Numerical simulation analyses of the collapse response of masonry structures under earthquake

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SUMMARY：
Masonry structures are very easily collapsed in earthquakes, but there are few researches on the collapse response of masonry structures. Numerical simulation analysis is a main method that studies on the collapse response of masonry structures under earthquake. This method can replay the whole collapse process, and the cause of the collapse of the structure can be discussed and the measures against the similar collapse of structures can be proposed according to the calculation results. The numerical simulation analyses of the collapse response of masonry structures under earthquakes in china are briefly summarized. The collapse responses simulation of a two-story masonry structures under earthquakes by ANSYS/LS-DYNA is given, the results show that ground floor and wall between windows of masonry structures are the weak parts under earthquakes.

Keywords: *earthquakes, masonry structures, collapse, numerical simulation*

1. INTRODUCTION

So many seismic damages prove that the masonry structures are very easily collapsed in earthquakes; it causes huge human casualties and property loss. From the point of view of development, we should obsolete the masonry structure in seismic area. However, the masonry structure has its own advantages, it is easy to get the material and to construct, its structure is simple and costs low etc. According to the modern fundamental realities of our country, the masonry structure will still be widely used for a long time, and our county has a so long history that lots of masonry structure buildings needed to be protected. To reduce the loss of collapse, we must find out some measures against collapse. Therefore, it has reality significance to study the anti-collapse measures of the masonry structure.

2. RESEARCH METHOD OF THE COLLAPSE RESPONSE OF MASONRY STRUCTURE

2.1. Earthquake Damage Investigation

Earthquake damage investigation is the most real and accurate way of studying the masonry structure's response in an earthquake. This method demands the earthquake engineering research workers to take statistical investigations to the collapsed buildings in the earthquake, and to make a comparison with the buildings before the earthquake to get the same features of the collapsed buildings, and then find the final anti-collapse method. People find the anti-collapse method in early stage basely from the earthquake damage investigation, and according to the result earthquake damage investigation our country revised some content details in standard after each huge earthquake. Earthquake damage survey is the most real and accurate research method, however, this kind of method takes the price of great casualties and property losses.

2.2. Vibration Table Experiment

Along with the development of large power machinery, vibration table simulation experiment becomes an important way of studying masonry structure collapse in the earthquake research. Vibration table experiment is an accurate method of researching masonry structure collapsed relatively. This method is to reduce an actual masonry structure according to certain proportion and make a physical model, then it will be installed in vibration model on the stage and simulated seismic effect by inputting the relevant seismic wave to shake table, recording the reaction part to study the collapsed analysis of structure characteristics in the process of vibration model. The materials used in the model are actual building materials; therefore, this method has a better accuracy.

Vibration table experiment also has limitations; the limitations are mainly performed in doing Scale test by the limits of the conditions, which cause the distortion of the experiment model. The parameters often need to make a lot of models and repeated tests. Especially for the seismic test, usually needs to input a group of seismic waves to measure the model's multiple responses. But a model maybe damaged under the action of a certain seismic wave, and it is difficult to evaluate the damaged structure accurately in the next working. Considering the whole process of the collapse simulation test will be to structural damage and even collapsed stage, it is very difficult to control test and protect the equipment in the test. And the vibration table also consumes a lot of human resource.

Despite the limitations of the method, the shaking table experiment is an important method to study the analysis of collapsed masonry structure; it is also an important part of structure seismic theory.

2.3. Numerical Simulation

Along with the development of numerical calculation, mechanics and the computer, numerical simulation has become a new way of studying masonry structure collapse. Numerical simulation is to simulate the collapsed process of masonry structure under the effect of earthquake by using the method of numerical calculation on the computer. Because of the house's collapse process is very complex; we can only make the results of damage and portents of destroy clear during the survey. It is difficult to recreate the experimental process and describe the failure process; also the development of the modern computer technology can repeat the whole process of collapsed in a computer.

According to the calculated results we can discuss and prevent the structure from the similar reasons of collapsing. And relative to the first two methods, numerical simulation resources consumes less and holds a large of advantages. Therefore, the numerical simulation becomes an important method of studying masonry structure's collapse under the effects of earthquake for the present time, along with the development of large finite element analysis software application, this technology is paid more and more attention to, Hillerbourg, Bocca, Pande have successfully simulated the development of the masonry structure crack.

At present, there are two kinds of numerical simulation models of masonry structure collapse, respectively; they are the separation unit and the whole successive. Because of the characteristics of masonry, can think of masonry as a two phase materials, elastic block embedded in the mortar layer. The two phase of inhomogeneous finite element model is taken as early as in 1987 by Page of the Australian, he devised the mortar and block into unit separately, connected both with the coupling unit. This model is the separation unit, according to different unit processes deal with the mortar joints between block and block adopting the respective modulus of elasticity. Then some scholars differentiated it by forming a unit with mortar and block together, namely the overall continuous, this model analyses the masonry materials as continuum, changes the homogeneous masonry materials into a new kind of material which has the real same work of structure characteristics and damage form.

These two kinds of models have different features, it is too trivial to model the separate model, and is too carefully to divide the unit, complicating matters. It is not applicable in the analysis of large-scale structural problem; it is only fit for the simulation test of the destruction of the small block. Overall continuous characteristics are just on the opposite, modeling relatively easy, less units, less time consuming calculation, and is suitable for the analysis of large-scale structure masonry structure, the continuous type model is suitable for studying the analysis of masonry structure collapse. Well, the separate calculation model is obviously more close to the actual situation than the whole continuity calculation model; the calculation result is more accurate. However, in the research of masonry structure collapsed, the research is mainly about masonry structure integrity, and low result accuracy, therefore, the overall continuous fits for the analysis of masonry structure collapse.

3. COMPUTATION EXAMPLE

3.1 Model Analysis

In order to simulate the real structure, we use the spatial 3D entity model. This is a two-story model, the story height is 3m, the windows' size is 1.4m×1.2m, the door's size is 2.2m×1.2m. Using cast-in-situ concrete floor, thickness of plating is 120mm.Flat roof model, its parapet wall is 0.5m high, and they are shown in Fig. 1 and Fig. 2.

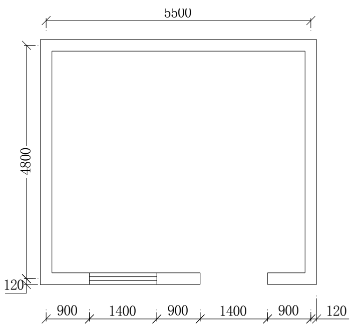

Figure 1. The ground floor plan

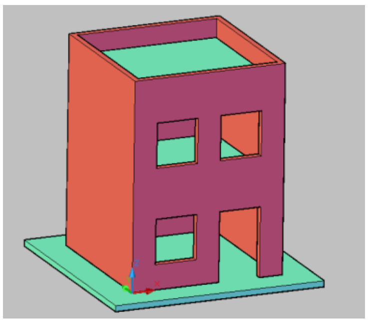

Figure 2. The model entity graph

Masonry Material’s constitutive relation use Material Model 3 in the LS-DYNA: Plastic Kinematic (Plastic with dynamic) Model. The density of the Masonry unit material is 1700kg/㎡, modulus of elasticity is 2704Mpa, Poisson’s radio is 0.2, compression strength is 1.69Mpa. The concrete floor level takes C25, its material constitutive relation is the same with masonry, density is 2500kg/㎡, modulus of elasticity is 28000Mpa, Poisson’s radio is 0.3, compression strength is 11.9Mpa. Failure strain takes 0.1.

3.2 Seismic Wave

Seismic wave in X direction is artificial seismic waves. Its peak acceleration value is 619 gal, it is shown in Fig.3.

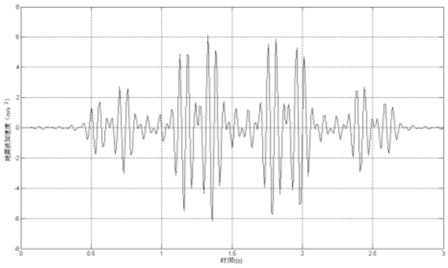

Figure 3. Artificial seismic waves

3.3 Simulation Result

This paper inflicted the seismic wave in the X direction to the two-story masonry structure and mutated its collapse process; the collapse process is shown in fig. 4:

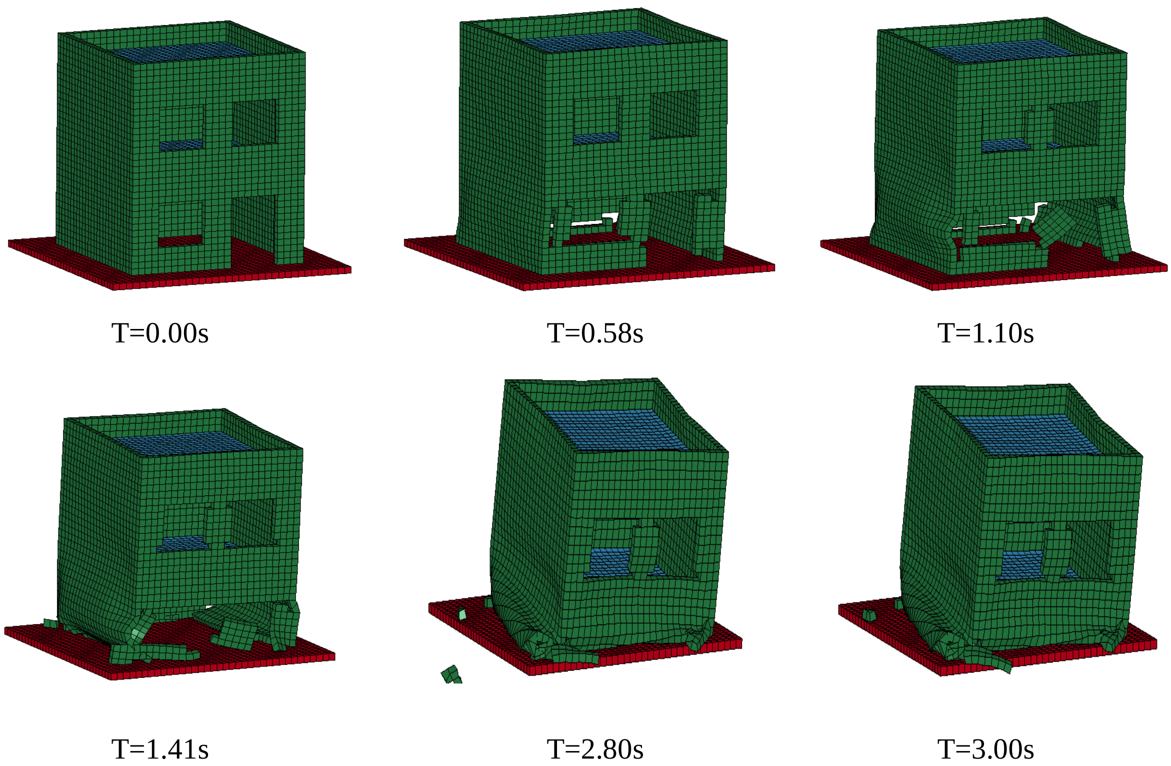

Figure 4. Collapse Process

2.4 Results Analysis

We can see from the collapse process, this model's major damage was at the bottom, but the super stratum's damage was small. Damage at the bottom began from the door and window corner between the wall and the damaged time was T = 0.58 s, at this time the corresponding earthquake acceleration was 127 gal. With the time passing by, the bottom's damage became worse and worse, there were not enough Load-carrying components, finally the whole bottom was destroyed, the time was T=1.10s, and the earthquake acceleration was 320 gal. A layer's damage caused the whole house collapsed. The results were consistent with masonry earthquake damage. The reason is that the bottom's shear is bigger and from the plane irregular eccentric reverse adding up the doors and windows weakened the wall.

We can also see from the collapsed process, it was easy to appear damage between the wall and the window; this result was consistent with the actual earthquake damage. Having this result mainly because it is easy to form stress concentration in the corner of door or window between the wall, and the wall between the windows is narrower than the normal wall (in-plane direction), its stiffness is small, its strength is low, causing shear stress of the wall between the window bear over load and cracking destruction. Therefore, under the effects of earthquake, the wall between windows is easy to damage.

In the process of collapse, the whole structure had significant phenomenon of clockwise turn around, as shown in fig. 5. It was due to cross-sectional area of the door in the bottom wall V1 was small, and its height was high, it offered the small constraints of the V3 which was close to the one side, while on the other side of the V3 it was the V2 which supported wall stiffness was far more outweigh than the wall V1, the constraint to V3 was strong on the side, the plane formed asymmetric stiffness. Under the effects of earthquake, the wall V3 would be more easily to have displacement to the small stiffness, forming turning along the clockwise, and driving the whole structure twist and turn, at last leading to the whole bottom collapsed.

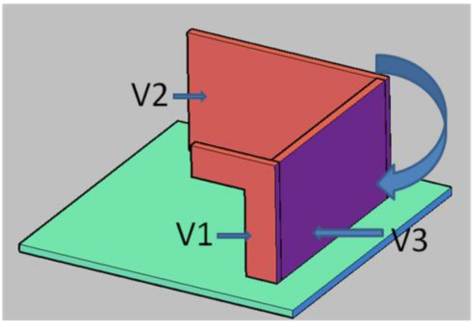

Figure 5. Sketch map of wall

3. CONCLUSION

From the simulation results, masonry structure's bottom is easily to be the damage part, so it is appropriate to improve the intensity of masonry structure bottom. Not too much improved, otherwise it will cause other parts to be the weak link, and cause the damage.

The wall between windows is also the weak position of the masonry structure house; therefore, in the design of the wall between windows, we should ensure the width of it, increase its strength to develop its carrying capacity and to avoid the whole building continuous collapse causing by the damage of the wall between windows.

REFERENCES

BOCCA P, CARPINTERI A, VALENTE S. Fracture mechanics of brick masonry: size effects and snap-back analysis . *Materials and Structures,* **1989, 22（6）:** 364-373.

HILLERBOURF A. Analysis of crack formation and crack growth in concrete by means of fracture mechanics and finite elements . *Cement Concrete Research, 6, Pergamon, 1976*.

HOU JIE. Collapsed analysis of brick wall under the action of earthquake. Wenchuan earthquake building damage investigation and the post-disaster reconstruction analysis report. Beijing: *China architecture &building press, 2008.*

LIU HAI-QING, NI ZHENG-GUO, OU JIN-PING.
Simulation analysis of the collapse response of masonry structures subjected to strong ground motion .*Journal Of Earthquake ngineering And Engineering Vibration,* **2008, 28（5）:** 38-42.

NI ZHEN GUO. Simulation analysis masonry structure collapsed process under the action of earthquake. *Liaoning: liaoning engineering technology university*, 2008.

PANDE GN, MIDDLETION J, LEE J S, et al. Numerical simulation of cracking and collapse of masonry panels subject to lateral loading[. *Proceeding of 10th International Block/Brick Masonry Conference*, Calgary, 1994., 107-115.

WANG MAO-LONG, LIUMING, ZHU FU-SHENG, et al. Application of Finite Element Analysis in Masonry Structures . *Journal of shen yang jian zhu university(natural science)* ,**2006, 22（1）:** 40-44.