SUMMARY OF CAUSE AND MEASUREMENT CONCRETE MOISTURE VAPOR EMISSION AND IN-SITU RELATIVE HUMIDITY

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Synopsis

Concrete moisture vapor emission is a natural constituent of any concrete slab. It may be encountered as the emission of mix water during the drying process of a new concrete slab. Concrete drying creates an emission from the slab regardless of whether the concrete slab is below, on or above grade. Moisture vapor emission from suspended concrete is often overlooked as a potential cause of floor covering failure and this specific problem may be exacerbated by the use of light-weight aggregates . Beyond the drying process, moisture vapor emission may be the result of moisture vapor transmission from sources below the slab. The moisture source can be water trapped in a blotter course over a vapor retarder or moisture from the earth passing through the slab system. The major concerns surrounding this issue have been driven by changes in floor covering adhesives and coatings, which are more sensitive to moisture and alkali attack than previous materials. More important than floor covering system failure is the concept that Sick Building Syndrome and other I.A.Q. issues often start at the floor surface and are fed by the high sustained humidity levels created by excessive concrete moisture vapor emission.

Vapor Pressure

At each gradient of temperature and humidity, a subtle pressure measured in "pounds per square inch" exists. This pressure has been studied, quantified and has for years been considered in the design of wall systems when moisture vapor movement through a wall is of concern. This same concern must now be recognized in the design of concrete floor slab systems. Inside a building envelope the static vapor pressure is often only half that of the pressure inside of, or below, a concrete floor slab. Therefore, available moisture is literally sucked into the building envelope and often trapped beneath floor covering materials.

Slab Permeability

The volume of moisture which may pass through a slab is governed by the permeability of that slab. Permeability of hardened concrete is a consequence of the water/cement ratio of the original concrete mix design and the grading of large aggregate. As the water/cement ratio increases in linear form, the permeability of the finished concrete product increases exponentially. The current use of smaller sized large aggregate, to facilitate pumping, along with the use of gap-graded aggregate mixes have necessitated the use of additional cement paste in each batch of concrete. Cement paste is the permeable constituent of concrete. Hard rock aggregates are not highly permeable.

Concrete Curing

The concept of curing concrete is often mistaken for the process of drying concrete. Curing is best described as the chemical reaction which turns the raw ingredients of a concrete mix into a man made agglomerate rock. Drying is the process of evacuating all of the excess water in the mix. This is water not used to hydrate the cement into a paste or bonding agent. Curing of modern concrete takes numerous forms and may use one of many methods. However, studies have shown that moist curing a slab, preferably through the use of curing blankets, results in increased strength and density when compared to other methods. As an additional benefit, the use of curing blankets allows a contractor complete control over both the curing and drying processes.

Sub-Slab Vapor Retarders

The importance of these materials has risen with the need to reduce moisture intrusion into building envelopes. Numerous companies are producing excellent products that offer measured permeability ratings below 0.1 U.S. perms. High quality vapor retarders are designed with tear and puncture resistant characteristics to ensure durability on a construction site. Typically they come with installation instructions that include methods of sealing around pipes and other protrusions that will necessarily penetrate the membrane. All of the earth has some amount of free moisture and construction processes often require adding moisture at a building site to achieve necessary compaction and stability. Regardless of source or causation the best means of preventing soil borne moisture from entering a concrete slab is through the employment of an effective sub-slab vapor retarding membrane. The American Society for Testing and Materials (ASTM) has published performance standards for sub-slab vapor retarders (ASTM - E 1745) along with a standard for the installation of sub-slab moisture vapor retarders (ASTM E-1643). These documents should be referenced on every construction project.
Currently, the American Concrete Institute (ACI) recommends placing concrete directly over a vapor retarder when moisture sensitive floor coverings are to be installed (ACI 302.1R and ACI 302.2R-06).

Schedules

One of the factors challenging everyone involved in modern construction is time. Fast track construction is becoming the norm and concrete is not being given sufficient time to naturally dry prior to the installation of floor covering materials and coatings. This issue is being exacerbated by the use of curing compounds, which inhibit or prevent concrete from drying. Realize that we are attempting to adhere floor covering materials utilizing water based adhesive systems to a water based agglomerate we call concrete. Excessive moisture emission, from concrete that has not sufficiently dried, will almost invariably interfere with the ability of an adhesive to bond or cure properly.

Testing

The Calcium Chloride Vapor Emission Test has been developed to quantify, in a meaningful way, the amount of moisture vapor emitting from the surface of a concrete slab. It has been known as the R.M.A. Test, the Moisture Dome Test and by it's current name. ASTM has published a standard for the use of calcium chloride to measure moisture vapor emission from concrete, ASTM F1869-04 is the most current edition of the protocol. The results, reported as "pounds per one thousand square feet per twentyfour hours" are accepted by most flooring, adhesive and resinous coating manufacturers in establishing the benchmark of acceptability for the installation of their products over a concrete substrate. The test is performed by placing a quantity of calcium chloride in an open dish and placing the dish on a clean concrete surface. The dish is covered by a dome of approximately 9" x 9" and 2" in height. This dome is sealed to the concrete to prevent normal humidity in the room from affecting the test. The test apparatus is left undisturbed for a period of from 60 to 72 hours. At the end of the test period the dish is retrieved and any weight gain experienced by the dish is attributed to moisture leaving the concrete and being absorbed by the calcium chloride. Through calculation, the test results are extrapolated to approximate the equivalent number of " pounds" of emission as outlined above. It should be noted that the environment of the air space in the building envelope is of critical importance during the test series. As discussed earlier, the vapor pressure differential, created by temperature and humidity have a controlling influence on moisture vapor movement. Testing should take place in a building envelope conditioned to the same ambient temperature and relative humidity levels as the occupant/tenant will require during use
of the space. If these conditions cannot be met, the ASTM standard offers tolerances which, at a minimum, should be honored if accurate test results are anticipated. Testing in a non-acclimated environment leads to erroneous results. Per ASTM, test density is required to equal 3 tests in the first 1,000 square feet, with one additional test per each additional 1,000 square feet of concrete slab surface.

ASTM committee F.06 on Resilient Flooring has developed and published a standard for In-Situ Testing of Concrete Relative Humidity. This test method has been used extensively in Europe and after side-by-side testing with calcium chloride kits, this agency believes that the In-Situ RH data is more useful and meaningful than calcium chloride test results. We will continue to utilize calcium chloride tests when investigating a floor covering failure, but recommend the in-situ RH test when evaluating new concrete. The ASTM standard for in-situ RH testing is designated ASTM F-2170-02 and closely follows the procedures used in Europe. The test standard requires drilling holes at a diameter of 5/8" to a depth equal to 40% of the slab's thickness. The hole is then lined with a plastic sleeve and the sleeve is capped. The test site must be permitted to acclimate for 72 hours prior to reading relative humidity levels. After or during acclimation, or equilibration, a probe is placed in the sleeve that permits readings to be obtained from the bottom of the hole, thereby offering a method to measure moisture content inside of the concrete slab reported as a relative humidity level. It is critically important that probe sensor temperature is at equilibrium with concrete slab temperature. Testing should take place in an acclimated building and at the same test placement density as noted above. However, it is our field experience that this test method is less affected by conditions occurring at the concrete surface, which may influence calcium chloride test results. Testing density is required to equal 3 tests in the first 1,000 square feet, with one additional test per each additional 1,000 square feet of concrete slab surface.

Prior to selecting a test method for any given project, it is recommended that the manufacturer(s) of floor coverings, coatings and adhesives selected for the project be contacted. In order to protect warranty rights, their guidance regarding acceptable test methods for determining suitability and dryness of a concrete slab should be followed. However, as a point that cannot be overemphasized, concrete dryness testing in any manner is a picture in time and neither method described above can do anything more than report the state or condition of the slab, at the elevation being tested, at he time of testing. Neither test can guarantee future conditions, but in our opinion the in-situ RH test appears to be a better predictor of potential problems.

Alkalinity is another natural constituent of all concrete. The internal alkaline state of concrete is the very chemistry that prevents reinforcing steel from rusting. However, when the surface of a concrete slab has an alkalinity over 9 on a pH scale, adhesive and bonding systems may be compromised. It is recommended that a pH meter or pH paper testing be performed at each site calcium chloride vapor testing is performed. Moisture causes damage, moisture at a high pH is devastating.

Decision

Too often a decision to install floor coverings or coatings is based on poor information or the simple demand to meet a schedule. If a concrete substrate has a moisture vapor emission level, in-situ relative humidity or a pH level in excess of that which can be tolerated by the flooring material, the losses are rarely limited to the flooring itself. The tenant may end up, at best, with an eyesore, at worst there may be a trip or slip and fall hazard with dire financial consequences. The need to vacate a floor after move in, while repairs are made, can be extremely costly. For many industries the loss of revenues from a clean-room or operating room can exceed the value of the floor by a magnitude of 50 or greater. Thoughtful design and placement of concrete may reduce or eliminate problematic conditions, but all concrete will have a constituent vapor emission for the life of the slab. Proactively testing the concrete prior to the installation of flooring may prevent the considerable losses attributed to excessive moisture vapor emission and related floor covering system failure.

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