Advanced Materials Research Vols. 133-134 (2010) pp 783-787

doi:10.4028/www.scientific.net/AMR.133-134.783

Investigation on Seismic Properties of Load-Bearing Masonry Walls in Chinese Historical Buildings

PENG Bin[1,a], LIU Weidong[b] and YANG Weibo[c]

[1]School of Environment and Architecture, University of Shanghai for Science and Technology, Shanghai, China

[a]PengTj77@hotmail.com [b]wdliu2010@126.com [c]weberyong@sina.com

Abstract: Masonry walls resist most of the lateral loads in some Chinese historical architecture. To investigate the seismic properties of these load-bearing masonry walls, blocks in a typical Chinese old building undergoing retrofit are reserved. Compressive test specimens and wall panel specimens are constructed using these blocks and lime mortar. Mixing of the lime mortar is similar to that used in the old building. Material tests and pseudo-static tests are then performed. The damage modes and hysteretic curves of the wall panel specimens are studied. The test results are expanded through computer simulation. Some characteristics of the load-bearing masonry walls are summarized based on the test and simulation results. The proposed methodology and results can be referred to in further researches on seismic properties of historical masonry architectures.

Keywords: Historical building, load-bearing masonry wall, seismic property, material test, pseudo-static test, computer simulation

Introduction

Masonry wall is a typical kind of members used to resist lateral loads in Chinese historical buildings (Wu 1997). Seismic properties of these buildings have decreased significantly because of the degradation in capacities of the load-bearing masonry wall (Liu et al. 2007). Earthquake has recurred frequently in China. To properly reserve these historical buildings, investigation of seismic properties of the adopted masonry wall based on their current state is needed.

Seismic properties of masonry wall relates to the mechanical properties of mortar and interactions between mortar and block (Yang et al. 2007). The mortar in historical buildings works in complicated stress states, because the block have cracked or damaged geometrically under long time of usage and weathering. For such aged masonry walls, mortar properties and block damages are key factors in their seismic properties.

In the following sections, material and pseudo static tests conducted on special specimens are described. The specimens are similar to the aged masonry in aspects of low mortar strength and block damages. The test results are expanded through computer simulation. Damage mode, hysteretic properties are discussed.

Material Tests of Masonry

Compressive Strength of the Aged Blocks Blocks used to make the specimens are reserved from a historical building undergoing retrofit. The blocks have obviously damaged after long time of usage and environmental impacts, as shown in Fig. 1. Surface of the blocks are smoothed using mortar

layer with thickness no more than 3 mm, and then cured for 5 days under constant temperature and humidity. Average compressive strength of 15 specimens is 16.3 N/mm^2.

Compressive Strength of the Mortar Stick rice jelly is a typical gradient of mortar mixing in ancient China since the Ming Dynasty. Starch in the jelly is excellent adhesive agent and can be used to enhance the integrity of masonry. The stick rice jelly is adopted into the mortar mixing of the test, to reproduce the adhesive properties of the historical mortar.

Two groups of lime mortar specimen are tested, average compressive strength are 1.3N/mm^2 and 0.6N/mm^2.

Compressive Strength of the Masonry Specimens used in compressive strength test for masonry are short columns with 370mm×370mm rectangular section. Height of the columns is 740mm. Top and bottom of the columns are smoothed using cement mortar, as shown in Fig. 2. The specimens need to be cured for 28 days.

Figure 1: *Block reserved from a historical building*

Figure 2: *Masonry specimens*

During the test, compression is increased from 0 to 300KN at the rate of 1kN/s, and then the loading is controlled by displacement at the rate of 2mm/min. Average compressive strength is 6.67N/mm^2 for the masonry specimens constructed by mortar with higher strength, and 3.24 N/mm^2 for the one constructed by mortar with lower strength.

The specimens exhibit good deformation capacity under low mortar strength.

Pseudo Static Test of the Masonry Wall Panels

Wall panels are constructed using the same block and mortar mentioned above. The pseudo static test is conducted to investigate the effect of mortar strength on seismic properties of masonry wall with damaged blocks. The mortar strength varies in a low range to reflect the properties of historical buildings.

Specimen and Transducer Distribution The historical blocks reserved can be used to construct two wall panels only. The specimens are named by T1 and T2. Compressive strength of mortar used for T1 specimen is 0.6N/mm^2, and for T2 specimen is 1.3N/mm^2. Thickness of the wall panel is 240mm.Thickness of the mortar bed is 10mm. The size is general for Chinese historical architectures. The blocks are laid in the same manner used for the old building. Surface of the wall panel is coarse, and the blocks are damaged and irregular. No strain gage is used for such specimens. The deformation is recorded using displacement transducers, as shown in Fig. 3.

Loading Procedure Vertical force is applied on the top concrete beam of the specimen firstly. The force is held when value of the compressive stress reach 0.30 N/mm^2. The cyclic lateral force is then applied on the top concrete beam, in the manner of 0.5 Hz sinusoid wave.

The fist loading cycle is controlled by cracking load. The next 2 cycles are controlled by cracking displacement times 2. The following 2 cycles are controlled by cracking displacement times 3. Then the cracking displacement is added to the controlling displacement of each following loading cycle. The specimen is supposed to be failure and the test is ceased when the load decreases to 85% of its peak value.

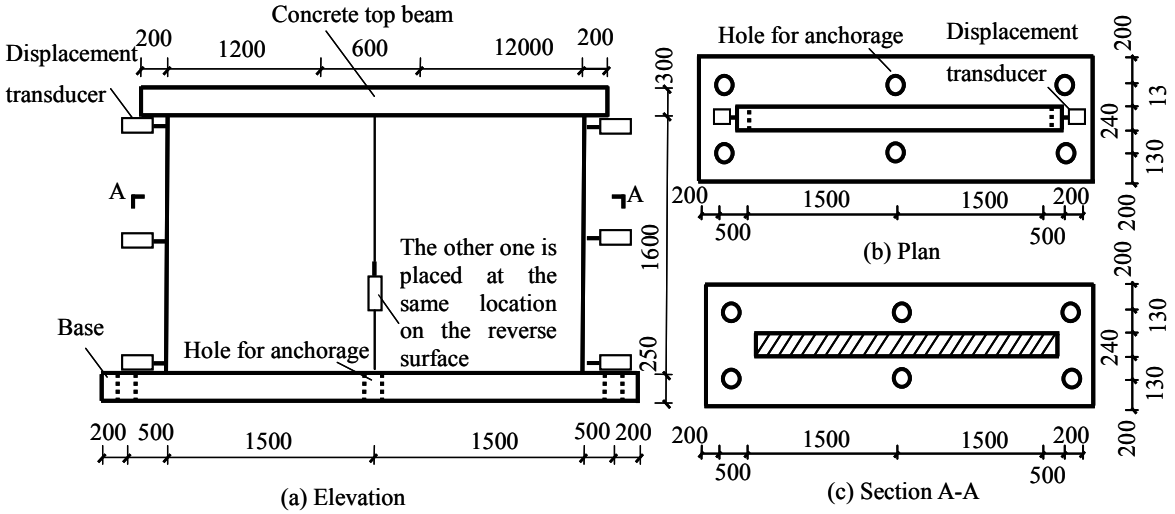
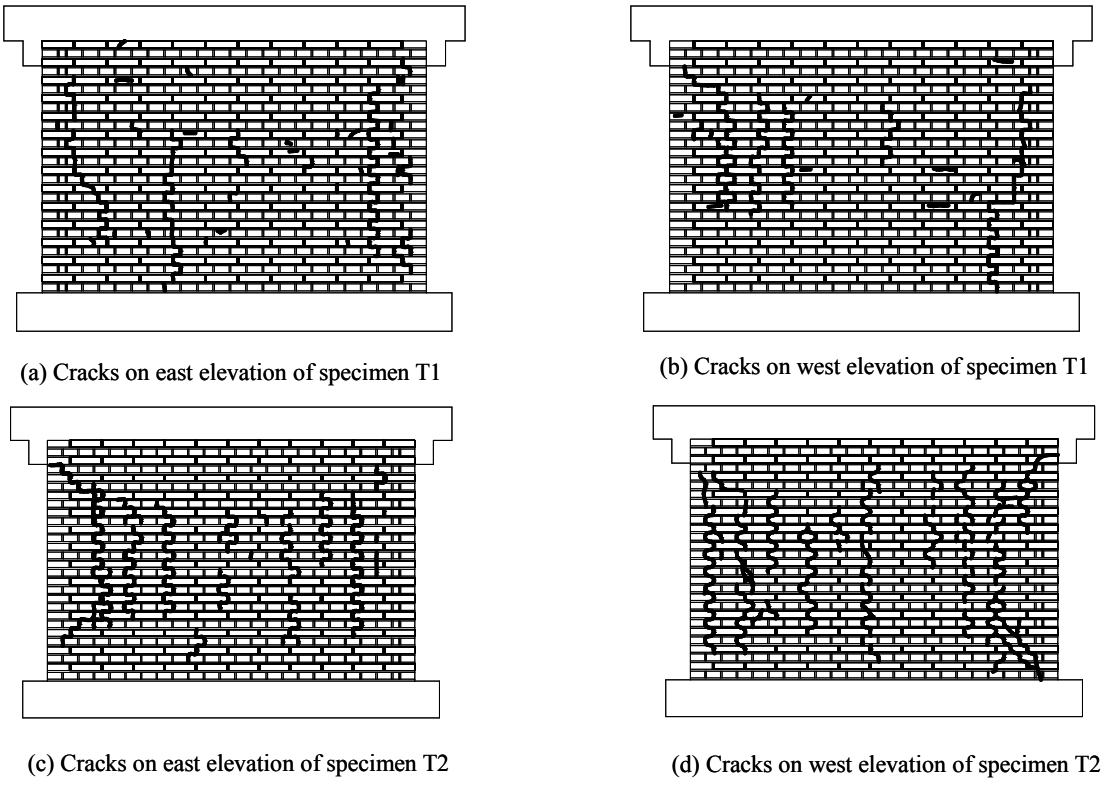


Figure 3: Dimension of the specimens and distribution of transducers

Test Results and Discussion Crack distribution and damage mode of the wall panels are similar to that of compressive failure. There is no critical inclined crack on the failure panels. Several stepped cracks have run form bottom to top through the panel, as shown in Fig. 4.



(a) Cracks on east elevation of specimen T1

(b) Cracks on west elevation of specimen T1

(c) Cracks on east elevation of specimen T2

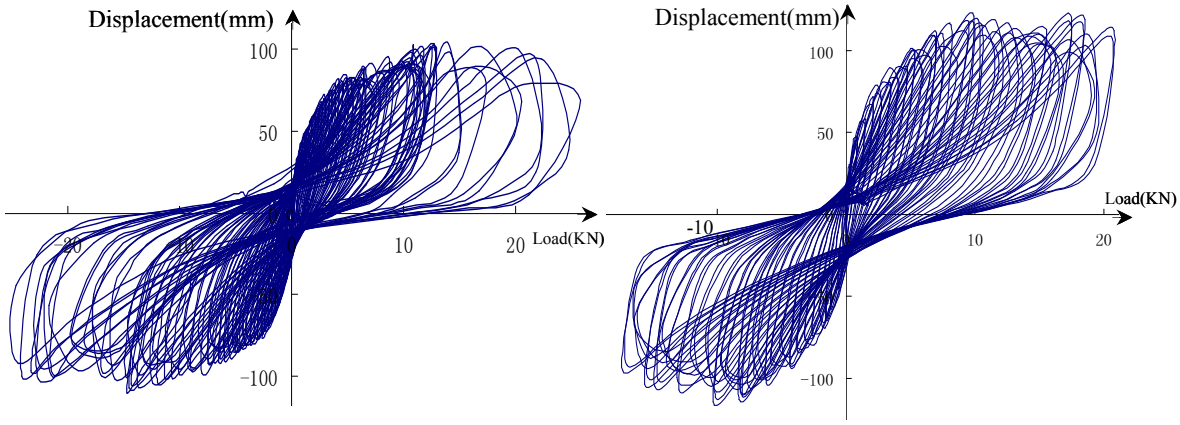
(d) Cracks on west elevation of specimen T2

Figure 4: Cracks distribution of failure specimens

It is shown by the crack distribution that the existing damages of the block change the stress distribution within the specimens. And the low strength mortar is damaged at early stage when loaded. Development of the cracks differs from that of modern wall panel constructed by entire block and high strength mortar.

Shape of the hysteretic curves of the specimens is obviously pinched. The peak load value decreases along with the mortar strength, as shown in Fig.5. Comparing to modern wall panels

constructed by entire block and high strength mortar, there is no significant difference in the energy dissipation mechanism. Mortar strength is an important factor of energy dissipation capacity.

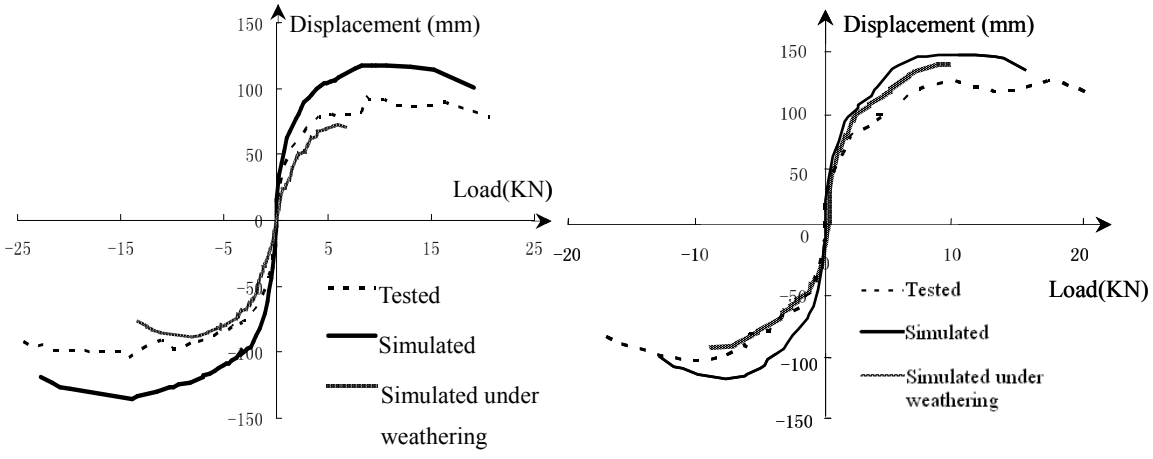


(a) Hysteretic curves of specimen T1 (b) Hysteretic curves of specimen T2

Figure 5: The hysteretic curves

Computer Simulations

To investigate the properties of weathered masonry wall in historical architectures. Computer simulation is conducted based on the test results. First, input parameters of the finite element model are verified using the test results. Then lower elastic modulus and mortar strength are used for some elements representing the weathered locations on the aged wall. The calculated skeleton curves show significant decrease of peak load value and ultimate displacement for the weathered model, as in Fig. 6.



(a) Skeleton curves of specimen T1 (b) Skeleton curves of specimen T2

Figure 6: Simulation results

Conclusions

Based on the test and simulation results, the following conclusions can be made on seismic properties of masonry walls in some Chinese historical buildings:

Damaged of the block and low strength of the mortar have significant effects on crack development in aged masonry walls.

Mortar strength has significant effects on energy dissipation capacity of the aged masonry walls.

Bearing and deformation capacities of aged masonry walls decrease under weathering.

References

[1] Liu, Q G, Shi, C X, and Huang, L (2007). "Analyses of the failure criteria of masonry in compression-shear." *Journal of Hunan University (Naturnal Science)*, 34(4), 19-23. (in Chinese)

[2] Wu, R (1997). "The State-of-Arts of the masonry structures in china," in *Proc. of 11th International Block/Brick Masonry Conference, Supplement Volume, Shanghai*, 1-6

[3] Yang, W J, Liu, L, and Yang, C X (2007). "The research on the seismic reliability of concrete perforated brick masonry structure." *Engineering Mechanics*, 24(10), 100-104. (in Chinese)