Development and Contrast of Bottom Frame Structure in China's Code for Seismic Design of Buildings

Hongyu Deng^{1*}, Peiyu Ying²

¹School of Water Conservancy and Civil Engineering, Northeast Agricultural University, Harbin, Heilongjiang, 150030, China

²Department of Construction Engineering, Dalian University of Technology, Dalian, Liaoning, 116024, China

Abstract. In order to strengthen the understanding and the development trend of seismic design of bottom frame structure, the similarities and differences of some seismic design provisions of bottom frame structure between "78 Code", "89 Code", "01 Code" and "10 Code" were compared. From the aspects of floor number and total height limit, spacing between seismic transverse walls and seismic effect in terms of methods of bottom floor and so on, the causes of development and changes were described. And the effects on practical projects were explained. On the whole, the code for masonry building with bottom frame-seismic wall is more and more strict, the requirements are more specific, and the design is more and more conservative. The masonry building with bottom frame-seismic wall will still exist for a long time under the current level of economic development in China, and reasonable seismic design and construction measures should be given full attention.

1 Introduction

Since China promulgated the seismic design code TJ 11-78 in 1978, "Code for Seismic Design of Industrial and Civil Buildings"[1] (hereinafter referred to as "78 Code"), the seismic design methods and seismic response theories in line with China's national conditions have been continuously developed. Based on the actual seismic data in China and the advanced experience of seismic design codes in other countries, GBJ 11-89 Code for Seismic Design of Buildings[2] (hereinafter referred to as "89 Code"), GB 50011-2001 Code for Seismic Design of Buildings[3] (hereinafter referred to as "01 Code"), GB 50011-2010 Code for Seismic Design of Buildings[4] (hereinafter referred to as "10 Code") have been promulgated successively. In the above four versions of seismic design codes, the "78 Code" and "89 Code" multi-storey masonry structure and masonry building with bottom frame-seismic wall are described separately. Starting from "01 Code" and "10 Code",

masonry building with bottom frame-seismic wall, as a special form of multi-storey masonry structure, is combined with multi-storey masonry structure in one chapter to explain. This paper compares with the development and changes of masonry building with bottom frame-seismic wall in the code from the following three aspects, in order to deeply understand the essence of the revision of the seismic code, to grasp the development trend of the relevant provisions in the code, and to analyze the causes of such changes and the impact on the structure of the project.

2 Layer number and total height limit

Starting from the actual experience of earthquake damage, it is necessary to limit the number of stories and the total height of masonry building with bottom frame-seismic wall. In the four versions of seismic design codes, the limit values of the number of stories and total height h are shown in Table 1.

Table 1. Limit values of layer number and total height of bottom frame structure

Code Editions	Minimum wall thickness /mm	Intensity			
		6(0.05g)	7(0.1/0.15g)	8(0.2/0.3g)	9(0.4g)
78 Code	240	Not specified	16	13	8
89 Code	240	19(7)	19(6)	16(5)	11(3)
01 Code	240	22(7)	22(7)	19(6)	—
	240(Common brick)	22(7)	22(7)/19(6)	16(5)/—	—
10 Code	190(Perforated brick)	22(7)	19(6)/16(5)	13(4)/—	—
	190(Small block)	22(7)	22(7)/19(6)	16(5)/—	—

Note: 1. "—" means that use is prohibited under this intensity;

*Corresponding author's e-mail: dengblue@163.com

2. The number in brackets is layer, and the number before brackets is layer height (m)

Figure 1. Limit value of total height

Figure 2. Limit value of layer number

The height and storey number of masonry building with bottom frame-seismic wall are not limited in the "78 Code" because there is no fortification at 6 degrees in the

"78 Code". From the change trend of "78 Code" to "01 Code", it can be seen that the height and storey number of buildings are increasing constantly. When the "10 Code" comes, the height and storey number will not increase further, on the contrary, the height of buildings in the areas of 7-degree and 0.15g and 8-degree will decrease by 3-6m (Figure 1), and the storey number will decrease by 1-2 (Figure 2). At the same time, the "01 Code" stipulates that masonry building with bottom frame-seismic wall is prohibited in the 9-degree area, and so that in the 8-degree and 0.3g area in "10 Code". After summarizing the experience of Wenchuan earthquake damage, the code considers that it is not suitable to adopt this structural in high intensity areas and high seismic risk areas, and the design of masonry building with bottom frame-seismic wall is more conservative.

3 Seismic transverse wall spacing

The limit value of the spacing between seismic transverse walls of masonry building with bottom frame-seismic wall can be divided into two parts: the bottom frame-seismic wall and the upper masonry layer. The maximum transverse wall spacing of the upper masonry layer is consistent with that of the multi-storey masonry building, as shown in Table 2. The maximum transverse wall spacing d' of the bottom frame-seismic wall section is shown in Table 3.

Table 2. The maximum distance between seismic cross wall of multistorey masonry structure(m)

Code Editions	Classification of buildings and roofs	Intensity			
		6	7	8	9
78 Code	cast-in-place reinforced concrete	Not specified	18	15	11
	prefabricated reinforced concrete	Not specified	15	11	7
	wood	Not specified	11	7	4
89 Code	cast-in-place or assembled monolithic reinforced concrete	18	18	15	11
	prefabricated reinforced concrete	15	15	11	7
	wood	11	11	7	4
01 Code	cast-in-place or assembled monolithic reinforced concrete	18	18	15	11
	prefabricated reinforced concrete	15	15	11	7
	wood	11	11	7	4
10 Code	cast-in-place or assembled monolithic reinforced concrete	15	15	11	7
	prefabricated reinforced concrete	11	11	9	4
	wood	9	9	4	—

Table 3. The maximum distance between seismic cross wall of frame shear wall stories(m)

Code Editions	Intensity			
	6	7	8	9
78 Code	Not specified	No more than 2.5 times the width of the house		

89 Code	25	21	18	15
01 Code	21	18	15	—
10 Code	18	15	11	—

The seismic force of multi-storey masonry buildings is mainly borne by the transverse walls, so the number of transverse walls directly determines the seismic capacity of masonry structures, and at the same time, the roof must have enough horizontal stiffness. Therefore, the maximum spacing of the transverse walls is related to the structural measures of the roof. The maximum spacing of seismic transverse walls of cast-in-place or assembled monolithic reinforced concrete roofs is the largest, followed by assembled roofs and wooden roofs. Figure 3-5 are diagrammatic diagrams of maximum spacing d of seismic transverse walls of multi-storey masonry structures. Except that the "78 Code" does not specify 6-degree areas, the spacing of seismic transverse walls of

different floor types from "78 Code" to "01 Code" remains unchanged, and the maximum spacing of seismic transverse walls of "10 Code" generally decreases. The maximum spacing of seismic transverse walls of cast-in-place or assembled monolithic reinforced concrete roofs decreases by 3m at 6-degree and 7-degree, and by 4m at 8-degree and 9-degree; the maximum spacing of seismic transverse walls of assembled reinforced concrete roofs decreases by 4m at 6-degree and 7-degree, 2m at 8-degree, and 3m at 9-degree; and the maximum spacing of seismic transverse walls of wooden roofs decreases by 2m at 6-degree and 7-degree, and 3m at 8-degree.

Figure 3. The maximum distance between seismic cross wall of cast-in-place or assembled monolithic reinforced concrete roof

Figure 4. The maximum distance between seismic cross wall of prefabricated reinforced concrete roof

Figure 6 shows the maximum transverse wall spacing of the bottom frame-seismic wall structure. Except that "78 Code" does not specify, the maximum spacing of the bottom seismic transverse wall from "89 Code" to "10 Code" is reduced from 25m to 18m in 6-degree, from 21m to 15m in 7-degree, and from 18m to 11m in

8-degree. Starting from "01 Code", the structure in 9-degree is forbidden to be used. From the development trend of the code, it can be seen that the maximum spacing of seismic transverse walls gradually was decreased, and the design is more conservative.

Figure 5. The maximum distance between seismic cross wall of wood building roof

Figure 6. The maximum distance between seismic cross wall of frame shear wall stories

4 Distribution of additional overturning torque in bottom layer

The structural system of masonry building with bottom frame-seismic wall is different from that of the upper masonry building, so special attention should be paid to the design. "78 Code" ignores this part of the impact. Starting from "89 Code", the seismic effect of the bottom

layer has been adjusted and written into the code as a mandatory provision. Because the masonry building with bottom frame-seismic wall is a structure with "upper rigidity and lower flexibility", the upper masonry storey will produce corner at the bottom floor under the action of seismic force, thus generating additional overturning moment. This moment causes additional bending moment on the bottom seismic wall and additional axial force on the bottom frame column (Figure 7). "78 Code" does not consider the additional overturning moment at

the bottom. Starting from "89 Code", the additional overturning moment "is determined according to the proportion of effective lateral stiffness of the bottom seismic wall and frame".

Figure 7. Additional overturning moment of bottom layer

4. (2010) GB 50011-2010 Code for seismic design of buildings, China Architecture & Building Press, Beijing.

5 Conclusion

Seismic design method of masonry building with bottom frame-seismic wall is first stipulated in the Code for Seismic Design of Buildings in 1978. Since then, the seismic design methods of bottom frame structure in "89 Code", "01 Code" and "10 Code" have been improved continuously, and the specific provisions have also changed. From the development trend of the code, it can be seen that the floor height and total height limit of the bottom frame structure are declining continuously, the maximum spacing of the seismic transverse wall is decreasing gradually, and the additional overturning moment of the bottom cannot be ignored. Generally speaking, the code has more and more strict restrictions on the bottom frame-seismic wall masonry building, more specific requirements, and more conservative design. Comparing with the relative regulations of masonry buildings with bottom frame-seismic wall in the four versions of seismic codes, finding out the factors affecting the seismic performance of bottom frame structures and the trend of the seismic codes' continuous development and change is of great significance for understanding the essence of the revision of seismic codes and grasping the influence of such differences on practical projects.

Acknowledgments

This research is supported by "Young Talents" Project of Northeast Agricultural University (17QC12).

References

1. (1978) TJ 11-78 Code for seismic design of Industrial and Civil Buildings, China Architecture & Building Press, Beijing.
2. (1989) GBJ 11-89 Code for seismic design of buildings, China Architecture & Building Press, Beijing.
3. (2001) GB 50011-2001 Code for seismic design of buildings, China Architecture & Building Press, Beijing.