Rain Penetration Performance Of Mortarless Interlocking Blockwork Walls

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Summary: This paper describes the observations on a rain penetration test on walls built from interlocking blocks. The test was conducted on four walls: three built from plain concrete interlocking units that were unplastered, plastered on internal face only, and plastered on both internal and external faces, respectively. The forth wall, unplastered, used block units from concrete with water proofing admixture. The results of tests on the unplastered and the internally plastered walls from plain concrete units showed very poor resistance to water penetration. Proper plastering on the external face of the wall provided acceptable rain penetration resistance. The wall from water proofed units provided better resistance to water penetration by absorption. Nevertheless, water penetration through the mortarless joints was still of concern.

Keywords. Block, blockwork, mortarless, interlocking, rain penetration.

1 INTRODUCTION

The system of utilising load-bearing interlocking mortarless blockwork in construction is not uncommon in the United States and Europe. Some of the popular brands of interlocking block units found in those countries are Haener, McGibbs and Sinustat. A number of housing projects in the Philippines and Thailand were found to use the system. Basically, the system used interlocking concrete block units that were laid dry without any mortar for bedding and jointing. The interlocking features were made either at bed joints (horizontal joints) or header joints (vertical joints) or both.

The system was first introduced to Malaysia in the 80’s as a prospective answer to the growing demand on low-cost housing. Initial work was to find a simple and cheap D.I.Y. (do-it-yourself) method of construction (Wardi 1987). Although the interlocking block unit costs more than the conventional block unit, the construction of the former saved time and labor which resulted in overall saving. Despite that, developers were skeptical to invest in the system and as a result only few units of such houses have been built. The use of the system in building construction in this country seemed to never get off the ground. There were several factors that led to this, among others were:

- Lacking of knowledge or experience amongst engineers on the design of load-bearing masonry structures.
- No standard design procedures and guidelines were available.
- Structural and serviceability performances of the system were uncertain. Developers and builders were not willing to invest in R&D works on the system.
- Model units built were limited to single-storey building only and the performance of these units have not been convincing. A case of a pilot project based on Wardi’s (1987) concept failed due to improper foundation design seems to have put developers and builders off.

Recently, interests in the system have been rejuvenated inspired by the American experience. Several studies (Azzam et al 1993, Maju 1994) on the system were carried out to ascertain the viability of using such system to suit the local climatic and social environments. One of the initiatives was by Maju Holdings (1994) whose immediate interest was to look into the possibility of utilizing the interlocking system for the construction of buildings up to 5-stories high. The company tested the interlocking block units and walls to study the structural performances, fire ratings, resistance to rain penetration, build-ability and others. The block units, called the ‘Maju Blocks’ were specially manufactured and shipped from the United States. These units were smaller and lighter as opposed to the US specifications in order to suit handling by local workers. Earlier tests
carried out showed that the system attained the required structural capability for the construction of buildings up to five stories high (Abdullah et al 1995). The rain simulation test described in this paper was part of the study carried out for Maju Holdings.

2 FUNCTIONAL REQUIREMENTS OF INTERLOCKING BLOCK UNITS

The design of interlocking block units must achieve several qualities that include (Maju 1994):

- axial load-bearing capacity
- efficient transfer of axial loads
- interlocking aid to alignment
- waterproofing at joints
- continuity of cores for grout filling
- good keying to provide nominal lateral shear resistance
- tolerances to maintain wall alignment
- simplicity of form for manufacturing
- suitable size for handling and ease of construction.

3 WATER PENETRATION THROUGH MASONRY WALLS

Water penetration is responsible for many of the problems encountered in masonry construction (Ritchie 1952). Moisturized walls subjected to freezing and thawing that may cause cracking, crazing, spalling and disintegration. Water can cause masonry to experience numerous effects such as shrinkage, corrosion of steel reinforcements and other metals built in the walls, loss of effectiveness in insulation, deterioration of the interior finishes, efflorescence and fungi growth, dampness and other problems.

3.1 The mechanism of rain penetration (Waldum 1995)

Water at the wall surface can penetrate the wall by several means including capillary action, gravitational flow, kinetic energy as well as water flow. When rainwater hits a masonry wall surface, the water that wetted the wall is first sucked into the wall material. If the rain continues faster than the suction, the water starts to run down the wall, forming a film of water, which is thicker on the lower part of a building than the upper part. This film of water forms a bridge over the unavoidable small cracks in the masonry wall. Wind acting on the wall forms a pressure difference over the wall. By this pressure, the water is forced into the wall. Rain penetration occurs in cracks between 0.1 and 5mm wide. The wind pressure is added to capillary suction. The latter seems to be important for openings smaller than 0.5mm.

With water-filled pores, a slight pressure difference is sufficient to make the water discernible on the inside of the wall. Factors that affect rain penetration are the properties of the wall materials, the amount of water hitting the wall, and wind pressure over the wall. The intensity of driving rain on a given surface determines whether a water film will be formed and the thickness of that film. The amount of water striking the wall during a longer period determines, in certain cases, the amount of water collected in the wall. Wind pressure is dependent of the velocity of the wind, the orientation, shape, height and exposure condition of the building.

3.2 Rain penetration on mortarless masonry

Rain penetration takes place in two ways: firstly, water absorption through the units and secondly, water seepage through the joints. The former problem can be overcome through proper material design such as using high density concrete, use of water repelling admixtures, brushing the wall with water repellent paint or solution and plastering the external face of the wall. The latter problem is the main concern with mortarless interlocking masonry. The mechanism of water penetration through the mortarless joints would be expected to be similar as for penetration through cracks found in the traditional masonry wall. For conventional masonry, the water penetration resistance is provided by the mortar joints. As for the mortarless masonry system, the design of the interlocking features is important in terms of rain penetration as well as fulfilling its other functional requirements stated earlier. It has been difficult to design interlocking features that provide good rain penetration resistance without affecting the other requirements.

Several methods have been found suitable to overcome the problem of rain penetration in mortarless masonry. In the U.S. the 'dry-stack' system and the surface bonded system are used. In the former system, the grouting of all cores stipulated as a standard construction procedure provides the water penetration resistance, while the latter system requires plastering on both wall faces with a strong mortar laced with chopped fiberglass for strength to provide the necessary water-tightness (ASTM 1991). Special premixed mortar products for this purpose are readily available on the US market. For a single-storey building, a longer roof eave construction had proven successful in protecting the walls from direct splash and long hours of rain as shown by a model house (Wardi 1987).
4 EXPERIMENTAL DETAILS

It should be pointed out that, the block units in this study were design and manufactured with the external stretcher face ‘finished’ without requiring any external plastering. This was to keep the cost of construction down as external plastering would incur about 20% additional cost on the wall construction. However, when preliminary tests indicated poor water penetration resistance, cheap alternatives to provide water penetration have to be looked into.

The objective of the tests was to evaluate the rain penetration performance of the interlocking blockwall system using a simple, cheap and commonly practiced construction method. Tests were conducted with the following purposes:

- To evaluate the effectiveness of the interlocking block construction against water penetration.
- To study the effect of plastering on water penetration: (i) internal plastering only, (ii) plaster both internal and external faces.
- To evaluate the performance in terms of water penetration, using the block with water proofing admixture.

4.1 Block units

Two types of block units were used; the stretcher and corner units for external walls. The stretcher unit had interlocking features at top (tongue) and bottom (groove) of the bed faces and on both of its header faces. The corner unit had similar horizontal tongue and groove features as the stretcher unit but with only one of the header face having vertical interlocking features. The vertical interlocking feature (tongue and groove feature running in the vertical direction) was made on the internal side of the stretcher faces. The features of the units are shown in Figure 1. In addition, two different types of mix were used in the manufacturing of the units: (i) plain concrete and (ii) concrete with water proofing admixtures. The block properties are given in Table 1.

<table>
<thead>
<tr>
<th>Table 1. Properties of block units</th>
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<td>Block Type</td>
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<td>Properties</td>
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4.2 Test walls

Test walls were constructed at an open area exposed to the ambient temperature and humidity. The walls comprised four corner (L-shaped) walls of about 1.2m by 1.2m, 1.5m high. A normal lime mortar mix with 12mm thickness was used. The construction details of the test walls are given in Table 2.

<table>
<thead>
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<th>Table 2. Test Wall Details</th>
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<td>Designation</td>
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<td>Wall 1</td>
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<td>Wall 3</td>
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<td>Wall 4</td>
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4.3 Test procedures

The test method followed a non-standard procedure simplified from procedures given in ASTM E514 (1985). Using a simple water jet set up, the corner of the test walls were sprayed at about 45° in the vertical plane and at a discharge rate of about 2.8 l/min to roughly simulate the average wind driven rain intensity on exposed wall. The walls’ rain penetration performance was evaluated through visual observation. Photo shots were taken up to 90 minutes at 5 minutes intervals. Figure 2 shows a typical test wall setup.
5 RESULTS

5.1 Unplastered wall (plain concrete units)

Figures 3(a-c) show the observations on the internal face of the unplastered mortarless wall built from plain concrete interlocking block units. Damp patches started to develop after about 2 minutes of spraying and became more substantial after 5 minutes. After 30 minutes, almost the whole wall face was covered with damp patches. During the early stage, the damp patches came from the water that seeps through both the vertical and horizontal (bed) joints. Water seepage through the joints intensified causing the damp patches to spread over the wall face when exposed further to water spraying. Water penetration also came from the absorption through the block but at a much slower rate as compared to water penetration through the joints.

Figure 3(b) illustrates that the moisture stains always start where the vertical joint intersects the lower horizontal joint. The vertical joints clearly perform worse than the horizontal joints. This indicates that the interlocking feature at the vertical joint was not as effective as at the horizontal joint. The size the gap at the horizontal joint was much smaller (tighter) due to the block self weight. Water from the external face of the wall seeped through the vertical joint and accumulated at the bottom horizontal joint through gravity.

Block units from concrete with waterproofing admixture which had a lower water absorption provided good resistance to water penetration. This was evident from the corner half-block units, which were not dampened as shown in Figure 3(c). The condition of the plain concrete unit and the admixture concrete unit after been exposed to water spraying is shown in Figures 4(a & b).

5.2 Wall plastered on internal face (plain concrete units)

Test observations on mortarless block wall internal plastering are shown in Figures 5(a-f). Internal plastering only seemed to delay the water penetration. The damp stains started to be visible after about 5 minutes of test. The extent of the damp stains at 60 minutes was about the same level of that for Wall 1 at 30 minutes. Water penetration came mostly through the joints. The damp patterns are quite similar to that of Wall 1.

5.3 Wall plastered on both faces (plain concrete units)

Observations on mortarless block wall plastered on both the internal and external faces being subjected to water spray are shown in Figures 6(a-d). The test showed that plastering on the external face of the block walls effectively resisted water from penetrating through the wall. The vertical damp stain observed was due to over-sprayed water that flowed down from top of the wall. Further examination on the wall section showed that water from outside penetrated through the plaster thickness only and did not affect the block unit (see Figure 6(d)).

5.4 Unplastered wall from blocks with admixture

The results of the rain simulation test on the wall constructed using blocks of concrete with waterproofing admixture are shown in Figures 7(a-f). No wet spot was detected for the first 30 minutes of test. After that period, only three isolated wet spots developed at the horizontal joint of the corner units. These wet spots propagated slowly along the bed joint up to a maximum of about 150 mm long. Further examination shows that at the joint, only the surface of the outer shell was affected (Figure 7(e)). Unabsorbed water that seeped through the joints only managed to move half way through the block web and then drained down the sides of the core. Within the test period, the water spray had only wet the skin of the block units and was not absorbed into the block mass. The wet spots that developed at the corner blocks were due to water moving in through the vertical joints (Figure 7(f)).

6 CONCLUSIONS

1. The interlocking features for the block units under investigation did not provide a satisfactory resistance to rain penetration. The moisture stains start at the intersection between the vertical joint and the lower horizontal joint. The penetration was worse at the vertical joints than the horizontal joints.

2. The addition of water proofing agent in the block making which decreased the water absorptiveness of the concrete block, consequently, improved the rain penetration resistance of the wall. Nevertheless, rain still penetrated the blockwork through the mortarless joints.

3. Proper plastering on the external face of the mortarless blockwork provided the necessary rain penetration resistance. Proper design and construction details as that for conventional masonry to drain off water collected at the bottom of the wall should be looked into.

7 REFERENCES

6. Ritchie, T. 1952, Some aspects of the problem of moisture penetration of brick masonry, Publication no. BRN-12, Masonry Society, USA.

Figure 1. Details of the block units
Figure 2. The test arrangement

(a) After 5 mins. spraying  (b) After 10 mins. spraying  (c) After 30 mins. spraying

Figure 3. Results of test wall 1 (unplastered wall)

Unit from concrete with water proofing admixtures
Figure 4. Water penetration through the block units

(a) Plain Concrete Unit  
(b) Unit From Concrete with Admixtures

(a) After 5 mins. Spraying  
(b) After 10 mins. spraying

(c) After 15 mins. Spraying  
(d) After 20 mins. spraying
(e) After 30 mins. Spraying

(f) After 60 mins. spraying

**Figure 5.** Observations on test wall 3 (plastered on internal face only)

(a) After 5 mins. spraying

(b) After 60 mins. spraying

(c) After 90 mins. spraying

(d) Conditions of Unit and Internal Plaster

**Figure 6.** Observations on test wall 4 (plastered on both faces)
Figure 7. Observations on test wall 5 (unplastered wall from units with water proofing admixture)