The Effect of Mortar Joints on the Permeance of Masonry Walls

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THE EFFECTS OF MORTAR JOINTS ON THE PERMEANCE OF MASONRY WALLS

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ABSTRACT

The masonry industry recommends a 10mm thick concave mortar joint to yield the most watertight masonry wall. An extensive review of literature on the subject revealed that, there is no experimental substantiation of this recommendation. This paper is abstracted from the first author's thesis that was prepared in partial fulfillment for the degree of Master of Architecture at the University of Texas at Arlington. The results presented were obtained from the measurement of water penetration through walls using different joint profiles. The tested profiles were concave joint, weather joint, vee joint, and the raked joint. The tests were conducted, as per ASTM E 514-86, on single wythe clay brick walls, 75mm thickness.

INTRODUCTION

The permeance of masonry walls to wind driven rain is affected by several parameters(1). (i) the type and quality of masonry units, (ii) the type of mortar, (iii) the compatibility of units and mortar, (iv) the extent and type of curing of the wall, (v) the profile of mortar joints and joint thickness, and (vi) the workmanship. This paper presents the result of study which examines the effect of mortar joint profiles on a masonry wall's resistance to water penetration.

Four mortar joint profiles are commonly employed in contemporary masonry construction; concave joint, weather joint, vee joint, and the raked joint, Figure 1.

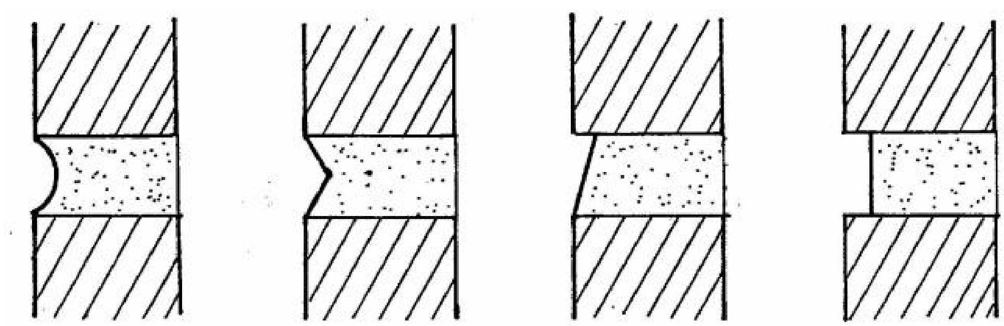

Figure 1 Joint Profiles

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The joint profile quoted as the most water resistant by masonry codes and standards is the tooled concave joint. It is this joint profile that is commonly used in external masonry cladding of present day buildings, in spite of the fact it is not the most appealing profile m aesthetic terms. An extensive search and review of published literature on the subject revealed to the authors that the recommendation for the concave joint is not based on any experimental investigation but on personal opinions and experience. Some masonry experts believe that the joint profile has little or no effect on the permeance of walls(1) (2).

In view of the unsubstantiated nature of recommendations contained in codes and standards, a decision was made to conduct experimental investigation of the permeance of masonry walls with different joint profiles. Testing was performed during the summer of 1990 at the School of Architecture, University of Texas at Arlington, using the laboratory facilities of the University's Construction Research Center.

SCOPE OF INVESTIGATION

A total of 24 clay brick masonry walls were tested. Each wall measured nearly 1.02 m wide and 1.40 m high. Six walls were constructed for each of the four joint profiles, three walls with a joint thickness of 10 mm and the other three with a thickness of 20 mm. To simulate actual construction practice for masonry cladding, the walls were of single wythe, 75 mm thickness. The bricks measured approximately 250 mm in length and two and 65 mm high. The mortar used was type 'S' Portland cement-lime mortar, formulated using the proportion specification as per ASTM C 270-79(3) (with the composition of one (1) part Portland cement; one-half (1/2) part lime, and three (3) parts mason's sand).

The water permeance of walls was evaluated using equipment, procedures and other guidelines contained in ASTM E 514-86: Standard Test Method for Water Penetration and Leakage through Masonry(4). Other test methods were examined and evaluated for possible use, particularly BS 4315: British Standard Method of Testing for Resistance to Air and Water Penetration, but in view of the available facilities and other considerations, it was decided to use ASTM E 514-86. Tests were conducted on walls fourteen (14) days and twenty-eight (28) days of age. The walls were not preconditioned with water before the tests.

CONSTRUCTION OF TEST WALLS

Since the objective of this investigation was to examine the effect of joint profile on masonry's permeance, other parameters were tightly controlled, as far as practical, to ensure no variation. Clay bricks were taken from one manufacturer. To ensure as small a variation as possible between the initial rates of absorption, IRA, of bricks, a check was made on their IRA values. The IRA tests were conducted in the laboratory using three randomly selected units from each of the seven (7) bundles of bricks used for the project. Due to the rather high IRA values obtained and a wide variation in them, the bricks were fogged 24 hours before installation, and the IRA re-measured, Figure 2.

The mortar was mixed in a mixer by first introducing half the required quantity of water in the mixer followed by half the required sand. This was allowed to mix for two minutes.

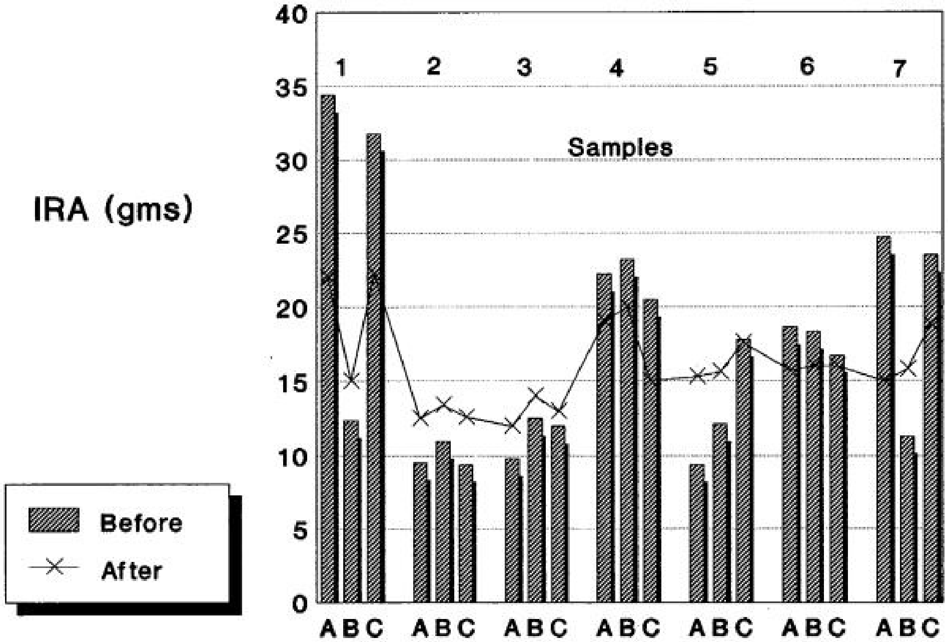

Figure 2 Comparison of IRA values before and after applying water fog.

Added next were Portland cement and the remaining quantity batch mixed for additional three minutes. The remaining sand was added and allowed to mix four minutes. Initial flow tests were conducted and if additional water was required, the batch was mixed for an additional 1-1/2 minutes. Additionally, in order to allow for actual construction practice, re-tempering of mortar was permitted. The entire mortar from a given batch was used in 45 to 60 minutes.

All 24 walls were constructed by two professional masons provided by a local masonry contractor. To minimize variation in their workmanship, the walls were built within wood frames specially prepared for the purpose. In addition, the masons were briefed as to the purpose of the construction and the importance of achieving a measure of uniformity in workmanship. All walls were constructed and tested in an open yard, Figure 3.

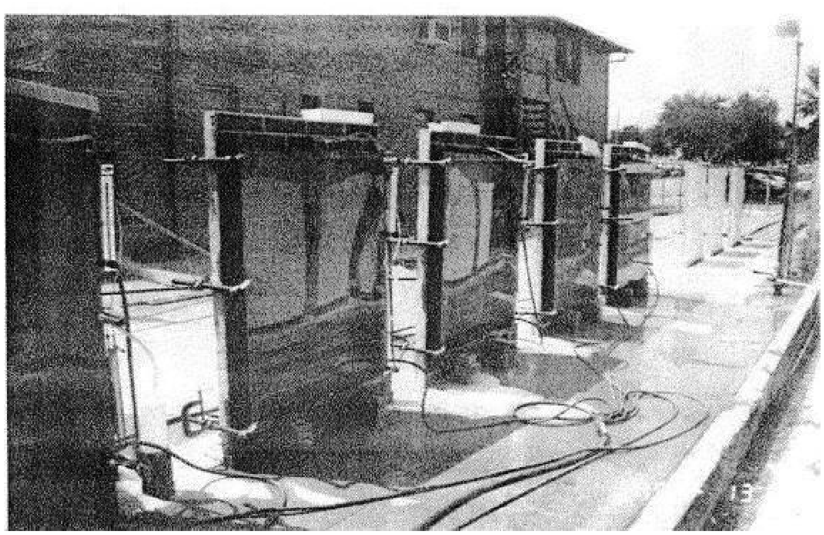

Figure 3 Testing yard with panels and equipment in place

Masonry units were placed in full bed amd head joints. Metal flashing bent into a trough was placed in the bed joint of the second course for the entire length of the wall. The trough was used to collect water that would run down the back of the wall after generation. Joints in the front face were tooled and profiled; the joints in the back face were flush cut. To conform with the requirements of the testing standard, the top and sides of each wall was faced with 10mm thick parsing. After each wall was constructed, it was wrapped with .15mm thick polyethylene sheet for 7 days, then removed. At 12 days of age, two thin coats of whitewash[(5)] were applied to the rear side of the walls. Edges were parged with mortar 10mm thick. Walls were allowed to air dry prior to testing at 14 days of age.

TESTING AND DISCUSSION OF RESULTS

Six identical test chambers used in the investigation were already available with the Construction Research Center of the University. Developed for several previously conducted research projects at the Center, they conformed with ASTM E 514-86 with minor adaptations to suit the particular needs of the Center. Each chamber, measuring approximately 1.0m in width and 1.3m in height, consisted of a steel angle frame, to which 6mm thick clear plexiglass was secured on one side with full bed of structural silicon. On the other side, the frame edges was lined with sponge rubber gasket. When the chamber was clamped to the wall, a fully sealed space between the wall and the chamber was obtained.

Water was introduced in the above space through a tube at the top of the chamber and the air from the bottom. Both the water flow and air pressure could be controlled and measured with instrumentation attached to the frame.

As stated earlier, each wall was tested at 14 and 28 days of age. When testing at 14 days of age was completed, the walls were allowed to air dry. No additional whitewash was applied after the first testing of a wall. Each wall was tested continuously for a period of 4 hours. The backs of the wall were observed for dampness and leakage and the information recorded. The permeance data, expressed as the total quantity or water (in milliliters) accumulated in the entire 4 hour period for each wall, is shown in Figures 4 and 5. From these figures, the following conclusions are drawn.

(i) The average accumulation (average of three walls) at 28 days for each joint type is less than that at 14 days, conforming the known fact(6) that as the wall ages, the lime's crystalline growth plugs the microscopic cracks developed within in the mortar, and at the interface between the units and the mortar, due to mortar's shrinkage.

(ii) Average accumulation was higher for walls with 20mm thick joints than those with 10 mm thick joints, although some individual walls performed differently from the above generalization.

(iii) The average accumulation is least for the concave joint, followed by the weathered and the vee joints. The raked joint has the most leakage, Figure 6.

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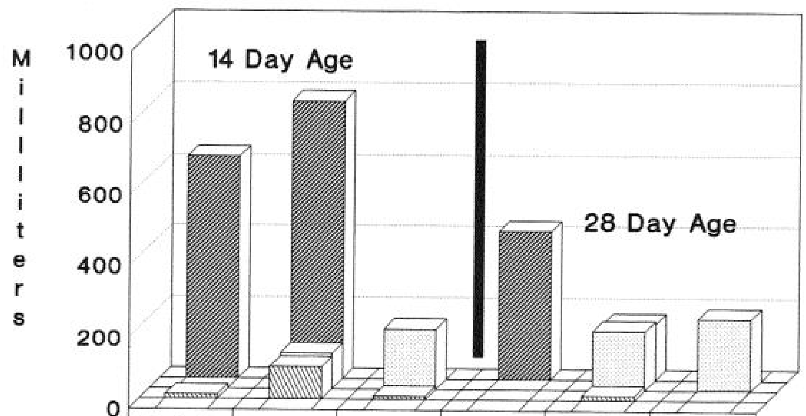
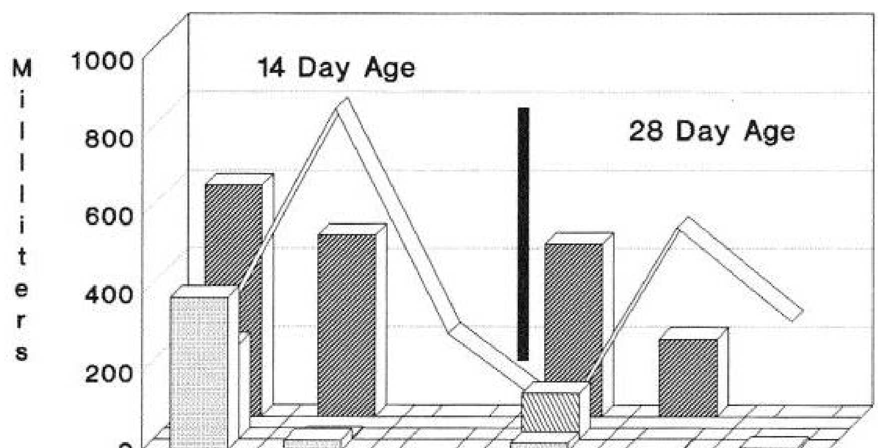
In some of the walls, one or two joints leaked profusely. This data was not included in the results because except for these joints, the remainder of these walls had no measurable accumulations. Upon completion of the testing, several of the above joints, that leaked excessively, were investigated to determine the cause of their leakages. Figure 7 shows a 10mm rake joint that was sliced open. This joint had produced large amounts of water while the rest of the wall had no accumulation



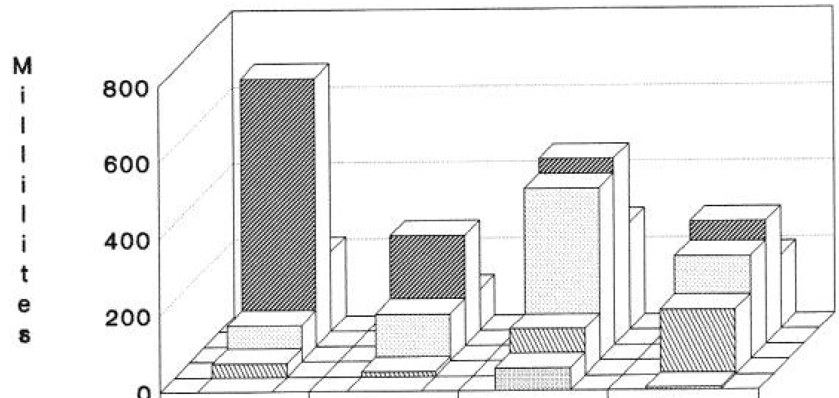
	Wall #1	Wall #2	Wall #3	Wall #1	Wall #2	Wall #3
Raked	624	778		414	157	
Vee	0	100	170	0	166	201
Weather	13	91	10	0	13	1
Concave	0	0	0		0	0

Figure 4 Average accumulations of water regarding the 10 mm thick joints at 14 and 28 days of age.



	Wall #1	Wall #2	Wall #3	Wall #1	Wall #2	Wall #3
Raked	590	462		440	198	
Vee	280	816	241	25	511	271
Weather	242	3	0	118	0	0
Concave	391	27	0	20	2	8

Figure 5 Average accumulations of water regarding the 20 mm thick joints at 14 and 28 days of age.



THICKNESS	10mm	10mm	20mm	20mm
AVERAGE	207.5	105	277.25	190.25
RAKED	701	286	485	319
VEE	94	122	446	268
WEATHER	35	12	120	168
CONCAVE	0	0	58	6
JOINT TYPES	14 DAYS	28 DAYS	14 DAYS	28 DAYS

Figure 6 Relative performance of various joints at 14 and 28 days of age.

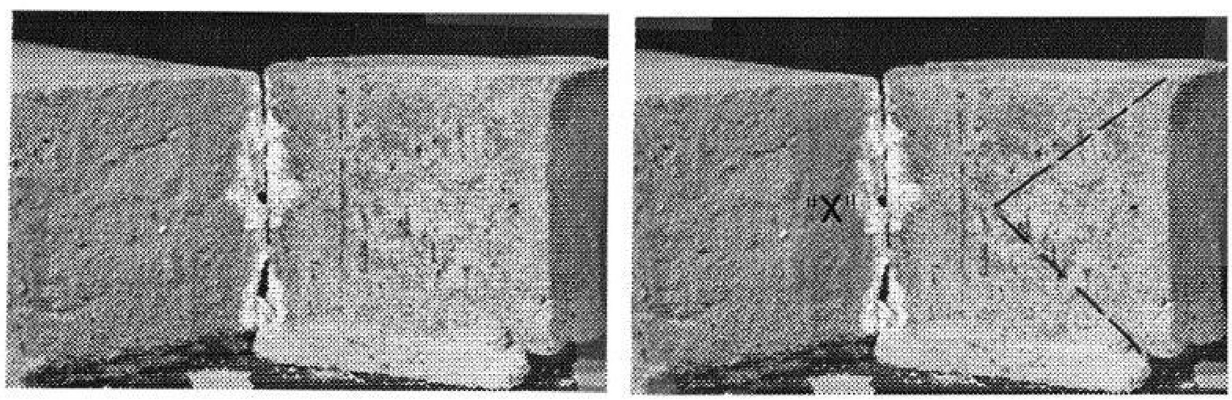


Figure 7 Rake joint, 10mm exposed from brick unit showing leak hole with whitewash and change of the mortar profile.

Recent studies[7] have indicated that units, particularly, those with high IRA values, should not be moved once laid. Thus, the common practice to tap the units to secure a better bond at the head joints, or to move the units to plumb the wall, may cause leakage in the wall. The darkening on the right side of the mortar in the shape of a (<) Figure 7, indicates that new mortar was added to the joint after the unit was tapped or moved. The leakage at the rear developed as a result of this movement. Notice also the whitewash that penetrated the leak hole. Figures 8 and 9 show another 10mm thick raked joint that leaked excessively from similar tapping(s). The leak hole was in the head joint, as indicated by letter (X) in Figures 7 and 8.

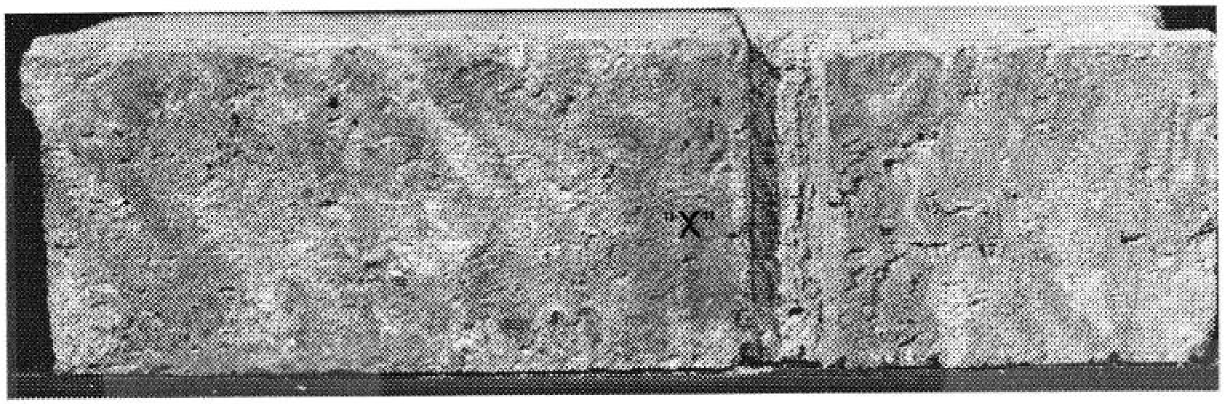


Figure 8 Front view of a 10mm concave joint. The (X) identifies a hole in the joint providing leakage.

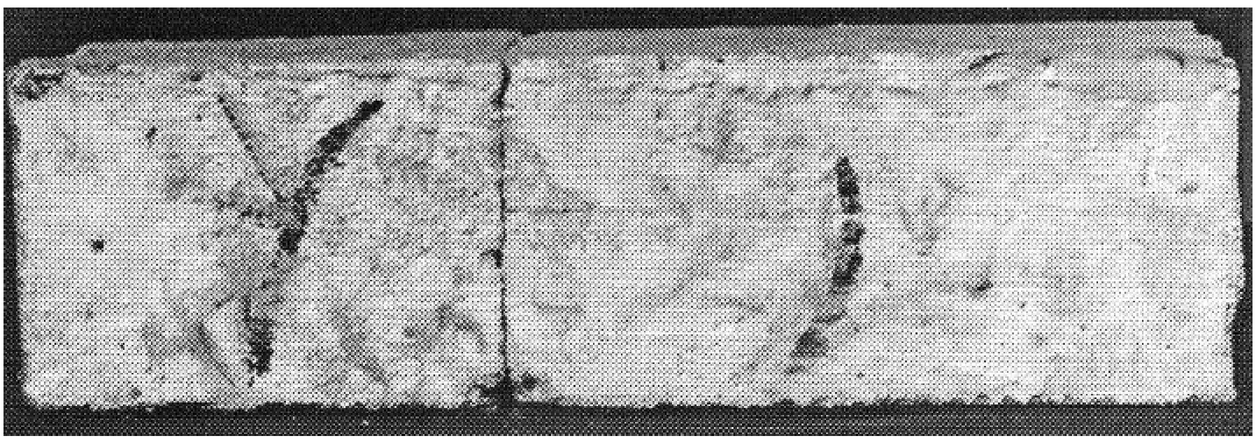


Figure 9 Rear view of the prism showing the leak hole.

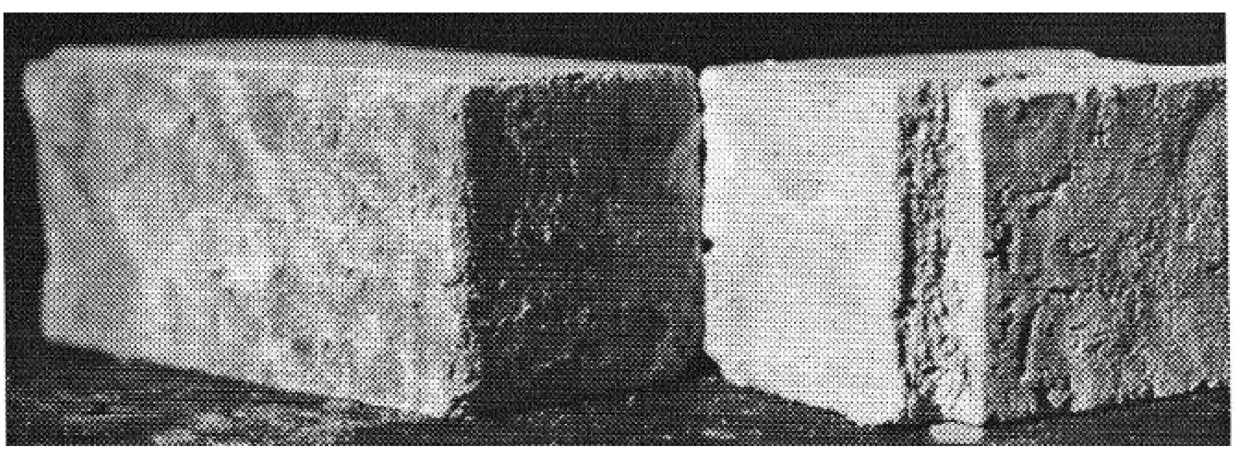


Figure 10 View of the joint and brick interface showing the leak hole - result of tapping.

SUMMARY

The data presented above seems to suggest that a tooled concave mortar joint is indeed the most water resistant profile. This confirms the masonry industries recommendation. Additionally a 10mm thick joint performs more favorably than a 20 mm thick joint.

Data also highlights the importance of good workmanship in masonry, promulgated by the accumulations in a few walls with concave joints. Those accumulations for a few walls exceeded those of other joint profiles, recommendation can be made that in so much as possible, the units should not be tapped or moved after being placed in the wall. Thus a recommendation can be made that in so much as possible, the units should not be tapped or moved after being placed in the wall[(8)].

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