Take the Ground Out of Play!

EFFECTIVE BELOW-SLAB MOISTURE PROTECTION IS THE ANSWER TO AVOIDING MANY FLOORING AND COATING PROBLEMS.

By Peter Craig and Monica Rourke

Moisture-related flooring problems have become one of the most common and costly construction issues faced today. Estimates of the direct and indirect costs associated with such problems now range from $300 million to over a billion dollars each year in this country alone. While such problems have been occurring since floor-covering materials were first installed over concrete, the frequency and magnitude of such problems have increased considerably in the past decade.

WHY NOW?

There are a number of reasons why moisture-related flooring problems have escalated in the past decade. First of all, we now live in a "get-it-up-and-get-it-open" world. Many of today's construction projects and schedules simply do not provide adequate time for concrete to dry to an acceptable level naturally. The lack of effective below-slab moisture protection on many projects significantly lengthens the drying time of concrete and leaves the slab unprotected from moisture entering from below. In addition, many of the tests being used to determine the moisture-related suitability of a concrete subfloor are either being performed inaccurately or insufficiently, or the results are not being properly interpreted.

Blistered epoxy floor

Moisture-related flooring distress

Dry Bulb Temperature °F	Typical vapor pressure range beneath slab (psi) ← Relative Humidity % →						Typical interior vapor pressure range above slab (psi)			
↓	100	90	80	70	60	50	40	30	20	10
100	0.948	0.854	0.758	0.663	0.569	0.474	0.379	0.284	0.189	0.095
90	.698	.628	.558	.489	.419	.349	.279	.209	.140	.070
80	.506	.455	.405	.357	.303	.253	.202	.152	.101	.051
75	.429	.386	.343	.300	.258	.214	.172	.129	.086	.043
70	.362	.326	.290	.253	.217	.181	.145	.108	.072	.036
65	.305	.274	.244	.213	.183	.152	.122	.091	.061	.030
60	.256	.230	.205	.179	.153	.128	.102	.077	.051	.026
55	.214	.192	.171	.149	.128	.107	.085	.064	.042	.021
50	.178	.160	.142	.124	.107	.089	.071	.053	.036	.018

Vapor pressure (psi) for various temperatures and relative humidities

WHERE DOES MOISTURE THAT CAN ADVERSELY AFFECT FLOORING MATERIALS COME FROM?

The first source of moisture that is a challenge to any new construction project is "free water" within the concrete mixture itself. All conventional concrete used for floor slabs contains more water than is necessary simply to satisfy hydration of the cementitious content. Free water, or "water of convenience," is necessary to bring a concrete mixture to a workable consistency. However, a good portion of this free, nonchemically bound water must escape from the concrete mass in order for the moisture content within to reach an acceptable level for the safe installation of floor-covering materials. Such materials include the flooring, adhesives, underlayments, and low-permeance coatings.

The second major source of moisture is from the ground beneath the slab. Regardless of the depth of the water table, once the building is constructed, evaporation of moisture from the ground is reduced. With the slab in place and covered, the natural process of diffusion will attempt to establish a state of moisture equilibrium between the water table and the covered slab. Relative humidity measured in the ground beneath covered slabs often tests close to 100%.

Concrete will lose or take on moisture based on its surroundings. Slabs placed in the open are subject to being rewetted by rainfall. Slabs placed in the more humid regions of the country will not dry as quickly as those in drier climates. However, beyond the challenge of getting concrete to test to an acceptable level of dryness is the challenge of keeping it dry once it is covered. Here, the solution is the use of an effective below-slab vapor barrier/retarder material placed in direct contact with the underside of the slab. Without such protection, the level of moisture within the concrete will increase over time, which can lead to flooring problems. In short, effective below-slab moisture protection is an absolute necessity beneath floors to be covered by moisture-sensitive flooring materials.

High pH condition below carpet tile

HOW DOES MOISTURE CAUSE A FLOORING PROBLEM?

Moisture alone can cause a flooring problem when it is high enough to inhibit the proper set of adhesives or to cause dimensional change in the flooring material. However, more often than not, it is moisture that acts as a necessary contributor to other mechanisms that are causing the problem. Moisture can lead to the development of a high-pH condition in the near-surface region of the slab. Not only can a saturated, high-pH condition attack and weaken adhesives, but recent studies suggest that a saturated, high-alkali condition in the near-surface region of the slab can also lead to a reaction occurring with fine aggregate particles when such materials are reactive in nature. This process is similar to conventional alkali silica reaction (ASR), except that the former can occur in a much shorter period of time. Such reactions can develop expansive forces on their own or through the process of osmosis.

Low-permeance, below-slab vapor barrier

WHAT IS THE ANSWER?

In simple terms, get rid of the moisture, and most flooring problems will be resolved. Today it is much easier than ever before to take the ground out of play. New generation vapor-retarder materials have permeance levels well below what has historically been thought to be acceptable. While a permeance of 0.1 perm is considered acceptable for air-barrier materials, it is desirable to have a permeance level well below that to protect moisture-sensitive flooring materials.

One should aim to have the permeance level of moisture protection beneath the slab be lower than that of the material applied above. Without this condition, the potential exists for moisture to increase in a covered slab over time. Ten years ago, it would have required a considerable expenditure to achieve such a goal. Today, there are many companies that offer below-slab moisture protection at an economical cost with permeance levels as low as 0.01 perm.

IF IT IS NOW EASY TO TAKE THE GROUND OUT OF PLAY, WHY IS BELOW-SLAB MOISTURE PROTECTION NOT BEING USED EVERYWHERE FLOORING MATERIALS ARE TO BE APPLIED?

It should be, and flooring guidelines require such. The use of effective below-slab moisture protection is mandatory when floors are to be covered with a resilient floor covering.

However, there have been many challenges to having the use of an effective below-slab vapor barrier/retarder accepted in all circles. For years, many on the concrete side of the discussion have been more concerned about the behavior of concrete placed directly in contact with a vapor retarder than they have been with the subsequent application of floor coverings. There has also been a thought process that below-slab moisture protection is not necessary in drier climates where the water table is well below the building site. Today, many of these mindsets have changed as those who once resisted the use of below-slab vapor protection have come to better understand and respect the science of moisture movement. Others have painfully come to a similar understanding only after being taken to task when an expensive flooring failure has occurred.

Drying Time to reach 3.0 Lbs/1000 sq ft / 24 hrs			
Water-Cement Ratio	Bottom Sealed	Bottom Exposed to Water Vapor	Bottom In Contact with Water
0.40	46	52	54
0.50	82	144	199
0.60	117	365	>> 365
0.70	130	>> 365	>> 365
0.80	148	>> 365	>> 365
0.90	166	>> 365	>> 365
1.0	190	>> 365	>> 365
4 inch thick specimen dried at 73 F and 50% relative humidity			

Four-inch-thick specimen dried at 73˚F and 50% relative humidity

HOW LONG DOES IT TAKE CONCRETE TO DRY TO AN ACCEPTABLE LEVEL FOR FLOOR COVERINGS?

The length of time it takes concrete to dry depends on many factors. The amount of free water in the concrete and the ambient conditions the slab will be exposed to after placement play the greatest roles. However, without an effective vapor barrier/retarder directly beneath the slab, concrete that reaches an acceptable level of dryness will not stay dry. Despite the perception of many, research supports that concrete placed in direct contact with a vapor barrier/retarder will dry faster than concrete exposed to water vapor from below.[1]

In general, with an effective below-slab vapor barrier/retarder in place directly beneath the slab, one needs to think in terms of a minimum of three months' drying time after the building is totally enclosed, watertight, free of any curing compounds, and an ambient environment conducive to drying is established.

Where high ambient humidity exists or effective below-slab moisture protection is not in place, it may not be possible to dry a concrete slab to the target level required by the manufacturer of the flooring material. In these cases, the use of a topical moisture- and pH-suppression system may be necessary to keep the project on schedule. If such a treatment was not considered and budgeted for in the project specifications, the project team will be faced with determining who bears the cost of the mitigation treatment, which can run many dollars per square foot.

The mitigation of excessive slab moisture has become a major segment of the flooring industry with, at last count, over 50 systems available for such use. One must be careful in the selection of a topical system, however, particularly with slabs-on-ground.

With adequate moisture protection or an unvented metal deck beneath the slab, many of the topical moisture remediation systems can be used successfully. However, without adequate moisture protection directly beneath the slab for slabs-on-ground, only a handful of systems have reasonably high success rates, as moisture over time will reach a level above the limits of many systems.

Application of topical moisture mitigation treatments

HOW DOES ONE DETERMINE IF A SLAB IS DRY ENOUGH FOR A FLOOR-COVERING MATERIAL?

Floor-covering, adhesive, and coating manufacturers publish concrete moisture limits for the safe installation of their materials. Historically, the most common requirement was to have the moisture vapor emission rate (MVER) not exceed either a 3-lb or a 5-lb level per 1000 sq ft in 24 hours when tested in accordance

Concrete internal relative humidity (RH) test

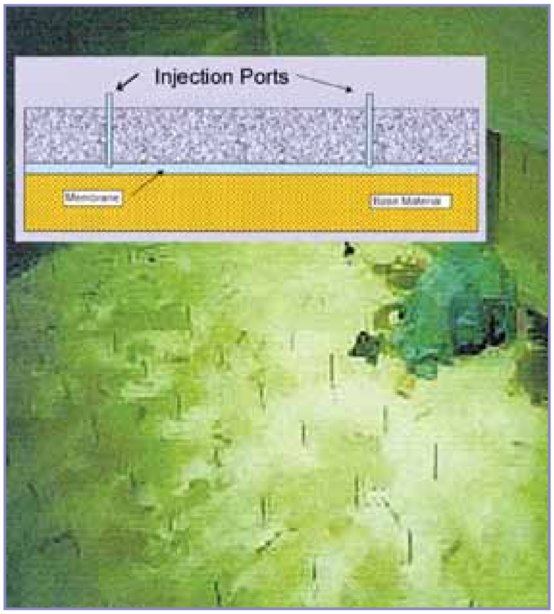
Self-contained RH sensor

with ASTM F 1869. However, in recent years, the science of the calcium chloride test used to measure the MVER has become far better understood and the limitations of the test method revealed. While knowing how much moisture is emitting from the slab surface can be helpful, the MVER test method does not detect the reservoir of moisture deeper in the slab that will rise to the slab surface once the floor is covered.

Today, most manufacturers of flooring materials also reference an internal concrete relative humidity target using ASTM test method F 2170. When a low-permeance vapor retarder is present directly beneath a thermally stable interior slab, and the concrete's internal relative humidity measures 75% or lower at a depth of 40% of the slab's thickness, there is little chance of a flooring problem that is related to moisture or alkali in the slab occurring . However, if a poor-quality vapor retarder has been used, omitted altogether, or placed below a fill-course layer that takes on water, any moisture-test result is subject to significant change, as moisture within the concrete will increase over time.

FIVE STEPS TO AVOIDING MOISTURE-RELATED FLOORING PROBLEMS:

1. Take the ground out of play by installing an extremely low-permeance vapor barrier/retarder material directly beneath the concrete.
2. Utilize a low-shrinkage, low-water-content concrete mixture to reduce drying time and minimize concrete drying shrinkage and curling (warping).[2]
3. Use moisture-retaining, cover-curing methods rather than curing compounds.



Injectable, below-slab moisture protection

4. Test both the moisture vapor emission rate and the concrete internal relative humidity.
5. If necessary, apply a topical moisture and pH suppression system approved by the manufacturer of the flooring material.

WHAT ARE MY OPTIONS IF THE FLOORING HAS ALREADY FAILED?

There are a number of approaches that can be taken to correct a moisture-related flooring failure. In the majority of cases, one of a select group of high-moisture-limit, topical treatments can be used.

Alternative flooring solutions such as stained or polished concrete, ceramic tile, or adhesiveless flooring materials can also be considered.

Most clinical and biotech facilities require welded, resilient sheet goods or polymer flooring. For these or other critical "failure-is-not-an-option" installations where below-slab moisture protection is absent or has failed, a membrane can be created beneath the slab at the slab-soil interface. Utilizing a systematic approach of specialized drilling patterns and injection techniques, a "swelling" membrane can be formed by injection of acrylate chemical grout; or, depending on the condition, a combination of chemical grout, microfine cement, polyurethane, or cementitious materials. Such below-slab, membrane-forming materials have been used for years as a solution to water cutoff problems beneath slabs-on-ground with several newer hybrid materials capable of providing a degree of vapor retardation. This approach is used in conjunction with a topical moisture mitigation treatment and can also be considered to help slow down or even possibly arrest an ASR condition that exists in unprotected slabs-on-ground by reducing the source of moisture feeding the process from below.

THE GOOD NEWS!

While moisture-related flooring issues continue to be problematic, today, with proper planning and execution, such problems can be avoided or corrected.

REFERENCES

1. H.W. Brewer, *Moisture Migration – Concrete Slab-on-Ground Construction, Bulletin D89*, Portland Cement Association, May 1965.
2. Many slab designers are also using continuous reinforcing to reduce or eliminate saw-cut contraction joints and help offset the potential increase in slab curl when concrete is placed in direct contact with a vapor barrier/retarder.

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