The Analysis on Earthquake Damage Influence Factors of Masonry Structure Buildings

Yu Jingjing

Jinan University, Guangzhou, Guangdong, China, 510000

614244290@qq.com

Keywords: Multistory masonry buildings; Anti-seismic; The analysis of earthquake damage influence factors; The resistance and suffering ratio

Abstract: The earthquake damages exist frequently and suffer great losses in our country. The Tangshan earthquake in 1976 and the Wenchuan earthquake in 2008, the collapse of masonry buildings caused people great casualties and property losses. The major stress components of multilayer masonry buildings are blockworks, the ring beam and constructional column strengthen the whole anti-seismic property[1]. The brick masonry structure is still a main structural form in civil structures, especially in towns and small-medium cities[1]. This paper summarized the factors from earthquake sites which influenced the anti-seismic property of brick masonry structures, then, based on the resistance and suffering ratio formula of reduction, we simplified the major five influenced factors.

1. Introduction

The main stressed components of masonry structure are walls and columns, the ring beam strengthen the whole shock resistance. The masonry walls consist by building blocks and mortar, blocks bond by mortar. The constitute materials and connection ways of masonry structure resolved to its fragility, which result to the weaker anti-seismic property. The buildings suffer heavy destroy when earthquake happens, hence for the multistory masonry structure, the constructional columns and ring beams help to enhance the anti-seismic property[2].

2. The earthquake damage influence factors of multistory masonry buildings

Using for reference of *Standards for Earthquake Resistance Evaluation of Buildings* (GB50023-2009) and *Code for seismic Design of Buildings* (GB50011-2010)(named code in the paper), considering the construction features of masonry structure and the earthquake disaster experience from Tangshan earthquake and Wenchuan earthquake, the conclusion as follows:

2.1.Seismic fortification intensity

According to the approval within national regulation, seismic fortification intensity is the earthquake fortification basis in a region, it uses the intensity that exceedance probability is 10% within 50 years[3]. The seismic fortification intensity in a region decided by the local economic and population density. Under the same earthquake magnitude, the different fortification intensity lead to varying degrees of seismic disaster. The seismic fortification intensity is a key factor to anti-seismic property of multistory masonry buildings.

2.2.Layer and height

The code be explicitly stipulated the total height and layer limiting value of multistory masonry structure. Basing on the past experience of earthquake, the damage aggravated with the layer increasing, especially the 6 floors buildings and above.

2.3.The space of cross wall

The code stipulate the maximum space of cross wall. The article 7.1.5 stipulate, the cross wall

  DOI: 10.25236/iclcea.2019.038

resist the main stress when earthquake happens. When the space of cross wall oversize, the stiffness of floor will weaken so that can not bear the earthquake stress. Therefore the space of cross wall should be limited, even if the longitudinal wall bearing[3].

2.4.Ring beam and constructional column

The code has explicit request to ring beam and constructional column. The earthquake damage experience indicated that, the constructional column can improved the bearing capacity almost 10% to 30%, the increasing scope related to the depth-width ratio and punch ratio of wall[4]. The article 7.33 and 7.3.4 stipulate that, ring beam can improve the whole anti-seismic property of buildings[3].

2.5.The type of floor and roof

The insufficient of splicing length between precast floor slab and wall generated to the floor slab falling, which caused the great casualties in Wenchuan earthquake. The cast-in-place floor combined with the ring beam or wall to a unified whole, it has better anti-seismic property compared to precast. Therefore to the anti-seismic property, the cast-in-place floor is superior to precast floor slab.

2.6.Material strength

The code has the minimun requirement to brickwork and mortar strength. The higher the design intensity, the higher the requirement to material strength, yet the cost increased corresponding. Hence we should overall considering the anti-seismic property and cost when choosing the material class, attempting to create the maximum anti-seismic property by the most reasonable cost range.

2.7.The type of site soil

The classification of site type depend on the site overburden thickness and the soil equivalent shear wave velocity[3], which divided into type I~IV. The resonance happens when the predominant period of site soil layer is closed to the natural vibration period of structure itself, it aggravated the seismic damage.

2.8.The regulation level of flat facade

Irregular flat facade arrangement made the stiffness center and the mass center mismatching, it made the twist happening which will sharpen the seismic damage. The irregularity reflected in the components out of roof such as the parapet wall and chimney out of roof, it reflected the whipping effect.

2.9.The local size of pier between windows and the like

The code require the minimum size of pier between windows and the like. The stiffness mutation happen on window opening, the stress will concentrate when earthquake happening, the opening broken easier. In addition, the destroy on pier between windows heavier than breast.

2.10.The thickness of bearing wall

Most of masonry buildings are under 7 layers and relatively regulation. The main analysis of masonry structure is shear capacity, and the mainly bearing components are masonry walls. The thicker the masonry wall, the higher the anti-seismic property.

3. The resistance and stressing ratio

The paper check the strength of masonry structure by calculating the resistance and stressing ratio R/S, then summarize the main influence factors of earthquake damage by R/S. The R/S refer to the ratio of seismic resistant capacity to seismic shear force on each layer. When the $R/S \geq 1$, we judge the structure can bear the corresponding seismic force, it meet the anti-seismic checking calculation.

3.1.The seismic shear force of layer

By the base shear method, the seismic shear force of number j layer:

$$V_j = \sum_{i=j}^{n} F_i \tag{1}$$

The standard horizontal seismic force of number i layer:

$$F_i = \frac{G_i H_i}{\sum_{i=1}^{n} G_i H_i} F_{EK} \tag{2}$$

Based on the equivalent base shear method from *Code for seismic Design of Buildings* (GB50011-2010), the overall standard horizontal seismic force:

$$F_{EK} = \alpha_{\max} G_{eq} \tag{3}$$

The maximum shear stress is the first floor, it is the sum of all standard values.

Simplified calculation, let $H_i = ih\ G_i = gA$

From (1)(2)(3), we can get the suffering stress S:

$$V_1 = 0.85 \alpha_{\max} ngA \tag{4}$$

$\alpha_{\max}$ ——the maximum horizontal seismic influence coefficient

g ——the average gravity load typical value of each layer unit area

A——the structure area of each layer

3.2.The seismic resistant capacity

When the mortar class＞M2.5, and $1 < \sigma_0 / f_v \le 4$, the result of calculate pincipal tensile stress and shear friction stress is closed, the seismic resistant capacity can be expressed by the same formula[3]:

$$V_1 = \frac{f_{ve} A_1}{\gamma_{RE}} \tag{5}$$

γ_{RE} ——the resistance anti-seismic adjustment coefficient, the self-suffering wall adopt 0.75

f_{ve} is the shear strength design value of masonry structure that the destruction along the trap cut section:

$$f_{ve} = \zeta_N f_v \tag{6}$$

Based on the calculate principal tensile stress formula, the normal stress influence coefficient of shear strength ζ_N is :

$$\zeta_N = \frac{1}{1.2} \sqrt{1 + 0.45 \sigma_0 / f_v} \tag{7}$$

σ_0 is the average pressure stress of number i layer seismic structural wall under 1/2 story height:

$$\sigma_0 = 0.1(n - i + 1) \tag{8}$$

f_v is the shear strength design value under no anti-seismic design:

$$f_v = 0.45 f_{vm} \tag{9}$$

f_{vm} is the average shear strength value of normal brick masonry:

$$f_{vm} = 0.125 \sqrt{f_2} \tag{10}$$

We can get the seismic resistant capacity of the first layer from (5) and (10):

$$V_1 = \frac{3}{64} A_1 \sqrt{f_2 + 0.8 n f_2} \quad (11)$$

n ——overall layers

f_2 ——the mean mortar compressive strength

A_1 ——the wall sectional area(horizontal and vertical)

3.3.The ratio of resistance and suffering

From the formula (4) and (11), the ratio of resistance and suffering is:

$$\frac{R}{S} = \frac{\frac{3}{64} A_1 \sqrt{f_2 + 0.8 n f_2}}{0.85 \alpha_{\max} ngA} \quad (12)$$

it can be simplified to:

$$\frac{R}{S} = \frac{\frac{3}{64} t \sqrt{f_2 + 0.8 n f_2}}{0.85 \alpha_{\max} ngB} \quad (13)$$

n ——the overall layers f_2 ——mortar strength

t ——the wall thickness B ——the space of cross wall

$\alpha_{\max}$ ——the maximum horizontal seismic influence coefficient

According to the resistance and suffering ratio formula of reduction (13), it contained the five main influence factors: the overall layers, the wall thickness, the earthquake intensity, the space of cross wall and mortar strength.

4. Conclusion

The paper made brief introduction on the characteristics of masonry structure, then summarized the seismic damage features of multistory masonry buildings according to the field seismic damage experience such as the Tangshan earthquake and Wenchuan earthquake. According to the resistance and suffering ratio formula of reduction, the overall layers, the wall thickness, the earthquake intensity, the space of cross wall and mortar strength are the five main seismic damage influence factors.

References

[1] Xu Shufang, Xiong Zhongming. Masonry structure[M]. Beijing: science press, 2004.

[2] PRC National Standard. *Code for Masonry Structural Design* (GB50011-2010)[S].Beijing: China Architecture and Building Press, 2011.

[3] PRC National Standard. *Code for Seismic Design of Buildings* (GB50011-2010)[S]. Beijing: China Architecture and Building Press, 2010.

[4] Cheng Shao-ge. Development and Improvement of Standard for Seismic Appraisal of Buildings in China[J]. Building science,2013,29(11):57-61.