

An Experiment on the Seismic Behavior of Reinforced Masonry Buildings with Transverse Bearing Wall

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Abstract. A 1:2 reduced scale ordinary masonry structure model with no seismic fortification measures was designed in this paper. After 6 degree rare earthquake, this model has been reinforced by additional concrete beams. Compared with resilience, displacement, acceleration and other characteristic in the case of before and after the reinforcement in 6 degrees rare of seismic action. By undertaking quasi-static test with the masonry structure after reinforcement, studied the ultimate bearing capacity, hysteretic curves, skeleton curves, stiffness degradation curve and carry out cracks, then compared with the skeleton curve in the previous studies.

Introduction

Currently, there are still a large number of ordinary masonry structure with no seismic fortification measures exists in China. It has seriously threatened the safety of people's live and properties^[1]. The tensile strength, shear strength of masonry materials and the overall seismic capacity are weak. These ordinary masonry buildings without seismic fortification measures which seismic strengthened after earthquake can meet the requirements of the current regulations or not pending further study. Therefore, it is very necessary to make comparison of the before and after the reinforcement masonry structure's seismic behavior and do further research on seismic behavior of the masonry structure after reinforcement.

In the previous studies, the model building only set L type constructional column in the four corners which makes the ring beams and constructional columns relatively large and not conformity with the actual situation. Therefore, this experimental model designed to be a two layer four rooms, 1:2 reduced scale based on the dormitory building of NCUT.

Model Design

The model was an ordinary masonry structure with no seismic fortification measures, which is shown in Fig.1. According to the specification^[2], the plane size of the structure was 6060mm×1260mm, open-plan was 1450mm and depth was 1140mm, each floor height was 1690mm. The model was built on the reinforced concrete baseplate which connected with ground by high strength bolts.

The section size of the beam was 120mm×100mm, set 4φ6 rebar. According to the specification^[3]^[4], L type section was used in reinforced concrete column in the corner of wall, dimensions of long and short side was 300mm and 120mm, longitudinal steels in ring-beam were 4φ6 and 12φ6 in column which were laid in two rows. No less than 0.9m steel ties were settled at bottom, mid and top of each story to tie columns and walls. The size of pin key was 100mm×100mm, connected with beam, column and wall, set 4φ6 rebar and stirrup 2φ6, 100mm depth in the wall. C25 concrete used in column, beam and baseplate. Mu10 fired common brick which size was 240mm×115mm×53mm and M7.5 cement mortar were used to build the model. The thickness of concrete precast slab was 70mm, and wall was 120mm. Reinforced masonry model is shown in Fig.2.

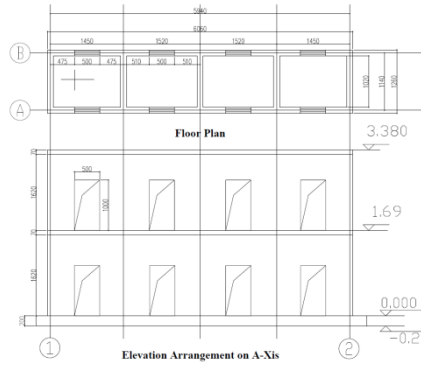


Fig.1 Masonry structure model



Fig.2 Reinforced masonry model

Pseudo-dynamic test

Working Condition and Seismic wave. Seismic wave shown in Fig.3 and Fig.4 was artificially synthesized according to working condition of the test (site classification is II, seismic design group is group I). Parameter used to synthetic seismic wave are shown in Table.1.

Table.1 Parameter used to synthetic seismic wave

seismic intensity (rare)	peak acceleration m/s^2	horizontal earthquake influence coefficient α_{\max}	Eigen period T_g/s	time span $\Delta t/\text{s}$
6	1.25	0.28	0.4	0.01
7	2.20	0.5	0.4	0.01

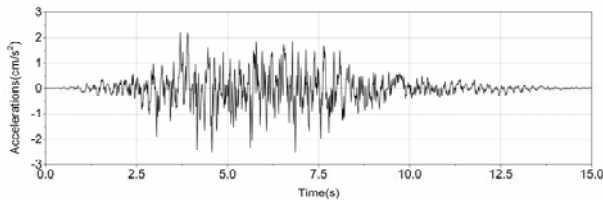


Fig.3. 6 degree rare earthquake wave

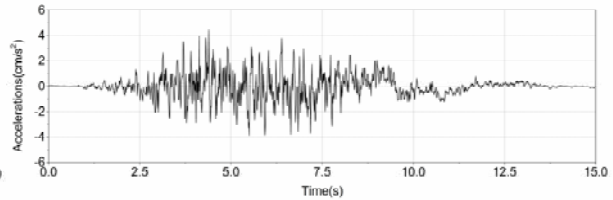


Fig.4. 7 degree rare earthquake wave

Seismic Response. The maximum value of displacement, velocity, and restoring force under the earthquake action of the model are shown in Table 2. The hysteretic curve of the structure can reflect the damage degree of the structure^[5] which is shown in Fig.5. The reinforcement ring beam and structural column improved the structural integrity and stiffness. The curve shown in linear relationship, plastic deformation is small and the structure is still in elastic stage.

Table.2 Maximum value of seismic response

reinforcement	seismic intensity (rare)	acceleration m/s^2	displacement mm	restoring force KN
before	6	-4.64	-0.57	-28.08
		3.42	0.42	31.78
after	6	-4.11	-0.51	-36.02
		4.22	0.44	35.69
	7	-7.64	-1.44	-67.86
		8.27	1.34	66.40

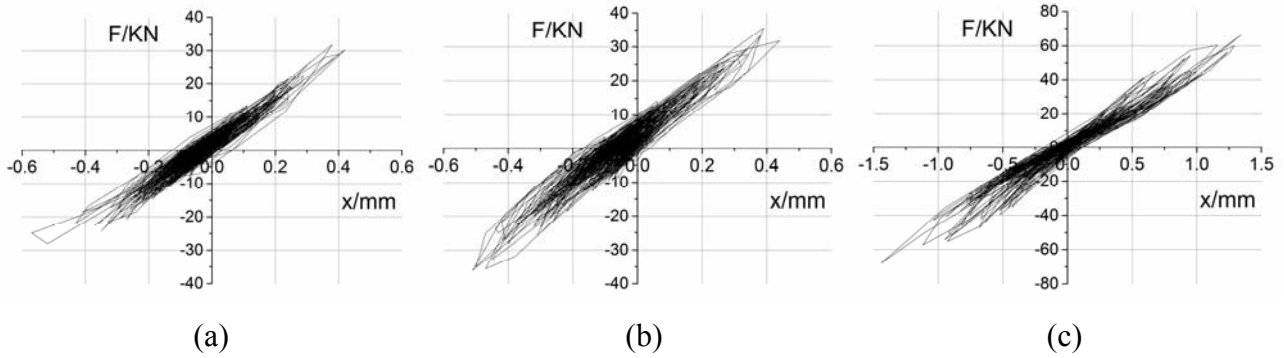


Fig.5. restoring force-displacement curve:(a) 6 degree rare earthquake of pre reinforcement (b) 6 degree rare earthquake of after reinforcement(c) 7 degree rare earthquake of after reinforcement

Quasi-static test

Track Development.One layer of wall cracked first along with the dropped off of mortar in the process of loading. The two layers of wall, beam, column joints also appeared cracks with the increase of load, crack extension along 45 degrees at four corners of windows and doors and formed cross cracks gradually, which is shown in Fig.6. Crack distribution is shown in Fig.7. After the ultimate load, the displacement increased and load began to decrease. The cracks appeared almost through the wall then the structure reached to the limit state.



Fig.6. Crack in wall, joint of beam and column

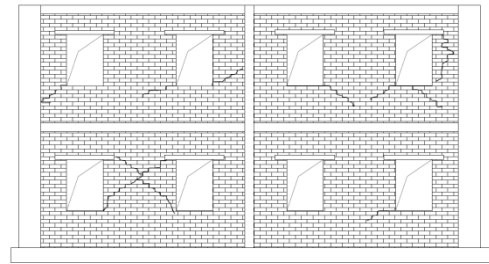


Fig.7. Crack patterns in the wall

Hysteretic Curve.Hysteretic curve of the structure is shown in Fig.8. We can see that at the beginning of loading, the restoring force-displacement curves of the structure shown in linear relationship, almost no residual deformation, and the structure was in the elastic stage. Then the curve was nonlinear, the slope decreases and relatively full with the load increased. The ultimate load is 161KN and the test was terminated when the displacement was close to 40mm.

Table.3. Eigen value of skeleton curve

structure type	craze		Ultimate load		Limit displacement	
	load P_{cr}/KN	displacement d_{cr}/mm	load P_{max}/KN	displacement d_{pmax}/mm	load P_{dmax}/KN	displacement d_{max}/mm
model	80	2.05	158.7	25	138.5	40
Prototype	320	4.1	634.8	50	554	80
Pre studies	189.29	4	295	32.6	265.9	72.3

Skeleton Curve.The skeleton curve ^[6](which is shown in Fig.9)of the model can reflect the characteristics of the restoring force, displacement and the ductility of the structure directly. Crack on the wall was large, the wall loss carrying capacity when the structure close to limit state. But because of the beam, constructional column, the structure still maintain good integrity, not collapsed.

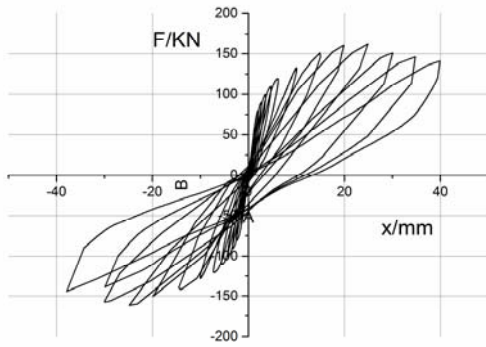


Fig.8 Hysteretic curve

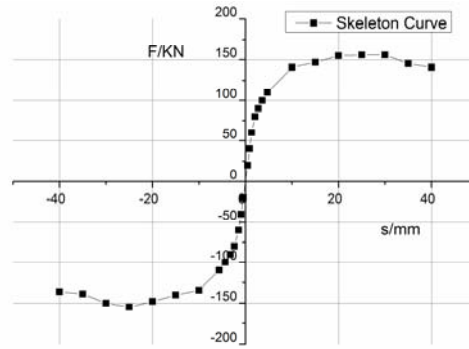


Fig.9 Skeleton curve

Hereon, compare the experiment status with previous studies^[7]. The model structure in the previous studies was a two layers and single bay full-scale masonry structure which only set L type constructional column in the four corners, and that made the ring beams and constructional columns relatively large. The plane size was 2400mm×3600mm and the section size of the structural column was 240mm×240mm. The skeleton curves are normalized^[8] by using non dimensional form, which is shown in Fig.10 and the eigenvalue is shown in Table.3. Structure's stiffness and restoring force of this test dropped uniformly with the increase of displacement when reached the ultimate load. But it decreased slowly in previous studies due to the large ring beam and structural column.

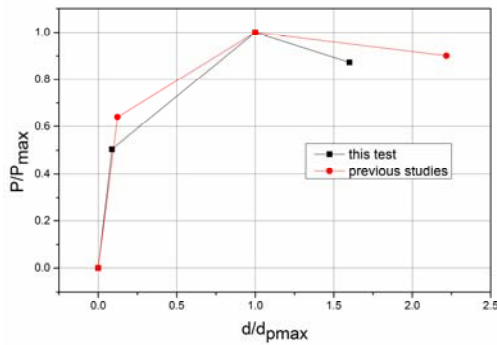


Fig.10. Normalized skeleton curves

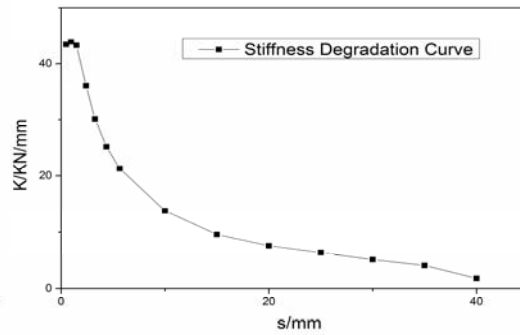


Fig.11. Stiffness degradation curve

Stiffness Degradation. Stiffness degradation curve of the structure is shown in Fig.11. The stiffness of the structure was 43.5KN/mm at the beginning of the experiment and 1.8 KN/mm in the end. The stiffness of the structure was obviously reduced with the development of the crack. With the development of the crack, concrete beam and column replaced the walls, bearing capacity and stiffness degrade slowly at that time.

Conclusions

There is little change in resilience, displacement, acceleration of before and after the reinforcement model in the case of 6 degrees rare seismic action. The reinforcement ring beam and structural column has improved the structural integrity and stiffness. Hysteretic curve was arch and full, indict that masonry structure reinforced by concrete beams and column have considerable plastic deformation capability and energy dissipation capability. Normalized skeleton curve show that the size of the ring beams and constructional columns have a certain effect on the stiffness and the bearing capacity of the structure. The utmost load of structure was 160 KN and utmost displacement was 40mm, far greater than the maximum recovery and maximum displacement under the earthquake action of 7 degrees. Therefore, after 6 degree rare earthquake, the ordinary masonry structure with no seismic fortification measures reinforced by additional concrete beams can meet the requirements of the current seismic code.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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