Measuring water penetration

A simple, inexpensive tube test can yield valuable, quantitative information

by Kim Basham and John Meredith

RILEM or MAT tubes are pipelike devices. The tube or stem portion is graduated from 0.0 to 5.0 ml. The volume of water absorbed over a specified time is read from this graduation.

Masonry walls that leak create problems for contractors, architects, and owners. Water that passes through exterior walls can damage interior wall finishes, floor coverings, ceilings, and building contents. And water need not pass completely through exterior walls to cause damage. Water that penetrates only the exterior face can cause staining, corrosion, organic decay, efflorescence, and freeze-thaw spalling. Therefore, any water that enters a masonry system can cause damage.

But locating leaks in a wall system can be a major task. When investigating leaks, you may need to evaluate the permeability of the masonry. Water penetration tests also may be done to demonstrate the performance of new masonry or assess the condition of existing masonry.

Three methods of measuring water penetration in masonry are the ASTM E 514 pressure chamber test, the permeability test, and the low-pressure tube test. (The low-pressure tube is also called the RILEM tube, masonry absorption test or MAT tube, or Kartens tube.)

There are other nondestructive test methods for analyzing wet walls, including the plastic test, the spray test, the mask and spray test, the drainage or cavity test, and moisture meter testing (see "Analyzing Wet Walls," *Masonry Construction*, July 1991, and "Measure the Moisture in a Wall Instantly," December 1989). These, however, don't measure water penetration quantitatively. When evaluating the severity of leaks in masonry walls or the effectiveness of repairs and water repellent treatments, you may need to use a quantitative test method.

Leak paths

Possible leak paths in the wall surface include the brick, mortar, and brick/mortar interface. Cracks and voids at the interface between the brick and mortar provide the most common pathway for rainwater to enter a masonry wall. Much less water penetrates through the units and mortar than enters through openings at the unit/mortar interface.

Unfilled mortar joints and poor bond between the brick and mortar are the main causes of leaks at the brick/mortar interface. Most joint defects and resulting leaks occur at the head joints. Unlike bed

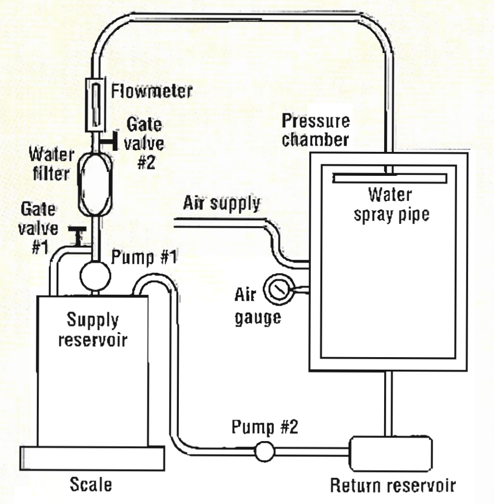


Figure 1. ASTM E 514 is a laboratory test method. However, a modified version is available for measuring wall permeability in the field. Unlike the standard test, the modified version uses a scale to measure the water that penetrates the front face of the masonry.

joints, head joints are not naturally compressed by the weight of masonry above. To be dense and leak-free, a joint must be fully packed and properly tooled; this is especially true for head joints.

Improper mortar proportioning, material incompatibilities, and poor workmanship cause poor bond between mortar and brick. For example, mortar mixed too wet or with too much cement may shrink substantially as setting occurs, causing a separation at the interface. Moving or tapping bricks after their initial placement also can impair bond. The single most important factor affecting the watertightness of a mortar joint, or the quality of masonry as a system, is workmanship.

Cracks at the brick/mortar interface can range from 0.004 to 0.040 inch (4 to 40 mils) in width. Wind-driven rain can enter cracks as narrow as 0.004 inch (4 mils). Yet cracks between 0.010 to 0.015 inch (10 to 15 mils) wide usually are considered visually acceptable, so unnoticeable or visually acceptable cracks can provide pathways for water to enter masonry.

ASTM E 514 test

ASTM E 514 "Standard Test Method for Water Penetration and Leakage through Masonry" is the only standard provided by the American Society for Testing and Materials for measuring water penetration of masonry (Ref. 1). ASTM E 514 is a laboratory test employing a 3x4-foot test chamber that simulates driving rain. After the chamber is mounted and sealed to the wall specimen, a spray bar mounted at the top of the chamber sprays water. A sheet of water forms and runs continuously down the masonry like rainwater on a building. Pressurizing the chamber during the test simulates the driving force of wind on the sheet of water. Pressure forces water into cracks and voids on the masonry surface. Flashing collects water running down the back of the wall and water moving down within the wall.

The standard test laboratory test procedure, which requires built-in flashings and access to the back of the wall, yields the following information: the time until the appearance of first dampness and first visible water on the back of the wall, the area of dampness at the end of the 4-hour test period, and the total water collected from flashings (Ref. 1).

There also is a version of the ASTM E 514 test modified for field testing, for which neither flashing nor access to the back of the wall is necessary. The field version measures only the amount of water passing through the front wall face. Figure 1 illustrates an ASTM E 514 equipment layout for field testing. The scale measures the amount of water that has penetrated through the front face of the masonry.

The field version includes a ½-hour preconditioning period (to saturate the wall with water) followed by a 4- to 8-hour testing period. Water is supplied from a calibrated tank and returned to the tank from the bottom of the chamber.

After the wall is preconditioned, water is sprayed on the wall for at least 4 hours but no more than 8 hours. The tank water level is recorded every ½ hour. The test is stopped when two consecutive water readings are the same. If this never occurs, the test is stopped after 8 hours. The quantity of water lost from the tank in the last hour of the test is measured as the water leakage rate.

The water penetration or leakage rate is measured in gallons per hour. ASTM offers no help with interpreting test results. However, the following rating system is commonly used to evaluate ASTM E 514 field test results (modified from Ref. 3):

Leakage rate (gals/hr)	Rating
Less than 3/16	Excellent
Less than ½	Average to Good
Greater than ½ but less than 1	Questionable
Greater than 1	Poor

Most construction and material laboratories can perform this test; it costs approximately $1,000 a test. One test can be performed a day with a setup time of 2 to 3 hours. The amount of wall damage is minimal, only the anchor holes used to secure the test chamber to the wall need to be repaired.

Because the ASTM E 514 pressure test chamber covers a large surface area, the test cannot establish individual water permeability values for different entry pathways. ASTM E 514 gives a composite measurement, representing the permeability of the brick, mortar, and brick/mortar interface. The permeability test and low-pressure tube test, on the other hand, can establish the individual water permeability of the unit and the joint. Joint permeability, in this case, represents the water penetrating both the mortar and unit/mortar interface.

Permeability test

Originally designed to test water penetration in concrete, this test has been adapted for use with masonry. Because the test devices are modified for masonry testing, various versions are being used. The device is secured to the wall with two clamps anchored to a bed joint using bolts. Either a reservoir on top or a separate water tank holds a known volume of water, and a dial allows the operator to select the pressure level.

Permeability is determined by measuring the time it takes to force a known volume of water into the masonry at a preselected pressure. The shorter the time period, the more permeable the masonry. Each device contacts about 5 square inches of surface area, so unlike ASTM E 514, this test indicates local or point-by-point wall permeability. Usually, test results are used for comparative purposes only; no interpretation guidelines or rating systems are available for this test. The test can be performed in about an hour including setup, at a cost of about $50 a test.

Low-pressure tube test

Low-pressure tube testing measures the quantity of water absorbed by a masonry surface over a specified time period. This test device is a simple, easy-to-use, inexpensive tool developed by the European organization RILEM, headquartered in Paris. RILEM is an acronym for the French name translated as International Union of Testing and Research Laboratories for Materials and Structures.

Equipment and method. The photo on page 539 illustrates the pipelike MAT tube used to test vertical surfaces. Similar tubes are available for testing horizontal surfaces. Made of either plastic or glass, the tube has a flat, circular brim at the bottom which is attached to the masonry surface with soft putty. The test area is small: only 1 square inch. The tube, which holds 5 milliliters (or 0.2 fluid ounces) of water, is graduated in 0.1-milliliter increments from 0.0 to 5.0 ml, making estimates to the nearest 0.05 ml possible.

As water is absorbed by the masonry, the water level in the tube falls. By monitoring the falling water level, you can determine how much water is absorbed over a specific time.

Capillary suction through the masonry's pores causes the water to move through the masonry as a front—a process called wetting. The wetting rate and pattern are directly related to the masonry's capillary structure and pore size distribution.

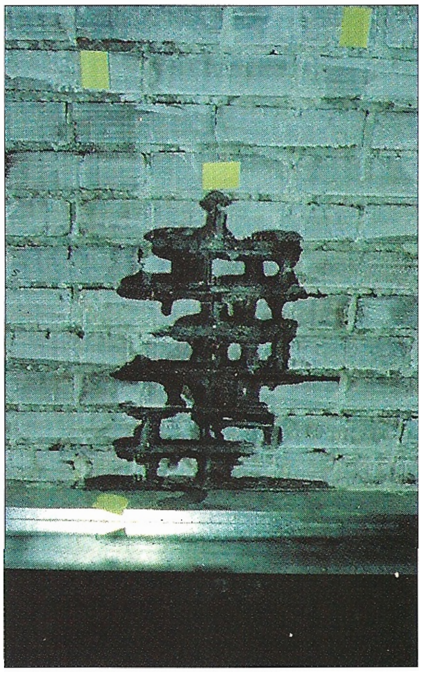
Operating pressures for MAT tubes range from about 23 to 5.8 psf (0.16 to 0.04 psi) depending on the level of the water in the tube. These pressures are equivalent to wind speeds of about 95 to 49 mph. As the water level falls, the test pressure decreases. If the tube is refilled, the pressure reverts to the maximum, then falls again as the masonry absorbs the water. Some investigators object to the falling and cyclic pressure of this test; others believe the variable pressure better simulates the effects of wind gusts than the constant pressures used in the ASTM E 514 and permeability tests.

MAT research findings. Recent research at the University of Wyoming has yielded a number of interesting observations:

- The bottom of a head joint usually has the highest water penetration values, followed by the middle of the head joint, bed joint, top of head joint, and brick (Refs. 4 and 5). However, leaks at a head joint usually occur at the top. This suggests that mortar at the bottom of a head joint is less dense than surrounding mortar but joint defects are more likely to occur at the top of the head joint.
- Furrowing bed joint mortar increases water penetration at the bed joint. Figure 2 graphically shows a comparison of average absorption values for the different joint locations.
- Joints that absorb 5 ml of water in 5 minutes or less are most likely to leak water through the wall, while joints requiring 15 to 25 minutes to absorb 5 ml of water show no signs of leakage or wetting patterns on the back of the wall (Ref. 4).

Interpreting test results. On brick, a circular wetting pattern usually occurs. On joints, the wetting pattern may be circular at the beginning of the test but will quickly spread along the brick/mortar interface of the joint. The quicker the wetting pattern spreads along the interface, the more questionable is the quality of the joint. The photo at right shows a typical wetting pattern for a leaky head joint being tested with a MAT tube.

Most of the time, leaky joints show no surface defects. The fact that a joint appears to be free of defects does not ensure it is watertight. When



Leaky joints allow water to leak to the back side of walls. A MAT tube test on the front of this leaky joint caused this wetting pattern.

testing, note and record the wetting pattern. Wetting rate and patterns yield valuable information about the permeability of the masonry.

Sometimes water enters the wall in one location and exits in

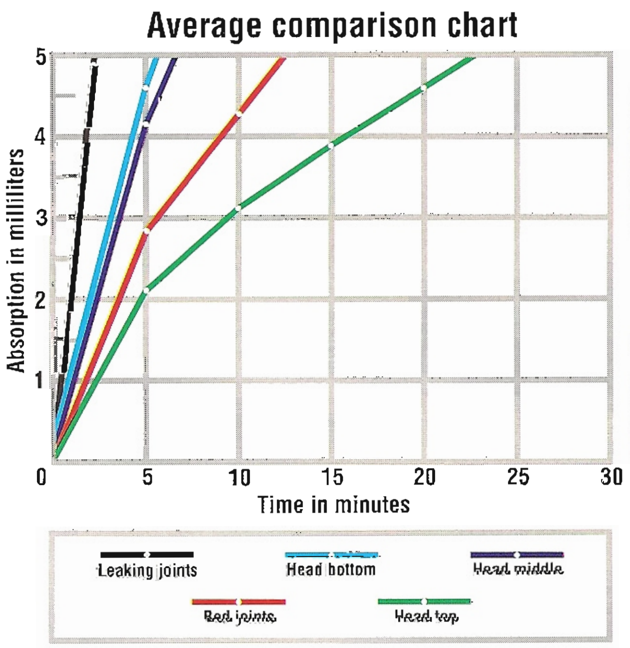
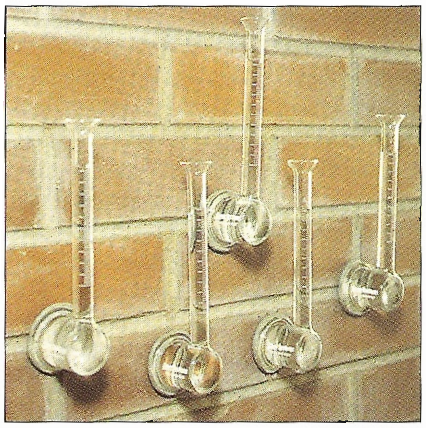


Figure 2. Absorption graphs show the volume of water absorbed in milliliters versus time. The more permeable the masonry, the faster 5 ml of water will be absorbed.

another. For example, water often enters at the top of a head joint but exits through the lower bed joint on either the front or back of the wall. Often, water exits several inches away from the tube location through pinhole flaws at the brick/mortar interface. Look for water exit points; if you find them, note and record their location.

A few MAT tube tests will not accurately indicate a wall's permeability characteristics. Due to the variable nature of masonry, test results will vary greatly, even within a small area. For panels tested at the University of Wyoming, a standard deviation of 20 ml per hour was found for a mean MAT reading of 15 ml per hour (Ref. 4). Variability and the small test area were responsible for the high standard deviation. Based on this variation, 1,665 tests are needed to achieve a sample error of 10% for an area of 12 square feet. For a sample error of 5%, 6,659 tests are required! What does this mean? Run as many tests as possible to gain a feel for overall wall permeability, but don't expect to achieve perfect reliability. To speed testing, use several tubes ganged as shown above right.

While the tube test is considered a quantitative test, users must interpret the results realistically. Don't set rigid acceptance and rejection criteria based on values obtained from MAT tubes. Use test results for comparative investigations. The test is ideal for comparing unweathered to weathered masonry. Establish average absorption values for protected masonry (e.g. under eaves or eastward facing walls) and compare them to values representing weathered walls or problem areas. Use MAT tubes, too, to measure the effectiveness of water-repellent treatments. Major reductions in absorption values should exist after repairs and the application of a water repellent (Ref. 5).



Gangs of MAT tubes can speed testing. Test head joints, bed joints, and bricks to establish permeability characteristics. Run as many tests as possible.

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Masonry absorption test procedure

1. Select test locations. Test several different locations—brick; top, middle, and bottom of head joint; bed joint. Remember that head joints, especially at the bottom, are more prone to defects and usually have high water penetration values compared to other locations. Bed joints and bricks usually have the lowest penetration values. Test both unweathered and weathered masonry. Run as many tests as possible. For faster testing, use several tubes and only determine the volume of water absorbed in the first 5 minutes.

2. Attach MAT tube. Roll a pinch of soft putty in hands to form a snakelike piece long enough to place around the flat brim of the tube's large opening. Place tube with putty on test location and press firmly. A watertight seal must be obtained between the tube and masonry. Where the brim bridges the joint, press on putty along the edge to ensure a tight seal. If putty does not stick, try again or select another, similar test location. To ensure a tight seal on textured brick, use extra putty and a lot of patience.

3. Record information. Record the type of surface, surface texture, test location, water exits if any, wetting pattern, and absorption value versus time. Use a simple method for recording test locations. For example, a test performed on the west side of a building, 4th course down, 2nd from right, middle head joint can be recorded as West/4D/2FR/MH. When comparing before-and-after readings, record the exact location of the tube. Before-and-after testing must be performed in exactly the same location.

4. Fill MAT tube with water. Fill tube to the 0.0 ml graduation mark and note time or start stopwatch. Check water level at 5-, 10-, 15-, 20-, 30- and 60-minute intervals. Record volume of water absorbed to the nearest 0.05 ml for each time interval. Refill tube if necessary. Record the amount of water added and the time it was added. For quicker testing, determine only the volume of water absorbed in the first 5 minutes of testing.

5. Interpret test results. Depending on the number of readings, plot test results for each test location on a graph showing water absorption versus time (see Figure 2). Compare results (i.e., weathered versus unweathered, treated versus untreated, head joints versus bed joints, etc.). If a joint absorbs 5 ml of water in 5 minutes or less, most likely it is a leaky joint. If mean weathered test values are about twice the mean unweathered values, weathering is a concern.