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中国建筑结构性能化抗震设计概况

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Abstract

The development history, the current situation and the future of performance-based seismic design in China are presented. The evolution of performance-based seismic design specified in the Chinese codes for seismic design of 5 editions (Edition 1974, 1978, 1989, 2001 and 2010) are introduced and compared. This paper details the provisions of performance-based seismic design in different codes ("Code for Seismic Design of Buildings" and "Technical Specification for Concrete Structures of Tall Building"), which presents the concepts and methods of performance-based seismic design adopted in Chinese codes. Lastly, according to those mentioned above, this paper points out the imperfections of current performance-based seismic design in China and proposes the possible direction for further improvement.

Keywords: Performance-based seismic design; Out-of-codes High-rise Building Structures

摘要

本文探讨了中国性能化抗震设计历史、现状及未来。首先，针对不同时期的五个版本的抗震规范，明确了性能化抗震设计出现、发展、变化的历程。其次，介绍了性能化抗震设计在相关规范《建筑抗震规范》、《高层建筑混凝土结构技术规范》中的内容，并对中国规范范围的性能化抗震设计要求做了介绍。最后，指出了中国性能化抗震设计尚存的问题并提出了对未来的改进提出了建议。

关键词：性能化设计 超限高层建筑

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Introduction

In China, 5 editions of seismic design codes have been promulgated so far. These are "Anti-seismic Design Code of Industrial and Civil Building (Trial)" TJ 11-74, "Anti-seismic Design Code of Industrial and Civil Building" TJ 11-78, "Specifications for anti-seismic construction design" GBJ11-89 (implemented since 1990, partially revised in 1993), "Code for Seismic Design of Buildings" GB 50011-2001 (partially revised after the 2008 Wenchuan Earthquake) and "Code for Seismic Design of Buildings" GB 50011-2010, hereinafter respectively referred to as Code74, Code78, Code89, Code01 and Code10.

In Chinese codes, fortification intensity is regarded as criterion of seismic design requirements, corresponding to basic seismic intensity. The basic seismic intensity of a certain region in China is defined as the impact of the earthquake with 10 percent probability of exceedance in 50 years, divided into 12 degrees, demarcated by maximum ground acceleration and the earthquake impact or damage extent on landform or buildings (Table 1) .

Code74 and Code78 use single seismic

Introduction

在中国， 至今共颁布了5个版本的建筑抗震设计规范，分别是：《工业与民用建筑抗震设计规范》（试行）TJ 11—74、《工业与民用建筑抗震设计规范》 TJ 11-78、《建筑抗震设计规范》 GBJ 11—89（于1990年开始实施，1993年作局部修订）、《建筑抗震设计规范》 GB 50011—2001（2008年 汶川地震后作了局部修订）《建筑抗震设计规范》、GB 50011—2010，以下分别简称74规范、78规范、89规范、01规范和10规范。

中国以设防烈度作为建筑结构抗震设计要求的基准，而设防烈度一般情况下与地震基本烈度相对应。中国任一地区的地震基本烈度的定义为该地区50年超越概率为10%的地震影响程度，共分为12度，以地面最大加速度、地震对地貌或建筑物的影响或破坏程度来标定（表1）。

中国74规范和78规范均采用单一水准设防（表1），规定了7度和7度以上设防，均要求结构在设防水准地震下不坏，即控制地震下的结构变形和保证结构足够的抗震承载力，在抗震设计的概念上这两部规范没有实质性区别，在前者中规定，对于一般建筑物，设计烈度可比基本烈度降低一度，基本烈度为7度时不降低；在1976年

demand level, see Table 1, taking design intensity of 7 degrees and above into consideration, requesting no damage under earthquakes of fortification level, which is to control structural deformation under earthquake and to ensure adequate structural seismic bearing capacity. In the former, for general buildings, the design intensity is one degree lower than the basic seismic intensity (not when the basic seismic intensity is 7 degrees) ; In the latter which was promulgated after the 1976 Tangshan Earthquake, the design intensity is equal to the basic seismic intensity.

In Code89, three-levels performance objectives of seismic design of buildings as "no damage under minor earthquakes, repairable under moderate earthquakes, no collapse under severe earthquakes" was proposed, which means "No damage or applicable without repair when suffered from frequent earthquake (minor earthquake), (10 percent probability of exceedance in 50 years); Applicable after normal repair when suffered from earthquake action of fortification intensity; No collapse or serious damage that can create hazard to life safety when suffered from predicted rare earthquake (severe earthquake), (2-3 percent probability of exceedance in 50 years)".

In Code89, to realize the three-levels of performance objectives, the "two-steps seismic design method" was developed, detailed as follows: 1st step, using ground motion parameter (ground motion peak acceleration and characteristic period of earthquake motion response spectrum) of minor earthquake, firstly calculate the elastic relative inter-story drift to be less than the limit value, in order to satisfy the requirement of "no breaking for nonstructural component and no damage for structure" of first level; secondly, combining the effect of earthquake action with effect of other loads to check the member bearing capacity, in order to satisfy the bearing capacity requirements of the first level. 2nd step, using ground motion parameter of severe earthquake, calculate the elastic-plastic relative inter-story drift to be less than the limit value, in order to satisfy the requirement of "no collapse of building structure" of third level.

Code89 is one of the first codes in which the performance-based seismic design (hereinafter referred to as PBSD) was introduced. However, imperfections exists: 1) The requirements for "no damage under minor earthquakes" and "no collapse under severe earthquakes" were given, see Table 1, but not for the "repairable under moderate earthquakes"; 2) In member bearing capacity checking of "no damage under minor earthquakes", partial factor of earthquake action larger than 1.0 is introduced, thus the earthquake action is not exactly the same as that of minor earthquake with 10 percent probability of exceedance in 50 years.

	First Level (Minor Earthquake) 第一水准（小震）	Second Level (Moderate Earthquake) 第二水准（中震）	Third Level (Severe Earthquake) 第三水准（大震）
Code74 74规范	Member Bearing capacity Checking 构件承载力验算	–	–
Code78 78规范	–	Member Bearing capacity Checking 构件承载力验算	–
Code89 89规范 Code 01 01规范 Code 10 10规范	1) Structural Elastic Deformation Checking 结构弹性变形验算 2) Member Bearing capacity Checking 构件承载力验算	–	Structural Elastic-Plastic Deformation Checking 结构弹塑性变形验算

Table 1. Seismic design requirements of building structures of China
表1. 中国建筑结构抗震设计要求

唐山大地震之后，经过局部修改，颁布了后者，规定一般建筑物的设防烈度按基本烈度采用。

在随后的89规范中，中国即提出了“小震不坏、中震可修、大震不倒”的建筑结构抗震设计三个水准性能化目标，即要求建筑结构“当遭受低于本地区设防烈度的多遇地震（即小震）影响时（50年超越概率为10%），一般不受损坏或不需修理仍可继续使用，当遭受本地区设防烈度的地震影响时，可能损坏，经一般修理或不需修理仍可继续使用，当遭受高于本地区设防烈度的预估的罕遇地震（即大震）影响时（50年超越概率为2%-3%），不致倒塌或发生危及生命的严重破坏”。

89规范是通过“两阶段设计”，试图实现上述三水准抗震设防目标的：第一阶段设计，采用“小震”地震动参数（地震动峰值加速度和地震动反应谱特征周期），先计算出结构的弹性层间位移角，使其不超过规定的限值，从而满足第一水准建筑结构的非结构构件不坏或结构不受损的要求；然后计算出结构在弹性状态下的地震作用效应，与风、重力等荷载效应组合，进行结构构件承载力验算，从而满足第一水准的结构承载力要求。第二阶段设计，采用“大震”地震动参数，计算出结构的弹塑性层间位移角，使之小于规范规定的限值，从而满足第三水准的防止建筑倒塌的要求。

中国在1989年即颁布实施的89规范应该是世界上较早引入性能化思想的建筑抗震设计国家标准，但该规范的缺陷是：1）规范只有“小震不坏”和“大震不倒”的性能设计要求（见表1），而没有“中震可修”的性能设计要求；2）在“小震不坏”的结构承载力验算要求中，由于引入了大于1的地震作用分项系数，因此进行结构承载力验算所采用的地震作用与50年超越概率为10%所对应的小震并不一致。

Seismic Design Provisions of PBSD in China

Provisions in "Code for Seismic Design of Buildings" GB 50011—2010

In Code10, requirements of PBSD are specified in 3.10, titled as "Performance-Based Design of Buildings". As it refers, when PBSD is adopted in designing, the objectives shall be evaluated both technically and economically, according to fortification intensity, site condition, structure type and irregularity, functional requirements of building and ancillary facility, investment, post-earthquake loss and repair cost. Objectives of PBSD could be targeted respectively to overall structure, parts of the structure, key members, important members, secondary members, construction members and electromechanical equipment.

中国建筑结构性能化抗震设计规定

GB 50011—2010《建筑抗震设计规范》的规定

GB 50011—2010《建筑抗震设计规范》3.10节题为“建筑抗震性能化设计”。规范中具体地指出，当建筑结构采用抗震性能化设计时，应根据其设防烈度、场地条件、结构类型和不规则性，建筑使用功能和附属设施功能的要求、投资大小、震后损失和修复难易程度等，对选定的抗震性能目标提出技术和经济可行性综合分析和论证；建筑结构的抗震性能化设计，应根据实际需要和可能，具有针对性：可分别选定针对整个结构、结构的局部部位或关键部位、结构的关键部件、重要构件、次要构件以及建筑构件和机电设备支座的性能目标。

建筑结构抗震性能化设计应符合如下步骤：首先选定地震动水准，其次选定性能目标，随后选定性能设计指标。可供选择的建筑抗震性能化设计的预期性能目标分为1/2/3/4，如表2所示。

The PBSD steps are: 1) Select the seismic ground motion level; 2) Select the performance objectives; 3) Select the performance-based design demand. The anticipated performance objectives of PBSD dividing into 1/2/3/4 to choose from are listed in Table 2.

The performance-based design demands on bearing capacity, inter-story drift and seismic grade of construction measures are then specified to realize the performance objectives.

Provisions in "Technical specification for concrete structures of tall building" (JGJ3-2010)

Similar to Code GB50011-2010, the performance objective of tall buildings is divided into four grades named A/B/C/D. In addition, the aseismic performance level is divided into 5 levels named 1/2/3/4/5. Each performance objective corresponds to a group of aseismic performances under different earthquake levels, see Table 3.

Seismic Level 地震水准	1 性能1	2 性能2	3 性能3	4 性能4
Frequent Earthquake 多遇地震	Perfect 完好	Perfect 完好	Perfect 完好	Perfect 完好
Design Earthquake 设防地震	Perfect, in normal use 完好，正常使用	Nearly perfect, applicable after maintenance 基本完好，检修后继续使用	Minor damage, applicable after slight repair 轻微损坏，简单修理后继续使用	**Minor to moderate damage, deformation < 3 [ΔU_e]** 轻微至接近中等损坏变形 < 3 [ΔU_e]
Rare Earthquake 罕遇地震	Nearly perfect, applicable after maintenance 基本完好，检修后继续使用	Minor damage, applicable after repair 轻微至中等破坏，修复后继续使用	Applicable after strengthening 其破坏需加固后继续使用	Serious damage, applicable after overhaul 接近严重破坏，大修后继续使用

Table 2. Anticipated performance objectives of PBSD for buildings
表2. 建筑抗震性能化设计的预期性能目标

Note: ΔU_e: maximum elastic inter-story drift caused by standard value of frequent earthquake action.
注：ΔU_e: 多遇地震作用标准值产生的楼层内最大的弹性层间位移。

以上性能目标是一般意义上的要求，具体针对承载力、层间位移和抗震等级，规范还给出了更为细致的要求。

《高层建筑混凝土结构技术规程》（JGJ3-2010）的规定

与GB50011-2010类似，在JGJ3-2010中将高层建筑结构抗震性能目标分为A、B、C、D共四个等级，将高层建筑结构抗震性能水准分为1、2、3、4、5共五个水准，每个等级的结构性能目标均与一组不同地震水准下的结构抗震性能水准对应见表3。

Seismic design provisions of out-of-codes high-rise buildings

In China, for high-rise buildings over the limits of the relevant codes, we are naming this group out-of-codes high-rise buildings. Out-of-codes high-rise buildings are divided into two types: 1) building height exceeding limits and 2) structure regularity exceeding limits. For the out-of-codes high-rise buildings, seismic tests shall be conducted when necessary and a peer review for the seismic design scheme shall be adopted.

The additional requirements for design of out-of-codes high-rise buildings mainly are: Using two independent structure analysis software programs to proceed the seismic calculations, respectively; Elastic time-history analysis demanded; Elastic-plastic time-history analysis demanded for buildings over 200m; Using two independent structure analysis programs to proceed elastic-plastic time-history analysis for buildings over 300m; Considering the elastic deformation of floor.

超限高层建筑的抗震设计规定

中国对超出有关规范抗震设计限定的高层建筑称之为超限高层建筑。超限高层建筑分为建筑高度超限和结构规则性超限两类。超限高层建筑抗震设计时，除须满足中国有关规范所有抗震要求外，在结构抗震计算还需满足额外要求，需要通过抗震专项专家审查的方式评判其抗震设计能否达到预定的抗震性能目标要求。

超限高层建筑抗震计算的额外要求主要有：采用两个独立的结构分析软件进行结构抗震计算；进行结构弹性时程分析；高度超过200m的超限高层建筑，应进行弹性时程分析；高度超过300m的超限高层建筑，应采用两个独立的软件进行弹塑性时程分析；应考虑楼板的弹性变形影响。

Conclusions and Suggestions

Primary Achievements

From the translation of "Codes for Buildings in Earthquake Zones" of the former Soviet Union in 1955 to the publication of "Code for Seismic Design of Buildings" GB 50011-2010 in 2010 with the proposition of the PBSD concept, significant achievements have been gained. These are:

Seismic Performance Level 性能水准	Macroscopic Damage 宏观受损程度	Damage Position 损坏部位			Possibility to Continue Using 继续使用的可能性
		Key Member 关键构件	General Vertical Member 普通竖向构件	No Damage 耗能构件	
1	Perfect, no damage 完好、无损坏	No damage 无损坏	No damage 无损坏	No damage 无损坏	Applicable without repair 不许修理即可继续使用
2	Nearly perfect, minor damage 基本完好，轻微损坏	No damage 无损坏	No damage 无损坏	**Minor damage** 轻微至接近中等损	Applicable after slight repair 稍加修理即可继续使用
3	Slight damage 轻度损坏	Minor damage 轻微损坏	Minor damage 轻微损坏	Slight damage, partially moderate damage 轻度损坏，部分中度损坏	Applicable after repair 一般修理后可继续使用
4	Moderate damage 中度损坏	Slight damage 轻度损坏	Moderate damage of certain members 部分构件中度损坏	Moderate damage, partially quite serious damage 中度损坏，部分比较严重损坏	Applicable after restoration or strengthening 修复或加固后可继续使用
5	Quite serious damage 比较严重损坏	Moderate damage 中度损坏	Quite serious damage of certain members 部分构件比较严重损坏	Quite serious damage 比较严重损坏	Needy of overhaul 需排险大修

Table 3. Anticipated post-earthquake performances
表3. 各性能水准结构预期的震后性能状况

- Three-levels of performance objectives for seismic design are "no damage under minor earthquakes, repairable under moderate earthquakes, no collapse under severe earthquakes" has been proposed.These include consideration for function, economy and life safety under earthquake, which is scientificly based;
- Different performance objectives are allowed to be adopted for different buildings, and performance-based aseismic requirements are proposed for different members;
- Additional performance-based aseismic requirements and judgement requirements are proposed for out-of-codes high-rise buildings.

Existing Problems

A few problems exist requiring further development. They are:

- Performance-based aseismic requirements of structural bearing capacity are considered under elastic minor earthquake action, with no distinction to different ductile structures. In fact, dissipative capacity, which is closely related to ductile deformation ability, is more suitable in judging the structural aseismic capacity. For the structures of the same bearing capacity, there is a positive correlation between dissipative capacity and ductile deformation ability; that is to say, for the structures with the same performance-based aseismic requirement, the bearing capacity can be lower while the ductile deformability is higher;
- Construction detail requirements are related to ductile deformation ability.In the codes, the construction detail requirements are highly correlated to seismic fortification intensity and structure height;
- It relies mainly on bearing capacity but not the member ductile deformation ability in defining the different seismic performance levels of members.

Improvement Suggestions

Three-levels of performance objectives of seismic design shall be adjusted and clarified as: ensuring "no damage under minor earthquakes" by checking elastic deformation, ensuring "repairable under moderate earthquakes" by checking bearing capacity while determining the earthquake action with consideration to ductile deformation ability of different structures, and determining construction requirements according to structural ductile deformability, ensuring "no collapse under severe earthquakes" by checking elastic-plastic deformation.

The definition for different seismic performance levels of members shall rely on ductile deformation ability aside from the bearing capacity.

Appendix

Basic design parameters specified in the codes of seismic design in China

In Code89, the seismic influence is characterized mainly by the seismic intensity zoning of that time, and the characteristic period was brought in to reflect the influence to the design response spectrum caused by near and distant earthquakes. Since Code01, the basic design acceleration of ground motion and the characteristic period were brought in, see Table 4 and 5.

总结及建议

主要成就

我国从1955年开始翻译出版苏联《地震区建筑规范》，到2010年出版《建筑抗震设计规范》、GB 50011—2010，正式提出性能化抗震设计的明确理念，在建筑结构性能化抗震设计方面取得了可观的成就：

- 提出了“小震不坏、中震可修、大震不倒”的建筑结构抗震设计三水准性能化目标。该目标兼顾了建筑功能在地震后的持续、建筑结构抗震的经济性、以及建筑结构应保证地震下的人员安全的综合要求，具有科学性；
- 允许不同建筑抗震设计采用不同的性能化目标，并对于不同性能化目标的建筑的构件，提出了明确的不同构件下抗震性能设计要求。
- 对于超限高层建筑，提出额外的抗震性能设计与评审要求。

存在问题

目前中国建筑结构性能化抗震设计主要的问题体现在：

- 结构承载力性能要求按小震弹性地震作用考虑，不考虑不同延性结构对结构抗震承载力性能要求的区别。实际上，结构延性变形抗震能力的衡量标准是结构耗能能力时比较合适来判断结构的抗震性能，而结构耗能能力与结构承载能力和延性变形能力有关，结构承载能力相同时，结构延性变形能力越大，耗能能力越大，换言之，在相同的抗震能力（或耗能能力）要求下，结构延性变形能力越大，结构承载能力要求可降低。
- 规范中结构构造要求与结构延性变形能力有关，但规范中构造要求与抗震设防烈度及结构高度相关，而不与结构延性变形能力要求相关。
- 对构件不同抗震性能水准的定义主要依据承载力水准，而不考虑构件延性变形能力的不同。

改进建议

调整并明确建筑结构抗震设计三水准性能化目标的具体要求为：验算结构弹性变形，保证“小震不坏”；考虑不同结构延性变形能力确定地震作用（承载力要求），验算结构承载力，并根据结构延性变形能力要求确定结构构造要求，以保证“中震可修”；验算结构弹塑性变形，保证“大震不倒”。

对构件不同抗震性能水准的定义，除依据承载力水准外，应更主要依据考虑构件延性变形能力。

附录

中国建筑抗震设计规范规定的设防基本参数

对建筑所在地区遭受的地震影响，89规范主要借助当时的地震烈度区划，确定设防基本地震加速度值，并引入了特征周期（反映震中距、场地类别等因素影响的设计反应谱下降段起始点对应的周期值），反映近震和远震对设计反应谱的影响。从01规范开始，引入了“设计基本地震加速度”和“特征周期”表征设防基本参数，如表4和表5所示。

中国建筑抗震设计规范构件承载力验算要求

在10规范中，结构构件的截面抗震验算采用下列设计表达式：

Fortification Intensity 抗震设防烈度	6	7	8	9
Basic design acceleration of ground motion 设防基本地震加速度值	0.05g	0.10(0.15)g	0.20(0.30)g	0.40g

Table 4. Relationship between the intensity and basic design acceleration of ground motion
表4. 抗震设防烈度和设计基本地震加速度值的对应关系

Checking requirements of member bearing capacity in codes of seismic design in China

In Code10, the checking of seismic resistance of cross section shall be made using the following design expression:

$$S \le R / \gamma_{RE}$$

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

where:

γ_{RE}—aseismic capacity factor, less than 1.0;

R—design value of bearing capacity of the structural member.

S—design value of the combination of inner forces, which shall be determined by the following equation:

γ_G—partial factor of gravity load, which shall be taken as 1.2 in ordinary conditions; when the effect of gravity load is favorable to the bearing capacity of the member, such factor shall not greater than 1.0;

γ_{Eh}, γ_{Ev}—partial factors for horizontal and vertical earthquake action respectively, see Table 6;

γ_w—partial factor of wind load, which shall be taken as 1.4;

S_{GE}—effects for representative value of gravity load;

S_{Eh}—effects for characteristic value of earthquake action in horizontal direction;

S_{Evk}—effects for characteristic value of earthquake action in vertical direction;

S_{wk}—effects for characteristic value of wind load;

ψ_w—factor for combination value of wind load, which shall be taken as 0.0 for ordinary structures, and taken as 0.2 for tall building structures that the wind load is the controlling load.

Seismic checking for deformation of codes of seismic design in China

In Code10, elastic deformation checking and elastic-plastic deformation checking shall be made, and the maximum elastic inter-story drift shall comply with the following requirement:

$$\Delta u_e \le [\theta_e]h , \quad \Delta u_p \le [\theta_p]h$$

where:

Δu_e—elastic inter-story drift caused by the characteristic value of the frequent earthquake action;

Δu_p—elastic-plastic inter-story drift;

$[\theta_e]$—Limit value of elastic-plastic relative inter-story drift, see Table 7;

Earthquake Action 地震作用	γ_{Eh}	γ_{Ev}
Only horizontal earthquake action 仅计算水平地震作用	1.3	0.0
Only vertical earthquake action 仅计算竖向地震作用	0.0	1.3
Both horizontal and vertical earthquake action (horizontal predominant) 同时计算水平与竖向地震作用（水平地震为主）	1.3	0.5
Both horizontal and vertical earthquake action (vertical predominant) 同时计算水平与竖向地震作用（竖向地震为主）	0. 5	1. 3

Table 6. Partial factor of earthquake action
表6. 地震作用分项系数

Design Earthquake Group 设计地震分组	Site-Class 场地类别				
	I_0	I_1	II	III	IV
1st Group 第一组	0.20	0.25	0.35	0.45	0.65
2nd Group 第二组	0.25	0.30	0.40	0.55	0.75
3rd Group 第三组	0.30	0.35	0.45	0.65	0.90

Table 5. Characteristic period value (s)
表5. 设计特征周期值（s）

$$S \le R / \gamma_{RE}$$

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

γ_{RE}—承载力抗震调整系数，小于1；

R—结构构件承载力设计值；

S—结构构件内力组合的设计值，按下式计算。

γ_G—重力荷载分项系数，一般情况应采用1.2，当重力荷载效应对构件承载能力有利时，不应大于1.0；

γ_{Eh}, γ_{Ev}—分别为水平、竖向地震作用分项系数，应按表6采用；

γ_w—风荷载分项系数，应采用1.4；

S_{GE}—重力荷载代表值的效应；

S_{Eh}—水平地震作用标准值的效应，尚应乘以相应的增大系数或调整系数；

S_{Evk}—竖向地震作用标准值的效应，尚应乘以相应的增大系数或调整系数；

S_{wk}—风荷载标准值的效应；

ψ_w—风荷载组合值系数，一般结构取0.0，风荷载起控制作用的建筑应采用0.20。

中国建筑抗震设计规范结构变形验算要求

在10规范中，多遇地震下弹性变形验算和罕遇地震下薄弱层（部位）弹塑性变形验算，应符合下式：

$$\Delta u_e \le [\theta_e]h , \quad \Delta u_p \le [\theta_p]h$$

式中：

Δu_e—多遇地震作用标准值产生的楼层内最大的弹性层间位移；

Δu_p—弹性层间位移角；

$[\theta_e]$—弹性层间位移角限值，宜按表7采用；

$[\theta_p]$—弹塑性层间位移角限值，可按表7采用，对钢筋混凝土框架

Material 材料	Type of Structure 结构类型	$[\theta_e]$	$[\theta_p]$
Reinforced Concrete 钢筋混凝土	Frame 钢筋混凝土框架	1/550	1/50
	Frame-wall, slab-column-wall, frame-core-tube 钢筋混凝土框架-抗震墙、板柱-抗震墙、框架-核心筒	1/800	1/100
	Wall, tube-in-tube 钢筋混凝土抗震墙、筒中筒	1/1000	1/120
Steel 钢	Multi-story and tall structures 多、高层钢结构	1/250	1/50

Table 7. Limit value of relative inter-story drift
表7. 层间位移角限值

$[\theta_p]$—limit value of elastic-plastic relative inter-story drift, which may be taken in accordance with Table 7;

h—height of story.

Foundation Interaction

For reinforced concrete tall buildings using box-type or a relatively rigid raft foundation or box-pile foundation for intensity 8 and 9 and with site-class III or IV, and the fundamental period of the structure is within the scope of 1.2 to 1.5 times of the characteristic period of the site, if the foundation interaction is to be considered, the horizontal shear forces assumed for the rigid base may be reduced, and the story drift may be calculated according to the reduced shear force.

Damping adopted in different editions of code (Table 8)

Nonstructural Systems

Gravity of nonstructural components and electromechanical components permanently attached to structures shall be taken into consideration in earthquake action calculations.

- Stiffness of members with a flexible connection can be neglected. For rigid nonstructural components implanted into the plane of lateral force resisting members, influence of its stiffness shall be taken into consideration. Generally, its earthquake resistant bearing capacity shall not be taken into consideration unless specific construction measures are adopted.
- For structural members which support nonstructural components, the effect of earthquake action of the latter shall be treated as an additional action.

Inspection Procedures

For general building structures, peer review shall be conducted by a qualified drawing review firm after the design has been completed. For out-of-codes high-rise buildings, peer review shall be conducted by the Expert Committee, organized by local or national construction department, according to the "Management Provisions for Seismic design of Out-of-codes High-rise Building Structures".

	Concrete Structure 混凝土结构	Masonry Structure 砌体结构	Steel Structure 钢结构		
Code10 10规范	0.05	0.05	Frequent Earthquake 多遇地震	Height ≤50m 高度≤50m	0.04
				50m< Height <200m 50m<高度<200m	0.03
				Height ≥200m 高度≥200m	0.02
			Rare Earthquake 罕遇地震		0.05

Table 8. Damping adopted in Code10
表8. 10规范中对阻尼的考虑

结构，当轴压比小于0.40时，可提高10%；

h—计算楼层层高。

基础的相互作用

8度和9度时建造于III、IV类场地，采用箱基、刚性较好的筏基和桩箱联合基础的钢筋混凝土高层建筑，当结构基本自振周期处于特征周期的1.2倍至5倍范围时，若计入地基与结构动力相互作用的影响，其层间变形可按折减后的楼层剪力计算。

抗震设计中对阻尼的考虑（表8）

非结构系统

地震作用计算时，应计入支承于结构构件的建筑构件和建筑附属机电设备的重力。

对柔性连接的建筑构件，可不计入刚度；对嵌入抗侧力构件平面内的刚性建筑非结构构件，应计入其刚度影响，可采用周期调整等简化方法；一般情况下不应计入其抗震承载力，当有专门的构造措施时，尚可按有关规定计入其抗震承载力。

支承非结构构件的结构构件，应将非结构构件地震作用效应作为附加作用对待。

复核程序

对于一般建筑结构，在完成设计之后，须由第三方有资质的审图公司对设计图纸进行审核；对于超限高层建筑，则应根据超限高层建筑工程抗震设防管理规定，由当地建设部门组织专家委员进行抗震设防专项审查。