Measuring Moisture in Walls

By Kenneth A. Trimber and Kevin J. Brown

Excessive moisture in masonry or concrete walls at the time of sealing or painting can destroy the performance of coating systems by interfering with film formation, adhesion, and/or inhibiting the cure of the coating. Masonry and concrete surfaces may appear to be dry by sight and touch prior to coating application but still contain detrimental levels of moisture within the substrate. Even when the substrate is dry at the time of application, subsequent moisture intrusion in service can cause blistering and detachment of the film (*Photo 1*).

While there is little controversy regarding the detrimental effects of moisture on coatings, there is substantial confusion when selecting the method(s) for measuring the moisture content and interpreting the results. Note that the Society of Protective Coatings (SSPC) is tackling this issue head-on in 2012 through its newly formed Commercial Coatings Committee. One of the immediate activities being undertaken is the development of a guide for the detection of moisture in concrete and masonry surfaces. The guide will address the location and frequency of measurements, the scheduling of testing within the construction or maintenance sequence, the instrumentation that is used, and interpretation of results.

A common construction trend seen in many commercial structures is the use of single-wythe concrete masonry units (CMU), commonly known as concrete block. It is extremely important to know the moisture content in this type of wall system. While single-wythe CMU provides a relatively economical wall system, excessive moisture in these units can cause serious problems for the performance of the exterior coatings and can create unfavorable interior conditions. The creation of an effective drainage plane can be extremely challenging, depending on the insulation type and integral structural components such as bond beams. Various factors such as solar loading, exterior climate, interior temperature and humidity conditions, wind-driven rain, roof system leaks, and moisture introduced during construction can all lead to excessive moisture content in single-wythe wall systems. Unfortunately, the damaging moisture may not always be visible on the surface of the

Photo 1 – Moisture in the substrate at the time of application or moisture intrusion months or years later is destructive to most coating systems.

Photo 2 – Drywall decay attached to insulation that is in contact with single-wythe masonry.

wall, giving a false sense of assurance that moisture is not a problem. Excessive moisture can become trapped within the fill insulation or accumulate behind the outward web of the block. Coating the exterior of wall systems when excessive moisture exists can lead to unfavorable appearance, patches of efflorescence, and blistering and peeling of the coating. If sustained, it can lead to the decay of materials in contact with the wall (*Photo 2*).

A few instruments and techniques are available for determining the presence of moisture in walls, providing both qualitative and quantitative results. Unfortunately, the quantitative methods do not always measure the same attributes, the results are in different units, and the conclusions that are derived from the various methods are often not in agreement. This article describes some of the methods that are used for determining moisture content, available ASTM standards, and some of the problems the industry is facing in interpreting the results.

MEASURING MOISTURE CONTENT IN CONCRETE WALLS

Only one ASTM test method addresses the moisture content of walls: ASTM D4263-83 (reapproved in 2005), *Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method.*

In contrast to walls, five ASTM test methods, in addition to ASTM D4263, address the measurement of moisture in floors. Although specifically designed for floors, some of the methods provide concepts that can be of value when evaluating walls. The ASTM test methods for floors are the following:

- ASTM F1869-11, *Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride*
- ASTM F2170-11, *Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using In-Situ Probes*
- ASTM F2420-05, reapproved 2011, *Standard Test Method for Determining Relative Humidity on the Surface of Concrete Floor Slabs Using Relative Humidity Probe Measurement and Insulated Hood*
- ASTM F2659-10, *Standard Guide for Preliminary Evaluation of Comparative Moisture Condition of Concrete, Gypsum Cement, and Other Floor Slabs and Screeds Using Nondestructive Electronic Moisture Meter*
- ASTM F710, *Standard Practice for Preparing Concrete Floors to Receive Resilient Flooring*

Various methods that have been used for determining the moisture content of walls, although not supported by ASTM standards (with the exception of ATSM D4263), are discussed below.

PLASTIC SHEET TEST – WALLS

This method is addressed in ASTM D4263-83 (2005), *Standard Test Method for*

Photo 4 – Moisture visible beneath plastic.

Photo 3 – Plastic sheet test in place overnight.

Photo 5 – Low (green) reading on mortar.

Photo 6 – High (red) reading on mortar.

Indicating Moisture in Concrete by the Plastic Sheet Method. This is a nondestructive test that requires firmly taping the perimeter of a sheet of plastic (measuring approximately 18 x 18 in.) to the wall and allowing it to remain in place for a minimum of 16 hours. At the end of the exposure, the underside of the sheet and surface of the concrete are visually examined for the presence of moisture (see *Figures 4* and *5*).

The test method recommends a test frequency of one location per 500 sq. ft. of wall area or portion thereof, with a minimum of one test for each 10 ft. of vertical rise in all elevations starting within 1 ft. of the floor (ground).

The use of a good-quality tape and preparation of the area beneath the tape are critical on walls. On previously coated surfaces, loose efflorescence, chalk, and dirt should be removed and a tape with good adhesive qualities used; otherwise, the tape will detach from the surface.

Acceptance criteria are not explicitly stated in the standard, but coatings are typically not applied if the test indicates that moisture is visibly present (see *Photos 3* and *4*). There can be problems with the reliability of this method if used in direct sunlight.

Moisture Testing Instruments – Walls

Three categories of commercially available instruments are discussed below. (The categories are not based on any standards; they have been developed for the purpose of this paper.) While many of the instruments in the categories below are typically used on floors, some are also used on CMU, brick, and concrete walls.

Moisture Meter Category A, Radio Frequency Meter

This instrument utilizes radio frequency to assess and monitor the relative moisture level in porous materials such as concrete. The instrument from one manufacturer provides readings on a relative scale between 0 and 999. The instrument displays results using both a color and a number. The green zone is from 0 to 145 units and signifies safe air-dry conditions. The yellow zone is between 146 and 230 units and signifies that moisture levels are higher than normal but not critical; further investigation is recommended. The red zone is greater than 230 units and represents excessive moisture levels. The instrument also has the ability to read through certain coatings and materials to a nominal depth of ¾ in. The levels and descriptions are specific to this manufacturer only and are not based on industry standards. *Photos 5* and *6* show low and high moisture readings on the mortar joints of a brick building (green and red zones respectively). *Photo 7* shows the relative moisture in block behind textured coating.

Moisture Meter Category B, Electrical Resistance (Conductivity) Meter

This instrument utilizes conductivity to determine moisture content. Two contact pins on the end of the instrument are

Photo 7 – Instrument used on CMU with coating.

pushed against the test surface to measure the conductivity of the material between the pins. One manufacturer recommends driving masonry nails into the surface about ¼ inch in depth and touching the probe to the head of the nails (see *Photo 8*).

Moisture meter B can also be used to determine the moisture content of insulation within the wall cavity. (Insulation can absorb and retain moisture depending on its cell structure.) Insulated contact pins 4 inches long are inserted through small holes that are drilled through the face of the block. The gauge determines the conductivity of the insulation in contact with the tips of the pins (*Photo 9*).

The instruments in Photos 8 and 9 display a numerical reading that classifies the relative moisture content in concrete in three general ranges:

- **Green:** <85 units (<2% moisture content)
- **Yellow:** 85 to 95 units (2% to 4% moisture content)
- **Red:** >95 units (>4% moisture content)

Moisture Meter Classification C, Electrical Impedance Meter

This instrument utilizes electrical impedance to determine moisture content. The electrical impedance is measured by creating a low-frequency alternating electric field between the electrodes on the bottom of the unit. For one of the manufacturers, the concrete moisture readings are displayed on a moving coil meter ranging from 0% to 6%.

Another approach for determining the presence of moisture is to combine the plastic sheet test with instrument readings (before and after installation of the plastic). Although it is described for use on floors in ASTM F710, the authors have found the procedure to provide meaningful results for walls.

Industry acceptance ranges for moisture content in walls are neither available, nor is guidance provided for the location and frequency of measurements. Typically, specifications only require that the surface be dry. Basing decisions on visual observations is risky, as it does not indicate whether detrimental amounts of moisture are present beneath the surface. (*Photos 5* and *6* of the brick demonstrate how appearance alone can be misleading for making decisions regarding moisture.) Unless the coating manufacturer specifically mandates moisture testing using instrumentation, it is often ignored.

Photo 9 – Conductivity meter with 4-in. probes inserted into the block cell. Instrument reading shows that the insulation is wet.

Photo 8 – Masonry nails are driven into mortar joints of CMU to assess the moisture below the surface.

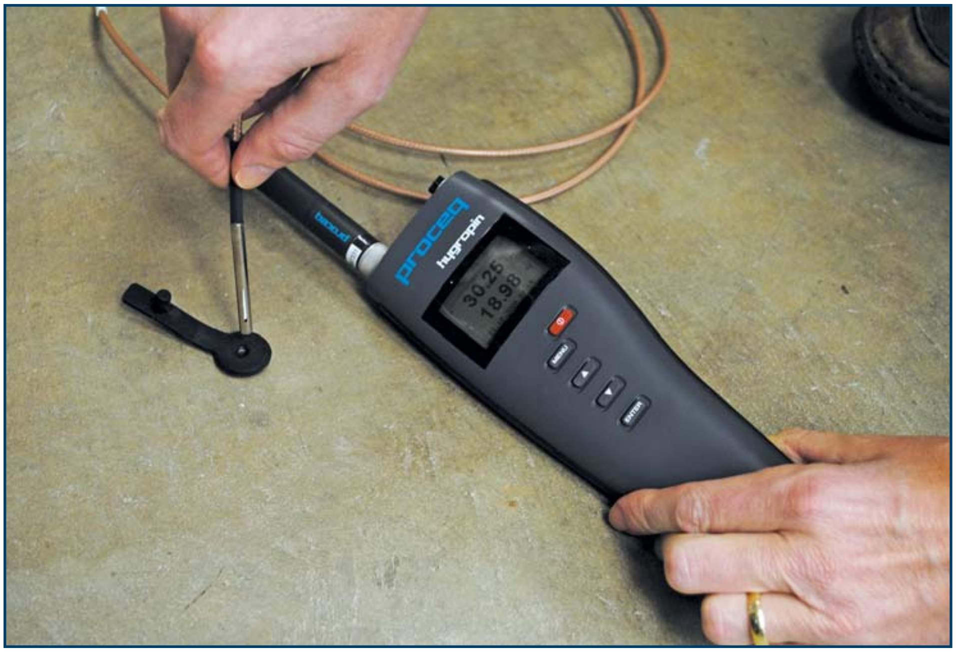


Photo 10 – Probe of a relative humidity instrument being inserted into a sleeve that lines a hole drilled into the surface.

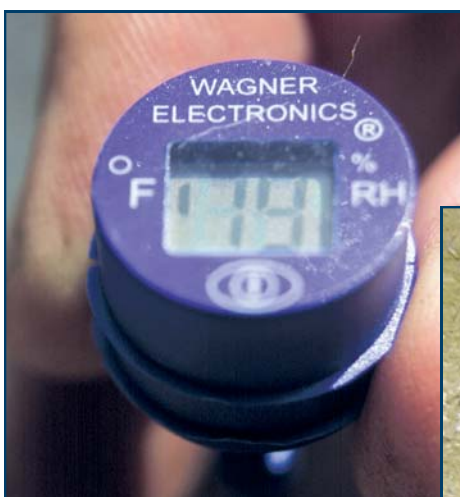
MOISTURE TESTING USING IN-SITU PROBES

While the ASTM standard for the relative humidity probes is designed for floors, there have been instances in which the relative humidity probes have been used to examine wall cavities, so even though a standard does not exist, the technique may have applications in various wall types. This method is addressed in ASTM F2170-11, *Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using In-Situ Probes.*

This is a destructive test that requires drilling holes in the concrete by dry-cut tooling. The diameter of the holes is not to be more than 0.04 inches larger than the diameter of the probe sleeve. The relative humidity is determined by inserting probes into the holes after a 72-hour stabilization period (see *Photos 10* and *11*).

DETECTING MOISTURE IN WALLS USING INFRARED THERMOGRAPHY

While infrared has become popular for detecting moisture in roof systems, it can also be used to assist in evaluating air leakage and moisture retention within the wall system. This method is addressed in ASTM C1060, *Standard Practice for Thermographic Inspection of Insulation Installations in*



Photos 11A and 11B – Another relative humidity instrument uses probes that are inserted into a sleeve. The relative humidity is displayed on the top of the reader.

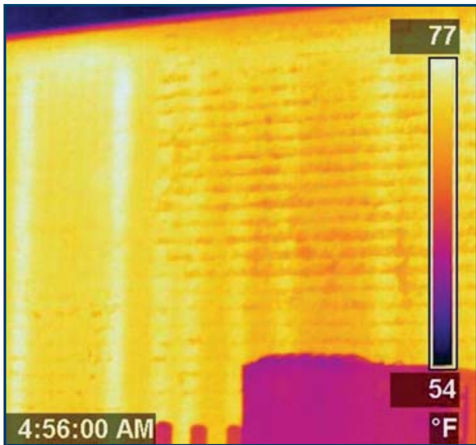


Photo 12 – Infrared thermography used to detect moisture in walls. Light areas are grouted cells.

Photo 13 – Brick sample removed to determine percentage of saturation.

Envelope Cavities of Frame Buildings. The standard was developed primarily to detect suspected missing or inadequate amounts of insulation; however, it can sometimes be used to identify areas of excessive moisture. The use of infrared thermography to identify moisture in walls can be difficult to properly perform and interpret. If done incorrectly or when weather conditions are not appropriate, the results can be misleading. What may appear to be moisture may actually be missing insulation, air leakage, or other deficiencies unrelated to moisture. As with any infrared scan, skill in interpreting the results is a necessity.

Using this method alone is risky, and it is best utilized in conjunction with other techniques such as the plastic sheet or the instruments described above. *Photo 12* shows an infrared still shot confirming the presence of moisture in a single-wythe CMU block wall.

Photo 14 – Very high levels of moisture detected behind EPDM on a parapet.

MEASURING PERCENTAGE SATURATION OF POROUS MATERIALS

Determining the saturation levels of porous materials is sometimes referred to as the "gold standard" in determining moisture in walls. However, in order to use this method on existing structures, some of the wall components must be removed for analysis. Measuring the percent saturation of porous materials when removed from the wall provides an absolute measurement of moisture saturation. Some ASTM standards exist that address measuring moisture content of porous materials, such as ASTM C1498, *Standard Test Method for Hygroscopic Sorption Isotherms of Building Materials*.

Although not specifically addressed by a standard, a more practical and simplified approach is to remove a unit from a wall and immediately seal it in plastic. The specimen should be "double bagged" to reduce the potential for drying. The sealed specimen is sent to a laboratory and weighed. The sample is then placed in a state of absolute saturation with water and weighed. After absolute saturation, the sample can then be oven-dried to a constant state and weighed. By knowing the weights at absolute saturation and at a constant dry state, the percent moisture saturation as removed from the structure can be plotted. *Photo 13* shows a brick specimen removed from a structure and bagged for shipment to a laboratory to measure the percent saturation of the unit.

MEASURING MOISTURE CONTENT THROUGH ROOFING MATERIALS

The authors have used a radio frequency device (*Photo 14*) to nondestructively determine the relative moisture content of the substrate through roofing materials on low-slope roofs such as single-ply membranes and built-up roofs. While the use of the instrument for this purpose is still under test, the results to date suggest positive results when verified with other methods or techniques to detect moisture. Most often, this approach has been used to deter-

Photo 15 – Elevated moisture identified in the coverboard underneath a built-up roof.

mine the presence of moisture content on parapet walls when diagnosing the disbonding of roofing materials or coating failures on the opposite side.

The same instrument has been used to nondestructively identify damp or wet coverboard materials on low-slope roofs. With its ability to read through most materials such as coatings and roofing materials, and its ability to read to depths up to ¾ in., it can help to determine the presence of wet areas. *Photo 15* shows the instrument being used on a low-slope, built-up roof.

PERCENT MOISTURE VS. RELATIVE HUMIDITY

Moisture in porous materials such as block and concrete is in the form of liquid water (percent moisture) or water vapor (relative humidity), with different instruments or methods available for measuring each. Unfortunately, the results obtained from the various instruments and techniques can be difficult to compare. Even when similar types of measurements are involved (e.g., percent moisture), the results between the instruments are frequently different, and the methods do not always indicate the presence of moisture at the same locations within the substrate. Some assess the moisture at the surface and some at varying depths in the substrate.

A comparison between the percent moisture in a substrate and relative humidity is shown in *Figure 1* for various substrates. *Figure 1* is taken from *Moisture in Concrete and Moisture-Sensitive Finishes and Coatings*, published by Cement Concrete & Aggregates, Australia (CCAA). The chart shows that approximately 75% RH in concrete equates to a moisture content of approximately 2%. The CCAA also points out that because of the tiny capillaries in concrete, a concrete substrate can be nearly saturated with water and still only register a moisture content of about 5%. Accordingly, a relatively low percentage of moisture in concrete as determined by the instruments may represent an unacceptable amount of moisture for painting or sealing.

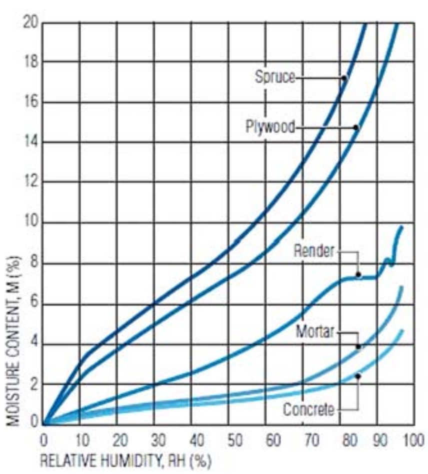


Figure 1 – Moisture content and relative humidity comparison chart. Source: Cement Concrete & Aggregates, Australia

CONCLUSION

While there are many ASTM standards that govern the conditioning of floors prior to moisture testing and test frequencies, similar guidance is not available for walls. Likewise, while acceptance criteria have been developed by manufacturers of floor coatings and coverings, similar criteria are typically not available for coatings applied to walls. The result is that most specifications fail to address the moisture content of walls.

Several methods for determining moisture in walls have been discussed; however, many of these methods were intended for other purposes and are not addressed in standards specifically for walls. Important factors for measuring moisture in walls are essentially unknown. Factors such as location of moisture detection within the substrate, whether standardized test frequencies are available, and the standardized acceptance criteria for moisture content in walls, all require significant development. On a positive note, one of the goals currently being addressed by the new SSPC Commercial Coatings Committee is the development of a guide that will serve as an overarching document for the testing of moisture in walls, with industry standards referenced when available.

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