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Solving Problems Caused by Moisture Vapor Transmission on Concrete Floors

By: Robert R. Cain

Abstract: Understanding the cause of moisture related bond failures on concrete surfaces is important in finding a solution. Failures can be vastly reduced with proper testing, evaluation, and surface treatment.

Introduction

Water, or more precisely water vapor, passing through a concrete slab on grade can cause the loss of adhesion, warping, peeling, unacceptable appearance of resilient floor coverings, and bubbles or efflorescence deposits beneath seamless flooring. While we are specifically discussing polymer type coatings and surfacings on concrete in this paper, any impermeable floor covering is detrimentally affected by moisture vapor transmission.

Moisture Migration

Excessive moisture in concrete slabs on grade usually originates from one or more sources:[1]

1. Residual water in or below the slab remaining from the construction process
2. Naturally occurring ground water from a permanent or seasonal high water table
3. Water from irrigation systems, broken plumbing pipes, or other man-made sources

A slab may appear dry, but actually have a deleterious level of moisture vapor passing through it. Moisture passing through the slab can carry alkaline salts from the ground or the concrete itself. According to authorities on the subject, the time required for slabs to dry out sufficiently so that floor coverings and finishes are not adversely affected ranges from four weeks to six months.

Excess moisture in or below the concrete slab is the cause for a large percentage of coating failures on concrete. While moisture in concrete during the application of a floor surfacing is an important criterion, it is not the ultimate cause of failure months or years later. Many epoxy materials can tolerate and bond to a concrete slab with a relatively high moisture content. It is the flow of moisture or moisture vapor, better described as moisture vapor transmission, that causes most adhesion problems. There are also reported cases of bond failures on above grade slabs, but almost all are related to moisture vapor transmission rather than moisture content. A good example would be an above grade concrete slab poured on a metal deck with no vents. Excess water pools on the metal deck and slowly comes to the surface as moisture vapor. The real area of greatest concern is slabs-on-grade and how to dry out and/or minimize the vapor transmission.

Although the curing process of concrete consumes water, it is only the first step in the drying process. This process depends on the relative humidity and temperature environment inside the building, which in turn influences the rate of vapor transmission through and out of the concrete.

Vapor transmission depends on the vapor pressure of air. The vapor pressure difference between air in voids of the concrete and the air above the slab will in part determine the vapor transmission rate.

The vapor pressure of air can be determined from figure A if the relative humidity and temperature are known.[2] To dry a slab, for example, the movement of moisture must be from the concrete to the air. If the environment at the bottom of the concrete has a relative humidity of 100 percent and temperature of 21°C (70°F), the vapor pressure of air within concrete will be about 2.48 kPa (0.36 psi). If the relative humidity and temperature inside the room are 60 percent and 27°C (80°F) respectively, air vapor pressure will be 2 kPa (0.29 psi).

[1] Butt, Thomas K., "Avoiding and Repairing Moisture Problems in Slabs-on –Grade," The Construction Specifier, Dec. 1992, pp 107-122.

[2] Lidholm, Eric H., "Slab Moisture Testing: Is it Always Reliable?" Concrete Construction, June 1996, pp 480-486.

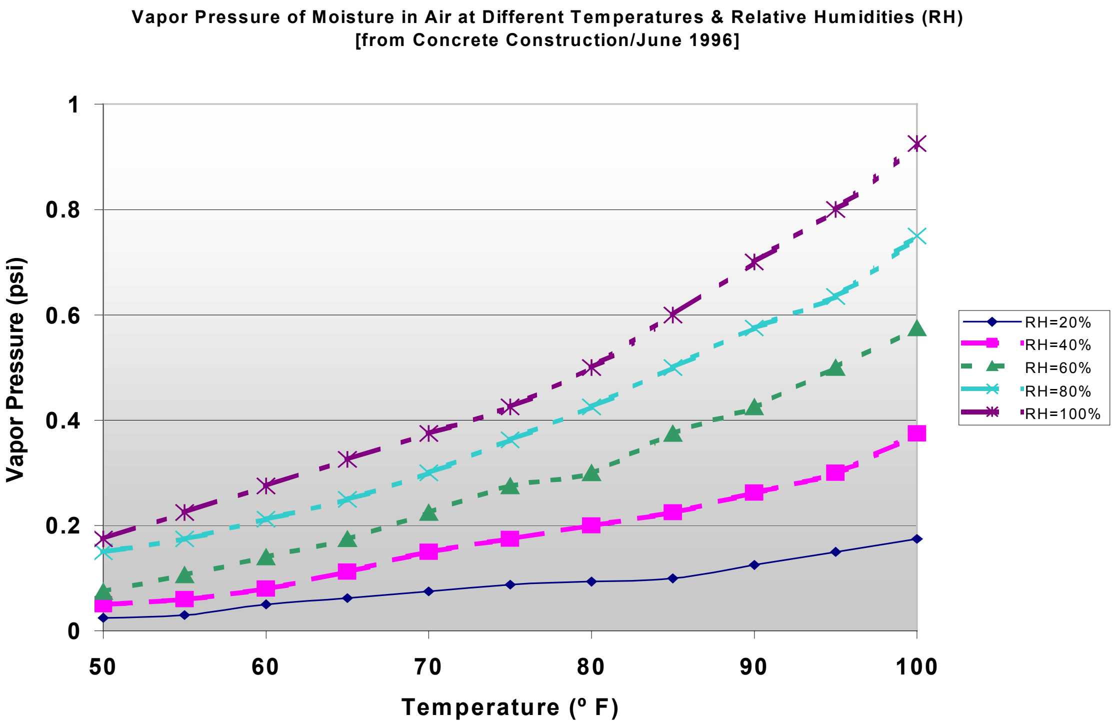

Figure A: The driving force for moisture movement through a slab is the differential in vapor pressure between the above slab and below-slab environments. Use this graph to determine the vapor pressure of moisture in air at different temperatures and reletive humidity.

High pressure moves to low pressure, so the pressure difference of 0.48 kPa (0.07 psi) is the driving force of moist air moving from the concrete to the room. Moisture passing through the slab can carry alkaline salts from the ground or the concrete itself. These salts will precipitate at the surface causing an upward force at the bond line. To force-dry the concrete, it is more desirable to lower the relative humidity in the room than to just raise the temperature. If any of the above conditions exist after the floor covering is installed, then the moisture becomes trapped under the covering and condenses.

Measuring Moisture Transmission

There are a multitude of tests used to establish moisture content and moisture vapor transmission.[3] These include the Plastic Sheet Test (ASTM D-4263), Calcium Chloride Test, Gravimetric Testing, Radio Frequency Test, Nuclear Density Test, and Electro-Conductive Testing (moisture meter). Most of these tests are designed to determine the moisture content or locate areas of excessive moisture. Only two, however, determine the transmission of moisture. The Plastic Sheet Test (ASTM D-4263) will give a qualitative, wet/not wet answer and the Calcium Chloride Test (ASTM F-1869-98) will provide a quantitative value.

The Calcium Chloride Test (ASTM F1869-98) uses a small dish of calcium chloride under an impermeable clear cover. By weighing the dish before and after a seventy-two hour exposure, you can quantify the amount of moisture flow in pounds per 1,000 ft² per 24 hours (kg per 90 m² per 24 hours). A value of 3 lbs. (1.4 kg) or less is believed to be acceptable to most flooring and coating manufacturers. Values on extremely wet floors have been recorded showing greater than 10 lbs. per 1,000 ft² per 24 hours (4.5 kg per 90 m² per 24 hours).

It is important to understand the difference between moisture vapor transmission and moisture content. You may have low moisture content and have a bond

[3] Rode, Malcolm, and Wendler, Doug, “Method for Measuring Moisture Control in Concrete,” Concrete Repair Bulletin, March/April, 1996, pp 12-14.

failure at some point in the future due to moisture vapor transmission through the slab. High moisture content in the slab will usually not cause a problem unless conditions are right to cause movement of that moisture to the surface. So it is moisture transmission to the surface, whether it is from high moisture content in the slab or under the slab, that causes the problem.

Water, more importantly, water vapor, will migrate to the surface when there is a higher vapor pressure in the concrete than in the air above the surface. In many cases, testing for moisture vapor transmission on new buildings is done prior to enclosing the building to allow the flooring contractor to proceed. Since the building is not enclosed, the conditions above the slab are similar to the slab itself and there is little moisture attraction to the surface and the test reads dry (less than 3 lbs. based on the calcium chloride test). When the building is enclosed, the air conditioning lowers the humidity and the temperature, which lowers the vapor pressure causing a gradient and creating a vapor drive.

The original theory on bond failures was that loss of bond was due to hydrostatic pressure caused by the vapor drive. However, this pressure is not caused by hydrostatic pressure. This pressure is caused by the upward movement of metal salts that gather at the surface and form silicates such as calcium and potassium in a typical alkali-silica reaction. All ingredients of such a reaction are present: amorphous silica, calcium hydroxide (lime), and moisture. Such reactions can cause pressures up to 1,500 psi, more than enough to cause bond failures in floor surfacings. By changing this combination, the pressures (and failures) are less common. Controlling the moisture migration is the best choice.

Controlling Moisture Transmission

The best way to control moisture vapor transmission is right at the beginning, from the subsoil to the concrete placement. When installing slabs-on-grade that are to receive an impermeable (non-breathing) coating or surfacing, an efficient vapor barrier must be used beneath the concrete.

The placement of a vapor barrier is also important. The American Concrete Institute (ACI) is vague about the ground moisture conditions requiring vapor barrier use. Section 302.IR-96, subsection 3.2.3 discusses the use of vapor retarders (barriers) and recommends the vapor retarder be placed under a minimum of 4 in. (100 mm) of compactible, granular fill (Section 4.1.5).[4] This is done to assist in the curing of the slab.

If a vapor barrier is installed in this manner (under a granular fill), an extended period of time (much longer than thirty days and in some cases over a year) is required to dry adequately enough for an impermeable coating to be used on the surface.

When using an efficient vapor barrier to control moisture vapor transmission, it should be placed directly under the slab and be more efficient than six-mil poly, which is easily punctured during concrete placement. ACI 302.IR-96 now recommends that a minimum of 10 mils (0.25mm) be used. Once the vapor barrier has been chosen and is in place, a good quality concrete and good placement techniques are important. A low water to cement ratio (0.45 max), designed for high compressive strength and low permeability, are important. A well-placed and properly-cured concrete slab will provide a hard, dense concrete surface of low permeability. The following job site conditions will minimize the excessive moisture transmission of a slab-on-grade:

1. Place concrete directly over an efficient vapor barrier (greater than six-mil poly and puncture resistant).
2. Use low water to cement ratios in the concrete mix (0.45 max) and 4 in. maximum slump.
3. Adequately cure the slab for maximum surface strength and low permeability.
4. Perform moisture transmission tests using the Calcium Chloride Test (ASTM F-1869-98) to quantify the degree of moisture transmission. Simulate in-use conditions of the building when running these tests. Only under a controlled environment will this test be meaningful.

Repairing Failures

The problem of moisture vapor transmission in concrete slabs on or below grade has been a recognized condition for many years. Called by a variety of names, such as hydrostatic pressure, osmosis, and capillary action, the problem is finally

[4] American Concrete Institute (ACI), "Guide for Concrete Floor and Slab Construction," Section 302.IR-96 subsections 3.2.3 and 4.1.5.

being defined properly to focus on solutions short of removing the concrete slab and starting over.

Several companies offer warranted treatments to the surface that are aimed at reducing or eliminating the problem. Floor coating manufacturers are also offering treatments to go under their systems for prevention of bond failure.

Some treatments that have shown promise are:

1. A common remedy and repair is to use a breathable system, which allows the passage of moisture vapor without interfering with the bond. These systems are typically some form of modified cementitious material.
2. The use of penetrating primers and hardeners, which reduce the rate of moisture transmission, are effective if the initial transmission rates are not excessively high. In these cases, as in all scenarios, testing along the way is important. The three-pound per one thousand square feet per twenty-four hour figure is the goal.
3. Semipermeable membranes are being used to reduce the moisture rate below three pounds. These systems are composed of a fiberglass mat or membrane impregnated with a resinous binder. The composition acts as a wick to diffuse moisture and prevent a build-up of salts. The membrane allows the moisture to be distributed laterally. Condensed moisture is also trapped and allowed to absorb back into the concrete as a liquid.
4. Multiple phase systems are also being designed to reduce moisture vapor transmission in concrete. These systems use multiple applications of material which gradually reduces porosity and increases density in the concrete surface. This is followed by successive layers of semi-permeable slurries which reduces vapor transmission to an acceptable level.

Conclusion

The problem of moisture in and under a concrete slab-on-grade is a problem of vapor transmission through the slab. The attraction or flow of moisture to the surface is the normal flow from a point of high vapor pressure to a point of low vapor pressure to create equilibrium. By controlling or lessening the rate of moisture transmission in slabs-on-grade, we can successfully use impermeable systems on these surfaces.

Once a moisture transmission problem is identified, it requires considerable time and testing to work through the sequence of treatments. Today’s technology, however, is slowly beginning to solve the problems associated with moisture vapor transmission.