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MULTISTORY BUILDINGS IN CONCENTRATED REINFORCED MASONRY

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ABSTRACT

While a lot of unreinforced masonry buildings collapsed, several multistorey buildings in confined masonry damaged slightly in the past earthquakes in China. Basd on the results of additional model experiments, the confined masonry and concentrated reinforced masonry structures have been widely applied to the low-rise and medium-rise buildings respectively in the seismic zone. For the low-rise buildings the reinforced concrete ring beams are placed at each floor and the postcast tie columns are placed at each intersections of interior and exterior masonry walls. For the medium-rise buildings in addition to the ring beams and tie columns, the postcast reinforced concrete intermediate columns and horizontal belts are placed in all the masonry walls at spacing of 2~3 m and 1~1.5 m respectively. Model experiments and engineering practices show that the concentrated reinfored masonry structures have a good strength, deformability, seismic reliability and can be applied to the multistorey buildings up to 12 storeys in the seismic zones.

KEYWORDS

Unreinforced masonry; confined masonry; concentrated reinforced masonry; ring beams; horizontal belts; tie columns; intermediate columns; deformability; aseismic reliability; low-cycle horizontal loading.

INTRODUCTION

Seismic zones are spreaded widely in the world. Masonry wall structures are the main structural type in the construction of the buildings. However unreinforced masonry buildings are easily to be destroyed under the action of earthquake. Therefore it is very important to take countermeasures to improve the horizontal load bearing capacity and aseismic reliability of the masonry buildings.

DAMAGE OF MASONRY BUILDINGS

Unreinforced Masonry Buildings

In recent thirty years there were several severe earthquakes occured in China. In these seismic zones a lot of brick masonry buildings were damaged. The typical damage state is that the brick masonry walls and the wall branches between the windows and doors were cracked diagonally(Fig. 1a).

In the seismic zone of high intensity, the exterior walls of masonry buildings were collapsed out of plane, the interior walls and the wall branches between windows of exterior walls collapsed after severe diagonal cracking (Fig. 1b).

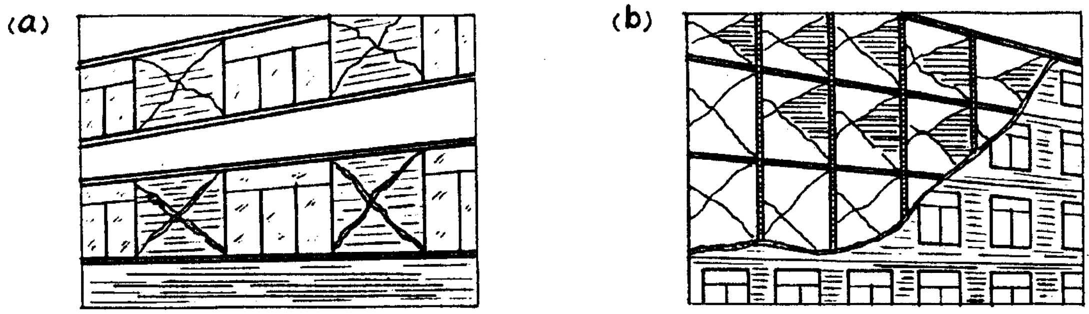

Fig. 1. Earthquake damage of masonry buildings.

Masonry Buildings with Ring Beams

In seismic zones there are a number of brick masonry buildings strengthened by reinforced concrete ring beams at every floor level. Under the shake of the earthquake the damage degree of these buildings is slighter than that of the unreinforced masonry buildings. Because of the restrictive action of the reinforced concrete ring beams, the structural integration of the buildings is to be ensured. The combination of the longitudinal walls and transverse walls act as a cantilever box. The collapse of the exterior wall out of plane is prevented. After earthquake the width of the diagonal cracks appeared on the wall surface are relatively smaller, and the diagonal cracks on the interior transverse walls were restricted within the story height (Fig. 2a) . However if there is no reinforced concrete ring beams at a certain floor level, the cracks of the walls would be larger and elongating across that floor level to lower story. The slope of the direction of the diagonal cracks becomes more steeper (Fig. 2b).

Confined Masonry Buildings

In seismic zones some 3 to 8 – storied brick masonry buildings were strengthened with reinforced concrete tie beams at every floor level and tie columns at every intersection of interior and exterior walls (Fig. 3a). It is called confined masonry buildings. During the strong earthquake these buildings perform very well, only a few small cracks appeared in the walls, no collapse of walls were occured.

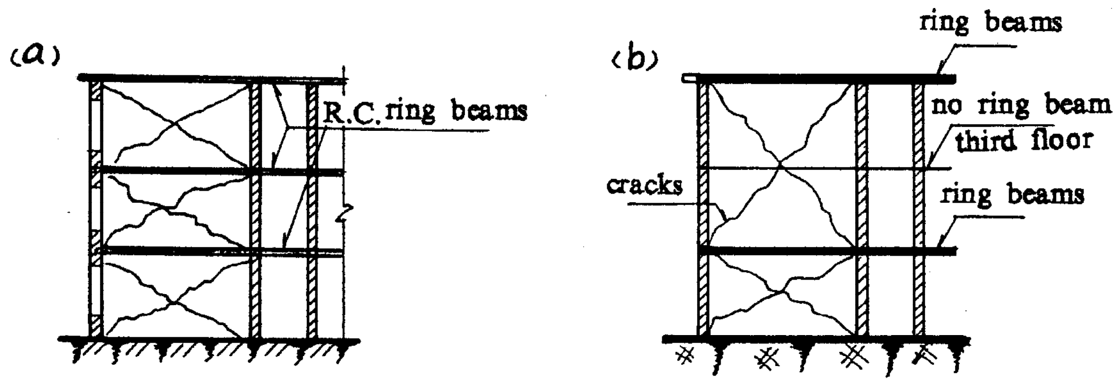

Fig. 2 Diagonal cracks on transverse walls.

In Tangshan Earthquake in China in 1976, even in the extreme seismic zone with M. M. scale intensity 10 degree, all of the unreinforced brick masonry buildings and masonry buildings strengthened with reinforced concrete ring beams were entirely collapsed onto ground, but several confined masonry buildings withstanded the severe earthquake and still stand there. No damage or slight damage appeared on the masonry walls of the 4-storied confined masonry buildings. The 8-storied confined masonry buildings were damaged more severely, many cracks appeared on the walls (Fig. 3b) . but no collapse occured. It shows that the confined masonry buildings have a good aseismic behaviour.

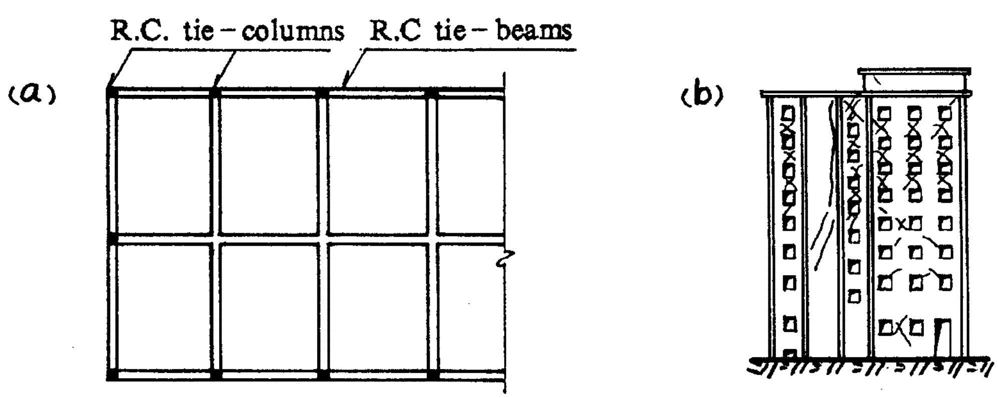

Fig. 3. Damage of confined masonry building in seismic zone of intensity 10.

STRUCTURAL EXPERIMENT

Horizontal Reinforcements

In order to improve further the aseismic property and horizontal bearing capacity of the confined masonry buildings during earthquake, in addition to the reinforced concrete tie-beams and tie-columns, for the unreinforced masonry area around by the tie-beams and tie-columns, the horizontal steel bars are to be placed in horizontal mortar joints of the wall at the vertical interval of about 0.2m (Fig. 4a). Under the action of the low-cycle horizontal loadings, both the ductility and the horizontal load bearing capacity are increased, the cracks spread all over the wall surface (Fig. 4b), but the width of the cracks are much smaller than the cracks appeared on the unreinforced masonry wall.

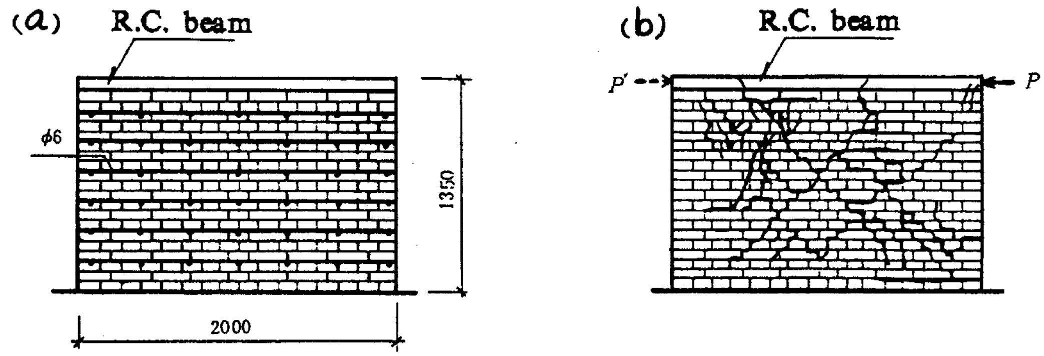

Fig. 4 Cracks on the wall having horizontal reinforcements.

Reinforced Concrete Belts

For strengthening the unreinforced masonry part of the confined masonry walls, another method is adopted and take a test of its structural model. The construction is that one or two reinforced concrete belts are placed at middle or one third point of the wall height (Fig. 5). Experimental result shows that the diagonal cracks across the wall was prevented, the cracks on the wall surface is restricted within the area between the belts. Experimental result shows also that on the increasement of the horizontal bearing capacity of the wall, the reinforced concrete belts is better than the mortar joint reinforcements.

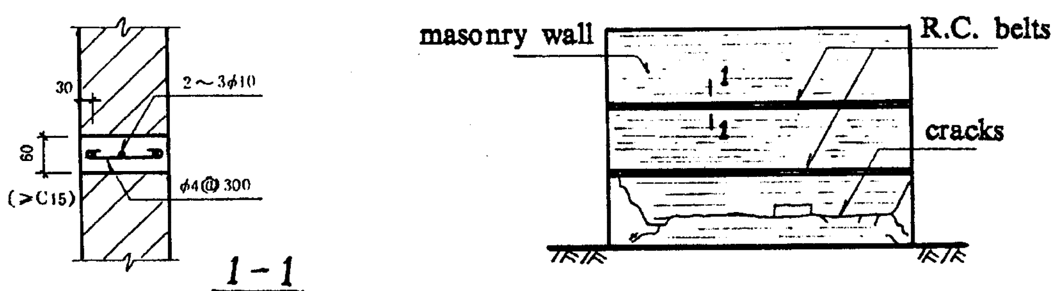

Fig. 5. Cracks on the wall having reinforced concrete belts.

Intermediate Columns

In addition to the tie columns at the intersections of the walls. one or two intermidiate columns ore placed at the middle or one-third points along the length of the wall (Fig. 6). They are postcasted in cavity resulting from the arrangement of the masonry wall sector s. Under the action of the low-cycle horizontal loadings with the certain vertical loadings, experiment datas show that owing to the confined action of the terminal and intermediate tie columns in the wall, both the horizontal and vertical load bearig capacities of the wall increase evidently. It gives a better practical method on the improvement of the ductility and bearing capacity of the masonry buildings.

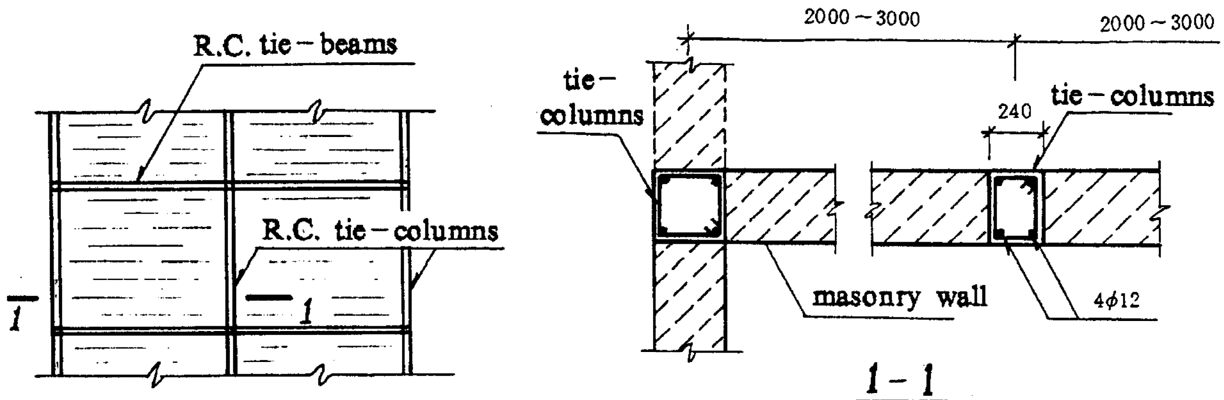

Fig. 6 Intermediate tie-columns.

ASEISMIC DESIGN AND CONSTRUCTION

Experiments and earthquake practices prove that confined masonry buildings have a good aseismic behaviour. The confined masonry has a good enough reliability as a structural system used for 5 to 6-stories buildings in the areas of seismic risk. Reinforced concrete tie-columns are placed at every intersection between longitudinal and transverse walls, while tie-beams are placed at every floor level. The distannce between tie-columns in any case should not be exceed 5m. The cross section of the tie-columns shall not be less than 180× 1800 mm and with vertical steel bars not less 4Φ12. The cross section of the tie-beams should not be less than 180×120 mm and the longitudinal steel bars should not be less than 4Φ10. Thus confined masonry buildings will withstand the moderate earthquakes without structural damage.

For the severe earthquakes or for 7 to 8-stories masonry buildings, the additional insert tie-columns and reinforced concrete belts should be placed in the longitudinal and transverse walls except the tie-columns and tie-beams. The horizontal spacing of the interior tie-columns may be 2 ~ 3 m, the vertical spacing of the reinforced concrete belts may be 1 ~ 1.5 m (Fig. 7). The cross section of the insert tie-columns may be 180 ×180 mm or 240×240 mm with 4Φ12 vertical steel bars. The cross section of the reinforced concrete belts may be 180×60 mm or 240×60 mm with 2Φ10 longitudinal steel bars. Two sides of the openning of the windows and doors may be strengthened by the reinforced concrete ribs. To ensure the integration of the structure, proper construction method is needed. The casting of the concrete of the tie-columns and ribs should be made after erection of the masonry of walls.

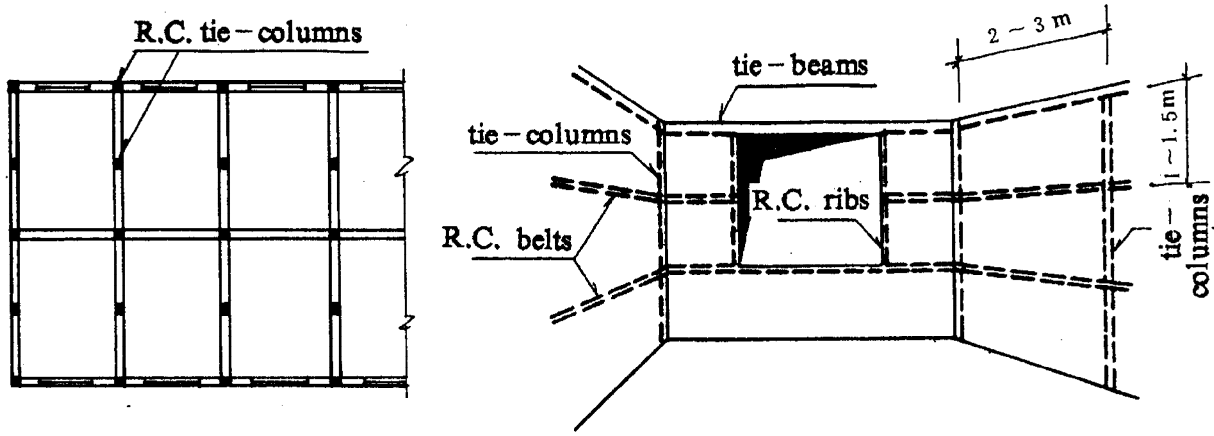

Fig. 7 Concentrated reinforced masonry buildings.

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