0837

A STUDY ON ALLOWANCE LIMITS OF RATIO OF HEIGHT TO WIDTH FOR FRICTION-SLIDING BASE-ISOLATED MASONRY BUILDING

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SUMMARY

The limitation values of ratio of height to width for the friction-sliding base-isolated masonry building subjected to seismic excitations are studied in this paper. The statistical results of the limit values for the isolated building are given by means of the Wilson-θ step-by-step integration approach.

INTRODUCTION

In order to mitigate earthquake disaster, the traditional methods of earthquake-resistant design mainly rely on structural own strength, stiffness and ductility etc, to resist the seismic actions. Yet, as the earthquake intensity gets to some extent, these approaches are not economical and do not achieve the expected results (Hall, 1994).

The base-isolated technique is that the isolated layer under the base of buildings subjected to seismic excitations is set to reduce the structural response by isolating the seismic energy propagation to the superstructure. It has been proved in practice that it is a very effective aseismic method (Li et al., 1991). In recent years, the researchers in more and more countries have begun to study the base-isolated technique. Many countries in the world have put this technique into practice. However, what the range of structural height is, (that is what the range of ratio of height to width adapting to the base-isolated technique is), is still an unresolved problem. So, the limits of ratio of height to width are discussed in this paper for the friction-sliding base-isolated multi-story brick building resistant to overturning, and the statistical results of limits of ratio of height to width of this kind of structural system are quantitatively given.

COMPUTATIONAL MODEL AND EQUATION OF MOTION

The connection actions between the superstructure and isolated layers should be not considered for the base-sliding isolated masonry building. So, the limits of ratio of height to width for the base-sliding isolated buildings are different from those of common non-isolated buildings. In the following research of the base-sliding isolated structural system, it is assumed that:

(1) as the overturning moment is more than resist-overturning moment, the structure is in the overturning stage;

(2) the seismic inputs for the structural system is the single-direction horizontal ground acceleration;

(3) the interaction between the structure and soil will be neglected.

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EQUATION OF MOTION

Figure 1 illustrates the simplified mechanical model of the base-isolated multi-story masonry structure. Under the action of horizontal ground acceleration, $\ddot{X}_g(t)$, the equation of motion is derived as follows

$$[M]\{\ddot{X}\}+[C]\{\dot{X}\}+[K]\{X\}=-[M](\{I\}\ddot{X}_g(t)+\{R\}) \quad (1)$$

where [*M*], [*C*] and [*K*] are the mass, damping, stiffness matrix respectively, {*X*} is the displacement vector for the system, {*I*} is the unit vector, and {*R*} is called as the frictional force influenced vector , as

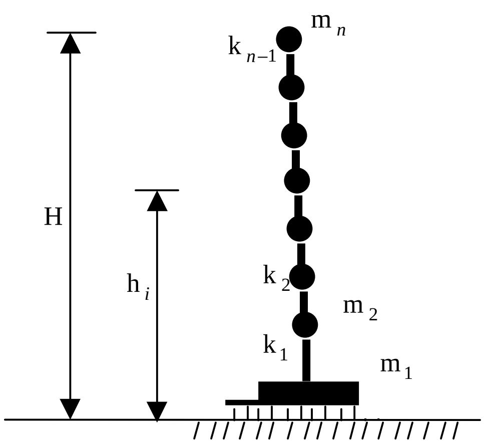

Fig.1. Computational Model

$$\{R\}=\begin{Bmatrix} sng(\dot{x}_1)\dfrac{\sum_{i=1}^{n} m_i}{m_1} f_k g \\ 0 \\ \vdots \\ 0 \end{Bmatrix} \quad (2)$$

in which f_k is the moving frictional factor, m_i is the mass of the ith layer for the structural system, $\dot{x}_1$ is the velocity of the first mass, m_1, sgn($\dot{x}_1$) is the sign function:

$$\mathrm{sgn}(\dot{x}_1)=\begin{cases} 1 & (\dot{x}>0) \\ -1 & (\dot{x}<0) \end{cases} \quad (3)$$

Sliding Condition for System

The system sliding condition is:

$$\left|\sum_{i=1}^{n} m_i(\dot{x}_i(t)+\ddot{X}_g(t))\right| \geq f_s g \sum_{i=1}^{n} m_i \quad (4)$$

where f_s is the static frictional factor.

Structural limits of ratio of height to width

The structural overturning moment is

$$M(t)=\sum_{i=1}^{n} m_i(\ddot{x}_i(t)+\ddot{X}_g(t))h_i \quad (5)$$

The structural resist-overturning moment is

$$M_r(t)=\sum_{i=1}^{n} m_i g[B/2-x_i(t)] \quad (6)$$

where $\ddot{x}_i(t)$ and $x_i(t)$ are the acceleration and the displacement of the ith story for the building respectively, h_i is the height of the ith story, B is the structural base width.

The structural overturning status is

$$M(t)>M_r(t) \quad (7)$$

According to the inequality (7), we can get minimal width that structure dose not overturn

$$B_{\min}=2\left\{\frac{\sum_{i=1}^{n} m_i[h_i\ddot{x}_i(t)+gx_i(t)+h_i x_g(t)]}{g\sum_{i=1}^{n} m_i}\right\}_{\min} \quad (8)$$

Define the maximal ratio of height to width for the structural system (that is the limit value of ratio of height to width):

$$D_{\max}=\frac{H}{B_{\min}} \quad (9)$$

where H is the total height of the structures.

NUMERICAL COMPUTATION AND ANALYSIS

The 30 American and Chinese seismic ground acceleration records are chosen as the input of structural base listed in Table 1. In order to analyze the effects of different earthquake intensities on the structural limit of ratio of height to width, we adjust the acceleration peaks of every seismic record to the corresponding earthquake intensity 7° (The Chinese 89'Code of Building Design Resistant to Earthquake (89'Code): the small earthquake intensity: 36 cm/s^2 and the big earthquake intensity: 220 cm/s^2; The Chinese 78'Code of Building Design Resistant to Earthquake (78'Code): 125 cm/s^2), 8° (89'Code: the small earthquake intensity: 72 cm/s^2, the big earthquake intensity: 400 cm/s^2; 78'Code: 250 cm/s^2), 9° (89'Code: the small earthquake intensity: 144 cm/s^2, the big earthquake intensity: 620 cm/s^2; 78'Code: 500 cm/s^2).

The equation of motion is solved by the Wilson-θ step-by-step integration method and let θ=1.4. The Table 2 and 3 illustrate the average values of limits of ratio of height to width for the masonry buildings under the actions of the thirty seismic excitations. From the results of the Table 2 and 3, it can be seen that the average values have almost increased twice with the increase of the site earthquake intensity. For the sake of simplification in the practical application, we suggest the results of the Tablet 3 for the practical structural design.

Table 1 The Seismic Records for Numerical Computation

Number	Earthquake	Record site	Date	Station No.	Acceleration Peak (cm/s^2)
1	San Fernando	Wheeler Ridge	1971.2.9	102	-26.5
2	San Fernando	Palmdale	1971.2.9	262	110.8
3	San Fernando	Los Angeles	1971.2.9	151	97.8
4	San Fernando	Los Angeles	1971.2.9	187	133.8
5	San Fernando	Los Angeles	1971.2.9	217	-146.7
6	San Fernando	CMD Bldg	1971.2.9	288	104.6
7	San Fernando	Los Angeles	1971.2.9	208	-133.8
8	San Fernando	Los Angeles	1971.2.9	199	-158.2
9	San Fernando	Los Angeles	1971.2.9	133	103.8
10	San Fernando	Lake hughes	1971.2.9	125	-145.5
11	San Fernando	Los Angeles	1971.2.9	428	-68.4
12	San Fernando	Navy Lab.	1971.2.9	127	-25.9
13	San Fernando	Lake Hughes	1971.2.9	272	-109.4
14	San Fernando	Santa Fel Dam	1971.2.9	284	198.3
15	San Fernando	Reservior	1971.2.9	121	-97.1
16	San Fernando	Anza Post Office	1971.2.9	103	-25.6
17	San Fernando	Lake Hughes	1971.2.9	125	108.9
18	San Fernando	Long Beach	1971.2.9	130	-28.1
19	San Fernando	Glendale	1971.2.9	122	-209.1
20	San Fernando	Port Hueneme	1971.2.9	272	25.2
21	San Fernando	Palos Verdes Estates	1971.2.9	411	-24.7
22	South California	San Luis Obispo	1952.11.21	083	-52.9
23	Imperial Valley	El Centro	1940.5.18	117	341.7
24	Imperial Valley	El Centro	1951.1.23	117	30.4
25	San Jose	San Jose Bank	1955.9.4	081	-100.2
26	Washington	Olympia	1065.4.29	325	134.2
27	San Francisco	Golden Gate Park	1957.3.22	077	-102.8
28	San Jose	San Jose Bank	1955.9.4	081	105.8
29	Imperial Valley	El centro	1951.1.23	117	-27.56
30	Tangshang Aftershock	Tianjin Hospital	1976.11.15	-	145.8

Table 2 The limits of ratio of height to width D_{max} (89'Code)

7°		8°		9°	
Small Earthq.	Big Earthq.	Small Earthq.	Big Earthq.	Small Earthq.	Big Earthq.
10.10	1.68	5.14	0.96	2.54	0.62

Table 3 The limit of ratio of height to width D_{max} (78'Code)

7°	8°	9°
2.85	1.51	0.75

CONCLUSIONS

The allowance limits of ratio of height to width for the resist-overturning of the friction-sliding base-isolated multi-story brick building are got in this paper and the corresponding computational formula are given. The numerical results obtained can be for the reference to codify the Architectural Isolation Design Code.

REFERENCES

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