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ANALYSIS OF SEISMIC RESISTANCE INFLUENCE FACTOR OF THE BRICK MASONRY

HUO Zizheng ZHANG Luo ZHANG Yao XU Yongtun

Shaanxi Research Institute of Building & Construction,
Huancheng West Road 142, Xian, China

SUMMARY

In this paper, according to test data of the brick masonry and statistics value of the strutural parameters built-up buildings, taking elastic-plastic seismic response analysis, the seismic response of the multistoried brick masonry is calculated, then the relation in the structural parameter, the ground motion parameter and seismic response are discussed. According to the theory of first order second moment, the relation in the structural parameter, the ground motion parameter and the structural probability of failure are calculated and discussed.

INTRODUCTION

In the people's Republic of China, the brick masonry is a traditional important building structure, at present, this structure has been using still. But the seismic resistance ability of the structure is not too better, its damage had been being quite serious in all past strong earthquakes. In order to improve seismic resistance property of the structure, the scientists and engineers of China have been doing a large amount of research work and advancing a lot of effective technical measures from different respects. In this paper, on the basis of collecting a large amount of test and analysing data in theory (Ref. 1), discussing the technical way problems of improving seismic resistant property.

THE EARTHQUAKE RESPONSE OF MULTISTORIED BRICK MASONRY BUILDING

As everyone knows, under the strong earthquake action, a structure is worked always in the range of elastic-plastic, so does a brick masonry, therefore, to evaluate seismic resistance ability of a structure is usually with the distinguishable standard of deformed condition, including response deformation of a structure under earthquake action and real deformation ability of the structure under a side thrust force. If we have got the response deformation and real deformation ability of a structure through testing and calculating analysis, then we may discuss seismic resistance reliability and evaluate its seismic resistance ability according to the theory of first order second moment (Refs. 2,3).

Under the earthquake action, the mathematics model of a multistoried brick masonry building may be considered as a series system of multiple degree of freedom (see fig. 1), we may get elastic-plastic response deformation of a structure through calculating following motion differential equation under any seismic wave (Ref. 4):

$$[M]\cdot\{\ddot{Y}\} + [C]\cdot\{\dot{Y}\} + [R]\cdot\{Y\} = -[M]\cdot\{\ddot{Y}_g\} \tag{1}$$

in which:

$[M]$, $[C]$, $[R]$ — mass, damping and rigidity matrixes of a system

$\{\ddot{Y}\}$, $\{\dot{Y}\}$, $\{Y\}$ — acceleration, velocity and displacement column matrixes of the mass point system

$\{\ddot{Y}_g\}$ — acceleration of seismic wave column matrix

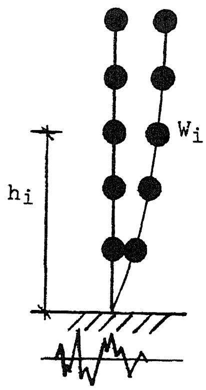

Fig. 1

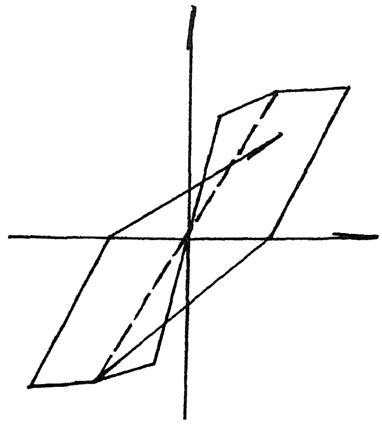
Fig. 2

Calculating response deformation utilizing eq. (1), it is necessary to determine the restitution force model of describing force and deformation all process under a side thrust force action. The authors have collected 500 odd test records of the brick wall fragment of many research institutes of China in recent years, we consider that it is right to select the restitution force model as shown in fig. 2, non-dimensional parameters of every characteristic point as shown in table 1.

To be arranged structural parameters in eq. (1), the authors have collected data of 100 odd brick masonry buidings built-up, calculating their average value and variation, we consider that it is right to select the structural parameters as shown table 2 (calculating according to unit architectural area).

Calculating results indicated: for different seismic waves, response defermation is also different, in order to consider influence of different fields and different spectrum characteristic seismic waves, we selected some seismographic records in China (such as TANGSHAN and SONGPAN) and in California of American. Because that change of damping is smaller, therefore all selected 0.05.

According to eq. (1) and the parameters shown in table 1 , 2 , the authors calculated 600 odd seismic responses according to different combination, for every deformation response, we calculated theirs average response selecting many seismic waves (adjusting every peak acceleration to same level). In calculating, we considered that relation in response deformation of a structure with weight, strength, rigidity, number of stories of the building and ground acceleration. Calculating results indicated: these factor are linear with the deformation response roughly, their regression equation as shown following:

$$\gamma = -9.422 + 0.902W - 0.046R - 0.09S + 1.33N + 27.525A \quad (2)$$

Correlation coefficient r=0.784 Mean square deviation $\sigma = 3.343 \times 10^{-4}$

in which:

γ —— maximum reponse deformation between stories (corner 10^{-4} rad);
R —— rigidity between stories of the structure according to unit area calculation;
S —— strength of anti-thrust force of the structure according to unit area calculation;
N —— story number of building;
A —— peak acceleration of the seismic wave (g);
W —— partical weight according to unit area calculation.

The Characteristic Point Parameters of Restitution Force Model

Table 1

Type of Test Piece	Initial Cleavage Point		Cleavage Point		Bearing Capacity Limit Point	
	B . C	D	B . C	D	B . C	D
	m / σ	m / σ	m / σ	m / σ	m / σ	m / σ
Not Contain Structural Column	0.71 / 0.16	0.23 / 0.11	0.85 / 0.39	0.42 / 0.24	1.00 / 0.42	1.00 / 0.60
Contain Structural Column	0.80 / 0.26	0.26 / 0.11	0.93 / 0.27	0.32 / 0.15	1.00 / 0.29	1.00 / 0.61
Contain Horizontal Reinforced Masonry	0.79 / 0.52	0.29 / 0.17	——	——	1.00 / 0.49	1.00 / 0.38

The Structural Parameters of 5 Story Brick Masonry Building

Table 2

Storied Number	Weight (KN/m)		Shearing Strength (KN/m)		Rigidity (KN/cm m)	
	m	σ	m	σ	m	σ
5	10	0.60	15	3.3	90	28
4	12	1.13	17	3.5	95	27
3	12	1.07	20	4.9	105	31
2	12	1.12	23	7.2	115	40
1	12	1.18	27	6.1	125	37

* Shearing Strength and Rigidity are all lateral parameters of the buildings.

in tables:

B . C means Bearing Capacity. D means Deformation.
A means Average Value. σ means Mean Square Deviation.

According to eq. (2), we may obtained seismic response deformation under the different combinations, regression results are alike roughly. With eq. (2), some interesting problems may be discussed, for example, under the condition of same deformation, increasing rigidity and strengh by two is alike decreasing weight to 2/3 (decreasing 1/3). Manufaturing reality shown: the cost of increasing rigidity and strength is quite large, but decreasing weight using hollow brick is quite effective.

THE RELIABILITY PROBLEM OF THE BRICK MASONRY

Seismic resistance reliability of a structure is decided by average value and mean square deviation of seismic response deformation and real deformation ability of the structure. Built-up multistoried brick masonry buildings of according to traditional custom, its change of structural parameters is always within the range of being definite, if the structural parameters aren't adjusted too large, then the change of seismic response deformation will be within the range of being difinite, thus, the key measure of raising seismic resistance ability of the brick masonry is its real deformation ability, specially anti-collapse ability (that is limit deformation).

According to the theory of first order second moment (Ref. 2), in case known response parameters (average value m_S and mean square deviation σ_S) of a structure and resistance parameters (average value m_R and mean square deviation σ_R) of the structure, and these variables all obey normal distribution, then, their reliability index (β) and probability of failure (P_f) may be calculated, according to eq. (3) and eq. (4).

$$\beta = \frac{m_Z}{\sigma_Z} = \frac{m_R - m_S}{\sqrt{\sigma_R^2 + \sigma_S^2}} \tag{3}$$

$$P_f = \Phi(-\beta) \tag{4}$$

If the structural parameters don't obey normal distribution, then , it is needed that statistical parameters in the formula of calculating reliability should be conducted equivalent normalization.

According to the structural parameters of built-up brick buildings and refering to experiences of earthquake disaster, the authors calculataed regression equations of perfect and collapse of the brick masonry through a large number of calculations.

$$P_{f\ perfect} = 47.732 - 0.269W - 0.154R + 2.077S - 2.977N - 105.683A \tag{5}$$

Correlation coefficient r=0.891 Mean square deviation =8.857

$$P_{f\ collapse} = -0.901 + 0.085W + 0.00013R - 0.016S + 0.024N + 0.845A \tag{6}$$

Correlation coefficient r=0.863 Mean square deviation =0.079

in eq. (5),(6), the annotation of symbol R,S,N,A is similar to eq. (2).

According to eq. (5),(6), some interesting problems may be discussed.

In order to raise reliability index (β) and reduce probability of failure (P_f), raising $m_R$value is focal point of our research work, then, to take some measures, for example, increasing structural column and using horizontal reinforced masonry etc (of couse, raising strength of mortar of the brick masonry, it is similar effective too, in some extent).

Testing data indicated: the limit deformation ability may be raised about 20% after increasing structural column, and about 40% using horizontal reinforced masonry. After taking these measures, the probability of a failure of collapse may be decreased greatly. These methods should be a dominant direction of raising seismic resistance ability of the brick masonry.

REFERENCES

1. The research institutes of the People's Repubic of China
   The Research Report about Side Thrust Test of the Brick Wall Fragments
2. The National Standard of the People's Repubic of China GBJ 68-84
   The Unified Standard of Architectural Structure Design (1984)
3. ZHAO Gufan etc The Ralibility of Engineering Structure
   The Publishing House of Hydro-electric Power
4. LIN Jiahao, DING Dianming , TIAN Yushan etc
   Analysis of Elastic-plastic Earthquake Response of Series Multi-Degree-of-Freedom Systems
   The Journal of DALIAN College of Engineering (the second periodical 1979)