ProREZ™
Performance Resins and Coatings

MOISTURE INDUCED BLISTERING

TECH PAPER

INTRODUCTION

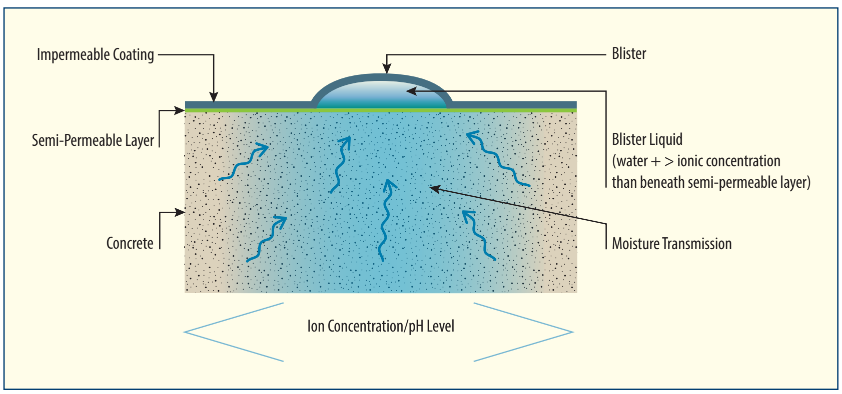
This Tech Paper should prove invaluable in helping installers and end-users whose floors have been affected by moisture induced blistering, microbial growth and even delamination, and to understand the uncertain and dynamic nature of this very costly challenge to the flooring industry. In fact, North American commercial property owners spend nearly $3 billion on remediation of structures and floor coverings as a result of moisture-related flooring failures annually. Over $1 billion is spent on topical moisture ("negative side") treatments- of varying effectiveness- in an effort to address these moisture issues prior to the flooring system being installed. As a result of these flooring failures due to moisture, this business sector has experienced much "finger pointing" among those affected, "head scratching" uncertainty, as well as an increasing number of scientific studies in recent years to critically examine and better understand the nature of this industry-wide challenge.

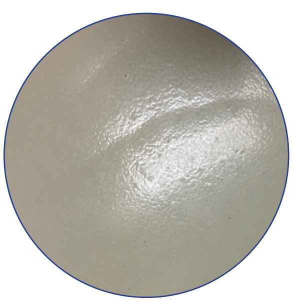
Even though we have made significant strides toward better understanding and mitigating moisture-related problems associated with concrete substrates and impermeable or low permeability resinous flooring materials, we are still challenged by the inexact science, as well as the many variables complicating definitive solutions. With all that said, these moisture-related concerns can be significantly mitigated, if not specifically eradicated, when carefully considering the precautions described herein this paper.

THE CONDITION

When compared historically, we are now experiencing a declining number of resinous flooring installations adversely affected by moisture-related conditions such as "osmotic blistering" as a result of better understanding the condition itself, the mechanisms precipitating the condition, proper testing and evaluation of the concrete prior to installing resinous floor coatings, as well as better engineered surface treatments for mitigating the condition. For those flooring systems affected, this condition often develops unexpectedly within the first year or a complete "seasonal cycle" of the floor's service life. In many cases, signs of "telltale" floor surface (osmotic) blisters may appear within the first 3-6 months following installation of an impermeable (non-breathable) or low permeability resinous flooring material. These osmotic blisters (i.e. moisture trapped beneath the surface of the floor coating) can vary in size from several millimeters to greater than a couple of inches. When drilled into or otherwise broken, they will release under pressure (~10-20 psi) a discolored aqueous liquid solution carrying alkalis (i.e. naturally inherent to the concrete like potassium & sodium hydroxide, etc.), as well as other soluble inorganic and organic compounds hydrolyzed in this water-based solution.

OSMOTIC CELL PRESSURE





Close-up of blistered surface

BRIEF HISTORY

Experimental studies in Germany by Siegfried Wisser of the Hoechst laboratory in Hamburg and also by Reinhold Stenner of the Polymer Institute in Wicke, have demonstrated that osmosis can cause surface blisters in resinous coatings. A survey in Europe of reported problems in flooring systems indicates that osmotic blisters occur only in non-breathable (impermeable) or low permeability resinous flooring up to about ¼" in thickness. The problem has not generally been observed with thicker troweled resin-type flooring systems, possibly because of their higher resistance to deformation by the development of isolated and pressurized osmotic cells, as well as a potentially greater degree of lateral permeability with the highly filled matrix itself.

OSMOSIS

The term "osmosis" is used generally to describe the dynamic and passive flow of liquid water or the diffusion and condensation water-vapor into an aqueous solution, or from a more dilute solution to a more concentrated one when the two are separated by a semipermeable membrane like a concrete slab. A semipermeable membrane like concrete is one that will allow the passage of water or water vapor through its pores and/or micro-capillaries, but not the dissolved substance. If the side of the membrane containing the higher concentration is sealed and non-breathable, then the passage of water or moisture-vapor through the membrane from bottom to top will cause a pressure to develop at the bond line interface between the substrate and the coating material. In the case of moisture-vapor, it will continue to diffuse through the slab's pores and micro-capillaries to the surface of the sealed substrate, condensing and forming an aqueous solution as a result of saturation.

Four conditions are required for osmosis to occur:

- A semipermeable (porous) membrane (e.g. concrete)
- A low permeability or impermeable (non-breathable) flooring (e.g. resinous coating) material adhered to the membrane
- A concentration of water-soluble material (e.g. soluble ions) within the concrete membrane
- A source of water

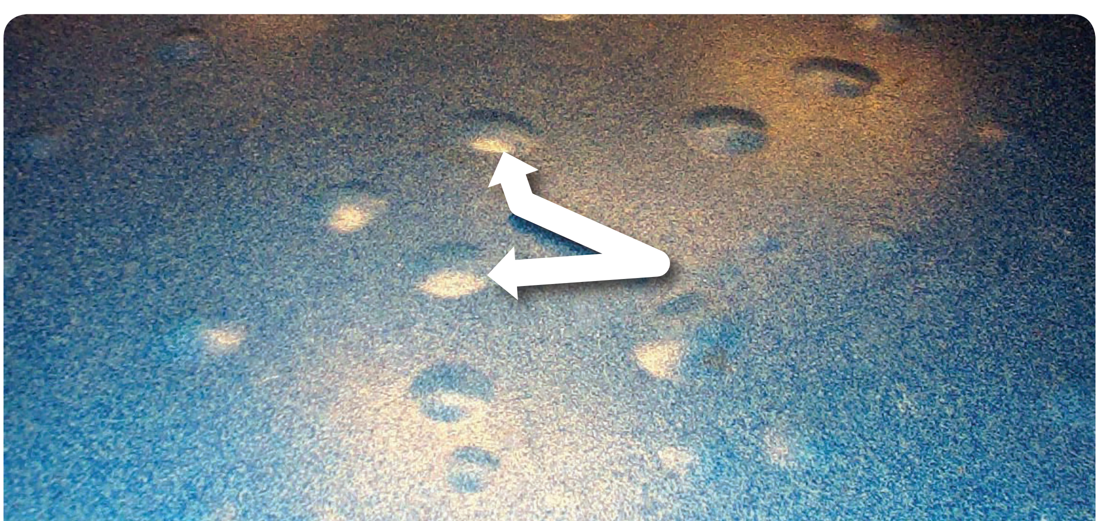
The mechanism for the blister formation is still not thoroughly understood across very unique and dynamic flooring failure scenarios, but the most likely explanation for their manifestation as well as their physical make-up is that by a process of Osmosis.

Blistering can also be caused in other ways such as by direct hydrostatic pressure, if the concrete slab is below the water table, or by water vapor trapped within the concrete slab as a result of still being too "green" (i.e. excess "moisture of convenience" yet to have evaporated in the curing concrete slab), or simply drying conditions above the curing concrete slab being excessively cool and high in humidity. In this particular case, a prematurely installed resinous floor coating might develop osmotic blisters shortly after application. Water or condensed water vapor lodged in the connected pores or micro-capillaries of the concrete can also prevent the proper wetting and lead to displacement and ultimately poor adhesion value to the concrete substrate. In some cases, the condensing moisture may occur so quickly within the concrete slab that an "osmotic cell" develops before the resinous floor coating material has fully cured, and thus rapidly accelerating the development of osmotic blisters at the "bond line" interface between the impermeable or low-permeability coating and the concrete substrate surface itself. Poor initial adhesion of the resinous coating material to the substrate is extremely problematic in severe moisture-related and alkaline conditions as a lack of bond strength or bond failure with the persistence in the aforementioned reduces the resistance properties of the material to perform successfully over time, and significantly increases the likelihood for osmotic blisters.

Other environmental factors driving this condition might include dynamic temperature differentials over relatively short periods of time closely following the installation of an impermeable or low-permeability resinous floor coating. For example, substrate exposure to sustained direct sunlight, acclimatization of a non-acclimatized building space, activating radiant heat in the floor of a curing concrete slab, heat from surrounding ovens, fryers, or other equipment that draws moisture to the substrate's surface.

OSMOTIC REACTION IN FLOORING

In most situations, the development of osmotic blisters may not appear for several weeks or months, a duration of time long enough for the internal pressure to build up at the surface interface between the resinous floor coating and the concrete substrate. The osmotic pressure generated by the movement of water or water vapor through the concrete pores or interconnected capillaries (e.g. bleed water channels) needs to be sufficient enough to deform the fully cured material. As aforementioned, these osmotic blisters will be pressurized and typically be full of aqueous solution. However, there are occasions when the blisters are drilled out and found to be dry. This scenario may indicate the water has migrated back below the surface of the slab through a bleed water channel or interconnected pore structure within the concrete. Pressure (e.g. temperature and relative humidity) differentials above, within, and below a concrete slab-on-grade, as well as water tables or water levels beneath the substrate devoid of a positive side vapor barrier or retarder would certainly influence this kind of movement. The size of the blisters formed may depend on several factors such as the pore and micro-capillary structure (e.g. interconnected pathways from top to bottom) of the concrete, initial concentration of water-soluble material (e.g. soluble ions) available within the substrate to "feed" their formation, as well as the initial adhesion value of the resinous floor coating material to the slab's surface, flooring type and thickness.



Water-soluble materials available for feeding osmotic blisters are typically made up of either inorganic or soluble organic elements. Inorganic soluble ions (e.g. sodium potassium, or chloride) that are found in higher concentrations at or near the surface of the concrete may be the result of the initial mix design, surface treatments such as silicate-based densifiers, acid etching, de-icing salts, etc. Soluble salts from the concrete mix design itself can migrate to the surface of the substrate where they concentrate during the slab's curing & drying period- similar to the formation of efflorescence on bricks. The process of finishing the concrete slab and the natural evaporation of moisture on or close to the surface means there will most always be a measurably higher level of soluble salt concentration in the uppermost portion (0-3+mm) of the flooring substrate.

Concentrations of water-soluble materials are typically attributed to one or more of the following, but may arise from a number of compounding factors:

- Previous contamination, e.g. cutting/ machine oils, food stuffs, blood, deicing salts, chemicals, etc.
- Residue from acid etching
- Detergent residues from cleaning processes
- Salts from poorly washed concrete aggregates – usually marine dredged or river-bed
- Water soluble and/or unreacted component(s) inherent to an inadequately formulated resinous floor coating material that leaches out from prolonged exposure to high moisture/alkaline conditions

Even when concrete or cement-based mortars are nominally dry, they will generally contain about 3 to 5% of "free water" by weight. This is enough water for osmotic activity to develop, and no other source is necessary, such as ground water. Although quite uncommon, there have been cases of osmotic blistering in resinous flooring "above grade" or "slab-on-deck" scenarios especially when poured onto non-vented or non-perforated steel pans. These elevated concrete slabs are also usually placed with higher water to cement ratios making the material more liquid and easier to pump. In addition, lightweight (e.g. vascular) aggregates often used in these mix designs tend to be more porous absorbing more water and consequently releasing it more slowly than conventional aggregate. As a result, the drying times of the concrete can be significantly extended delaying the application of impermeable or low-permeability resinous floor coating materials. Dynamic temperature differentials above and below slabs on elevated decks can also contribute to potential osmotic activity especially when the concrete is still drying.

In general, osmotic activity will tend to slow down and potentially cease when the concentration of the alkaline solution on either side of the semipermeable membrane equilibrates. However, this activity may remain dynamic in the continual presence of "free" (e.g. non-alkaline) water or water vapor moving from the lower portion of the concrete slab to the upper, more concentrated (e.g. alkaline) portion. Changes in the availability and movement of this "free water" can be influenced by:

- Lack of or damaged vapor barrier or retarder
- Leaking drains or broken pipes below the concrete
- Improper outside drainage run-off

Concrete exhibits high levels of internal relative humidity (wetness) due to non-acclimatization of the building space, high amounts of moisture trapped within the concrete as a result of over-burnishing the surface when power-troweling, or an excess of unreacted (water-soluble) silicate-based (e.g. concrete densifier) material occupying pores near or at the concrete surface. Typically, densifying silicates can penetrate as deep as 1/8"-1/4" into the concrete making them difficult to remove through normal mechanical surface preparation (e.g. shotblasting).

The implications of osmotic blistering, which is a type of resinous floor coating "bond failure" can be very significant. Subsequent to non-performance, any forms of reparation become logistically challenging when the flooring environment is in full operation- a burdensome inconvenience with unexpected repairs and expense.

REDUCING THE RISK

In recent years, continual experience and testing has provided flooring material manufacturers with valuable knowledge for formulating and specifying certain types of surface treatments to be more resistant to this moisture-related condition.

Despite our progress, the science still remains inexact, and it remains difficult to consistently identify what installations might potentially be subject to osmotic blistering because of the unpredictable and complex nature of this phenomenon. However, some general precautions can be used in order to reduce the associated risk.

Complete moisture testing, following ASTM-F2170, a standard test method for determining internal relative humidity levels in concrete slabs using "in situ" Probes after the subject space(s) has been acclimatized for a minimum of 48 hours to reflect in-service temperatures and relative humidities;

If possible, explore and examine the previous use of the floor to determine whether there might have been exposures to soluble contaminants that may have been absorbed into the surface;

Core sampling (e.g. chemical analysis using "ion chromatography") should be considered especially with existing concrete where the history of the slab is unknown. Cores should be abstracted as early as possible to ensure all parties have time to evaluate the risk and determine how to move forward. There are 3^{rd} party independent laboratories specializing in this form of analysis throughout the U.S.

High risk empirical results from concrete testing and analysis may require additional provisions exceeding what was originally specified to be communicated and agreed to in WRITING by the parties involved such as: (i). Additional (intensive and extensive) surface preparation; (ii). Alternate surface treatments; and any (iii) Changes in warranty agreements or clauses. Written communication is key to avoid liability issues in the future.

If applicable, a breathable or semi-permeable floor coating material may need to be specified and approved in Writing.

Another alternative surface treatment used successfully in situations with elevated levels of moisture and soluble ions is Cementitious Urethanes. This type of flooring material can easily be installed at thicknesses greater than ¼". In the absence of a resinous topcoat, this type of material is less likely to be susceptible

to deformation caused by osmotic cells. Also, tenacious bonding to the concrete substrate tends to enable the Cementitious Urethane to be very resistant to "osmotic blisters"- a form of bond failure.

In new construction, it would be advisable to ensure the concrete mix design has specified clean washed aggregate. Also, ensure the concrete has been moisture-cured immediately subsequent to pouring and placement for 7 days. Osmotic blisters can also develop when the concrete has poor integral strength.

Avoid applying resinous floor coating materials in a non-acclimatized building. The building space(s) to receive these types of flooring finishes should be acclimatized at in-service temperatures and humidities for at least 3 weeks.

If moisture levels are elevated above what is recommended by the floor coating manufacturer, a suitable moisture mitigating primer system should be specified. As outlined by the International Concrete Repair Institute (ICRI), a Concrete Surface Profile (CSP) of 4-5 is preferred.

Avoid acid etching and do not wash the concrete with a detergent cleaner. If a degreaser is used, ensure the concrete is thoroughly neutralized and allowed to dry, with pH levels suitable for a resinous floor coating application.

Ensure complete removal of any possible surface contamination like residual glues or adhesives present on existing concrete left from removed carpet, VCT, or sheet vinyl. Diamond grinding can often heat-up and push residual glue back into the concrete capillaries forming a bond breaker, as well as creating a potentially adverse chemical reaction that may compromise the cured integrity and/or substrate adhesion of the resinous flooring material.

Any leveling materials should be polymer modified to minimize permeability and potential salt migration. Never install a resinous flooring material over a Gypsum-based leveling system.

Ensure accurate mix ratio and mix well as specified by the resinous floor coating manufacturer.

If "osmotic blisters" develop after your resinous flooring system has been installed, it is strongly recommended to enlist the Manufacturer's Technical Representative to accompany you to the job site to review the situation. Gathering useful information through sampling and empirical testing as advised by the Technical Representative is critical to understanding the mode of failure or non-performance of the resinous flooring material. Once results have been generated and analyzed, it will be equally important to provide a Report for the end-user clearly outlining any findings, as well as whatever mode(s) of reparation including any newly specified materials that will be required to restore a successful flooring system.