Zusammenfassung einer Publikation

«Welches Erdbeben mit welchen Folgeereignissen / welche Standortcharakterisierung wird dokumentiert?»

Hollow block masonry wall reinforced by built-in structural configuration: Seismic behavior analysis, X. Zhou, J. Du, Q. Peng and P. Chen, in Soil Dynamics and Earthquake Engineering 126 (2019)

1. Introduction

The construction of masonry walls is more efficient with hollow blocks than solid clay blocks due to their size. Some types of hollow blocks are environmentally friendly and more cost-effective because they are manufactured from recycling materials.

Unreinforced hollow block masonry buildings have to be carefully designed for seismic performance, because the structures are highly vulnerable to earthquakes because of their low tensile and shear strength.

Existing strengthening schemes can be divided into two categories: reinforced hollow-block masonry (RHM) and external or internal strengthening with fiber-reinforced polymer, steel or other materials. Internal strengthening is used for new builds and external is used to strengthen or repair existing structures. RHM is more commonly used than external or internal strengthening.

There are three different methods of RHM:

- 1. Method: URHM is built followed by filling selected hollow cores with reinforced grout containing a single bar and no shear ties. They are called “partially grouted masonry” or PGM in this paper.
- 2. Method: Is called “confined masonry” or CM. Here, the structures consist of load-bearing masonry walls and confining elements at the wall perimeter. These elements are reinforced with concrete tie-beams and tie columns.
- 3.Method: consists of a T-shaped cross section of masonry walls and has rectangular wall and boundary elements at the ends. These method is called “fully grouted masonry with boundary elements” or FGM-B. This wall is stronger and more ductile with less strength degradation. It is preferred for reinforced masonry walls in multi-to-high rise buildings.

All these types of walls are used for load-bearing walls in ordinary masonry structures. A new type of wall is presented in this paper. The wall should be a reinforced hollow block masonry wall based on the common single row hollow block. The new wall will be called “partially grouted masonry with built in boundary elements” or PGM-BB.

In this type of wall the block serves as a grouted recess to construct a built in structural column, built in core column and built in diagonal bracing. This wall easy to construct and cost effective. This paper discusses one experiment and the non-linear finite element analysis.

2. Experimental program

Four hollow-block walls were designed and fabricated for the experiment. The image below shows the size and structural layout of the specimens.

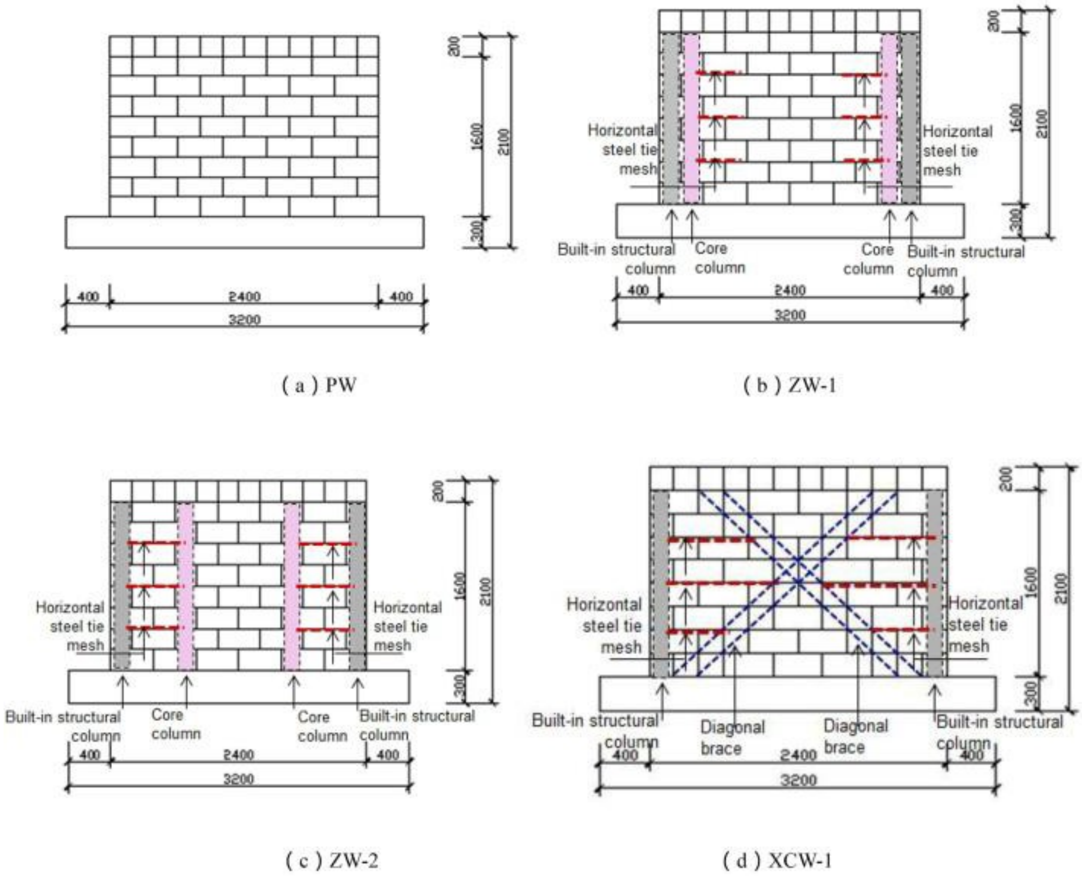

Abbildung 10 - Size and structural layout

They are called PW, ZW-1, ZW-2 and XCW-1.

To simulate the mechanical state of the wall under an earthquake, the bottom of the wall should be fixed while the top is able to translate. Cyclic lateral load was applied at the end of the top beam by an electro-hydraulic actuator. For free lateral movement, low friction sliding plates were placed on the jacks. The vertical load applied was 160 kN and the vertical compressive stress was 0.35 MPa. Before cracking of the specimen, one fully loaded cycle was applied at each displacement amplitude level. Three cycles were applied after cracking. Failure was assumed to occur when the strength of the specimen was reduced by more than 15% of the peak strength.

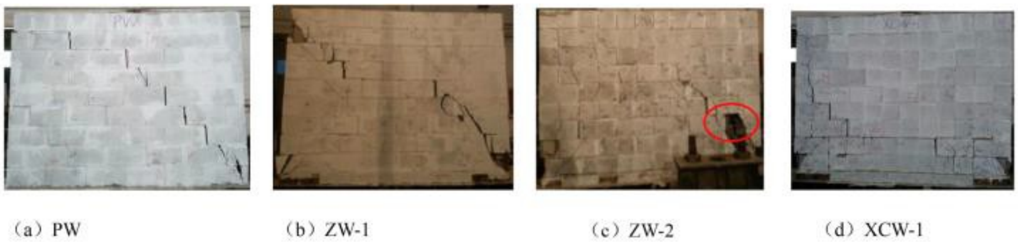

Fig. 7. Specimen failure modes.

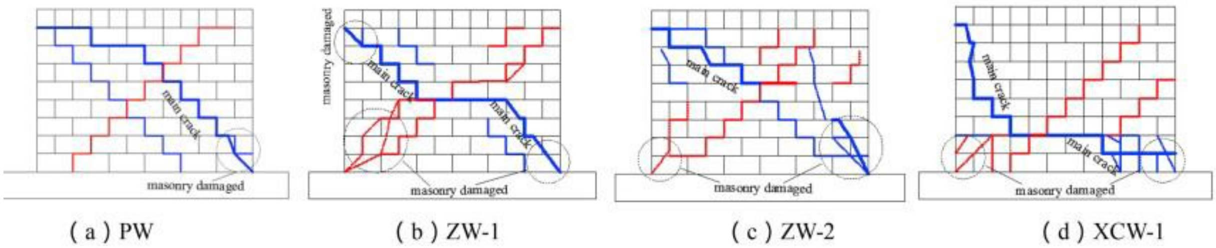

Abbildung 11 - Crack distribution

The experiment showed the following results:

- PW was split into two parts along the diagonal or stepped main crack, which indicates brittle characteristics.
- ZW-1: the built-in structural column and core column arranged at the ends formed a composite section with large stiffness.
- ZW-2 showed structural uniformity as the horizontal steel tie mesh bonded the structural columns and core columns dispersedly arranged in the wall.
- Both ZW-1 and ZW-2 failed when the built in structural column and core column presented inclined cracks along the direction of the stepped main crack of the wall. The ends of the wall are crucial to the walls working performance.
- The diagonal braces bore tensile and compressive stress during the loading process in specimen XCW-1, which improved the horizontal bearing capacity of the wall. When this wall failed, the upper part of the wall was almost intact. The roots of the diagonal braces and the surrounding masonry were severely damaged.
- A dispersed structural column and a core column layout or a structural column with a built in diagonal brace appear to be more advantageous in terms of bearing capacity.
- In regards of stiffness, it is advantageous to build a concentrated built-in structural column and a core column layout.
- The concentrated built in structural column and core column layout was optimal for the displacement ductility of the wall.

3. Finite element model verification

The models discussed above were established in ABAQUS software. The rationality of the model was verified by comparison with the experimental results. The three dimensional finite element model established in this study had two types of elements. The 3D linear reduction integral element was adopted for the masonry, core concrete and top beam. The steel bar is a slender material and its shear resistance is weak, so the shearing effect was neglected in the model. The steel bar was simplified into a 3D truss element with two degrees of freedom. The connection between steel and concrete was represented by embedding technology.

A vertical compressive stress of 0.35 MPa was applied to the top beam and the bottom surface of the masonry was completely fixed. A bilinear elastic-plastic model was adopted for reinforcements. The plastic damage model in ABAQUS was used for the masonry and grouted concrete. The curves obtained by finite element analysis deviate from the measured load displacement curves but overall the trends are consistent.

The reason for the deviation is that after entering the elastoplastic stage, the finite element analysis does not consider the damage caused by the cracks opening and closing under cyclic loading. The simulated load displacement curve drops more steeply in the two loading directions while the test values agree well with the simulated values only in a single loading direction.

The tests and simulations both indicate that the built-in structural column, core column and diagonal brace can improve the bearing capacity, initial stiffness and displacement ductility of the wall structure. The compression damage distributions of the specimens obtained by the finite element simulation are consistent with the damage modes of the walls observed during the test.

The defects of the material itself during the test and the neglect of material damage under cyclic loading during the finite element simulation created some deviation between the finite element analysis and the measured wall stiffness degradation curve but the trends are consistent. The finite element method proposed is reliable for all wall types tested. Two additional models were built to analyze the seismic performance of the wall with different built-in structural measures to determine the optimal scheme. (ZW-3 and ZW-4).

4. Influence of grouted concrete strength on seismic performance of wall

Four finite element models of the wall were established based on the optimal structure scheme of ZW-4 with the same hollow-block strength but different concrete grades (C15, C20, C25 and C30). To determine the effects of grouted concrete strength on the seismic performance of reinforced hollow-block masonry structures.

The cracking, load, peak load, stiffness and failure load of the wall improved as the grouted concrete strength increased. The displacement ductility of the wall was maximal with grouted concrete strength C20. The damage area at the point of cracking decreased but the damage severity increased as concrete strength increased.

The extent of damage to the structural and core columns decreased as the grouted concrete strength increased. There was a larger damage area in the walls of C20 and C25, which suggests that these walls have higher energy consumption than others.

5. Conclusion

- Compared to normal masonry walls, walls with built-in structural configurations are more efficient and cost effective.
- When the built-in structural column and core column are in a concentrated layout at two ends of the wall, the bearing capacity, equivalent initial stiffness and displacement ductility are enhanced compare to normal scheme. If these types of columns are in a dispersed layout in the wall, it benefits its overall working performance.
- The built-in diagonal brace greatly improves the bearing capacity and stiffness but does not improve its ductility.

- The optimal design scheme includes built-in structural columns placed at two ends of the wall and core columns placed at the ends and in the middle. The appropriate grouted concrete strength for the hollow block is C20 or C25.