Analysis on the Space Action Factors of Multistory Brick Masonry Building without Interior Wall

Liu Ji, Wang Huanding, Li Xuan*

Summary

On the basis of analysing the results obtained from field measurements and tests, this paper puts forward a computational model of multistory brick masonry building without interior wall. According to the model the computer analysis of the buildings is arranged by orthogonality design method. Through orthogonality regression analysis, the empirical formulas and the figures of space action factors of multistory brick masonry building have been provided and can be used in engineering design.

1. Computational Model for Analysing space work of Multi-story Building Without transverse Wall

A multistory masonry building is a very complex space structure. In order to analyses its space action, the building can be devided into transverse plane systems and longitudinal connecting systems. The former consists of the expernal walls and columns of each bay; the latter is composed of the floors roof and also the action of the longitudinal walls. A detail discussion has been carried out in paper [2] and [3] on the computational modle for transverse plane system and longitudinal system. Owing to the limited space, here we give only the main results of analyses.

* Liu Ji Harbin Civil Engineering Institute, (China).
Member, National Technical Committee for Mason ry Standards of China
Member, National Earthquake Association of China.
Wang Huan Ding Harbin Civil Engineering Institute, (China).
Li Xuan Harbin Civil Engineering Institute, (China).

(1) Computation Model of Transverse plane System

The results of experimentation on the single-story building and multistory buildings show that the actual behavior of the plane system is quite different from that of the hinged frame system show in Fig. 1. In paper [2] we compared the actual plane displacements $\Delta_{p,m}$ of more than ten single-story masonry buildings in our country with the plane displacements calculated according to the "hinged frame" system $\Delta_{p,c}$, and found that the ratio of the latter to the former is up to 2-3. For the experimental building the ratio $\Delta_{p,c}/\Delta_{p,m} = 2.12$ for the single storey. The calculated plane displacements are also much greater than these of actual measurement for the two story. This shows that the effect of unhinged connection is very strong, and the plane system should not be calculated as hinged frame as shown in Fig 1, and an system with elastic joints havink anti-roration rigidity shown in Fig 6 should be used as the computational model of the plane system. In Fig 2, c is the anti-rotation stiffness of elastic joing (i,e. the moment required for causing a unit angle of relative rotation). In paper 2, we calculated the stiffness values of the elastic joints of the plane systems of more than ten single-story buildings measured and found that all of them are of the order of magnitude of 10^8kg-cm, We also calculated the joint stiffnesses of the plane systems of the experimental building without gable. For the onestory plane system (without top layer on the floor) $c = 0.898 \times 10^8$ kg-cm. For the one-story plane system (with top layer of casted-in-place concrete) $c = 1.137 \times 10^8$ kg-cm. For the two-story plane system $c_1 = 1.367 \times 10^8$kg-cm, $c_2 = 0.577 \times 10^8$ kg-cm.

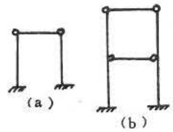


Fig 1.

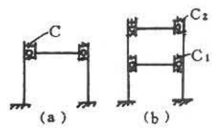


Fig 2.

According to the results of anslyses in paper [2]we suggest that for analysing the space work of a multi-story masonry building

c_n=0.7 x 10^8kg-cm (for top story -nth story) and

c_i=1.2 x 10^8kg-cm) [for 1st, 2nd, ...(n-1) th story].

(2) Computation Model of longitudinal System

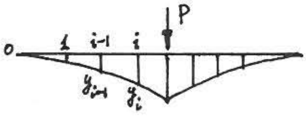
The longitudinal systems, the roof and floor, are very complex space systems. The force diagram of the connection among the flanged plates, purlins, tiles and trusses is not very clear, The prefabricated floor slabs are usually placed on the girders and connected with them by friction. If we consider at the same time the effect of the external walls, the problem will become exceedingly complex.

If we set up a very complex computation model, the amount of computation work would be very large and some parameters in the model could not be defined. Based on field measuring and testing on many buildings, we set up a computation model which can describe the regularity of the data measured. In our model of computation some of the necessary parameters can be obtained directly from the measured results.

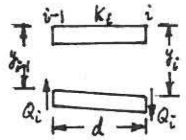
Up till now, we have not found any information at home or abroad about static measuring and tesing on multistory building. We measure the lateral displacements of the walls (or columns) of each bay at storey levels when a concentrated load is applied to the central bay. According to these displacements we can calculate the equivalent shear stiffness k_i of the roof and floor of each bay.

$$K_i = \frac{Q_i d}{y_i - y_{i-1}} \qquad (1)$$

where Q_i - total equivalent shear of the roof or floor of the ith bay, as shown in Fig, 3.



(a) The displacement of the longitutinal system



(b) The shear of the ith bay

Fig 3

For measured single-story and multistory buildings we have calculated the equivalent shear stiffness of each bay. The results of calculation show the following regularity:

(A) The order of magnitude of equivalent shear stiffness for a certain kind of floor or roof is definite. For the floor it is 10^8kg, for the roof of flanged plate it is 10^7kg, for purlin-tile roof it is 10^6kg.

(B) From the testing on the expermental building we knew that the equivalent stiffness with the gables is larger than one without the gables. But when the distance between the two gables is 48^m or 40^m, the difference of the equivalent shear stiffness of the central bay is very small.

(C) The equivalent shear stiffness in the floor and roof of all bays are not the same. The equivalent stiffness of the central bay K_p is the smallest. The nearer to the gables, the greater its stiffness.

According to the anslyses mentioned in paper [2] and [3] in order to provide greater safety, we recommed the equivalent stifiness of the central bay K_p to be $K_p = 1.0 \times 10^8$kg (for the floor), $K_p = 1.3 \times 10^7$kg (for the roof of flanged plates), $K_p = 2.0 \times 10^6$kg (for purlin - and - tile roof). The regularity of variation of the equivalent shear stiffness along the longitudinal direction of the building can be described quite well with the following regression equation.

$$K_i = K_n \left[1 + \beta \frac{(n-i)^2}{n^2} \right] \quad (2)$$

where n - the series number of the bay to which the load is applied. in paper [2] and [3], we recommend $\beta = 0.2$(for the floor), $\beta = 2.0$ (for roof of flanged plate), $\beta = 2.5$ (for purlin-tile roof).

Thus, we can use the beams with equivalent ununiform shear stifness as a computation model of longitudinal systems and a frame with elastic joints as a computation model of transverse plane systems.

2. Conputer Analyses of Space Action Factors of Multistory Brick Masonry Building Without transverse Wall

With the computation model set up above, we have calculated with computer the space action factors of many different multistory masonry burlding, analyzed with regression method and set up regression equations for space action factors.

The space action factors of a building are closely related to a series of factors, such as number of the bays NN, the height of each story $H_1, H_j = H_2$ ($j=2,3,4...n$), the span B, the thickness T of the gable and external walls, the elastic modulus E, the size of wall posts of the external walls HT, the length of the bay ND, the type of the roof, with or without interor colums, etc. In order to minimize the amount of comptation and at the same time reflect the effects various factors on space action factors, we planned our computation work according to the orthogonality method [5], [6], and we calculated 1536 buildings only, reduced the smount of the computation work by 126 times.

In paper [4] we give the regression equations and charts of space action factors of multistory masonry buildings with different type of structure. Based on the regularity of space action factors obtained by computer analyses in order to provide greater safety, here we simplify the matrixs and charts of space action factors, given in paper [4], and thus make them only relate to the type of the roof, the length L of the building (the distance between the gables) and the condition of interior column.

(1) The matrix of space action factors

(a) for two - story building

$$[m] = \begin{bmatrix} m^2_{11} & m^2_{12} \\ m^2_{21} & m^2_{22} \end{bmatrix} \qquad (3)$$

(b) for three story building without interior column with class I roff*

$$[m] = \begin{bmatrix} m^3_{11} & m^3_{12} & 0 \\ m^3_{21} & m^3_{22} & 0 \\ 0 & -0.7m^2_{22} & m^2_{22} \end{bmatrix} \qquad (4)$$

with class II roof

$$[m] = \begin{bmatrix} m^3_{11} & 0 & 0 \\ m^3_{12} & m^3_{22} & -m^2_{22} \\ 0 & 0 & 0 \end{bmatrix} \qquad .(5)$$

---

*Class I roof: prefabricated hollow concrete plate, large roof plate,

Class II roof: flanged plate, channel plate,

Class III roof: purlins - tites.

with class III roof

$$[m] = \begin{bmatrix} m^3_{11} & 0 & 0 \\ m^3_{12} & m^3_{22} & -m^3_{22} \\ 0 & 0 & m^2_{22} \end{bmatrix} \qquad (6)$$

The superscript numbers (2) or (3) indicate that the factor value is obtained from calculating two-story or three-story building.

(c) for multistory building with interior column to the top

Three story building with class I roof

$$[m] = \begin{bmatrix} m^3_{11} & m^3_{12} & 0 \\ m^3_{12} & m^3_{22} & m^2_{12} \\ 0 & m^2_{12} & m^2_{22} \end{bmatrix} \qquad (7)$$

Three story building with class II roof

$$[m] = \begin{bmatrix} m^3_{11} & m^3_{12} & 0 \\ m^3_{12} & m^3_{22} & m^2_{12} \\ 0 & 0 & m^2_{22} \end{bmatrix} \qquad (8)$$

Multistory building with class I roof

$$[m] = \begin{bmatrix} m^3_{11} & m^3_{12} & & & \\ & m^3_{12} & m^3_{22} & m^3_{12} & \\ & & \vdots & \vdots & \ddots \\ & & m^3_{12} & m^3_{22} & m^2_{12} \\ & & & m^2_{12} & m^2_{22} \end{bmatrix} \qquad (9)$$

Multistory building with class II roof

$$[m] = \begin{bmatrix} m^3_{11} & m^3_{12} & & & \\ m^3_{12} & m_{ii} & m^3_{12} & & \\ & m^3_{12} & m_{ii} & m^3_{12} & \\ & & \vdots & \vdots & \vdots \\ & & m^3_{12} & m^3_{22} & m^2_{12} \\ & & & & m^2_{22} \end{bmatrix} \qquad (10)$$

wher $m_{ii} = ½(m^3_n + m^2_{22})$

(2) The charts of space action factors

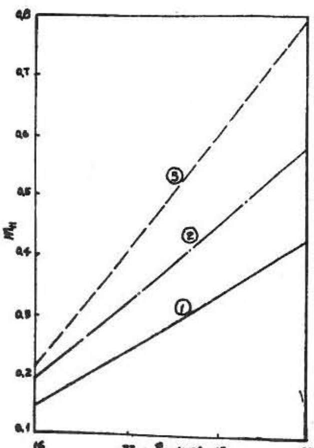


Fig 4 **3

L(M)-distance between the gables

**3

1) for two story building class III roof without interior column.

2) for two story building with class II roof without interior column or with class III roof and interior column not to the top.

3) for two story building with class I roof, or with class II roof and interior column to or not to the top; for three story building with any class of roof and without interior column; for three or multi-story building with interior column to the top and class

I or class II roof.

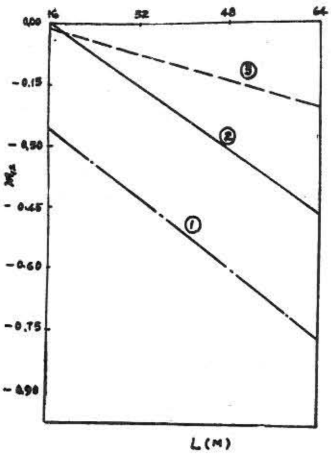


Fig 5 **4

**4 1) for two-story building with class III roof without interior column or with interior column not to the top

2) for two story building with class II roof and interior columns to or not to the top or without interior column.

3) for two-story building with class I roof and interior column to the top; for three story building with any class of roof and without interior column; for three story building with class I or class II roof and interior column to the top.

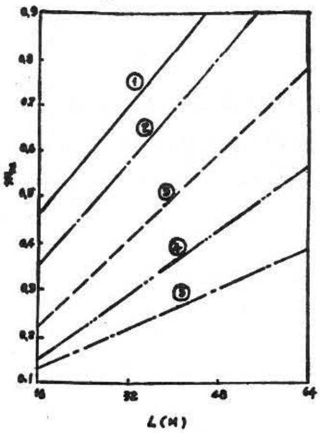


Fig 6 **5

**5 1) for two story building with class III roof but with out interior column or with interior column not to the top.

2) for two story building with class II roof and interior column to the top.

3) for two-story building with class II roof but without interior column or with interior column not to the top; three story building with class I roof and without interior column, three story building with interior column to the top and class I or class II roof.

4) for two story building with a class I roof and interior column to the top; three story building with class II roof but without interior column.

5) for two story building with class I roof and without interior column or with interior column not to be top; three story building with class III roof and without interior columns.

3. Conclusion

All the values of each parameter in the analysis of this paper have been chosen, taking safety into full account. Therefore, the space action factors given in this paper can be used in engineering design.

Reference

1. Liu Ji, Wang Huanding, Li Xuan, "A Research on Space Work of Multistory Brick Masonry Building" paper, 6th IBMAC, 1981.
2. Liu Ji, Wang Huanding, Li Xuan and Zhang Ying, "Experimental Research of the Space Action of Multistory Masonry Industrial Building" Journal of Harbin Civil Engineering Institute (HCEI), 1980, 8.
3. Liu Ji, Wang Huanding, Li Xuan, Zhang Ying and Deng Xixuan, "Feild Measurement and Experimentation of Multistory Masonry Building" Journal 《Building Structure》, 1981, 4.
4. Liu Ji, Wang Huanding, Li Xuan and Zhang Ying, "Analyses on the Space Action Factors of Multistory Masonry Building Without Interior Wall" Collected reports on space work of multistory masonry building, HCEI, 1980, 8.
5. Orthogonality Design, Department of mathematics and mechanics of Beijing University, Beijing, Oil-Chemical Industry publishers, 1976.
6. Zhu Weiyong, The Application of Orthogonal and Regress-Orthogonal Testing Method, Lian-nin (China) People's Publishers, 1978