抗震空心砌块研究

RESEARCH ON EARTHQUAKE PROOF HOLLOW BLOCKS

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ABSTRACT In this paper we introduce a kind of small-model-block building which possesses excellent earthquake proof capacity with few or even no steel bars, yet is convenient to build. Numerous facts show that in earthquake catastrophies, brick and small-block buildings are always destroyed by stepped fractures developed along mortar joints where shear strength is low. Therefore limitation exists for construction of such buildings in earthquake areas. But our earthquake proof particular model hollow block buildings fairly satisfactorily settle this difficulty. We introduce the shape design and experimental results for them. After test use in a high intensity earthquake area, all designers, building operation personnel and end users show their appreciation.

摘　要

本文介绍一种抗震性能良好、不用或少用钢筋、砌筑方便的小型砌块房屋。大量地震灾害表明，砖房及一般的小型砌块房屋遭受地震时，往往沿抗剪强度低的阶梯形灰缝开裂，导致房屋的破坏，本文介绍的抗震砌块房屋，较好的解决了问题。文中将介绍砌块的形状设计及试验结果等。经在高烈度地震区试用，设计人员、施工人员及用户都表示欢迎。

1. FOREWORD

In brick buildings, earthquakes are liable to produce stepwise slant cracks or horizontal dislocations along mortar joints with low shear rigidity. In this paper we consider particular model hollow units (for brevity called EPB-pieces) which change the shape of the units in order to give more strength during earthquakes. If cracks keep going on, the seismic shear force must destroy the bodies of the hollow units rather than the mortar joints. The former are stronger than the latter, thus buildings of this kind of hollow unit possess more powerful seismic proof ability.

Beijing Architecture Engineering Institute, Yunnan Institute of Technology and Xa-kong Associating Section combined to take part in this research work.

2. FORM AND SIZE OF THE EPB-PIECE

There are four kinds of the EPB-pieces.

(1) Fundamental piece: Fig. 1(a) and (b) are the front view and top view of it. For the sake of better thermal performance and to facilitate construction, there are two round holes in the block. The vertical position of all holes is arranged uniformly in a line, to put reinforced concrete in if necessary. Except the adjusting block, all possess holes, the effects are all alike. The thickness of walls in the two experiment buildings is 20cm, if the wall thickness varies, then the width of block would vary accordingly.

(2) A semi-piece is half of a fundamental piece but with 6mm less length (the half breadth of a mortar joint). It is used at vertical position of door or window. Fig. 2 (a) and (b) are its front view and top view respectively.

(3) Corner piece: It is used at corner of exterior wall, the front view, top view and corner planar view are shown respectively in Fig. 3(a), (b) and (c). The upper and lower lapping length at corner pieces is just the wall thickness. The lapping length varies accordingly with the varying of wall thickness.

(4) T-joint piece is made from a corner piece by decreasing 150mm of its right side, which is used in T-joint and is located layerly alternating with corner piece. T-joint piece may also be used in cross joint.

(5) Adjusting piece: Fig. 4(a) and (b) correspond its front view and top view. It is to fulfill building modulus so as to give facility by increasing the usage of the EPB-piece. The thickness of adjusting piece changes with the change of wall thickness.

3. EXPERIMENT OF SHEAR RIGIDITY FOR SINGLE WALL

We apply method comparative test between EPB-pieces wall and common clay brick wall to find out the ratio r between shear strength of EPB-pieces block RjEPB and of clay brick Rj brick ($r = \frac{Rj\ EPB}{Rj\ brick}$). Based on it, one may precede seismic proof checking calculation according to our nation's contemporary seismic proof design rules for the EPB-piece buildings.

Owing to restriction of condition, the EPB-pieces are made by 200# concrete only. There are nine single walls, made in two groups, six in first, the average length is 187 cm, with height 129 cm, thickness 23.8cm, built in 25# mortar; three in second, for base beam is fairly thick, the height is 135 cm and the other size is the same as the first time, built in 50# mortar. The brick block specimens are twelve and also made in two groups, six in first with average length 193cm, thickness 24cm built in 75# bricks and about 25# mortar; six in second with average length 190cm height 136cm built in 75# bricks and average 50# mortar. The first six specimens are in excellent building quality but not so for the second six.

The experiments proceed in four comparing groups, three specimens for each group (in the third group there are six brick specimens). The fourth group uses blocks of the first and second groups and the broken specimens to give inverse loading experiments. In plane, nine apply horizontal load, uniformly distributed vertical load and eccentric concentrated vertical load for

equilibrium moment (or: for balancing overturning moment) to make specimens yielding slant shearing fracture rings in order to measure the ratio r registered in the following list:-

LIST 1

Group order		Average initial fracture load(t)	Ratio	Average destructive load(t)	Ratio	Average shear intensity $R_j(kg/cm^2)$	Ratio $r = \frac{RjEPB}{Rjbrick}$
1 ~ 2	EPBpiece / brick	22.2 / 12.7	1.7	36.6 / 20.0	1.8	7.9 / 2.9	2.7
3	EPBpiece / brick	16.6 / 11.1	1.5	25.0 / 13.6	1.8	5.0 / 1.9	2.6
4	EPBpiece / brick	22.3 / 12.2	1.8	32.6 / 21.0	1.6	6.5 / 2.8	2.3
Average	EPBpiece / brick	20.2 / 11.9	1.7	31.4 / 18.3	1.7	6.5 / 2.6	2.5

Notice: the void ratio of EPB-pieces is 13%, its shear area is smaller than brick.

It is easily seen from figures in List 1 that EPB-piece block made of 200# concrete has it shear intensity R jEPB stronger than that of the Rjbrick for a block made of 75# bricks and the same kind of mortar. The average value of r is 2.5, i.e.

$$r = \frac{RjEPB}{Rjbrick} = 2.5$$

4. COMPARISON OF EARTHQUAKE PROOF INTENSITY FOR MULTI-STOREY BUILDINGS

According to the experimental results based on our national contemporary seismic proof design rules TJ11-78, calculations to seismic proof intensity of two experimental buildings, one residential building and a school building in Beijing show evidently that the buildings of EPB-pieces have increased earthquake proof resistance. One example is given in List 2. Analysis shows: in nine degree area four-storey buildings can be built with 200# concrete EPB-pieces and the wall thickness is 20cm. If the wall thickness increased to 24cm and 30cm, then five or six-storey buildings would be done. But for brick buildings, if the bottom wall has thickness 24cm plus structural columns, only three-storey buildings can be made. If four-storey buildings must be built, the bottom wall would have thickness 36cm together with supplemental structural columns, still the seismic proof ability is lower than that of EPB-piece buildings. In eight degree area adopting 200# concrete EPB-pieces, the building would be eight storied if the transverse wall is 20cm thick and longitudinal wall is 24cm thick in the bottom storey. Still two or three stories could be added if wall thickness is increased to 30cm. But for brick buildings even if structural columns are supplemented with transverse wall 36cm thick and longitudinal wall 49cm thick, the seismic proof intensity is still lower than demand.

LIST 2: The residential building for colleagues of Xakung Municipal Construction Committee (a four storey building with field-made R. C. floors, nine degrees, second category ground)

floor	strength of mortar	EPB-pieces with thickness 20cm and void ratio 26.2%		bricks supplemented structural columns, wall thickness 36cm	
		safety factor K	compared with the design rules "+" means increasing	safety factor K	compared with the design rules, "+" means increasing
4th	50	4.34	+117%	3.82	+91%
3rd	50	2.48	+24%	2.02	+1%
2nd	100	2.42	+21%	2.06	+3%
1st	100	2.34	+17%	1.91	-4%

5. THE PRODUCTION AND BUILDING SITUATIONS

The production and building situations of two experimental buildings made of EPB-pieces illustrate: The production of EPB-pieces is fairly straightforward, the building construction is also very simple, without trouble, and the wall builds over twice as fast as a brick wall.

6. ANALYTIC RESEARCH OF ECONOMIC BENEFIT

Through practice and survey of these two experimental buildings, under premise of almost equivalent seismic proof capacity (EPB-piece block are always stronger than bricks with supplemental structural columns), the following advantages are possessed by EPB-pieces:

(1) Increasing applicable area 8% of the building.

(2) The weight of walls decreased about 1/4 - 1/3.5, which is advantageous for diminishing the breadth of foundation.

(3) Easy to build, so as the quality being guaranteed.

(4) Less mortar being used. Accompanying the realization of machined fashioning technique, the breadth of mortar joint and thickness of mortar or wall surface will be decreased, thus the amount of mortar is use could be diminished again.

(5) With EPB-pieces buildings could be built much higher than brick ones, thus several kinds of frame or frame-shear structures may be substituted.

7. DISCUSSION

(1) All the above experimental analysis and calculation derives from our nation's earthquake resistant regulations which are based upon the traditional viewpoint that horizontal seismic force is dominant. The second author of this paper has pointed out since 1957, and was proved further by analysing earthquake damage induced by many strong earthquakes in our country, that this traditional viewpoint is incorrect. Practically the vertical seismic force plays a leading role. For an earthquake in eight degree area, vertical seismic force may exceed own weight. Upon that viewpoint, the EPB-pieces building may give much higher seismic resistant capacity than the above calculated results.

(2) A strong earthquake may not occur within a hundred years, thus building damage on a certain level short of falling down and injuring people should be permitted. If the consideration is to prevent cracks from extending further after they have appeared, then the EPB-piece buildings possess higher earthquake resistant ability than the above calculated results.

(3) The increasing of seismic resistant capacity for EPB-piece buildings mainly depends on increasing the strength of block pieces or bricks, other than strength of mortar. Thus a further step to increase the earthquake resistant capacity is to raise the strength of block piece or brick.

(4) The EPB-pieces used in weak seismic areas also prevent slant cracks appearing in walls.

Photo 1. Masonry building condition

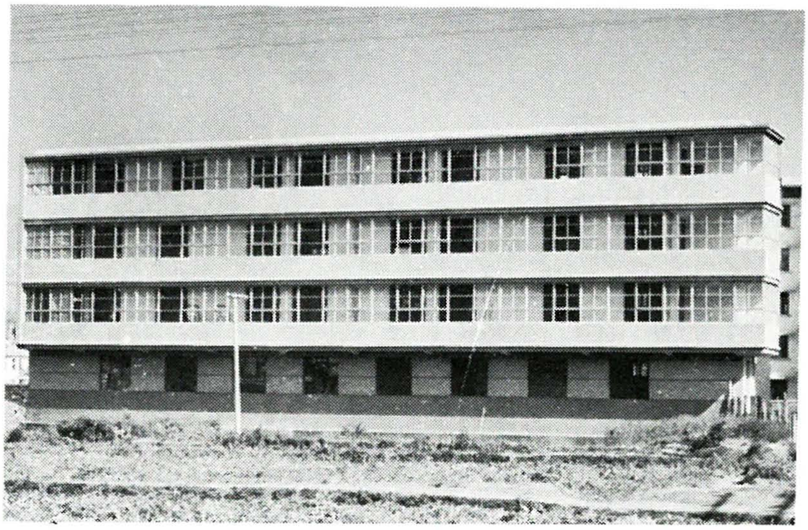

Photo 2. Dalee Design Institute

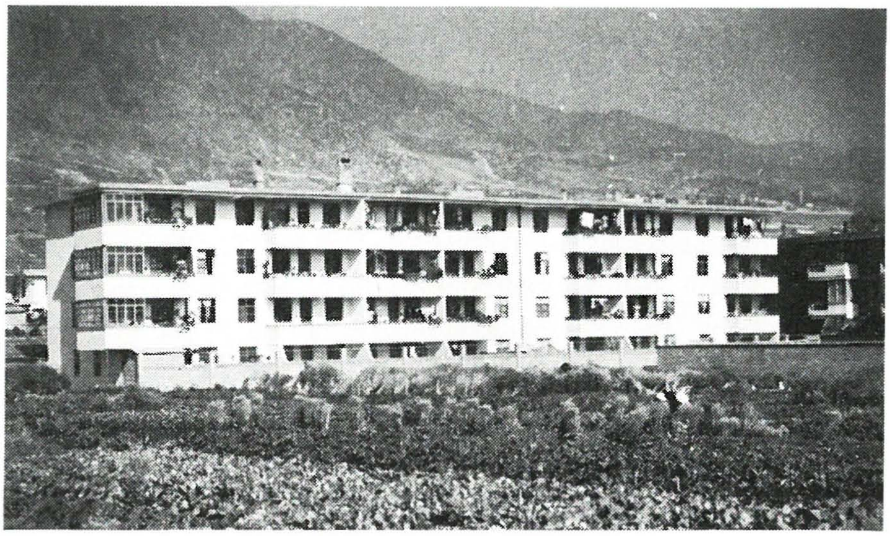

Photo 3. The residential building for colleagues of Xa-kung Municipal Construction Committee

Unit: mm.

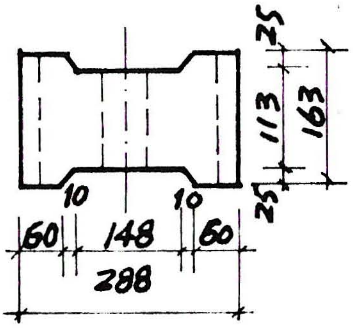

Fig. 1(a). Front standing view of fundamental block

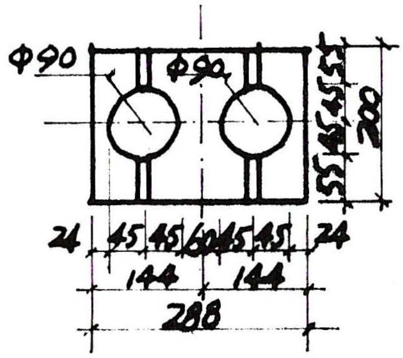

Fig. 1(b). Plane of fundamental block

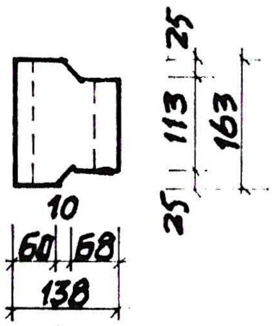

Fig. 2(a). Front standing view of semi-block

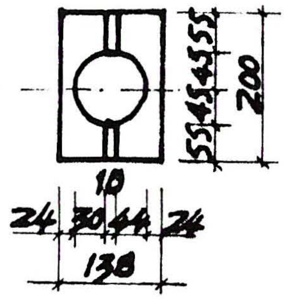

Fig. 2(b). Plane of semi-block

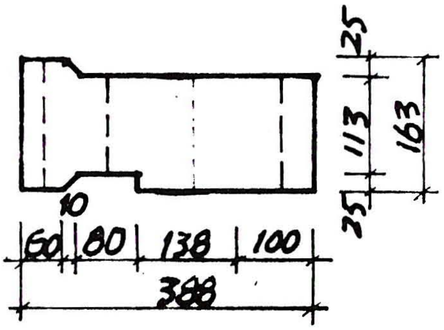

Fig. 3(a). Front standing view of turning corner block

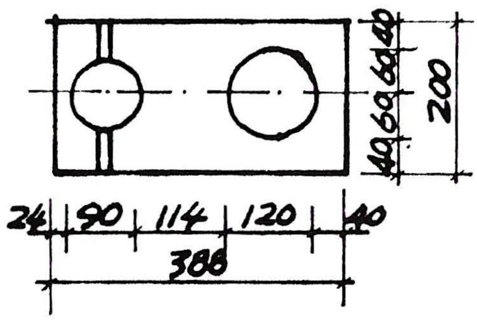

Fig. 3(b). Plane of turning corner block

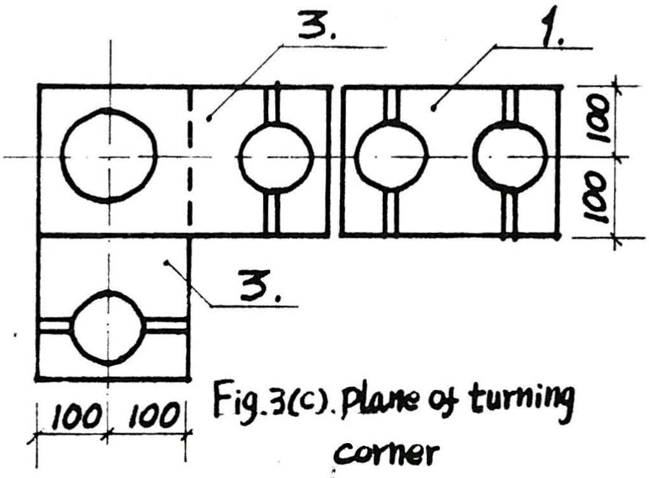

Fig.3(c). Plane of turning corner

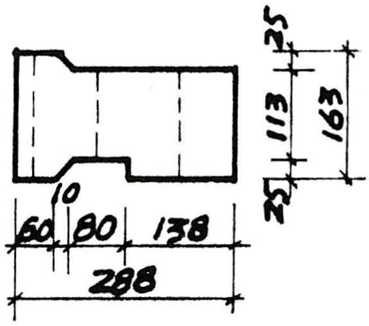

Fig.4(a). Front standing view of T-joint block

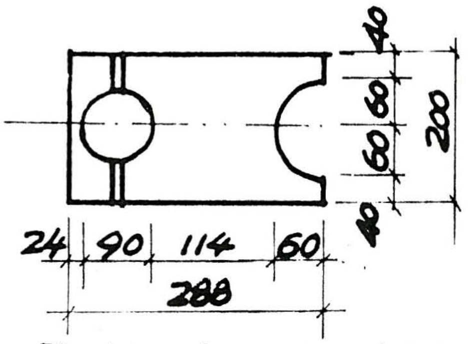

Fig.4(b). Plane of T-joint block

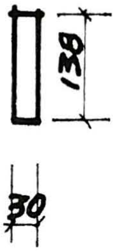

Fig.5(a). Standing view of adjusting block

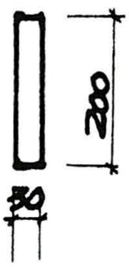

Fig.5(b). Plane of adjusting block

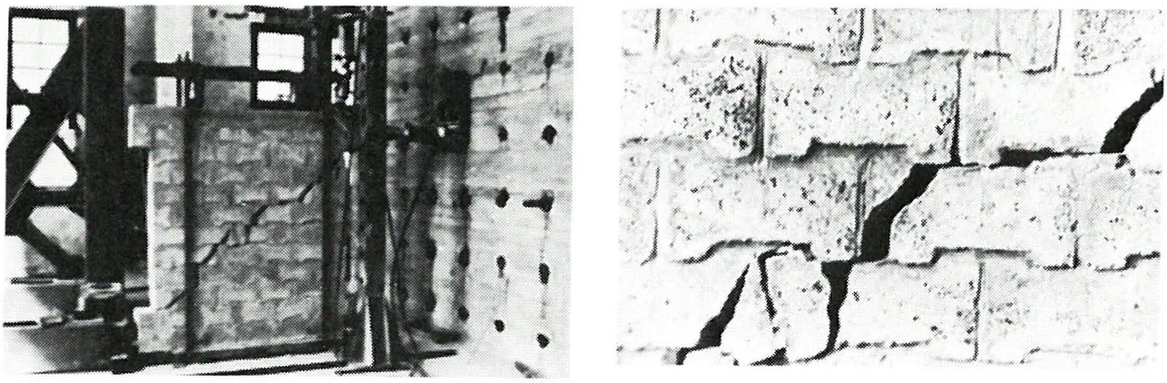

photo.4. Destructive situations of testing specimen

8. REFERENCES

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