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Controling Moisture Migration with Advances in Polymer Technology

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Abstract: Moisture migration in buildings has become a monumental problem for formulators servicing the construction industry. Specialty floor and wall systems fail due to moisture intrusion into buildings, molded carpeting has caused schools to close, resilient tile, sheet goods, and wood floors blister and lose bond to the substrate. Understanding the problem has been a long and difficult process. Each of the various theories on the causes of moisture migration contribute to a complete description of the problem. Recent advances in both available raw materials and formulating have given us the opportunity to control moisture migration to eliminate these problems.

Moisture vapor transmission failure of epoxy quartz system.

Introduction

Formulators who supply resinous materials in the civil-engineering market, particullarly those who supply protective surfacings for concrete, have had a common problem in searching for long-term protection. Moisture migration into buildings, through concrete, has become a monumental stumbling point in this market. Specialty floor and wall systems fail due to moisture intrusion into buildings. Molded carpeting has closed schools, resilient tile, sheet goods, and wood floors have blistered and buckled, losing bond to the substrate. Blister formation is the common mode of failure for most coatings and adhesives. I could personally relate a hundred different horror stories about major problems encountered in the field.

Moisture Migration

Understanding this problem has been a long and difficult process. Before finding a solution, the problem had to be identified. There are a wide variety of publications expressing different perspectives and causes of moisture migration. The overall cause and effect is the one recognized phenomenon.

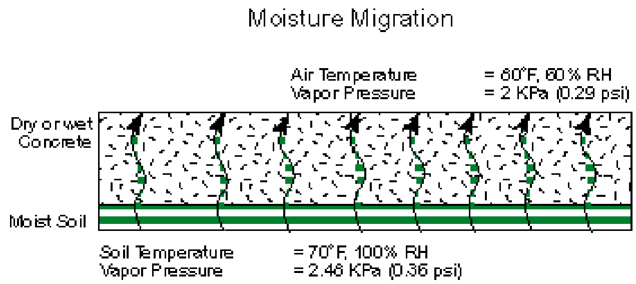

Figure A

In the past moisture migration through concrete has been mistakenly identified as moisture content in concrete. Concrete is considered to be dry when its moisture content is in equilibrium with the ambient conditions. Nearly everyone knows how to get a pretty good bond to concrete that has a high moisture content. It is when that moisture begins to move that problems start.

The common mode of failure is blistering of the coating or floor covering. This blistering seems to relate in some way to a build-up of pressure. Lawsuits claiming hydrostatic pressure have been lost because there is not any detected in jobs exhibiting moisture migration.

There are three basic theories describing moisture migration failures that are worth mentioning.

1. Osmotic Blistering[1]

Pressures generated by osmosis can greatly exceed other forces (e.g. adhesion) and ultimately cause the delamination of a coating or other surfacing on concrete. Three things are required for osmosis to take place: water (liquid or vapor), soluble salts (which are always found in concrete), and a semi-permeable membrane (the concrete itself). All three are part of the initial concrete mixture. The difference in soluble salt concentration, coupled with concrete permeability for inorganic salts between the top and bottom sections, have been identified as major contributors to the formation of an osmotic cell. Higher concentrations of soluble salts are typically found in the top section of the concrete and are the attraction for the moisture to migrate to the surface. As the concentration of salts accumulate and precipitate, pressures are formed which exceed the bond strength of most adhesives.

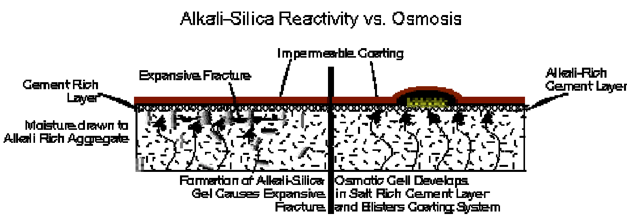

Figure B

2. Alkali-Silica-Reactivity (ASR)

ASR is a common problem that occurs when the alkali salts in large and fine aggregates react with the silica in the cement rich top layer of concrete and form an expansive gel which can break concrete apart and create pressures over 1,000 psi. It is important to note that the same ingredients are needed for ASR as are needed for an osmotic cell: water, alkali salts, and the silica/cement paste.

[1] Warlow, WJ & Pye, PW, MRIC, "Osmosis as a Cause of Blistering of In-Situ Resin Flooring on Wet Concrete," Department of the Environment, Building Research Establishment

3. Vapor Transmission

The third and final contributor to the problem is really the main cause: moisture vapor transmission. High moisture content in the slab will not usually cause a problem unless the conditions are right to cause the moisture to move from within or below the slab to the surface of the concrete. Thus, it is moisture transmission to the surface, whether it is from high moisture content in the concrete or under the slab, that is the real cause. The vapor transmission rate depends on the vapor pressure of the air and the differences above the concrete slab and those below the concrete slab.

Water vapor will migrate to the surface when the vapor pressure in the concrete is higher than the vapor pressure in the air above the surface of the concrete. There are charts for determining the vapor pressure of air if the relative humidity and temperature are known.[2]

High pressure moves to low pressure, so the difference is the force driving moist air from in and below the concrete to the surface. Moisture passing through the slab can carry alkaline salts from the ground or the concrete itself. The upward drive is the contributor to the osmosis and ASR which acculmulate the salts. It causes high alkalinity and pressures sufficient to cause bond and adhesion failures.

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

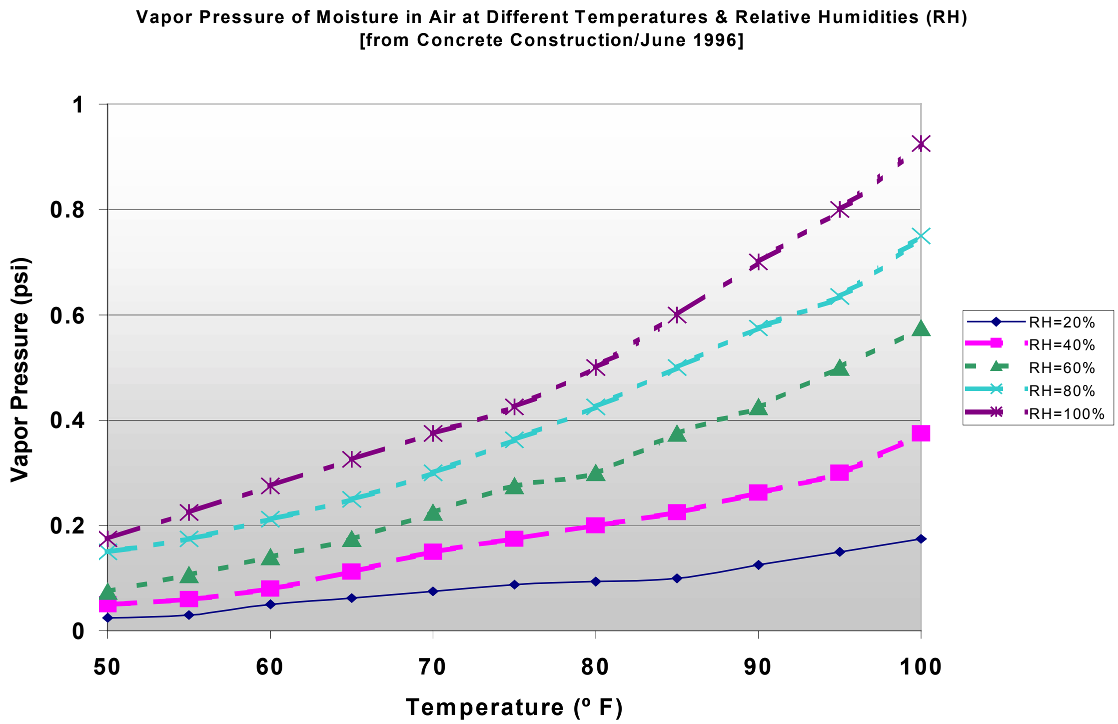

Figure C: The driving force for moisture movement through a slab is the differential in vapor pressure between the above slab and below-slab environments. Use this graph to determine the vapor pressure of moisture in air at different temperatures and reletive humidity.

Controlling Moisture Transmission

Now that there is a better understanding of the problem, we can shift the tide and neutalize the negative effects of moisture vapor transmission. As with most problem solving solutions, a variety of products have been introduced to the market with various degrees of success or failure. Most solutions, to date, incorporate breatheable systems that slow down the moisture flow and rely on allowing the moisture to flow through the system and evaporate. However, if impermeable coatings are then applied over these systems, failures can still occur. We have been able to combine some reactions to first slow down the pressures caused by osmosis and ASR and then dissipate the residual moisture flow to eliminate its desire to move.

The use of a metal additive (K-911) has been found to neutralize the alkali-silica reactiveity at the surface and eliminate the pressure buildup caused by ASR reactivity. Metals of sodium and potassium actually contribute to ASR but K-911 acts to pacify the surface to stop further activity.

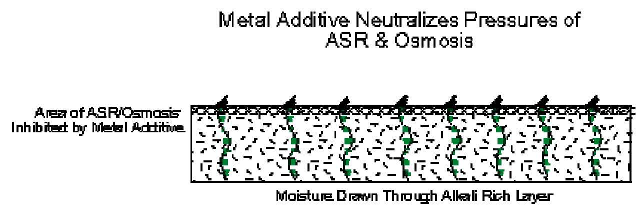

Figure D

Another ingredient put to good use is the development of the breatheable waterborne epoxy technology of Anquamine-701/Anquamine-401[3] which, when formulated, generate a micro-porous morphology, allowing the coating system to be breatheable once fully cured.

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[3] Cook, Michael, Lohe, Mattias, and Klippstein, Achim, "Novel Technology for 2K Water Vapour Permeable Epoxy Floor Systems: A European Perspective," JPCL, Feb. 2002, pp 51-56.

Water Vapour Permeability of Epoxy-Self-Leveling Floors[4]

Properties	Water-Borne	Cycloaliphatic
Film Thickness (µm)	2,550	1,870
WVT (g/m^2/24 hrs)	8.1	0.4
Permeance (perms)	11.7	0.09
Permeance ($g/s/m^2/Pa$)	6.7×10^{-7}	0.05×10^{-7}
µ-Factor	1,000	30,000

The water vapor permeability, versus a 100% solids epoxy/cycloaliphatic self-leveling floor system, shows the measured permeability of the waterborne coating is 20-30 times greater than that of the solvent-free coating system.[5]

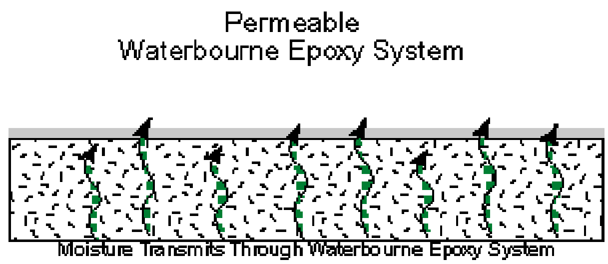

Figure E

Coatings and floor surfacings are classified as permeable when a US permeability rating of greater than 3 perms (1.7×10^{-7} $g/s/m^2$, Pa) is achieved.[6] Standard concrete, by comparison, with a compressive strength of 3,045 psi (21 MPa) typically exhibits a permeability of 20-30 perms ($1.1\text{-}1.5 \times 10^{-6}$ $g/s/m^2$, Pa).

At this point we have an additive to control the pressures caused by osmosis and ASR and a breathable system which allows moisture transmision to continue through the system. We need to conbine these performance characteristics to eliminate the pressure and dissipate the moisture flow. By using the K-911 metal pacifier in conjunction with the waterborne epoxy, we can achieve both requirements in one application. The modified system pacifies and neutralizes the concrete surface which diminishes the ASR and the osmotic pressures. In so doing, the permeability is reduced and the moisture vapor transmission is lowered by as much as 50% or more. The permeability then becomes much closer to the permeability of the waterborne epoxy. The moisture vapor works its way through the surface of the concrete and enters the maze of micro-porosity at which time it loses the desire to go any further. As stated previously, concrete is considered to be dry when its moisture content is in equilibrium with the ambient conditions. We can then cover the modified system with any impermeable system.

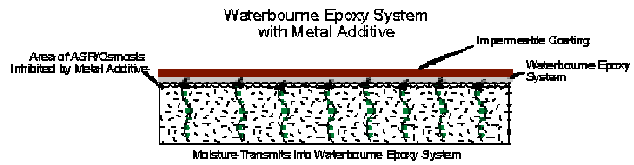

Figure F

Conclusion

Moisture migration continues to be a problem for formulators in the construction industry. 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, impermeable systems can successfully be installed on these surfaces. Combining the technologies offered by the various raw material suppliers enables formulators the opportunity to solve these problems faced on a day to day basis.

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[4] Ibid.

[5] Ibid.

[6] Ibid.