STUDY ON THE LIMIT VALUE OF PLAN DIMENSION FOR FRAME-COREWALL STRUCTURES

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ABSTRACT:
Codes for design of china about aspect ratio of corewall are given the lower limit values that do not distinguish the fortification intensities, but it is unspecific in terms of the control of seismic behavior of structures. Several typical examples are employed to analyze in this paper, in which the effect of fortification intensities, aspect ratio of corewall are considered as significant factors. From that, the reasonable aspect ratio limit value is discussed based on the inter-story displacement angel and internal force. Based on the analysis results, the aspect ratio limit values of corewall corresponding with fortification intensities are proposed in the paper.

KEYWORDS:
Frame-corewall structure, Fortification intensity, Horizontal shear force, Aspect ratio

1. INTRODUCTION

The frame-corewall structure is widely used in the high buildings, which seismic performances have been one of the hot issues. China's current Codes, Technical specification for concrete structures of tall building (JGJ3-2002) (hereinafter referred to as "JGJ3-2002"), specified the corewall plan dimension on 9.2.1 should obey the following provisions, "the width of corewall should not be less than the 1/12 height". Apparently, from the provisions of expression can be found in the JGJ3-2002 emphasized the structure rigidity characteristics, namely, the aspect ratio of corewall, but equally significant impact on the structure performances of the earthquake intensity has not been considered. The more reasonable provisions should be redefine the aspect ratio of corewall in accordance with different earthquake intensity.

2. ANALYSIS IDEAS AND CALCULATION EXAMPLES

2.1 Ideas of Analysis

Plan dimension of corewall is the key factor for the overall structure lateral rigidity. It is primary factors that affecting its size limits will directly affect the structural deformation and internal force distribution. In order to explore the reasonable values of the aspect ratio of corewall under different fortification intensities, 19 examples are adopted to be analysis considering fortification intensity of 6 (0.05 g), 7 (0.10 g and 0.15 g), 8 (0.20 g and 0.3 g) and different aspect ratio of corewall. Through inspection of the story drift, shear distribution, axial compression ratio, the wall ratio of the structure and other factors influencing displacement and internal forces, the structure performance regulation influenced by aspect ratio of corewall and earthquake intensity are exploded, ultimately, the reasonable values of aspect ratio of corewall are proposed with different earthquake intensity.

2.2 Example Design

Consider the representation of analysis models, the examples used a plan showing the typical frame-corewall layout of the form (Figure1).

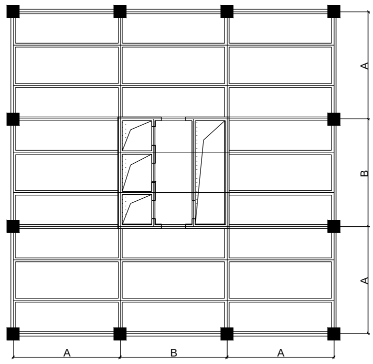


Figure 1 Diagrammatic arrangement of examples

In order to be comparison convenience, the examples are defined as the height of bottom floor 4.5 m and the height of standard floor 3.3 m. The dead loading is 4.5 kN/m^2, live loading is 2.5 kN/ m^2. Basic wind pressure is 0.45 kN/ m^2, Class B surface roughness. The floor slab thickness is 100 mm.
The detailed example information is presented in Table 2.1. In the pursuit of overall performance tends to the upper limit, the dimensional of structural members lowest as possible and this point can be reflected in the results. In this paper, ETABS is employed as finite element analysis software, which computing power and precision have been widely approved in structure analysis.

Table 2.1 Detail information of examples

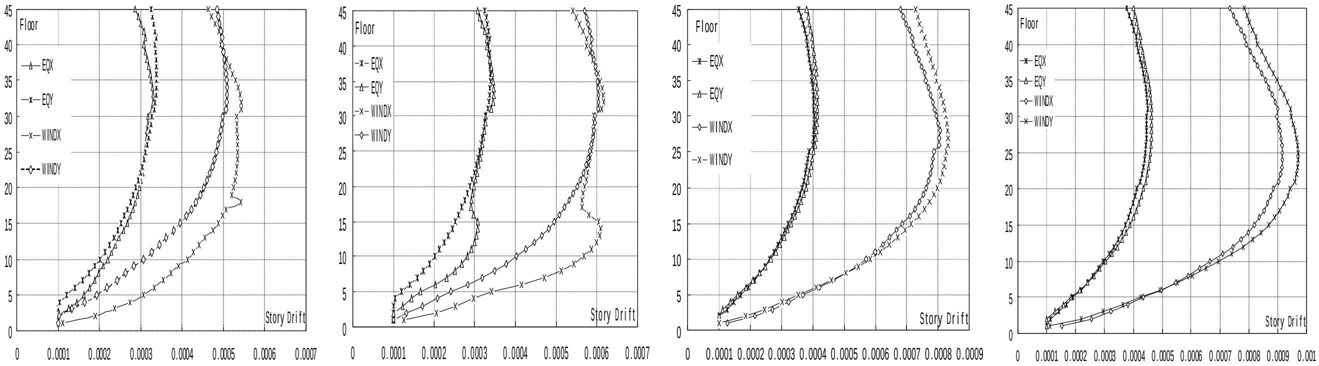
Intensity(acceleration)	A	B	Aspect ratio	Floor	Height(upper limit)
Intensity 6(0.05g)	7.5	12	1/12.48 (≈1/12)	45	149.7(150)
	7.5	10.5	1/14 (≈1/14)	45	149.7(150)
	8.0	9.0	1/16.7 (≈1/16)	45	149.7(150)
	8.5	8.0	1/18.7 (≈1/18)	45	149.7(150)
Intensity 7(0.10g)	8	11.0	1/11.8 (≈1/12)	39	129.9(130)
	8	9.0	1/14.4 (≈1/14)	39	129.9(130)
	8	8.0	1/16.2 (≈1/16)	39	129.9(130)
	8	7.0	1/18.6 (≈1/18)	39	129.9(130)
Intensity 7(0.15g)	8	11.0	1/11.8 (≈1/12)	39	129.9(130)
	8	9.0	1/14.4 (≈1/14)	39	129.9(130)
	8	8.0	1/16.2 (≈1/16)	39	129.9(130)
	8	7.0	1/18.6 (≈1/18)	39	129.9(130)
Intensity 8(0.20g)	7	8.0	1/12.1 (≈1/12)	29	96.9(100)
	7	7.5	1/12.9 (≈1/13)	29	96.9(100)
	7	7.0	1/13.8 (≈1/14)	29	96.9(100)
	7	6.5	1/14.9 (≈1/15)	29	96.9(100)
Intensity 8(0.30g)	7	8.0	1/12.1 (≈1/12)	29	96.9(100)
	7	7.5	1/12.9 (≈1/13)	29	96.9(100)
	7	7	1/13.8 (≈1/14)	29	96.9(100)

3. STUDY ON THE ASPECT RATIO LIMIT VALUES OF COREWALL BASED ON DISPLACEMENT

The largest story drift is commonly used as the main guidepost of high-rise buildings. In China and other country codes present a generic approach to limit the inter-story displacement angel without including the bending deformation of the overall displacement of structure. Such as the UBC94 (1994), the largest inter-story displacement angel should not exceed 1/200 (T <0.7s), or 1/250 (T> 0.7s). Britain and Canada Code define the index should be between 1/120 and 1/200. The same index of shear-wall structure and frame corewall structure is presented as not more than 1/800 (0.00125) in JGJ3-2002 (article 4.6). Easy to infer that the corewall plan dimension should be controlled directly by the story drift.

3.1. Story Drifts under Fortification Intensity 6(0.05 g)

Considering the wind load and earthquake action (0.05g) respectively, the analysis results of story drifts of examples with different aspect ratio are shown in Figure 2. As shown in the illustration, the distribution of lateral drift present as shear-bending form, and the drift response of structure cased by wind load is significant greater than the earthquake. Wind loads play a major role in controlling drift. Based the corewall aspect ratio (AR) ranging between 1/12.48 and 1/18.7, the largest story drift vary small with the AR become large. When the AR about equal to 1/12 which proposed by the Code JGJ3-2002, the largest inter-story displacement angel is 1/3048 under X direction earthquake action, and it is 1/1839 as the wind load action. Whether the earthquake or wind action, the inter-story displacement angel are obviously smaller than the limit value (1/800) defined by the code. Even AR of corewall reducing to 1/16.7 or 1/18.7, the inter-story displacement angel is increased to 1/1204 or 1/1031. So, the AR of corewall can be reduced more than 1/12 as fortification intensity is 6.



AR≈1/12 **AR≈1/14** **AR≈1/16** **AR≈1/18**

Figure 2 Distribution of story drifts with different aspect ratio (AR.) under fortification intensity 6

3.2 Story Drifts under Fortification Intensity 7 and 8

The analysis results show that the story drifts vary large with seismic intensity increase. As the fortification intensity is 7 (0.1g), the story drift cased by earthquake effect is above equal to the wind load. So, the AR limit value should be controlled mainly by the fortification intensity. Distribution of later-story displacement angel is shown in figure 3 under fortification intensity 7 and 8.

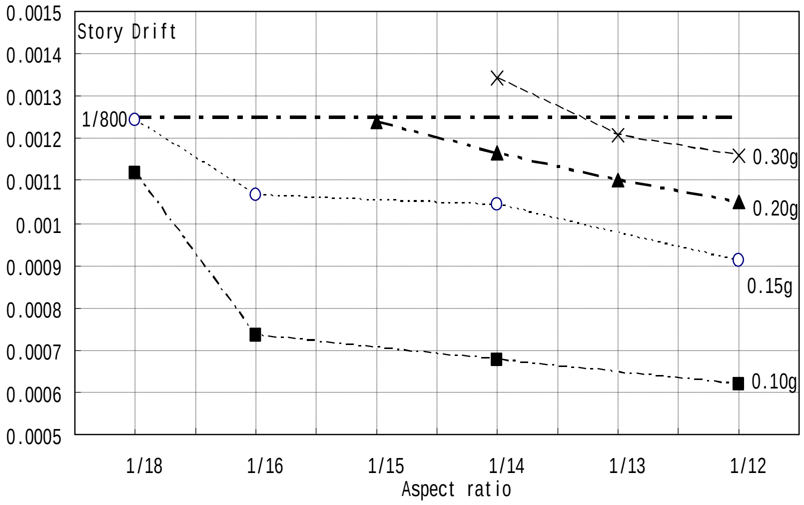


Figure 3 Distribution of later-story displacement angel under fortification intensity 7 and 8

As fortification intensity is 7 (0.1g and 0.15g), the largest inter-story displacement angel change little with AR is

between 1/12 and 1/16. As AR equal to 1/18, the largest inter-story displacement angel is closer to 1/800.
As fortification intensity is 8 (0.2g and 0.3g), the largest inter-story displacement angel is full controlled by the seismic effect. When the horizontal acceleration is 0.2g, the largest angel has reached 1/819 as AR is 1/15. With further increase the acceleration to 0.30g, the AR limit value should be defined below 1/13.
Based on the above analysis, wind load plays a major role in controlling inter-story displacement angel as fortification intensity is 6. So, the aspect ratio of corewall should be defined mainly according as wind load in region 6. As fortification intensity increased to 7 and 8, the horizontal acceleration has become the major factor of controlling inter-story displacement angel. The aspect ratio of corewall should be defined according as the horizontal acceleration. Briefly, the proposed AR limit value of corewall is shown in Table 3.2.

Table 3.2 Proposed AR limit values of corewall based on displcement

Fortification Intensity	Proposed AR Limit Value
6(0.05g)	1/18
7(0.10g)	1/16
7(0.15g)	1/15
8(0.20g)	1/14
8(0.30g)	1/13

4. STUDY ON THE ASPECT RATIO LIMIT VALUES OF COREWALL BASED ON INTERNAL FORCE

The lateral displacement is not the only controlling factor to determine the aspect ratio. Sometimes the internal force factor, such as axial compression ratio, floor shear distribution and overturning moment distribution, can also be the significant condition for determining the aspect ratio of corewall (Xia et al., 2004. Gu, 2007).

4.1 Axial Compression Ratio

In order to guarantee sufficient ductility and energy consumption capacity, the upper values of axial compression ratio on column and shear walls is stringent defined by the Codes. The column and shear walls axial compression ratio requirement is shown in Table 4.1.

Table 4.1 Limit values of axial compression ratio in code JGJ3-2002

<table>
<tr><th colspan="2" rowspan="2">Structure Type</th><th colspan="3">Seismic Design Category</th></tr>
<tr><th>I</th><th>II</th><th>III</th></tr>
<tr><td rowspan="4">Column</td><td>Frame</td><td>0.7</td><td>0.8</td><td>0.9</td></tr>
<tr><td>Frame-shear wall</td><td rowspan="2">0.75</td><td rowspan="2">0.85</td><td rowspan="2">0.95</td></tr>
<tr><td>Frame corewall, Tube-in-tube</td></tr>
<tr><td>Parts of frame-shear wall</td><td>0.6</td><td>0.7</td><td>-</td></tr>
<tr><td colspan="2" rowspan="2">Shear wall</td><td>I
(intensity 9)</td><td>I
(intensity7,8)</td><td>II</td></tr>
<tr><td>0.4</td><td>0.5</td><td>0.6</td></tr>
</table>

Based on 19 examples, the analysis results of axial compression ratio are shown in Table 4.2. The vertical load effect is significant in low-intensity region, the axial compression ratio of several models has been overrun or very close to the upper limit, which is indicated bold in Table 4.2. It is can be found that, although the later-story displacement angel in the intensity 6 and 7 region is not exceed the limit value (1/800) as AR is lower than the code defining limit value (1/12), but the axial compression ratio has overrun the limit. So, the later-story displacement angel is not the primary controlling factor to determine the AR.
High-rise building in general only bottom build-in, with the building height to increase the lateral displacement of structure will increase rapidly (Wei 2006). This part of deformation of the structure will eventually be sent to the bottom. So, the bottom component will be under greater vertical pressure. Considering the high compression ratio

coupled with additional pressure caused by the overall lateral deformation of structure is detrimental to structural performance. The AR limit value should be determined by the condition of moderate axial compression ratio.

Table 4.2 Analysis results of axial compression ratio

Intensity (acceleration)	Aspect ratio	Axial compression ratio			
		WALL(exterior)	WALL(interior)	COL(corner)	COL(mid)
6（0.05g）	1/12	0.56	0.56	0.72	0.86
	1/14	0.54	0.56	0.78	0.84
	1/16	0.54	0.54	0.81	0.86
	1/18	**0.59**	**0.60**	0.71	0.81
7（0.10g）	1/12	0.56	0.56	0.83	0.83
	1/14	0.59	0.58	0.75	0.82
	1/16	0.58	058	0.78	0.82
	1/18	**0.62**	0.58	0.78	0.87
7（0.15g）	1/12	0.51	0.52	0.78	0.82
	1/14	0.55	0.55	0.69	0.80
	1/16	0.58	**0.59**	0.81	0.81
	1/18	**0.59**	0.58	0.81	0.82
8（0.20g）	1/12	0.39	0.39	0.51	0.61
	1/13	0.40	0.45	0.59	0.67
	1/14	0.43	0.45	0.61	0.68
	1/15	0.44	0.46	0.60	0.69
8（0.30g）	1/12	0.39	0.39	0.59	0.6
	1/13	0.40	0.45	0.63	0.72
	1/14	0.48	**0.49**	**0.81**	**0.86**

Synthesize the analysis results of basing displacement and axial compression ratio, the proposed aspect ratio of corewall limit value is shown in Table 4.3.

Table 4.3 Proposed AR limit values of corewall based on axial compression ratio

Intensity(acceleration)	6(0.05g)	7(0.10g)	7(0.15g)	8(0.20g)	8(0.30g)
Proposed AR limit values	1/16	1/16	1/14	1/13	1/12

4.2 Distribution of Horizontal Shear Force

Story shear force distribution of several models in fortification intensity 6 is given in figure 6. The horizontal story shear force of frame-corewall structure is composed of two parts.

$$P=P_W+P_f \tag{4.1}$$

Which, P_w is the horizontal shear force beard by frame columns and P_f is the force beard by shear wall. At present, the most national codes specify the smallest proportion of shear force that frame beard based on the seismic fortification considerations and ensure that the frame is the second effective defense line.UBC97 specifies that frame should bear 25% design value of lateral load in every story. The 8.1.4 of the JGJ3-2002 that in seismic design, the every story shear force that frame beard in frame-shear wall structure or frame corewall structure correspond to characteristic value of seismic action of structure shall comply with the eqn. 4.2, when story shear doesn’t meet the requirements, taking the less of both $0.2V_f$ and $1.5V_{f,max}$.

$$P_f \geq \min(0.2V_0,\ 1.5V_{f,max}) \tag{4.2}$$

Which, V_0 is the base shear force of the structure, V_f is the characteristic value of every story shear force corresponding to seismic effect without adjustment, and $V_{f,max}$ is the maximum value of lateral shear beard by frame under seismic effect without adjustment. Analysis results shown that the shear force that frame beard will be increase with the aspect ratio of corewall decreasing. For example as intensity 6, the distribution of horizontal shear force is illustrated in figure 4.

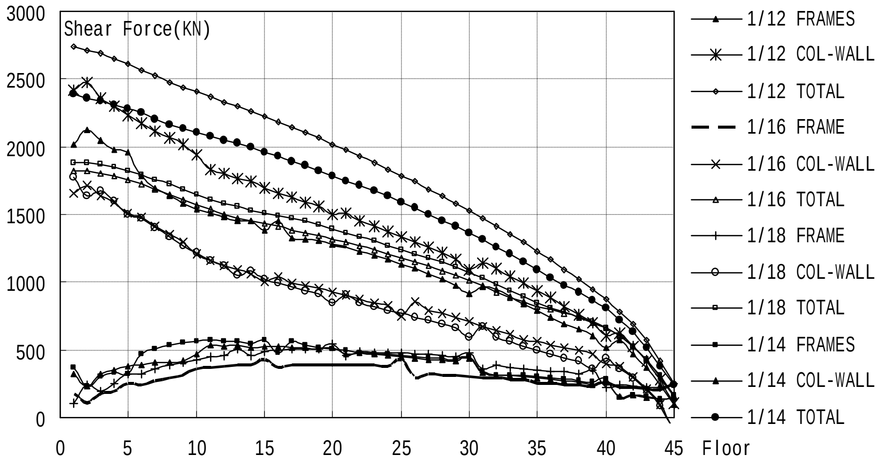


Figure 4 Distribution of horizontal shear force under fortification intensity 6

With shown in figure 4, the absolute value of shear force beard by the frame is similar as AR of corewall is between 1/12 and 1/18, but the percent of frame beard shear force is quite different. That decreasing the AR of corewall appropriately will decrease the total base shear force of structure. Thought the percent of frame beard shear force maybe exceed 20%, the analysis results (Chen, 2007) indicated that the frame is still great potential capacity to resistant earthquake.

5. CONCLUSIONS

Baaed on the analysis results of examples, the conclusions are given as below.

First, wind load plays a major role in controlling inter-story displacement angel as fortification intensity is 6. The aspect ratio of corewall should be determined mainly considering the value of wind load by the further research. As elementary result, the AR limit value is proposed as 1/16 in intensity 6.

Second, the aspect ratio of corewall can be defined based on the fortification intensity in region 6 and 7. The proposed AR limit value is shown in table 5.1.

Table 5.1 Proposed AR limit values of corewall

Intensity(acceleration)	6(0.05g)	7(0.10g)	7(0.15g)	8(0.20g)	8(0.30g)
Proposed AR limit values	1/16	1/16	1/14	1/13	1/12

To sum up, the aspect ratio limit value of corewall should be treated differently according to fortification intensity. The AR limit value should be clear to relax in low-intensity area.

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