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FUNCTIONS OF TIED CONCRETE COLUMNS IN BRICK WALLS

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SUMMARY

This paper reviews the functions of tied concrete columns of brick wall by means of the mechanism of earthquake disaster of the brick buildings in the city of Tangshan and research results made in recent years in our country. It is suggested that tied concrete columns should be provided uniformly and consecutively, that the height of brick building should accord with the demands of both its height and stories so as to strengthen the aseismatic performance of brick building in seismic region.

INTRODUCTION

In the past, many people had sought the anticollapse methods of brick building, however, neither perceptual knowledge nor experience related to earthquake disaster and damage features in the epicentral region has been gained. There was no answer to the potential and performance of brick building during a violent tremor. The 1976' s Tangshan Earthquake has offered such experience and lessons, appraising the aseismatic capacity of various structures in a violent epicentral region, and revealing the brittleness, plasticity and lack of ductility of brick structures as well.

Tangshan before quake, covered a total floor space of 14.13 million M^2 of which 7.8 million were residential quarters. 85 percent of residential buildings were of brick structure, most of them were badly collapsed during the violent earthquake. Therefore the people' s lives and property suffered heavy losses. On the quake site, the brick building with tied columns has offered valuable experience in the aseismatic performance of brick buildings. That is why, it attracted many people' s attention to it.

EARTHQUAKE DISASTER FEATURES

Failure Mechanism of Brick Walls Before quake, most of the brick walls in Tangshan were built with 50-75# clay bricks, 150# construction bricks laid with 10—15# mortar. A few of brick building were built with cement sandy brick. On the brick walls, the main load— bearing component, with a very complicated seismic behaviour would occur a variety of cracks during the violent earthquake.

Oblique or X—shape shear cracks usually occurred in crosswalls, walls between windows, transverse walls of large stiff buildings and the building cornerings. The higher the masonary grade, the cleaer the cracks, very often the lateral wings of the wall would slide away, the upper, lower parts would become unstable, displaced or collapsed. The lower the masonary grade, the more indistinct the cracks, usually the wall would collapse into pieces. In addition, on brick spandrels the weaken part for architectural treatment would occur plastic damage and x—shape shear cracks. As for the building with inside frames, with flat slabs building or with spacious rooms, it was easy to cause shear damage at plane cornerings and bigger oblique cracks.

Vertical cracks would occur when a wall bears shearing, bending, tensile or compressive forces. Intersecting portions and rigidity—changing sections of two sides of wall openings usually were subject to shear damage, leading to vertical cracks. Horizontal inertial force of a floor slab would make the intersecting portion between outside walls and inner walls produce not only up—wide and down—narrow vertical cracks, but in another case also down—wide and up—narrow vertical cracks, but the latter were rarely happened. Horizontal outwardly thrust of a longitudinal wall, usually made the transverse wall produce a up—wide and down—narrow vertical through crack along the construction joint of a longitudinal prefabricated floor. Under the action of the horizontal seismic force, the rigidity—changing sections of opening of a window or a door, or a large area of a wall would cause flexural failure, producing vertical cracks. In addition, in case the load being uneven, walls weaken by the flue, or uneven settlement of the foundation, vertical cracks had to appear on the walls. The developing various vertical cracks would cause the walls be out of stability and collapse.

Horizontal cracks were usually caused by bending or shearing damage. Owing to the out—plane inertial force of a wall with wider span between the transverse walls could not be fully transmitted to the transverse wall, so the longitudinal wall became bend, the horizontal cracks usually concentrated along up or down edges on the window openings, or on the spandrels. Under the shear action of the horizontal inertial force of a floor slab against a wall, the horizontal through cracks would be caused on the level at reinforced concrete floor slabs or beam bottom. Appearing of horizontal cracks on brick wall made itself lose the shear resisting capacity.

After the bearing walls of a brick building got cracks, the continuous action of the repeated—seismic force would rapidly make the cracked walls displace, slide away or collapse; in result, the roof would fall down, and brick building would be thoroughly collapsed.

<u>Function of Tied Concrete Columns</u> According to the custom prevailing in Tangshan, most of the houses were fitted with tied concrete grids to enhance the integrity of the houses in face of the strong shock, the wall of the brick house first exhibited X—shaped principal tensile stress cracks and under the effect of repeated shock, the wall which had been separated into four parts could be seen to slump, displace, be smashed and collapse, the grid failed to perform its function of controlling the slumping, faulting of the already cracked wall, the reinforced concrete beam—column systems of the houses with inner frame structures were different from the outside load—bearing walls in rigidity and ductility. Usually, the cross walls with high rigidity and low ductlity showed shear failure due to principal tensile stress while the longitudinal walls showed curved throughcracks in the horizontal direction. The weakest point of a house with inside frame structure laid on the failure of the outside load—bearing walls, the grid was unable to prevent the wall from failure. As for a house with spacious rooms, the longitudinal walls tended, under the bending effect, to crack and break off due to the large area of the wall and due to the fact that its bending strength was much lower than its shear strength. This resulted in the collapse of the whole house. The larger the height—width ratio, the more harmful it was to the house. The broad spacing of the grid could only exert poor constraint over the walls, leading to their failure and collapse. If the grid was cut short by smoke flue and vent, lack of reinforcement or insuffricent in overlapping lengths, it would be more unfavourable to the shockproof characteristics of the house.

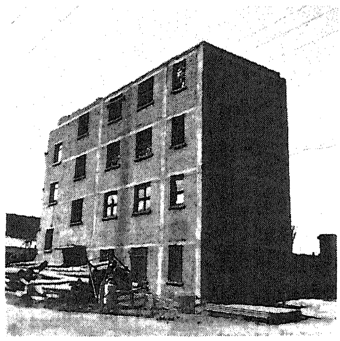
After the earthquake, we could see a lot of broken tied concrete grids in the shape of necklaces on the site. It proved that the grids were unable to prevent the walls from shear cracking, slumping, faulting, be smashed and collapse. Thus the collapse of the houses was unavoidable (see Fig. 1) .

As seen from the numerous damaged houses, the tied concrete columns demonstrated great vitality. In combination with the reinforced concrete grids, they could improve the shockproof properties of the walls. During violent earthquake, the houses, though cracked, could still stand firm on the ground. Thus, loss was reduced and people' s lives saved.

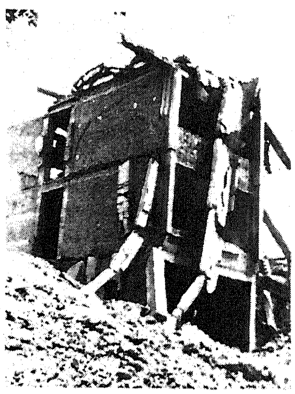
Tied concrete columns on houses in mixed structure were installed with an aim to enhance the bearing capacity of the brick walls. After the Haicheng earthquake which took place in 1975, a small number of tied concrete columns were fitted to strengthen the relatively weak walls. These columns played important role during the severe earthquake.

Tied concrete columns, being securely attached to the grids and girders running in two directions, and rationally attached to the transverse and longitudinal walls with careful construction, could produce good effect. They could prevent a three-storeyed house in brick-concrete structure(see Fig. 4), an eight-storeyed house with inside frame structure (see Fig. 7)and a spacious house in brick load-bearing structure from collapse in presence of serious cracks. However, on plane and facade the partial and discontinuous tied concrete columns were ineffective on seismic resistance of the houses (see Fig 2, 3).

(Fig.1) Broken R.C. grids in the shape of necklaces on the site.



(Fig.3) Tied concrete columns were on seismc resistance, only on half a plan.



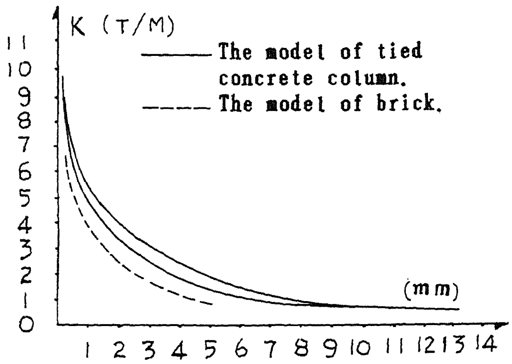
(Fig.2) Partially provided tied concrete columns were ineffective on seismic resistance of the house.

(Fig.4) Uniformly and continuously provided tied concrete columns could prevent a brick house from collapse.

(Fig.5)The base storey of whole uniform tied concrete columns, after earthquake.

(Fig.6)The storey of discontinuous tied concrete columns were ineffective for seismic resistance of the houses.

(Fig.7) The continuous tied concrete columns with inside frame structure, could produce good effect.



(Fig.8) K--△

The tied concrete columns in the vertical constituted the rims with the horizontal grids, enclosing the walls, thus improved the shockproof characteriatic running in two directions. Horizontal grids and girders could slso constituted the rims surrounding the floor slabs, thus improving their integrity. The shear strength of the brick masonry and the effect of the rims were not brought into full play at the same period. During the elastic stage, the elastic force was mainly borne by the brick masonry. It was only after the elasticity of the brick masonry failed and the integrity was weakened that the rims began to play their roles. The tied concrete columns and the grids were under the effect of a combination of forces, i. e. , tension, compression, shear and bend. It was noteworthy that at the juncture of tied columns and grids articulation of plastic nature were generally formed. Oblique cracks and horizontal cracks mostly concentrated at the juncture position. The walls near juncture position were subject to shear or got smashed. The larger the area of this part, the more serious were the cracks at the ends of the grids and columns. Therefore, the connections between the tied columns and the grids were of great importance(see Fig.5, 6).

Rational installation of uniform continuous tied concrete columns and grids might improve the integrity and ductility of the houses in mixed structures, the load-bearing capacity and lateral resisting strength of walls. It was considered as one of the best approaches of ensuring the houses in magistoseismic area not to collapse in presence of serious cracks.

RESEARCH OUTCOME ANALYSIS

Variations of Rigidity Taking the seismic failure mechanism of a brick building as an example, the shear−type vibration is the main cause. If tied concrete columns are added, the rigidity of the building will become stronger and never weaker. such result has been confirmed by three model experiments(Fig. 8).

Variations of Strength the contrast experiments of models show clearly that load−bearing capacity can be increased by 54−58 per cent if there are tied concrete columns in the building, the initial cracking load can be raised by 20−57 per cent. But lateral resisting capacity is the most important element when the wall is in the elastic stage.

Formulas:

$$Q_p=\frac{R_\tau A}{\xi}+0.07R_hA_h+a_1A_g'R_g \quad \text{------ (1)}$$

where R_τ is shearing strength of masonry. A is section area of brick masonry. ξ is uneven coefficent of shear stress. R_h is axial compressive standard strength of concrete. A_h is section area of tied columns. a_1 is shearing strength influence coefficient of bars. A_g is total area of tensile and compressive bars in tied column, R_g is design tensile strength of hoop bars.

$$Q_p=\frac{R_jA}{\xi}+0.8f\sigma_0A+\beta\left(\frac{2A_gR_gb_0}{H}+\frac{0.5R_abb_0^2}{H}\right) \quad \text{------ (2)}$$

| Where R_j is shearing strength of masonry. f is friction coefficient. $2A_g$ is section area of tensile reinforcement in columns, 2 for symmetric columns. bb_0 is width of column side and spacing of bars in tied column. H is height of wall. β is loading influence coefficent on tied columns and wall 1.4.

$$(Q_p)_{ij}=0.5(\sigma_0)_{ij}A_{ij}+0.056(R_a)_{ij}b_{ij}(h_0)_{ij}+1.2(R_g)_{ij}\frac{(A_K)_{ij}}{S_{ij}}(h_0)_{ij} \quad \text{------ (3)}$$

Where f is sliding friction coefficient between brick masonrys, 0.6. $(\sigma_0)_{ij}$ is normal compressive stress. A_{ij} is shearing section area of brick masonry. $(R_a)_{ij}$ is compressive strength of tied column concrete. b_{ij} is width of tied column. $(h_0)_{ij}$ is effective height of tied column section. $(A_K)_{ij}$ is total leg area of hoop bars assembled in same section in tied column end. S_{ij} is spacing of hoop bars in tied column end. $(R_g)_{ij}$ is design tensile strength of hoop bars.

These three formulas are check formulas for the walls with tied columns. Table 1 shows the results obtained by experiments on walls with or without columns.

Table 1

Experimental unit	Shearing strength per cent raised
Beijing Architectural Designing Institute	10%
Dalian Engineering Institute	5−20%
Harbin Institute of Engineering Mechanics	10-13%

Table 2

Experimental Content	$\mu=\frac{\Delta u}{\Delta y}$	Remarks
Single wall without tied columns	1	
Single wall with tied columns	3.24−3.84	
Model without tied columns	1.81	81% increase over a single wall
Model with tied columns	3−4	1.9−2.18 times over a model without column

Variations of Ductility If tied concrete columns are placed in a brick wall, the deformation capacity of the wall will be raised(See Table 2), making the brick building get a change from a lower ductile structure to a general ductile structure with a ductility coefficient 4. Therefore the anti-collapse capacity of a building is raised.

SUGGESTION

The Tangshan killer earthquake levelled almost the whole brick buildings in the city. A bitter lesson has been obtained that Tangshan people and their property suffered heavy losses, It compels people to consider that the people's security should be first guaranteed, then the aseismic defence standard is economically required. The double defence criterion is "No damage by a little tremor, no collapse by a violent tremor". That is to say, the brick building should be ensured to be in the good position when it is subject to an intensity corresponding to a design one; the building can stand a tremor with an intensity of 1—2 degrees higher than a design one when it is subject to an unexpected violent earthquake.

Suggestions for buildings with tied concrete columns are as follows:

1. Tied concrete columns for a brick building should be evenly distributed in a plan and provided continuously along stories of the building so as to link them well with concrete grids;
2. placing tied concrete columns in a building can raise 10 percent of shearing strength so as to be as safety reserve, not be used as controlling strength;
3. Height restrictions of a brick building without tied concrete column can be seen in Table 3, as a method of controlling both its height and stories.

Table 3 Height Restrictions (metre)

Walling	design Intensity (degree)		
	7 (story)	8 (story)	9 (story)
Solid walls with a thickness 24 cm or more than 24cm	19 (6)	16 (5)	13 (4)

Only by realizing correctly and placing resonably tied concrete columns, and by designing and working carefully can a brick building be ensured "no damage by a litte tremor, no collapse by a violent tremor", and can the people's lives and property be guaranteed.

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