

## **Mortar Replacement Reinforcement Method for Existing Masonry Structures**

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**Abstract** For load-bearing capacity reducing of the walls of multi-storey masonry structure caused by the lower mortar strength and quality defects, the mortar replacement method was used to reinforce the perforated brick load-bearing walls. The strength of mortar used for replacing, the depth of replacement, construction methods and quality control have been studied. The reliability of this method is verified by testing in situ including axial compression test and double brick double-shear test for reinforced brick masonry. This method could be also used in reinforcement for the historical masonry buildings.

**Keywords:** Masonry structure, reinforcement, mortar replacement

### **Introduction**

Fig.1 shows the site plan of residential buildings, in which #1, #2, #5 and #21 buildings are six-storey masonry structures with the height of 19.927 m, and #3, #4, #6, #7 and #8 buildings are four-storey masonry structures with the height of 14.327m.

According to the design, the masonry bearing walls with thickness of 240mm below the indoor ground level of all the nine houses are constructed with MU15 solid clay bricks and Mb10 cement mortar. The bearing walls of floor 1 to 3 are constructed with MU10.0 perforated bricks and M10.0 mixed mortar and the bearing walls of floor 4 to 6 are constructed with MU10.0 perforated bricks and M7.5 mixed mortar.

The detection report submitted by Housing Quality Detection Station of Tongji University shows that the quality of masonry bearing walls below the indoor ground level is good enough and there are many quality defects for the bearing walls constructed with perforated bricks and mixed mortar in these buildings. The main defects are that the masonry mortar is unconsolidated, cement content ratio is low, the strength of the mortar is too low and even to be zero, and the mortar in the brick joints even could be dig out with fingers. The brick strength grade of some walls is lower than the design strength grade (Housing Quality Detection Station of Tongji University “Housing Quality Detection Report (2009)).

In order to ensure the compression and shear capacity of the masonry bearing walls, the walls of all the buildings must be reinforced properly and effectively from the indoor ground level to the roof level.

### **Mortar Replacement Reinforcement Method**

**Mortar Replacement** The design strength grade of perforated brick is MU10.0 and the design strength grade of mixed mortar is M10.0. According to masonry computing indices in Code for Design of Masonry Structures (GB50003-2001), the masonry design compressive strength is 1.89MPa. So the minimum compressive strength of the reinforced wall tested in-situ should be 3.02MPa in accordance with conversion relation between the design values and the standard values. (Building Engineering Code of China. “Technical Specification for the Porous Brick Masonry Structure”)(National Standard of China. “Code for Design of Masonry Structure”)

Normally, enlarging the section of wall with other structural materials such concrete or mortar could be used to improve the compression and shear capacity. Thus will lead to reduce the indoor

usable floor area, and it is complicated to pass the rebar (or wire mesh) through floors along the walls. Also considering that the main reason resulting in deficiency of compression and shear capacity of the masonry bearing walls is its unconsolidated and lower strength in this project, therefore it is considered to reinforce the masonry walls by replacing the mortar in brick joints.

Mortar replacement consists of two processes, eliminating all or part of the original low strength mortar and pouring the high strength mortar into brick joint. The keys of this method are defining the strength grade of pouring mortar, mortar replacement depth, construction method of mortar replacement and quality control.

According to the preliminary calculation, the mortar replacement depth shouldn't be less than 80mm (more than one third of the thickness of the masonry wall), and the strength grade of the new placed mortar should be M12.0 at least.

Based on the engineering conditions, the double-side mortar replacement was used for interior walls and the single-side mortar replacement for the outer walls, which could avoid destroying original facades, the waterproof and insulating layer of the outer wall. The construction details of mortar replacement for the masonry walls are showed in Fig.2.

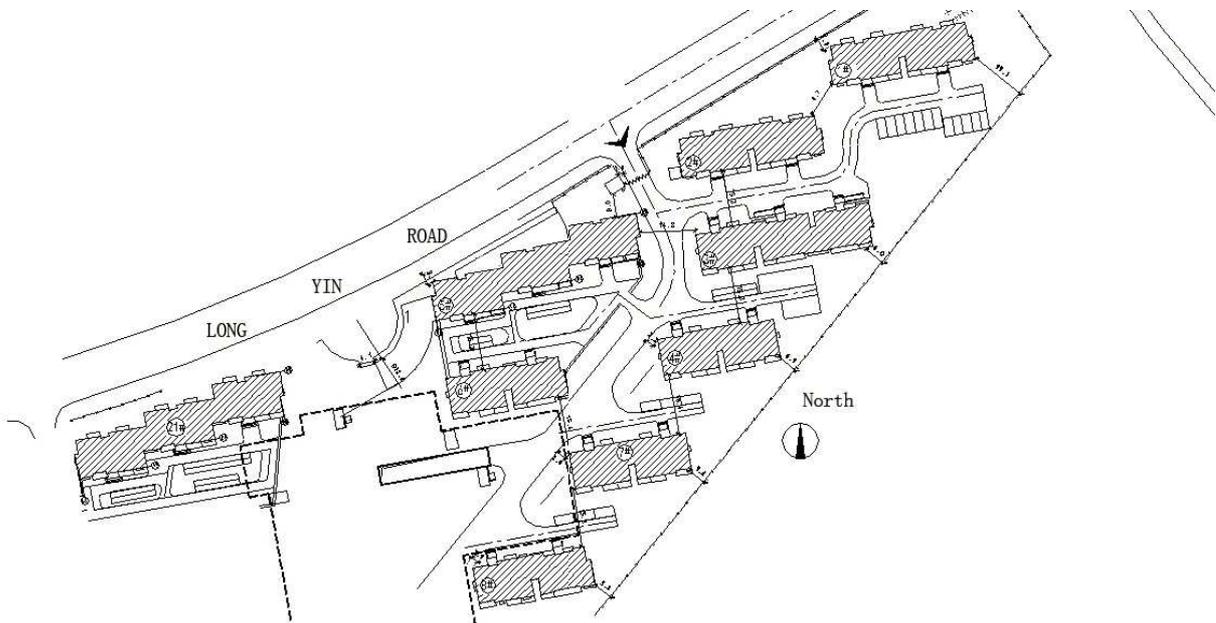


Figure 1: Site plan

Table 1: The main quality defects of the buildings

main quality defects	building No.								
	1#	2#	3#	4#	5#	6#	7#	8#	21#
masonry mortar is unconsolidated, cement content is low, the strength of the mortar is very low	√	√	√	√	√	√	√	√	√
brick actual strength grade(MU7.5) is lower than the design strength grade (MU10.0)	—	√	—	—	—	√	√	—	—

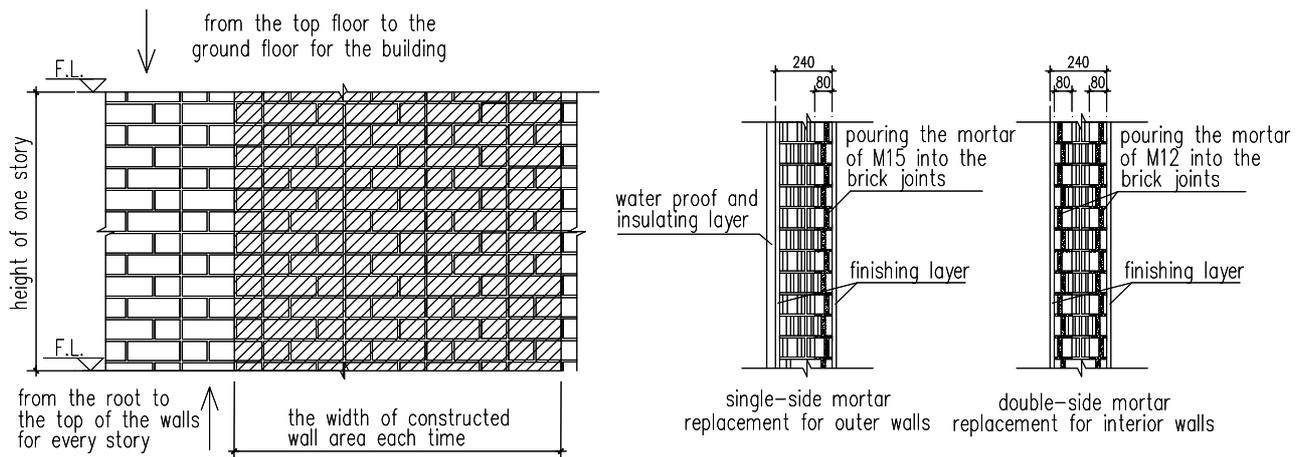


Figure 2: The construction details of mortar replacement for the masonry walls

### Test In-Situ

**Test Purposes** Owing to the lack of relevant calculation theory, formulas and detected data, the reliability of using mortar replacement method to improve the compression capacity and shear resisting capacity of masonry wall built with perforated bricks and mixed masonry is not approved. So it is necessary to do some tests for determining whether the mortar replacement could achieve original design or not.

**Test Method** Twenty-one pieces of wall built with perforated bricks and mixed masonry have been chosen for testing mortar replacement reinforcement construction, as shown in fig.3 and fig.4.

17 groups of axial compressive tests in-situ and 4 groups of double-brick double-shear tests in-situ have been done according to the wall positions (interior walls or outer walls) and different ways of mortar replacement (double-side replacement or single-side replacement) after the mortar age.

In axial compressive tests, there were 12 groups for double-side replacement walls and 5 for single-side replacement walls. In double-brick double-shear tests, there are 3 groups for double-side replacement walls and 1 for single-side replacement wall.

**Test Results** The test results showed that the standard compression strength of the tested masonry walls reinforced by using double-side mortar replacement were between 3.11~4.46MPa, the mean value was 4.15MPa, thus its design value was 2.22MPa. The standard compression strength of tested masonry walls reinforced by using single-side mortar replacement were between 3.97~4.39MPa, the mean value was 4.25MPa, thus its design value was 2.20MPa. No matter the wall reinforced by using double-side mortar replacement or single-side mortar replacement, the standard shear resisting strength of the test walls were all great than 0.16MPa (Housing Quality Detection Station of Shanghai Building Science and Research Institute. "Report on In-situ Testing of Reinforced Walls (2009)). All these values met the original design requires of the buildings.

The high strength of the new placed mortar and the good construction quality increased the bearing capacity of the reinforced masonry walls. In the other hand, it could be observed that the holes of the original perforated bricks were almost empty and with no mortar in them, as shown in fig.5, but the new high strength cement mortar filled in the side holes of the porous brick after the mortar replacement and formed a row of mortar pins which worked together with the perforated bricks, as shown in fig.6.



*Figure 3: The wall before mortar replacement (no mortar in the brick holes)*



*Figure 4: The wall after mortar replacement (brick holes is full of mortar)*



*Figure.5: bearing strength test in situ after mortar replacement*



*Figure 6: shear strength test in situ after mortar replacement*

### Construction Scheme

**Construction Method** At first chip away the finishing layer of the original walls, eliminate the original low strength mixed mortar and the depth of eliminated mortar should not be less than 80 mm, then rinse and brush the brick joints, and use cement slurry as a binder, finally fill the brick joints with high-strength cement mortar.

For the double-side mortar replacement walls, the strengthening operation should be carried out on one side of the wall first, and then construct on another side.

The width of constructed wall area each time should not be more than 1.5 m and the height of constructed wall area each time should not be more than the story height. For the wall which width is less than 1.5 m, the width of constructed wall area each time should not be more than the half of the width of the wall.

The mortar replacement construction should be executed from the top floor to the ground floor and mortar should be replaced from the root to the top of the walls in every story.

**Strength Grade of Mortar** The strength grade of the new placed cement mortar for double-side mortar replaced wall is M12.0. The strength grade of the new placed cement mortar for single-side mortar replaced wall is M15.0.

**Construction Requirements** All construction personnel should be trained specially before practical operation in site.

Special construction tools should be used and the mortar replacement depth must be not less than 80mm.

The original mortar in the side holes of the perforated bricks must be removed completely.

The high strength cement mortar should be poured into the joints from the bottom of one brick and the operating should not stop until the mortar overflow from the top of the brick holes.

The loose bricks should be fixed by wooden wedge before mortar replacing.

The mortar dropped down the ground is forbidden to be used again.

**The Quality Control and Detection Requirements** The mortar replacement construction must be carried out by a qualified company and the quality of the construction must be controlled strictly in site by a supervision company.

After mortar replacement construction and the mortar age, the sampling inspection including in-situ testing the compression strength and the shear strength of the reinforced masonry walls should be done. The compression strength of the strengthened walls must be not less than 3.02MPa.

## Conclusions

The mortar replacement reinforcement could improve the performances of the masonry structures and increase its compression and shear capacity.

The keys to mortar replacement reinforcement method are the strength of the newly placed cement mortar, the mortar replacement depth and the construction quality control.

This method could be also used in reinforcement for the historical masonry buildings.

## References

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