 20m under the ground, the critical value of standard penetration blow count for liquification evaluation may be calculated according to following Equation:

$$N_{cr} = N_0 \beta [\ln(0.6d_s + 1.5) - 0.1d_w] \sqrt{3/\rho_c} \tag{4.3.4}$$

Where $N_{cr}$——Critical value of standard penetration blow count for liquification evaluation;

$N_0$——Reference value of standard penetration blow count for liquification evaluation, which may be taken from Table 4.3.4;

$d_s$——Depth of standard penetration point for saturated soil (m);

$d_w$——ground water level (m);

$\rho_c$——Percentage content of sticky particles, which shall be taken as 3 if it is less than 3 or the soil is sandy soil;

$\beta$——Adjustment coefficient, which shall be taken as 0.80 for design earthquake Group 1, 0.95 for Group 2 and 1.05 for Group 3.

**Table 4.3.4 Reference Value ($N_0$) of Standard Penetration Blow Count for Liquification Evaluation**

| Design basic acceleration of ground motion ($g$) | 0.10 | 0.15 | 0.20 | 0.30 | 0.40 |
|---|---|---|---|---|---|
| Reference value of standard penetration blow count for liquification evaluation | 7 | 10 | 12 | 16 | 19 |

**4.3.5** For the soil profile with liquefied sandy soil layer and/or silt layer, the depth and thickness of each liquefied soil layer shall be explored, the liquification index of each drilling hole shall be calculated according to the following equation, and the liquification grade of soil shall be classified according to Table 4.3.5:

$$I_{lE}=\sum_{i=1}^{n}[1-\frac{N_i}{N_{cri}}]d_iW_i \tag{4.3.5}$$

Where $I_{lE}$——Liquification index;

$n$——Total number of standard penetration test points for each drilling hole within the evaluated depth range;

$N_i$, $N_{cri}$——Measured value and the critical value of the standard penetration blow count at the $i^{th}$ point respectively, and the measured value shall be taken as critical value if the measured value is larger than the critical value, when the evaluated depth is 15m, the measured value bellow 15m may also be taken as critical value;

$d_i$——Thickness of soil layer represented by the $i^{th}$ point, which may be taken as half the difference between the depth values at these two upper and lower standard penetration test points adjoining this standard penetration test point, however, its upper limit shall not be larger than the ground water level and its lower limit shall not be deeper than the liquification depth;

$W_i$——Weight function value (unit: $m^{-1}$) of unit thickness of the $i^{th}$ soil layer, which shall be taken as 10 for the depth of midpoint of this layer no larger than 5m, zero for the depth equal to 20m, and linear interpolation value for the depth from 5m to 20m.

**Table 4.3.5 Corresponding Relationship between Liquification Grade and Liquification Index**

| Liquification grade | Light | Moderate | Serious |
|---|---|---|---|
| Liquification index $I_{lE}$ | $0<I_{lE}\leq 6$ | $6<I_{lE}\leq 18$ | $I_{lE}>18$ |

**4.3.6** If the liquefied sandy soil layer and silt layer is relatively even and uniform, the anti-liquefaction measures for soil should be selected from Table 4.3.6. The effect of gravity load of upper structure may also be considered, and the anti-liquefaction measures shall be properly adjusted depending upon the estimated result of liquification subsidence amount.

The untreated liquefied soil layer should not be used as the bearing soil layer of natural foundation.

Table 4.3.6 Anti-liquefaction Measures

| Building category | Liquification grade of soil | | |
|---|---|---|---|
| | Light | Moderate | Serious |
| B | Eliminating the liquefaction differential settlement partially or taking measures for the foundation and upper structure | Eliminating the liquefaction differential settlement completely, or eliminating the liquefaction differential settlement partially and taking measures for the foundation and upper structure | Eliminating the liquefaction differential settlement completely |
| C | Taking measures or no measures for the foundation and upper structure | Taking measures for the foundation and upper structure, or taking other measures of higher requirements | Eliminating the liquefaction differential settlement completely, or eliminating the liquefaction differential settlement partially and r taking measures for the foundation and upper structure |
| D | May not take measures | May not take measures | Taking measures for the foundation and upper structure, or taking other economical measures |

Note: For the buildings assigned to Category A , the anti-liquefaction measures of soil shall be determined by special studies, and should not be less than the corresponding requirements for Category B buildings.

**4.3.7** The measures for eliminating completely the liquefaction differential settlement of soil shall comply with the following requirements:

**1** When pile foundation is used, the length (pile-tip not included) of the pile tip driven into the stable soil layer below the liquefaction depth shall be determined through calculation, which shall not be less than 0.8m for detritus, gravel, coarse and medium sands, stiff cohesive soil, and dense silt and should not be less than 1.5m for other non-rocky soil.

**2** When deep foundation is used, the bottom of foundation shall be embedded in the stable soil layer below the liquefaction depth, and the embedded depth shall not be less than 0.5m.

**3** When a compaction method (e.g. vibroflotation, vibration compaction, gravel pile compaction, and dynamic compaction) is used for strengthening, compaction shall be carried out down to the lower margin of liquefaction depth. After being strengthened by the vibroflotation or compaction gravel piles, the standard penetration blow count of soil between piles should not be less than the critical value of standard penetration blow count for liquification evaluation as specified in Article 4.3.4 of this code.

**4** The liquefied soil layer shall be replaced with non-liquefied soil totally, or the thickness of the upper covered non-liquefied soil layer shall be increased.

**5** When treating by adopting compaction method or replacing soil method, the treatment width outside the foundation edge shall exceed 1/2 of the treatment depth bellow the foundation bottom and shall not be less than 1/5 of the foundation width.

**4.3.8** The measures for eliminating partially the liquefaction differential settlement of soil shall comply with the following requirements:

**1** The treatment depth shall be enough to ensure that the liquefaction index of soil should be reduced and t not greater than 5. For the central zone of raft foundation and box foundation, the liquefaction index of the treated soil may be reduced to 4. For individual foundation and strip foundation, the treatment depth also shall not be less than the larger value between characteristic depth of liquefied soil under the foundation bottom and the foundation width.

Note: The central zone refers to the zone located within the foundation outer edge, and with a distance to the outer edge of over 1/4 length/width along the length/width direction.

**2** After being strengthened by the vibroflotation or compaction gravel piles, the standard penetration blow count of soil between piles should not be less than the critical value of standard penetration blow count for liquification evaluation as specified in Article 4.3.4 of this code.

**3** The treatment width outside the foundation edge shall comply with the requirements of Item 5 in Article 4.3.7 of this code.

**4** Other measures, such as thickening the upper covered non-liquefied soil layer and improving the peripheral drainage condition, etc., may be used to reduce liquefaction differential settlement.

**4.3.9** The measures for foundation and upper structure to reduce the liquification affect may be taken as one or more of the followings based on comprehensive considerations:

**1** Selecting appropriate embedded depth of foundations.

**2** Adjusting the bottom area of foundation to reduce the eccentricity of foundation.

**3** Increasing the integrity and stiffness of foundation, for instance, using box foundation, raft foundation or reinforced concrete cross strip foundation, installing foundation ring beams in addition, etc.

**4** Reducing the loads, increasing the integral stiffness, uniform, symmetry of upper structure, arranging the settlement joints reasonably, and avoiding the use of a structural configuration sensitive to differential settlement.

**5** For the case that pipelines pass through the buildings, adequate space shall be left , otherwise, the flexible joints shall be used.

**4.3.10** Within the sections with possibility of lateral expansion of liquification or flowsliding, such as the fossil river course and zones near to the river bank, seacoast, side slope and so on, permanent buildings should not be constructed. Otherwise, anti-sliding checks shall be carried out, and anti-sliding measures for the earth and anti-cracking measures for the structure shall be taken.

**4.3.11** The seismic subsidence evaluation of soft cohesive soil layer in the soil profile may be performed using the following methods. The hazardness of the seismic subsidence of saturated powdery clay and the anti-seismic subsidence measures shall be determined through comprehensive study based on settlement, lateral deformation, etc. For Intensity 8 (0.30*g*) and Intensity 9, the saturated powdery clay may be evaluated as seismic subsidence soft soil if the plasticity index is less than 15 and the following requirements are satisfied:

$$W_s \geq 0.9 W_L \tag{4.3.11-1}$$

$$I_L \geq 0.75 \tag{4.3.11-2}$$

Where $W_s$——Natural moisture content;

$W_L$——Liquid limit moisture content, which shall be measured by liquid limit method and plastic limit method jointly;

$I_L$——Liquidity index.

**4.3.12** If soft cohesive soil layer and collapsible loess with high moisture content exist within the scope of main bearing layer of subsoil, the measures such as using pile foundation, strengthening the subsoil or those specified in Article 4.3.9 of this code may be taken based on the comprehensive consideration of actual conditions, and the corresponding measures may also be taken based on the estimation of seismic settlement of soft soil.

## 4.4 Pile Foundation

**4.4.1** For the following buildings with low-cap pile foundations used to mainly bear vertical loads, no liquefied soil under the ground and without mud, muddy soil and filled soil with bearing capacity characteristic value not greater than 100kPa around the cap, the seismic bearing capacity of pile foundations may not be checked:

**1** The following buildings with seismic precautionary intensity 6~8:

**1)** Ordinary single-storey factory buildings and single-storey spacious buildings;

**2)** Ordinary civil frame or frame-seismic wall structure buildings not exceeding 8 storeys and 24m in height;

**3)** Multi-storey frame factory buildings and multi-storey concrete wall buildings, of which the foundation load is equivalent to those specified in Item 2).

**2** Buildings as specified in Item 1 of Article 4.2.1 of this code and masonry buildings.

**4.4.2** The seismic check of low-cap pile foundation in non-liquefied soil shall comply with the following requirements:

**1** Both the characteristic values of vertical and horizontal seismic bearing capacity of individual pile may be increased by 25% than those of non-seismic design.

**2** When the back filled soil surrounding the pile cap is tamped to ensure the dry density satisfy the requirements for filled soil as specified in the current national standard GB 50007 "*Code for Design of Building Foundation*", the front filled soil of cap and the pile may together undertake the horizontal earthquake action, however, the frictional force between the bottom surface of cap and the foundation soil shall not be taken into account.

**4.4.3** The seismic check of low-cap pile foundation in liquefied soil shall comply with the following requirements:

**1** For the ordinary shallow cap, the resistance of soil surrounding the cap and the horizontal seismic resistance of rigid ground floor should not be taken into account.

**2** If non-liquefied soils or non-soft soils exist above and below the bottom surface of pile cap with thickness no less than 1.5m and 1.0m, respectively, the seismic check of pile may be carried out according to the following two cases, and the design shall be performed in accordance with the unfavorable case:

**1)** The pile shall be designed to undertake the whole seismic action, the bearing capacity of pile shall be determined according to Article 4.4.2 of this code, and the friction and horizontal resisting force of pile in liquefied soil shall be multiplied by the reduction coefficient listed in Table 4.4.3.

**Table 4.4.3 Reduction Coefficient for Liquification Effect of Soil**

| Actual standard penetration blow count/critical standard penetration blow count | Depth $d_s$ (m) | Reduction coefficient |
|---|---|---|
| ≤0.6 | $d_s \leq 10$ | 0 |
| | $10 < d_s \leq 20$ | 1/3 |
| >0.6~0.8 | $d_s \leq 10$ | 1/3 |
| | $10 < d_s \leq 20$ | 2/3 |
| >0.8~1.0 | $d_s \leq 10$ | 2/3 |
| | $10 < d_s \leq 20$ | 1 |

**2)** The seismic action shall be determined according to 10% of the maximum value of horizontal seismic influence coefficient, the pile bearing capacity shall be still determined according to Item 1 in Article 4.4.2 of this code, however, all the friction force of liquefied soils and the frictional resistance of non-liquefied soil around pile within a depth range of 2m bellow the cap shall be deducted.

**3** For the hammered precast piles and other compaction piles with average space of 2.5~4 times of pile diameter and quantities of not less than 5×5, the compaction effects of driving piles and the beneficial effects of piles to the deformation of liquefied soil may be taken into account. Provided that the standard penetration blow count of the soil between piles meets the non-liquification requirements, the bearing capacity of individual pile may not be reduced, however, the stress dispersion angle outside the pile group shall be taken as zero when checking the capacity of the pile-tip bearing stratum. The standard penetration blow count of soil between piles after driving should be determined by tests or also may be calculated from following equation:

$$N_1 = N_p + 100\rho(1 - e^{-0.3N_p}) \tag{4.4.3}$$

Where $N_1$——Standard penetration blow count after driving;

$\rho$——Ratio of the soil area replaced by precast piles;

$N_p$——Standard penetration blow count before driving.

**4.4.4** The space surrounding the cap of pile foundation in liquefied soil should be filled and tamped with dry soil. If the sandy soil or silt is used, the standard penetration blow count of the soil shall be not less than the critical value of standard penetration blow count for liquification evaluation as specified in Article 4.3.4 of this code.

**4.4.5 The reinforcement range of pile in liquefied soil or seismic subsidence soft soil shall cover from the pile top down to the level that is below the liquification depth and meets the requirements of eliminating completely the liquefaction differential settlement. The longitudinal reinforcements shall be same as the pile top and the hoops shall be thickened (by increasing diameter) and densified (by reducing spacing).**

**4.4.6** In the plats where lateral expansion of liquification exists, the design of pile foundation, besides the other requirements of this section, shall take the lateral-force produced by soil-flow into account, and the area bearing lateral thrust shall be calculated using the width between the outer edges of side piles.

# 5 Earthquake Action and Seismic Checking for Structures

## 5.1 General

**5.1.1 The earthquake actions of various building structures shall comply with the following requirements:**

**1 Generally, the horizontal earthquake actions shall be at least calculated separately along the two orthogonal major axial directions of the building structure; and the horizontal earthquake action in each direction shall be undertaken by the lateral-force-resisting components in this direction.**

**2 For the structures having the oblique lateral-force-resisting components with intersection angle greater than 15°, the horizontal earthquake action along the direction of each lateral- force-resisting component shall be calculated respectively.**

**3 For the structures having obvious asymmetric mass and stiffness distribution, the torsional effects caused by bi-directional horizontal earthquake actions shall be considered; for other cases, it shall be permitted to consider the torsional effects by adjusting the earthquake action effect.**

**4 For the large-span structures and long-cantilevered structures with seismic precautionary intensity 8 or 9 and the tall buildings with seismic precautionary Intensity 9, the vertical earthquake action shall be calculated.**

**Note: For seismically isolated building structures with seismic precautionary Intensity 8 and 9, the vertical earthquake action shall be calculated according to relevant regulations of this code.**

**5.1.2** For the seismic calculation of various building structures, the following methods shall be used:

**1** For structures with heights not greater than 40m, which have shear deformation predominant in total deformation and a rather uniform distribution of mass and stiffness along the height direction, or other structures similar as a single-mass system, the simplified methods, such as base shear method, may be used.

**2** For building structures other than those as stated in Item 1, the modal response spectrum method should be used.

**3** For the especially irregular buildings, buildings assigned to Category A and tall buildings with height belonging to the range listed in Table 5.1.2-1, time-history analysis method shall be used for the additional calculation under frequent earthquake ground motion. If only three pairs of ground motions are used for the time-history analysis, the greater value between the maximum value of the time-history results and the results of the modal response spectrum method should be used for design. If seven or more pairs of ground motions are used for analysis, the greater value between the average value of the time-history results and the results of the modal response spectrum method may be used for design.

Where a time-history analysis is performed, a suite of appropriate ground motions, consisting of actual recorded accelerograms and artificially simulated accelerograms, shall be selected based on site class and the design earthquake group. Thereinto, the quantities of the actual recorded accelerograms shall be not less than 2/3 the total of ground motions. The average seismic influence coefficient curve of the ground motions used for time-history analysis shall be in conformity with that used for modal response spectrum method in statistical sense, and the maximum value of accelerograms may be scaled in accordance with

Table 5.1.2-2. When an elastic time history analysis is performed, the structure base shear force calculated from each ground motion shall be not less than 65% of the result of modal response spectrum method, and the average value from several ground motions shall be not less than 80% of the result with modal response spectrum method.

**Table 5.1.2-1 Height Range of Buildings Using Time-history Analysis Method**

| Intensity and site class | Height range of building (m) |
|---|---|
| Intensity 7, and Class I and II sites with Intensity 8 | >100 |
| Class III and IV sites with Intensity 8 | >80 |
| Intensity 9 | >60 |

**Table 5.1.2-2 Maximum Value of Accelerogram Used for Time-history Analysis ($cm/s^2$)**

| Earthquake level | Intensity 6 | Intensity 7 | Intensity 8 | Intensity 9 |
|---|---|---|---|---|
| Frequent earthquake | 18 | 35 (55) | 70 (110) | 140 |
| Rare earthquake | 125 | 220 (310) | 400 (510) | 620 |

Note: The values in parentheses are used for the regions where the design basic acceleration of ground motion is 0.15*g* and 0.30*g*.

**4** The structural deformation under rare earthquake ground motion shall be calculated using simplified elasto-plastic analysis method or elasto-plastic time-history analysis method according to those specified in Section 5.5 of this code.

**5** For the space structures with very large horizon projection size, the seismic calculation shall be performed by the input mode of ground motion such as single point uniformity, multi-point and multiway single point or multiway multi-point based on the structural type and supporting condition. Where the structure is analyzed by multi-point input mode, the travelling wave effect and local site effect shall be taken into consideration. For the space structures located at Class I or II sites with Intensity 6 or 7, the seismic checking of supporting structures, superstructures and foundations may be performed using simplified methods, that is to say, the components of short edges may be multiplied by an additional seismic effect coefficient of 1.15~1.30 based on the span and length of structures. For the space structures with Intensity 8 or 9,or located at Class III and IV sites with Intensity 7 , the seismic checking shall be carried out using time-history analysis method.

**6** For the seismic isolation and energy dissipation design of building structures, the methods specified in Chapter 12 of this code shall be used.

**7** For the design of subterranean building structures, the methods specified in Chapter 14 of this code shall be used.

**5.1.3 In the calculation of earthquake action, the representative value of the gravity load of building shall be taken as the sum of the standard value of the weight of structure and its components and the combination values of variable loads on the structure. The combination coefficient for variable loads shall be taken from Table 5.1.3.**

Table 5.1.3 Combination Coefficient

| Type of variable load | Combination Coefficient |
|---|---|
| Snow load | 0.5 |
| Dust load on the roof | 0.5 |
| Live load on the roof | Not considered |
| Live load on floor, calculated according to actual conditions | 1.0 |

Table 5.1.3 (continued)

| Type of variable load | | Combination Coefficient |
|---|---|---|
| Live load on floor, calculated according to equivalent uniform load | Library and archives | 0.8 |
| | Other civil buildings | 0.5 |
| Gravity of objects suspended by crane | Crane with hard hook | 0.3 |
| | Crane with flexible hook | Not considered |

Note: The crane with hard hook is with high hoisting capacity, and the coefficient for combination value shall be adopted depending on actual conditions.

**5.1.4 The seismic influence coefficient of a building structure shall be determined according to the Intensity, site class, design earthquake group, and natural vibration period and damping ratio of structure. The maximum value of horizontal seismic influence coefficient shall be taken from Table 5.1.4-1. The characteristic period shall be taken from Table 5.1.4-2 based on the site class and design earthquake group, and the characteristic period shall be increased by 0.05s for rare earthquake ground motion.**

Note: For the building structures with period larger than 6.0s, the seismic influence coefficient used for analysis shall be studied especially.

Table 5.1.4-1 Maximum Value of Horizontal Seismic Influence Coefficient

| Earthquake level | Intensity 6 | Intensity 7 | Intensity 8 | Intensity 9 |
|---|---|---|---|---|
| Frequent earthquake | 0.04 | 0.08 (0.12) | 0.16 (0.24) | 0.32 |
| Rare earthquake | 0.28 | 0.50 (0.72) | 0.90 (1.20) | 1.40 |

Note: The values in parentheses are used for the regions where the design basic acceleration of ground motion is 0.15*g* and 0.30*g*.

Table 5.1.4-2 Values of Characteristic Period (s)

| Design earthquake group | Site class | | | | |
|---|---|---|---|---|---|
| | $I_0$ | $I_1$ | II | III | IV |
| Group 1 | 0.20 | 0.25 | 0.35 | 0.45 | 0.65 |
| Group2 | 0.25 | 0.30 | 0.40 | 0.55 | 0.75 |
| Group 3 | 0.30 | 0.35 | 0.45 | 0.65 | 0.90 |

**5.1.5** The damping adjustment and the form parameters of the seismic influence coefficient curve (Figure 5.1.5) of building structure shall meet the following requirements:

**1** Unless otherwise specified, the damping ratio of building structure shall be taken as 0.05, the damping adjustment coefficient of seismic influence coefficient curve shall be taken as 1.0 and the form parameters shall meet the following requirements:

**1)** Linear ascending section with period less than 0.1s.

**2)** Horizontal section with periods greater than or equal to 0.1s and less than or equal to characteristic period, $T_g$, the seismic influence coefficient, , in this section shall be taken as the maximum value, $\alpha_{max}$.

3) Curvilinear descending section with periods greater than the characteristic period, $T_g$, and less than or equal to 5 times of the characteristic period, $T_g$, the attenuation index shall be taken as 0.9.

4) Linear descending section with periods greater than 5 times of the characteristic period, $T_g$, and less than or equal to 6s, the adjustment coefficient for descending slope shall be taken as 0.02.

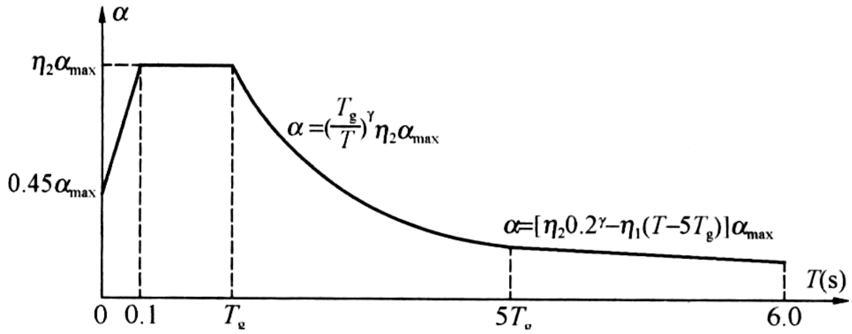



**Figure 5.1.5 Seismic Influence Coefficient Curve**

$\alpha$—The seismic influence coefficient; $\alpha_{max}$—The maximum value of seismic influence coefficient;

$\varepsilon_1$—The adjustment coefficient for descending slope in the linear decreasing section; $\gamma$—The attenuation index;

$T_g$—The characteristic period; $\varepsilon_2$—The damping adjustment coefficient; $T$—The period of the structure

**2** If the damping ratio of building structure is not equal to 0.05 according to the relevant regulations, the damping adjustment coefficient and form parameter of the seismic influence coefficient curve shall meet the following requirements:

1) The attenuation index of curvilinear descending section shall be determined from the following equation:

$$\gamma = 0.9 + \frac{0.05-\zeta}{0.3+6\zeta} \tag{5.1.5-1}$$

Where $\gamma$——Attenuation index of curvilinear descending section;

$\delta$——Damping ratio.

2) The adjustment coefficient for descending slope of linear descending section shall be determined from the following equation:

$$\eta_1 = 0.02 + \frac{0.05-\zeta}{4+32\zeta} \tag{5.1.5-2}$$

Where $\varepsilon_1$——The adjusting coefficient for descending slope of the linear decrease section, which shall be taken as 0 if it is less than 0.

3) The damping adjustment coefficient shall be determined from the following equation:

$$\eta_2 = 1 + \frac{0.05-\zeta}{0.08+1.6\zeta} \tag{5.1.5-3}$$

Where $\varepsilon_2$——Damping adjustment coefficient, which shall be taken as 0.55 if it is less than 0.55.

**5.1.6 The section seismic check of structure shall comply with the following requirements:**

**1 For the buildings with Intensity 6 (excluding the irregular buildings as well as the higher buildings built on Class IV site) and the unfired earth houses and wood houses, the section seismic check of structural members shall be permitted to not be performed. However, the relevant seismic detail requirements for those buildings shall be satisfied.**

**2 For the irregular buildings and the higher buildings built on Class IV site with Intensity 6, and the buildings with seismic precautionary intensity higher than or equal to Intensity 7 (excluding the unfired earth houses and wood houses, etc.), the section seismic check of structural members under frequent earthquake ground motion shall be carried out.**

**Note: For seismically isolated building structures, the seismic check shall comply with the relevant regulations.**

**5.1.7** For the structures meeting those specified in Section 5.5 of this code, the deformation analysis shall be performed in addition to the section seismic check under frequent earthquake ground motion as required.

## 5.2 Calculation of Horizontal Earthquake Action

**5.2.1** When the base shear force method is used for the calculation of horizontal earthquake action, only one degree of freedom may be considered for each storey; the standard value of horizontal earthquake action of the structure shall be determined according to the following equations (Figure 5.2.1):

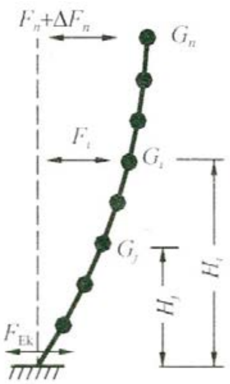



**Figure 5.2.1 Diagram of the Horizontal Earthquake Action of Structure**

$$F_{EK}=\alpha_1 G_{eq} \tag{5.2.1-1}$$

$$F_i=\frac{G_iH_i}{\sum_{j=1}^{n}G_jH_j}F_{EK}(1-\delta_n) \quad (i=1, 2,\ldots n) \tag{5.2.1-2}$$

$$\Delta F_n=\delta_n F_{EK} \tag{5.2.1-3}$$

Where $F_{EK}$——Standard value of the total horizontal earthquake action of a structure;

$\alpha_1$——Horizontal seismic influence coefficient corresponding to the fundamental period of the structure as determined from Article 5.1.4 and Article 5.1.5 of this code. For the multi-storey masonry building and the masonry buildings with bottom frame, it should be taken as the maximum value of horizontal seismic influence coefficient, $\alpha_{max}$;

$G_{eq}$——Total equivalent gravity load of a structure, which shall be taken as the representative value of the total gravity load for single mass point and 85% of the representative value of total gravity load for multi-mass points;

$F_i$——Standard value of the horizontal earthquake action at the $i^{th}$ mass point;

$G_i$, $G_j$——The representative values of the gravity loads concentrated at the $i^{th}$ and $j^{th}$ mass points, respectively, which shall be determined from Article 5.1.3 of this code;

$H_i$, $H_j$——The calculated height of the $i^{th}$ and $j^{th}$ mass points , respectively;

$\delta_n$——Additional earthquake action coefficient at top. For the multi-storey reinforced concrete buildings and the steel structure buildings, it may be taken from Table 5.2.1; for other buildings it may be taken as 0.0;

$\Delta F_n$——Additional horizontal earthquake action at top.

**Table 5.2.1 Additional Earthquake Action Coefficient at Top**

| $T_g$ (s) | $T_1$>1.4$T_g$ | $T_1$≤1.4$T_g$ |
|---|---|---|
| $T_g$≤0.35 | 0.08$T_1$+0.07 | 0.0 |
| 0.35<$T_g$≤0.55 | 0.08$T_1$+0.01 | |
| $T_g$>0.55 | 0.08$T_1$−0.02 | |

Note: $T_1$ is the fundamental period of the structure.

**5.2.2** When the modal response spectrum method is used for the calculation of horizontal earthquake action, for the structures without torsional effects considered, the earthquake action and action effects shall be calculated according to the following requirements:

**1** The standard value of the horizontal earthquake action of the $i^{th}$ mass point produced by the $j^{th}$ mode shall be determined from the following equations:

$$F_{ji}=\alpha_j\gamma_j X_{ji}G_i \quad (i=1, 2,\dots n, j=1, 2,\dots m) \tag{5.2.2-1}$$

$$\gamma_j=\sum_{i=1}^{n}X_{ji}G_i/\sum_{i=1}^{n}X_{ji}^2G_i \tag{5.2.2-2}$$

Where $F_{ji}$——Standard value of horizontal seismic action of the $i^{th}$ mass point produced by the $j^{th}$ vibration mode;

$\alpha_j$——Seismic influence coefficient corresponding to the natural period of the $j^{th}$ mode, which shall be determined from Article 5.1.4 and Article 5.1.5 of this code;

$X_{ji}$——Horizontal relative displacement of the $i^{th}$ mass point of the $j^{th}$ mode;

$\gamma_j$——Participation coefficient of the $j^{th}$ mode.

**2** Provided that the period ratio of adjacent modes is less than 0.85, the horizontal earthquake action effects (bending moment, shear force, axial force and deformation) may be determined from the following equation:

$$S_{Ek}=\sqrt{\Sigma S_j^2} \tag{5.2.2-3}$$

Where $S_{EK}$——Standard value of horizontal seismic effect;

$S_j$——Standard value of horizontal seismic effect of the $j^{th}$ mode. Generally, only the first 2 or 3 modes need to be taken into account, however, the number of modes taken into account shall be increased properly if the fundamental period is greater than 1.5s or the height-width ratio of the building exceeds

5.

**5.2.3** The horizontal seismic effects of the building structure with torsional effects considered shall comply with the following requirements:

**1** For the regular structures without torsional effects calculated, the seismic effects of the components on the two sides parallel to the earthquake action direction shall be multiplied by an enhancement coefficient. Generally, the enhancement coefficient may be taken as 1.15 for the short side and as 1.05 for the long side; if the torsion stiffness is smaller, the enhancement coefficient should not be less than 1.3. And for the components located at corners of building structure, the earthquake action effects should be multiplied by the enhancement coefficients in these two directions simultaneously.

**2** When the translation-torsion coupled modal response spectrum method is used for the calculation of horizontal earthquake action, three degrees of freedom including two orthogonal horizontal deformations and a rotation, may be selected for each floor, and the earthquake actions and seismic effects shall be calculated according to the following equations. If sufficient references are available, the earthquake action effect also may be determined using simplified calculation methods.

**1)** The standard value of horizontal earthquake action of the $i^{th}$ storey produced by the $j^{th}$ mode shall be determined according to the following equations:

$$F_{xji}=\alpha_j\gamma_{tj}X_{ji}G_i$$

$$F_{yji}=\alpha_j\gamma_{tj}Y_{ji}G_i \quad (i=1, 2,\ldots n, j=1, 2,\ldots m)$$

$$F_{tji}=\alpha_j\gamma_{tj}r_i^2\varphi_{ji}G_i \tag{5.2.3-1}$$

Where $F_{xji}$, $F_{yji}$, $F_{tji}$——The standard values of earthquake actions of the $i^{th}$ storey produced by the $j^{th}$ mode in the $x$ direction, $y$ direction and rotating direction , respectively;

$X_{ji}$, $Y_{ji}$——The horizontal relative displacement of the mass center of the $i^{th}$ storey produced by the $j^{th}$ mode respectively in the $x$ and $y$ directions;

$\varphi_{ji}$——The relative torsion angle of the $i^{th}$ storey produced by the $j^{th}$ mode;

$r_i$——The radius of rotation of the $i^{th}$ storey, which may be taken as the square root of result of the rotating moment of inertia around the mass center of the $i^{th}$ storey divided by the mass of this storey;

$\gamma_{tj}$——Participation coefficient of the $j^{th}$ vibration mode considering rotation effect, which may be determined according to the following equations:

When only the earthquake action in $x$ direction is considered

$$\gamma_{\mathrm{tj}}=\sum_{i=1}^{n}X_{ji}G_i/\sum_{i=1}^{n}(X_{ji}^2+Y_{ji}^2+\varphi_{ji}^2r_i^2)G_i \tag{5.2.3-2)}$$

When only the earthquake action in $y$ direction is considered

$$\gamma_{\mathrm{tj}}=\sum_{i=1}^{n}X_{ji}G_i/\sum_{i=1}^{n}(X_{ji}^2+Y_{ji}^2+\varphi_{ji}^2r_i^2)G_i \tag{5.2.3-3}$$

When the earthquake action oblique with the $x$ direction is considered

$$\gamma_{tj} = \gamma_{xj}\cos\theta + \gamma_{yj}\sin\theta \tag{5.2.3-4}$$

Where $\gamma_{xj}$, $\gamma_{yj}$——The participation coefficients calculated from equation (5.2.3-2) and (5.2.3-3), respectively;

$\zeta$——Angle between the direction of earthquake action and the $x$ direction.

**2)** The translation-torsion coupled effects under the unidirectional horizontal earthquake action may be determined in accordance with following equations:

$$S_{\mathrm{Ek}} = \sqrt{\sum_{j=1}^{m}\sum_{k=1}^{m}\rho_{jk}S_jS_k} \tag{5.2.3-5}$$

$$\rho_{jk} = \frac{8\sqrt{\zeta_j\zeta_k}(\zeta_j+\lambda_{\mathrm{T}}\zeta_k)\lambda_{\mathrm{T}}^{1.5}}{(1-\lambda_{\mathrm{T}}^2)^2+4\zeta_j\zeta_k(1+\lambda_{\mathrm{T}})^2\lambda_{\mathrm{T}}+4(\zeta_j^2+\zeta_k^2)\lambda_{\mathrm{T}}^2} \tag{5.2.3-6}$$

Where $S_{\mathrm{EK}}$——The standard value of the translation-torsion coupled effect under earthquake action;

$S_j$, $S_k$——The standard value of seismic effect produced by the $j^{\mathrm{th}}$ and $k^{\mathrm{th}}$ mode, respectively. Generally, only the first 9~15modes need to be taken into account;

$\delta_j$, $\delta_k$——The damping ratio of the $j^{\mathrm{th}}$ and $k^{\mathrm{th}}$ mode, respectively;

$\rho_{jk}$——Coupling coefficient of the $j^{\mathrm{th}}$ and $k^{\mathrm{th}}$ mode;

$\lambda_{\mathrm{T}}$——Ratio between the natural periods of the $k^{\mathrm{th}}$ and $j^{\mathrm{th}}$ mode.

**3)** The translation-torsion coupled effects under the bi-directional horizontal earthquake actions may be taken as the greater value of the two following equations:

$$S_{\mathrm{Ek}} = \sqrt{S_{\mathrm{x}}^2+(0.85S_{\mathrm{y}})^2} \tag{5.2.3-7}$$

Or

$$S_{\mathrm{Ek}} = \sqrt{S_{\mathrm{y}}^2+(0.85S_{\mathrm{x}})^2} \tag{5.2.3-8)}$$

Where $S_{\mathrm{x}}$, $S_{\mathrm{y}}$——the translation-torsion coupled effect of horizontal earthquake actions in the $x$ and $y$ direction, respectively, calculated from equation (5.2.3-5).

**5.2.4** When the base shear method is used for the calculation of horizontal earthquake action, the seismic effects of penthouse, parapet wall and chimney on the roof should be multiplied by an enhancement coefficient of 3. Such increased part of effect shall not be transmitted to the lower part of the structure, but the members connected with this projecting part shall be considered. When modal analysis method is used, the projecting part may be considered as one mass. The enhancement coefficient for the seismic effect of projecting skylight frame of a single-storey factory building shall be taken according to the relevant requirements of Chapter 9 of this code.

**5.2.5 The horizontal seismic shear force at any storey of the structure shall comply with the requirements of the following equation:**

$$V_{\mathrm{ek}i} > \lambda\sum_{j=1}^{n}G_j \tag{5.2.5}$$

**Where $V_{\mathrm{ek}i}$——The $i^{\mathrm{th}}$ storey shear corresponding to the standard value of total**

**horizontal earthquake action;**

$\lambda$——**Shear coefficient , which shall not be less than the minimum seismic shear force coefficient of storey as specified in Table 5.2.5. For the weak-soft stories of vertical irregular structures, the values listed in Table 5.2.5 shall be also multiplied by an enhancement coefficient of 1.15;**

$G_j$——**The representative value of gravity load of the $j^{th}$ storey.**

**Table 5.2.5 Minimum Seismic Shear Force Coefficient Value of a Storey**

| Type | Intensity 6 | Intensity 7 | Intensity 8 | Intensity 9 |
|---|---|---|---|---|
| Structures with obvious torsion effect or fundamental period less than 3.5s | 0.008 | 0.016 (0.024) | 0.032 (0.048) | 0.064 |
| Structures with fundamental period greater than 5.0s | 0.006 | 0.012 (0.018) | 0.024 (0.036) | 0.048 |

**Note: 1 For the structures with fundamental period between 3.5s and 5s, the minimum seismic shear force coefficient shall be determined using interpolation method;**

**2 The values in parentheses are used for the regions with design basic acceleration of ground motion 0.15*g* and 0.30*g* respectively.**

**5.2.6** The horizontal seismic storey shear force of a structure shall be distributed according to the following principles:

**1** For the buildings with rigid diaphragms, such as the cast-in-situ and monolithic-fabricated concrete floors and roofs, the horizontal seismic shear force should be distributed according to the proportion of equivalent stiffness of lateral-force-resisting components.

**2** For the buildings with flexible diaphragms, such as wood floors and wood roofs, the horizontal seismic shear force should be distributed according to the proportion of the representative values of gravity loads in the tributary area of lateral-force-resisting components.

**3** For the buildings with semi-rigid diaphragms such as ordinary prefabricated concrete floors and roofs, the horizontal seismic shear force may be taken as the average value of the above two distribution results.

**4** If the effects of space interaction of lateral-force-resisting components, floor deformation, wall elasto-plastic deformation and torsion are considered, the above distribution results may be adjusted properly according to the relevant provisions in this code.

**5.2.7** Generally, the soil-structure interaction may not be taken into account for the seismic calculation of a structure. For the reinforced concrete tall buildings with box foundations, relatively rigid raft foundation or the combined pile-box foundations used, that are built in the Class III and or IV sites for with Intensity 8 or 9, if the fundamental period is within the scope of 1.2 to 5 times of the characteristic period of Site and the soil-structure interaction need to be considered, the horizontal seismic shear force, calculated by the assumption of rigid base, may be reduced according to the following requirements and the storey drift may be calculated in accordance with the reduced storey shear force.

**1** For the structures with height-width ratio less than 3, the reduction coefficient for the horizontal seismic shear force of each storey may be calculated according to following equation:

$$\psi = (\frac{T_1}{T_1 + \Delta T})^{0.9} \tag{5.2.7}$$

Where $\psi$——The reduction coefficient for the seismic shear force with the soil-structure interaction considered;

$T_1$——Fundamental period (s) of the structure, calculated by the assumption of rigid base;

$\Delta T$——the additional period with the soil-structure interaction considered, which may be taken from Table 5.2.7.

**Table 5.2.7 Additional Period (s)**

| Intensity | Site class | |
|---|---|---|
| | III | IV |
| 8 | 0.08 | 0.20 |
| 9 | 0.10 | 0.25 |

**2** For the structures with height-width ratio not less than 3, the seismic shear force at bottom may be reduced according to those specified in Item 1, that at top may not be reduced, and that at the middle storeys may be reduced according to the linear interpolation values.

**3** The reduced horizontal seismic shear force of each storey shall comply with those specified in Article 5.2.5 of this code.

## 5.3 Calculation of Vertical Earthquake Action

**5.3.1** For the tall buildings with Intensity 9, the standard value of vertical earthquake action shall be determined according to the following equations (Figure 5.3.1). The effects of vertical earthquake action at a storey may be distributed in proportion of the representative values of gravity loads acting on components, which should be multiplied by an enhancement coefficient of 1.5.

$$F_{\mathbf{Evk}} = a_{\mathbf{vmax}} G_{\mathbf{eq}} \tag{5.3.1-1}$$

$$F_{\mathbf{v}i} = \frac{G_i H_i}{\sum G_j H_j} F_{\mathbf{Evk}} \tag{5.3.1-2}$$

Where $F_{\mathrm{Evk}}$——Standard value of the total vertical earthquake action of a structure;

$F_{\mathrm{v}i}$——Standard value of the vertical earthquake action at the $i^{\mathrm{th}}$ mass point;

$\alpha_{\mathrm{vmax}}$——Maximum value of vertical seismic influence coefficient, which may be taken as 65% of the maximum value of horizontal seismic influence coefficient;

$G_{\mathrm{eq}}$——Total equivalent gravity load of the structure, which may be taken as 75% of the representative value of its gravity load.

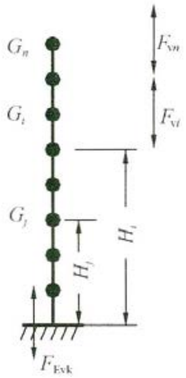



**Figure 5.3.1 Diagram of the Vertical Earthquake Action of Structure**

**5.3.2** For regular flat lattice truss roof with span or length less than those specified in Item 5 in Article 5.1.2 of this code as well as the roof truss, roof transverse beam and bracket with span greater than 24m, the standard value of vertical earthquake action should be taken as the product of the representative value of their gravity load and the vertical earthquake action coefficient, in which, the vertical earthquake action coefficient may be taken from Table 5.3.2.

**Table 5.3.2 Vertical Earthquake Action Coefficient**

| Structure type | Intensity | Site class | | |
|---|---|---|---|---|
| | | I | II | III, IV |
| Flat lattice truss and steel roof truss | 8 | Not considered (0.10) | 0.08 (0.12) | 0.10 (0.15) |
| | 9 | 0.15 | 0.15 | 0.20 |
| Reinforced concrete roof truss | 8 | 0.10 (0.15) | 0.13 (0.19) | 0.13 (0.19) |
| | 9 | 0.20 | 0.25 | 0.25 |

Note: The values in parentheses are used for the regions where the design basic acceleration of ground motion is 0.30*g*.

**5.3.3** For the long-cantilever components or other large-span structures not specified in Article 5.3.2 of this code, the standard value of vertical earthquake action may be taken as10% and 20% of the representative value of gravity load of components or structures for Intensity 8 and 9, respectively. For the regions where the design basic acceleration of ground motion is 0.30g, the vertical earthquake action standard value may be taken as 15% of the representative value of gravity load of this structure or component.

**5.3.4 For** the large-span space structures, the vertical earthquake action may also be calculated using vertical modal response spectrum method. The vertical seismic influence coefficient hereof may be taken as 65% of the horizontal seismic influence coefficient specified in Article 5.1.4 and Article 5.1.5 of this code, however, the characteristic period shall be taken as that belonging to the design earthquake group 1.

## 5.4 Seismic Checking for the Sections of Structural Member

**5.4.1 The fundamental combination of the earthquake action effects and other load effects of the structural members shall be calculated from the following equation:**

$$S=\gamma_G S_{GE}+\gamma_{Eh} S_{Ehk}+\gamma_{Ev} S_{Evk}+\psi_w \gamma_w S_{wk} \qquad (5.4.1)$$

**Where** $S$**——Design values of combination of the internal forces in a structural member, including the design values of the combined bending moment, combined axial force and combined shear force, etc.;**

$\gamma_G$——Partial coefficient of gravity load, which generally shall be taken as 1.2 and shall be not greater than 1.0 if the gravity load effect is favorable to the bearing capacity of member;

$\gamma_{Eh}$, $\gamma_{Ev}$——The partial coefficients of the horizontal and vertical earthquake actions respectively, which shall be taken from Table 5.4.1;

$\gamma_w$——Partial coefficient of wind load, which shall be taken as 1.4;

$S_{GE}$——Effects of the representative value of gravity load, which may be determined according to Article 5.1.3 of this code, however, it still shall include the effect of the standard value of hanging weight if crane is used;

$S_{Ehk}$——Effects of the standard value of horizontal earthquake action, which shall be also multiplied by the corresponding enhancement coefficient or adjustment coefficient;

$S_{Evk}$——Effect of the standard value of vertical earthquake action, which shall be also multiplied by the corresponding enhancement coefficient or adjustment coefficient;

$S_{wk}$——Effect of standard value of wind load;

$\psi_w$——Combination value coefficient of wind load, which shall be 0.0 for ordinary structures and shall be 0.2 for tall buildings on which the wind load plays the control action.

Note: Generally, the subscript representing the horizontal direction is omitted in this code.

Table 5.4.1 Partial Coefficient of Earthquake Action

| Earthquake action | $\gamma_{Eh}$ | $\gamma_{Ev}$ |
|---|---|---|
| Only calculating the horizontal earthquake action | 1.3 | 0.0 |
| Only calculating the vertical earthquake action | 0.0 | 1.3 |
| Simultaneously calculating the horizontal and vertical earthquake actions (mainly based on horizontal earthquake action) | 1.3 | 0.5 |
| Simultaneously calculating the horizontal and vertical earthquake actions (mainly based on vertical earthquake action) | 0.5 | 1.3 |

**5.4.2** Seismic checking for section of structural member shall be performed using the following design expression:

$$S \leq R/\gamma_{RE} \tag{5.4.2}$$

Where $\gamma_{RE}$——Seismic adjustment coefficient of load-bearing capacity, which, unless otherwise specified, shall be taken from Table 5.4.2;

$R$——Design value of the load-bearing capacity of structural member.

**Table 5.4.2 Seismic Adjustment Coefficient of Load-Bearing Capacity**

| Material | Structural member | Stress state | $\gamma_{RE}$ |
|---|---|---|---|
| Steel | Column, beam, brace, gusset plate, bolt and welded joint | Strength | 0.75 |
| | Column and brace | Stable | 0.80 |
| Masonry | Seismic wall with tie-columns and core-columns at both ends | Shear | 0.9 |
| | Other seismic walls | Shear | 1.0 |
| Concrete | Beam | Bending | 0.75 |
| | Columns with axial force ratio less than 0.15 | Eccentric compression | 0.75 |
| | Columns with axial force ratio no less than 0.15 | Eccentric compression | 0.80 |
| | Seismic wall | Eccentric compression | 0.85 |
| | Various members | Shear, eccentric tension | 0.85 |

**5.4.3 If only the vertical earthquake action is considered, the seismic adjustment coefficient of load-bearing capacity of various structural members shall be taken as 1.0.**

## 5.5 Seismic Checking for the Storey Drift

**5.5.1** For the structures listed in Table 5.5.1, the seismic checking for the storey drift under the frequent earthquake ground motion shall be performed, and the maximum elastic storey drift shall comply with the following requirements:

$$\Delta u_{\mathrm{e}} \leq [\theta_{\mathrm{e}}]h \tag{5.5.1}$$

Where $\Delta u_{\mathrm{e}}$——Maximum elastic storey drift caused by the standard value of frequent earthquake action. It shall be calculated in accordance with the following requirements: 1) generally, the overall bending deformation of structure may be included except for the tall buildings mainly with bending deformation; 2) the torsional deformation shall be considered; 3) all the partial coefficients of actions shall be taken as 1.0;4) for the reinforced concrete member, the elastic stiffness may be used;

$[\zeta_{\mathrm{e}}]$——Allowable elastic storey drift as obtained from Table 5.5.1;

$h$——The storey height.

**Table 5.5.1** Allowable Elastic Storey Drift

| Structure | $[\zeta_{\mathrm{e}}]$ |
|---|---|
| Reinforced concrete frame | 1/550 |
| Reinforced concrete frame seismic-wall, slab-column seismic-wall, and frame core-tube | 1/800 |
| Reinforced concrete seismic-wall, tube-in-tube | 1/1000 |
| Reinforced concrete structure with frame-supporting storey | 1/1000 |
| Multi-storey and tall steel structures | 1/250 |

**5.5.2** The elasto-plastic deformation checking of the weak-soft storey of a structure under rare earthquake ground shall be performed in accordance with the following requirements:

**1** For the following structures, the elasto-plastic deformation checking shall be performed:

**1)** The transverse bent-frames of tall single-storey factory buildings with RC columns that are located at; Class III and IV sites with Intensity 8 or the regions with Intensity 9;

**2)** Reinforced concrete frame structures and bent-frame structures with yield strength coefficient of the storey less than 0.5, that are located at regions with Intensity 7~9;

**3)** Structures with height greater than 150m;

**4)** Reinforced concrete structures and steel structures, that are assigned to Category A buildings or Category B buildings located at regions with Intensity 9; and

**5)** The seismically isolated structures and structures with energy-dissipated systems.

**2** For the following structures, the elasto-plastic deformation check should be carried out:

**1)** The tall building structures with heights within the scope specified in Table 5.1.2-1 of this code and the vertical irregularities listed in Table 3.4.3-2;

**2)** The reinforced concrete structures and the steel structures, that are assigned to Category C buildings located at Class III and IV sites with Intensity 7 or Category B buildings located at regions with Intensity 8;

**3)** Slab-column seismic-wall structures and masonry buildings with bottom-frames;

**4)** Tall steel structures with height not greater than 150m; and

**5)** The structures of irregular subterranean buildings as well as the subterranean space complex structures.

Note: The yield strength coefficient of a storey is the ratio of the storey shear capacity calculated according to the actual reinforcement and material strength standard value of RC members, and the storey elastic seismic shear force calculated according to the standard values of rare earthquake action. For the bent-frame columns, it refers to the ratio of the bend bearing capacity of normal section calculated according to the actual reinforcement area, material strength standard value and axial force, and the elastic seismic bending moment calculated according to the standard values of rare earthquake action.

**5.5.3** The elasto-plastic deformation of the weak-soft storey (or portion) of a structure under rare earthquake action may be calculated using the following methods:

**1** For the reinforced concrete frames and bent-frame structures with no more than 12 stories and no abrupt changes of storey lateral stiffness, and the single-storey factory buildings with RC columns, the simplified methods specified in Article 5.5.4 of this code may be used.

**2** For the building structures other than those specified in Item 1, the static elasto-plastic analysis method or the elasto-plastic time-history analysis method may be used.

**3** For the regular structures, the shear-bending storey models or planar line-member system models may be used. For the irregular structures having the irregularities specified in Section 3.4 of this code, the spatial t structural models may be used.

**5.5.4** The simplified calculation of the elasto-plastic storey drift of the weak-soft stories (or portions) of a structure should meet the following requirements:

**1** The weak-soft storeys (or portions) of the structure may be identified as follows:

**1)** For the structures with storey yield strength coefficient uniformly distributed along the height, the bottom storey may be identified as weak-soft storey;

**2)** For structures with non-uniform distribution of storey yield strength coefficient along the height of the structure, the stories (or portions) with minimum/relatively smaller yield strength coefficient may be identified as the weak-soft stories (or portions). Generally, the amount of the weak-soft stories (or portions) needed to check may not be more than two or three stories (or portions); or

**3)** For single-storey factory buildings, the upper portions of the columns may be taken as the weak-soft portions.

**2** The elasto-plastic storey drift may be calculated from the following equations:

$$\Delta u_p = \varepsilon_p \Delta u_e \tag{5.5.4-1}$$

Or

$$\Delta u_p = \mu \Delta u_y = \frac{\eta_p}{\xi_y} \Delta u_y \tag{5.5.4-2}$$

Where $\Delta u_p$——Elasto-plastic storey drift;

$\Delta u_y$——Yield storey drift;

$\mu$——Ductility coefficient of storey;

$\Delta u_e$——The elastic storey drift under rare earthquake ground motion;

$\varepsilon_p$——Enhancement coefficient for elasto-plastic storey drift. For the weak-soft storey (or portion) with yield strength coefficient not less than 80% of average values of that of the adjacent stories (or potions), it may be taken from Table 5.5.4; for the weak-soft storey (or portion) with yield strength coefficient not greater than 50% of average values of that of the adjacent stories (or potions), it may be taken as 1.5 times of the corresponding values listed in Table 5.5.4; for other cases, it may be determined by interpolation method;

$\xi_y$——Yield strength coefficient of storey.

**Table 5.5.4 Enhancement Coefficient for Elasto-plastic Storey Drift**

| Structure type | Total number of stories or portions | $\xi_y$ | | |
|---|---|---|---|---|
| | | 0.5 | 0.4 | 0.3 |
| Multi-storey uniform frame structure | 2~4 | 1.30 | 1.40 | 1.60 |
| | 5~7 | 1.50 | 1.65 | 1.80 |
| | 8~12 | 1.80 | 2.00 | 2.20 |
| Single-storey factory building | Upper column | 1.30 | 1.60 | 2.00 |

**5.5.5** The elasto-plastic storey drift of the weak-soft storey(or portions) of a structure shall comply with the following requirement:

$$\Delta u_p \le [\zeta_p] h \tag{5.5.5}$$

Where $[\zeta_p]$——Allowable elasto-plastic storey drift which may be taken from Table 5.5.5. For the RC frame structures, if the axial–force ratio is less than 0.40, the allowable elasto-plastic storey drift may be increased by 10%; if the hoop characteristic value along the overall height of the column is 30% greater than those specified in Table 6.3.9, the allowable elasto-plastic storey drift may be increased by 20%, however, it shall not be increased by over 25% totally;

$h$——Height of weak-soft storey or the column height of single-storey factory building.

**Table 5.5.5** Allowable Elasto-plastic Storey Drift

| Structure | $[\zeta_p]$ |
| --- | --- |
| Single-storey bent frame with RC columns | 1/30 |
| Reinforced concrete frame | 1/50 |
| Frame seismic-wall in masonry building with bottom frame | 1/100 |
| Reinforced concrete frame seismic-wall, slab-column seismic-wall, and frame-core-tube | 1/100 |
| Reinforced concrete seismic-wall, tube-in-tube | 1/120 |
| Multi-storey and tall steel structures | 1/50 |

# 6 Multi-storey and Tall Reinforced Concrete Buildings

## 6.1 General

**6.1.1** This Chapter applies to the seismic design of those cast-in-situ reinforced concrete buildings with structural types and applicable maximum heights specified in Table 6.1.1. For structure with horizontal and vertical irregularities simultaneously, the applicable maximum height should be reduced properly.

Note: The –seismic wall” in this chapter refers to the reinforced concrete shear wall in the lateral force-resisting system of structure, excluding the concrete wall only bearing gravity load.

**Table 6.1.1 Applicable Maximum Height of Cast-in-situ Reinforced Concrete Buildings (m)**

| Structural type | | Seismic Precautionary Intensity | | | | |
|---|---|---|---|---|---|---|
| | | 6 | 7 | 8 (0.2*g*) | 8 (0.3*g*) | 9 |
| Frame structure | | 60 | 50 | 40 | 35 | 24 |
| Frame-seismic wall structure | | 130 | 120 | 100 | 80 | 50 |
| Seismic wall structure | | 140 | 120 | 100 | 80 | 60 |
| Partial frame-supported seismic wall structure | | 120 | 100 | 80 | 50 | Inapplicable |
| Tube structure | Frame-core-tube structure | 150 | 130 | 100 | 90 | 70 |
| | Tube-in-tube structure | 180 | 150 | 120 | 100 | 80 |
| Slab-column-seismic wall structure | | 80 | 70 | 55 | 40 | Inapplicable |

Note: 1 The height of building refers to the distance from the outdoor ground level to the main roof(excluding partially protruding roof) level of the building;

2 The frame-core-tube structure refers to the structure composed of the perimeter frames and the core tube;

3 Partial frame-supported seismic wall structure refers to the seismic-wall structure having some discontinuous seismic-walls supported by frames in the first storey or the two stories at the bottom, that excludes the seismic-wall structure having only few seismic-walls supported by frames;

4 The frames stated in the above table exclude the frames with special-shaped columns;

5 The slab-column-seismic wall structure refers to the structure with lateral-force-resisting system consisting of slab-columns, frames and seismic walls;

6 The applicable maximum height of buildings assigned to Category B may be determined according to the seismic precautionary intensity of this region;

7 For the buildings with heights exceeding those specified in this Table, special studies and demonstrations shall be conducted and effective strengthening measures shall be taken.

**6.1.2 The reinforced concrete building shall be assigned a seismic grade based on the seismic precautionary category, seismic precautionary intensity, structural type and building height, and shall be designed in accordance with the corresponding requirements of calculation and details. The seismic grade of buildings assigned to Category C shall be determined from Table 6.1.2.**

**Table 6.1.2 Seismic Grades of Cast-in-situ Reinforced Concrete Buildings**

<table>
<tr><th colspan="3" rowspan="2">Structural type</th><th colspan="10">Seismic Precautionary Intensity</th></tr>
<tr><th colspan="2">6</th><th colspan="3">7</th><th colspan="3">8</th><th colspan="2">9</th></tr>
<tr><td rowspan="3">Frame structure</td><td colspan="2">Height (m)</td><td>≤24</td><td>>24</td><td colspan="2">≤24</td><td>>24</td><td colspan="2">≤24</td><td>>24</td><td colspan="2">≤24</td></tr>
<tr><td colspan="2">Frame</td><td>IV</td><td>III</td><td colspan="2">III</td><td>II</td><td colspan="2">II</td><td>I</td><td colspan="2">I</td></tr>
<tr><td colspan="2">Large-span frame</td><td colspan="2">III</td><td colspan="3">II</td><td colspan="3">I</td><td colspan="2">I</td></tr>
<tr><td rowspan="3">Frame-seismic-wall structure</td><td colspan="2">Height (m)</td><td>≤60</td><td>>60</td><td>≤24</td><td>25~60</td><td>>60</td><td>≤24</td><td>25~60</td><td>>60</td><td>≤24</td><td>25~50</td></tr>
<tr><td colspan="2">Frame</td><td>IV</td><td>III</td><td>IV</td><td>III</td><td>II</td><td>III</td><td>II</td><td>I</td><td>II</td><td>I</td></tr>
<tr><td colspan="2">Seismic-wall</td><td colspan="2">III</td><td>III</td><td colspan="2">II</td><td>II</td><td colspan="2">I</td><td colspan="2">I</td></tr>
<tr><td rowspan="2">Seismic-wall structure</td><td colspan="2">Height (m)</td><td>≤80</td><td>>80</td><td>≤24</td><td>25~80</td><td>>80</td><td>≤24</td><td>25~80</td><td>>80</td><td>≤24</td><td>25~60</td></tr>
<tr><td colspan="2">Seismic-wall</td><td>IV</td><td>III</td><td>IV</td><td>III</td><td>II</td><td>III</td><td>II</td><td>I</td><td>II</td><td>I</td></tr>
<tr><td rowspan="4">Partial frame-supported seismic-wall structure</td><td colspan="2">Height (m)</td><td>≤80</td><td>>80</td><td>≤24</td><td>25~80</td><td>>80</td><td>≤24</td><td>25~80</td><td rowspan="4"></td><td colspan="2" rowspan="4"></td></tr>
<tr><td rowspan="2">Seismic -wall</td><td>Common Portion</td><td>IV</td><td>III</td><td>IV</td><td>III</td><td>II</td><td>III</td><td>II</td></tr>
<tr><td>Strengthened Portion</td><td>III</td><td>II</td><td>III</td><td>II</td><td>I</td><td>II</td><td>I</td></tr>
<tr><td colspan="2">Frames of frame-supporting storey</td><td colspan="2">II</td><td colspan="2">II</td><td>I</td><td colspan="2">I</td></tr>
<tr><td rowspan="2">Frame-core-tube structure</td><td colspan="2">Frame</td><td colspan="2">III</td><td colspan="3">II</td><td colspan="3">I</td><td colspan="2">I</td></tr>
<tr><td colspan="2">Core tube</td><td colspan="2">II</td><td colspan="3">II</td><td colspan="3">I</td><td colspan="2">I</td></tr>
<tr><td rowspan="2">Tube-in-tube structure</td><td colspan="2">Exterior tube</td><td colspan="2">III</td><td colspan="3">II</td><td colspan="3">I</td><td colspan="2">I</td></tr>
<tr><td colspan="2">Interior tube</td><td colspan="2">III</td><td colspan="3">II</td><td colspan="3">I</td><td colspan="2">I</td></tr>
<tr><td rowspan="3">Slab-column seismic -wall structure</td><td colspan="2">Height (m)</td><td>≤35</td><td>>35</td><td colspan="2">≤35</td><td>>35</td><td colspan="2">≤35</td><td>>35</td><td colspan="2" rowspan="3"></td></tr>
<tr><td colspan="2">frame and columns of slab-column</td><td>III</td><td>II</td><td colspan="2">II</td><td>II</td><td colspan="3">I</td></tr>
<tr><td colspan="2">Seismic-wall</td><td>II</td><td>II</td><td colspan="2">II</td><td>I</td><td colspan="2">II</td><td>I</td></tr>
</table>

Note: 1 If the building site is of Class I, except for Intensity 6, the grades of design details shall be permitted to be determined according to the Intensity one degree lower than the seismic precautionary intensity listed in the above table, but the corresponding calculation requirements shall not be reduced;

2 When the height of building is close to or equal to the height dividing line, the seismic grade shall be permitted to be determined appropriately in consideration of the degree of the building irregularity and the conditions of site, soil and foundation;3 The large-span frame refers to the frame with span no less than 18m;

4 For the frame-core-tube structure with height not exceeding 60m that is designed according to the requirements of frame-seismic-wall structure, the seismic grade shall be determined according to the provisions for frame-seismic-wall structure as stated in the above table.

**6.1.3** The determination of the seismic grade of reinforced concrete building shall also meet the following requirements:

**1** For the frame structures with a few seismic-walls arranged, if the seismic overturning moment undertaken by the frame components at bottom storey under the specified horizontal force is more than 50% of the total seismic overturning moment of the structure, the seismic grade of the frame components shall be determined according to frame structure, and the seismic grade of the seismic–wall components may be taken the same as that of frame components.

Note: The bottom storey refers to the storey where the fixing ends of the mathematical model are set.

**2** For the podium connected to the main building, the seismic grade shall be determined according to the structural type of podium itself, but the seismic grade of the relevant range shall not be lower than that of the main building. And seismic details of the main building shall be strengthened appropriately at the two adjacent stories including one above and one bellow the roof level of podium. For the podium separated from the main building, the seismic grade shall be determined according to the structural type of podium itself.

**3** When the top-slab of the basement is used as the fixing location of supper structure, the seismic grade of the first storey underground shall be the same as that of the upper structure, the detail grade of other stories underground may be reduced one grade by one storey, but shall not be less than Grade 4. For the portions of the basement without upper structure, the detail grade may be taken as Grade 3 or 4 according to specific conditions.

**4** For buildings assigned to Category A or B, whose seismic grade shall be determined according to the intensity of one degree higher than the precautionary intensity, if the height of building exceeds the height as specified in Table 6.1.2 of this code, the seismic details much more efficient than that of Grade 1 shall be taken.

Note: ―Grade 1, 2, 3 and 4" in this chapter are short for ―seismic grade **1(I), 2(II), 3(III) and 4(IV)**".

**6.1.4** For the reinforced concrete buildings with seismic joints needed to be arranged, the following requirements shall be satisfied:

**1** The width of seismic joint shall comply with the following requirements:

**1)** For frame structure buildings (including frame structures with a few seismic-walls arranged), if the height of the building does not exceed 15m, the width of seismic joint shall not be less than 100mm; if not, the width should be increased by 20mm respectively when the height is increased by every 5m, 4m, 3m and 2m, for Intensity 6, 7, 8 and 9;

**2)** For frame-seismic-wall structure buildings, the width of seismic joint shall not be less than 70% of the value specified in Subitem **1)** of this Item; for seismic wall structure buildings, the width shall not be less than 50% of the value specified in Subitem 1). Besides those provisions above, the widths of seismic joints should not be less than 100mm; and

**3)** When the structures on the two sides of the seismic joint are of different types, the joint width shall be determined according to the structure type requiring wider seismic joint and the smaller building height.

**2** For the frame structure buildings with Intensity 8 or 9, if the storey heights on both sides of the seismic joint are different greatly, the spacing of stirrups of the frame columns on both sides of the seismic joint shall be densified along the overall height of the building, and at least two pounding walls perpendicular to the seismic joint may be built on both sides of the seismic joint along the overall height of the building as required. The arrangement of the pounding walls should avoid increasing the torsional effect, the wall length may not be greater than 1/2 of the storey height, the seismic grade of these walls may be same as that of the frame structure; the frame components shall be designed according to the unfavorable situations of two calculation models with or without pounding walls.

**6.1.5** In the frame structures and the frame-seismic wall structures, both the frames and the seismic walls shall be arranged in two directions, and the influence of eccentricity shall be taken into consideration if the eccentricity between the center lines of the column and the seismic wall as well as between the center lines of beam and column is greater than 1/4 of the column width.

For the buildings assigned to Category A and B and the Category C buildings with height greater than 24m, the single-span frame structures shall not be used; and For the Category C buildings with height not greater than 24m, the single-span frame structures should not be used.

**6.1.6** For the frame-seismic-wall structures, slab-column-seismic-wall structures and frame-supported stories of the partial frame-supported seismic-wall structures, the length-width ratio of the floors or roofs between two adjacent seismic walls, except for the cases with large openings arranged, should not exceed those specified in Table 6.1.6; otherwise, the influence of the deformation in plane of the floor shall be taken into account.

**Table 6.1.6 Length-width Ratio of Floor (or Roof) between two adjacent Seismic-Walls**

| Type of floor and roof | | Precautionary Intensity | | | |
|---|---|---|---|---|---|
| | | 6 | 7 | 8 | 9 |
| Frame-seismic-wall structure | Cast-in-situ or superimposed floors and roofs | 4 | 4 | 3 | 2 |
| | Prefabricated monolithic floors and roofs | 3 | 3 | 2 | Should not be used |
| Cast-in-situ floors and roofs of slab-column-seismic-wall structures | | 3 | 3 | 2 | — |
| Cast-in-situ floors and roofs of frame-supporting storey | | 2.5 | 2.5 | 2 | — |

**6.1.7** When the prefabricated monolithic floors and roofs are used as diaphragms of buildings, proper measures shall be taken so as to ensure the integrity of floors and roofs and their reliable connections with the seismic-walls. When cast-in-situ surface course with reinforcements is used to strengthen the prefabricated monolithic floors and roofs, the thickness shall not be less than 50mm.

**6.1.8** The arrangement of seismic-walls in the frame-seismic-wall structures and the slab-column-seismic-wall structures should comply with the following requirements:

**1** The seismic wall should be built through the overall height of the building.

**2** At the staircase, some seismic walls should be arranged, but large torsional effects caused by the walls should be avoided.

**3** The seismic wall should be arranged with end columns at both ends (excluding both sides of the opening) or be connected with the seismic wall in the other direction.

**4** For the long buildings, the longitudinal seismic walls with large stiffness should not be arranged at the end bays of the building.

**5** The openings of the seismic-walls should be aligned up and down, and the distance from the opening edge to the end column should not be less than 300mm.

**6.1.9** The arrangement of seismic-walls in the seismic-wall structures and the partial frame-supported seismic-wall structures shall meet the following requirements:

**1** The seismic wall should be arranged with end columns at both ends (excluding both sides of the opening) or be connected with the seismic wall in the other direction. The seismic walls continuous to ground, located at the frame-supported portions, shall be arranged with end columns at both ends (excluding both sides of the opening) or be connected with the seismic wall in the other direction.

**2** The relatively longer seismic-wall should be divided into several uniform segments by openings formed by installing of coupling beams with span-depth ratio greater than 6, the height-width ratio of each wall segment should be not less than 3.

**3** The length of wall pier along the overall height of the structure should be stable. The relatively larger openings of the seismic walls and the openings located at the bottom strengthened portions of seismic walls assigned to Grade 1 and 2, should be aligned up and down.

**4** For the partial frame-supported seismic wall structure with rectangular plane, the lateral stiffness of the frame-supporting storey shall be not less than 50% of that of the adjacent non-frame-supporting storey above; the spacing of the seismic walls continuous to the ground, located at the frame-supporting storey, should not be greater than 24m, the plan arrangement of the lateral-force-resisting components of frame-supporting storey should be symmetric and the seismic tubes should be also set; the seismic overturning moment undertaken by the frame components bottom storey shall be not greater than 50% of the total seismic overturning moment of the structure.

**6.1.10** The range of bottom strengthened portion of seismic wall shall be determined according to the following requirements:

**1** The height of the bottom strengthened portion shall be counted from the top-slab of basement.

**2** For the seismic walls of partial frame-supported seismic-wall structures, the height of the bottom strengthened portion may be taken as the greater one between the total height of the frame-supporting storey and two stories above and 1/10 of the total height of seismic-wall continuous to ground. For the seismic walls of other structures, if the height of the building is greater than 24m, the height of bottom strengthened portion may be taken as the greater one between the height of two bottom stories and 1/10 of the total height of the seismic-wall; if the height of the building does not exceed 24m, the bottom storey may be regarded as the bottom strengthened portion.

**3** When the calculated fixing end of the structure is located at or below the bedplate of underground storey, the bottom strengthened portion shall be extended downward to the level of fixing end.

**6.1.11** For single column foundations of frame component, if one of the following cases is satisfied, the foundation tie beams should be installed along the directions of the two principal axes:

**1** Frames are assigned to Grade 1, or frames located at Category IV site, are assigned to Grade 2;

**2** The compression stresses on the bottom surface of column foundations caused by the representative value of gravity load are different greatly;

**3** The embedded depths of foundations are relatively larger or the embedded depths of foundations are different greatly;

**4** Soft cohesive soil layers, liquefaction soil layers or extremely non-uniform soil layers exist within the range of the main load-bearing layers of the subsoil; or

**5** Pile caps are used as the single column foundations.

**6.1.12** The foundations of seismic-walls in the frame-seismic-wall structures and slab-column-seismic-wall structures as well as the foundations of the seismic-walls continuous to the ground in partial frame-supported seismic-wall structures shall be with excellent integrality and anti-rotational capability.

**6.1.13** If the main building is connected with the podium and is adopted with natural foundation, in addition to those specified in Article 4.2.4 of this code, the foundation bottom face of main building should be free from zero stress zones under the frequent earthquake action.

**6.1.14** When the top-slab of basement is designed as the fixing end of upper structure, the following requirements shall be satisfied:

**1** The top-slab of basement shall not be set with large openings; the cast-in-situ beam and slab floor system shall be used for the top-slab within the relevant scope of the upper structure and should be used outside this scope; the slab thickness should not be less than 180mm, the concrete strength grade of the slab should not be less than C30, the double-layer two-way reinforcements shall be arranged and the reinforcement ratio in each direction of each layer should not be less than 0.25%.

**2** The lateral stiffness of the first storey of the upper structure should not be greater than 0.5 times of that of the first underground storey within the relevant scope. Along the periphery of the basement, the seismic-walls should be arranged to connect with the top-slab.

**3** In addition to the requirements of seismic calculation, the beam-column joint of the basement top-slab corresponding to the overground frame column shall also satisfy one of the following requirements:

**1)** The longitudinal reinforcement on each side of column section at the first underground storey shall be not less than 1.1 times of the longitudinal reinforcement corresponding to the first overground storey, and the total actual seismic bent bearing capacity of the upper end of lower column and the beam ends on the right and left sides of the joint shall be greater than 1.3 times of that of the lower end of upper column.

**2)** When the stiffness of the beams of the first underground storey are relatively larger, the area of the longitudinal reinforcements on each side of the lower column shall be greater than 1.1 times of those of upper column; meanwhile, the area of longitudinal reinforcements arranged at top and bottom of beam end shall be increased by over 10% of the calculated values.

**4** The area of the longitudinal reinforcements of boundary elements at ends of the seismic-wall piers on the first underground storey shall not be less than that of upper structure.

**6.1.15** The staircase shall be designed in accordance with the following requirements:

**1** Generally, the cast-in-situ reinforced concrete stairs should be used.

**2** For frame structures, the arrangement of staircase shall not result in the especial irregularity of structure in plan. For the case that the staircase components are connected with major structure, the influence of the staircase components on the earthquake action and effect shall be taken into consideration, and the seismic capacity checking for the staircase components shall also be carried out. Meanwhile, some proper details of seismic design should be taken to reduce the influence of staircase components on the stiffness of major structure.

**3** The infilled walls on both sides of staircase shall be connected to the columns firmly.

**6.1.16** The infilled walls of frame shall comply with those specified in Chapter 13 of this code.

**6.1.17** The seismic design of the high strength concrete structures shall comply with those specified in Appendix B of this code.

**6.1.18** The seismic design of the prestressed concrete structures shall comply with those specified in Appendix C of this code.

## 6.2 Essentials in Calculation

**6.2.1** For the reinforced concrete structures, the design value of the combined internal force of components shall be adjusted according to those specified in this section, the storey drift shall comply with the relevant regulations in Section 5.5 of this code. For the seismic check of component section, the design value of the non-seismic bearing capacity shall be divided by the seismic adjustment coefficient of bearing capacity specified in this code; for all the components not concerned in this chapter and appendixes of this code, the seismic checking shall be performed in accordance with the requirements of the relevant current codes for structural design.

**6.2.2** At the beam-column joints of frames assigned to Grade 1, 2, 3 or 4 , except for the joints in the top storey or with axial-force-ratio of column less than 0.15 as well as the joints of frame-supporting beams with frame-supporting columns, the design value of the combined bending moment at column ends shall satisfy the requirements of the following equation:

$$\sum M_{\mathrm{c}} = \eta \sum M_{\mathrm{b}} \tag{6.2.2-1}$$

For frame structures assigned to Grade 1 as well as frame components assigned to Grade 1 with Intensity 9, the requirements above may not be satisfied, but the following condition shall be satisfied:

$$\sum M_{\mathrm{c}} = 1.2 \sum M_{\mathrm{bua}} \qquad \text{(6.2.2-2}$$

Where $\Sigma M_{\mathrm{c}}$——Sum of the design value of combined clockwise or counterclockwise bending moment of the columns framing the joint. The design value of the bending moment at the upper and lower column end may be distributed according to the elastic analysis results;

$\Sigma M_{\mathrm{b}}$——Sum of the design value of combined counterclockwise or clockwise bending moment of the beams framing the joint. For frames assigned to Grade 1, if the moments of the beams on the right and left sides of joint are both negative, the bending moment of smaller absolute value shall be taken as zero;

$\Sigma M_{\mathrm{bua}}$——Sum of counterclockwise or clockwise bending moment values of the beams framing the joint, corresponding to the actual seismic bending capacities of normal sections of beams which shall be determined according to the actual area of reinforcements (including reinforcements of compression zone of beam and reinforcements of related floor slabs) and the characteristic value of material strength;

$\varepsilon_{\mathrm{c}}$——Enhancement coefficient of the moment of column end. For the frame structures assigned to Grades 1, 2, 3 and 4, it may be taken as 1.7, 1.5, 1.3

and 1.2 respectively; for the frame components in other types of structures, it may be taken as 1.4 for Grade 1, 1.2 for Grade 2 and 1.1 for Grade 3 and 4.

If the zero-moment-point is outside the scope of storey height of column, the design value of the combined bending moment on the section at column end may be multiplied by the above-mentioned enhancement coefficient.

**6.2.3** The design value of combined bending moment of the lower end of column at the bottom storey of frame structure assigned to Grades 1, 2, 3 and 4, shall be multiplied by an enhancement coefficient of 1.7, 1.5, 1.3 and 1.2 respectively. The longitudinal reinforcements of the columns at bottom storey shall be arranged according to the unfavorable situations at the upper and lower ends.

**6.2.4** For the frame beams and coupling beams of seismic walls, that are assigned to Grade 1, 2 or 3, the design value of combined shear force on the beam end section shall be adjusted according to the following equation:

$$V = \eta_{vb}(M_b^l + M_b^r)/l_n + V_{Gb} \tag{6.2.4-1}$$

For beams of frame structures assigned to Grade 1 as well as other frame beams and coupling beams assigned to Grade 1 with Intensity 9, the requirements above may not be satisfied, but the following condition shall be satisfied:

$$V = 1.1(M_{bua}^l + M_{bua}^r)/l_n + V_{Gb} \tag{6.2.4-2}$$

Where $V$——Design value of combined shear force on the end section of beam;

$l_n$——Net span of the beam;

$V_{Gb}$——Design value of shear force on the end section of beam under the action of the representative value of its gravity load (the characteristic value of vertical earthquake action still shall be included for tall buildings with Intensity 9), which shall be calculated according to simple-supported beam;

$M_b^l$, $M_b^r$——Respectively the design value of combined counterclockwise or clockwise bending moment on the right and left ends of the beam. For frame beams assigned to Grade 1, if the moments on the right and left ends are both negative, the bending moment of smaller absolute value shall be taken as zero;

$M_{bua}^l$, $M_{bua}^r$—Respectively the actual counterclockwise or clockwise bending moment values on the right and left ends of the beam corresponding to the actual seismic bending capacities of normal sections of beams which shall be determined according to the actual area of reinforcements (including reinforcements of compression zone of beam and reinforcements of related floor slabs) and the characteristic value of material strength;;

$\varepsilon_{vb}$——Enhancement coefficient for the shear force at beam end, which may be taken as 1.3 for Grade 1, 1.2 for Grade 2 and 1.1 for Grade 3.

**6.2.5** For the frame columns and frame-supporting columns assigned to Grade 1, 2, 3 or 4, the design value of combined shear force shall be adjusted according to the following equation:

$$V = \eta_{\mathrm{vc}}(M_{\mathrm{c}}^{\mathrm{b}} + M_{\mathrm{c}}^{\mathrm{t}}) / H_{\mathrm{n}} \tag{6.2.5-1}$$

For frame structures assigned to Grade 1 as well as frame components assigned to Grade 1 with Intensity 9, the requirements above may not be satisfied, but the following condition shall be satisfied:

$$V = 1.2(M_{\mathrm{cua}}^{\mathrm{b}} + M_{\mathrm{cua}}^{\mathrm{t}}) / H_{\mathrm{n}} \tag{6.2.5-2}$$

Where $V$——Design value of combined shear force of the section at column end; for the frame-supporting columns, the design value of shear force shall also comply with those specified in Article 6.2.10 of this code;

$H_{\mathrm{n}}$——Net height of the column;

$M_{\mathrm{c}}^{\mathrm{b}}$, $M_{\mathrm{c}}^{\mathrm{t}}$——Respectively the design value of combined bending moment of the sections at the upper and lower ends of a column in clockwise or counterclockwise direction, which shall comply with those specified in Article 6.2.2 and Article 6.2.3 of this code; for frame-supporting columns, the design value of bending moment shall also comply with those specified in Article 6.2.10 of this code;

$M_{\mathrm{bcua}}^{t}$, $M_{\mathrm{cua}}^{b}$——Respectively the bending moment values corresponding to the actual seismic bending capacities of normal section in the clockwise or counterclockwise direction at the upper and lower ends of the eccentric compression column, which shall be determined according to the actual area of reinforcements, the characteristic value of material strength and the axial force, etc.;

$\varepsilon_{\mathrm{vc}}$——Enhancement coefficient for shear force of column. For frame structures assigned to Grades 1, 2, 3 and 4, the enhancement coefficient may be taken as 1.5, 1.3, 1.2 and 1.1 respectively; and for other structures, it may be taken as 1.4 for Grade 1, 1.2 for Grade 2 and 1.1 for Grade 3 and 4.

**6.2.6** For the corner frame columns assigned to Grades 1, 2, 3 and 4, the design values of combined bending moment and combined shear force, adjusted according to Articles 6.2.2, 6.2.3, 6.2.5 and 6.2.10 of this code, shall also be multiplied by an enhancement coefficient no less than 1.10.

**6.2.7** For the piers of the seismic walls, the design values of the combined internal forces shall be determined according to the following provisions:

**1** For the portions above the bottom strengthened portion of seismic-wall assigned to Grade 1, the design value of combined bending moment of piers shall be multiplied by an enhancement coefficient, which may be taken as 1.2, and the value of combined shear force shall be adjusted correspondingly.

**2** For the seismic walls continuous to the ground in partial frame-supported seismic-wall structures, the small eccentric tension state shall not occur in the piers.

**3** For the coupled seismic-wall, the small eccentric tension state should not occur in the piers; if any one pier suffers the eccentric tension, the design values of the shear force and bending moment of the other pier shall be multiplied by an enhancement coefficient of 1.25.

**6.2.8** For the bottom strengthened portions of seismic walls assigned to Grade 1, 2 and 3, the design value of combined shear force shall be adjusted according to the following equation:

$$V = \eta_{\mathrm{vw}} V_{\mathrm{w}} \tag{6.2.8-1}$$

For seismic walls assigned to Grade 1 with Intensity 9, the design value of combined shear force may not be adjusted according to the above equation, but the following requirements shall be satisfied:

$$V = 1.1 \frac{M_{\mathrm{wua}}}{M_{\mathrm{w}}} V_{\mathrm{w}} \tag{6.2.8-2}$$

Where $V$——Design value of combined shear force at the bottom strengthened portion of seismic-wall;

$V_{\mathrm{w}}$——Calculated value of combined shear force at the bottom strengthened portion of seismic-wall;

$M_{\mathrm{wua}}$——Bending moment of the bottom section of seismic wall corresponding to the actual seismic bending capacities which shall be calculated according to the actual area of longitudinal reinforcements, the characteristic value of material strength and the axial force. The longitudinal reinforcements within one time of the thickness of flange-wall on both sides of the web-wall shall be taken into account;

$M_{\mathrm{w}}$——Design value of combined bending moment on the bottom section of seismic wall;

$\varepsilon_{\mathrm{vw}}$——Enhancement coefficient for shear force of seismic wall, which may be taken as 1.6 for Grade 1, 1.4 for Grade 2 and 1.2 for Grade 3.

**6.2.9** For the beams, columns, seismic walls and coupling beams of a reinforced concrete structure, the design values of the combined shear forces shall satisfy the following requirements:

For beams and coupling beams with span-depth ratio greater than 2.5 and columns and seismic walls with shear-span ratio greater than 2:

$$V \le \frac{1}{\gamma_{\mathrm{RE}}}(0.20 f_{\mathrm{c}} b h_0) \tag{6.2.9-1}$$

For coupling beams with span-depth ratio not greater than 2.5, columns and seismic walls with shear-span ratio not greater than 2, and the frame-supporting columns, the frame-supporting beams and the bottom strengthened portions of seismic walls continuous to the ground of the partial frame-supported seismic-wall structures:

$$V \le \frac{1}{\gamma_{\mathrm{RE}}}(0.15 f_{\mathrm{c}} b h_0) \tag{6.2.9-2}$$

The shear-span ratio shall be calculated from the following equation:

$$\lambda = M^{\mathrm{c}} / (V^{\mathrm{c}} h_0) \tag{6.2.9-3}$$

Where $\lambda$——Shear-span ratio, which shall be determined according to the calculated value

$M^c$ of the combined bending moment at column end or wall end, the calculated value $V^c$ of the combination shear force and the effective height $h_0$ of the section, and shall be the greater value of the calculated results for the upper and lower ends. For the frame column with the zero-moment-point located at the middle of column, it may be taken as the ratio of the net height of column to 2 times of the section height of column;

$V$——Design value of combined shear force at the beam end, column end or wall end, which is adjusted according to those specified in Articles 6.2.4, 6.2.5, 6.2.6, 6.2.8 or 6.2.10 of this code;

$f_c$——Design value of the axial compressive strength of concrete;

$b$——Sectional width of beam, column or wall pier. For circular section, it may be taken as the width of equivalent square section according to the principle of equal area;;

$h_0$——Effective height of section, which may be taken as the length of pier for the seismic-wall.

**6.2.10** The frame-supporting columns of partial frame-supported seismic-wall structure shall also satisfy the following requirements:

**1** The minimum seismic shear forces that the frame-supporting columns shall be able to undertake, shall satisfy the following requirements: if the quantity of frame-supporting columns is no less than 10, the sum of the seismic shear force borne by the columns shall not be less than 20% of the total seismic shear force at bottom of the structure; otherwise, the seismic shear force borne by each column shall not be less than 2% of the total seismic shear force at the bottom of structure. The seismic bending moment of frame-supporting columns shall be adjusted correspondingly.

**2** The additional axial forces of frame-supporting columns assigned to Grades 1 and 2, produced by frequent earthquake ground motions, shall be multiplied by an enhancement coefficient of 1.5 and 1.2, respectively. But this additional axial force may not be multiplied by the enhancement coefficient for the calculation of axial-force ratio of column.

**3** For the upper end of top storey and the lower end of the bottom storey of the frame-supporting columns assigned to Grade 1 and 2, the design value of the combined bending moment shall be respectively multiplied by an enhancement coefficient of 1.5 and 1.25, and the middle joints of frame-supporting columns shall meet the requirements in Article 6.2.2 of this code.

**4** The center line of frame-supporting beam should be coincided with the center line of frame-supporting column.

**6.2.11** The bottom strengthened portion of the Grade 1 seismic wall continuous to the ground in partial frame-supported seismic-wall structures shall also meet the following requirements:

**1** When the tie bars with diameter not less than 8mm and spacing not greater than 400mm are set between two rows of reinforcements beyond the boundary elements, the shear capacity of the concrete may be included in the shear capacity of seismic-wall .

**2** When the large eccentric tension state appears in the bottom section of pier, additional cross anti-slip diagonal bars should be arranged at the bottom section of pier, and the seismic shear force undertaken by these anti-slip diagonal bars may be taken as 30% of the design value of shear force at the bottom section of pier.

**6.2.12** The floor diaphragm located at the top level of frame-supporting columns of partial frame-supported seismic wall structures shall comply with those specified in Section E.1 in Appendix E of this code.

**6.2.13** The seismic calculation of reinforced concrete structures shall also satisfy the following requirements :

**1** For the frame-seismic-wall structures and frame-core-tube structures with basically uniform distribution of lateral stiffness along vertical direction, the shear force undertaken by the frame portion at any storey shall not be less than the smaller one of the followings: 1) 20% of the total seismic shear force at bottom of the structure, and 2) 1.5 times of the maximum seismic shear force distributed to the frame portion, that shall be obtained from the analysis of the frame-seismic-wall structure and frame-core-tube structure.

**2** To calculate the seismic internal force of seismic wall, the stiffness of coupling beam may be reduced and the reduction coefficient should not be less than 0.50.

**3** When calculating the internal force and deformation of the seismic-wall structure, partial frame-supported seismic-wall structure, frame-seismic-wall structure, frame-core-tube structure, tube-in-tube structure and slab-column-seismic-wall structure, the interaction of the flange walls of the seismic walls shall be taken into account.

**4** For the frame structure arranged with a few seismic-walls, the seismic shear force of the frame portion should be taken as the greater value between the calculation results from frame structure model and frame-seismic-wall structure model.

**6.2.14** The seismic checking of the core zone of frame joint shall meet the following requirements:

**1** For the frames assigned to Grades 1, 2 and 3, the seismic checking of joint core zones shall be carried out; for the frames assigned to Grade 4, the seismic checking of the joint core zones may not be carried out, but the detail requirements of seismic design shall be satisfied.

**2** The seismic checking method of core zone shall comply with those specified in Appendix D of this code.

## 6.3 Details of Seismic Design for Frame Structures

**6.3.1** The sectional dimensions of beam should meet the following requirements:

**1** The width of section should not be less than 200mm;

**2** The depth-width ratio of the section should not be larger than 4;

**3** The ratio between the net span and the depth of section should not be less than 4.

**6.3.2** The flat beams with width greater than column width shall meet the following requirements:

**1** Floors and roofs with flat beams shall be cast in-situ, the centerlines of the beams and columns should be coincided, and the flat beams shall be arranged in two principal axial directions. The sectional dimensions of the flat beam shall satisfy the following requirements and the provisions controlling the deflection and cracked width as stated in the relevant current codes.

$$b_b \leq 2b_c \tag{6.3.2-1}$$

$$b_b \le b_c + h_b \tag{6.3.2-2}$$

$$h_b \ge 16d \tag{6.3.2-3}$$

Where $b_c$——Section width of column, which shall be taken as 0.8 times of the diameter for the circular columns;

$b_b$, $h_b$——Respectively the width and depth of the beam section;

$d$——Diameter of longitudinal reinforcement in the column.

**2** The flat beams should not be used for frame structures assigned to Grade 1.

**6.3.3 Arrangement of reinforcements for beams shall meet the following requirements:**

**1 The ratio of the height to the effective height of the concrete compression zone (its end cross-section) with the compression reinforcement considered (counted) in shall not be greater than 0.25 for frames assigned to Grade 1 and 0.35 for frames assigned to Grade 2 or 3.**

**2 In addition to being determined through calculation, the ratio of the bottom-reinforcements to the top-reinforcements of the end cross-section of beams shall also not be less than 0.5 for frames assigned to Grade 1 and 0.3 for frames assigned to Grade 2 or 3.**

**3 The length of critical region of beam, the maximum spacing of hoops and the minimum diameter of hoops shall be taken from Table 6.3.3. If the reinforcement ratio of tension zone of the end cross-section exceeds 2%, the minimum diameters of hoops in the Table shall be increased by 2mm.**

**Table 6.3.3 Length, Maximum Spacing and Minimum Diameter of Hoops of Critical Region**

| Seismic Grade | Length of critical region (the greater value shall be taken) (mm) | Maximum spacing of hoops (the minimum value shall be taken) (mm) | Minimum diameter of hoops (mm) |
|---|---|---|---|
| Grade 1 | $2h_b$, 500 | $h_b/4$, $6d$, 100 | 10 |
| Grade 2 | $1.5h_b$, 500 | $h_b/4$, $8d$, 100 | 8 |
| Grade 3 | $1.5h_b$, 500 | $h_b/4$, $8d$. 150 | 8 |
| Grade 4 | $1.5h_b$, 500 | $h_b/4$, $8d$, 150 | 6 |

**Note: 1 $d$ is the diameter of longitudinal reinforcement and $h_b$ is the depth of section of beam;**

**2 If the diameter of the hoop is larger than 12mm, the quantity of the hoop limbs is no less than 4 and the spacing of the hoop limbs is not greater than 150mm, the maximum spacing of hoops for Grade 1 and 2 may be increased properly but shall not be greater than 150mm.**

**6.3.4** Arrangement of reinforcements for beams shall also meet the following requirements:

**1** The longitudinal tension reinforcement ratio at the end cross-section of beam should not be greater than 2.5%. For frames assigned to Grade 1 or 2, the top-reinforcements and bottom-reinforcements along the entire length of the beam shall be not less than 2ø14 and also not less than 1/4 of the greater values of those at the two end cross-sections of beam, respectively; for frames assigned to Grade 3 or 4, the top-reinforcements and bottom-reinforcements along the entire length of the beam shall not be less than 2ø12.

**2** For the beams of the frame structures assigned to Grade 1, 2 or 3, the diameter of each longitudinal reinforcement extending through the mid-column, shall not be greater than 1/20 of the sectional dimension of column with rectangular section parallel to the reinforcement 1/20 of the chord length of circular column section where the longitudinal reinforcement is located; for the frame beams of other structure types, this diameter should not be greater than 1/20 of the sectional dimension of column with rectangular section parallel to the reinforcement 1/20 of the chord length of circular column section where the longitudinal reinforcement is located.

**3** For beam of frame assigned to Grade 1,the spacing of hoop limbs in critical region should not be greater than the greater value between 200mm and 20 times of the hoop diameter; for beam of frame assigned to Grade 2 or 3, the spacing should not be greater than the greater value between 250mm and 20 times of the hoop diameter; and for the beam of frame assigned to Grade 4, the spacing should not be larger than 300mm.

**6.3.5** The sectional dimension of column should comply with the following requirements:

**1** For columns assigned to Grade 4 or columns not exceeding 2 stories, the width or depth of section should not be less than 300mm, the diameter of circular column should not be less than 350mm; for columns exceeding 2 stories, assigned to Grade 1, 2 or 3, the width an depth should not be less than 400mm, the diameter of circular column should not be less than 450mm.

**2** The shear span ratio should be greater than 2.

**3** The ratio of the longer cross-sectional dimension to the perpendicular dimension should not be greater than 3.

**6.3.6** The axial-force ratio of column should not exceed those specified in Table 6.3.6; as for the tall buildings built at Site-class IV site, the allowable axial–force ratio shall be reduced properly.

**Table 6.3.6 Allowable Axial–force Ratio of Column**

| Structure type | Seismic grade | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Frame structure | 0.65 | 0.75 | 0.85 | 0.90 |
| Frame-seismic-wall, slab-column-seismic-wall, frame-core-tube and tube-in-tube | 0.75 | 0.85 | 0.90 | 0.95 |
| Partial frame-supported seismic-wall | 0.6 | 0.7 | — | |

Note: 1 The axial-force ratio refers to the ratio of the design value of combined axial compressive force of column to the product of the total cross-sectional area and the design value of axial compressive strength of concrete; as for such structures without seismic action calculation as specified in this code, the axial–force ratio may be calculated with the design value of combined axial force without seismic effects;

2 The allowable values in the above table are applicable to the columns with shear-span ratio greater than 2 and concrete strength grade not higher than C60; for the columns with shear-span ratio not greater than 2, the allowable axial-force ratio shall be reduced by 0.05; for the columns with shear span ratio less than 1.5, the allowable axial-force ratio shall be studies especially and special details shall be taken;

3 The allowable axial-force ratio may be increased by 0.10 if one of the following conditions is satisfied: 1) the cross complex hoops with spacing not greater than 100mm, spacing of limbs not greater than 200mm and diameters of hoops not less than 12mm, are used along the total height of column; 2) the complex spiral hoops with spacing of screws not greater than 100mm, spacing of limbs not greater than 200mm and diameters of hoops not less than 12mm, are used along the total height of column; 3) the continuous complex rectangular spiral hoops with net spacing of screws not greater than 80mm, spacing of limbs not greater than 200mm and diameters of hoops not less than 10mm, are used along the total height of column. The minimum hoop characteristic values of the three conditions above shall be determined according to Table 6.3.9 of this code based on the increased axial–force ratio;

4 If the additional core-column with total added longitudinal reinforcements not less than 0.8% of the cross-section

area of column, is arranged at the central portion of the column section, the allowable axial-force ratio may be increased by 0.05. If this measure is used together with the measure in Note 3, the allowable axial-force ratio may be increased by 0.15, but the volume hoop ratio still may be determined according to the requirements that the axial-force ratio shall be increased by 0.10;

5 The axial-force ratio of column shall not be greater than 1.05.

**6.3.7 Arrangement of reinforcements for columns shall comply with the following requirements:**

**1 The minimum total reinforcement ratio of columns shall be taken from Table 6.3.7-1, meanwhile, the reinforcement ratio of each side of the cross-section shall not be less than 0.2%; for the taller buildings built at Site-class IV site, the minimum total reinforcement ratio shall be increased by 0.1%.**

**Table 6.3.7-1 Minimum Total Reinforcement Ratio (Percentage) of the Cross-section of Column**

| Type | Seismic grade | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Middle column and side column | 0.9 (1.0) | 0.7 (0.8) | 0.6 (0.7) | 0.5 (0.6) |
| Corner column and frame-supporting column | 1.1 | 0.9 | 0.8 | 0.7 |

**Note: 1 The values bracketed in the table are applicable to the columns of frame structure;**

**2 If the characteristic value of reinforcement strength is less than 400MPa, the values in table shall be increased by 0.1; if the characteristic value of reinforcement strength is 400MPa, the values in table shall be increased by 0.05;**

**3 If the concrete strength grade is higher than C60, the above-mentioned values shall be increased by 0.1 correspondingly.**

**2 The hoops of columns shall be densified within the critical regions, the spacing and diameter of hoops in the critical hoops shall comply with the following requirements:**

**1) Generally, the maximum spacing and the minimum diameter of hoops shall be taken from Table 6.3.7-2**

**Table 6.3.7-2 Maximum Spacing and Minimum Diameter of hoops in the critical regions of Column**

| Seismic grade | Maximum spacing of hoops (the smaller value shall be taken, mm) | Minimum diameter of hoop (mm) |
|---|---|---|
| 1 | 6*d*, 100 | 10 |
| 2 | 8*d*, 100 | 8 |
| 3 | 8*d*, 150 (100 at column root) | 8 |
| 4 | 8*d*, 150 (100 at column root) | 6 (8 at column root) |

**Note: 1 *d* is the minimum diameter of longitudinal (vertical) reinforcements of column;**

**2 The column root refers to the critical region at the lower end of column at the bottom storey.**

**2) For the frame columns assigned to Grade 1 with hoop diameter greater than 12mm and spacing of hoop limbs greater than 150mm as well as the columns assigned to Grade 2 with hoop diameter not less than 10mm and spacing of hoop limbs not greater than 200mm, except for the lower ends of columns at the bottom storey, the maximum spacing of hoops shall be permitted to be taken as 150mm. For the columns assigned to Grade 3 with sectional dimension not greater than 400mm, the minimum diameter of hoop shall be permitted to be taken as 6mm. For columns with shear-span ration not greater than 2, assigned to Grade 4, the diameter of**

**hoop shall not be less than 8mm.**

3) **As for the frame-supporting columns and the frame columns with shear-span ratio not greater than 2, the hoop spacing shall not be greater than 100mm.**

**6.3.8** Arrangement of longitudinal reinforcements for columns shall also comply with the following requirements:

**1** The longitudinal reinforcements of columns should be arranged symmetrically.

**2** For the columns with the side length of section greater than 400mm, the spacing of longitudinal reinforcements should not be greater than 200mm.

**3** The total reinforcement ratio of column shall not be greater than 5%; for the columns with shear-span ratio not greater than 2, which are assigned to Grade 1, the longitudinal reinforcement ratio on each side should not be greater than 1.2%.

**4** For the side columns, corner columns as well as the end columns of seismic wall, if they are in small eccentric tension state under the frequent earthquake ground motion, the total cross-sectional area of the longitudinal reinforcements shall be increased by 25% on the basis of calculated value.

**5** The banding joints of the column longitudinal reinforcements shall be kept clear from the critical regions at the column end.

**6.3.9** The arrangement of hoops of columns shall also comply with the following requirements:

**1** The length of the critical regions (with hoops) of a column shall be determined according to the following requirements:

1) Generally, at the column end, the length of critical region shall be taken as the maximum value of the largest cross-sectional dimension of the column, , 1/6 of the net height of the column and 500mm;

2) At the lower end of column of the bottom storey, the length of critical region shall be not less than 1/3 of the net height of column;

3) For the rigid ground surface, the regions up and down to 500mm from the ground surface of the column shall be considered as being critical regions; and

4) For the columns with shear-span ratio not greater than 2, the columns with the ratio of net height to depth not greater than 4 which is produced by the infilled walls, the frame-supporting columns and the corner columns of the frames assigned to Grade 1 and 2, the length of critical regions shall be taken as the total height of the columns.

**2** In the critical region of column, the spacing of hoop limbs should not be greater than 200mm for Grade 1 250mm for Grade 2 or Grade 3 and 300mm for Grade 4. The hoops or tie-bars should be arranged in two directions for every other longitudinal reinforcement for confinement; if tie-bar complex hoops are used, the tie-bars shall abut against the longitudinal reinforcement and hook with the hoops.

**3** The volume hoop ratio in the critical region of column shall be determined according to the following requirements:

1) The volume hoop ratio in the critical region of column shall satisfy the requirement of the following equation:

$$\rho_{\mathrm{v}} \geq \lambda_{\mathrm{v}} f_{\mathrm{c}} / f_{\mathrm{yv}} \tag{6.3.9}$$

Where $\rho_v$——Volume hoop ratio in the critical region of column, which shall not be less than 0.8% for Grade 1, 0.6% for Grade 2 and 0.4% for Grade 3 or 4. For the complex spiral hoops, the volume of non-spiral hoops shall be multiplied by a reduction coefficient of 0.80 while calculating the volume hoop ratio;

$f_c$——Design value of the axial compressive strength of concrete, which shall be taken as C35 if the strength grade is less than C35;

$f_{yv}$——Design value of the tensile strength of hoop or tie-bar;

$\lambda_v$——Minimum hoop characteristic value, which should be taken from Table 6.3.9.

**Table 6.3.9 Minimum Hoop Characteristic Value in Critical Region of Column**

| Seismic grade | hoop type | Axial-force ratio of column | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ≤0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | 1.05 |
| 1 | Ordinary hoop and complex hoop | 0.10 | 0.11 | 0.13 | 0.15 | 0.17 | 0.20 | 0.23 | — | — |
| | Spiral hoop, complex or continuous complex rectangular spiral hoop | 0.08 | 0.09 | 0.11 | 0.13 | 0.15 | 0.18 | 0.21 | — | — |
| 2 | Ordinary hoop and complex hoop | 0.08 | 0.09 | 0.11 | 0.13 | 0.15 | 0.17 | 0.19 | 0.22 | 0.24 |
| | Spiral hoop, complex or continuous complex rectangular spiral hoop | 0.06 | 0.07 | 0.09 | 0.11 | 0.13 | 0.15 | 0.17 | 0.20 | 0.22 |
| 3, 4 | Ordinary stirrup and complex hoop | 0.06 | 0.07 | 0.09 | 0.11 | 0.13 | 0.15 | 0.17 | 0.20 | 0.22 |
| | Spiral hoop, complex or continuous complex rectangular spiral hoop | 0.05 | 0.06 | 0.07 | 0.09 | 0.11 | 0.13 | 0.15 | 0.18 | 0.20 |

Note: ―Ordinary hoop" refers to single rectangular hoop and single circular hoop, ―complex hoop" refers to the rectangular, polygonal and circular hoop or the hoop composed of tie bars; ―complex spiral hoop" refers to spiral hoop, rectangular, polygonal and circular hoop or the hoop composed of tie bars; ―continuous complex rectangular spiral hoop" refers to a stick of full-length hoop processed with reinforcements.

**2)** For the frame-supporting columns, the complex spiral hoops or cross complex hoops should be used, the minimum hoop characteristic value shall be increased by 0.02 on the basis of the values stated in Table 6.3.9, and the volume hoop ratio shall not be less than 1.5%.

**3)** For the columns with shear-span ratio not greater than 2, the complex spiral hoops or cross complex hoops should be used, the volume hoop ratio shall not be less than 1.2% and also shall not be less than 1.5% for the columns with seismic Intensity 9 assigned to Grade 1.

**4** The arrangement of hoops in the non-critical region of column shall comply with the following requirements:

**1)** The volume hoop ratio in non-critical region of column should not be less than 50% of that in the critical region.

**2)** The spacing of hoops in the non-critical region shall not be greater than 10 times of the diameter of longitudinal reinforcement for frame columns assigned to Grade 1 or 2, and 15 times of the diameter of longitudinal reinforcement for frame columns assigned to Grade 3 or 4.

**6.3.10** The maximum spacing and minimum diameter of the hoops in the joint core zone of frame should be determined according to Article 6.3.7 of this code. For the joint core zones of the frames assigned to Grade 1, 2 and 3, the hoop characteristic value should not be less than

0.12, 0.10 and 0.08 respectively and the volume hoop ratio should not be less than 0.6%, 0.5% and 0.4% respectively. For the joint core zone of frame column with shear-span ratio not greater than 2, the volume hoop ratio should not be less than the greater of those in the critical regions of column ends above and below the core zone.

## 6.4 Details of Seismic Design for Seismic Wall Structures

**6.4.1** For the seismic-walls assigned to Grade 1 or 2, the thickness shall not be less than 160mm and should not be less than 1/20 of the storey height or the non-branch length; and for the seismic-walls assigned to Grade 3 or 4, the thickness shall not be less than 140mm and should not be less than 1/25 of the storey height or the non-branch length. For the seismic-walls without end columns or flange-walls, this thickness should not be less than 1/16 of the storey height or the non-branch length for Grade 1 or 2 and 1/20 of that for Grade 3 or 4.

For the bottom strengthened portions of seismic-walls assigned to Grade 1or 2, the thickness shall not be less than 200mm and should not be less than 1/16 of the storey height or the non-branch length; and for the bottom strengthened portions of seismic-walls assigned to Grade 3 or 4, the thickness shall not be less than 160mm and should not be less than 1/20 of the storey height or the non-branch length. For the seismic-walls without end-columns or flange-walls, the thickness of the bottom strengthened portion should not be less than 1/12 of the storey height or the non-branch length for Grade 1 or 2 and 1/16 of that for Grade 3 or 4.

**6.4.2** For the seismic-walls assigned to Grade 1, the axial-force ratio of the wall-piers under the action of the representative value of gravity load should not be greater than 0.4 for Intensity 9 and 0.5 for Intensity 7 or 8; for the seismic-walls assigned to Grade 2 or 3, this ratio also should not be greater than 0.6.

Note: The axial-force ratio of wall-pier refers to the ratio of the design value of the axial compressive force of wall to the product of the gross cross-sectional area of wall and the design value of axial compressive strength of concrete.

**6.4.3 The vertically and horizontally distributed reinforcements of seismic-wall shall comply with the following requirements:**

**1 The minimum reinforcement ratio of the vertically and horizontally distributed reinforcements shall not be less than 0.25% for seismic-walls assigned to Grade 1, 2 or 3, and 0.20% for seismic-walls assigned to Grade 4.**

**Note: For the Grade 4seismic walls with height less than 24m and very small shear** compression **ratio, the minimum reinforcement ratio of the vertically distributed reinforcements may be taken as 0.15%.**

**2 For the bottom strengthening portion of seismic walls of partial frame-supported seismic-wall structures, the reinforcement ratio of vertically and transversely distributed reinforcements shall not be less than 0.3%.**

**6.4.4** Arrangement of the vertically and horizontally distributed reinforcements for seismic walls shall also comply with the following requirements:

**1** The spacing of the vertically and horizontally distributed reinforcements for seismic walls should not be greater than 300mm; in the bottom strengthened portions of the seismic walls continuous to the ground of partial frame-supported seismic-wall structures, this spacing o should not be greater than 200mm.

**2** For the seismic-walls with thickness greater than 140mm, the vertically and horizontally distributed reinforcement shall be arranged in two layers, the spacing of the tie bars with diameter not less than 6mm, between the two layers of distributed reinforcements, should not be greater than 600mm.

**3** The diameters of the vertically or horizontally distributed reinforcements for seismic walls should not be greater than 1/10 of wall thickness and shall not be less than 8mm; the diameters of vertically distributed reinforcement should not be less than 10mm.

**6.4.5** At the at two ends of the seismic-wall and the two sides of the opening, boundary elements, including hidden columns, end columns and flange walls, shall be arranged in accordance with the following requirements:

**1** For the seismic-wall structures, the constructed boundary elements may be arranged at both ends of the wall-piers of seismic-walls assigned to Grade 1, 2 and 3 with the axial-force ratio in the bottom section not greater than those specified in Table 6.4.5-1 or the same positions of seismic-walls assigned to Grade 4, the range of constructed boundary elements may be determined from Figure 6.4.5-1, the reinforcements of constructed boundary elements shall satisfy the requirements of necessary bending capacity, and should also comply with those specified in Table 6.4.5-2.

**Table 6.4.5-1 Maximum Axial-force Ratio of Constructed Boundary Elements of Seismic Walls**

| Seismic grade or intensity | Grade 1 (Intensity 9) | Grade 1 (Intensity 7 and 8 ) | Grade 2 and 3 |
|---|---|---|---|
| Axial-force ratio | 0.1 | 0.2 | 0.3 |

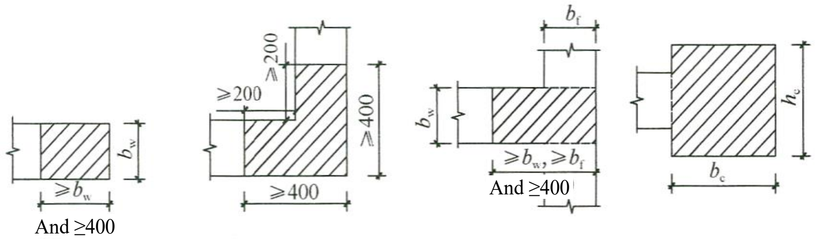
**Table 6.4.5-2 Reinforcement Requirements of Constructed Boundary Elements of Seismic Wall**

| Seismic grade | Bottom strengthened portions | | | Other portions | | |
|---|---|---|---|---|---|---|
| | Minimum longitudinal reinforcement (larger value shall be used) | Hoop | | Minimum longitudinal reinforcement (larger value shall be used) | Tie bar | |
| | | Minimum diameter (mm) | Maximum vertical spacing (mm) | | Minimum diameter (mm) | Maximum vertical spacing (mm) |
| 1 | $0.010A_c$, 6ø16 | 8 | 100 | $0.008A_c$, 6ø14 | 8 | 150 |
| 2 | $0.008A_c$, 6ø14 | 8 | 150 | $0.006A_c$, 6ø12 | 8 | 200 |
| 3 | $0.006A_c$, 6ø12 | 6 | 150 | $0.005A_c$, 4ø12 | 6 | 200 |
| 4 | $0.005A_c$, 4ø12 | 6 | 200 | $0.004A_c$, 4ø12 | 6 | 250 |

Note: 1 $A_c$ is the cross-sectional area of boundary element;

2 The horizontal spacing of tie bars at the other portions shall not be greater than 2 times of the spacing of longitudinal reinforcements; and hoops should be used at the corners;

3 For the end columns subjected to the concentrated loads, the diameter and spacing of the longitudinal reinforcements and hoops shall satisfy the corresponding requirements of frame column.




(a) Hidden column (b) Flange column (c) End column

**Figure 6.4.5-1 Range of Constructed Boundary Elements of Seismic Wall**

**2** For the seismic-walls assigned to Grade 1, 2 and 3 with the axial-force ratio in the bottom section of wall-pier at bottom storey greater than those specified in Table 6.4.5-1 as well as the seismic-walls of partial frame-supported seismic-wall structures, the confining boundary elements shall be set at the bottom strengthened portions and the adjacent storey above, and the constructed boundary elements may be set at other portions above. The length of confining boundary element along the wall-pier, the hoop characteristic value, and the hoops and longitudinal reinforcements should be in accordance with the requirements of Table 6.4.5-3 (Figure 6.4.5-2).

**Table 6.4.5-3 Range and Reinforcement Requirements of Confining Boundary Elements of Seismic Wall**

| Item | Grade 1 (Intensity 9) | | Grade 1 (Intensity7, 8) | | Grade 2 and 3 | |
|---|---|---|---|---|---|---|
| | $\lambda \le 0.2$ | $\lambda > 0.2$ | $\lambda \le 0.3$ | $\lambda > 0.3$ | $\lambda \le 0.4$ | $\lambda > 0.4$ |
| $l_c$ (Hidden column ) | $0.20h_w$ | $0.25h_w$ | $0.15h_w$ | $0.20h_w$ | $0.15h_w$ | $0.20h_w$ |
| $l_c$ (Flange column and end column) | $0.15h_w$ | $0.20h_w$ | $0.10h_w$ | $0.15h_w$ | $0.10h_w$ | $0.15h_w$ |
| $\lambda_v$ | 0.12 | 0.20 | 0.12 | 0.20 | 0.12 | 0.20 |
| Longitudinal reinforcement (larger value shall be used) | $0.012A_c$, 8ø16 | | $0.012A_c$, 8ø16 | | $0.010A_c$, 6ø16 (6ø14 for Grade 3) | |
| Vertical spacing of hoops or tie bars | 100mm | | 100mm | | 150mm | |

Note: 1 If the length of flange-wall of a seismic-wall is less than 3 times of the wall thickness or the section length of the end-column of a seismic-wall is less than 2 times of the wall thickness, the wall shall be seemed as the seismic-wall without flange-wall or end-column; for the end columns subjected to the concentrated loads, the reinforcement detailing also shall meet the requirements of frame column with the same seismic grade as the wall;

2 $l_c$ is the length of confining boundary element along the wall-pier, which shall be not less than the wall thickness or 400mm. For the seismic-wall with flange-walls or end-columns, the length shall be not less than the sum of the thickness of the flange-wall or the section height of end-column along the direction of wall-pier with 300mm;

3 $\lambda_v$ is the hoop characteristic value of confining boundary element, the volume hoop ratio may be calculated from Equation(6.3.9) in this code, and the cross-sectional area of the horizontally-distributed reinforcements meeting the construction requirements and anchoring reliably at wall ends may be included properly;

4 $h_w$ is the length of seismic wall-pier;

5 $\lambda$ is the axial-force ratio of wall-pier;

6 $A_c$ is the cross-sectional area of the shaded area of confining boundary elements in Figure 6.4.5-2.

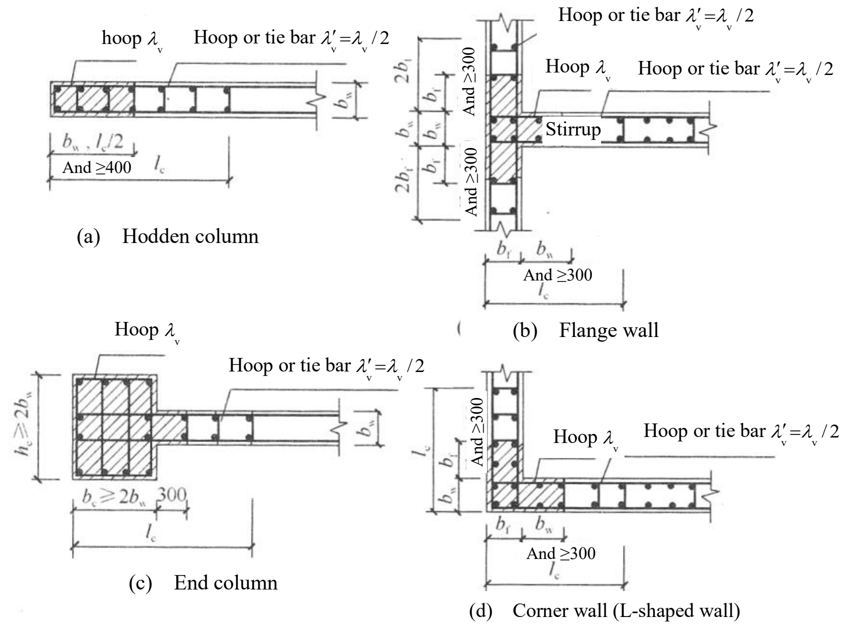



**Figure 6.4.5-2 Restraining Boundary Components of Seismic Wall**

**6.4.6** The wall-pier with length not greater than 3 times of the wall thickness, shall be designed according to the relevant requirements of frame column; thereinto, if the thickness of the wall-pier with rectangular section is not greater than 300mm, the hoops shall be also densified along the total height of the wall-pier.

**6.4.7** The high coupling beams with small span-depth ratio may be divided into double or multiple coupling beams by horizontal gaps or may be designed using details to increase the shear bearing capacity. Within the anchorage length scope of the longitudinal reinforcements of the coupling beams at top storey in the seismic-wall, hoops shall be arranged.

## 6.5 Details of Seismic Design for Frame-seismic-Wall Structures

**6.5.1** For the frame-seismic wall structures, the thickness of seismic-wall and the arrangement of edge frames shall comply with the following requirements:

**1** The thickness of seismic-wall shall not be less than 160mm and should not be less than 1/20 of the storey height or the non-branch length, the thickness of the seismic-wall located at the bottom strengthened portion shall not be less than 200mm and should not be less than 1/16 of the storey height or the non-branch length.

**2** For the seismic-walls with end columns, the hidden beams with sectional depth not less than the thickness of wall or 400mm located at the floors should be arranged; the end columns should be designed with the same sections as that of the frame columns at the same storey and also in accordance with the design requirements for frame columns as stated in Section 6.3 of this code; for the end columns of the bottom strengthened portion of seismic-wall and the end columns adjacent to the opening of seismic–wall, the hoops along the overall height should be densified according to the requirements for the critical regions of frame column.

**6.5.2** For the seismic-walls of frame seismic-wall structure, the vertically or horizontally distributed reinforcements with reinforcement ratio not less than 0.25%, diameter not less than 10mm and spacing not greater than 300mm, shall be arranged in two layers with tie-bars installed.

**6.5.3** If the floor beam is connected with the outer plane of seismic wall, it should not be supported on the coupling beam at opening; the beam should be supported on the seismic wall arranged along the axial direction of the beam, and the longitudinal reinforcements of the beam shall be anchored into the wall; the beam may also be supported on the counterfort column or hidden column arranged at the supporting position of beam, and the sectional dimensions and reinforcements of the counterfort column or the hidden column shall be determined by calculation.

**6.5.4** The other details of seismic design of the frame-seismic wall structures shall comply with the relevant requirements of Section 6.3 and Section 6.4 of this code.

Note: As for the frame structures with a few seismic walls, the details of seismic design of these seismic walls still may be carried out according to the requirements for seismic wall as stated in Section 6.4 of this code.

## 6.6 Requirements for Seismic Design of Slab-column-seismic-Wall Structures

**6.6.1** For the seismic-walls of slab-column-seismic-wall structures, in addition to this section, the details of seismic design shall also comply with the relevant regulations specified in Section 6.5 of this code; the details of seismic design of columns (including the end-columns of seismic wall) and beams shall comply with the relevant regulations specified in Section 6.3 of this code.

**6.6.2** The structural configuration of slab-column-seismic-wall shall also comply with the following requirements:

**1** The thickness of seismic-wall shall not be less than 180mm and should not be less than 1/20 of the storey height or the non-branch length; if the height of buildings is larger than 12m, the wall thickness shall not be less than 200mm.

**2** The framed beams shall be arranged at the perimeter of the floor, and the edge framed beams should be arranged at the perimeter of the opening for the stairs and the elevators.

**3** For the slab-column-seismic-wall structure with Intensity 8, the slab-column joint with supporting plate or column cap should be used, and the thickness (including the thickness of the floor slab) of supporting plate or column cap at root should not be less than 16 times of the diameter of longitudinal reinforcement of column. The side length of supporting plate or column cap should not be less than the sum of 4 times of slab thickness and corresponding side length of column section.

**4** The top slab of first underground storey of a building should be designed using beam–slab floor system.

**6.6.3** The seismic calculation of slab-column-seismic-wall structure shall be performed in accordance with the following requirements:

**1** If the height of the building is larger than 12m, the seismic wall shall undertake all the earthquake action of the structure; if not, the seismic wall should undertake all the earthquake action of the structure. The slab-columns and frames at each storey shall be able to undertake no less than 20% of the seismic shear force of this storey.

**2** When the slab-column structure under the frequent earthquake ground motion is analyzed using the equivalent plane-framed model, the width of the equivalent beam should be taken as the sum of 1/4 of the spacing of columns on each side of the axis of the equivalent plane-frame.

**3** For the slab-column joint, the seismic checking for the punching shear bearing capacity shall be performed with the punching by the unbalanced bending moment included, the design value of the punching counterforce caused by the combined unbalanced bending moment at the joint under frequent earthquake ground motion, shall be multiplied by an enhancement coefficient, and this enhancement coefficient may be taken as 1.7, 1.5 and 1.3 for the slab columns assigned to Grade 1, 2 and 3 respectively.

**6.6.4** The details of slab-column joints of slab-column-seismic-wall structure shall comply with the following requirements:

**1** For the flat slab without column cap, hidden beams shall be arranged within the slab strip on column, the width of the hidden beam may be taken as the column width increased by no more than 1.5 times of slab thickness on each side of the column. The top reinforcements of the hidden beam at the supports shall not be less than 50% of total reinforcements within the slab strip on column, the bottom reinforcements of the hidden beam should not be less than 1/2 of the top reinforcements; and the hoops with diameter not less than 8mm, spacing not greater than 3/4 of the slab thickness, and spacing of limbs not greater than 2 times of the slab thickness, shall be arranged along the length of the beam within the end regions of the hidden beam, the hoops shall be densified.

**2** The bottom reinforcements within the slab strip on column of the flat slap without column cap should be connected away from the column surface by no less than 2 times of the slab thickness, and for the overlapped reinforcements, the end hooks perpendicular to the slab surface should be set.

**3** The total cross-sectional area of the continuous bottom reinforcements passing through the column section along the two principal axial directions shall satisfy the following requirement:

$$A_s \geq N_G / f_y \tag{6.6.4}$$

Where $A_s$——Total cross-sectional area of continuous bottom reinforcements;

$N_G$——Design value of axial force of column under the action of the representative value of gravity load on the slab of this storey (the vertical earthquake action should also be considered for Intensity 8);

$f_y$——Design value of tensile strength of the reinforcements of floor slab.

**4** Based on the requirements of the punching shear bearing capacity, the shear resistant studs or punching resistant reinforcements shall be arranged within the slab-column joints.

## 6.7 Requirements for Seismic Design of Tube Structures

**6.7.1** The configuration of the frame-core-tube structures shall comply with the following requirements:

**1** The floors between the core-tube and the perimeter frames should be designed using the beam-slab floor system; for the some floors designed using the flat-slab floor system, proper strengthening measures shall be taken.

**2** Except for the strengthening storeys as well as their adjacent storey up and down, the maximum value of seismic shear force of the storeys in frame portions, calculated using the frame-core-tube analytical model, should not be less than 10% of the total seismic shear force at bottom of the structure, otherwise, the seismic shear force of the core-tube wall shall be increased appropriately and the details of seismic design of the boundary elements shall be strengthened properly; the seismic shear force bear by the frame potion of any storey shall not be less than 15% of the total seismic shear force at bottom of the structure.

**3** The configuration of strengthening storey shall meet the following requirements:

**1)** The strengthening storey shall not be used for the buildings with Intensity 9;

**2)** The girder or truss of the strengthening storey shall be penetrated through the wall-piers in core tube; the connection of the girder or truss with the perimeter frame columns should be designed as hinged connection or semi-rigid connection;

**3)** The integral analysis of the structure shall be performed with the influence of the deformation of strengthening storey considered; and

**4)** The proper measures, from the perspectives of construction procedures and connection details, shall be taken to reduce the influence of the vertical temperature deformation and axial compression of structure on the strengthening storey.

**6.7.2** For the core-tube of frame-core-tube structure and inner tube of tube-in-tube structure, the seismic-walls not only shall meet the relevant regulations specified in Section 6.4 of this code, but also shall comply with the following requirements:

**1** The thickness of the seismic-wall and the vertically and horizontally distributed reinforcements shall comply with those specified in Section 6.5 of this code; at the bottom strengthened portion of the tube and the adjacent upper storey, the wall thickness should not be changed when the lateral stiffness is free from sudden changes.

**2** The boundary elements at corners of the tubes assigned to Grade 1 and 2 in frame-core-tube structure should be strengthened according to the following requirements: within the bottom strengthening portion, hoops should be used in the range of confining boundary elements, and the length of the confining boundary elements along the wall-pier should be taken as 1/4 of the section height of wall-pier; within the above portion, the confining boundary elements should be arranged according to the requirements for the corner-wall.

**3** The door opening of inner tube should not be near to corners.

**6.7.3** The floor girder should not be supported on the coupling beam of inner tube. The connection of floor girder with the wall of inner tube or core tube outside the plane, shall meet those specified in Article 6.5.3 of this code.

**6.7.4** For the coupling beams with span-height ratio not greater than 2 in core tubes and inner tubes assigned to Grade 1 or 2, if the width of the coupling beam is not less than 400mm, the diagonal hidden columns with diagonal reinforcements and hoops arranged may be used, meanwhile, the common hoops shall be arranged along the length of the beam; if the width of the coupling beam is less than 400mm, but not less than 200mm, in addition to the common hoops, only the diagonal reinforcements may be added.

**6.7.5** The seismic design of the transfer storey of tube structure shall comply with those specified in Section E.2 of this code.

# 7 Multi-storey Masonry Buildings and Multi-storey Masonry Buildings with RC Frames on Ground Floors

## 7.1 General

**7.1.1** This chapter is applicable to multi-storey masonry buildings in which the masonries such as common bricks (including fired, autoclaved and concrete common bricks), perforated bricks (including fired and concrete perforated bricks) or small concrete hollow blocks used to bear weight loads, as well as masonry buildings with RC frames and seismic-walls in the first storey or first and second stories.

The seismic design of buildings with small reinforced concrete hollow blocks shall meet the requirements specified in Appendix F of this code.

Note: 1 For masonry buildings with fired bricks, autoclaved bricks and concrete bricks by adopting non-clay, the material property of such blocks shall be provided with reliable test data; they may comply with the corresponding requirements of buildings with common bricks and perforated bricks, when not specified in this chapter;

2 In this chapter, “small concrete hollow block” is hereinafter referred to as “small block”;

3 The seismic design for non-spacious single-storey masonry buildings may be carried out according to principles specified in this chapter.

**7.1.2 The total height and number of stories of multi-storey buildings shall meet the following requirements:**

**1 In general conditions, the total height and number of stories of the masonry buildings shall not exceed those specified in Table 7.1.2.**

**Table 7.1.2 The Allowable Number of Stories and Total Height of Buildings (m)**

| Building category | | Minimum thickness of seismic wall (mm) | Intensity and design basic acceleration of ground motion | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | | 7 | | | | 8 | | | | 9 | |
| | | | 0.05$g$ | | 0.10$g$ | | 0.15$g$ | | 0.20$g$ | | 0.30$g$ | | 0.40$g$ | |
| | | | Height | number of stories | Height | number of stories | Height | number of stories | Height | number of stories | Height | number of stories | Height | number of stories |
| Multi-storey masonry building | Common brick | 240 | 21 | 7 | 21 | 7 | 21 | 7 | 18 | 6 | 15 | 5 | 12 | 4 |
| | Perforated brick | 240 | 21 | 7 | 21 | 7 | 18 | 6 | 18 | 6 | 15 | 5 | 9 | 3 |
| | Perforated brick Small | 190 | 21 | 7 | 18 | 6 | 15 | 5 | 15 | 5 | 12 | 4 | — | — |
| | block | 190 | 21 | 7 | 21 | 7 | 18 | 6 | 18 | 6 | 15 | 5 | 9 | 3 |
| Masonry buildings with RC frames and seismic-wall on ground floors | Common brick and perforated brick | 240 | 22 | 7 | 22 | 7 | 19 | 6 | 16 | 5 | — | — | — | — |
| | Perforated brick | 190 | 22 | 7 | 19 | 6 | 16 | 5 | 13 | 4 | — | — | — | — |
| | Small block | 190 | 22 | 7 | 22 | 7 | 19 | 6 | 16 | 5 | — | — | — | — |

Note: 1 The total height of buildings refers to the distance from the outdoor ground up to the top level of the main roof slab or the cornice. For the building with semi-basement, the total height shall be counted from the indoor ground of the basement; for the building with whole basement or semi-basement fixed better，the total height shall be permitted to be counted from the outdoor ground; for the building with garret below the slope roof, the total height shall be counted up to 1/2 height of the pediment wall;

2 For the case that the height difference of the indoor and outdoor is greater than 0.6m, the total height of building shall be permitted to be properly increased over the data given in the table; but the increment shall be less than 1.0m;

3 For the multi-storey masonry buildings assigned to Category B, the allowable number of stories and total height shall be still determined from the table according to the precautionary Intensity of the zone, but the allowable number of stories shall reduce one and the allowable total height shall be lower 3m; meanwhile, the masonry structures with R.C frames and seismic-walls on ground floors shall not be used;

4 The small blocks buildings in this table exclude reinforced small concrete hollow blocks buildings.

**2 For multi-storey masonry buildings with fewer transverse walls, the total height shall be reduced 3m than those specified in Table 7.1.2, and the numbers of stories shall be reduced by one correspondingly; for multi-storey masonry buildings with very few transverse walls at each storey, the number of stories number still shall be reduced one more.**

**Note: The multi-storey masonry buildings with fewer transverse walls refer to the buildings in which the rooms with span greater than 4.2m occupy more than 40% of the total area of the same storey; hereinto, the multi-storey masonry buildings with very few transverse walls refer to the buildings in which the rooms with span not greater than 4.2m occupy less than 20% of the total area of the storey and rooms with span greater than 4.8m occupy more than 50% of the total area of the storey.**

**3 For the multi-storey masonry buildings with fewer transverse walls assigned to Category C, located at the zone of Intensity 6 and 7, if the strengthening measures are taken in accordance with the provisions and the requirements of seismic capacity are satisfied, the total heights and numbers of stories shall be permitted to be taken from Table 7.1.2.**

**4 For the masonry buildings with autoclaved lime-sand bricks and autoclaved fly ash bricks, if the shear strength of masonry only reaches 70% that of the masonry with common clay bricks, the number of stories shall be reduced by one from that of common brick buildings, and the total height shall be reduced by 3m; if the shear strength of masonry reaches that of the masonry with common clay bricks, the requirements of the number of stories and total height of buildings shall be as the same of the common brick buildings.**

**7.1.3** The storey height of multi-storey masonry buildings shall not exceed 3.6m.

For the masonry buildings with RC frames and seismic-walls on ground floors, the storey height of the bottom portions shall not exceed 4.5m; if the confined masonries are used as the seismic-walls on ground floors, the storey height of the ground floor shall not exceed 4.2m.

Note: The storey height shall not exceed 3.9m for common brick buildings with strengthening measures such as the confined masonry used if there is indeed in need of the functions of use.

**7.1.4** The maximum ratio of the total height to the total width of multi-storey masonry buildings should be in accordance with those specified in Table 7.1.4.

**Table 7.1.4 Maximum Height-width Ratio of Buildings**

| Intensity | 6 | 7 | 8 | 9 |
|---|---|---|---|---|
| Maximum height-width ratio | 2.5 | 2.5 | 2.0 | 1.5 |

Note: 1 The total width of buildings with single-side corridors excludes the corridor width;

2 The height-width ratio should be reduced properly if the architectural plane is close to the square.

**7.1.5 The spacing of seismic transverse walls of buildings shall not exceed those specified in Table 7.1.5:**

**Table 7.1.5 Spacing of Seismic Transverse Walls of Buildings**

| Building category | | Intensity | | | |
|---|---|---|---|---|---|
| | | 6 | 7 | 8 | 9 |
| Multi-storey masonry building | Cast-in-situ and monolithic-fabricated reinforced concrete floors and roofs | 15 | 15 | 11 | 7 |
| | Fabricated reinforced concrete floors and roofs | 11 | 11 | 9 | 4 |
| | Wooden roof | 9 | 9 | 4 | — |
| masonry buildings with Bottom R.C frames and seismic-walls | Upper storeys | Same as the multi-storey masonry building | | | — |
| | Ground floor or two storeys from the ground floor | 18 | 15 | 11 | — |

**Note: 1 For the top storey of multi-storey masonry buildings, the maximum transverse wall spacing, except that of the wooden roof, shall be permitted to be broaden properly, but the corresponding strengthening measure shall be taken;**

**2 If the thickness of seismic transverse walls of perforated bricks is 190mm, the maximum transverse wall spacing shall be reduced 3m on the basis of the value given in the table.**

**7.1.6** The local dimension of masonry wall in multi-storey masonry buildings should comply with the requirements of Table 7.1.6:

**Table 7.1.6 Limitations of local dimension for masonry walls (m)**

| Location | Intensity 6 | Intensity 7 | Intensity 8 | Intensity 9 |
|---|---|---|---|---|
| Minimum width of a bearing wall between windows | 1.0 | 1.0 | 1.2 | 1.5 |
| Minimum distance from the end of bearing external wall to the edge of door/window opening | 1.0 | 1.0 | 1.2 | 1.5 |
| Minimum distance from the end of non-bearing external wall to the edge of door/window opening | 1.0 | 1.0 | 1.0 | 1.0 |
| Minimum distance from the exposed corner of the internal wall to the edge of door/window opening | 1.0 | 1.0 | 1.5 | 2.0 |
| Maximum height of non-anchoring parapet walls (non-exit-and-entrance positions) | 0.5 | 0.5 | 0.5 | 0.0 |

Note: 1 If the partial dimension is not enough, the partial strengthening measures shall be taken to make up, but in any case, the minimum width should not be less than 1/4 of the storey height or 80% of the tabular data;

2 Parapet walls at the position of exits and entrances shall be anchored.

**7.1.7** The architectural arrangement and structural system of multi-storey masonry buildings shall comply with the following requirements:

**1** The structural system that the weight loads are borne by transverse walls or jointly borne by longitudinal and transverse walls shall be used prior. The mixing structural system that the weight loads are borne by masonry walls and concrete walls shall not be used.

**2** The arrangement layout of longitudinal and transverse masonry seismic walls shall meet the following requirements:

**1)** The arrangement of the longitudinal and transverse walls should be uniform, symmetrical and aligned along the axis in plane, and shall be continued up and down along the vertical direction; and the number of longitudinal and transverse walls should not differ largely;

**2)** The concave-convex dimension of the plane profile shall not exceed 50% of the typical dimension; and strengthening measures shall be taken at corners of buildings if the concave-convex dimension exceeds 25% of the typical dimension;

**3**) The dimension of the opening of the floor-slab should not exceed 30% of the floor-slab width and openings shall not be arranged simultaneously at the both sides of the wall;

**4**) If the height difference of the floor-slabs of the building split-stories exceeds 500mm, the split-stories shall be seemed as two stories; and strengthening measures shall be taken for the walls located at the split-storey positions;

**5**) The width of walls between windows on the same axes should be uniform, the vertical area of the opening of the wall surface should not be greater than 55% of the total area of the wall surface for Intensity 6 and 7, should not be greater than 50% of the total area of the wall surface for Intensity 8 and 9;

**6**) Inner longitudinal walls shall be arranged in the middle portion of the building along the width direction, and the accumulative total length should not be less than 60% of the total length of the building (the walls with height-width ratio greater than 4 are not counted in).

**3** If the building has one of the following cases, the seismic joint with walls on both sides should be arranged, and the net joint width shall be determined dependent on the Intensity and building height, generally, it may be taken as 70mm~100mm:

**1**) The height difference in elevation of the building is greater than 6m;

**2**) The building has split-storey and the floor-slab height difference of the spilt-storey is larger than 1/4 of the storey height;

**3**) The structural stiffness and mass of each part is completely different.

**4** The staircase should not be arranged at the end of or at the corner of the building.

**5** The corner window shall not be arranged at the corner of the building.

**6** For the buildings with less transverse walls and larger spans, the cast-in-situ reinforced concrete floor and roof should be used.

**7.1.8 The structural arrangement of masonry buildings with RC** frames and seismic-walls on ground floors **shall meet the following requirements:**

**1 Besides the exceptional wall fragment nearby the staircase, the upper masonry walls shall be aligned with the bottom frame beams or seismic walls.**

**2 At the bottom of the buildings, the certain quantity of seismic walls shall be arranged evenly and symmetrically along longitudinal and transverse directions. For the masonry buildings with RC frames and seismic-walls on ground floors which have no more than 4 stories and are located at the regions of Intensity 6, the masonry seismic walls with confined common brick masonry or confined small block masonry infilled in the frames shall be permitted to be used; but the additional axial force and shear force applied on frames by the masonry walls shall be counted in and the seismic check for ground floors shall be carried out, and the reinforced concrete seismic wall and confined masonry seismic wall shall not be used simultaneously in the same direction. For other cases, the reinforced concrete seismic wall shall be used for Intensity 8, the reinforced concrete seismic wall or the seismic wall of small block masonry with reinforcement shall be used for Intensity 6 and 7.**

**3 In the longitudinal and transverse directions of masonry buildings with RC frames and seismic-walls on ground floors, the ratio of the lateral stiffness of the second storey, with the effect of the constructional column counted in, to the lateral stiffness of the ground floor, shall not be greater than 2.5 for Intensity 6 and 7, and 2.0 for Intensity 8, wherever, the ratio shall not be less than 1.0.**

**4 In the longitudinal and transverse directions of masonry buildings with RC frames and seismic-walls on two stories from ground floors, the lateral stiffness's of the ground floor and the second storey of the bottom shall be close to each other; the ratio of lateral stiffness of the third storey, counted in the effect of the constructional column, to the lateral stiffness of the second storey of the bottom shall not be greater than 2.0 for Intensity 6 and 7, and 1.5 for Intensity 8, wherever, the ratio shall not be less than 1.0.**

**5 For the seismic walls of masonry buildings with RC frames and seismic-walls on ground floors, the foundations of good integrity such as strip foundations and raft foundations shall be used.**

**7.1.9** For the design of the reinforced concrete structural components of masonry buildings with RC frames and seismic-walls on ground floor, the relevant requirements of Chapter 6 of this code shall also be met; where, the seismic grade of bottom RC frames shall be assigned to Grades 3, 2 and 1 for Intensity 6, 7 and 8, respectively; the seismic grade of concrete walls shall be assigned to Grade 3, 3 and 2 for Intensity 6, 7 and 8, respectively.

## 7.2 Essentials in Calculation

**7.2.1** For the seismic calculation of multi-storey masonry buildings and masonry buildings with RC frames and seismic-walls on ground floors, the base shear method may be used, and the seismic effects shall be adjusted according to the requirements of this section.

**7.2.2** For masonry buildings, the seismic capacity checking of walls may only be carried out for the walls with greater subordinate area or less vertical stress.

**7.2.3** When carrying out the seismic shear force distribution and the cross section checking, the storey equivalent lateral stiffness of masonry wall segment shall be determined according to the following principles:

**1** For the calculation of stiffness, the effect of height-width ratio of the wall segment shall be taken into consideration. When this ratio is less than 1, only shear deformation of wall needs to be taken into account. When this ratio is not greater than 4 and not less than 1, the bend and shear deformation shall be simultaneously taken into consideration, And when this ratio is greater than 4, the equivalent lateral stiffness may be taken as 0.0.

Note: The height-width ratio of wall segment refers to the ratio of storey height to the length of the wall segment; for the small wall segment between the door openings or window openings, it refers to the ratio of the net height of the opening to the lateral length of the wall segment.

**2** The wall segments should be divided according to the openings of doors and windows; for the small opening wall segments with constructional columns arranged, the equivalent lateral stiffness may be taken as the product of the gross section stiffness and the opening influence coefficient specified in Table 7.2.3:

**Table 7.2.3 The Opening Influence Coefficient of Wall Segment**

| Opening rate | 0.10 | 0.20 | 0.30 |
|---|---|---|---|
| Influence coefficient | 0.98 | 0.94 | 0.88 |

Note: 1 The opening rate is the ratio of the horizontal section area of the opening to the horizontal gross section area of the wall segment; the wall segment with the net width less than 500mm shall be seemed as opening;

2 If the distance from the opening center line to the wall section center line is greater than 1/4 of the wall section length, the influence coefficient in the table shall be multiplied a reduction factor 0.9; if the height of the door opening is greater than 80% of the storey height, values listed in the table are not applicable; if the window opening height is larger than 50% of the storey height, it shall be treated as a door opening.

**7.2.4 The seismic effect of masonry buildings with RC frames and seismic-walls on ground floors and shall be adjusted according to the following requirements:**

**1 For masonry buildings with RC frames and seismic-walls on ground floors, the design value of the longitudinal and transverse seismic shear force on the ground floor all shall be multiplied the enhancement coefficient; the value of the enhancement coefficient shall be permitted to be taken within the range of 1.2~1.5; according to the principle that if the lateral stiffness ratio of the second storey to ground floor is greater, then greater value shall be taken.**

**2 For masonry buildings with two stories of RC frames and seismic-walls at bottom portion, the design value of the longitudinal and transverse seismic shear force on the ground floor and the second storey shall all be multiplied the enhancement coefficient; the value of the enhancement coefficient shall be permitted to be taken within the range of 1.2~1.5 according to the principle that if the lateral stiffness ratio of the third storey to the second storey is greater, then greater value shall be taken.**

**3 The design value of the longitudinal and transverse seismic shear force on the ground floor or the two stories from the ground floor shall be undertaken by the seismic walls along the direction and distributed according to the proportion of lateral stiffness.**

**7.2.5** For the frame components of the masonry buildings with RC frames and seismic-walls on ground floors, the seismic effects should be determined using the following methods:

**1** The seismic shear forces and axial forces of frame columns should be adjusted according to the following requirements:

1) The design value of seismic shear forces undertaken by frame columns may be determined in proportion of the effective lateral stiffness of the lateral-force-resisting components. In this case, the effective lateral stiffness of the frame shall not be reduced; the effective lateral stiffness of the concrete wall or the reinforced small concrete block wall may be multiplied the reduction coefficient 0.30; and the effective lateral stiffness of the confined common brick r small block seismic wall may be multiplied the reduction coefficient 0.20;

2) The additional axial force caused by the seismic overturning moment shall be counted in the axial force of the frame column; the upper brick portion may be seemed as rigid body; the seismic overturning moment undertaken by each axe on the ground floor may be determined approximately in proportion of the effective lateral stiffness of the seismic walls and frames;

3) If the length-width ratio of the floor between seismic walls is greater than 2.5,

the seismic shear forces and axial forces undertaken by each axe of frame columns shall also include the influence of deformation in the plane of the floor.

**2** For the reinforced concrete spandrel girder of the masonry building with RC frames and seismic-walls on ground floor, an suitable calculation sketch shall be used for the calculation of the seismic combination internal forces. If the composite effect of the upper wall and its spandrel girder is taken into account, the unfavorable influence caused by the cracking of the upper wall during earthquake shall also be taken into consideration by means of adjusting the relevant bending moment factors, axial factors and so on.

**7.2.6 The design value of seismic shear strength along the ladder shaped damage of various masonry structures shall be determined according to the following equation:**

$$f_{vE} = \xi_N f_v \tag{7.2.6}$$

**Where $f_{vE}$——The design value of seismic shear strength along the ladder shaped damage of masonry;**

**$f_v$——Design value of the shear strength of masonry with the non-seismic design;**

**$\xi_N$——Normal stress influence coefficient of the seismic shear strength of masonry, which shall be taken from Table 7.2.6.**

**Table 7.2.6 Normal Stress Influence Coefficient of Masonry Strength**

| Masonry type | $\sigma_0/f_v$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0.0 | 1.0 | 3.0 | 5.0 | 7.0 | 10.0 | 12.0 | ≥16.0 |
| Common brick and perforated brick | 0.80 | 0.99 | 1.25 | 1.47 | 1.65 | 1.90 | 2.05 | — |
| Small block | — | 1.23 | 1.69 | 2.15 | 2.57 | 3.02 | 3.32 | 3.92 |

**Note: $\sigma_0$ is the mean compression stress of masonry section under the representative value of the gravity load.**

**7.2.7** For the common brick walls and the perforated brick walls, checking of the section seismic shear capacity shall be performed in accordance with the following requirements:

**1** Generally, the checking shall be performed according to the following Equation:

$$V \le f_{vE} A / \gamma_{RE} \tag{7.2.7-1}$$

Where $V$——Design value of shear of the wall;

$f_{vE}$——The design value of seismic shear strength along the ladder shaped damage of masonry;

$A$——cross-sectional area of wall, for the perforated brick wall, it shall be taken as the gross sectional area;

$\gamma_{RE}$——Seismic adjustment coefficient of bearing capacity. For the bearing wall, it shall be taken from Table 5.4.2 of this code; for the self-bearing wall, it shall be taken as 0.75.

**2** For the walls with horizontal reinforcements, the checking shall be performed according to the following equation:

$$V \le \frac{1}{\gamma_{RE}}(f_{vE} A + \xi_s f_{yh} A_{sh}) \tag{7.2.7-2}$$

Where $f_{yh}$——Design value of the horizontal reinforcement tensile strength;

$A_{sh}$——Total areas of the horizontal reinforcements in height of the storey, the reinforcement ratio shall be not less than 0.07% and not greater than 0.17%;

$\xi_s$——the participation factor of reinforcement, it may be taken from Table 7.2.7.

**Table 7.2.7 Participation Factor of Reinforcement**

| Height-width ratio of wall | 0.4 | 0.6 | 0.8 | 1.0 | 1.2 |
|---|---|---|---|---|---|
| $\xi_s$ | 0.10 | 0.12 | 0.14 | 0.15 | 0.12 |

**3** When the Equation 7.2.7-1 or 7.2.7-2 is not satisfied, the improving effects on shear capacity, made by the constructional columns that have cross sections not less than 240mm×240mm (240mm×190mm if the wall thickness is 190mm) and spacing not greater than 4m and are uniformly arranged in the middle of the wall segment, may be counted in, and the shear capacity may be checked using the following simplified method:

$$V \le \frac{1}{\gamma_{RE}}[\eta_c f_{vE}(A-A_c)+\xi_c f_t A_c + 0.08 f_{yc} A_{sc} + \xi_s f_{yh} A_{sh}] \tag{7.2.7-3}$$

Where $A_c$——Total cross-sectional area of the middle constructional columns (for the transverse wall and the inner longitudinal wall, $A_c$ will be taken as 0.15A if $A_c$>0.15$A$; for the outer longitudinal wall, it will be taken as 0.25$A$ if $A_c$>0.25$A$);

$f_t$——Design value of concrete axial tensile strength in the middle constructional column;

$A_{sc}$——Total cross-sectional area of the longitudinal reinforcement of the middle constructional column (the reinforcement ratio shall not be less than 0.6%, and shall be taken as 1.4% if it is greater than 1.4%);

$f_{yh}$, $f_{yc}$——Respectively the design value of the tensile strength of wall horizontal reinforcement and constructional column reinforcement;

$\xi_c$——Participation factor of the middle constructional column; it shall be taken as 0.5 for only one column arranged in the center, 0.4 for more than one columns arranged;

$\varepsilon_c$——Confined coefficient of the wall. Generally, it shall be taken as 1.0, and for the case that the spacing of the constructional columns is not greater than 3.0m, it shall be taken as 1.1;

$A_{sh}$——Total horizontal reinforcement area of the vertical section of the storey wall. For the wall without horizontal reinforcement arranged, it shall be taken as 0.0.

**7.2.8** The seismic shear capacity of the small block wall shall be checked according to the following equation:

$$V \le \frac{1}{\gamma_{RE}}[f_{vE}A+(0.3 f_t A_c + 0.05 f_y A_s)\xi_c] \tag{7.2.8}$$

Where $f_t$——Design value of concrete axial tensile strength of core column;

$A_c$——Total cross-sectional area of the core column;

$A_s$——Total cross-sectional area of the reinforcements in core column;

$f_y$——Tensile strength design value of the reinforcement in core column;

$\xi_c$——Participation factor of the core column, which may be taken from Table 7.2.8.

Note: When the core column and constructional column are arranged simultaneously, the cross-section of the constructional column may be regarded as the cross-section of the core column; the reinforcement of the constructional column may be regarded as the reinforcement of the core column.

**Table 7.2.8 Participation Factor of Core Column**

| Hole-filling ratio $\rho$ | $\rho$<0.15 | 0.15≤$\rho$<0.25 | 0.25≤$\rho$<0.5 | $\rho$≥0.5 |
|---|---|---|---|---|
| $\xi_c$ | 0.0 | 1.0 | 1.10 | 1.15 |

Note: The Hole-filling ratio refers to the ratio of the number of the core columns (including the number of the constructional columns and the infill holes) and the total number of the holes.

**7.2.9** For the masonry wall with common bricks or small blocks built-in frames in masonry buildings with RC frames and seismic-walls on ground floors, if it meets the detail requirements of Article 7.5.4 and Article 7.5.5 of this code, the seismic check shall meet the following requirements:

**1** For the frame column on the ground floor, the additional axial force and shear force caused by the brick wall or small block wall shall be counted into the axial force and shear force; the values may be determined according to the following equation:

$$N_{\mathrm{f}} = V_{\mathrm{w}} H_{\mathrm{f}} / l \tag{7.2.9-1}$$

$$V_{\mathrm{f}} = V_{\mathrm{w}} \tag{7.2.9-2}$$

Where $V_{\mathrm{w}}$——Design value of the shear distributed to the masonry wall. If walls exist on both sides of the column simultaneously, the greater value may be used;

$N_{\mathrm{f}}$——Additional axial pressure design value of the frame column;

$V_{\mathrm{f}}$——Additional shear force design value of the frame column;

$H_{\mathrm{f}}$, $l$——Storey height and span of the frame respectively.

**2** For the common brick walls or small block walls filled in frames as well as the both end frame columns, the seismic shear capacity shall be checked and calculated according to the following equation:

$$V \le \frac{1}{\gamma_{\mathrm{REc}}} \sum (M_{\mathrm{yc}}^{\mathrm{u}} + M_{\mathrm{yc}}^{l}) / H_0 + \frac{1}{\gamma_{\mathrm{REw}}} \sum f_{\mathrm{vE}} A_{\mathrm{w0}} \tag{7.2.9-3}$$

Where $V$——Design value of shear force of the filled common brick walls or small block walls as well as the both end frame columns;

$A_{\mathrm{w0}}$——Calculated area of the horizontal section of the brick wall or small block wall. For the wall without openings, it shall be taken as 1.25 times of the actual section area; for the walls with openings, it shall be taken as the net area of the section, but the section area of the wall pier with width less than 1/4 of the opening height shall not be counted in;

$M_{\mathrm{yc}}^{\mathrm{u}}$、$M_{\mathrm{yc}}^{l}$——Respectively the non-seismic bending bearing capacity design values at the upper and lower end of the frame columns in the first storey and it may be determined by the provision in the current national standard GB 50010 "*Code for Design Of Concrete Structure* ".

$H_0$——Calculated height of frame column on the ground floor; for the case that there are masonry walls on both sides of the column, it shall be taken as 2/3 clear height of the column; for other cases, it shall be taken as the clear height of column;

$\gamma_{REc}$——Seismic adjustment coefficient of bearing capacity of the frame column on the ground floor, it may be taken as 0.8;

$\gamma_{REw}$——Seismic adjustment coefficient of bearing capacity of filled common brick walls or small block walls, it may be taken as 0.9.

### 7.3 Details of Seismic Design of Multi-storey Brick Buildings

**7.3.1 For various multi-storey brick masonry buildings, the cast-in-situ reinforced concrete constructional columns (hereinafter referred to as —constructional column") shall be arranged according to the following requirements:**

**1 The arranged position of the constructional column generally shall meet the requirements specified in Table 7.3.1.**

**2 For multi-storey buildings with gallery type corridor or one-side type corridor, the constructional columns shall be arranged according to those specified in Table 7.3.1, but the building shall be assumed with one more storey, and the longitudinal walls on the both sides of the one-sided corridor shall be regarded as exterior walls.**

**3 For buildings with fewer transverse walls, the constructional column shall be arranged according to those specified in Table 7.3.1, but the buildings shall be assumed with one more stories. If such buildings are designed as the multi-storey masonry buildings with gallery type corridor or one-side type corridor, the constructional column shall be arranged according to the requirements of Item 2 of this article; but if the building does not exceed four stories for Intensity 6, three stories for Intensity 7 and two stories for Intensity 8, the constructional column shall be arranged according to the assumption of the building with two more stories.**

**4 For buildings with very few transverse walls at each storey, the constructional columns shall be arranged according to the storey number increased by two.**

**5 As for the masonry buildings adopted with autoclaved lime-sand bricks and autoclaved fly ash bricks, if the shear strength of masonry only reaches 70% of that of the masonry with common clay bricks, the constructional columns shall be arranged in accordance with the requirements of Item 1~4 of this article based on the storey number increased by one; but it shall be treated according to the storey number increased by two if the building does not exceed four stories for Intensity 6, three stories for Intensity 7 or two stories for Intensity 8.**

**Table 7.3.1 Arrangement Requirements of Constructional Columns of Multi-Storey Brick Masonry Buildings**

<table>
<tr><th colspan="4">Storey number of building</th><th colspan="2" rowspan="2">Arranged position</th></tr>
<tr><th>Intensity 6</th><th>Intensity 7</th><th>Intensity 8</th><th>Intensity 9</th></tr>
<tr><td>4 and 5</td><td>3 and 4</td><td>2 and 3</td><td></td><td rowspan="3">Four corners at the staircase and elevator room. the corresponding wall at up and down ends of the inclined ladder of the staircase; four corners of external walls and corresponding corners; joints of transverse walls and outer longitudinal walls at split-storey positions; joints of internal and external walls in big rooms; both sides of bigger openings</td><td>Every 12m or joints of unit transverse walls and outer longitudinal walls; joints of inner transverse walls and outer longitudinal walls at the corresponding opposite side of staircases</td></tr>
<tr><td>6</td><td>5</td><td>4</td><td>2</td><td>Joints of transverse walls(axes) and external walls in separate rooms; joints of gable walls and inner longitudinal walls</td></tr>
<tr><td>7</td><td>≥6</td><td>≥5</td><td>≥3</td><td>Joints of internal walls (axes) and external walls; partial smaller piers of internal walls; joints of inner longitudinal walls and transverse walls (axes)</td></tr>
</table>

**Note: Bigger opening, for inner walls, it refers to the openings with width no less than 2.1m; for external walls, if constructional columns have been already arranged at the joint of inner wall and external wall, the opening shall be permitted to be widened properly, but the walls close to opening shall be strengthened.**

**7.3.2** The constructional columns of multi-storey brick masonry buildings shall meet the following detail requirements:

**1** The minimum section of the constructional columns may be 180mm×240mm (180mm× 190mm if the wall thickness is 190mm); the longitudinal reinforcement should adopt 4ø12; the stirrup spacing should not be greater than 250mm and the spacing shall be properly reduced at the upper and lower ends of the constructional column; as for the buildings exceeding six stories for Intensity 6 and 7, exceeding five stories for Intensity 8 and buildings for Intensity 9, the longitudinal reinforcements of constructional column should adopt 4ø14; the stirrup spacing shall not be greater than 200mm; the section and reinforcement of the constructional columns at four corners of the building shall be properly increased.

**2** The connection of the constructional column and the adjacent walls shall be built into horse-toothed joints; 2ø6 horizontal reinforcement and tie meshes composed by spot welding in ø4 distributed short reinforcement plane or ø4 mesh reinforcement steel fabric composed by spot welding shall be arranged every 500mm along the wall height; the length of each side stretched into the wall should not be less than 1m. At the 1/3 of stories of bottom portion for Intensity 6 and 7, 1/2 of stories of bottom portion for Intensity 8 and whole storeys for Intensity 9, the above-mentioned tie reinforcement meshes shall be arranged along the horizontal full length of the wall.

**3** At the joints of constructional columns and ring-beams, the longitudinal reinforcements of constructional columns shall be drilled through from the inside of longitudinal reinforcements of ring-beams to guarantee longitudinal reinforcements of constructional columns through up and down.

**4** The constructional column may be designed without individual foundation, but it shall extend 500mm into the outdoor subsurface or be connected with the foundation ring-beam whose buried depth is less than 500mm.

**5** When the building heights and number of stories are close to the limit values given in Table 7.1.2 of this code, the spacing constructional columns in longitudinal and transverse walls shall also meet the following requirements:

**1)** For the transverse wall, the spacing of the constructional columns should not be greater than 2 times of the storey height; and this spacing of constructional columns in lower 1/3 of stories should be reduced properly;

**2)** For the longitudinal wall, when the bays of building are greater than 3.9m, the exterior longitudinal walls shall be adopted strengthening measures; the spacing of tie-columns of the interior longitudinal wall should not be greater than 4.2m.

**7.3.3 The arrangement of the cast-in-situ reinforced concrete ring-beam of multi-storey brick masonry buildings shall meet the following requirements:**

**1 As for fabricated reinforced concrete floors and roofs or the wooden roofs, the ring-beams shall be arranged according to those specified in Table 7.3.3; for the buildings designed using longitudinal wall as the bearing wall, the spacing of ring-beams on the seismic transverse wall shall be reduced properly.**

**2 For the building with in-situ cast or assembly-monolithic reinforcement concrete floors and roof that have reliable connection with the walls, the ring-beams shall be permitted to not be installed, but the strengthened reinforcements of in-situ slabs shall be arranged along the wall perimeters and shall be reliably connected with corresponding constructional columns.**

**Table 7.3.3 Cast-in-situ Reinforced Concrete Ring-beam Arrangement Requirements of Multi-storey Brick Masonry Buildings**

| Wall Type | Intensity | | |
|---|---|---|---|
| | 6 and 7 | 8 | 9 |
| External wall and inner longitudinal wall | Roof and floor of each storey | Roof and floor of each storey | Roof and floor of each storey |
| Inner transverse wall | As above; the roof spacing shall not be greater than 4.5m; floor spacing shall not be greater than 7.2m; corresponding position of constructional column | As above; all the transverse wall at each storey and the spacing shall not be greater than 4.5m; corresponding position of constructional column | As above; all the transverse wall at each storey |

**7.3.4** The cast-in-situ concrete ring-beam structure of multi-storey brick masonry buildings shall meet the following requirements:

**1** The ring-beam shall be enclosed; at the location of opening, the ring-beam shall be spliced with two limbs along the upper and lower of opening. The ring-beams should be installed in the same level of the precast slabs or immediate next to the bottom of the slab.

**2** If there is no transverse wall in the ring-beam spacing required in Article 7.3.3 of this code, the ring-beam shall be replaced using the beam or reinforcement in slab joints;

**3** The cross-section height of the ring-beam shall not be less than 120mm, the reinforcement shall be in accordance with those specified in Table 7.3.4; for the foundation ring-beam added according to the requirements of Item 3 in Article 3.3.4 of this code, the cross-section height shall not be less than 180mm, the reinforcement shall not be less than 4ø12.

**Table 7.3.4 Ring-beam Reinforcement Requirements of Multi-storey Brick Masonry Buildings**

| Reinforcement | Intensity | | |
|---|---|---|---|
| | 6 and 7 | 8 | 9 |
| Minimum longitudinal reinforcement | 4ø10 | 4ø12 | 4ø14 |
| Maximum spacing of stirrups (mm) | 250 | 200 | 150 |

**7.3.5 The floors and roofs of multi-storey brick masonry buildings shall meet the following requirements:**

**1 The length that the cast-in-situ reinforced concrete floor-slab or roof slab extends into the longitudinal or transverse wall all shall not be less than 120mm.**

**2 For fabricated reinforced concrete floor slab or roof slab, if the ring-beams are not arranged at the same elevation of the slab, the slab shall extend into the external wall with length not less than 120mm; the slab shall extend into the internal wall with length not less than 100mm, or be connected with the wall by adopting the hard-strut framework; the slab shall be supported on the beam with length not less than 80mm or shall be connected by adopting the hard-strut framework.**

**3 For the precast slab with span greater than 4.8m and parallel to the exterior wall, the side of the precast slab next to the exterior wall shall be tied with the exterior wall or ring-beam.**

**4 The precast slabs of the large room at the end of the building, which are used as the roof for Intensity 6 or as the floors and roof for Intensity 7-9, shall be tied with each other, and connected with the beam, wall or the ring-beam installed at the bottom of the slab.**

**7.3.6 Reinforced concrete girders or roof trusses of the floor and roof shall be reliably connected with walls and columns (including constructional columns) or ring-beams; independent brick columns shall not be used as supporting members. For the girder withe span not less than 6m, the supporting members shall be designed using strengthening measures such as combination masonry and satisfy the bearing capacity requirements.**

**7.3.7** For the walls of the large rooms with length greater than 7.2m at the regions of Intensity 6 and 7, and the corners of exterior wall and the intersections of exterior and inner wall at the regions of Intensity 8 and 9, the tie bars of 2ø6 extending through the full length of the wall and tie meshes composed by spot welding in ø4 distributed short reinforcement plane or ø4 mesh reinforcement steel fabric composed by spot welding, shall be arranged every 500mm along the wall height.

**7.3.8 The staircase also shall meet the following requirements:**

**1 For the staircase wall of the top storey, the tie bars of 2ø6 extending through the full length of the wall and tie meshes composed by spot welding in ø4 distributed short reinforcement plane or ø4 mesh reinforcement steel fabric composed by spot welding, shall be arranged every 500mm along the wall height; for the staircase wall of other storey for Intensity 7~9, the reinforced concrete strips with thickness of 60mm and longitudinal reinforcement not less than 2ø10, or the reinforced brick strips with layers not less than 3 layers, reinforcements not less than 2ø6 in each layer, the mortar strength**

**grade not less than M7.5 or the mortar strength grade of the wall on the same storey, shall be arranged on the stair landing or half height of the storey.**

**2 At the staircase or the salient corner of the interior wall for the vestibule, the girder shall be supported on the wall with a supporting length not less than 500mm, and shall also be connected with the ring-beam.**

**3 The precast waist slabs shall be reliably connected with the beam of the landing platform, the precast waist slabs shall not be used for Intensity 8 or 9; the stairs with the cantilevered steps tread from wall or the steps riser interposed the walls shall not be used, and the plain brick railing shall not be adopted.**

**4 For staircase or elevator shaft exceeding the roof level, the constructional column shall be extended to the top and be connected with the top ring-beam, the tie bars of 2ø6 extending through the full length of the wall and tie meshes composed by spot welding in ø4 distributed short reinforcement plane or ø4 mesh reinforcement steel fabric composed by spot welding, shall be arranged every 500mm along the wall height.**

**7.3.9** The trusses of pitch roof shall be reliably connected with ring-beams of top storey, the purlines or roof slabs shall be reliably connected with walls and roof trusses; eaves tiles at the exit and entrance of buildings shall be anchored with roof components. When adopting hard purlin roofs, stepped piers bearing gable walls should be built on top of inner longitudinal walls in the top storey in addition, and constructional columns should be set.

**7.3.10** The plain brick lintels shall not be used at door and window openings; the supporting length of lintel shall not be less than 240mm for Intensity 6~8 and 360mm for Intensity 9.

**7.3.11** For Intensity 6 and 7, the precast balcony shall be reliably connected with the ring-beam and the cast-in-situ sheet strip of the floor-slab ; for Intensity 8 and 9, the precast balcony shall not be used.

**7.3.12** The post-built non-bearing masonry partition wall, flue, air duct and refuse channel shall comply with the relevant requirements of Section 13.3 of this code.

**7.3.13** The foundation (or the pile capping) of the same structural unit should be designed using the same type of foundation. The bottom of foundation shall be buried at the same level; otherwise, foundation ring-beams shall be added and gradually sloped according to the step ratio of 1:2.

**7.3.14** For the multi-storey brick masonry buildings assigned to category C, if the transverse walls are fewer and the total height and number of stories are close to or reach the limits specified in Table 7.1.2 of this code, the following strengthening measures shall be adopted:

**1** The size of the largest bay in the building shall not be greater than 6.6m..

**2** Within the same structural unit, the number of staggered-axis transversal wall should not exceed 1/3 of the total number of walls; and furthermore, successive staggered-axis walls should not exceed two. The constructional-columns shall be added at all of intersection of the staggered-axis walls and longitudinal walls, and the floors and roof shall be designed using in-situ reinforced concrete slabs..

**3** The width of openings in transverse walls and inner longitudinal walls should not be greater than 1.5m; the width of openings in outer longitudinal walls should not be greater than 2.1m or half of the bay dimension; and furthermore, the opening positions in internal or external walls shall not influence the whole connections of inner and outer longitudinal walls and transverse walls.

**4** The strengthened cast-in-situ reinforced concrete ring-beams shall be arranged at the floor and roof elevation for all the longitudinal and transverse walls: the section height of the strengthened ring-beams should not be less than 150mm, the up and down longitudinal reinforcements respectively shall not be less than 3ø10, the stirrup shall not be less than ø6, the spacing shall not be greater than 300mm.

**5** In the intersections of all transversal and longitudinal walls as well as the middle of the transversal walls, the added constructional columns shall be installed in accordance with following requirements: the spacing of columns in the longitudinal and transverse walls should not be greater than 3.0m; the minimum section dimension should not be less than 240mm×240mm (or 240mm×190mm if the wall thickness is 190mm); the reinforcement should be in accordance with Table 7.3.14.

**Table 7.3.14 Longitudinal Reinforcement and Stirrup Arrangement Requirements of Added Constructional Columns**

| Position | Longitudinal reinforcement | | | Stirrup | | |
|---|---|---|---|---|---|---|
| | Maximum reinforcement ratio (%) | Minimum reinforcement ratio (%) | Minimum diameter (mm) | Range of densified area (mm) | Spacing of densified areas (mm) | Minimum diameter (mm) |
| Corner column | 1.8 | 0.8 | 14 | Total height | 100 | 6 |
| Side column | | | 14 | Upper end 700 and lower end 500 | | |
| middle column | 1.4 | 0.6 | 12 | | | |

**6** The floor slab and roof slab of the same construction unit shall be arranged at the same level.

**7** At the windowsill level of the top and first storey of the building, the in-situ reinforced concrete horizontal strip should be installed along overall length of the transversal walls and longitudinal walls. The cross-sectional height of this strip shall not be less than 60mm, the width shall not be less than the wall thickness, and the diameter of the transverse distribution reinforcement is not less than ø6 and the spacing is not greater than 200mm.

## 7.4 Details of Seismic Design of Multi-storey Concrete Block Buildings

**7.4.1 For multi-storey small block buildings, the reinforced concrete core columns shall be arranged according to those specified in Table 7.4.1. For multi-storey buildings with gallery corridor and one-side corridor, buildings with fewer transverse walls and buildings with very a few transverse walls on each storey, the core columns shall be arranged in accordance with Table 7.4.1 and the corresponding requirements on adding the storey number specified in Item 2, 3 and 4 in Article 7.3.1 of this code, respectively.**

**7.4.2** The core columns of multi-storey small block buildings shall meet the following detail requirements:

**1** The core column section of small block buildings should not be less than 120mm×120mm.

**2** The concrete strength grade of the core column shall not be less than Cb20.

**3** The vertical dowel-bar of the core column shall penetrate the wall and be connected with the ring-beam; generally, the dowel-bar shall not be less than 1ø12; for the buildings with number of stories more than 5 for Intensity 6 and 7, more than 4 for Intensity 8 or located at the region of Intensity 9, the dowel-bar shall not be less than 1ø14.

**Table 7.4.1 Core Column Arrangement Requirements of Multi-storey Small Block Buildings**

<table>
<tr><th colspan="4">number of building stories</th><th rowspan="2">Arranged position</th><th rowspan="2">Arranged quantity</th></tr>
<tr><th>Intensity 6</th><th>Intensity 7</th><th>Intensity 8</th><th>Intensity 9</th></tr>
<tr><td>4 and 5</td><td>3 and 4</td><td>2 and 3</td><td></td><td>Corners of external walls, four corners of staircase and elevator rooms, corresponding walls at up and down ends at inclined ladders of staircases;<br>Joints of internal and external walls in big rooms;<br>Joints of transverse walls and outer longitudinal walls at split-storey positions;<br>Joints of every 12m or unit transverse walls and exterior longitudinal walls</td><td rowspan="2">Full-grouting 3 holes at corners of external walls;<br>Full-grouting 4 holes at joints of internal and external walls;<br>Full-grouting 2 holes at corresponding walls at up and down ends at inclined ladders of staircases</td></tr>
<tr><td>6</td><td>5</td><td>4</td><td></td><td>As Above;<br>Joints of transverse walls (axes) and exterior longitudinal walls in separate rooms</td></tr>
<tr><td>7</td><td>6</td><td>5</td><td>2</td><td>As above;<br>Joints of each internal wall (axes) and exterior longitudinal walls;<br>Joints of inner longitudinal walls and transverse walls (axes) as well as both sides of openings</td><td>Full-grouting 5 holes at corners of external walls;<br>Full-grouting 4 holes at joints of internal and external walls;<br>Full-grouting 4~5 holes at joints of internal walls;<br>Respectively full-grouting 1 hole at both sides of openings</td></tr>
<tr><td></td><td>7</td><td>≥6</td><td>≥3</td><td>As Above;<br>The inner core column spacing of the transverse wall is no greater than 2m</td><td>Full-grouting 7 holes at corners of external walls;<br>Full-grouting 5 holes at joints of internal and external walls;<br>Full-grouting 4~5 holes at joints of internal walls;<br>Respectively full-grouting 1 hole at both sides of openings</td></tr>
</table>

**Note: At positions such as corners of external walls, joints of internal and external walls and four corners of staircase and elevator rooms, reinforced concrete constructional columns shall be permitted to be used to replace a part of core columns.**

**4** The core column shall extend into 500mm of the outdoor subsurface or be connected with the foundation ring-beam whose buried depth is less than 500mm.

**5** The core column arranged for improving the wall seismic shear bearing capacity should be evenly arranged in the wall, the maximum clear distance should not be greater than

2.0m.

**6** At the joints of walls or connections of core columns and walls of multi-storey small block buildings, the tie bar meshes throughout the horizontal full length of wall shall be arranged along the wall height with spacing not greater than 600mm. The meshes may be made by spot welding with 4mm-diameter steel bars. Within the 1/3 stories of bottom portion for Intensity 6 and 7, 1/2 stories of bottom portion for Intensity 8, and all stories for Intensity 9, the spacing of the above-mentioned meshes along the wall height shall be not greater than 400mm.

**7.4.3** The reinforced concrete constructional columns used to replace core columns in small block buildings shall meet the following detail requirements:

**1** The constructional column section should not be less than 190mm×190mm, the longitudinal reinforcement should adopt 4ø12; the stirrup spacing should not be greater than 250mm and the stirrups shall be properly densified at the upper and lower ends of the constructional column; as for the buildings with number of stories more than 5 for Intensity 6 and 7, more than 4 for Intensity 8 or located at the region of Intensity 9, the longitudinal reinforcements of the constructional column should adopt 4ø14; the stirrup spacing shall not be greater than 200mm; the section and reinforcement of the constructional columns at corners of external walls shall be increased properly.

**2** The connection of the constructional-column and the adjacent block walls shall be built into horse-toothed joints; masonry block holes adjacent to constructional columns, should be filled for Intensity 6, shall be filled for Intensity 7, shall be filled and inserted bars for Intensity 8 and 9. The welded tie bar meshes composed by spot welding with ø4 steel bars shall be arranged every 600mm along the wall height among constructional columns and block walls and shall be arranged along the horizontal full length of walls. Within the 1/3 stories of bottom portion for Intensity 6 and 7, 1/2 stories of bottom portion for Intensity 8, and all stories for Intensity 9, the spacing of the above-mentioned meshes along the wall height shall be not greater than 400mm.

**3** At the joints of constructional columns and ring-beams, the longitudinal reinforcements of constructional columns shall be drilled through from the inside of longitudinal reinforcements of ring-beams to guarantee longitudinal reinforcements of constructional columns through up and down.

**4** The constructional column may be designed without individual foundation, but it shall extend 500mm into the outdoor subsurface or be connected with the foundation ring-beam whose buried depth is less than 500mm.

**7.4.4 The arranged position of cast-in-situ reinforced concrete ring-beams of multi-storey small block buildings shall be implemented according to the ring-beam requirements of multi- storey brick masonry buildings specified in Article 7.3.3 of this code, the ring-beam width shall not be less than 190mm, the reinforcement shall not be less than 4ø12, and the stirrup spacing shall not be greater than 200mm.**

**7.4.5** For the multi-storey small block buildings with number of stories exceeding 5, 4 and 3 for Intensity 6, 7 and 8, respectively, or located at regions of Intensity 9, the full length horizontal cast-in-situ reinforced concrete strip shall be arranged along longitudinal and transverse walls at the windowsill elevation of the ground floor and top storey; thereof the section height shall be not less than 60mm, the longitudinal reinforcement shall be not less than 2ø10 and the distributed tie bar shall be existed; the concrete strength grade shall not be less than C20.

The formwork of the horizontal cast-in-situ concrete strip may be replaced by groove shape block, but the longitudinal reinforcement and tie bar shall be not changed.

**7.4.6** For the multi-storey small block masonry buildings assigned to category C, if the transverse walls are fewer and the total height and number of stories are close to or reach the limits specified in Table 7.1.2 of this code, the relevant requirements in Article 7.3.14 of this code shall be satisfied; where the constructional column in the middle of the wall may be replaced by core column, and the quantity of pouring hole of core column shall not be less than 2, the diameter of the dowel-bar reinforcement into each hole shall not be less than 18mm

**7.4.7** Other details of seismic design of small block buildings also shall meet the relevant requirements specified from Article 7.3.5 to Article 7.3.13 of this code. Hereinto, the spacing of the tie bar meshes of walls shall meet the corresponding requirements of this section, and shall be taken as 600mm and 400mm, respectively.

## 7.5 Details of Seismic Design of Multi-storey Masonry Buildings with RC Frames and Seismic-Walls on Ground Floors

**7.5.1** The reinforced concrete constructional columns or core columns shall be arranged at the walls of the upper portion of masonry buildings with RC frames and seismic walls on ground floors, and shall meet the following requirements:

**1** The arranged positions of reinforced concrete constructional columns and core columns shall be determined in the basis of the total storey number of the building according to the requirements of Article 7.3.1 and Article 7.4.1 of this code, respectively.

**2** Besides the requirements of Article 7.3.2, 7.4.2 and 7.4.3 of this code, the details of the constructional columns and core columns shall also comply with the following requirements:

- **1**) The constructional column section in brick masonry walls should not be less than 240mm×240mm (or 240mm×190mm if the wall thickness is 190mm);
- **2**) The longitudinal reinforcement of constructional columns should not be less than 4ø14, the stirrup spacing should not be greater than 200mm; the dowel-bar reinforcement in each hole of core columns shall not be less than 1ø14, ø4 welded steel fabric meshes shall be arranged every 400mm along wall heights among core columns.

**3** Constructional columns and core columns shall be connected with ring-beams at each storey, or reliably pulled and tied with cast-in-situ floor-slabs.

**7.5.2** The details of the walls of the transitional storey shall be in accordance with the following requirements:

**1** The center line of the upper masonry wall should coincide with that of the frame beam or the seismic wall on the ground ; the constructional column or core column should penetrate frame column up and down.

**2** For transitional storey, constructional columns or core columns shall be arranged on positions corresponding to the frame columns, concrete walls or constructional columns of confined masonry walls on the ground floor; the spacing of the constructional columns in walls should not be greater than the storey height; the core columns shall be arranged according to the requirements of Table 7.4.1 of this code and the maximum spacing should not be greater than 1m.

**3** Longitudinal reinforcements of constructional columns in transitional storey should be not less than 4ø16 for Intensity 6 and 7, and not less than 4ø18 for Intensity 8. Longitudinal reinforcements of core columns in transitional storey should be not less than 1ø16 one hole for Intensity 6 and 7, and not less than 1ø18 one hole for Intensity 8. Generally, the longitudinal reinforcements shall be anchored into the lower frame columns or concrete walls; when longitudinal reinforcements are anchored into bressummers, the relevant positions of bressummers shall be strengthened.

**4** At the windowsill elevation of the masonry wall in transitional storey, the horizontal cast-in-situ reinforced concrete strips along the full length of longitudinal and transverse walls shall be arranged; the section height of the strip shall be not less than 60mm, and the width shall be not less than the wall thickness. The longitudinal reinforcement of the strip shall be not less than 2ø10, and the diameter of transverse distribution reinforcement shall be not less than 6mm and the spacing of the transverse distribution reinforcement shall be not greater than 200mm. Furthermore, for the brick masonry wall among adjacent constructional columns, the horizontal reinforcement 2ø6 along full length and the tie meshes composed by spot welding in ø4 distributed short reinforcement plane or ø4 mesh reinforcement steel fabric composed by spot welding, shall be arranged every 360mm along the wall height, and shall be anchored into constructional columns; for small block masonry walls among core columns, the ø4 horizontal mesh reinforcement steel fabric composed by spot welding along full length shall be arranged every 400mm along the wall height.

**5** For the walls of the transitional storey, the constructional columns with the section area no less than 120mm×240mm (or 120mm×190mm if the wall thickness is 190mm) or the single-pore core columns should be arranged at both sides of the openings with width not less than 1.2m for door openings and 2.1m for window openings.

**6** If a masonry seismic wall in transitional storey are not aligned with the bottom frame beams or walls, a transfer spandrel girder shall be arranged in bottom frame, and much higher strengthening measures than that of Item 4 of this article shall be taken for brick walls or block walls in transitional storey.

**7.5.3** For the reinforced concrete walls used as the bottom seismic walls of the masonry buildings with RC frames and seismic walls on ground floors, the section and details shall meet the following requirements:

**1** In the perimeter of the wall panel, a boundary frame formed by side beams (or hidden beams) and end columns shall be installed. The cross section width of the side beams should not be less than 1.5 times of the wall panel thickness, the cross-sectional height should not be less than 2.5 times of the wall panel thickness. The cross-sectional height of the end column should not be less than 2 times of the wall panel thickness.

**2** The thickness of the seismic-wall panel shall not be less than 160mm, or not less than 1/20 of the clear height of the wall panel. The seismic-wall should be installed openings to form several short wall-segments, and the height-width ratio of each wall-segment shall not be less than 2.

**3** The steel ratio for both vertical and horizontal distributed reinforcements of the seismic-wall shall not be less than 0.25%, which shall be arranged in two layers. The spacing of tie bars for two rows shall not be greater than 600 mm, and the diameter of the tie bar shall not be less than 6 mm.

**4** The boundary elements of the seismic-wall may be installed according to the requirements for general portions in Section 6.4 of this code.

**7.5.4** For the confined brick masonry walls used as the bottom seismic-walls of the brick buildings with RC frames and seismic walls on the ground floor for Intensity 6, the details shall be in accordance with the following requirements:

**1** The brick wall thickness shall not be less than 240mm, the masonry mortar strength grade shall not be less than M10 and the frames shall be casted after the masonry wall built.

**2** The tie meshes and composed by 2ø8 horizontal reinforcement and ø4 distributed short reinforcement spot welded in plane, shall be arranged every 300mm along frame columns and horizontal full length of brick walls; the reinforced concrete horizontal tie beams connected with frame columns also shall be arranged on the half height of the wall.

**3** The reinforced concrete constructional columns shall be added inside the walls with length greater than 4m or at both sides of openings.

**7.5.5** For the confined small block walls used as the bottom seismic-walls of the concrete block buildings with RC frames and seismic walls on the ground floor for Intensity 6, the details shall be in accordance with the following requirements:

**1** The wall thickness shall not be less than 190mm, the masonry mortar strength grade shall not be less than Mb10 and the frames shall be casted after the masonry wall built.

**2** The tie meshes and composed by 2ø8 horizontal reinforcement and ø4 distributed short reinforcement spot welded in plane, shall be arranged every 400mm along frame columns and horizontal full length of brick walls; the reinforced concrete horizontal tie beams connected with frame columns also shall be arranged on the half height of the wall; the tie beam section shall not be less than 190mm× 190mm, the longitudinal reinforcement shall not be less than 4ø12; the stirrup diameter shall not be less than ø6 and the spacing shall not be greater than 200mm.

**3** Core columns shall be arranged on both sides of door or window openings on walls; core columns shall be added in walls with length greater than 4m, and the core column shall meet the relevant requirements of Article 7.4.2 of this code; reinforced concrete constructional columns should be used to replace core columns for other positions; and the reinforced concrete constructional columns shall meet the relevant provisions of Article 7.4.3 of this code.

**7.5.6** The frame columns in masonry buildings with RC frames and seismic walls on ground floors shall be in accordance with the following requirements:

**1** The column section shall not be less than 400mm×400mm; the circular column diameter shall not be less than 450mm.

**2** The axial force ratio of the column should not be greater than 0.85 for Intensity 6, 0.75 for Intensity 7 and 0.65 for Intensity 8.

**3** If the strength characteristic value of reinforcement is lower than 400MPa, the minimum total reinforcement ratio of the longitudinal reinforcements shall comply with the following requirements: for middle columns, it shall not be less than 0.9% for Intensity 6 and

7 and 1.1% for Intensity 8; for side columns, corner columns and end columns of concrete seismic wall, it shall not be less than 1.0% for Intensity 6 and 7 and 1.2% for Intensity 8.

**4** The stirrup diameter of columns shall not be less than 8mm for Intensity 6 and 7 10mm for Intensity 8, and the stirrup shall be densified along the total height with the spacing no greater than 100mm.

**5** The design value of the combined bending moment at the top and bottom ends of columns shall be multiplied by an enhancement coefficient of 1.5, 1.25 and 1.15 for Grade 1, 2 and 3,respectively.

**7.5.7 The floor (and roof) of masonry building with RC frames and seismic walls on ground floors shall be in accordance with the following requirements:**

**1 For the transitional storey, the floor shall adopt in-situ reinforced concrete slab. This slab thickness shall not be less than 120mm; the openings in slab shall be cut down or small; when the dimension of the opening exceeds 800mm, boundary beams shall be installed along the perimeters of the opening.**

**2. For other stories, when precast reinforced concrete slabs are adopted, in-situ cast ring-beams shall be installed; only in-situ reinforced concrete slabs are adopted, ring-beams shall be permitted not installed, but the strengthened reinforcements of in-situ slabs shall be arranged along the wall perimeters and shall be reliably connected with corresponding constructional columns.**

**7.5.8 The reinforced concrete spandrel girder of buildings with bottom-frame shall comply with the following requirements:**

**1 The cross sectional width of the girder shall not be less than 300mm, and the cross sectional height shall not be less than 1/10 of the span.**

**2 The diameter of the hoops shall not be less than 8mm, and the spacing of hoops shall not be greater than 200mm. At the girder end within 1.5 times of girder height and not less than 1/5 of the clear span, and the both sides for the opening of the upper wall within 500mm and not less than the girder height, the spacing of hoops shall not be greater than 100mm.**

**3 The spacer bars shall be arranged along the girder height, the amount shall not be less than 2ϕ14, and the spacing shall not be less than 200mm.**

**4 The main reinforcements and spacer bars of the girder shall be developed to the column according to the requirements for tensile bars; besides, the developed length of the upper longitudinal bars of girder in the support shall comply with relevant requirements for reinforced concrete frame-supporting girders.**

**7.5.9** The material strength grade of masonry buildings with RC frames and seismic walls on ground floors shall meet the following requirements:

**1** The concrete strength grade of frame columns, concrete walls and spandrel girder shall not be less than C30.

**2** The strength grade of masonry block materials in transitional stories shall not be less than MU10; the mortar strength grade of brick masonry shall not be less than M10; the masonry mortar strength grade of block masonry shall not be less than Mb10.

**7.5.10** Other details of seismic design for masonry buildings with RC frames and seismic walls on ground floors shall comply with the relevant requirements of Section 7.3, Section 7.4 and Chapter 6 of this code.

# 8 Multi-Storey and Tall Steel Buildings

## 8.1 General

**8.1.1** The structure type and maximum height of steel structure civil buildings to which this chapter is applicable shall be in accordance with those specified in Table 8.1.1. For steel structure that has horizontal irregularities and vertical irregularities simultaneously, the applicable maximum height should be reduced properly.

Note: 1 The seismic design of composite steel brace and concrete frame structures and composite steel frame and concrete tube structures shall meet the requirements of Appendix G of this code;

2 The seismic design of multi-storey steel structure factory buildings shall meet the requirements of Section H.2 in Appendix H of this code.

**Table 8.1.1 Applicable Maximum Height of Steel Structure Buildings (m)**

| Structure type | Intensity 6 and 7 | Intensity 7 | Intensity 8 | | Intensity 9 |
|---|---|---|---|---|---|
| | (0.10*g*) | (0.15*g*) | (0.20*g*) | (0.30*g*) | (0.40*g*) |
| Frame | 110 | 90 | 90 | 70 | 50 |
| Frame-concentrically-braced | 220 | 200 | 180 | 150 | 120 |
| Frame-eccentrically-braced (ductility wall-) | 240 | 220 | 200 | 180 | 160 |
| Tube (frame tube, tube in tube, truss tube and bundled tube) and giant frame | 300 | 280 | 260 | 240 | 180 |

Note: 1 The height of buildings refers to the height from the outdoor ground to the top of main roof slab (excluding partial projection over roof);

2 The professional study and demonstration shall be carried out and effective strengthening measures shall be taken for buildings whose height exceeds that given in the table;

3 The tube in the table excludes the concrete tube.

**8.1.2** The maximum height-width ratio of steel structure civil buildings applicable in this chapter should not exceed those specified in Table 8.1.2.

**Table 8.1.2 Applicable Maximum Height-width Ratio of Steel Structure Civil Buildings**

| Intensity | 6 and 7 | 8 | 9 |
|---|---|---|---|
| Maximum height-width ratio | 6.5 | 6.0 | 5.5 |

Note: For the tower buildings with large base plate at bottom, the height-width ratio may be calculated based on the upper portion of structure from the top of large base plate.

**8.1.3 Steel structure buildings shall be assigned to different seismic grades according to the precautionary category, Intensity and building height, and also shall satisfy the corresponding calculation and details requirements. The seismic grade of Category C buildings shall be determined from Table 8.1.3.**

**Table 8.1.3 Seismic Grade of Steel Buildings**

| **Building height** | **Intensity** | | | |
|---|---|---|---|---|
| | **6** | **7** | **8** | **9** |
| **≤50m** | | **IV** | **III** | **II** |
| **>50m** | **IV** | **III** | **II** | **I** |

**Note: 1 If the height is close to or equivalent to the height boundary, the seismic grade shall be allowed to determine by considering the degree of irregularity, site and base condition of buildings;**

**2 Generally, the seismic grade of components shall be the same as the structure; when the bearing capacity of each component at some position all meet the internal force requirements of 2 times combined earthquake action, the seismic grade of components for Intensity 7~9 shall be allowed to determine by reducing one Intensity.**

**8.1.4** For the steel structure buildings with seismic joints, the joint width shall not be less than 1.5 times of that for corresponding reinforced concrete structure buildings.

**8.1.5** For Steel structure buildings assigned to seismic grade 1 and 2 the energy-dissipated braces or tube structures such as the eccentrically braces, reinforced concrete seismic wall panel with vertical joints, reinforced concrete wall panel with built-in steel brace, and buckling constrained brace, should be used.

When frame structures are used as the resisting-lateral-force system of buildings, single-span frame structural system shall not be used for buildings assigned to Category A or B or the tall buildings assigned to Category C, and should not be used for multi-storey buildings assigned to Category C.

Note: ~~"G~~rade 1, 2, 3 and 4" in this chapter is short for ~~"se~~ismic grade 1, 2, 3 and 4".

**8.1.6** Steel structure buildings adopting frame braced structures shall meet the following requirements:

**1** The arrangement of the braced frame shall be basically symmetrical in two directions, the length-to-width ratio of the floor between two adjacent braced frames should not be greater than 3.

**2** For the steel structures assigned to Grade 3 and 4 with height no greater than 50m, the concentrically-braces should be adopted; the energy-dissipated braces such as the eccentrically braces and buckling constrained braces may also be adopted.

**3** For the concentrically-braced frames, the cross braces should be used, the inverted-V shape braces or single diagonal brace may also be used, but the K-shaped braces should not be used; the brace axis should meet at the intersection point of the beam centroid axis and column centroid axis; the eccentricity that deviate the intersection point shall not exceed the width of the braced member and the additional bending moment produced herefrom shall be counted in. Two groups of diagonal in different directions of inclination shall be arranged simultaneously if the only-tensile single diagonal system is adopted for the central braces, and the projected area difference in horizontal direction shall not be greater than 10% for the cross-section area of the single diagonal in different directions in each group.

**4** For the eccentrically braced frames, at least one end of each brace shall be connected with the frame beam in order to form an energy-dissipating beam-segment that is located from the brace-to-beam joint to beam-to-column connection or between the two brace-to-beam connections with the same span.

**5** When adopting buckling restrained braces, inverted-V shape brace and single diagonal braces of twined arrangement should be adopted and no K-shaped or X-shaped braces should be used. The angle between the brace and the column should be within 35°~55°. When the buckling restrained brace is compressed, determination of the design parameters and performance test as well as selection of the calculation method for the brace used as a kind of energy-dissipating component may be performed according to the relevant requirements.

**8.1.7** For the steel frame-tube structures, a strengthening storey composed by the outrigger trusses or the outrigger trusses and the perimeter trusses may be installed if necessary.

**8.1.8** The floors of steel structure buildings shall meet the following requirements:

**1** The cast-in-situ reinforced concrete composite floor slabs of profiled steel slabs or reinforced concrete floor slabs should be adopted and shall be reliably connected with the steel beams.

**2** For steel structures with height no greater than 50m located at regions of Intensity 6 and 7, the precast-monolithic reinforced concrete floor slab, the precast floor slab or other floor of light type may also be adopted; but the embedded parts of the floor shall be welded with the steel beam, or other details to ensure the integrity of the floor shall be taken.

**3** for the floor of transfer storey or the floor-slab with a large opening, a horizontal brace system may be arranged if necessary.

**8.1.9** The basement arrangement of steel structure buildings shall meet the following requirements:

**1** For the frame-brace( or seismic wall panel) structures with basement arranged, , the vertical braces (seismic wall panel) arranged continuously shall be extended to the foundation; the steel frame columns shall be at least extended to first floor underground and the vertical load on the frame shall be directly transferred to the foundation.

**2** For the steel structure buildings with height greater than 50m, basements shall be arranged. The embedded depth of foundation of the basement should not be less than 1/15 of the total height of buildings for natural subsoil and 1/20 of that for pile foundations.

## 8.2 Essentials in Calculation

**8.2.1** The earthquake action effect of steel structures shall be adjusted according to the requirements of this section; the storey deformation of steel structures shall meet the relevant requirements of Section 5.5 of this code. When seismic checking for member sections and connections, the non-seismic design value of bearing capacity shall divide by the specified seismic adjustment coefficient of bearing capacity of this code; others that are not specified in this chapter shall meet the requirements of the current and relevant design codes and standards.

**8.2.2** The damping ratio of the steel structure used for seismic calculation should meet the following requirements:

**1** Under the frequent earthquake ground motions, the damping ratio may be taken as 0.04 for the steel structures with height not greater than 50m, 0.03 for the steel structures with height greater than 50m and less than 200m; and for the steel structures with height not less than 200m, it should be taken as 0.02.

**2** For the steel frame eccentrically-brace structures, if the seismic overturning moment undertaken by the eccentrically-braced frames is greater than 50% of the total seismic overturning moment of structures, the damping ratio may be correspondingly added 0.005 in the basis of Item 1 of this article.

**3** For structural Elasto-plastic analysis under rare earthquakes, the damping ratio may be taken as 0.05.

**8.2.3** The internal force and deformation analysis for steel structures under earthquake ground motions shall meet the following requirements:

**1** The gravity second-order effect on steel structures shall be counted in according to the requirements of Article 3.6.3 of this code. The hypothetical horizontal force shall be appended on the top of columns for each storey according to the relevant requirements of the current national standard GB 50017 "*Code for Design of Steel Structures*" when carrying out the elasticity analysis of the second-order effect.

**2** Frame beams may be designed according to the internal force on the section of beam ends. For I-shaped section columns, the influence of shear deformation of beam-to-column joint zone on the lateral displacement of structures should be counted in; for box column frames, concentrically- braced frames and steel structures not exceed 50m, the influence of the shear deformation of beam-to-column joint panel zone may be neglected, the storey drift may be analyzed approximately according to the frame axes.

3 For the steel frame-brace structure, the brace may be assumed to the pin-connection at the end, and the calculated seismic shear force of the frame part shall be multiplied by the adjustment factor, in order to make sure that the frame part may be resisted at least of the smaller value between the 25% total seismic shear of structure and 1.8 times of calculated maximum storey shears of frame part.

**4** For the concentrically-braced frame structure, if the axes of diagonal brace deviates the intersection points of beam and column axes within the width of brace member, the structure also may be analyzed as the concentrically-braced frame structure; but the additional bending moment produced wherefrom shall be counted in.

**5** In eccentrically-braced frame structures, the internal force design value of members connected with energy-dissipating beams shall be adjusted according to the following requirements:

**1**) The axial force design value of the brace member shall be taken as the product of the brace axial force corresponding to the shear bearing capacity of the connecting energy-dissipating beam-segment and the amplifying factor, and the amplifying factor shall not be less than 1.4 for Grade 1, 1.3 for Grade 2 or 1.2 for Grade 3;

**2**) The internal force design value of frame beam-segments located at the same span of the energy- dissipating beam-segment shall take the product of the internal force of the frame beam-segments corresponding to the shear bearing capacity of the energy-dissipating beam-segment and an enhancement coefficient, and the enhancement coefficient shall not be less than 1.3 for Grade 1, 1.2 for Grade 2 or 1.1 for Grade 3;

**3**) The internal force design value of frame columns shall be taken as the product of the column internal force corresponding to the shear bearing capacity of the energy-dissipating beam-segment and an enhancement coefficient; and the enhancement coefficient shall not be less than 1.3 for Grade 1, 1.2 for Grade 2 or 1.1 for Grade 3.

**6** The reinforced concrete wall panel with steel braces inside and reinforced concrete wall panel with vertical joints shall be calculated according to the relevant requirements; reinforced concrete wall panel with vertical joints may only bear the shear force produced by the horizontal load but not bearing the vertical load.

**7** The seismic interior force of frame columns supporting the transfer members of the steel structure shall be multiplied by the amplifying factor, this value may be taken as 1.5.

**8.2.4** If the upper flange of steel frame beams is connected with the composite floor slabs by shear resistant connecting elements, the checking of integral stability of beams under seismic action may be omitted.

**8.2.5** The seismic capacity check for joints of steel frames shall meet the following requirements:

**1** Except for one of the following conditions, the plastic bearing capacity of the right and left beam ends and the upper and lower column ends of the joint shall meet the requirements of the following equation:

**1**) The shear bearing capacity of the storey where the column is located is 25% greater than that of the adjacent upper storey;

**2**) The column axial force ratio is not greater than 0.4 or $N_2 \leq \varphi A_c f$ (where, $N_2$ is the design value of composite axial force under 2 times earthquake action);

**3**) Joints connected with brace members.

Beams with uniform cross section

$$\Sigma W_{pc}(f_{yc}-N/A_c) \geq \eta \Sigma W_{pb} f_{yb} \tag{8.2.5-1}$$

Beams with variable cross section of end flange

$$\Sigma W_{pc}(f_{yc}-N/A_c) \geq \Sigma(\eta W_{pb1} f_{yb} + V_{pb} s) \tag{8.2.5-2}$$

Where $W_{pc}$, $W_{pb}$——Respectively the plastic section modulus of columns and beams meeting at joints;

$W_{pb1}$——Plastic section modulus of beams of sections where the plastic hinge of beams is located;

$f_{yc}$, $f_{yb}$——Respectively the steel yield strength of columns and beams;

$N$——Column axial force of seismic combination;

$A_c$——Cross-sectional area of frame columns;

$\varepsilon$——Strong column coefficient, it shall be taken as 1.15 for Grade 1, 1.10 for Grade 2 and 1.05 for Grade 3;

$V_{pb}$——Shear force of beam plastic hinge;

$s$——Distance from the plastic hinge to column surface, the plastic hinge may take the minimum part of flange on variable cross section at beam ends.

**2** The yield bearing capacity of joints zone shall meet the following requirements:

$$\psi(M_{pb1} + M_{pb2})/V_p \leq (4/3) f_{yv} \tag{8.2.5-3}$$

I-shaped section column

$$V_p = h_{b1} h_{c1} t_w \tag{8.2.5-4}$$

Box section column

$$V_p = 1.8 h_{b1} h_{c1} t_w \tag{8.2.5-5}$$

Section column of round tube

$$V_p = (\pi / 2) h_{b1} h_{c1} t_w \tag{8.2.5-6}$$

**3** The joint zone of I-shaped section column and box section column shall be checked and calculated according to the following equation:

$$t_w \geq (h_b + h_c) / 90 \tag{8.2.5-7}$$

$$(M_{b1} + M_{b2}) / V_p \leq (4/3) f_v / \gamma_{RE} \tag{8.2.5-8}$$

Where $M_{pb1}$, $M_{pb2}$——Respectively full plastic bending capacity of two side beams in joints zone;

$V_p$——Volume of joint zone;

$f_v$——Shear strength design value of steels;

$f_{yv}$——Yield shear strength of steels, taken as 0.58 times the yield strength of steels;

$\psi$——Reduction coefficient; it shall be taken as 0.6 for Grade 3 and 4 and 0.7 for Grade 1 and 2;

$h_{b1}$, $h_{c1}$——Respectively the distance among the thickness midpoints of beam flanges and the thickness midpoints of column flanges (or the tube wall on the diameter line of steel tube);

$t_w$——Web thickness of columns in joint zone;

$M_{b1}$, $M_{b2}$——Respectively the bending moment design value of two side beams in joint zone;

$\gamma_{RE}$——Seismic adjustment coefficient of bearing capacity in joint zone, it shall be taken as 0.75.

**8.2.6** The seismic capacity check for concentrically-braced frame components shall meet the following requirements:

**1** The compression bearing capacity of brace diagonals shall be checked according to the following equation:

$$N(\varphi A_{br}) \leq \psi f / \gamma_{RE} \tag{8.2.6-1}$$

$$\psi = 1/(1+0.35\lambda_n) \tag{8.2.6-2}$$

$$\lambda_n = (\lambda / \pi) \sqrt{f_{ay} / E} \tag{8.2.6-3}$$

Where $N$——Axial force design value of brace diagonals;

$A_{br}$——Sectional area of brace diagonals;

$\varphi$——Stability coefficient of axial compression components;

$\psi$——Strength reduction factor when cyclic loading;

$\lambda$, $\lambda_n$——Slenderness ratio of brace diagonals and the regularization slenderness ratio;

$E$——Elasticity modulus of steels with brace diagonals;

$f$, $f_{ay}$——Respectively the steel strength design value and yield strength;

$\gamma_{RE}$——Seismic adjustment coefficient of bearing capacity for brace stability disruption.

**2** The frame beams of inverted-V shaped and V-shaped braces shall keep continuous at the connections of braces; the gravity load and the bearing capacity under the action of unbalanced force during the brace buckling shall be checked and calculated according to beams which the supporting affection is not counted in; the unbalanced force shall be calculated according to 0.3 times the minimum yield bearing capacity of tensioned braces and the maximum buckling bearing capacity of compressed braces. The inverted-V shaped and V-shaped brace may be arranged in turn along the vertical direction or zipper columns may be used, if necessary.

Note: This item may not be implemented for beams of the top storey and rooms with exposed-roofs.

**8.2.7** The seismic capacity check for eccentrically-braced frame components shall meet the following requirements:

**1** The shear bearing capacity of energy-dissipating beams shall meet the following requirements:

When $N \leq 0.15Af$

$$V \leq \varphi V_l / \gamma_{\mathrm{RE}} \tag{8.2.7-1}$$

$V_l = 0.58 A_{\mathrm{w}} f_{\mathrm{ay}}$ or $V_l = 2M_{l\mathrm{p}} / a$, the smaller value shall be taken

$$A_{\mathrm{w}} = (h - 2t_{\mathrm{f}}) t_{\mathrm{w}}$$

$$M_{l\mathrm{p}} = fW_{\mathrm{p}}$$

When $N > 0.15Af$

$$V \leq ø V_{l\mathrm{c}} / \gamma_{\mathrm{RE}} \tag{8.2.7-2}$$

$$V_{l\mathrm{c}} = 0.58 A_{\mathrm{w}} f_{\mathrm{ay}} \sqrt{1 - [N/(Af)]^2}$$

Or $V_{l\mathrm{c}} = 2.4 M_{l\mathrm{p}} [1 - N/(Af)] / a$, the smaller value shall be taken

Where $N$, $V$——Respectively the design values of axial force and shear force of energy-dissipating beams;

$V_l$, $V_{l\mathrm{c}}$——Respectively the shear bearing capacity of energy-dissipating beams without and with the axial force influence included;

$M_{l\mathrm{p}}$——Full plastic bending capacity of energy-dissipating beams;

$A$, $A_{\mathrm{w}}$——Respectively the cross-sectional area of energy-dissipating beams and web plates;

$W_{\mathrm{p}}$——Plastic section modulus of energy-dissipating beams;

$a$, $h$——Respectively the net length and section height of energy-dissipating beams;

$t_{\mathrm{w}}$, $t_{\mathrm{f}}$——Respectively the web thickness and flange thickness of energy-dissipating beams;

$f$, $f_{\mathrm{ay}}$——Compression strength design value and yield strength of steels of energy-dissipating beams;

ø——Coefficient, it may be taken 0.9;

$\gamma_{\mathrm{RE}}$——Seismic adjustment coefficient of bearing capacity of energy-dissipating beams, it shall be taken 0.75.

**2** The connected bearing capacity of brace diagonals and energy-dissipating beams shall not be less than that of braces. The connection of braces and beams shall be designed according to the connection which resists compression and bending if braces need to resist bending moments.

**8.2.8** The connection calculation of lateral-force-resisting components of steel structures shall meet the following requirements:

**1** The bearing capacity design value for the connection of lateral-force-resisting components of steel structures shall not be less than that of connected components; and the connected high-strength bolts shall not glide.

**2** The ultimate bearing capacity for the connection of lateral-force-resisting components of steel structures shall be greater than the yield bearing capacity of the connected components.

**3** The ultimate bearing capacity for the rigid connection of beams and columns shall be checked according to the following equation:

$$M_{u}^{j} \geq \eta_{j} M_{p} \tag{8.2.8-1}$$

$$M_{u}^{j} \geq 1.2(2M_{p}/l_{n}) + V_{Gb} \tag{8.2.8-2}$$

**4** The connection ultimate bearing capacity of braces and frames and the splicing ultimate bearing capacity of beams, columns and braces shall be checked and calculated according to the following equation:

Connection and splicing of braces $$N_{ubr}^{j} \geq \eta_{j} A_{br} f_{v} \tag{8.2.8-3}$$

Splicing of beams $$M_{ub,sp}^{j} \geq \eta_{j} M_{p} \tag{8.2.8-4}$$

Splicing of columns $$M_{ub,sp}^{j} \geq \eta_{j} M_{pc} \tag{8.2.8-5}$$

5 The connection ultimate bearing capacity of column feet and foundations shall be checked and calculated according to the following equation:

$$M_{u,base}^{j} \geq \eta_{j} M_{pc} \tag{8.2.8-6}$$

Where $M_p$, $M_{pc}$——Respectively the plastic bending capacity of beams and that of columns considered the axial force influence;

$V_{Gb}$——Design value of section shear force at beam ends analyzed according to simple beams when beams are under the action of gravity load representative value (the normal value of vertical earthquake action also shall be included for tall buildings for Intensity 9);

$l_n$——Clear span of a beam;

$A_{br}$——Sectional area of brace struts;

$M_{u}^{j}, V_{u}^{j}$——Respectively the ultimate bending and shear bearing capacity of connections;

$N^{j}_{ubr}, M^{j}_{ub,sp}, M^{j}_{uc,sp}$ ——Respectively the ultimate compression (tension) and bending capacity for connection and splicing of braces, splicing of beams and splicing of columns;

$M^{j}_{u,base}$ ——Ultimate bending capacity of the column foot.

$\varepsilon_j$——Connection coefficient, it may be taken according to those specified in Table 8.2.8.

**Table 8.2.8 Connection Coefficient of Seismic Design of Steel Structure**

| Base material designation | Connection of beam and column | | Brace connection and component splicing | | Column foot | |
|---|---|---|---|---|---|---|
| | Welding | Bolted connection | Welding | Bolted connection | | |
| Q235 | 1.40 | 1.45 | 1.25 | 1.30 | Embedded | 1.2 |
| Q345 | 1.30 | 1.35 | 1.20 | 1.25 | Epibolic | 1.2 |
| Q345GJ | 1.25 | 1.30 | 1.15 | 1.20 | Exposed | 1.1 |

Note: 1 The steels with yield strength greater than Q345 are adopted according to the requirements of Q345;

2 The GJ steels with yield strength greater than Q345 GJ are adopted according to the requirements of Q345 GJ;

3 When welding flange and bolting web plate, the connection coefficient shall be taken respectively according to the connection type in the table.

## 8.3 Details for Steel Frame Structures

**8.3.1 The slenderness ratio of frame columns shall be not greater than 60 $\sqrt{235/f_{ay}}$ for Grade 1, 80 $\sqrt{235/f_{ay}}$ for Grade 2, 100 $\sqrt{235/f_{ay}}$ for Grade 3 or 120 $\sqrt{235/f_{ay}}$ for Grade 4.**

**8.3.2** The width-to-thickness ratio of plates of frame beams and columns shall be in accordance with those specified in Table 8.3.2:

**Table 8.3.2 Width-to-thickness Ratio Limit of Plate of Frame Beam and Column**

| Plate name | | Grade 1 | Grade 2 | Grade 3 | Grade 4 |
|---|---|---|---|---|---|
| Column | Overhung part of I-shaped section flange | 10 | 11 | 12 | 13 |
| | Web plate of I-shaped section | 43 | 45 | 48 | 52 |
| | Box section wall plate | 33 | 36 | 38 | 40 |
| Beam | Overhung part of I-shaped section and box section flange | 9 | 9 | 10 | 11 |
| | Part of box section flange between two web plates | 30 | 30 | 32 | 36 |
| | Web plate of I-shaped section and box section | $72-120N_b/(Af)$ ≤60 | $72-100N_b/(Af)$ ≤65 | $80-110N_b/(Af)$ ≤70 | $85-120N_b/(Af)$ ≤75 |

Note: 1 The values listed in the table are applicable to steel Q235; they shall be multiplied $\sqrt{235/f_{ay}}$ if steels of other designations are used.

2 $N_b/(Af)$ is the axial compression ratio of the beam.

**8.3.3** The lateral braces of beam and column components shall meet the following requirements:

**1** The compression flanges of beam and column components shall be arranged with lateral braces as required.

**2** For the section where the plastic hinges will be occurred on the beam and column components, lateral braces shall be arranged at the upper and lower flanges

**3** The slenderness ratio of components between the adjacent two lateral braced points shall meet the relevant requirements of the current national standard GB 50017 “*Code for Design of Steel Structures*”.

**8.3.4** The details of connection of beams and columns shall meet the following requirements:

**1** The connection of beams and columns should adopt the column-penetration type.

**2** When a column is connected to beams by rigid connection in two orthogonal directions, the box section should be adopted, and partition plate shall be arranged at the position corresponding to the connection of beam flanges; when the partition plate is connected to the columns using slag welding, the thickness of column wall plate should not be less than 16mm, I-shaped columns may be adopted or penetrating partition plates may be used if the column wall plate thickness is less than 16mm. When a column is connected to beams by rigid connection in only one direction, I-shaped columns should be adopted, and the column web plates shall be placed within the plane of the rigid-connection frame.

**3** The rigid connection of beams with I-shaped columns (around strong axis) and box columns shall meet the following requirements (Figure 8.3.4-1):

**1**) The full penetration groove weld shall be adopted between the beam flange and the column flange; the V-shaped cut impact ductility of welded joints shall be tested for Grade 1 and 2, the Charpy impact ductility is no less than 27J at –20℃;

**2**) The horizontal ribbed stiffeners (partition plates)shall be arranged at corresponding positions of columns at beam flanges, the thickness of ribbed stiffeners (partition plates) shall not be less than that of beam flanges; the strength of ribbed stiffeners (partition plates) shall be the same as that of beam flanges;

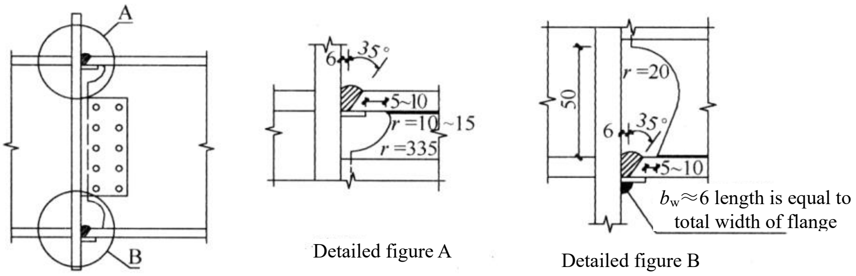



**Figure 8.3.4-1 On-site Connection of Frame Beam and Column**

**3**) Connections of high-strength bolts of friction-type and column connection plates should be adopted for web plates of beams (gas shielded welding also may be used to weld if plates are qualified after the technological test and the field welding quality can be guaranteed); welding holes shall be arranged at angles of web plates, the hole shape shall completely separate full penetration groove weld joints between web plate ends and flanges of beams and columns;

4) The welding of web connection plates and columns, the twin fillet welding seam shall be adopted if the plate thickness is not greater than 16mm, the effective throat thickness shall meet the requirements of equal strength and shall not less than 5mm; the K-shaped groove butt weld shall be adopted if the plate thickness is greater than 16mm. The gas shielded welding should be adopted for the above-mentioned weld, and the contour welding shall be adopted for slab ends;

5) For Grade 1 and 2, the end enlarged connection that can shift the plastic hinge from the beam end, beam end combined with cover plate or bone connection should be adopted.

**4** When the rigid connection of cantilever beams and columns are adopted for frame beams (Figure 8.3.4-2), the all welded connection shall be adopted for cantilever beams and columns, here the shape of welding holes on upper and lower flanges should be the same; the flanges welding with web bolted connections or all bolted connections may be adopted for field splice of beams.

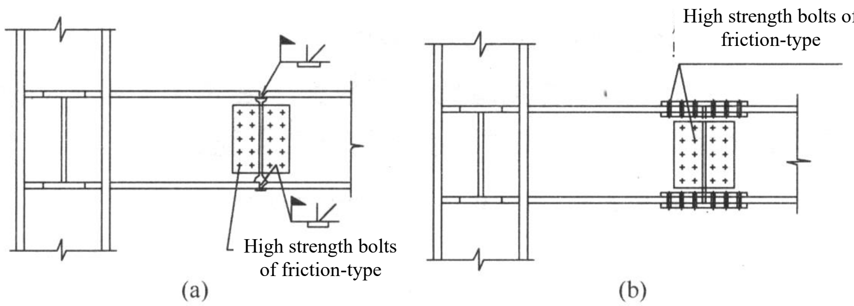



**Figure 8.3.4-2 Connection of Frame Column and Cantilever Section of Beam**

**5** The partition plate arranged at the corresponding position of the beam flange for the box column shall be connected with wall panels by adopting the full penetration butt weld. The full penetration butt weld connection shall be adopted for the horizontal ribbed stiffener of the I-shaped column and the column flange; the fillet weld connection may be adopted for the horizontal ribbed stiffener of the I-shaped column and the web plate.

**8.3.5** If the web thickness of the joint zone doesn't meet those specified in Item 2 and 3 of Article 8.2.5 of this code, measures such as thickening the column web plate or sticking the weld repair stiffening plate shall be taken. The thickness of the stiffening plate and its welded joints shall be designed according to the requirements of delivering the shear force shared by the stiffening plate.

**8.3.6 As for the rigid connection of beams and columns, within the range of 500mm up and down the beam flange, the full penetration groove weld shall be adopted for the attachment weld between the column flange and the column web plate or the box column wallboards.**

**8.3.7** The splice joint of frame column shall be located at the position with a distance to the upside frame beam by the smaller one of 1.3m and the half the clear height.

The full penetration weld shall be adopted for butt joint of upper and lower columns; within the range of respective 100mm upper and lower of splicing joints of columns, the full penetration weld shall be adopted for welds among I-shaped column flanges and web plates as well as wallboards of box column corners.

**8.3.8** The embedded type of rigid connection column foot of steel structures should be adopted, the Epibolic type may also be adopted; the exposed type may also be used if the height of the building is less than 50m for Intensity 6 and 7.

## 8.4 Details for Steel Frame-concentrically-braced Structures

**8.4.1 The limits for slenderness ratio of member bars and for width-to-thickness ratio of plates of the concentrically braces shall meet the following requirements:**

**1 When the braced member bars is designed according to compression bars, the slenderness ratio of it shall not be greater than 120** $\sqrt{235/f_{ay}}$ **; the design of tie rods shall not be adopted for concentrically supports for Grade 1, 2 and 3; the slenderness ratio shall not be greater than 180 when the design of tie rods is adopted for Grade 4.**

**2 The plate width-to-thickness ratio of brace member bars shall not be greater than the specified limit in Table 8.4.1. The strength and stability of gusset plates shall be noticed when connecting by adopting gusset plates.**

**Table 8.4.1 Width-to-thickness Ratio Limit of Concentrically-braced Plate for Steel Structure**

| Plate name | Grade 1 | Grade 2 | Grade 3 | Grade 4 |
|---|---|---|---|---|
| Overhung part of flange | 8 | 9 | 10 | 13 |
| Web plate of I-shaped section | 25 | 26 | 27 | 33 |
| Box section wall panel | 18 | 20 | 25 | 30 |
| Wall ratio and outside diameter of round tube | 38 | 40 | 40 | 42 |

**Note: The values listed are applicable to steel Q235, they shall be multiplied** $\sqrt{235/f_{ay}}$ **when other designations of steels are adopted; and for round tubes, they shall be multiplied** $235/f_{ay}$**.**

**8.4.2** The details of concentrically-braced joints shall meet the following requirements:

**1** The brace should be made by adopting H-shaped steels for Grade 1, 2 and 3; rigid connection may be used for the both ends and frames; and the connection part of the beam and column with the brace shall be installed with stiffener ribs; when the welded I-shaped section brace is adopted for Grade 1 and 2, the full penetration continuous weld should be adopted to connect the flanges and web plate.

**2** At the location of connection between the brace and the frame, the diagonal ends should be made into arc shape..

**3** At the intersecting place of beam with the inverted-V and V-shaped braces, lateral braces shall be installed.; the lateral slenderness ratio ($\lambda_y$) and supporting force between the above-mentioned supporting point and that of the beam end shall meet the requirements about the plastic design specified in the current national standard GB 50017 "*Code for Design of Steel Structures*".

**4** If the gusset plates are adopted for connections of braces and frames, they shall meet the requirements about that gusset plates have angles no less than 30° on each side of connecting member bars, specified in the current national standard GB 50017 "*Code for Design of Steel Structures*"; the distance from the brace end to the nearest built-in point of the gusset plate (the end of gusset plate and the attachment weld of frame component) along the axial direction of the brace member bar shall not be less than 2 times thickness of the gusset plate.

**8.4.3** For the frame part of frame-concentrically-braced structures, when the building height is not greater than 100m and the seismic shear force on frame parts distributed by calculation is not greater than 25% of the total seismic shear force on the structure bottom, the details of seismic design for Grade 1, 2 and 3 may be adopted according to the corresponding requirements that reduce one grade according to frame structures. Other details of seismic design shall meet the requirements of details of seismic design for frame structures specified in Section 8.3 of this code.

## 8.5 Details for Steel Frame-eccentrically-braced Structures

**8.5.1 The steel yield strength of energy-dissipating beam-segment on eccentrically-braced frames shall not be greater than 345MPa. For the energy-dissipating beam-segment and other beam segment at the same span, the width-to-thickness ratio of plates shall not be greater than the limits specified in Table 8.5.1.**

**Table 8.5.1 Limits for Width-to-thickness Ratio of Plates of the Eccentrically-braced-frame-beams**

| Plate name | | Width-to-thickness ratio limit |
|---|---|---|
| Overhung part of flange | | 8 |
| Web plate | Where $N/(Af)\leq 0.14$ | $90\ [1-1.65\ N/(Af)]$ |
| | Where $N/(Af)>0.14$ | $33\ [2.3-N/(Af)]$ |

**Note: The values listed are applicable to steel Q235, they shall be multiplied $\sqrt{235/f_{ay}}$ when materials are other designations of steels, $N/(Af)$ is the axial compression ratio of the beam.**

**8.5.2** The slenderness ratio of brace member bars on eccentrically-braced frames shall not be greater than 120, the width-to-thickness ratio of plates of brace member bars shall not exceed the width ratio limit of the elastic design on the axial compression components specified in the current national standard GB 50017 "*Code for Design of Steel Structures*".

**8.5.3** The details of energy-dissipating beam-segment shall meet the following requirements:

**1** When $N>0.16Af$, the length of energy-dissipating beam-segment shall meet the following requirements:

When $\rho(A_w/A)<0.3$

$$a<1.6M_{lp}/V_l \tag{8.5.3-1}$$

When $\rho(A_w/A)\geq 0.3$

$$a\leq[1.15-0.5\rho(A_w/A)1.6M_{lp}/V_l] \tag{8.5.3-2}$$

$$\rho=N/V \tag{8.5.3-3}$$

Where $a$——Length of energy-dissipating beam-segment;

$\rho$——Ratio of design value of axial force and shear force on energy-dissipating beam-segment.

**2** The web plate of energy-dissipating beam-segment shall not be stuck by welding stiffening plate and shall not be punched holes.

**3** At the connection of the energy-dissipating beam-segment and the brace, stiffening ribs shall be installed on the two sides of the web, the depth of the stiffening ribs shall be the same as the that of the beam. The width of the stiffening ribs on one side shall not be smaller than ($b_f/2-t_w$), the thickness shall not be less than the bigger value of $0.75t_w$ and 10mm.

**4** On the web of the energy-dissipating beam-segment, the intermediate stiffening ribs shall be installed according to the following requirements:

**1**) When $a \leq 1.6M_{lp}/V_l$, the spacing of the stiffening ribs shall not be greater than ($30t_w-h/5$);

**2**) When $2.6M_{lp}/V_l < a \leq 5M_{lp}/V_l$, the intermediate stiffening ribs shall be installed at $1.5b_f$ from the end of the energy-dissipating beam-segment, and the spacing of the intermediate stiffening ribs shall not be greater than ($52t_w-h/5$);

**3**) When $1.6M_{lp}/V_l < a \leq 2.6M_{lp}/V_l$, the spacing of the intermediate stiffening ribs should be linearly-inserted between the above-mentioned two;

**4**) When $a > 5M_{lp}/V_l$, the intermediate stiffening ribs may not be installed;

**5**) The intermediate stiffening ribs shall be the same depth as the web of the energy- dissipating beam-segment, when the depth of the energy-dissipating beam-segment is not greater than 640mm, the stiffening ribs may be installed at only one-sided of web; when the depth of the energy-dissipating beam-segment is greater than 640mm, stiffening ribs shall be installed at the both sides of the web, the width of the stiffening rib installing at only one-side shall not be less than ($b_f/2-t_w$), the thickness shall not be less than $t_w$ or 10mm.

**8.5.4** The connection of energy-dissipating beam-segments with columns shall meet the following requirements:

**1** When the energy-dissipating beam-segment connects with the column, its length shall not be greater than $1.6M_{lp}/V_l$, and the requirements of relevant standards shall be met.

**2** The full penetration butt weld of groove shall be adopted for the connection of energy- dissipating beam-segment flanges and column flanges; the fillet weld (gas shielded welding) shall be adopted for the connection between web plates of energy-dissipating beam-segment and column connection plates; the bearing capacity of the fillet weld shall not be less than the bearing capacity acted simultaneously with the axial force, shear force and the bending moment of web plates of energy-dissipated beams.

**3** When energy-dissipating beam-segments are connecting with column web plates, the full penetration butt weld of groove shall be adopted for the connection of energy-dissipating beam-segment flanges and horizontal stiffening plates; the fillet weld (gas shielded welding) shall be adopted for the connection of web plates and column connection plates; the bearing capacity of the fillet weld shall not be less than the bearing capacity acted simultaneously with the axial force, shear force and bending moment of web plates of energy-dissipating beam-segments.

**8.5.5** Lateral braces shall be installed on the upper and lower flange for ends of the energy-dissipating beam-segment; the axial force design value of braces shall not be less than 6% of the design value of the axial bearing capacity for flanges of energy-dissipating beam-segments, that is $0.06b_f t_f f$.

**8.5.6** The lateral brace shall be arranged at upper and lower flanges of non-energy-dissipating beam-segments for eccentrically-braced-frame beams, the axial force design value of braces shall not be less than 2% of the design value of the axial bearing capacity for beam flanges, that is 0.02 $b_f t_f f$.

**8.5.7** For the frame part of frame-eccentrically-braced structures, if the building height is not greater than 100m and the earthquake action on frame parts distributed through calculation is not greater than 25% of the total seismic shear force on the structure bottom, the details of seismic design for Grade 1, 2 and 3 may be adopted according to the corresponding requirements that are reduced by one grade according to frame structures. Other details of seismic design shall meet the requirements on details of seismic design of the frame structures specified in Section 8.3 of this code.

# 9 Single-storey Factory Buildings

## 9.1 Single-storey Factory Buildings with Reinforced Concrete Columns

### (I) General

**9.1.1** This section is mainly applicable to the fabricated single-storey factory buildings with RC columns, and the structural layout shall be in accordance with the following requirements:

**1** Height and length of each span in multi-span factory building should be equal. The structural layout with one-end opening should not be adopted for the high-low span factory building .

**2** Auxiliary buildings of a factory building should not be arranged at the corners or close to the seismic joints.

**3** The seismic joints should be arranged in the factory buildings with an irregular configuration or with auxiliary houses and structures. The clear width of the seismic joint may be taken as 100~150mm for the junction of the longitudinal and the transversal factory units, the lager bay factory and the no-brace factory, and 50~90mm for others.

**4** For the transition span between two main buildings, at least, one seismic joint shall be arranged at one end to separate from the main building.

**5** The steel ladder of crane within the factory building shall not be arranged close to the seismic joint. The steel ladder of crane at each span of multi-span factory building should not be arranged near the same transverse axial line.

**6** The operation platform and rigid workshop should be separated from the mail structure of the factory building.

**7** Different structural systems shall not be used in the same structural unit of factory building. At the end of the factory building, not the gable wall but the roof truss shall be installed to bear load. The compounded load-bearing system composing of transverse masonry wall and bent shall be avoided.

**8** The column space in factory building should be equal, and the lateral stiffness of longitudinal row of the columns should be even. When one column is removed from its position, special seismic measures shall be taken.

Note: The seismic design for concrete frame-bent structure factory building shall be in accordance with the requirements of Section H.1 in Appendix H of this code.

**9.1.2** The installation of the skylight truss shall comply with the following requirements:

**1** The skylight should be designed as the wind-sheltered type skylight with small part outstanding from the roof, and the basin type skylight should be adopted if possible or for Intensity 9.

**2** For the convex-type skylight, the steel skylight truss should be adopted, and the reinforced concrete skylight truss with rectangular section elements may be adopted for Intensity 6~8.

**3** The first skylight truss should not be installed on the first bay of the structural unit of factory building. And for Intensity 8 and 9, the first skylight truss should be installed on the third bay from the end to middle of factory buildings.

**4** The roof and perimeter walls of skylight should be made of lightweight materials, and the end perimeter wall shall not be used to replace the end skylight truss.

**9.1.3** The installation of the roof truss for factory buildings shall comply with the following requirements:

**1** Factory buildings should adopt steel truss or pre-stressed concrete and reinforced concrete truss with lower gravity center.

**2** When the span is not greater than 15m, reinforced concrete roof girders may be used.

**3** When the span is greater than 24m or for Intensity 8 with site class III and IV or Intensity 9, the steel roof truss shall be used in priority.

**4** When the column space is 12m, pre-stressed concrete spandrel truss (or girder) may be used. For steel truss, the steel spandrel truss (or girder) may also be used.

**5** The roof truss with convex-type skylight shall not adopt pre-stress concrete or reinforcement concrete opening-web truss.

**6** For Intensity 8 (0.30*g*) and Intensity 9, the factory buildings with span greater than 24m should not adopt large-scale roof slab.

**9.1.4** Installation of columns in factory building shall comply with the following requirements:

**1** For Intensity 8 and 9, the rectangular, I-shaped section columns or double limb columns with inclined web-bar should be adopted, and the thin-web I-shape columns, the opening web I-shape columns, the precast web I-shape columns and the tube columns should not be adopted.

**2** Rectangular sections should be used from the bottom of the column to the scope of 500mm above the ground floor level, or the upper column of stepped columns.

**9.1.5** The arrangement and details for the enclosure wall and the parapet wall of the factory building shall comply with relevant provisions of non-structural members in Section 13.3 of this code.

### (II) Essentials in Calculation

**9.1.6** For the single-storey factory buildings that adopt the seismic details in accordance with provisions of this code and satisfy one of the following conditions, the seismic analysis of traversal and longitudinal directions need not be carried out:

**1** The factory buildings(expect zigzag-type factory building) assigned to single-span or multi-span with equal height that the column height was less than or equal 10m, gable walls were installed at both sides of the structure unit, and the seismic precautionary intensity was Intensity 7 with the site class I and II.

**2** The open-air crane trestle for Intensity 7 and Intensity 8 (0.20*g*) with site class I and II.

**9.1.7** The following methods shall be used for seismic calculation in the traversal direction of a factory building:

**1** For the factory building with reinforced concrete roof, the traverse elastic deformation of roof, the multi-mass spacious structure analysis model considering the affection of transversal planar elastic deformation of the roof should be used in seismic calculation generality. When the conditions in Appendix J of this code were satisfied, the planar bent analysis model may be used, but the corresponding modification factors for seismic shear and bending moment of the bent as set forth in Appendix J in this code shall be used.

**2** For the factory buildings with lightweight roofs and the column bays are equal, the planar bent analysis model may be used.

Note: Lightweight roof is refers to a roof with purlins that made of fluted steel sheets, or corrugated iron sheets, or asbestos sheets.

**9.1.8** The following methods shall be used for seismic calculation in longitudinal direction of a factory building:

**1** For the factory buildings with concrete roof or lightweight roof with considerably complete bracing system, the following methods may be used:

1) In generality, it should be analyzed as multi-mass spacious structures, considering the affection of longitudinal planar elastic deformation of the roof, effective stiffness of enclosure walls and partition walls, as well as torsion due to non-symmetry.

2) For factory buildings with single-span or multi-spans with equal height that column height less than or equal 15m and the average span less than 30m, it should be analyzed by using the modification rigidity method as specified in Section K.1 of Appendix K of this code.

**2** For single-span factory buildings and multi-span factory buildings with lightweight roof that longitudinal wall arrangement symmetry, it may be analyzed by using the longitudinal bent consisting of each column rows separately.

**9.1.9** The following methods may be used for seismic calculation in the traversal direction of roof truss of convex-type skylight:

**1** The base shear method may be used for seismic calculation of reinforced concrete or steel three-hinged skylight truss with struts. When the span of the skylight truss is greater than 9m or for Intensity 9, the seismic effect of the concrete skylight truss shall be multiplied by an amplifying coefficient, which value may be taken as 1.5.

**2** In other cases, the horizontal seismic action of the skylight truss may adopt the mode analysis method with response spectrum.

**9.1.10** The following methods may be used for seismic calculation in the longitudinal direction of roof truss of convex-type skylight:

**1** The spacious structure analysis method may be used for seismic calculation of skylight truss in the longitudinal direction, considering planar elastic deformation of the roof and effective stiffness of the longitudinal walls.

**2** Base shear method may be used in the calculation of longitudinal seismic action for skylight truss in the single-span or multi-span with equal height factory building, which reinforced concrete roof without purlin is used and the height of columns does not exceed 15m. But the seismic effect of the skylight truss shall be multiplied by the following amplifying coefficients:

**1)** For the single span roof, side span roofs or mid-span roof with longitudinal internal partition wall:

$$\eta = 1 + 0.5n \qquad (9.1.10\text{-}1)$$

**2)** For other mid-span roofs:

$$\eta = 0.5n \qquad (9.1.10\text{-}2)$$

Where $\varepsilon$—— Amplifying coefficient of seismic effect,

$n$—— Number of spans in the factory building, if the number of spans exceeds 4, it shall be taken as 4.

**9.1.11** For a factory building with the column spacing of which in both direction is not less than 12m, and without a bridge-type crane and column braces, the horizontal seismic action in two major axis directions shall be considered simultaneously in seismic checking of cross-section. And the P-delta effect shall be considered also.

**9.1.12** In factory buildings with unequal heights, the section area of the longitudinal tension reinforcement in the column bracket, which supporting the roof on the lower span, shall be determined according to the following equation:

$$A_s \geq \left( \frac{N_G \alpha}{0.85 h_0 f_y} + 1.2 \frac{N_E}{f_y} \right) \gamma_{RE} \tag{9.1.12}$$

Where $A_s$——Section area of longitudinal horizontal tension reinforcement,

$N_G$——Design value of compression on the column bracket subjected the representative value of gravity load

$a$—— Distance from the action axis of the gravity load to the near edge of the lower column bracket, when it is less than $0.3h_0$, it shall be equal $0.3h_0$

$h_0$——Effective height of the largest vertical section of the bracket.

$N_E$——Design value of horizontal tension in the seismic combination on the top of column bracket

$f_y$——Design value of tensile strength of reinforcement

$\gamma_{RE}$——Seismic adjusting factor for loading capacity, it may be taken as 1.0.

**9.1.13** The seismic effect of the crosswise column braces and the seismic check for connection point of the brace with the column may be carried out according to the provisions specified in Section K.2 of Appendix K of this code. When the lower joints of the crosswise braces between lower columns were located at the positions above the top surface of foundation according to those specified in Article 9.1.23 of this code, the shear bearing capacity of the oblique sections of longitudinal column root should be checked.

**9.1.14** The seismic calculations for the wind-resistant columns, small posts of roof truss and considering the affection of working deck, shall comply with the following provisions:

**1** For Intensity 8 and 9, the out-of-plane seismic check shall be made for the wind-resistant column of tall gables

**2** When the wind-resisting column connects with the bottom chord of roof truss, the connecting point shall be arranged at the node of the transverse brace of the bottom chord, and seismic check shall be made for the section of the transverse brace and its connection.

**3** When the working deck and rigid separation wall connect with the main structural members of the factory building, the calculation structural model shall comply with the actual working state of this factory, and the additional seismic effect of that on this factory shall be taken into consideration. And the columns of bent frames whose deflection is restricted and shear-span ratio not more than 2, the shear capacity shall be checked according to the provisions in the current national standard GB50010 "*Code for Design of Concrete Structures*", and the corresponding seismic details according to the Article 9.1.25 of this code shall be taken.

**4** For Intensity 8 with Site-class III and IV and Intensity 9, the arched and polygonal bowstring truss with small posts adjusting roof pitch or the truss with longer top chord portion and larger bow-height, the torsion capacity check should be made for the top chord of these trusses.

### (III) Design Details

**9.1.15** The connection of members and arrangement of braces in the roof with purlins shall comply with the following requirements:

**1** The purlins shall be welded tightly with the roof truss (or roof girder) and adequate supported length of purlins on the roof shall be provided.

**2** The double-ridge purline shall be tied each other at 1/3 of the span.

**3** The fluted steel sheets shall be connected firmly with purlins, and the corrugated iron sheets and asbestos sheets shall be tied with purlins.

**4** Arrangement of braces shall comply with the requirements in Table 9.1.15.

**Table 9.1.15 Braces arrangement for roof with Purlins**

<table>
<tr><th colspan="2" rowspan="2">Braces</th><th colspan="3">Intensity</th></tr>
<tr><th>6, 7</th><th>8</th><th>9</th></tr>
<tr><td rowspan="4">Braces of the roof truss</td><td>Transverse braces at the top chord</td><td>One row in each end bay of a factory building unit</td><td>One row in each end bay of a factory unit, the column-brace bay of a unit with length greater than 66m;<br>Local both end bays of the opening zone caused by the skylight</td><td rowspan="3">One row in each end bay of a factory unit,<br>the column-brace bay of a unit with length greater than 42m;<br>Local both end bays of the opening zone caused by the skylight</td></tr>
<tr><td>Transverse braces at bottom chord</td><td colspan="2" rowspan="2">Same as in the non-seismic design<br>Same as in the non-seismic design</td></tr>
<tr><td>Vertical brace at middle of span</td></tr>
<tr><td>Vertical brace at end of span</td><td colspan="3">For the end vertical member with height greater then 900mm of a truss, one row in each end bay and column-brace bay of a factory unit</td></tr>
<tr><td rowspan="2">Braces of the skylight</td><td>Transverse braces at the top chord</td><td>One row in each end bay of skylight</td><td rowspan="2">One row in each end bay of skylight and in each 30m spacing</td><td rowspan="2">One row in each end bay of skylight and in each 18m spacing</td></tr>
<tr><td>Vertical brace at two sides</td><td>One row in each end bay of skylight and in each 36m spacing</td></tr>
</table>

**9.1.16** Connection of members and arrangement of braces in the roof without purlins shall comply with the following requirements:

**1** Large-size roof panels shall be welded firmly with the roof truss (roof girder), and length of the welding seam in the connection of the roof panel adjacent to the row of columns and the roof truss (roof gird) should be not less than 80 mm.

**2** For the end bay of a factory unit with a skylight of Intensity 6 and 7, and for each bay of Intensity 8 and 9, adjacent large-size roof panels which orthogonal to the roof truss should be welded with each other at their top surfaces.

**3** For Intensity 8 and 9, angle steel should be used as embedded parts at the bottom of the end of the large-size roof panel, and it shall be welded firmly with the main reinforcement in the panel.

**4** For non-standard roof panel, precast monolithic joint should be used, or the all of corners of the panel should be cut and then welded firmly with the roof truss (girder).

**5** Anchorage bars of the embedded parts on the top of the end of the roof truss (roof girder) should be not less than 4ϕ10 and 4ϕ12 for Intensity 8 and 9 respectively.

**6** Arrangement of braces should be comply with the requirements in Table 9.1.16-1 and in Table 9.1.16-2 for the basin-type skylight. When the roof gird with the span not greater than 15 m for Intensity 8 and 9, it may be installed only the vertical bracing at each end of a factory unit. The arrangement of braces for the lean-to roof girders should be carried out according to that for the roof truss with end height greater than 900mm.

**Table 9.1.16-1 Braces arrangement for roof without purlins**

| Braces | | | Intensity | | |
|---|---|---|---|---|---|
| | | | 6, 7 | 8 | 9 |
| Braces of the roof truss | Transverse braces at the top chord | | Same as non-seismic design when the span is less than 18m.<br>One row in each end bay of a factory unit when the span ≥18m. | One row in each end bay of a factory unit, and the column-brace bay.<br>Local end bay of the opening zone caused by the skylight. | |
| | Horizontal tie rod through all factory at top chord | | Same as non-seismic design | One row along the bay in each 15m, but non-necessary for precast monolithic roof;<br>And non-necessary at truss end when in-situ bring-beam of curtain wall installed at top chord level | One row along the bay in each 12m, but non-necessary for precast monolithic roof;<br>And non-necessary at truss end when in-situ bring-beam of curtain wall installed at top chord level |
| | Transverse braces at the bottom chord | | Same as non-seismic design | Same as non-seismic design | Same as transverse braces at top chord |
| | Vertical brace at middle of span | | Same as non-seismic design | Same as non-seismic design | Same as transverse braces at top chord |
| | Vertical brace at ends of truss | end height <900mm | Same as non-seismic design | One row in each end bay of a factory unit | One row in each end bay of a factory unit and in each 48m spacing |
| | | end height >900mm | One row in each end bay of a factory unit | One row in each end bay of a factory unit and the column-brace bay | One row in each end bay of a factory unit, the column-brace bay and in each 30m spacing |
| Braces of the skylight | Vertical brace at two sides | | One row in each end bay of skylight and in each 30m | One row in each end bay of skylight and in each 24m | One row in each end bay of skylight and in each 18m spacing |

| Braces | | Intensity | | |
|---|---|---|---|---|
| | | 6, 7 | 8 | 9 |
| | Transverse braces at the top chord | Same as non-seismic design | For span of skylight is not less than 9m, one row in each end bay of skylight and the column-brace bay | One row in each end bay of skylight and the column-brace bay |

**Table 9.1.16-2 Braces arrangement of basin-type skylight roof without purlin**

| Braces | | Intensity 6 and 7 | Intensity 8 | Intensity 9 |
|---|---|---|---|---|
| Transverse braces at the top chord and bottom chord | | One row in each end bay of a factory unit | One row in each end bay of a factory unit and the column-brace bay | |
| Horizontal tie rod through over factory at top chord | | In the joints of the top chord of the truss within the opening zone caused by skylight | | |
| Horizontal tie rod through over factory at bottom chord | | In both sides of skylight and in the joints of the bottom chord of the truss within the opening zone caused by skylight | | |
| Vertical brace at middle of span | | In bay with transverse braces at the top chord, they location corresponds to the tie rod through over factory at bottom chord | | |
| Vertical brace at both ends | End height <900mm | Same as non-seismic design | | Bay with the top chord transverse braces, and spacing ≤ 48m |
| | End height ≥900mm | One row in each end bay of a factory unit | Bay with the top chord transverse braces, and spacing ≤ 48m | Bay with the top chord transverse braces, and spacing ≤ 30m |

**9.1.17** The braces of the roof shall also conform to the following requirements:

**1** Within the opening zone caused by skylight, a horizontal compression rod of top chord through over zone shall be installed at the ridge of the truss;

**2** The spacing of vertical braces at middle of span shall not be greater than 15m for Intensity 6 through Intensity 8, and greater than 12m for Intensity 9. When only one row is installed, the location shall be the ridge of the truss; when two rows are to be installed, they shall be distributed evenly.

**3** The relative segments of horizontal tie rod of the top and bottom chord through over factory should be treated as the component part of the vertical brace of the truss.

**4** For factory with column bays not less than 12m and the truss spacing is 6m, bottom chord longitudinal horizontal braces shall be installed in the bay of spandrel truss (beam) and its next bays.

**5** The brace members of the roof truss should adopt shaped steel.

**9.1.18** For the reinforced concrete convex-type skylight, the wall panels on both sides should be connected with vertical post of skylight by using bolts.

**9.1.19** The cross section and reinforcement of the reinforced concrete roof truss shall comply with the following requirements:

**1** For the first portion for the top chord of the truss and the end vertical post of the trapezoid-shaped truss, they reinforcement should be not less than 4ϕ12 for Intensity 6 and 7, and not less than 4ϕ14 for Intensity 8 and 9.

**2** The cross-sectional width of the end vertical post of the trapezoid-shaped truss should be the same as that of the top chord.

**3** For the small posts supporting the roof panels at the end of the top chord of the arched and polygonal bowstring truss, the cross section dimension should not be less than 200mm x 200mm, and the height should not be greater than 500mm. Major reinforcements in the small post shall be Π-shape and not less than $4\phi12$ for Intensity 6 and 7, and less than $4\phi14$ for Intensity 8 and 9; the hoops in small post may be used $\phi6$, and the spacing should be 100mm.

9.1.20 The hoops in a column of the factory shall comply with the following requirements:

**1** The hoops shall be densified in the range below:

**1)** The column top, for a length of 500 mm from the top of the column, and also not less than the dimension of the longer side of the column cross section;

**2)** Upper column, from the bracket surface to a distance of 600mm above the crane beam surface of a stepped column;

**3)** Bracket (the column shoulder), through over height;

**4)** The column foot, from the bottom of the lower column to a distance of 500mm above the indoor ground level;

**5)** The connection of the column and its brace, such as the locations that the column displacement is constrained by the platform or other, a distance 300 mm above and below of the joint.

**2** The spaces of hoops in the densified zone shall not be greater than 100 mm, and the spaces between limbs and diameters of the hoops shall comply with the provisions in Table 9.1.20

**Table 9.1.20 Maximum Space and Minimum Diameter of Hoops in the Densified Zone**

| Intensity and Site class | | Intensity 6, Intensity 7 with Site-class I, II | Intensity 7 with Site-class III and IV, Intensity 8 with Site-class I and II | Intensity 8 with Site-class III and IV, Intensity 9 |
|---|---|---|---|---|
| Maximum space for limbs of hoop (mm) | | 300 | Ø 250 | Ø 200 |
| Min. diameter of hoops | Common column top and foot | Ø6 mm | Ø 8 mm | Ø 8 (10) mm |
| | Column top of corner column | Ø 8 mm | Ø 10 mm | Ø 10 mm |
| | Bracket of upper column and column root with brace | Ø 8 mm | Ø 8 mm | Ø 10 mm |
| | Column top with brace and location at which column deformation is constrained | Ø 8 mm | Ø 10 mm | Ø 10 mm |

Note: values in the brackets are used for the column foot.

**3** For the laterally-constrained bent frame columns with shear-span-ratio of no greater than 2, the details of the embedded steel plate on the column top and the hoops in the densified zone of column shall also meet the following requirements:

**1)** The length of the embedded steel plate on the column top in the direction of the bent frame plane should be taken as the height of the section at the column top, and shall not be less than 1/2 of the section height or 300mm;

**2)** The installation of the roof truss on the top of the column should minimize the eccentricity between the installation position and the center of column section; the eccentricity between the action point of axial force and the section center of the column top shall not be greater than 1/4 of the section height;

**3)** When the axial force eccentricity of column top in the direction of the plane of bent frame is at the range of 1/6~1/4 of the section height, the volume reinforcement ratio of hoop in hoop densified zone of column top should not be less than 1.2% for Intensity 9; 1.0% for Intensity 8; 0.8% for Intensity 6 and 7;

**4)** Hoop in the densified zone should be four-limb hoops with no larger than 200mm limb space.

**9.1.21** The section and reinforcement of column for factory with large-spacing of column shall comply with the following requirements:

**1** The column section should adopted the square or nearly square rectangular shapes, and the depth should not be less than 1/18~1/16 of the total height of the column.

**2** The axial-force-ratio of column for heavy weight roof factory, should not be greater than 0.8 for Intensity 6 and 7, greater than 0.7 for Intensity 8, and greater than 0.6 for Intensity 9.

**3** Longitudinal steel bars should be arranged symmetrically along the perimeters of the cross section, the spacing should not be greater than 200mm; and the steel bars with greater diameter shall be arranged at the corner of section.

**4** The hoops in the column top and column foot shall be densified and comply with the following requirements:

**1)** For the column foot, the densified length from the bottom of column to a distance of 1m above the indoor ground level, and this distance shall not be less than 1/6 of the total height of the column. For the column top, 500mm below the top of the column and the distance shall not be less than the larger dimension of the column cross section;

**2)** The spacing, diameter and the limb spacing of the hoops shall conform to the provisions in Article 9.1.20 of this code.

**9.1.22** Reinforcement of wind-resisting column of the gable shall comply with the following requirements:

**1** For the hoops within the scope of 300mm below the top of the wind-resisting column and 300mm above the brackets (column shoulder), the diameter should not be less than 6mm, the spacing should not be greater than 100mm, and the spacing of limbs should not be greater than 250mm.

**2** Longitudinal tensile reinforcements should be installed at the brackets (column shoulder) of the variation section of the wind-resisting column.

**9.1.23** The arrangement and details of the column-braces in the factory building shall comply with the following requirements:

**1** The arrangement of column-braces shall comply with the following provisions:

**1)** Generally, column-braces shall be installed for the upper and lower columns in the middle of the factory building unite, and the braces of the lower column and the upper columns shall be installed correspondingly;

**2)** When there are cranes or for Intensity 8 and 9, added braces of upper columns shall be installed at the both ends bay of the factory-building unit;

**3)** When the factory building unit is long or for Intensity 8 with Site-class Ⅲ and Ⅳ or for Intensity 9, two rows of column-braces may be arranged in 1/3 length scope measured from both ends of the factory unit.

**2** The column-braces shall adopt shaped steel, the brace type should be of the crosswise type, the angel between the struts and the horizontal level should not be greater than 55º.

**3** The slenderness ratio of the brace strut should not exceed the provisions in Table 9.1.23.

**Table 9.1.23 Maximum slenderness ratio of crosswise brace diagonals**

| Intensity and Site class | Intensity 6 , Intensity 7 with Site-class I and II | Intensity 7 with Site-class III and IV, Intensity 8 with Site-class I and II | Intensity 8 with Site-class III and IV, Intensity 9 with Site-class I and II | Intensity 9 with Site-class III and IV |
|---|---|---|---|---|
| Brace of upper column | 250 | 250 | 200 | 150 |
| Brace of lower column | 200 | 200 | 150 | 150 |

**4** The location of the lower joint for the brace of lower column shall ensure to transfer the seismic action to the foundation. For Intensity 6 and 7, if it cannot transfer the seismic action directly to the foundation, the unfavorable affection of the brace on the column and the foundation shall be considered.

**5** The gusset plate shall be installed at the intersecting point of the crosswise brace struts, and the plate thickness shall not be less than 10mm. The struts shall be welded to the gusset plate of intersection point of crosswise brace and should be welded to the gusset plate of end joint.

**9.1.24** The horizontal compression bars should be installed along the top level of the middle column rows for multi-span factory building with a span not less than 18m at Intensity 8, or along the top level of all columns rows for multi-span factory building at Intensity 9. This compression bar may be taken instead of the horizontal tie rod installed at the support of the trapezoid-shape roof truss. The clearance between the end of the reinforcement concrete tie rod and the roof truss shall be filled with concrete.

**9.1.25** The connection of the structural members in a factory building shall comply with the following requirements:

**1** The roof truss (girder) should be connected with columns on top by bolts for Intensity 8 and by hinge plate for Intensity 9, but bolts may also be used for Intensity 9. The thickness of the bearing plate at the end of the roof truss (girder) should not be less than 16 mm.

**2** The anchorage bars of embedded parts on top of a column should be 4$\phi$14 for Intensity 8 and 4$\phi$16 for Intensity 9. For columns with braces, shear plate shall be installed additionally other than embedded parts.

**3** The embedded plate shall be put on the top of the wind-resisting column in a gable wall, so that top of the column can be reliably connected with the top chord of the end truss (or top flange of the roof girder). The connected point shall be installed at the joint of top chord transverse brace and roof truss; if not, the transverse brace may installed additionally sub-web or shaped steel beam to transfer the horizontal seismic force to this joint.

**4** The embedded parts in the bracket (column shoulder) of the middle-column supporting the lower-span roof shall be welded with the longitudinal reinforcement subjected to the calculated horizontal tension in the bracket (column shoulder). And the welded reinforcements shall not be less than 2$\phi$12 for Intensity 6 and 7, than 2$\phi$14 for Intensity 8, and than 2$\phi$16 for Intensity 9.

**5** For Intensity 8 with Site-class III or IV and for Intensity 9, the steel angles together with end plate should be used as anchors of the embedded parts at the joint of the brace and the column. And in other cases, the steel bars of grade HRB335 or HRB400 may be used as anchors, but the developed length shall be not less than 30 times the diameter of the anchor bar or added end plate shall be adopted

**6** The crane corridor panel, the small roof panel filled the space between the end roof truss and gable, valley plate, and the fascia masonry underneath the skylight end plate and side plate etc. shall have reliable connection with its supporting structural members.

## 9.2 Single-storey Steel Factory Buildings

### (I) General

**9.2.1** This section is mainly applicable to single-storey factory buildings with bearing steel columns and steel roof trusses or steel roof girders. The seismic design for single-storey factory buildings with lightweight steel structures shall meet the special requirements.

**9.2.2** The structural system of the factory building shall be in accordance with the following requirements:

**1** The transverse lateral-force-system of the factory building may adopt with rigid-jointed frame, hinged frame, gabled frame or other structural system. For Intensity 8 and 9, the longitudinal lateral-force-system of factory building shall adopt column-braces; for Intensity 6 and 7, it should adopt column-braces, and rigid-frame may also be used when the braces setting was limited.

**2** When a bridge-crane is set in the factory building, the connection between the members of crane girder system and the frame column of factory building shall be able to reliably transfer horizontal earthquake action in the longitudinal direction.

**3** The roof shall have a complete brace system. When the transversal girder of the roof is hinged with the column top, bolted connection should be used.

**9.2.3** The plan configuration of the factory building, the requirements of reinforced concrete roof panels and skylight truss may refer to the relevant requirements of Section 9.1 —Single-storey Factory Buildings with RC Columns" in this code. When seismic joints are set, the joint width should not be less than 1.5 times of that of single-storey factory building with reinforced concrete column.

**9.2.4** The retaining walls of factory buildings shall be in accordance with the relevant requirements of Section 13.3 in this code.

### (II) Seismic Check

**9.2.5** In the seismic calculation of factory buildings, the mathematical models shall be in accordance with the actual working conditions of factory building structures, based on the height difference and the arrangement of crane.

The damping ratio of single-storey factory building may be taken as 0.045~0.05 according to the types of roofs and retaining walls.

**9.2.6** In calculation of seismic action for factory building, the weight and stiffness of enclosure wall shall comply with the following requirements:

**1** For lightweight panels or precast reinforced concrete panels that flexibly connected with columns, the overall weight of the wall shall be considered, but affection of stiffness may not be considered.

**2** For masonry walls nestling closely to the outside face of column and tied with the column, the overall weight of walls shall be considered. But in the calculation of seismic action in the direction parallel to the wall, the contribution of the stiffness of masonry walls may be considered, and the stiffness coefficient may be taken as 0.6, 0.4 and 0.2 for Intensity 7, 8 and 9, respectively.

**9.2.7** The following methods may be adopted for the seismic calculation in transversal direction of the factory building:

**1** The spacious structure analysis considering the affection of transversal planar elastic deformation of the roof should be used generally.

**2** For the lightweight roof factory building with regular plan and uniform lateral rigidity, the calculation may be made according to planar frame. For the equal-height factory buildings, the base shear method may be used, and for the high-low span factory buildings, the mode-decomposition response spectrum method shall be adopted.

**9.2.8** The following methods may be adopted for seismic calculation in the longitudinal direction of the factory buildings:

**1** For factory buildings with lightweight enclosure walls or large-size wall panel flexibly connected with columns, it may be calculated using base shear method. The seismic force may be distributed among the column rows according to the following principles:

**1)** For lightweight roof, it may be distributed according to the ration of the gravity load representative value of column rows;

**2)** For reinforced concrete roof without purline roof, it may be distributed according to the rigidity ratio of the column rows

**3)** For reinforced concrete roof with purlines, the average value of the above mentioned two results may be adopted.

**2** For factory buildings with common brick masonry enclosure walls nestling closely to the outside face of column, it may be calculated according to the requirements of Section 9.1 of this code.

**3** For the column rows with braces, the seismic effects after buckling of braces shall be considered.

**9.2.9** The **s**eismic calculation of the roof components shall be in accordance with the following requirements:

**1** The web members of the vertical truss shall be able to bear and transmit horizontal earthquake action of the roof. The strength of the connection shall be greater than that of the web member, and details of the connection shall be in accordance with relevant requirements.

**2** The diagonal members of the transversal horizontal braces and longitudinal horizontal braces may be designed as tensile bars with the same section.

**3** For the brackets of roof girders with spans greater than 24m and the roof girders with heavier equipments in the region of Intensity 8 and 9, the vertical earthquake action shall be calculated according to Section 5.3 of this code.

**9.2.10** For the X-shape, V-shape or Λ-shape column-braces, the combined action of tensile strut and compressive strut shall be taken into consideration. And the calculation of earthquake actions and seismic check may be carried out according to the requirements for tensile strut of Section K.2 in Appendix K of this code, where the affection of compressive struts shall be considered, but the unloading coefficient of the compressive strut should be instead of 0.30.

For the connection of the end of diagonal brace, the strengthen reduction shall be considered for single angle steel brace that shall not be used for Intensity 8 and 9. When one of the two struts is non-whole piece in the diagonal brace, the gusset plate at the intersecting point shall be strengthened, and the bearing capacity of the gusset plate shall not be less than 1.1 times of that of strut.

The stress ratio of the brace section should not be greater than 0.75.

**9.2.11** The calculation for the bearing capacity of connection of the brace components shall comply with the following requirements:

**1** The splicing positions of upper columns shall be at the zones where the bending moments are relative smaller. The splicing bearing capacity shall not be less than the internal force of the splicing position, which was calculated under the conditions that the whole sections of the both end of upper columns were in the state of plastic yielding, and must not be less than 0.5 times of tensile yielding bearing capacity of column total section.

**2** When the splicing position of the girder of the rigid-connection roof truss was located beyond the maximum stress zone of the girder, it should be designed according to the principle of equal strength.

**3** The rigid connection of solid-web roof beam and column, and the splicing of the girder at end shall be designed at elastic stage by adopting combination inner force of seismic action affection. The limit bend bearing capacities of the rigid connection of beam-column and the splicing of the girder at end shall be in accordance with the following requirements:

**1)** In general, it shall be checked according to those specified in Article 8.2.8 of this code about the rigid connection of steel structure beam-columns and the spicing of beams considering the connection coefficient. Herein, when the maximum stress zone was located at the upper column, total plastic bend bearing capacity shall be taken as the smaller value of that of the solid web beam and upper column;

**2)** When the plate width-to-thickness ratio of the roof girders at the elastic design stage was taken as that of steel structures, the beam-column rigid connection and girder splicing shall be able to reliably transfer the combination inner force of seismic action affection under precautionary intensity earthquake, or shall be checked according to Subitem 1) of this item.

The connection plate of the top chord of roof truss and the column in the rigid-connection frame should not have plastic deformation under precautionary intensity earthquake.

**4** The bearing capacity of the connection of brace and other component shall not be less than 1.2 times of the plastic bearing capacity of brace.

### (III) Design Details

**9.2.12** The roof braces of factory building shall be in accordance with the following requirements:

**1** The arrangement of braces of roof without purlins should be in accordance with those specified in Table 9.2.12-1.

**2** The arrangement of braces of roof with purlins should be in accordance with those specified in Table 9.2.12-2.

**Table 9.2.12-1 Braces arrangement for roof without purlins**

<table>
<tr><th colspan="3" rowspan="2">Brace</th><th colspan="3">Intensity</th></tr>
<tr><th>6, 7</th><th>8</th><th>9</th></tr>
<tr><td rowspan="5">Braces of Roof truss</td><td colspan="2">Transverse braces of top and bottom chords</td><td>Same as non-seismic design when the span of roof truss <18m. One row in each end bay of a factory unit when the span ≥18m.</td><td colspan="2">One row in each end bay of a factory and the column-brace bay. One row local braces of top chords shall be arranged at the end bay of the opening zone caused by the skylight. When the roof truss end is supported on the top chord of roof truss, the transverse braces of bottom chord shall be the same as non-seismic design</td></tr>
<tr><td colspan="2">Horizontal tie rod through over factory at top chord</td><td rowspan="4">Same as non-seismic design</td><td colspan="2">At the ridge of roof, location of vertical braces of the skylight truss, joints of the transverse braces and the ends of the roof truss</td></tr>
<tr><td colspan="2">Horizontal tie rod through over factory at bottom chord</td><td colspan="2">At the joints of vertical braces of the roof truss. When the roof truss was connected with the column in rigidity, it shall be set according to the external slenderness ratio of bottom chord no larger than 150.</td></tr>
<tr><td rowspan="2">Vertical braces</td><td>Span of roof truss <30m</td><td>One row in each end bay of a factory unit and each end of the roof truss located the bay with upper-column-brace</td><td>Same as Intensity 8, and the space of the vertical braces ≤42m</td></tr>
<tr><td>Span of roof truss ≥ 30m</td><td>It shall be set at each end bay of factory, at 1/3 span and end of the roof truss located the bay with upper-column-brace, and shall correspond to the transverse braces of top and bottom chord</td><td>Same as Intensity 8, and the space of the vertical braces ≤36m</td></tr>
<tr><td rowspan="3">Braces of the longitudinal skylight truss</td><td colspan="2">Transverse races at the top chord</td><td>One row in each end bay of the skylight truss unit</td><td colspan="2">One row in each end bay of the skylight truss unit and the bay with column-braces</td></tr>
<tr><td rowspan="2">Vertical support</td><td>Mid-span</td><td>It shall be set the place where the span is not less than 12m and the number shall be the same as both sides</td><td colspan="2">It shall be set the place where the span is not less than 9m and the number shall be the same as both sides</td></tr>
<tr><td>Both sides</td><td>One row in each end bay of skylight and in each 36m</td><td>One row in each end bay of skylight and in each 30m</td><td>One row in each end bay of skylight and in each 24m</td></tr>
</table>

**3** When the lightweight roofs adopt the frame systems with rigid connection of solid web roof girder and column, the roof horizontal braces may be arranged on the top flange plane of roof girder. The lower flange of roof girder shall be equipped with lateral knee-brace, the other side of knee-brace may be connected with the roof purline. The arrangement for the transverse braces of the roof and the braces of the longitudinal skylight truss may refer to the requirements in Table 9.2.12.

**Table 9.2.12-2 Braces arrangement for roof with purlins**

| Brace | | Intensity | | |
|---|---|---|---|---|
| | | 6, 7 | 8 | 9 |
| Braces of roof truss | Transverse brace of top chord | One row in each end bay of a factory and in each 60m. | One row in each end bay of a factory and the bay with upper column-braces. | Same as Intensity 8, and one row local braces of top chords shall be arranged additionally at the end bays of the opening zone caused by the skylight. |
| | Transverse braces of bottom chord | Same as the non-seismic design. When the roof truss end was supported at the bottom chord of roof truss, it shall be the same as the transverse braces of top chord | | |
| | Vertical braces at the mid-span | Same as the non-seismic design | | One additional row at mid-span when the span of roof truss is greater than or equal to 30m |
| | Vertical braces at both sides | One row in each end bay of a factory and the column-brace bay when the end height of roof truss is greater than 900mm | | |
| | Horizontal tie rod through over factory at bottom chord | Same as the non-seismic design | At the ends of roof truss and the joints of vertical braces of the roof truss. When the roof truss was connected with the column in rigidity, it shall be set according to the external slenderness ratio of bottom chord no larger than 150. | |
| Longitudinal braces of skylight truss | Transverse braces at top chord | One row in each end bay of the skylight truss unit. | One row in each end bay of the skylight truss unit an in each 54m. | One row in each end bay of the skylight truss unit an in each 48m. |
| | Vertical braces at both sides | One row in each end bay of the skylight truss unit an in each 42m | One row in each end bay of the skylight truss unit an in each 36m | One row in each end bay of the skylight truss unit an in each 24m |

**4** The arrangement of the horizontal braces of roof in the longitudinal direction shall also comply with the following requirements:

**1)** When the roof structure that the roof girders were supported on the spandrel trusses was adopted, the horizontal braces in the longitudinal direction shall be installed through over the factory unit.

**2)** For the high-low span factory building, the horizontal braces in the longitudinal direction through over roof shall be installed at the ends of roof girders in low-span.

**3)** When the roof girders located at a certain bay along the longitudinal row were supported by spandrel trusses, the horizontal roof braces in the longitudinal direction shall be installed at the bay with spandrel trusses and the expanding one bay at both sides at least.

**4)** The horizontal braces in the longitudinal direction through over the structural unit shall be combined with that in the transversal direction to form a close horizontal brace system. The space of the horizontal roof braces in the longitudinal direction of multi-span factory building should not exceed 2 spans and shall not exceed 3 spans. The high span roof and the low span roof should have relatively independent close brace systems according to their elevations, respectively.

**5** The braces should use the shaped steels. For the crosswise type braces, the maximum slenderness ratio of the brace may be taken as 350.

**9.2.13** The slenderness ratio of the column should not be greater than 150 for the axial-force-ratio <0.2, and should not be greater than $120\sqrt{235/f_{ay}}$ for the axial-force-ratio ≥0.2.

**9.2.14** The width-to-thickness ratio of the elements of column and girder in factory building shall comply with the following requirements:

**1** For the heavy-weight roof factory building, the limit value of the width-to-thickness ratio of the elements may be adopted according to those specified in Article 8.3.2 of this code and the seismic grades for Intensity 7, 8 and 9 may be taken as IV, III and II, respectively.

**2** For the lightweight-roof factory building, the limit value of the width-to-thickness ratio in plastic energy-dissipation zone may be determined according to the performance objectives based on the bearing capacity. The limit value of the width-to-thickness ratio beyond plastic energy-dissipation zone may be taken as that at elastic design stage specified in the current national standard GB 50017 *"Code for Design of Steel Structures"*.

Note: Width-to-thickness ratio of web may be reduced by setting longitudinal ribbed stiffener.

**9.2.15** The column braces shall comply with the following requirements:

**1** For the longitudinal row of factory building unit, one row brace shall be arranged inter the lower columns in the middle of factory building unit. For the length of factory building unit greater than 120m(150m for light protective materials) and 90m(120m for light protective materials) for Intensity 7and Intensity 8 and 9,respectively, one row lower column brace shall be arranged at the 1/3 zone of factory building unit. When the number of the spaces of columns not exceeds 5 and the length of factory building is less than 60m, the lower column braces may also be arranged at both ends of factory building units. The upper column braces shall be arranged at both ends of factory building unit and the bay with lower column braces.

**2** The column brace type should be of X-shape in priority, and may be of V-shape, Λ-shape or other types if conditions constrained. The angle between the X-shape brace diagonal and the horizontal level, and the thickness of the gusset plate at the junction of brace diagonals shall comply with the requirements of Section 9.1 in this code.

**3** The limit value of the slenderness ratio of column braces shall be in accordance with those specified in the current national standard GB 50017 *"Code for Design of Steel Structures"* .

**4** The column braces should adopt whole shaped steels. When the length of brace exceeds the maximum length specified for the hot rolled shape steels, splicing according to the principle of equal strength may be used.

**5** The energy-dissipation brace may be used if conditions permitted.

**9.2.16** The column root shall be able to reliably transfer the bearing capacity of column and should be of the embedded type, plug-in type or encased type. For Intensity 6 and 7, the exposed type column root may also be used. The design for column root shall be in accordance with the following requirements:

**1** The embedment depth for solid-web steel column with embedded type or plug-in type column root shall be determined by calculation and shall not be less than 2.5 times of the section height of steel column.

**2** The embedment length of lattice type column with plug-in type column root shall be determined by calculation, and the minimum insertion depth shall not be less than 2.5 times of the single-limb section height (or external diameter) and 0.5 times of the total column width.

**3** When the encased type column root is adopted, the reinforced concrete encased height should not be less than 2.5 times of the section height for the H-section column with solid-web, 3.0 times of the section height for the box or circle tube section column.

**4** When the exposed type column root is adopted, the ultimate bearing capacity of column root should not be less than 1.2 times of the plastic yielding strength of the column section. The anchor bolts of column root should not be used to bear the horizontal base shear of column. The horizontal base shear of the column shall be undertaken by the friction force between steel plate and foundation, the shear key or others. The anchor bolts of column root shall be reliably anchored.

## 9.3 Single-storey Factory Buildings with Brick Columns

### (I) General

**9.3.1** This Section is applicable to the following medium-size and small-size single-storey factory buildings with fired common brick (clay brick and shale brick) columns (piers) and concrete common brick columns (piers):

**1** The factory buildings with single-span or equal-height multi-span without bridge crane.

**2** The factory buildings in which the span is not greater than 15m and the column top elevation is not greater than 6.6m.

**9.3.2** The structural configuration of a factory building should be in accordance with the relevant requirements of Article 9.1.1 of this code, and shall comply with the following requirements:

**1** Brick bearing gable wall shall be installed at both ends of factory building.

**2** Seismic brick wall should be used for the longitudinal and transversal internal partition wall which is connected to the column with equal height.

**3** The arrangement of the seismic joint shall comply with the following requirements:

**1)** The seismic joint need not be installed for a factory building with lightweight roof.

**2)** A seismic joint should be installed between the factory building with reinforced concrete roof and auxiliary buildings, and clear width of the seismic joint may be taken as 50mm~70mm. Double columns or double walls shall be installed at the seismic joint.

**4** The skylight shall not penetrate to the end bays of the factory unit, and brick bearing walls shall not adopted at end of skylight.

Note: The lightweight roof in this chapter refers to a roof of wood and light steel truss, fluted steel sheets, corrugated iron sheets and so on.

**9.3.3** The structural system of a factory building shall also comply with the following requirements:

**1** Lightweight roof should be used for a factory building.

**2** The cross-shaped section plain brick columns may be used for Intensity 6 and 7. The plain brick columns shall not be used for Intensity 8.

**3** The brick seismic-walls, resisting longitudinal seismic action and having the same height as the column, may be installed between brick columns in the longitudinal row of a factory building. A through horizontal compression bar shall be installed on top of the column without brick seismic-walls.

**4** Transversal and longitudinal interior partition walls should be designed as seismic-walls. Lightweight walls should be used as non-bearing transversal partition-walls or longitudinal partition- walls which height is less than that of column. For the normal-weight walls, the additional seismic shear induced by the partition wall on the column and its connection with the roof truss shall be considered. The independent transversal and longitudinal partition-walls shall be designed to ensure the stability outside the plane, and the in-situ cast reinforced concrete coping beams shall be installed on the top.

### (II) Essentials in Calculation

**9.3.4** For the single-storey factory buildings with brick columns designed according to the seismic details of this section in the zone of Intensity 7 with site-class I and II, d, when one of the following requirements is satisfied, the seismic check in transversal or longitudinal direction need not be carried out:

**1** For the single-span or equal-height multi-span factory building of brick columns with gable walls installed at both ends of structural unit and top elevation of column not exceeding 4.5m, the seismic check in transversal and longitudinal direction may not be carried out.

**2** For the single-span factory building with top elevation of column not exceeding 6.6m, outer longitudinal walls whose thickness is no less than 240mm and opening section area is no larger than 50% at both sides, and gable walls installed at both ends of structural unit, the seismic check in longitudinal direction may not be carried out.

**9.3.5** The following methods may be used for seismic calculation in the transversal direction of factory building:

**1** Lightweight roof factory buildings may be calculated according to planar bents.

**2** The factory building assigned to reinforced concrete roof or wood roof with fully covered sheathings may be calculated according to planar bents that the work of space has been considered; the seismic effect shall be adjusted according to Appendix J of this code.

**9.3.6** The following methods may be used for seismic calculation in the longitudinal direction of factory building:

**1** For the factory buildings with reinforced concrete roof, the modal-analysis-response -spectrum method should be adopted.

**2** For the factory buildings with reinforced concrete roof, multi-span and equal-height brick columns, the modification rigidity method as set forth in Appendix K of this code may be adopted.

**3** For single-span factory buildings and multi-span factory building with light roof that longitudinal walls arranged symmetrically, the method that the column rows are calculated separately may be adopted.

**9.3.7** The transversal and longitudinal seismic calculation of skylight rising out the roof shall be in accordance with the provisions specified in Article 9.1.9 and Article 9.1.10 of this code.

**9.3.8** For eccentric compressive brick-columns, the seismic check shall comply with the following requirements:

**1** For plain brick columns, the eccentricity of the seismic combinatory axial force design value should not exceed 0.9 times of the distance from the section centroid to the section edge in the direction where the axial force locates; and the seismic capacity adjustment factor may adopt 0.9.

**2** The reinforcement amount for composite brick column shall be determined through calculation, and the seismic capacity adjustment factor may adopt 0.85.

### (III) Design Details

**9.3.9** The braces of lightweight roofs with steel trusses, corrugated iron sheets or asbestos tiles may be installed according to those specified in Table 9.2.12-2 of this code. The Transversal braces at top and bottom chords shall be arranged at the second bay at both sides. The arrangement of braces in a wood roof should comply with the requirements in Table 9.3.9. The braces shall be connected with the roof truss or skylight truss by bolts. The connection between side column of wood skylight truss and roof truss should be strengthened by full-length wood clamping plate or iron plate bolted.

**Table 9.3.9 Arrangement of Braces in A Wood Roof**

<table>
<tr><th colspan="2" rowspan="3">Braces</th><th colspan="3">Intensity</th></tr>
<tr><th>6, 7</th><th colspan="2">8</th></tr>
<tr><th>All types of roofs</th><th>In full sheathing</th><th>Scattered or no sheathing</th></tr>
<tr><td rowspan="3">Brace of roof truss</td><td>Transversal braces at top chord</td><td colspan="2">Same as non-seismic design</td><td>When the span of roof truss is greater than 6m, one row in the second end bay and in each 20m.</td></tr>
<tr><td>Transversal braces at bottom chord</td><td colspan="3">Same as non-seismic design</td></tr>
<tr><td>Vertical braces at middle of span</td><td colspan="3">Same as non-seismic design</td></tr>
<tr><td rowspan="2">Braces of skylight truss</td><td>Vertical braces at both sides</td><td rowspan="2">Same as non-seismic design</td><td colspan="2" rowspan="2">It should not install skylight</td></tr>
<tr><td>Transversal braces at top chord</td></tr>
</table>

**9.3.10** The purlins shall be connected reliably with the coping-beam along the roof levels at the gable, and the shelf length shall not be less than 120mm. The roof-structure in which the purlins extend to out-gable may be adopted if conditions permitted.

**9.3.11** The design details for reinforced concrete roofs shall be in accordance with the relevant requirements of Section 9.1 of this code.

**9.3.12** A cast-in-place closed ring-beam shall be installed along the exterior wall and the bearing interior walls at the top level of the column; for Intensity 8, the ring-beams shall be also added in each 3~4 m along height of the wall. Depth of the ring-beam shall not be less than 180mm and its reinforcement shall not be less than 4$\phi$12. Foundation ring-beam shall also be installed, when the subsoil is weak cohesive soil, liquefaction-soil, newly filled soil or a seriously non-uniformly distributed soil layer. When the ring-beam also serves as the lintel or resisting uneven-settlement, besides satisfying the above detail requirements, its cross-sectional dimension and reinforcements shall also be determined based on calculation for actual action.

**9.3.13** A cast-in-place reinforced concrete coping-beam along the roof levels shall be installed at the gable wall and anchored with the roof members. The cross-sectional area and reinforcements of the buttress of the gable wall should not be less than those of the bent-column. The buttress shall be extended through to top of the gable wall and connected with the coping-beam at the gable wall or other roof members.

**9.3.14** The ring-beam on top of the wall or bearing plate on top of the column shall be connected firmly with roof truss (girder) by bolts or welding. Thickness of the bearing plate on top of the column shall be not less than 240 mm, and two layers of reinforcement mesh with a diameter of not less than 8mm and spacing not greater than 100mm shall be installed in the plate. The ring-beam on top of the wall and the bearing plate on top of the column shall be poured at the same time. For Intensity 9 and scope in a distance of 500mm on both sides of the bearing plate, the spacing of hoops in the ring-beam shall be not greater than 100 mm.

**9.3.15** The details of brick columns shall conform to the following requirements:

**1** The brick strength grade shall not be less than MU10, the strength grade of mortar shall not be less than M5; the concrete strength grade for composite brick column shall adopt C 20.

**2** The damp-proof course of the brick column shall adopt waterproof mortar.

**9.3.16** Factory buildings with brick columns and reinforced concrete floor panel, the horizontal sectional area of the opening on the gable should not exceed 50% of the gross cross-sectional area. For the Intensity 8, the reinforced concrete tie-columns shall be installed at the two ends of the gable and transverse wall. The cross-sectional dimension of the reinforced concrete tie-column may adopt 240mm ×240mm, the vertical reinforcements of the tie-column shall not be less than 4$\phi$12, the hoops may adopt $\phi$6, and the spacing of hoop should select 250~300mm.

**9.3.17** The details of brick wall shall comply with the following requirements:

**1** For brick column factory buildings with reinforcement concrete roof without purlins of Intensity 8, 1$\phi$8 vertical reinforcement should be embedded in each 1m along the length of the brick protection wall and extended into ring-beam of the top of the wall.

**2** For the wall height is greater than 4.8m of Intensity 7 or for Intensity 8, at the corner of the exterior wall and the intersection of the bearing interior transverse wall and the exterior longitudinal wall, the strengthened reinforcement shall be arranged, when no tie-column is installed. In where, the reinforcements 2$\phi$6 shall be arranged in each 500mm along the height of the wall, and the length for each side extended into the wall should not be less than 1 m.

**3** The seismic detail requirements for parapet with rising out the roof shall conform to relevant provisions in Section 13.3 of this code.

# 10 Large-span Buildings

## 10.1 Single-storey Spacious Buildings

### (I) General

**10.1.1** This Section is applicable to the public building consisting of spacious single-storey hall and annex buildings.

**10.1.2** Seismic joint should not be installed between hall, ante-hall and stage, and also may not be installed between hall and attached buildings at both sides. However, connection shall be strengthened at the above placement where no seismic joint is set.

**10.1.3 The load-bearing structures for the hall of single-storey spacious building shall not adopt plain brick columns in the following situations:**

**1 The halls of the buildings for Intensity 7 (0.15*g*), Intensity 8 and Intensity 9.**

**2 The halls with cantilever platform inside.**

**3 For Intensity 7 (0.10*g*), the halls that the span is greater than 12m or the top elevation of column is greater than 6 m.**

**4 For Intensity 6, the halls that the span is greater than 15m or the top elevation of column is greater than 8m.**

**10.1.4** The load-bearing structure of the roof at longitudinal wall for the hall of single-storey spacious buildings, besides the provisions in Article 10.1.3, may also add composite buttress with reinforced concrete and brick at the supports of roof, but plain brick buttress shall not be adopted.

**10.1.5** The lateral stiffness in the transversal direction of the ante-hall shall be increased by the structural member layout, the gatepost and independent columns in the ante-hall shall adopt reinforced concrete columns.

**10.1.6** The lateral stiffness of transverse walls, which in the connection of the ante-hall and the hall, as well as of the hall and the stage, shall be increased, and a certain number of reinforcement concrete walls shall be established.

**10.1.7** For other requirements regarding the hall can refer to Chapter 9 of this code, and attached rooms of hall shall comply with relevant provisions in this code.

### (II) Essentials in Calculation

**10.1.8** In seismic calculation of the single-storey spacious buildings, which may be divided into several separate units, such as the ante-hall, the stage, the hall, and attached rooms, than each unit calculated according to relevant structural system provision in this code, but one another affection for those units shall be considered.

**10.1.9** The seismic calculation for single-storey spacious building may adopt the base shear method; the seismic influence coefficient may be taken as the maximum value.

**10.1.10** The horizontal longitudinal seismic action characteristic value of halls may be calculated according to the following equation:

$$F_{\mathbf{Ek}}=\alpha_{\max}G_{\mathbf{ep}} \tag{10.1.10}$$

Where $F_{\mathrm{Ek}}$——The characteristic value horizontal longitudinal seismic action on the longitudinal wall or column row in one side of the hall;

$G_{eq}$——Equivalent gravity load representative value; including the half of weight for the roof of hall, the half of weight for roof of adjacent attached rooms, 50% of the snow load characteristic value, and the conversed weight of the longitudinal wall or column row in one side of hall.

**10.1.11** The transversal seismic calculation for hall should comply with the following principles:

**1** In case of hall without attached rooms on the two sides, the part with and without cantilever platform may choose a typical bay for the calculation respectively; when the provisions in Chapter 9 of this code are satisfied, the space structural model may also be taken into consideration.

**2** In case of hall with attached rooms on the two sides, proper calculation methods shall be selected based on the structural types of the attached rooms.

**10.1.12 The seismic checking of out-of-plane for the buttress of the tall gable wall shall be carried out for Intensity 8 and 9.**

### (III) Design Details

**10.1.13** The roof details of the hall shall comply with the provisions of Chapter 9 in this code.

**10.1.14** he reinforced concrete column and composite brick-column of the hall shall comply with the following requirements:

**1** The reinforcement bars of composite brick-columns shall be developed to the reinforced concrete ring-beam at the bottom of the truss. The longitudinal reinforcements of each side for the composite brick-column, besides to be determined by calculation, shall not be less than 4ϕ14 for Intensity 6 with Site-class III or IV and Intensity 7(0.10g) with Site-class l or II, and 4ϕ16 for Intensity 7(0.10g) with Site-class III or IV.

**2** The reinforced concrete column shall be designed according to Grade 2 frame columns, and the reinforcement ratio shall be determined by calculation.

**10.1.15 The transversal walls connecting the ante-hall with hall or the hall with stage shall comply with the following requirements:**

**1 The tie-columns or reinforced concrete columns shall be installed on the two ends of the transverse wall, the supports of longitudinal girders and both edges of large opening of the walls.**

**2 The some transversal wall that built-in plane of the reinforced concrete frame columns shall be designed according to Grade 2 reinforcement concrete wall.**

**3 The reinforcement concrete structure shall be adopted for girder and columns of the front of stage. For the bearing masonry wall above the girder in front of the stage, the pillars spacing not exceeding 4m and tie-beams spacing not exceeding 3m shall be installed. And their cross-sectional dimension, reinforcement ratio, and connection with the masonry wall shall conform to the requirements for multi-storey masonry buildings.**

**4 Brick wall on the girder in front of the stage shall not be used for bearing loads for Intensity 9.**

**10.1.16** A cast-in-place ring-beam shall be installed at the top of the column (wall) of the hall, and an additional ring-beam shall be installed in each about 3m along the height of the wall. When the height of end of the trapezoid-shaped truss is greater than 900mm, the additional ring-beam shall also be installed at the level of the top chord. The depth of ring-beam should be not less than 180 mm, and width of ring-beam should be the same as thickness of the wall, the reinforcements should not be less than 4ϕ12, and hoop spacing should not exceed 200 mm.

**10.1.17** When no seismic joint is installed between the hall and the attached rooms, a closed ring-beam shall be installed at the same level and tied through overall the intersection place of the hall and the attached rooms. And at the intersection of walls, 2ϕ6 tie bars shall be installed in each 500mm along the height of the wall, and the ties should extend into the wall on both sides with length not less than 1m.

**10.1.18** The cantilever platform shall be reliably anchored, and details shall be taken to prevent its overturning.

**10.1.19** The reinforced concrete coping-beams along the roof levels shall be installed at the gable wall and shall be tied with the roof members. The tie-columns or composite brick-columns shall be installed in the gable wall; more, their cross-sectional area and reinforcements shall not be less than those of the bent column or composite brick-column in the longitudinal wall respectively. These columns shall extend to the top of the gable wall and be connected with the coping-beam on the gable wall.

**10.1.20** The operation platform or floor diaphragm shall be used as the horizontal support of the tall gables, which are the back wall of the stage and the junction wall of the hall and the ante-hall.

## 10.2 Large-span Roof Buildings

### (I) General

**10.2.1** This section is applicable to large-span steel roof buildings consisting of the basic structural types such as arch, plane truss, spatial truss, space truss, reticulated shell, beam string structure, suspend-dome and so on.

For the large-span steel roof buildings that consist of non-conventional types or that the span is greater than 120m, the length of structural unit is greater than 300m or the cantilever length is greater than 40m, the seismic design shall be in accordance with the results of the special study and argumentation, and at the same time, more effective strengthening measures shall be adopted.

**10.2.2** The selection and arrangement of the roof and its supporting structure shall comply with the following requirements:

**1** The structure shall be able to transfer earthquake action from roof to the lower supporting structure effectively.

**2** The structure shall be provided with reasonable distribution of stiffness and strength. The arrangement of the roof and its supports should be even and symmetrical.

**3** The spatial-force-transmission systems with balance stiffness in two horizontal directions should be adopted in priory.

**4** The structural arrangement shall avoid weak parts due to partial weakening or mutation that will be produce over-large internal force and deformation under earthquake ground motion. Measures to increase the seismic capacity shall be taken for the possible weak parts.

**5** Lightweight roof systems should be adopted.

**6** The lower supporting structures shall be arranged reasonably to avoid producing excessive torsional effects on roofs under seismic ground motion.

**10.2.3** The structural configuration of roof system shall comply with the following requirements:

**1** The structural configuration of unidirectional-force-transmission systems shall comply with the following requirements:

**1)** Braces shall be installed reliably between major structures (truss, arch and beam string structure) in order to transfer the horizontal earthquake action in the direction which is perpendicular to the major structures.

**2)** When the truss is supported at the joint of lower chord, the installation of longitudinal truss between the supports or other reliable measures shall be taken to avoid the torsion of truss out of plane at the support.

**2** The structural configuration of spatial-force-transmission systems shall comply with the following requirements:

**1)** For the rectangular roof structures with three sides supported and one side free, the free side shall be strengthened to ensure the adequate rigidity.

**2)** For the orthogonal two-way space truss structures and bi-directional beam string structures, the close horizontal brace systems along the supports shall be installed.

**3)** For the single-storey reticulated shell, rigid connection joints shall be adopted.

Note: Unidirectional-force-transmission system refers to plane arch, unidirectional plane truss, unidirectional spatial truss, unidirectional beam string structure, etc.; space-force-transmission system refers to space truss, reticulated shell, bidirectional spatial truss, bidirectional beam string structure and suspend-dome, etc..

**10.2.4** When different roof structure types are adopted by zone, the members and joints in border areas shall be strengthened, or the seismic joints with width not less than 150mm may be installed.

**10.2.5** The non-structural components, such as enclosing system of roof, suspended ceiling and suspender, shall be reliably connected with structure and their seismic details shall be in accordance with the relevant requirements of Chapter 13 in this code.

### (II) Essentials in Calculation

**10.2.6** For the following roof structures, the calculation of seismic action need not be carried out, but the seismic details shall be in accordance with the relevant requirements of this section:

**1** In the zone of Intensity 7, for the unidirectional plane truss and unidirectional spatial truss structures with rise-span ratio less than 1/5, the horizontal and vertical seismic action along truss may not be carried out.

**2** In the zone of Intensity 7, for the space truss structure, the seismic action may not be carried out.

**10.2.7** The mathematical models of roof structures for seismic analysis shall comply with the following requirements:

**1** The mathematical models shall be reasonably determined, and the assumption for the connections between roof and main supports shall be in accordance with the details.

**2** The collaborative work between the roof and lower supporting structures shall be considered.

**3** The seismic action of braces in unidirectional-force-transmission system should be calculated according to the entire model of roof structure.

**4** For the calculation of seismic action of the beam string structures and suspend-domes, the influence of geometrical rigidity should be included in the mathematical models.

**10.2.8** In the collaborative analysis of roof steel structure and lower supporting structure, the damping ratio shall comply with the following requirements:

**1** For the lower support structures that are steel structures or nature ground, the damping ratio may be taken as 0.02.

**2** For the lower support structures that are concrete structures, the damping ratio may be taken as 0.025~ 0.035.

**10.2.9** The calculation for the horizontal seismic action of roof structure shall be complied with the following requirements:

**1** For the unidirectional-force-transmission system, the horizontal seismic action in the direction along or perpendicular to the major structure may be calculated respectively.

**2** For the space-force-transmission system, at least two principal axis directions shall be selected to calculate the horizontal seismic action simultaneously. For the roof structure that has two or more principal axis or that the distribution of the quality and rigidity is obviously non-symmetrical, the calculation direction of horizontal seismic action shall be increased.

**10.2.10** In general, the calculation of seismic action of roof structure under the frequent earthquake ground motion may be carried out by the mode-decomposition response spectrum method. For the structure with complex configuration or larger span, the multi-directional earthquake response spectrum method or time-history analysis method may also be used as an additional computation. For the regular space truss, plane truss and spatial truss structure with peripheral support or combination of peripheral support and multipoint support, the simplified method for calculation of vertical seismic action may be used according to those specified in Article 5.3.2 of this code.

**10.2.11** The combination for the seismic effect of roof structural components shall be in accordance with the following requirements:

**1** For the unidirectional-force-transmission system, the seismic checking for the capacity of major structural components may be carried out according to the combination of the horizontal seismic effect along the direction of major structures and vertical seismic effect, and the checking for the capacity of braces between structural components may be carried out according to the horizontal seismic effect in the direction perpendicular to the major structures.

**2** For general structures, the combination of three-dimensional seismic action effects shall be used.

**10.2.12** The combination value of deflection of large-span roof structures under the gravity load representative value and the standard value of vertical frequent earthquake ground motion should not exceed the limit value in Table 10.2.12.

**Table 10.2.12 The Limit Value of Deflection of Large-span Roof Structure**

| Structural system | Roof structure (short span $l_1$) | Cantilever structure (cantilever span $l_2$) |
|---|---|---|
| Plane truss, spatial truss, space truss and beam string structure | $l_1/250$ | $l_2/125$ |
| Arch and single-storey reticulated shell | $l_1/400$ | — |
| Double-storey reticulated shell and suspend-dome | $l_1/300$ | $l_2/150$ |

**10.2.13** The seismic checking for capacity of roof components shall comply with the following requirements besides that in Section 5.4 of this code:

**1** The design values of the seismic combination internal force for key components shall be multiplied by amplification factors. The amplification factor should be taken as 1.1, 1.15 and 1.2 for Intensity 7, 8 and 9, respectively.

**2** The design values of the seismic combination internal force for key joints shall be multiplied by amplification factors. The amplification factor should be taken as 1.15, 1.2 and 1.2 5for Intensity 7, 8 and 9, respectively.

**3** The travel cables in pretension structure shall not sag under frequent earthquake ground motion.

Note: For space-force-transmission system, the key components refer to the component close to support, namely, the chord and web member within the minimum scope of 2 zones (grids) and range of 1/10 span close to the support. For the unidirectional-force-transmission system, the key components refer to the chord and web member in the section directly adjacent to the support. Key joints refer to joints connected with key components.

## (III) Seismic Design Details

**10.2.14** The slenderness ratio of roof steel component should be in accordance with those specified in Table 10.2.14:

**Table 10.2.14 The Limit Value for the Slenderness Ratio of Steel Component**

| Component type | Tension | Compression | Bending | Tension-bending |
|---|---|---|---|---|
| General component | 250 | 180 | 150 | 250 |
| Key component | 200 | 150 (120) | 150 (120) | 200 |

Note: 1 Values in parentheses are applied to Intensity 8 and 9;

2 The data in the table is not applicable travel cable and other flexible components.

**10.2.15** The seismic details of the joints of the roof components shall be in accordance with the following requirements:

**1** For the joint that the plate is used to connect components, the thickness of the joint plate should not be less than 1.2 times of the maximum wall thickness of the connected components.

**2** For the through joints, the component with lager internal force shall be thoroughly connected. The wall thickness of the thoroughly-connected components shall not be less than that of any component welded on it.

**3** For the welded spherical joints, the sphere wall thickness shall not be less than 1.3 times of the maximum wall thickness of connected components.

**4** All components should be intersected at the joint center.

**10.2.16** The seismic details of supports shall comply with the following requirements:

**1** The supports shall have adequate strength and rigidity to avoid the damage that the broken of the support is prior to the components and the non-negligible deformation under the expected load. The details of the support joint shall ensure that the forces can be transmitted reliably and the components can be connected simply, and at the same time, it shall be in accordance with the calculation assumption.

**2** For the horizontal slide-able supports, it shall be ensured that the roof sliding does not exceed the support surface under rare earthquake ground motion, and at the same time, the measures for displacement resistance shall be taken.

**3** For Intensity 8 and 9, the supports that only bear vertical pressures under frequent earthquake ground motions should adopt the tension-compression type.

**10.2.17** For the seismic-isolation and seismic energy-dissipation supports that are used in the roof structure, the performance parameters, durability and associated details shall comply with the relevant requirements of Chapter 12 in this code.

# 11 Earth, Wood and Stone Houses

## 11.1 General

**11.1.1** The architectural and structural configuration of earth, wood and stone houses shall be in accordance with the following requirements:

**1** The plane configuration of building with corners or protruding shall be avoided.

**2** The arrangement of transversal and longitudinal walls should be symmetrical, even, and not be staggered-axis along the plain, shall be continued from footing to top, and the widths of all wall-segments between windows in an axis should be equivalent.

**3** For the multi-storey houses, the staggered-floors with significant level differences and the slab-type cantilever stairs shall not be adopted.

**4** Bearing components made of different materials shall not be used at the same level.

**5** Masonry shall not be built on the eave beams.

**11.1.2** For the houses with wood floor or roof, the tying measures shall be taken at the following locations:

**1** Vertical diagonal braces shall be installed in the roof trusses that locate at the both end bays and every other bay in the middle of house;

**2** The horizontal through tie bar in the longitudinal direction shall be arranged at the eave level. The tie bars shall be connected firmly with the transversal walls, the wood beam or the bottom chord of roof truss by the wall-retaining components. The end of the longitudinal horizontal tie bar should be butted by wood splints, and the wall-retaining components may be made of square timber, angle iron and other materials.

**3** The gable wall and pediment wall shall be tied with wood roof truss, wood-frame or purline by the wall-retaining components.

**4** The top of internal partition wall shall be tied with beam or bottom chord of roof truss.

**11.1.3** The supporting length of the wood floor and roof components shall not be less than those specified in Table 11.1.3:

**Table 11.1.3 Minimum Supporting Length of Wood Floor and Roof Components (mm)**

| Component name | Wood roof truss and wood beam | Butted wood joist and wooden purline | | Overlapped wood joist and wooden purline |
|---|---|---|---|---|
| Position | On wall | On roof truss | On wall | On roof truss and wall |
| Supporting length and connecting type | 240 (wood cushion pads) | 60 (wood splint and bolt) | 120 (wood splint and bolt) | Fully overlapping |

**11.1.4** The supporting length of lintel at door and window opening shall not be less than 240mm for Intensity 6~8 and 360mm for Intensity 9.

**11.1.5** For the cold-spreading tile roof, the under-tile should be connected firmly with the rafter by the iron nails through the tack holes at the corners, and the upper-tiles shall be bonded firmly with the under-tiles by lime or cement mortar .

**11.1.6** The height of the easy-collapse components such as chimney, parapet wall and others on the roof of earth, wood and stone houses shall not be greater than 600mm for Intensity 6 and 7, 500mm for Intensity 8 (0.20*g*), and 400mm for Intensity 8 (0.30*g*) and Intensity

9,respectively. And at the same time, the tying measures shall also be taken.

Note: Chimney height on the sloping roof shall be calculated from the upper edge of the chimney foot.

**11.1.7** The structured materials of earth, wood and stone houses shall be in accordance with the following requirements:

**1** Wood members shall be made of those dry and rot-free woods with straight streak, fewer knots.

**2** Unfired earth wall soil shall be the cohesive soil with little dirt.

**3** Stone shall be solid and free from weathering, delamination and crack.

**11.1.8** Construction of earth, wood and stone houses shall be in accordance with the following requirements:

**1** A 180° hook shall be installed at the end of the reinforcement HPB300.

**2** Rust prevention treatment shall be done for the exposed ironworks.

## 11.2 Unfired Earth Houses

**11.2.1** This Section is applicable to the houses with unfired adobe, lime-earth and rammed bearing walls, as well as earth-caves and earth-arch houses for Intensity 6 and 7 (0.10*g*).

Note: 1 Lime-earth wall refers to the wall made of earth added with lime (or other cementing materials) or the wall made of adobe added with lime;

2 Earth-cave refers to the cliff dwelling excavated in the non-disturbed original soils.

**11.2.2** The total height and the space of the load-bearing transversal walls of the unfired earth house shall be in accordance with the following requirements:

**1** The unfired earth houses should be of one storey only. In the zone of Intensity 6 and 7, the two storey houses with lime-earth-walls may be built, but the total height of houses shall not exceed 6m.

**2** For the single-storey unfired earth houses, the height of eave level should not be greater than 2.5m.

**3** For the single-storey unfired earth houses, the space of load-bearing transversal walls should not exceed 3.2m.

**4** The clear span of earth-cave should not exceed 2.5m.

**11.2.3** The roof of the unfired earth house shall be in accordance with the following requirements:

**1** The lightweight roof materials shall be used.

**2** For houses with purlins supported at gable wall, the double-pitch roof or arch-shaped roof should be adopted, and bearing wood plate shall be installed to support purlins. The purlins on gable wall shall extend out of the wall; the purlins on the interior wall shall be overlapped entirely or shall be connected by wood splice pieces or dovetail-dowel-connection.

**3** Members of the wood roof shall be connected each other by nails, cramp iron and galvanized wire.

**4** Wood roof truss and beam should be fully overlapped on the external wall, and wood ring-beam or bearing wood plate shall be installed at the support. The length, width and thickness of the bearing wood plate should not be less than 500mm, 370mm and 60mm, respectively. The mortar or clay stone cushion courses shall be laid under the bearing wood plate.

**11.2.4** The bearing walls of unfired earth houses shall be in accordance with the following requirements:

**1** The width of door and window opening of bearing walls shall not be greater than 1.5m for Intensity 6 and 7.

**2** The wood lintel should be installed at the door and window opening. When the wood lintel is composed of multiple wood poles, all the wood poles shall be connected into integrity by clasp nail, lead wire and other materials

**3** The interior and exterior earth walls of unfired earth-house shall be laid by zigzag joints or rammed simultaneously in each layer. In the four quoins of the exterior wall and the intersection of the exterior wall and the interior wall, a layer of tying materials such as bamboo bundles, timber battens or twigs of the chaste tree etc., should be laid at an interval of 500 mm along height of the wall. The tying materials shall be extended into the wall with the length not less than 1000mm or to the edge of the door and window opening. At the intersection points of the tying materials, banding or other measures to strengthen integrity shall be taken.

**11.2.5** For all types of unfired earth-houses, the subsoil shall be rammed firmly, the rubble stone, slab-stone, chiseled pebble or common brick footing shall be adopted, and the foundation wall shall be built by cement lime mortar or cement mortar. The moisture protection treatment should be done for external wall (wall foundation should be covered with damp-proof course).

**11.2.6** The adobe shall be molded by wet-process, using cohesive soil as raw material and straw and reed shall be added in the soil as tying materials. Adobe shall be built in flat course and mud paste or mud-lime mortar should be used in laying walls.

**11.2.7** For the houses with lime-earth walls, the ring-beam shall be installed in each storey and shall pass through all transversal walls; and step-wise buttress should be added at each side of the gable wall up to the top of the interior longitudinal walls.

**11.2.8** For the earth-arch houses, the multi-span arch structure shall be adopted and arranged continuously, the each arch footing shall be supported on the stable natural ground or artificial earth-walls. Thickness of the earth-arch should be 300~400 mm; the arch shall be laid by use formwork and not be laid by inclined bonds without formwork. For the exterior artificial earth-walls and the earth-arch, the doors or windows shall not be arranged.

**11.2.9** For the construction of earth-caves, sites where land-slides or slumping are liable to occur shall be avoided; the soil of the earth cliff, from which the cave is cut, shall be dense and stable, and the cliff shall be smooth in slope, with no obvious vertical joints. For front of the cliff-cave, no adobe wall or walls of other materials shall be laid as the front wall; caves at different elevations should not be made, otherwise sufficient spacing between each other shall be kept for such caves, and they shall not be in line vertically.

### 11.3 Wood Houses

**11.3.1** This section is applicable to the houses with mortised timber frames, timber trusses and wood columns, or wood columns and wood beams for Intensity 6~9.

**11.3.2** For the wood houses, the mixed structural systems of bearing with wood columns and brick columns or brick walls used simultaneously shall be not adopted. At the gable wall, an end roof truss (or wood beam) shall be installed, and the purlins shall be not supported directly on the top of gable wall.

**11.3.3** The height of wood structure houses shall comply with the following requirements:

**1** For the houses with timber trusses and wood columns or mortised timber frames, the total stories and total height should not exceed two stories and 6m for Intensity 6~8, respectively; and for Intensity 9, the single-storey house with total height not exceeding 3.3m should be built.

**2** The houses with wood columns and beams should be of single-storey only and the height should not exceed 3m.

**11.3.4** For spacious houses of considerable large span, such as auditoriums, theaters and cereal warehouses, three-bay timber frame with four columns should be used.

**11.3.5** The arrangement of roof brace of the timber truss shall comply with the related requirements in Section 9.3 of this code, but the roof braces on both ends of the house shall be installed in the end bay.

**11.3.6** The diagonal brace shall be installed between the wood column and the truss (or beam) in spacious houses; the diagonal brace shall be installed also in non-seismic partition walls in dwelling houses with considerable transverse walls; but brace need not be used in houses with mortised timber frames. Diagonal bracing should be made of both timber plates and extend to the top chord of the truss.

**11.3.7** For the houses with mortised timber frames, along both of longitudinal and transversal direction of houses, a piece of wood shall be installed at both the upper and lower ends of the timber column, passing through and connected with the other column. And one or two diagonal column braces shall be installed in each row of columns in the longitudinal direction of house.

**11.3.8** The connection between the components of wood houses shall comply with the following requirements:

**1** The top of the column shall be mortised to the bottom chord of the truss and connected by means of U-shaped cramp iron. For Intensity 8 and 9, foot of the column shall be anchored in the foundation by use of iron joining means. Depth of the foundations of columns shall be not less than 200mm.

**2** The diagonal braces and roof bracing members shall be connected with main structural members by bolts. Except for the mortised timber members, the connection of other wood members should be adopted bolts.

**3** The connection part of the rafters and the purlins shall be nailed completely to ensure the integrity of the roof. In the case of wood structures, vertical diagonal bracing should be installed above the eaves along the longitudinal direction of the houses, and the aim is to improve the longitudinal stability of the houses.

**11.3.9** The wood components shall comply with the following requirements:

**1** The tip diameter of the wood column should not be less than 150mm. The slotting on the same level of the column in both of longitudinal and horizontal directions shall be avoided; besides, the slotting area on the same section shall not exceed 1/2 of the total section area.

**2** The whole piece wood shall be adopted for the columns.

**3** The penetrating purlins shall through overall of all columns of the wood structure.

**11.3.10** The enclosure walls shall comply with the following requirements:

**1** The tying measures between the enclosure walls and wood columns shall comply with the following requirements:

**1)** The horizontal tying materials inside the walls shall be tied with the wood columns by 8 # steel wire at an interval of 500mm along height of the wall.

**2)** The reinforcement brick ring beams or reinforcement mortar strips shall be tie with wood columns by ø6 bar or 8# steel wire.

**2** The opening widths of the adobe enclosure walls shall be in accordance with the requirements of Section 11.2 in this code. The opening width of the brick enclosure walls should not exceed 1.5m for the transversal walls and internal longitudinal walls, not exceed 1.8m or half of the bay for external longitudinal walls.

**3** The enclosure walls with adobes or bricks shall not enclose the wood columns completely and should be sat outside of the wood columns.

## 11.4 Stone Houses

**11.4.1** This section is applicable to masonry buildings with coursed square stone bearing walls (with or without chips of stone) laid by mortar for Intensity of 6 through Intensity 8.

**11.4.2** Height of each storey of multi-storey stone buildings shall not exceed 3m, and the total height and the number of stories shall not exceed the values as set forth in Table 11.4.2:

**Table 11.4.2 Limit Value for Total Height (m) and Number of stories of Multi-storey stone Building**

| Type of masonry | Intensity 6 | | Intensity 7 | | Intensity 8 | |
|---|---|---|---|---|---|---|
| Fine and semi-fine stone masonry (without chips) | 16 m | 5 stories | 13 m | 4 stories | 10 m | 3 stories |
| Course and gross stone masonry (with chips) | 13 m | 4 stories | 10 m | 3 stories | 7 m | 2 stories |

Note: 1 Determination for total height of building is specified in Note of Table 7.1.2 in this code.

2 Total heights for building with fewer transverse walls shall be reduced by 3m and the storey numbers shall be reduced by one storey correspondingly.

**11.4.3** The storied height of multi-storey stone masonry buildings shall not exceed 3m.

**11.4.4** The spacing of the seismic-wall of multi-storey stone masonry buildings shall not exceed the values as set forth in Table 11.4.4.

**Table 11.4.4 Spacing for Seismic Transverse walls in Multi-storey stone Buildings**

| Type of roofing | Intensity 6 | Intensity 7 | Intensity 8 |
|---|---|---|---|
| In-situ or precast monolithic reinforced concrete slab | 10 | 10 | 7 |
| Precast reinforced concrete slab | 7 | 7 | 4 |

**11.4.5** Multi-storey stone buildings should adopt in-situ cast or precast monolithic reinforced concrete roof and floors.

**11.4.6** The seismic checked of stone wall may refer to Section 7.2 of this code; and its shear strength shall be determined according to data obtained from tests.

**11.4.7** Reinforced concrete tie-columns shall be installed at the four quoins of the exterior wall and of the staircase and the intersections of interior walls and exterior walls in every other bay in multi-storey stone buildings.

**11.4.8** Horizontal sectional area of the opening in a seismic transverse wall shall be not greater than one-third of the gross sectional area.

**11.4.9** Ring-beams shall be installed on the longitudinal and transverse walls in each storey, the depth of which shall not be less than 120 mm, and the width should be the same as the wall thickness. Longitudinal reinforcements in the ring-beam shall be not less than 4ϕ10, and spacing of hoops shall not be exceeding 200 mm.

**11.4.10** At the intersection of the longitudinal wall and transverse wall, where no tie-columns are installed, the dressed rags shall be laid without chip of stone, and steel mesh shall be laid at intervals of about 500 mm along the height of the walls. The mesh of intersection should be extended into the walls on each side with length not less than 1 m.

**11.4.11** Slab-stones shall be not adopted as the bearing components.

**11.4.12** For other relevant detail requirements refer to provisions in Chapter 7 of this code.

# 12 Seismically Isolated and Energy-Dissipated Buildings

## 12.1 General

**12.1.1** This chapter is applicable to designs for the seismically isolated buildings with a seismic isolation layer installed to isolate the horizontal earthquake ground motions, as well as to designs for seismically energy-dissipated buildings with energy-dissipating devices installed to dissipate the seismic energy.

The seismically isolated and seismic energy-dissipated buildings shall comply with the provisions specified in Article 3.8.1 of this code, and the seismic precautionary objectives shall comply with the provisions specified in Article 3.8.2 of this code.

Note: 1 The design of seismically isolated buildings in this chapter refers to the installation of seismic isolation layer with integral reset function, that consists of the rubber isolator units, the damping devices and so on, between the foundation or the lower portion of the structure and the upper portion of the structure. The purpose for the installation of seismic isolation layer is to increase the vibration period of the whole structural system, reduce the seismic energy introduced to the upper portion of the structure by the horizontal earthquake ground motion, and satisfy the expected seismic precautionary requirements.

2 The design of energy-dissipated buildings refers to the installation of energy-dissipating devices in the building structures to dissipate the seismic energy introduced to the structures and satisfy the expected seismic requirements by the additional damping provided by the relative deformation and relative velocity of energy-dissipating devices.

**12.1.2** The design schemes of seismic isolation or energy-dissipation for building structures shall be determined in accordance with the provisions specified in Article 3.5.1 of this code. And furthermore, the design schemes shall be compared with the seismic design schemes.

**12.1.3** The design for the seismically isolated buildings shall comply with the following requirements:

**1** The height-width ratio of the seismically isolated building structure should be less than 4 and shall not be greater than the specific requirements for the non-isolated structures in relevant standards or specifications. The deformation behavior of the seismically isolated structure shall be close to the shear deformation, and the maximum height shall meet the requirements for non-isolated structures in this code. For the seismically isolated structures with the height-width ratio greater than 4 or greater than the specific requirements for the non-isolated structures, special studies shall be carried out.

**2** The seismically isolated buildings shall be located on the site I, II and III with stable foundation types.

**3** The total horizontal force generated by the horizontal load of wind load and other non- earthquake action should not exceed 10% of the total structure gravity.

**4** The seismic isolation layers shall possess necessary load bearing capacity, lateral stiffness and damping. The flexible connections or other effective measures shall be taken for the pipes and wires of equipments through the seismic isolation layers to withstand the horizontal drift of the seismic isolation layers under rarely earthquake ground motions.

**12.1.4** The energy-dissipation design may be applied to the buildings with steel structures, reinforced concrete structures or composite steel and concrete structures.

The energy-dissipating devices shall be able to provide sufficient additional damping to the structures, and shall respectively comply with the requirements for the corresponding structural types in this code.

**12.1.5 For the design for the seismically isolated and energy-dissipated buildings, the seismic isolator units and the energy-dissipating devices shall comply with the following requirements:**

**1 The design parameters of the seismic isolator units and the energy-dissipating devices shall be determined by testing.**

**2 At the location where the seismic isolator units or the energy-dissipating devices are installed, the measures for the convenience of check and renewal shall be taken.**

**3 The property requirements for seismic-isolator units and energy-dissipating devices shall be stated clearly in the design document. The sampling check of prototype shall be carried out before installation to ensure that the properties are in accordance with the requirements.**

**12.1.6** The design for the seismically isolated and energy-dissipated buildings shall also comply with the provisions of relevant special standards, and may also be carried out as performance-based design according to the requirements for seismic performance objectives.

## 12.2 Essentials in Design of Seismically Isolated Buildings

**12.2.1 For the design of seismically isolated buildings, the appropriate seismic isolation layer consisting of seismic isolator units and wind resistance devices shall be selected, according to the excepted vertical bearing capacity, horizontal seismic-reduced factor and the requirements for seismic displacement control.**

**For the seismic isolator units, the check of the vertical bearing capacity and the horizontal displacement under rarely earthquake ground motions shall be carried out.**

**For the upper portion of the structure, the horizontal seismic action shall be determined according to the horizontal seismic-reduced factor, and the standard values of vertical seismic action shall be not less than 20%, 30% and 40% of the total gravity representative values of the upper portion of the structure for Intensity 8 (0.20*g*), Intensity 8 (0.30*g*) and Intensity 9, respectively.**

**12.2.2** The calculation analysis for the design of seismically isolated buildings shall comply with the following requirements:

1 The mass points composed of seismic isolator units and the beam-slab system above it shall be added in the calculation model of the seismically isolated structure system. For the upper structure with deformation behavior of shear pattern, the calculation model of the seismically isolated building may adopt the shear type model (Figure 12.2.2). When the gravity center of the structure above the isolation layer and the rigidity center of the isolation layer are not in a line, the influence of torsion deformation shall be taken into consideration. The beam-slab structures above the isolation interface shall be deemed as a part of the structure above the isolation layer for calculation and design.

**2** In generally, the time-history analyzing method should be used for the seismic calculation; the response spectrum characteristics and amount of the input seismic waves shall comply with the provisions in Article 5.1.2 of this code; the design result should choose the envelope value. When the building is located within 10km of the causative fault, the calculation results shall be multiplied by the following near-field affected factors, and the factors should be taken as 1.5 for the fault distance ≤5km, and not less than 1.25 for the fault distance >5km.

**3** For the masonry structures and the similar structures with equivalent foundational period, the seismic calculation may be carried out by the simplified methods specified in the Appendix L of this code.

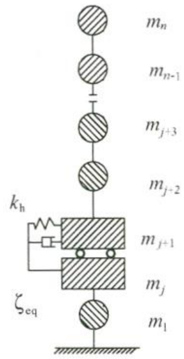



**Figure 12.12.2 Calculation sketch for Seismically Isolated Structure**

**12.2.3** The rubber seismic isolator units of the seismically isolation layer shall comply with the following requirements:

**1** The ultimate horizontal displacement of the robber seismic isolator unit under the compressive stress listed in Table 12.2.3 shall be greater than the greater value of the 0.55 times of its effective diameter and 3 times of the total thickness of all rubber layers.

**2** After passing the durability tests of corresponding design reference period, the stiffness and damping characteristic variations of seismic isolator unit shall not exceed ±20% of the initial value, and the creep shall not exceed 5% of the total thickness of all rubber layers.

**3** The vertical compressive stress of rubber seismic isolator units under the gravity load representative values shall not exceed the provisions in Table 12.2.3.

**Table 12.2.3 Limit values of Compressive Stress for Rubber Isolator unit**

| Building category | A | B | C |
|---|---|---|---|
| Limit values of compressive stress (MPa) | 10 | 12 | 15 |

Note: 1 The design value of compressive stress shall be determined by the combination of permanent load and variable load, in which, the floor live loads shall be multiplied the reduction factors according to the provisions of the national standard *Load Code for the Design of Building Structures* GB5009.

2 For structures that need to check overturning, the horizontal seismic action combination shall also be taken into consideration. For structures that need to calculate the vertical seismic action, the vertical seismic action combination shall also be taken into consideration.

3 For the rubber isolator units with secondary form-factor, (that is the ratio of the effective diameter to the total thickness of all rubber layers) less than 5.0, the limit value of compressive stress shall be reduced by 20% for the factor less than 5 but not less than 4 ,and by 40% for the factor less than 4 but not less than 3.

4 For the rubber isolator units with outer diameter less than 300mm in the buildings assigned to Category C, the limit values of the compressive stress shall be taken equal to 10MPa.

**12.2.4** The arrangement, vertical bearing capacity, lateral stiffness and damping of the seismic-isolation storey shall comply with the following requirements:

**1** The seismic-isolation storey should be installed at the bottom or the lower portion of the structure. The rubber isolator units shall be placed at locations where the interior forces are greater, the spaces of the isolator units should be not too large; and the size, amount and distribution of the isolator units shall be determined according to the requirements of the vertical bearing capacity, the lateral stiffness and the damping. The seismic-isolation layer shall be stabilized under rarely earthquake ground motion, and should not have non-restorable deformations. The tensile stress of the rubber isolator units under the horizontal and vertical ground motion of rarely earthquake simultaneously shall not be greater than 1MPa.

**2** The horizontal dynamic stiffness and effective damping ratio of the seismic isolation layer may be calculated according to the following equations:

$$K_h = \Sigma K_j \tag{12.2.4-1}$$

$$\delta_{eq} = \Sigma K_j \delta_j / K_h \tag{12.2.4-2}$$

Where $\delta_{eq}$——— Effective damping ratio of the seismic isolation layer.

$K_h$——Horizontal dynamic stiffness of the seismic isolation layer

$\delta_j$—— Effective damping ratio of the $j$-th isolator unit determined by testing; when damper is set up independently, corresponding damping ratio of the damper shall also be taken into account.

$K_j$——Horizontal dynamic stiffness of the $j$-th isolator unit determined by testing.

**3** When the design parameters of the isolator units are to be determined by testing, the vertical load shall keep the limit values of compressive stress of provision in Table 12.2.3. For the calculation of horizontal seismic-reduced factors, the effective stiffness and effective damping ratio at the 100% shear deformation of the unit shall be adopted. For checking of frequently earthquakes, the effective stiffness and effective damping ratio at the 250% shear deformation of the unit shall be adopted, and if the diameter of isolator unit is relatively greater, the effective stiffness and effective damping ratio at the 100% shear deformation of the unit may also be adopted. For the time-history analysis, the hysteretic curves determined by test shall be adopted.

**12.2.5** The calculation of seismic actions for the upper portion of the structures shall comply with the following requirements:

**1** For multi-storey structures, the horizontal seismic actions may be distributed according to ratio of the gravity load representative values along the height of structure.

**2** The horizontal seismic influence coefficient used for the calculation of the horizontal seismic actions for the upper portion of the structures may be determined according to the provisions in Article 5.1.4 and 5.1.5 of this code. Herein, the maximum value of the horizontal seismic influence coefficient may be calculated according to following equations:

$$\alpha_{max1} = \beta \alpha_{max} / \psi \tag{12.2.5}$$

Where $\alpha_{max1}$——Maximum value of horizontal seismic influence coefficient after seismic isolation;

$\alpha_{max}$——Maximum value of horizontal seismic influence coefficient of non-seismic isolation, which may be adopted according to those specified in Article 5.1.4 of this code.

$\beta$——Horizontal seismic-reduced factor. For multi-storey building, the horizontal seismic-reduced factor shall be taken as the maximum value of the ratio of the storey shears in isolation system to that in non-isolation system calculated by elastic analysis. For the high-rise building structures, the horizontal seismic-reduced factor shall be taken as the greater value of the maximum storey shear ratio and the maximum over-turning moment ratio.

$\psi$——Modification factor; it shall be taken equal to 0.80 for general rubber units and 0.85 for the rubber units with the shearing performance deviation Category S-A. For the seismic isolator units with dampers, it shall correspondingly reduce 0.05.

Note: 1 During elasticity calculation, the simplified calculation and response spectrum analysis should be carried out according to the performance parameters at the 100% horizontal shear strain of units. The time-history analysis shall be carried out according to the design basic acceleration of earthquake ground motion;

2 The shearing performance deviation of unit shall be determined according to the current national standard GB 20688.3 "*Rubber Bearing—Part 3: Elastomeric Seismic-protection Isolators for Buildings*".

**3** The total horizontal seismic action of the upper portion of the structure shall not be lower than that of non-isolated structure for Intensity 6. The horizontal storey shear force of each storey shall also comply with the provisions regarding the minimum shear force factors in Article 5.2.5 of this code.

**4** The calculation of the vertical seismic action of the upper portion of the structures shall be carried out for Intensity 9 or for Intensity 8 with the horizontal seismic-reduced factor 0.30.

When calculating the vertical seismic action characteristic values of the upper portion of the structures, each storey may be deemed as a mass, and the vertical seismic action characteristic values may be distributed over the height of structure in accordance with the Equation (5.3.1-2) of this code.

**12.2.6** The shear force of the isolator unit shall be determined by the total horizontal shear of the seismic-isolation layer under the rarely earthquake that shall be distributed among the isolator units according to their horizontal stiffness. When the torsional effects were included in the calculation, the torsion stiffness of the isolator unit shall been taken into consideration.

The horizontal displacement of the isolator unit of seismic-isolation layer under the rarely earthquakes shall comply with the following requirements:

$$u_i \leq [u_i] \tag{12.2.6-1}$$

$$u_i = \varepsilon_i u_c \tag{12.2.6-2}$$

Where $u_i$——Horizontal displacement of the *i*-th isolator unit including the torsional effects under the rarely earthquakes.

$[u_i]$——Limit value of horizontal displacement of *i*-th isolator unit. For the rubber isolator unit, it shall not exceed the smaller value of the 0.55 times of the effective diameter of the unit and 3 times of the total thickness of all rubber layers.

$u_c$——The horizontal displacement of the center of the seismic-isolation layer not including the torsional effects under rarely earthquakes.

$\varepsilon_i$——Torsional factor of the *i*-th seismic-isolator unit, that shall be taken as the ratio of the calculated displacement including torsional effects to that not including torsional effects. When the mass center of the upper portion of structure and the rigidity center of the seismic-isolation layer are not eccentric in both major axial directions, the torsional factor of the side unit shall not be less than 1.15.

**12.2.7** The details of the seismically isolated structures shall meet the following requirements:

**1** The following details shall be taken in order to avoid the restraining for the large deformation of the seismic-isolation layer under rarely earthquakes:

1) The isolation joints shall be installed along the perimeter of the upper portion. The width of the joint should be taken as 1.2 times of the maximum horizontal displacement of the each seismic-isolator unit under the rarely earthquake, and should not be less than 200mm. For the adjacent seismically isolated structures, the width of the joint shall be taken as the summation of the maximum horizontal displacements of the two seismic-isolation layers unit under the rarely earthquake, and shall not be less than 400mm.

2) Full-through horizontal isolating joint shall be installed between the upper portion and the lower portion of the structure. The joint height may be taken as 20mm and the joint shall be filled with flexible materials. When it is difficult to install horizontal isolating joint, a reliable horizontal slipped cushion shall be installed.

**3)** For the locations where the corridors, the staircase, and the elevators etc. passing the seismic-isolation layer, effective measures shall be taken to avoid the possible pounding.

**2** The seismic measures of the upper portion of the structure shall comply with the requirements for the non-isolated structures of this code for the structure with horizontal seismic-reduced factor greater than 0.40 (0.38 when damper is installed). For the structures with horizontal seismic-reduced factors not greater than 0.40 (0.38 when damper is installed), the seismic measures of upper portion may be taken as the requirements of non-isolated provisions with properly loosening, but the reduction degree shall not exceed one grade lower than that of the local precautionary intensity, and the vertical seismic detail requirements shall not be loosened.

For masonry structures, seismic-measures may be taken according to Appendix L of this code.

Note: The vertical seismic detail requirements refer to the requirements for the axial compression ratio of walls and columns for reinforced concrete structures, and the requirements for the minimum size of the end of walls and ring beams for masonry structures.

**12.2.8** The connection between the seismic-isolated layer and the upper portion of structure shall comply with the following requirements:

**1** Beam-slab type floor shall be installed on top of the seismic-isolation layer, and shall comply with the following requirements:

1) Cast-in-place concrete floor slab shall be adopted; the thickness of the in-situ slab shall not be less than 160 mm.

2) The stiffness and the bearing capacity of the beams and slabs on the top of the seismic-isolation layer shall be greater than that of ordinary beams and slabs;

3) The punching-shear and local-compression capacity of the beams and columns near the isolator units shall be checked. The hoops of the beams and columns shall be densified and mesh reinforcements shall be installed if necessary.

2 The connected details of the isolator units and the dampers shall comply with the following requirements:

1) The isolator units and the dampers shall be installed at the locations where the maintenance personnel can access easily.
2) The connected elements of the isolator unit with the upper portion and the lower portion of the structure shall be able to transfer the maximum horizontal shear force and moment of the isolator unit under rarely earthquake.
3) The exposed embedded iron elements shall have reliable anti-rust treatment. The anchoring reinforcement of the embedded elements shall be connected to the steel plate firmly, the developed length of the anchoring reinforcement should be greater than 20 times of diameter of the anchoring bar or 250mm, whichever is greater.

**12.2.9 The lower portion of the structure and the foundation shall be in accordance with the following requirements:**

**1 The seismic check of loading capacity for the buttresses, the pillars and the connected elements shall be carried out according to the vertical force, horizontal force and moment at the bottom of the isolator units under rarely earthquakes.**

**2 The relevant components of the lower portion (including basement and the base-plate of tower) of structure that directly support the upper portion, shall comply with the requirements of rigidity ratio for fixed ends, the requirements of earthquake resistant capacity that ensure the components still in elastic phase under precautionary earthquakes including the seismically isolation effects, and the requirements of shear bearing capacity that ensure the sections of the components remain integrity under rarely earthquakes. The storey drift of the lower portion of the structure above ground under rarely earthquakes shall be in accordance with the requirements specified in Table 12.2.9.**

**3 The seismic check for the foundation and the foundation treatment of the seismic-isolated buildings shall be carried out according to the local Intensity. The anti-liquefaction measures for buildings assigned to Category A and B shall be determined according to one grade higher than the liquefaction grade, until all liquefaction settlements are eliminated.**

**Table 12.2.9 The Limit Value of the Elasto-Plastic Storey Drift of Lower Portion of Structure Above Ground under Rarely Earthquakes**

| The structure type of lower portion | $[\theta_p]$ |
|---|---|
| Reinforced concrete frame structure and steel structure | 1/100 |
| Reinforced concrete frame-seismic wall | 1/200 |
| Reinforced concrete seismic wall | 1/250 |

## 12.3 Essentials in Design of Seismic-energy-dissipated Buildings

**12.3.1** For the seismic energy-dissipating buildings, the proper energy-dissipating components shall be installed according to the structural expectance displacement under rarely earthquakes. The energy-dissipating components may be consisted of the energy-dissipating device and the diagonal bracing, the wall, the beam or joints. The energy-dissipating device may adopt the speed-related type, the displacement-related type or other types.

Note: 1. The speed-related type energy-dissipating device refers to the viscous energy dissipating device and viscoelastic energy-dissipating device etc.;

2. The displacement-related type energy-dissipating device refers to metal yield energy dissipating device and friction energy dissipating device etc.

**12.3.2** The energy-dissipating components may be installed along the two main axis of the structure respectively if necessary. The energy-dissipating components shall be installed at locations where the storey drift is significant, its number and distribution shall be determined according to comprehensive analysis, and shall be favorable for increasing the energy-dissipating capacity and for composing an even and reasonable lateral-force-resistant system of the whole structure.

**12.3.3** The calculating analysis of the energy-dissipated building structures shall comply with the following provisions:

**1** When the main structure is basically in elastic working stage, the linear analysis method may be adopted for simplified estimation. The linear analysis method may be the base-shear method, mode analysis response spectrum method or time-history analysis method specified in Section 5.1 of this code according to the deformation characteristics and height of the structure. The seismic influence coefficient can be adopted according to the provisions in Article 5.1.5 of this code, which depend on the total damping ratio of the energy-dissipated building structures.

The period of the energy-dissipated building structure shall be determined according to the total stiffness of the energy-dissipated structure. The total stiffness shall be the total sum of the structural stiffness and the effective stiffness of the energy-dissipating components.

The total damping ratio of the energy-dissipated structure shall be the total sum of the structural damping ratio and the effective damping ratio added to the structure by the energy dissipating components. The total damping ratio under frequently earthquake and rarely earthquake shall be calculated respectively.

**2** When the main structure is in elasto-plastic stage, the static nonlinear analysis method or nonlinear time-history analysis method shall be adopted according to the characteristic of main structure.

In nonlinear analysis, the restoring-force characteristic model of the energy-dissipated building structure shall include that of structure and that of the energy-dissipating components.

**3** The limit value of the elasto-plastic storey drift of the energy-dissipated structure shall comply with the structural expectance displacement requirements, and should be properly smaller than that of the non-energy dissipated structure.

**12.3.4** The effective damping ratio and effective stiffness added to the structure by energy-dissipating components may be determined according to the following methods:

**1** The effective stiffness added to the structure by the displacement-related type energy-dissipating components and nonlinear speed-related type energy-dissipating components shall be determined by equivalent linear method.

**2** The effective damping ratio added by the energy dissipating components, may be estimated with the following equation:

$$\xi_a = \sum_j W_{cj} / (4\pi W_s) \qquad (12.3.4\text{-}1)$$

Where $\xi_a$ ————Effective damping ratio added by the energy dissipating components.

$W_c$——Energy dissipated by all energy-dissipated components in one cycle of expected displacement of the structure.

$W_s$——Total strain energy of energy-dissipated structures under expected displacement.

**3** When the torsion effect is not taken into consideration, the total strain energy of the energy- dissipated structure under horizontal seismic action can be estimated with the following equation:

$$W_s = (1/2)\sum F_i u_i \qquad (12.3.4\text{-}2)$$

Where $F_i$————Horizontal seismic action characteristic value of i-th mass;

$u_i$ ——Displacement of $i$-th mass corresponds to horizontal seismic action characteristic value.

**4** The energy dissipated by the linear speed-relating type energy-dissipating device under horizontal seismic action can be estimated with the following equation:

$$W_{cj} = (2\pi^2/T_1)\sum C_j \cos^2\zeta_j \Delta u_j^2 \qquad (12.3,4\text{-}3)$$

Where $T_1$ ———Foundational vibration period of the energy-dissipated structure.

$C_j$——Linear damping factor determined by testing for $j$-th energy-dissipating device.

$\zeta$——Angel between the energy-dissipating direction and the horizon for $j$-th energy-dissipating device.

$\Delta u_j$——Relative horizontal displacement at the two ends of $j$-th energy-dissipating device.

When the damping factor and effective stiffness of the energy-dissipating device have dependent on the structure vibration period, the value corresponding to the foundational vibration period of the energy-dissipated structure may be selected.

**5** The energy dissipated by displacement-related type, speed non-linear-related type and other types of energy-dissipating devices can be estimated with the following equation:

$$W_{cj} = \sum A_j \qquad (12.3.4\text{-}4)$$

Where $A_j$ ————The area of restoring-force characteristics of the $j$--th energy-dissipating device at the relative horizontal displacement $\Delta u_j$.

The effective stiffness of energy-dissipating devices can be the secant stiffness of restoring-force characteristics of the $j$--th energy-dissipating device at the relative horizontal displacement $\Delta u_j$.

**5** When the effective damping ratio added to the structure by the energy-dissipating components exceeds 25%, it should be counted according to 25%.

**12.3.5** The design parameters of the energy-dissipating components shall comply with the following provisions:

**1** For energy-dissipating components consisted of the speed-related energy-dissipating device with support members such as the diagonal, wall or beam, the stiffness of the energy-dissipating components in the direction of energy-dissipating device shall satisfy the following requirement:

$$K_b \geq (6\pi/T_1)C_D \quad (12.3.5\text{-}1)$$

Where $K_b$————Stiffness of the energy-dissipating component in the direction of the energy dissipating device.

$C_D$——Linear damping factor of the energy-dissipating device.

$T_1$——Foundational vibration period of the energy-dissipated structure.

**2** The total thickness of viscoelastic materials in viscoelastic energy-dissipated devices shall satisfy the following equation:

$$t \geq \Delta u / [\gamma] \quad (12.3.5\text{-}2)$$

Where $t$——Total thickness of viscoelastic materials in viscoelastic energy-dissipated devices;

$\Delta u$——Maximum possible drift along the direction of energy-dissipated devices;

$[\gamma]$——Maximum allowable shear strain of viscoelastic materials.

**3** For energy-dissipating components consisted of the displacement- related energy-dissipating device with the support members such as the diagonal, wall or beam, the restoring force characteristic model parameters of this component shall comply with the following requirements:

$$\Delta u_{py} / \Delta u_{sy} \leq 2/3 \quad (12.3.5\text{-}3)$$

Where $\Delta u_{py}$———Yield displacement of energy-dissipating component.

$\Delta u_{sy}$——Yield storey drift of energy-dissipated structure.

**4** The ultimate displacement of energy-dissipated device shall not be less than 1.2 times of the maximum displacement of energy-dissipated devices under rarely earthquakes. The ultimate speed of energy-dissipated device shall not be less than 1.2 times of the maximum speed of energy-dissipated devices under earthquake ground motion, and the bearing capacity requirements under the ultimate speed shall also be satisfied.

**12.3.6** The tests of energy-dissipated devices shall comply with the following requirements:

**1** For the viscous fluid energy-dissipated devices, the sampling check shall be carried out by the third party. The quantity shall be 20% of the sum of each specification in the same project, and shall not be less than 2. The quality rate of the sampling check shall be 100%. The energy-dissipated devices after sampling check may be used in the major structures.

For other type energy-dissipated devices, the quantity of sampling check shall be 3% of the sum of each specification, and may be 3% of the sum of each type when the sum of each specification are few, but total quantity shall not be less than 2. The quality rate of the sampling check shall be 100%. The energy-dissipated devices after sampling check shall not be used in major structures.

**2** For the speed-related type energy-dissipated devices, under the design displacement and the design speed value and repeated 30 cycles in the loading frequency as the basic frequency of structure, the error and decrement of the main design index of energy-dissipated device shall not be greater than 15%.

For the displacement-related type energy-dissipated devices, under design displacement value and repeated 30 cycles, the error and decrement of the main design index shall not be greater than 15%, and shall not have obvious low-cycle fatigue.

**12.3.7** For the energy-dissipated building structures**,** the relevant parts of the energy dissipation component shall be in accordance with the following requirements:

**1** The connection between energy-dissipated device and supporting component shall be in accordance with the detail requirements of component connection in this code and relevant specifications.

**2** The connection component between energy-dissipated device and main structure shall be within elastic range under the maximum damping force acted on the main structure by energy-dissipated device.

**3** For the design of the structural components connected with the energy dissipation components, the additional internal force transferred by the energy dissipation components shall be taken into account.

**12.3.8** When the seismic performance of the energy-dissipated building structure is obviously higher than that of non-energy-dissipated structure, the seismic detail requirements for the main structure may be properly reduced. The reduction degree may be determined according to the ratio of the seismic influence coefficient of the energy-dissipated structure to that of the non-energy-dissipated structure, but the reduction degree shall be controlled within one grade lower than that of the local precautionary intensity.

# 13 Nonstructural Components

## 13.1 General

**13.1.1** This chapter is mainly applicable to the connection of nonstructural components with the building structure. The nonstructural components include the permanent building nonstructural components and auxiliary mechanical and electrical equipments supported on building structure.

Note: 1 Nonstructural components of building refer to the fixed components and parts except the load-bearing skeleton system in the building, mainly include non-bearing wall, components attached to the floor and roof structure, decorating components and parts ,and large-sized storage racks fixed on the floor, etc..

2 Auxiliary mechanical and electrical equipments of building refer to the mechanical and electrical members, parts and systems serving the functions of modern buildings, mainly include elevators, lighting, emergency power, communication facility, pipeline, heating and air-conditioning system, smoke and fire monitoring and protection system, and community antenna.

**13.1.2** The different seismic-measures for nonstructural components shall be taken according to the Category of the building, the consequence and the range of influence to the whole building structure due to nonstructural components earthquake damage, in order to reach the corresponding performance-based design objective.

In order to reach the performance-based design objective for the nonstructural components and auxiliary mechanical and electrical equipments of building, some methods specified in Section M .2 of Appendix M in this code may be used.

**13.1.3** When two nonstructural components with different seismic requirements are connected together, the seismic design shall be carried out according to the higher requirements. Herein, when the connections of one nonstructural component are damaged, the damage shall not cause the failure of the other adjacent nonstructural component with higher requirements.

## 13.2 Basic Requirements for Calculation

**13.2.1** The influence of nonstructural components shall be taken into consideration during the seismic calculation of building structure according to the following requirements:

**1** When calculating the seismic action, the gravity of architectural members and the mechanical and electrical equipment attached to the structural members shall be taken into consideration.

**2** For architectural members using flexible connection, the stiffness may not be taken into consideration. For rigid nonstructural components filled in the lateral-force-resisting member plane, the stiffness influence shall be taken into consideration by adopting simplified methods such as the period adjustment.

In generally, the seismic bearing capacity of nonstructural components shall not be taken into consideration. While special measures have been taken for the nonstructural components, the seismic bearing capacity may be taken into consideration according to relevant specifications.

**3** For structural components supporting nonstructural components, the seismic action of nonstructural components shall be regarded as additional action and the anchoring requirements of connection shall be satisfied.

**13.2.2** The calculating method of seismic action for the nonstructural components shall be in accordance with the following requirements:

**1** The seismic force of all members and components shall be applied at its center of gravity, and the horizontal seismic force shall be applied non-concurrently in any horizontal direction.

**2** In generally, the seismic action produced by nonstructural components themselves can adopt the equivalent lateral-force method for the calculation. For nonstructural components supported in the different floors or the two sides of the isolation joints, besides considering the seismic action produced by the self-gravity, the effect of the relative displacement appeared between all supporting points shall be taken into consideration simultaneously.

**3** For the auxiliary facility of building (including bracket), that the system natural vibration period is greater than 0.1s and its gravity exceed 1% of weight of the storey it located or the gravity exceeds 10% weight of the storey it located, the whole structure model should be used for the seismic calculation, and the Floor Response Spectrum(FRS) method specified in Section M.3 in Appendix M of this code may also be used. Herein, for the equipment non-elastically connected with the floor of the building, the equipment and the floor can be deemed as a mass in calculation for whole structure, and such the seismic action of equipment may be obtained.

**13.2.3** When equivalent lateral-force method is adopted, the characteristic value of the horizontal seismic action should be calculated according to the following equation:

$$F = \gamma\eta\zeta_1\zeta_2\alpha_{\max}G \tag{13.2.3}$$

Where: $F$——The horizontal seismic action characteristic value centered at the center of gravity of the nonstructural components in the most unfavorable direction.

$\gamma$——Functional factor of the nonstructural components, which shall be determined according to relevant standards or the provisions in Section M.2 of Appendix M in this code.

$\varepsilon$——Type factor of nonstructural components, which shall be determined according to relevant standards or the provisions in Section M.2 of Appendix M in this code.

$\delta_1$——Factor of state, in cases such as precast members, cantilever members, any equipment braced to structural member lower its center of mass, and flexible systems, the factor should be taken as 2.0, and in other cases may be taken as 1.0.

$\delta_2$——Factor of location. The factor should be taken as 2.0 for the top of structures, 1.0 for the bottom, and linear distribution along the height of structures. For the structures that need adopt the time-history analyzing method to carry out calculations according to the provision in Section 5.1 of this code, the factor shall be adjusted dependent to the results of calculation.

$\alpha_{\max}$——The maximum value of seismic influence coefficient, that may be adopted in accordance with the provision for frequently earthquakes in Article 5.1.4 of this code.

G——Gravity of nonstructural components, it shall include the gravity of relevant personnel, media in the container and tube during operations, as well as the gravity of the storage cabinet.

**13.2.4** The internal force, which produced by the relative horizontal displacement between the supporting points of the nonstructural component, shall be calculated. That may be determined by using the product of the stiffness of the component in the displacement direction and the nominal relative horizontal displacement between the supporting points.

The stiffness of the nonstructural component in the displacement direction shall be determined based on the practical connected state, which may be adopted simplified mechanic models such as rigid connection, hinge connection, elastic connection or sliding connection.

The relative horizontal displacement between the adjacent both floors may be determined according to the limit values of storey-drift of structure specified in this code.

**13.2.5** The basic combination of the seismic effect and other loading effect of nonstructural components shall be determined according to the provision in Section 5.4 of this code. For the curtain walls, the wind loading effect shall also be combined; for the containers, the temperature effect of equipment operation and the working pressure shall also be taken into consideration.

For seismic checking of nonstructural components, the frictional resistance shall not be taken into consideration. The seismic adjustment factor of the bearing capacity may be taken as 1.0.

## 13.3 Basic Seismic-Measures for Architectural Members

**13.3.1** In building structures, the locations installing the embedded and anchoring iron elements that are used to connect the architectural members such as curtain, enclosure, separation wall, parapet, awning, signs, billboards, ceilings and large-sized storage cabinets, shall be strengthened to resist the seismic action transferred by the nonstructural components.

**13.3.2** The materials, types and arrangement of non-bearing walls shall be determined through comprehensive analysis according to the Intensify, height of the building, configuration of the building, storey drift of the structure, and the lateral-force-resisting performance of the wall itself, and shall also comply with the following requirements:

**1** The non-bearing wall shall first adopt lightweight wall materials. When the masonry walls are adopted, measures shall be taken to reduce unfavorable influence on the seismic-force-resisting system, and the tie-bars, the horizontal tie-bands, the ring-beams, and the tie-columns shall be installed to ensure reliable tying with the seismic-force-resisting system.

**2** The arrangement of rigid non-bearing walls shall try to avoid abrupt changes in the stiffness and strength of the structure. When the enclosure walls are asymmetrically and uniformly arranged at the plane of buildings, the unfavorable influence of the enclosure walls on the seismic performance of main structure due to the difference of quality and rigidity, shall be taken into consideration

**3** The walls shall be tied reliably to the seismic-force-resisting system and shall be able to suit the storey drift of any direction of seismic-force-resisting system. For intensity 8 or 9, the walls shall have the capability of deformation to satisfy the requirements of storey drift; and the walls shall also have the capability to satisfy the requirements of vertical deflection due to joint- zone rotation of adjacent cantilever structural members.

**4** The connected part of the exterior wall panels shall have sufficient ductility and proper rotating capability so that the requirements for storey drift of the seismic-force-resisting system under the fortification earthquake can be satisfied.

**5** The masonry parapet walls that located at the entrances, exits and the passageways shall be anchored with the seismic-force-resisting structural system. For the major masonry parapet walls that located at other positions, the height of walls without anchorage should not be greater than 0.5m for Intensity 6~8, and the anchorage measures must be taken for Intensity 9. For the major masonry parapet walls that located at seismic joints, the clear width of the seismic joints shall be sufficient, and the free ends of parapet at the two sides of the joints shall be intensified.

**13.3.3** In the multi-storey masonry structures, the nonstructural components of building such as non-bearing walls shall be in accordance with the following requirements:

**1** The post-laying non-bearing partition walls shall have 2ϕ6 tie-bars in each 500mm along the height of the wall for tying with the load-bearing wall or the column, and shall be extended into each wall with length not less than 500mm. For Intensity 8 and 9, the length of the post-laying partition walls is greater than 5m, the top of these walls shall be tied together with the slabs or beams. The reinforced concrete tie-columns should be installed at the limb ends of independent walls and the edges of larger door openings.

**2** The flue, air duct, and refuse chute shall not weaken the structure walls; otherwise, strengthening measures shall be taken. The chimney without vertical reinforcements, which is adhered to wall or has a height exceeding the roof surface, should not be adopted.

**3** The precast reinforcement concrete eaves plate without anchorage shall not be used.

**13.3.4** The masonry filling walls in the reinforcement concrete structures shall comply with the following requirements:

**1** The arrangement of filling wall in plane and vertical directions should be symmetrical and even to avoid producing weak storey or short columns.

**2** The strength grade of the mortar used for the masonry shall not be lower than M5, the brick strength grade should not be glower MU2.5 and MU 3.5 for solid brick and hollow block, respectively. The top of the wall shall combine with the frame beam closely.

**3** The 2ϕ6 tie-bars, which in each 500mm along the height of the filling wall, shall be installed. And the tie-bar length extended into the wall should be the full length of the wall for Intensity 6 and 7, and shall be the full length of the wall for Intensity 8 and 9.

**4** When the length of the filling wall is greater than 5m, the top of the wall shall be tied with the beam; when the length of the wall exceeds 8m or 2 times of the filling wall height, tie-columns shall be installed. When the height of the filling wall is more than 4m, the horizontal tie-band shall be installed at the half height of the wall and be connected to column on both ends of wall.

**5** The filling walls located at the staircases or passageways shall be strengthened with steel mesh mortar layer at the same time.

**13.3.5** Masonry partition walls and enclosure walls of single-storey reinforced concrete column factory buildings shall comply with the following requirements:

**1** The enclosure walls should adopt lightweight wall panel or large-sized reinforced concrete wall panel; the masonry enclosure walls shall be arranged at the outside of the column and tied reliably with the column; when the spacing of the side-columns is 12m, lightweight wall panels or large-sized reinforced concrete wall panels shall be adopted.

**2** The rigid enclosure walls in the longitudinal direction of the factory building should be even and symmetrical. The arrangement type should not be outer-bonded type for one side and built-in type or opening type for the other side. The wall material should not adopt masonry for one side and light wall board for the other side.

**3** The high span enclosing wall of factory buildings with different heights and the suspending wall at the intersection of longitudinal and transversal factory units should adopt lightweight wall panels. For Intensity 6 and 7, the masonry wall may be used, but it shall not be built on the lower roof directly.

**4** Cast-in-place reinforced concrete ring beams shall be installed at the following positions for the masonry enclosure wall:

**1)** The ring-beam shall be installed at the levels of top chord of the trapezoid truss end and the top of the column, respectively; however, when the height of the truss end post is not greater than 900mm, the two ring-beams above may be incorporated into one ring-beam.

**2)** A ring-beam shall be additionally installed at the top level of the window in each 4 m approximately, according to the principle that the vertical spacing of the ring-beam in upper portion is smaller than that in lower portion. Meanwhile, for the fascia walls above lower roof level of factory buildings with different heights and the suspending walls at the intersection of longitudinal and transversal units, the vertical spacing of the bring-beam shall not be greater than 3m.

**3)** A ring-beam shall be installed on the gable wall along the roof level, and shall be connected with the ring-beam at top chord level of roof truss end.

**5** The details of the ring-beam shall comply with the following requirements:

**1)** Ring-beam should be enclosed. The beam width should be the same as the thickness of the wall, the beam depth shall not be less than 180mm, and the longitudinal reinforcement shall not be less than 4$\phi$12 for Intensity 6, 7, 8 and than 4$\phi$14 for Intensity 9.

**2)** For the bring-beam on the level of column top that located at the corner of the factory unit, the longitudinal reinforcements within the scope of the end bay should not be less than 4$\phi$14 for Intensity 6, 7, 8 and 4$\phi$16 for Intensity 9; and the hoops within the length of 1m on the two sides of the corner should satisfy the requirements that the diameter should not be less than $\phi$8 and the spacing shall not be greater than 100mm. At least, three horizontal diagonal bars with the diameters same as the longitudinal bars shall be added to the corner of the ring beam.

**3)** Ring-beam shall be firmly connected with the column or the roof truss, the ring-beam of the gable shall be tied with the roof slabs. The anchoring bars connecting the top ring-beam with the column or roof truss should not be less than 4$\phi$12 with an anchoraged length not less than 35 times of the bar diameter.

At the seismic joints, the tying between the ring-beam with the column or the roof truss should be intensified.

**6** The wall-beam should adopt in-situ cast beam. If precast beams are adopted for wall-beams, the bottom of the beams shall be firmly tied with the top of the brick walls, and the end of the beams shall be tied with the columns. The two adjacent wall-beams at the corner of the factory building shall be firmly connected with one another.

**7** The masonry partition wall shall be separated from the columns or flexibly connected with the columns, and necessary measures shall be taken to ensure the stability of the wall, in-situ cast reinforced concrete coping shall be installed on the top of the partition wall.

**8** For Intensity 8 with Site class III and IV or Intensity 9, the precast foundation beam of the brick enclosure wall shall adopt in-situ cast joints. When stripped footing of enclosure wall is established, continuous in-situ cast reinforced concrete ring-beams shall be installed at the level of the top of column footing, and the reinforcement of ring-beam shall not be less than 4$\phi$12.

**9** The height of masonry parapet wall should not be larger than 1m and necessary measures to prevent collapsing during earthquake shall be taken.

**13.3.6** The enclosure walls of steel structure factory building shall be in accordance with the following requirements:

**1** The enclosure walls of factory building shall adopt lightweight wall panels or precast reinforced concrete wall panels with flexible connection with columns in priority. For Intensity 9, lightweight wall panels should be adopted.

**2** The masonry enclosure wall of single-storey steel-structural factory building shall be tied with columns in term of outer-bonded type, and the necessary measures for the walls shall also be taken to avoid hindering the horizontal displacement of the column rows in the longitudinal direction of the factory building. For Intensity 8 and 9, the built-in type shall not be adopted.

**13.3.7** The connection elements of various ceilings with the floor shall be able to undertake the self-weight of the ceiling, the suspending heavy objects, and the relevant mechanic and electrical equipment, as well as the additional seismic action. The bearing capacity of the anchoring iron elements shall be greater than the bearing capacity of the connection elements.

**13.3.8** Cantilever awnings or awnings with one end supported by the column shall be reliably connected with the seismic force-resisting system.

**13.3.9** The seismic-details of the glass curtain, precast wall panels, the cantilever members subordinating to the floor and large-sized storage rack shall comply with the provisions of relevant specifications.

## 13.4 Basic Seismic-Measures for the Supports of Mechanical and Electrical Components

**13.4.1** The mechanical and electrical component and system are that such as the elevator, lighting, emergency-power system, smoke-fire monitoring and protection system, heating and air-conditioning system, communication system, and community antenna. The seismic-details of connections between that with the building structure shall be determined according to the provisions of relevant specifications. In which the comprehensive analysis shall be made to consider the Intensity, the use function and the height of the building, the type and the deformation characteristics of structures, the supporting locations and the operational requirements for the equipment.

**13.4.2** Seismic precaution requirements need not be taken into account for following brackets of the mechanical and electrical components:

**1** The equipment that has gravity not exceeded 1.8kN;

**2** The gas pipe that has less than 25mm inside diameter, and electrical conduit that has less than 60mm inside diameter;

**3** The rectangular air-pipes that have a cross-sectional area less than 0.38 $m^2$ and air-pipes that has less than 0.7m diameter;

**4** The conduits suspended by hangers less than 600mm in length from the top of the conduit to the supporting structure.

**13.4.3** The mechanical and electrical equipment shall not be installed at locations that may cause its operation failure or other secondary harms. For equipment with isolation devices, it shall be paid attention to that the strong vibration to influence on connection parts, and resonance of the equipment with the building structure shall also be avoided.

The braced frame of mechanical and electrical equipment shall have sufficient stiffness and strength; that must have reliable connection and anchoring with the building structure, so the equipment can be able to restore failure-free operation after the fortification earthquake occurrence.

**13.4.4** The openings for pipelines, cables, air-pipes, and equipment shall try to reduce the weakening caused to the load-bearing structural members; strengthened measures shall be taken for perimeter of the openings.

The connections of pipelines and equipment with the building structures shall be able to allow a certain relative deflection between the each other.

**13.4.5** The supports or the connecting parts of the mechanical and electrical equipment shall be able to transfer all the seismic action of the equipment to the building structures. In building structures, locations installing the imbedded and anchoring parts where are connect the mechanical and electrical equipment, the strengthened measures shall be taken to resist the seismic action transferred by mechanical and electrical components.

**13.4.6** The water tank located at upper portion of the building shall be connected with the structural members reliably. And the additional seismic effect on the main structures caused by the weight of the tank and water therein should also be taken into consideration.

**13.4.7** The mechanical and electrical equipment, which need opening continuously within the fortification earthquake, should be installed at locations of the building structure where the seismic response is smaller, corresponding strengthened measures shall be taken for the structural members in relevant portion.

# 14 Subterranean Buildings

## 14.1 General

**14.1.1** This chapter is mainly applicable to the separate-building type subterranean buildings that include underground garage, underground passage, underground substation, underground mixed-use building and so on, and exclude subway and urban highway tunnel, etc.

**14.1.2** Subterranean building should be built on dense, homogeneous, and stable soil. When it is located on the unfavorable area such as weak soil, liquefied soil or fracture zone of fault, the influence on seismic stability of structure shall be assessed and the corresponding seismic measures shall also be taken.

**14.1.3** The configuration of subterranean buildings shall be simple, symmetrical, regular, flat and smooth to ensure that the transverse section shape will not mutate in the longitudinal direction.

**14.1.4** The structural system of subterranean building shall be determined according to the functional requirements, geological conditions of site, construction method and so on. The structural system shall be provided with favorable integrity to avoid the mutation of the lateral stiffness and bearing-capacity of the lateral-force-resisting-system.

For the reinforced concrete subterranean building assigned to seismic precautionary category C, the seismic measure grade shall not be lower than Grade 4 for Intensity 6, 7, and should not be lower than Grade 3 for Intensity 8, 9.

For the reinforced concrete subterranean building assigned to seismic precautionary category B, the seismic measure grade should not be lower than Grade 3 for Intensity 6, 7 and Grade 2 for Intensity 8, 9, respectively.

**14.1.5** For the side slopes at the passageway and the front slope at entrance and exit of the subterranean buildings that located in rock, the structure types shall be determined reasonably according to the topography and geologic conditions to increase their seismic stabilities.

## 14.2 Essentials in Calculation

**14.2.1** For the following subterranean buildings that are designed in details according to the requirements in this chapter, the calculation for earthquake action need not be carried out:

**1** The subterranean buildings with seismic precautionary category C located at the zone of Intensity 7 with site Class I and II.

**2** The subterranean buildings with seismic precautionary category C located at the zone of Intensity 8(0.20g) with site Class I and II, and meanwhile meeting the conditions of no more than 2 stories, regular configuration, and medium-small span.

**14.2.2** The seismic calculation model of subterranean buildings shall be determined according to the actual conditions of structure and shall be in accordance with the following requirements:

**1** The model shall reflect the actual force conditions of the surrounding retaining structures and the internal components accurately. For the internal structures separated from the surrounding retaining structures, the model same as that used for the aboveground buildings may be adopted.

**2** For the regular and symmetric subterranean buildings with longer length in the longitudinal direction that located in uniform soil, the plane strain models may be adopted for the structural analysis using the response displacement method, the equivalent horizontal seismic acceleration method, or the equivalent lateral force method.

**3** For the subterranean buildings with length-width ratio and height-width ratio all less than 3 and those beyond specified in Item 2 of this Article, the spatial models should be adopted the structural analysis using the soil-structure time-history analysis method.

**14.2.3** The design parameters for seismic calculation of subterranean buildings shall be in accordance with the following requirements:

**1** The directions of earthquake actions shall meet the following requirements:

**1)** For the underground structures to which the plane strain model is applicable, the horizontal earthquake action may be calculated only in the transversal direction.

**2)** For the irregular underground structures, the horizontal earthquake action should be calculated simultaneously in the longitudinal and transversal direction.

**3)** For the complex underground structures such as underground mixed-use buildings, the vertical earthquake action shall also be considered for Intensity 8, 9.

**2** The values of earthquake action shall be reduced with the increasing of the underground depth. In generally, the earthquake action on the top of bedrock may be taken half of that on the ground, and the earthquake action at different depth between the ground and the top of bed rock may be determined by interpolation. For the area with ground surface, soil layer interface and the top surface bedrock relatively even, the one-dimensional-wave method may also be used to determine the earthquake action; and for the area with acute topographic undulation, the two-dimensional or three-dimensional finite element analysis method should be used to determine the earthquake action.

**3** The representative value of gravity load of the structure shall be taken as the summation of the characteristic values of the selfweight of the structure and members, the characteristic values of water and soil pressures and the combination values of variable loads.

**4** For soil-structure time-history analysis method and the equivalent horizontal seismic acceleration method, the dynamic parameters of soil and rock may be determined by test.

**14.2.4** In addition the requirements in Chapter 5 of this code, the seismic check of subterranean building, shall also be in accordance with the following requirements:

**1** The seismic check for the section load-bearing capacity and the element deformation of underground buildings under frequent earthquake ground motion shall be carried out.

**2** For the underground substations, underground mixed-use buildings and other irregular subterranean buildings, the seismic check for the deformation under rare earthquake ground motion shall also be carried out. The simplified method specified in Section 5.5 of this code may be adopted for the calculation of elasto-plastic deformation. For the concrete subterranean buildings, the limit value of the elasto-plastic storey drift $[\zeta_p]$ should be taken as 1/250.

**3** For the subterranean buildings located in liquefied soil, the anti-floating stability during liquification shall be checked. The frictional resistance of the liquefied soil to the underground continuous wall and uplift pile shall be reduced, and the liquefied reduction factor should be determined according to the ratio of measured value of standard penetration resistance (in blow-number) to the critical value of standard penetration resistance (in blow-number).

### 14.3 Seismic Details and Anti-liquefaction Measures

**14.3.1** The seismic details of reinforced concrete subterranean buildings shall comply with the following requirements:

**1** Cast-in-place structure should be adopted for the reinforced concrete subterranean buildings. When precast components are needed to install, they shall be reliably connected with the other surrounding components.

**2** The minimum size of the elements of the underground reinforced concrete frame structure shall not be less than that of the aboveground structure with the same type.

**3** Minimum total steel ratio of longitudinal bars in medium columns shall be increased by 0.2% with respect to that specified in Table 6.3.7-1. The hoops at the connections of medium columns with beams, roof slabs, floor slabs or base slabs shall be densified, and the regions and details of densified hoops shall be the same as that of the columns of aboveground frame structure.

**14.3.2** The roof, base and floors of subterranean building shall be in accordance with the following requirements:

**1** Beam and slab structure should be adopted for the roof, base or floor structures. If slab-column-wall structure without column-capitals was adopted, the hidden beams of slab with the same detail measures as that stated in Item 1 of Article 6.6.4 should be arranged on the column strip.

**2** For the composite wall of the underground continue walls, at least 50% of the bars arranged at the negative moment regions of the roof slab, base slab and floor slabs, shall be anchored into the continue walls with anchorage length determined by calculation; and the bars arranged at the positive moment regions of the above slabs shall be anchored into inside liners with anchorage length not less than the specified value.

**3** The opening width of the floor slab shall not be greater than 30% of the floor width. The arrangement of openings should ensure the uniformity and symmetry of the structure mass and stiffness to avoid mutation. The boundary beams or hidden beams with the details satisfying relevant requirements shall be installed around the opening.

**14.3.3** For the subterranean buildings with liquefied soil layer in the surrounding soil and the base soil, the following measures shall be taken:

**1** Measures to eliminate or reduce liquification influence, such as grouting stabilization and soil replacement, shall be taken for liquefied soil layer.

**2** The computations of the liquefied anti-floating for the underground structures shall be carried out, and if necessary, the corresponding anti-floating measures such as arrangement of additional uplift piles and configuration of additional weights shall be taken.

**3** For the soil with thin interbeded layer or the enclosure structures of underground continue walls with buried depth greater than 20m, the anti-liquefaction measures may not be taken, but the influences of soil liquefaction such as the soil pressure increaseing and the pile shaft resistance decreasing shall be taken into consideration for the calculation of the load-bearing capacity and anti-floating stability.

**14.3.4** For the subterranean buildings passing through the ancient river whose slopes may slide during earthquake or the soft soil zone where obvious uneven settlement may occur, measures such as replacement of soft soil or arrangement of piles shall be taken.

**14.3.5** For subterranean buildings located in rocks, the following seismic measures shall be taken:

**1** For the passageways of entrance and exit and the composite supporting structures located at the fault fracture zone without grouting and strengthening treatment measures, the inner lining structure shall adopt the reinforced concrete structure instead of the plain concrete structure.

**2** For the separate lining, the horizontal supporting elements shall be installed at the joints of the arch and wall to against the enclosing rock.

**3** For the drilling-blasting method, the gap between the preliminary supporting structure and the enclosing rock shall be backfilled compactly. If the dry masonry block stones are used to backfill, the grouting and strengthening treatment measures shall be taken.

# Appendix A The Seismic Precautionary Intensity, Design Basic Acceleration of Ground Motion and Design Earthquake Groups of Main Cities and Towns in China

This Appendix only specifies seismic precautionary intensity (hereinafter referred to as “intensity”), design basic acceleration of ground motion (hereinafter referred to as “acceleration”) and corresponding design earthquake groups (hereinafter referred to as “group”) which are applied to seismic design of buildings in cities and towns at or above the county level in China.

### A.0.1 Beijing City

| Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|
| 8 | 0.20g | Group II | Dongcheng District, Xicheng District, Chaoyang District, Fengtai District, Shijingshan District, Haidian District, Mentougou District, Fangshan District, Tongzhou District, Shunyi District, Changping District, Daxing District, Huairou District, Pinggu District, Miyun District and Yanqing District |

### A.0.2 Tianjin City

| Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|
| 8 | 0.20g | Group II | Heping District, Hedong District, Hexi District, Nankai District, Hebei District, Hongqiao District, Dongli District, Jinnan District, Beichen District, Wuqing District, Baodi District, Binhai New District and Ninghe District |
| 7 | 0.15g | Group II | Xiqing District, Jinghai District and Ji County |

### A.0.3 Hebei Province

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Shijiazhuang City** | 7 | 0.15g | Group I | Xinji City |
| | 7 | 0.10g | Group I | Zhaoxian County |
| | 7 | 0.10g | Group II | Chang’an District, Qiaoxi District, Xinhua District, Jingxing Mining District, Yuhua District, Luancheng District, Gaocheng District, Luquan District, Jingxing County, Zhengding County, Gaoyi County, Shenze County, Wuji County, Pingshan County, Yuanshi County and Jinzhou City |
| | 7 | 0.10g | Group III | Lingshou County |
| | 6 | 0.05g | Group III | Xingtang County, Zanhuang County and Xinle City |
| **Tangshan City** | 8 | 0.30g | Group II | Lunan District and Fengnan District |
| | 8 | 0.20g | Group II | Lubei District, Guye District, Kaiping District, Fengrun District and Luanxian County |
| | 7 | 0.15g | Group III | Caofeidian District (Tanghai), Laoting County and Yutian County |
| | 7 | 0.15g | Group II | Luannan County and Qian’an City |
| | 7 | 0.10g | Group III | Qianxi County and Zunhua City |
| **Qinhuangdao** | 7 | 0.15g | Group II | Lulong County |

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **City** | 7 | 0.10g | Group III | Qinglong Manchu Autonomous County and Haigang District |
| | 7 | 0.10g | Group II | Funing District, Beidaihe District and Changli County |
| | 6 | 0.05g | Group III | Shanhaiguan District |
| **Handan City** | 8 | 0.20g | Group II | Fengfeng Mining District, Linzhang County and Cixian County |
| | 7 | 0.15g | Group II | Hanshan District, Congtai District, Fuxing District, Handan County, Cheng'an County, Daming County, Weixian County and Wu'an City |
| | 7 | 0.15g | Group I | Yongnian County |
| | 7 | 0.10g | Group III | Qiuxian County and Guantao County |
| | 7 | 0.10g | Group II | Shexian County, Feixiang County, Jize County, Guangping County and Quzhou County |
| **Xingtai City** | 7 | 0.15g | Group I | Qiaodong District, Qiaoxi District, Xingtai County[1], Neiqiu County, Baixiang County, Longyao County, Renxian County, Nanhe County, Ningjin County, Julu County, Xinhe County and Shahe City |
| | 7 | 0.10g | Group II | Lincheng County, Guangzong County, Pingxiang County and Nangong City |
| | 6 | 0.05g | Group III | Weixian County, Qinghe County and Linxi County |
| **Baoding City** | 7 | 0.15g | Group II | Laishui County, Dingxing County, Zhuozhou City and Gaobeidian City |
| | 7 | 0.10g | Group II | Jingxiu District, Lianchi District, Xushui District, Gaoyang County, Rongcheng County, Anxin County, Yixian County, Lixian County, Boye County and Xiongxian County |
| | 7 | 0.10g | Group III | Qingyuan District, Laiyuan County and Anguo City |
| | 6 | 0.05g | Group III | Mancheng District, Fuping County, Tangxian County, Wangdu County, Quyang County, Shunping County and Dingzhou City |
| **Zhangjiakou City** | 8 | 0.20g | Group II | Xiahuayuan District, Huailai County and Zhuolu County |
| | 7 | 0.15g | Group II | Qiaodong District, Qiaoxi District, Xuanhua District, Xianhua County[2], Yuxian County, Yangyuan County, Huai'an County and Wanquan County |
| | 7 | 0.10g | Group III | Chicheng County |
| | 7 | 0.10g | Group II | Zhangbei County, Shangyi County and Chongli County |
| | 6 | 0.05g | Group III | Guyuan County |
| | 6 | 0.05g | Group II | Kangbao County |
| **Chengde City** | 7 | 0.10g | Group III | Yingshouyingzi Mining District and Xinglong County |
| | 6 | 0.05g | Group III | Shuangqiao District, Shuangluan District, Chengde County, Pingquan County, Luanping County, Longhua County, Fengning Manchu Autonomous County and Kuancheng Manchu Autonomous County |
| | 6 | 0.05g | Group I | Weichang Manchu and Mongolian Autonomous County |
| **Cangzhou City** | 7 | 0.15g | Group II | Qingxian County |
| | 7 | 0.15g | Group I | Suning County, Xian County, Renqiu City and Hejian City |
| | 7 | 0.10g | Group III | Huanghua City |

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| | 7 | 0.10g | Group II | Xinhua District, Yunhe District, Cangxian County[3], Dongguang County, Nanpi County, Wuqiao County and Botou City |
| | 6 | 0.05g | Group III | Haixing County, Yanshan County and Mengcun Hui Autonomous County |
| **Langfang City** | 8 | 0.20g | Group II | Anci District, Guangyang District, Xianghe County, Dachang Hui Autonomous County and Sanhe City |
| | 7 | 0.15g | Group II | Gu'an County, Yongqing County and Wen'an County |
| | 7 | 0.15g | Group I | Dacheng County |
| | 7 | 0.10g | Group II | Bazhou City |
| **Hengshui City** | 7 | 0.15g | Group I | Raoyang County and Shenzhou City |
| | 7 | 0.10g | Group II | Taocheng District, Wuqiang County and Jizhou City |
| | 7 | 0.10g | Group I | Anping County |
| | 6 | 0.05g | Group III | Zaoqiang County, Wuyi County, Gucheng County and Fucheng County |
| | 6 | 0.05g | Group II | Jingxian County |

Note: 1. The Government of Xingtai County is located in Qiaodong District, Xingtai City; 2. The Government of Xianhua County is located in Xuanhua District, Zhangjiakou City; 3. The Government of Cangxian County is located in Xinhua District, Cangzhou City.

### A.0.4 Shanxi Province

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Taiyuan City** | 8 | 0.20g | Group II | Xiaodian District, Yingze District, Xinghualing District, Jiancaoping District, Wanbailin District, Jinyuan District, Qingxu County, Yangqu County |
| | 7 | 0.15g | Group II | Gujiao City |
| | 7 | 0.10g | Group III | Loufan County |
| **Datong City** | 8 | 0.20g | Group II | Cheng District, Kuang District, Nanjiao District and Datong County |
| | 7 | 0.15g | Group III | Hunyuan County |
| | 7 | 0.15g | Group II | Xinrong District, Yanggao County, Tianzhen County, Guangling County, Lingqiu County and Zuoyun County |
| **Yangquan City** | 7 | 0.10g | Group III | Yuxian County |
| | 7 | 0.10g | Group II | Cheng District, Kuang District, Jiao District and Pingding County |
| **Changzhi City** | 7 | 0.10g | Group III | Pingshun County, Wuxiang County, Qinxian County and Qinyuan County |
| | 7 | 0.10g | Group II | Cheng District, Jiao District, Changzhi County, Licheng County, Huguan County and Lucheng City |
| | 6 | 0.05g | Group III | Xiangyuan County, Tunliu County and Zhangzi County |
| **Jincheng City** | 7 | 0.10g | Group III | Qinshui County and Lingchuan County |
| | 6 | 0.05g | Group III | Cheng District, Yangcheng County, Zezhou County and Gaoping City |
| **Shuozhou City** | 8 | 0.20g | Group II | Shanyin County, Yingxian County and Huairen County |
| | 7 | 0.15g | Group II | Shuocheng District, Pinglu District and Youyu County |

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Jinzhong City** | 8 | 0.20g | Group II | Yuci District, Taigu County, Qixian County, Pingyao County, Lingshi County and Jiexiu City |
| | 7 | 0.10g | Group III | Yushe County, Heshun County and Shouyang County |
| | 7 | 0.10g | Group II | Xiyang County |
| | 6 | 0.05g | Group III | Zuoquan County |
| **Yuncheng City** | 8 | 0.20g | Group III | Yongji City |
| | 7 | 0.15g | Group III | Linyi County, Wanrong County, Wenxi County, Jishan County and Jiangxian County |
| | 7 | 0.15g | Group II | Yanhu District, Xinjiang County, Xiaxian County, Pinglu County, Ruicheng County and Hejin City |
| | 7 | 0.10g | Group II | Yuanqu County |
| **Xinzhou City** | 8 | 0.20g | Group II | Xinfu District, Dingxiang County, Wutai County, Daixian County and Yuanping City |
| | 7 | 0.15g | Group III | Ningwu County |
| | 7 | 0.15g | Group II | Fanshi County |
| | 7 | 0.10g | Group III | Jingle County, Shenchi County and Wuzhai County |
| | 6 | 0.05g | Group III | Kelan County, Hequ County, Baode County and Pianguan County |
| **Linfen City** | 8 | 0.30g | Group II | Hongdong County |
| | 8 | 0.20g | Group II | Yaodu District, Xiangfen County, Guxian County, Fushan County, Fenxi County and Huozhou City |
| | 7 | 0.15g | Group II | Quwo County, Yicheng County, Puxian County and Houma City |
| | 7 | 0.10g | Group III | Anze County, Jixian County, Xiangning County and Xixian County |
| | 6 | 0.05g | Group III | Daning County and Yonghe County |
| **Lvliang City** | 8 | 0.20g | Group II | Wenshui County, Jiaocheng County, Xiaoyi City and Fenyang City |
| | 7 | 0.10g | Group III | Lishi District, Lanxian County, Zhongyang County and Jiaokou County |
| | 6 | 0.05g | Group III | Xingxian County, Linxian County, Liulin County, Shilou County and Fangshan County |

## A.0.5 Inner Mongolia Autonomous Region

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Hohhot City** | 8 | 0.20g | Group II | Xincheng District, Huimin District, Yuquan District, Saihan District and Tumd Left Banner |
| | 7 | 0.15g | Group II | Tuoketuo County, Horinger County and Wuchuan County |
| | 7 | 0.10g | Group II | Qingshuihe County |
| **Baotou City** | 8 | 0.30g | Group II | Tumd Right Banner |
| | 8 | 0.20g | Group II | Donghe District, Shiguai District, Jiuyuan District, Hondlon District and Qingshan District |
| | 7 | 0.15g | Group II | Guyang County |
| | 6 | 0.05g | Group III | Bayan Obo Mining District and Darhan Muminggan United Banner |
| **Wuhai City** | 8 | 0.20g | Group II | Haibowan District, Hainan District and Wuda District |

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Chifeng City** | 8 | 0.20g | Group I | Yuanbaoshan District and Ningcheng County |
| | 7 | 0.15g | Group I | Hongshan District and Harqin Banner |
| | 7 | 0.10g | Group I | Songshan District, Ar Horqin Banner and Aohan Banner |
| | 6 | 0.05g | Group I | Bairin Left Banner, Bairin Right Banner, Linxi County, Hexigten Banner and Ongniud Banner |
| **Tongliao City** | 7 | 0.10g | Group I | Keerqin District and Kailu County |
| | 6 | 0.05g | Group I | Horqin Left Middle Banner, Horqin Left Rear Banner, Hure Banner, Naiman Banner, Jarud Banner and Huolin Gol City |
| **Erdos City** | 8 | 0.20g | Group II | Dalate Banner |
| | 7 | 0.10g | Group III | Dongsheng District and Jungar Banner |
| | 6 | 0.05g | Group III | Otog Front Banner, Otog Banner, Hanggin Banner and Ejin Horo Banner |
| | 6 | 0.05g | Group I | Uxin Banner |
| **Hulunbeier City** | 7 | 0.10g | Group I | Jalainur District, New Barag Right Banner and Zhalantun City |
| | 6 | 0.05g | Group I | Hailar District, Arun Banner, Morin Dawa Daur Autonomous Banner, Oroqen Autonomous Banner, Evenk Autonomous Banner, Old Barag Banner, New Barag Left Banner, Manzhouli City, Yakeshi City, Ergun City and Genhe City |
| **Bayinnaoer City** | 8 | 0.20g | Group II | Hanggin Rear Banner |
| | 8 | 0.20g | Group I | Dengkou County, Urad Front Banner and Urad Rear Banner |
| | 7 | 0.15g | Group II | Linhe District and Wuyuan County |
| | 7 | 0.10g | Group II | Wulate Middle Banner |
| **Ulanqab City** | 7 | 0.15g | Group II | Liangcheng County, Chahar Right Front Banner and Fengzhen City |
| | 7 | 0.10g | Group III | Chahar Right Middle Banner |
| | 7 | 0.10g | Group II | Tsining District, Zhuozi County and Xinghe County |
| | 6 | 0.05g | Group III | Siziwang Banner |
| | 6 | 0.05g | Group II | Huade County, Shangdu County and Chahar Right Rear Banner |
| **Hinggan League** | 6 | 0.05g | Group I | Ulanhot City, Arxan City, Horqin Right Front Banner, Horqin Right Middle Banner, Jalaid Banner and Tuquan County |
| **Xilin Gol League** | 6 | 0.05g | Group III | Taipusi Banner |
| | 6 | 0.05g | Group II | Zhenglan Banner |
| | 6 | 0.05g | Group I | Erenhot City, Xilinhot City, Abag Banner, Sonid Left Banner, Sonid Right Banner, East Ujimqin Banner, West Ujimqin Banner, Boarder Yellow Banner, Plain and Bordered White Banner and Duolun County |
| **Alxa League** | 8 | 0.20g | Group II | Alxa Left Banner and Alxa Right Banner |
| | 6 | 0.05g | Group I | Ejin Banner |

### A.0.6 Liaoning Province

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Shenyang City** | 7 | 0.10g | Group I | Heping District, Shenhe District, Dadong District, Huanggu District, Tiexi District, Sujiatun District, Hunnan District (the former Dongling District), Shenbei New Area, Yuhong District and Liaozhong County |
| | 6 | 0.05g | Group I | Kangping County, Faku County and Xinmin City |
| **Dalian City** | 8 | 0.20g | Group I | Wafangdian City and Pulandian City |
| | 7 | 0.15g | Group I | Jinzhou District |
| | 7 | 0.10g | Group II | Zhongshan District, Xigang District, Shahekou District, Ganjingzi District and Lushunkou District |
| | 6 | 0.05g | Group II | Changhai County |
| | 6 | 0.05g | Group I | Zhuanghe City |
| **Anshan City** | 8 | 0.20g | Group II | Haicheng City |
| | 7 | 0.10g | Group II | Tiedong District, Tiexi District, Lishan District, Qianshan District and Xiuyan Manchu Autonomous County |
| | 7 | 0.10g | Group I | Tai'an County |
| **Fushun City** | 7 | 0.10g | Group I | Xinfu District, Dongzhou District, Wanghua District, Shuncheng District and Fushun County[1] |
| | 6 | 0.05g | Group I | Xinbin Manchu Autonomous County and Qingyuan Manchu Autonomous County |
| **Benxi City** | 7 | 0.10g | Group II | Nanfen District |
| | 7 | 0.10g | Group I | Pingshan District, Xihu District and Mingshan District |
| | 6 | 0.05g | Group I | Benxi Manchu Autonomous County and Huanren Manchu Autonomous County |
| **Dandong City** | 8 | 0.20g | Group I | Donggang City |
| | 7 | 0.15g | Group I | Yuanbao District, Zhenxing District and Zhen'an District |
| | 6 | 0.05g | Group II | Fengcheng City |
| | 6 | 0.05g | Group I | Kuandian Manchu Autonomous County |
| **Jinzhou City** | 6 | 0.05g | Group II | Guta District, Linghe District, Taihe District and Linghai City |
| | 6 | 0.05g | Group I | Heishan County, Yixian County and Beizhen City |
| **Yingkou City** | 8 | 0.20g | Group II | Laobian District, Gaizhou City and Dashiqiao City |
| | 7 | 0.15g | Group II | Zhanqian District, Xishi District and Bayuquan District |
| **Fuxin City** | 6 | 0.05g | Group I | Haizhou District, Xinqiu District, Taiping District, Qinghemen District, Xihe District, Fuxin Mongolia Autonomous County and Zhangwu County |
| **Liaoyang City** | 7 | 0.10g | Group II | Gongchangling District, Hongwei District and Liaoyang County |
| | 7 | 0.10g | Group I | Baita District, Wensheng District, Taizihe District and Dengta City |
| **Panjin City** | 7 | 0.10g | Group II | Shuangtaizi District, Xinglongtai District, Dawa County and Panshan County |
| **Tieling City** | 7 | 0.10g | Group I | Yinzhou District, Qinghe District, Tieling County[2], Changtu County and Kaiyuan City |
| | 6 | 0.05g | Group I | Xifeng County and Diaobingshan City |

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Chaoyang City** | 7 | 0.10g | Group II | Lingyuan City |
| | 7 | 0.10g | Group I | Shuangta District, Longcheng District, Chaoyang County[3], Jianping County and Beipiao City |
| | 6 | 0.05g | Group II | Harqin Left Wing Mongol Autonomous County |
| **Huludao City** | 6 | 0.05g | Group II | Lianshan District, Longgang District and Nanpiao District |
| | 6 | 0.05g | Group III | Suizhong County, Jianchang County and Xingcheng City |

Note: 1. The Government of Fushun County is located at the middle section of Xincheng Road, Shuncheng District, Fushun City; 2. The Government of Tieling County is located at Gongren Street, Yinzhou District, Tieling City; 3. The Government of Chaoyang County is located at Qianjin Street, Shuangta District, Chaoyang City.

## A.0.7 Jilin Province

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Changchun City** | 7 | 0.10g | Group I | Nanguan District, Kuancheng District, Chaoyang District, Erdao District, Lvyuan District, Shuangyang District and Jiutai District |
| | 6 | 0.05g | Group I | Nong' an County, Yushu City and Dehui City |
| **Jilin City** | 8 | 0.20g | Group I | Shulan City |
| | 7 | 0.10g | Group I | Changyi District, Longtan District, Chuanying District, Fengman District and Yongji County |
| | 6 | 0.05g | Group I | Jiaohe City, Huadian City and Panshi City |
| **Siping City** | 7 | 0.10g | Group I | Yitong Manchu Autonomous County |
| | 6 | 0.05g | Group I | Tiexi District, Tiedong District, Lishu County, Gongzhuling City and Shuangliao City |
| **Liaoyuan City** | 6 | 0.05g | Group I | Longshan District, Xi'an District, Dongfeng County and Dongliao County |
| **Tonghua City** | 6 | 0.05g | Group I | Dongchang District, Erdaojiang District, Tonghua County, Huinan County, Liuhe County, Meihekou City and Ji'an City |
| **Baishan City** | 6 | 0.05g | Group I | Hunjiang District, Jiangyuan District, Fusong County, Jingyu County, Changbai Korean Autonomous County and Linjiang City |
| **Songyuan City** | 8 | 0.20g | Group I | Ningjiang District and Qian Gorlos Mongol Autonomous County |
| | 7 | 0.10g | Group I | Qian'an County |
| | 6 | 0.05g | Group I | Changling County and Fuyu City |
| **Baicheng City** | 7 | 0.15g | Group I | Da'an City |
| | 7 | 0.10g | Group I | Taobei District |
| | 6 | 0.05g | Group I | Zhenlai County, Tongyu County and Taonan City |
| **Yanbian Korean Autonomous Prefecture** | 7 | 0.15g | Group I | Antu County |
| | 6 | 0.05g | Group I | Yanji City, Tumen City, Dunhua City, Hunchun City, Longjing City, Helong City and Wangqing County |

### A.0.8 Heilongjiang Province

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Harbin City** | 8 | 0.20g | Group I | Fangzheng County |
| | 7 | 0.15g | Group I | Yilan County, Tonghe County and Yanshou County |
| | 7 | 0.10g | Group I | Daoli District, Nangang District, Daowai District, Songbei District, Xiangfang District, Hulan District, Shangzhi City and Wuchang City |
| | 6 | 0.05g | Group I | Pingfang District, Acheng District, Binxian County, Bayan County, Mulan County and Shuangcheng District |
| **Tsitsihar City** | 7 | 0.10g | Group I | Ang'angxi District, Hulan Ergi District and Tailai County |
| | 6 | 0.05g | Group I | Longsha District, Jianhua District, Tiefeng District, Nianzishan District, Meilisi Daur District, Longjiang County, Yi'an County, Gannan County, Fuyu County, Keshan County, Kedong County, Baiquan County and Nehe City |
| **Jixi City** | 6 | 0.05g | Group I | Jiguan District, Hengshan District, Didao District, Lishu District, Chengzihe District, Mashan District, Jidong County, Hulin City and Mishan City |
| **Hegang City** | 7 | 0.10g | Group I | Xiangyang District, Gongnong District, Nanshan District, Xing’an District, Dongshan District, Xingshan District and Luobei County |
| | 6 | 0.05g | Group I | Suibin County |
| **Shuangyashan City** | 6 | 0.05g | Group I | Jianshan District, Lingdong District, Sifangtai District, Baoshan District, Jixian County, Youyi County, Baoqing County and Raohe County |
| **Daqing City** | 7 | 0.10g | Group I | Zhaoyuan County |
| | 6 | 0.05g | Group I | Sartu District, Longfeng District, Ranghulu District, Honggang District, Datong District, Zhaozhou County, Lindian County and Dorbod Mongol Autonomous County |
| **Yichun City** | 6 | 0.05g | Group I | Yichun District, Nancha District, Youhao District, Xilin District, Cuiluan District, Xinqing District, Meixi District, Jinshantun District, Wuying District, Wumahe District, Tangwanghe District, Dailing District, Wuyiling District, Hongxing District, Shangganling District, Jiayin County and Tieli City |
| **Kiamusze City** | 7 | 0.10g | Group I | Xiangyang District, Qianjin District, Dongfeng District, Jiao District and Tangyuan County |
| | 6 | 0.05g | Group I | Huanan County, Huachuan County, Fuyuan County, Tongjiang City and Fujin City |
| **Qitaihe City** | 6 | 0.05g | Group I | Xinxing District, Taoshan District, Qiezihe District and Boli County |
| **Mudanjiang City** | 6 | 0.05g | Group I | Dong'an District, Yangming District, Aimin District, Xi'an District, Dongning County, Linkou County, Suifenhe City, Hailin City, Ning'an City and Muling City |
| **Heihe City** | 6 | 0.05g | Group I | Aihui District, Nenjiang County, Xunke County, Sunwu County, Bei'an City and Wudalianchi City |
| **Suihua City** | 7 | 0.10g | Group I | Beilin District and Qing'an County |

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| | 6 | 0.05g | Group I | Wangkui County, Lanxi County, Qinggang County, Mingshui County, Suileng County, Anda City, Zhaodong City and Hailun City |
| **Daxinganling Region** | 6 | 0.05g | Group I | Jiagedaqi District, Huma County, Tahe County and Mohe County |

## A.0.9 Shanghai City

| Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|
| 7 | 0.10g | Group II | Huangpu District, Xuhui District, Changning District, Jing'an District, Putuo District, Zhabei District, Hongkou District, Yangpu District, Minhang District, Baoshan District, Jiading District, Pudong New District, Jinshan District, Songjiang District, Qingpu District, Fengxian District and Chongming County |

## A.0.10 Jiangsu Province

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Nanjing City** | 7 | 0.10g | Group II | Luhe District |
| | 7 | 0.10g | Group I | Xuanwu District, Qinhuai District, Jianye District, Gulou District, Pukou District, Qixia District, Yuhuatai District, Jiangning District and Lishui District |
| | 6 | 0.05g | Group I | Gaochun District |
| **Wuxi City** | 7 | 0.10g | Group I | Chong’an District, Nanchang District, Beitang District, Xishan District, Binhu District, Huishan District and Yixing City |
| | 6 | 0.05g | Group II | Jiangyin City |
| **Xuzhou City** | 8 | 0.20g | Group II | Suining County, Xinyi City and Pizhou City |
| | 7 | 0.10g | Group III | Gonglou District, Longyun District, Jiawang District, Quanshan District and Tongshan District |
| | 7 | 0.10g | Group II | Peixian County |
| | 6 | 0.05g | Group II | Fengxian County |
| **Changzhou City** | 7 | 0.10g | Group I | Tianning District, Zhonglou District, Xinbei District, Wujin District, Jintan District and Liyang City |
| **Suzhou City** | 7 | 0.10g | Group I | Huqiu District, Wuzhong District, Xiangcheng District, Gusu District, Wujiang District, Changshu City, Kunshan City and Taicang City |
| | 6 | 0.05g | Group II | Zhangjiagang City |
| **Nantong City** | 7 | 0.10g | Group II | Chongchuan District, Gangzha District, Hai'an County, Rudong County and Rugao city |
| | 6 | 0.05g | Group II | Tongzhou District, Qidong City and Haimen City |
| **Lianyungang City** | 7 | 0.15g | Group III | Donghai County |
| | 7 | 0.10g | Group III | Lianyun District, Haizhou District, Ganyu District and Guanyun County |
| | 6 | 0.05g | Group III | Guannan County |
| **Huai'an City** | 7 | 0.10g | Group III | Qinghe District, Huaiyin District and Qingpu District |
| | 7 | 0.10g | Group II | Xuyi County |

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| | 6 | 0.05g | Group III | Huai'an District, Lianshui County, Hongze County and Jinhu County |
| Yancheng City | 7 | 0.15g | Group III | Dafeng District |
| | 7 | 0.10g | Group III | Yandu District |
| | 7 | 0.10g | Group II | Tinghu District, Sheyang County and Dongtai City |
| | 6 | 0.05g | Group III | Xiangshui County, Binhai County, Funing County and Jianhu County |
| Yangzhou City | 7 | 0.15g | Group II | Guangling District and Jiangdu District |
| | 7 | 0.15g | Group I | Hanjiang District and Yizheng City |
| | 7 | 0.10g | Group II | Gaoyou City |
| | 6 | 0.05g | Group III | Baoying County |
| Zhenjiang City | 7 | 0.15g | Group I | Jingkou District and Runzhou District |
| | 7 | 0.10g | Group I | Dantu District, Danyang City, Yangzhong City and Jurong city |
| Taizhou City | 7 | 0.10g | Group II | Hailing District, Gaogang District, Jiangyan District and Xinghua City |
| | 6 | 0.05g | Group II | Jingjiang City |
| | 6 | 0.05g | Group I | Taixing City |
| Suqian City | 8 | 0.30g | Group II | Sucheng District and Suyu District |
| | 8 | 0.20g | Group II | Sihong County |
| | 7 | 0.15g | Group III | Shuyang County |
| | 7 | 0.10g | Group III | Siyang County |

## A.0.11 Zhejiang Province

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| Hangzhou City | 7 | 0.10g | Group I | Shangcheng District, Xiacheng District, Jianggan District, Gongshu District, Xihu District and Yuhang District |
| | 6 | 0.05g | Group I | Binjiang District, Xiaoshan District, Fuyang District, Tonglu County, Chun'an County, Jiande County and Lin'an City |
| Ningbo City | 7 | 0.10g | Group I | Haishu District, Jiangdong District, Jiangbei District, Beilun District, Zhenhai District and Yinzhou District |
| | 6 | 0.05g | Group I | Xiangshan County, Ninghai County, Yuyao City, Cixi City and Fenghua City |
| Wenzhou City | 6 | 0.05g | Group II | Dongtou District, Pingyan County, Cangnan County and Rui'an City |
| | 6 | 0.05g | Group I | Lucheng District, Longwan District, Ouhai District, Yongjia County, Wencheng County, Taishun County and Yueqing City |
| Jiaxing City | 7 | 0.10g | Group I | Nanhu District, Xiuzhou District, Jiashan County, Haining City, Pinghu City and Tongxiang City |
| | 6 | 0.05g | Group I | Haiyan County |
| Huzhou City | 6 | 0.05g | Group I | Wuxing District, Nanxun District, Deqing County, Changxing County and Anji County |
| Shaoxing City | 6 | 0.05g | Group I | Yuecheng District, Keqiao District, Shangyu District, Xinchang County, Zhuji City and Shengzhou City |

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Jinhua City** | 6 | 0.05g | Group I | Wucheng District, Jindong District, Wuyi District, Pujiang County, Pan'an County, Lanxi City, Yiwu City, Dongyang City and Yongkang City |
| **Quzhou City** | 6 | 0.05g | Group I | Kecheng District, Qujiang District, Changshan County, Kaihua County, Longyou County and Jiangshan City |
| **Zhoushan City** | 7 | 0.10g | Group I | Dinghai District, Putuo District, Daishan County and Shengsi County |
| **Taizhou City** | 6 | 0.05g | Group II | Yuhuan County |
| | 6 | 0.05g | Group I | Jiaojiang District, Huangyan District, Luqiao District, Sanmen County, Tiantai County, Xianju County, Wenling City and Linhai City |
| **Lishui City** | 6 | 0.05g | Group II | Qingyuan County |
| | 6 | 0.05g | Group I | Liandu District, Qingtian County, Jinyun County, Suichang County, Songyang County, Yunhe County, Jingning She Autonomous County and Longquan City |

## A.0.12 Anhui Province

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Hefei City** | 7 | 0.10g | Group I | Yaohai District, Luyang District, Shushan District, Baohe District, Changfeng County, Feidong County, Feixi County, Lujiang County and Chaohu City |
| **Wuhu City** | 6 | 0.05g | Group I | Jinghu District, Yijiang District, Jiujiang District, Sanshan District, Wuhu County, Lichang County, Nanling County and Wuwei County |
| **Bengbu City** | 7 | 0.15g | Group II | Wuhe County |
| | 7 | 0.10g | Group II | Guzhen County |
| | 7 | 0.10g | Group I | Longzihu District, Bengshan District, Yuhui District, Huaishang District and Huaiyuan County |
| **HuainanCity** | 7 | 0.10g | Group I | Datong District, Tianjia'an District, Xiejiaji District, Bagongshan District, Panji District and Fengtai County |
| **Ma'anshan city** | 6 | 0.05g | Group I | Huashan District, Yushan District, Bowang District, Dangtu County, Hanshan County and Hexian County |
| **Huaibei City** | 6 | 0.05g | Group III | Duji District, Xiangshan District, Lieshan District and Suixi County |
| **Tongling City** | 7 | 0.10g | Group I | Tongguanshan District, Shizishan District, Jiao District and Tongling County |
| **Anqing City** | 7 | 0.10g | Group I | Yingjiang District, Daguan District, Yixiu District, Zongyang County and Tongcheng City |
| | 6 | 0.05g | Group I | Huaining County, Qianshan County, Taihu County, Susong County, Wangjiang County and Yuexi County |
| **Huangshan City** | 6 | 0.05g | Group I | Tunxi District, Huangshan District, Huizhou District, Shexian County, Xiuning County, Yixian County and Qimen County |
| **Chuzhou City** | 7 | 0.10g | Group II | Tianchang City and Mingguang City |
| | 7 | 0.10g | Group I | Dingyuan County and Fengyang County |
| | 6 | 0.05g | Group II | Langya District, Nanqiao District, Lai'an County and Quanjiao County |

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Fuyang City** | 7 | 0.10g | Group I | Yingzhou District, Yingdong District and Yingquan District |
| | 6 | 0.05g | Group I | Linquan County, Taihe County, Funan County, Yingshang County and Jieshou City |
| **Suzhou City** | 7 | 0.15g | Group II | Sixian County |
| | 7 | 0.10g | Group III | Xiaoxian County |
| | 7 | 0.10g | Group II | Lingbi County |
| | 6 | 0.05g | Group III | Yongqiao District |
| | 6 | 0.05g | Group II | Dangshan County |
| **Liu'an City** | 7 | 0.15g | Group I | Huoshan County |
| | 7 | 0.10g | Group I | Jin'an District, Yu'an District, Shouxian County and Shucheng County |
| | 6 | 0.05g | Group I | Huoqiu County and Jinzhai County |
| **Bozhou City** | 7 | 0.10g | Group II | Qiaocheng District and Woyang County |
| | 6 | 0.05g | Group II | Mengcheng County |
| | 6 | 0.05g | Group I | Lixin County |
| **Chizhou City** | 7 | 0.10g | Group I | Guichi District |
| | 6 | 0.05g | Group I | Dongzhi County, Shitai County and Qingyang County |
| **Xuancheng City** | 7 | 0.10g | Group I | Langxi County |
| | 6 | 0.05g | Group I | Xuanzhou District, Guangde County, Jingxian County, Jixi County, Jingde County and Ningguo City |

### A.0.13 Fujian Province

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Fuzhou City** | 7 | 0.10g | Group III | Gonglou District, Taijiang District, Cangshan District, Mawei District, Jin'an District, Pingtan County, Fuqing City and Changle City |
| | 6 | 0.05g | Group III | Lianjiang County and Yongtai County |
| | 6 | 0.05g | Group II | Minhou County, Luoyuan County and Minqing County |
| **Xiamen City** | 7 | 0.15g | Group III | Siming District, Huli District, Jimei District and Xiang'an District |
| | 7 | 0.15g | Group II | Haicang District |
| | 7 | 0.10g | Group III | Tong'an District |
| **Putian City** | 7 | 0.10g | Group III | Chengxiang District, Hanjiang District, Licheng District, Xiuyu District and Xianyou County |
| **Sanming City** | 6 | 0.05g | Group I | Meilie District, Sanyuan District, Mingxi County, Qingliu County, Ninghua County, Datian County, Youxi County, Shaxian County, Jiangle County, Taining County, Jianning County and Yong'an City |
| **Quanzhou City** | 7 | 0.15g | Group III | Licheng District, Fengze District, Luojiang District, Shishi City and Jinjiang City |
| | 7 | 0.10g | Group III | Quangang District, Hui'an County, Anxi County, Yongchun County and Nan'an City |
| | 6 | 0.05g | Group III | Dehua County |
| **Zhangzhou City** | 7 | 0.15g | Group III | Zhangpu County |

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| | 7 | 0.15g | Group II | Xiangcheng District, Longwen District, Zhao'an County, Changtai County, Dongshan County, Nanjing County and Longhai City |
| | 7 | 0.10g | Group III | Yunxiao County |
| | 7 | 0.10g | Group II | Pinghe County and Hua'an County |
| **Nanping City** | 6 | 0.05g | Group II | Zhenghe County |
| | 6 | 0.05g | Group I | Yanping District, Jianyang District, Shunchang County, Pucheng County, Guangze County, Songxi County, Shaowu City, Wuyishan City and Jianou City |
| **Longyan City** | 6 | 0.05g | Group II | Xinluo District, Yongding District and Zhangping City |
| | 6 | 0.05g | Group I | Changting County, Shanghang County, Wuping County and Liancheng County |
| **Ningde City** | 6 | 0.05g | Group II | Jiaocheng District, Xiapu County, Zhouning County, Zherong County, Fu'an City and Fuding City |
| | 6 | 0.05g | Group I | Gutian County, Pingnan County and Shouning County |

### A.0.14 Jiangxi Province

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Nanchang City** | 6 | 0.05g | Group I | Donghu District, Xihu District, Qingyunpu District, Wanli District, Qingshanhu District, Xinjian District, Nanchang County, Anyi County and Jinxian County |
| **Jingdezhen City** | 6 | 0.05g | Group I | Changjiang District, Zhushan District, Fuliang County and Leping City |
| **Pingxiang City** | 6 | 0.05g | Group I | Anyuan District, Xiangdong District, Lianhua County, Shangli County and Luxi County |
| **Jiujiang City** | 6 | 0.05g | Group I | Lushan District, Xunyang District, Jiujiang County, Wuning County, Xiushui County, Yongxiu County, De'an County, Xingzi County, Duchang County, Hukou County, Pengze County, Ruichang City and Gongqingcheng City |
| **Xinyu City** | 6 | 0.05g | Group I | Yushui District and Fenyi County |
| **Yingtan City** | 6 | 0.05g | Group I | Yuehu District, Yujiang County and Guixi City |
| **Ganzhou City** | 7 | 0.10g | Group I | Anyuan County, Huichang County, Xunwu County and Ruijin City |
| | 6 | 0.05g | Group I | Zhanggong District, Nankang District, Ganxian County, Xinfeng County, Dayu County, Shangyou County, Chongyi County, Longnan County, Dingnan County, Quannan County, Ningdu County, Yudu County, Xingguo County and Shicheng County |
| **Ji'an City** | 6 | 0.05g | Group I | Jizhou District, Qingyuan District, Ji'an County, Jishui County, Xiajiang County, Xin'gan County, Yongfeng County, Taihe County, Suichuan County, Wan'an County, Anfu County, Yongxin County and Jinggangshan City |

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Yichun City** | 6 | 0.05g | Group I | Yuanzhou District, Fengxin County, Wanzai County, Shanggao County, Yifeng County, Jing'an County, Tonggu County, Fengcheng City, Zhangshu City and Gao'an City |
| **Fuzhou City** | 6 | 0.05g | Group I | Linchuan District, Nancheng County, Lichuan County, Nanfeng County, Chongren County, Le'an County, Yihuang County, Jinxi County, Zixi County, Dongxiang County and Guangchang County |
| **Shangrao City** | 6 | 0.05g | Group I | Xinzhou District, Guangfeng District, Shangrao County, Yushan County, Yanshan County, Hengfeng County, Yiyang County, Yugan County, Poyang County, Wannian County, Wuyuan County and Dexing City |

### A.0.15 Shandong Province

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Jinan City** | 7 | 0.10g | Group III | Changqing District |
| | 7 | 0.10g | Group II | Pingyin County |
| | 6 | 0.05g | Group III | Lixia District, Shizhong District, Huaiyin District, Tianqiao District, Licheng District, Jiyang County, Shanghe County and Zhangqiu City |
| **Qingdao City** | 7 | 0.10g | Group III | Huangdao District, Pingdu City, Jiaozhou City and Jimo City |
| | 7 | 0.10g | Group II | Shinan District, Shibei District, Laoshan District, Licang District and Chengyang District |
| | 6 | 0.05g | Group III | Laixi City |
| **Zibo City** | 7 | 0.15g | Group II | Linzi District |
| | 7 | 0.10g | Group III | Zhangdian District, Zhoucun District, Huantai County, Gaoqing County and Yiyuan County |
| | 7 | 0.10g | Group II | Zichuan District and Boshan District |
| **Zaozhuang City** | 7 | 0.15g | Group III | Shanting District |
| | 7 | 0.15g | Group II | Tai'erzhuang District |
| | 7 | 0.10g | Group III | Shizhong District, Xuecheng District and Yicheng District |
| | 7 | 0.10g | Group II | Tengzhou City |
| **Dongying City** | 7 | 0.10g | Group III | Dongying District, Hekou District, Kenli County and Guangrao County |
| | 6 | 0.05g | Group III | Lijin County |
| **Yantai City** | 7 | 0.15g | Group III | Longkou City |
| | 7 | 0.15g | Group II | Changdao County and Penglai City |
| | 7 | 0.10g | Group III | Laizhou City, Zhaoyuan City and Qixia City |
| | 7 | 0.10g | Group II | Zhifu District, Fushan District and Laishan District |
| | 7 | 0.10g | Group I | Muping District |
| | 6 | 0.05g | Group III | Laiyang City and Haiyang City |
| **Weifang City** | 8 | 0.20g | Group II | Weicheng District, Fangzi District, Kuiwen District and Anqiu City |
| | 7 | 0.15g | Group III | Zhucheng City |

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| | 7 | 0.15g | Group II | Hanting District, Linqu County, Changle County, Qingzhou City, Shouguang City and Changyi City |
| | 7 | 0.10g | Group III | Gaomi City |
| **Jining City** | 7 | 0.10g | Group III | Weishan County and Liangshan County |
| | 7 | 0.10g | Group II | Yanzhou District, Wenshang County, Sishui County, Qufu City and Zoucheng City |
| | 6 | 0.05g | Group III | Rencheng District, Jinxiang County and Jiaxiang County |
| | 6 | 0.05g | Group II | Yutai County |
| **Taian City** | 7 | 0.10g | Group III | Xintai City |
| | 7 | 0.10g | Group II | Taishan District, Daiyue District and Ningyang County |
| | 6 | 0.05g | Group III | Dongping County and Feicheng City |
| **Wiehai City** | 7 | 0.10g | Group I | Huancui District, Wendeng District and Rongcheng City |
| | 6 | 0.05g | Group II | Rushan City |
| **Rizhao City** | 8 | 0.20g | Group II | Juxian County |
| | 7 | 0.15g | Group III | Wulian County |
| | 7 | 0.10g | Group III | Donggang District and Lanshan District |
| **Laiwu City** | 7 | 0.10g | Group III | Gangcheng District |
| | 7 | 0.10g | Group II | Laicheng District |
| **Linyi City** | 8 | 0.20g | Group II | Lanshan District, Luozhuang District, Hedong District, Tancheng County, Yishui County, Junan County and Linshu County |
| | 7 | 0.15g | Group II | Yinan County, Lanling County and Feixian County |
| | 7 | 0.10g | Group III | Pingyi County and Mengyin County |
| **Dezhou city** | 7 | 0.15g | Group II | Pingyuan County and Yucheng City |
| | 7 | 0.10g | Group III | Linyi County and Qihe County |
| | 7 | 0.10g | Group II | Decheng District, Lingcheng District and Xiajin County |
| | 6 | 0.05g | Group III | Ningjin County, Qingyun County, Wucheng County and Leling City |
| **Liaocheng City** | 8 | 0.20g | Group II | Yanggu County and Shenxian County |
| | 7 | 0.15g | Group II | Dongchangfu District, Chiping County and Gaotang County |
| | 7 | 0.10g | Group III | Guanxian County and Linqing City |
| | 7 | 0.10g | Group II | Dong’e County |
| **Binzhou City** | 7 | 0.10g | Group III | Bincheng District, Boxing County and Zouping County |
| | 6 | 0.05g | Group III | Zhanhua District, Huimin County, Yangxin County and Wudi County |
| **Heze City** | 8 | 0.20g | Group II | Juancheng County and Dongming County |
| | 7 | 0.15g | Group II | Mudan District, Yuncheng County and Dingtao County |
| | 7 | 0.10g | Group III | Juye County |
| | 7 | 0.10g | Group II | Caoxian County, Shanxian County and Chengwu County |

### A.0.16 Henan Province

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Zhengzhou City** | 7 | 0.15g | Group II | Zhongyuan District, Erqi District, Guancheng Hui District, Jinshui District and Huiji District |
| | 7 | 0.10g | Group II | Shangjie District, Zhongmu County, Gongyi City, Xingyang City, Xinmi City, Xinzheng City and Dengfeng City |
| **Kaifeng City** | 7 | 0.15g | Group II | Lankao County |
| | 7 | 0.10g | Group II | Longting District, Shunhe Hui District, Gonglou District, Yuwangtai District, Xiangfu District, Tongxu County and Weishi County |
| | 6 | 0.05g | Group II | Qixian County |
| **Luoyang City** | 7 | 0.10g | Group II | Laocheng District, Xigong District, Chanhe Hui District, Jianxi District, Jili District, Luolong District, Mengjin County, Xin'an County, Yiyang County and Yanshi City |
| | 6 | 0.05g | Group III | Luoning County |
| | 6 | 0.05g | Group II | Songxian County and Yichuan County |
| | 6 | 0.05g | Group I | Luanchuan County and Ruyang County |
| **Pingdingshan City** | 6 | 0.05g | Group I | Xinhua District, Weidong District, Shilong District, Zhanhe District [1], Baofeng County, Yexian County, Lushan County and Wugang City |
| | 6 | 0.05g | Group II | Jiaxian County and Ruzhou City |
| **Anyang City** | 8 | 0.20g | Group II | Wenfeng District, Yindu District, Long'an District, Beiguan District, Anyang County [2] and Tangyin County |
| | 7 | 0.15g | Group II | Huaxian County and Neihuang County |
| | 7 | 0.10g | Group II | Linzhou City |
| **Hebi City** | 8 | 0.20g | Group II | Shancheng District, Qibin District and Qixian County |
| | 7 | 0.15g | Group II | Heshan District and Xunxian County |
| **Xinxiang City** | 8 | 0.20g | Group II | Hongqi District, Weibin District, Fengquan District, Muye District, Xinxiang County, Huojia County, Yuanyang County, Yanjin County, Weihui City and Huixian City |
| | 7 | 0.15g | Group II | Fengqiu County and Changyuan County |
| **Jiaozuo City** | 7 | 0.15g | Group II | Xiuwu County and Wuzhi County |
| | 7 | 0.10g | Group II | Jiefang District, Zhongzhan District, Macun District, Shanyang District, Boai County, Wnxian County, Wuzhi City and Mengzhou City |
| **Puyang City** | 8 | 0.20g | Group II | Fanxian County |
| | 7 | 0.15g | Group II | Hualong District, Qingfeng County, Nanle County, Taiqian County and Puyang County |
| **Xuchang City** | 7 | 0.10g | Group I | Weidu District, Xuchang County, Yanling County, Yuzhou City and Changge City |
| | 6 | 0.05g | Group II | Xiangcheng County |
| **Luohe City** | 7 | 0.10g | Group I | Wuyang County |
| | 6 | 0.05g | Group I | Zhaoling District, Yuanhui District, Yancheng District and Linying County |
| **Sanmenxia City** | 7 | 0.15g | Group II | Hubin District, Shanzhou District and Lingbao City |

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| | 6 | 0.05g | Group III | Mianchi County and Lushi County |
| | 6 | 0.05g | Group II | Yima City |
| **Nanyang City** | 7 | 0.10g | Group I | Wancheng District, Wolong District, Xixia County, Zhenping County, Neixiang County and Tanghe County |
| | 6 | 0.05g | Group I | Nanzhao County, Fangcheng County, Xichuan County, Sheqi County, Xinye County, Tongbai County and Dengzhou City |
| **Shangqiu City** | 7 | 0.10g | Group II | Liangyuan District, Suiyang District, Minquan County and Yucheng County |
| | 6 | 0.05g | Group III | Suixian County and Yongcheng City |
| | 6 | 0.05g | Group II | Ningling County, Zhecheng County and Xiayi County |
| **Xinyang City** | 7 | 0.10g | Group I | Luoshan County, Huangchuan County and XixianCounty |
| | 6 | 0.05g | Group I | Shihe District, Pingqiao District, Guangbei County, Xinxian County, Shangcheng County, Gushi County and Huaibin County |
| **Zhoukou City** | 7 | 0.10g | Group I | Fugou County and Taikang County |
| | 6 | 0.05g | Group I | Chuanhui District, Xihua County, Shangshui County, Shenqiu County, Dancheng County, Huaiyang County, Luyi County and Xiangcheng City |
| **Zhumadian City** | 7 | 0.10g | Group I | Xiping County |
| | 6 | 0.05g | Group I | Yicheng District, Shangcai County, Pingyu County, Zhengyang County, Queshan County, Biyang County, Ru'nan County, Suiping County and Xincai County |
| **County-level administrative unit directly under the provincial government** | 7 | 0.10g | Group II | Jiyuan City |

Note: 1. The Government of Zhanhe District is located at Shuguang Street, Xinhua District, Pingdingshan City; 2. The Government of Anyang County is located at Dengta Road, Beiguan District, Anyang City.

## A.0.17 Hubei Province

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Wuhan City** | 7 | 0.10g | Group I | Xinzhou District |
| | 6 | 0.05g | Group I | Jiang'an District, Jianghan District, Qiaokou District, Hanyang District, Wuchang District, Qingshan District, Hongshan District, Dongxihu District, Hannan District, Caidian District, Jiangxia District and Huangpi District |
| **Huangshi City** | 6 | 0.05g | Group I | Huangshigang District, Xisaishan District, Xialu District, Tieshan District, Yangxin County and Daye City |
| **Shiyan City** | 7 | 0.15g | Group I | Zhushan County and Zhuxi County |
| | 7 | 0.10g | Group I | Yunyang District and Fangxian County |
| | 6 | 0.05g | Group I | Maojian District, Zhangwan District, Yunxi County and Danjiangkou City |
| **Yichang city** | 6 | 0.05g | Group I | Xiling District, Wujiagang District, Dianjun District, Xiaoting District, Yiling District, Yuan'an County, Xingshan County, Zigui County, Changyang Tujia Autonomous County, Wufeng Tujia Autonomous County, YiduCity, Dangyang City and Zhijiang City |
| **Xiangyang City** | 6 | 0.05g | Group I | Xiangcheng District, Fancheng District, Xiangzhou District, Nanzhang County, Gucheng County, Baokang County, Laohekou City, Zaoyang City and Yicheng City |
| **Ezhou City** | 6 | 0.05g | Group I | LiangzihuDistrict, Huarong District and Echeng District |
| **Jingmen City** | 6 | 0.05g | Group I | Dongbao District, Duodao District, Jingshan County, Shayang County and Zhongxiang City |
| **Xiaogan City** | 6 | 0.05g | Group I | Xiaonan District, Xiaochang County, Dawu County, Yunmeng County, Yingcheng City, Anlu City and Hanchuang City |
| **Jingzhou City** | 6 | 0.05g | Group I | Shashi District, Jingzhou District, Gong’an County, Jianli County, Jiangling County, Shishou City, Honghu City and Songzi City |
| **Huanggang City** | 7 | 0.10g | Group I | Tuanfeng County, Luotian County, Yingshan County and Macheng City |
| | 6 | 0.05g | Group I | Huangzhou District, Hong’an County, Xishui County, Qichun County, Huangmei County and Wuxue City |
| **Xianning City** | 6 | 0.05g | Group I | Xian’an District, Jiayu County, Tongcheng County, Chongyang County, Tongshan County and Chibi City |
| **Suizhou City** | 6 | 0.05g | Group I | Zengdu District, Suixian County and Guangshui City |
| **Enshi Tujia and Miao Autonomous Prefecture** | 6 | 0.05g | Group I | Enshi City, Lichuan City, Jianshi County, Badong County, Xuanen County, Xianfeng County, Laifeng County and Hefeng County |
| **County-level administrative unit directly under the provincial government** | 6 | 0.05g | Group I | Xiantao City, Qianjiang City, Tianmen City, Shennongjia Forestry District |

### A.0.18 Hunan Province

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Changsha City** | 6 | 0.05g | Group I | Furong District, Tianxin District, Yuelu District, Kaifu District, Yuhua District, Wangcheng District, Changsha County, Ningxiang County and Liuyang City |
| **Zhuzhou City** | 6 | 0.05g | Group I | Hetang District, Lusong District, Shifeng District, Tianyuan District, Zhuzhou County, Youxian County, Chaling County, Yanling County and Liling City |
| **Xiangtan City** | 6 | 0.05g | Group I | Yuhu District, Yuetang District, Xiangtan County, Xiangxiang City and Shaoshan City |
| **Hengyang City** | 6 | 0.05g | Group I | Zhuhui District, Yanfeng District, Shigu District, Zhengxiang District, Nanyue District, Hengyang County, Hengnan County, Hengshan County, Hengdong County, Qidong County, Leiyang City and Changning City |
| **Shaoyang City** | 6 | 0.05g | Group I | Shuangqing District, Daxiang District, Beita District, Shaodong County, Xinshao County, Shaoyang County, Longhui County, Dongkou County, Suining County, Xinning County, Chengbu Miao Autonomous County and Wugang City |
| **Yueyang City** | 7 | 0.10g | Group II | Xiangyin County and Miluo City |
| | 7 | 0.10g | Group I | Yueyanglou District and Yueyang County |
| | 6 | 0.05g | Group I | Yunxi District, Junshan District, Huarong County, Pingjiang County and Linxiang City |
| **Changde City** | 7 | 0.15g | Group I | Wuling District and Dingcheng District |
| | 7 | 0.10g | Group I | Anxiang County, Hanshou County, Lixian County, Linli County, Taoyuan County and Jinshi City |
| | 6 | 0.05g | Group I | Shimen County |
| **Zhangjiajie City** | 6 | 0.05g | Group I | Yongding District, Wulingyuan District, Cili County and Sangzhi County |
| **Yiyang City** | 6 | 0.05g | Group I | Ziyang District, Heshan District, Nanxian County, Taojiang County, Anhua County and Yuanjiang City |
| **Chenzhou City** | 6 | 0.05g | Group I | Beihu District, Suxian District, Guiyang County, Yizhang County, Yongxing County, Jiahe County, Linwu County, Rucheng County, Guidong County, Anren County and Zixing City |
| **Yongzhou City** | 6 | 0.05g | Group I | Lingling District, Lengshuitan District, Qiyang County, Dong'an County, Shuangpai County, Daoxian County, Jiangyong County, Ningyuan County, Lanshan County, Xintian County and Jianghua Yao Autonomous County |
| **Huaihua City** | 6 | 0.05g | Group I | Hecheng District, Zhongfang County, Yuanling County, Chenxi County, Xupu County, Huitong County, Mayang Miao Autonomous County, Xinhuang Dong Autonomous County, Zhijiang Dong Autonomous County, Jingzhou Miao and Dong Autonomous County, Tongdao Dong Autonomous County and Hongjiang City |

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Loudi City** | 6 | 0.05g | Group I | Louxing District, Shuangfeng County, Xinhua County, Lengshuijiang City and Lianyuan City |
| **Xiangxi Tujia and Miao Autonomous Prefecture** | 6 | 0.05g | Group I | Jishou City, Luxi County, Fenghuang County, Huayuan County, Baojing County, Guzhang County, Yongshun County and Longshan County |

## A.0.19 Guangdong Province

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Guangzhou City** | 7 | 0.10g | Group I | Liwan District, Yuexiu District, Haizhu District, Tianhe District, Baiyun District, Huangpu District, Panyu District and Nansha District |
| | 6 | 0.05g | Group I | Huadu District, Zengcheng District and Conghua Conghua |
| **Shaoguan City** | 6 | 0.05g | Group I | Wujiang District, Zhenjiang District, Qujiang District, Shixing County, Renhua County, Wengyuan County, Ruyuan Yao Autonomous County, Xinfeng County, Lechang City and Nanxiong City |
| **Shenzhen City** | 7 | 0.10g | Group I | Luohu District, Futian District, Nanshan District, Bao'an District, Longgang District and Yantian District |
| **Zhuhai City** | 7 | 0.10g | Group II | Xiangzhou District and Jinwan District |
| | 7 | 0.10g | Group I | Doumen District |
| **Shantou City** | 8 | 0.20g | Group II | Longhu District, Jinping District, Haojiang District, Chaoyang District, Chenghai District and Nan'ao County |
| | 7 | 0.15g | Group II | Chaonan District |
| **Foshan City** | 7 | 0.10g | Group I | Chancheng District, Nanhai District, Shunde District, Sanshui District and Gaoming District |
| **Jiangmen City** | 7 | 0.10g | Group I | Pengjiang District, Jianghai District, Xinhui District and Heshan City |
| | 6 | 0.05g | Group I | Taishan City, Kaiping City and Enping City |
| **Zhanjiang City** | 8 | 0.20g | Group II | Xuwen County |
| | 7 | 0.10g | Group I | Chikan District, Xiashan District, Potou District, Mazhang District, Suixi County, Lianjiang City, Leizhou City and Wuchuan City |
| **Maoming City** | 7 | 0.10g | Group I | Maonan District, Dianbai District and Huazhou City |
| | 6 | 0.05g | Group I | Gaozhou City and Xinyi City |
| **Zhaoqing City** | 7 | 0.10g | Group I | Duanzhou District, Dinghu District and Gaoyao District |
| | 6 | 0.05g | Group I | Guangning County, Huaiji County, Fengkai County, Deqing County and Sihui City |
| **Huizhou City** | 6 | 0.05g | Group I | Huicheng District, Huiyang District, Boluo County, Huidong County and Longmeng County |
| **Meizhou City** | 7 | 0.10g | Group II | Dabu County |
| | 7 | 0.10g | Group I | Meijiang District, Meixian District and Fengshun County |
| | 6 | 0.05g | Group I | Wuhua County, Pingyuan County, Jiaoling County and Xingning City |
| **Shanwei City** | 7 | 0.10g | Group I | Cheng District, Haifeng County and Lufeng City |
| | 6 | 0.05g | Group I | Luhe County |
| **Heyuan City** | 7 | 0.10g | Group I | Yuancheng District and Dongyuan County |

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| | 6 | 0.05g | Group I | Zijin County, Longchuan County, Lianping County and Heping County |
| **Yangjiang City** | 7 | 0.15g | Group I | Jiangcheng District |
| | 7 | 0.10g | Group I | Yangdong District and Yangxi County |
| | 6 | 0.05g | Group I | Yangcheng City |
| **Qingyuan City** | 6 | 0.05g | Group I | Qingcheng District, Qingxin District, Fogang County, Yangshan County, Lianshan Zhuang and Yao Autonomous County, Liannan Yao Autonomous County, Yingde City and Lianzhou City |
| **Dongguan City** | 6 | 0.05g | Group I | Dongguan City |
| **Zhongshan City** | 7 | 0.10g | Group I | Zhongshan City |
| **Chaozhou City** | 8 | 0.20g | Group II | Xiangqiao District and Chaoan District |
| | 7 | 0.15g | Group II | Raoping County |
| **Jieyang City** | 7 | 0.15g | Group II | Rongcheng District and, Jiedong District |
| | 7 | 0.10g | Group II | Huilai County and Puning City |
| | 6 | 0.05g | Group I | Jiexi County |
| **Yunfu** | 6 | 0.05g | Group I | Yuncheng District, Yun'an District, Xinxing County, Yu'nan County and Luoding City |

## A.0.20 Guangxi Zhuang Autonomous Region

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Nanning City** | 7 | 0.15g | Group I | Long'an County |
| | 7 | 0.10g | Group I | Xingning District, Qingxiu District, Jiangnan District, Xixiangtang District, Liangqing District, Yongning District and Hengxian County |
| | 6 | 0.05g | Group I | Wuming District, Mashan County, Shanglin County and Binyang County |
| **Liuzhou City** | 6 | 0.05g | Group I | Chengzhong District, Yufeng District, Liunan District, Liubei District, Liujiang County, Liucheng County, Luzhai County, Rong'an County, Rongshui Miao Autonomous County and Sanjiang Dong Autonomous County |
| **Guilin City** | 6 | 0.05g | Group I | Xiufeng District, Diecai District, Xiangshan District, Qixing District, Yanshan District, Lingui District, Yangshuo County, Lingchuan County, Quanzhou County, Xing'an County, Yongfu County, Guanyang County, Multinational Autonomous County of Longsheng, Ziyuan County, Pingle County, Lipu County and Gongcheng Yao Autonomous County |
| **Wuzhou City** | 6 | 0.05g | Group I | Wanxiu District, Changzhou District, Longxu District, Cangwu County, Tengxian County, Mengshan County and Cenxi City |
| **Beihai City** | 7 | 0.10g | Group I | Hepu County |
| | 6 | 0.05g | Group I | Haicheng District, Yinhai District and Tieshangang District |
| **Fangchenggang City** | 6 | 0.05g | Group I | Gangkou District, Fangcheng District, Shangsi County and Dongxing City |
| **Qinzhou City** | 7 | 0.15g | Group I | Lingshan County |

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| | 7 | 0.10g | Group I | Qinnan District, Qinbei District and Pubei County |
| **Guigang City** | 6 | 0.05g | Group I | Gangbei District, Gangnan District, Qintang District, Pingnan County and Guiping City |
| **Yulin City** | 7 | 0.10g | Group I | Yuzhou District, Fumian District, Luchuan County, Bobai County, Xingye County and Beiliu City |
| | 6 | 0.05g | Group I | Rongxian County |
| **Baise City** | 7 | 0.15g | Group I | Tiandong County, Pingguo County and Leye County |
| | 7 | 0.10g | Group I | Youjiang District, Tianyang County and Tianlin County |
| | 6 | 0.05g | Group II | Xilin County and Multinational Autonomous County of Longlin |
| | 6 | 0.05g | Group I | Debao County, Napo County and Lingyun County |
| **Hezhou City** | 6 | 0.05g | Group I | Babu District, Zhaoping County, Zhongshan County and Fuchuan Yao Autonomous County |
| **Hechi City** | 6 | 0.05g | Group I | Jinchengjiang District, Nandan County, Tian'e County, Fengshan County, Donglan County, Luocheng Mulao Autonomous County, Huanjiang Maonan Autonomous County, Bama Yao Autonomous County, Du'an Yao Autonomous County, Dahua Yao Autonomous County and Yizhou City |
| **Laibin City** | 6 | 0.05g | Group I | Xingbin District, Xincheng County, Xiangzhou County, Wuxuan County, Jinxiu Yao Autonomous County and Heshan City |
| **Chongzuo City** | 7 | 0.10g | Group I | Fusui County |
| | 6 | 0.05g | Group I | Jiangzhou District, Ningming County, Longzhou County, Daxin County, Tiandeng County and Pingxiang City |
| **County-level administrative unit directly under the autonomous region** | 6 | 0.05g | Group I | Jingxi City |

### A.0.21 Hainan Province

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Haikou City** | 8 | 0.30g | Group II | Xiuying District, Longhua District, Qiongshan District and Meilan District |
| **Sanye City** | 6 | 0.05g | Group I | Haitang District, Jiyang District, Tianya District and Yazhou District |
| **Sanha City** | 7 | 0.10g | Group I | Sansha City [1] |
| **Danzhou City** | 7 | 0.10g | Group II | Danzhou City |
| **County-level administrative unit directly under the provincial government** | 8 | 0.20g | Group II | Wenchang City and Ding'an County |
| | 7 | 0.15g | Group II | Chengmai County |
| | 7 | 0.15g | Group I | Lingao County |
| | 7 | 0.10g | Group II | Qionghai City and Tunchang County |
| | 6 | 0.05g | Group II | Baisha Li Autonomous County and Qiongzhong Li and Miao Autonomous County |
| | 6 | 0.05g | Group I | Wuzhishan City, Wanning City, Dongfang City, Changjiang Li Autonomous County, Ledong Li Autonomous County, Lingshui Li Autonomous County and Baoting Li and Miao Autonomous County |

Note: 1. The Government of Sansha City is located at Yongxing Island of Xisha.

### A.0.22 Chongqing City

| Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|
| 7 | 0.10g | Group I | Qianjiang District and Rongchang District |
| 6 | 0.05g | Group I | Wanzhou District, Fuling District, Yuzhong District, Dadukou District, Jiangbei District, Shapingba District, Jiulongpo District, Nan'an District, Beibei District, Qijiang District, Dazu District, Yubei District, Banan District, Changshou District, Jiangjin District, Hechuan District, Yongchuan District, Nanchuan District, Tongliang District, Bishan District, Tongnan District, Liangping County, Chengkou County, Fengdu County, Dianjiang County, Wulong County, Zhongxian County, Kaixian County, Yunyang County, Fengjie County, Wushan County, Wuxi County, Shizhu Tujia Autonomous County, Xiushan Tujia and Miao Autonomous County, Youyang Tujia and Miao Autonomous County and Pengshui Miao and Tujia Autonomous County |

### A.0.23 Sichuan Province

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Chengdu City** | 8 | 0.20g | Group II | Dujiangyan City |
| | 7 | 0.15g | Group II | Pengzhou City |
| | 7 | 0.10g | Group III | Jinjiang District, Qingyang District, Jinniu District, Wuhou Distrct, Chenghua District, Longquanyi District, Qingbaijiang District, Xindu District, Wenjiang District, Jintang County, Shuangliu County, Pixian County, Dayi County, Pujiang County, Xinjin County, Qionglai City and Chongzhou City |
| **Zigong City** | 7 | 0.10g | Group II | Fushun County |
| | 7 | 0.10g | Group I | Ziliujing District, Gongjing District, Da'an District and Yantan District |
| | 6 | 0.05g | Group III | Rongxian County |
| **Panzhihua City** | 7 | 0.15g | Group III | Dong District, Xi District, Renhe District, Miyi County and Yanbian County |
| **Luzhou City** | 6 | 0.05g | Group II | Luxian County |
| | 6 | 0.05g | Group I | Jiangyang District, Naxi District, Longmatan District, Hejiang County, Xuyong County and Gulin County |
| **Deyang City** | 7 | 0.15g | Group II | Shifang City and Mianzhu City |
| | 7 | 0.10g | Group III | Guanghan City |
| | 7 | 0.10g | Group II | Jingyang District, Zhongjiang County and Luojiang County |
| **Mianyang City** | 8 | 0.20g | Group II | Pingwu County |
| | 7 | 0.15g | Group II | Beichuan Qiang Autonomous County (new) and Jiangyou City |
| | 7 | 0.10g | Group II | Fucheng District, Youxian District and Anxian County |
| | 6 | 0.05g | Group II | Santai County, Yanting County and Zitong County |
| **Guangyuan City** | 7 | 0.15g | Group II | Chaotian District and Qingchuan County |
| | 7 | 0.10g | Group II | Lizhou District, Zhaohua District and Jiange County |
| | 6 | 0.05g | Group II | Wangcang County and Cangxi County |
| **Suining City** | 6 | 0.05g | Group I | Chuanshan District, Anju District, Pengxi County, Shehong County and Daying County |
| **Neijiang City** | 7 | 0.10g | Group I | Longchang County |
| | 6 | 0.05g | Group II | Weiyuan County |
| | 6 | 0.05g | Group I | Shizhong District, Dongxing District and Zizhong County |
| **Leshan City** | 7 | 0.15g | Group III | Jinkouhe District |
| | 7 | 0.15g | Group II | Shawan District, Muchuan County, Ebian Yi Autonomous County and Mabian Yi Autonomous County |
| | 7 | 0.10g | Group III | Wutongqiao District, Qianwei County and Jiajiang County |
| | 7 | 0.10g | Group II | Shizhong District and Emeishan City |
| | 6 | 0.05g | Group III | Jingyan County |
| **Nanchong City** | 6 | 0.05g | Group II | Langzhong City |
| | 6 | 0.05g | Group I | Shunqing District, Gaoping District, Jialing District, Nanbu County, Yingshan County, Peng'an County, Yilong County and Xichong County |

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Meishan City** | 7 | 0.10g | Group III | Dongpo District, Pengshan District, Hongya County, Danleng County and Qingshen County |
| | 6 | 0.05g | Group II | Renshou County |
| **Yibin City** | 7 | 0.10g | Group III | Gaoxian County |
| | 7 | 0.10g | Group II | Cuiping District, Yibin County and Pingshan County |
| | 6 | 0.05g | Group III | Gongxian County andJunlian County |
| | 6 | 0.05g | Group II | Nanxi District, Jiang'an County, Changning County |
| | 6 | 0.05g | Group I | Xingwen County |
| **Guang'an City** | 6 | 0.05g | Group I | Guang'an District, Qianfeng District, Yuechi County, Wusheng County, Linshui County and Huaying City |
| **Dazhou City** | 6 | 0.05g | Group I | Tongchuan District, Dachuan District, Xuanhan County, Kaijiang County, Dazhu County, Quxian County and Wanyuan City |
| **Ya'an City** | 8 | 0.20g | Group III | Shimian County |
| | 8 | 0.20g | Group I | Baoxing County |
| | 7 | 0.15g | Group III | Xingjing County and Hanyuan County |
| | 7 | 0.15g | Group II | Tianquan County and Lushan County |
| | 7 | 0.10g | Group III | Mingshan District |
| | 7 | 0.10g | Group II | Yucheng District |
| **Bazhong City** | 6 | 0.05g | Group I | Bazhou District, Enyang District, ongjiang County and Pingchang County |
| | 6 | 0.05g | Group II | Nanjiang County |
| **Ziyang City** | 6 | 0.05g | Group I | Yanjiang District, Anyue County and Lezhi County |
| | 6 | 0.05g | Group II | Jianyang City |
| **Ngawa Tibetan and Qiang Autonomous Prefecture** | 8 | 0.20g | Group III | Jiuzhaigou County |
| | 8 | 0.20g | Group II | Songpan County |
| | 8 | 0.20g | Group I | Wenchuan County and Maoxian County |
| | 7 | 0.15g | Group II | Lixian County and :Aba County |
| | 7 | 0.10g | Group III | Jinchuan County, Xiaojin County, Heishui County, Rangtang County, Ruoergai County and Hongyuan County |
| | 7 | 0.10g | Group II | Maerkang County |
| **Ganze Tibetan Autonomous Prefecture** | 9 | 0.40g | Group II | Kangding City |
| | 8 | 0.30g | Group II | Daofu County and Luhuo County |
| | 8 | 0.20g | Group III | Litang County and Ganzi County |
| | 8 | 0.20g | Group II | Luding County, Dege County, Baiyu County, Batang County and Derong County |
| | 7 | 0.15g | Group III | Jiulong County, Yajiang County and Xinlong County |
| | 7 | 0.15g | Group II | Danba County |
| | 7 | 0.10g | Group III | Shiqu County, Sertar County and Daocheng County |
| | 7 | 0.10g | Group II | Xiangcheng County |
| **Ganzi Tibetan Autonomous** | 9 | 0.40g | Group III | Xichang City |
| | 8 | 0.30g | Group III | Ningnan County, Puge County and Mianning County |

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Prefecture** | 8 | 0.20g | Group III | Yanyuan County, Dechang County, Butuo County, Zhaojue County, Xide County, Yuexi County and Leibo County |
| | 7 | 0.15g | Group III | Tibetan Autonomous County of Muli, Huidong County, County, Ganluo County and Meigu County |
| | 7 | 0.10g | Group III | Huili County |

## A.0.24 Guizhou Province

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Guiyang City** | 6 | 0.05g | Group I | Nanming District, Yunyan District, Huaxi District, Wudang District, Baiyun District, Guanshanhu District, Kaiyang County, Xifeng County, Xiuwen County and Qingzhen City |
| **Liupanshui City** | 7 | 0.10g | Group II | Zhongshan District |
| | 6 | 0.05g | Group III | Panxian County |
| | 6 | 0.05g | Group II | Shuicheng County |
| | 6 | 0.05g | Group I | Liuzhi Special District |
| **Zunyi City** | 6 | 0.05g | Group I | Honghuagang District, Huichuan District, Zunyi County, Tongzi County, Suiyang County, Zheng'an County, Daozhen Gelao and Miao Autonomous County, Wuchuan Gelao and Miao Autonomous County, Fenggang County, Meitan County, Yuqing County, Xishui County, Chishui City and Renhuai City |
| **Anshun City** | 6 | 0.05g | Group I | Xixiu District, Pingba District, Puding County, Zhenning Buyei and Miao Autonomous County, Guanling Buyi and Miao Autonomous County, Ziyun Miao and Buyi Autonomous County |
| **Tongren City** | 6 | 0.05g | Group I | Bijiang District, Wanshan District, Jiangkou County, Yuping Dong Autonomous County, Shiqian County, Sinan County, Yinjiang Tujia and Miao Autonomous County, Dejiang County, Yanhe Tujia Autonomous County and Songtao Miao Autonomous County |
| **Qiannan Buyei and Miao Autonomous Prefecture** | 7 | 0.15g | Group I | Wangmo County |
| | 7 | 0.10g | Group II | Pu'an County and Qinglong County |
| | 6 | 0.05g | Group III | Xingyi City |
| | 6 | 0.05g | Group II | Xingren County, Zhenfeng County, Ceheng County and Anlong County |
| **Bijie City** | 7 | 0.10g | Group III | Weining Yi, Hui and Miao Autonomous County |
| | 6 | 0.05g | Group III | Hezhang County |
| | 6 | 0.05g | Group II | Qixingguan District, Dafang County and Nayong County |
| | 6 | 0.05g | Group I | Jinsha County, Qianxi County and Zhijin County |
| **Qiandongnan Miao and Dong Autonomous Prefecture** | 6 | 0.05g | Group I | Kaili City, Huangping County, Shibing County, Sansui County, Zhenyuan County, Cengong County, Tianzhu County, Jinping County, Jianhe County, Taijiang County, Liping County, Rongjiang County, Congjiang County, Leishan County, Majiang County and Danzhai County |

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Qiannan Buyei and Miao Autonomous Prefecture** | 7 | 0.10g | Group I | Fuquan City, Guiding County and Longli County |
| | 6 | 0.05g | Group I | Duyun City, Libo County, Weng'an County, Dushan County, Pingtang County, Luodian County, Changshun County, Huishui County and Sandu Shui Autonomous County |

### A.0.25 Yunnan Province

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Kunming City** | 9 | 0.40g | Group III | Dongchuan District and Xundian Hui and Yi Autonomous County |
| | 8 | 0.30g | Group III | Yiliang County and Songming County |
| | 8 | 0.20g | Group III | Wuhua District, Panlong District, Guandu District, Xishan District, Chenggong District, jinning County, Shilin Yi Autonomous County and Anning City |
| | 7 | 0.15g | Group III | Fumin County and Luquan Yi and Miao Autonomous County |
| **Qujing City** | 8 | 0.20g | Group III | Malong County and Huize County |
| | 7 | 0.15g | Group III | Qilin District, Luliang County and Zhanyi County |
| | 7 | 0.10g | Group III | Shizong County, Fuyuan County, Luoping County and Xuanwei City |
| **Yuxi City** | 8 | 0.30g | Group III | Jiangchuan County, Chengjiang County, Tonghai County, Huaning County and Eshan Yi Autonomous County |
| | 8 | 0.20g | Group III | Hongta District and Yimen County |
| | 7 | 0.15g | Group III | Xinping Yi and Dai Autonomous County and Yuanjiang Hani, Yi and Dai Autonomous County |
| **Baoshan City** | 8 | 0.30g | Group III | Longling County |
| | 8 | 0.20g | Group III | Longyang District and Shidian County |
| | 7 | 0.15g | Group III | Changning County |
| **Zhaotong City** | 8 | 0.20g | Group III | Qiaojia County and Yongshan County |
| | 7 | 0.15g | Group III | Daguan County, Yiliang County and Ludian County |
| | 7 | 0.15g | Group II | Suijiang County |
| | 7 | 0.10g | Group III | Zhaoyang District and Yanjin County |
| | 7 | 0.10g | Group II | Shuifu County |
| | 6 | 0.05g | Group II | Zhenxiong County and Weixin County |
| **Lijiang City** | 8 | 0.30g | Group III | Gucheng District, Yulong Naxi Autonomous County and Yongsheng County |
| | 8 | 0.20g | Group III | Ninglang Yi Autonomous County |
| | 7 | 0.15g | Group III | Huaping County |
| **Puer City** | 9 | 0.40g | Group III | Lancang Lahu Autonomous County |
| | 8 | 0.30g | Group III | Menglian Daizu Lahuzu Wazu Autonomous County and Ximeng Va Autonomous County |
| | 8 | 0.20g | Group III | Simao District and Ning'er Hani and Yi Autonomous County |
| | 7 | 0.15g | Group III | Jingdong Yi Autonomous County and Jinggu Dai and Yi Autonomous County |

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| | 7 | 0.10g | Group III | Mojiang Hani Autonomous County, Zhenyuan Yi, Hani and Lahu Autonomous County, and Jiangcheng Hani and Yi Autonomous County |
| **Lincang City** | 8 | 0.30g | Group III | Shuangjiang Lahu, Va, Blang and Dai Autonomous County, Gengma Dai and Wa Autonomous County and Cangyuan Va Autonomous County |
| | 8 | 0.20g | Group III | Linxiang District, Fengqing County, Yunxian County, Yongde County and Zhenkang County |
| **Chuxiong Yi Autonomous Prefecture** | 8 | 0.20g | Group III | Chuxiong City and Nanhua County |
| | 7 | 0.15g | Group III | Shuangbai County, Mouding County, Yao'an County, Dayao County, Yuanmou County, Wuding County and Lufeng County |
| | 7 | 0.10g | Group III | Yongren County |
| **Honghe Hani and Yi Autonomous Prefecture** | 8 | 0.30g | Group III | Jianshui County and Shiping County |
| | 7 | 0.15g | Group III | Gejiu City, Kaiyuan City, Mile City, Yuanyang County and Honghe County |
| | 7 | 0.10g | Group III | Mengzi City, Luxi County, Jinping Miao, Yao and Dai Autonomous County and Lvchun County |
| | 7 | 0.10g | Group I | Hekou Yao Autonomous County |
| | 6 | 0.05g | Group III | Pingbian Miao Autonomous County |
| **Wenshan Zhuang and Miao Autonomous Prefecture** | 7 | 0.10g | Group III | Wenshan City |
| | 6 | 0.05g | Group III | Yanshan County and Qiubei County |
| | 6 | 0.05g | Group II | Guangnan County |
| | 6 | 0.05g | Group I | Xichou County, Malipo County, Maguan County and Funing County |
| **Xishuangbanna Dai Autonomous Prefecture** | 8 | 0.30g | Group III | Menghai County |
| | 8 | 0.20g | Group III | Jinghong City |
| | 7 | 0.15g | Group III | Mengla County |
| **Dali Bai Autonomous Prefecture** | 8 | 0.30g | Group III | Eryuan County, Jianchuan County and Heqing County |
| | 8 | 0.20g | Group III | Dali City, Yangbi Yi Autonomous County, Xiangyun County, Binchuan County, Midu County, Nanjian Yi Autonomous County and Weishan Yi and Hui Autonomous Coun |
| | 7 | 0.15g | Group III | Yongping County and Yunlong County |
| **Dehong Dai and Jingpo Autonomous Prefecture** | 8 | 0.30g | Group III | Ruili City and Mang City |
| | 8 | 0.20g | Group III | Lianghe County, Yingjiang County and Longchuan County |
| **Nujiang Lisu Autonomous Prefecture** | 8 | 0.20g | Group III | Lushui County |
| | 8 | 0.20g | Group II | Fugong County and Gongshan Derung and Nu Autonomous County |
| | 7 | 0.15g | Group III | Lanping Bai and Pumi Autonomous County |
| **Diqing Tibetan Autonomous Prefecture** | 8 | 0.20g | Group II | Shangri-La City, Deqin County and Weixi Lisu Autonomous County |

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **County-level administrative unit directly under the provincial government** | 8 | 0.20g | Group III | Tengchong City |

## A.0.26 Tibet Autonomous Region

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Lhasa City** | 9 | 0.40g | Group III | Damxung County |
| | 8 | 0.20g | Group III | Chengguan District, Lhünzhub County, Nyêmo County and Doilungdêqên County |
| | 7 | 0.15g | Group III | Qüxü County, Dagzê County and Maizhokunggar County |
| **Qamdo City** | 8 | 0.20g | Group III | Karuo District, Banbar County and Lhorong County |
| | 7 | 0.15g | Group III | Riwoqê County, Dênqên County, Chagyab County, Baxoi County and Zogang County |
| | 7 | 0.15g | Group II | Jomda County and Markam County |
| | 7 | 0.10g | Group III | Gonjo County |
| **Shannan Prefecture** | 8 | 0.30g | Group III | Cona County |
| | 8 | 0.20g | Group III | Sangri County, Qusum County and Lhünzê County |
| | 7 | 0.15g | Group III | Nêdong County, Chanang County, Konggar County, Qonggyai County, Comai County, Lhozhag County, Gyaca County and Nagarzê County |
| **Shigatse City** | 8 | 0.20g | Group III | Rinbung County, Kangmar County and Nyalam County |
| | 8 | 0.20g | Group II | Lhazê County, Dinggyê County and Yadong County |
| | 7 | 0.15g | Group III | Sangzhuzi District (the former Xigaze City), Namling County, Gyangzê County, Tingri County, Sa'gya County, Bainang County, Gyirong County, Saga County and Kamba County |
| | 7 | 0.15g | Group II | Ngamring County, Xietongmen County and Zhongba County |
| **Nagqu Prefecture** | 8 | 0.30g | Group III | Shenza County |
| | 8 | 0.20g | Group III | Nagqu County, Amdo County and Nyima County |
| | 8 | 0.20g | Group II | Lhari County |
| | 7 | 0.15g | Group III | Nyainrong County and Baingoin County |
| | 7 | 0.15g | Group II | Sog County, Baqing County and Shuanghu County |
| | 7 | 0.10g | Group III | Biru County |
| **Ngari Prefecture** | 8 | 0.20g | Group III | Purang County |
| | 7 | 0.15g | Group III | Gar County and Rutog County |
| | 7 | 0.15g | Group II | Zanda County and Gêrzê County |
| | 7 | 0.10g | Group III | Gê'gya County |
| | 7 | 0.10g | Group II | Coqen County |
| **Nyingchi City** | 9 | 0.40g | Group III | Mêdog County |
| | 8 | 0.30g | Group III | Mainling County and Bomê County |

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| | 8 | 0.20g | Group III | Bayi District (the former Nyingchi County) |
| | 7 | 0.15g | Group III | Zayü County and Nang County |
| | 7 | 0.10g | Group III | Gongbo'gvamda County |

## A.0.27 Shaanxi Province

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Xi'an city** | 8 | 0.20g | Group II | Xincheng District, Beilin District, Lianhu District, Baqiao District, Weiyang District, Yanta District, Yanliang District, Lintong District, Chang'an District, Gaoling District, Lantian County, Zhouzhi County and Huxian County |
| **Tongchuan City** | 7 | 0.10g | Group III | Wangyi District, Yintai District and Yaozhou District |
| | 6 | 0.05g | Group III | Yijun County |
| **Baoji City** | 8 | 0.20g | Group III | Fengxiang County, Qishan County, Longxian County and Qianyang County |
| | 8 | 0.20g | Group II | Weibin District, Jintai District, Chencang District, Fufeng County and Meixian County |
| | 7 | 0.15g | Group III | Fengxian County |
| | 7 | 0.10g | Group III | Linyou County and Taibai County |
| **Xianyang City** | 8 | 0.20g | Group II | Qindu District, Yangling District, Weicheng District, Jingyang County, Wugong County and Xingping City |
| | 7 | 0.15g | Group III | Qianxian County |
| | 7 | 0.15g | Group II | Sanyuan County and Liquan County |
| | 7 | 0.10g | Group III | Yongshou County and Chunhua County |
| | 6 | 0.05g | Group III | Binxian County, Changwu County and Xunyi County |
| **Weinan City** | 8 | 0.30g | Group II | Huaxian County |
| | 8 | 0.20g | Group II | Linwei District, Tongguan County, Dali County, Huayin City |
| | 7 | 0.15g | Group III | Chengcheng County and Fuping County |
| | 7 | 0.15g | Group II | Heyang County, Pucheng County and Hancheng City |
| | 7 | 0.10g | Group III | Baishui County |
| **Yan'an City** | 6 | 0.05g | Group III | Wuqi County, Fu County, Luochuan County, Yichuan County, Huanglong County and Huangling County |
| | 6 | 0.05g | Group II | Yanchang County and, Yanchuan County |
| | 6 | 0.05g | Group I | Baota District, Zichang County, Ansai County, Zhidan County and Ganquan County |
| **Hanzhong City** | 7 | 0.15g | Group II | Lüeyang County |
| | 7 | 0.10g | Group III | Liuba County |
| | 7 | 0.10g | Group II | Hantai District, Nanzheng County, Mianxian County and Ningqiang County |
| | 6 | 0.05g | Group III | Chenggu County, Yangxian County, Xixiang County and Foping County |
| | 6 | 0.05g | Group I | Zhenba County |

| | | | | |
|---|---|---|---|---|
| **Yulin City** | 6 | 0.05g | Group III | Fugu County, Dingbian County and Wubu County |
| | 6 | 0.05g | Group I | Yuyang District, Shenmu County, Hengshan County, Jingbian County, Suide County, Mizhi County, Jiaxian County, Qingjian County and Zizhou County |
| **Ankang City** | 7 | 0.10g | Group I | Hanbin District and Pingli County |
| | 6 | 0.05g | Group III | Hanyin County, Shiquan County and Ningshan County |
| | 6 | 0.05g | Group II | Ziyang County, Langao County, Xunyang County and Baihe County |
| | 6 | 0.05g | Group I | Zhenping County |
| **Shangluo City** | 7 | 0.15g | Group II | Luonan County |
| | 7 | 0.10g | Group III | Shangzhou District and Zhashui County |
| | 7 | 0.10g | Group I | Shangnan County |
| | 6 | 0.05g | Group III | Danfeng County, Shanyang County and Zhen'an County |

## A.0.28 Gansu Province

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Lanzhou City** | 8 | 0.20g | Group III | Chengguan District, Qilihe District, Xigu District, Anning District and Yongdeng County |
| | 7 | 0.15g | Group III | Honggu District, Gaolan County and Yuzhong County |
| **Jiayuguan City** | 8 | 0.20g | Group II | Jiayuguan City |
| **Jinchang City** | 7 | 0.15g | Group III | Jinchuan District and Yongchang County |
| **Baiyin City** | 8 | 0.30g | Group III | Pingchuan District |
| | 8 | 0.20g | Group III | Jingyuan County, Huining County and Jingtai County |
| | 7 | 0.15g | Group III | Baiyin District |
| **Tianshui City** | 8 | 0.30g | Group II | Qinzhou District and Maiji District |
| | 8 | 0.20g | Group III | Qingshui County, Qin'an County, Wushan County and Zhangjiachuan Hui Autonomous County |
| | 8 | 0.20g | Group II | Gangu County |
| **Wuwei City** | 8 | 0.30g | Group III | Gulang County |
| | 8 | 0.20g | Group III | Liangzhou District and Tianzhu Tibetan Autonomous County |
| | 7 | 0.10g | Group III | Minqin County |
| **Zhangye City** | 8 | 0.20g | Group III | Linze County |
| | 8 | 0.20g | Group II | Sunan Yugur Autonomous County and Gaotai County |
| | 7 | 0.15g | Group III | Ganzhou District |
| | 7 | 0.15g | Group II | Minle County and Shandan County |
| **Pingliang City** | 8 | 0.20g | Group III | Huating County, Zhuanglang County and Jingning County |
| | 7 | 0.15g | Group III | Kongtong District and Chongxin County |
| | 7 | 0.10g | Group III | Jingchuan County and Lingtai County |
| **Jiuquan City** | 8 | 0.20g | Group II | Subei Mongol Autonomous County |
| | 7 | 0.15g | Group III | Suzhou District and Yumen City |
| | 7 | 0.15g | Group II | Jinta County and Aksai Kazakh Autonomous County |
| | 7 | 0.10g | Group III | Guazhou County and Dunhuang City |
| **Qingyang City** | 7 | 0.10g | Group III | Xifeng District, Huanxian County and Zhenyuan County |

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| | 6 | 0.05g | Group III | Qingcheng County, Huachi County, Heshui County, Zhengning County and Ningxian County |
| **Dingxi City** | 8 | 0.20g | Group III | Tongwei County, Longxi County and Zhangxian County |
| | 7 | 0.15g | Group III | Anding District, Weiyuan County, Lintao County and Minxian County |
| **Longnan City** | 8 | 0.30g | Group II | Xihe County and Lixian County |
| | 8 | 0.20g | Group III | Liangdang County |
| | 8 | 0.20g | Group II | Wudu District, Chengxian County, Wenxian County, Tanchang County, Kangxian County and Huixian County |
| **Linxia Hui Autonomous Prefecture** | 8 | 0.20g | Group III | Yongjing County |
| | 7 | 0.15g | Group III | Linxia City, Kangle County, Guanghe County, Hezheng County and Dongxiang Autonomous County |
| | 7 | 0.15g | Group II | Linxia County |
| | 7 | 0.10g | Group III | Jishishan Baoan, Dongxiang and Salazu Autonomous County |
| **Gannan Tibetan Autonomous Prefecture** | 8 | 0.20g | Group III | Zhouqu County |
| | 8 | 0.20g | Group II | Maqu County |
| | 7 | 0.15g | Group III | Lintan County, Zhuoni County and Diebu County |
| | 7 | 0.15g | Group II | Hezuo City and Xiahe County |
| | 7 | 0.10g | Group III | Luqu County |

## A.0.29 Qinghai Province

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Xining City** | 7 | 0.10g | Group III | Chengzhong District, Chengdong District, Chengxi District, Chengbei District, Datong Hui and Tu Autonomous County, Huangzhong County and Huangyuan County |
| **Haidong City** | 7 | 0.10g | Group III | Ledu District, Ping'an District, Minhe Hui and Tu Autonomous County, Huzhu Tu Autonomous County, Hualong Hui Autonomous County and Xunhua Salar Autonomous County |
| **Haibei Tibetan Autonomous Prefecture** | 8 | 0.20g | Group II | Qilian County |
| | 7 | 0.15g | Group III | Menyuan Hui Autonomous County |
| | 7 | 0.15g | Group II | Haiyan County |
| | 7 | 0.10g | Group III | Gangcha County |
| **Huangnan Tibetan Autonomous Prefecture** | 7 | 0.15g | Group II | Tongren County |
| | 7 | 0.10g | Group III | Jianzha County and Henan Mongol Autonomous County |
| | 7 | 0.10g | Group II | Zeku County |
| **Hainan Tibetan Autonomous Prefecture** | 7 | 0.15g | Group II | Guide County |
| | 7 | 0.10g | Group III | Gonghe County, Tongde County, Xinghai County and Guinan County |
| **Guoluo Tibetan Autonomous Prefecture** | 8 | 0.30g | Group III | Maqin County |
| | 8 | 0.20g | Group III | Gande County and Darlag County |
| | 7 | 0.15g | Group III | Maduo County |

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| | 7 | 0.10g | Group III | Banma County and Jiuzhi County |
| **Yushu Tibetan Autonomous Prefecture** | 8 | 0.20g | Group III | Qumarlêb County |
| | 7 | 0.15g | Group III | Yushu City and Zadoi County |
| | 7 | 0.10g | Group III | Chindu County |
| | 7 | 0.10g | Group II | Zadoi County and Nangqên County |
| **Haixi Mongol and Tibetan Autonomous Prefecture** | 7 | 0.15g | Group III | Delhi City |
| | 7 | 0.15g | Group II | Ulan County |
| | 7 | 0.10g | Group III | Geermu City, Dulan County and Tianjun County |

## A.0.30 Ningxia Hui Autonomous Region

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Yinchuan City** | 8 | 0.20g | Group III | Lingwu City |
| | 8 | 0.20g | Group II | Xingqing District, Xixia district, Jinfeng District, Yongning County and Helan County |
| **Shizuishan City** | 8 | 0.20g | Group II | Dawukou District, Huinong District and Pingluo County |
| **Wuzhong City** | 8 | 0.20g | Group III | Litong District, Hongsibu District, Tongxin County and Qingtongxia City |
| | 6 | 0.05g | Group III | Yanchi County |
| **Guyuan City** | 8 | 0.20g | Group III | Yuanzhou District, Xiji County, Longde County and Jingyuan County |
| | 7 | 0.15g | Group III | Pengyang County |
| **Zhongwei City** | 8 | 0.30g | Group III | Haiyuan County |
| | 8 | 0.20g | Group III | Shapotou District and Zhongning County |

## A.0.31 Xinjiang Uygur Autonomus Region

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Urumqi City** | 8 | 0.20g | Group II | Tianshan District, Saybag District, Xinshi District, Shuimogou District, Toutunhe District, Dabancheng District, Midong District and Urumqi County1 |
| **Karamay City** | 8 | 0.20g | Group III | Dushanzi District |
| | 7 | 0.10g | Group III | Karamay District and Baijiantan District |
| | 7 | 0.10g | Group I | Urho District |
| **Turpan City** | 7 | 0.15g | Group II | Gaochang District (the former Turpan City) |
| | 7 | 0.10g | Group II | Piqan County and Tuokexun County |
| **Hami Region** | 8 | 0.20g | Group II | Barkol Kazakh Autonomous County |
| | 7 | 0.15g | Group II | Yiwu (Aratrk) County |
| | 7 | 0.10g | Group II | Hami City |
| **Changji Hui Autonomous Prefecture** | 8 | 0.20g | Group III | Changji City and Manas County |
| | 8 | 0.20g | Group II | Mulei Kazakh Autonomous County |
| | 7 | 0.15g | Group III | Hutubi County |
| | 7 | 0.15g | Group II | Fukang City and Jmsa County |

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| | 7 | 0.10g | Group II | Qitai County |
| **Bortala Mongol Autonomous Prefecture** | 8 | 0.20g | Group III | Jinghe County |
| | 8 | 0.20g | Group II | Alashankou City |
| | 7 | 0.15g | Group III | Bole City and Arixang County |
| **Bayingolin Mongol Autonomous Prefecture** | 8 | 0.20g | Group II | Korla City, Yanqi Hui Autonomous County, Hejing Town, Hoshut County and Bohu County |
| | 7 | 0.15g | Group II | Bugur County |
| | 7 | 0.10g | Group III | Qarqan County |
| | 7 | 0.10g | Group II | Lopnur County and Ruoqiang County |
| **Aksu Region** | 8 | 0.20g | Group II | Akesu City, Wensu County, Kuqa County, Baicheng County, Uqturqan County and Kalqin County |
| | 7 | 0.15g | Group II | Xinhe County |
| | 7 | 0.10g | Group III | Xayar County and Awat County |
| **Kizilsu Kirghiz Autonomous Prefecture** | 9 | 0.40g | Group III | Ulugqat County |
| | 8 | 0.30g | Group III | Atushi City |
| | 8 | 0.20g | Group III | Akto County |
| | 8 | 0.20g | Group II | Akqi County |
| **Kashgar Region** | 9 | 0.40g | Group III | Taxkorgan Tajik Autonomous County |
| | 8 | 0.30g | Group III | Kashi City, Shufu County and Yengisar County |
| | 8 | 0.20g | Group III | Shule County, Yopurga County, Payzawat County and Marabishi County |
| | 7 | 0.15g | Group III | Poskam Country and Yecheng County |
| | 7 | 0.10g | Group III | Yarkant County and Makit County |
| **Hotan Region** | 7 | 0.15g | Group II | Hotan City, Hotan County2, Karakax County, Lop County and Qira County |
| | 7 | 0.10g | Group III | Pishan County |
| | 7 | 0.10g | Group II | Yutian County and Niya County |
| **Yili Kazak Autonomous Prefecture** | 8 | 0.30g | Group III | Zhaosu County, Tekes County and Nilka County |
| | 8 | 0.20g | Group III | Yining City, Kuytun City, Korgas City, Yining County, Huocheng County, Gongliu County and Xinyuan County |
| | 7 | 0.15g | Group III | Qapqal Xibe Autonomous County |
| **Tacheng Region** | 8 | 0.20g | Group III | Usu City and Shawan County |
| | 7 | 0.15g | Group II | Toli County |
| | 7 | 0.15g | Group I | Hoboksar Mongol Autonomous County |
| | 7 | 0.10g | Group II | Yumin County |
| | 7 | 0.10g | Group I | Tacheng City and Emin County |
| **Altay Region** | 8 | 0.20g | Group III | Fuyun County and Qinggil County |
| | 7 | 0.15g | Group II | Aletai City and Kaba County |
| | 7 | 0.10g | Group II | Burqin County |
| | 6 | 0.05g | Group III | Fuhai County and Jeminay County |
| **County-level** | 8 | 0.20g | Group III | Shihezi City andCocodala City |

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **administrative unit directly under the autonomous region** | 8 | 0.20g | Group II | Tiemenguan City |
| | 7 | 0.15g | Group III | Tumu Shuker City, Wujiaqu City and Shuanghe City |
| | 7 | 0.10g | Group II | Beitun City and Alaer City |

Note: 1. The Government of Urumqi County is located at South Nanhu Road, Shuimogou District, Urumqi City; 2. The Government of Hotan County is located Gujiangbage Street, Hotan City.

### A.0.32 Hong Kong and Macao Special administrative Regions and Taiwan Province

| | Intensity | Acceleration | Group | Cities and towns at or above the county level |
|---|---|---|---|---|
| **Hong Kong Special Administrative Region** | 7 | 0.15g | Group II | Hong Kong |
| **Macao Special Administrative Region** | 7 | 0.10g | Group II | Macao |
| **Taiwan Province** | 9 | 0.40g | Group III | Chiayi County, Chiayi City, Yunlin County, Nantou County, Changhua County, Taichung City, Miaoli County and Hualien County |
| | 9 | 0.40g | Group II | Tainan County and Taichung County |
| | 8 | 0.30g | Group III | Taibei City, Taipei County, Keelung City, Taoyuan County, Hsinchu County, Hsinchu City, Yilan County, Taitung County and Pingtung County |
| | 8 | 0.20g | Group III | Kaohsiung City, Kaohsiung County and Kinmen County |
| | 8 | 0.20g | Group II | Penghu County |
| | 6 | 0.05g | Group III | Mazu County |

# Appendix B Requirements for Seismic Design of High Strength Concrete Structures

**B.0.1** The concrete strength grade for high strength concrete structures shall meet the requirements of Article 3.9.3 in this code; its seismic design shall not only meet the requirements for seismic design of ordinary concrete structures, but also meet the requirements of this Appendix.

**B.0.2** Among the section shear force design limits of structural components, the item with the design value ($f_c$) of concrete axes compression strength shall be multiplied by the influence coefficient ($\beta_c$) of concrete strength. It shall take 1.0 and 0.8 where the concrete strength grade is C50 and C80 respectively; it shall take the interpolated value where the concrete strength grade is between C50 and C80.

During calculation on the compressive area height and check for bearing capacity of structural components, the item with the design value ($f_c$) of concrete axes compression strength in the Equation shall also be multiplied by the corresponding influence coefficient of concrete strength in accordance with the relevant requirements of the national standard GB 50010 "*Code for Design of Concrete Structures*".

**B.0.3** The details of seismic design for high strength concrete frames shall meet the following requirements:

**1** The reinforcement ratio of longitudinal tension reinforcement at beam end should not be greater than 3% (Grade HRB335 steel reinforcement) and 2.6% (Grade HRB400 steel reinforcement). The minimum diameter of stirrup in critical region of beam end shall be 2mm greater than that of ordinary concrete beam stirrup.

**2** The axial compression ratio limit of column should be adopted according to the following requirements: The axial force ratio limit of concrete column not greater than C60 may be the same as that of ordinary concrete column; the axial force ratio limit of concrete column between C65~C70 should be 0.05 less than that of ordinary concrete column; the axial force ratio limit of concrete column between C75~C80 should be 0.1 less than that of ordinary concrete column.

**3** When the concrete strength grade is greater than C60, the minimum total reinforcement ratio of column longitudinal steel reinforcement shall be 0.1% greater than that of ordinary concrete column.

**4** The minimum stirrup characteristic value at the critical region of column should be determined according to the following requirements: When the concrete strength grade is greater than C60, it should adopt compound stirrup, compound spiral stirrup or continuous compound rectangular spiral stirrup as stirrup.

**1)** When the axial force ratio is not greater than 0.6, the minimum stirrup characteristic value at the critical region of column should be 0.02 greater than that of ordinary concrete column;

**2)** When the axial force ratio is greater than 0.6, the minimum stirrup characteristic value at the critical region of column should be 0.03 greater than that of ordinary concrete column.

**B.0.4** When the concrete strength grade of seismic wall is greater than C60, it shall make special research and take strengthening measures.

# Appendix C Requirements for Seismic Design of Prestressed Concrete Structures

**C.0.1** This Appendix is applicable to the seismic design of pre-tensioning and post-tensioning bonded prestressed concrete structures for Intensity 6, 7 and 8; for Intensity 9, special research shall be carried out.

As for the seismic design of unbounded prestressed concrete structures, measures shall be taken to prevent the relaxation of effective pre-applied force outside plastic hinge zone of structural components under rarely earthquake action; and it shall also meet the special requirements.

**C.0.2** As for the prestressed concrete structures in seismic design, measures shall be taken to ensure that they have good deformation and seismic energy dissipation ability so as to reach the basic requirements of ductile structures; it shall avoid the shear failure of components ahead of bending failure, the joint is damaged before connected components and that the anchoring of prestressed tendon is damaged before components.

**C.0.3** During seismic design, post-tensioned prestressed frames, gantry and the transfer beam of transfer storey should be fabricated with bonded prestressed tendon. The tension members of bearing structures and the frames with seismic Grade 1 shall not be fabricated with unbonded prestressed tendon.

**C.0.4** During seismic design, the seismic grade of prestressed concrete structures and the adjustment of corresponding seismic combination internal force shall meet the requirements for reinforced concrete structures in Chapter 6 of this code.

**C.0.5** The concrete strength grade of prestressed concrete structures, the frames and the transfer components at transfer storey should not be less than C40. The prestressed concrete members of other anti-lateral force shall not be less than C30.

**C.0.6** The seismic calculation of prestressed concrete structures shall not only meet the requirements of Chapter 5 in this code, but also meet the following requirements:

**1** The damping ratio of prestressed concrete structures may be taken as 0.03; and it may be taken as the equivalent damping ratio which is converted from the proportion of total deformation energy of reinforced concrete structures and prestressed concrete structures in the whole structures.

**2** During component section seismic check of prestressed concrete structures, prestressed action effect item shall be added in the fundamental combination of earthquake action effect in Article 5.4.1 of this code; generally, its partial factor shall be taken as 1.0. When the prestressed action effect is unfavorable to the bearing capacity of components, it shall be taken as 1.2.

**3** When the prestressed tendon crosses the joint core zone of frames, the section seismic check of joint core zone shall give consideration to the influence by the total effective pre-applied force and prestressed tunnel-weakening the effective check width of core zone.

**C.0.7** The seismic details of prestressed concrete structures shall not only meet the following requirements, but also meet the requirements of reinforced concrete structures in Chapter 6 of this code.

**1** The prestressed concrete members of anti-lateral force shall be reinforced with mixed prestressed tendon and non-prestressed tendon; their proportion shall be controlled based on seismic grade according to the relevant requirements; the prestressed strength ratio should be not greater than 0.75.

**2** As for the maximum reinforcement ratio of longitudinal tension steel reinforcement at prestressed concrete frame beam end as well as the non-prestressed steel reinforcement ratio of bottom surface and top surface, it shall meet the requirements of reinforced concrete frame beam after corresponding conversion of prestressed strength ratio.

**3** Asymmetric reinforcement may be used for prestressed concrete frame column. The calculation of its axial compression ratio shall give consideration to the design value of axial pressure formed by total effective pre-applied force of prestressed tendon; and it shall meet the requirements of corresponding frame column in reinforced concrete structures. The stirrup should be densified throughout the total height.

**4** In the slab-column-seismic wall structures, the section area of prestressed steel reinforcement shall give consideration to the slab-bottom-crossed continuous steel reinforcement within the range of column section.

**C.0.8** The anchorage device of post-tensioning prestressed tendon should not be set up at the core zone of beam-column joint; the anchorage performance of prestressed tendon and anchorage assembly parts shall meet special requirements.

# Appendix D Section Seismic Check for the Beam-column Joint Core Zone of Frames

## D.1 Beam-column Joint of Ordinary Frames

**D.1.1** The design value for combination shear force at beam-column joint core zone of Grade 1, 2 and 3 frames shall be determined according to the following equation:

$$V_j = \frac{\eta_{jb} \sum M_b}{h_{b0} - \alpha'_s}\left(1 - \frac{h_{b0} - \alpha'_s}{H_c - h_b}\right) \tag{D.1.1-1}$$

The Grade 1 frame structures and Grade 1 frames of Intensity 9 may not be determined according to the above equation, but it shall meet the following equation:

$$V_j = \frac{1.15 \sum M_{bua}}{h_{h0} - \alpha'_s}\left(1 - \frac{h_{b0} - \alpha'_s}{H_c - h_b}\right) \tag{D.1.1-2}$$

Where $V_j$——Design value of combination shear force at beam-column joint core zone;

$h_{b0}$——Effective height of beam section, which may take the average value where the beam section heights on both sides of the joint are unequal;

$\alpha'_s$——Distance between the centroid of beam compressive reinforcement and the compressive edge;

$H_c$——Column calculated height, which may take the distance between inflection points on upper and lower column of joints;

$h_b$——Beam section height, which may take the average value where the beam section height on both sides of the joint are unequal;

$\varepsilon_{jb}$——Strong joint coefficient; as for frame structures, taking 1.5 for Grade 1, l.35 for Grade 2 and 1.2 for Grade 3; as for frames in other structures, taking l.35 for Grade 1, 1.2 for Grade 2 and 1.1 for Grade 3;

$\Sigma M_b$——Sum of combined bending moment design values at counterclockwise or clockwise direction of joint right-left beam ends; If the both bending moments at the left and right end of the joint are negative together for Grade 1, the bending moment with smaller absolute value shall choose zero;

$\Sigma M_{bua}$——Sum of bending moment values corresponding to the reinforced normal section seismic bend bearing capacity at counterclockwise or clockwise direction of joint right-left beam ends; it may be determined according to the reinforced area (counting compressed reinforcement) and the standard value of material strength.

**D.1.2** The section effective check width at core zone shall be determined according to the following requirements:

**1** As for the section effective check width at core zone, it may adopt the section width of lateral column, where the beam section width at the check direction is not less than 1/2 section width of lateral column; it may adopt the smaller value of the following two values, where the beam section width at the check direction is less than 1/2 section width of lateral column.

$$b_j=b_b+0.5h_c \tag{D.1.2-1}$$

$$b_j=b_c \tag{D.1.2-2}$$

Where $b_j$——Section effective check width at joint core zone;

$b_b$——Beam section width;

$h_c$——Column section height at the check direction;

$b_c$——Column section width at the check direction.

**2** When the center lines of beam and column misalign and the eccentricity is not larger than 1/4 of the column width, the section effective check width at core zone may take the smaller value of the above value and the value calculated from the following equation.

$$b_j=0.5(b_b+b_c)+0.25h_c-e \tag{D.1.2-3}$$

Where $e$——Eccentricity between center lines of beam and column.

**D.1.3** Design value of combination shear force at joint core zone shall meet the following requirements:

$$V_j \le \frac{1}{\gamma_{RE}}\left(0.30\eta_j f_c b_j h_j\right) \tag{D.1.3}$$

Where $\varepsilon_j$——Confined factor of orthogonal beam. It may take 1.5 where the floor slab is cast-in-place, the axes of the beam and column are concord, the beam section width of four sides is not less than 1/2 section width of lateral column and the orthogonal beam height is not less than 3/4 of frame beam height; it should adopt 1.25 for Grade 1 of Intensity 9 and 1.0 for other conditions;

$h_j$——Section height at joint core zone, which may take column section height at the check direction;

$\gamma_{RE}$——Seismic adjustment coefficient of bearing capacity, which may take 0.85.

**D.1.4** The section seismic shear bearing capacity at joint core zone shall be checked according to the following equation:

$$V_j \le \frac{1}{\gamma_{RE}}\left(0.1\eta_j f_t b_j h_j + 0.05\eta_j N\frac{b_j}{b_c} + f_{yv}A_{svj}\frac{h_{b0}-\alpha'_s}{s}\right) \tag{D.1.4-1}$$

Grade 1 of Intensity 9

$$V_j \le \frac{1}{\gamma_{RE}}\left(0.9\eta_j f_t b_j h_j + f_{yv}A_{svj}\frac{h_{b0}-\alpha'_s}{s}\right) \tag{D.1.4-2}$$

Where $N$——The smaller axial compressive force of the upper column corresponds to the combination shear design value. Such value shall not be greater than 50% of production of the column cross section area and the specified concrete compressive strength design value; and when N is tensile force, shall take as zero;

$f_{yv}$——Design value of stirrup tensile strength;

$f_t$——Design value of concrete axes tensile strength;

$A_{svj}$——Total section area of stirrup at the same section check direction within the range of effective check width at core zone;

$s$——Space between stirrup.

## D.2 Beam-column Joint of Flat-beam Frames

**D.2.1** When the beam width of flat-beam frames is greater than the column width, the beam-column joint shall meet the requirements of this segment.

**D.2.2** As for the beam-column joint core zone of flat-beam frames, the shear bearing capacity shall be checked within and beyond the range of column width according to the section area ratio of beam longitudinal reinforcement within and beyond the column width range.

**D.2.3** The check method at core zone shall not only meet the requirements of beam-column joint for ordinary frames, but also meet the following requirements:

**1** When the shear force limit at core zone is checked according to Equation (D.1.3) of this code, the effective width of core zone may take the average value for the sum of beam width and column width;

**2** The confined coefficient with beams on four sides may take 1.5 where checking the shear bearing capacity of core zone within the column width range; it should take 1.0 where checking the shear bearing capacity of core zone beyond the column width range;

**3** When checking the shear bearing capacity of core zone, the value of axial force may be the same as that of ordinary beam-column joint at the core zone within the column width range; the favourable effect of axial force on shear bearing capacity may not be considered at the core zone beyond column width;

**4** The total reinforcements developed to the range of column width should be greater than 60% of total reinforcements in the top-face of the flat beam.

## D.3 Beam-column Joint of cylinder Column Frames

**D.3.1** When the axes of the beam and the column are concord, the combination shear force design value of joint core zone for the cylinder column frame shall meet the following requirements:

$$V_{\mathrm{j}} \leq \frac{1}{\gamma_{\mathrm{RE}}}\left(0.30\eta_{\mathrm{j}} f_{\mathrm{c}} A_{\mathrm{j}}\right) \tag{D.3.1}$$

Where $\varepsilon_{j}$——Confined factor of orthogonal beam shall be determined according to Article D.1.3 of this code; the width of the column section shall take the column diameter;

$A_{j}$——Effective section area at joint core zone. When the beam width ($b_{b}$) is not less than half of column diameter ($D$), taking $A_{j}=0.8D^{2}$; when the beam width ($b_{b}$) is less than half of column diameter ($D$) and is not less than $0.4D$, taking $A_{j}=0.8D\,(b_{b}+D/2)$.

**D.3.2** When the axes of beam and column are concord, the section seismic shear bearing capacity at beam-column joint core zone of column frames shall be checked according to the following requirements:

$$V_{\mathrm{j}} \leq \frac{1}{\gamma_{\mathrm{RE}}}\left(1.5\eta_{\mathrm{j}} f_{\mathrm{t}} A_{\mathrm{j}} + 0.05\eta_{\mathrm{j}}\frac{N}{D^{2}}A_{\mathrm{j}} + 1.57 f_{\mathrm{yv}} A_{\mathrm{sh}}\frac{h_{\mathrm{b0}}-\alpha'_{\mathrm{s}}}{s} + f_{\mathrm{yv}} A_{\mathrm{svj}}\frac{h_{\mathrm{b0}}-\alpha'_{\mathrm{s}}}{s}\right) \tag{D.3.2-1}$$

Grade 1 under Intensity 9

$$V_{\mathrm{j}} \le \frac{1}{\gamma_{\mathrm{RE}}}\left(1.2\eta_{\mathrm{j}} f_{\mathrm{t}} A_{\mathrm{j}} + 1.57 f_{\mathrm{yv}} A_{\mathrm{sh}} \frac{h_{\mathrm{b0}} - \alpha'_{\mathrm{s}}}{s} + f_{\mathrm{yv}} A_{\mathrm{hvj}} \frac{h_{\mathrm{b0}} - \alpha'_{\mathrm{s}}}{s}\right) \tag{D.3.2-2}$$

Where $A_{\mathrm{sh}}$——Section area of single round stirrup;

$A_{\mathrm{svj}}$——Total section area of tie bar and non-round stirrup at the same section check direction;

$D$——Column section diameter;

$N$——Design value of axial force; it may be taken according to the requirements of ordinary beam-column joint.

# Appendix E Requirements for Seismic Design of the Transfer Storey Structures

## E.1 Design Requirements for Frame-supported Floor Slab of Rectangular Plane Seismic Wall Structure

**E.1.1** Cast-in-place floor slab shall be used for frame-supported storey; its thickness should not be less than 180mm and its concrete strength grade should not be less than C30. It shall adopt double-layer two-way reinforcement and the reinforcement ratio for each layer at each direction shall not be less than 0.25%.

**E.1.2** The design value for shear force of frame-supported floor slab in partial frame-supported seismic wall structure shall meet the following requirements:

$$V_f \leq \frac{1}{\gamma_{RE}}(0.1 f_c b_f t_f) \tag{E.1.2}$$

Where $V_f$——Design value for combination shear force of frame-supported floor slab, which is calculated according to rigid floor slab assumption where the shear force is transmitted from non-ground seismic wall to ground seismic wall. For Intensity 8, it shall be multiplied by enhancement coefficient 2; for Intensity 7, it shall be multiplied by enhancement coefficient 1.5; when checking ground seismic wall, this enhancement coefficient shall be given no consideration;

$b_f$, $t_f$——Width and thickness of frame-supported floor slab respectively;

$\gamma_{RE}$——Seismic adjustment coefficient of bearing capacity, it may take 0.85.

**E.1.3** The seismic shear capacity at the intersecting section of the frame-supported slab and the continuous to ground seismic-wall in partial frame-supported seismic wall structure shall be checked according to the following equation:

$$V_f \leq \frac{1}{\gamma_{RE}}(f_y A_s) \tag{E.1.3}$$

Where $A_s$——Section area of all steel reinforcement in frame-supported storey floor (including beam and plate) crossing ground seismic wall.

**E.1.4** The edge of frame-supported floor slab and the surrounding of large openings shall be set up with boundary beam, whose width should not be less than 2 times of plate thickness; the reinforcement ratio of longitudinal steel reinforcement shall not be less than 1%. The connections of steel reinforcement should be connected mechanically or welded; the steel reinforcement of floor slab shall be anchored inside the boundary beam.

**E.1.5** For frame-supported storey with longer size plain or irregular in configuration or the internal force of the seismic-wall have big differences, the in-plane flexural and shear bearing capacity of the slab may also be checked that may be adopted simplification methods.

## E.2 Requirements for Seismic Design of Tube-structure Transfer Storeys

**E.2.1** The structural quality center at upper and lower transfer storey should superpose approximately (excluding podiums); the lateral rigidity ratio between upper and lower transfer storey should not be greater than 2.

**E.2.2** The discontinuous vertical anti-lateral force components (wall, column) at upper transfer storey should be directly connected to the main structure components of transfer storey.

**E.2.3** The thick plates transfer-storey structures should not be used in tall buildings for Intensity 7 or above.

**E.2.4** The floor of transfer storey shall not have larger openings, and should be close to infinite-rigidity diaphragm.

**E.2.5** The floor of transfer storey shall be reliably connected with tube or seismic wall; the seismic check and construction of transfer-storey floor slab should meet the relevant requirements of frame-supported floor slab in Article E.1 of this Appendix.

**E.2.6** Vertical earthquake action shall be considered for transfer-storey structure for Intensity 8.

**E.2.7** No transfer-storey structure shall be adopted for Intensity 9.

# Appendix F Requirements for Seismic Design of Reinforced Concrete Small-sized Hollow Block Seismic -Wall Buildings

## F.1 General

**F.1.1** The maximum height of the reinforced concrete small-sized hollow block seismic-wall buildings applicable to this Appendix shall be in accordance with those specified in Table F.1.1-1; and the ratio between the total height and total width of the buildings should not exceed the requirements of Table F.1.1-2.

**Table F.1.1-1 Applicable Maximum Height of Reinforced Concrete Small-sized Hollow Block Seismic-Wall Buildings (m)**

| Minimum wall thickness (mm) | Intensity 6 | Intensity 7 | | Intensity 8 | | Intensity 9 |
|---|---|---|---|---|---|---|
| | 0.05*g* | 0.10*g* | 0.15*g* | 0.20*g* | 0.30*g* | 0.40*g* |
| 190 | 60 | 55 | 45 | 40 | 30 | 24 |

Note: 1 When the height of buildings exceeds the height specified in the Table, it shall carry out special research and demonstration and take effective strengthening measures;

2 When the building area of rooms with the bay at certain storey (stories) greater than 6.0m accounts for over 40% of the building area at corresponding storey, the data in the Table shall reduce 6m correspondingly;

3 The height of buildings refers to the height between outdoor ground and the top of main roof slab (excluding partial projection over roof).

**Table F.1.1-2 Maximum Height-width Ratio of Small Reinforced Concrete Small-sized Hollow Block Seismic-Wall Buildings**

| Intensity | Intensity 6 | Intensity 7 | Intensity 8 | Intensity 9 |
|---|---|---|---|---|
| Maximum height-width ratio | 4.5 | 4.0 | 3.0 | 2.0 |

Note: When the horizontal and vertical layout of buildings is irregular, the maximum height-width ratio shall be reduced properly.

**F.1.2** Different seismic grades shall be assigned to reinforced concrete small-sized hollow block seismic-wall buildings according to the seismic precautionary category and Intensity as well as building height; and it shall meet the requirements of corresponding calculation and construction measures. The seismic grade of Category C buildings should be determined according to those specified in Table F.1.2.

**Table F.1.2 Seismic Grade of Small Reinforced Concrete Small-sized Hollow Block Seismic-Wall Buildings**

| Intensity | Intensity 6 | | Intensity 7 | | Intensity 8 | | Intensity 9 |
|---|---|---|---|---|---|---|---|
| Height (m) | ≤24 | >24 | ≤24 | >24 | ≤24 | >24 | ≤24 |
| Seismic grade | **IV** | **III** | **III** | **II** | **II** | **I** | **I** |

Note: The seismic grade may be determined according to building irregularity as well as site and base conditions when it is approximate or equal to height boundary.

**F.1.3** The reinforced concrete small-sized hollow block seismic-wall buildings shall avoid applying irregular building structure scheme specified in Section 3.4 of this code and shall meet the following requirements:

**1** The plan configuration should be simple, regular and re-entrant corners should not be too significant; the vertical layout should be regular, even and the setback or overhang should not be too significant.

**2** The each longitudinal and transversal seismic-walls should be arranged through overall an axis-line; the length of each independent wall segment should be not greater than 8m and should be not less than 5 times of the wall thickness; the ratio between total height and length of the wall segment should be not less than 2; the door openings should be in a line and should be arranged in rows.

**3** When cast-in-situ RC floors and roofs are adopted, the maximum space between seismic transverse walls shall be in accordance with those specified in Table F.1.3.

**Table F.1.3 The Maximum Space between Reinforced Concrete Small-sized Hollow-block Seismic Transverse Walls**

| Intensity | Intensity 6 | Intensity 7 | Intensity 8 | Intensity 9 |
|---|---|---|---|---|
| Maximum space (m) | 15 | 15 | 11 | 7 |

**4** When the buildings need be set up with seismic joint, the minimum width of joint shall meet the following requirements:

When the height of buildings does not exceed 24m, it may take 100mm; when the height of buildings is greater than 24m, it should be widened for 20mm with the height increased by 6m, 5m, 4m and 3m for Intensity 6, Intensity 7, Intensity 8 and Intensity 9 correspondingly.

**F.1.4** The storey height of reinforced concrete small-sized hollow block seismic-wall buildings shall meet the following requirements:

**1** The storey height of strengthening portion at bottom should be not greater than 3.2m for Grade I and II and shall be not greater than 3.9m for Grade III and IV.

**2** The storey height of other positions shall be not greater than 3.9m for Grade I and II and shall be not greater than 4.8m for Grade III and IV.

Note: The strengthening portion at bottom refers to the height range is not less than 1/6 of building height and is not less than the height of the first two stories; it shall take the height of the first storey when the total height of building is less than 21m.

**F.1.5** The short wall of reinforced concrete small-sized hollow block seismic -wall buildings shall meet the following requirements:

**1** It shall not adopt reinforcement small-block seismic wall structure with entire short wall; and it shall form seismic wall structure which the short seismic wall and ordinary seismic wall resist horizontal earthquake action together. Short wall should not be adopted for Intensity 9.

**2** Under the action of specified horizontal force, the bottom seismic overturning moment of ordinary seismic wall shall be not less than 50% of the total overturning moment on structures; the ratio between section area of short seismic walls and total section area of seismic walls at the same storey at two principal axis directions should be not greater than 20%.

**3** The short wall should be set up with wing wall; no floor and roof beams shall be arranged outside straight short wall plane to intersect with it unilaterally.

**4** The seismic grade of short wall shall be used by increasing one grade according to the requirements of Table F.1.2; for Grade I, the reinforcement shall be improved according to the requirements of Intensity 9.

Note: The short seismic wall refers to seismic wall with a ratio of 5~8 between height and width of wall column section; the ordinary seismic wall refers to seismic wall with the height-width ratio of wall column section greater than 8. The long and short property of the section of ―L-shaped”, ―T-shaped” and ―+-shaped” multi-pier walls etc. shall be determined by the longer one.

## F.2 Essentials in Calculation

**F.2.1** During seismic calculation of reinforced concrete small-sized hollow block seismic-wall buildings, it shall adjust the earthquake action effect according to the requirements of this section. For Intensity 6, it may not carry out section seismic check, but details of seismic design shall be taken according to the relevant requirements of this Appendix. The reinforced concrete small-sized hollow block seismic-wall buildings shall be carried out with seismic check for deformation under frequent earthquake action. The maximum elastic storey drift angle inside the storey should not exceed 1/1200 for ground floor and should not exceed 1/800 for other storey.

**F.2.2** As for the bearing capacity calculation of reinforced concrete small-sized block seismic wall, the design value for combination shear force of the section of strengthening portion at bottom shall be adjusted according to the following requirements:

$$V=\eta_{\mathrm{vw}}V_{\mathrm{w}} \tag{F.2.2}$$

Where $V$——Design value for combination shear force of strengthening portion at bottom on seismic wall:

$V_{\mathrm{w}}$——Calculated value for combination shear force of strengthening portion at bottom on seismic wall;

$\varepsilon_{\mathrm{vw}}$——Enhancement coefficient of shear force; it shall take 1.6 for Grade 1, l.4 for Grade 2, 1.2 for Grade 3 and l.0 for Grade 4.

**F.2.3** The design value for combination shear force of reinforced concrete small-sized hollow-block seismic wall section shall meet the following requirements: The shear span ratio is greater than 2

$$V\leq\frac{1}{\gamma_{\mathrm{RE}}}(0.2f_{\mathrm{g}}bh) \tag{F.2.3-1}$$

The shear span ratio is not greater than 2

$$V\leq\frac{1}{\gamma_{\mathrm{RE}}}(0.15f_{\mathrm{g}}bh) \tag{F.2.3-2}$$

Where $f_{\mathrm{g}}$——Design value for compressive strength of small-sized block masonry of grouting holes;

$b$——Section width of seismic wall;

$h$——Section height of seismic wall;

$\gamma_{\mathrm{RE}}$——Seismic adjustment coefficient of bearing capacity, taking 0.85.

Note: The shear span ratio shall be calculated according to Equation (6.2.9-3) of this code.

**F.2.4** The shear bearing capacity of reinforced concrete small-sized hollow-block seismic wall section under eccentric compression shall be checked according to the following equation:

$$V\leq\frac{1}{\gamma_{\mathrm{RE}}}\left[\frac{1}{\lambda-0.5}\left(0.48f_{\mathrm{gv}}bh_0+0.1N\right)+0.72f_{\mathrm{yh}}\frac{A_{\mathrm{sh}}}{s}h_0\right] \tag{F.2.4-1}$$

$$0.5V \leq \frac{1}{\gamma_{RE}}\left(0.72 f_{yh}\frac{A_{sh}}{s}h_0\right) \tag{F.2.4-2}$$

Where $N$——Combined axial compression design value of seismic wall; when $N>0.2f_g bh$, taking $N=0.2f_g bh$;

$\lambda$——Shear span ratio at calculated section, taking $\lambda=M/Vh_0$; when it is less than 1.5, taking 1.5; when it is greater than 2.2, taking 2.2;

$f_{gv}$——Design value for shear strength of small-block masonry of grouting holes; $f_{gv}=0.2f_g^{0.55}$;

$A_{sh}$——Section area of horizontal steel reinforcement on the same section;

$s$——Space between horizontally-distributed reinforcements;

$f_{yh}$——Design value for tensile strength of horizontally-distributed reinforcement ;

$h_0$——Effective height of seismic wall section.

**F.2.5** There shall be no small eccentric tension on the wall column of reinforced concrete small-sized hollow-block seismic wall under frequent earthquake action assembly. The diagonal section shear bearing capacity of reinforced concrete small-sized hollow-block seismic wall under large eccentric tension shall be calculated according to the following equation:

$$V \leq \frac{1}{\gamma_{RE}}\left[\frac{1}{\lambda-0.5}\left(0.48f_{gv}bh_0-0.17N\right)+0.72f_{yh}\frac{A_{sh}}{s}h_0\right] \tag{F.2.5-1}$$

$$0.5V \leq \frac{1}{\gamma_{RE}}\left(0.72 f_{yh}\frac{A_{sh}}{s}h_0\right) \tag{F.2.5-2}$$

When $0.48f_{gv}bh_0-0.17N \leq 0$, taking $0.48f_{gv}bh_0-0.17N=0$

Where $N$——Combined axial tension design value of seismic wall.

**F.2.6** Reinforced concrete coupling beam should be used for coupling beam with the span-height ratio of reinforced concrete small-sized hollow-block seismic wall greater than 2.5; the design value of combined sectional shear force and the shear bearing capacity of diagonal section shall meet the relevant requirements of coupling beam in the current national standard —Code for Design of Concrete Structures" GB 50010.

**F.2.7** When reinforced concrete small-sized hollow-block masonry coupling beam is used for seismic wall, it shall meet the following requirements:

**1** The section of coupling beam shall meet the requirements of the following equation:

$$V \leq \frac{1}{\gamma_{RE}}(0.15f_g bh_0) \tag{F.2.7-1}$$

**2** The diagonal section shear bearing capacity of coupling beam shall be calculated according to the following equation:

$$V \leq \frac{1}{\gamma_{RE}}\left(0.56f_{gv}bh_0+0.7f_{yv}\frac{A_{sv}}{s}h_0\right) \tag{F.2.7-2}$$

Where $A_{sv}$——Total section area of each limb of stirrup inside the same section;

$f_{yv}$——Design value for tensile strength of stirrup.

## F.3 Details of Seismic Design

**F.3.1** The reinforced concrete small-sized hollow block seismic-wall buildings shall apply hole-grouting concrete with large slump, excellent flowability and workability and good bonding characters with masonry block. The strength grade of hole-grouting concrete shall be not less than Cb20.

**F.3.2** The seismic wall of reinforced concrete small-sized hollow block seismic-wall buildings shall be fully filled with hole-grouting concrete.

**F.3.3** The transversely and vertically distributed steel reinforcement of reinforced concrete small-sized hollow-block seismic wall shall be in accordance with those specified in Tables F.3.3-1 and F.3.3-2. The transversely distributed steel reinforcement should be arranged in double rows; the space between tie bars among double-row distributed steel reinforcement shall be not greater than 400mm; the diameter shall be not less than 6mm. The vertically distributed steel reinforcement should be arranged in single row; the diameter shall be not greater than 25mm.

**Table F.3.3-1 Detailing Requirements for Transversely Distributed Steel Reinforcement in Reinforced Concrete Small-sized Hollow-block Seismic Wall**

| Seismic grade | Minimum reinforcement ratio (%) | | Maximum space (mm) | Minimum diameter (mm) |
|---|---|---|---|---|
| | General position | Strengthening position | | |
| **I** | 0.13 | 0.15 | 400 | ø8 |
| **II** | 0.13 | 0.13 | 600 | ø8 |
| **III** | 0.11 | 0.13 | 600 | ø8 |
| **IV** | 0.10 | 0.10 | 600 | ø6 |

Note: For Intensity 9, the reinforcement ratio shall be not less than 0.2%; the maximum space shall be not greater than 400mm at the top storey or the bottom strengthening position.

**Table F.3.3-2 Detailing Requirements for Vertically Distributed Steel Reinforcement in Reinforced Concrete Small-sized Hollow-block Seismic Wall**

| Seismic grade | Minimum reinforcement ratio (%) | | Maximum space (mm) | Minimum diameter (mm) |
|---|---|---|---|---|
| | General position | Strengthening position | | |
| **I** | 0.15 | 0.15 | 400 | ø12 |
| **II** | 0.13 | 0.13 | 600 | ø12 |
| **III** | 0.11 | 0.13 | 600 | ø12 |
| **IV** | 0.10 | 0.10 | 600 | ø12 |

Note: For Intensity 9, the reinforcement ratio shall be not less than 0.2%; the maximum space shall be properly reduced at the top storey or the bottom strengthening position.

**F.3.4** The axial compression ratio of reinforced concrete small-sized hollow-block seismic wall under the action of gravity-load representative value shall meet the following requirements:

**1** As for the bottom strengthening position of common wall, it should be not greater than 0.4, 0.5 for Grade 1 (Intensity 9) and Grade 1 (Intensity 8) respectively, and not greater than 0.6 for, Grade 2 and 3; it should be not greater than 0.6 for general position.

**2** As for the overall height of short wall, it should be not greater than 0.50 for Grade 1, not greater than 0.60 for Grade 2 and 3; as for straight short wall without any flange, the axial compression ratio limit shall be reduced for 0.1 correspondingly.

**3** If the wall column section in all directions is independent small wall column with $3b<h<5b$, it should be not greater than 0.4 for Grade 1, and not greater than 0.5 for Grade 2 and 3; the axial compression ratio limit of independent small straight-wall column without any flange shall be reduced for 0.1 correspondingly.

**F.3.5** The wall column end of reinforced concrete small-sized hollow-block seismic wall shall be set up with boundary components; when the axial compression ratio of bottom strengthening position is greater than 0.2 and 0.3 for Grade 1 and Grade 2 respectively, it shall set up constrained boundary components. The reinforcement scope of structural boundary components: 3-hole reinforcement at the ends of flange-free wall; 3-hole reinforcement at L-shaped corner joint; 4-hole reinforcement at T-shaped corner joint; horizontal stirrup shall be set up within the range of boundary components; the minimum reinforcement shall be in accordance with those specified in Table F.3.5. As for the range of constrained boundary components, one more hole shall be added along the forced direction than structural boundary components. The horizontal stirrup shall be strengthened correspondingly; or it may also be strengthened with concrete frame column.

**Table F.3.5 Reinforcement Requirements for Boundary Components of Seismic Wall**

| Seismic grade | Minimum reinforcement quantity of vertical steel reinforcement in each hole | | Minimum diameter of horizontal stirrup | Horizontal stirrup |
|---|---|---|---|---|
| | Bottom strengthening position | General position | | Maximum space |
| **I** | 1ø20 | 1ø18 | ø8 | 200mm |
| **II** | 1ø18 | 1ø16 | ø6 | 200mm |
| **III** | 1ø16 | 1ø14 | ø6 | 200mm |
| **IV** | 1ø14 | 1ø12 | ø6 | 200mm |

Note: 1 The horizontal stirrup of boundary components should adopt the form of overlapping spot-welding meshes;

2 For Grade 1, 2 and 3, the stirrup of boundary components shall apply hot rolled reinforcement no less than Grade HRB335;

3 When the axial compression ratio for Grade 2 is greater than 0.3, the minimum diameter of horizontal stirrup for bottom strengthening position shall be not less than 8mm.

**F.3.6** The overlapping length of vertically and transversely distributed steel reinforcement in reinforced concrete small-sized hollow-block seismic wall shall be not less than 48 times of reinforcement diameter; the anchorage length shall be not less than 42 times of reinforcement diameter.

**F.3.7** The transversely distributed steel reinforcement in reinforced concrete small-sized hollow-block seismic wall shall be arranged continuously along the wall; the anchorage on both ends shall meet the following requirements:

**1** As for Grade 1 and 2 seismic wall, the transversely distributed steel reinforcement may bend for l80 degree into a hook along vertical main reinforcement; the length of straight reach at hook end should be not less than 12 times of reinforcement diameter. The transversely distributed steel reinforcement may also bend into the end hole-grouting concrete; the anchorage length shall be not less than 30 times of steel reinforcement diameter and shall be not less than 250mm.

**2** As for Grade 3 and 4 seismic wall, the transversely distributed steel reinforcement may bend into end hole-grouting concrete; the anchorage length shall be not less than 25 times of steel reinforcement diameter and shall be not less than 200mm.

**F.3.8** In reinforced concrete small-sized hollow-block seismic wall, masonry coupling beam may be adopted for those with span-height ratio less than 2.5; its construction shall meet the following requirements:

**1** As for the upper and lower longitudinal steel reinforcement in coupling beam, the anchored length into the wall shall be not less than 1.15 for Grade 1 and 2 and not less than 1.05 times of anchored length for Grade 3 and 4 respectively; it shall be not less than the anchored length for Grade 4. All of them shall be not less than 600mm.

**2** The stirrup of coupling beam shall be set up along the full length of beam; the diameter of stirrup shall be 10mm for Grade 1 and 8mm for Grade 2, 3 and 4. The space between stirrups shall be not greater than 75mm, 100mm and 120mm for Grade 1, Grade 2 and Grade 3 respectively.

**3** Structural stirrup with a space of not greater than 200mm shall be set up for top coupling beam within the range of the length of longitudinal steel reinforcement which is anchored into the wall; its diameter shall be the same as the diameter of stirrup in coupling beam.

**4** Within the range between 200mm from beam top surface and 200mm from beam bottom surface, waist reinforcement shall be added and its space shall be not greater than 200mm. The quantity of waist reinforcement at each layer shall be not less than 2ø12 for Grade 1 and 2ø10 for Grade 2~4 respectively. The length of waist reinforcement anchored into the wall shall be not less than 30 times of steel reinforcement diameter and shall be not less than 300mm.

**5** No holes shall be cut on coupling beam; when it need cut holes, the following requirements shall be met:

- **1)** Steel sleeve with the external diameter not greater than 200mm shall be embedded at 1/3 beam height of mid-span;
- **2)** The upper and lower effective height of opening shall be not less than 1/3 of beam height and shall be not less than 200mm.
- **3)** The strengthened bars shall be arranged near the openings; the shear bearing capacity shall be checked for section weakened by the opening.

**F.3.9** The construction of ring-beam of reinforced concrete small-sized hollow-block seismic wall shall meet the following requirements:

**1** The wall shall be set up with cast-in-place reinforced concrete ring-beam at the foundation and the elevation of each storey; the width of ring-beam shall be the same as the wall thickness; its section height should be not less than 200mm.

**2** The ring-beam concrete compressive strength shall be not less than the corresponding hole-grouting small-block masonry strength and shall be not less than C20.

**3** The diameter of ring-beam longitudinal steel reinforcement shall be not less than that of transversely distributed steel reinforcement in the wall and shall be not less than 4ø12. The ring-beam longitudinal reinforcement in the foundation shall be not less than 4ø12; the diameters of ring-beam and foundation ring-beam stirrup shall be not less than 8mm and the space between them shall be not greater than 200mm. When the ring-beam height is greater than 300mm, waist reinforcement shall be set up along the direction of ring-beam section height and the space between them shall be not greater than 200mm; the diameter shall be not less than 10mm.

**4** When the ring-beam bottom is embedded into the hole of small block, at the top of wall, the depth should be not less than 30mm; the top of ring-beam shall be in rough surface.

**F.3.10** Cast-in-situ reinforced concrete slab shall be used for the floor, roof of reinforced concrete small-sized hollow block seismic-wall buildings and tall building for Intensity 9. Cast-in-situ RC slab should be adopted for multi-storey building; when the seismic grade is Grade 4, it may also adopt assembled monolithic reinforced concrete floor.

# Appendix G Requirements for Seismic Design of Buildings with Steel Brace-Concrete Frame Structures and Steel Frame-Reinforced Concrete Core Tube Structures

## G.1 Steel Brace-Reinforced Concrete Frames

**G.1.1** When the seismic precautionary Intensity is between Intensity 6~8 and the height of buildings exceeds the maximum applicable height of reinforced concrete frame structures in Article 6.1.1 of this code, it may use structures whose lateral resistant system is composed of steel brace-concrete frame.

When the seismic design is carried out according to the requirements of this section, the applicable maximum height should be not greater than the average value for the maximum applicable height of reinforced concrete frame structures and frame-seismic wall structures in Article 6.1.1 of this code. The buildings exceeding the maximum applicable height shall be carried out with special research and demonstration and effective strengthening measures shall also be taken.

**G.1.2** Different seismic grade shall be selected for buildings with steel brace-concrete frame structures according to different precautionary category, Intensity and building height; and it shall meet the requirements of corresponding calculation and construction measures. The steel brace frame part of Category C building shall be higher than the requirements of frame structure in Article 8.1.3 and Article 6.1.2 of this code by one seismic grade; the reinforced concrete frame part shall also be determined according to the frame structures in Article 6.1.2 of this code.

**G.1.3** The structural arrangement of steel brace-concrete frame structures shall meet the following requirements:

**1** The steel brace frames shall be set up simultaneously in the two principal axis directions of structure.

**2** The steel brace should be laid continuously at up and down; when continuous layout can't be carried out due to the influence of building scheme, it should be extended for arrangement at adjoining span.

**3** The steel brace should adopt cross brace, or it may also adopt inverted-V shape brace or V-shaped brace; when single brace is used, the diagonal member on both directions shall be basically symmetrical.

**4** The planar layout of steel brace shall avoid producing torsional effect. As for buildings without large opening between steel braces, the length-width ratio of floors and roof should meet the requirements of space between seismic walls in Article 6.1.6 of this code the staircase should be set up with steel brace.

**5** As for steel brace frames at the ground floor, the seismic overturning moment distributed according to rigidity shall be greater than 50% of the total seismic overturning moment.

**G.1.4** The seismic calculation of steel brace-concrete frame structures shall also meet the following requirements:

**1** The damping ratio of structures shall be not greater than 0.045; or it may use the equivalent damping ratio which is converted from the proportion of concrete frame part and steel brace part in the total deformation energy of the structure.

**2** The diagonal member of steel brace frame part may be calculated according to the hinge bar at ends. When the axes of diagonal member deviate from the concrete column axes by 1/4 of the column width, additional bending moment shall be considered.

**3** The earthquake action undertaken by concrete frame part shall be calculated according to the two models of frame structure and bracing frame structure and the larger value should be taken.

**4** The storey drift limit of steel brace-concrete frame should be interpolated according to frames and frame-seismic wall structures.

**G.1.5** The connecting construction between steel brace and concrete column shall meet the relevant requirements of the brace and column connection for single-storey reinforced concrete column factory buildings in Section 9.1 of this code. The connecting construction between steel brace and concrete beam shall meet the requirement that the connection failure doesn't come before brace failure.

**G.1.6** The steel brace part in steel brace-concrete frame structures shall be designed according to the requirements of Chapter 8 in this code as well as the current national standard GB 50017 "*Code for Design of Steel Structures*"; the reinforced concrete frame part shall be designed according to the requirements of Chapter 6 in this code.

## G.2 Steel frame-Reinforced Concrete Core Tube Structures

**G.2.1** When the seismic precautionary Intensity is between Intensity 6~8 and the height of buildings exceeds the maximum applicable height of concrete frame-core tube structure in Article 6.1.1 of this code, it may adopt structure with lateral resistant system composed of Steel-frame concrete core tube.

When the seismic design is carried out according to the requirements of this section, the applicable maximum height should be not greater than the average value for the maximum applicable height of reinforced-concrete frame core tube structures in Article 6.1.1 of this code and the maximum applicable height of steel frame- concentrically brace structure in Article 8.1.1 of this code. The buildings exceeding the maximum applicable height shall be carried out with special research and demonstration and effective strengthening measures shall also be taken.

**G.2.2** Different seismic grade shall be selected for buildings with steel-frame concrete core tube structure according to different precautionary category, intensity and building height; and the building shall meet the requirements of corresponding calculation and construction measures. The steel frame part of Category C building shall also be determined according to Article 8.1.3 of this code. The concrete part shall increase by one seismic grade (more than Grade 1 for Intensity 8) than the requirements of Article 6.1.2 in this code.

**G.2.3** The structural layout of buildings with Steel frame-reinforced concrete core tube structure shall also meet the following requirements:

**1** Rigid connection shall be used for the beam and column connection of external steel frame for steel frame-core tube structure; and it should adopt steel floor beam. The rigid connection position of concrete wall and steel beam should be set up with construction profile steel for connection.

**2** The maximum storey seismic shear force of steel frame which is distributed according to rigidity calculation should be not less than 10% of the total structural seismic shear force. When it is less than 10%, the earthquake action undertaken by the core tube wall shall be increased properly;  the seismic grade of wall construction shall be increased by one grade, and it shall be improved properly under Grade 1.

**3** The floor of steel frame-core tube structure shall have good rigidity and ensure integrity under rare earthquake action. The floor shall adopt assembly floor with profiled steel sheet or cast-in-situ RC floor slab; and measures shall be taken to strengthen the connection between floor and steel beam. When there is large opening on floor or the floor has transfer storey, cast-in-situ solid floor shall be used for strengthening.

**4** When the profile steel concrete column is adopted for the lower part of steel frame column, the frame column joint between different materials shall be set up with transition layer to avoid mutation of rigidity and bearing capacity. After the steel column in transition layer is counted into the encasing concrete, the section rigidity may take the average value of the two section rigidity of profile steel concrete column at the lower part of transition layer and the steel column at the upper part of transition layer.

**G.2.4** The seismic calculation of Steel frame-reinforced concrete core tube structure shall also meet the following requirements:

**1** The damping ratio of structures shall be not greater than 0.045; or it may use the equivalent damping ratio which is converted from the proportion of reinforced concrete tube part and steel frame part in the total deformation energy of the structure.

**2** As for any storey with steel frame part, except semi-girder reinforced storey and adjacent storeys, the seismic shear force distributed according to calculation shall be multiplied by enhancement coefficient so as to take the smaller value of greater than or equal to 20% of the total seismic shear force at structure bottom and 1.5 times of maximum storey seismic shear force for frame part; and it shall be not less than 15% of the seismic shear force at structure bottom. Corresponding adjustment shall be made for all calculated values of shear force, bending moment and axial force on the storey frame component caused by earthquake action.

**3** The structural calculation should give consideration to the influence of different axial deformation of steel frame column and reinforced concrete wall.

**4** The limit of structural storey drift may refer to the limit of reinforced concrete structure.

**G.2.5** The steel structure and concrete structure in buildings with steel frame-reinforced concrete core tube structure shall also be designed according to the requirements of Chapter 6 and Chapter 8 of this code as well as the current national standard GB 50017 "*Code for Design of Steel Structures*".

# Appendix H Requirements for Seismic Design of Multi-storey Factory Buildings

### H.1 Factory Buildings with Reinforced Concrete Frame-bent Structures

**H.1.1** This section is applicable to the seismic design for the factory buildings with lateral frame-bent structures that are compose of reinforced concrete frames and bent frames in the horizontal direction and the factory buildings with vertical frame-bent structures that are compose of reinforced concrete frames at lower portion and bent frames at top storey. For the aspects that the requirements in this section do not involve, the seismic design of the multi-storey concrete factory buildings shall comply with the provisions of Chapter 6 and Section 9.1 in this code.

**H.1.2** For the frame portion of the factory buildings with frame-bent structure, the different measure grade shall be adopted according to the precautionary intensity, the structural type, the building height, and it shall meet the corresponding requirements of calculation and details.

For the factory buildings without storage pocket, the grade may be determined according to Chapter 6 of this code. For the factory buildings witht storage pocket, the seismic grade of lateral frame-bent structures may be adopted according to the requirements of the national standard GB50191 *"Code for Seismic Design of Special Structures"*, and the seismic grade of vertical frame-bent structures shall be determined according to the requirements for frame structure in Chapter 6 of this code with the height boundary reduced by 4m.

Note: For the factory buildings with storage pocket that the span-height ratio of vertical wall is greater than 2.5, the seismic grade may be still determined according to that without storage pocket.

**H.1.3** The configuration of the structure of factory buildings shall satisfy the following requirements:

**1** The factory buildings should have rectangular plane as well as simple and symmetrical elevation.

**2** Within the plane of structural units, the lateral-force-resisting components such as frames, braces between columns and so on, shall be arranged symmetrically and uniformly to avoid the sudden change of lateral stiffness and lateral load-bearing capacity of the lateral-force-resisting structure.

**3** The heavy equipment should be arranged at the position close to the rigidity center instead of the edge of structural unit. Otherwise, the equipment platform should be separated from main structure; or it should be arranged at the floor as low as possible under the conditions that the production process requirements were met.

**H.1.4** The structural configuration for the buildings with vertical frame-bent structure shall also meet the following requirements:

**1** The non-purlin roof system should be taken as the roof structure. For other roof systems, special attention shall be paid to the arrangement of the roof braces and the connections between the roof elements to ensure the adequate horizontal stiffness of the roof structure.

**2** At the end of the factory building in the longitudinal direction, the roof truss, roof beam or frame structure shall be used as the load-bearing element instead of the gable wall. Within the span of the bent frame, the composite load-bearing system consisting of the transversal wall and bent frame shall not be used.

**3** The bent frames at top storey shall also meet the following requirements:

**1)** The gravity center of bent frames at top storey should be approximate to or overlap with the rigidity center of the lower portion of the structure. Each multi-span bent should have equal height and equal length.

**2)** The floor slab shall be cast-in-place. The floor, at which the top bents were fixed, shall avoid large opening, and the thickness of floor slab should not be less than 150mm.

**3)** The columns of bent shall extend to the foundation continuously along vertical direction.

**4)** At the locations of the floors corresponding to the positions of the longitudinal column-braces installed for bent at top storey, the staircase openings or other openings shall not be arranged. The central line of the diagonal element of column-brace and the central lines of the beam and column connected with the brace shall intersect at one point.

**H.1.5** The calculation of the earthquake action for the factory buildings with vertical frame-bent structures shall satisfy the following requirements:

**1** The calculation of earthquake action should be carried out with spiral structure model, and the mass points of the model should be arranged at the intersection points of the beam axes and column axes, the brackets, the column tops, the section handovers of the columns with variable cross-section and the points of the concentrated load of columns.

**2** During determining the representative value of gravity load, the combination coefficients for different variable loads shall be taken the corresponding values according to the characteristics of industry. For the loads of the stored materials, the combination coefficients may be taken as 0.9.

**3** For the storage pockets and other equipments with higher gravity center supported on the floor, the additional moments caused by the horizontal earthquake actions of the storage hoppers, the storage pockets and the equipments shall be considered for the design of the supporting components and the connections. The horizontal earthquake actions may be calculated according to following Equation:

$$F_{s}=\alpha_{max}(1.0+H_{x}/H_{n})G_{eq} \tag{H.1.5}$$

Where

$F_s$ ——The characteristic value of the horizontal earthquake action at the gravity center of equipment or hopper.

$\alpha_{max}$ ——The maximum value of horizontal seismic influence coefficient.

$G_{eq}$ ——The representative value of gravity load of the equipment or hopper.

$H_x$ ——The distance between the gravity center of equipment or hopper and the level of outdoor ground.

$H_n$ ——The height of factory buildings.

**H.1.6** The adjustments of the seismic action effects and the seismic checks for the factory buildings with vertical frame-bent structures shall satisfy the following requirements:

**1** For the frame columns with Grade 1, 2, 3 or 4 supporting the vertical walls of storage pockets, the combination bending moment design values and the shear force design values, after adjusted according to Article 6.2.2, 6.2.3 and 6.2.5 of this code, shall also be multiplied by the amplification coefficient with value not less than 1.1.

**2** For the frame joints with a bent-column connected above, the combination bending moment design values of columns shall be adjusted according to Article 6.2.2of this code. For other frame joints without bent-column connected above, the combination bending moment design values at the ends of column and beam need not be adjusted.

**3** For the lower frame-columns located at the positions of longitudinal column-braces installed between bent-columns of top storey, the axial forces caused by earthquake shall be multiplied by an adjustment coefficient with value of 1.5 and 1.2 for Grade 1 and Grade 2, respectively. For the calculation of the axial-force-ratio, the axial forces need not be adjusted.

**4** The seismic check of factory buildings with frame-bent structures shall also meet the following requirements:

**1)** For Intensity 8 with site class III and IV and Intensity 9, the checking of the elastic-plastic deformations of the bent-columns in the frame-bent structure and the independent upper columns supporting the roof shall be carried out, and the limit values of elastic-plastic drift may be taken as 1/30.

**2)** For the frame beam-column joint with Grade 1 or 2, when the section height difference of beams on the two sides of the joint is greater than 25% of the maximum section height of the beams or greater than 500mm, the seismic shear capacity of the lower column shall be checked according to the following Equation:

$$\frac{\eta_{jb} M_{b1}}{h_{01} - a_s'} - V_{col} \leq V_{RE} \tag{H.1.6-1}$$

For Intensity 9 or Grade 1, the above Equation may not be satisfied, but the following Equation must be satisfied:

$$\frac{1.15 M_{b1ua}}{h_{01} - a_s'} - V_{col} \leq V_{RE} \tag{H.1.6-2}$$

Where

$\eta_{jb}$——The shear amplification factor with value 1.35 and 1.2 for Grade 1 and Grade 2, respectively.

$M_{b1}$——The positive combination bending moment design values of the higher beam at the end.

$M_{b1ua}$——The positive flexural capacity of the higher beam at the end, determined according to the reinforcement bars (including the bars located at the compressive zone) and the characteristic values of material strength.

$h_{01}$——The effective height of higher beam section;

$\alpha'_s$——The distance between the force point of compression steel reinforcement and the edge of compressive zone.

$V_{col}$——The shear design value of the lower column from calculation.

$V_{RE}$——The shear capacity of the lower column.

**H.1.7** The basic seismic details of the factory buildings with vertical frame-bent structures shall also meet the following requirements:

**1** The limit value for the axial-force-ratio of the frame-columns supporting the storage pockets should be less than that of frame structures specified in Table 6.3.6 of this code by 0.05.

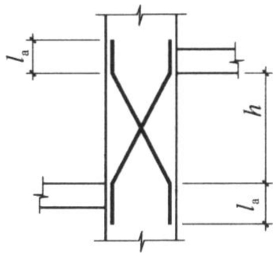
**2** The minimum total steel ratio of longitudinal bars in the frame-columns supporting the storage pockets shall not less than the requirements for the corner columns in Table 6.3.7 of this code.

**3** For the lower frame-columns located at the positions of longitudinal column-braces installed between bent-columns of top storey, the steel ratio of longitudinal bars and the arrangement of the hoop shall meet the requirements of the supporting-columns in Article 6.3.7 of this code. The length of the regions of densified hoops shall be taken as the overall height of the columns.

**4** For the frame-columns with shear-span-ratio not greater than 1.5, the following requirements shall be satisfied:

**1)** The hoop shall be arranged according to the requirements improved by one grade. For the columns with Grade 1, the requirements for hoop arrangement may be improved properly.

**2)** In each direction of the frame-column section, two diagonal bars shall be arranged in the column (see Fig. H.1.7). The diameter of the diagonal bar shall not be less than 20mm, 18mm, 16mm, 16mm for Grade 1,2,3,4, respectively; and the anchorage length of diagonal bar shall not be less than 40 times of the bar diameter.




*h*—Net height of short column ; $l_a$—Anchorage length of diagonal bar

**Figure H.1.7**

**5** For the columns with bracket installed, the hoops within the region that include the height of the bracket and each 500mm above and below bracket shall be densified. If the ratio of the net height of the portion of column above or below the bracket to the height of column section is not greater than 4, the column hoop shall be densified through the overall height.

**H.1.8** For the lateral frame-bent structure, the configuration of structure, the adjustment for seismic action effects, the seismic checking, the brace arrangement of the roof system shall satisfy the relevant requirements of the national standard GB50191 "*Design Code for Anti-seismic of Special Structures*".

## H.2 Factory Buildings with Multi-storey Steel Structures

**H.2.1** This section is applicable to the multi-storey factory buildings with steel structures such as frame, braced frame, frame bent and so on. For the aspects that the requirements in this section do not involve, the seismic design of the multi-storey factory buildings shall comply with the provisions of Chapter 8 with the height boundary value for seismic grade reduced by 10m, and the seismic design of the single-storey factory buildings shall comply with the provisions of Section 9.1 in this code.

**H.2.2** The configuration of the multi-storey steel structure factory buildings shall not only meet the relevant requirements of Chapter 8 in this code, but also satisfy the following requirements:

**1** For the multi-storey factory buildings with complex plane shape, much larger height difference among different portions or obvious difference between storey loads, the installation of the seismic joints or other seismic measures shall be taken. The net width of the seismic joint shall not be less than 1.5 times of that for concrete structure buildings.

**2** The heavy equipment shall be installed at the position as low as possible.

**3** The equipment that is supported on the foundation directly and need pass through the floor in vertical direction, shall be separated from the floor structure. The width of the separation between the floor structure and the equipment shall not be less the width of seismic joint.

**4** The equipments located on the floor shall not be installed across the seismic joint. For the strip equipments such as conveyers, pipelines and so on, that must be arranged across the seismic joint, the requirements of the capacity adapting to the structural deformation and the measures to prevent rupture under earthquake shall be satisfied.

**5** The structure of the operating platform inside the factory buildings should be separated from the main frame structure by seismic joint. If the structure of the operating platform was connected with the main structure into an integral unit, the level of the platform should be consistent with the corresponding floor level.

**H.2.3** The brace arrangement of the multi-storey steel structure factory buildings shall satisfy the following requirements:

**1** The column-braces should be arranged at the bay with heavy vertical loads, and shall be thoroughly connected up and down at the same bay. If the arrangement of the column-braces must be staggered because of limited conditions, the braces shall be arranged continuously at the adjacent bays, and meanwhile, the measures increasing the horizontal braces of the adjacent floor or roof properly or overlapping the column-braces at the adjacent bays by one storey shall be taken to ensure that the horizontal earthquake action undertaken by the braces may be transferred to the foundation reliably.

**2** For the structure with some columns removed, the horizontal braces of the adjacent floors or roof shall be increased properly, and meanwhile, vertical braces shall be installed at the adjacent bays.

**3** For the structure that every transversal frame is different in lateral stiffness and the column-braces are arranged irregularly, the horizontal braces shall be installed at the floor system consisting of steel plankings.

**4** The stiffness of each row of columns in the longitudinal direction of the factory building should be equal or close.

**H.2.4** The floors of the factory building should adopt cast-in-place concrete composition floor systems, prefabricated concrete floors or steel planking floors and shall also meet the following requirements:

**1** The concrete floor shall be reliably connected with steel beams.

**2** For the floor slabs with openings, reliable measures shall be taken to ensure that the floor slab be able to transfer earthquake action.

**H.2.5** For the multi-storey factory buildings with steel frame-bent structures, the integrated brace systems shall be installed at the roofs, and the following requirements shall also be satisfied:

**1** The levels of the connection supports between the roof crossgirders of bent frames and the multi-storey frame structure, should be consistent with the corresponding floor level of the multi-storey frame, and meanwhile, the horizontal roof-brace systems in the longitudinal direction of building shall be arranged along overall length of the row of columns connected with the multi-storey frames.

**2** The relative independent closed roof-brace-systems shall be installed at the roof of high bay and low bay, respectively.

**H.2.6** The calculation for earthquake action of factory buildings with multi-storey steel structure shall also meet the following requirements:

**1** Generally, spiral mathematic models shall be used for structure analysis. For the structures with regular structural configuration and uniform distribution of loads, the analysis may be carried out along the transversal and longitudinal directions of the structures, respectively. The cast-in-place reinforced concrete floor slab with smaller openings, that was connected with the steel beams tightly by the shear connection pieces, may be regarded as rigid diaphragm

**2** The damping ratio of structure may be taken as 0.03~0.04 for frequently earthquakes, and 0.05 for rarely earthquake.

**3** During determining the representative value of gravity load, the combination coefficients for different variable loads such as floor repair loads, production or material stacking loads, the loads of the materials inside the equipment, hopper or pipes and so on, shall be taken the corresponding values according to the characteristics of industry.

**4** For the storage hoppers and other equipments supported on the floor, the horizontal earthquake actions of the storage hoppers and the equipments shall be considered for the design of the supporting components and the connections. The horizontal earthquake actions may be calculated according to provisions of Article H.1.5 in this Appendix, and the additional bending moments and torsional moments caused by the above horizontal earthquake actions shall be calculated in the basis of the distance between equipment gravity center and supporting component centroid.

**H.2.7** The seismic capacity checking for the components and joints of factory buildings with multi-storey steel structure shall also meet the following requirements:

**1** For the checking for the completely plastic bearing capacities of the right-left beam ends and up-down column ends at the column-beam joint according to Equation (8.2.5) in this code, the strong column factor shall be taken as 1.25 for Grade 1 or the design controlled by earthquake action, 1.20 for Grade 2 or the design controlled by 1.5 times of earthquake action, and 1.10 for Grade 3 or the design controlled by 2.0 times of earthquake action, respectively.

**2** The requirements of Equation (8.2.5) in this code need not be satisfied for the following cases:

**1)** The top end of the column of single-storey frames or the top end of the column located at the top storey of multi-storey frames.

**2)** The frame columns that satisfy both of the following conditions:

a. At every storey, the sum of shear bearing capacity of the frame columns that do not comply with the requirement of Equation (8.2.5) of this code, is less than 20% of the total storey shear bearing capacity in the checked direction.

b. At each row of columns, the sum of shear bearing capacity of the frame columns that do not comply with the requirement of Equation (8.2.5) of this code, is less than 33% that of all the columns in the row.

**3** For the column-braces, the ratio of the design internal force to the design value of bearing capacity should not be greater than 0.8. If the column-braces undertake at least 70% of the storey shear force, the above ratio should not be greater than 0.65.

**H.2.8** The basic seismic details of the factory buildings with multi-storey steel structures shall also satisfy the following requirements:

**1** The slenderness ratio of frame column should not be greater than 150. For the columns with the axial-force-ratio greater than 0.2, the slenderness ratio should not be greater than $125(1-0.8N/Af)\sqrt{235/f_y}$.

**2** The width-to-thickness ratio of plates of the column and beam in factory buildings shall meet the following requirements:

**1)** For the single-storey portion and the multi-storey portion with total height not greater than 40m, the provisions of Section 9.2 of this code may be applied.

**2)** For the multi-storey portion with total height greater than 40m, the provisions of Section 8.3 of this code may be applied.

**3** At the maximum stress regions of the frame beam and column, the flange section shall not be changed suddenly, and additional lateral supporting elements shall be installed at the upper and lower flanges with the requirements that the distance between the additional supporting element and other adjacent supporting point shall meet the relevant requirements of plastic design in GB50017 *"Code for Design of Steel Structures"*.

**4** The column-braces should satisfy the following requirements:

**1)** The column-braces located at the multi-storey portion should be put together with the frame girder to make up X shape or other favorable shape for earthquake resisting, and their slenderness ratio should not be greater than 150.

**2)** The width-to-thickness ratio of braces shall meet the requirements of Section 9.2 of this code.

**5** For the frame beams spliced by frictional high-strength bolts, the splicing position should be kept away from the maximum stress zones (calculated from the end of beam and the length taken as the maximum value of 1/10 net span of beam and 1.5 times of beam height). In the case of beam flange splicing, the high-strength bolts paralleled to the internal force direction should not be less than 3 rows, and the section modulus of splicing plate shall be greater than 1.1 times that of spliced plate.

**6** The column root shall be able to reliably transfer the bearing capacity of column to foundation, and should be of the embedded type, plug-in type or encased type. And meanwhile, the provisions of Section 9.2 of this code shall be applied

# Appendix J Seismic Effect Adjustment for Transversal Planar-Bent of Single-Storey Factory

## J.1 Adjustment of Fundament Natural Period

**J.1.1** When the horizontal seismic action of the factory is calculated by planar-bent structural model, the fundament natural period of the bent shall be adjusted to consider the some fixing-effect of the connection between the longitudinal wall and the roof truss with the column. And this adjustment may be made according to the following provisions:

**1** For bent consisted of reinforcement concrete truss or steel truss and reinforced concrete columns, when there is longitudinal walls, the natural period may be taken as 80% of the computed value of the period; and taken as 90% of the computed value when there is no longitudinal wall.

**2** For bent consisted of reinforcement concrete truss or steel truss with brick columns, the natural period may be taken as 90% of the computed period value.

**3** For bent consisted of wooden truss, steel-wood composed truss or light steel truss with brick column, the natural period may be taken as the computed period value.

## J.2 Adjusting Coefficients of Bent Column Seismic Shear and Bending Moment

**J.2.1** The seismic analyses of single-storey reinforced concrete column factory with reinforced concrete roof, when satisfying the following requirements, may take the space work and torsion effect into consideration. In which, the seismic shear and bending moment of column for plain bent, that the fundament natural period determined by **J.1.1**, shall be adjusted according to the provisions in Causes **J.2.3**:

**1** For Intensity 7 or 8.

**2** The ratio of the roof length to the total span for the factory building unit is less than 8, or the total span of the factory building unit is greater than 12m.

**3** The thickness of the gable wall is not less than 240mm, the horizontal sectional area of the opening does not exceed 50% of the gross sectional area of gable wall and is reliable connected with the roof system.

**4** The height of the top of column is not greater than 15m.

Note: 1 The roof length refers to the spacing from the gable to the other gable; when there is only one gable, the distance from the gable to the bent that is considered,

2 For factory buildings with unequal height span where the difference between higher and the lower vary significantly, the total span may not include the lower span.

**J.2.2** The seismic analyses of the single-storey brick column factories with reinforced concrete roof or wooden roof in full sheathing, when satisfying the following requirements, the space work may be taken into considerations. In which, the seismic shear force and bending moment of column for plan bent, that the fundament natural period determined by J.1.1, shall be adjusted according to the provisions in J.2.3:

**1** For Intensity 7 or 8.

**2** There are load-bearing gables at the both end of factory building.

**3** The thickness of the gable wall or load-bearing transversal wall is not less than 240mm, the horizontal sectional area of the opening does not exceed 50% of the gross sectional area and is reliably connected with the roof system.

**4** The length of the gable or the load-bearing transversal wall should not be less than their heights.

**5** The ratio of the roof length to the total span for the factory building unit is less than 8, or the total span of the factory building unit is greater than 12m.

Note: the roof length refers to the distance from the gable to the other gable (or the load-bearing transversal wall).

**J.2.3** The shear and bending moment of the bent column shall be multiplied with correspondent adjusting factors respectively. For reinforced concrete columns, except the upper column at the intersecting portion of the high and low span, the values may be adopted according to Table J.2.3-1; for brick columns with gables at the both ends, the values may be adopted according to Table J.2.3-2.

**Table J.2.3-1 Adjusting Factors Considering Space and Torsion Effect for Reinforced Concrete Column (Except the Upper Column at the Intersection Portion of High and Low Span)**

| Roof Type | Gable | | Roof length (m) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | <30 | 36 | 42 | 48 | 54 | 60 | 66 | 72 | 78 | 84 | 90 | 96 |
| With-out purlin | Both gables | Equal height | | | 0.75 | 0.75 | 0.75 | 0.80 | 0.80 | 0.80 | 0.85 | 0.85 | 0.85 | 0.90 |
| | | Unequal height | | | 0.85 | 0.85 | 0.85 | 0.90 | 0.90 | 0.90 | 0.95 | 0.95 | 0.95 | 1.00 |
| | Only one end gable | | 1.05 | 1.15 | 1.20 | 1.25 | 1.30 | 1.30 | 1.30 | 1.30 | 1.35 | 1.35 | 1.35 | 1.35 |
| With purlin | Both gables | Equal height | | | 0.80 | 0.85 | 0.90 | 0.95 | 0.95 | 1.00 | 1.00 | 1.05 | 1.05 | 1.10 |
| | | Unequal height | | | 0.85 | 0.90 | 0.95 | 1.00 | 1.00 | 1.05 | 1.05 | 1.10 | 1.10 | 1.15 |
| | Only one end gable | | 1.00 | 1.05 | 1.10 | 1.10 | 1.15 | 1.15 | 1.15 | 1.20 | 1.20 | 1.20 | 1.25 | 1.25 |

**Table J.2.3-1 Adjusting Factors Considering Space Effect for Brick Column**

| Roof Type | Distance between gable or load-bearing transverse walls (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | <12 | 18 | 24 | 30 | 36 | 42 | 48 | 54 | 60 | 66 | 72 |
| RC roof without purlin | 0.60 | 0.65 | 0.70 | 0.75 | 0.80 | 0.85 | 0.85 | 0.90 | 0.95 | 0.95 | 1.00 |
| RC roof with purlin or wooden roof with full sheathing | 0.65 | 0.70 | 0.75 | 0.80 | 0.90 | 0.95 | 0.95 | 1.00 | 1.05 | 1.05 | 1.10 |

**J.2.4** The seismic shear and bending moment determined by to the base shear method for all the sections of the reinforced concrete column above the bracket, supported the low span roof at the intersection of the high and low span of the factory, shall be multiplied by the amplifying factor. Such values may be adopted according to the following equation:

$$\eta = \zeta\left(1 + 1.7\frac{n_{\mathrm{h}}}{n_0}\cdot\frac{G_{\mathrm{EL}}}{G_{\mathrm{Eh}}}\right) \tag{J.2.4}$$

Where

$\varepsilon$——The seismic shear and the bending moment amplifying factor.

$\delta$——The space effect factor at the intersection of high and low span in factory buildings with unequal height, that may be taken in accordance with Table J.2.4.

$n_{\mathrm{h}}$——The number of spans for the higher span.

$n_0$——The number of span for computation; if only one side has low span, that shall be taken as the total number of span; if there are low spans on the two sides, shall be taken as the sum of the total number of span and the number of high span.

$G_{EL}$—— Total gravity load representative value, which concentrating at the roof level of all the low spans on one side of the intersection.

$G_{Eh}$—— Total gravitational load representative value, which concentrating at the level of column top of the entire high spans.

**Table J.2.4 Space Effect Factor of Reinforced Concrete Upper Column at The Intersection of The High and Low Spans**

| Roof Type | Gable | Roof length (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 36 | 42 | 48 | 54 | 60 | 66 | 72 | 78 | 84 | 90 | 96 |
| Without purlin | Both gables | | 0.70 | 0.76 | 0.82 | 0.88 | 0.94 | 1.00 | 1.06 | 1.06 | 1.06 | 1.06 |
| | Only one end gable | 1.25 | | | | | | | | | | |
| With purlin | Both gables | | 0.90 | 1.00 | 1.05 | 1.10 | 1.10 | 1.15 | 1.15 | 1.15 | 1.20 | 1.20 |
| | Only one end gable | 1.05 | | | | | | | | | | |

**J.2.5** For the upper column section at the level of top of the crane girder in reinforced concrete single-storey factory building, the seismic shear and the bending moment caused by the bridge crane shall be multiplied with the amplifying factor. For that determined by the base shear method, such values may be adopted according to Table J.2.5.

**Table J.2.5 Amplifying Factor of Seismic Shear and Bending Moment Caused by Bridge Crane**

| Type of roof | Gable | Side column | Column of high and low spans | Other mid-columns |
|---|---|---|---|---|
| Without purlin | Both gables | 2.0 | 2.5 | 3.0 |
| | Only one end gable | 1.5 | 2.0 | 2.5 |
| With purlin | Both gables | 1.5 | 2.0 | 2.5 |
| | Only one end gable | 1.2 | 2.0 | 2.0 |

# Appendix K Longitudinal Seismic Check for Single-Storey Factory

### K.1 Modifying Stiffness Method for Longitudinal Seismic Analyses of Single-Storey Factory Buildings with Reinforced Concrete Columns

**K.1.1** The calculation of longitudinal fundament nature period:

The longitudinal seismic action of the single-span and multi-span reinforced concrete column factory buildings shall be computed by its longitudinal fundament natural period in this Appendix. And the longitudinal fundament natural period of the single-span and multi-span reinforced concrete column factory buildings, which the level of column top is not greater than 15m and the average span is not greater than 30m, may be determined according to the following equations:

**1** The fundament natural period of such factory with brick enclosure wall may be obtained according to the following equation:

$$T_1 = 0.23 + 0.00025\psi_1 l\sqrt{H^3} \tag{K.1.1-1}$$

Where

$\psi_1$——The roof type factor; for reinforced concrete truss with large-sized roof slab, that may be taken as 1.0; and for steel truss taken as 0.85.

$l$ ——The span of the factory building (m); for multi-span factory building, the average value for all spans may be adopted.

$H$ ——The column height, which is the distance computing from the surface of the footing to the top of the column (m).

**2** The fundament natural period of factory buildings, which is no enclosure wall, half no wall or that the wall panels are flexibly connected with columns, may be calculated according to equation (J.1 .1-1) of point 1 in this Article, and then multiply with the enclosure wall influence factor below:

$$\psi_2 = 2.6 - 0.002l\sqrt{H^3} \tag{K.1.1-2}$$

Where

$\psi_2$——The factor of the enclosure wall influence; if it is less than 1.0, shall equal 1.0.

**K.1.2** The calculation for the seismic action of column-row:

**1** For factory buildings with equal height and multi-span reinforced concrete floor, the seismic action characteristic value at the top level of all longitudinal column-rows may be determined according to the following equations:

$$F_i = \alpha_1 G_{\mathrm{eq}} \frac{K_{\mathrm{ai}}}{\sum K_{\mathrm{ai}}} \tag{K.1.2-1}$$

$$K_{\mathrm{ai}} = \psi_3\psi_4K_i \tag{K.1.2-2}$$

Where

$F_{\mathrm{i}}$——The longitudinal seismic action characteristic value at the top level of the i-th column row.

$\alpha_1$——The horizontal seismic influence coefficient, which corresponding to the longitudinal fundament natural period of the factory building, shall be determined according to Article 5.1.5 of this code.

$G_{eq}$——The representative value of total equivalent gravity load of all column-rows for factory building unit. It shall include such as the roof gravity load representative value that determined according to Article 5.1.3 of this code, 70% of the weight of the longitudinal wall, 50% of the weight of the transversal wall and the gable, and the conversed weight of the column. (The conversed weight of column adopts 10% of the column weight when the factory there is crane, and 50% of the column weight when there is no crane).

$K_i$——Total lateral stiffness of the i-th column-row. It shall include the lateral stiffness of the inner columns of the *i*-th row, the column bracing between the upper and lower column, and the total sum of the reduced lateral stiffness of the longitudinal wall. The reducing factor for the lateral stiffness of the brick enclosure wall may adopt 0.2~0.6 dependent on the lateral displacement value of the column-row.

$K_{ai}$——Adjusting lateral stiffness at the top of the *i*-th column-row.

$\psi_3$——The enclosure wall influence factor of the lateral stiffness of column-row, which may be adopted according to Table K.1.2-1; for four-span and five-span factory buildings with longitudinal brick enclosure wall, the factor of 3rd column-row counted from the side column-row may be adopted according to 1.15 times of the corresponding values in this Table.

$\psi_4$——The column bracing influence factor for lateral stiffness of column-row; when the longitudinal wall is of brick enclosure wall, the factor of side column-row may adopt 1.0, and the mid-column-row may adopt the values as per set in Table K.1.2-2.

**Table K.1.2-1 Enclosure Wall Influence Factors**

| Type of enclosure wall and Intensity | | Type of column-row and roof | | | | |
|---|---|---|---|---|---|---|
| | | Side-column-row | Mid-column-row | | | |
| | | | Roof without purlin | | Roof with purlin | |
| 240mm brick wall | 370mm brick wall | | Side span without skylight | Side span with skylight | Side span without skylight | Side span with skylight |
| | Intensity 7 | 0.85 | 1.7 | 1.8 | 1.8 | 1.9 |
| Intensity 7 | Intensity 8 | 0.85 | 1.5 | 1.6 | 1.6 | 1.7 |
| Intensity 8 | Intensity 9 | 0.85 | 1.3 | 1.4 | 1.4 | 1.5 |
| Intensity 9 | | 0.85 | 1.2 | 1.3 | 1.3 | 1.4 |
| No wall, asbestos sheet, or wall panel | | 0.90 | 1.1 | 1.1 | 1.2 | 1.2 |

**Table K.1.2-2 Bracing Influence Factor of Mid-Column-Row for The Longitudinal Brick Enclosure Wall**

| Number of bay with lower column bracing | Slenderness ratio of lower column bracing | | | | | Mid-column-row without bracing |
|---|---|---|---|---|---|---|
| | <40 | 41~80 | 81~120 | 121~150 | >150 | |
| One bay | 0.90 | 0.95 | 1.00 | 1.10 | 1.25 | 1.40 |
| Two bays | / | / | 0.90 | 0.95 | 1.10 | 1.40 |

**2** For factory buildings with equal height and multi-span reinforced concrete floor, the longitudinal seismic action characteristic value at the level of top of the crane beam of column-rows may be determined according to the following equation:

$$F_{ci}=\alpha_1 G_{ci}\frac{H_{ci}}{H_i} \tag{K.1.2-3}$$

where

$F_{ci}$——The longitudinal seismic action characteristic value at the level of top of crane beam of $i$-th column-row.

$G_{ci}$——The equivalent gravity load representative value concentrating at the level of top of crane beam of $i$-th column-row. It shall include the gravity load representative values of the crane beam and the suspended object, which determined according to Article 5.1.3 of this code, and 40% of the weight of the column.

$H_{ci}$——Height of the top of crane beam for the $i$-th column-row.

$H_i$——Height of the top for the $i$-th column-row.

## K.2 Seismic Effect and Check for Column Braces of Single-Storey Factory Buildings with Reinforced Concrete Columns

**K.2.1** The horizontal displacement of column bracing under the unit lateral force, that slenderness ratio is not greater than 200, may be determined according to the following equation:

$$u=\sum\frac{1}{1+\varphi_i}u_{ti} \tag{K.2.1}$$

where

$u$——The displacement of unit lateral force application point.

$\varphi_i$——The diagonal axes compression stability coefficient of the $i$-th portion of column bracing, that shall be determined according to the provisions of current national standard GB 50017 "*Code for Design of Steel Structures*".

$u_{ti}$——The relative displacement of the $i$-th portion of column bracing under the unit lateral force when only the tensile diagonal tie is taken into consideration.

**K.2.2** Diagonal cross section with slenderness ratio not greater than 200 may only be checked the tensile capacity, but the unloading effect of the compressive diagonal bar shall be taken into consideration, the tensile force may be determined according to the following equation:

$$N_t=\frac{l_i}{(1+\psi_c\varphi_i)s_c}V_{bi} \tag{K.2.2}$$

Where

$N_t$——The axial tensile force design value of the diagonal tie of $i$-th portion of column bracing for tensile capacity check.

$l_i$—— The total length of the diagonal tie of $i$-th portion of column bracing.

$\psi_c$——The unloading factor of the compressive diagonal bar; when the slenderness ratios of the compressive bar are separately 60, 100 and 200, such factor may be taken as 0.7, 0.6 and 0.5 separately.

$V_{bi}$——The seismic shear design value of $i$-th portion of column bracing.

$s_c$——The net bay of the column bracing location.

**K.2.3** For the longitudinal column-row without the masonry walls nestling closely to the outside face of column, the bracing of the upper column and lower column should be designed with uniform strength.

## K.3 Section Seismic Check for Joint Embedded Parts at Column Support End of Single-storey Factory Buildings with Reinforced concrete Columns

**K.3.1** When anchor bar is adopted for anchoring embedded parts at column support and column connecting joint, its section seismic bearing capacity should be checked according to the following Equation:

$$N \leq \frac{0.8 f_{\mathrm{y}} A_{\mathrm{s}}}{\gamma_{\mathrm{RE}}\left(\dfrac{\cos\theta}{0.8\zeta_{\mathrm{m}}\,\psi}+\dfrac{\sin\theta}{\zeta_{\mathrm{r}}\,\psi}\right)} \tag{K.3.1-1}$$

$$\psi = \frac{1}{1+\dfrac{0.6e_0}{\zeta_{\mathrm{r}} s}} \tag{K.3.1-2}$$

$$\zeta_{\mathrm{m}} = 0.6 + 0.25t/d \tag{K.3.1-3}$$

$$\zeta_{\mathrm{v}} = (4-0.08d)\sqrt{f_{\mathrm{c}}/f_{\mathrm{y}}} \tag{K.3.1-4}$$

Where $A_s$——Gross section area of anchor bar;

$\gamma_{RE}$——Seismic adjustment coefficient of bearing capacity; it may take 1.0;

$N$——Diagonal tension of embedded plate; it may adopt 1.05 times of support diagonal member axial force calculated based on yield point strength of total cross section;

$e_0$——Eccentricity between diagonal tension and anchor-bar resultant action line; it shall be less than 20% (mm) of the distance between anchor bars at outer row;

$\zeta$——Included angle between diagonal tension and its horizontal projection;

$\psi$——Influence coefficient of eccentricity;

$s$——Distance (mm) between anchor bars at outer row;

$\delta_m$——Influence coefficient of embedded plate flexural deformation;

$t$——Thickness (mm) of embedded plate;

$d$——Diameter (mm) of anchor bar;

$\delta_r$——Influence coefficient of anchor-bar row quantity in the check direction; it may take 1.0, 0.9 and 0.85 for the second, the third and the fourth row;

$\delta_v$——Shear influence coefficient of anchor bar; it shall take 0.7 where it is greater than 0.7.

**K.3.2** When angle steel is adopted for anchoring embedded parts at column support and column connecting joint, its section seismic bearing capacity should be checked according to the following Equation:

$$N \leq \frac{0.7}{\gamma_{\mathrm{re}}\left(\dfrac{\cos\theta}{\psi N_{\mathrm{u0}}}+\dfrac{\sin\theta}{\psi V_{\mathrm{u0}}}\right)} \tag{K.3.2-1}$$

$$V_{uo} = 3n\zeta_r \sqrt{W_{min} b f_a f_c} \tag{K.3.2-2}$$

$$N_{uo} = 0.8 n f_a A_s \tag{K.3.2-3}$$

Where $n$——Quantity of angle steel;

$b$——Width of angle steel limb;

$W_{min}$——Minimum section modulus of angle steel perpendicular to direction of shear force;

$A_s$——Section area of foot angle steel;

$f_a$——Design value for tensile strength of angle steel.

## K.4 Modifying Stiffness Method of Longitudinal Seismic Analysis for Single-Storey Factory with Brick Columns

**K.4.1** This section is applicable to the longitudinal seismic check for single-storey brick column factory with the reinforced concrete roof (with or without purlin) and equal height and multi-spans.

**K.4.2** Longitudinal fundament natural period of structures of single-storey brick column factory may be determined according to the following equation:

$$T_1 = 2\psi_T \sqrt{\frac{\sum G_s}{\sum K_s}} \tag{K.4.2}$$

Where: $\psi_T$——Period modifying factor, and it may be adopted according to Table K.0.2.

$G_s$——Concentrating gravity load of the $s$-th column-row. It shall include the gravity load of half of span roofing and gable in the left and right of the column-row, and the conversed gravity load concentrated at the top level of the column or the wall. In which, the gravity of wall and column is conversed according to the principle of dynamic energy equivalence.

$K_s$——Lateral stiffness of the s-th column-row.

**Table K.4.2 Modifying Factor of Longitudinal Fundament Natural Period of Factory Buildings**

| Type of roof | RC roof without purlin | | RC roof with purlin | |
|---|---|---|---|---|
| | Side span without skylight | Side span with skylight | Side span without skylight | Side span with skylight |
| Factors | 1.3 | 1.35 | 1.4 | 1.45 |

**K.4.3** The total horizontal seismic action characteristic value in the longitudinal direction of single-storey brick-column factory shall be determined according to the following equation:

$$F_{Ek} = \alpha_1 \sum G_s \tag{K.4.3}$$

Where $\alpha_1$——Seismic influence coefficient corresponds to the longitudinal fundament natural period of single-storey brick column factory building.

$G_s$——The conversed gravity load representative value concentrated at the top level of the wall of the $s$-th column-row; that conversed according to the principle of base shear force equality.

**K.4.4** Horizontal seismic action of the top of the s-th longitudinal column-row of the factory building may be determined according to the following equation:

$$F_s = \frac{\psi_s k_s}{\Sigma \psi_s K_s} F_{Ek} \tag{K.4.4}$$

Where $\psi_s$——Stiffness adjusting factor of column-row considering to the horizontal deformation of the roof, and it shall be adopted according to the values in Table K.4.4 depend on the type of the roof and the arrangement of longitudinal wall in all of column-rows.

**Table K.4.4 Stiffness Adjusting Factor of Column-Rows**

| Type of longitudinal walls | | Type of roof | | | |
|---|---|---|---|---|---|
| | | RC roof without purlin | | RC roof with purlin | |
| | | Side-column-row | Mid-column-row | Side-column-row | Mid-column-row |
| All of row without wall | | 0.95 | 1.1 | 0.9 | 1.6 |
| All of row with wall | | 0.95 | 1.1 | 0.9 | 1.2 |
| Side-row with wall | Wall of mid-row is not less 4 bays | 0.7 | 1.4 | 0.75 | 1.5 |
| | Wall of mid-row is less 4 bays | 0.6 | 1.8 | 0.65 | 1.9 |

# Appendix L  Simplified Calculation for Seismically Isolated Design and Seismically Isolated Measures of Masonry Structures

## L.1  Simplified Calculation for Seismically Isolated Design

**L.1.1** When the multi-storey masonry structures and other structures with foundational periods equivalent to that of masonry structures are seismically isolated, the total horizontal earthquake actions of the upper portion of structures may be determined simply according to Equation (5.2.1-1) of this code, but the following requirements shall be satisfied:

**1** The horizontal seismic-reduced factor that depended on the foundational period of isolated structure, should be determined according to the following Equation:

$$\beta = 1.2\eta_2 (T_{\mathrm{gm}} / T_1)^{\gamma} \tag{L.1.1-1}$$

Where

$\beta$——The horizontal seismic-reduced factor.

$\varepsilon_2$——The damping adjustment factor of seismic influence coefficient, it shall be determined according to Article 5.1.5 of this code dependent on the equivalent damping of the seismic-isolation layer.

$\gamma$—— The damped exponential index of the curvilinear decrease portion of the seismic influence coefficient, it shall be determined according to Article 5.1.5 of this code dependent on the equivalent damping of the seismic-isolation layer.

$T_{\mathrm{gm}}$——The design characteristic period of seismically isolated design for the masonry structure. It shall be determined according to Article 5.1.4 of this code dependent on the design earthquake group, and shall not be less than 0.4s.

$T_1$—— The foundational period of the seismic-isolation system, it shall not be greater than the greater of 2.0s and 5 times of the design characteristic period.

**2** For the structures with foundational periods equivalent to that of masonry structures, the horizontal seismic-reduced factor should be determined according to the following Equation:

$$\beta = 1.2\eta_2 (T_{\mathrm{g}} / T_1)^{\gamma} (T_0 / T_{\mathrm{g}})^{0.9} \tag{L.1.1-2}$$

Where

$T_0$—— The computed foundational period of non-isolation structure. Where it is less than the period characteristic value, it shall be taken as the characteristic period.

$T_1$—— The foundational period of the seismic-isolation system, it shall not be greater than 5 times of the characteristic period.

$T_{\mathrm{g}}$—— Characteristic period; other signs are the same as described above.

**3** The foundational periods of the seismically isolated masonry structures or other similar structures may be calculated according to following Equation:

$$T_1 = 2\pi\sqrt{G / K_{\mathrm{h}} g} \tag{L.1.1-3}$$

Where

$T_1$——The foundational period of seismic isolation system;

$G$——The gravity load representative value of upper portion of structures above the seismic isolation interface.

$K_h$——The horizontal dynamic stiffness of the seismic isolation layer; it may be calculated according to the requirements of Article 12.2.4 in this code;

$g$—— Gravity acceleration.

**L.1.2** The horizontal shear force of seismic isolation layer under rarely earthquake may be calculated according to following Equation:

$$V_c = \lambda_s \alpha_1(\zeta_{eq})G \tag{L.1.2}$$

Where $V_c$——the horizontal shear force of seismic isolation layer under rarely earthquake.

**L.1.3** The horizontal displacement at the centroid of the isolation layer under rarely earthquake may be calculated according to following Equation:

$$u_e = \lambda_s \alpha_1(\zeta_{eq})G / K_h \tag{L.1.3}$$

Where

$\lambda_s$—— Near-field affected factors. It shall be taken as 1.5 for the area within 5km of the causative fault, and at least 1.25 for the area within 5~10km.

$\alpha_1(\delta_{eq})$—The seismic influence coefficient value under rarely earthquake, it may be determined according to Article 5.1.5 of this code dependent on the design parameters of seismic-isolation layer.

$K_h$——The horizontal dynamic stiffness of the seismic-isolation layer under rarely earthquake, it shall be determined according to provisions in Article 12.2.4 of this code.

**L.1.4** For the isolated structure with rectangular or nearly rectangular plain configuration of isolator unites, that the mass center of the upper portion does not coincide with the rigidity center of the seismic isolation layer, the torsion influence factor of the isolator unit may be determined as follows:

**1** When only the torsion under unidirectional earthquake action is considered (Figure L.1.4), the torsion influence factor may be estimated according to the following Equation:

$$\eta = 1 + 12es_i / (a^2 + b^2) \tag{L.1.4-1}$$

Where

$e$ ——Eccentricity of the mass center of upper portion of the structure and the rigidity center of the isolation layer in the direction perpendicular to that of seismic action.

$s_i$ —— The distance from the $i$-th isolator-unite to the rigidity center of the isolation layer in the direction perpendicular to that of seismic action.

$a$, $b$——The length of two sides of the seismic isolation layer plane.

For the side isolator unit, the torsion influence factor should not be less than 1.15. Only when effective torsion resistant measures are taken for seismic isolation layer and upper portion of the structure or the torsion period is less than 70% of the translation period, the torsion influence factor may be taken as 1.15.

**2** While considering the torsion of bi-directional earthquake action, the torsion influence factor may still be calculated according to Equation (L.1.4-1); but the value of the eccentricity ($e$) shall be replaced by the greater value of the followings:

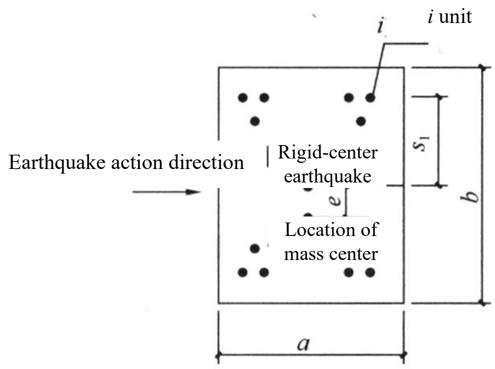



**Figure L.1.4 Sketch Map of Torsion Calculation**

$$e=\sqrt{e_{\mathrm{x}}^{2}+(0.85e_{\mathrm{y}})^{2}} \tag{L.1.4-2}$$

$$e=\sqrt{e_{\mathrm{y}}^{2}+(0.85e_{\mathrm{x}})^{2}} \tag{L.1.4-3}$$

Where $e_{\mathrm{x}}$——Eccentricity under earthquake action in the $y$ direction;

$e_{\mathrm{y}}$——Eccentricity under earthquake action in the $x$ direction.

For the side isolator unit, the torsion influence factor should not be less than 1.20.

**L.1.5** When vertical seismic check for masonry structures is made according to the provisions in Article 12.2.5 of this code, the normal-stress affected factors for the seismic shear strength of masonry should be determined according to the mean compression stress which the gravity load is subtracted the vertical seismic effect.

**L.1.6** For the longitudinal or transversal beams at the top of the seismic-isolation layer of the masonry structure, the design calculation may be adopted the single-span simple support or the multi-span continuous beam under the uniformly distributed load. The uniformly distributed load values may be determined according to the provisions for reinforced concrete spandrel girder in Article 7.2.5 of this code. When the mid-span bending moment computed by continuous beam is less than 0.8 times of that computed by the single-span simple support beam, the reinforcement shall be arranged according to 0.8 times of that computed by the single-span simple support beam.

## L.2 The Details Requirement for Seismic-Isolation Masonry Structure

**L.2.1** When the horizontal seismic-reduced factor of masonry structure assigned to Category C is not greater than 0.40 (0.38 when damper is installed), the limit value of number of stories, the total height and the height-width ratio may be adopted according to the provisions of Section 7.1 of this code dependent on the reduced Intensity by one grade.

**L.2.2** The details for the seismic isolation layer shall conform to the following provisions:

1 When the seismic-isolation layer of multi-storey masonry building locates at the top of the basement, the isolator-unites should not be placed on the masonry wall directly, and the local compressive capacity of the masonry wall shall be checked too.

**2** The details of the longitudinal and transversal beams at the top of the seismic-isolation layer shall comply with the requirements for reinforced concrete spandrel girder of brick buildings with bottom-frame, as set forth in Article 7.5.8 of this code.

**L.2.3** The seismic details for the upper portion of masonry structures assigned to Category C shall comply with the following requirements:

**1** The minimum distance from a bearing exterior wall end to the side of the door or window opening, as well as the cross section and reinforcement detailing of the ring beam, shall comply with relevant provisions in Sections 7.1, 7.3and 7.4 in this code.

**2** For the multi-storey masonry buildings with horizontal seismic-reduced factor greater than 0.40 (0.38 when damper is installed), the reinforcement concrete tie-columns shall be arranged according to the requirements of Table 7.3.1 in this code. For the multi-storey masonry buildings located at the Intensity 7 to 9 zones with horizontal seismic-reduced factor not greater than 0.40( 0.38 when damper is installed), the reinforcement concrete tie-columns shall be arranged according to the requirements of Table **L.2.3-1**.

**Table L.2.3-1 Requirements for Tie-Column Arrangement of Seismically Isolated Masonry Buildings**

<table>
<tr><th colspan="3">Number of stories in building</th><th colspan="2" rowspan="2">Location of installation</th></tr>
<tr><th>Int. 7</th><th>Int. 8</th><th>Int. 9</th></tr>
<tr><td>3, 4</td><td>2, 3</td><td></td><td rowspan="4">Four corners of the exterior wall, staircase and elevator shaft; intersections of the transversal wall in the slit-level part and the exterior longitudinal wall; both sides of larger openings; inter-sections of interior wall and exterior longitudinal walls of large rooms</td><td>Intersections of each 12m or the unit transversal wall and exterior longitudinal wall</td></tr>
<tr><td>5</td><td>4</td><td>2</td><td>Intersection of each 3bay transversal wall and exterior longitudinal wall</td></tr>
<tr><td>6, 7</td><td>5</td><td>3, 4</td><td>Intersections of every other transversal wall (axis) and exterior wall; intersections of gable and interior walls; intersections of exterior and interior walls for four stories and Intensity 9</td></tr>
<tr><td>8</td><td>6,7</td><td>5</td><td>Intersections of interior wall and exterior wall, smaller piers of the interior wall;<br>Intersections of interior longitudinal and transversal wall (axis)</td></tr>
</table>

**3** For the multi-storey small-block buildings with horizontal seismic-reduced factor greater than 0.40 (0.38 when damper is installed), the reinforcement concrete core-columns shall be arranged according to the requirements of Table 7.4.1 in this code. For the multi-storey masonry buildings located at the Intensity 7 to 9 zones with horizontal seismic-reduced factor not greater than 0.40( 0.38 when damper is installed), the reinforcement concrete core-columns shall be arranged according to the requirements of Table **L.2.3-2**.

**4** For the structures with horizontal seismic-reduced factor greater than 0.40 (0.38 when damper is installed), the other seismic details for the upper portions of structures shall still comply with the requirements of Chapter 7 in this code. For the structures with horizontal seismic-reduced factor not greater than 0.40( 0.38 when damper is installed), the other seismic details for the upper portions of structures shall comply with the requirements of Chapter 7 in this code dependent on the reduced Intensity by one grade.

**Table L.2.3-2 Requirements for Arrangement of Core Column of Small-Block Buildings**

| Number of stories | | | Location of core-columns | Number of core-columns (filled holes) |
|---|---|---|---|---|
| Int. 7 | Int. 8 | Int. 9 | | |
| 3, 4 | 2, 3 | | Corner of exterior wall, four corners of staircase, intersection of interior and exterior walls in large rooms, intersections of each 12m or the unit transversal wall and exterior longitudinal wall | Corners of the exterior wall, 3 holes shall be filled; intersection of interior and exterior walls, 4 holes |
| 5 | 4 | 2 | Corner of exterior wall, four corners of staircase, intersection of interior and exterior walls in large rooms, intersection of the interior wall and the gable, intersection of each 3 bay transversal wall (axis) and exterior longitudinal wall | |
| 6 | 5 | 3 | Corner of exterior wall, four corners of staircase, intersection of interior and exterior walls in large rooms, intersection of the interior wall and the gable, intersection of other bay transversal wall (axis) and exterior longitudinal wall;<br>For Intensity 8, 9, intersection of exterior longitudinal wall and transversal wall (axis), both sides of bigger openings | Corners of the exterior wall, 5 holes shall be filled; intersection of interior and exterior walls, 4 holes; intersection of interior walls, 4 or 5 holes; both sides of opening, 1 holes |
| 7 | 6 | 4 | Corner of exterior wall, four corners of staircase, intersection of all interior and exterior walls;<br>Intersection of interior longitudinal wall and transversal wall (axis), both sides of bigger openings | Corners of the exterior wall, 7 holes shall be filled; intersection of interior and exterior walls, 5 holes; intersection of interior walls, 4 or 5 holes; both sides of opening, 1 hole |

# Appendix M  Reference Procedures of Performance-based Seismic Design

## M.1  Performance-Based Seismic Design Methods for Structural Components

**M.1.1** In order to achieve the requirements of seismic performances, the structural components may be designed using the seismic grades of load-bearing capacity, deformability and details that determined according to the following provisions. The same or different seismic performance requirements may be selected for components (including vertical and horizontal components) at different positions of the whole structure.

**1** When priority is given to the improvement of seismic safety, the reference index of load-bearing capacity for structural components, corresponding to different performance requirements, may be selected according to those specified in Table M.1.1-1.

**Table M.1.1-1  Reference Index of Load-bearing Capacity For Structural Components to Achieve The Seismic Performance Requirements**

| Performance requirement | Frequently earthquakes | Precautionary earthquake | Rarely earthquake |
|---|---|---|---|
| Performance 1 | Intact.<br>Normal design | Intact.<br>The load-bearing capacity shall be checked according to the design value of seismic action effects adjusted by seismic grade | Basically intact.<br>The load-bearing capacity shall be checked according to the design value of seismic action effects not adjusted by seismic grade |
| Performance 2 | Intact.<br>Normal design | Basically intact.<br>The load-bearing capacity shall be checked according to the design value of seismic action effects not adjusted by seismic grade | Minor or moderate damage<br>The ultimate value of load-bearing capacity shall be checked according to the characteristic combination value of seismic action effects. |
| Performance 3 | Intact.<br>Normal design | Minor damage<br>The characteristic value of load-bearing capacity shall be checked according to the characteristic combination value of seismic action effects. | Moderate damage.<br>The ultimate value of load-bearing capacity shall be able to maintain stability with reduction less than 5% |
| Performance 4 | Intact.<br>Normal design | Minor or moderate damage<br>The ultimate value of load-bearing capacity shall be checked according to the characteristic combination value of seismic action effects. | No severe damage<br>The ultimate value of load-bearing capacity shall be able to maintain stability basically, with reduction less than 10% |

**2** When the service performance need be determined according to earthquake residual deformation, the above requirements of improving seismic safety for the structural components shall be satisfied, and meanwhile, the reference index of storey drift with different performance requirements may also be selected according to those specified in Table M.1.1-2.

**Table M.1.1-2 Reference index of storey drift for structural components to achieve the seismic performance requirements**

| Performance requirement | Frequently earthquakes | Precautionary earthquake | Rarely earthquake |
|---|---|---|---|
| Performance 1 | Intact with deformation far less than the limit value of elastic drift | Intact with deformation less than the limit value of elastic drift | Basically intact with deformation slightly greater than the limit value of elastic drift |
| Performance 2 | Intact with deformation far less than the limit value of elastic drift | Basically intact with deformation slightly greater than the limit value of elastic drift | Minor damage with deformation less than 2 times of the limit value of elastic drift |
| Performance 3 | Intact with deformation apparently less than the limit value of elastic drift | Minor damage with the deformation less than 2 times of the limit value of elastic drift | Moderate damage with deformation about 4 times of the limit value of elastic drift |
| Performance 4 | Intact with deformation less than the limit value of elastic drift | Minor or moderate damage with deformation less than 3 times of the limit value of elastic drift | No severe damage with deformation not greater than 0.9 times of the limit value of plastic deformation. |

Note: For the calculation of the deformation under precautionary earthquake and rarely earthquake, the second-order effect of gravity shall be taken into account, but the whole flexural deformation may be deducted.

**3** The seismic grade for details of structural components corresponding to different performance requirements may be selected according to those specified in Table M.1.1-3. For the different components at the same position of the structure that may be divided into vertical components and horizontal components, the different seismic grade corresponding to the lowest performance requirement may be selected.

**Table M.1.1-3 The Seismic Grade For Details of Structural Components Corresponding to Different Performance Requirements**

| Performance requirement | Seismic grade for details |
|---|---|
| Performance 1 | Basic seismic details.<br>The structural components may be designed according to the relevant provisions of normal design which is dependent on the Intensity reduced by two grade. In any case, the reduced Intensity shall not be less than Intensity 6, and the structural components shall avoid brittle failures. |
| Performance 2 | Low-ductility details.<br>The structural components may be designed according to the relevant provisions of normal design which is dependent on the Intensity reduced by one grade. For the structural components with load-bearing capacity greater than the demands of the frequent earthquakes that corresponds to the Intensity improved by two grade, they may be designed according to the Intensity reduced by two grade. And in any case, the reduced Intensity shall not be less than Intensity 6, and the structural components shall avoid brittle failures. |
| Performance 3 | Medium-ductility details.<br>When the structural components have the load-bearing capacity which is greater than the demands of the frequent earthquakes corresponding to the Intensity improved by one grade, they may be designed according to the relevant provisions of normal design which is dependent on the Intensity reduced by one grade, however, the reduced Intensity shall not be less than Intensity 6. Otherwise, the components shall be designed according to the provisions of normal design. |
| Performance 4 | High-ductility details.<br>The structural components shall be designed according to the provisions of normal design. |

**M.1.2** When the load-bearing capacities of structural components according to different requirements are checked, the calculation and adjustment of seismic internal forces, the combination of seismic action effects, the selection of material strength values and the checking methods, shall comply with the following requirements:

**1** When the load-bearing capacities of structural components, including the bending-compression, bending-tension, shearing and flexural capacities for concrete components, and the tension, compression and flexural capacities and stability for steel components, are checked according to the design value of seismic action effects adjusted by seismic grade under precautionary Intensity earthquake, the fundamental combination of seismic action effects without the wind load effects shall be used, and the checking shall be carried out according to the following Equation:

$$\gamma_G S_{GE}+\gamma_E S_{EK}\left(I_2,\lambda,\zeta\right)\leq R/\gamma_{RE} \tag{M.1.2-1}$$

Where $I_2$——The precautionary earthquake ground motion. For the seismically isolated structures, the horizontal seismic-reduced influence shall be considered.

$\lambda$——The adjustment factor for the seismic action effect corresponding to the seismic grade of normal design;

$\delta$——The factor that is used to consider the influences of the rigidity degradation of some secondary components due to plastic deformation and the influences of the additional damping of energy-dissipated structures.

Other symbols are the same as those for normal design.

**2** When the load-bearing capacities of structural components are checked according to the design value of seismic action effects not adjusted by seismic grade, the fundamental combination of seismic action effects without the wind load effects shall be used, and the checking shall be carried out according to the following Equation:

$$\gamma_{G} S_{GE} + \gamma_{E} S_{EK}\left(I, \zeta\right) \leq R / \gamma_{RE} \tag{M.1.2-2}$$

Where $I$—— The ground motion under precautionary earthquake or rare earthquake. For the seismically isolated structures, the horizontal seismic-reduced influence shall be considered.

$\delta$——The factor that is used to consider the influences of the rigidity degradation of some secondary components due to plastic deformation and the influences of the additional damping of energy-dissipated structures.

**3** When the characteristic values of the load-bearing capacities of structural components are checked, the characteristic combination of seismic action effects without the wind load effects shall be used, and the checking shall be carried out according to the following Equation:

$$S_{GE} + S_{EK}\left(I, \zeta\right) \leq R_{k} \tag{M.1.2-3}$$

Where $I$—— The ground motion under precautionary earthquake or rare earthquake. For the seismically isolated structures, the horizontal seismic-reduced influence shall be considered.

$\delta$——The factor that is used to consider the influences of the rigidity degradation of some secondary components due to plastic deformation and the influences of the additional damping of energy-dissipated structures.

$R_k$——The characteristic values of the load-bearing capacities calculated according to the standard value of material strength.

**4** When the ultimate values of the load-bearing capacities of structural components are checked, the characteristic combination of seismic action effects without the wind load effects shall be used, and the checking shall be carried out according to the following Equation:

$$S_{GE} + S_{EK}\left(I, \zeta\right) < R_{u} \tag{M.1.2-4}$$

Where $I$—— The ground motion under precautionary earthquake or rare earthquake. For the seismically isolated structures, the horizontal seismic-reduced influence shall be considered.

$\delta$——The factor that is used to consider the influences of the rigidity degradation of some secondary components due to plastic deformation and the influences of the additional damping of energy-dissipated structures.

$R_u$——The characteristic values of the load-bearing capacities calculated according to the minimum limit strength of material. The minimum limit strength of material may be taken as the minimum limit value for steel, 1.25 times of the yield strength for reinforcement and 0.88 times of the cube strength for concrete, respectively.

**M.1.3** When the elastoplastic inter-storey deformations of vertical structural components under precautionary earthquake or rare earthquake are checked according to different objectives, the calculation of storey shear force, the adjustment of seismic action effects, the computation of the inter-storey drift of vertical components and the checking methods, shall comply with the following requirements:

**1** The calculating for the storey shear force and adjusting for the seismic action effects shall be carried out by different methods according to the different degree of elastoplastic deformation of different portion in the whole structure. When the components are in cracking phase generally or just enter the yielding stage, the equivalent linear method that is dependent on the equivalent rigidity and equivalent damping may be used. When the components are in the phase that is from the yielding point to the ultimate value point of load-bearing capacity generally, the static or dynamic elastoplastic analysis method may be used. When the components are at the descending stage of load-bearing capacity, the dynamic elastoplastic analysis method including the parameters of descending stage shall be used.

**2** Under the precautionary earthquake ground motion, the initial rigidity of concrete components should be taken as the long-term rigidity.

**3** The inter-storey elastoplastic deformation of components shall be calculated dependant on the actual load-bearing capacity, and the second-order effects of gravity shall be counted in according to the requirements of this code. Note that the deformations caused by wind loads or gravity actions need not be combined with the seismic action effects.

**4** The inter-storey elastoplastic deformation of components may be checked according to the following Equation:

$$\Delta u_{\mathrm{p}}(I,\zeta,\xi_{\mathrm{y}},G_{\mathrm{E}}) \lhd [\Delta u] \tag{M.1.3}$$

Where

$\Delta u_{\mathrm{p}}$ (…) ——The inter-storey elastoplastic drift of vertical components under precautionary earthquake or rare earthquake including the gravity second-order effect and damping influence, which depends on the actual load-bearing capacity. For structures with height-width ratio greater than 3, the influence of whole rotation may be deducted

$[\Delta u]$——The limit value of elastoplastic drift. It shall be determined according to the performance objective. For the vertical component with maximum inter-storey deformation in the whole structure, the value may be taken as the average value of those specified in Table 5.5.1 and Table 5.5.5 for moderate damage, half of the average value above for Minor damage, and 0.9 times of the value specified in Table 5.5.5 for no severe damage.

## M.2 Performance-based Seismic Design Methods for Architectural Components and the Supports of The Equipments

**M.2.1** When the nonstructural components and auxiliary mechanical and electrical equipments are designed using the performance-based design procedures in accordance with the special requirements of functions, the performance requirements under precautionary earthquake may be selected according to those specified in Table M.2.1.

**Table M.2.1 Reference Performance Levels of Nonstructural Components and Auxiliary Mechanical and Electrical Equipments**

| Performance level | Function description | Deformation index |
|---|---|---|
| Performance 1 | The appearances may be damaged, and the safety glasses may crack, but the damage will not affect the normal use and the fireproof capacity. The operation systems and the emergency system may run as usual | The nonstructural components and supports of equipments may endure the deformation with value as 1.4 times of the design deflection of connected structural component |
| Performance 2 | It may be basically operated as normal or recovered quickly. The fire endurance may be reduced by 1/4 The tempered glasses may be broken. The operation system may run after overhaul, the emergency system may run as usual | The nonstructural components and supports of equipments may endure the deformation with value as 1.0 times of the design deflection of connected structural component |
| Performance 3 | The fire endurance may be reduced obviously. The glasses are broken and fall. The entrances and exits are obstructed by fragments. The operation system is damaged obviously and may be recovered after repairing. The emergency system is damaged slightly, and can still run basically. | The nonstructural components and supports of equipments may endure the deformation with value as 0.6 times of the design deflection of connected structural component |

**M.2.2** When the enclosure walls, auxiliary components and fixed cabinets are designed using the performance-based design procedures, the type factor and functional factor of components for the calculating of earthquake action may be determined by reference to Table M.2.2.

**Table M.2.2 Type Factors and Functional Factors of Nonstructural Components**

| Name of elements or components | Type factors of components | Functional factors | |
|---|---|---|---|
| | | Category B | Category C |
| Non-bearing outer walls: | | | |
| Enclosure walls | 0.9 | 1.4 | 1.0 |
| Glass curtain walls | 0.9 | 1.4 | 1.4 |
| Connections: | | | |
| Connections of walls | 1.0 | 1.4 | 1.0 |
| Connections of Veneers | 1.0 | 1.0 | 0.6 |
| Connections of fireproof ceilings | 0.9 | 1.0 | 1.0 |
| Connections of nonfireproof ceilings | 0.6 | 1.0 | 0.6 |
| Auxiliary components: | | | |
| Marks or billboards | 1.2 | 1.0 | 1.0 |
| Supports of cabinets with height greater than 2.4m: | | | |
| File cabinets, storage cabinets | 0.6 | 1.0 | 0.6 |
| Antiquity cabinets | 1.0 | 1.4 | 1.0 |

**M.2.3** When the supports and connections of the equipments are designed using the performance-based design procedures, the type factor and functional factor for the calculating of earthquake action may be determined by reference to Table M.2.3.

**Table M.2.3 Type Factors and Functional Factors of Auxiliary Equipments**

| System of elements of components | Type factors of components | Function coefficient | |
|---|---|---|---|
| | | Category B | Category C |
| The Master Control System(MCS), generators and refrigeration compressors of the Emergency Power Supply(EPS) | 1.0 | 1.4 | 1.4 |
| The supporting structure, guide track, brackets and the guide components of compartment of elevator | 1.0 | 1.0 | 1.0 |
| Suspended or pendular light fittings | 0.9 | 1.0 | 0.6 |
| Other light fittings | 0.6 | 1.0 | 0.6 |
| Supports of cabinet-type equipments | 0.6 | 1.0 | 0.6 |
| Supports of water tanks or cooling towers | 1.2 | 1.0 | 1.0 |
| Supports of boilers or pressure vessels | 1.0 | 1.0 | 1.0 |
| Supports of common antennas | 1.2 | 1.0 | 1.0 |

## M.2.3 Floor Response Spectrum Method for Seismic Calculation of Nonstructural Components and Auxiliary Equipments

**M.3.1** The floor response spectra of nonstructural components shall be able to reflect the dynamic characteristics of main structures, the floor position where the nonstructural components located, and the amplification effects of the structural and nonstructural damping characteristic on the seismic ground motion.

In general, the single mass point models may be used for the colocation of floor response spectra of nonstructural components. However, for the nonstructural components with relative displacement between different supports, the multi-supporting-point system should be used for the calculation.

**M.3.2** When the floor response spectrum method is to be adopted, the horizontal seismic action characteristic value of nonstructural components may be calculated with the following equation:

$$F = \gamma \eta \beta_s G \tag{M.3.2}$$

Where

$\beta_s$——The floor response spectrum value of nonstructural components, which is dependent on precautionary Intensity, site conditions, the period-ratio, mass-ratio and damping between nonstructural and structural system, as well as the supporting location, number of supports and connection properties of the connections between nonstructural components and main structure.

$\gamma$——The functional factor of nonstructural component, which depends on the precautionary category and the use requirements of building and may be taken as 1.4, 1.0 and 0.6 in general for performance level 1, 2 and 3, respectively.

$\eta$——The type factor of nonstructural component, which depends on material properties of components and other factors and may be taken the value 0.6~1.2 in general.

# Explanation of Wording in This Code

**1.** In order to treat different provisions according to their individual conditions during the implementation of this code, words denoting the different degrees of strictness of demands are explained as follows:

(1) Words denoting a very strict or mandatory requirement:

—must” is used for affirmation;

—must not” is used for negation.

(2) Words denoting a strict requirement under normal conditions:

“shall” is used for affirmation;

—shall not” is used for negation.

(3) Words denoting a permission of slight choice or an indication of the most suitable choice when conditions allow:

—should” is used for affirmation;

—should not" is used for negation.

(4) And —may” denoting a permission of choice or an indication of the suitable choice when conditions allow.

**2**. —Be in accordance with” or —be comply with” are used to indicate that it is necessary to implement items in this code according to other relative standards, codes or regulations.

## List of Quoted Standards

1. GB 50007, *Code for Design of Building Foundation*
2. GB 50009, *Load Code for the Design of Building Structures*
3. GB 50010, *Code for Design of Concrete Structures*
4. GB 50017, *Code for Design of Steel Structures*
5. GB 50191, *Code for Seismic Design of Special Structures*
6. GB 50204, *Code for Acceptance of Constructional Quality of Concrete Structures*
7. GB 50223, *Standard for Classification of Seismic Protection of Building Constructions*
8. GB 50330, *Technical Code for Building Slope Engineering*
9. GB 20688.3, *Rubber Bearing - Part 3: Elastomeric Seismic-protection Isolators for Buildings*
10. GB/T 5313, *Steel Plate with Through-thickness Characteristics*

END