Moisture Testing of Concrete Slabs

When 3 lbs is not 3 lbs

BY PETER CRAIG AND GEORGE DONNELLY

The long-awaited day has come, the project is complete, and everyone involved is eager to show off the new look of the facility. But wait a minute. Something is terribly wrong. Adhesive is bleeding through joints between the floor tiles, and there are bubbles in the sheet goods (Fig. 1) and epoxy flooring. Worse yet, there is a noticeable odor in the air. Sabotage? No, unfortunately what is occurring on this project has become all too common across the country. Such problems are being caused by moisture and moisture-induced high pH levels beneath flooring materials.

How can this be? The slabs were tested for moisture, and the results appeared to comply with the requirements of the flooring material manufacturer.

To understand what happened on this project and many others, we must examine a test method that is commonly used in the U.S. to quantify the moisture vapor emission rate (MVER) of a concrete subfloor. The method, the calcium chloride test developed by the Rubber Manufacturers Association (RMA) in the 1950s, is now published as ASTM F 1869[1] by ASTM International. MVER testing by the calcium chloride method involves placing an open dish containing a specified, known weight of anhydrous calcium chloride crystals beneath a plastic dome that is sealed to the concrete surface for 60 to 72 hours (Fig. 2). During the test, the crystals absorb moisture vapor in the air beneath the plastic dome. At the end of the exposure period, the difference between the initial and final weight of the crystals is used to calculate the MVER in pounds of water per thousand square feet per 24 hours (commonly referred to simply as "lbs").

Fig. 1: Problems such as these warped and bubbled floor tiles can be caused by moisture and moisture-induced high pH levels beneath the flooring materials

Fig. 2: Typical calcium chloride test kit containing a dish, calcium chloride crystals, and a plastic dome

Today, manufacturers of most flooring materials and coatings require that the MVER not exceed a 3-lb or, in some cases, a 5-lb limit.

WHAT HAPPENED?

So how do floors that initially test to an acceptable level end up testing to a much higher rate after a problem develops? We've found that the following five conditions can contribute to artificially low emission-test results, inaccurate results, or an increase in moisture within the slab once the flooring is installed.

Curing, sealing, or bondbreaking compounds

Curing, sealing, or bondbreaking compounds are commonly used in concrete slab construction and inhibit the release of free moisture from within the slab. These materials are designed to provide moisture retention for curing, surface densification, or the free release of concrete tilt-up wall panels cast on the slab. Most flooring material manufacturers and flooring standards require that these materials be removed before the flooring is installed. Testing conducted over a curing, sealing, or bondbreaking compound will result in a considerably lower MVER than will exist after the material is removed.

Adhesive residue from previous flooring

Adhesive residue is found on most remodeling projects. Testing surfaces without fully removing these residues can lead to artificially low test results. In all cases, we must realize that, while each test occupies less than 1 ft^2 (0.09 m^2) of floor area, the results are considered to represent the surrounding 1000 ft^2 (90 m^2). Preparation of the test site must assure that the concrete surface is free from any material or substance that could hinder the free release of moisture from the slab. Light, dry vacuum-grinding is the most practical and reliable means of properly preparing a concrete slab surface for testing.

HVAC system operation

Conducting calcium chloride tests before doors and windows are installed or before heating, ventilation, and air conditioning (HVAC) systems have been activated can result in MVERs that are different than those that would be measured with the building under its normal operating environment. Bare concrete is a hygroscopic material that will take on or give up moisture depending upon its surroundings. For calcium chloride test results to be as meaningful as possible, it's essential that the tests be conducted with ambient conditions above the slab that are close to the building's normal operating environment. Because flooring installations are frequently scheduled to occur before HVAC systems are in operation, this is often a difficult requirement to meet.

ASTM F 1869 sets requirements for calcium chloride testing that include the testing environment. The standard allows testing in environments that are not under HVAC control within certain reasonable parameters (75 ± 10 °F [23.9 ± 5.6 °C] and 50 ± 10% relative humidity).

Temporary forced drying of the top surface of the concrete may bring calcium chloride test results to a desired level, only to result in flooring problems at a later date due to moisture redistribution within the concrete once the slab is covered.

Redistribution of moisture

Most experts in moisture testing believe that the calcium chloride test is an indicator of moisture present in only the top 1/2 to 3/4 in. (13 to 19 mm) of the slab. As slab-on-ground concrete dries from the top down, it's common for a closed-in, uncovered slab to have a lower moisture content in the top portion of the slab than in the lower regions. Once the slab is covered, moisture will redistribute within the slab, which most often leads to a higher amount of moisture in the upper region than when the emission tests were conducted. Redistribution of moisture within the slab after it's covered is a major contributor to higher emission results being observed when the floor is retested after a problem has developed.

Below-slab vapor retarder

Without effective, low-permeance moisture protection directly beneath the slab, moisture migrating from sources below the floor can, over time, lead to an increase in the moisture content of the slab after the flooring material is installed.[2] Once the slab is covered, relative humidity beneath the slab will often measure close to 100% regardless of the depth of the water table or soil moisture content. The relative humidity in the slab will also increase and can also rise close to 100%. Without an effective vapor retarder directly beneath the slab even a properly measured 3-lb floor will not remain 3 lb for very long once the floor is covered.

WHAT CAN WE DO?

The following suggestions for conducting calcium chloride tests can help provide the most meaningful test results for evaluation:

- Always completely remove curing, sealing, and bond-breaking compounds or adhesive residue by dry, mechanical methods such as light vacuum grinding before conducting the tests;
- Always conduct tests when ambient conditions reflect the normal operating environment of the facility. On projects where HVAC systems are not active, insist on closing in a number of rooms or spaces where conditions can either be brought to anticipated normal conditions or into compliance with the environmental requirements of ASTM F 1869;

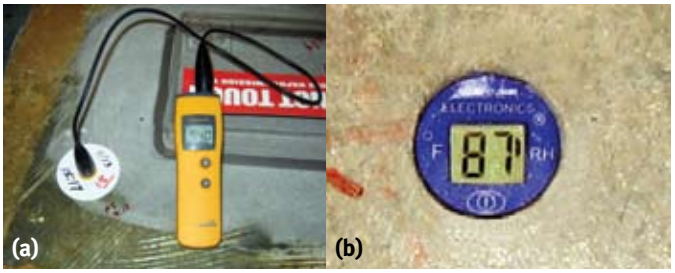

Fig. 3: The internal relative humidity at a depth of 40% of the slab thickness is measured with a digital meter connected to a hygrometer sensor installed in a hole drilled after the slab has hardened: (a) a common system uses a hand-held meter and a probe that's plugged into plastic sleeves installed in the slab; and (b) a recently developed system uses a self-contained probe and meter that remain in the slab

- Conduct testing using both the standard ASTM F 1869 method and a modified method that can give an indication of the effects on MVER that are likely after the floor is covered. In this modified method, curing, sealing, and bondbreaking compounds or adhesive residue are completely removed from a 20 x 40 in. (0.5 x 1.0 m) area, half of which is then covered with aluminum foil, solid vinyl, or rubber for a period of time before the start of testing. The time period for moisture to equalize within the slab will vary; therefore, the longer one can leave the area covered before the start of testing the better. In no case should the time period be less than 1 week, and 2 to 4 weeks is recommended when the schedule will allow. Weight down the cover material to be sure it remains in direct contact with the slab surface. After the cover period, conduct two calcium chloride tests at each location. First, remove the cover material, and immediately place one test kit on the surface of the concrete that has just been uncovered. Next, place a second test kit on the prepared concrete surface adjacent to the area that was covered. The comparative results of these tests serve as an indicator of changes in MVER that are likely to occur once the floor is covered;
- Use internal relative humidity testing (ASTM F 2170[3]) to complement and help with the interpretation of calcium chloride test results. In-place concrete relative humidity tests are widely used in Europe to determine when a flooring installation can proceed safely. In 2003, ASTM F 2170 was introduced in the U.S. for relative humidity testing in concrete. The test procedure calls for measuring the internal relative humidity of concrete (Fig. 3) at a depth of 40% of the slab thickness below the slab surface 72 hours after the drilled test holes and sleeves have been installed. The target level for in-place relative humidity given in ASTM F 710[4] is 75% or lower, but several floor covering manufacturers allow a maximum of 80%. It's important that the sensors are left in place long enough to reach a stable reading. This time period will vary with the type of sensor used and can take up to 3 hours. If sensors are not installed in the sleeves for the entire test period, it's recommended that they be installed the night before the readings are taken; and
- If any moisture test result is to be relied upon, it's important to remember that adequate moisture protection must be in-place directly beneath the slab so that moisture levels within the concrete will not increase significantly once the flooring is installed. Without it, the MVER may increase over time once flooring or coating material is installed.

WHO SHOULD CONDUCT THE TESTS?

Preinstallation moisture and pH testing should be conducted by personnel qualified to conduct the tests in accordance with ASTM standards. Interpretation or evaluation of the moisture and pH test results should be made only by those experienced with the testing methods, moisture migration, conditions, influences, and the floor covering manufacturer's requirements. The calibration of test equipment should be maintained and checked before

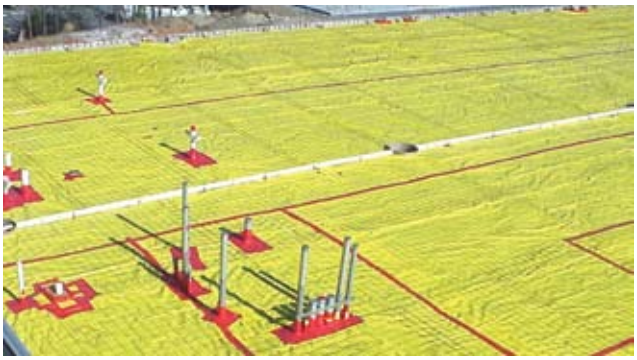

Fig. 4: A properly installed, low-permeability vapor retarder prevents moisture from migrating up through the slab *Photo courtesy of William Munyan*

the start of each project. No flooring installation should proceed without the approval of those responsible for the installation warranty. If ample concrete drying time can't be provided in the construction schedule, a topical moisture and pH suppression system should be incorporated into the project costs from the very beginning.

WHAT SHOULD WE EXPECT?

Properly conducted calcium chloride tests often result in values higher than the 3-lb MVER required by most flooring material manufacturers. The normal construction timeline seldom provides sufficient time or an adequate environment for a new slab to dry and test to a 3-lb requirement. Knowledge of the ambient conditions before and during calcium chloride testing can help determine if reaching the target MVER is achievable. Rewetting a concrete surface after a period of drying has been shown to increase the MVER.[5] Because an open slab surface will take on moisture from the air, testing during and after periods of high ambient relative humidity will make achieving a 3-lb MVER difficult, if not impossible. Even if the ambient relative humidity is subsequently reduced, reaching a 3-lb MVER may not be possible within a short period of time.

Because it's measured at a depth of 40% of the slab's thickness, the internal relative humidity test is far less sensitive to ambient conditions than the calcium chloride test. Slab temperature is a consideration and is recorded by the sensor, along with the concrete's internal relative humidity. Concrete internal relative humidity test results can not only help determine the moisture-related suitability of a concrete subfloor, but they can also help determine whether the inability to reach a 3-lb emission rate is the result of ambient conditions prior to the test or moisture present at a high level deeper within the concrete.

A new type of stay-in-place relative humidity sensor has been recently introduced that can help the project team monitor the drying of new concrete placements. Several of these sensors are installed in each slab placement once the roof is on, the building closed in and watertight, and any curing compound is removed. When the weekly readings reach a relative humidity less than 80%, the testing firm can be contacted to conduct the full ASTM-compliant, preinstallation moisture study with reasonable confidence of favorable results. This approach can save thousands of dollars in repetitive moisture testing costs.

RECOMMENDATIONS

Most problems with floor coverings over concrete slabs-on-ground can be avoided by using a properly designed slab system (Fig. 4) and providing ample drying time or using commercial drying services. A low-permeance vapor-retarding material, properly installed and in direct contact with the underside of the slab, greatly reduces the likelihood of moisture moving from the ground into the concrete and shortens the concrete drying time.[2]

Concrete to receive floor coverings or coatings can be cured with dry, wet-strength curing paper or lay-flat polyethylene for up to 7 days. These methods don't retard the loss of moisture from the slab beyond the curing period. Slabs cast in the open, however, are subject to rewetting until the building is enclosed and watertight.

If a curing compound is used for initial curing or rewetting protection for slabs placed in the open, the material must be completely removed from the slab surface as soon as the building is considered watertight. Otherwise, a letter of compatibility must be obtained from both the floor covering and adhesive manufacturers. Our experience has been that most manufacturers of flooring materials will not issue such a letter, making removal of the curing compound a requirement. Removal should not be delayed beyond enclosure of the building to provide as much drying time as possible before moisture testing.

Finally, the slab must be reliably tested and the data presented to the flooring manufacturer, flooring contractor, general contractor, architect, owner, and any other party associated with the flooring installation.

We're fully aware that these recommendations go well beyond what is presently being done or required on most projects. Given the very common, serious, and costly nature of flooring failures, however, it's believed that these measures are necessary to reduce the risk of flooring problems and the significant cost associated with failure of the flooring system.

References

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Selected for reader interest by the editors.

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